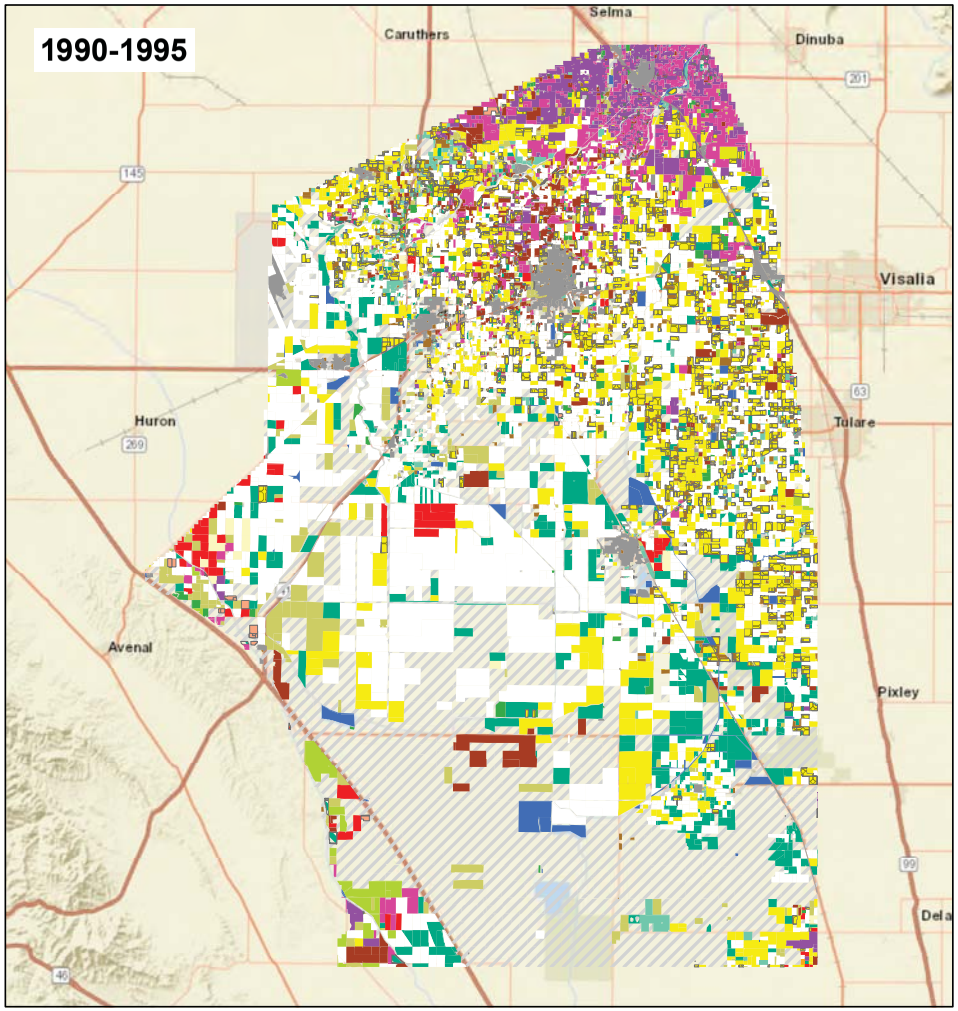
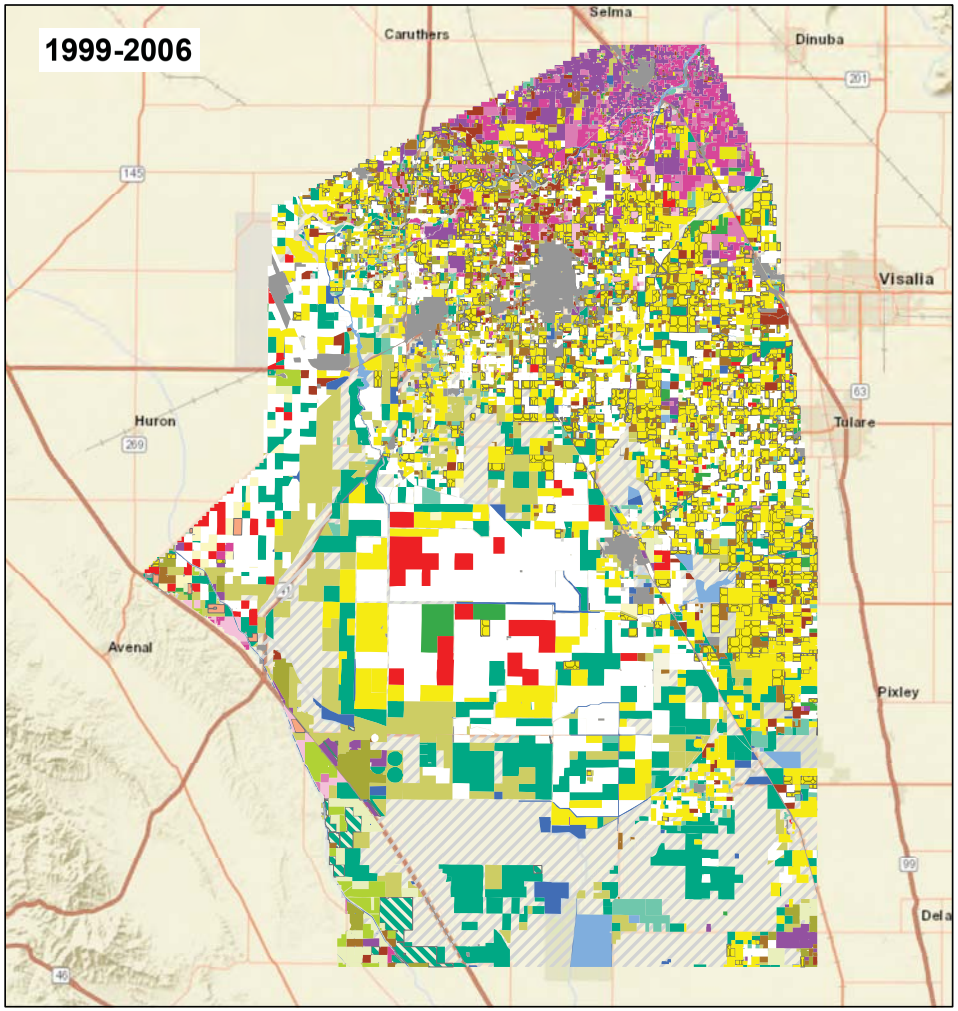




Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community

Explanation

- Alfalfa Hay and Clover
- Almonds (Young)
- Almonds (Adolescent)
- Almonds (Mature)
- Berries
- Carrot Single Crop
- Citrus (no ground cover)
- Corn and Grain Sorghum
- Cotton
- Dairy Single Crop
- Fallow Land
- Forest
- Grain and Grain Hay
- Melons
- Misc. field crops
- Onions and Garlic
- Open Water
- Pasture and Misc. Grasses
- Pistachio (Young)
- Pistachio (Adolescent)
- Pistachio (Mature)
- Pomegranates (Young)
- Pomegranates (Adolescent)
- Potatoes, Sugar beets, Turnip etc..
- Riparian
- Small Vegetables
- Stone Fruit (Young)
- Stone Fruit (Adolescent)
- Stone Fruit (Mature)
- Tomatoes and Peppers
- Urban, Commercial
- Urban, Industrial
- Wine Grapes with 80% canopy
- Winter Wheat

N

0 20,000 40,000

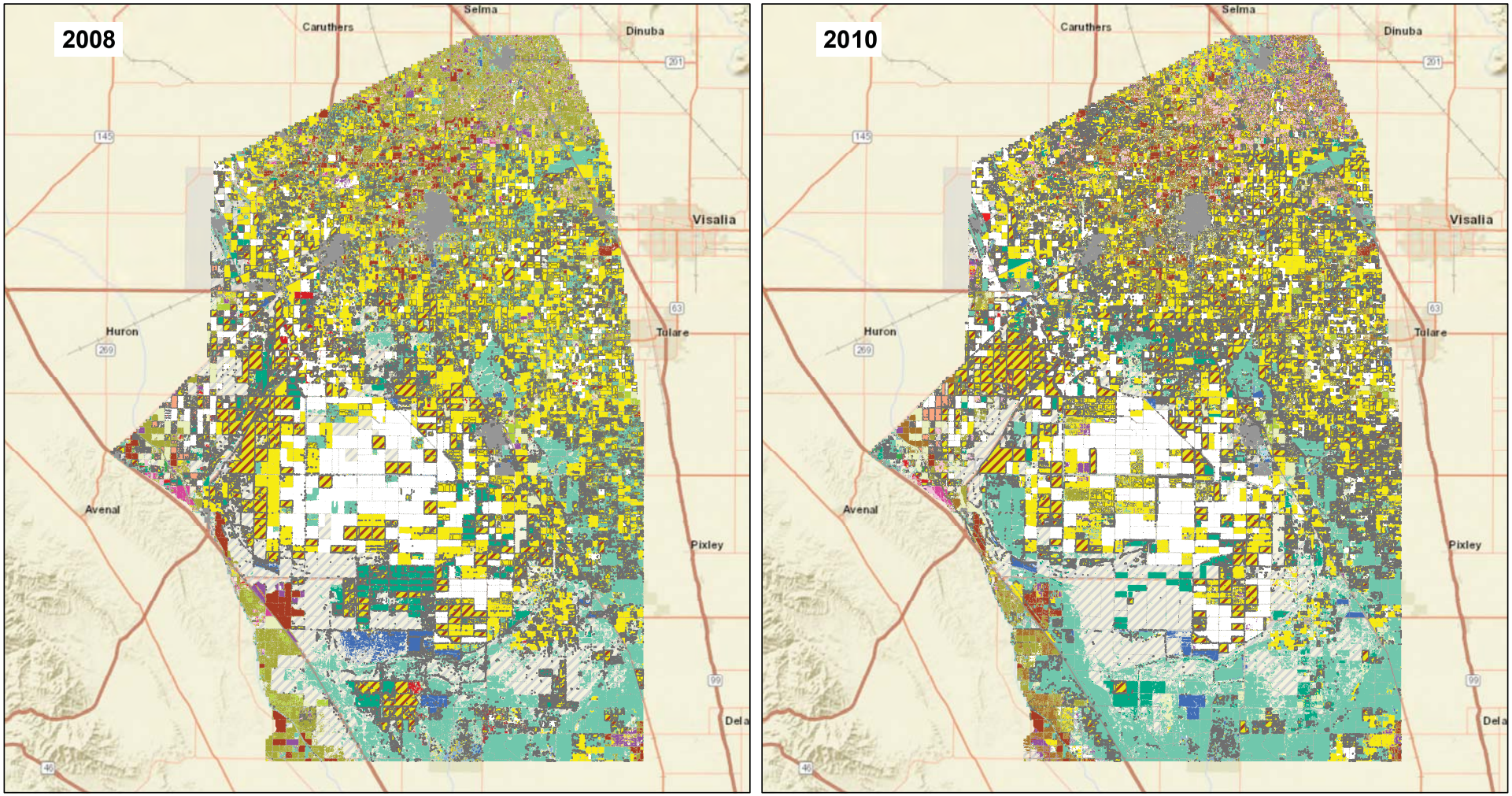
APPROXIMATE SCALE IN FEET

Crop Distributions

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: jmp	Date: 3/26/2019	Project No.: FR18161220
		Figure 3-8a

\\fsn-fs1\Graphics_FR_projects\FR18s\FR18161220\gis\maps\2018\Hydrogeologic_Conceptual_Model\Arcmap 10.4_fig3-8a_CropDistributions_rev.mxd



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Explanation

- Alfalfa Hay and Clover
- Almonds (Young)
- Almonds (Adolescent)
- Almonds (Mature)
- Berries
- Carrot Single Crop
- Citrus (no ground cover)
- Corn and Grain Sorghum
- Cotton
- Dairy Single Crop
- Fallow Land
- Forest
- Grain and Grain Hay
- Melons
- Misc. field crops
- Onions and Garlic
- Open Water
- Pasture and Misc. Grasses
- Pistachio (Young)
- Pistachio (Adolescent)
- Pistachio (Mature)
- Pomegranates (Young)
- Pomegranates (Adolescent)
- Potatoes, Sugar beets, Turnip etc..
- Riparian
- Small Vegetables
- Stone Fruit (Young)
- Stone Fruit (Adolescent)
- Stone Fruit (Mature)
- Tomatoes and Peppers
- Urban, Commercial
- Urban, Industrial
- Wine Grapes with 80% canopy
- Winter Wheat

N

0 20,000 40,000

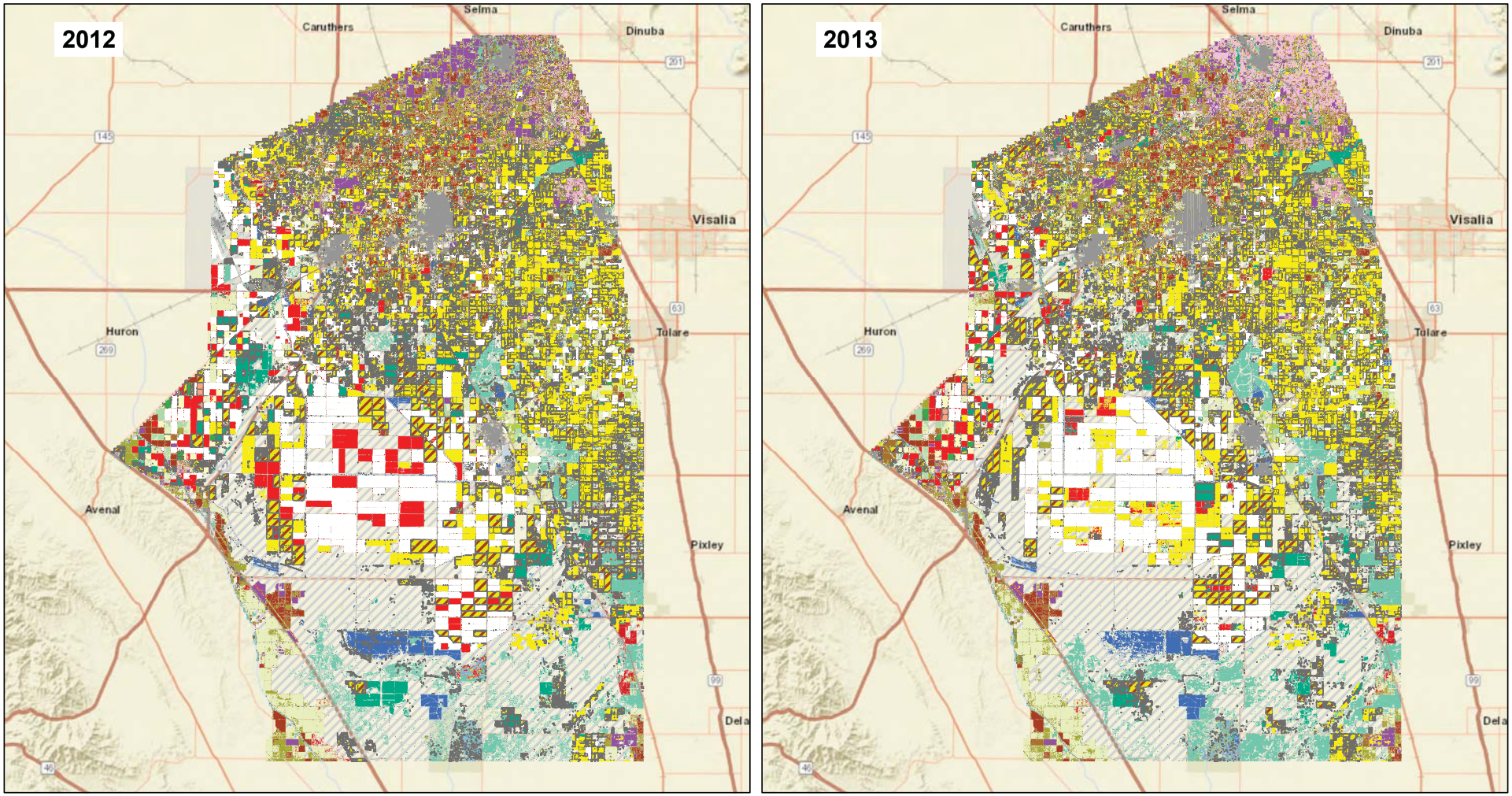
APPROXIMATE SCALE IN FEET

Crop Distributions

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: jmp	Date: 3/26/2019	Project No.: FR18161220
		Figure 3-8b

\\fsn-fs1\Graphics_FR_projects\FR18s\FR18161220\gismaps\2018\Hydrogeologic_Conceptual_Model\Arcmap 10.4_fig3-8b_CropDistributions_rev.mxd



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Explanation

- Alfalfa Hay and Clover
- Almonds (Young)
- Almonds (Adolescent)
- Almonds (Mature)
- Berries
- Carrot Single Crop
- Citrus (no ground cover)
- Corn and Grain Sorghum
- Cotton
- Dairy Single Crop
- Fallow Land
- Forest
- Grain and Grain Hay
- Melons
- Misc. field crops
- Onions and Garlic
- Open Water
- Pasture and Misc. Grasses
- Pistachio (Young)
- Pistachio (Adolescent)
- Pistachio (Mature)
- Pomegranates (Young)
- Pomegranates (Adolescent)
- Potatoes, Sugar beets, Turnip etc..
- Riparian
- Small Vegetables
- Stone Fruit (Young)
- Stone Fruit (Adolescent)
- Stone Fruit (Mature)
- Tomatoes and Peppers
- Urban, Commercial
- Urban, Industrial
- Wine Grapes with 80% canopy
- Winter Wheat

N

0 20,000 40,000

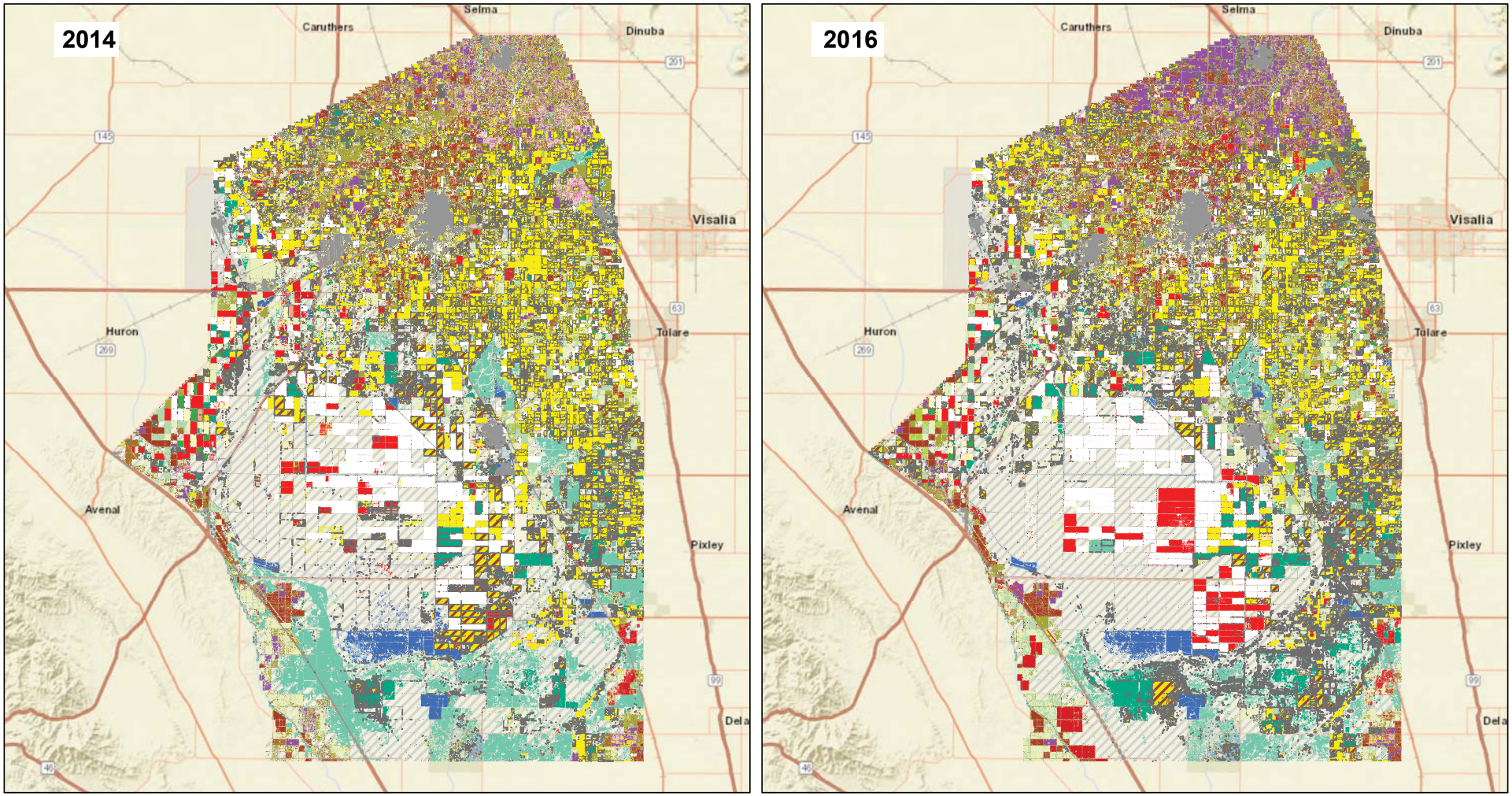
APPROXIMATE SCALE IN FEET

Crop Distributions

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: jmp	Date: 3/26/2019	Project No.: FR18161220
		Figure 3-8c

\\fsn-fs1\Graphics_FR_projects\FR18s\FR18161220\gismaps\2018\Hydrogeologic_Conceptual_Model\Arcmap 10.4_fig3-8c_CropDistributions_rev.mxd



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Explanation

- Alfalfa Hay and Clover
- Almonds (Young)
- Almonds (Adolescent)
- Almonds (Mature)
- Berries
- Carrot Single Crop
- Citrus (no ground cover)
- Corn and Grain Sorghum
- Cotton
- Dairy Single Crop
- Fallow Land
- Forest
- Grain and Grain Hay
- Melons
- Misc. field crops
- Onions and Garlic
- Open Water
- Pasture and Misc. Grasses
- Pistachio (Young)
- Pistachio (Adolescent)
- Pistachio (Mature)
- Pomegranates (Young)
- Pomegranates (Adolescent)
- Potatoes, Sugar beets, Turnip etc..
- Riparian
- Small Vegetables
- Stone Fruit (Young)
- Stone Fruit (Adolescent)
- Stone Fruit (Mature)
- Tomatoes and Peppers
- Urban, Commercial
- Urban, Industrial
- Wine Grapes with 80% canopy
- Winter Wheat

N

0 20,000 40,000

APPROXIMATE SCALE IN FEET

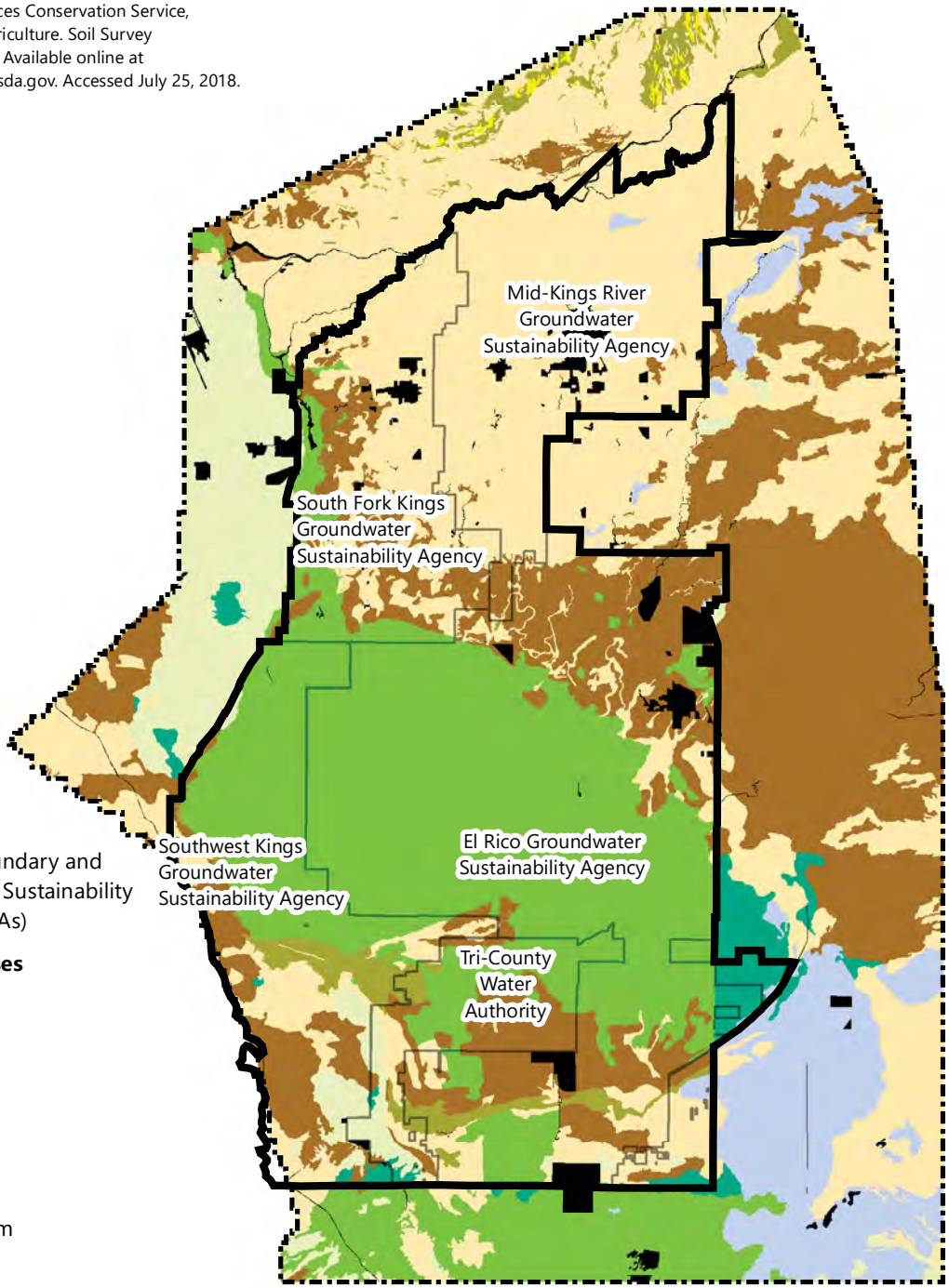
Crop Distributions

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: jmp	Date: 3/26/2019	Project No.: FR18161220
		Figure 3-8d

\\fsn-fs1\Graphics_FR_projects\FR18s\FR18161220\gis\maps\2018\Hydrogeologic_Conceptual_Model\Arcmap 10.4_fig3-8d_CropDistributions_rev.mxd

Soil texture data adapted from:
Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) database. Available online at https://sdmdataaccess.sc.egov.usda.gov. Accessed July 25, 2018.



Explanation

- Study area
- Subbasin boundary and Groundwater Sustainability Agencies (GSAs)

USDA soil textural classes

- Clay
- Silty clay
- Clay loam
- Silty clay loam
- Silt loam
- Loam
- Sandy loam
- Loamy sand
- Sand
- Unweathered bedrock
- Soil data unavailable

Miles
0 2 4 8
0 2.5 5 10
Kilometers

N

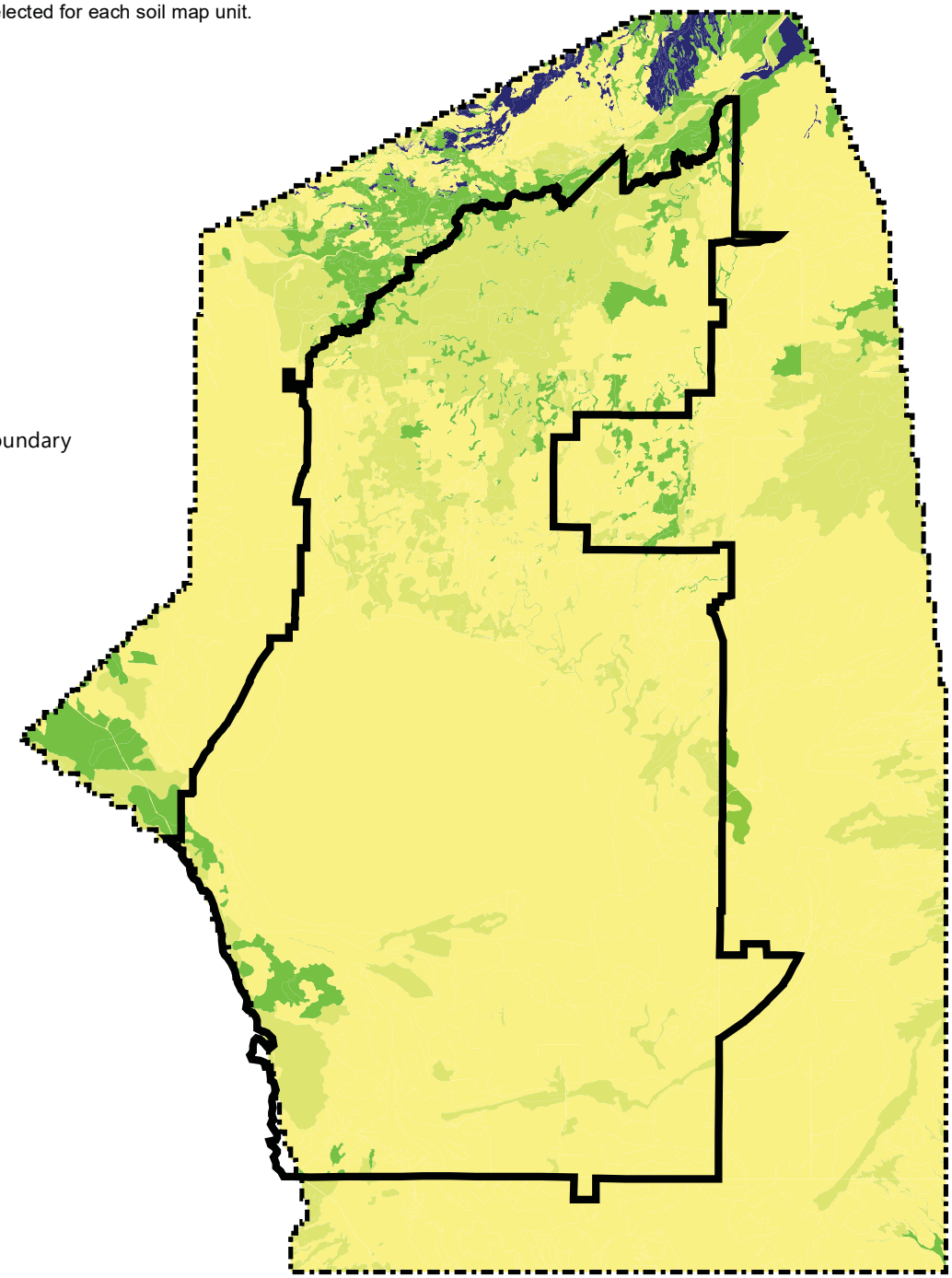
Soil Texture Map

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/15/2019	Project No.: FR18161220
		Figure **3-9**

Date: 11/15/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting\8.5x11_fig3-9_SoilTexture.mxd

NOTES:
1) Minimum horizon Ksat selected for each soil map unit.



Explanation

Study area

Subbasin boundary

Ksat (µm/sec)

- 0.0 - 5.0
- 5.0 - 10.0
- 10.0 - 15.0
- 15.0 - 20.0
- 20.0 - 25.0
- 25.0 - 30.0
- 30.0 - 35.0
- 35.0 - 40.0
- 40.0 - 45.0
- 45.0 - 50.0
- 50.0 - 55.0
- 55.0 - 60.0
- 60.0 - 65.0
- 65.0 - 70.0
- 70.0 - 75.0
- 75.0 - 80.0
- 80.0 - 85.0
- 85.0 - 90.0
- 90.0 - 95.0

Miles
0 2 4 8
0 2.5 5 10
Kilometers

N

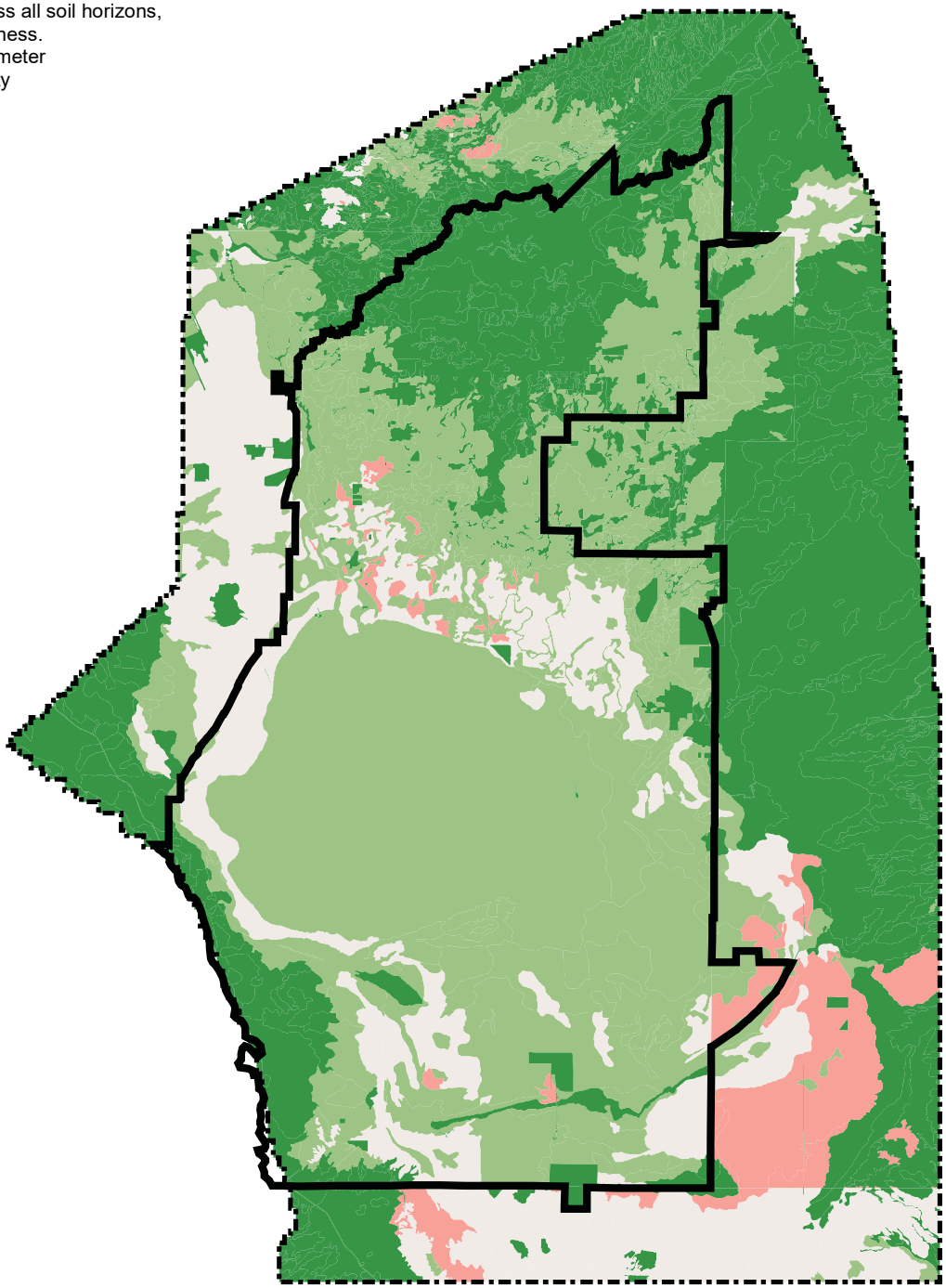
Soil Permeability Map
Minimum Ksat

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/15/2019	Project No.: FR18161220
		Figure **3-10**

Date: 11/15/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting\8.5x11_fig3-10_SoilPermeability.mxd

Notes:
1. EC values averaged across all soil horizons, weighted by horizon thickness.
2. dS/m = deciSiemens per meter
3. EC = electrical conductivity



Explanation

Study area

Subbasin boundary

EC (dS/m)

- 0.0 - 4.5
- 4.5 - 9.0
- 9.0 - 15.0
- 15.0 - 18.0
- 18.0 - 25.0

Miles
0 2 4 8
0 2.5 5 10
Kilometers

N

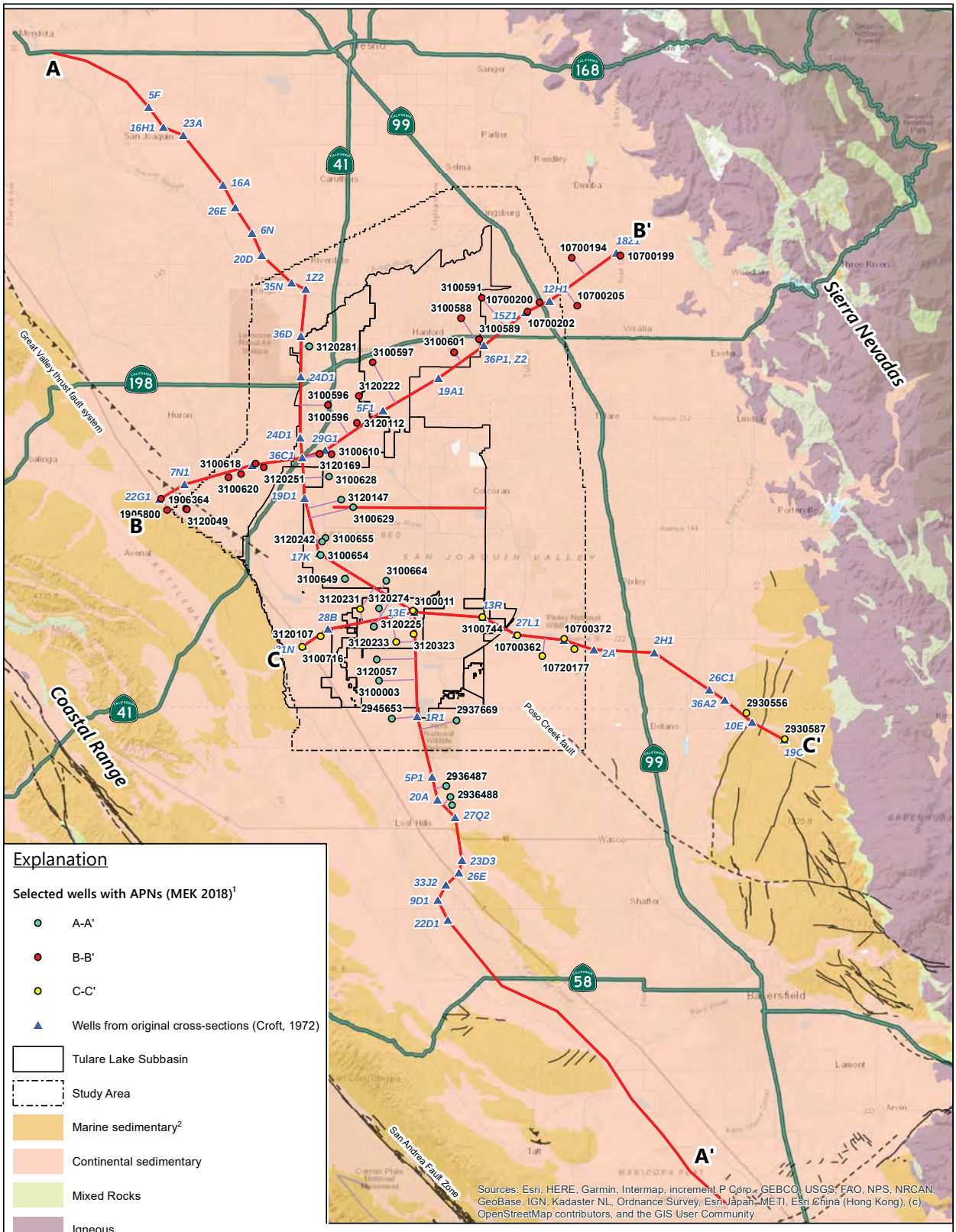
Soil Characteristics
Weighted Average on Salinity/ EC

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/15/2019	Project No.: FR18161220
		Figure **3-11**

Date: 11/15/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting\8.5x11_fig3-11_SoilSalinity.mxd

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting_fig3-12_SurficialGeology_20181106.mxd



Explanation

Selected wells with APNs (MEK 2018)[1]

- A-A'
- B-B'
- C-C'
- Wells from original cross-sections (Croft, 1972)
- Tulare Lake Subbasin
- Study Area
- Marine sedimentary[2]
- Continental sedimentary
- Mixed Rocks
- Igneous
- Metamorphic
- Wells projected onto cross-section lines
- Cross-section lines (Croft, 1972)
- Highways (TIGER/Line 2016)
- Constrained fault line[3]
- Inferred fault
- Inferred thrust fault

N

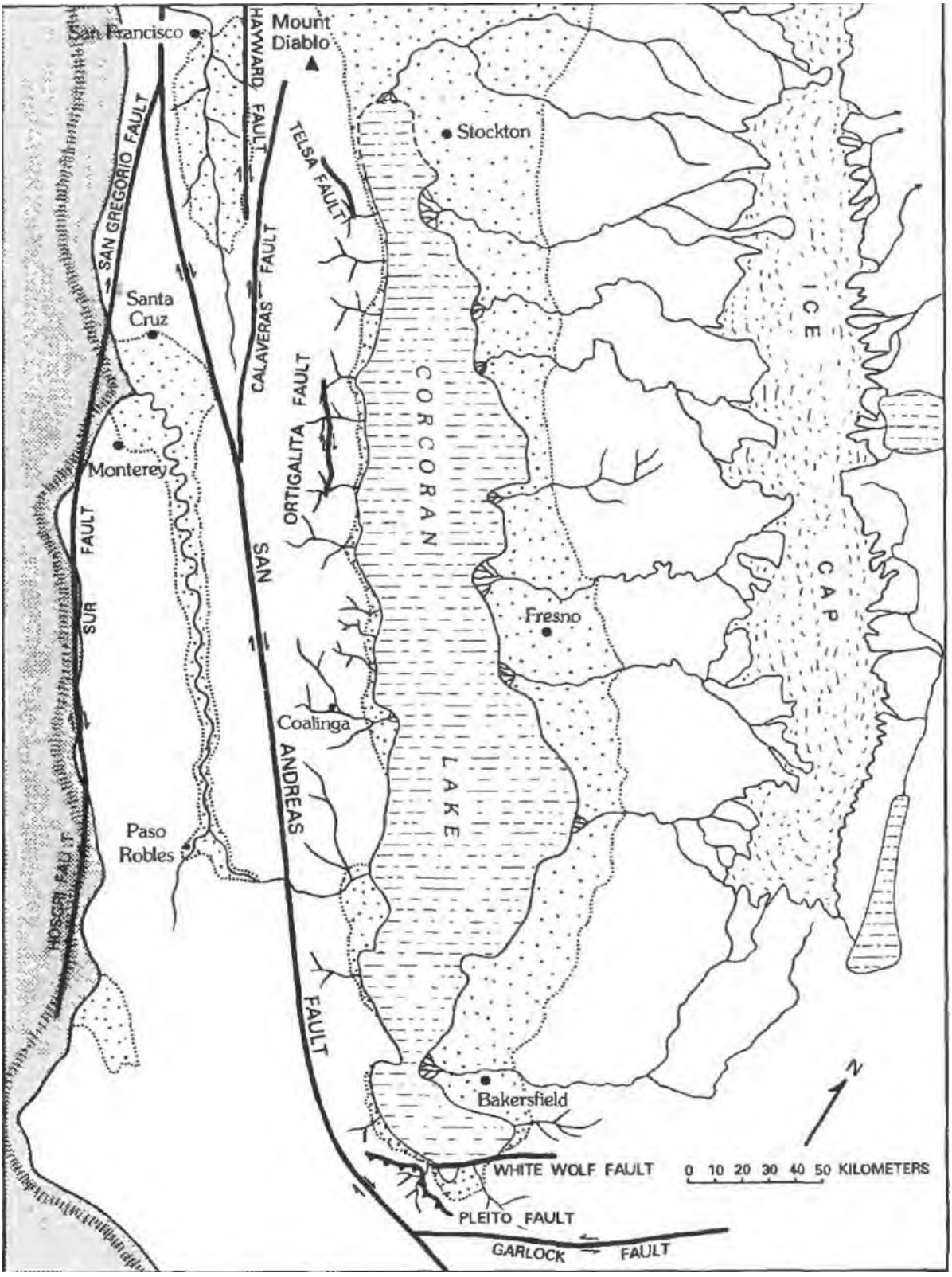
Approximate Scale in Miles
0 5 10 20

Approximate Scale in Kilometers
0 5 10 20

Notes:
1) Well records obtained from DOGGR well search. 2018. https://secure.conservation.ca.gov/WellSearch
2) Geologic Units derived from Geologic Map of California, 1977. USGS. https://mrdata.usgs.gov/geology/state
3) Fault data adapted from Quaternary Fault and Fold Database of the US. 2018 https://earthquake.usgs.gov/hazards/qfaults/

Geologic Map of the Southern San Joaquin Valley and Cross Section Locations
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure 3-12



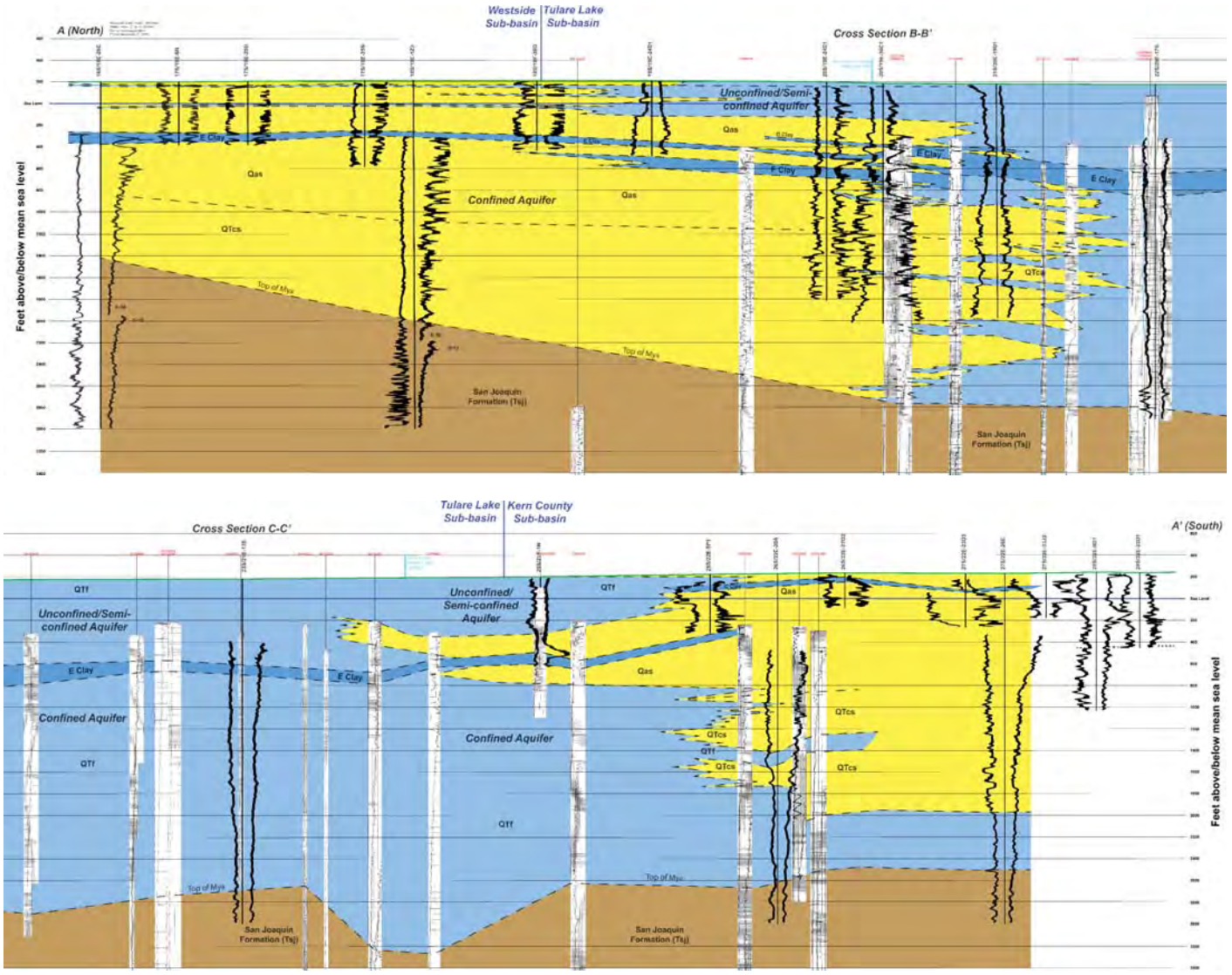
Pleistocene Extent of Corcoran Lake

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: SCM	Date: 1/9/2020	Project No.: FR18161220
		Figure **3-13**

Note:
1) Adapted from Figure 13 of Bartow (1991).

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting_fig3-13_CorcoranLake.mxd



Explanation

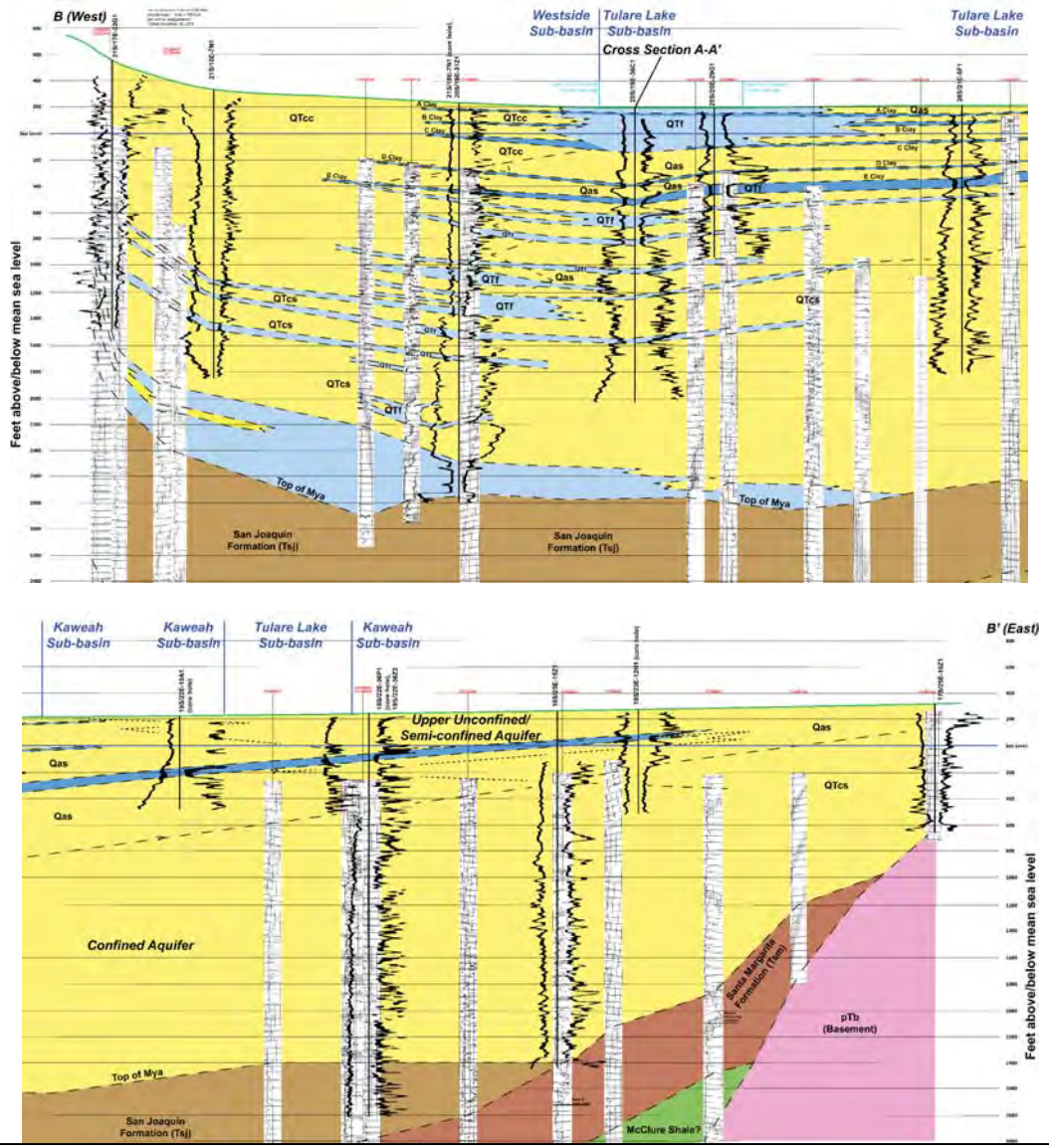
- Coarse-grained alluvium / Tulare Formation
- San Joaquin Formation
- Alluvium / Tulare Formation lacustrine sediments
- Regional clay marker beds as defined by Croft (1972)
- 25S/21E-1N — CA DWR well name
- 03120281 — CA DOGGR well APN
- 0 30 — Electric log resistivity scale (ohmmeters)

Notes:
1) Contacts dashed where inferred.
2) CA DWR = California Department of Water Resources.
2) CA DOGGR = Division of Oil, Gas, and Geothermal Resources, California Department of Conservation.

Cross Section A-A'
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings county, California

By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure **3-14a**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PA_projects\FR18\FR18161220\gis\maps\2019\Basin_Setting_fig3-14a_xsecA-A'.mxd



Explanation

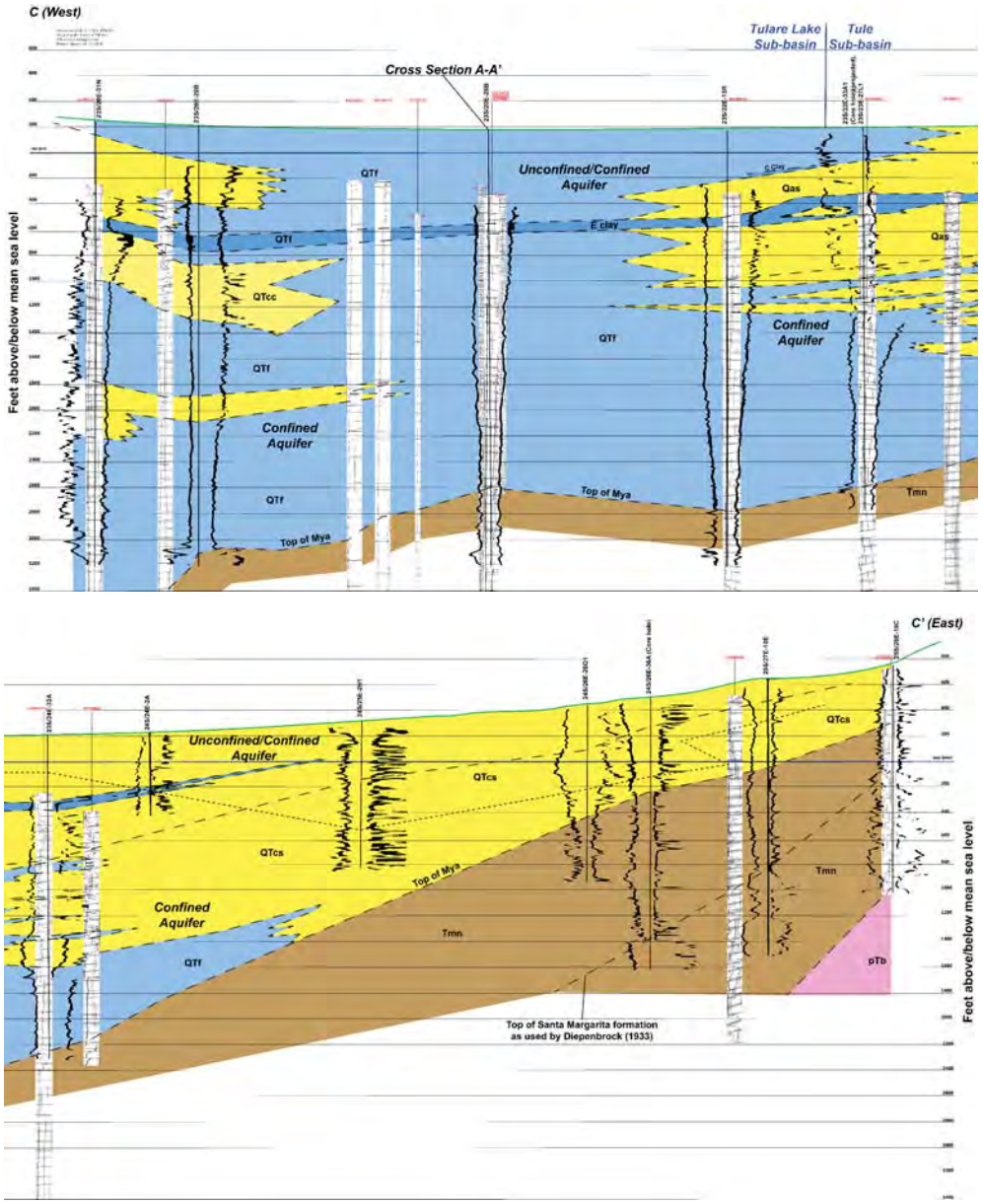
- Coarse-grained alluvium / Tulare Formation
- San Joaquin Formation
- Etchegoin Formation
- Santa Margarita Formation
- Alluvium / Tulare Formation lacustrine sediments
- Regional clay marker beds as defined by Croft (1972)
- Crystalline basement
- 25S/21E-1N — CA DWR well name
- 03120281 — CA DOGGR well APN
- 0 30 — Electric log resistivity scale (ohmmeters)

Notes:
1) Contacts dashed where inferred.
2) CA DWR = California Department of Water Resources.
2) CA DOGGR = Division of Oil, Gas, and Geothermal Resources, California Department of Conservation.

Cross Section B-B'
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure **3-14b**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PR_projects\FR18xx\FR18161220\gis\maps\2019\Basin_Setting_fig3-14b_xsecB-B'.mxd



Explanation

- Coarse-grained alluvium / Tulare Formation
- San Joaquin Formation
- Alluvium / Tulare Formation lacustrine sediments
- Regional clay marker beds as defined by Croft (1972)
- Crystalline basement
- **25S/21E-1N** — CA DWR well name
- **03120281** — CA DOGGR well APN
- 0 30 — Electric log resistivity scale (ohmmeters)

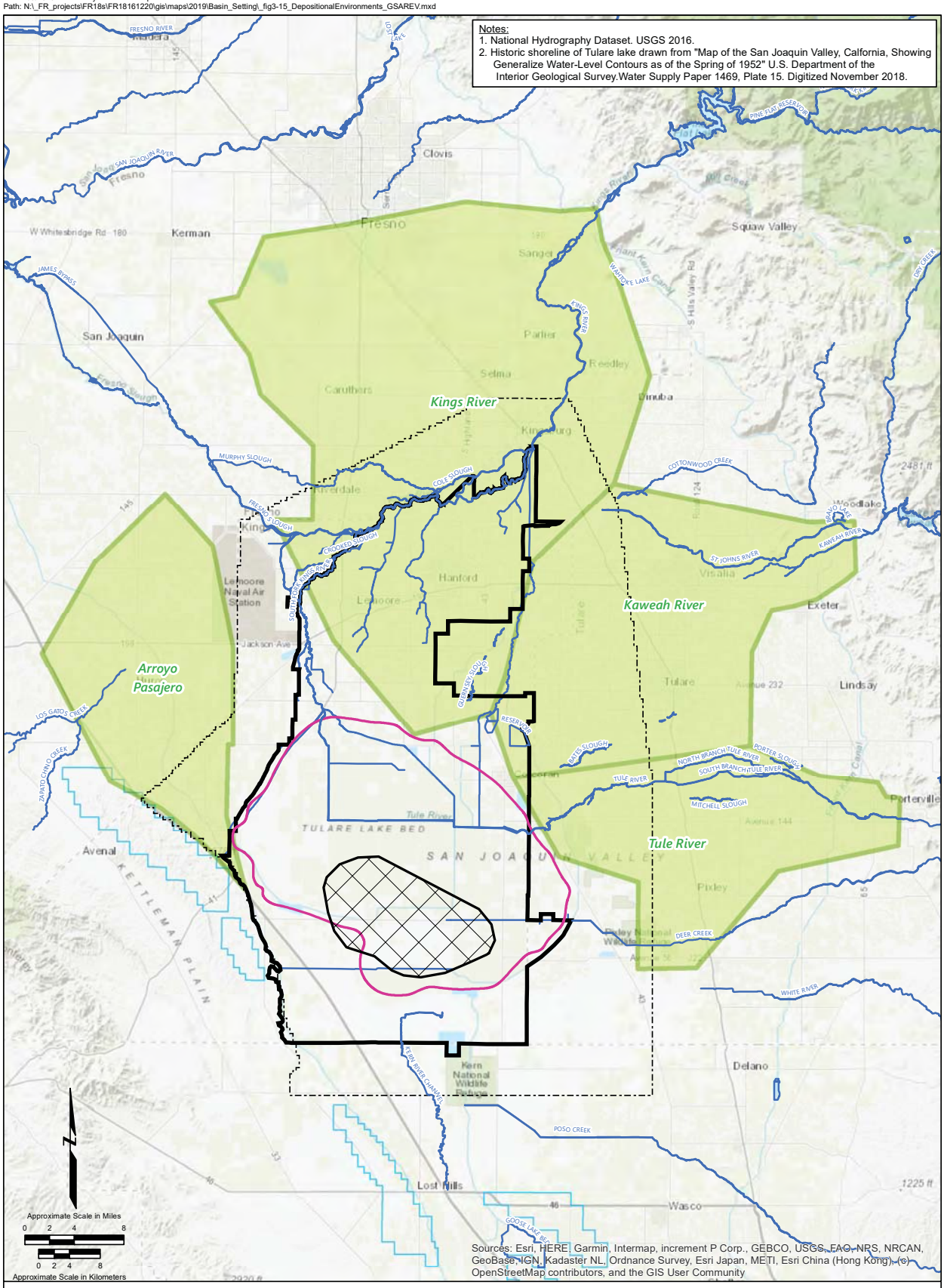
Notes:
1) Contacts dashed where inferred.
2) CA DWR = California Department of Water Resources.
3) CA DOGGR = Division of Oil, Gas, and Geothermal Resources, California Department of Conservation.

Cross Section C-C'
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure **3-14c**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PA_projects\FR18\FR18161220\gis\maps\2019\Basin_Setting_fig3-14c_xsecC-C.mxd

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting_fig3-15_DepositionalEnvironments_GSAREV.mxd



Explanation

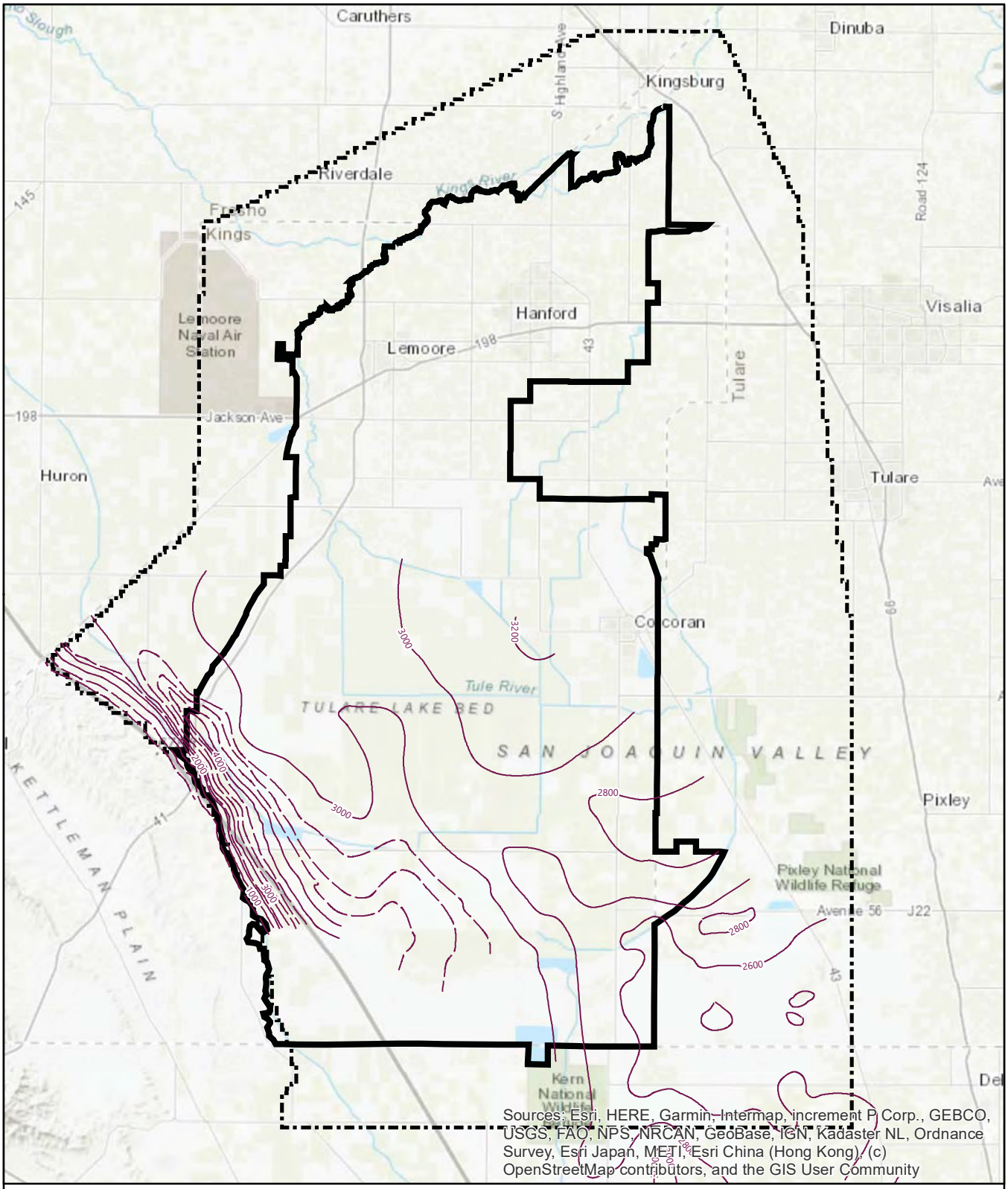
- NHD natural water bodies[1]
- Estimated extent of clay plug below E-clay
- Study Area
- Subbasin boundary
- Historic shoreline of Tulare Lake (modified from Summers, 1969)
- Alluvial fans (modified from Davis, 1959)
- DOGGR[2] Oil and Gas Fields

Notes:
1. NHD= National Hydrography Dataset. USGS 2016.
2. California Department of Conservation, 2017, Division of Oil, Gas, and geothermal Resources (DOGGR), http://www.conservation.ca.gov/dog/.

Depositional Environments in the Tulare Lake Subbasin

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure **3-15**



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Explanation

- Study area
- Subbasin boundary
- 2000 — Line of equal depth and thickness of Tulare Formation in 200 foot intervals

Miles: 0 2 4 8

Kilometers: 0 2.5 5 10

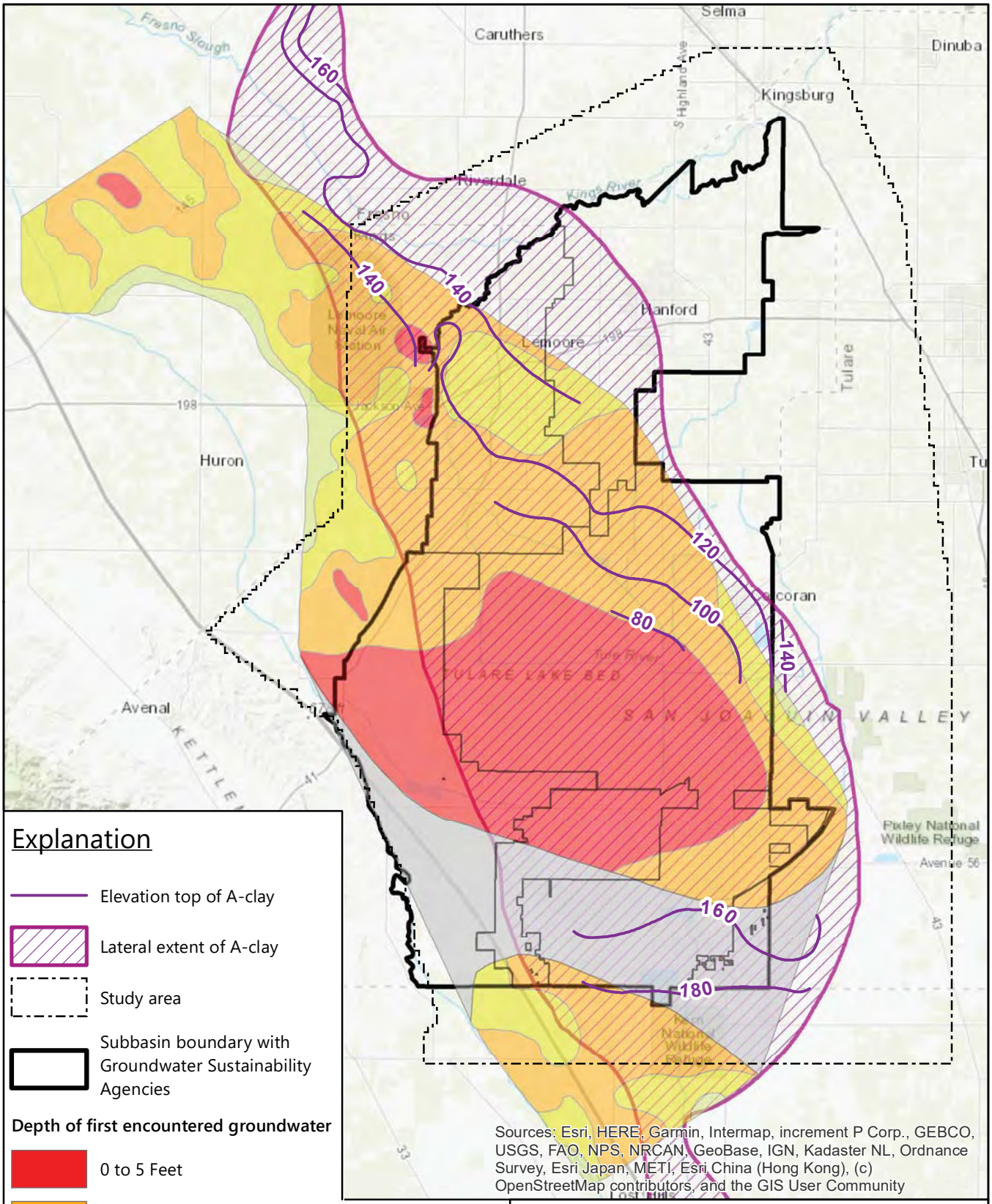
Notes: 1. Contours adapted from *Geology beyond Kettleman Hills* R.W. Page, 1980.

Map of Equal Depth to Base of Tulare Formation

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/8/2019	Project No.: FR18161220
		Figure **3-16**

Date: 11/8/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting\8.5x11_fig3-16_baseofTulareFrm.mxd



Explanation

- Elevation top of A-clay
- Lateral extent of A-clay
- Study area
- Subbasin boundary with Groundwater Sustainability Agencies

Depth of first encountered groundwater

- 0 to 5 Feet
- 5 to 10 Feet
- 10 to 15 Feet
- 15 to 20 Feet
- Data gap

Miles
0 2 4 8
0 2.5 5 10
Kilometers

Notes:
Depth of first encountered groundwater data adapted from DWR "Present and Potential Drainage Problem Areas, San Joaquin Valley" Map, 2008

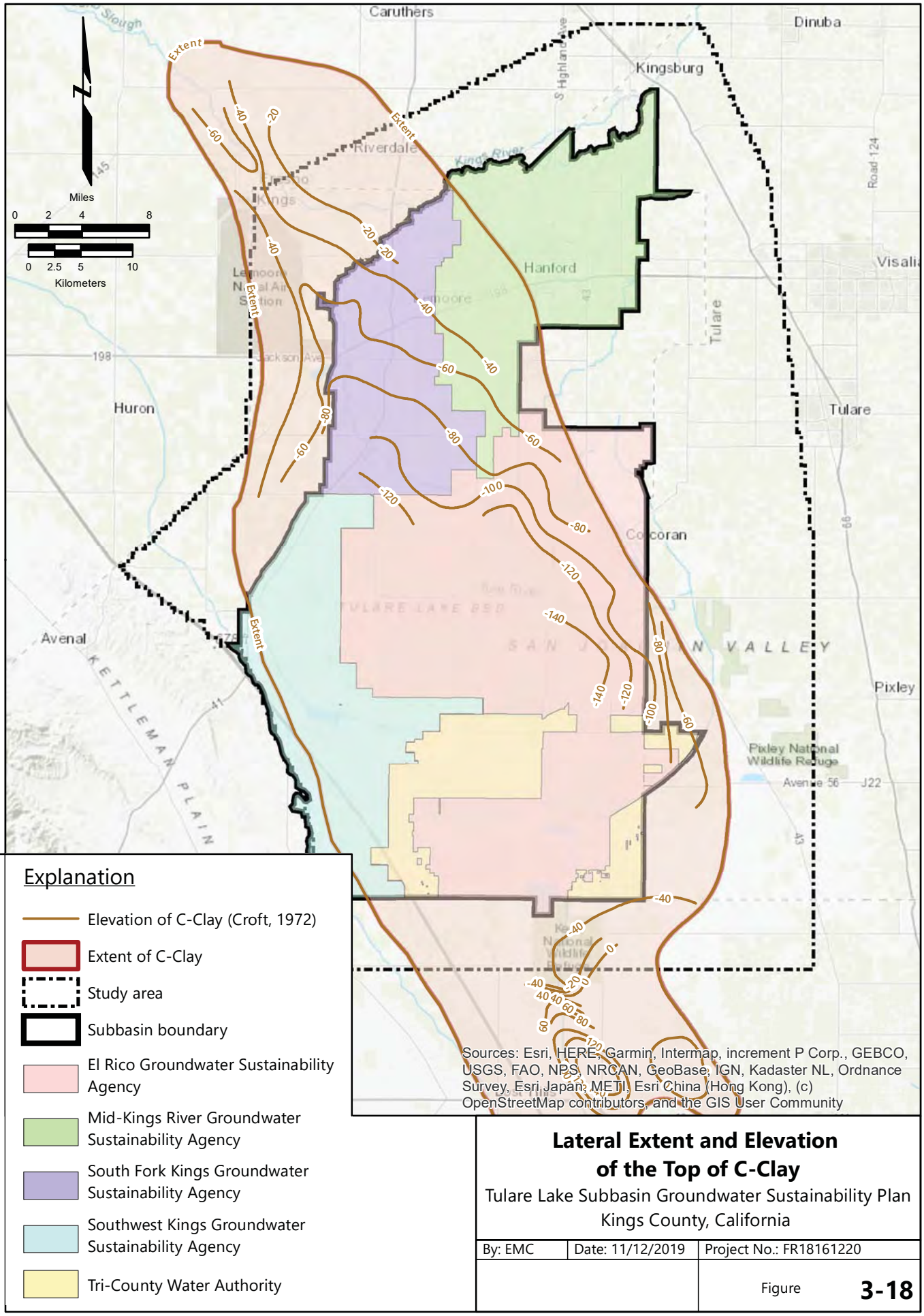
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Lateral Extent and Elevation of the A-Clay and First Encountered Groundwater 2010

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/5/2019	Project No.: FR18161220
		Figure 3-17

Date: 12/5/2019 Printed by: elizabeth.chapman
Path: \\fsn-fs1\Graphics_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting\8.5x11_fig3-17_LateralExtentofAClayFirstEncounteredGW2010.mxd



Explanation

- Elevation of C-Clay (Croft, 1972)
- Extent of C-Clay
- Study area
- Subbasin boundary
- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

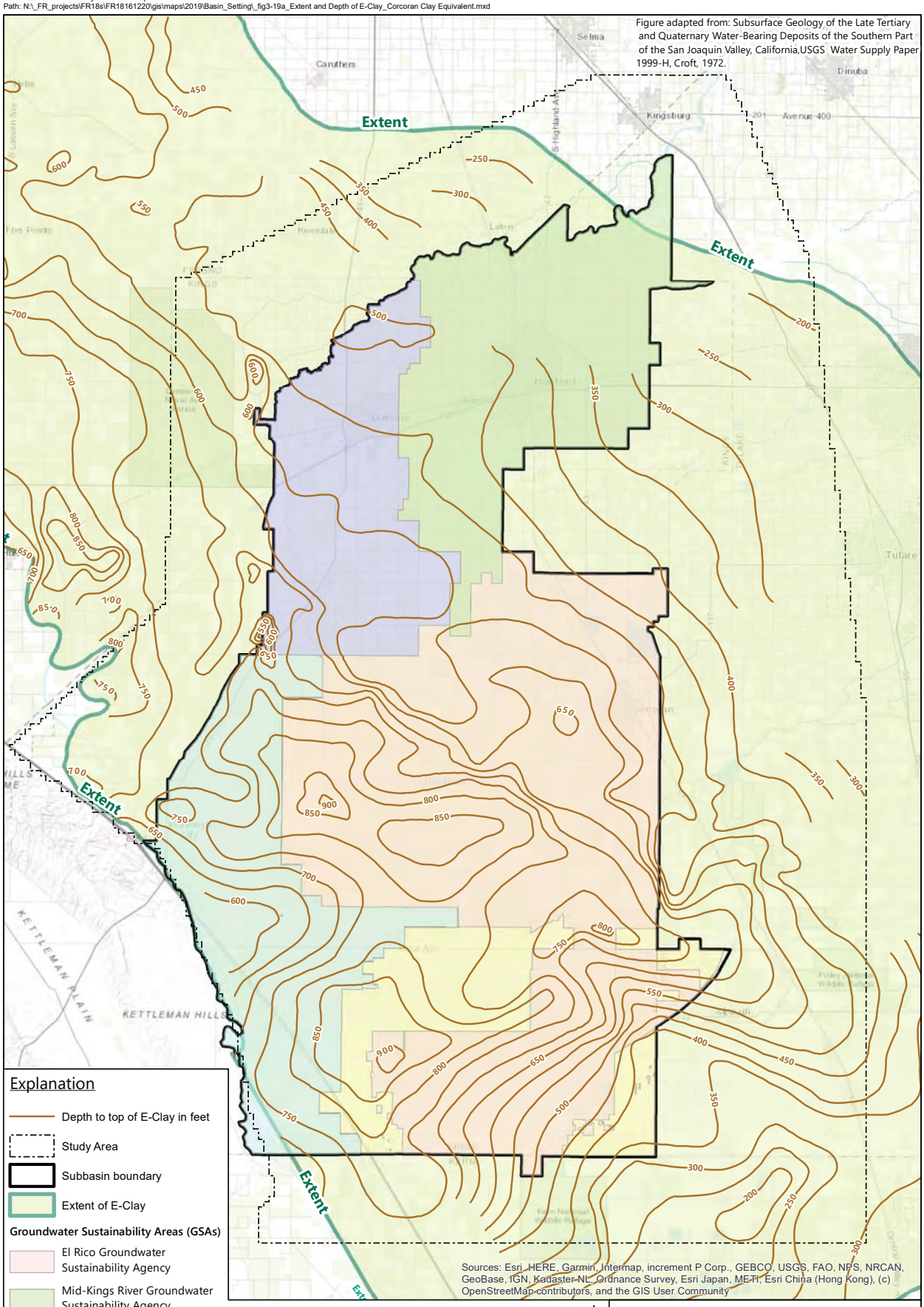
Lateral Extent and Elevation of the Top of C-Clay

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/12/2019	Project No.: FR18161220
		Figure **3-18**

Date: 11/12/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting\8.5x11_fig3-18_LateralExtentElev_C_Clay.mxd

Date: 1/9/2020 Printed by: elizabeth.chapman
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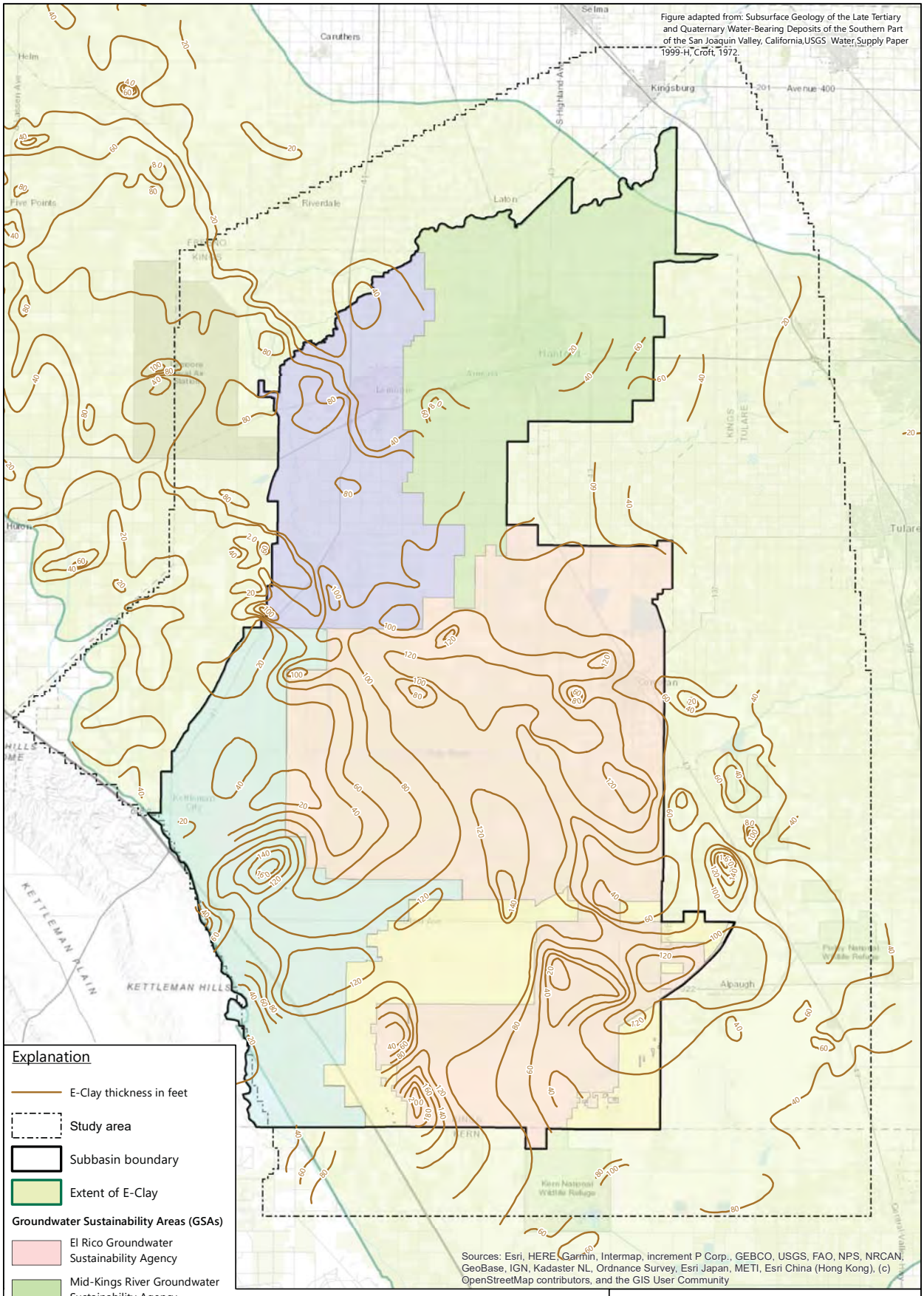


Lateral Extent and Depth to Top of E-Clay

Tulare Lake Subbasin Hydrologic Model
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR16181220
		Figure **3-19a**

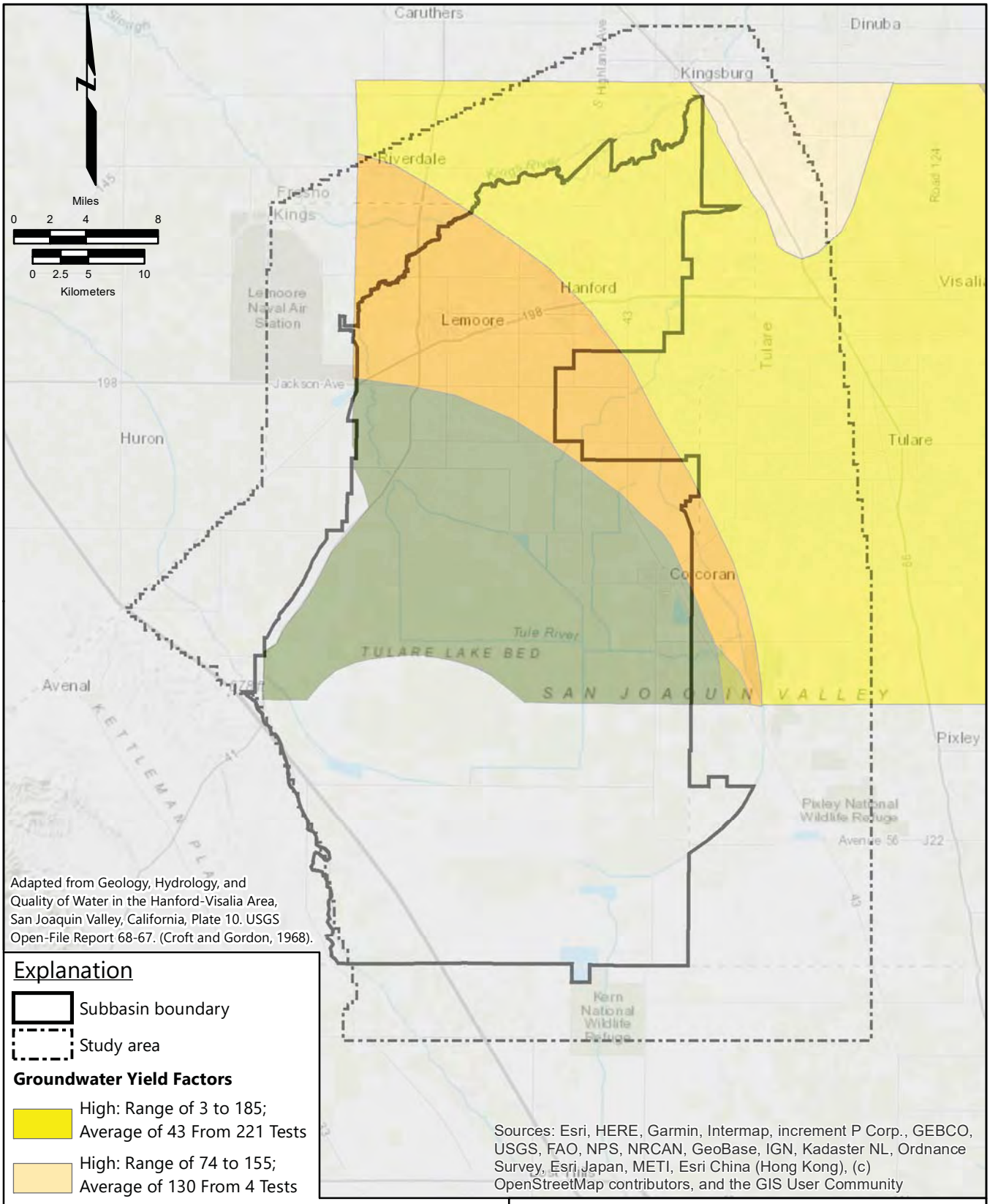
Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting_fig3-19b_Extent and Thickness of E-Clay.mxd



Lateral Extent and Thickness of E-Clay

Tulare Lake Subbasin Hydrologic Model
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR16181220
		Figure **3-19b**



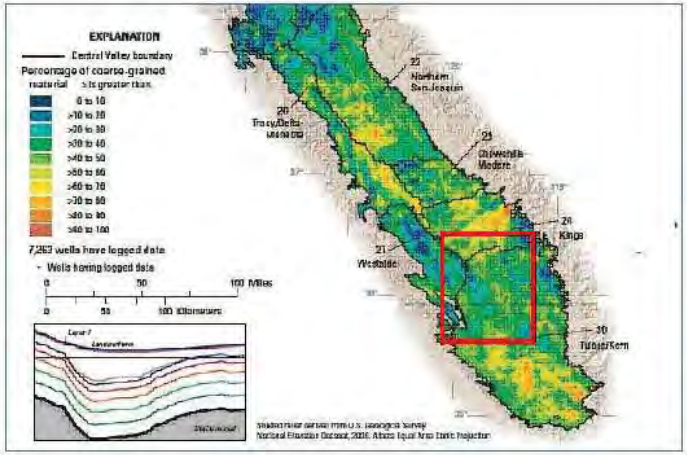
Map of Relative Permeability of Geologic Units as Interpreted from Yield Factors

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

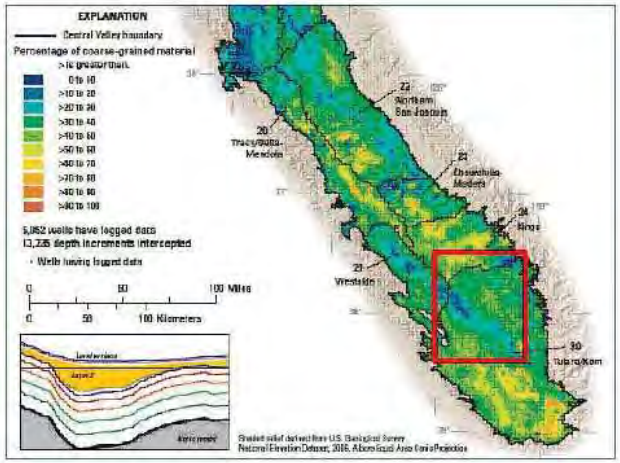
By: EMC	Date: 11/13/2019	Project No.: FR18161220
		Figure **3-20**

Date: 11/13/2019 Printed by: elizabeth.chapman
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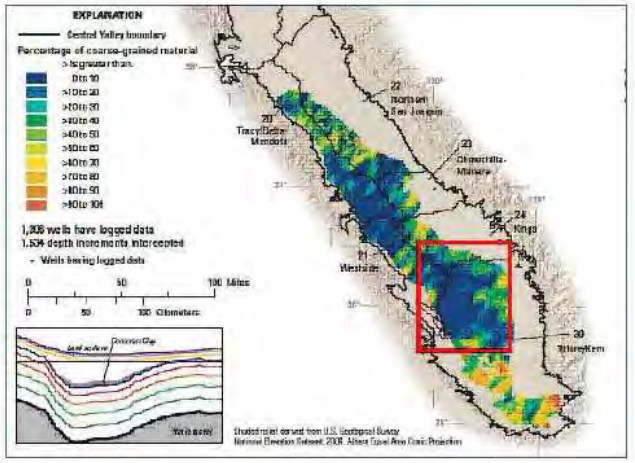
a. 0 - 50 foot depth interval



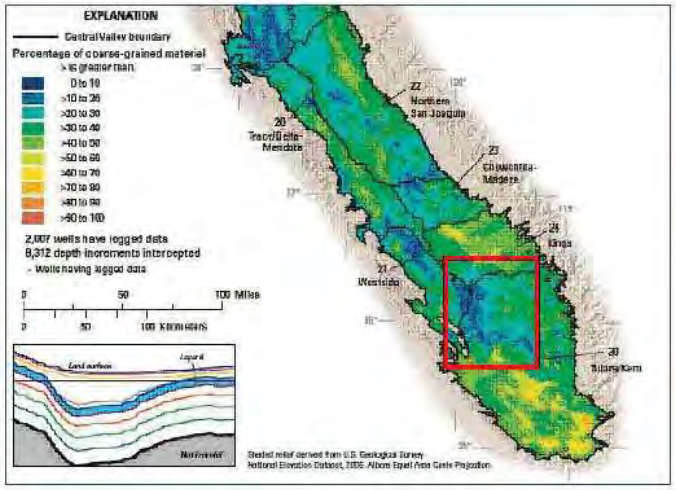
b. 50 - 200 foot depth interval



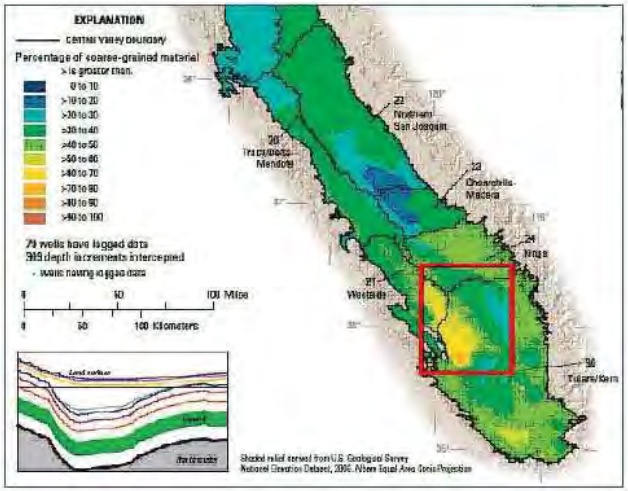
c. Corcoran Clay Depth interval



d. 100 foot depth interval immediately below Corcoran Clay



e. 200 foot depth interval from 400 to 700 feet bgs



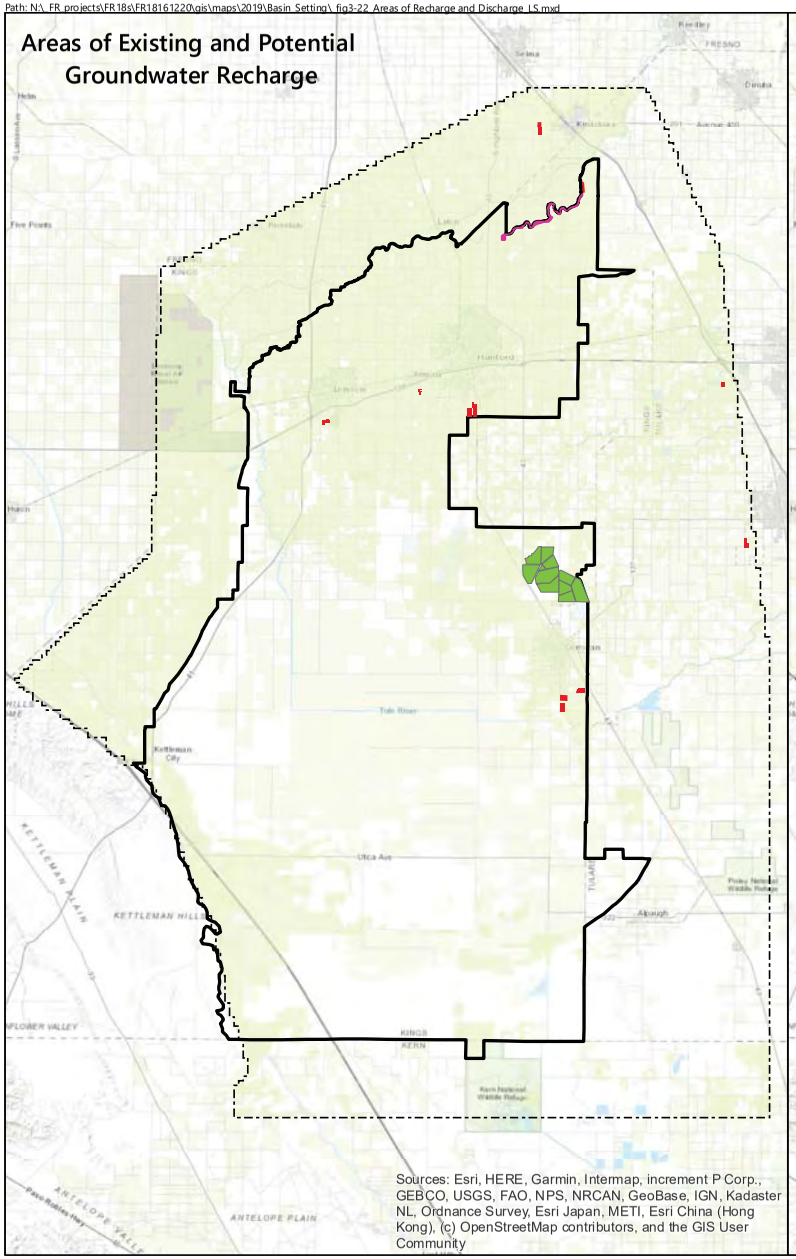
Tulare Lake Subbasin Hydrologic Model study area

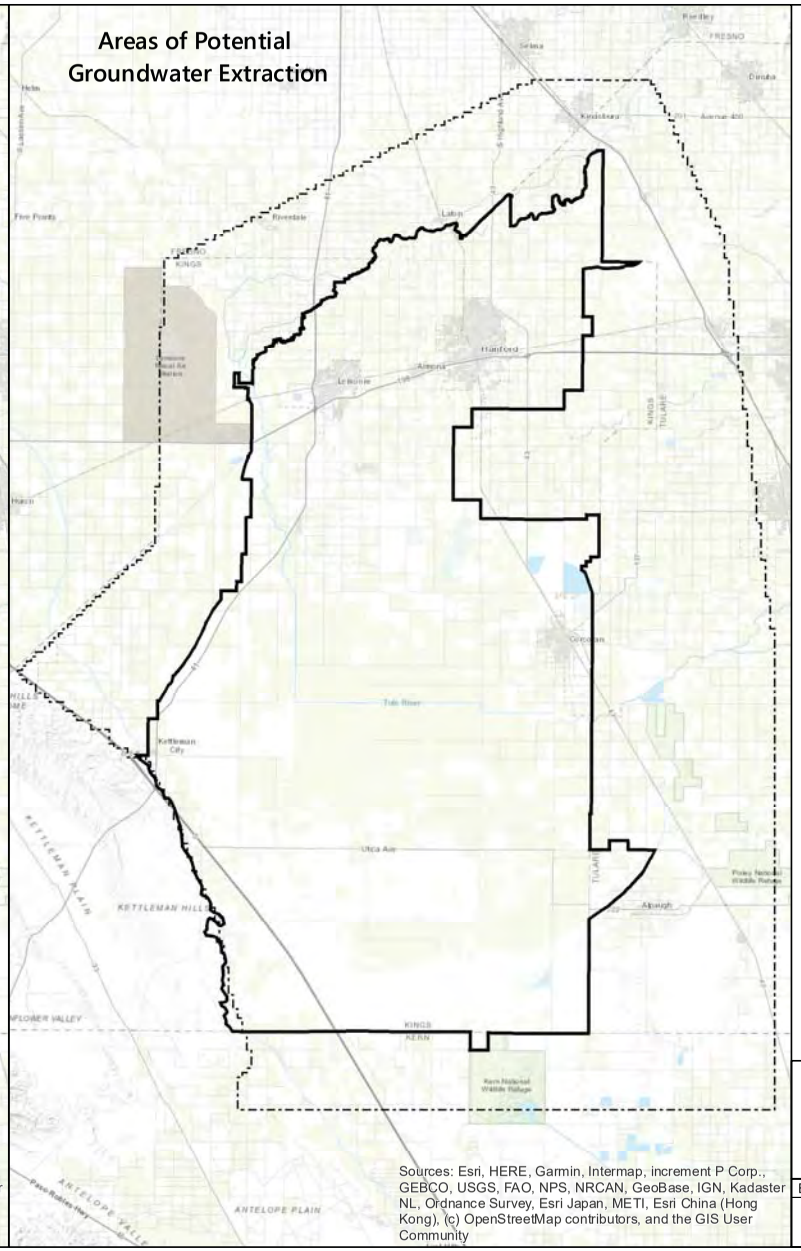
Kriged Distribution of Coarse Fraction for San Joaquin Valley Basin-Fill Sediments

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR16181220
		Figure **3-21**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting_fig3-22_Areas of Recharge and Discharge_LS.mxd





Explanation

- Study area
- Subbasin boundary
- Subsurface (tile) drained areas
- Area of potential groundwater extraction
- Stream and canal recharge
- Potential recharge area

Existing areas of intentional recharge

- Waste Water Treatment Ponds
- Corcoran Irrigation District ponds
- Old river/ APEX Ranch

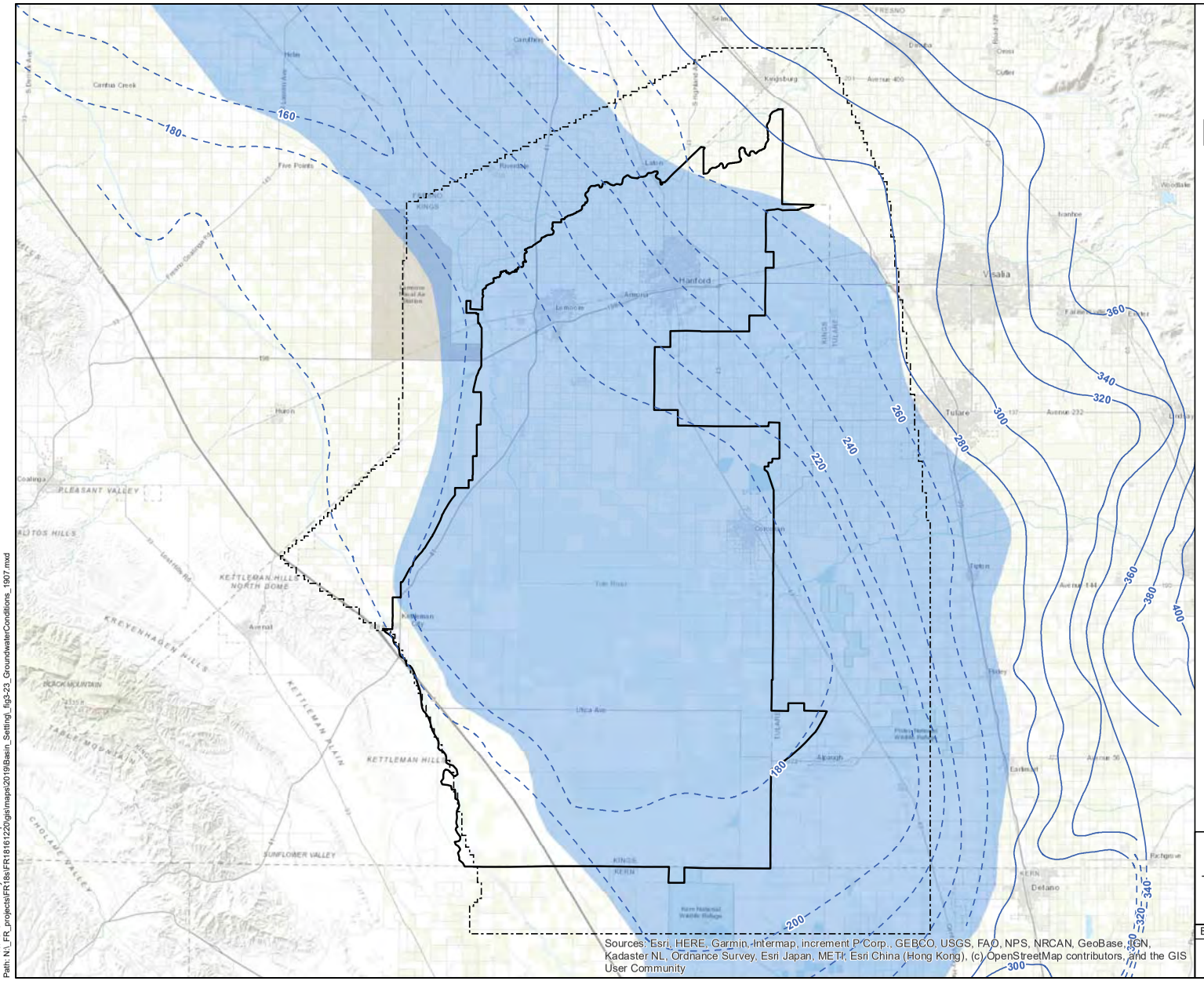
N

Approximate Scale in Feet
0 17,500 35,000 70,000

0 4,000 8,000 16,000
Approximate Scale in Meters

Areas of Existing and Potential Recharge and Extraction
Tulare Lake Subbasin Groundwater Sustainbility Plan
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure **3-22**



Explanation

- Areas of flowing wells
- Study area
- Subbasin boundary

20-ft groundwater elevation contours (fmsl)

- Certain
- Uncertain

Notes:
1) Map adapted from Mendenhall et al (1916), Plate 1.
2) Elevations in feet above mean sea level.

N

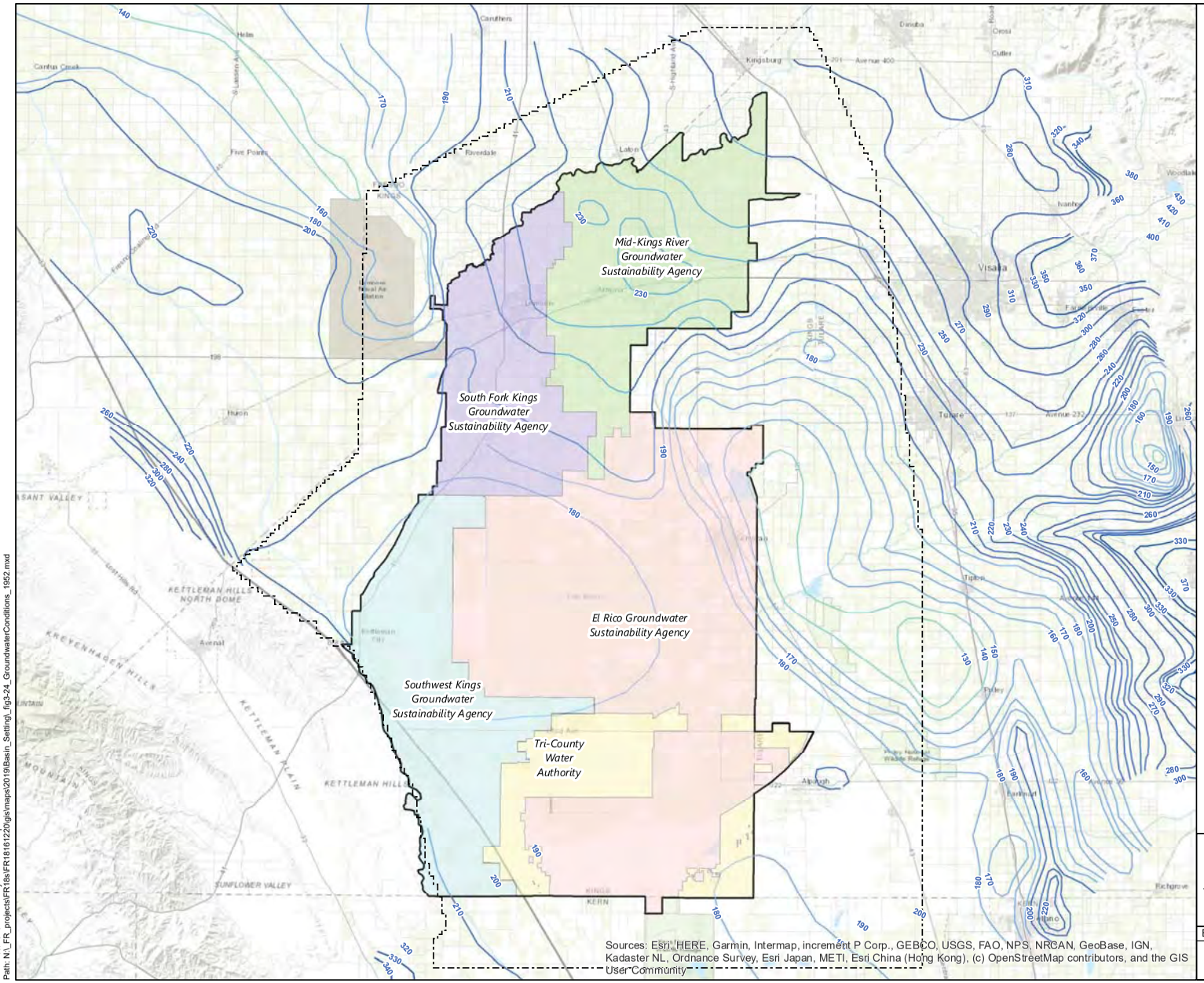
Miles
0 2.5 5 10

0 3 6 12
Kilometers

Area of Flowing Wells 1905-1907
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure **3-23**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18\161220\gis\maps\2019\Basin_Setting_fig3-23_GroundwaterConditions_1907.mxd



Explanation

- Study Area
- Subbasin boundary

10-ft groundwater elevation contours

- 100 - 150ft
- 150 - 200ft
- 210 - 250ft
- 260 - 300ft
- 310-450ft
- 460 - 500ft
- 510-580ft

Groundwater Sustainability Agencies (GSAs)

- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

N

Approximate Scale in Miles
0 2½ 5 10
0 2½ 5 10
Approximate Scale in Kilometers

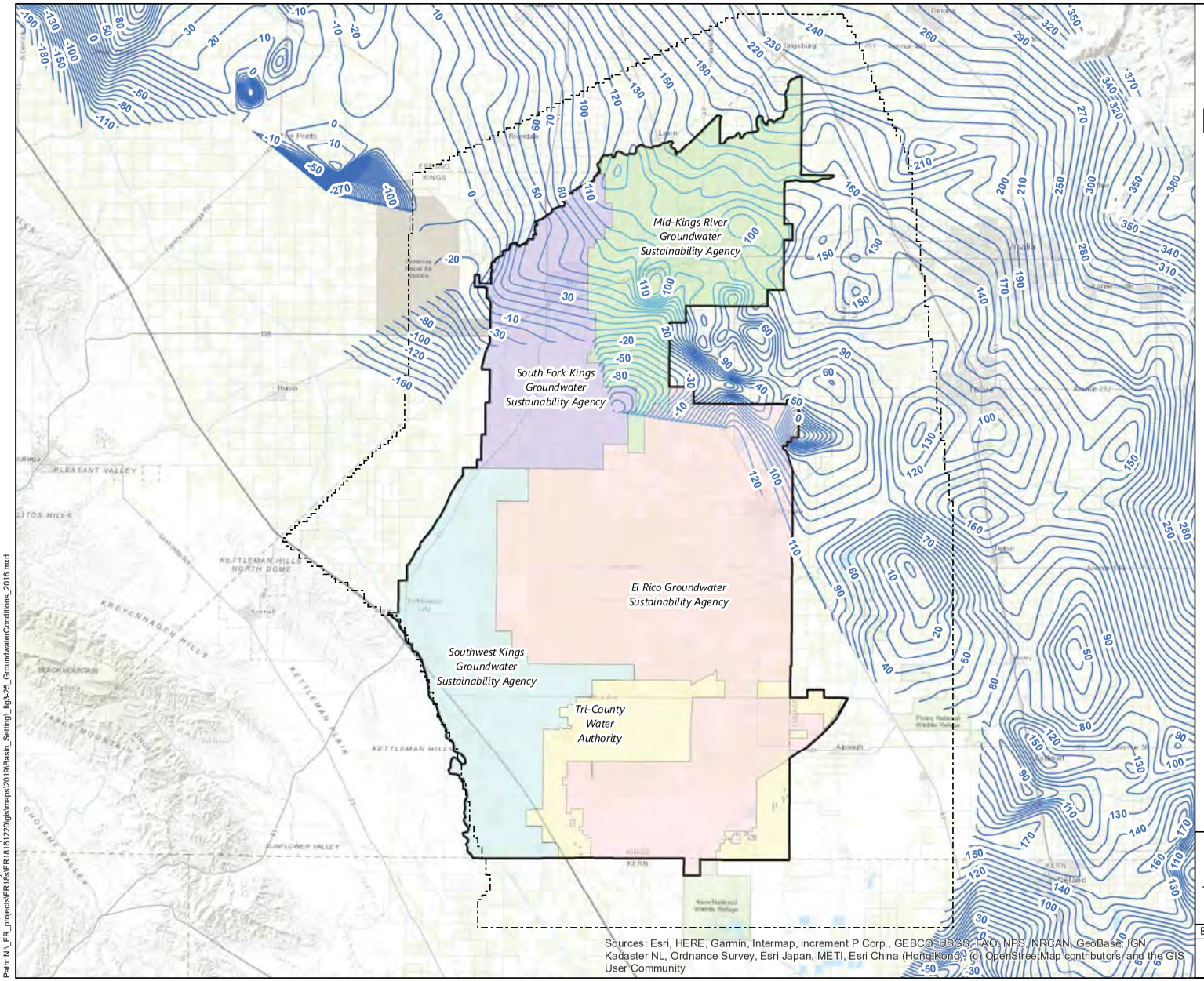
Notes:
1) Map adapted from Davis (1959), Plate 15.
2) Elevations in feet above mean sea level.

Map of Unconfined Groundwater Conditions1952

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure **3-24**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting_fig3-24_GroundwaterConditions_1952.mxd



Explanation

- 10-ft lines of equal groundwater elevation
- Study area
- Subbasin boundary

Groundwater Sustainability Areas (GSAs)

- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

N

Approximate Scale in Miles
0 2½ 5 10
0 2½ 5 10
Approximate Scale in Kilometers

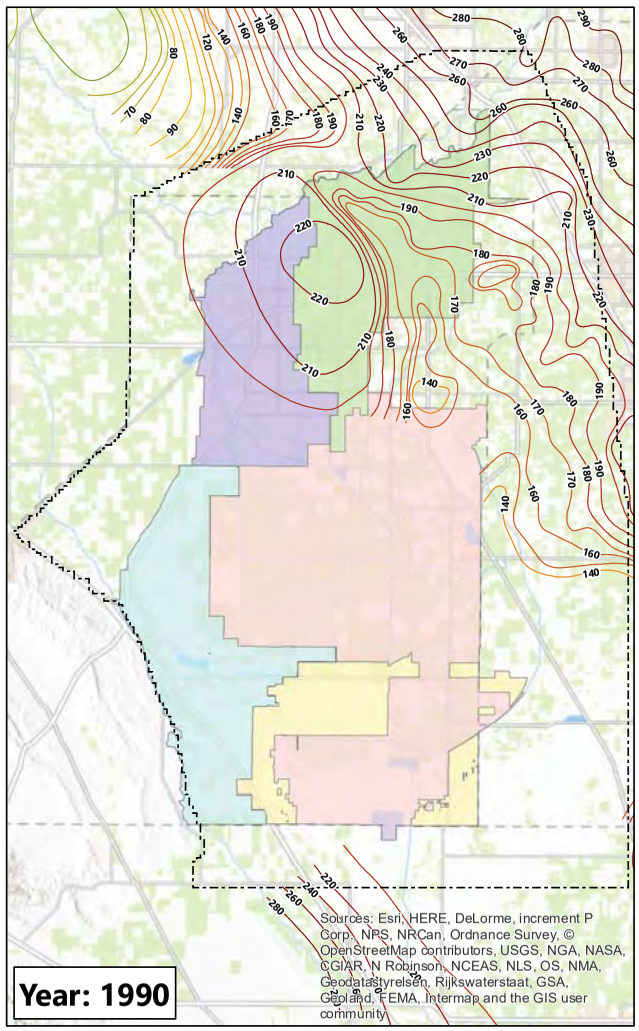
Notes:
1) Map adapted from DWR, June 2018.
2) Elevations in feet above mean sea level.

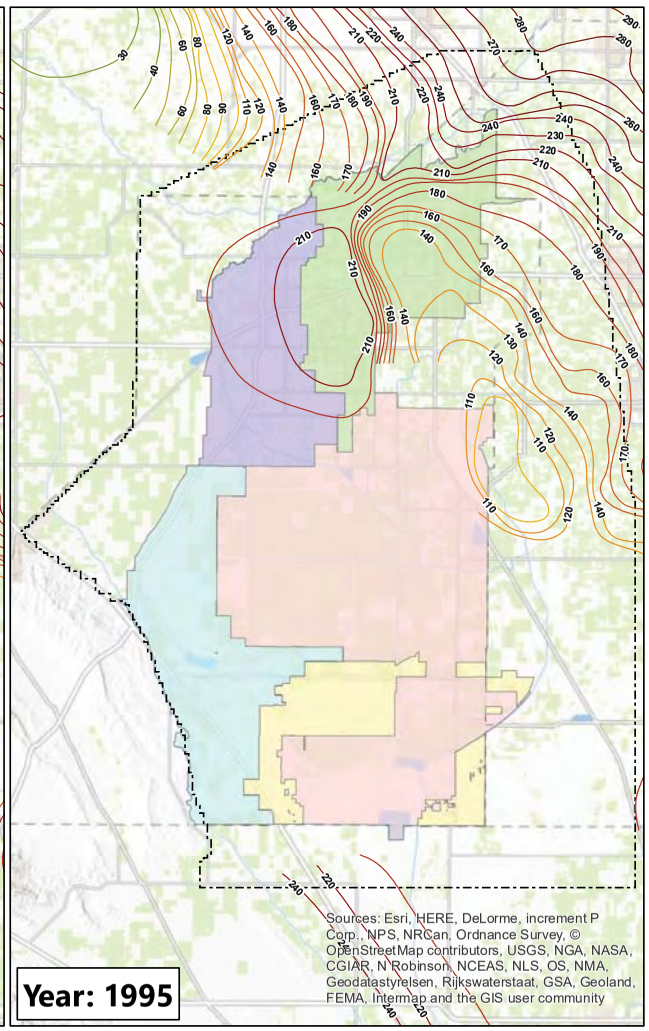
Map of Unconfined Groundwater Elevations 2016

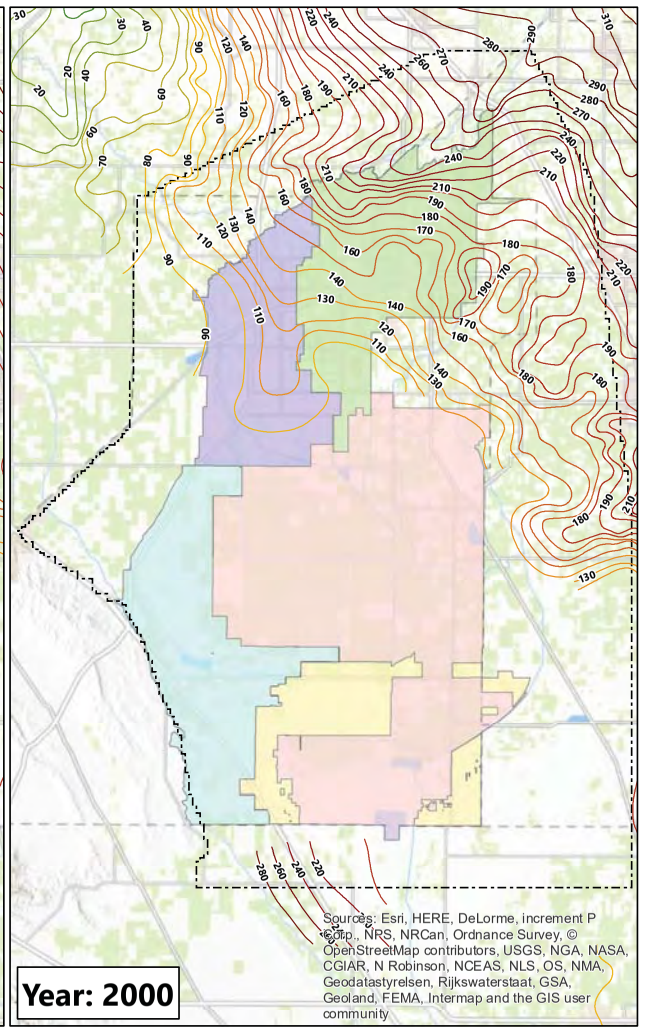
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/15/2019	Project No.: FR18161220
		Figure 3-25

Date: 11/15/2019 Printed by: shaina.price
Path: N:_FR_projects\FR18\FR18161220\gis\maps\2019\Basin_Setting_fig3-25_GroundwaterConditions_2016.mxd







Explanation

- Study area
- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

Groundwater elevation (FMSL)
-700
-350

APPROXIMATE SCALE IN MILES
0 5 10 20
0 5 10 20
APPROXIMATE SCALE IN KILOMETERS

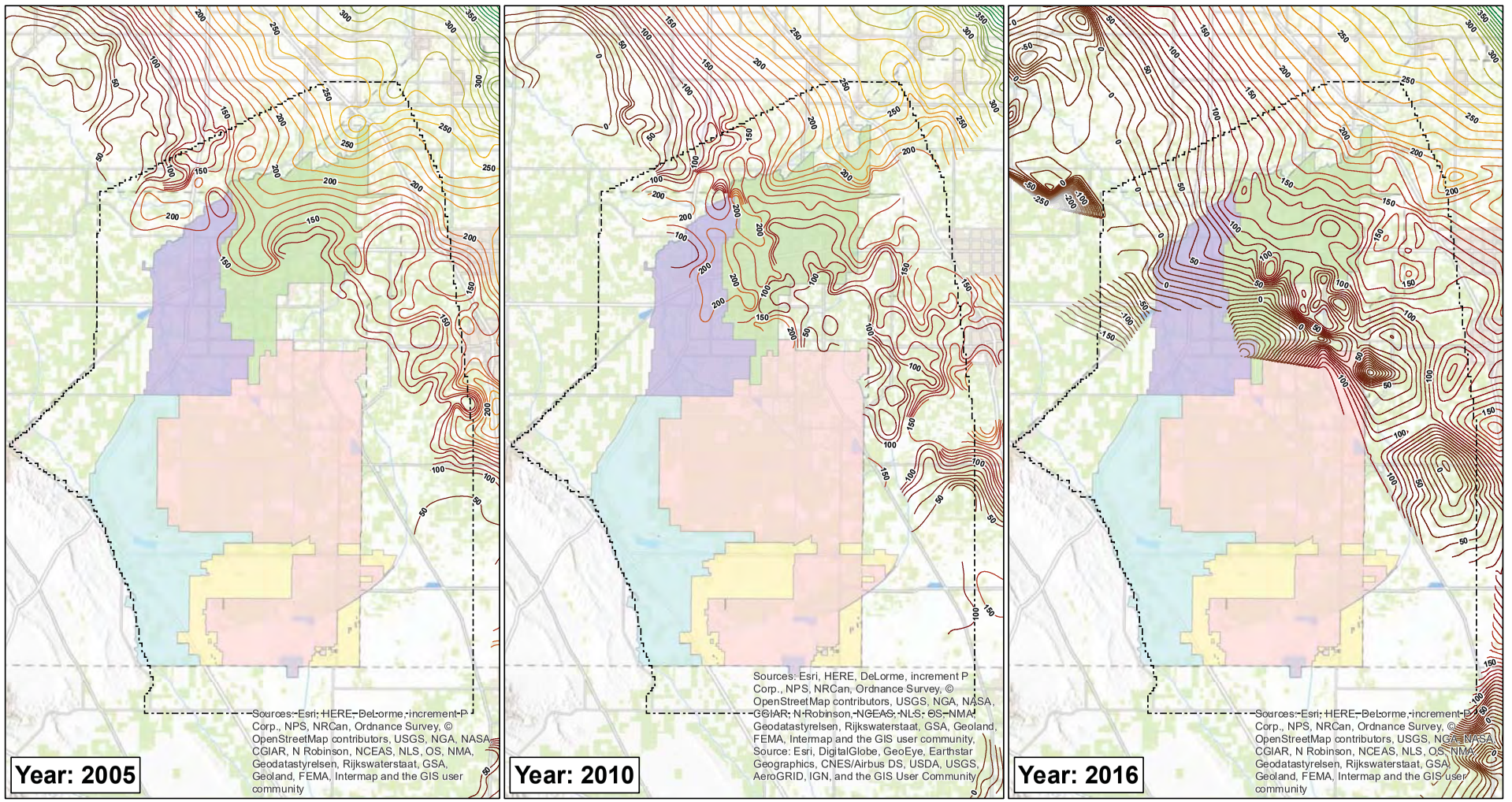
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Historical DWR Groundwater Elevation Maps Unconfined Aquifer

Tulare Lake Subbasin Hydrologic Model
Kings County, California

By: EMC	Date: 11/15/2019	Project No.: FR18161220
		Figure 3-26

Date: 11/15/2019 Printed by: shaina.price
Path: N:_FR_projects\FR18\FR18161220\gis\maps\2019\Basin_Setting_fig3-26_RecentGroundwaterConditions_1990_1995_2000.mxd



Explanation

- Study area
- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

Groundwater elevation (FMSL)

-700

-350

APPROXIMATE SCALE IN MILES

0 5 10 20

0 5 10 20

APPROXIMATE SCALE IN KILOMETERS

N

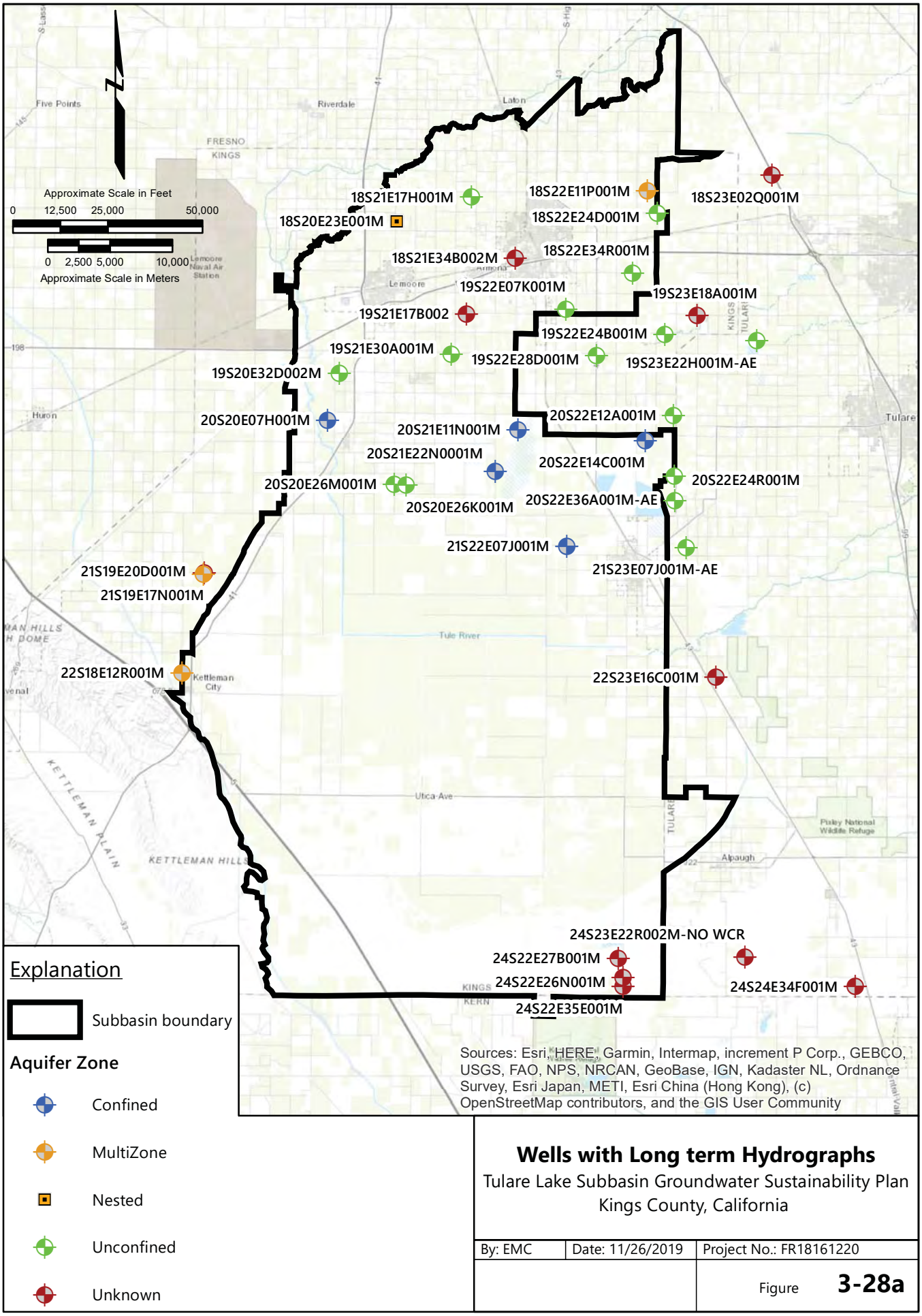
NOTE:
1) Groundwater elevation data obtained from California Department of Water Resources (CA DWR), June 2018: https://databasin.org/datasets/b05820cda86b4921a515065fa1deffcc
2) FMSL = Feet above mean sea level.

Historical DWR Groundwater Elevation Maps, Unconfined Aquifer

Tulare Lake Subbasin Hydrologic Model
Kings County, California

By: EMC	Date: 11/15/2019	Project No.: FR18161220
		Figure 3-27

Date: 11/15/2019 Printed by: shaina.price
Path: N:_FR_projects\FR18\FR18161220\gis\maps\2019\Basin_Setting_fig3-27_RecentGroundwaterConditions_2005_2010_2016.mxd



Explanation

Subbasin boundary

Aquifer Zone

- Confined
- MultiZone
- Nested
- Unconfined
- Unknown

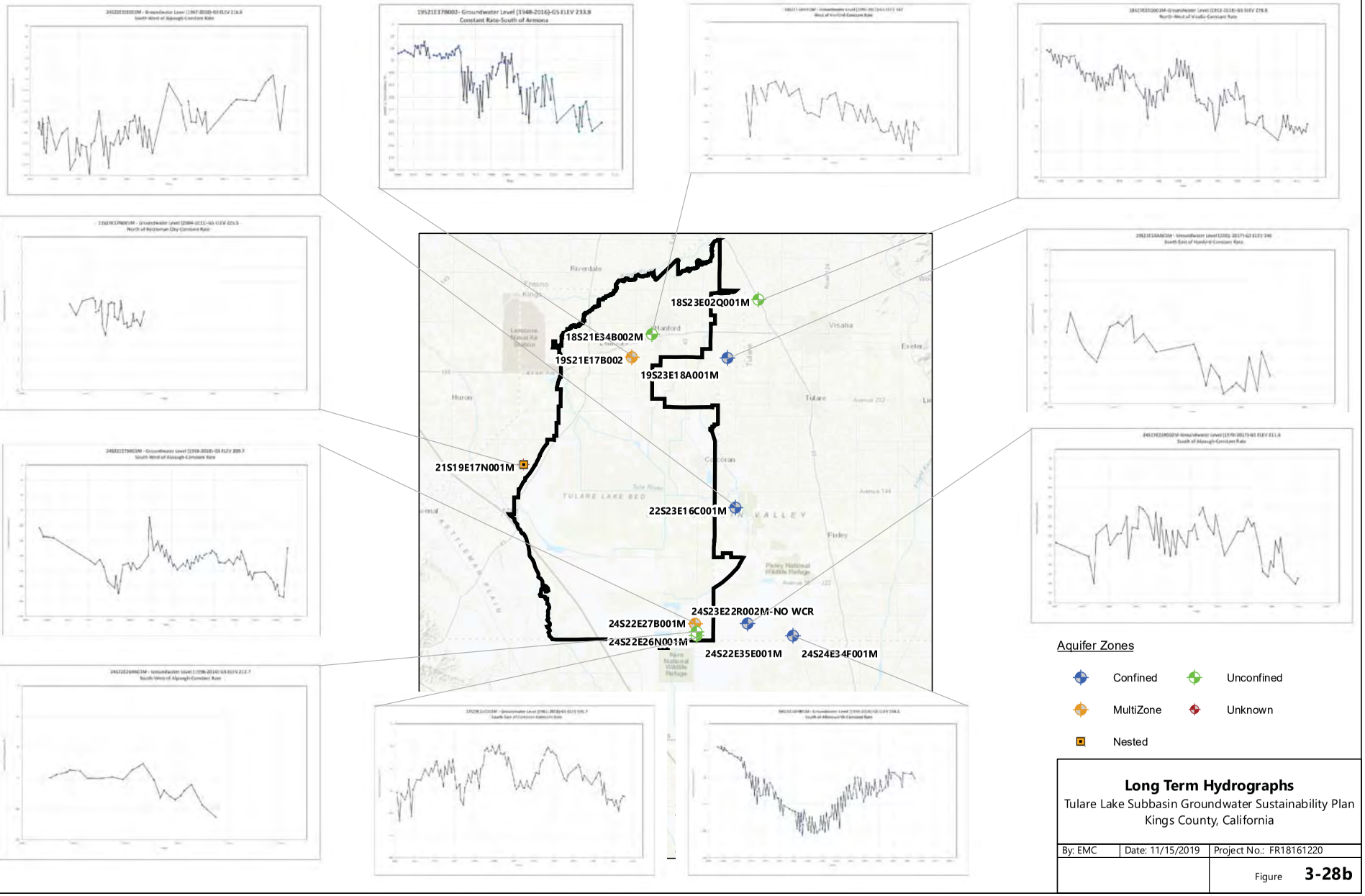
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Wells with Long term Hydrographs

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/26/2019	Project No.: FR18161220
		Figure **3-28a**

Date: 11/26/2019 Printed by: elizabeth.chapman
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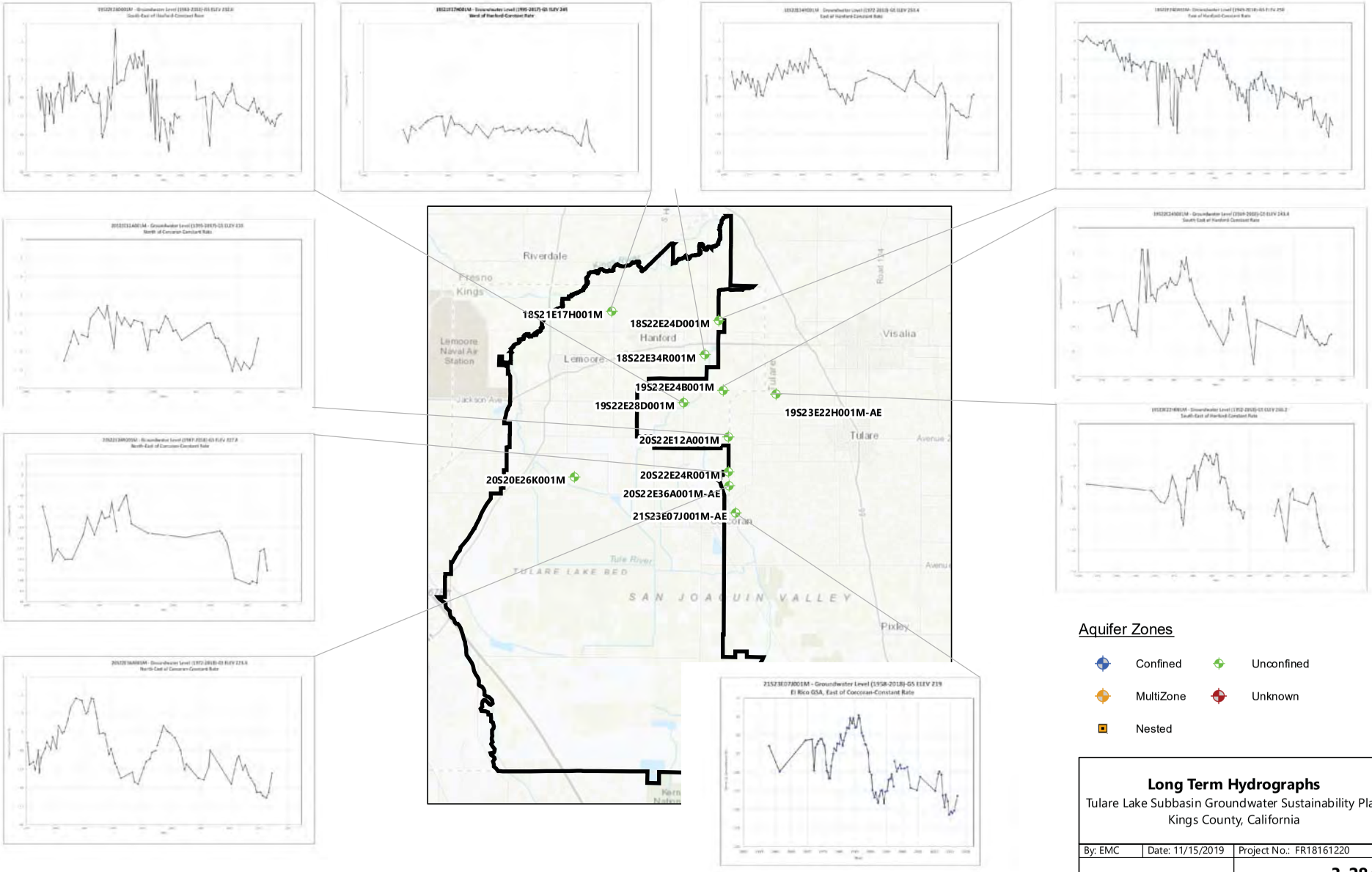


Long Term Hydrographs

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/15/2019	Project No.: FR18161220
		Figure **3-28b**

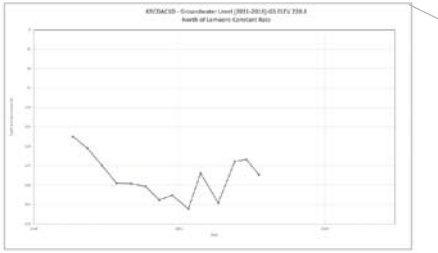
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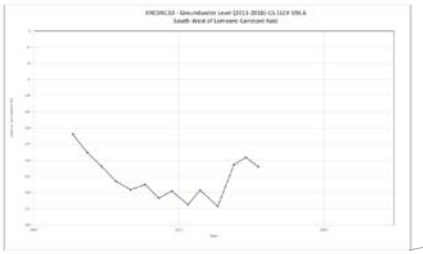


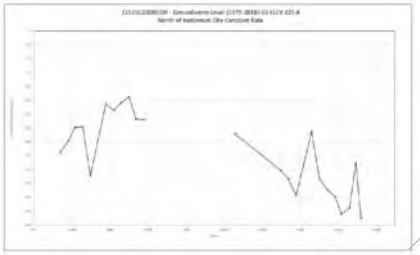
Long Term Hydrographs
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

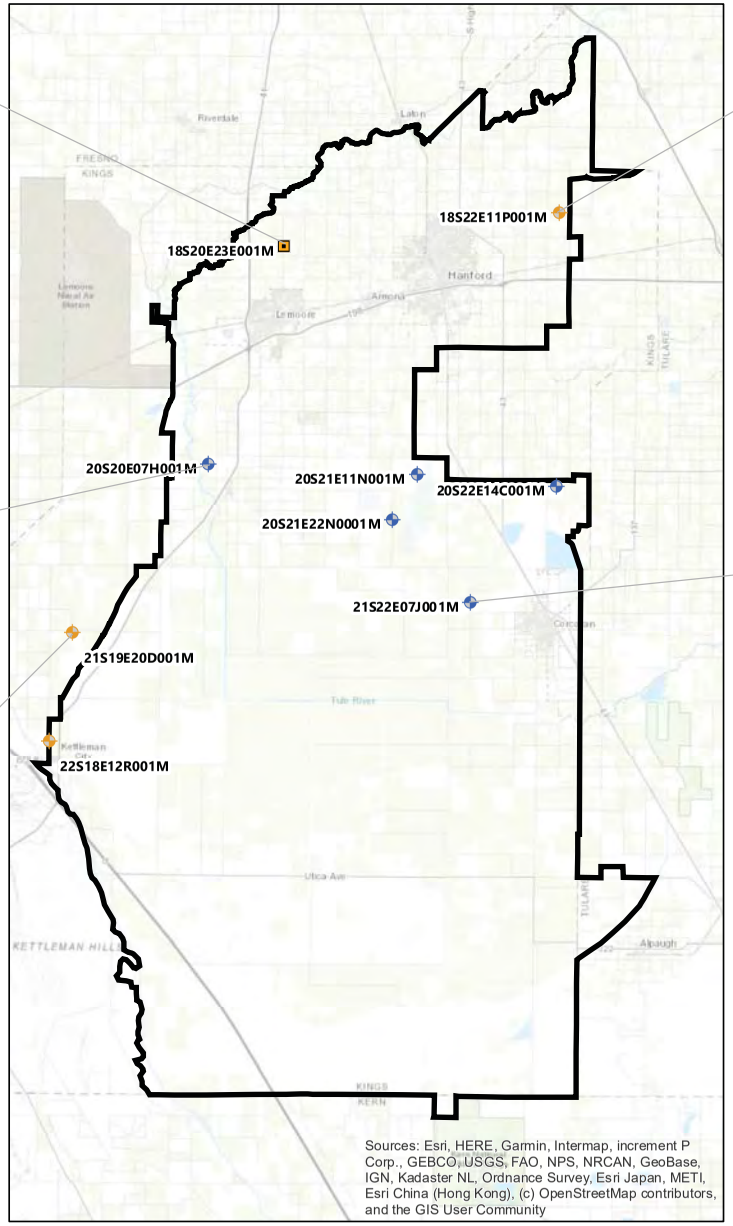
By: EMC	Date: 11/15/2019	Project No.: FR18161220
		Figure **3-28c**

Date: 11/15/2019 Printed by: shaina.price
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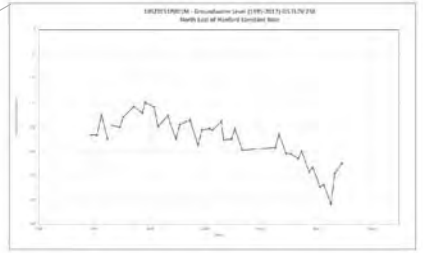


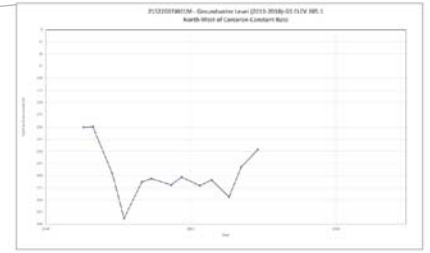






Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community





Aquifer Zones

- Confined
- Unconfined
- MultiZone
- Unknown
- Nested

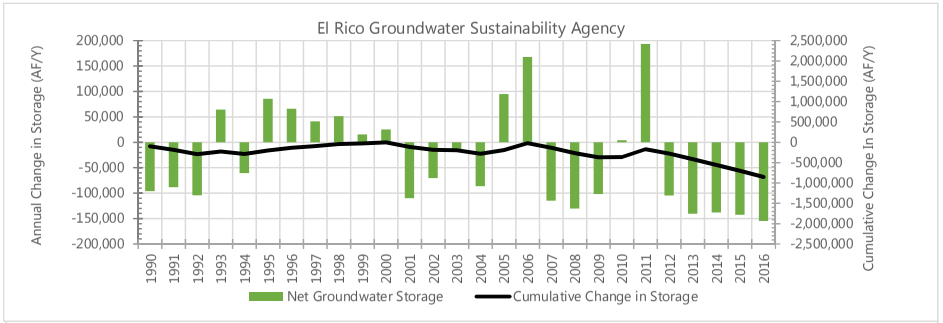
Long Term Hydrographs

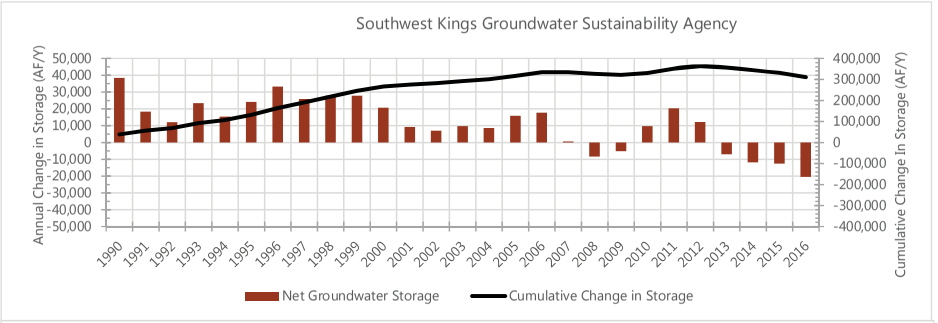
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

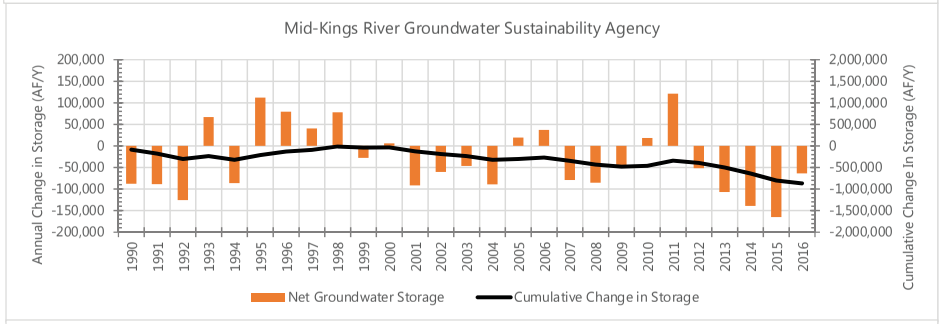
By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure **3-28d**

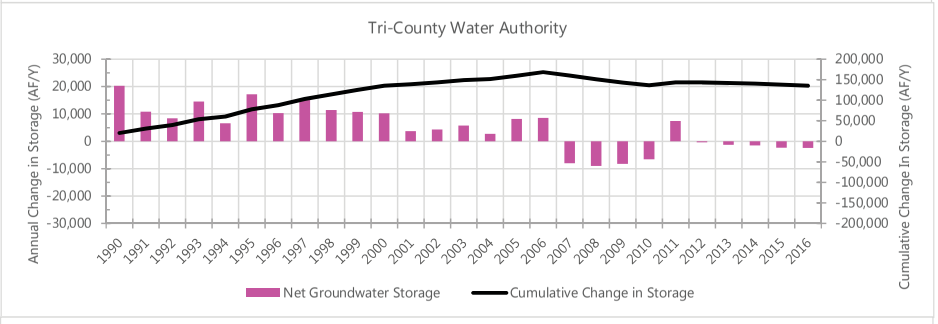
Date: 1/9/2020 Printed by: elizabeth.chapman
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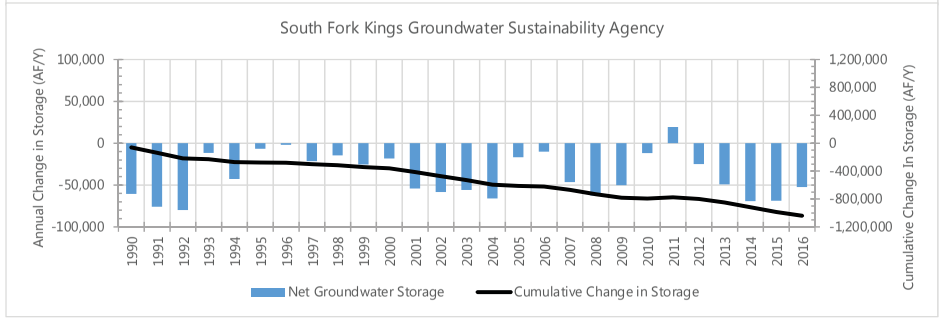
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\3-BasinSetting\Figures\DAVES FOLDER\GSPFigures 3-29_3-53_120619.xlsmFigure 3-29a 1/8/2020

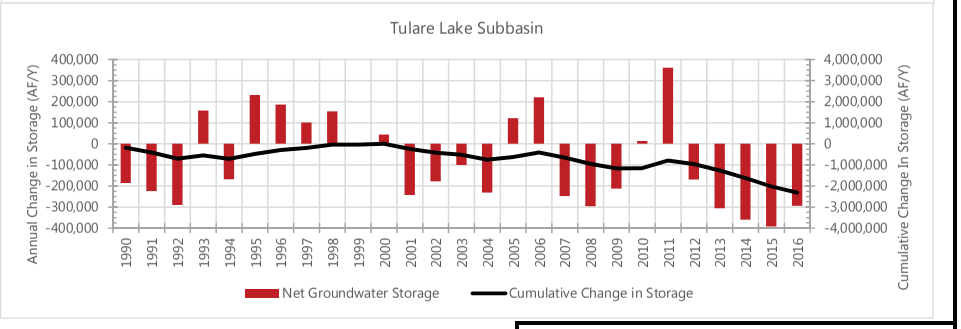










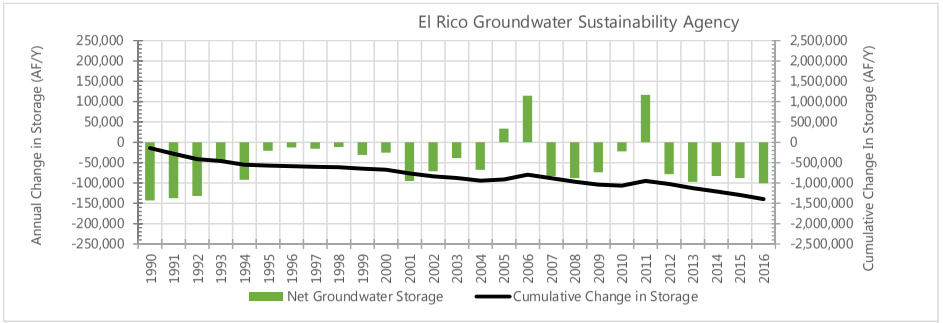


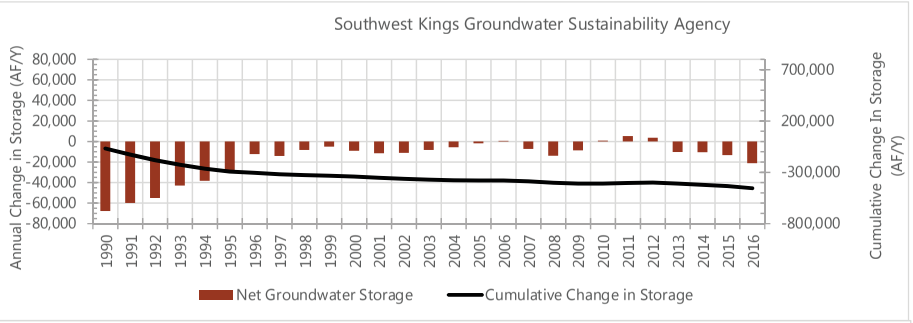
Notes:
1. AF/Y = acre-feet per year

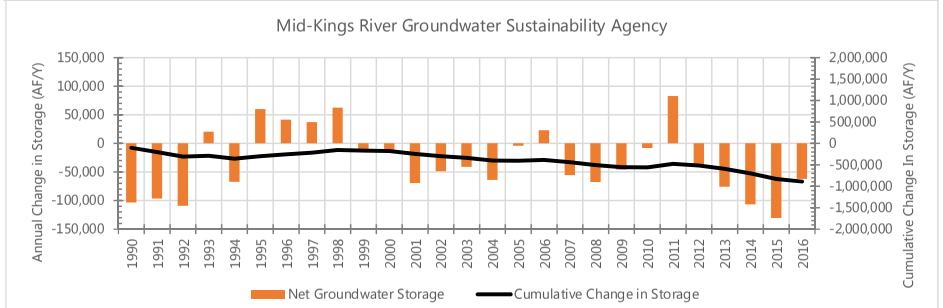
Change in Groundwater Storage
All Aquifer Zones 1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

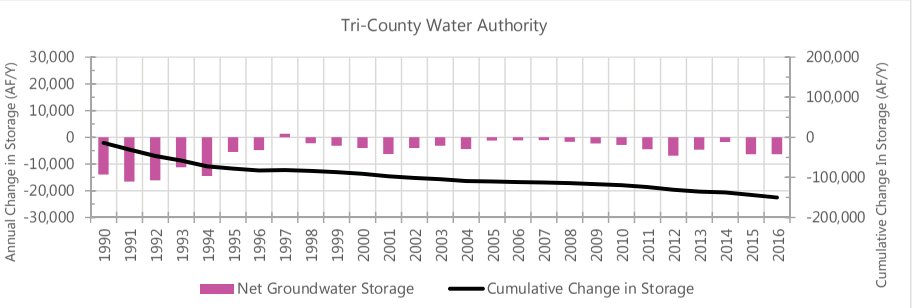
By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure: 3-29a

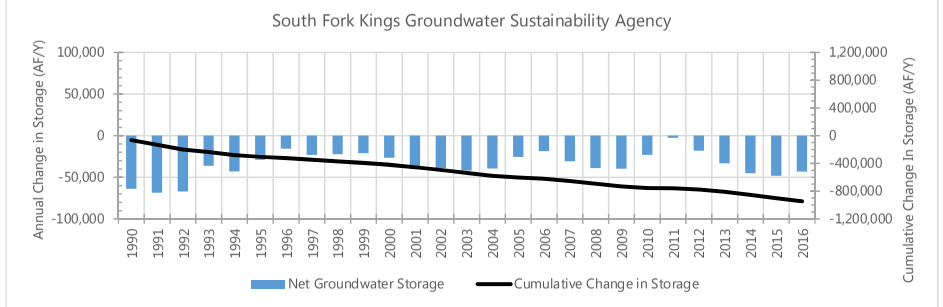
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\3-BasinSetting\Figures\DAVES FOLDER\GSPFigures 3-29_3-53_120619.xlsmFigure 3-29b 1/8/2020

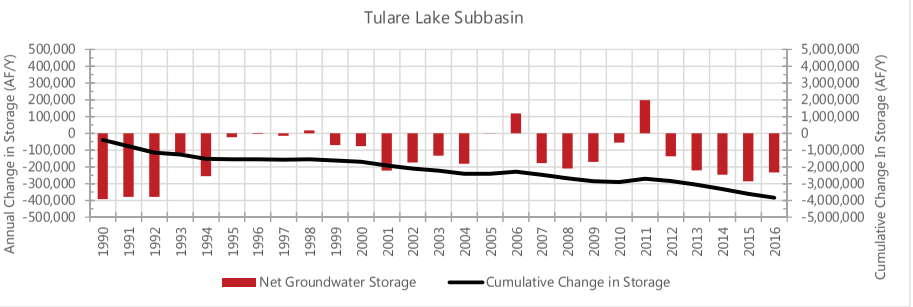










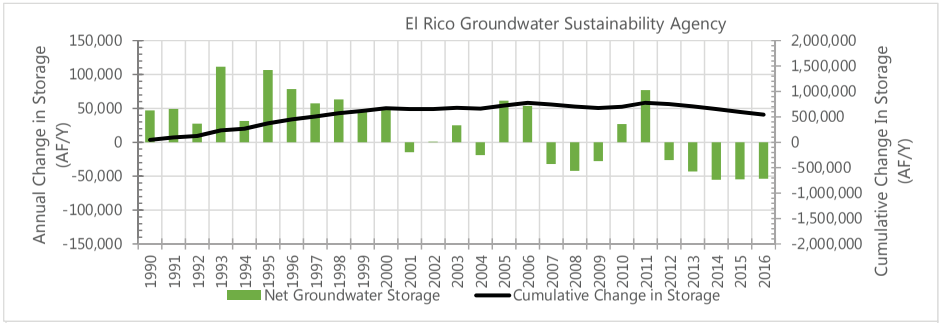


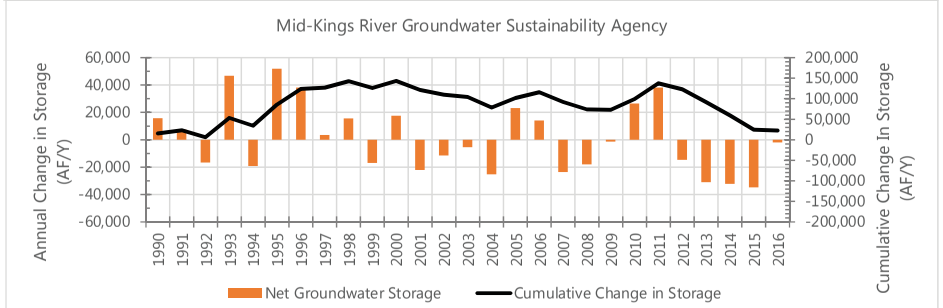
Notes:
1. AF/Y = acre-feet per year

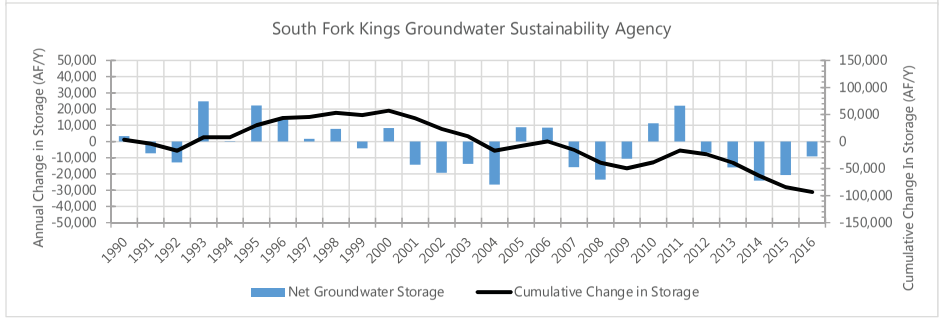
Change in Groundwater Storage
Upper Aquifer Zone 1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

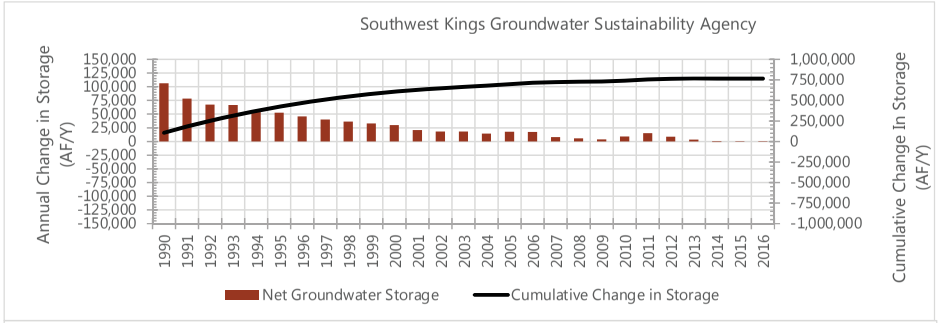
By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure: 3-29b

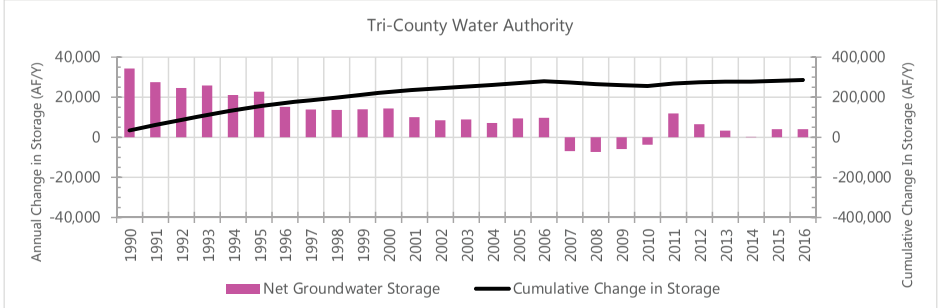
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\3-BasinSetting\Figures\DAVES FOLDER\GSPFigures 3-29_3-53_120619.xlsmFigure 3-29c 1/8/2020

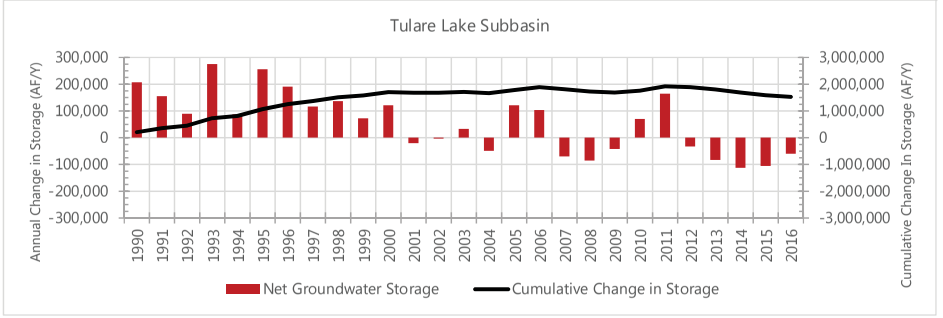








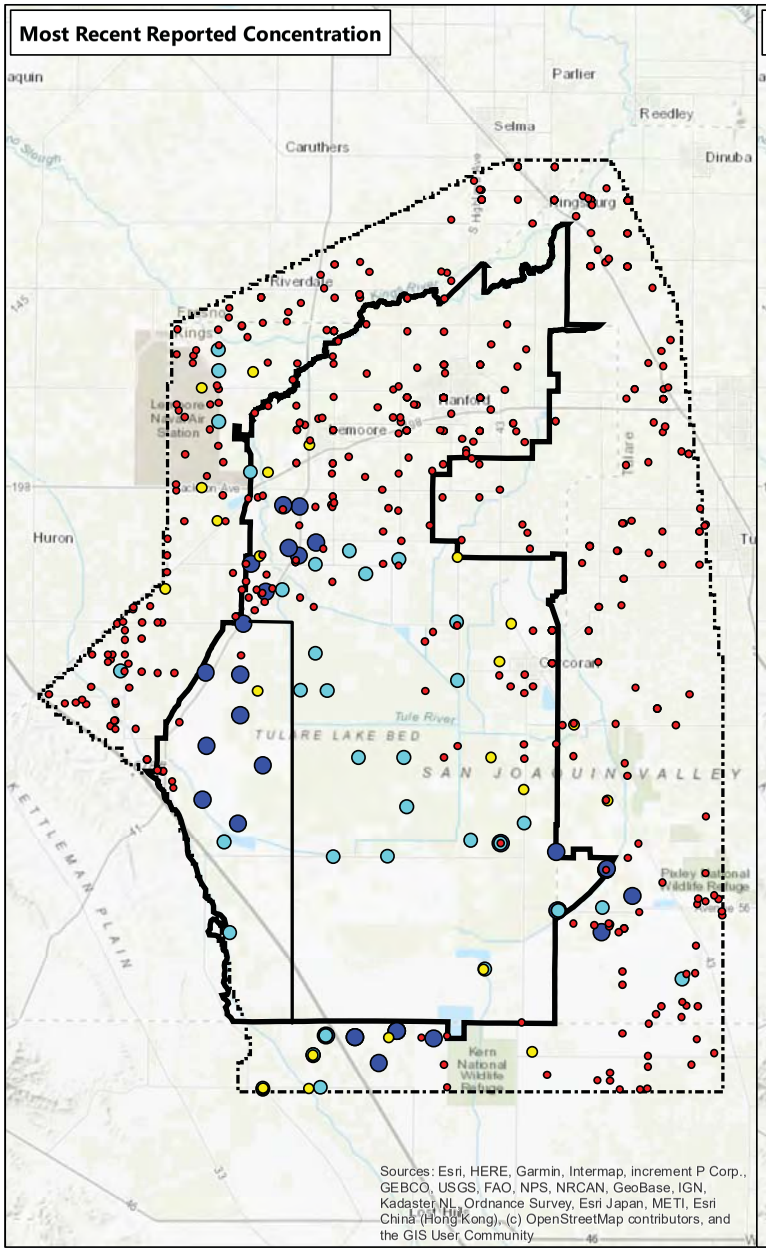


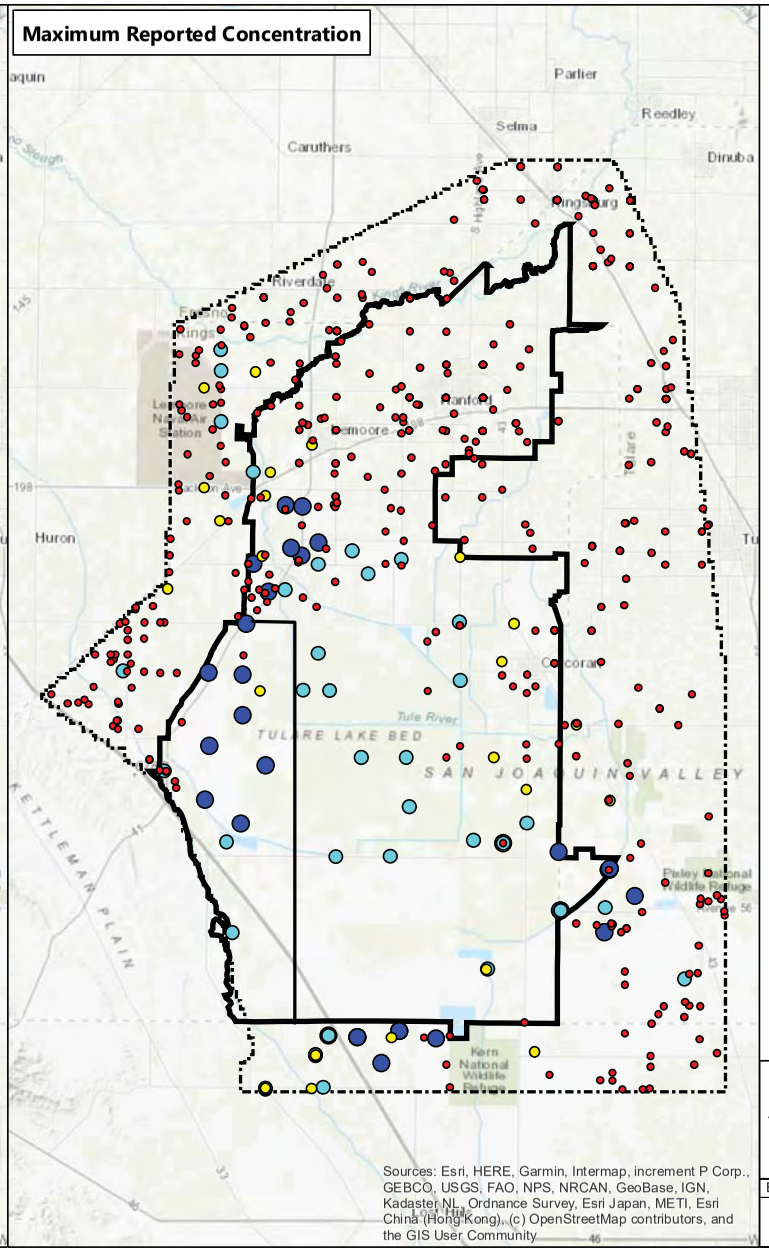


Notes:
1. AF/Y = acre-feet per year

Change in Groundwater Storage
Lower Aquifer Zone 1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure: 3-29c





Explanation

- <1,500 mg/L
- 1,500 - 3,000 mg/L
- 3,000 - 10,000 mg/L
- >10,000 mg/L
- Study Area
- Subbasin boundary

Notes:

1) Data compiled from California Water Boards Geotracker. November 2018: https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/Default.asp

N

Approximate Scale in Miles

0 5 10 20

0 5 10 20

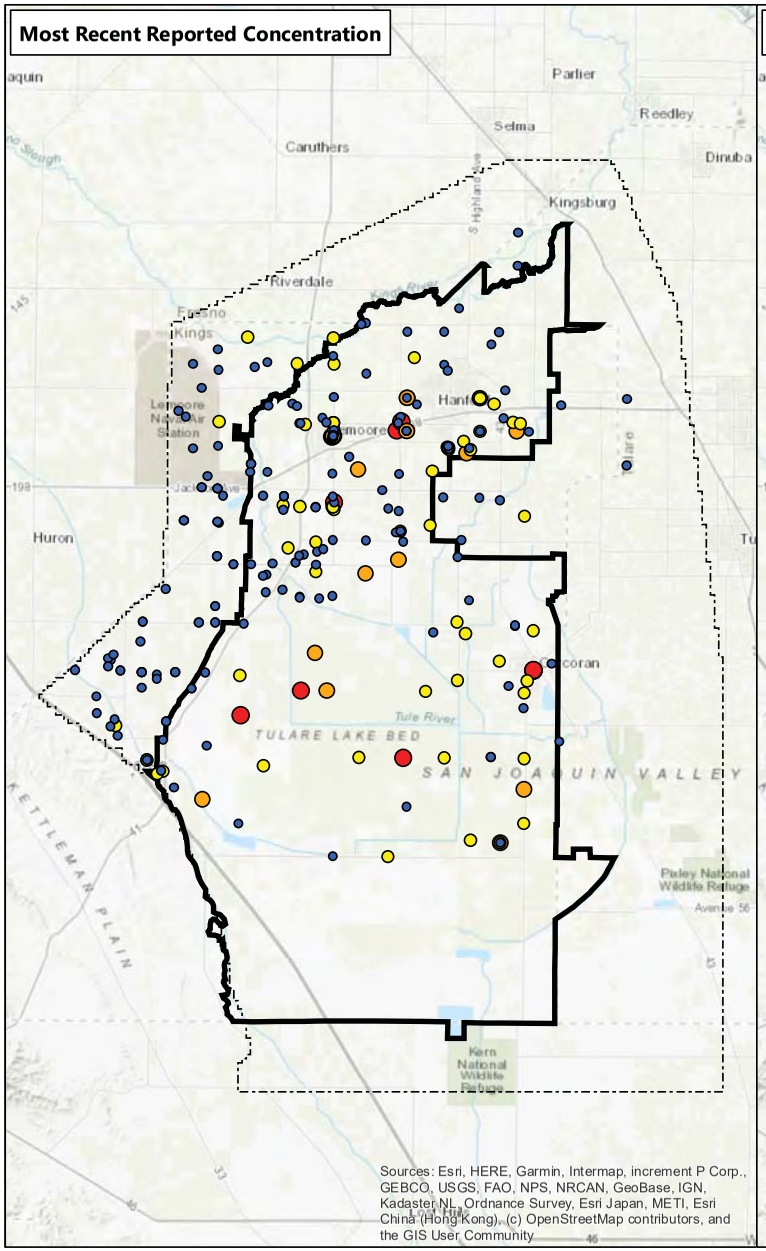
Approximate Scale in Kilometers

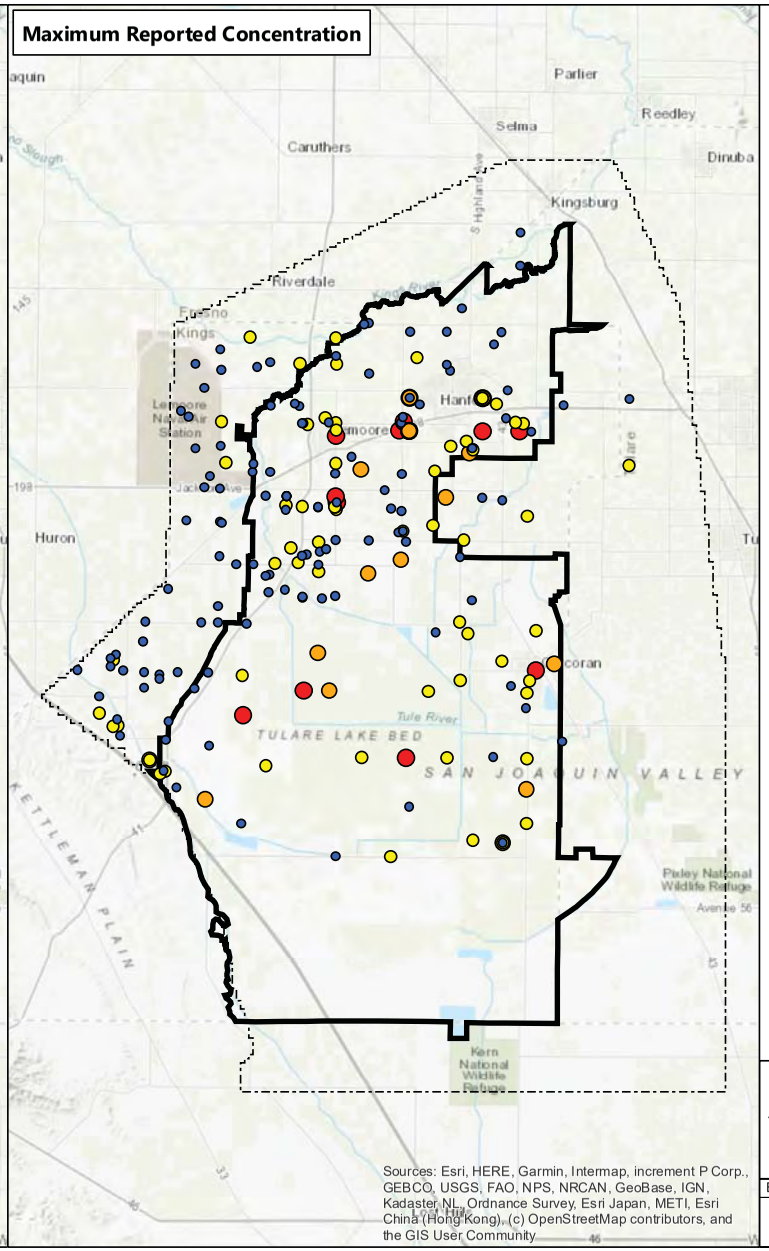
Total Dissolved Solids in Groundwater

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: SCM	Date: 1/9/2020	Project No.: FR16181220
		Figure **3-30**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PA_projects\FR\BS\FR16181220\gis\maps\2019\Basin_Setting_fig3-30_Total_Dissolved_Solids_NEW.mxd





Explanation

- <10 µg/L
- 10.01 - 50.0 µg/L
- 50.1 - 100.0 µg/L
- >100 µg/L
- Study Area
- Subbasin boundary

Notes:

1) Data compiled from California Water Boards. November 2018: https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/Default.asp

N

Approximate Scale in Miles

0 5 10 20

0 5 10 20

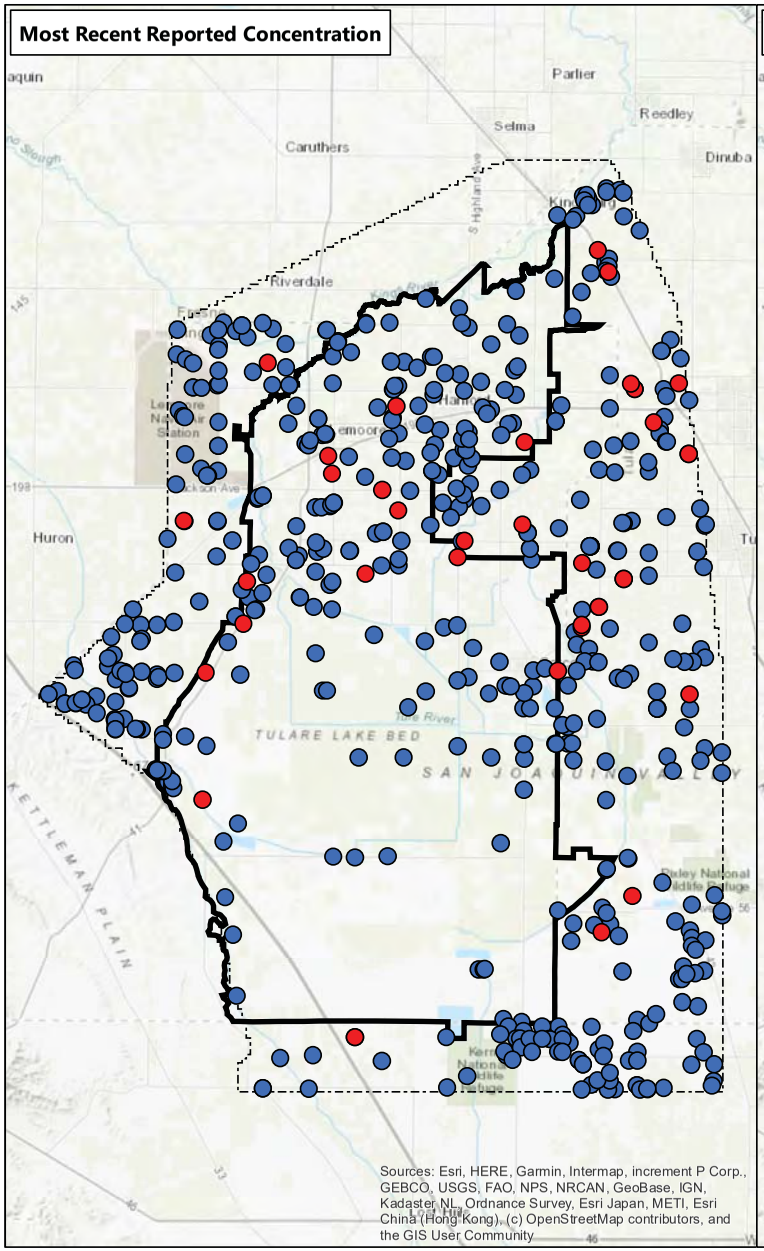
Approximate Scale in Kilometers

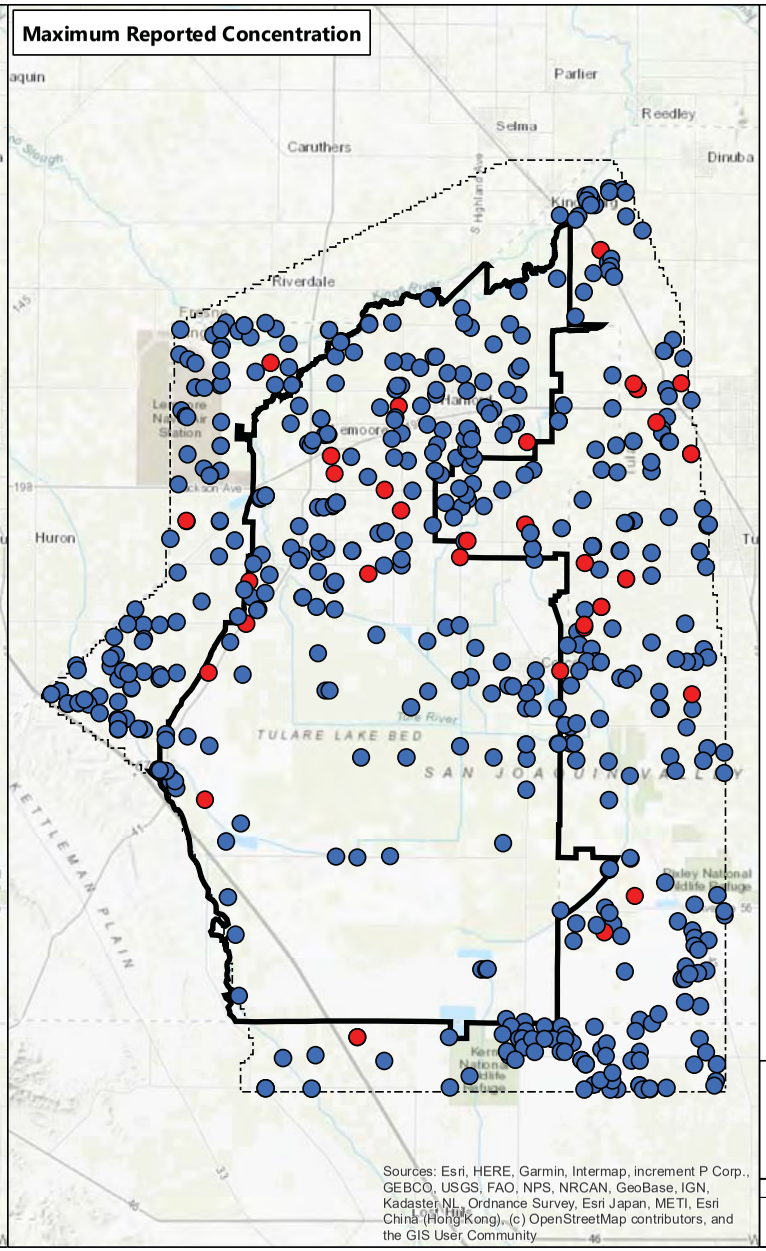
Arsenic in Groundwater

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: SCM	Date: 1/9/2020	Project No.: FR16181220
		Figure **3-31**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PROJECTS\FR\BAS\FR16181220\gis\maps\2019\Basin_Setting_fig3-31_Arsenic_in_Groundwater_NEW.mxd





Explanation

- <10 mg/L
- >10 mg/L
- Study Area
- Subbasin boundary

Notes:

1) Data compiled from California Water Boards. November 2018: https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/Default.asp

N

Approximate Scale in Miles

0 5 10 20

0 5 10 20

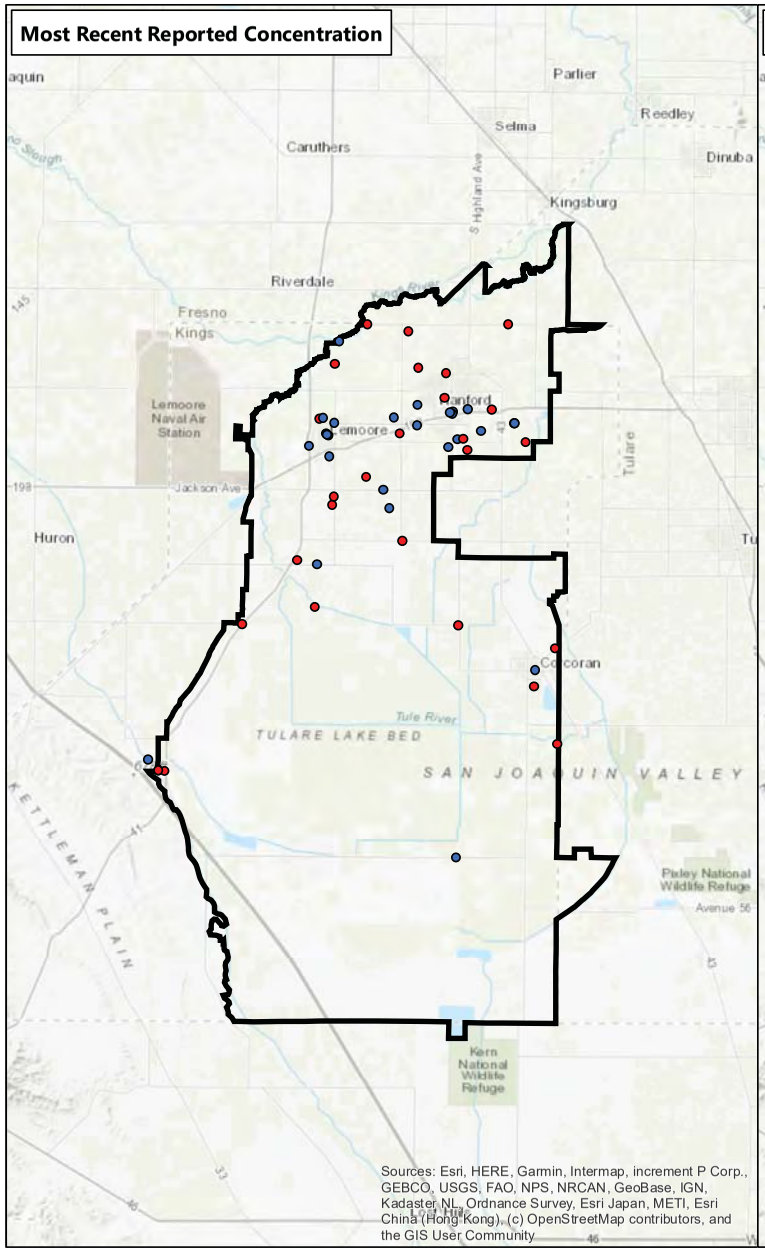
Approximate Scale in Kilometers

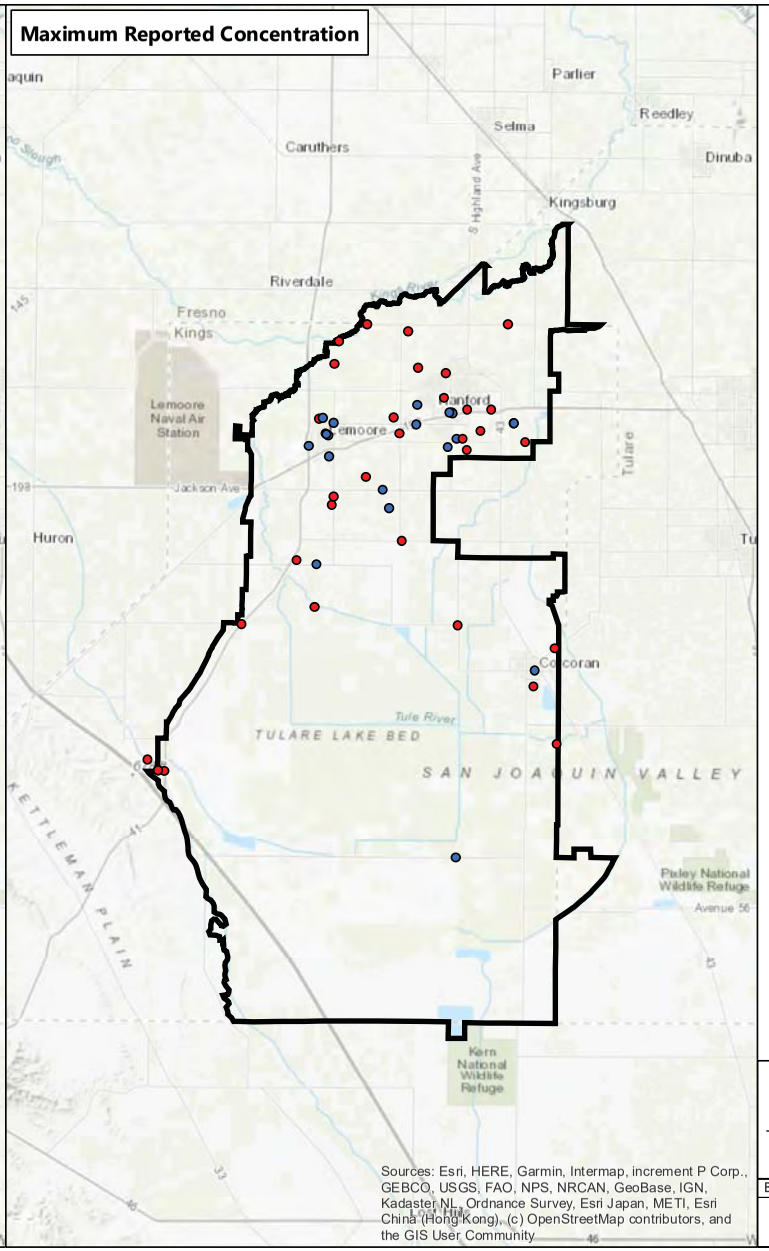
Nitrate in Groundwater

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: SCM	Date: 1/9/2020	Project No.: FR16181220
		Figure **3-32**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PA_projects\FR\BS\FR16181220\gis\maps\2019\Basin_Setting_fig3-32_Nitrate_in_Groundwater_NEW.mxd





Explanation

1,2,3-TCP

- <0.005
- >0.005
- Subbasin boundary

Notes:

1) Data compiled from California Water Boards. November 2018: https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/Default.asp

N

Approximate Scale in Miles

0 5 10 20

0 5 10 20

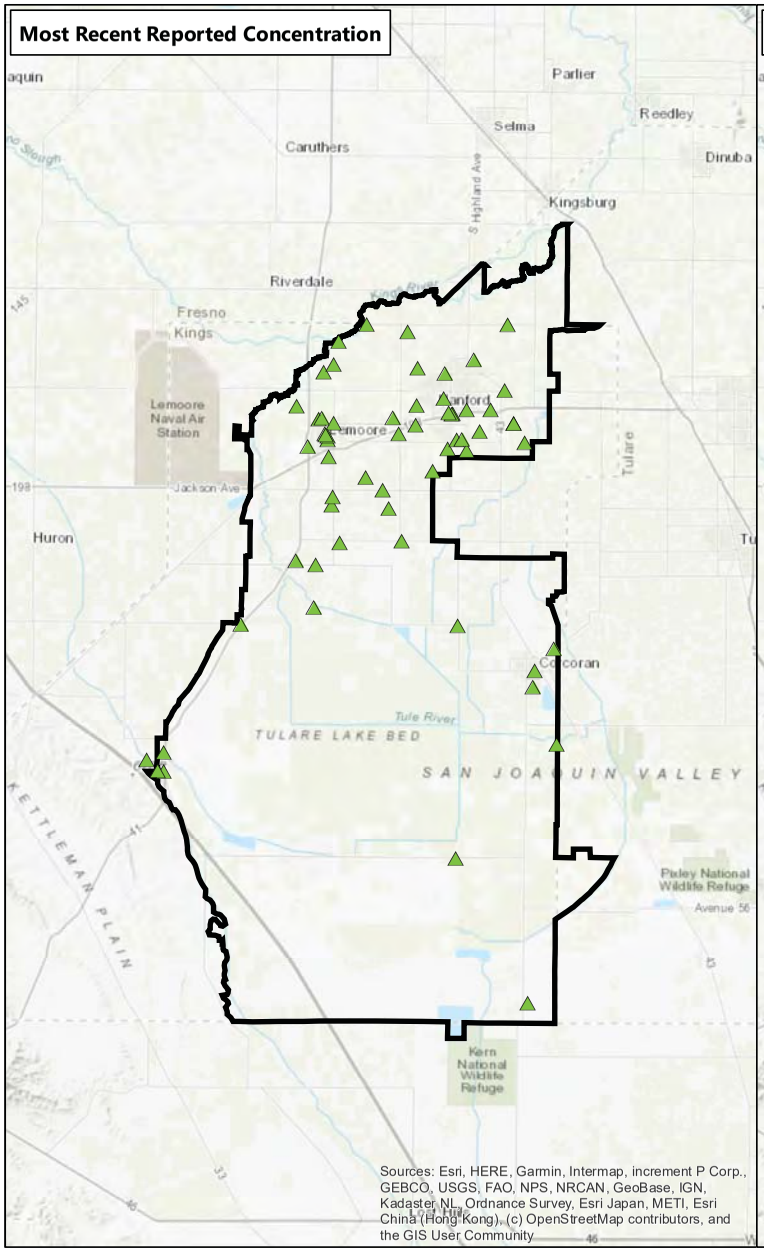
Approximate Scale in Kilometers

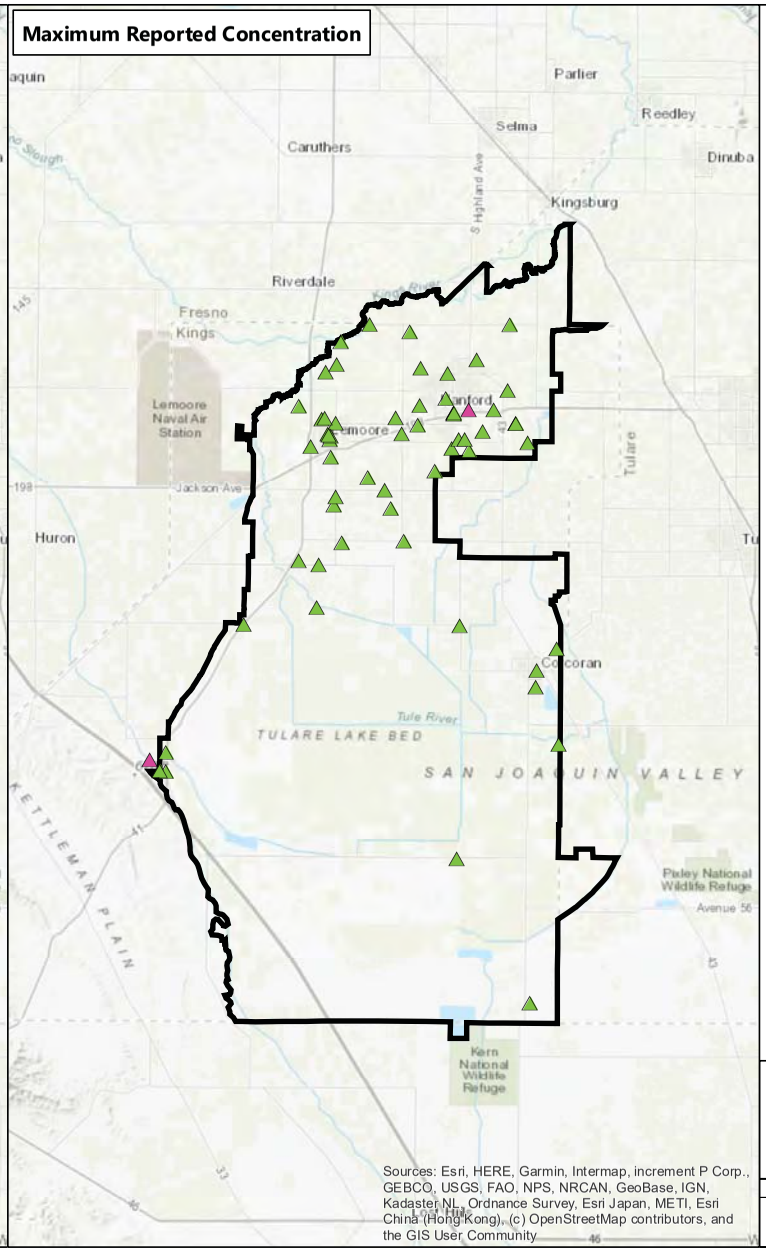
Volatile Organic Compounds in Groundwater

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: SCM	Date: 1/9/2020	Project No.: FR16181220
		Figure **3-33a**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PR_projects\FR\BS\FR16181220\gis\maps\2019\Basin_Setting_fig3-33_VOCs_in_Groundwater_NEW.mxd





Explanation

DBCP

- <0.20 µg/L
- >0.21 µg/L
- Subbasin boundary

Notes:

1) Data compiled from California Water Boards. November 2018: https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/Default.asp

N

Approximate Scale in Miles

0 5 10 20

0 5 10 20

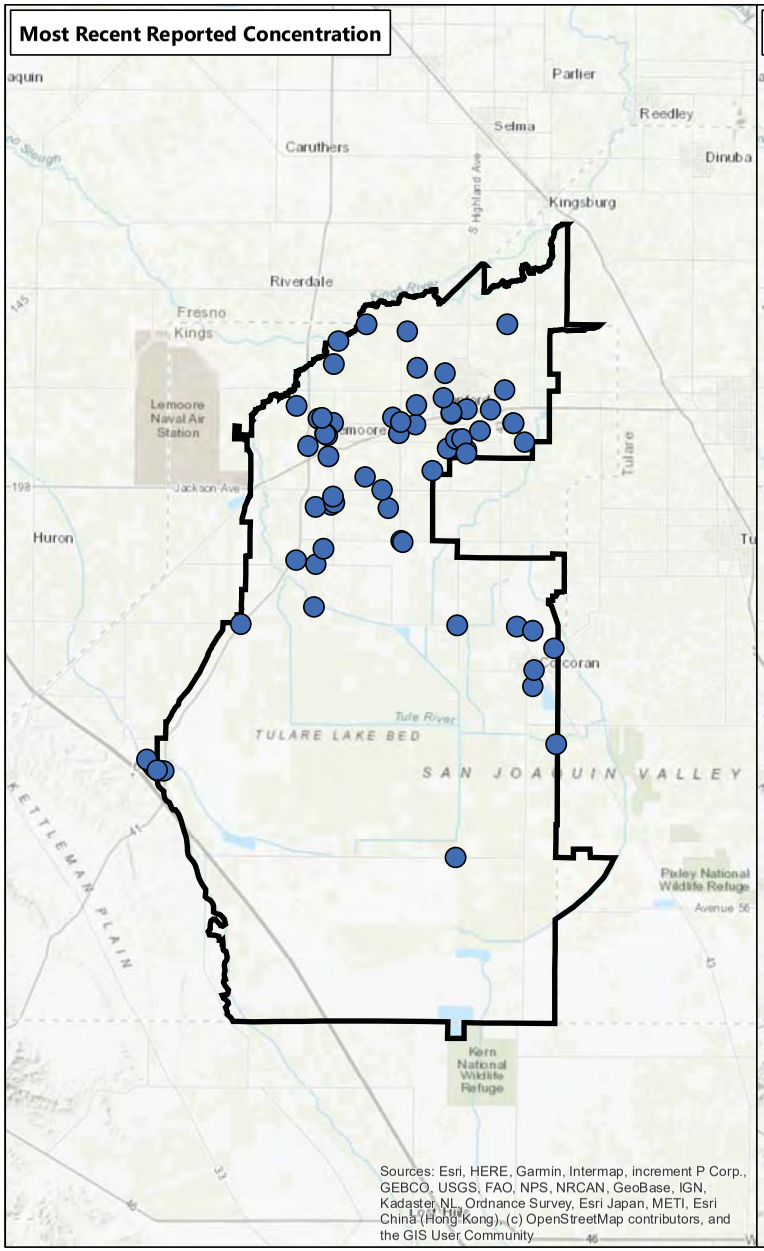
Approximate Scale in Kilometers

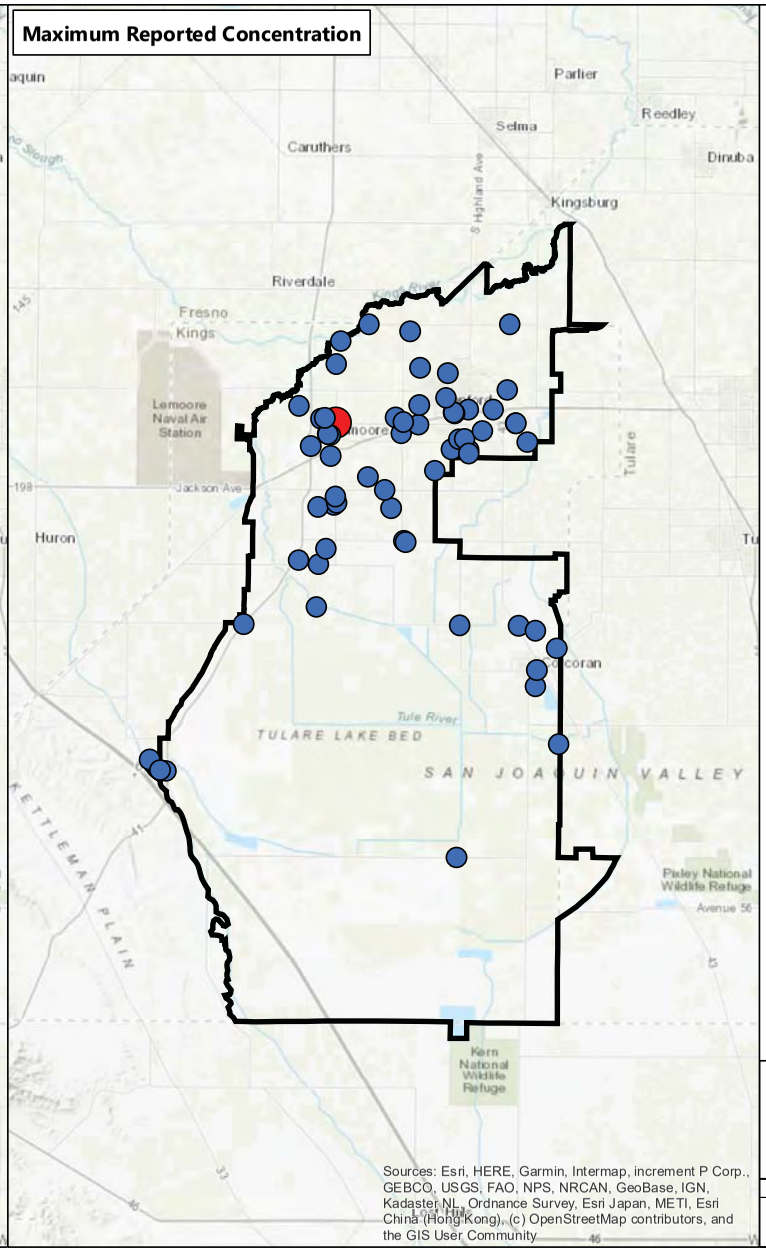
Volatile Organic Compounds in Groundwater

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: SCM	Date: 1/9/2020	Project No.: FR16181220
wood.		Figure **3-33b**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PA_projects\FR\BAS\FR16181220\gis\maps\2019\Basin_Setting_fig3-33b_VOCs_in_Groundwater_DBCP.mxd





Explanation

TCE

- <5.00 µg/L
- >5.01 µg/L
- Subbasin boundary

Notes:

1) Data compiled from California Water Boards. November 2018: https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/Default.asp

N

Approximate Scale in Miles

0 5 10 20

0 5 10 20

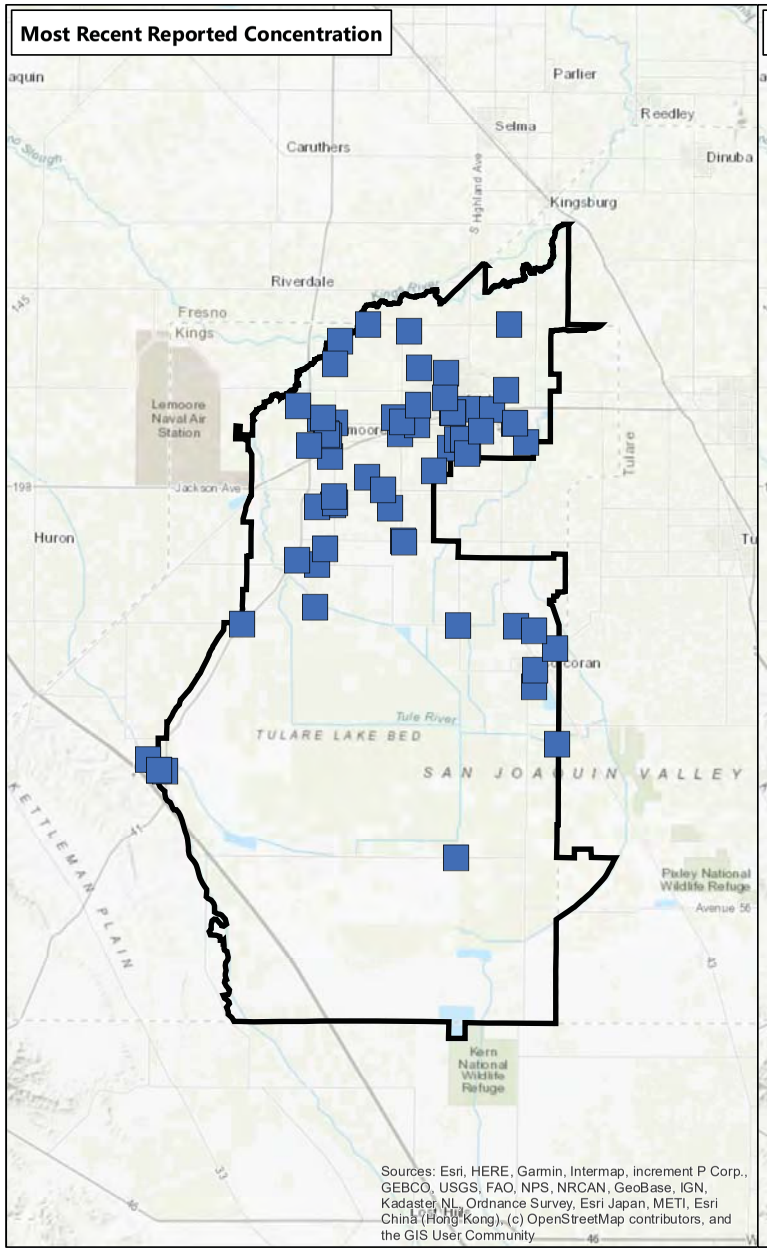
Approximate Scale in Kilometers

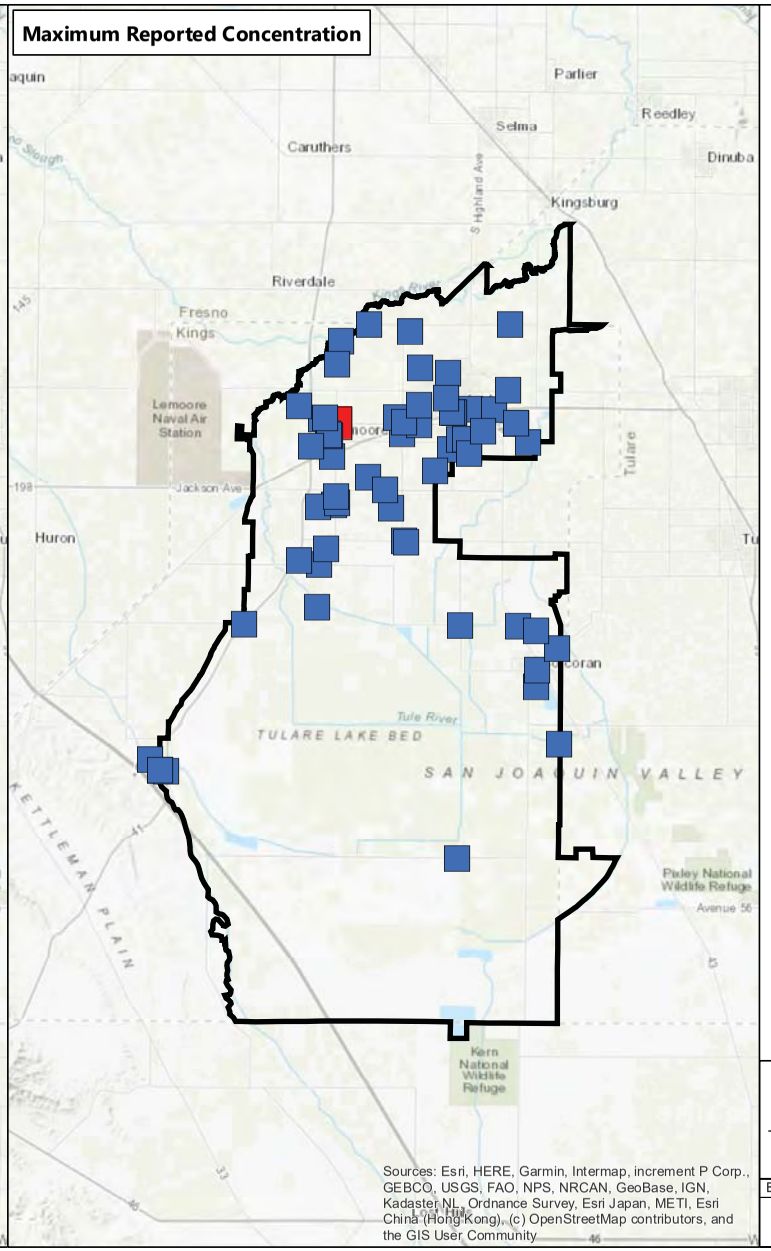
Volatile Organic Compounds in Groundwater

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: SCM	Date: 1/9/2020	Project No.: FR16181220
wood.		Figure **3-33c**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PA_projects\FR\BAS\FR16181220\gis\maps\2019\Basin_Setting_fig3-33c_VOCs_in_Groundwater_TCE.mxd





Explanation

PCE

- <5.00 µg/L
- >5.01 µg/L
- Subbasin boundary

Notes:

1) Data compiled from California Water Boards. November 2018: https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/Default.asp

N

Approximate Scale in Miles

0 5 10 20

0 5 10 20

Approximate Scale in Kilometers

Volatile Organic Compounds in Groundwater

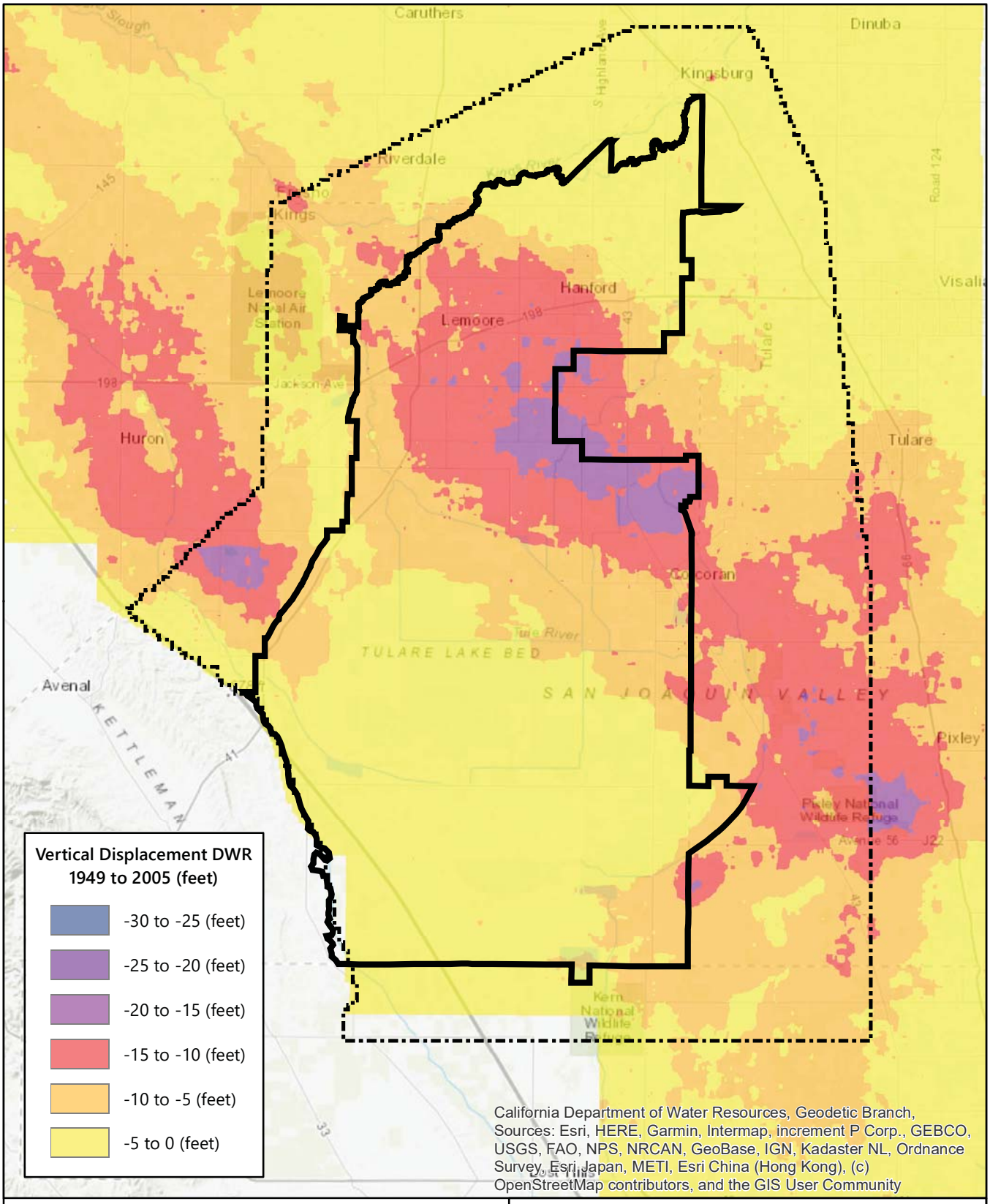
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: SCM	Date: 1/9/2020	Project No.: FR16181220

wood.

Figure **3-33d**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PR_projects\FR16\FR16181220\gis\maps\2019\Basin_Setting_fig3-33d_VOCs_in_Groundwater_PCE.mxd



Explanation

Study Area

Subbasin boundary

Miles
0 2 4 8
0 2.5 5 10
Kilometers

N

Notes:

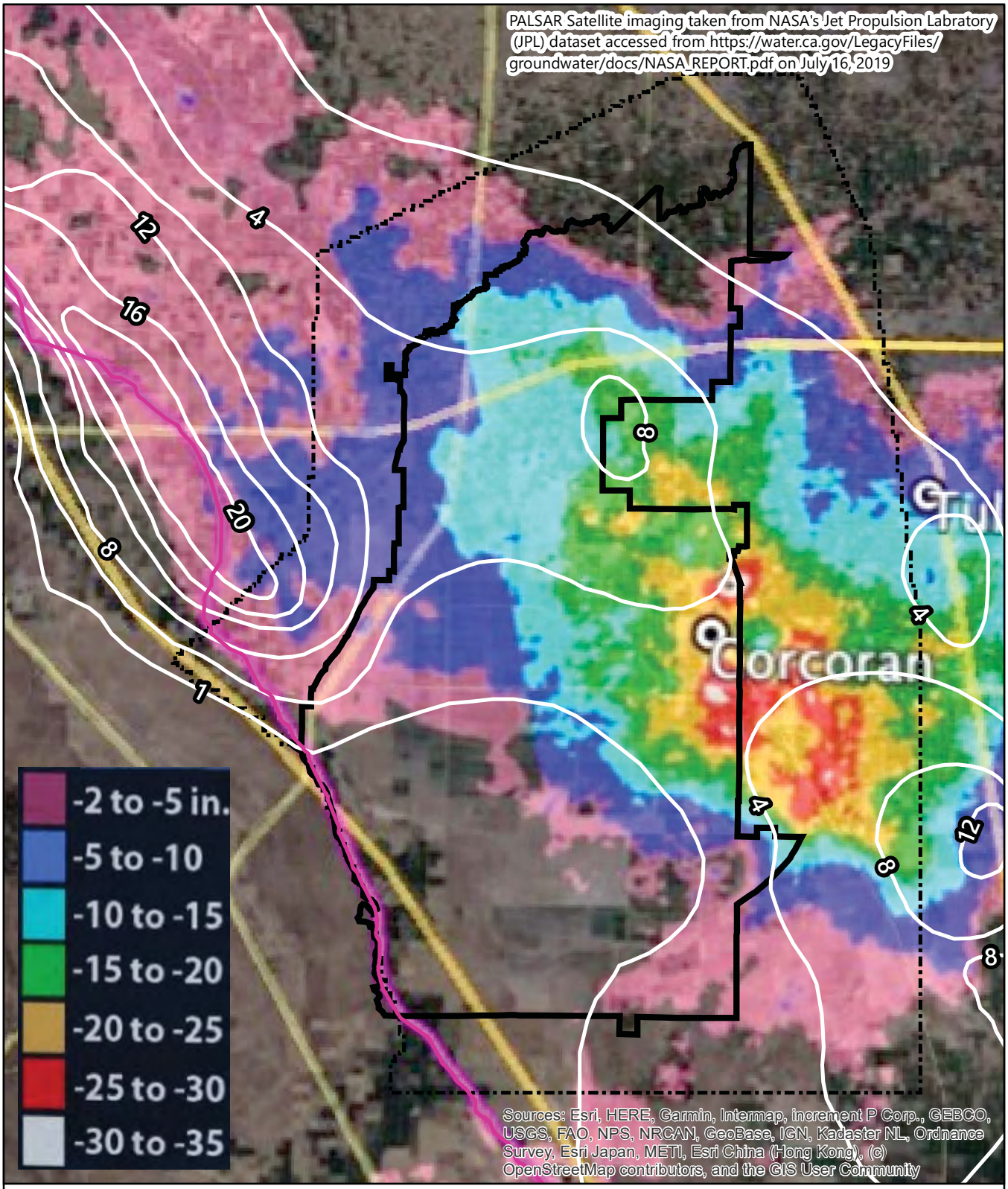
1. Vertical Displacement dataset taken from California Department of Water Resources (DWR) https://sgma.water.ca.gov/webgis. Accessed July 9, 2019.

Historical Subsidence of the Tulare Lake Subbasin

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/15/2019	Project No.: FR18161220
		Figure **3-34**

Date: 11/15/2019 Printed by: shaina.price
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting\8.5x11_fig3-34_HistoricalSubsidenceTLSB.mxd



Explanation

- Study Area
- Subbasin boundary
- Edmund G. Brown California Aqueduct
- White line shows historical subsidence data from 1926-1970 (ft.)

Miles
0 2 4 8
0 2.5 5 10
Kilometers

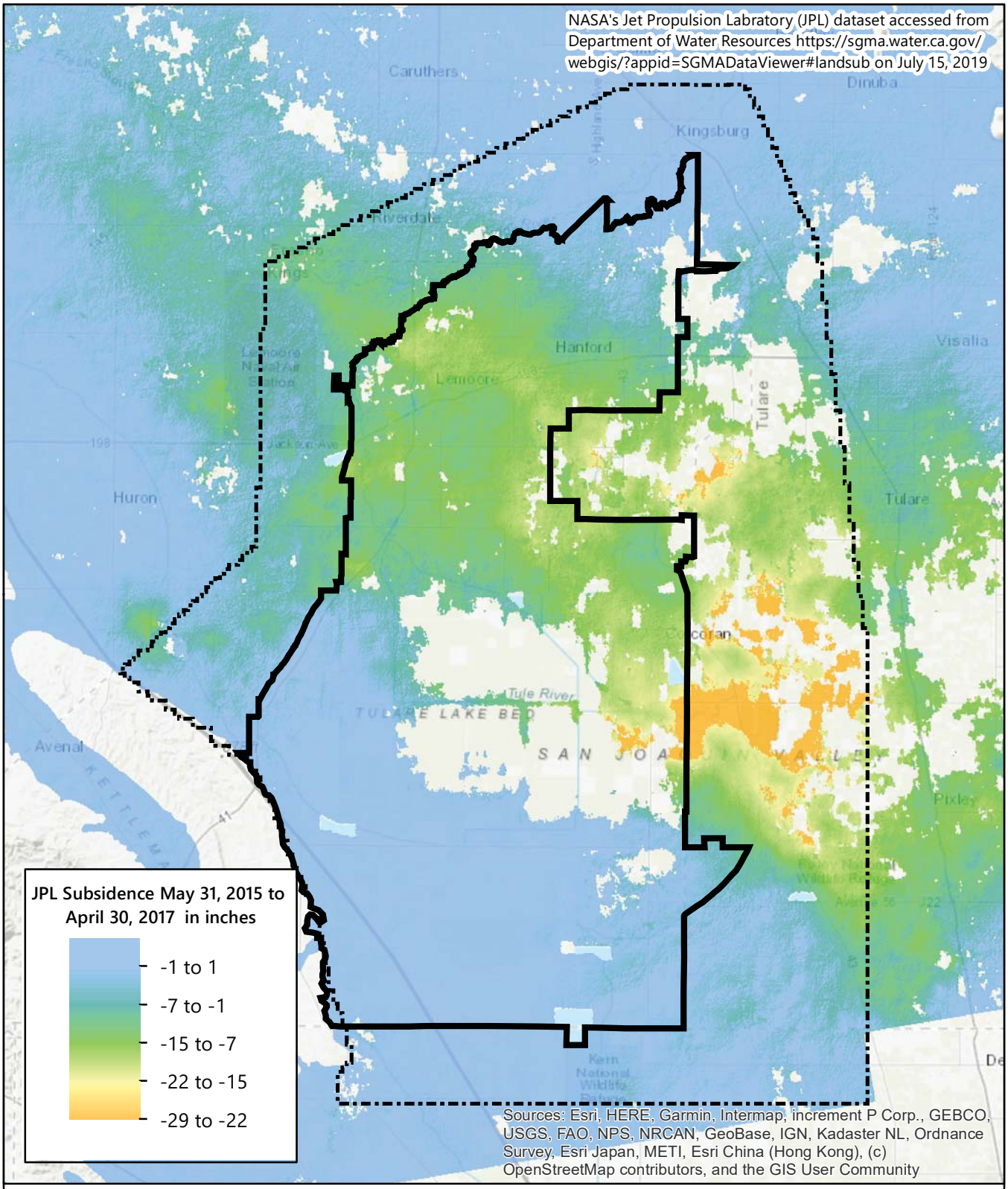
N

Subsidence in the Tulare Lake Subbasin 2007 to 2010

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/7/2019	Project No.: FR18161220
		Figure **3-35a**

Date: 11/7/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting\8.5x11_fig3-35a_Subsidence2007-2010_8x11.mxd



Explanation

- Study Area
- Subbasin boundary

Miles
0 2 4 8
0 2.5 5 10
Kilometers

N

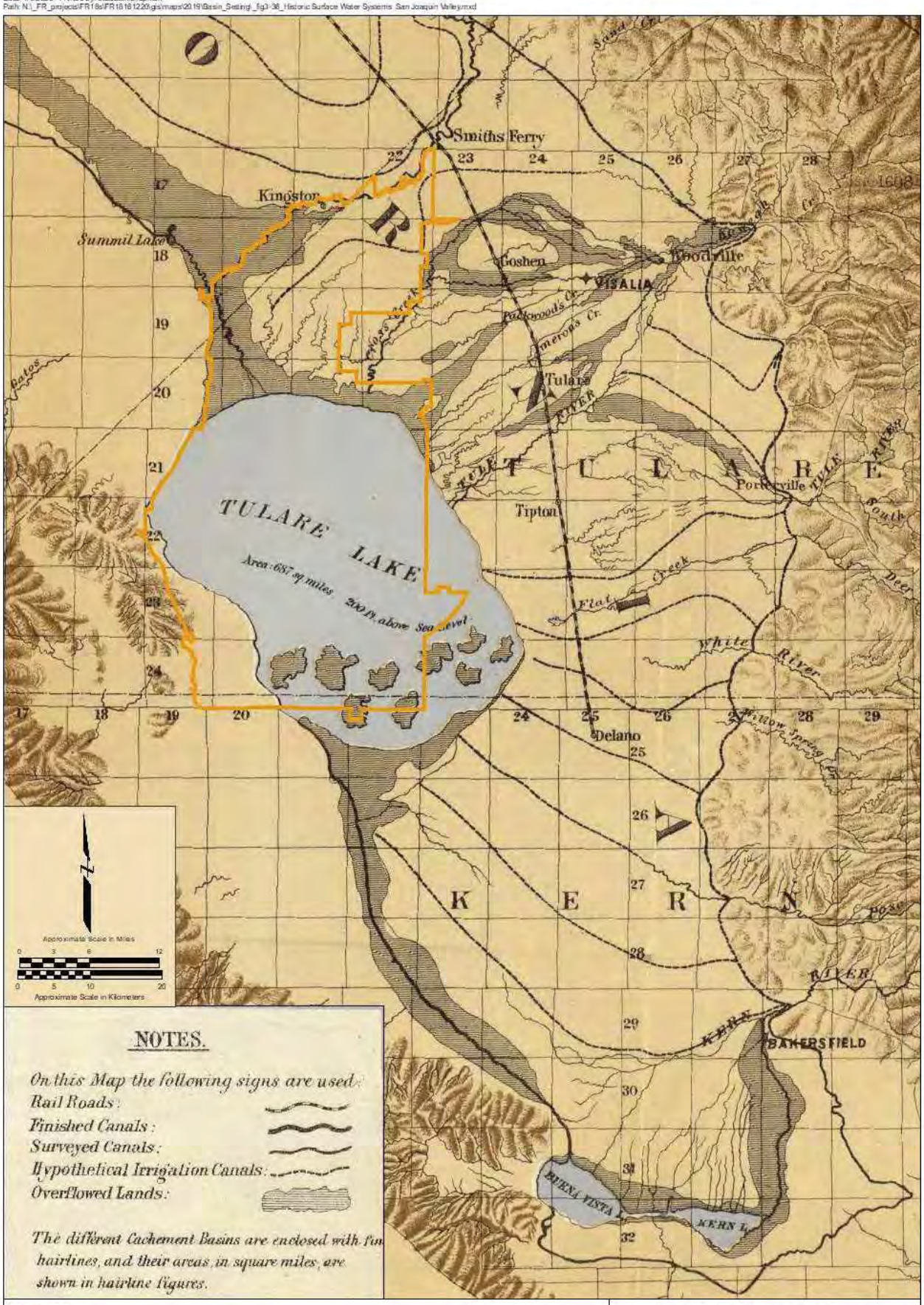
Subsidence in the Tulare Lake Subbasin 2015 to 2017

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/7/2019	Project No.: FR18161220
		Figure **3-35b**

Date: 11/7/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting\8.5x11_fig3-35b_Subsidence2015-2017_8x11.mxd

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR16s\FR16181220\gis\maps\2019\Basin_Setting_fig3-36_Historic Surface Water Systems San Joaquin Valley.mxd



Explanation

Boundary of Tulare Lake Subbasin

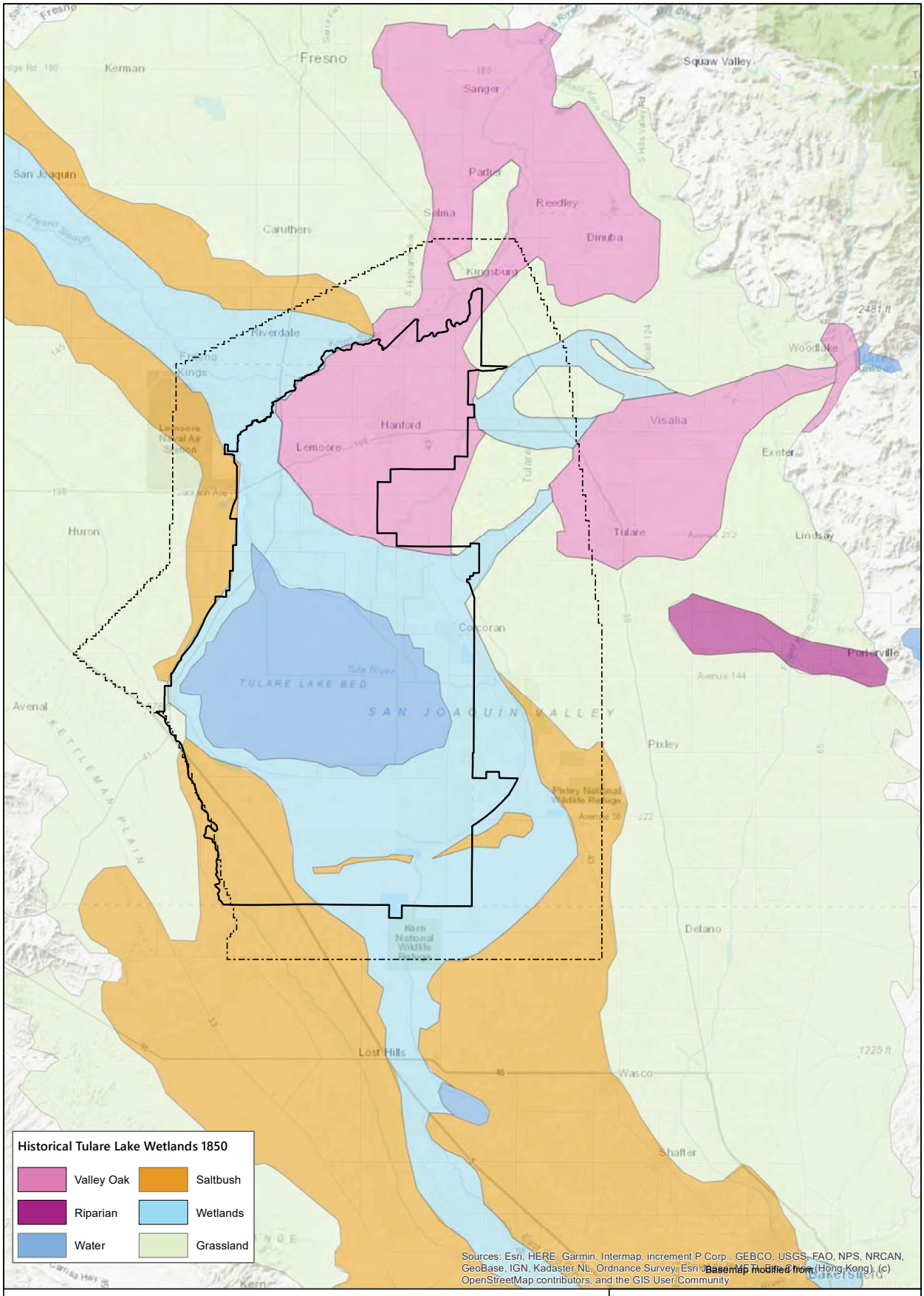
Note:

Adapted from "Map of the San Joaquin, Sacramento and Tulare Valleys, State of California, Prepared Under The Direction of the Board of Commissioners on Irrigation, 1873"

Historic Drainage System
Tulare Lake Basin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: GLK	Date: 1/9/2020	Project No.: FR16181220
		Figure **3-36**

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Basin_Setting_fig3-37_HistoricalTulareLakeWetlands.mxd



Explanation

Study area

Subbasin boundary

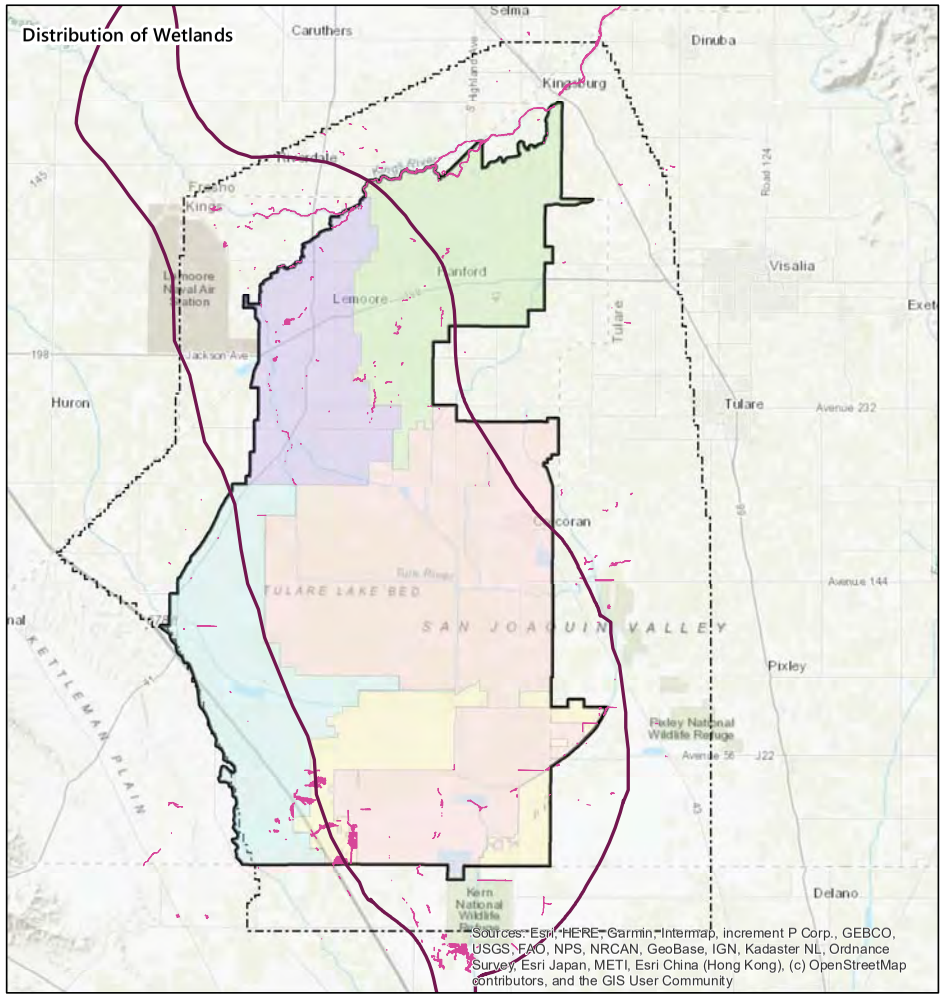
Miles
0 3.5 7 14
0 5 10 20
Kilometers

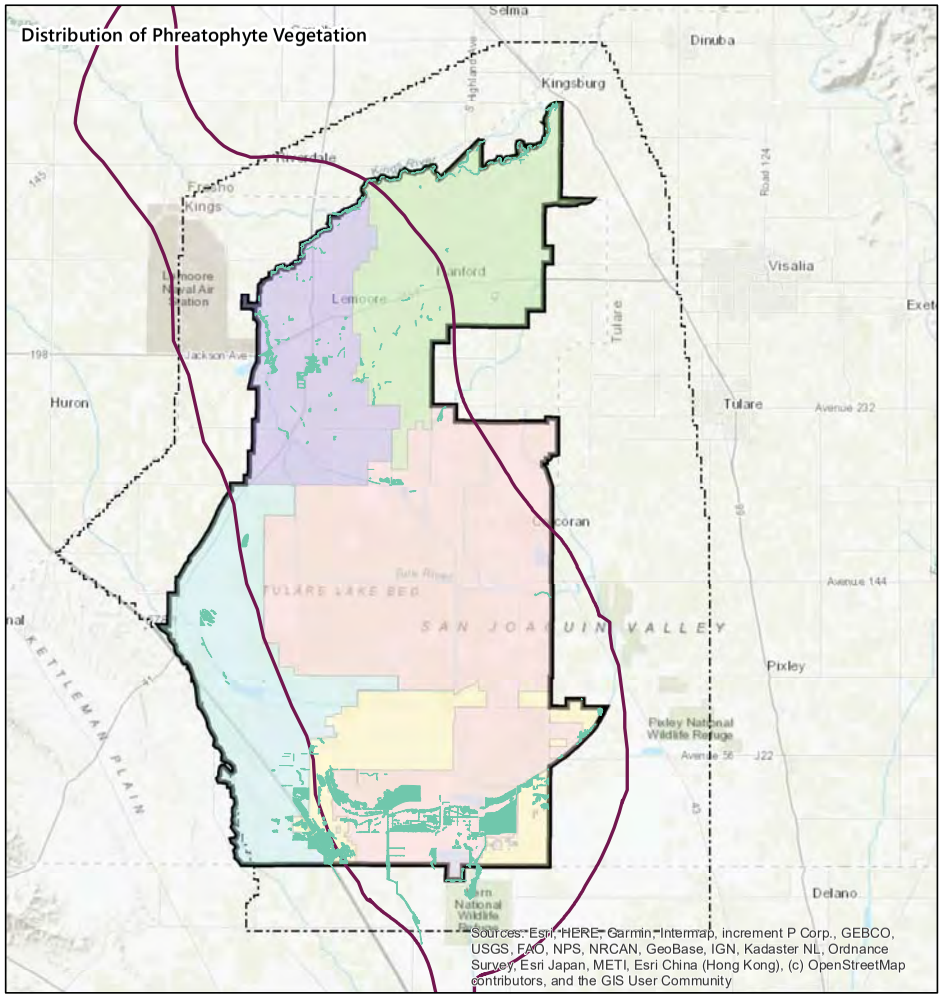
Notes:
figure adapted from http://www.tularebasinwildlife partners.org/history.html. July 16, 2019

N

Historical Wetlands Distribution
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure 3-37





Explanation

- Extent of A-Clay
- Subbasin boundary
- Study area
- California Natural Resources Agency wetlands
- California Natural Resources Agency phreatophyte vegetation

Groundwater Sustainability Agencies (GSAs)

- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

Miles: 0 4 8 16
Kilometers: 0 5 10 20

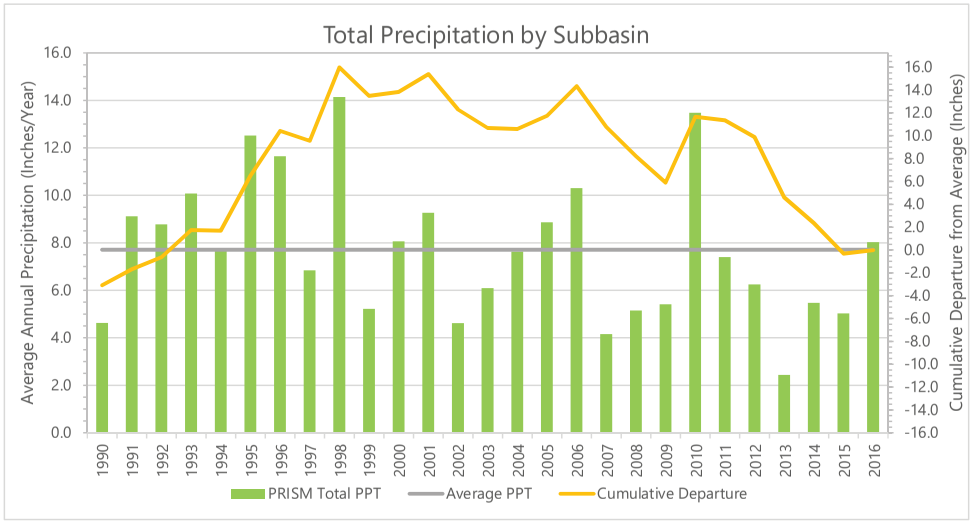
Notes:
1) California Natural Resources Agency data taken from http://resources.ca.gov/wetlands/inventories/inventories.html, accessed November 2018.

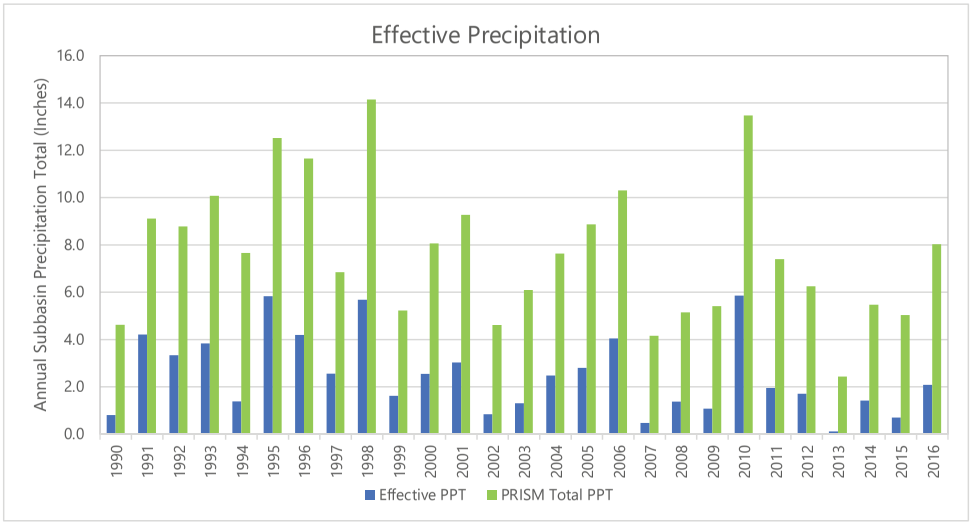
Distribution of Wetlands and Phreatophyte Vegetation
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

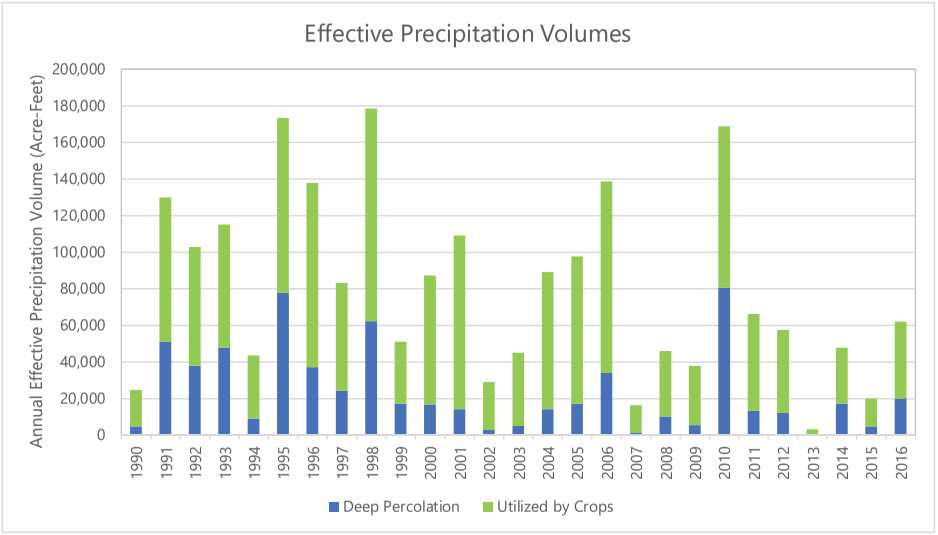
By: EMC	Date: 1/9/2020	Project No.: FR18161220
		Figure 3-38

Date: 1/9/2020 Printed by: elizabeth.chapman
Path: N:_PR_projects\FR18\FR18161220\gis\maps\2019\Basin_Setting_fig3-38_DistributionofWetlandsPhreatophyteVeg.mxd

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\3-BasinSetting\Figures\DAVES FOLDER\GSPFigures 3-39_3-40_120619.xlsmFigure 3-39 12/9/2019





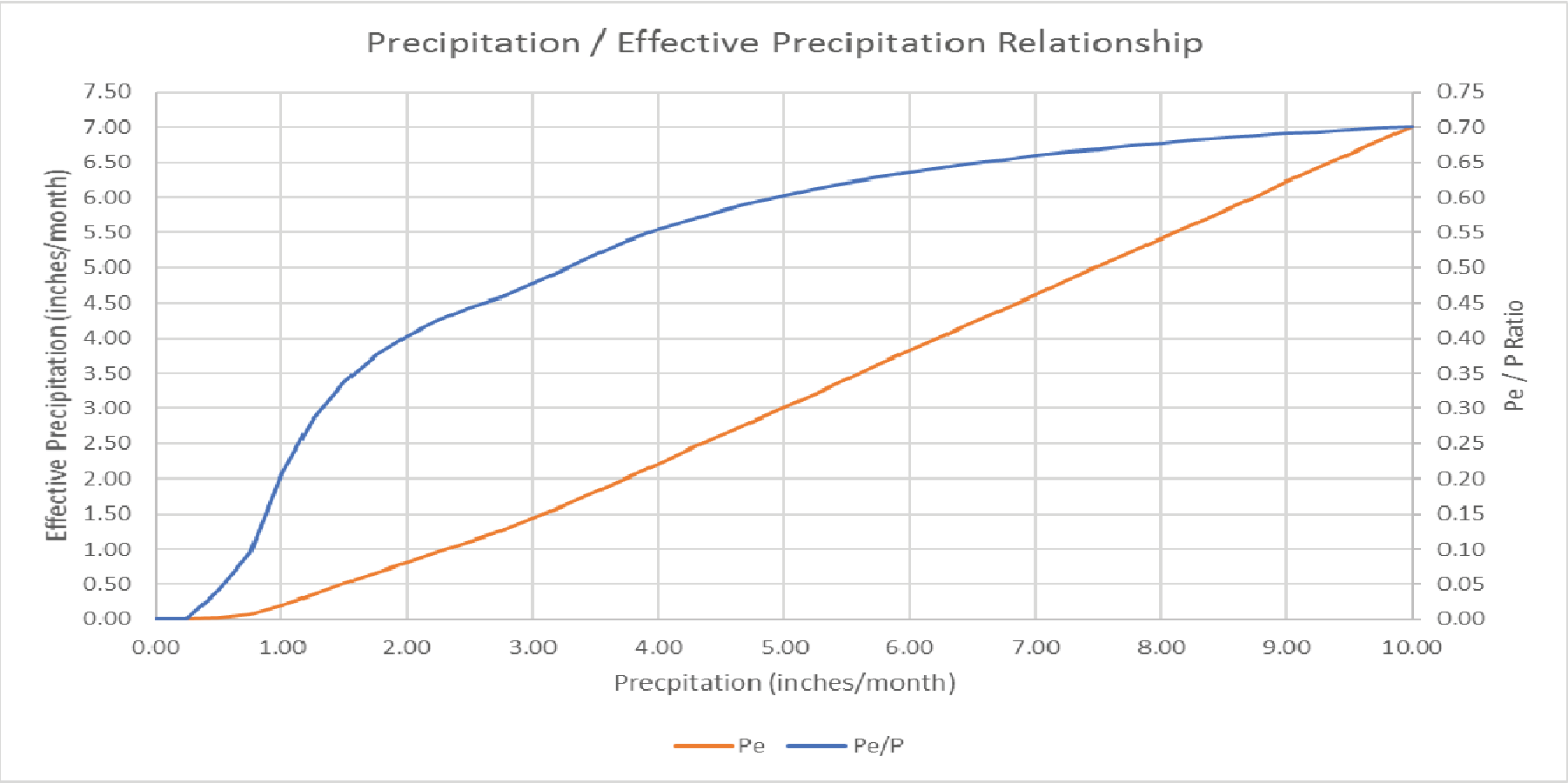


Notes:
1. PPT = precipitation
2. Climate data accessed from Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate group.. http://www.prism.oregonstate.edu/ Accessed November 2018

Annual Precipitation, Effective Precipitation, and Effective Precipitation Volumes
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure: 3-39

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Notes:

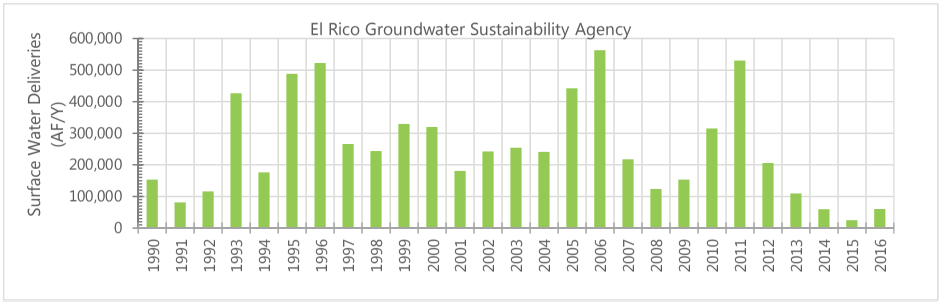
Modified from:
United Nations Food and Agriculture Organization (FAO)
FAO 56,Chapter 3 Table 6
Precipitation (P) and Effective Precipitation (Pe) in inches/month

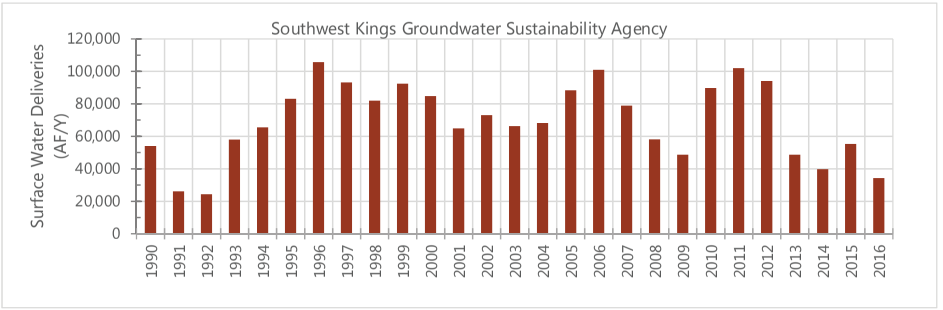
Precipitation Versus Effective Precipitation
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

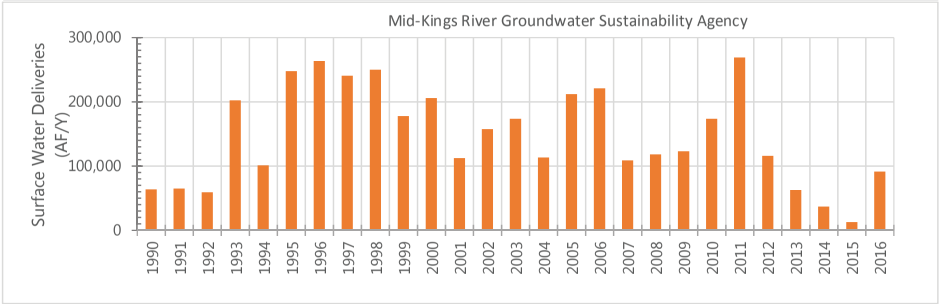
By: GLK	Date: 11/20/2018	Project No.: FR18161220

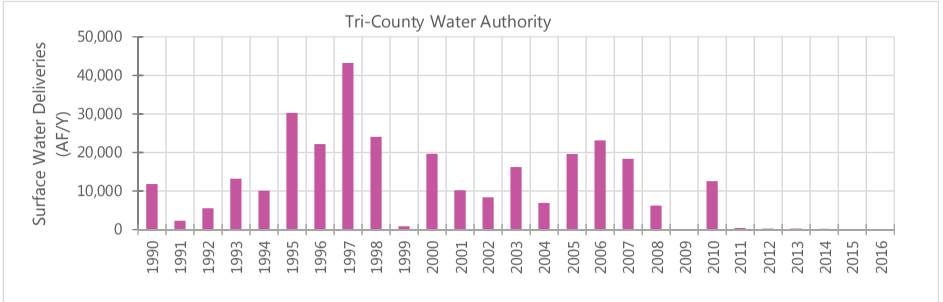
Figure 3-40

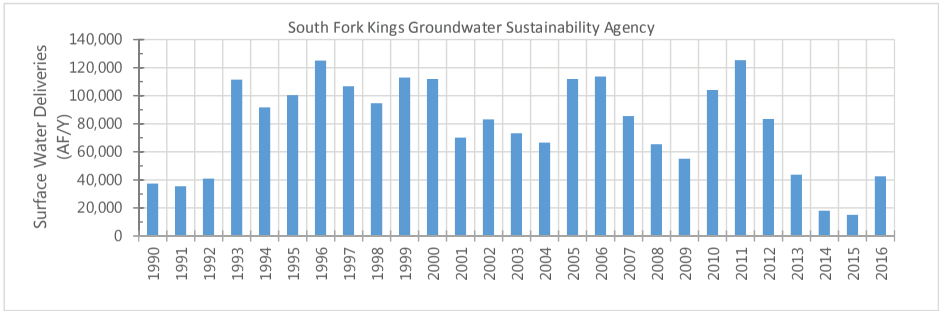
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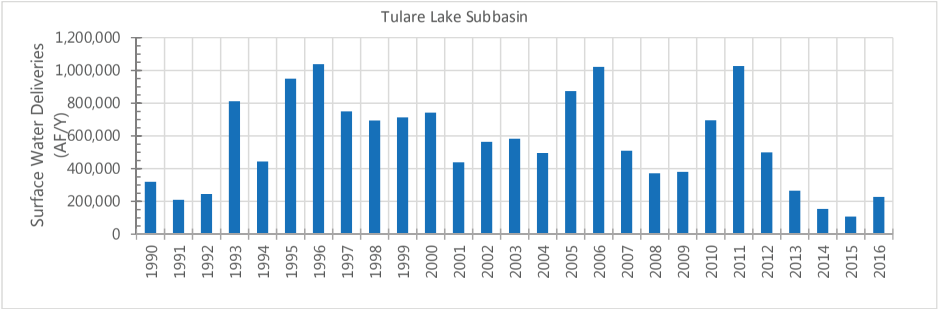










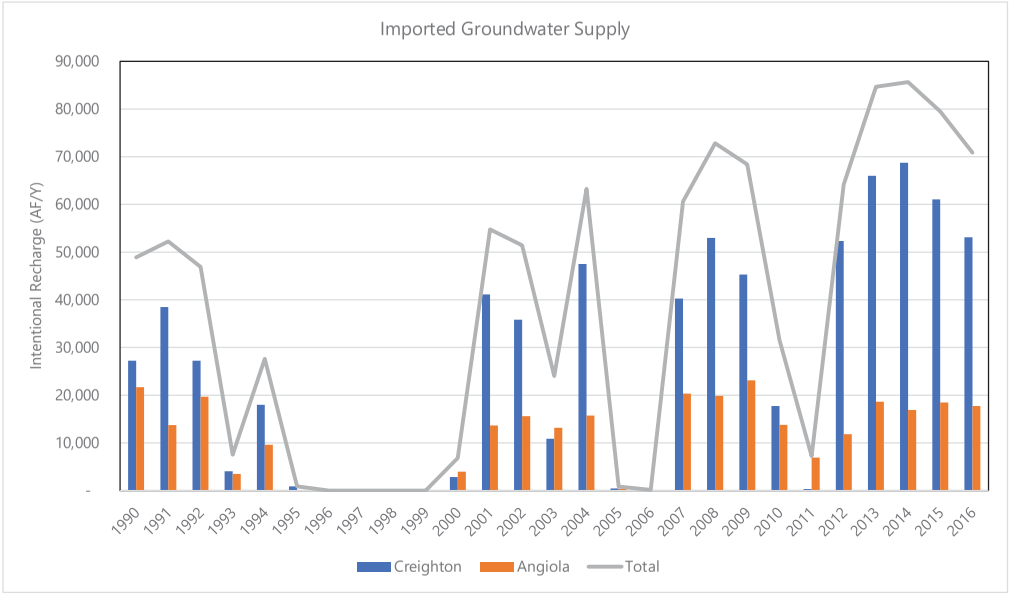


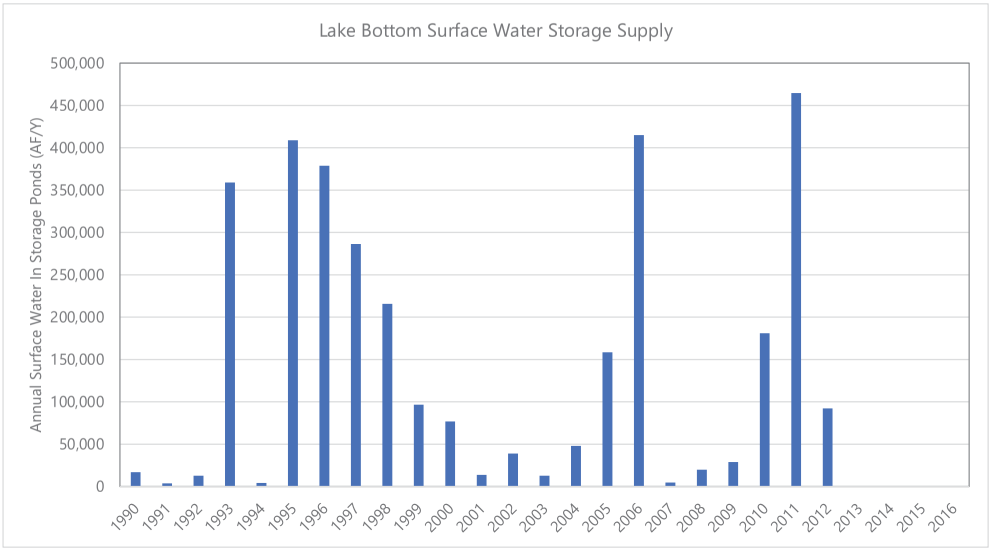
Notes:
1. AF/Y = acre-feet per year

Surface Water Diversions
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2018	Project No.: FR18161220
		Figure: 3-41

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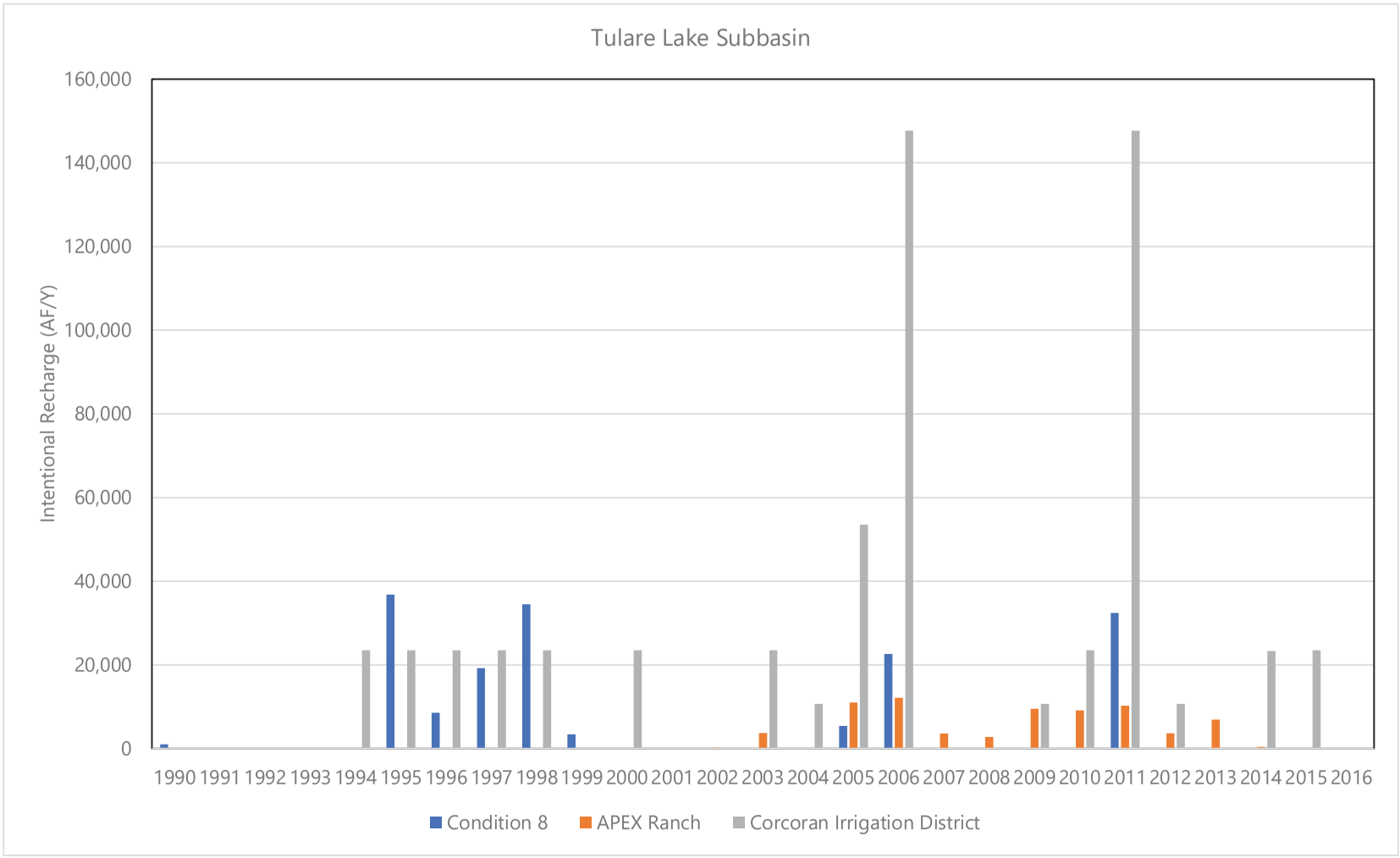
Notes:
1. Only EL Rico and TCWA GSAs import groundwater into the Tulare Lake Subbasin.
2. Only EL Rico and TCWA GSAs have significant surface water storage facilities.
3. Mid-Kings River GSA, South Fork Kings GSA, and Southwest Kings GSA do not have significant surface water storage facilities.
4. AF/Y = acre-feet per year

Lake Bottom Surface Water Storage and Imported Groundwater Supplies 1990-2016

Tulare Lake Subbasin Groundwater sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **3-42**

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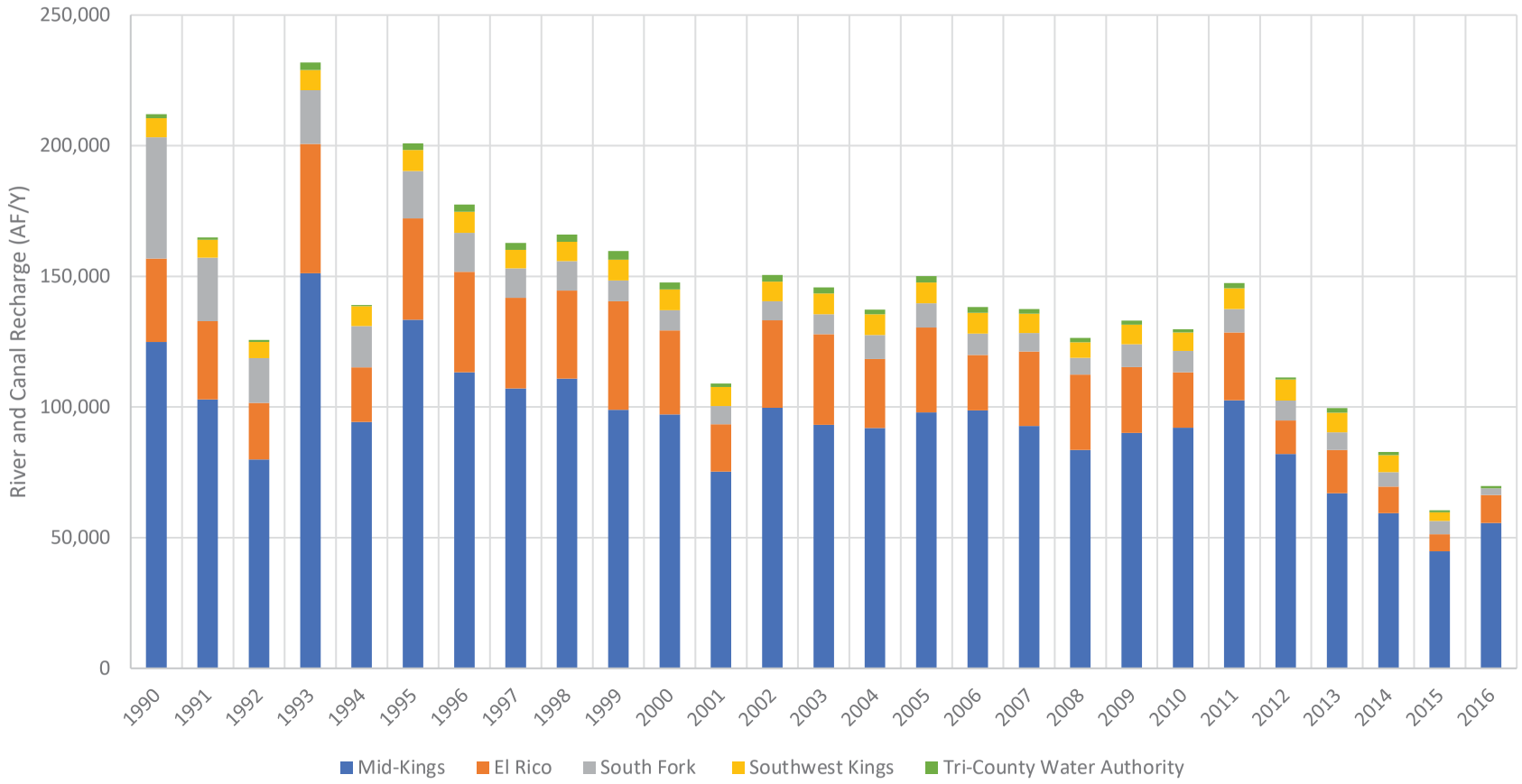
Notes:
1. The APEX Ranch recharge facility did not begin operation until 2002
   Condition 8 water is only available in flood years
   Corcoran Irrigation District (CID) recharge occurs in most years using only 1 or 2 ponds total 440 acres.
   In flood years CID may recharge using 2,760 acres of ponds
2. AF/Y = acre-feet per year

Tulare Lake Subbasin
Intentional Recharge
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: GLK	Date: 11/20/2018	Project No.: FR18161220

Figure 3-43

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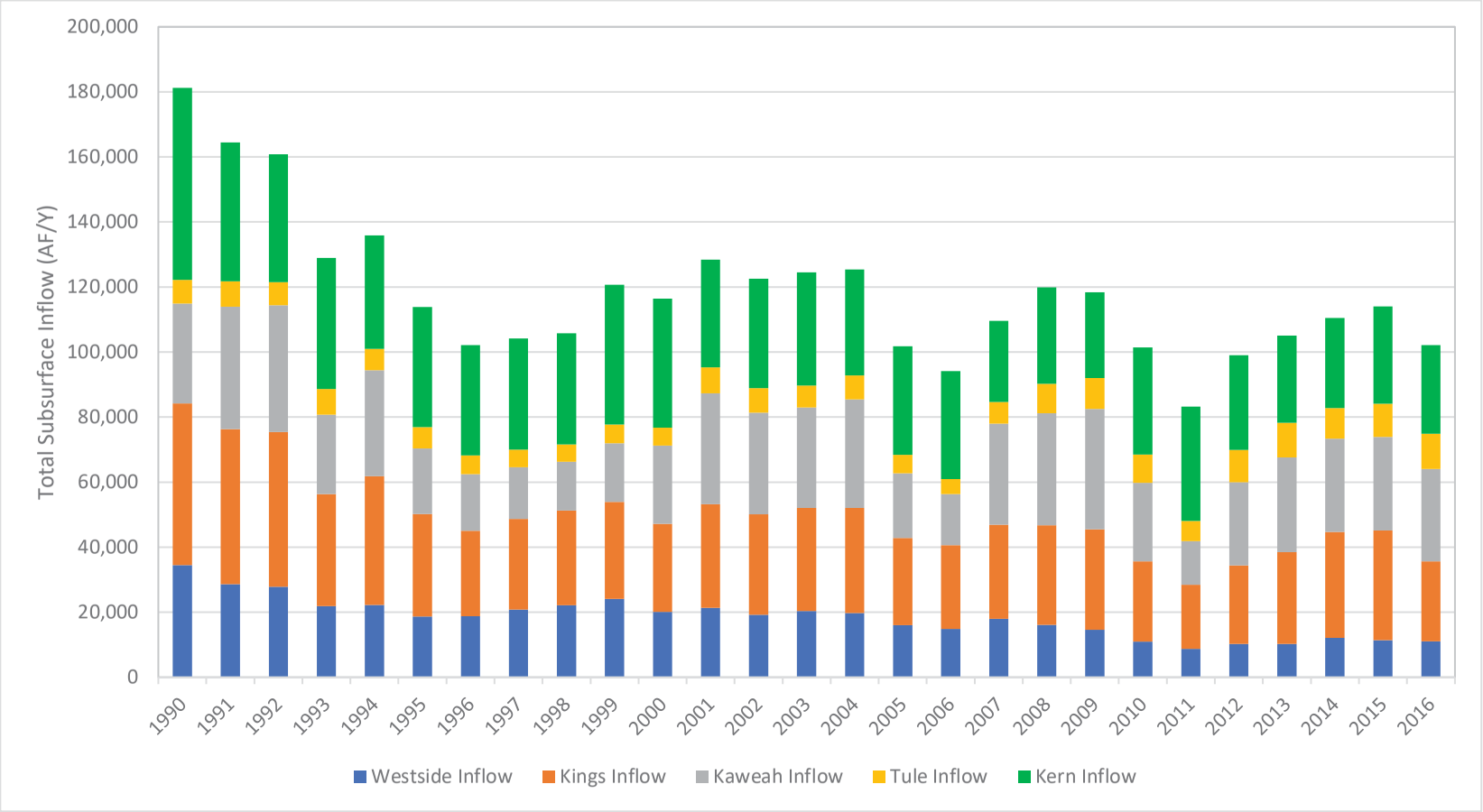
Notes:
1. AF/Y = acre-feet per year

Tulare Lake Subbasin
River and Canal Recharge
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220

Figure 3-44

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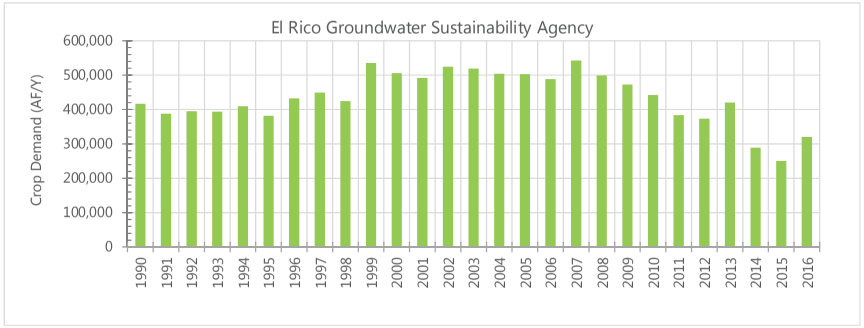


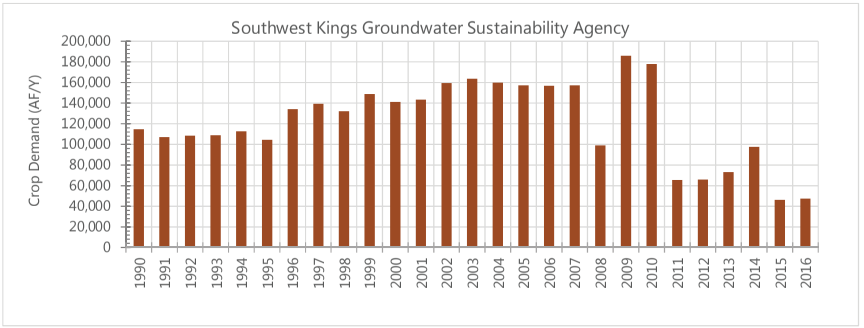
Notes:
1. AF/Y = acre-feet per year

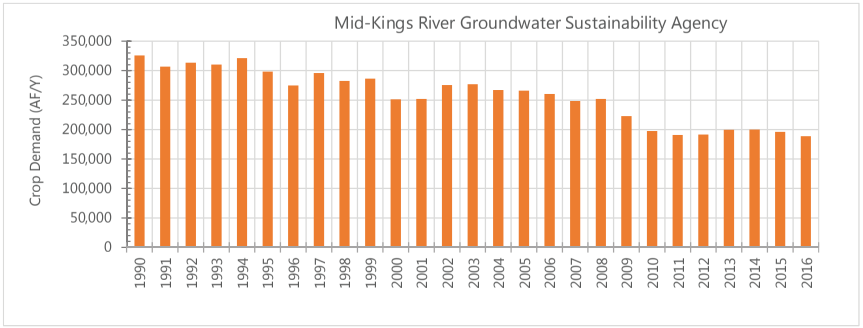
Tulare Lake Subbasin
Total Subsurface Inflows
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

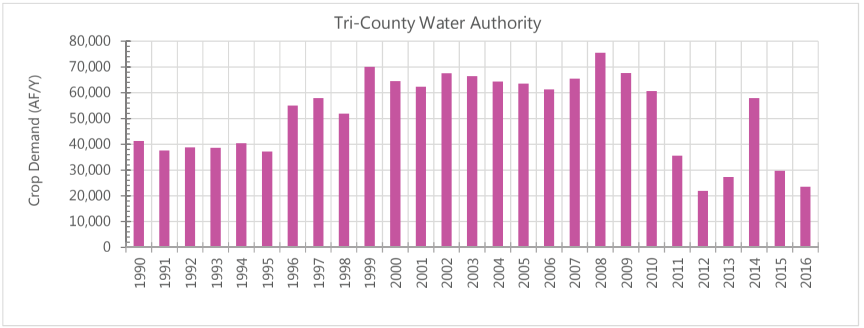
By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure 3-45

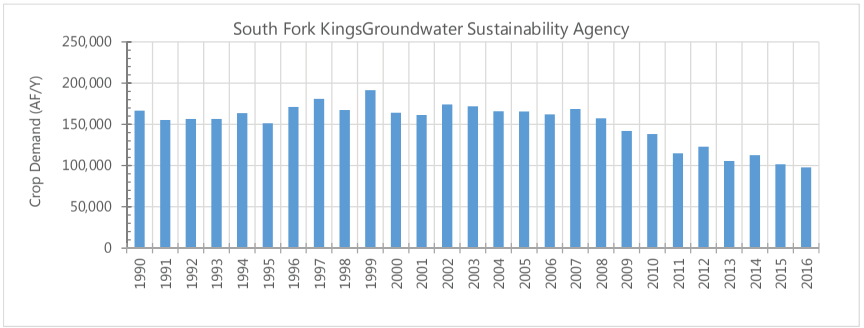
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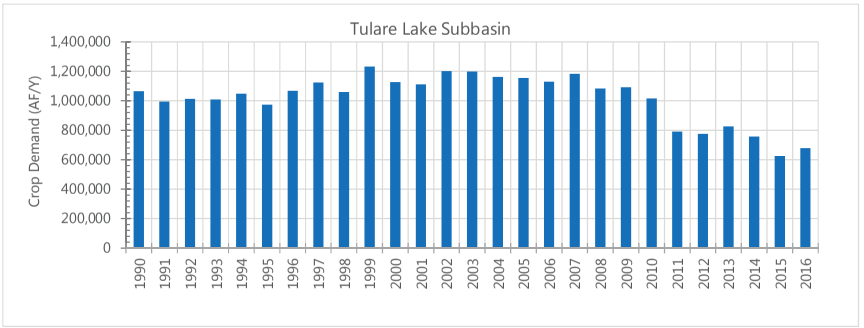












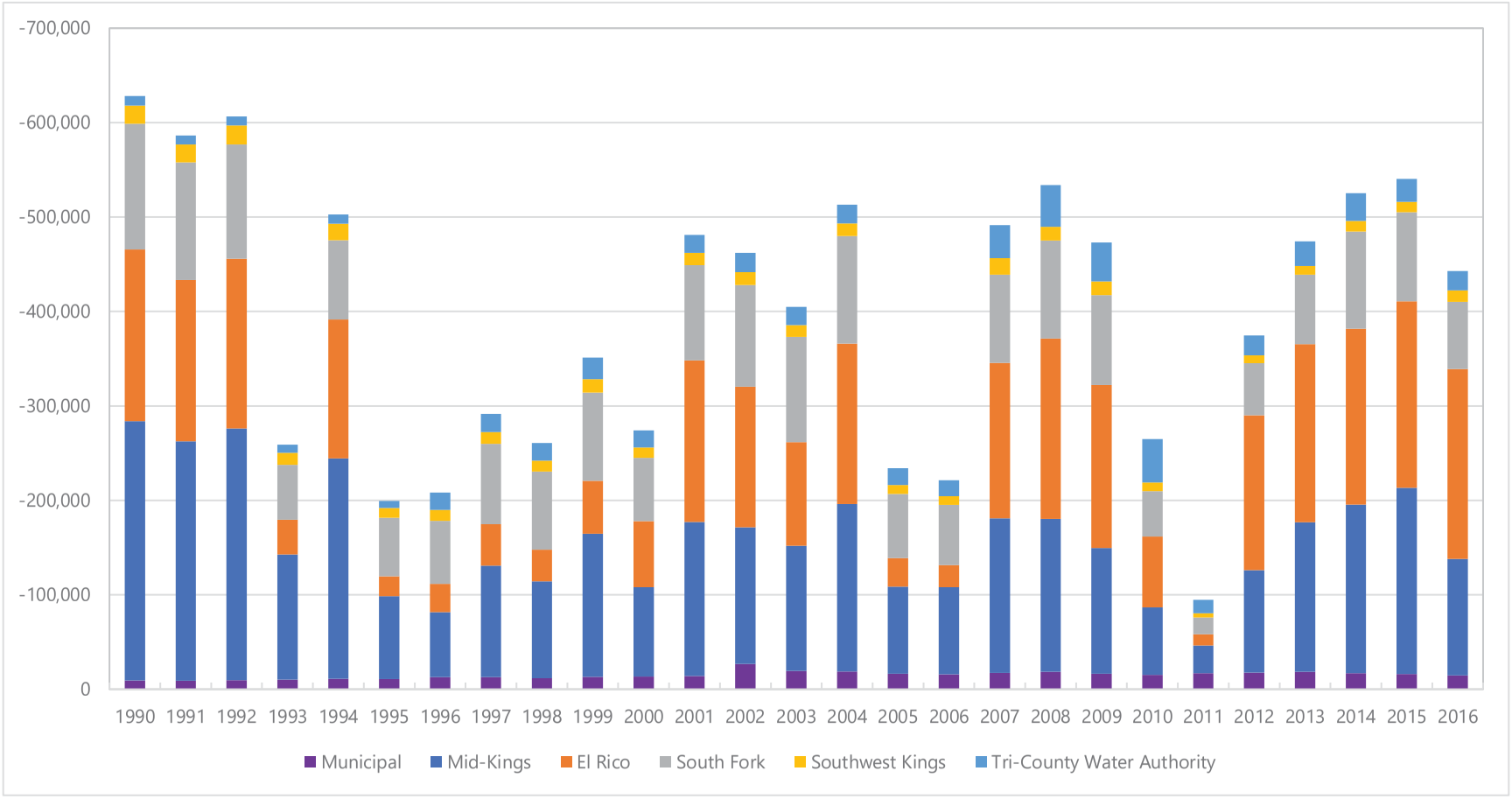
Notes:
1. AF/Y = acre-feet per year

Irrigated Crop Demand
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220

Figure: 3-46

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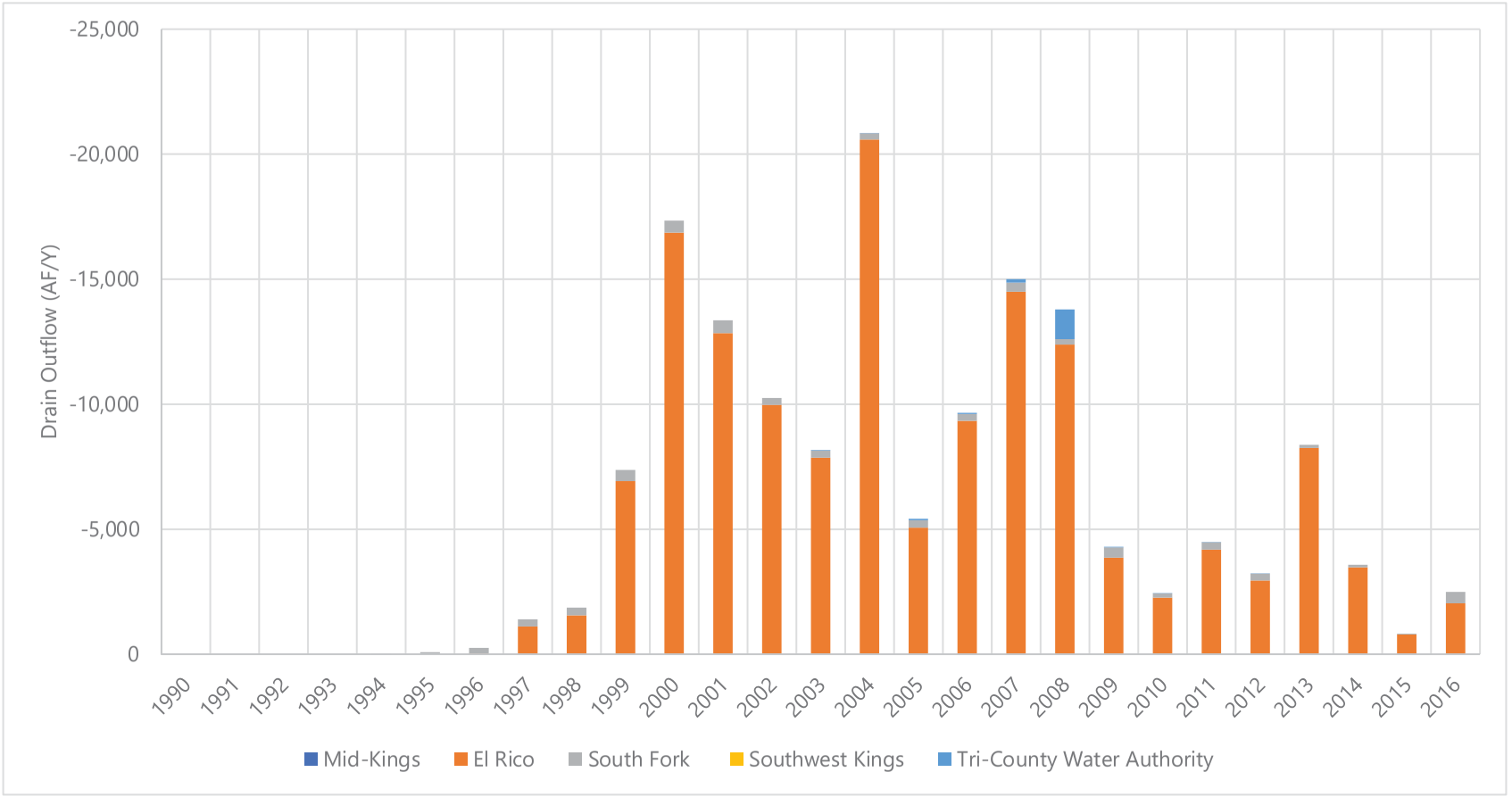


Notes:
1. AF/Y = acre-feet per year
2. TCWA = Tri-County Water Authority

Agricultural and Municipal Pumping
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure 3-47

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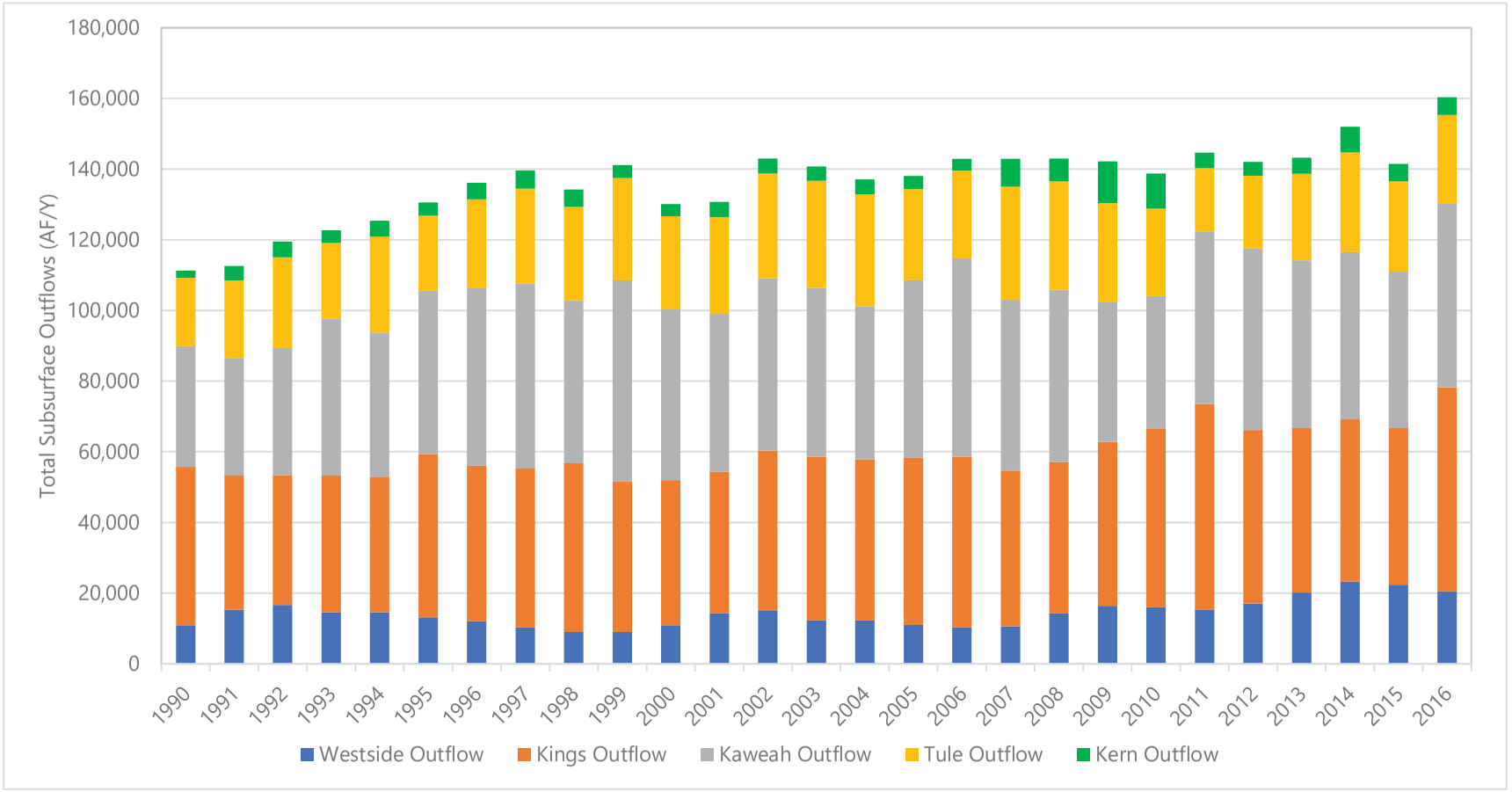


Notes:
1. Mid-Kings River GSA, South Fork Kings GSA, and Southwest Kings GSA do not have agricultural drain outflows.
2. AF/Y = acre-feet per year

Tulare Lake Subbasin Agricultural Drainage Outflows
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure 3-48

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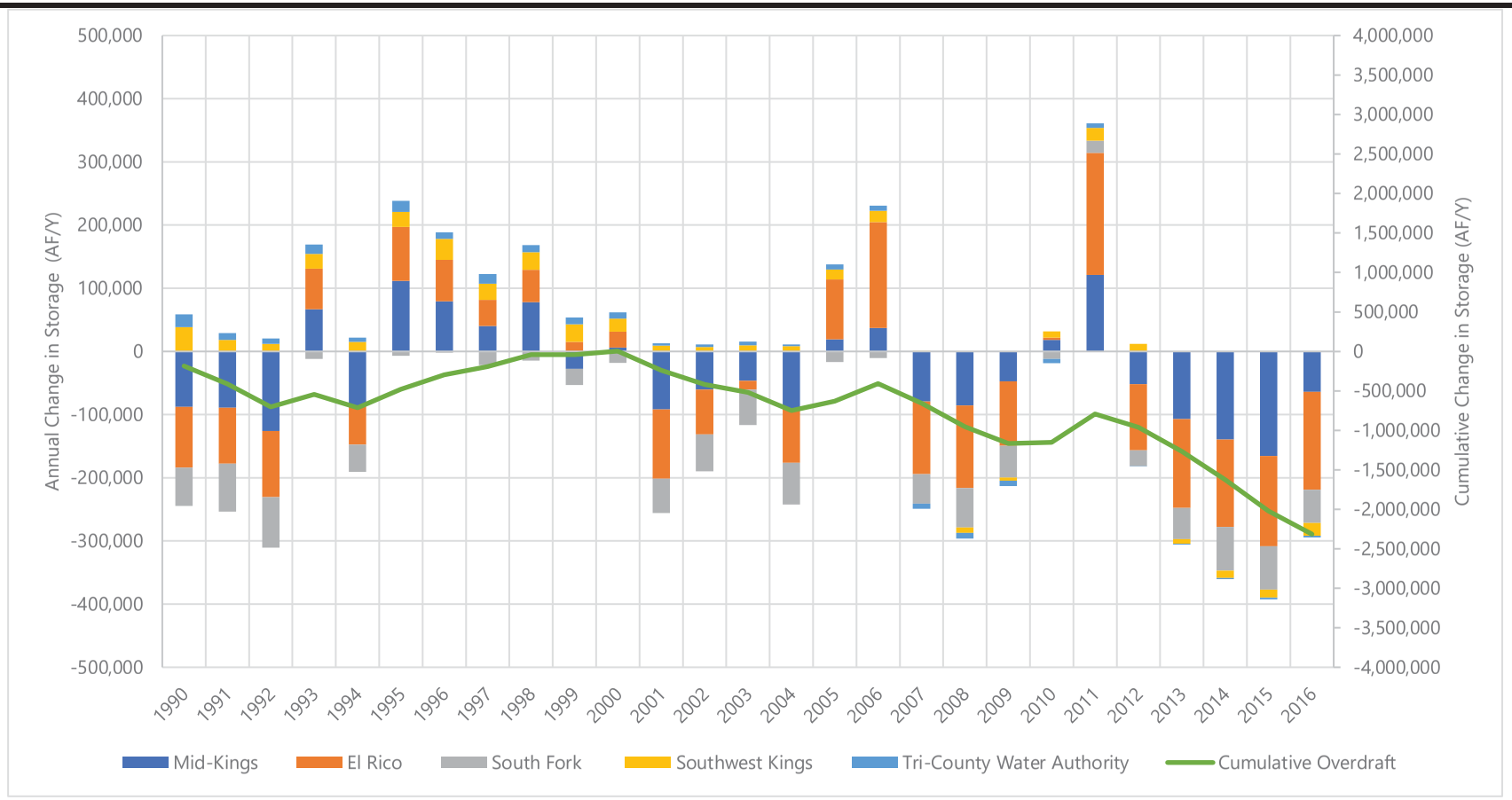


Notes:
1. AF/Y = acre-feet per year

Tulare Lake Subbasin
Total Subsurface Outflows
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure 3-49

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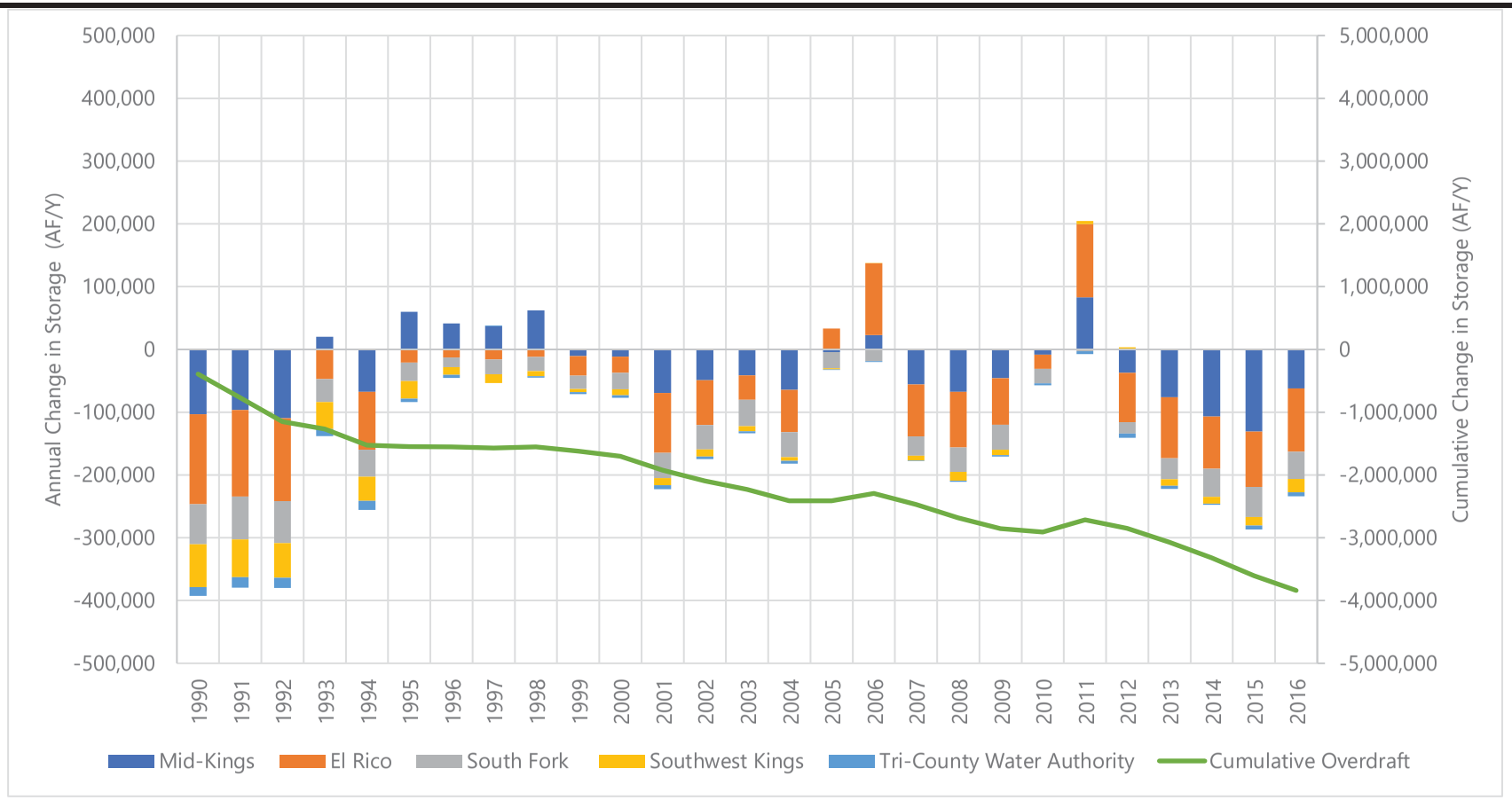


Notes:
1. AF/Y = acre-feet per year

Tulare Lake Subbasin
Total Overdraft
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure 3-50a

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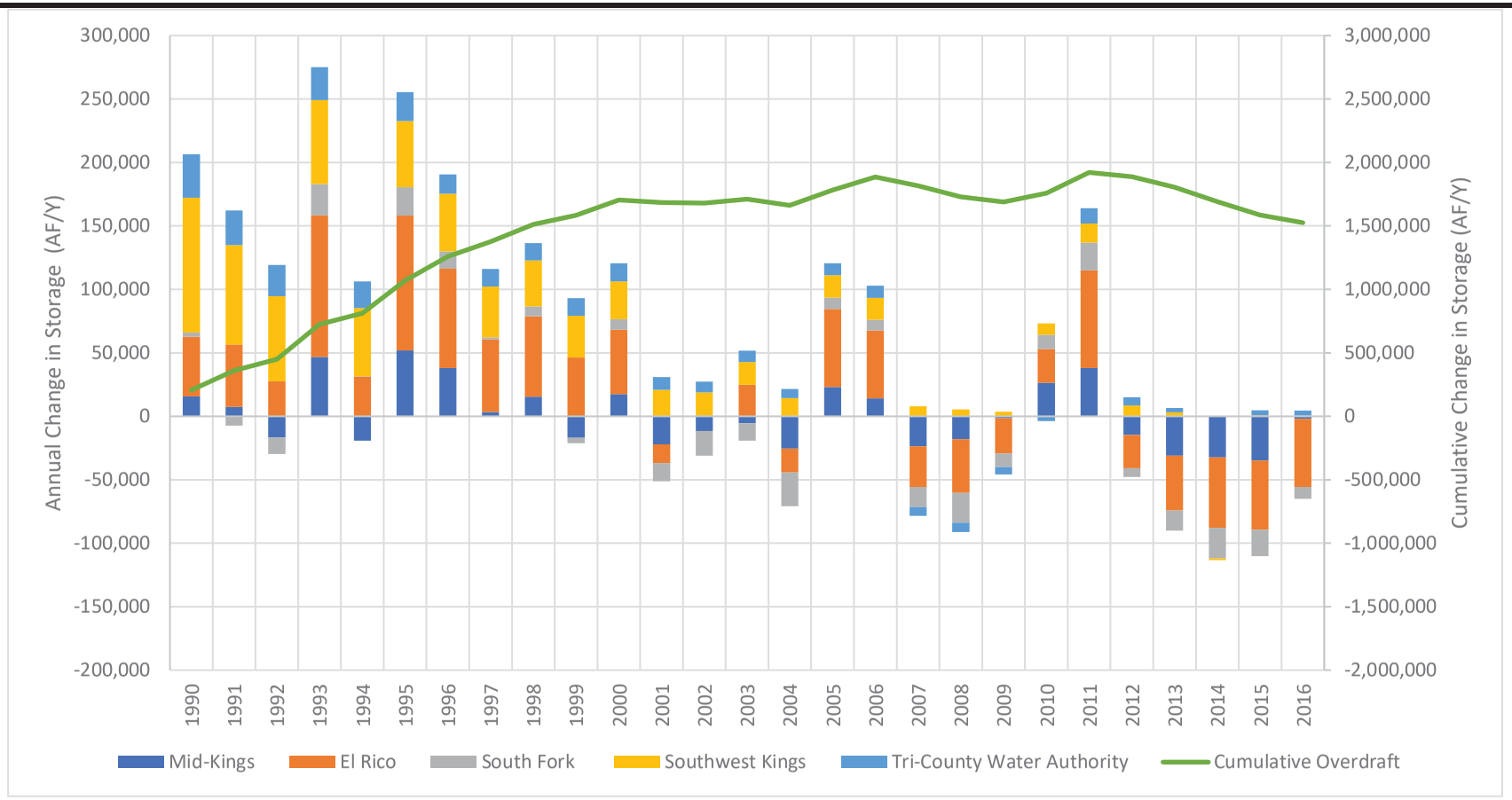


Notes:
1. AF/Y = acre-feet per year

Tulare Lake Subbasin
Upper Aquifer Overdraft
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure 3-50b

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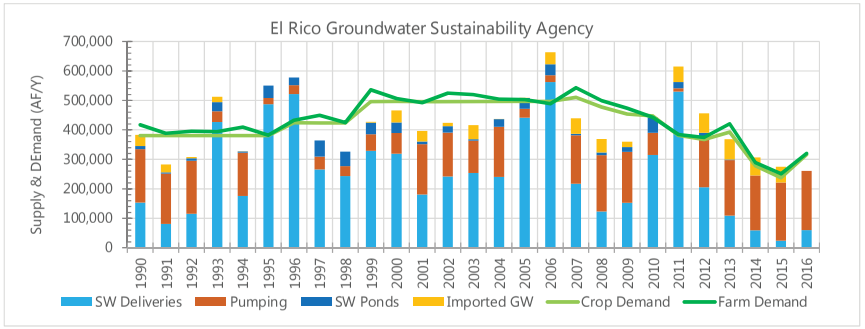


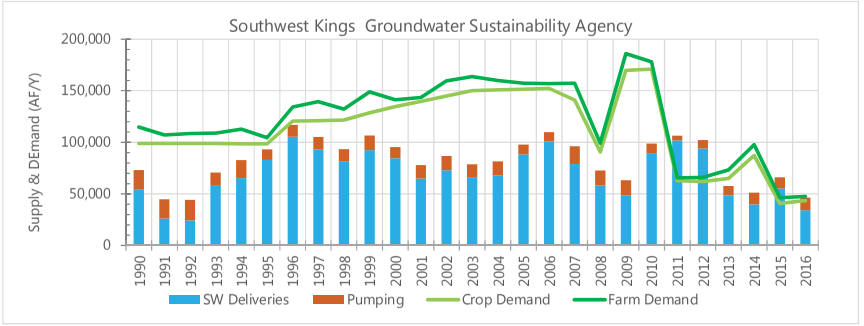
Notes:
1. AF/Y = acre-feet per year

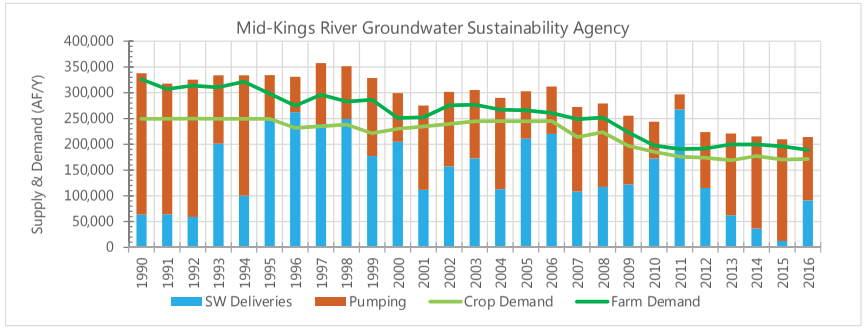
Tulare Lake Subbasin
Lower Aquifer Overdraft
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

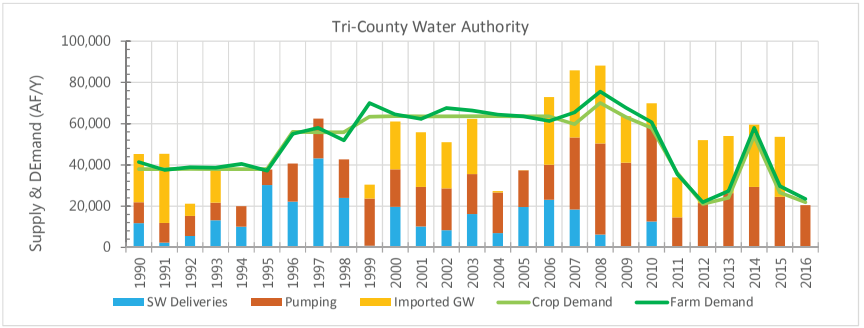
By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure 3-50c

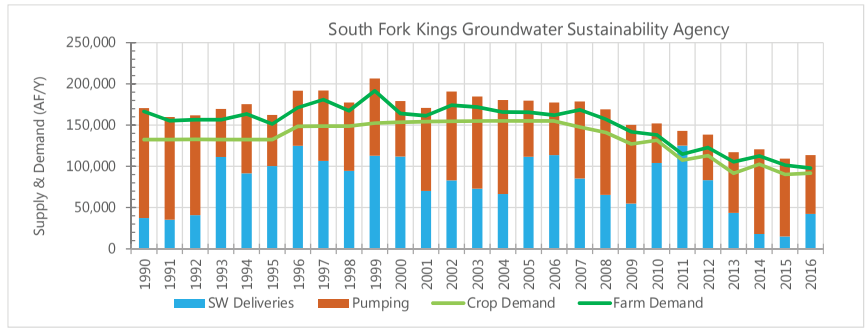
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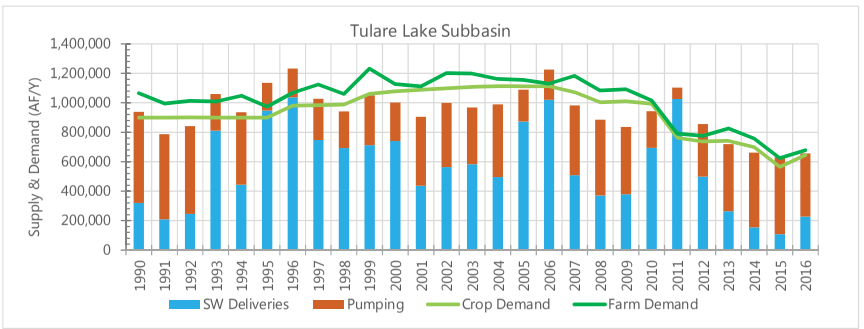










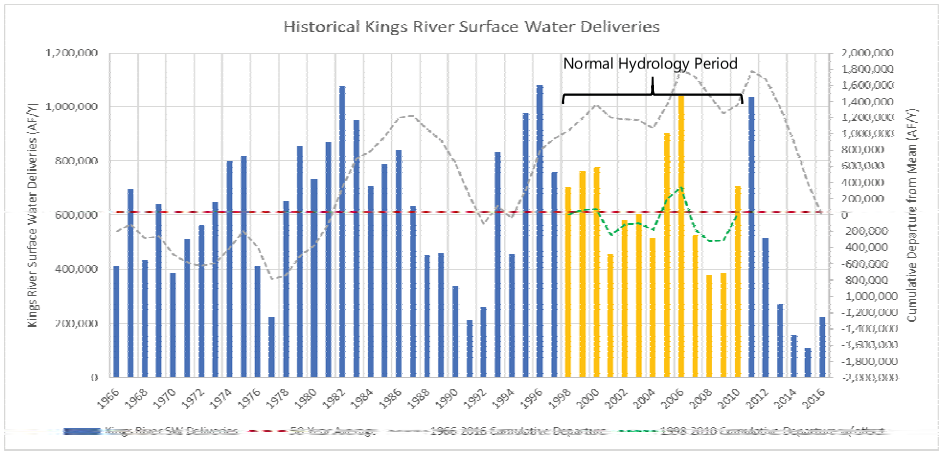


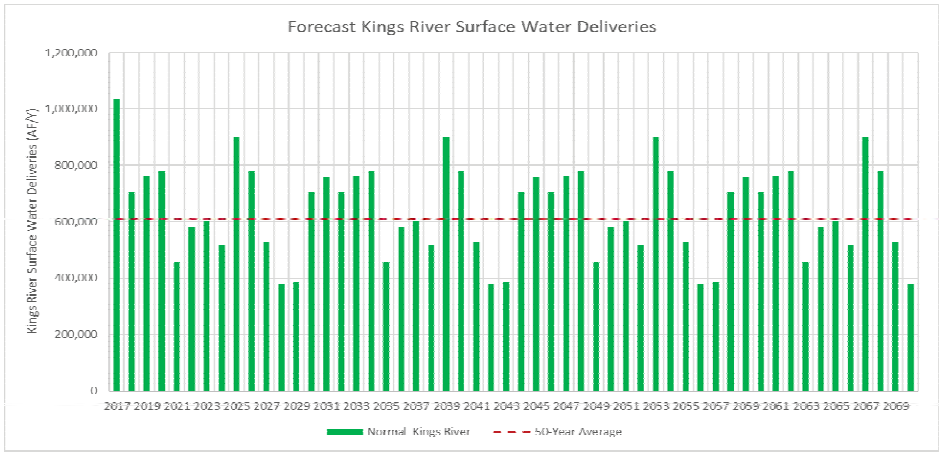
Notes:
1. AF/Y = acre-feet per year

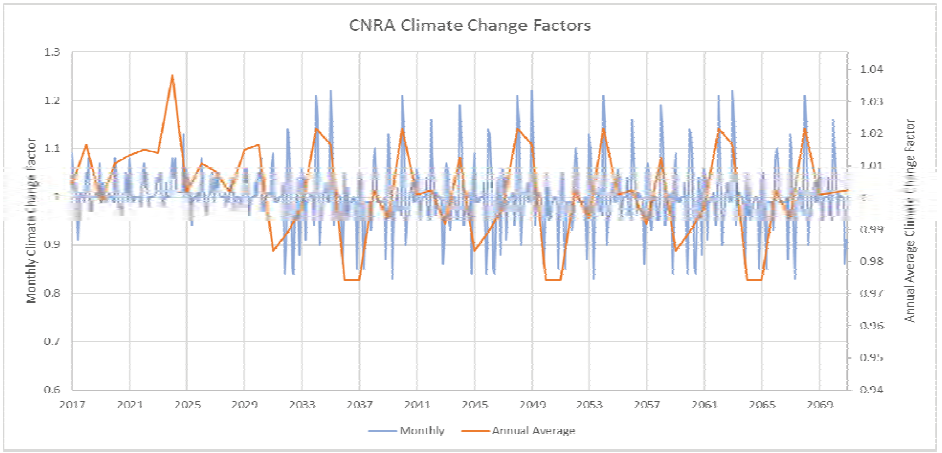
Water Supply and Demand
1990 to 2016
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

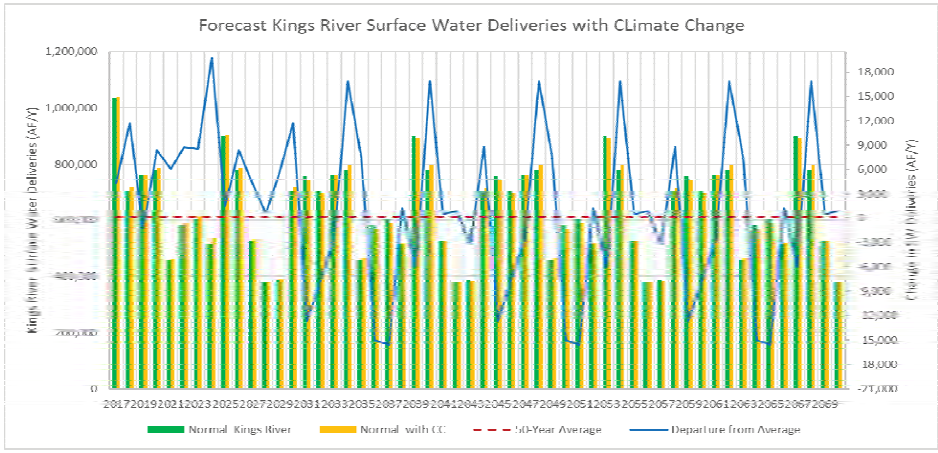
By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure: 3-51

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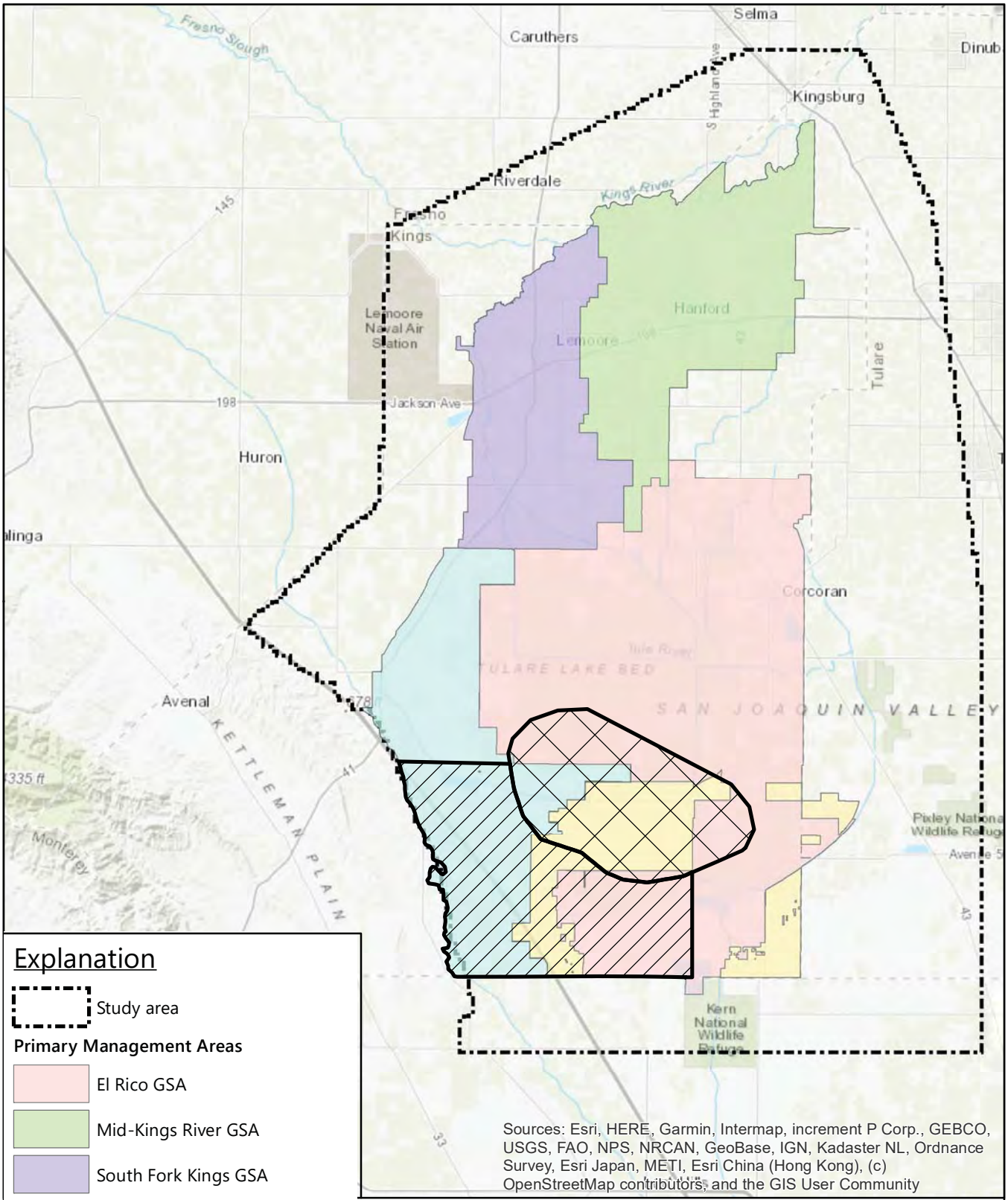




Notes:
1. AF/Y = acre-feet per year

Surface Water Delivery Foreacst with Climate Change
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/2019	Project No.: FR18161220
		Figure: 3-52



Explanation

- Study area

Primary Management Areas

- El Rico GSA
- Mid-Kings River GSA
- South Fork Kings GSA
- Southwest Kings GSA
- Tri-County Water Authority GSA

Secondary management areas

- Estimated extent of clay plug below E-clay
- Southwest Poor Quality Groundwater

Miles
0 2 4 8
0 2.5 5 10
Kilometers

N

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

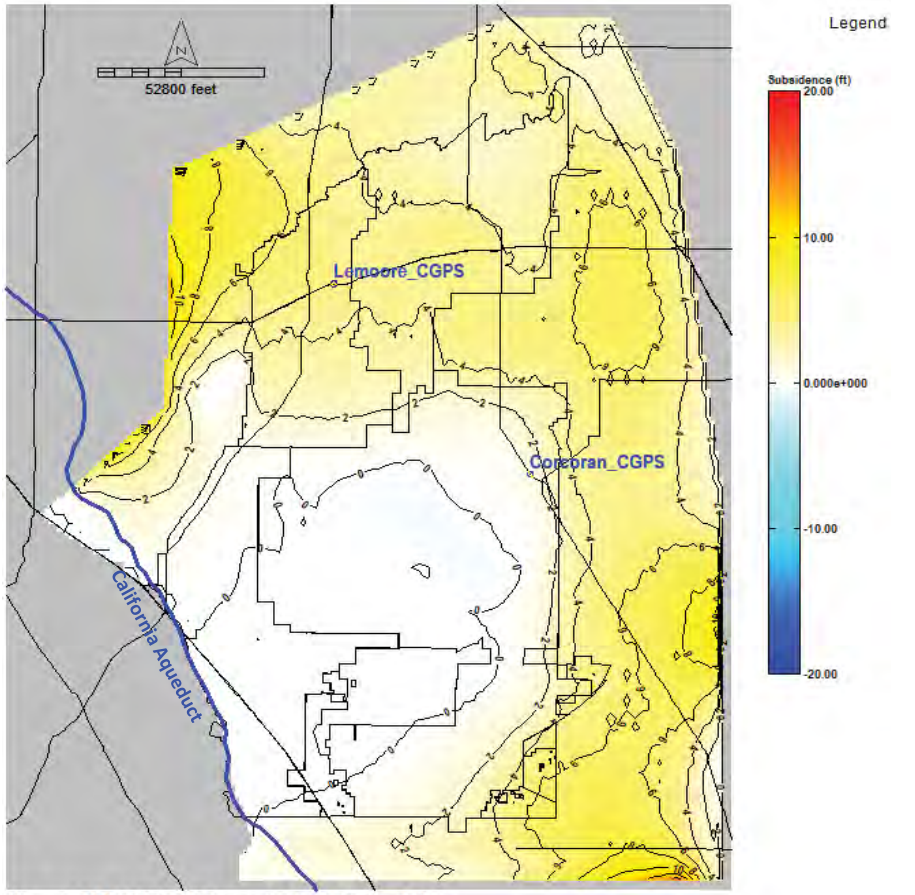
Management Areas

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

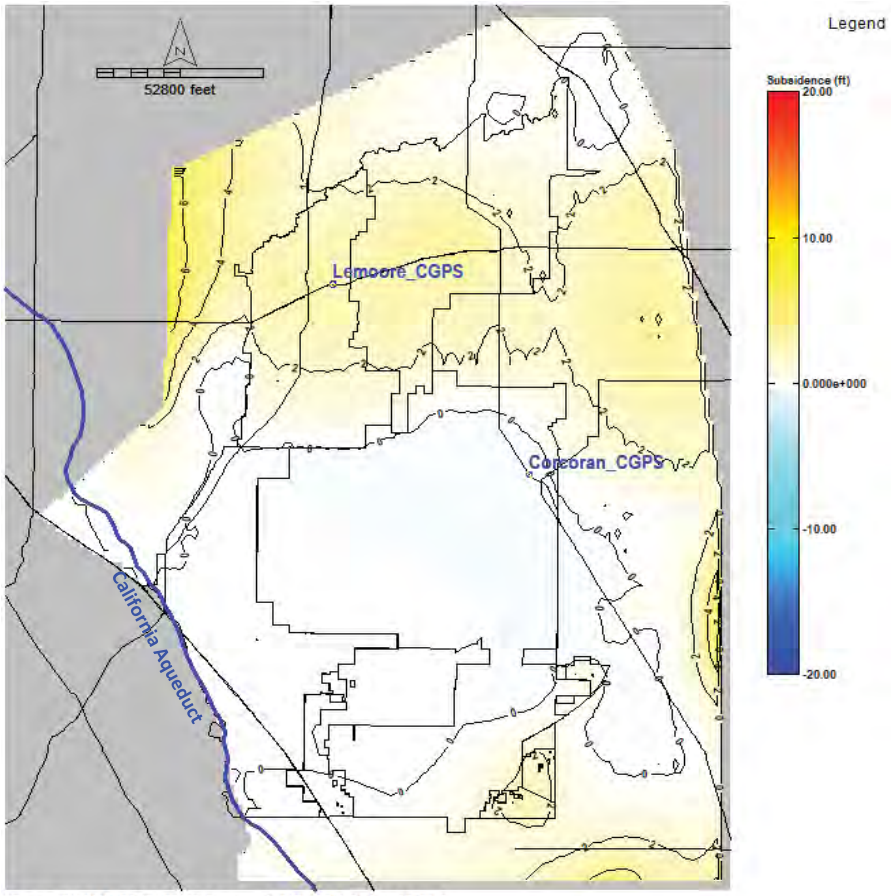
By: EMC	Date: 11/26/2019	Project No.: FR18161220
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Baseline



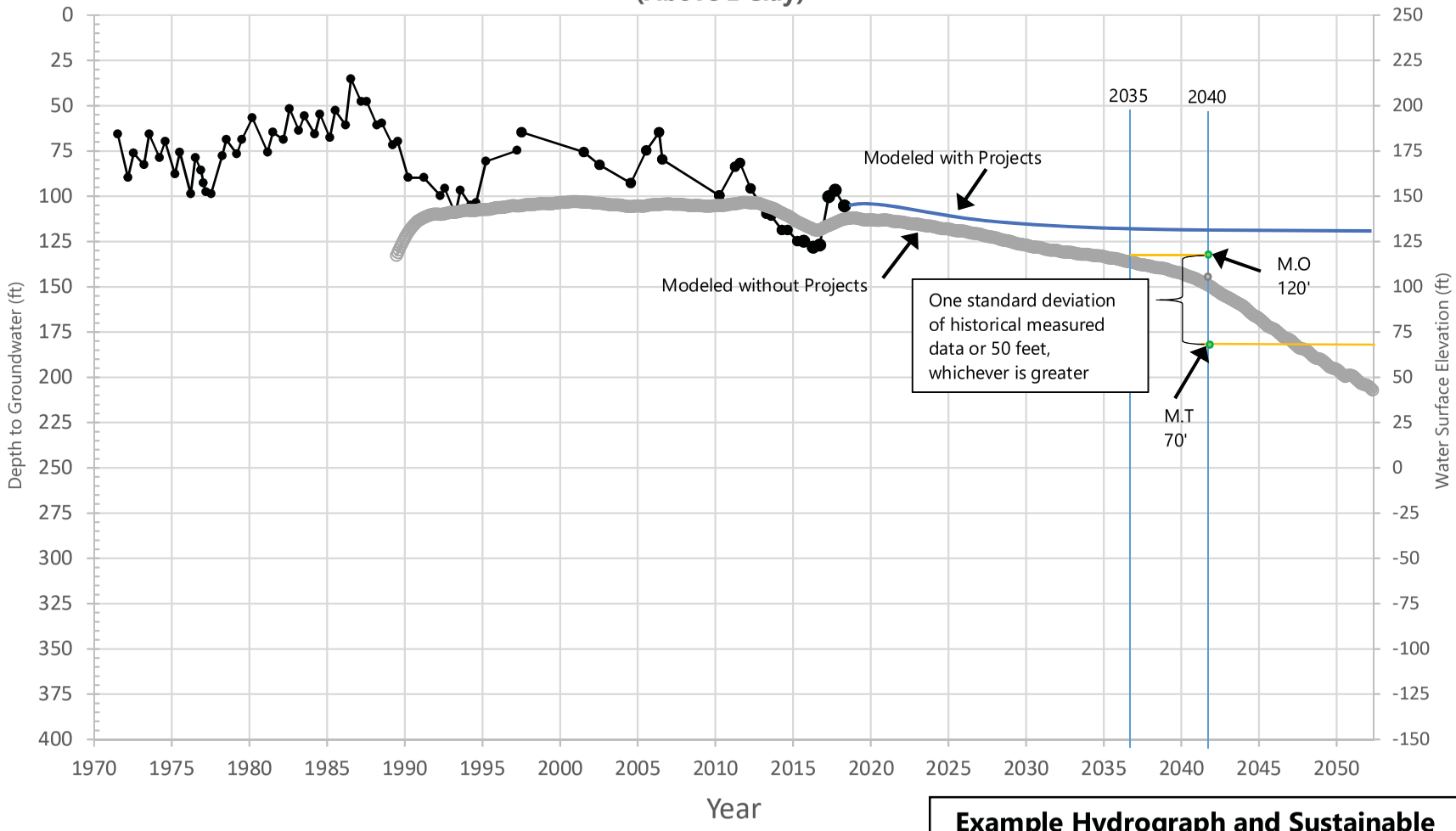
Projects

Note:
Cumulative Subsidence from January 2017 to July 2040

Forecast 2040 Subsidence
Baseline and Projects Forecast
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 01/06/2020	Project No.: FR18161220
		Figure 4-1

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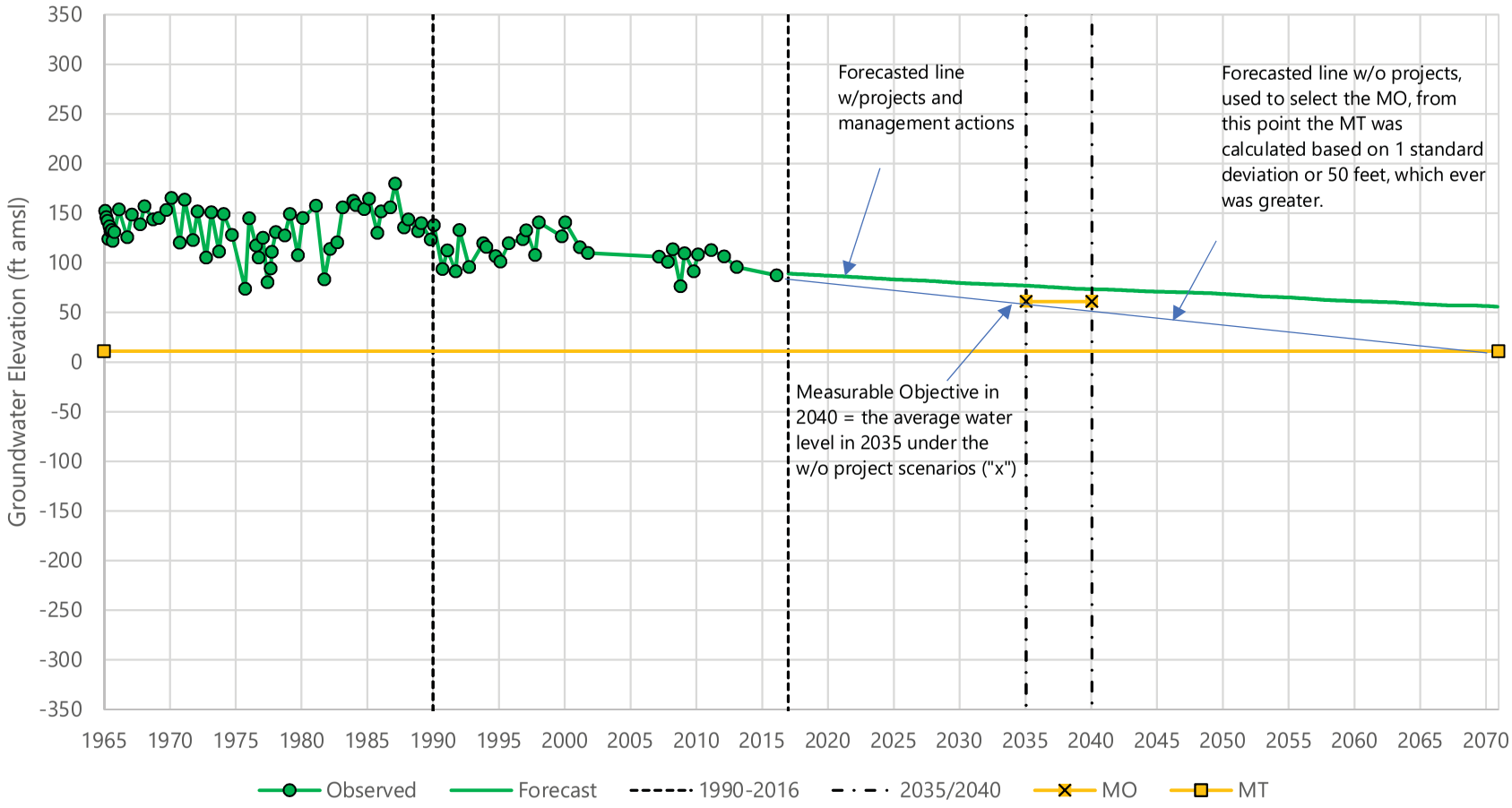
M.O - Measurable Objective
M.T - Minimal Threshold

Example Hydrograph and Sustainable Management Criteria

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/27/19	Project No.: FR18161220
		Figure **4-2**

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M.O Measurable Objective

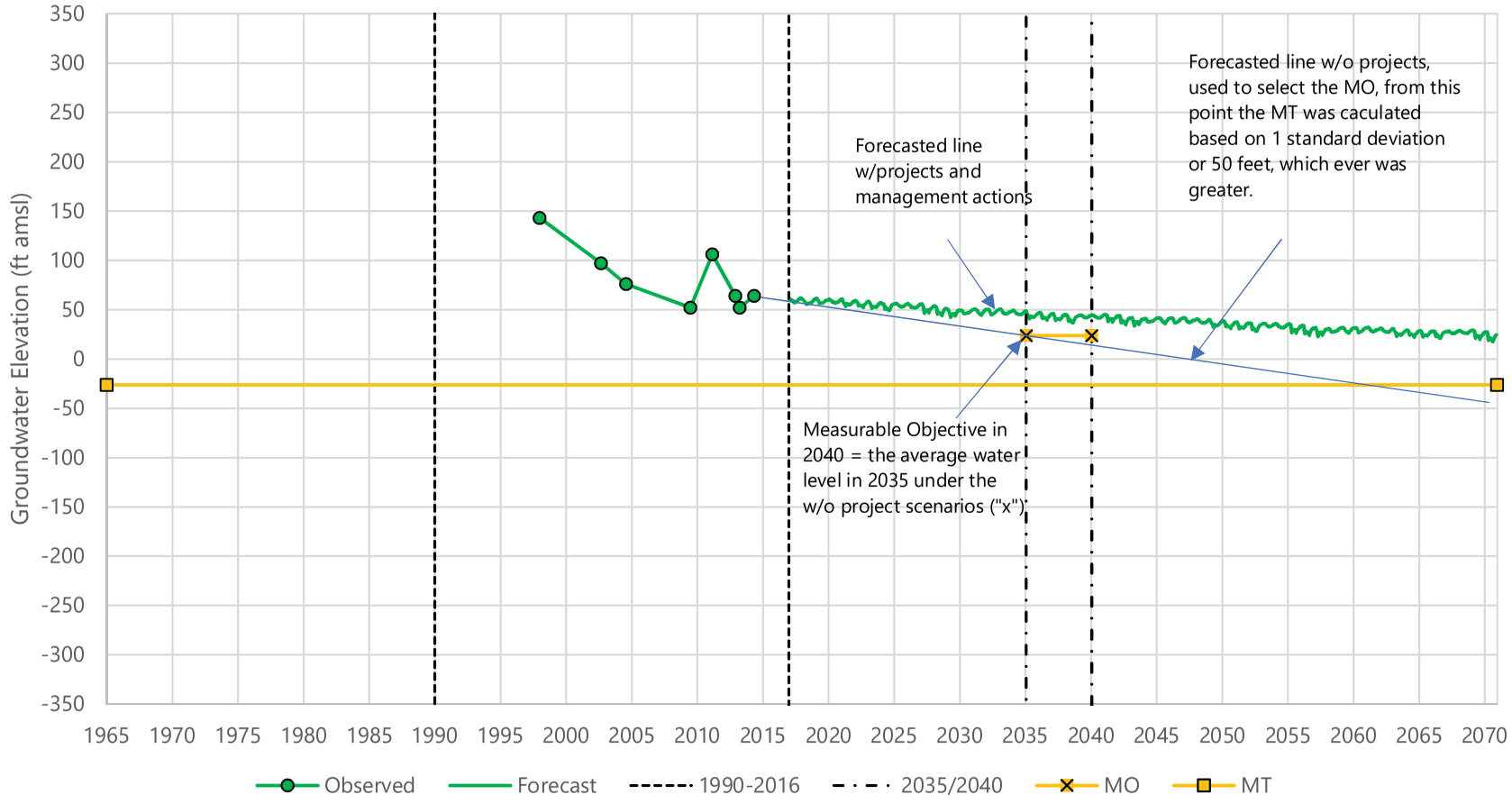
M.T Measurable Threshhold

Example Hydrograph and Sustainable Management Criteria Mid-Kings River GSA

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 08/28/2019	Project No.: FR18161220
		Figure **4-3**

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M.O Measurable Objective

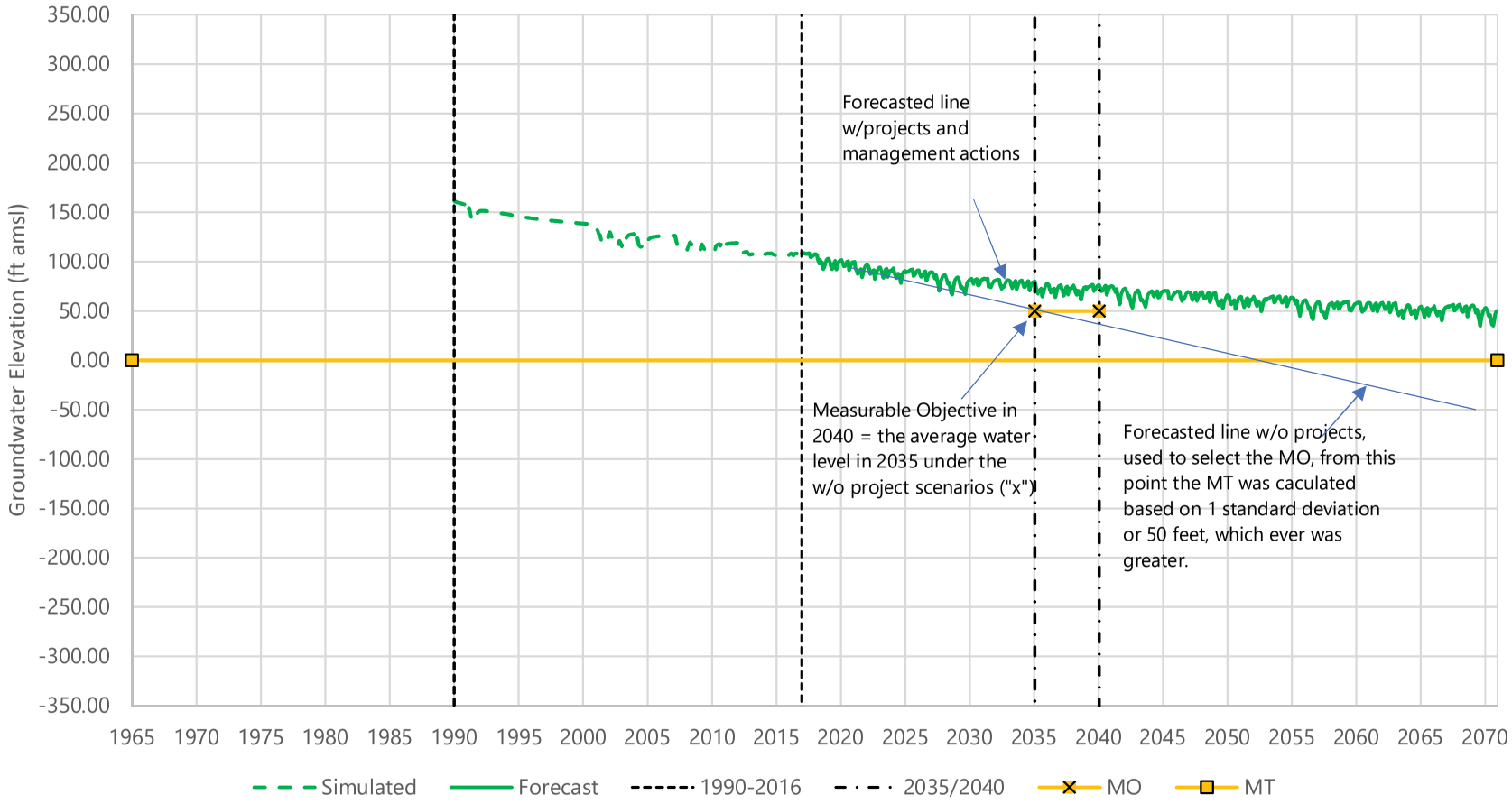
M.T Measurable Threshhold

Example Hydrograph and Sustainable Management Criteria South Fork Kings GSA

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 08/28/2019	Project No.: FR18161220
		Figure **4-4**

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M.O Measurable Objective

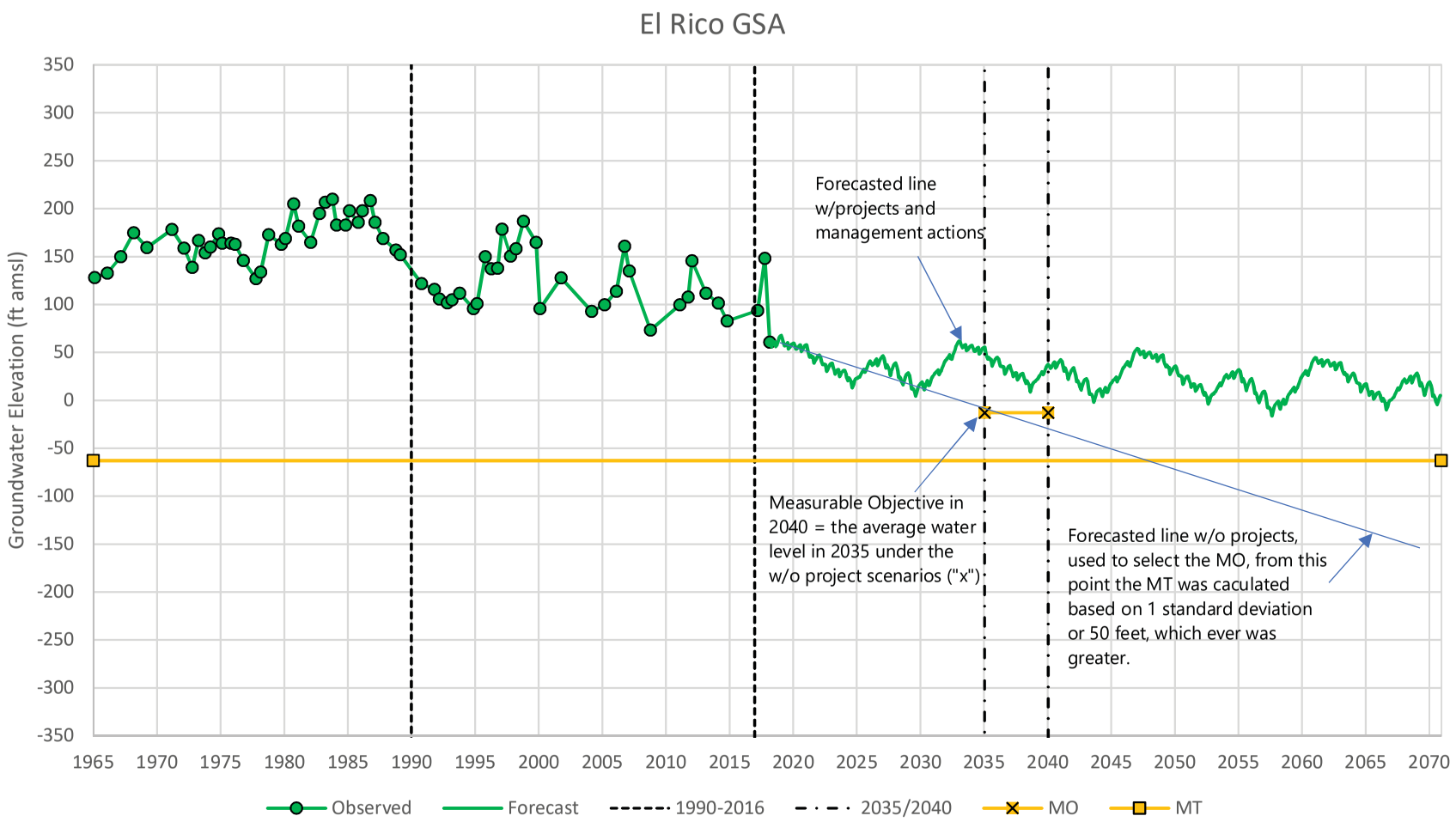
M.T Measurable Threshhold

Example Hydrograph and Sustainable Management Criteria Southwest Kings GSA

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 08/28/2019	Project No.: FR18161220
		Figure **4-5**

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M.O Measurable Objective

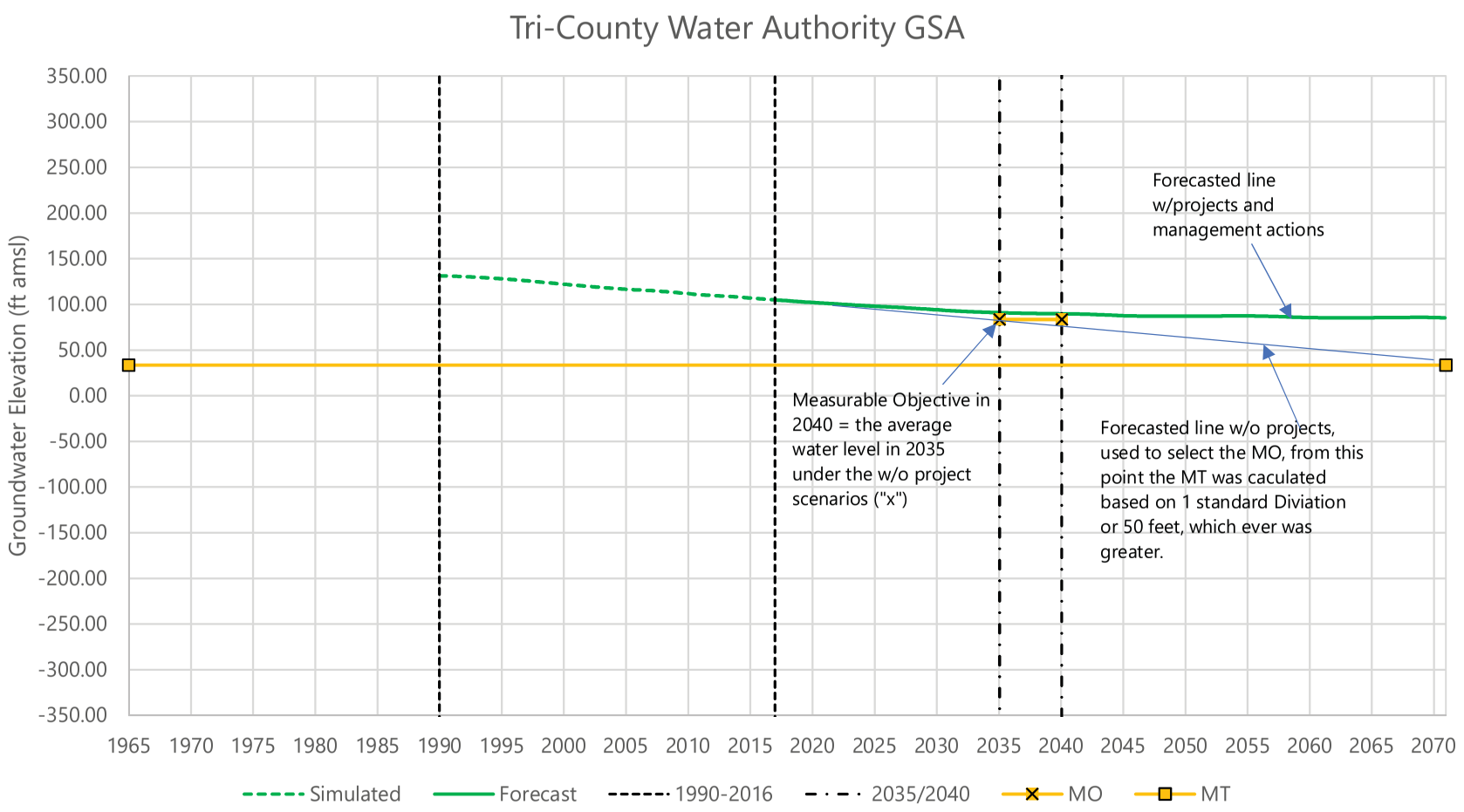
M.T Measurable Threshhold

Example Hydrograph
And Sustainable Management Criteria
El Rico GSA

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 08/28/2019	Project No.: FR18161220
		Figure **4-6**

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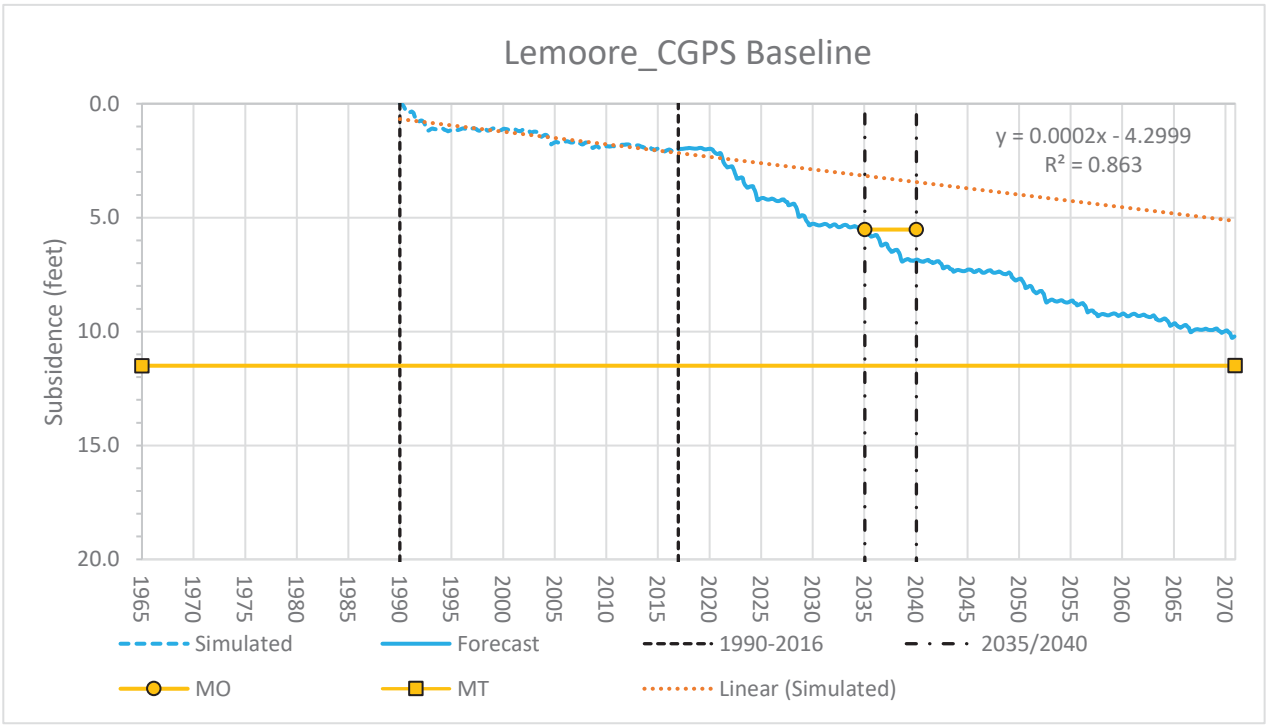


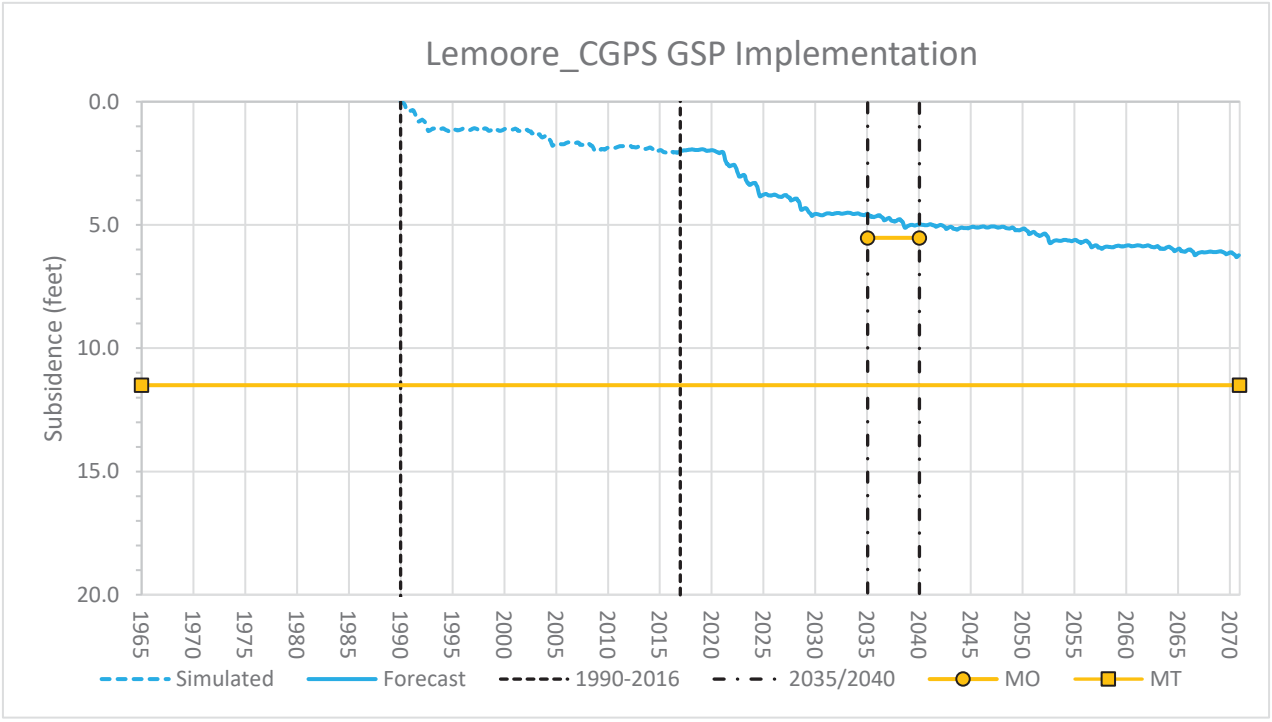
M.O Measurable Objective

M.T Measurable Threshhold

Example Hydrograph
and Sustainable Management Criteria
Tri-County Water Authority GSA
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 08/28/2019	Project No.: FR18161220
		Figure **4-7**

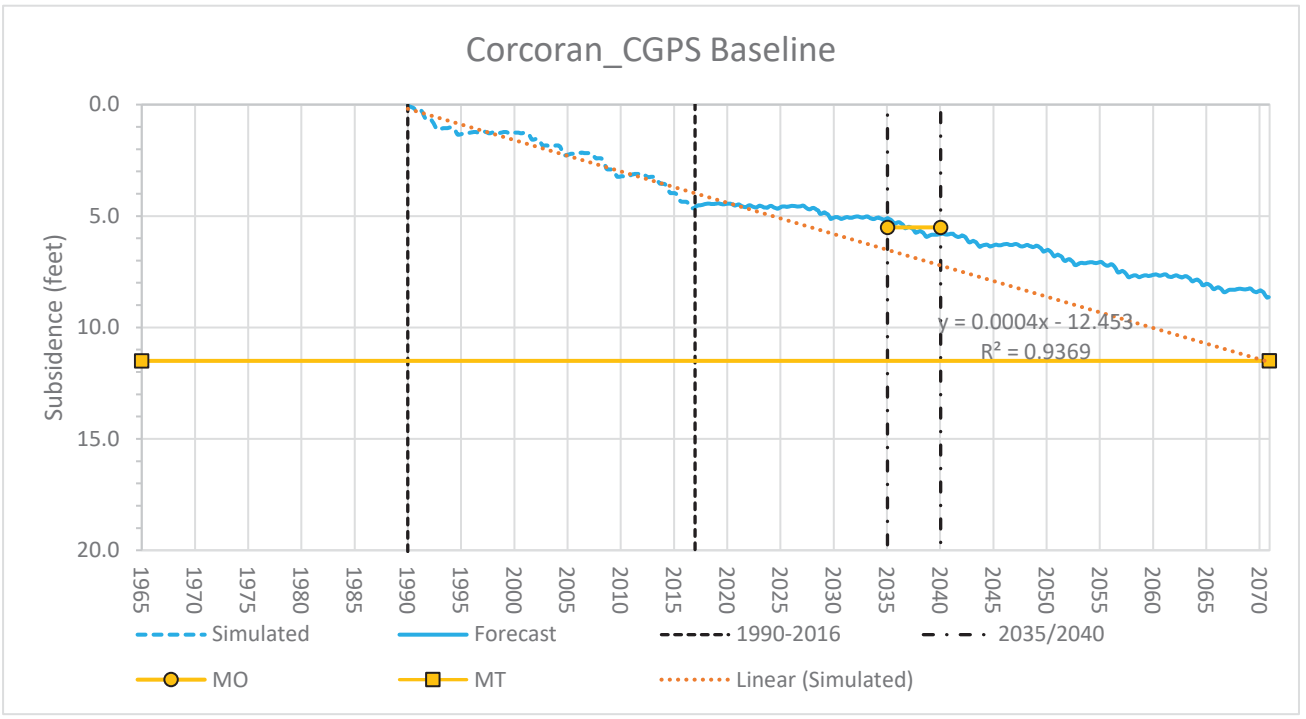


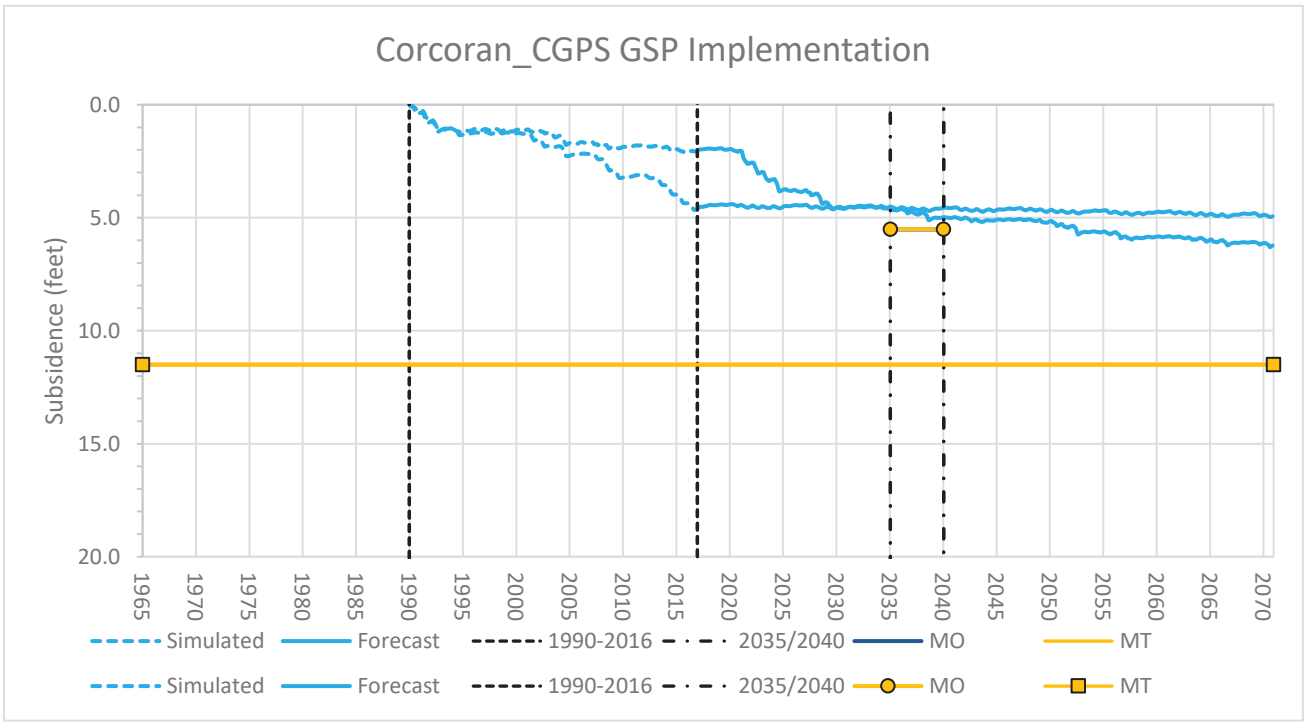


Forecast Land Subsidence under Baseline Conditions and with GSP Implementation
Lemoore RMS

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 01/07/2020	Project No.: FR18161220
		Figure **4-8**



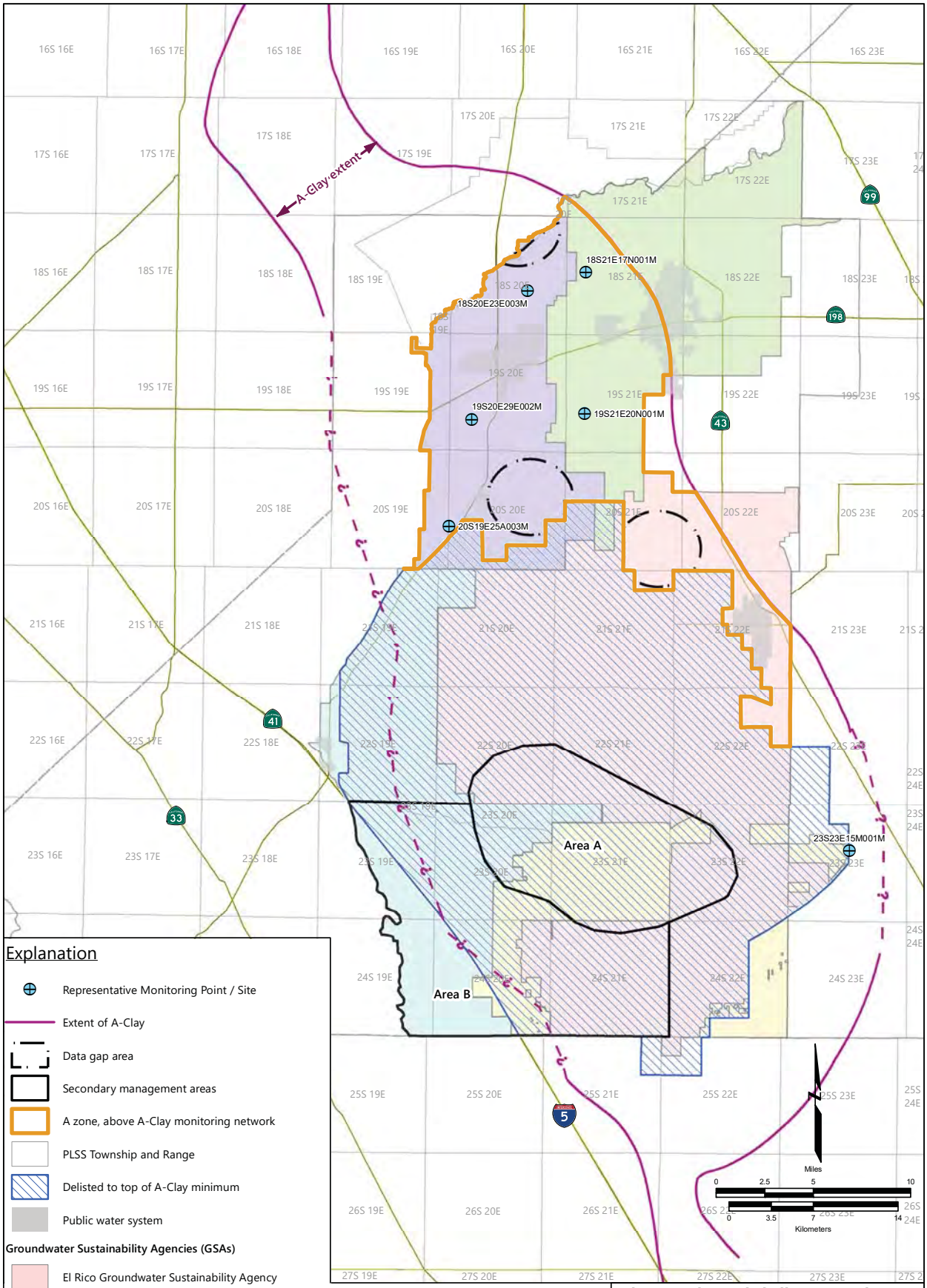


Forecast Land Subsidence under Baseline Conditions and with GSP Implementation
Corcoran RMS

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 01/07/2020	Project No.: FR18161220
		Figure **4-9**

Date: 12/17/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Monitoring_Network_fig5-1_AClay_ZoneA.mxd



Explanation

- Representative Monitoring Point / Site
- Extent of A-Clay
- Data gap area
- Secondary management areas
- A zone, above A-Clay monitoring network
- PLSS Township and Range
- Delisted to top of A-Clay minimum
- Public water system

Groundwater Sustainability Agencies (GSAs)

- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

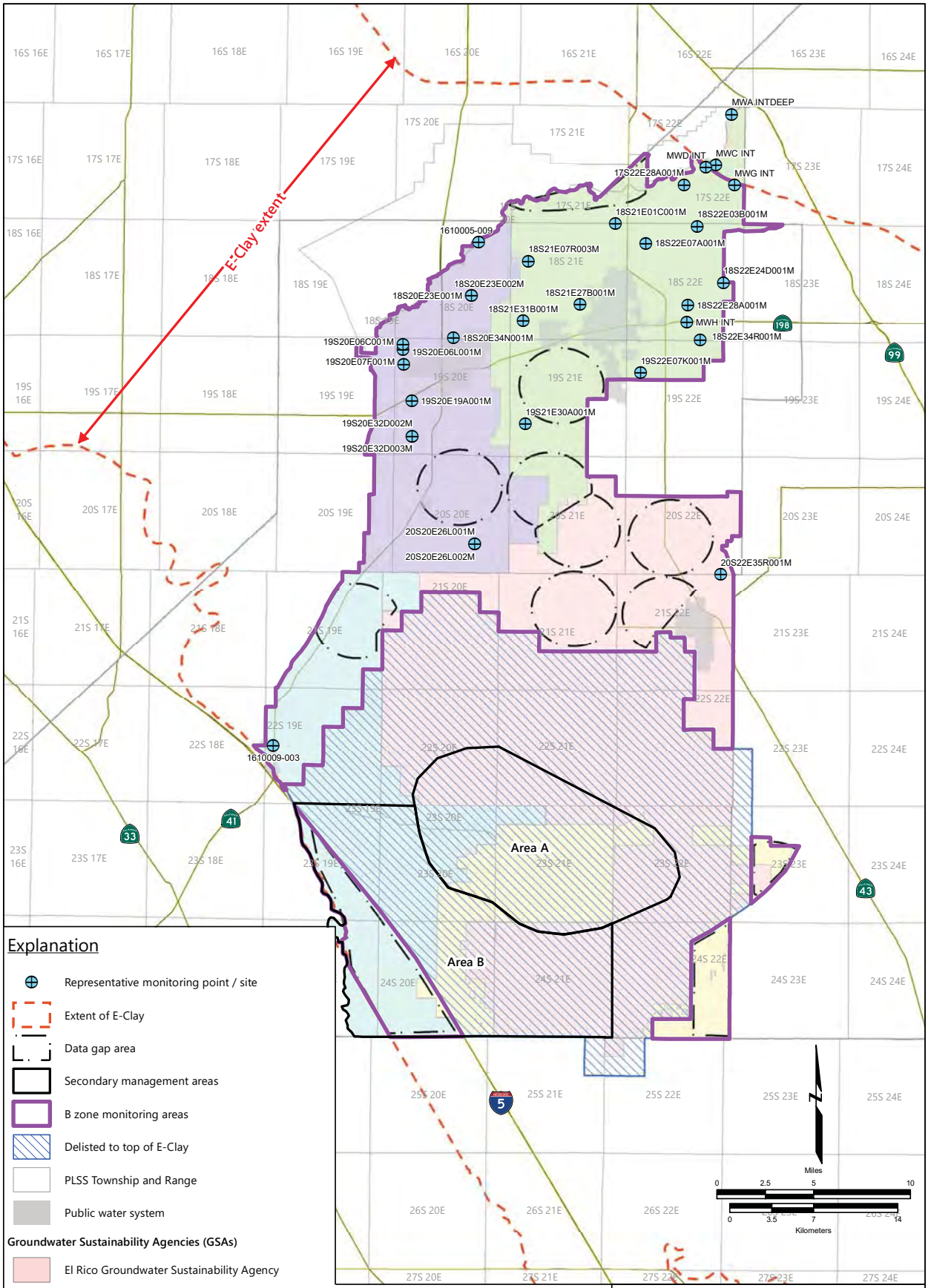
Notes:
1. A Clay extent adapted from USGS Water-SupplyPaper 1999-H, Plate 6, Croft (1972). See Section 3.1.8.3.
2. PLSS = public land survey system

Above A-Clay and Shallow Groundwater Level Respresentative Monitoring Network, A Zone

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/17/2019	Project No.: FR18161220
		Figure 5-1

Date: 12/16/2019 Printed by: elizabeth.chapman
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Explanation

- Representative monitoring point / site
- Extent of E-Clay
- Data gap area
- Secondary management areas
- B zone monitoring areas
- Delisted to top of E-Clay
- PLSS Township and Range
- Public water system

Groundwater Sustainability Agencies (GSAs)

- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

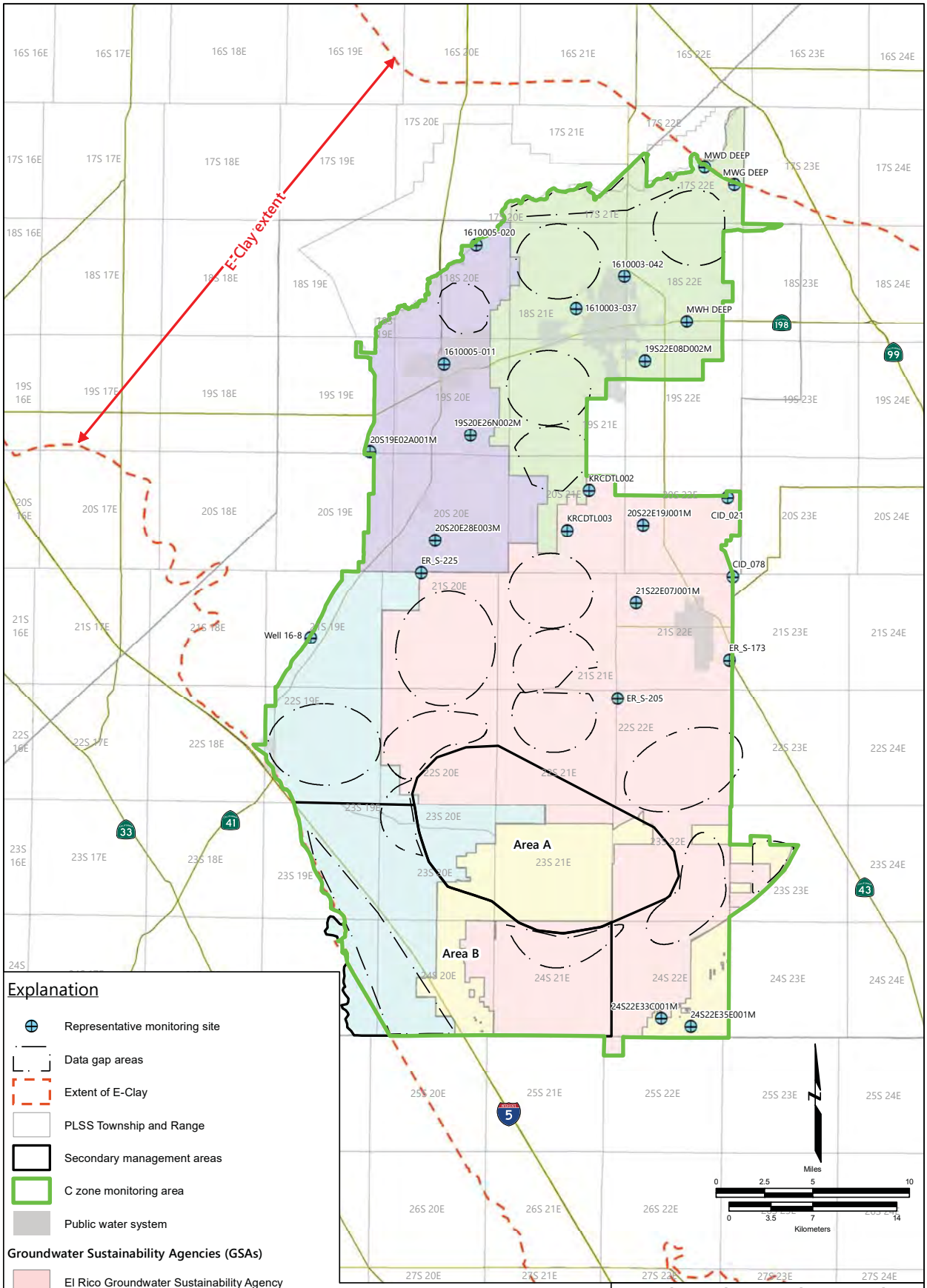
Notes:
1. E-Clay extent from USGS CVSD (2012). Based on Page (1986). See Section 3.1.8.3.
2. B Zone is above E-clay and below A-clay where the A-clay is present, and elsewhere above E-clay

Groundwater Level Representative Monitoring Network, B Zone

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/16/2019	Project No.: FR18161220
		Figure 5-2

Date: 12/16/2019 Printed by: elizabeth.chapman
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Explanation

- Representative monitoring site
- Data gap areas
- Extent of E-Clay
- PLSS Township and Range
- Secondary management areas
- C zone monitoring area
- Public water system

Groundwater Sustainability Agencies (GSAs)

- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

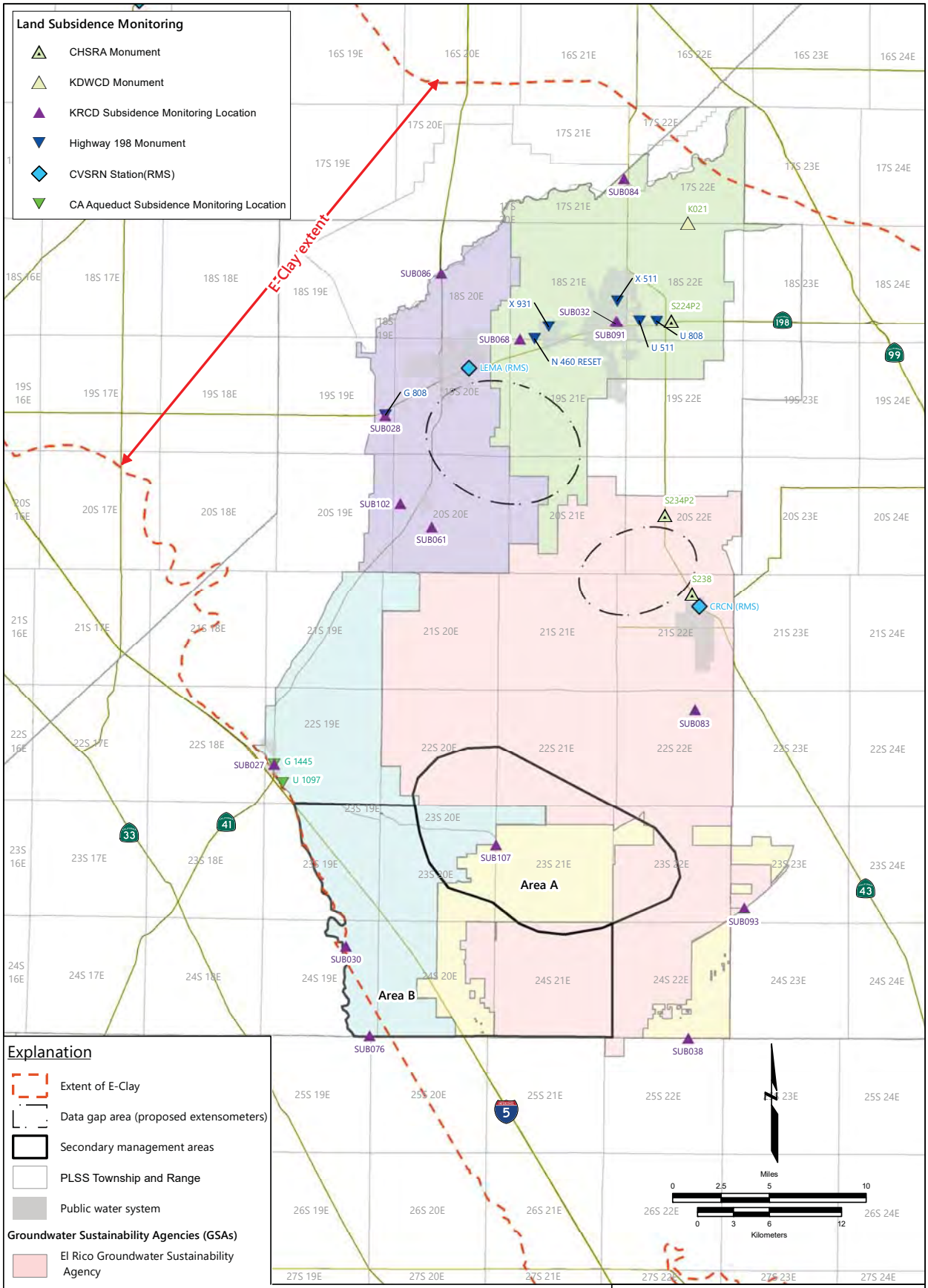
Notes:
E-Clay extent from USGS CVSD (2012). Based on Page (1986). See Section 3.1.8.3.

Below E-Clay Groundwater Level Representative Monitoring Network, C Zone

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/16/2019	Project No.: FR18161220
		Figure 5-3

Date: 12/16/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Monitoring_Network_fig5-4_SubsidenceMonitoring.mxd

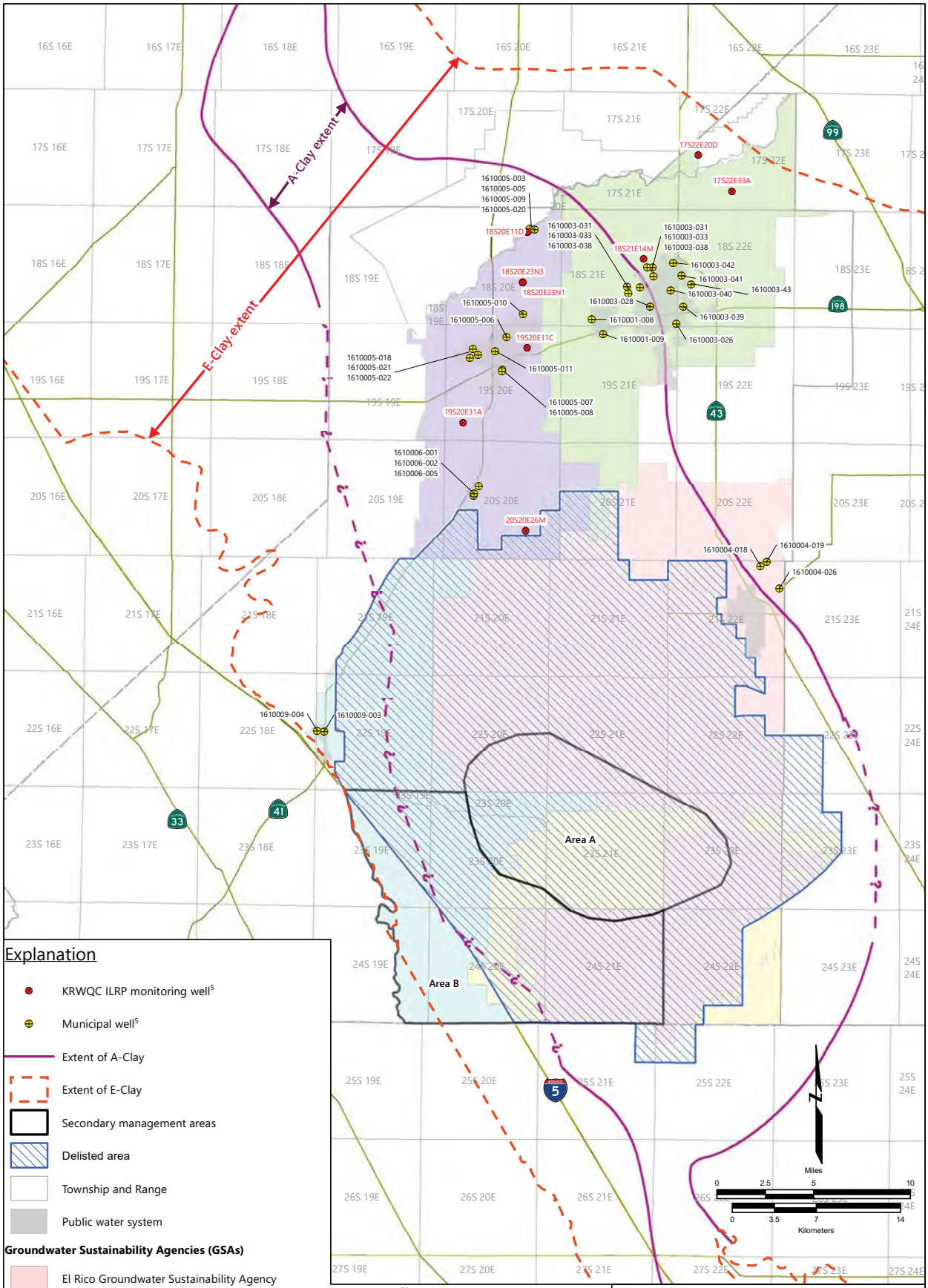


Notes:
1. E-Clay extent from USGS CVSD (2012). Based on Page (1986). See Section 3.1.8.3.
2. CHSRA = California High Speed Rail Authority
3. KRCD = Kings River Conservation District
4. KDWCD = Kaweah Delta Water Conservation District
5. CVSRN = Central Valley Spatial Reference Network

Subsidence Monitoring Network
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/16/2019	Project No.: FR18161220
		Figure 5-4

Date: 12/16/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Monitoring_Network_fig5-5_GWQualityMonitoring_rev.mxd



Explanation

- KRWQC ILRP monitoring well[5]
- Municipal well[5]
- Extent of A-Clay
- Extent of E-Clay
- Secondary management areas
- Delisted area
- Township and Range
- Public water system

Groundwater Sustainability Agencies (GSAs)

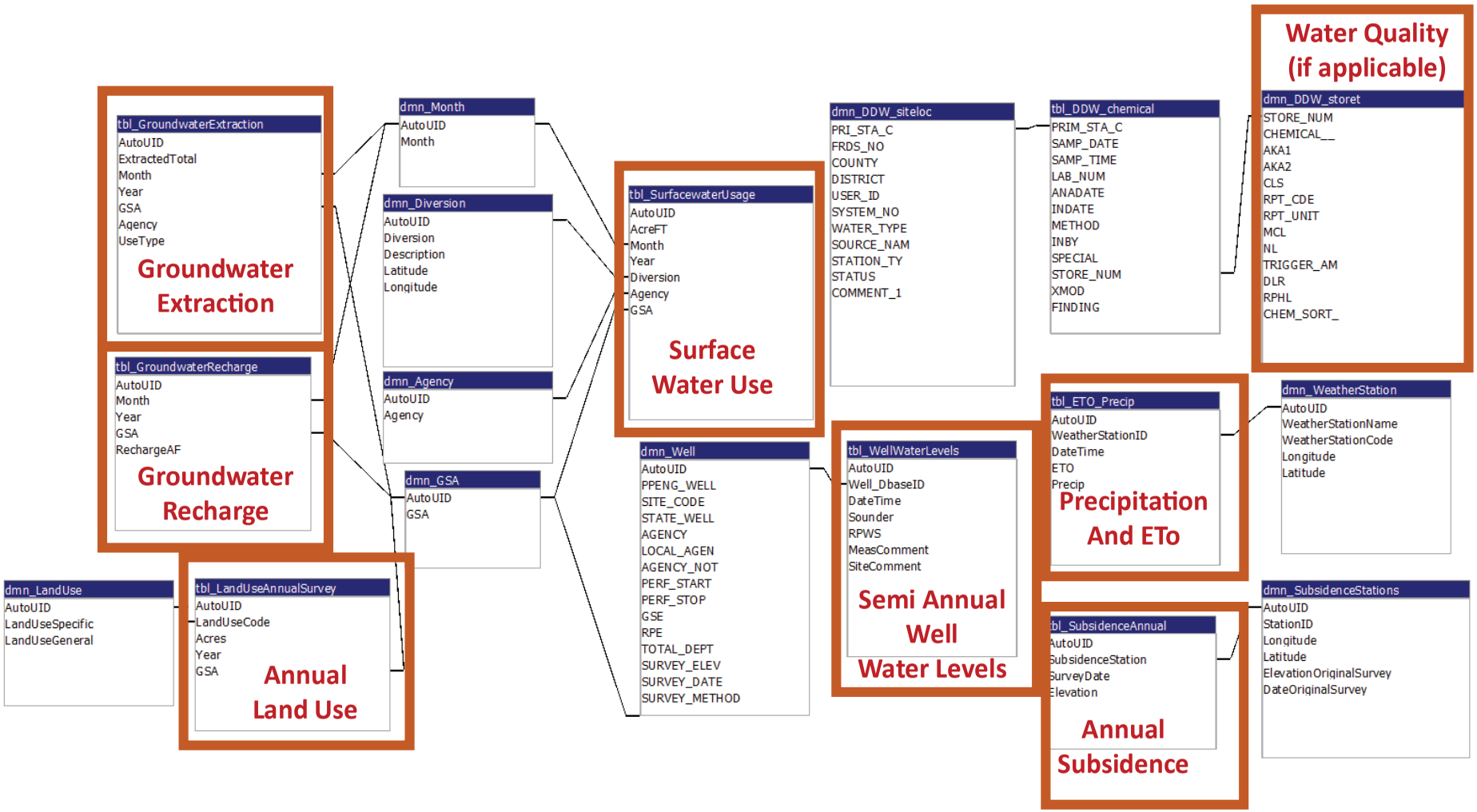
- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

Notes:
1. A-Clay extent adapted from USGS Water-SupplyPaper 1999-H, Plate 6, Croft (1972). See Section 3.1.8.3.
2. E-Clay extent from USGS CVSD (2012). Based on Page (1986). See Section 3.1.8.3.
3. KRWQA = Kings River Water Quality Coalition
4. ILRP = Irrigated Lands Regulatory Program
5. Wells are labeled with either water system ID or township, range, section designation

Groundwater Quality Monitoring Network

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/16/2019	Project No.: FR18161220
		Figure 5-5



DMS Table Relationships

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/25/2019	Project No.: 006741
		Figure **5-6**

Date: 08/20/2019 Printed by Elizabeth.Chapman
Path: I:\FR18s\FR18161220 Tulare Lake GSP\Figures\5-MonitoringNetwork\Figures\November2019_fig5-6_TLSB_Draft.pdf

tbl_GroundwaterExtraction

AutoUID	ExtractedTotal	Month	Year	GSA	Agency	UseType	Click to Add
1	0	1	2016	1	1	1	
2	0	1	2016	1	2	2	
3	0	2	2016	2	4	3	

tbl_GroundwaterRecharge

AutoUID	Month	Year	GSA	RechargeAF	Click to Add
(New)		0		0	

tbl_LandUseAnnualSurvey

AutoUID	LandUseCode	Acres	Year	GSA	LUGeneral	Click to Add
5313		581.7	2014	El Rico Groundwater Sustainability Agency	FIELD CROPS	
5306		44.2	2014	El Rico Groundwater Sustainability Agency	TRUCK, NURSERY AND BERRY CROPS	
5320		451.6	2014	El Rico Groundwater Sustainability Agency	IDLE	

tbl_SubsidenceAnnual

AutoUID	SubsidenceID	Year	Elevation	SurveyDate	Click to Add
1	SUB001	2010			
2	SUB002	2010			
3	SUB003	2010			

tbl_SurfacewaterUsage

AutoUID	Month	Year	Diversion	Agency	AcreFT	GSA	Click to Add
1225	1	2016	1	1	0	1	
1226	2	2016	1	1	207	1	
1227	3	2016	1	1	0	1	

tbl_WellWaterLevels

AutoUID	PPENG_ID	SITE_CODE	COOP_ORG_NAME	COOP_AGENCY_ORG_ID	MSMT_CMT	WLM_ORG_NAME	WLM_ORG_ID	WLM_ACC_DESC	WLM_DESC
360	357320N1196997W001	357320N1196997W001	Department of Water Re		1	Department of Water Resources	1	Water level accuracy is unknown	Unknown
361	357320N1196997W001	357320N1196997W001	Department of Water Re		1	Department of Water Resources	1	Water level accuracy is unknown	Unknown
362	357320N1196997W001	357320N1196997W001	Department of Water Re		1	Department of Water Resources	1	Water level accuracy is unknown	Unknown

tbl_WellWaterLevels

WLM_DESC	WLM_QA_DESC	GSE_WSE	RPE_WSE	WSE	RDNG_RP	RDNG_WS	WLM_GSE	WLM_RPE	MSMT_DATE	WLM_ID	STN_ID_1	Click to Add
Unknown		6.3	8.3	216.08	8.3	0	222.38	224.38	7/9/2010	852041	24614	
Unknown		5.7	7.7	216.68	7.7	0	222.38	224.38	4/26/2010	852040	24614	
Unknown		6.1	8.1	216.28	8.1	0	222.38	224.38	1/28/2010	852039	24614	

Sample DMS Tables with Associated Fields

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 11/20/2019	Project No.: FR18161220
		Figure 5-7

Date: 08/20/2019 Printed by Elizabeth.Chapman
Path: I:\FR18s\FR18161220 Tulare Lake GSP\Figures\5-MonitoringNetwork\Figures\November2019_fig5-7_DMSTemplate.pdf

Table 1-1. GSP Requirements

Requirements
Groundwater conditions must be adequately defined and monitored to demonstrate the GSPs are achieving the sustainability goals for the basin
GSAs must be sufficiently defined and compatible to evaluate the effect of GSPs on adjacent basins
GSPs must meet substantial compliance standards
A GSA shall provide a description of basin setting and establish criteria that will maintain or achieve sustainable groundwater management
DWR will consider state policy regarding to the human right to water when implementing these regulations
The GSP sustainable groundwater management criteria, projects, and management actions should be based on the level of understanding of the basin setting including an understanding of uncertainty and data gaps
A GSP must achieve the sustainability goals for the basin in 20 years

Table 1-2. Participating GSA Contact Information

GSA	Plan Manager	Address	Telephone	Email
Mid-Kings River	Dennis Mills, Secretary	200 North Campus Dr. Hanford, CA 93230	(559) 584.6412	kcwdh2o@sbcglobal.net
El Rico	Jeof Wyrick, Chairman	101 W. Walnut St. Pasadena, CA 91103	(626) 583.3000	jwyrick@jgboswell.com
South Fork Kings	Charlotte Gallock, Program Administrator	4886 E. Jensen Ave. Fresno, CA 93725	(559) 242.6128	cgallock@krcd.org
Southwest Kings	Dale Melville, Executive Director	286 Cromwell Ave. Fresno, CA 93711	(559) 449.2700	dmelville@ppeng.com
Tri-County Water Authority	Deanna Jackson, Executive Director	944 Whitley Ave. Suite E. Corcoran, CA 93212	(559) 762.7240	djackson@tcwater.org

See Acronyms and Abbreviations list for definitions.

Table 1-3. GSA Member Agencies

GSA	GSA Member Agencies	
Mid-Kings River	▪ Kings County Water District ▪ City of Hanford	▪ Kings County
El Rico	▪ Alpaugh Irrigation District ▪ City of Corcoran ▪ Corcoran Irrigation District ▪ Kings County ▪ Lovelace Reclamation District No. 739	▪ Melga Water District ▪ Salyer Water District ▪ Tulare Lake Basin Water Storage District ▪ Tulare Lake Drainage District
South Fork Kings	▪ City of Lemoore ▪ Empire West Side Irrigation District ▪ Stratford Irrigation District	▪ Stratford Public Utility District ▪ Kings County
Southwest Kings	▪ Dudley Ridge Water District ▪ Tulare Lake Reclamation District No. 761	▪ Kettleman City Community Services District ▪ Tulare Lake Basin Water Storage District ▪ Kings County
Tri-County Water Authority	▪ Angiola Water District ▪ Kings County	▪ Deer Creek Storm Water District ▪ Wilbur Reclamation District #825

Table 1-4. Proportionate Costs Breakdown of Each GSA

GSA	Acres	Acreage Portion	Participant Portion	Total Cost Allocation
Mid-Kings River GSA	97,384.6	0.09084	0.1	0.19084
El Rico GSA/Alpaugh ID	228,653.4	0.21328	0.1	0.31328
South Fork Kings GSA	71,310.9	0.06652	0.1	0.16652
Southwest Kings GSA	90,037.1	0.08398	0.1	0.18398
Tri-County WA	48,656.5	0.04538	0.1	0.14538
Totals	536,042.5	0.50000	0.5	1.00000

Table 1-5. Estimate of Costs GSP Planning

Description	Mid-Kings River	South Fork Kings	El Rico	Southwest Kings	Tri-County Water Authority	Total
Model Development	$95,470.00	$83,260.00	$156,640.00	$91,990.00	$76,690.00	$500,000.00
GSP Development	$348,283.00	$303,899.00	$571,736.00	$335,764.00	$265,318.00	$1,825,000.00
Totals	$443,753.00	$387,159.00	$728,376.00	$427,754.00	$342,008.00	$2,325,000.00

See Acronyms and Abbreviations list for definitions.

Table 1-6. Estimate of Costs GSP Implementation

	Mid-Kings River		South Fork Kings		El Rico		Southwest Kings		Tri-County Water Authority		Total
	Cost (Dollars)	Annual Yield (AF/yr)	Cost (Dollars)	Annual Yield (AF/yr)	Cost (Dollars)	Annual Yield (AF/yr)	Cost (Dollars)	Annual Yield (AF/yr)	Cost (Dollars)	Annual Yield (AF/yr)	
Description											
Administration	$50,000		$50,000		$20,000		$5,000		$5,000		$130,000
Monitoring	$50,000		$50,000		$10,000		$5,000		$5,000		$120,000
Fill Data Gaps	$50,000		$50,000		$50,000		$50,000				$150,000
Annual Costs											$400,000
Projects											
Existing System Improvements	$8,800,000	6,000.00									$8,800,000
Recharge	$93,000,000	27,700.00	$28,000,000	7,000.00							$121,000,000
Aquifer Storage and Recovery			$15,000,000	13,000.00							$15,000,000
Surface Storage and Reregulation			$6,000,000	2,000.00	$100,000,000	26,000.00			$45,000,000	15,000.00	$151,000,000
On Farm Flooding											$0
Surface Water System Improvements			$5,000,000	5,000.00							$5,000,000

See Acronyms and Abbreviations list for definitions.

Table 1-6. Estimate of Costs GSP Implementation (Continued)

	Mid-Kings River		South Fork Kings		El Rico		Southwest Kings		Tri-County Water Authority		Total
	Cost (Dollars)	Annual Yield (AF/yr)	Cost (Dollars)	Annual Yield (AF/yr)	Cost (Dollars)	Annual Yield (AF/yr)	Cost (Dollars)	Annual Yield (AF/yr)	Cost (Dollars)	Annual Yield (AF/yr)	
Demand Management											
Crop Rotation/Fallowing	$1,380,000	6,250.00	$5,000,000	13,000.00		15,000.00					$6,380,000
Groundwater Measurement			$500,000	1,500.00							$500,000
On Farm Improvement			$1,000,000	2,500.00							$1,000,000
Conservation/Reuse			$1,000,000	1,000.00							$1,000,000
	$103,330,000	39,950	$61,650,000	45,000	$100,080,000	41,000	$60,000		$45,010,000	15,000	$309,680,000

See Acronyms and Abbreviations list for definitions.

Table 2-1. Land Use in Tulare Lake Subbasin (2014)

Land Use Classification	Percent of Total Area
Commercial	0.3%
Deciduous Fruit and Nuts	14.6%
Field Crops	30.1%
Grain and Hay Crops	6.2%
Idle	22.9%
Industrial	0.3%
Pasture Crops	7.1%
Residential	0.4%
Riparian Vegetation	2.8%
Semi agricultural	1.8%
Truck, Nursery, and Berry Crops	6.0%
Urban	3.8%
Urban Landscape	0.1%
Vineyards	1.5%
Water Surface	2.0%
Young Perennials	0.1%
TOTAL	**100.0%**

Source: DWR 2014.

Table 2-2. Primary Water Uses and Water Sources

Groundwater Sustainability Agency	Water Use Sector (Agency / Water Company)	Water Use	Water Source Type
El Rico GSA	Alpaugh Irrigation District	Irrigation	Groundwater
	City of Corcoran	Residential Commercial Residential	Groundwater
	Corcoran Irrigation District	Irrigation Recharge	Kings River Kaweah River St. John's River
	Corcoran Irrigation Company	Irrigation Recharge	Kings River Kaweah River St. John's River
	Peoples Ditch Company	Irrigation Recharge	Kings River
	Last Chance Water Ditch Company	Irrigation Recharge	Kings River
	Lakeside Canal Company	Irrigation Recharge	Kaweah River St. John's River CVP
	Tulare Lake Basin Water Storage District	Irrigation	Kings River Kaweah River St. John's River Tule River SWP
Tri-County Water Authority GSA	Angiola Water District	Irrigation Recharge	SWP CVP Kings River Tule River Deer Creek Groundwater Poso Creek
	Atwell Island Water District	Irrigation	Groundwater
	Deer Creek Storm Water District	Flood Control	Deer Creek Poso Creek
	W. H. Wilbur Reclamation District #825	Irrigation	Poso Creek
Mid-Kings River GSA	City of Hanford	Residential Commercial Industrial	Groundwater
	Armona Community Services District	Residential Commercial	Groundwater

See Acronyms and Abbreviations list for definitions.

Table 2-2. Primary Water Uses and Water Sources (Continued)

Groundwater Sustainability Agency	Water Use Sector (Agency / Water Company)	Water Use	Water Source Type
Mid-Kings River GSA (Continued)	Home Garden Community Services District	Residential	Groundwater
	Kings County Water District	Irrigation Recharge Banking	Kings River Kaweah River St. John's River CVP
	Lakeside Irrigation Water District & Canal Company	Irrigation Recharge	Kaweah River St. John's River CVP
	Peoples Ditch Company	Irrigation Recharge	Kings River
	Last Chance Water Ditch Company	Irrigation Recharge	Kings River
	Santa Rosa Rancheria	Residential Commercial	Groundwater
Southwest Kings GSA	Dudley Ridge Water District	Irrigation	SWP
	Tulare Lake Reclamation District #761	Irrigation	Kings River SWP Groundwater
	Tulare Lake Basin Water Storage District	Irrigation	Kings River Kaweah River St. John's River Tule River SWP
	Kettleman City Community Services District	Residential Commercial Industrial	SWP Groundwater (emergency supply)
South Fork Kings GSA	Lemoore Canal and Irrigation Company	Irrigation	Kings River
	Stratford Irrigation District	Irrigation	Kings River
	Stratford Public Utility District	Residential Commercial	Groundwater
	Santa Rosa Rancheria	Residential Commercial	Groundwater
	City of Lemoore	Municipal	Groundwater

See Acronyms and Abbreviations list for definitions.

Table 2-3. Summary of Applicable Plans

County	Plan	Online Source
Kings County	Kings County 2035 General Plan (adopted January 2010, includes Land Use, Circulation, Noise, Open Space, Resource Conservation, Health and Safety, and Air Quality Elements; Housing Element updated January 2016; Dairy Element adopted July 2002)	https://www.countyofkings.com/departments/community-development-agency/information/2035-general-plan
	Armona Community Plan (2009)	https://www.countyofkings.com/home/showdocument?id=13505
	Home Garden Community Plan (2015)	https://www.countyofkings.com/home/showdocument?id=13507
	Kettleman City Community Plan (2009)	https://www.countyofkings.com/home/showdocument?id=13509
	Stratford Community Plan (2009)	https://www.countyofkings.com/home/showdocument?id=3106
	City of Hanford – 2035 General Plan (April 2017)	http://www.cityofhanfordca.com/document_center/Planning/Plans/Hanford%20General%20Plan/2035%20General%20Plan%20%20Policy%20Document.pdf
	City of Lemoore – 2030 General Plan (May 2008)	http://lemoore.com/communitydevelopment/general-plan/
	City of Corcoran – 2025 General Plan (March 2007), 2005-2025 General Plan Enhancement (November 2014)	http://www.cityofcorcoran.com/civica/filebank/blobdload.asp?BlobID=3796
County of Tulare	County of Tulare – 2030 General Plan (August 2012)	http://generalplan.co.tulare.ca.us/documents/GP/001Adopted%20Tulare%20County%20General%20Plan%20Materials/000General%20Plan%202030%20Part%20I%20and%20Part%20II/GENERAL%20PLAN%202012.pdf
Kern County	Kern County – General Plan (September 2009)	https://kernplanning.com/planning/planning-documents/general-plans-elements/

See Acronyms and Abbreviations list for definitions.

Table 2-4. Beneficial Uses and Users by GSA

Stakeholder Group	Description
Mid-Kings River GSA	
Agricultural Users	Service area is composed of mostly agricultural lands and agricultural users.
Domestic Well Owners	There are domestic wells within the Mid-Kings River GSA, and it is understood that many rural domestic users will fall into the "de minimis extractor" category, so further work is being conducted to understand to what extent domestic users will be affected by GSP requirements.
Public Water Systems	Armona CSD, Home Garden CSD and Hardwick Water Company, as well as several transient public water systems for school districts are included in this category (Kings River-Hardwick, Pioneer, Hanford Christian).
Municipal Water Systems	City of Hanford
Local Land Use Planning Agencies	City of Hanford and Kings County
California Native American Tribes	See Appendix B, Section C.2
Disadvantaged Communities	Armona, Home Garde, Hardwick
Entities monitoring and reporting Subbasin groundwater elevations	Kings CWD monitors groundwater levels within its service area and is providing a subset of that information to the KRCD for submission to the CASGEM system.
South Fork Kings GSA	
Agricultural Users	Service area is composed of mostly agricultural lands and agricultural users.
Domestic Well Owners	There are domestic wells within the South Fork Kings GSA, and it is understood that many domestic users will fall into the "de minimis extractor" category, so further work is being conducted to understand to what extent domestic users will be affected by GSP requirements.
Municipal Well Operators	City of Lemoore, Stratford PUD
Local Land Use Planning Agencies	City of Lemoore, Kings County
California Native American Tribes	See Appendix B, Section C.2
Disadvantaged Communities	Community of Stratford
Entities monitoring and reporting Subbasin groundwater elevations	KRCD is the designated monitoring entity for the Kings and Tulare Lake Subbasins under CASGEM program. South Fork Kings GSA will coordinate its SGMA monitoring efforts with the CASGEM monitoring effort led by KRCD.
Southwest Kings GSA	
Agricultural Users	Approximately 99% of the GSA is composed of agricultural lands. Representatives of the agricultural community are currently involved on the GSA Board of Directors.
Domestic Well Owners	Only one or two landowners utilize a domestic well and are represented on the Board of Directors through member agencies.

See Acronyms and Abbreviations list for definitions.

Table 2-4. Beneficial Uses and Users by GSA (Continued)

Stakeholder Group	Description
Municipal Well Operators	Kettleman City CSD relies solely on surface water supply (effective October 2019). Their municipal wells are a back-up source to provide well water to residential and commercial customers within the GSA boundary in emergency situations when surface water is not accessible.
Local Land Use Planning Agencies	Kings County
California Native American Tribes	See Appendix D, Section C.2
Disadvantaged Communities	Kettleman City
Entities monitoring and reporting Subbasin groundwater elevations	KRCD is the designated monitoring entity for the Kings and Tulare Lake Subbasins under CASGEM program. Southwest Kings GSA will coordinate its SGMA monitoring efforts with the CASGEM monitoring effort led by KRCD.
El Rico GSA	
Agricultural Users	Represented through many of the GSA member agencies and/or by Kings County.
Domestic Well Owners	Represented through member agencies including Kings County or via exemption for small amounts of groundwater extraction.
Municipal Well Operators	City of Corcoran
Public Water Systems	City of Corcoran
Local Land Use Planning Agencies	City of Corcoran, Kings County
Surface Water Users	Represented through GSA member agencies
Disadvantaged Communities	City of Corcoran
Entities monitoring and reporting Subbasin groundwater elevations	Represented by GSA member agencies including TLBWSD that collects and reports data for multiple members of the agency via the Tulare Lake Coordinated Groundwater Management Plan.
Tri-County Water Authority GSA	
Agricultural Users	Composed almost entirely of agricultural users, including nut grower commodity groups and other agricultural use growers.
Domestic Well Owners	There are domestic wells within the GSA area, but because SGMA excludes “de minimis extractors,” it is anticipated that the GSP will exclude domestic wells from such requirements.
Local Land Use Planning Agencies	Kings County
Federal Government	Bureau of Land Management
Entities monitoring and reporting Subbasin groundwater elevations	Angiola WD, TLBWSD

Source: Appendix B.

Table 3-1. Historical Hanford Precipitation (Inches), Tulare Lake Subbasin SGMA Model, Kings County, California

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1899	M	M	M	M	M	M	M	M	0	0.67	M	0.87	M
1900	1.38	0	1.18	1.04	M	M	M	M	M	M	M	M	M
1901	M	M	M	M	M	M	M	T	1.04	T	M	0.15	M
1902	0.4	2	1.78	0.47	0.09	M	0	M	0	0.36	1.67	0.56	M
1903	1.31	0.38	1.71	0.5	0	0	0	0	0	0.05	0.47	0.15	4.57
1904	0.52	2.03	2.05	0.72	0	0	0	0	2.48	0.84	0.31	1.16	10.11
1905	1.28	1.09	2.1	0.56	0.65	0	0	0	0.07	0	1.16	0.23	7.14
1906	1.59	1.92	4.05	0.62	2.06	0.02	0	0	0	0	M	M	M
1907	M	M	M	M	M	M	M	M	M	M	M	M	M
1908	M	M	M	M	M	M	M	M	M	M	M	0.31	M
1909	M	M	M	M	M	M	M	M	M	M	M	M	M
1910	M	M	M	M	M	M	M	M	M	M	M	M	M
1911	M	M	M	M	M	M	M	M	M	M	M	M	M
1912	M	0.02	3.24	1.52	0.27	0	0	0	0	0	0.61	0.21	M
1913	1.26	1.55	0.34	0.78	0.76	0.06	0.08	0	M	M	M	1.35	M
1914	4.36	1.25	0.37	0.11	M	1.06	0	0	0	0	0.02	M	M
1915	M	M	0.3	1.37	M	M	M	M	M	M	M	M	M
1916	4.68	M	M	M	0.16	M	M	0.28	0.47	1.09	M	1.35	M
1917	M	M	M	M	0.31	M	M	M	M	M	M	M	M
1918	M	4.5	3.43	M	M	M	M	M	0.88	0.12	M	M	M
1919	M	M	1.01	0.15	0.1	M	M	M	M	M	M	M	M
1920	M	2.72	3.05	0.24	M	M	M	M	M	M	M	M	M
1921	M	0.89	M	M	0.87	M	M	M	M	M	M	M	M
1922	M	M	M	M	M	M	M	T	M	M	M	M	M
1923	M	M	M	2.43	M	M	M	M	M	M	M	0.22	M
1924	M	M	1.86	M	0	M	M	T	0	0.65	M	2.12	M
1925	M	M	1.58	M	M	M	0	M	0	M	M	M	M

See Acronyms and Abbreviations list for definitions.

Table 3-1. Historical Hanford Precipitation (Inches), Tulare Lake Subbasin SGMA Model, Kings County, California (Continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1926	0.82	1.44	0.2	2.67	T	0	0	0	0	0.76	3.67	0.65	10.21
1927	1.33	2.52	2.04	0.18	0.06	T	0	0.04	T	1.67	1.63	0.78	10.25
1928	0.09	0.96	1.55	0.08	0.1	0	0	0	0	T	1.47	1.69	5.94
1929	0.81	0.61	1.4	0.81	0	0.24	T	0	0.03	0	0	0.42	4.32
1930	1.66	1	1.66	0.15	0.37	0	0	0.02	0.38	0.07	0.67	0.3	6.28
1931	2.32	0.72	0.07	0.91	0.2	1.12	0	0.08	0.08	0	1.36	2.54	9.4
1932	1.85	1.52	0.47	0.71	0.13	0	0	0	0	0	0.28	0.93	5.89
1933	3.12	0.16	0.72	0.28	0.41	0.07	0	0	0	0.15	0	1.01	5.92
1934	0.17	1.53	0.05	0	0.22	0.14	0	0	0	1.06	2.15	1.84	7.16
1935	2.5	1.77	2	2.05	0	0	0.03	0	0.06	0.51	0.4	0.89	10.21
1936	0.66	4.7	0.97	0.55	T	T	0	0	0	1.84	0	2.87	11.59
1937	1.95	2.46	2.23	0.22	0	0	0	0	0	0.11	0.21	2.16	9.34
1938	1.76	3.51	4.59	1.15	0.11	0.17	0.07	0	0.13	0.19	0.19	1.42	13.29
1939	1.54	0.77	1.44	0.82	T	0.12	0	0	0.04	0.57	0.06	0.22	5.58
1940	3.53	3.61	0.99	0.18	T	T	0	0	0	0.85	T	3.61	12.77
1941	1.51	3.9	2.05	2.41	T	T	0	T	0	0.9	0.57	3.11	14.45
1942	1.21	0.88	0.94	1.19	0.16	0	0	M	0	0	0.43	1.1	M
1943	2.73	1.14	3.35	0.87	0	0	0	0	0	0.03	0.22	1.03	9.37
1944	1.28	2.97	0.22	0.86	0.28	0.23	0	0	0.02	0.23	2.25	0.97	9.31
1945	0.26	2.71	1.81	0.16	0.1	0.17	0	0	T	0.71	1.15	1.51	8.58
1946	0.34	1.53	2.56	0.07	0.41	0	0.11	0	0	1.33	1.1	2.06	9.51
1947	0.41	0.49	0.56	0.11	0.41	0	0	0	T	0.59	0.29	0.51	3.37
1948	0	0.44	1.46	1.55	0.54	0	0	0	0	0.03	0.01	0.99	5.02
1949	0.51	0.85	1.94	0.07	0.53	0	0	T	0	0	0.6	0.68	5.18
1950	1.93	1.13	1.1	0.4	0	0	0.08	0	0	0.34	0.63	1.06	6.67
1951	1.24	0.76	0.22	1.17	0.07	0	0	0	0	0.08	1.11	2.39	7.04
1952	3.08	0.27	2.18	0.79	0.01	0.02	T	0	0.17	0.05	0.65	2.96	10.18
1953	1.1	0.27	0.34	0.83	0.29	0.02	T	0	0	0.02	1.01	0.09	3.97
1954	1.89	0.78	2.21	0.52	0.34	0.08	0	0	0	0	0.66	1.61	8.09

See Acronyms and Abbreviations list for definitions.

Table 3-1. Historical Hanford Precipitation (Inches), Tulare Lake Subbasin SGMA Model, Kings County, California (Continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1955	3.25	1.31	M	M	0.9	0	0	M	0	0.02	0.92	4.67	M
1956	1.2	0.38	0.1	0.73	0.83	0	0	0	0	0.72	0	0.15	4.11
1957	1.39	1.17	0.56	0.67	0.63	0	0	0	0	0.2	1.39	1.41	7.42
1958	1.85	2.3	3.92	2.04	0.24	0	0	T	0.88	0	0.23	0.16	11.62
1959	0.86	1.9	0.11	0.52	T	0	0	T	0.11	0	0	0.17	3.67
1960	0.8	1.71	0.61	0.57	0	0	0.02	0	0	0.53	2.61	0.03	6.88
1961	1.34	0.22	0.67	0.22	0.37	0	0	0	0	0	1.11	1.28	5.21
1962	0.71	4.88	1.06	0	0.11	0	0	0	0.01	0.1	0	0.19	7.06
1963	1.19	1.68	1.37	2.88	0.56	0.17	0	0	0.33	0.75	1.23	0.29	10.45
1964	0.61	0.02	0.94	0.64	0.2	0	0	0.34	0	0.95	1.31	1.44	6.45
1965	1.18	0.33	0.33	1.6	0	0	0	0.05	0.07	0.05	2.15	1.97	7.73
1966	0.63	0.71	0.1	0	0.07	0.06	0.04	0	0.29	0	1.28	2.57	5.75
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1967	1.41	0.05	2.42	2.95	0.07	0.23	0	0	0.31	0	1.99	0.5	9.93
1968	0.57	0.64	1	0.5	0.08	0	0	0	0	1.33	0.98	1.64	6.74
1969	6.69	4.54	0.79	0.85	0.32	0.21	0.07	0	0.15	0.05	0.51	0.7	14.88
1970	1.6	1.33	1.42	0.16	0	T	T	0	0	T	2.4	1.23	8.14
1971	0.35	0.19	0.23	0.4	1.44	0	0	T	0.04	0.06	0.41	1.87	4.99
1972	0.04	0.35	0	0.23	0	0	0	0	0.24	0.21	2.9	0.65	4.62
1973	M	2.29	2.2	0.12	M	M	0	0	0	M	M	M	M
1974	2.97	0.11	1.75	0.03	0	0	0	0	0	0.65	0.24	1.4	7.15
1975	0.09	2.26	M	0.49	0	0	0	0	0.96	M	0.05	0.22	M
1976	T	2.94	0.19	1.47	0.03	0.51	0	0.22	1.47	0	1.15	0.96	8.94
1977	0.59	0.03	0.43	0	0.91	0.07	0	0	0	0.05	0.66	2.85	5.59
1978	2.22	5.05	4.12	1.71	0	0	0	0	1.1	0	0.79	0.5	15.49
1979	2.19	1.61	1.16	0.03	0	0	0.04	0	0.08	0.41	0.62	0.41	6.55
1980	2.9	2.71	1.28	0.05	0.04	0	0	0	0	0.09	0	0.2	7.27
1981	1.77	0.86	2.1	0.68	0.17	0	0	0	0	0.76	1.08	0.29	7.71
1982	0.84	0.38	3.52	1.75	0	0.45	0.18	0	0.64	1.03	2.15	0.71	11.65

See Acronyms and Abbreviations list for definitions.

Table 3-1. Historical Hanford Precipitation (Inches), Tulare Lake Subbasin SGMA Model, Kings County, California (Continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1983	3.74	2.59	3.39	1.63	0.04	0	0	0.05	0.82	0.43	1.66	1.22	15.57
1984	0.01	0.42	0.27	0.18	0	0	0	0	0	M	M	M	M
1985	0.59	M	0.7	0.12	0	0	M	0	T	M	2.11	0.66	M
1986	1.46	2.6	3.43	0.5	0	0	T	T	0.15	0	0.21	0.77	9.12
1987	1.77	2.07	2.02	0.06	0.13	0.05	0	0	0	0.58	0.47	1.7	8.85
1988	1.37	0.4	0.93	1.99	0.07	0	0	0	0	0	1.31	2.29	8.36
1989	0.17	1.04	0.85	0.02	0.39	0	0	T	0.67	0.32	0.2	0	3.66
1990	1.66	1.1	0.3	0.97	0.87	0	T	T	T	0.01	0.22	0.15	5.28
1991	0.31	0.12	6.62	0.19	T	0.12	0	0	0.11	0.41	0.14	M	M
1992	1.4	2.82	0.85	0.1	T	0	0.01	0.01	T	0.58	T	2.62	8.39
1993	3.88	2.48	2.16	0.07	0.08	0.3	0	0	0	0.24	0.64	0.66	10.51
1994	0.94	1.45	1.02	0.72	0.66	0	T	0	1.06	0.35	1.54	0.33	8.07
1995	4.7	0.51	4.77	0.65	0.87	0.04	T	0	T	0	T	1.59	13.13
1996	1.68	2.89	2.27	0.85	0.1	T	0	0	0	2.43	0.69	3.27	14.18
1997	3.02	0.12	0.21	0	0	T	T	0	0.06	0.09	1.96	1.8	7.26
1998	2	4.05	2.63	1.68	1.31	0.44	0	0	T	0.68	0.63	0.65	14.07
1999	3.01	0.56	0.43	1.37	0	0	0	T	0.01	0	0.15	T	5.53
2000	1.8	3.28	1.59	0.97	0.48	0.35	0	0	0.03	1.31	T	0.05	9.86
2001	1.98	1.48	1.24	1.12	0	0	0.09	0	T	0.18	1.84	1.99	9.92
2002	0.87	0.31	1.04	0.03	0.01	0.82	0	0	0	0	1.42	1.14	5.64
2003	0.24	1.08	1.01	1.5	0.62	0	T	0.07	0	0	0.49	2	7.01
2004	2	2.18	0.29	0.02	0.01	0	0	0	0	2.06	0.52	2.23	9.31
2005	2.63	1.58	2.24	0.71	0.83	0	0	T	0.01	0.01	0.19	2.07	10.27
2006	3.54	0.55	2.72	3.39	0.53	0	0	0	0	0.06	0.22	1.01	12.02
2007	0.65	0.89	0.26	0.33	0.01	0	0	0.12	0.37	0.35	0.12	1.32	4.42
2008	2.18	1.18	T	0	0.11	0	0	0	0	0.15	1.04	1.49	6.15
2009	0.8	1.86	0.2	0.02	0.41	0.22	0	0	0.18	1.32	0.28	1.42	6.71
2010	2.64	1.91	0.34	1.65	0.17	0	0	0	0	0.64	1.32	6.46	15.13
2011	1.52	1.53	2.87	0.3	0.4	1.04	0	0.08	0.01	0.55	0.8	0.06	9.16

See Acronyms and Abbreviations list for definitions.

Table 3-1. Historical Hanford Precipitation (Inches), Tulare Lake Subbasin SGMA Model, Kings County, California (Continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2012	M	M	M	1.39	0.03	M	T	0	0	0.28	0.49	1.9	M
2013	0.22	0.48	0.79	0.08	0.17	0	0	0	0.01	T	0.33	0.16	M
2014	0.3	1.38	0.27	0.35	T	0	0	0	0.03	0	0.94	2.52	5.79
2015	0.08	0.72	0.02	0.77	0.1	0	0.45	0	0	0.38	0.91	1.4	4.83
2016	2.56	0.58	1.99	0.57	0.02	0.09	0	0	0	0.76	0.4	1.6	8.57
2017	3.7	2.8	0.31	1.02	0.36	0.01	0	0.01	0.17	0.06	0.21	0.08	8.73
Mean	1.59	1.5	1.47	0.75	0.25	0.09	0.01	0.01	0.15	0.38	0.82	1.24	8.28
Min	6.69	5.05	6.62	3.39	2.06	1.12	0.45	0.34	2.48	2.43	3.67	6.46	15.57
	1969	1978	1991	2006	1906	1931	2015	1964	1904	1996	1926	2010	1983
Max	0	0	0	0	0	0	0	0	0	0	0	0	3.37
	1948	1900	1972	2008	2018	2015	2017	2016	2016	2014	1980	1989	1947

Source: https://w2.weather.gov/climate/xmacis.php?wfo=hnx.

Notes:
M – Data missing
T – Trace precipitation

Table 3-2. Historical Land Use, Tulare Lake Subbasin SGMA Model, Kings County, California

Tulare Lake Subbasin	1990-1995 (Acres)	1996-1998 (Acres)	1999-2006 (Acres)	2007 (Acres)	2008 (Acres)	2009 (Acres)	2010 (Acres)	2011 (Acres)	2012 (Acres)	2013 (Acres)	2014 (Acres)	2015 (Acres)	2016 (Acres)	Average (Acres)
Tulare Lake Subbasin														
Alfalfa Hay and Clover	41,604	32,564	54,301	72,459	80,600	71,504	69,685	38,789	42,131	49,318	35,820	29,665	24,245	45,987
Almonds (Adolescent)			2,908			5,127	7,927	3,222	4,464	7,476	6,526	6,222	5,365	2,470
Almonds (Mature)	7,682	5,241	4,550	12,897	11,825	9,826	8,374	10,140	10,818	11,441	12,876	15,046	15,105	7,852
Almonds (Young)		3,278	9,290	16,538	25,966	14,678	20,887	13,968	14,564	20,341	17,678	16,983	21,576	9,557
Berries	20								1	2		0		5
Carrot Single Crop								11	5	12	2	2	16	2
Citrus (no ground cover)			25		13	14	4	120	29	100	89	22	9	21
Corn and Grain Sorghum	14,280	38,896	29,349	39,271	31,762	34,643	23,031	33,780	29,175	27,566	22,638	18,826	17,400	25,404
Cotton	159,534	180,960	124,764	109,605	88,304	72,441	98,167	105,541	88,993	89,317	63,385	44,532	73,720	118,794
Dairy Single Crop*	3,816	4,077	4,385											2,438
Fallow Land*	193,695	138,392	89,606	65,169	85,144	99,688	90,192	152,391	172,697	172,486	195,172	237,790	200,972	136,159
Forest*	420	809	2,955	6	5	46	5			1		4	0	952
Grain and Grain Hay	28,708	48,533	62,962	19,266	27,870	27,406	25,980	7,758	9,968	11,194	12,213	21,196	19,069	34,833
Melons	250	56	284				14	2	11	7	797	18	86	170
Misc. field crops	17,116	12,819	51,311		2			0			2			18,531
Onions and Garlic	457	479	770			7	1,358	411	302	94	502	149	644	483
Open Water*	5,568	9,092	8,968	5,576	4,296	4,049	5,434	7,703	5,443	5,045	6,824	5,919	5,435	6,637
Pasture and Misc. Grasses	2,500	5,029	5,615	50,688	44,232	66,944	53,080	14,680	13,368	15,355	33,551	15,744	13,743	14,473
Pistachio (Adolescent)								170	218	370	882	3,575	3,836	335
Pistachio (Mature)	4,694	3,808	3,804	6,096	1,907	934	404	394	380	348	330	485	469	2,888
Pistachio (Young)		1,580	4,390	4,351	4,259	8,527	8,083	12,985	14,676	15,878	19,195	22,678	22,570	6,247
Pomegranates (Adolescent)											3	16	27	2
Pomegranates (Young)				61	1,705	545	256	5,012	804	1,395	2,207	1,312	3,111	608
Potatoes, Sugar beets, Turnip etc..	5,736	1	209	6		3		9		41		2	2	1,331
Riparian*		668	1,120	517	134	398	615	226	138	313	239	248	194	477
Small Vegetables	1,599	647	4,518	20	2	13	212	142	133	244	165	78	198	1,643
Stone Fruit (Adolescent)			1,478			14	66	100	125	69	47	191	170	412
Stone Fruit (Mature)	7,070	4,985	3,854	1,314	544	168	18	3	23	41	23	27	39	3,206
Stone Fruit (Young)		1,827	4,185	672	1,609	1,573	2,502	1,077	712	1,641	1,340	1,183	713	1,770
Tomatoes and Peppers	5,634	1,627	14,676	117	2	110	12	21,482	23,670	7,114	11,922	19,211	23,420	9,203
Urban, Industrial*	12,654	17,391	19,875	33,427	34,711	44,471	32,218	32,091	28,576	29,366	33,901	30,530	30,930	22,128
Wine Grapes with 80% canopy	2,948	3,226	5,779	5,588	3,499	2,240	2,746	5,361	9,228	4,655	6,472	4,672	10,985	4,565
Winter Wheat*				72,238	67,458	50,451	64,526	48,212	45,118	44,530	30,950	19,420	21,690	17,207
Tulare Lake Subbasin Irrigated Crop Acreage	**299,832**	**345,557**	**389,021**	**338,951**	**324,102**	**316,717**	**322,806**	**275,156**	**263,796**	**264,018**	**248,665**	**221,837**	**256,519**	**310,792**
Tulare Lake Subbasin Total Crop Acreage	**515,986**	**515,986**	**515,931**	**515,883**	**515,849**	**515,821**	**515,796**	**515,779**	**515,768**	**515,759**	**515,751**	**515,747**	**515,741**	**496,788**

Notes: Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year

See Acronyms and Abbreviations list for definitions.

Table 3-3. Generalized Stratigraphic Column for Tulare Lake Subbasin

System	Series	Geologic Unit		Lithologic Character	Maximum Thickness (feet)	Water-Bearing Character	Areas Where Important
QUATERNARY	Holocene	Tulare Formation	Flood Basin Deposits	Interbedded silt, clay, and fine sand. Interfingers with and age equivalent to Younger Alluvium.	<50	Poorly permeable, poor quality water, unconfined.	Not important source of water.
			Younger Alluvium	Interstratified and discontinuous beds of clay, silt, sand, and gravel, primarily located on recent alluvial fans and along stream channels. Interfingers with flood-basin and lake bed deposits.	0 - 100	Highly permeable, but largely unsaturated or seasonally saturated. Serves as conduit for recharge to underlying units.	May provide sufficient supplies for domestic and stock use where saturated.
	Pleistocene		Older Alluvium	Poorly to well sorted fine to coarse sand, gravel, silt and clay. Represents older alluvial fan material and contains well-developed soil profiles and hardpan horizons. Interfingers with lacustrine clays.	300 - 500	Moderately to highly permeable, unconfined and semiconfined. Yields large quantities of water to wells, major aquifer.	Important source of groundwater on eastern and northern portions of TLSB.
			Lacustrine Deposits	Corcoran Clay is extensive reduced clay formed in large fresh-water lake in late Pleistocene that extended throughout most of the San Joaquin Valley. Has been deformed across valley axis and has been dated at about 600,000 Ma.	50 - 200	Poorly permeable, forms major aquitard within San Joaquin Valley.	Occurs beneath nearly the entire TLSB, including Tulare Lake. Important aquitard on eastern and northern portions of TLSB.
				Tulare Lake bed clays are thick deposits that extend vertically from the surface beneath the former lake. These beds interfinger with alluvial and continental deposits to the east and west. Croft (1972) identified several of these interfingering lacustrine clay beds as the A-D and F clays. His E-clay is equivalent to the Corcoran Clay (above).	0 - 3,000	Poorly permeable, forms significant barrier to lateral groundwater flow in the TLSB and lateral tongues can form local confining conditions in alluvial and continental deposits.	Tulare Lake bed forms clay plug on western portion of TLSB. A and C clays are thin (10 - 60 feet) beds that may be important aquitards on the northern and eastern portions of TLSB.
TERTIARY	Pliocene		Continental Deposits, undifferentiated	Poorly to moderately sorted fine to medium sand, silt, gravel, and clay. Deposits may be reduced or oxidized. Provenance may be from Sierra Nevada or Coast Ranges. Sierran deposits typically arkosic and coarser grained than Coast Ranges deposits. Deposits from each provenance interfingering in an east-west line, depending upon major transgressive deposition from each mountain range.	2,000+	Poorly to moderately permeable, semi-confined to confined conditions. Yields significant quantities of groundwater, especially below Corcoran Clay.	Important source of groundwater on eastern and northern portions of TLSB and northwest and southeast of TLSB.
		San Joaquin Formation	Marine Deposits	Poorly sorted fine-grained sandstone, siltstone, and mudstone.	1,500+	Exposed in Kettleman Hills, dips steeply to east beneath Tulare formation. Semi-consolidated to consolidated, containing connate water of poor quality. Formation is poorly permeable and forms substantial aquitard at base of Tulare Formation.	No known beneficial uses of water, typical TDS of 3,000 to 20,000 mg/L.
		Etchegoin Formation	Marine Deposits	Silty and clayey sands, sandy silt, silty clay, blue sandstone, and conglomeratic sandstone.	3,000+	Exposed in Kettleman Hills, dips steeply to east beneath San Joaquin formation. Fine grained, interbedded nature, contains saline water.	No known wells into formation, not expected to be an aquifer.
	Miocene	Santa Margarita Formation	Marine Deposits	Fairly well-sorted to well-sorted gray sandstone.	0 - 600	Contains good quality water and yields significant water to wells for irrigation in places. However, sodium chloride front exists about 7 to 10 miles east of Highway 99.	Extensively used as aquifer in area from Terra Bella to Richgrove, east of Highway 99. Not an important aquifer in the TLSB.
	Eocene/Oligocene	Other Tertiary Sediments (undifferen-tiated)	Marine and Non-Marine Deposits		----	Few formations that contain usable water quality.	Too deep to be of concern in or near TLSB.
PRE-TERTIARY	Paleozoic/ Mesozoic	Metamorphic and Igneous Rocks	Basement Complex	Crystalline rocks of metamorphosed sedimentary and igneous rocks invaded by largely granitic plutonic rocks.	----	Largely impermeable, contain fractures, faults, and joints that may yield small quantities of water to domestic and stock wells.	Used as water source only in foothills and mountain areas of Sierra Nevada.

Notes: Generalized stratigraphic column after Hilton et al., 1963; Croft and Gordon, 1968; Davis et al., 1959; Loomis, 1990; and Wood, 2018.

See Acronyms and Abbreviations list for definitions.

Table 3-4. Annual Specified Well Field Pumping, Tulare Lake Subbasin SGMA Model, Kings County, California

Date	El Rico GSA Well Field (AF/Y)	Creighton Ranch Well Field (AF/Y)	Corcoran ID Well Field (AF/Y)	Angiola Well Field (AF/Y)	Westlands Well Field (AF/Y)	Municipal Well Fields (AF/Y)	Apex Ranch Well Field (AF/Y)
1990	70,716	27,222	87,977	34,500	67,131	9,370	--
1991	57,509	38,484	84,438	23,396	98,656	9,109	--
1992	80,012	27,255	72,348	33,494	98,344	9,666	--
1993	11,395	4,035	14,248	5,956	44,056	10,208	--
1994	48,043	17,986	78,297	16,389	72,674	10,928	--
1995	2,897	905	7,145	-	27,589	10,775	--
1996	-	-	20,261	-	28,516	12,719	--
1997	-	-	15,586	-	27,000	12,775	--
1998	-	-	2,484	-	20,988	11,555	--
1999	-	-	33,406	-	37,185	13,087	--
2000	14,910	2,849	40,672	6,784	43,392	13,421	--
2001	89,799	41,120	64,353	23,244	65,947	13,895	--
2002	68,933	35,843	64,736	26,537	66,530	26,701	-
2003	32,420	10,856	62,246	22,429	40,841	19,349	526
2004	82,875	47,511	74,007	26,805	42,115	18,777	912
2005	-	468	20,138	662	14,744	16,536	-
2006	-	72	14,034	141	16,526	15,822	6,939
2007	69,863	40,266	85,434	32,894	40,373	17,221	6,319
2008	92,269	52,980	79,362	32,502	63,519	18,432	5,435
2009	78,097	45,292	81,493	37,798	69,904	16,354	7,677
2010	36,129	17,740	29,669	22,568	34,895	15,271	6,345
2011	606	314	7,328	11,336	15,509	17,042	-
2012	95,154	52,325	70,008	19,388	55,298	17,467	9,044
2013	100,275	66,005	78,175	30,528	70,940	18,411	4,970
2014	108,976	68,726	69,880	27,695	94,077	16,930	298
2015	116,254	61,050	67,982	30,220	90,723	16,146	-
2016	126,886	53,113	67,982	29,047	93,853	14,555	-
1990-2016 Average	51,260	26,386	51,618	18,308	53,382	14,908	4,847
1998-2010 Average	43,484	22,692	50,156	17,874	42,843	16,648	4,879
Well Count	99	52	98	51	150	30	5

See Acronyms and Abbreviations list for definitions.

Table 3-5. Historical Kings River Diversions, Tulare Lake Subbasin SGMA Model, Kings County, California

| | GSA | Mid Kings River | | | | | South Fork Kings | | | | | | | Southwest Kings | | | | | | |

	GSA	Mid Kings River					South Fork Kings							Southwest Kings										El Rico																						Tri-County Water Authority												
	Agency	Peoples Ditch Company	Last Chance Water Ditch Co.				Stratford Irrigation District	Empire West Side Irrigation District			Lemoore Canal & Irrigation Company			Dudley Ridge Water District-Monthly Diversions Assumed																																																				
Kings River Water Years	Diversion	*Peoples Canal- MKRGSA Total*	*Last Chance Canal- MKRGSA Total*	*Lakeside IWD*	Imported Water	Mid Kings	Stratford Canal	Empire West Side ID total from SWP	Empire West Side Canal	Westlake Canal	Lemoore Canal	Imported Water	South Fork Kings River	*Blakeley Canal-Kings River & Lateral A*	TLBWSD Lateral C, T203	Dudley Ridge State Turnout (DR-1), T201	Dudley Ridge State Turnout (DR-1B), T202	Dudley Ridge State Turnout (DR-1A), T204	Dudley Ridge State Turnout (DR-2), T205	Dudley Ridge State Turnout (Paramount), T207	Dudley Ridge State Turnout (DR-3), T208	Imported Water, Angiola/Green Valley Well Fields, City of Lemoore and Westlands RD 761	Southwest Kings	*Empire Weir No. 2 (over #2 weir to river extension, River Water) Modified Total-(Empire Weir No. 2 minus Tri-County Kings River*	*TLBWSD Lateral A, T200 (State Water)-Modified Total-(SWP Total for Lateral A minus Tri-County Entitlement, Then 20% taken*	*TLBWSD Lateral B, T206 (State Water)-Modified Total-(SWP Total for Lateral B minus Tri-County Entitlement)*	Lakelands Canal-Total	Tulare Lake Canal	*Melga Canal-Diversion of Peoples Canal, El Rico GSA Total*	Kern River	*Deer Creek-30% of Deer Creek Total*	Tule River-El Rico	Kaweah River	*Loan Oak/New Deal- Diversion of Last Chance, El Rico GSA Total*	Imported Water	El Rico	Poso Creek	*TLBWSD Lateral A, T200 (State Water)-Assumed Full Entitlement-25% to Lateral A*	*TLBWSD Lateral B, T206 (State Water)-Assumed Full Entitlement-75% to Lateral B*	Tule River-Tri-County	*Deer Creek-70% of Deer Creek Total*	White River	Kings River-Tri-County	Other Water	Imported Water	Tri-County	Annual Totals
		(acre-feet per year)																																																						
73%	1985	105,362	39,583	-	-	144,944	4,869	4,677	5,209	6,827	103,148	-	124,731	34,288	0	7,791	2,232	5,581	26,788	22	13,394	-	90,096	16,118	49,527	84,042	20,108	29,821	70,241		0	367	73,859	16,964	-	361,048	0	5,881	17,644	826	0	0	1,586	0	-	25,937	746,756
190%	1986	111,962	62,457	-	-	174,419	7,329	2,070	7,345	16,723	87,761	-	121,227	27,361	0	6,427	1,841	4,604	22,098	18	11,049	-	73,398	28,395	23,163	41,528	50,896	51,205	74,641		5,144	43,384	71,918	26,767	-	417,043	2,572	1,269	3,806	1,701	12,004	1,715	11,054	0	-	34,121	820,207
45%	1987	70,406	24,792	-	-	95,198	5,177	3,961	4,959	10,982	90,541	-	115,620	28,582	0	5,816	1,666	4,166	19,996	17	9,998	-	70,242	18,250	35,048	60,441	27,104	57,023	46,938	-	0	0	44,445	10,625	-	299,874	0	3,517	10,550	0	0	0	9,366	0	-	23,432	604,366
48%	1988	60,312	21,844	-	-	82,156	3,953	3,128	4,457	2,949	76,554	-	91,041	21,261	0	6,030	1,728	4,319	20,733	17	10,367	-	64,456	8,209	23,389	40,544	18,863	17,816	40,208	-	0	0	25,873	9,362	-	184,264	0	2,207	6,622	0	0	0	984	0	-	9,814	431,730
53%	1989	60,579	19,935	-	-	80,514	0	2,700	0	-	56,519	-	59,219	13,458	0	7,168	2,054	5,134	24,645	21	12,323	-	64,802	0	44,142	75,859	7,458	0	40,386	-	0	0	24,550	8,544	-	200,939	0	4,605	13,814	150	0	0	0	1,580	-	20,149	425,623
40%	1990	53,292	9,909	-	-	63,201	0	2,979	0	-	34,465	-	37,444	6,485	0	4,606	1,320	3,299	15,836	13	7,918	14,540	54,016	0	21,271	37,168	15,114	0	35,528	-	0	0	39,853	4,247	-	153,181	0	1,810	5,430	0	0	0	0	4,556	-	11,796	319,638
63%	1991	45,654	18,622	-	-	64,276	1,760	199	1,006	964	31,492	-	35,420	5,941	0	1,670	479	1,196	5,743	5	2,871	8,181	26,085	344	1,536	2,855	6,143	2,870	30,436	-	0	0	28,897	7,981	-	81,060	0	16	49	604	0	0	1,604	0	-	2,274	209,115
41%	1992	49,394	9,361	-	-	58,755	1,759	1,219	0	0	37,968	-	40,945	6,003	0	1,696	486	1,215	5,831	5	2,915	6,095	24,245	0	19,688	35,181	0	0	32,930	-	279	0	23,442	4,012	-	115,532	140	1,156	3,469	0	652	93	0	0	-	5,510	244,987
149%	1993	147,363	53,498	-	-	200,860	5,070	2,467	4,314	8,612	91,166	-	111,629	30,546	0	2,917	836	2,090	10,031	8	5,016	6,480	57,925	25,174	31,782	58,745	66,990	44,555	68,050	-	101	0	108,379	22,928	-	426,703	50	565	1,694	1,155	235	34	6,919	2,575	-	13,226	810,344
50%	1994	69,510	30,738	-	-	100,248	2,997	1,499	3,808	6,811	76,550	-	91,666	26,295	0	3,834	1,099	2,747	13,184	11	6,592	11,642	65,404	15,625	15,834	28,204	0	49,718	38,072	-	0	0	28,376	-	-	175,829	0	990	2,970	0	0	0	6,098	0	-	10,058	443,205
202%	1995	143,785	102,300	-	-	246,085	6,123	1,468	6,419	1,410	85,049	-	100,469	34,039	0	5,715	1,637	4,094	19,650	16	9,825	8,131	83,107	51,722	34,276	59,720	52,969	48,240	75,670	-	2,285	13,777	149,232	-	-	487,891	1,142	3,032	9,095	6,040	5,331	762	4,902	0	-	30,303	947,854
122%	1996	166,765	95,338	-	-	262,103	6,774	1,681	5,576	5,778	105,398	-	125,206	41,813	0	6,886	1,973	4,933	23,677	20	11,839	14,505	105,645	33,027	60,026	107,966	61,767	36,006	81,522	-	1,847	236	139,238	-	-	521,635	924	3,055	9,165	1,913	4,311	616	2,219	0	-	22,202	1,036,790
155%	1997	133,158	85,505	20,657	-	239,321	7,460	0	8,239	2,079	89,117	-	106,896	25,259	0	7,895	2,262	5,655	27,146	23	13,573	11,319	93,132	19,089	5,679	2,107	32,557	25,047	65,232	-	9,220	40,122	66,638	-	-	265,690	4,610	1,895	5,684	1,701	21,513	3,073	4,729	0	-	43,206	748,244
181%	1998	141,107	77,863	29,871	-	248,841	5,578	488	4,596	8,447	75,590	-	94,698	17,157	3,528	6,955	1,993	4,982	23,916	20	11,958	11,348	81,857	4,514	5,745	17,487	32,918	16,707	75,570	-	5,590	26,731	58,340	-	-	243,601	2,795	1,057	3,171	2,083	13,042	1,863	50	0	-	24,061	693,058
74%	1999	101,773	62,938	12,119	-	176,830	4,971	2,858	6,135	3,624	95,504	-	113,092	25,132	0	7,958	2,280	5,701	27,363	23	13,681	10,280	92,418	4,359	59,502	140,451	8,184	13,492	49,810	-	0	2,235	51,184	-	-	329,217	0	95	286	274	0	0	167	0	-	822	712,379
90%	2000	108,835	82,526	13,181	-	204,541	4,598	1,619	2,184	4,566	99,074	-	112,041	21,426	0	7,397	2,119	5,299	25,433	21	12,717	10,299	84,711	16,796	39,928	86,346	35,062	33,304	56,416	-	871	2,900	48,050	-	-	319,674	435	3,935	11,804	1,166	2,032	290	0	0	-	19,663	740,630
59%	2001	73,419	31,031	7,017	-	111,467	4,959	1,674	1,993	2,680	58,979	-	70,285	11,377	0	6,030	1,728	4,319	20,732	17	10,366	10,306	64,875	21,146	21,658	39,067	2,122	38,045	38,433	-	0	8	20,131	-	-	180,610	0	1,027	3,082	0	0	0	3,044	3,000	-	10,154	437,390
67%	2002	99,376	52,020	5,354	-	156,751	4,104	1,265	1,364	2,202	74,196	-	83,131	13,083	0	6,930	1,986	4,964	23,828	20	11,914	10,291	73,016	14,150	20,707	33,324	46,842	7,942	45,043	-	0	490	73,770	-	-	242,267	0	2,004	6,011	124	0	0	0	190	-	8,329	563,493
83%	2003	104,545	54,735	13,325	-	172,605	4,356	1,292	752	3,362	63,511	-	73,273	8,256	0	6,657	1,907	4,768	22,888	19	11,444	10,359	66,299	13,153	14,887	44,894	36,750	45,168	48,228	-	0	1,748	49,413	-	-	254,241	0	2,152	6,455	790	0	0	6,652	160	-	16,209	582,626
61%	2004	79,743	27,306	5,667	-	112,717	2,019	3,206	1,650	1,480	58,257	-	66,611	12,382	0	6,383	1,829	4,572	21,946	18	10,973	10,072	68,176	17,145	22,857	42,460	40,917	16,768	40,719	-	0	1,106	59,030	-	-	241,003	0	265	795	559	0	0	0	5,293	-	6,912	495,419

See Acronyms and Abbreviations list for definitions.

	GSA	Mid Kings River					South Fork Kings						Southwest Kings										El Rico																						Tri-County Water Authority											
	Agency	Peoples Ditch Company	Last Chance Water Ditch Co.				Stratford Irrigation District	Empire West Side Irrigation District			Lemoore Canal & Irrigation Company			Dudley Ridge Water District-Monthly Diversions Assumed																																															
Kings River Water Years	Diversion	*Peoples Canal- MKRGSA Total*	*Last Chance Canal- MKRGSA Total*	*Lakeside IWD*	Imported Water	Mid Kings	Stratford Canal	Empire West Side ID total from SWP	Empire West Side Canal	Westlake Canal	Lemoore Canal	Imported Water	South Fork Kings River	*Blakeley Canal-Kings River & Lateral A*	TLBWSD Lateral C, T203	Dudley Ridge State Turnout (DR-1), T201	Dudley Ridge State Turnout (DR-1B), T202	Dudley Ridge State Turnout (DR-1A), T204	Dudley Ridge State Turnout (DR-2), T205	Dudley Ridge State Turnout (Paramount), T207	Dudley Ridge State Turnout (DR-3), T208	Imported Water, Angiola/Green Valley Well Fields, City of Lemoore and Westlands RD 761	Southwest Kings	*Empire Weir No. 2 (over #2 weir to river extension, River Water) Modified Total-(Empire Weir No. 2 minus Tri-County Kings River*	*TLBWSD Lateral A, T200 (State Water)-Modified Total-(SWP Total for Lateral A minus Tri-County Entitlement, Then 20% taken*	*TLBWSD Lateral B, T206 (State Water)-Modified Total-(SWP Total for Lateral B minus Tri-County Entitlement)*	Lakelands Canal-Total	Tulare Lake Canal	*Melga Canal-Diversion of Peoples Canal, El Rico GSA Total*	Kern River	*Deer Creek-30% of Deer Creek Total*	Tule River-El Rico	Kaweah River	*Loan Oak/New Deal- Diversion of Last Chance, El Rico GSA Total*	Imported Water	El Rico	Poso Creek	*TLBWSD Lateral A, T200 (State Water)-Assumed Full Entitlement-25% to Lateral A*	*TLBWSD Lateral B, T206 (State Water)-Assumed Full Entitlement-75% to Lateral B*	Tule River-Tri-County	*Deer Creek-70% of Deer Creek Total*	White River	Kings River-Tri-County	Other Water	Imported Water	Tri-County	Annual Totals
		(acre-feet per year)																																																				
148%	2005	131,193	54,799	24,547	-	210,539	5,619	3,451	2,664	1,946	98,279	-	111,958	24,480	0	7,366	2,111	5,276	25,327	21	12,663	11,115	88,360	73,872	27,755	75,546	42,290	64,243	67,430	-	1,767	2,372	86,750	-	-	442,024	884	116	347	1,680	4,123	589	10,632	1,235	-	19,605	872,486
172%	2006	129,571	65,459	24,718	-	219,748	6,065	2,954	5,417	2,368	96,857	-	113,661	34,147	0	7,766	2,225	5,563	26,702	22	13,351	11,115	100,891	70,800	22,444	52,463	80,614	74,920	69,623	-	2,392	17,135	171,601	-	-	561,992	1,196	126	378	795	5,581	797	14,253	0	-	23,126	1,019,418
40%	2007	84,144	20,918	3,312	-	108,374	4,836	1,876	3,810	4,727	70,288	-	85,536	25,308	0	6,090	1,745	4,363	20,940	17	10,470	9,975	78,909	21,586	20,496	39,927	17,889	31,676	46,218	-	0	153	39,474	-	-	217,420	0	50	149	0	0	0	18,083	63	-	18,345	508,584
72%	2008	81,364	29,000	6,764	-	117,128	2,037	852	1,470	1,081	59,988	-	65,428	10,209	0	5,292	1,516	3,791	18,195	15	9,097	10,016	58,131	9,553	9,155	11,833	8,051	5,282	41,851	-	0	158	37,662	-	-	123,545	0	156	468	828	0	0	4,756	0	-	6,208	370,440
79%	2009	85,743	30,617	5,829	-	122,189	2,047	148	1,811	1,771	49,297	-	55,074	7,997	0	3,982	1,141	2,852	13,691	11	6,846	12,178	48,699	855	8,865	13,750	22,036	99	43,482	-	0	1,383	62,389	-	-	152,859	0	7	21	0	0	0	0	0	-	28	378,849
121%	2010	113,146	42,817	16,103	-	172,066	4,318	2,545	3,644	2,900	90,694	-	104,101	17,655	0	4,144	1,187	2,969	14,249	12	7,125	42,300	89,641	34,789	9,185	32,026	38,210	37,297	55,771	-	0	5,059	102,754	-	-	315,091	0	2	7	1,676	0	0	10,587	282	-	12,555	693,453
180%	2011	163,801	79,589	23,764	-	267,154	4,979	1,364	4,625	4,947	109,605	-	125,519	43,781	0	3,373	966	2,416	11,597	10	5,799	34,012	101,953	89,121	13,902	25,964	88,052	78,409	83,250	-	0	11,316	140,553	-	-	530,567	0	68	205	-	0	0	0	-	-	273	1,025,466
49%	2012	80,025	30,309	4,595	-	114,929	4,203	1,151	4,594	2,289	71,207	-	83,443	22,689	0	2,775	795	1,988	9,543	8	4,771	51,435	94,006	24,964	16,910	43,921	3,483	15,977	39,616	-	0	200	60,683	-	-	205,755	0	57	170	-	0	0	0	-	-	227	498,360
41%	2013	49,246	12,881	110	-	62,236	0	536	0	0	43,206	-	43,741	3,284	0	3,591	1,029	2,572	12,346	10	6,173	19,602	48,606	0	10,771	13,062	58,140	0	27,281	-	-	-	-	-	-	109,253	0	58	174	-	0	0	0	-	-	232	264,069
32%	2014	27,801	8,824	0	-	36,626	0	158	0	0	17,905	-	18,062	567	0	2,136	612	1,530	7,345	6	3,672	23,852	39,720	0	1,858	3,681	41,472	0	12,461	-	-	-	-	-	-	59,473	0	38	115	-	0	0	0	-	-	154	154,035
21%	2015	12,430	-	0	-	12,430	0	326	0	0	14,759	-	15,085	184	0	3,271	937	2,343	11,247	9	5,623	31,718	55,333	0	605	0	21,076	0	2,493	-	-	-	-	-	-	24,175	0	45	0	-	0	0	0	-	-	45	107,068
75%	2016	67,310	20,567	2,986	-	90,863	0	-	0	0	42,532	-	42,532	-	-	-	-	-	-	-	-	34,248	34,248	0	-	-	32,114	0	27,677	-	-	-	-	-	-	59,791	0			-	0	0	0	-	-	0	227,433
204%	2017	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Annual Averages	93,943	44,985	4,312		143,240	3,669	2,156	4,804	5,315	77,554		93,499	20,737	68	5,535	1,586	3,965	19,033	16	9,516	8,734	69,598	26,210	21,684	40,175	31,229	26,107	54,847	0	1,383	8,586	45,614	10,052		268,189	705	1,816	5,446	666	3,227	470	3,333	364		16,175	590,701

Notes provided on next page.

See Acronyms and Abbreviations list for definitions.

1.) Values highlighted have been modified.
2.) Values with "0" indicate no surface water delivery to the best of our knowledge.
3.) Values with "-" have no verified data.
4.) Total flow from Peoples Canal is split 60% to Mid Kings, 40% to Melga.
5.) Last Chance Diversion is split 50% between Mid Kings and El Rico.
6.) Blakeley has added State Water from Lateral A for Southwest.
7.) Total flow from Deer Creek split 30% to El Rico, 70% to Tri-County.
8.) Tule River for El Rico includes the total of Elk Bayou and TID Spill.
8.) SWP from TLBWSD Split Throughout Tri-County & Southwest Kings.
9.) Kings River water in Tri-County was subtracted from the total in Empire Weir No. 2. 1976 and 2010 are 0 for Empire Weir No. 2 because of negative values.
10.) Lakeside is a portion of Kaweah River, Reduced Total Kaweah River between Mid Kings and El Rico
11.) Additional Tule River flow data added for Tri-County
12.) Empire West Side ID total from SWP reduce annual totals by 10%
13.) Dudley Ridge Water District reduce annual totals by 10%
14.) Lateral A (T200) & Lateral B (T206) reduce annual totals by 18% for El Rico & Tri-County
15.) Modifications to Peoples Canal and Last Chance as a result of discussions with Mid Kings River GSA 02/14/2019

Key	Average Annual
Wet Year	816,660
Dry Year	423,464
Average Precipitation	686,577
GSA Annual Totals	
Kings River Watershed Total	

Reduction in Entitlement	
Empire West Side ID Total from SWP	10%
Dudley Ridge State Turnouts	10%
Lateral A & B for El Rico & Tri-County	18%

See Acronyms and Abbreviations list for definitions.

Table 3-6A. 1990 - 2016 Historical Water Balance Total Subbasin, Tulare Lake Subbasin SGMA Model, Kings County, California

Date	Tulare Lake Drain Net (AF/Y)	Tulare Lake GHB Net (AF/Y)	Tulare Lake Well Net (AF/Y)	Tulare Lake River Net (AF/Y)	Tulare Lake Lake Net (AF/Y)	Tulare Lake Recharge Net (AF/Y)	Tulare Lake Farm Demand (AF/Y)	Tulare Lake Storage Net (AF/Y)	Tulare Lake Net Subsurface Inflow (AF/Y)	Tulare Lake Net Subsurface Outflow (AF/Y)	Tulare Lake Westside Net (AF/Y)	Tulare Lake Kings Net (AF/Y)	Tulare Lake Kaweah Net (AF/Y)	Tulare Lake Tule Net (AF/Y)	Tulare Lake Kern Net (AF/Y)	Tulare Lake Mid-Kings Net (AF/Y)	Tulare Lake El Rico Net (AF/Y)	Tulare Lake South Fork Net (AF/Y)	Tulare Lake Southwest Net (AF/Y)	Tulare Lake TCWA Net (AF/Y)	Tulare Lake Total Net (AF/Y)	Cumulative Delta Storage (AF)
1990	0	0	-618,843	212,023	0	150,920	-1,065,856	-185,926	181,209	-111,280	23,632	4,815	-3,467	-12,024	56,971	298	-6,672	5,316	22,658	-21,601	298	-185,926
1991	0	0	-577,240	164,892	0	135,941	-994,832	-224,464	164,488	-112,589	13,271	9,747	4,376	-14,187	38,693	-1,273	-6,163	2,959	24,852	-20,376	-1,273	-410,391
1992	0	0	-596,994	125,681	0	139,491	-1,012,909	-290,389	160,839	-119,495	11,225	10,812	2,987	-18,583	34,904	-245	-10,703	4,143	26,835	-20,030	-245	-700,780
1993	0	0	-248,824	231,839	0	167,981	-1,008,709	157,279	128,914	-122,683	7,344	-4,219	-20,133	-13,496	36,736	1,631	-6,528	-857	24,396	-18,642	1,631	-543,501
1994	-26	0	-491,956	139,080	0	173,457	-1,047,937	-168,707	135,909	-125,412	7,647	1,210	-8,114	-20,670	30,426	-2,370	-4,557	2,695	23,956	-19,723	-2,370	-712,208
1995	-82	0	-188,622	200,925	0	235,917	-973,503	231,421	113,880	-130,598	5,564	-14,723	-26,071	-14,705	33,217	8,131	-6,163	-10,023	24,809	-16,753	8,131	-480,786
1996	-251	0	-195,586	177,508	0	238,753	-1,067,962	186,481	102,129	-136,119	6,788	-17,826	-32,867	-19,334	29,250	12,774	1,109	-16,866	23,951	-20,968	12,774	-294,305
1997	-1,392	0	-278,726	162,833	0	252,651	-1,123,726	100,786	104,214	-139,610	10,524	-17,146	-36,466	-21,396	29,090	11,582	1,267	-17,016	25,376	-21,209	11,582	-193,519
1998	-1,870	0	-249,086	165,955	0	266,380	-1,059,009	153,536	105,817	-134,203	13,146	-18,649	-31,067	-21,177	29,362	13,428	145	-19,305	26,305	-20,573	13,428	-39,983
1999	-7,376	0	-338,241	159,660	0	201,878	-1,232,448	522	120,686	-141,114	15,099	-12,823	-38,853	-23,234	39,384	8,567	5,298	-17,001	26,326	-23,190	8,567	-39,461
2000	-17,343	0	-260,726	147,624	0	172,534	-1,127,412	43,638	116,391	-130,053	9,202	-14,008	-24,256	-20,878	36,279	12,669	-1,467	-16,122	26,034	-21,114	12,669	4,177
2001	-13,351	0	-467,326	108,934	0	119,202	-1,111,506	-243,059	128,384	-130,759	7,046	-8,208	-10,602	-19,402	28,791	13,602	-4,429	-14,996	27,329	-21,506	13,602	-238,882
2002	-10,253	0	-435,270	150,502	0	128,082	-1,201,455	-178,393	122,597	-142,986	4,116	-14,310	-17,484	-22,160	29,448	17,210	-4,785	-18,209	28,055	-22,272	17,210	-417,275
2003	-8,170	0	-385,602	145,737	0	157,010	-1,198,411	-101,083	124,533	-140,750	7,968	-14,505	-16,849	-23,580	30,749	18,229	-2,895	-22,651	29,364	-22,046	18,229	-518,358
2004	-20,849	0	-494,263	137,236	0	138,732	-1,162,011	-231,122	125,398	-137,076	7,475	-13,320	-9,952	-24,296	28,416	13,215	-6,077	-14,260	29,378	-22,256	13,215	-749,480
2005	-5,413	0	-217,488	150,074	0	227,638	-1,155,548	121,017	101,739	-138,073	4,993	-20,418	-30,344	-20,294	29,728	13,527	-585	-19,200	27,026	-20,768	13,527	-628,463
2006	-9,651	0	-205,429	138,230	0	339,860	-1,129,741	220,649	94,159	-142,864	4,446	-22,451	-40,403	-20,192	29,895	14,152	1,839	-20,925	24,221	-19,288	14,152	-407,814
2007	-14,999	0	-474,153	137,542	0	123,827	-1,183,096	-248,490	109,552	-142,905	7,330	-14,948	-17,451	-25,274	16,990	13,841	2,341	-15,691	26,046	-26,536	13,841	-656,305
2008	-13,795	0	-515,546	126,421	0	117,419	-1,083,093	-296,277	119,872	-143,019	1,856	-12,181	-14,428	-21,584	23,191	15,124	1,866	-14,493	28,346	-30,843	15,124	-952,581
2009	-4,295	0	-456,641	133,032	0	135,636	-1,091,697	-213,010	118,378	-142,215	-1,793	-15,575	-2,407	-18,590	14,527	18,226	6,659	-21,735	28,060	-31,210	18,226	-1,165,591
2010	-2,440	0	-249,776	129,805	0	171,969	-1,016,725	13,129	101,421	-138,727	-5,091	-25,818	-13,379	-16,097	23,078	17,294	7,760	-18,014	26,354	-33,394	17,294	-1,152,462
2011	-4,486	0	-77,680	147,432	0	355,590	-791,090	361,228	83,220	-144,621	-6,641	-38,331	-35,573	-11,696	30,840	15,170	-5,654	-15,516	22,355	-16,355	15,170	-791,234
2012	-3,226	0	-357,301	111,314	0	120,601	-776,133	-169,947	99,000	-141,994	-6,733	-25,065	-25,720	-10,775	25,299	16,520	-4,782	-14,082	22,062	-19,718	16,520	-961,181
2013	-8,381	0	-455,726	99,564	0	90,038	-826,405	-305,607	105,083	-143,219	-9,909	-18,283	-18,315	-13,933	22,304	14,998	-4,112	-12,022	24,044	-22,907	14,998	-1,266,788
2014	-3,579	0	-508,253	82,742	0	107,427	-757,265	-360,352	110,508	-151,969	-11,151	-13,313	-18,684	-18,842	20,529	15,626	2,274	-17,973	26,111	-26,037	15,626	-1,627,140
2015	-829	0	-524,338	60,439	0	99,444	-624,647	-392,279	114,003	-141,493	-10,951	-10,641	-15,502	-15,383	24,986	13,276	-5,612	-12,806	26,751	-21,609	13,276	-2,019,419
2016	-2,497	0	-428,423	69,718	0	123,037	-677,936	-294,325	102,102	-160,350	-9,455	-33,115	-23,497	-14,438	22,257	16,359	-11,753	-11,101	26,620	-20,125	-2,088	-2,313,744
1990-2016 Average	-5,724	0	-381,410	141,361	0	173,756	-1,018,558	-85,694	83,220	-111,280	3,961	-13,826	-19,427	-18,379	29,457	11,539	-2,310	-12,806	25,838	-22,261	10,856	-720,867
1998-2010 Average	-9,985	0	-365,350	140,827	0	176,936	-1,134,781	-73,765	181,209	-160,350	5,830	-15,939	-20,575	-21,289	27,680	14,545	436	-17,893	27,142	-24,230	14,545	-535,575

See Acronyms and Abbreviations list for definitions.

Table 3-6B. 1990 - 2016 Historical Water Balance Upper Aquifer, Tulare Lake Subbasin SGMA Model, Kings County, California

Date	Tulare Lake Drain Net (AF/Y)	Tulare Lake GHB Net (AF/Y)	Tulare Lake Well Net (AF/Y)	Tulare Lake River Net (AF/Y)	Tulare Lake Lake Net (AF/Y)	Tulare Lake Recharge Net (AF/Y)	Tulare Lake ET Net (AF/Y)	Tulare Lake Storage Net (AF/Y)	Tulare Lake Net Subsurface Inflow (AF/Y)	Tulare Lake Net Subsurface Outflow (AF/Y)	Tulare Lake Westside Net (AF/Y)	Tulare Lake Kings Net (AF/Y)	Tulare Lake Kaweah Net (AF/Y)	Tulare Lake Tule Net (AF/Y)	Tulare Lake Kern Net (AF/Y)	Tulare Lake Mid-Kings Net (AF/Y)	Tulare Lake El Rico Net (AF/Y)	Tulare Lake South Fork Net (AF/Y)	Tulare Lake Southwest Net (AF/Y)	Tulare Lake TCWA Net (AF/Y)	Tulare Lake Total Net (AF/Y)	Cumulative Delta Storage (AF)
1990	0	0	-363,970	212,023	0	150,920	0	-392,438	60,944	-52,493	10,293	-6,068	2,356	-2,438	4,309	-8,770	7,916	7,068	3,123	-9,337	-8,770	-392,438
1991	0	0	-351,785	164,892	0	135,941	0	-379,415	59,832	-44,466	9,849	-337	6,851	-3,950	2,953	-8,028	6,401	5,211	3,601	-7,185	-8,028	-771,853
1992	0	0	-345,307	125,681	0	139,491	0	-379,874	58,304	-43,733	9,211	1,619	7,092	-5,396	2,045	-6,955	5,529	3,812	3,711	-6,097	-6,955	-1,151,727
1993	0	0	-239,755	231,839	0	167,981	0	-117,785	51,892	-42,526	7,943	-136	4,801	-4,918	1,676	-4,786	5,130	2,368	3,440	-6,153	-4,786	-1,269,512
1994	-26	0	-310,055	139,080	0	173,457	0	-255,820	52,755	-44,438	7,097	625	5,581	-6,383	1,398	-4,950	4,717	2,121	3,471	-5,360	-4,950	-1,525,332
1995	-82	0	-205,637	200,925	0	235,917	0	-23,977	45,868	-50,708	5,953	-9,550	3,591	-6,120	1,286	-2,716	3,395	746	3,431	-4,856	-2,716	-1,549,309
1996	-251	0	-184,321	177,508	0	238,753	0	-4,023	42,064	-47,154	5,561	-7,356	979	-5,613	1,340	-1,526	3,881	-427	3,567	-5,495	-1,526	-1,553,331
1997	-1,392	0	-204,969	162,833	0	252,651	0	-15,247	40,618	-50,417	5,470	-9,442	-1,210	-5,876	1,259	-791	3,397	-1,403	3,400	-4,603	-791	-1,568,578
1998	-1,870	0	-191,289	165,955	0	266,380	0	17,175	38,754	-55,626	5,112	-14,784	-2,171	-6,255	1,226	-228	3,124	-2,136	3,467	-4,226	-228	-1,551,403
1999	-7,376	0	-227,049	159,660	0	201,878	0	-71,374	41,389	-47,970	5,311	-6,241	-1,422	-5,855	1,627	44	3,916	-2,399	3,599	-5,159	44	-1,622,778
2000	-17,343	0	-201,799	147,624	0	172,534	0	-76,900	41,391	-44,741	5,135	-5,270	889	-6,253	2,149	713	3,385	-2,978	3,773	-4,892	713	-1,699,678
2001	-13,351	0	-264,888	108,934	0	119,202	0	-222,719	44,167	-45,556	5,150	-3,924	1,956	-6,748	2,177	215	3,431	-2,996	3,872	-4,521	215	-1,922,397
2002	-10,253	0	-272,312	150,502	0	128,082	0	-174,685	46,006	-45,147	4,999	-2,792	3,355	-6,755	2,052	-373	3,874	-2,666	3,785	-4,620	-373	-2,097,082
2003	-8,170	0	-255,270	145,737	0	157,010	0	-133,547	45,798	-46,552	4,757	-3,317	2,678	-6,922	2,049	-308	4,005	-2,944	3,826	-4,578	-308	-2,230,628
2004	-20,849	0	-279,593	137,236	0	138,732	0	-181,729	46,099	-46,854	4,686	-2,691	2,602	-7,402	2,050	-688	3,857	-2,647	3,846	-4,368	-688	-2,412,358
2005	-5,413	0	-194,492	150,074	0	227,638	0	516	41,121	-48,908	4,301	-5,838	-1,307	-7,087	2,145	212	3,616	-3,177	3,796	-4,447	212	-2,411,841
2006	-9,651	0	-174,179	138,230	0	339,860	0	117,742	37,534	-56,025	3,971	-11,267	-6,576	-6,948	2,329	1,405	2,956	-3,767	3,678	-4,271	1,405	-2,294,099
2007	-14,999	0	-264,654	137,542	0	123,827	0	-177,972	42,192	-52,530	4,404	-5,195	-3,761	-7,669	1,883	385	3,549	-3,225	3,501	-4,210	385	-2,472,071
2008	-13,795	0	-283,431	126,421	0	117,419	0	-210,701	43,266	-49,766	4,321	-3,743	-38	-8,161	1,122	-622	4,068	-2,880	3,259	-3,825	-622	-2,682,773
2009	-4,295	0	-268,843	133,032	0	135,636	0	-170,773	43,877	-49,818	4,722	-3,492	961	-8,469	338	-626	4,176	-3,145	3,179	-3,584	-626	-2,853,545
2010	-2,440	0	-187,770	129,805	0	171,969	0	-56,332	37,974	-47,711	3,677	-4,768	-334	-8,179	-134	400	3,717	-3,559	3,094	-3,653	400	-2,909,877
2011	-4,486	0	-126,313	147,432	0	355,590	0	197,345	32,182	-58,840	2,822	-16,373	-6,573	-6,907	374	2,222	2,629	-4,345	3,147	-3,652	2,222	-2,712,533
2012	-3,226	0	-205,013	111,314	0	120,601	0	-137,135	34,819	-52,627	2,733	-7,480	-6,645	-7,386	969	1,491	2,935	-4,085	3,111	-3,452	1,491	-2,849,668
2013	-8,381	0	-252,639	99,564	0	90,038	0	-222,003	38,673	-50,934	3,106	-4,297	-4,573	-7,569	1,071	520	3,719	-3,772	3,013	-3,481	520	-3,071,671
2014	-3,579	0	-276,394	82,742	0	107,427	0	-247,305	41,277	-51,497	3,633	-2,586	-3,508	-8,263	503	-96	3,951	-3,688	2,996	-3,163	-96	-3,318,976
2015	-829	0	-283,699	60,439	0	99,444	0	-286,779	41,875	-50,653	3,580	-1,050	-3,164	-8,423	279	-674	3,899	-3,598	3,107	-2,734	-674	-3,605,754
2016	-2,497	0	-248,557	69,718	0	123,037	0	-234,011	36,829	-60,070	3,401	-14,540	-4,136	-8,370	403	-321	3,744	-3,738	3,005	-2,691	-2,088	-3,839,765
1990-2016 Average	-5,724	0	-246,814	141,361	0	173,756	0	-142,214	32,182	-42,526	5,230	-5,566	-64	-6,678	1,514	-1,291	4,034	-1,565	3,437	-4,615	-1,356	-2,160,777
1998-2010 Average	-9,985	0	-235,813	140,827	0	176,936	0	-103,177	60,944	-60,070	4,658	-5,640	-244	-7,131	1,616	41	3,667	-2,963	3,590	-4,335	41	-2,243,118

See Acronyms and Abbreviations list for definitions.

Table 3-6C. 1990 - 2016 Historical Water Balance Lower Aquifer, Tulare Lake Subbasin SGMA Model, Kings County, California

Date	Tulare Lake Drain Net (AF/Y)	Tulare Lake GHB Net (AF/Y)	Tulare Lake Well Net (AF/Y)	Tulare Lake River Net (AF/Y)	Tulare Lake Lake Net (AF/Y)	Tulare Lake Recharge Net (AF/Y)	Tulare Lake ET Net (AF/Y)	Tulare Lake Storage Net (AF/Y)	Tulare Lake Net Subsurface Inflow (AF/Y)	Tulare Lake Net Subsurface Outflow (AF/Y)	Tulare Lake Westside Net (AF/Y)	Tulare Lake Kings Net (AF/Y)	Tulare Lake Kaweah Net (AF/Y)	Tulare Lake Tule Net (AF/Y)	Tulare Lake Kern Net (AF/Y)	Tulare Lake Mid-Kings Net (AF/Y)	Tulare Lake El Rico Net (AF/Y)	Tulare Lake South Fork Net (AF/Y)	Tulare Lake Southwest Net (AF/Y)	Tulare Lake TCWA Net (AF/Y)	Tulare Lake Total Net (AF/Y)	Cumulative Delta Storage (AF)
1990	0	0	-254,873	0	0	0	0	206,511	120,265	-58,787	13,339	10,884	-5,823	-9,586	52,663	9,068	-14,587	-1,752	19,535	-12,264	9,068	206,511
1991	0	0	-225,455	0	0	0	0	154,951	104,657	-68,123	3,422	10,084	-2,475	-10,237	35,740	6,755	-12,564	-2,252	21,251	-13,191	6,755	361,463
1992	0	0	-251,686	0	0	0	0	89,485	102,535	-75,762	2,013	9,193	-4,106	-13,187	32,859	6,710	-16,232	331	23,124	-13,932	6,710	450,947
1993	0	0	-9,069	0	0	0	0	275,064	77,023	-80,157	-600	-4,082	-24,934	-8,578	35,060	6,416	-11,659	-3,226	20,957	-12,489	6,416	726,011
1994	0	0	-181,901	0	0	0	0	87,113	83,154	-80,974	550	585	-13,695	-14,288	29,028	2,579	-9,275	573	20,484	-14,362	2,579	813,124
1995	0	0	17,015	0	0	0	0	255,398	68,012	-79,891	-388	-5,174	-29,662	-8,585	31,931	10,847	-9,559	-10,769	21,378	-11,896	10,847	1,068,522
1996	0	0	-11,265	0	0	0	0	190,504	60,065	-88,966	1,227	-10,470	-33,846	-13,721	27,910	14,300	-2,772	-16,439	20,385	-15,474	14,300	1,259,026
1997	0	0	-73,758	0	0	0	0	116,032	63,597	-89,192	5,054	-7,705	-35,256	-15,520	27,831	12,373	-2,130	-15,613	21,976	-16,606	12,373	1,375,059
1998	0	0	-57,797	0	0	0	0	136,362	67,063	-78,577	8,034	-3,865	-28,896	-14,922	28,136	13,656	-2,978	-17,169	22,838	-16,347	13,656	1,511,420
1999	0	0	-111,192	0	0	0	0	71,897	79,296	-93,144	9,788	-6,582	-37,432	-17,379	37,757	8,524	1,382	-14,601	22,726	-18,031	8,524	1,583,317
2000	0	0	-58,927	0	0	0	0	120,539	75,001	-85,312	4,067	-8,738	-25,145	-14,625	34,130	11,957	-4,852	-13,144	22,261	-16,221	11,957	1,703,855
2001	0	0	-202,438	0	0	0	0	-20,340	84,217	-85,202	1,896	-4,283	-12,559	-12,654	26,614	13,388	-7,861	-12,000	23,458	-16,985	13,388	1,683,515
2002	0	0	-162,957	0	0	0	0	-3,708	76,591	-97,839	-883	-11,518	-20,839	-15,405	27,396	17,582	-8,658	-15,543	24,270	-17,652	17,582	1,679,807
2003	0	0	-130,332	0	0	0	0	32,464	78,735	-94,198	3,210	-11,188	-19,527	-16,659	28,700	18,537	-6,900	-19,706	25,538	-17,468	18,537	1,712,271
2004	0	0	-214,670	0	0	0	0	-49,393	79,299	-90,221	2,789	-10,629	-12,554	-16,894	26,366	13,904	-9,935	-11,614	25,533	-17,888	13,904	1,662,878
2005	0	0	-22,996	0	0	0	0	120,500	60,617	-89,165	692	-14,580	-29,037	-13,207	27,583	13,315	-4,201	-16,023	23,231	-16,321	13,315	1,783,378
2006	0	0	-31,250	0	0	0	0	102,907	56,625	-86,840	475	-11,184	-33,827	-13,243	27,566	12,747	-1,116	-17,157	20,543	-15,017	12,747	1,886,285
2007	0	0	-209,499	0	0	0	0	-70,518	67,360	-90,375	2,925	-9,752	-13,691	-17,605	15,108	13,455	-1,207	-12,467	22,545	-22,326	13,455	1,815,767
2008	0	0	-232,114	0	0	0	0	-85,575	76,606	-93,253	-2,465	-8,438	-14,390	-13,423	22,069	15,746	-2,202	-11,613	25,088	-27,018	15,746	1,730,191
2009	0	0	-187,798	0	0	0	0	-42,237	74,501	-92,397	-6,514	-12,082	-3,368	-10,120	14,189	18,852	2,483	-18,590	24,881	-27,626	18,852	1,687,954
2010	0	0	-62,006	0	0	0	0	69,461	63,446	-91,016	-8,768	-21,050	-13,046	-7,919	23,212	16,894	4,043	-14,456	23,260	-29,741	16,894	1,757,415
2011	0	0	48,633	0	0	0	0	163,884	51,038	-85,781	-9,463	-21,958	-28,999	-4,789	30,466	12,948	-8,283	-11,171	19,208	-12,702	12,948	1,921,299
2012	0	0	-152,288	0	0	0	0	-32,812	64,180	-89,367	-9,466	-17,585	-19,076	-3,389	24,330	15,029	-7,718	-9,997	18,951	-16,266	15,029	1,888,486
2013	0	0	-203,087	0	0	0	0	-83,604	66,410	-92,285	-13,015	-13,986	-13,742	-6,364	21,233	14,477	-7,831	-8,251	21,031	-19,426	14,477	1,804,883
2014	0	0	-231,859	0	0	0	0	-113,047	69,232	-100,472	-14,784	-10,727	-15,176	-10,580	20,026	15,722	-1,678	-14,285	23,115	-22,875	15,722	1,691,836
2015	0	0	-240,639	0	0	0	0	-105,501	72,128	-90,840	-14,531	-9,591	-12,338	-6,960	24,707	13,951	-9,511	-9,208	23,645	-18,876	13,951	1,586,335
2016	0	0	-179,866	0	0	0	0	-60,314	65,273	-100,280	-12,856	-18,575	-19,362	-6,068	21,854	16,680	-15,498	-7,363	23,614	-17,433	0	1,526,021
1990-2016 Average	0	0	-134,595	0	0	0	0	56,519	51,038	-58,787	-1,269	-8,259	-19,363	-11,700	27,943	12,830	-6,344	-11,241	22,401	-17,646	12,212	1,439,910
1998-2010 Average	0	0	-129,537	0	0	0	0	29,412	120,265	-100,472	1,173	-10,299	-20,331	-14,158	26,063	14,504	-3,231	-14,929	23,552	-19,895	14,504	1,707,542

See Acronyms and Abbreviations list for definitions.

Table 3-7. Historical and Current Water Balance, Tulare Lake Subbasin SGMA Model, Kings County, California

Land Surface Water Budget													
Year	Kings River Flows	Year Type	Inflows						Outflows				Net Inflow-Outflow (AF)
			Effective Precipitation (AF)	Applied Surface Water (AF)	Applied Pond Water (AF)	Imported Groundwater (AF)	Applied Groundwater (AF)	Total Inflows (AF)	Drain Outflow (AF)	Farm Demand Evapotranspiration (AF)	Deep Percolation (AF)	Total Outflows (AF)	
1990	40%	D	19,958	319,870	10,310	48,885	609,474	1,008,496	0	1,065,856	132,933	1,198,789	-190,293
1991	63%	D	78,722	209,568	3,793	52,225	568,130	912,439	0	994,832	125,674	1,120,507	-208,068
1992	41%	D	64,818	245,345	8,619	46,926	587,328	953,036	0	1,012,909	126,365	1,139,274	-186,238
1993	149%	W	67,191	811,312	31,153	7,533	238,616	1,155,805	0	1,008,709	124,472	1,133,181	22,624
1994	50%	D	34,514	443,731	4,237	27,612	481,028	991,122	26	1,047,937	129,432	1,177,394	-186,272
1995	202%	W	95,479	948,773	42,079	905	177,847	1,265,083	82	973,503	116,897	1,090,481	174,601
1996	122%	N	100,745	1,038,046	26,566	0	182,868	1,348,225	251	1,067,962	127,604	1,195,817	152,408
1997	155%	W	58,885	749,117	54,380	0	265,952	1,128,333	1,392	1,123,726	143,342	1,268,459	-140,126
1998	181%	W	116,167	693,908	49,104	0	237,530	1,096,709	1,870	1,059,009	128,533	1,189,412	-92,703
1999	74%	D	34,039	713,206	39,371	0	325,154	1,111,771	7,376	1,232,448	151,647	1,391,471	-279,701
2000	90%	N	70,413	741,494	35,618	6,833	247,306	1,101,664	17,343	1,127,412	95,624	1,240,379	-138,714
2001	59%	D	94,963	437,871	8,911	54,771	453,432	1,049,949	13,351	1,111,506	90,933	1,215,791	-165,841
2002	67%	D	26,034	564,134	21,817	51,428	408,568	1,071,981	10,253	1,201,455	85,417	1,297,125	-225,143
2003	83%	N	40,108	583,124	4,687	24,029	366,253	1,018,201	8,170	1,198,411	95,332	1,301,914	-283,713
2004	61%	D	74,858	495,764	25,863	63,254	475,486	1,135,226	20,849	1,162,011	86,876	1,269,736	-134,510
2005	148%	W	80,390	873,425	36,085	857	200,953	1,191,709	5,413	1,155,548	101,553	1,262,513	-70,804
2006	172%	W	104,703	1,020,922	37,530	154	189,607	1,352,916	9,651	1,129,741	108,496	1,247,887	105,029
2007	40%	D	14,800	508,886	4,613	60,608	456,931	1,045,839	14,999	1,183,096	97,935	1,296,030	-250,191
2008	72%	D	35,836	371,231	9,331	72,842	497,113	986,354	13,795	1,083,093	89,622	1,186,511	-200,157
2009	79%	N	32,367	379,590	16,632	68,391	440,286	937,266	4,295	1,091,697	94,173	1,190,165	-252,899
2010	121%	N	88,203	694,592	51,406	31,531	234,505	1,100,238	2,440	1,016,725	78,915	1,098,080	2,158
2011	180%	W	52,937	1,026,568	21,035	7,241	60,638	1,168,420	4,486	791,090	83,959	879,535	288,885
2012	49%	D	45,317	498,937	20,785	64,173	339,834	969,046	3,226	776,133	62,058	841,417	127,629
2013	41%	D	2,800	264,515	1,725	84,661	437,315	791,017	8,381	826,405	65,687	900,473	-109,456
2014	32%	D	30,586	154,346	0	85,650	491,323	761,906	3,579	757,265	62,755	823,599	-61,693
2015	21%	D	15,085	107,212	0	79,517	508,193	710,008	829	624,647	49,756	675,231	34,777
2016	75%	D	41,890	227,755	0	70,864	413,868	754,377	2,497	677,936	53,544	733,977	20,400
1990-2016 Avg	91%		56,363	560,120	20,950	37,440	366,501	1,041,375	5,724	1,018,558	100,353	1,124,635	-83,260
1998-2010 Avg	96%		62,529	621,396	26,228	33,438	348,702	1,092,294	9,985	1,134,781	100,389	1,245,155	-152,861

See Acronyms and Abbreviations list for definitions.

Table 3-7. Historical and Current Water Balance, Tulare Lake Subbasin SGMA Model, Kings County, California (Continued)

Subsurface Water Budget																	
			Inflows							Outflows					Annual Change in Storage		
			Deep Percolation				Interbasin Inflow			Groundwater Pumping		Interbasin Outflow					
Year	Kings River Flows	Year Type	Precipitation Infiltration (AF)	Applied Water Infiltration (AF)	Stream Leakage (AF)	Intentional Recharge (AF)	Upper Aquifer (AF)	Lower Aquifer (AF)	Total Inflows (AF)	Upper Aquifer (AF)	Lower Aquifer (AF)	Upper Aquifer (AF)	Lower Aquifer (AF)	Total Outflows (AF)	Upper Aquifer (AF)	Lower Aquifer (AF)	Total Aquifer (AF)
1990	40%	D	17,012	132,933	222,466	1,021	60,944	120,265	554,640	363,970	254,873	52,493	58,787	730,124	-392,438	206,512	-185,926
1991	63%	D	10,310	125,674	149,106	0	59,832	104,657	449,578	351,785	225,455	44,466	68,123	689,829	-379,415	154,951	-224,464
1992	41%	D	13,215	126,365	122,515	0	58,304	102,535	422,934	345,307	251,686	43,733	75,762	716,488	-379,874	89,485	-290,389
1993	149%	W	43,499	124,472	178,243	61	51,892	77,023	475,190	239,755	9,069	42,526	80,157	371,507	-117,785	275,064	157,279
1994	50%	D	20,701	129,432	121,447	23,540	52,755	83,154	431,028	310,055	181,901	44,438	80,974	617,368	-255,820	87,113	-168,707
1995	202%	W	58,569	116,897	160,315	60,372	45,868	68,012	510,032	205,637	17,015	50,708	79,891	353,250	-23,977	255,398	231,421
1996	122%	N	78,864	127,604	161,750	32,081	42,064	60,065	502,429	184,321	11,265	47,154	88,966	331,705	-4,023	190,504	186,481
1997	155%	W	65,946	143,342	153,373	42,787	40,618	63,597	509,662	204,969	73,758	50,417	89,192	418,336	-15,247	116,032	100,786
1998	181%	W	75,095	128,533	152,395	61,425	38,754	67,063	523,264	191,289	57,797	55,626	78,577	383,288	17,175	136,362	153,536
1999	74%	D	47,885	151,647	180,710	0	41,389	79,296	500,928	227,049	111,192	47,970	93,144	479,355	-71,374	71,897	522
2000	90%	N	51,238	95,624	159,781	23,540	41,391	75,001	446,574	201,799	58,927	44,741	85,312	390,779	-76,900	120,539	43,638
2001	59%	D	26,775	90,933	124,376	0	44,167	84,217	370,468	264,888	202,438	45,556	85,202	598,085	-222,719	-20,340	-243,059
2002	67%	D	41,347	85,417	164,069	0	46,006	76,591	413,429	272,312	162,957	45,147	97,839	578,256	-174,685	-3,708	-178,393
2003	83%	N	36,128	95,332	174,955	23,540	45,798	78,735	454,487	255,270	130,332	46,552	94,198	526,352	-133,547	32,464	-101,083
2004	61%	D	40,008	86,876	148,458	10,700	46,099	79,299	411,440	279,593	214,670	46,854	90,221	631,339	-181,729	-49,393	-231,122
2005	148%	W	64,268	101,553	185,872	58,945	41,121	60,617	512,376	194,492	22,996	48,908	89,165	355,562	516	120,500	121,017
2006	172%	W	57,791	108,496	169,501	170,266	37,534	56,625	600,213	174,179	31,250	56,025	86,840	348,293	117,742	102,907	220,649
2007	40%	D	23,538	97,935	174,019	0	42,192	67,360	405,044	264,654	209,499	52,530	90,375	617,057	-177,972	-70,518	-248,490
2008	72%	D	26,373	89,622	137,369	0	43,266	76,606	373,236	283,431	232,114	49,766	93,253	658,564	-210,701	-85,575	-296,277
2009	79%	N	29,563	94,173	167,126	10,700	43,877	74,501	419,939	268,843	187,798	49,818	92,397	598,856	-170,773	-42,237	-213,010
2010	121%	N	67,953	78,915	145,364	23,540	37,974	63,446	417,193	187,770	62,006	47,711	91,016	388,504	-56,332	69,461	13,129
2011	180%	W	88,853	83,959	180,036	180,066	32,182	51,038	616,133	126,313	48,633	58,840	85,781	319,567	197,345	163,884	361,228
2012	49%	D	46,276	62,058	126,057	10,700	34,819	64,180	344,090	205,013	152,288	52,627	89,367	499,295	-137,135	-32,812	-169,947
2013	41%	D	23,005	65,687	123,434	0	38,673	66,410	317,209	252,639	203,087	50,934	92,285	598,945	-222,003	-83,604	-305,607
2014	32%	D	20,546	62,755	92,469	23,320	41,277	69,232	309,598	276,394	231,859	51,497	100,472	660,223	-247,305	-113,047	-360,352
2015	21%	D	25,814	49,756	74,156	23,540	41,875	72,128	287,269	283,699	240,639	50,653	90,840	665,831	-286,779	-105,501	-392,279
2016	75%	D	26,426	53,544	32,070	42,659	36,829	65,273	256,801	248,557	179,866	60,070	100,280	588,773	-234,011	-60,314	-294,325
1990-2016 Avg	91%		41,740	100,353	147,460	30,474	43,981	74,331	438,340	246,814	139,458	49,547	86,978	522,797	-142,214	56,519	-85,694
1998-2010 Avg	96%		45,228	100,389	160,307	29,435	42,274	72,258	449,892	235,813	129,537	49,016	89,811	504,176	-103,177	29,412	-73,765

See Acronyms and Abbreviations list for definitions.

Table 3-8. Historical Evapotranspiration Demand, Tulare Lake Subbasin SGMA Model, Kings County, California

Tulare Lake Subbasin	1990-1995 (AF/Y)	1996-1998 (AF/Y)	1999-2006 (AF/Y)	2007 (AF/Y)	2008 (AF/Y)	2009 (AF/Y)	2010 (AF/Y)	2011 (AF/Y)	2012 (AF/Y)	2013 (AF/Y)	2014 (AF/Y)	2015 (AF/Y)	2016 (AF/Y)	Average (AF/Y)
Tulare Lake Subbasin														
Alfalfa Hay and Clover	172,519	135,032	225,167	300,041	333,752	296,086	288,555	160,621	174,457	204,219	148,325	122,839	100,395	190,580
Almonds (Adolescent)			8,113			11,218	19,864	8,127	10,631	18,529	16,937	15,155	13,714	6,332
Almonds (Mature)	26,791	18,278	15,869	47,030	43,122	35,832	30,537	36,976	39,450	41,720	46,956	54,869	55,084	28,083
Almonds (Young)		2,287	6,480	12,062	26,125	15,445	17,964	13,431	14,580	18,458	17,621	15,779	20,206	8,292
Berries	47								2	6		1		11
Carrot Single Crop								37	16	41	7	6	56	6
Citrus (no ground cover)			91		42	46	14	405	99	335	300	74	32	74
Corn and Grain Sorghum	36,877	100,450	75,793	101,418	82,027	89,467	59,478	87,236	75,344	71,190	58,462	48,619	44,935	65,605
Cotton	463,179	525,386	362,232	320,870	258,511	212,071	287,383	308,970	260,527	261,476	185,559	130,368	215,815	345,645
Dairy Single Crop*	14,290	15,268	16,421											9,129
Fallow Land*														-
Forest*														-
Grain and Grain Hay	50,167	84,811	110,025	33,572	48,563	47,755	45,271	13,518	17,369	19,505	21,282	36,934	33,228	60,837
Melons	413	92	468				21	3	16	10	1,182	27	128	275
Misc. field crops	40,450	30,296	121,265		5			1			4			43,795
Onions and Garlic	807	846	1,359			12	2,417	731	538	167	893	266	1,146	854
Open Water*														-
Pasture and Misc. Grasses	10,799	21,726	24,256	218,974	191,082	289,198	229,306	63,417	57,751	66,333	144,942	68,014	59,370	62,524
Pistachio (Adolescent)								213	315	559	1,290	4,713	5,704	474
Pistachio (Mature)	15,229	12,354	12,341	17,831	5,680	2,825	1,236	1,283	1,237	1,135	1,075	1,412	1,374	9,256
Pistachio (Young)		394	2,265	1,091	1,370	2,454	2,395	3,729	5,770	7,498	8,281	8,231	9,024	2,477
Pomegranates (Adolescent)											5	23	41	3
Pomegranates (Young)				11	303	99	52	901	210	376	537	567	746	141
Potatoes, Sugar beets, Turnip etc..	18,604	4	676	19		10		29		127		7	7	4,317
Riparian*														-
Small Vegetables	2,835	1,147	8,009	33	3	20	340	227	212	390	264	126	317	2,905
Stone Fruit (Adolescent)			4,238			28	138	232	291	171	106	414	425	1,166
Stone Fruit (Mature)	25,350	17,875	13,818	4,560	1,886	584	64	11	80	141	79	95	136	11,485
Stone Fruit (Young)		1,310	3,001	466	1,234	1,217	1,879	1,010	547	1,250	1,186	913	667	1,308
Tomatoes and Peppers	12,971	3,747	33,791	261	5	246	26	47,851	52,725	15,847	26,555	42,793	52,168	20,892
Urban, Industrial*														-
Wine Grapes with 80% canopy	7,586	8,301	14,872	14,203	8,893	5,692	6,980	13,625	23,455	11,832	16,450	11,874	27,920	11,683
Winter Wheat*														-
Tulare Lake Subbasin Irrigated ET Demand	884,626	964,336	1,044,130	1,072,442	1,002,603	1,010,305	993,918	762,584	735,624	741,315	698,299	564,117	642,636	879,019
Tulare Lake Subbasin GSA Total ET Demand	898,916	979,604	1,060,551	1,072,442	1,002,603	1,010,305	993,918	762,584	735,624	741,315	698,299	564,117	642,636	888,148

Notes: Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year.

See Acronyms and Abbreviations list for definitions.

Table 4-1. Groundwater Levels - Measurable Objectives, Minimum Thresholds, and Interim Milestones (elevation in feet above mean sea level)

Index	Well ID	MO	MT	2017	2025	2030	2035	2040
1	ER_CID-021	-179.60	-229.60	-140.19	-152.59	-166.62	-210.38	-176.63
2	ER_Proposed_B2	105.64	55.64	118.05	107.92	97.52	117.63	96.87
3	ER_Proposed_B3	110.23	60.23	117.43	113.73	111.99	110.27	108.47
4	ER_Proposed_B4	106.13	56.13	121.59	114.46	109.19	105.60	102.02
5	ER_20S21E11N001M	-43.02	-93.02	-4.27	-12.39	-31.58	-77.55	-35.77
6	ER_20S21E24F001M	-126.33	-176.33	-68.10	-97.87	-112.62	-147.51	-113.27
7	ER_20S22E14C001M	-104.85	-154.85	-64.80	-75.71	-89.20	-136.63	-96.80
8	ER_21S22E07J001M	-146.77	-196.77	-40.70	-123.09	-135.64	-159.98	-131.32
9	ER_CID_078	-98.89	-148.89	-60.24	-73.92	-86.39	-130.18	-91.25
10	ER_KRCDTL002	7.43	-42.57	55.10	39.51	20.23	-24.08	15.70
11	ER_KRCDTL003	-153.55	-203.55	-106.50	-126.62	-143.64	-174.74	-144.25
12	ER_M-140	-146.62	-196.62	-110.87	-113.63	-128.31	-153.98	-114.08
13	ER_S-173	-192.36	-242.36	-60.83	-146.83	-153.70	-170.02	-142.00
14	ER_S-205	-280.27	-330.27	-239.05	-226.83	-233.70	-250.02	-222.00
15	ER_S-225	-208.49	-258.49	-150.47	-184.98	-191.70	-201.67	-167.46
16	ER_Proposed_C1	33.84	-16.16	40.29	46.93	35.43	25.72	38.25
17	ER_Proposed_C2	45.62	-4.38	43.42	51.73	43.94	44.67	47.34
18	ER_Proposed_C3	32.02	-17.98	36.64	44.70	33.79	24.40	37.87
19	ER_Proposed_C4	16.94	-33.06	22.23	32.42	21.43	8.12	28.22
20	ER_Proposed_C5	27.02	-22.98	14.22	28.46	24.35	28.82	30.11
21	ER_Proposed_C6	-46.08	-96.08	-28.52	-26.26	-50.49	-48.83	-39.29
22	ER_Proposed_C7	-0.37	-50.37	22.56	19.13	-14.82	4.87	-0.89
23	ER_Proposed_C8	86.76	36.76	96.11	91.72	76.91	90.46	90.44
24	MKR_18S21E17N001M	213.38	163.38	217.33	215.97	214.35	213.67	213.96
25	MKR_19S21E20N001M	210.10	160.10	212.72	212.37	211.51	210.59	210.07
26	MKR_17S22E28A001M	156.77	106.77	170.05	158.71	151.21	158.75	152.68
27	MKR_18S21E01C001M	169.09	119.09	178.38	176.59	170.04	167.95	166.34
28	MKR_18S21E07R003M	195.06	145.06	216.92	209.68	200.89	194.34	187.38
29	MKR_18S21E27B001M	70.00	20.00	100.88	87.71	73.98	66.05	59.51
30	MKR_18S21E31B001M	67.13	17.13	89.10	81.91	74.48	67.74	59.76
31	MKR_18S22E03B001M	134.48	84.48	138.88	139.13	134.60	135.56	135.80
32	MKR_18S22E07A001M	124.04	74.04	131.48	130.38	125.06	123.94	122.17
33	MKR_18S22E24D001M	110.23	60.23	119.30	115.80	112.82	111.53	110.07
34	MKR_18S22E28A001M	95.97	45.97	107.86	103.33	98.74	97.17	96.82
35	MKR_18S22E34R001M	144.38	94.38	123.50	151.00	147.01	145.74	145.10

See Acronyms and Abbreviations list for definitions.

Table 4-1. Groundwater Levels - Measurable Objectives, Minimum Thresholds, and Interim Milestones (elevation in feet above mean sea level) (Continued)

Index	Well ID	MO	MT	2017	2025	2030	2035	2040
36	MKR_19S21E30A001M	185.18	135.18	202.24	196.33	190.78	185.96	179.82
37	MKR_19S22E07K001M	48.48	-1.52	65.08	61.48	54.93	49.32	43.13
38	MKR_MWA_INTDEEP	253.50	203.50	242.06	256.37	252.08	254.02	253.67
39	MKR_MWC_INT	186.02	136.02	188.76	187.13	182.27	188.52	185.29
40	MKR_MWD_INT	191.22	141.22	185.58	191.51	186.29	194.26	188.87
41	MKR_MWG_INT	181.23	131.23	184.21	183.50	182.38	184.26	182.74
42	MKR_MWH_INT	110.17	60.17	115.63	117.87	113.63	110.76	109.24
43	MKR_Proposed_B1	215.15	165.15	220.91	218.68	212.12	215.81	212.50
44	MKR_Proposed_B2	178.95	128.95	183.87	186.04	179.11	177.75	176.67
45	MKR_Proposed_B3	84.90	34.90	102.29	96.83	91.02	85.88	79.45
46	MKR_Proposed_B4	84.84	34.84	99.81	94.01	89.49	85.43	80.26
47	MKR_19S22E08D002M	-39.50	-89.50	62.10	-12.10	-42.77	-63.99	-55.37
48	MKR_1610003-037	39.87	-10.13	83.60	60.44	33.03	20.67	19.35
49	MKR_1610003-042	67.63	17.63	105.80	84.32	57.53	45.99	46.68
50	MKR_MWD_DEEP	158.78	108.78	171.80	175.25	141.09	133.72	146.97
51	MKR_MWG_DEEP	132.82	82.82	151.18	150.45	117.77	108.79	121.59
52	MKR_MWH_DEEP	38.47	-11.53	26.80	67.29	33.50	10.96	22.80
53	MKR_Proposed_C1	104.91	54.91	133.56	116.58	92.65	85.24	91.79
54	MKR_Proposed_C2	79.29	29.29	122.48	100.96	66.57	50.59	63.84
55	MKR_Proposed_C3	69.22	19.22	105.75	86.11	61.35	51.89	54.08
56	MKR_Proposed_C4	0.39	-49.61	53.45	27.05	-6.17	-24.14	-18.10
57	MKR_Proposed_C5	-5.36	-55.36	42.75	20.47	-9.76	-31.74	-18.59
58	SFK_18S20E23E003M	198.40	148.40	199.90	199.81	199.49	199.12	198.78
59	SFK_19S20E29E002M	183.63	133.63	182.08	183.95	184.32	184.86	185.13
60	SFK_20S19E25A003M	199.21	149.21	197.05	200.17	198.83	199.87	200.39
61	SFK_Proposed_A1	182.42	132.42	182.77	183.43	183.10	182.92	183.64
62	SFK_Proposed_A2	236.77	186.77	235.98	237.33	237.02	237.07	237.14
63	SFK_1610005-009	31.30	-18.70	56.38	45.60	33.46	25.94	19.00
64	SFK_18S20E23E001M	26.39	-23.61	51.36	42.78	33.85	25.91	17.82
65	SFK_18S20E23E002M	28.42	-21.58	53.89	44.81	35.89	27.95	19.86
66	SFK_18S20E34N001M	68.17	18.17	110.82	82.17	75.93	69.21	61.60
67	SFK_19S20E19A001M	-77.73	-127.73	-38.99	-59.36	-76.06	-89.90	-91.31
68	SFK_19S20E06C001M	9.03	-40.97	42.14	25.85	18.50	10.47	1.42
69	SFK_19S20E06L001M	-46.58	-96.58	23.00	-26.06	-47.07	-57.97	-63.48

See Acronyms and Abbreviations list for definitions.

Table 4-1. Groundwater Levels - Measurable Objectives, Minimum Thresholds, and Interim Milestones (elevation in feet above mean sea level) (Continued)

Index	Well ID	MO	MT	2017	2025	2030	2035	2040
70	SFK_19S20E07F001M	-17.82	-67.82	24.00	-1.96	-8.90	-16.39	-24.89
71	SFK_19S20E32D002M	-26.91	-76.91	2.94	-15.48	-21.41	-26.36	-32.50
72	SFK_19S20E32D003M	-26.91	-76.91	-7.68	-15.48	-21.41	-26.36	-32.50
73	SFK_20S20E26L001M	45.75	-4.25	52.71	51.59	48.64	46.38	42.63
74	SFK_20S20E26L002M	-19.25	-69.25	-12.95	-13.40	-16.35	-18.61	-22.36
75	SFK_Proposed_B1	83.63	33.63	97.09	92.14	88.27	84.36	79.72
76	SFK_19S20E26N002M	-3.81	-53.81	41.56	18.16	-2.91	-26.38	-14.88
77	SFK_20S19E02A001M	-67.47	-117.47	-30.60	-48.13	-72.04	-91.94	-89.90
78	SFK_20S20E07H001M	-102.74	-152.74	-4.83	-82.67	-100.16	-126.98	-112.22
79	SFK_20S20E28E003M	-41.13	-91.13	-56.13	-23.02	-37.11	-61.17	-43.32
80	SFK_1610005-020	7.21	-42.79	43.24	22.11	0.63	-6.76	-9.05
81	SFK_1610005-011	-91.02	-141.02	-42.55	-71.85	-97.00	-114.74	-112.99
82	SFK_Proposed_C1	-5.54	-55.54	44.21	15.76	-9.25	-24.57	-24.06
83	SWK_1610009-003	70.58	20.58	78.00	72.98	72.02	71.04	69.90
84	SWK_Proposed_B1	107.75	57.75	120.01	114.77	111.38	107.77	103.95
85	SWK_Proposed_B2	177.02	127.02	176.13	176.37	176.36	176.90	177.87
86	SWK_Well_16-8	50.96	0.96	63.83	62.42	48.13	47.85	41.71
87	SWK_Proposed_C1	80.24	30.24	86.80	87.11	77.77	78.55	76.59
88	SWK_Proposed_C2	105.94	55.94	105.10	109.01	102.83	107.41	105.94
89	SWK_Proposed_C3	152.29	102.29	151.88	153.49	145.92	154.77	155.34
90	TCWA_23S23E15M001M	199.21	149.21	197.05	200.17	198.83	199.87	200.39
91	TCWA_Proposed_B1	89.18	39.18	115.99	105.46	97.53	89.33	81.42
92	TCWA_24S22E33C001M	-41.39	-91.39	-23.25	-21.72	-87.56	-36.65	-39.74
93	TCWA_24S22E35E001M	16.76	-33.24	22.94	41.02	-40.93	18.72	16.69
94	TCWA_Proposed_C1	-60.88	-110.88	-21.93	-29.46	-99.02	-62.31	-71.16
95	TCWA_Proposed_B2	105.57	55.57	115.39	111.71	108.88	105.98	102.97

See Acronyms and Abbreviations list for definitions.

Table 4-2a. Land Subsidence @ Baseline - Measurable Objectives, Minimum Thresholds, and Interim Milestones – Lemoore RMS (feet of cumulative subsidence since 1990)

MO	MT	Interim Milestones				
		2017	2025	2030	2035	2040
5.52	11.5	1.98	4.19	5.33	5.76	6.92

Table 4-2b. Land Subsidence w/GSP Implementation - Measurable Objectives, Minimum Thresholds, and Interim Milestones – Lemoore RMS (feet of cumulative subsidence since 1990)

MO	MT	Interim Milestones				
		2017	2025	2030	2035	2040
5.52	11.5	1.97	3.80	4.59	4.67	5.00

Table 4-3a. Land Subsidence @ Baseline - Measurable Objectives, Minimum Thresholds, and Interim Milestones – Corcoran RMS (feet of cumulative subsidence since 1990)

MO	MT	Interim Milestones				
		2017	2025	2030	2035	2040
8.90	11.5	4.52	4.58	5.07	5.21	5.82

Table 4-3b. Land Subsidence w/GSP Implementation - Measurable Objectives, Minimum Thresholds, and Interim Milestones – Corcoran RMS (feet of cumulative subsidence since 1990)

MO	MT	Interim Milestones				
		2017	2025	2030	2035	2040
8.90	11.5	4.51	4.49	4.54	4.59	4.57

See Acronyms and Abbreviations list for definitions.

Table 5-1. Summary of Existing & Proposed Monitoring Network Sites

Existing RMS Network	Water Level	Water Quality	Land Subsidence
Mid-King River GSA	25	18	11
South Fork King GSA	21	21	6
Southwest Kings GSA	2	2	4
El Rico GSA	10	3	5
Tri-County GSA	3	0	2
Total	61	44	28
Proposed Additions to RMS Network	**Water Level**	**Water Quality**	**Land Subsidence**
Mid-King River GSA	9	TBD	0
South Fork King GSA	4	TBD	1
Southwest Kings GSA	5	TBD	0
El-Rico GSA	13	TBD	1
Tri-County GSA	3	TBD	0
Total	34	0	2

Notes:

1) Summary of network includes nested (multiple casings installed in a single borehole) or clustered monitoring wells (multiple wells located close together) for water levels and water quality.

Table 5-2. Mid-Kings River GSA: Existing & Proposed Representative Monitoring Network

	Mid Kings River GSA						Facility				
	State Well ID / System Well Number *(if applicable)*	Local Agency Well ID *(if applicable)*	Aquifer Zone	Township	Range	Section	Type	Existing Program	Sustainability Indicator(s)[6]	SGMA Monitoring Frequency	Aquifer Monitored
Representative Monitoring Sites	18S21E17N001M	18S21E17N001M	A Zone	18S	21E	17	Unknown Use	KCWD	WL	Semiannual	Above A-Clay
	19S21E20N001M	19S21E20N001M	A Zone	19S	21E	20	Unknown Use	KCWD	WL	Semiannual	Above A-Clay
		MW-A	B Zone	17S	22E	1	Monitoring Well	KCWD	WL	Semiannual	Local
	17S22E28A001M	KRCDKCWD01	B Zone	17S	22E	28	Irrigation Well	DWR	WL	Semiannual	Above E-Clay
	18S22E03B001M	18S22E03B001M	B Zone	18S	22E	3	Unknown Use	KCWD	WL	Semiannual	Above E-Clay
	18S21E01C001M	18S21E01C001M	B Zone	18S	21E	1	Unknown Use	KCWD	WL	Semiannual	Above E-Clay
	18S22E07A001M	18S22E07A001M	B Zone	18S	22E	24	Unknown Use	USBR	WL	Semiannual	Above E-Clay
	18S22E24D001M	18S22E24D001M	B Zone	18S	22E	24	Irrigation Well	Lakeside Irrigation WD	WL	Semiannual	Above E-Clay
	18S22E28A001M	KRCDKCWD08	B Zone	18S	22E	28	Irrigation Well	KCWD	WL	Semiannual	Above E-Clay
	18S22E34R001M	18S22E34R001M	B Zone	18S	22E	34	Residential	KDWCD	WL	Semiannual	Above E-Clay
	19S22E07K001M	KRCDKCWD11	B Zone	19S	22E	7	Unknown Use	Lakeside Irrigation WD	WL	Semiannual	Above E-Clay
	18S21E27B001M	KRCDKCWD05	B Zone	18S	21E	27	Irrigation Well	KCWD	WL	Semiannual	Above E-Clay
	18S21E07R003M	18S21E07R003M	B Zone	18S	21E	7	Unknown Use	DWR	WL	Semiannual	Above E-Clay
	18S21E31B001M	18S21E31B001M	B Zone	18S	21E	31	Unknown Use	KCWD	WL	Semiannual	Above E-Clay
	19S21E30A001M	KRCDKCWD06	B Zone	19S	21E	30	Irrigation Well	KCWD	WL	Semiannual	Above E-Clay
		MW-C	B Zone	17S	22E	14	Monitoring Well	KCWD	WL	Semiannual	Above E-Clay
		MW-D	B & C Zone	17S	22E	23	Monitoring Well	KCWD	WL	Semiannual	Above/Below E-Clay
		MW-G	B & C Zone	17S	22E	25	Monitoring Well	KCWD	WL	Semiannual	Above/Below E-Clay
		MW-H	B & C Zone	18S	22E	34	Monitoring Well	KCWD	WL	Semiannual	Above/Below E-Clay
	1610003-042[/1]	Well_48	C Zone	18S	21E	13	Municipal Well	Hanford	WL/WQ[/3]	Semiannual	Below E-Clay
	1610003-037[/1]	Well 43	C Zone	18S	21E	27	Municipal Well	Hanford	WL/WQ[/3]	Semiannual	Below E-Clay
	19S22E08D002M	19S22E08D002M	C Zone	19S	22E	8	Observation	KDWCD	WL	Semiannual	Below E-Clay
Water Quality Sites	17S22E20D		B Zone	17S	22E	20	Domestic Well	ILRP	WQ[/4]	Annual	Above E-Clay[/5]
	17S22E33A		B Zone	17S	22E	33	Domestic Well	ILRP	WQ[/4]	Annual	Above E-Clay[/5]
	18S21E14M		B Zone	18S	21E	14	Irrigation Well	ILRP	WQ[/4]	Annual	Above E-Clay[/5]
	1610001-008			18S	21E	32	Municipal Well	Armona CSD	WQ[/3]	Annual	
	1610001-009			19S	21E	4	Municipal Well	Armona CSD	WQ[/3]	Annual	
	1610003-031		C Zone	18S	21E	23	Municipal Well	Hanford	WQ[/3]	Annual	Below E-Clay
	1610003-039		C Zone	18S	22E	30	Municipal Well	Hanford	WQ[/3]	Annual	Below E-Clay
	1610003-036		C Zone	18S	21E	22	Municipal Well	Hanford	WQ[/3]	Annual	Below E-Clay
	1610003-041			18S	22E	19	Municipal Well	Hanford	WQ[/3]	Annual	
	1610003-033		C Zone	18S	21E	14	Municipal Well	Hanford	WQ[/3]	Annual	Below E-Clay
	1610003-040			18S	21E	25	Municipal Well	Hanford	WQ[/3]	Annual	
	1610003-026			18S	21E	36	Municipal Well	Hanford	WQ[/3]	Annual	
	1610003-038		C Zone	18S	21E	14	Municipal Well	Hanford	WQ[/3]	Annual	Below E-Clay
	1610003-028		C Zone	18S	21E	26	Municipal Well	Hanford	WQ[/3]	Annual	Below E-Clay
	1610003-043			18S	22E	19	Municipal Well	Hanford	WQ[/3]	Annual	
	1610003-034			18S	21E	23	Municipal Well	Hanford	WQ[/3]	Annual	

See Acronyms and Abbreviations list for definitions.

Table 5-2. Mid-Kings River GSA: Existing & Proposed Representative Monitoring Network (Continued)

	Mid Kings River GSA						Facility					
	State Well ID / System Well Number *(if applicable)*	Local Agency Well ID *(if applicable)*	Aquifer Zone	Township	Range	Section	Type	Existing Program	Sustainability Indicator(s)[6]	SGMA Monitoring Frequency	Aquifer Monitored
Land Subsidence	SUB084			NA	NA	NA	Subsidence Monument	KRCD	LS	Semiannual	All
	K021			17S	22E	34	Subsidence Monument	KDWCD	LS	Semiannual	All
	S224P2			18S	22E	28	Subsidence Monument	CHSRA	LS	Semiannual	All
	U 808			18S	22E	29	Subsidence Monument	CalTrans	LS	Semiannual	All
	U 511			18S	22E	30	Subsidence Monument	CalTrans	LS	Semiannual	All
	X 511			18S	21E	24	Subsidence Monument	CalTrans	LS	Semiannual	All
	U 157, SUB091			18S	21E	36	Subsidence Monument	KRCD	LS	Semiannual	All
	Hanford RM1, SUB032			18S	21E	36	Subsidence Monument	KRCD	LS	Semiannual	All
	X 931			18S	21E	32	Subsidence Monument	CalTrans	LS	Semiannual	All
	N 460 RESET			18S	21E	32	Subsidence Monument	CalTrans	LS	Semiannual	All
	SUB068			18S	21E	31	Subsidence Monument	KRCD	LS	Semiannual	All
Proposed Facilities			B Zone	17S	22E	19	Monitoring Well		WL	Semiannual	Above E-Clay
			B Zone	17S	22E	27	Monitoring Well		WL	Semiannual	Above E-Clay
			B Zone	19S	21E	16	Monitoring Well		WL	Semiannual	Above E-Clay
			B Zone	20S	21E	8	Monitoring Well		WL	Semiannual	Above E-Clay
			C Zone	17S	21E	26	Monitoring Well		WL	Semiannual	Below E-Clay
			C Zone	18S	22E	3	Monitoring Well		WL	Semiannual	Below E-Clay
			C Zone	18S	21E	3	Monitoring Well		WL	Semiannual	Below E-Clay
			C Zone	19S	21E	8	Monitoring Well		WL	Semiannual	Below E-Clay
			C Zone	19S	21E	32	Monitoring Well		WL	Semiannual	Below E-Clay

Notes:
/1 Representative Monitoring Sites that are also included for Water Quality
/2 Proposed monitoring areas pending funding or collaboration with DWR or USGS
/3 State Water Resources Control Board Division (SWRCB) Division of Drinking Water (DDV)
/4 Kings River Water Quality Coalition (KRWQC), Irrigation Lands Regulatory Program (ILRP), samples annually, data will be retrieved annually
/5 Tentatively identified as B Zone Well
/6 WL -= water level, WQ = water quality, LS = land subsidence

Table 5-3. South Fork Kings GSA: Existing & Proposed Representative Monitoring Network

	South Fork Kings River GSA						Facility	Existing Program	Sustainability Indicator(s)[5]	SGMA Monitoring Frequency	Aquifer Monitored
	State Well ID / System Well Number *(if applicable)*	Local Agency Well ID *(if applicable)*	Aquifer Zone	Township	Range	Section	Type				
Representative Monitoring Sites	18S20E23E003M[/1]	KRCDAC1S	A Zone	18S	20E	23	Monitoring Well	CASGEM	WL/WQ[/3]	Semiannual	Above A-Clay
	19S20E29E002M	19S20E29E002M	A Zone	19S	20E	29	Unknown Use	DWR	WL	Semiannual	Above A-Clay
	20S19E25A003M	20S19E25A003M	A Zone	20S	19E	25	Monitoring Well	DWR	WL	Semiannual	Above A-Clay
	1610005-009[/1]	LEM_N-5	B Zone	18S	20E	11	Municipal Well	Lemoore	WL/WQ[/3]	Semiannual	Above E-Clay
	18S20E23E002M[/1]	KRCDAC1M	B Zone	18S	20E	23	Monitoring Well	CASGEM	WL/WQ[/4]	Semiannual	Above E-Clay
	18S20E23E001M	KRCDAC1D	B Zone	18S	20E	23	Monitoring Well	CASGEM	WL	Semiannual	Above E-Clay
	18S20E34N001M	18S20E34N001M	B Zone	18S	20E	34	Residential Well	DWR	WL	Semiannual	Above E-Clay
	19S20E06C001M	19S20E06C001M	B Zone	19S	20E	6	Irrigation Well	DWR	WL	Semiannual	Above E-Clay
	19S20E07F001M		B Zone	19S	20E	7	Unknown Use	DWR	WL	Semiannual	Above E-Clay
	19S20E32D002M[/1]	KRCDAC3M	B Zone	19S	20E	32	Monitoring Well	CASGEM	WL/ WQ[/4]	Semiannual	Above E-Clay
	19S20E32D003M	KRCDAC3D	B Zone	19S	20E	32	Monitoring Well	CASGEM	WL	Semiannual	Above E-Clay
	20S20E26L001M[/1]	KRCDAC5M	B Zone	20S	20E	26	Monitoring Well	CASGEM	WL/ WQ[/4]	Semiannual	Above E-Clay
	20S20E26L002M	KRCDAC5D	B Zone	20S	20E	26	Monitoring Well	CASGEM	WL	Semiannual	Above E-Clay
	19S20E06L001M	19S20E06L001M	Composite	19S	20E	6	Irrigation Well	DWR	WL	Semiannual	Above/Below E-Clay
	19S20E19A001M	19S20E19A001M	Composite	19S	20E	19	Irrigation Well	DWR	WL	Semiannual	Above/Below E-Clay
	1610005-020[/1]	LEM_N-6	C Zone	18S	20E	11	Municipal Well	Lemoore	WL/WQ[/3]	Semiannual	Below E-Clay
	1610005-011[/1]	LEM_12	C Zone	19S	20E	9	Municipal Well	Lemoore	WL/ WQ[/4]	Semiannual	Below E-Clay
	19S20E26N002M	CU-ELEM SCHOOL	C Zone	19S	20E	26	Municipal Well	Public Water Systems	WL	Semiannual	Below E-Clay
	20S19E02A001M	20S/19E-02A01	C Zone	20S	19E	2	Irrigation Well	Westlands Water District	WL	Semiannual	Below E-Clay
	20S20E07H001M	20S20E07H001M	C Zone	20S	20E	7	Irrigation Well	DWR	WL	Semiannual	Below E-Clay
	20S20E28E003M		C Zone	20S	20E	28	Unknown Use	DWR	WL	Semiannual	Below E-Clay
Water Quality Sites	1610006-001		Composite	20S	20E	17	Municipal Well	Stratford PUD	WQ[/3]	Annual	Above/Below E-Clay
	1610006-002			20S	20E	17	Municipal Well	Stratford PUD	WQ[/3]	Annual	
	1610006-005			20S	20E	17	Municipal Well	Stratford PUD	WQ[/3]	Annual	
	1610005-021			19S	20E	8	Municipal Well	Lemoore	WQ[/3]	Annual	
	1610005-007			19S	20E	15	Municipal Well	Lemoore	WQ[/3]	Annual	
	1610005-010			18S	20E	35	Municipal Well	Lemoore	WQ[/3]	Annual	
	1610005-003			18S	20E	11	Municipal Well	Lemoore	WQ[/3]	Annual	
	1610005-022			19S	20E	8	Municipal Well	Lemoore	WQ[/3]	Annual	
	1610005-005			18S	20E	11	Municipal Well	Lemoore	WQ[/3]	Annual	
	1610005-018			19S	20E	8	Municipal Well	Lemoore	WQ[/3]	Annual	
	1610005-008			19S	20E	15	Municipal Well	Lemoore	WQ[/3]	Annual	
	1610005-006			19S	20E	3	Municipal Well	Lemoore	WQ[/3]	Annual	
	19S20E11C			19S	20E	11	Unknown Use		WQ	Annual	
	18S20E11D			18S	20E	11	Public Well		WQ	Annual	

See Acronyms and Abbreviations list for definitions.

Table 5-3. South Fork Kings GSA: Existing & Proposed Representative Monitoring Network (Continued)

	South Fork Kings River GSA						Facility	Existing Program	Sustainability Indicator(s)[5]	SGMA Monitoring Frequency	Aquifer Monitored
	State Well ID/System Well Number *(if applicable)*	Local Agency Well ID *(if applicable)*	Aquifer Zone	Township	Range	Section	Type				
Land Subsidence	SOUTHFORK, SUB086			18S	20E	16	Subsidence Monument	KRCD	LS	Semiannual	All
	LEMA (RMS)			19S	20E	10	Subsidence Monument	CVSRN	LS	Semiannual	All
	G808	SUB028		19S	19E	24	Subsidence Monument	CalTrans/KCRD	LS	Semiannual	All
	SUB102			20S	20E	18	Subsidence Monument	KRCD	LS	Semiannual	All
	SUB061			20S	20E	21	Subsidence Monument	KRCD	LS	Semiannual	All
Proposed Facilities	Proposed Well		A Zone	19S	20E	32	Monitoring Well		WL	Semiannual	Above A-Clay
	Proposed Well		A Zone	20S	20E	26	Monitoring Well		WL	Semiannual	Above A-Clay
	Proposed Well		B Zone	19S	20E	26	Municipal Well		WL	Semiannual	Above E-Clay
	Proposed Well		C Zone	18S	20E	27	Monitoring Well		WL	Semiannual	Below E-Clay
	/2		All	19S	20E	35	Extensometer		LS	Semiannual	All

Notes:
/1 Representative Monitoring Sites that are also included for Water Quality
/2 Proposed monitoring areas pending funding or collaboration with DWR or USGS
/3 State Water Resources Control Board Division (SWRCB) Division of Drinking Water (DDW)
/4 Kings River Water Quality Coalition (KRWQC), Irrigated Lands Regulatory Program (ILRP) samples annually, data will be retrieved annually
/5 WL -= water level, WQ = water quality, LS = land subsidence

Table 5-4. Southwest Kings GSA: Existing & Proposed Representative Monitoring Network

	Southwest Kings GSA						Facility				
	State Well ID / System Well Number *(if applicable)*	Local Agency Well ID *(if applicable)*	Aquifer Zone	Township	Range	Section	Type	Existing Program	Sustainability Indicator(s)[5]	SGMA Monitoring Frequency	Aquifer Monitored
Representative Monitoring Sites	1610009-003/1	Becky Pease Well	B Zone	22S	19E	19	Municipal Well	Kettleman City CSD	WL/WQ/3	Semiannual	Above E-Clay
		Well 16-8	C Zone	21S	19E	21	Irrigation Well		WL	Semiannual	Below E-Clay
Water Quality Sites	1610009-004	Maud St. Well	B Zone	22S	19E	8	Municipal Well	Kettleman City CSD	WQ/3	Annual	Above E-Clay
Land Subsidence	G 1445, SUB027			22S	19E	30	Subsidence Monument	KRCD, California Aqueduct	LS	Semiannual	All
	U 1097			22S	19E	30	Subsidence Monument	California Aqueduct	LS	Semiannual	All
	SUB030			24S	19E	11	Subsidence Monument	KRCD	LS	Semiannual	All
	SUB076			24S	19E	36	Subsidence Monument	KRCD	LS	Semiannual	All
Proposed Facilities			B Zone	21S	19E	21	Monitoring Well		WL	Semiannual	Above E-Clay
	/2		B Zone	24S	20E	19	Monitoring Well		WL	Semiannual	Above E-Clay
			C Zone	22S	19E	18	Monitoring Well		WL	Semiannual	Below E-Clay
	/2		C Zone	23S	20E	8	Monitoring Well		WL	Semiannual	Below E-Clay
	/2		C Zone	24S	20E	18	Monitoring Well		WL	Semiannual	Below E-Clay

Notes:
/1 Representative Monitoring Sites that are also included for Water Quality
/2 Proposed monitoring areas pending funding or collaboration with DWR or USGS
/3 State Water Resources Control Board Division (SWRCB) Division of Drinking Water (DDW)
/4 Kings River Water Quality Coalition (KRWQC), Irrigated Lands Regulatory Program (ILRP) samples annually, data will be retrieved annually
/5 WL -= water level, WQ = water quality, LS = land subsidence

Table 5-5. El Rico GSA: Existing & Proposed Representative Monitoring Network

	El Rico GSA						Facility				
	State Well ID / System Well Number *(if applicable)*	Local Agency Well ID *(if applicable)*	Aquifer Zone	Township	Range	Section	Type	Existing Program	Sustainability Indicator(s)[5]	SGMA Monitoring Frequency	Aquifer Monitored
Representative Monitoring Sites	20S22E35R001M	20S22E35R001M	B Zone	20S	22E	35	Irrigation Well	DWR	WL	Semiannual	Above E-Clay
		ER_S-225	C Zone	20S	20E	32	Unknown Use		WL	Semiannual	Below E-Clay
		ER_S-173	C Zone	21S	22E	25	Unknown Use		WL	Semiannual	Below E-Clay
		ER_S-205	C Zone	22S	22E	6	Unknown Use		WL	Semiannual	Below E-Clay
		CID_078	C Zone	21S	22	1	Unknown Use		WL	Semiannual	Below E-Clay
	21S22E07J001M	21S22E07J001M	C Zone	21S	22E	7	Observation	KDWCD	WL	Semiannual	Below E-Clay
		CID 021	C Zone	20S	22E	13	Irrigation Well	CID	WL	Semiannual	Below E-Clay
	20S22E19J001M	20S22E19J001M	C Zone	20S	22E	19	Irrigation Well	DWR	WL	Semiannual	Below E-Clay
		KRCDTL002	C Zone	20S	21E	11	Irrigation Well		WL	Semiannual	Below E-Clay
		KRCDTL003	C Zone	20S	22E	22	Irrigation Well		WL	Semiannual	Below E-Clay
Water-Quality /1	1610004-026			21S	22E	12	Municipal Well	Corcoran	WQ/3	Annual	
	1610004-018			21S	22E	2	Municipal Well	Corcoran	WQ/3	Annual	
	1610004-019			21S	22E	1	Municipal Well	Corcoran	WQ/3	Annual	
Land Subsidence	S234P2			20S	22E	16	Subsidence Monument	CHSRA	LS	Semiannual	All
	S238			21S	22E	10	Subsidence Monument	CHSRA	LS	Semiannual	All
	CRCN (RMS)			21S	22E	11	Subsidence Monument	CVSRN	LS	Semiannual	All
	SUB083			22S	22E	11	Subsidence Monument	KRCD	LS	Semiannual	All
	SUB093			23S	23E	31	Subsidence Monument	KRCD	LS	Semiannual	All
Proposed Facilities			A Zone	20S	21E	26	Monitoring Well		WL	Semiannual	Above A-Clay
			B Zone	20S	21E	23	Monitoring Well		WL	Semiannual	Above E-Clay
			B Zone	20S	22E	21	Monitoring Well		WL	Semiannual	Above E-Clay
			B Zone	21S	21E	21	Monitoring Well		WL	Semiannual	Above E-Clay
			B Zone	21S	22E	9	Monitoring Well		WL	Semiannual	Above E-Clay
			C Zone	21S	20E	10	Monitoring Well		WL	Semiannual	Below E-Clay
			C Zone	21S	21E	9	Monitoring Well		WL	Semiannual	Below E-Clay
			C Zone	21S	21E	27	Monitoring Well		WL	Semiannual	Below E-Clay
			C Zone	21S	21E	21	Monitoring Well		WL	Semiannual	Below E-Clay
	/2		C Zone	22S	21E	9	Monitoring Well		WL	Semiannual	Below E-Clay
	/2		C Zone	24S	21E	9	Monitoring Well		WL	Semiannual	Below E-Clay
	/2		All	20S	22E	31	Extensometer		LS	Semiannual	All

Notes:
/1 Representative Monitoring Sites that are also included for Water Quality
/2 Proposed monitoring areas pending funding or collaboration with DWR or USGS
/3 State Water Resources Control Board Division (SWRCB) Division of Drinking Water (DDW)
/4 Kings River Water Quality Coalition(KRWQC), Irrigated Lands Regulatory Program (ILRP) samples annually, data will be retrieved annually

Table 5-6. Tri-County Water Authority GSA Existing & Proposed Representative Monitoring Network

	Tri County Water Authority GSA						Facility	Existing Program	Sustainability Indicator(s)[5]	SGMA Monitoring Frequency	Aquifer Monitored
	State Well ID / System Well Number *(if applicable)*	Local Agency Well ID *(if applicable)*	Aquifer Zone	Township	Range	Section	Type				
Representative Monitoring Sites	23S23E15M001M		A Zone	23S	23E	15	Unknown Use	DWR	WL	Semiannual	Above A-Clay
	24S22E35E001M		C Zone	24S	22E	35	Unknown Use	DWR	WL	Semiannual	Below E-Clay
	24S22E33C001M		C Zone	24S	22E	33	Unknown Use	DWR	WL	Semiannual	Below E-Clay
Land Subsidence	SUB107			23S	21E	18	Subsidence Monument	KRCD	LS	Semiannual	All
	SUB038			24S	22E	34	Subsidence Monument	KRCD	LS	Semiannual	All
Proposed Facilities			B Zone	24S	22E	24	Monitoring Well		WL	Semiannual	Above E-Clay
			B Zone	23S	23E	16	Monitoring Well		WL	Semiannual	Below E-Clay
			C Zone	23S	23E	16	Monitoring Well		WL	Semiannual	Above E-Clay

Notes:
/1 Representative Monitoring Sites that are also included for Water Quality
/2 Proposed monitoring areas pending funding or collaboration with DWR or USGS
/3 State Water Resources Control Board Division (SWRCB) Division of Drinking Water (DDW)
/4 Kings River Water Quality Coalition (KWRQC), Irrigated Lands Regulatory Program (ILRP) samples annually, data will be retrieved annually
/5 WL -= water level, WQ = water quality, LS = land subsidence

Table 5-7. Annual Reporting Requirements

SGMA Section	Annual Reporting Requirement	Input to DMS (or link)
356.2(b)(1)(B)	Hydrographs including water year type from Jan 2015(?) to current	Generated in DMS from water level data input by GSAs
356.2(b)(1)(A)	GW Elevation Contours (spring & fall)	Generated outside DMS using data from DMS then contour maps created and a linked PDF maps from the DMS
356.2(b)(2)	GW extraction by water use sector including method of determination and map	Determined outside DMS. Total use by sector input by each GSA then summarized for subbasin in DMS as a summary table
356.2(b)(3)	Surface Water use by source	Total by GSA for input to DMS and summarized for subbasin in DMS as a summary table
356.2(b)(4)	Total Water use by sector	DMS summary table of water supplies by sector per GSA
356.2(b)(5)(A)	Change in GW Storage maps	Calculated outside DMS from contour data using basin-wide method then total per GSA input into DMS as a summary table
356.2(b)(5)(B)	Graph with Water Year type, est. GW use, annual & cumulative GW Storage change	DMS generated basin total graph using data in DMS.

Table 5-8. Reporting Standards

Category of Information	Reporting Units
Water Volumes	AF
Surface Water Flows Groundwater Flows	AF/Y or CFS AF/Y
Field Measurements of Elevations Groundwater Surface Water Land Surface	to nearest 0.1 ft relative to NAVD 88
Reference Point Elevations	To within 0.5 feet, or best available information relative to NAVD 88
Geographic Locations	GPS coordinates by latitude and longitude in decimal degrees to five decimal places, to a minimum accurate of 30 feet, relative to NAD 83

See Acronyms and Abbreviations list for definitions.

Table 6-1. Summary of Projects and Management Actions Chosen for Mid-Kings River GSA

Project	Implementing Agency	Cost	Annual Yield (AF/Y)
Rehabilitation of Existing Recharge Basins	Kings County Water District	$ 800,000	1,500
Conveyance Improvements and Construction on Riverside Canal	Kings County Water District	$ 320,000	1,500
Fallowing Program	Mid-Kings River GSA	$ 1,380,000	6,250
Cartright Basin Improvements	Kings County Water District, Lakeside Irrigation Water District	$ 884,000	650
Last Chance Side Ditch Improvements	Kings County Water District, Landowners	$ 6,798,000	1,000
Recharge Basin Construction	Kings County Water District, Mid-Kings River GSA	$ 90,000,000	44,444

Table 6-2. Summary of Projects and Management Actions Chosen for South Fork Kings GSA

Project	Implemented by	Annualized Benefit (AF/Y)	Priority	Estimated CAPEX ($)
Groundwater Measurement and Reporting	South Fork Kings GSA/Landowners	1,500	High	$ 500,000
Surface Water Delivery Improvement	South Fork Kings GSA/Landowners	5,000	High	$ 5,000,000
On-Farm Improvements	South Fork Kings GSA/Landowners	2,500	Med	$ 1,000,000
Conservation Reuse	South Fork Kings GSA/Lemoore	1,000	Med	$ 1,000,000
Cropping/Fallowing Program	South Fork Kings GSA	13,000	High	$ 5,000,000
Demand Reduction Sub-Total		**23,000**		**$ 12,500,000**
Aquifer Storage and Recovery	South Fork Kings GSA/Landowners	13,000	High	$ 15,000,000
Surface Storage	South Fork Kings GSA/Landowners	2,000	Low	$ 6,000,000
Mid-Kings Recharge Basin	South Fork Kings GSA	7,000	Med	$ 28,000,000
Supply Enhancement Sub-Total		**22,000**		**$ 49,000,000**
TOTAL		**45,000**		**$ 61,500,000**

See Acronyms and Abbreviations list for definitions.

Table 6-3. Summary of Projects and Management Actions Chosen for El Rico GSA

Project	Annual Project Use (Days)	Acres	Cost/Acre	Average Annual Yield (AF/Y)	Total Cost	Project Life (Years)
Storage Ponds	60	5,000	$20,000	26,000	$100,000,000	60
Canal Lining/Piping	150		3M/mile	25,000	$100,000,000	60
Demand Reduction	360	5,000		15,000		
Total				**76,000**		

Table 6-4. Summary of Projects and Management Actions Chosen for Tri-County Water Authority GSA

Project	Annual Project Use (Days)	Acres	Cost/Acre	Average Annual Yield (AF/Y)	Total Cost	Project Life (Years)
Storage Ponds	60	1,500	30,000	15,000	$45,000,000	
Demand Reduction						
Total				**15,000**		

See Acronyms and Abbreviations list for definitions.

Table 6-5. Project and Management Actions

§354.44 Projects and Management Actions
(a) Each Plan shall include a description of the projects and management actions the Agency has determined may achieve the sustainability goal for the Subbasin, including projects and management actions to respond to changing conditions in the Subbasin.
(b) Each Plan shall include a description of the projects and management actions that include the following 1-9:
(c) Projects and management actions shall be supported by best available information and best available science.
(d) An Agency shall take into account the level of uncertainty associated with the Subbasin setting when developing projects or management actions.

#	Management Action (b)(1) *	Description (b)(1)	Measurable Objective (b)(1)	Circumstances of Implementation (b)(1)(A)	Quantification of Demand Reduction (b)(2)	Permitting & Regulatory Process (b)(3)	Status, Start, End, and Accrual of Benefits (b)(4)	Explanation of Benefits and Method of Evaluation (b)(5)	Explanation of Water Source and Reliability (b)(6)	Cost and Funding Options (b)(8)	Management of Groundwater Extraction and Recharge (b)(9)	Level of Uncertainty Associated with the Basin Setting, 1=uncertain 5=certain (d)
Projects												
1	Infiltration Basin Project	The Subbasin may adopt a policy to incentivize groundwater extractors through subsidies to utilize designated lands for banking only and or designated lands for scheduled banking under contract during certain periods of the season.	The goal is to encourage landowners to fallow land and replenish the groundwater, as well as encourage water trading between GSAs in the Tulare Lake Subbasin.	The policy will begin shortly after GSP approval and will solicit volunteers first. Project lands area needed will designed by GSA.	Demand reduction will be based on acreage removed from farming practices.	No permits or regulatory processes are required for the Subbasin to adopt the policy. The Subbasin has the power as outlined in the SGMA and related provisions to adopt ordinances.	Policy to be written by 2023 and implemented by 2025 and to remain indefinitely, but can be revised as needed.	A direct benefit to the groundwater levels will be accomplished through this policy. Groundwater elevation data will be utilized, and the amount (volume) of water recharged will be used as the evaluation method.	The management action may be accomplished through policy adoption by the Subbasin. Current water sources will be used in most cases and some external water sources may be needed.	Estimated cost to draft and adopt policy is $50,000. Costs associated with tracking resources have not been evaluated.	Chronic lowering of groundwater levels or depletion of supply during periods of drought may be partially offset by storing water in wetter years.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.
2	Storage Project	The Subbasin may adopt a policy to incentivize groundwater extractors through subsidies to utilize designated lands for storage only and or designated lands for scheduled storage under contract during certain periods of the season.	The goal is to encourage landowners to fallow land and replenish the groundwater, as well as encourage GSA water trading between GSAs in the Tulare subbasin.	The policy will begin shortly after GSP approval and will solicit volunteers first. Project lands area needed will designed by GSA.	Demand reduction will be based on acreage removed from farming practices.	No permits or regulatory processes are required for the Subbasin to adopt the policy. The Subbasin has the power as outlined in the SGMA and related provisions to adopt ordinances.	Policy to be written by 2023 and implemented by 2025 and to remain indefinitely, but can be revised as needed.	A direct benefit to the groundwater levels will be accomplished through this policy, for in-lieu groundwater supplies. Groundwater elevations will be utilized as the evaluation method.	The management action may be accomplished through policy adoption by the Subbasin. Existing surface water sources will be used.	Estimated cost to draft and adopt policy is $50,000. Costs associated with tracking resources have not been evaluated.	Chronic lowering of groundwater levels or depletion of supply during periods of drought may be partially offset by storing water in wetter years.	Level of uncertainty of the project is 4; in wet years there is water available for this area as well as the infrastructure to deliver it.

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3	Existing Infrastructure and/or Rehabilitation of New Construction	The Subbasin may adopt efforts to fund projects to rehabilitate existing facilities and construct new facilities to divert, or bank water in areas conducive of these activities. Including diversion systems, check structures, banking facilities, and storage facilities. Also, would allow groundwater trading within the Subbasin. Not intended to restrict water right holders.	The goal is to modify or develop new facilities that can deliver a larger amount of water when needed, as well as service an area that does not have a delivery system.	Development of the projects will begin shortly after GSP approval.	These projects will work in conjunction with a banking project or other projects as needed.	No permits or regulatory processes are required for the Subbasin to adopt the project. The Subbasin has the power as outlined in the SGMA and related provisions to adopt ordinances or approve projects related to SGMA.	Projects to be included in the GSP. Soon after adoption of GSP projects to begin development.	A direct benefit to the groundwater levels will be accomplished through these projects, for in-lieu groundwater supplies. Groundwater elevations will be utilized as the evaluation method.	The management action may be accomplished through policy adoption by the Subbasin. Existing water sources will be used in most cases and some external water sources may be needed.	Estimated cost to draft and adopt policy is $50,000. Project costs will vary.	Chronic lowering of groundwater levels or depletion of supply during periods of drought may be partially offset by storing water in wetter years, trading of groundwater to minimize the concentration of pumping in one area.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.
4	Lining and/or piping of canals	Larger canals may be piped or lined to increase capacity and/or efficiency of water deliveries.	Increased water supply or efficiency to reduce fallowed land.	The project will begin after assessment is made and funding is secured.	Demand reduction will be minimized to capturing more water via efficient delivery.	No permits or regulatory process is required for the Subbasin to adopt the policy. The Subbasin has the power as outlined in the SGMA, and related provisions to adopt ordinances.	Project included in GSP, but funding not yet secured. Benefits would start upon completion of piping/lining. Benefits would accrue for duration of project.	A direct benefit to groundwater levels will be accomplished due to decreased pumping via increased deliveries.	Reliability is high, as many canals are used each year.	Estimated cost to line and pipe major canals is $100,000,000. Willing partners and participants are being approached.	Less extraction would occur. No extra monitoring required.	Level of uncertainty of the project is 3, because the project would save water year in and year out. However, the funding for the project is not yet certain.

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5	Agricultural land fallowing subsidies	The Subbasin may adopt a policy to incentivize farmers to annually fallow land through leases.	The goal is to reduce irrigated acreage. The MO is the acreage of fallowed land and offset groundwater pumping.	The policy development will begin shortly after GSP approval.	Demand reduction will be based on acreage removed from farming practices and offset groundwater pumping.	No permits or regulatory processes are required for the Subbasin to adopt the policy. The Subbasin has the power as outlined in the SGMA and related provisions to adopt ordinances.	Policy to be written by 2023 and implemented by 2025 and to remain indefinitely, but can be revised as needed.	A direct benefit to the groundwater levels will be accomplished through this policy, based on demand reduction. Groundwater elevations will be utilized as the evaluation method.	The management action may be accomplished through policy adoption by the Subbasin. No external water source is used.	Estimated cost to draft and adopt policy is $50,000.	Chronic lowering of groundwater levels or depletion of supply during periods of drought may be partially offset by permanent fallowing.	Level of uncertainty of the project is 2; in wet years there is water available for this area as well as the infrastructure to deliver it.
6	Aquifer Storage and Recovery (ASR)	ARS is a way to recharge an aquifer directly, using an existing well. ASR utilizes the aquifer as a means of local storage for use a later period..	Increased water levels and supply and reduce groundwater demand	Implementation will occur after GSP approval and landowner agreements are in place. The projects are likely to be implemented by individual landowners .	Demand reduction will occur, as the stormwater water will be used for recharge and will offset groundwater pumping.	It is expected that permits from the State Water Resources Control Board will be needed as well as Local compliance	Project can begin after adoption and approval of GSP upon GSA's development of the program.	A direct benefit to the groundwater levels will be accomplished through this policy. Groundwater elevation data will be utilized, and the amount (volume) of water injected will be used as the evaluation method.	Reliability is high, as there are many wells. Water source will be dependent on individual participants access to water.	Estimated total program cost is $15,000,000. Individual participants will fund projects.	Chronic lowering of groundwater levels or depletion of supply during periods of drought may be partially offset by storing water in wetter years.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.
Outreach												
1	Education of groundwater use per acre	The Subbasin may adopt a policy which provides groundwater extractors their approximate groundwater extraction on a per acre basis, and how SGMA will be enforced, as well as other policies developed by the Subbasin.	The goal is to provide education and promote awareness of the Subbasin overdraft condition particularly for those groundwater extractors who do not have meters. The MO is annual statements of groundwater extraction in acre-feet.	Implementation to occur at year one and thereafter, if extractor exceeds their extraction amount.	If individual extractors are over drafting, demand reduction will occur with compliance of this policy.	No permits or regulatory process is required for the Subbasin to adopt the policy.	The policy has not been drafted. It is expected to commence shortly after the adoption of the GSP and be completed within the first three years.	The expected benefit is to educate extractors of overdraft; this is the first step in policing SGMA. Extractors will be monitored.	The management action may be accomplished by Subbasin policy adoption. No external water source is used.	Estimated $50,000 cost to draft and adopt policy.	Within the education course, a description of how recharge and groundwater extraction will be credited to each extractor during drought and other periods.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.

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Assessment												
1	Pumping fees for groundwater allocation exceedances	Policy for exceedance of pumping beyond the current groundwater allocation. Can increase with each occurrence.	The goal is to incentivize groundwater extractors to pump only their groundwater allocation per year. The MO is the volume of groundwater extraction in acre-feet.	First phase of the policy will be written by 2023 and implemented by Jan 2025. Fees will increase every year after 2025 and with each occurrence.	This policy reduces demand and/or charges each extractor based on the budgeted amount of groundwater.	No permits or regulatory processes are required for the Subbasin to adopt the policy. The Subbasin has the power as outlined in SGMA and related provisions to adopt ordinances, levy financial penalties, and enforce policies.	Policy is expected to be drafted and commence after the adoption of the GSP. Benefits will be added revenue to mitigate other projects in the area.	The expected benefit is to deter groundwater extractors from exceeding their allocation. Other benefits will be revenue for projects to mitigate local overdraft. The method of evaluation will be a summary of over-extractors and the reduction of those over-extractors over time.	The management action may be accomplished by Subbasin policy adoption and enforcement. No external water source is used.	Estimated $50,000 cost to draft and adopt policy. Initial GSA assessments will be needed to fund the development of this policy.	Chronic lowering of groundwater levels or depletion of supply during periods of drought may be offset by temporary increases in fee structure or groundwater pumping restrictions.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.
2	Pumping fees for groundwater extractions	The Subbasin may adopt a policy to impose fees on groundwater extractors on a per acre-foot basis. Fees are intended to support GSA activities and are not intended to be overbearing.	The goal is to incentivize groundwater extractors to reduce pumping and look for other sources of water. The MO is the revenue generated to support GSA operations.	Policy to be written and implemented by 2025 and to remain indefinitely.	No direct reduction in demand.	No permits or regulatory processes are required for the Subbasin to adopt the policy. The Subbasin has the power as outlined in the SGMA and related provisions to adopt ordinances, levy financial penalties, and enforce policies.	Policy is expected to be drafted and commence after the adoption of the GSP. Benefits will be added revenue to support GSA operations.	The expected benefits will provide funding for GSAs to operate under the SGMA.	The management action may be accomplished through policy adoption by the Subbasin and enforcement. No external water source is used.	Estimated $50,000 cost to draft and adopt policy. Initial GSA assessments will be needed to fund the development of this policy.	This policy in intended to be a part of the entire GSA operational Bylaws; there is no direct offset of chronic lowering of groundwater.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.
Groundwater Allocation												
1	Flood Flows (spills into the Subbasin) include Tule River, Deer Creek, Cross-Creeks and Kings River	The Subbasin may adopt a policy for actions to divert flows during flood releases to needed areas and a credit system for those who divert.	Validate Water Rights and existing agreements. MO is to allocate water to the rightful owner.	Policy to be drafted by 2023 and implemented by 2025.	This management action alone may not generate a quantifiable demand reduction. However, it allocates water to be used in the proper service area.	No permits or regulatory processes are required for the Subbasin to adopt the policy. SWRCB is paying close attention to policies within a GSA that pertain to water rights and flood water diversion.	Policy to be written by 2023 and implemented by 2025 and to remain indefinitely, but can be revised as needed.	The expected benefit is to encourage diversion of flood flows to areas to make the most groundwater level impact.	Contract holder; reliability varies based on allocation.	Estimated $25,000 cost to draft and adopt policy.	Banked water will offset a depletion of supply during periods of drought.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.

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2	Development of groundwater allocation	The Subbasin may adopt a policy which provides a finite groundwater allocation, either based on the modeling efforts or the sustainable yield. Ultimate groundwater allocation may take into consideration the existing water rights holders, disadvantaged communities (DACs) and CA Native American tribes. The Subbasin may allocate to agencies or individual landowners.	The goal is to ensure a fair groundwater allocation which clearly defines the acceptable groundwater extraction volume per year at a certain rate, based on crop growing season(s). The MO is the volume of groundwater extraction in acre-feet.	Policy to be written by 2023 and implemented by 2025.	This policy will be a direct reduction in demand as extractors will need to operate within the means of the allocation. Groundwater levels and pumped volumes will be used to evaluate demand reduction.	No permits or regulatory processes are required for the Subbasin to adopt the policy. The Subbasin has the power as outlined in SGMA and related provisions to adopt ordinances.	Policy to be written by 2023 and implemented by 2025 and can be revised as needed.	The expected benefits may mitigate overdraft by ensuring groundwater supplies are withdrawn in a sustainable manner. Extractions will be monitored.	The management action may be accomplished by Subbasin policy adoption. No external water source is used.	Estimated $100,000 cost to draft and adopt policy.	Chronic lowering of groundwater levels or depletion of supply during periods of drought may be eliminated by implementation of sustainable change in groundwater allocation.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.
3	Groundwater Marketing	This policy will include groundwater marketing. Marketing will include groundwater from within the Subbasin with options to market within the GSAs, between GSAs.	The goal is to set policy that encourages water marketing within the Subbasin while not causing undesirable results.	Policy to be written by 2023 and implemented by 2025.	This policy will be a direct reduction in demand as small volume extractors will be encouraged to fallow land and market groundwater within their allocated amount. Groundwater levels and market volumes will be used as the quantification of demand reduction.	No permits or regulatory processes are required for the Subbasin to conduct the study. Through the study, multiple jurisdictions and agencies may be contacted for the potential permits and regulatory requirements for new surface water supplies.	The water marketing strategy grant has been approved by the USBR; Funding opportunity to close in May of 2019. Other grant solicitations are expected.	The expected benefits include utilizing groundwater supplies within the Subbasin. Encourage demand reduction through fallowing. Groundwater levels and marketed volumes will be evaluated.	The management action may be accomplished by Subbasin policy adoption. No external water source is used.	Estimated cost is $100,000 to draft and adopt policy.	This policy will include the requirement that landowners who are a purchaser or seller of groundwater shall install a water meter on their wells and report all activities to their GSAs.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.

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Development												
1	Require new developments (non-de minimis extractors) to prove sustainable water supplies	This policy requires all permitted developments (non-de minimis extractors) to prove sustainable water supplies based upon the current Subbasin groundwater allocation and constant with current State Law. The Subbasin may review and comment on all new development environmental documents to ensure water balance and corresponding mitigation measures are implemented. Requires County support.	The goal is to ensure all new developments (non-de minimis extractors) do not exceed the current Subbasin groundwater allocation and groundwater supplies are consumed or retained within the Subbasin boundary. The MO is to monitor and hold developers accountable as well as promote connection to city services where applicable.	To be implemented as a revision to the local ordinances.	Policy is to minimize undesirable effects by requiring construction of wells to be designed for MTs. To be implemented after approval of GSP.	The regulatory process may require cooperation from the county/city to ensure the Subbasin has had the opportunity to review and comment on the environmental documents prior to county/city approval. The Subbasin GSAs have the power as outlined in the SGMA and related provisions to adopt ordinances. Potential incorporation into a peer review process.	Policy to be written and implemented by 2023.	The expected benefits may mitigate overdraft by ensuring new developments utilize groundwater supplies in accordance with current Subbasin groundwater allocations, and groundwater supplies are consumed or retained within the Subbasin boundary. The method of evaluation may be quantifying the number of new developments that are approved with and without Subbasin comment/approval.	The management action may be accomplished through Subbasin policy adoption and coordination with the county/city. The Subbasin may request county/city development procedures to include the circulation of environmental documents and approval from Subbasin GSAs prior to county/city approval. No external water source is used.	Estimated cost to draft and adopt policy is $25,000.	Policy will help in data collection and extraction reporting as part of the permitting process.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.
Monitoring Reporting												
1	Flood Flows (spills into the Subbasin) include Tule River, Deer Creek, Cross-Creeks and Kings River	The Subbasin may adopt a policy for actions to divert flows during flood releases to needed areas and a credit system for those who divert.	Validate the water right; MO is to allocate water to the rightful owner.	Policy will begin soon after GSP is approved and will help fill data gaps.	This management action alone may not generate a quantifiable demand reduction. However, it allocates water to be used in the proper service area.	No permits or regulatory processes are required for the Subbasin to adopt the policy. SWRCB is paying close attention to policies within a GSA that pertain to water rights and flood water diversion.	Policy to be written and implemented in 2023.	The expected benefit is the guarantee that purchased water is credited to correct area. Data gathered will fill data gaps. Groundwater elevations will be the method of evaluation.	Contract holder; reliability varies based on allocation.	Estimated cost to draft and adopt policy is $25,000.	Utilized contract volumes to be included in the calculation of the groundwater extraction proportionate share.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.

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2	Registration of extraction facilities	The Subbasin may adopt a policy to require registration of a groundwater extraction facility within the Subbasin. Requires county support. Includes existing and future facilities.	The goal is to improve the Subbasin's database of groundwater extraction locations. The MO is the number of new registered facilities and fill data gaps.	The policy may be implemented shortly after the adoption of the GSP and remain until the Subbasin's overdraft has ended or indefinitely. The county must also support the policy.	This policy will help fill data gaps and give a better understanding of the groundwater within the Subbasin.	The regulatory process may require cooperation from the county to ensure new well permits issued within the Subbasin adhere to the Subbasin's policy. The Subbasin has the power as outlined in SGMA and related provisions to adopt ordinances.	Policy to be written and implemented in 2023.	The expected benefits may mitigate overdraft by improving the Subbasin's knowledge of groundwater extraction locations. The method of evaluation may be comparing the number of registered wells vs. the county/state databases known wells.	The management action may be accomplished by policy adoption by the Subbasin and coordination with the county. The Subbasin may request county well permit procedures to include the Subbasin's requirements prior to issuance. No external water source is used.	Estimated cost to draft and adopt policy is $25,000. There will be a cost to administer the policy, which is not known at this time.	Fill data gaps and include this information in the calculation of the groundwater extraction proportionate share.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.
3	Require self-reporting of groundwater extraction, water level, and water quality data	The Subbasin may adopt a policy to require groundwater users (excluding de minimis extractors) to self-report groundwater extractions, static water levels, and water quality data twice per year.	The goal is to improve the Subbasin's database of groundwater extractions, water level and quality monitoring network, and serve other management actions.	This policy will fill data gaps. To be incorporated into a well testing policy for wells with meters. The policy may be implemented shortly after the adoption of the GSP and remain indefinitely or until Subbasin's overdraft has ended.	This policy will help fill data gaps and give a better understanding of the groundwater within the Subbasin.	No permits or regulatory processes are required for the Subbasin to adopt the policy. The Subbasin has the power as outlined in SGMA and related provisions to adopt ordinances, levy financial penalties, and charge administrative fees.	Policy to be written and implemented in 2023.	The expected benefits may mitigate overdraft by improving the Subbasin's knowledge of groundwater extractions, water levels, water quality and provide extractors with useful information. The method of evaluation may be reviewing the number of responses from groundwater users (excluding de minimis extractors), analyzing data validity/accuracy, and filling data gaps.	The management action may be accomplished by policy adoption by the Subbasin. The Subbasin may develop an online reporting tool. No external water source is used.	Estimated cost to draft and adopt policy is $25,000. There will be a cost to administer the policy, which is not known at this time, but is expected to be high.	Fill data gaps and include this information in the calculation of the groundwater extraction proportionate share.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.

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4	Require well meters, sounding tubes, and water quality sample ports	The Subbasin may adopt a policy to require meters, sounding tubes, and sample ports be installed on wells, pump and motor replacements, and well repairs (excluding de minimis extractors). Requires county support. Calibration of meters shall conform to Senate Bill 88.	The goal is to improve the Subbasin's data collection of groundwater extractions, water level and quality monitoring network. The MO is the number of well permits and filling the data gaps.	The policy may be implemented shortly after the adoption of the GSP and remain until Subbasin's overdraft has ended or indefinitely. The county must also support the policy.	This policy will help fill data gaps and give a better understanding of the groundwater within the Subbasin.	The regulatory process may require cooperation from the county to ensure new well permits issued within the Subbasin adhere to the Subbasin's policy. The Subbasin has the power as outlined in SGMA and related provisions to adopt ordinances.	Policy to be written and implemented in 2023.	The expected benefits may mitigate overdraft by improving the Subbasin's knowledge of groundwater extractions, water levels, water quality, and fill data gaps. The method of evaluation may be reviewing the number of well permits and confirming whether meters, sounding tubes, and sample ports were installed.	The management action may be accomplished by policy adoption by the Subbasin and coordination with the county. The Subbasin may request county well permit procedures to include the Subbasin's requirements prior to issuance. No external water source is used.	Estimated cost to draft and adopt policy is $25,000. There will be a cost to implement the policy, it is not known at this time, but is expected to be high.	Fill data gaps and include this information in the calculation of the groundwater extraction proportionate share.	Level of uncertainty of the project is 3; in wet years there is water available for this area as well as the infrastructure to deliver it.
Existing Contracts												
1	Flood Flows (spills into the Subbasin) include Tule River, Deer Creek, Cross-Creeks and Kings River	The Subbasin may adopt a policy for actions to divert flows during flood releases to needed areas and a credit system for those who divert.	Validate water rights and existing agreements. MO is to allocate water to the rightful owner.	Policy to be drafted by 2023 and implemented by 2025.	This management action alone may not generate a quantifiable demand reduction. However, it allocates water to be used in the proper service area.	No permits or regulatory processes are required for the Subbasin to adopt the policy. SWRCB is paying close attention to policies within a GSA that pertain to water rights and flood water diversion.	Policy to be written by 2023 and implemented by 2025 and to remain indefinitely, but can be revised as needed.	The expected benefit is to encourage diversion of flood flows to areas to make the most groundwater level impact.	Contract Holder; reliability varies based on allocation.	Estimated $25,000 cost to draft and adopt policy.	Diverted water will offset a depletion of supply during periods of drought.	Level of uncertainty of the project is 2; in wet years there is water available for this area as well as the infrastructure to deliver it.

* (b)1() refers to the subsection of §354.44 that the column addresses.

Note: The following sections were noted below because they apply to all management actions with very little variance.

Public Notice (b)(1)(B): The Subbasin may provide public notice in multiple formats and platforms, adopted policies may reside in Subbasin Board Meeting minutes and Subbasin Policy Manual available on the Subbasin website. Electronic notice may be provided to any person who requests email notifications. The Subbasin Board may hold regular monthly meetings and annual education workshops.

Legal Authority (b)(7): The Subbasin has the power as outlined in the SGMA, and related provisions to adopt ordinances, levy financial penalties, and enforce programs.

Cost & Funding Options (b)(8): Subbasin administrative and operating costs may be funded through various financial avenues discussed further in GSP Chapter 7.2.

See Acronyms and Abbreviations list for definitions.

Table 7-1. Proposed SFK GSA GSP Implementation Timeline

	Current Year (2020)	YEAR 1 (2021)		YEAR 2 (2022)		YEAR 3 (2023)		YEAR 4 (2024)	
	Q1/2	Q3/4	Q1/2	Q3/4	Q1/2	Q3/4	Q1/2	Q3/4	Q1/2
Administrative Actions									
Pumping Measurement Program	Landowner Well Survey		**Adopt measurement standards and reporting requirements**		Land Use/Metering Update		Land Use/Metering Update		Land Use/Metering Update
Land Use/Land Cover Program	Land Cover & Demand Study								
Groundwater Accounting Program			Accounting Program White Paper	Public Outreach	**Adopt GW Accounting System**	Public Outreach			
Monitoring Program	**Annual Report**		**Annual Report**		**Annual Report**		**Annual Report**		**Annual Report**
Data Management Program									
Annual Reports									
KRCD Admin + Legal									
GSP 5-Year Update									
Funding Activities	State/Federal						Current Funding Sunsets	Adopt New Funding Method	
	Private/Foundation/ NGO								
	Other Mechanisms								

Table 7-1. Proposed SFK GSA GSP Implementation Timeline (Continued)

<table>
<tr><th></th><th>Current Year (2020)</th><th colspan="2">YEAR 1 (2021)</th><th colspan="2">YEAR 2 (2022)</th><th colspan="2">YEAR 3 (2023)</th><th colspan="2">YEAR 4 (2024)</th></tr>
<tr><th></th><th>Q1/2</th><th>Q3/4</th><th>Q1/2</th><th>Q3/4</th><th>Q1/2</th><th>Q3/4</th><th>Q1/2</th><th>Q3/4</th><th>Q1/2</th></tr>
<tr><td colspan="10">Demand Reduction Actions</td></tr>
<tr><td>SW Delivery Improvements</td><td>SW Delivery Agreements</td><td colspan="2">Surface Water Efficiency Study</td><td>Adopt Canal Program</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>On-Farm Efficiency Improvements</td><td rowspan="3">Conjunctive Use White Paper</td><td rowspan="3">Targeted Outreach</td><td rowspan="3">Develop On-Farm Efficiency Targets and Dry-Farming/Fallowing Program</td><td rowspan="3">Public Outreach</td><td rowspan="3">Develop On-Farm Efficiency Targets and Dry-Farming/Fallowing Program</td><td colspan="2" rowspan="3">Surface Water Improvement Implementation</td><td colspan="2" rowspan="3">Surface Water Improvement Implementation</td></tr>
<tr><td>Permanent/Long Term Fallowing</td></tr>
<tr><td>Seasonal Fallowing Program</td></tr>
<tr><td colspan="10">Supply Enhancement Actions</td></tr>
<tr><td>Aquifer Storage and Recovery</td><td>Work Plan</td><td></td><td></td><td>ASR Pilot Test</td><td></td><td colspan="2">ASR CEQA</td><td colspan="2">ASR Implementation</td></tr>
<tr><td>Surface Recharge</td><td></td><td colspan="2" rowspan="2">Review & Coordinate Recharge Projects in Surrounding Basins</td><td rowspan="2"></td><td rowspan="2">Approve Surface Recharge Investments</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Surface Storage</td><td></td></tr>
</table>

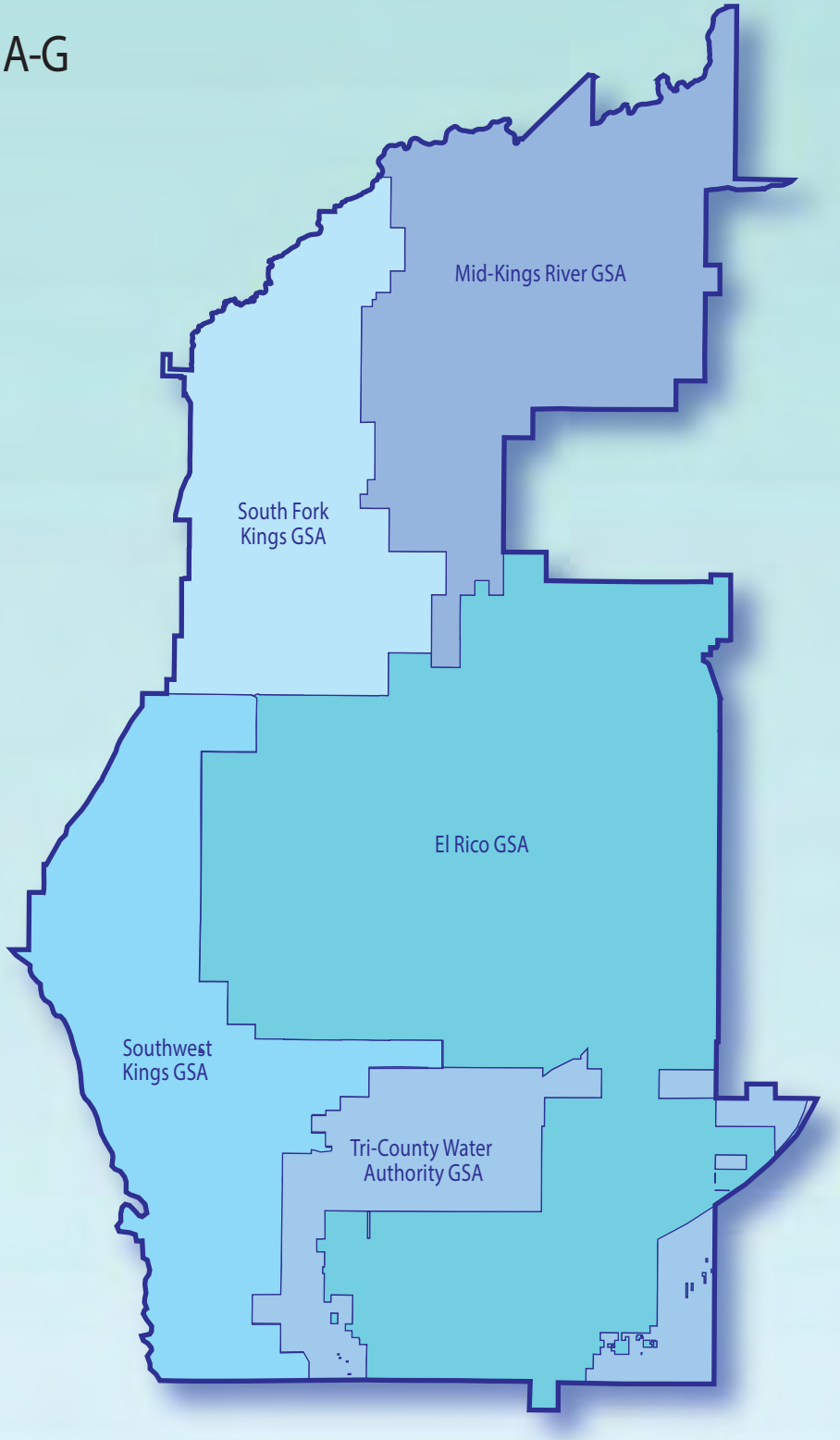
Table 7-2. DMS Annual Reporting Requirements

Regulation	Requirement	Input to DMS
356.2(b)(1)(B)	Hydrographs incl water year type from Jan 2015	Generated in DMS from water level data input by GSAs
356.2(b)(1)(A)	GW Elevation Contours (spring & fall)	Generated outside DMS using data from DMS then contour lines uploaded into DMS
356.2(b)(2)	GW extraction by water use sector incl method of determination and map	Determined outside DMS. Total use by sector input by each GSA then summarized for basin in DMS
356.2(b)(3)	Surface Water use by source	Total by GSA input to DMS and summarized for basin in DMS
356.2(b)(4)	Total Water use by sector	DMS summary table of water supplies by sector per GSA
356.2(b)(5)(A)	Change in GW Storage map	Calculated outside DMS from contour data using basin-wide method then total per GSA input into DMS
356.2(b)(5)(B)	Graph with Water Year type, GW use, annual & cumulative GW Storage change	DMS generated basin total graph using data in DMS

January 2020

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MID-KINGS RIVER
GROUNDWATER SUSTAINABILITY AGENCY

South Fork Kings
Groundwater Sustainability Agency

ER El Rico GSA

SWK
Southwest Kings
Groundwater Sustainability Agency

TRI-COUNTY
WATER AUTHORITY

APPENDIX A

CONTACT INFORMATION FOR GSAs

APPENDIX A

Contact Information for the Tulare Lake Subbasin Groundwater Sustainability Agencies

Groundwater Sustainability Agency	Plan Manager	Address	Telephone	Email
Mid-Kings River	Dennis Mills, Secretary	200 North Campus Dr. Hanford, CA 93230	(559) 584.6412	kcwdh2o@sbcglobal.net
El Rico	Jeof Wyrick, Chairman	101 W. Walnut St. Pasadena, CA 91103	(626) 583.3000	jwyrick@jgboswell.com
South Fork Kings	Charlotte Gallock, Program Administrator	4886 E. Jensen Ave. Fresno, CA 93725	(559) 242.6128	cgallock@krcd.org
Southwest Kings	Dale Melville, Executive Director	286 Cromwell Ave. Fresno, CA 93711	(559) 449.2700	dmelville@ppeng.com
Tri-County Water Authority	Deanna Jackson, Executive Director	944 Whitley Ave. Suite E. Corcoran, CA 93212	(559) 762.7240	djackson@tcwater.org

APPENDIX B

STAKEHOLDER COMMUNICATION AND ENGAGEMENT PLAN

Appendix B: Stakeholder Communication & Engagement

A. Communication & Engagement Overview

As required by SGMA, GSAs must consider the interests of all beneficial uses and users of groundwater and include them in the GSP development process. The five GSAs within the Tulare Lake Subbasin developed a joint Communication & Engagement (**C&E**) Plan that addressed how stakeholders within the individual GSA boundaries (and when collaboration was plausible, at the subbasin-level) would be engaged through stakeholder education and opportunities for input and public review during the development and implementation of the GSP. This plan provides an overview of the Tulare Lake Subbasin GSAs, their stakeholders, and decision-making process; identifies opportunities for public engagement and discussion of how public input and responses would be used; describes how the Tulare Lake Subbasin GSAs encouraged the active involvement of diverse, social, cultural, and economic elements of the population within their individual boundaries and subbasin boundary; and the methods to be used to inform the public stakeholders about the progress of GSP development, public review and implementation. The Tulare Lake Subbasin GSAs' complete C&E Plan can be downloaded from the GSAs' individual websites.

As outlined by the DWR in the GSP Stakeholder Communication and Engagement Guidance Document, the Communication & Engagement Plan defines the Tulare Lake Subbasin GSAs' process for accomplishing the seven general steps in stakeholder communication and engagement:

- **Set Goals and Desired Outcomes –** Description of the situation at a high level with clear goals and objectives, identifying overriding concerns
- **Identify Stakeholders –** Development of a broad list of individuals, groups and organizations who need to be engaged in the process
- **Stakeholder Survey and Mapping –** Conducting a stakeholder survey to develop a "Lay of the Land" overview
- **Messages and Talking Points –** Definition of the key messages needed to effectively convey to the various subbasin stakeholders
- **Venues for Engaging –** Identification of opportunities (venues and methods) to engage stakeholders
- **Implementation Timeline –** Creation of a timeline to inform the process and highlight when to engage with stakeholders
- **Evaluation and Assessment –** Definition of a process to evaluate if communication and engagement goals are being met at the individual GSA level and through collaborative subbasin efforts

A.1 Communication Objectives to Support the GSP

The ultimate goal of communication objectives during the formation/coordination, GSP development, public review and implementation phases of the SGMA compliance, is to encourage active involvement of diverse,

social, cultural, and economic elements of the population within the GSA boundary. The Tulare Lake Subbasin GSAs have given beneficial users and users of groundwater opportunities to engage in the GSP process, and provided educational outreach opportunities for stakeholders while reaching out through specific communication avenues. As active stakeholders, members of the Boards of Directors and Stakeholder/Advisory Committees are direct representatives of their districts, communities and industries, and they continually gather feedback/input, and the concerns/needs of their constituents and report back to their respective meetings. Any stakeholder input received was reviewed by the GSA and Subbasin technical teams and taken into consideration during GSP development.

A.1.1 Phase 1: GSA Formation and Coordination

Phase 1: GSA Formation and Coordination was the first phase completed. This phase stretched from 2015 through 2018, and consisted of forming the individual GSAs, development of a subbasin coordination agreement, establishing the List of Interested Parties, and creating the Communication & Engagement Plan to outline communication efforts for the GSP development, public review and implementation phases. Stakeholder input was utilized during the GSA formation phase, as beneficial users and stakeholders with interests in groundwater usage within the GSAs' boundaries were notified via public meeting notices as soon as the process began.

A.1.2 Phase 2: GSP Preparation and Submission

Phase 2: GSP Preparation and Submission spanned from 2018 through January 31, 2020. With the goal of having the draft GSP before the end of the third quarter in 2019, 2018 was primarily the technical development of the plan, while working with GSA Boards of Directors, technical teams/committees, and GSA management at the subbasin level, as well as stakeholders for feedback and input. During the last quarter of 2018, the first round of public outreach meetings and interaction with stakeholder groups and other community organizations and entities was held with the purpose of educating and informing stakeholders about SGMA and the GSP process, while also soliciting feedback and input from these groups to consider and possibly include feedback and input into the GSP. Public outreach for this phase was completed by the individual GSAs.

A.1.3 Phase 3: GSP Review and Evaluation

During 2019, Phase 3: GSP Review and Evaluation, the communication and engagement efforts continued. Once the draft of the GSP was completed in September 2019, the public review process began. A 90-day comment period was held, with the GSP draft posted on the Tulare Lake Subbasin GSAs' websites for all stakeholders to conveniently download and review and provide comments. Outreach meetings were held during this phase both on subbasin-wide level, as well as by individual GSAs. These meetings focused on an overview of the GSP content, while giving stakeholders a public forum to provide their feedback and comments. The public review period concluded with a public hearing regarding the GSP Draft on December 2, 2019.

Once the public review period was completed, public comments were taken into consideration and incorporated into the final version of the Tulare Lake Subbasin GSP before submitting to the DWR by January 31, 2020. Following submittal, stakeholders will be given a second 60-day comment period through the DWR's SGMA portal at http://sgma.water.ca.gov/portal/. Comments will be posted to the DWR's website prior to the state agency's evaluation, assessment and approval.

A.1.4 Phase 4: Implementation and Reporting

Phase 4: Implementation and Reporting will begin once the plan is submitted by January 31, 2020. Even while the DWR is reviewing the GSP, SGMA-implementation at the GSA-level must begin. During the implementation phase, communication and engagement efforts will be shifted to educational and

informational awareness of the requirements and processes for reaching groundwater sustainability as set forth in the submitted GSP. Active involvement of all stakeholders will be encouraged during this phase, and public notices are required for any public meetings and prior to imposing, and later increasing, any fees. Public outreach for this phase will also be completed by the individual GSAs with collaborative subbasin-wide efforts when target audiences span more than one GSA boundary.

B. Tulare Lake Subbasin GSAs' Decision-Making Process

The Tulare Lake Subbasin GSAs' decision-making process is broken down by the roles of the subbasin management team, Board of Directors and Stakeholder/Advisory Committees. The roles of these subbasin and GSA entities and their responsibilities are outlined below.

- **Subbasin Management Team –** Comprised of a representative from each of the five GSAs working collaboratively to jointly manage groundwater within the Tulare Lake Subbasin and to develop a GSP. These individuals met on a monthly and then bi-weekly basis throughout the GSP development and public review phases.
- **Boards of Directors –** Adopts general policies regarding development and implementation of the individual GSAs and the GSP.
- **Stakeholder/Advisory Committees –** Representing all beneficial uses and users of groundwater within the individual GSA boundaries, makes recommendations to the Boards of Directors and technical consultants regarding feedback from stakeholders and adoption of a GSP that accounts for local interests. Not all GSAs have stakeholder/advisory committees, and while allowed within SGMA, these committees are not required.

B.1 Role of Boards of Directors

The Tulare Lake Subbasin GSAs' Boards of Directors all consistently function as the governing body of the specific GSA, formed to adopt general policies regarding development and implementation of the GSP. Governance of each GSA is described below, and meeting dates, times and locations for each board are noted. All meetings were open to the public during the formation, development and public review phases, and will continue to be open to the public during the implementation phase.

B.1.1 El Rico GSA

El Rico GSA's Board of Directors consists of seven directors: one representative appointed by the Tulare Lake Basin Water Storage District board, one representative appointed by the governing board of Salyer Water District, two representatives appointed by the Corcoran Irrigation District, two representatives appointed by Melga Water District, and one representative appointed by the Lovelace Reclamation District No. 739.

El Rico GSA's board meetings are held on the first Wednesday of each month at 1 p.m. at the Tulare Lake Basin Water Storage District's office, located at 1001 Chase Avenue in Corcoran, unless otherwise posted on the Kings River Region Groundwater Portal's calendar.

B.1.2 Mid-Kings River GSA

The Board of Directors of the Mid-Kings River GSA are appointed, three elected members of the KCWD, and one elected member of the City of Hanford. The Mid-Kings River GSA Board of Directors meet on the second Tuesday of every month at 1 p.m. at the Kings County Water District, located at 200 Campus Drive in Hanford.

B.1.3 South Fork Kings GSA

The governing board of the South Fork Kings GSA is composed of one appointee of each member agency as a "principal director." The principal director is an individual currently serving on the board or council of each of the members. Board of Directors meetings for the South Fork Kings GSA are held bi-monthly on the third Thursday of every February, April, June, August, October and December at 5:30 p.m. in the Lemoore City Council Chambers, located at 429 C Street in Lemoore.

B.1.4 Southwest Kings GSA

Southwest Kings GSA is governed by a five-person board of directors comprised of two members of the Dudley Ridge Water District, two members of the Tulare Reclamation District No. 761, and one director selected by a majority vote of the other four appointed members. The non-district member is a landowner, or his/her representative, who owns land in the white areas of the GSA boundary.

The Southwest Kings GSA's board meetings are held on the second Wednesday of every month at 3 p.m. at 286 W. Cromwell Avenue in Fresno. A monthly GSA status report is posted on the GSA's website.

B.1.5 Tri-County Water Authority GSA

The Tri-County Water Authority GSA JPA board of directors is comprised of four signatories and five board seats: Angiola Water District (general manager and a representative), Deer Creek Storm Water District (general manager and representative), Wilbur Reclamation District #825 (one representative), and County of Kings (non-voting representative). The Board of Directors meetings are held on the second Thursday of every other month at 1 p.m. at the Tri-County Water Authority Boardroom, located at 944 Whitley Avenue in Corcoran.

B.2 Role of Stakeholder/Advisory Committees

In Section 10727.8 "Public Notification and Participation; Advisory Committee" of the Sustainable Groundwater Management Act, GSAs may appoint and consult with an advisory committee for the purpose of developing and implementing a GSP. Through a stakeholder/advisory committee, a GSA is able to encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin prior to and during the development and implementation of the GSP.

B.2.1 Tri-County Water Authority GSA

The Tri-County Water Authority GSA's Technical Advisory Committee and Stakeholder Advisory Committee meet jointly on the fourth Wednesday of every month at 10 a.m. at the Tri-County Water Authority, located at the 944 Whitley Avenue in Corcoran.

C. Beneficial Uses and Users of Groundwater

Based on the applicable interests identified in SGMA, Section 10723.2 "Consideration of All Interests of All Beneficial Uses and Users of Groundwater", the five Tulare Lake Subbasin GSAs (El Rico, Mid-Kings River, South Fork Kings, Southwest Kings and Tri-County Water Authority) identified the stakeholder groups with interests within their GSA boundaries. These specific stakeholder groups have financial, political, business or personal stakes in the management of groundwater within the jurisdiction of the Tulare Lake Subbasin and were the focus of communication and engagement efforts during the GSP development and public review phases, and will continue to be engaged during the implementation phase. These stakeholders are listed by GSA in **Table 1**, **Table 2**, **Table 3**, **Table 4** and **Table 5**.

C.1 Environmental Users of Groundwater

It should be noted that environmental users of groundwater within the Tulare Lake Subbasin were investigated by the El Rico GSA, MKRGSA, SFKGSA, SWKGSA and TCWA, but there were not any identified that have specific groundwater interests within the subbasin.

C.2 Native American Tribes

The only Native American Tribe within the Tulare Lake Subbasin boundary is the Santa Rosa Rancheria Tachi-Yokut Tribe. The Tachi-Yokut Tribe was invited to participate in GSP development via a letter sent on June 28, 2016 by the then Upper Tulare Lake GSA MOU Group (now known as the South Fork Kings GSA). A copy of the letter is included in the Appendix A of the Tulare Lake Subbasin GSAs' Communication & Engagement Plan. The Tribe's EPA director attended one of the South Fork Kings GSA's board meetings, and has been on their Interested Parties List since April 2017, receiving regular updates about GSP development within the SFKGSA and the Tulare Lake Subbasin. In addition, a Sacred Lands File & Native American Contacts List Request was also sent to the Native American Heritage Commission.

C.3 Subbasin Industries and DACs

C.3.1 Industries

Collaboration meetings were held with the companies and organizations within the following industries to make sure their organizational visions and groundwater needs for facility operations were taken into consideration during GSP development and implementation phases. While an overview of the main industries within the Tulare Lake Subbasin are described below, the industries specific to each GSA are described in **Section C.4**.

Agriculture

Agriculture is one of the top three industries in Kings County. According to the 2017 Kings County Agricultural Crop Report published by the Kings County Ag Commissioner's office, the county is the tenth largest agriculture production county in California and grossed over $2 billion in 2017. With over 818,000 acres of farmland, the top commodities produced in Kings County are milk, cotton, cattle, nuts (almonds, pistachios and walnuts), tomatoes, silage corn, grapes, and stone fruit. As one of the primary industries, agriculture is the largest private employer in the county.

Because of the significant presence of agriculture production within the Tulare Lake Subbasin, agriculture industry stakeholders needed to be involved and informed during the development and public review phases of the GSP. Implementation will have a significant direct impact on the industry, and ultimately the local, state and national economies. The Tulare Lake Subbasin GSAs engaged with agriculture stakeholders routinely on an individual GSA-basis, and collaboratively at a subbasin level.

Food Processing

Kings County is a home to multiple food processors. Four of the top employers within the county are food processing facilities, accounting for over 4,000 jobs for the local workforce. Within the South Fork Kings GSA, Leprino Foods, alone, is responsible for 40 percent of water usage and provides just over 1,000 jobs. Because of their direct tie to the agricultural industry and reliance on groundwater supplies, to operate their facilities, food processors are included in the groundwater sustainability management within the subbasin boundary. The Tulare Lake Subbasin GSAs met with the food processing companies within their GSA

boundaries on an individual basis for direct input and feedback during the GSP development and public review phases, and will continue to do so during the implementation phase.

Oil Production

Oil production is a main industry in certain areas of Kings County and the Tulare Lake Subbasin, primarily within in the Kettleman City area. Oil was discovered in the Kettleman Hills in 1928 at the Kettleman North Dome Oil Field. This oil field became one of the most productive oil fields in the United States in the early 1930s. Within this region, oil and agricultural production share the land surface, and will continue with joint usage of well drilling rigs and agricultural production activities such as grazing. The oil industry is considered a beneficial user of groundwater, and Tulare Lake Subbasin GSAs engaged with the oil companies within their GSA boundaries on an individual basis for direct input and feedback during the GSP development and public review phases, and will continue to do so during implementation phases.

C.3.2 DACs

Communication and educational outreach efforts with disadvantaged communities (**DAC**) and severely disadvantaged communities (**SDAC**) was needed for the development and implementation of the Tulare Lake Subbasin's GSP according to the Department of Water Resources' Best Management Practices. Information used to communicate to and engage the DACs in the GSP process, included an explanation of SGMA and soliciting feedback. GSA representatives regularly communicated with DACs and gave presentations on SGMA to community representatives, while gathering their feedback and input.

By including DACs and SDACs in communication efforts during the development, public review and implementation phases of the GSP, residents were more likely to participate and provide feedback that could be crucial to long-term solutions for groundwater sustainability within their communities. Any feedback received from DAC/SDAC residents was reviewed and evaluated by the Tulare Lake Subbasin GSAs during the GSP development and public review phases.

C.4 GSA-Specific Stakeholders

The GSAs worked cooperatively with their respective stakeholders throughout the development and public review of the GSP, and will continue to do so through the implementation phase.

C.4.1 El Rico GSA Stakeholders

The interests of the parties identified in **Table 1** were considered in the operation of the El Rico GSA and the development and implementation of the GSP. The primary industry within the El Rico GSA is agriculture. Other industries within the boundary include food processing, as well as warehousing and distribution, and standard commerce industry that is standard in a community of 10,000 people (automotive shops, supermarkets, etc.).

Table 1. Stakeholder Groups with Interests in the El Rico GSA

Stakeholder Group	Description
Agricultural Users	Represented through many of the GSA member agencies and/or by the County of Kings.
Domestic Well Owners	Represented through member agencies including the County of Kings or via exemption for small amounts of groundwater extraction.
Municipal Well Operators	City of Corcoran
Public Water Systems	City of Corcoran
Local Land Use Planning Agencies	City of Corcoran, County of Kings
Surface Water Users	Represented through GSA member agencies
Disadvantaged Communities	City of Corcoran
Entities monitoring and reporting groundwater elevations in all or part of a groundwater basin	Represented by GSA member agencies including Tulare Lake Basin Water Storage District that collects and reports data for multiple members of the agency via the Tulare Lake Coordinated Groundwater Management Plan.

C.4.2 Mid-Kings River GSA Stakeholders

The interests of all beneficial uses and users of groundwater within the MKRGSA are identified in **Table 2**. The primary industries within the Mid-Kings River GSA is agriculture and food processing.

Table 2. Stakeholder Groups with Interests in the Mid-Kings River GSA

Stakeholder Group	Description
Agricultural Users	Service area is composed of mostly agricultural lands and agricultural users
Domestic Well Owners	There are domestic wells within the MKRGSA area, and it is understood that many rural domestic users will fall into the “de minimis extractor” category, so further work is being conducted to understand to what extent domestic users will be affected by GSP requirements.
Public Water Systems	Armona CSD, Home Garden CSD and Hardwick Water Company, as well as several transient public water systems for school districts are included in this category (Kings River-Hardwick, Pioneer, Hanford Christian).
Municipal Water Systems	City of Hanford
Local Land Use Planning Agencies	City of Hanford and County of Kings
California Native American Tribes	See Section C.2.
Disadvantaged Communities	Armona, Home Garden, Hardwick
Entities monitoring and reporting groundwater elevations in all or part of a groundwater basin	Kings County Water District monitors groundwater levels within its service area and is providing a subset of that information to the Kings River Conservation District for submission to the CASGEM system.

C.4.3 South Fork Kings GSA Stakeholders

An initial list of stakeholders within the South Fork Kings GSA is described in **Table 3**. The primary industries within the South Fork Kings GSA is agriculture and food processing.

Table 3. Stakeholder Groups with Interests in the South Fork Kings GSA

Stakeholder Group	Description
Agricultural Users	Service area is composed of mostly agricultural lands and agricultural users
Domestic Well Owners	There are domestic wells within the SFKGSA, and it is understood that many domestic users will fall into the "de minimis extractor" category. Further work is being conducted to understand to what extent domestic users will be affected by GSP requirements.
Municipal Well Operators	City of Lemoore, Stratford Public Utility District
Local Land Use Planning Agencies	City of Lemoore, County of Kings
California Native American Tribes	See Section C.2.
Disadvantaged Communities	Community of Stratford
Entities monitoring and reporting groundwater elevations in all or part of a groundwater basin	KRCD is the designated monitoring entity for the Kings and Tulare Lake Subbasins under CASGEM program. SFKGSA will coordinate its SGMA monitoring efforts with the CASGEM monitoring effort led by KRCD.

C.4.4 Southwest Kings GSA Stakeholders

The interests of all beneficial uses and users of groundwater within the Southwest Kings GSA are described in **Table 4**. The primary industries within the Southwest Kings GSA are agriculture, oil production and commercial usage specific to Kettleman City.

Table 4. Stakeholder Groups with Interests in the Southwest Kings GSA

Stakeholder Group	Description
Agricultural Users	Approximately 99 percent of the GSA's area is composed of agricultural lands. Representatives of the agricultural community are currently involved on the GSA Board of Directors.
Domestic Well Owners	Only one or two landowners utilize a domestic well, and are represented on the Board of Directors through member agencies.
Municipal Well Operators	Kettleman City CSD relies solely on surface water supply (effective October 2019). Their municipal wells are a back-up source to provide well water to residential and commercial customers within the GSA boundary in emergency situations when surface water is not accessible.
Local Land Use Planning Agencies	County of Kings
California Native American Tribes	See Section C.2.
Disadvantaged Communities	Kettleman City
Entities monitoring and reporting groundwater elevations in all or part of a groundwater basin	KRCD is the designated monitoring entity for the Kings and Tulare Lake Subbasins under CASGEM program. SWKGSA will coordinate its SGMA monitoring efforts with the CASGEM monitoring effort led by KRCD.

C.4.5 Tri-County Water Authority GSA Stakeholders

The Tri-County Water Authority provided stakeholder groups identified in **Table 5** with opportunities to provide input throughout the process of developing, operating and implementing the GSA and GSP. The primary industry within the Tri-County Water Authority GSA is almost entirely agriculture.

Table 5. Stakeholder Groups with Interests in the Tri-County Water Authority GSA

Stakeholder Group	Description
Agricultural Users	Composed almost entirely of agricultural users, including nut grower commodity groups and other agricultural use growers
Domestic Well Owners	There are domestic wells within the GSA area, but because SGMA excludes "de minimis extractors," it is anticipated that the GSP will exclude domestic wells from such requirements.
Local Land Use Planning Agencies	County of Kings
Federal Government	Bureau of Land Management
Entities monitoring and reporting groundwater elevations in all or part of a groundwater basin	Angiola Water District, Tulare Lake Basin Water Storage District

D. Public Outreach Meetings/Stakeholder Involvement Opportunities

D.1 Communication & Outreach Methods

There were a variety of opportunities, venues and methods for the Tulare Lake Subbasin GSAs to connect with and engage stakeholders throughout GSA formation, GSP development, GSP review, and will continue to be utilized through the GSP implementation phases. Stakeholder groups identified in **Section C** were engaged through communication methods outlined in this section.

D.1.1 Printed Communication

Printed materials incorporated the visual imagery established through individual GSA branding efforts and was tailored for specific means of communication throughout the phases of GSP development, public review and implementation. Printed materials were also translated into Spanish, when necessary for thorough, diverse stakeholder education.

- **Fliers –** Fliers designed and tailored for stakeholder audiences, encompassed infographics and text with key messages that were pertinent for that phase of GSP development. Distribution was via GSA-website posting, direct mail, email, and direct distribution as handouts throughout communities, GSA and subbasin outreach meetings. For outreach to DACs/SDACs, fliers were available in both English and Spanish languages.
- **Letter Correspondence –** When letter correspondence was necessary, particularly during the public review and implementation phases, letters were distributed via email and/or direct mail. Letters included pertinent facts and explanations that needed to be communicated to specific stakeholder groups.
- **Presentation Materials –** Power Point presentations were utilized at educational/outreach public meetings. For a consistent message subbasin-wide, a draft presentation was developed for the GSP development and public review phases, with placeholder slides for GSAs to update with GSA-

specific information. Handouts of presentations and smaller versions of display boards were distributed to stakeholders in attendance, emailed to the Interested Parties list, and posted on individual GSAs' websites for stakeholders to access, particularly if they were unable to attend.

D.1.2 Digital Communication

Digital communication outlets were also designed to incorporate Tulare Lake Subbasin GSAs' branding and was a significant mode of communication through the GSP development and public review phases, and will continue to be crucial during the implementation phase.

- **Websites –** Public meeting notices, agendas and minutes of the Board of Directors and Stakeholder/Advisory Committee meetings were posted on the individual GSAs' websites. These websites serve as integral resources for stakeholders within the Tulare Lake Subbasin boundary. Electronic files of printed materials, presentations and other educational resources, and direct links to stakeholder surveys (English and Spanish versions) were also accessible via the websites.

  As printed materials were created, PDFs of the same information were added to the GSAs' websites. This served as a way for stakeholders to easily educate themselves on the GSP process and phases.

  Table 6. Tulare Lake Subbasin GSAs' Websites

GSA	Website
El Rico GSA	None – Meetings posted at kingsgroundwater.info
Mid-Kings River GSA	www.midkingsrivergsa.org
South Fork Kings GSA	southforkkings.org
Southwest Kings GSA	www.swkgsa.org
Tri-County Water Authority GSA	tcwater.org
Kings River Regional Groundwater Info Portal *(an additional online informational resource)*	kingsgroundwater.info

- **Interested Parties List –** As required by SGMA 10723.4 "Maintenance of Interested Persons List," the Tulare Lake Subbasin GSAs maintain contact lists and regularly distribute emails to those who have expressed interest in the GSAs' progress. These emails consist of meeting notices and other documents that are pertinent to the Tulare Lake Subbasin GSAs and their communication efforts. This process will continue through the GSP implementation phase.
- **Email Blasts –** Email blasts for meeting notices, stakeholder surveys, public review notices, and other crucial information were coordinated with community organizations and stakeholder groups by utilizing their distribution lists. Examples of these organizations are Kings County Farm Bureau, and water/irrigation districts within the individual GSAs' boundaries.

D.1.3 Media Coverage

Press releases were written and distributed to the media list of local newspaper publications. These press releases focused on notification of public engagement opportunities such as targeted stakeholder meetings, public review/comment processes and opportunities, and will be distributed for meetings and notifications during the GSP implementation.

D.1.4 Stakeholder Surveys

Stakeholder surveys were used for the deliberate polling of stakeholders to give them a direct voice in the GSP development phase. The South Fork Kings GSA and Southwest Kings GSA circulated physical surveys, while the remaining three GSAs conducted verbal surveys through one-on-one discussions with stakeholders

within their GSA boundaries. For the GSAs who administered physical stakeholder surveys, they developed both online and printed versions of their surveys. Survey links were posted as Google Forms on the individual GSAs' websites and were utilized in email blasts to the Interested Parties Lists. Hard copies were also available for distribution throughout the respective GSA. An outline of the survey questions is provided in **Table 7**.

Table 7. GSAs Circulating Stakeholder Surveys

GSA	Survey Questions
El Rico GSA	Conducted verbal stakeholder survey discussions.
Mid-Kings River GSA	Conducted verbal stakeholder survey discussions.
South Fork Kings GSA	1. How important are the following uses of water to you personally? *Please rank the categories with 1 being the most important use of water and 6 being the least important. (Municipal, Agricultural, Recreational, Mining/Petroleum, Manufacturing, Wildlife/Fisheries)* 2. How important are the following uses of water to the region? *Please rank the categories with 1 being the most important use of water and 6 being the least important. (Municipal, Agricultural, Recreational, Mining/Petroleum, Manufacturing, Wildlife/Fisheries)* 3. Please rank the categories with 1 being the most important for reason for managing groundwater and 5 being the least important. *(Ensure drinking water supply for domestic uses; My ability to earn a living is directly linked; Future economic growth for region; Ensure water supply for future generations; Provide reliable water for industry/business; Other)* 4. How knowledgeable do you consider yourself of local water issues? *(Circle one – Extremely Knowledgeable to Not Very Knowledge)* 5. How knowledgeable do you consider yourself of the new groundwater regulation, the Sustainable Groundwater Management Act? *(Circle one – Extremely Knowledgeable to Not Very Knowledge)* 6. Are you currently engaged in activity or discussions regarding groundwater management in your area? 7. How important to you is information on anticipated impacts of new state regulations. *(Circle one – Extremely Important to Not Very Important)* 8. Which format or formats would you prefer for receiving information about groundwater management planning process? *(Check all that apply – Newsletters, phone number to call for information, regular public meetings, electronic media, news stories, information through interest groups, don't know)* 9. Which applies to you? I am a stakeholder representing pumping for… (*Check all that apply – business use, small community use, domestic use, school use, agricultural use, federal use, industrial use, municipal use, tribal use, environmental use, does not apply)* 10. Which best describes the community in which you or your industry/business resides? *(Circle all that apply – Rural Kings County, within the City of Lemoore, within the Community of Stratford, outside of the South Fork Kings GSA service area, don't know)* 11. Please indicate your age range? *(Circle one – 25 and under, 26-35 years, 36-45 years, 46-55 years, 56-65 years, over 65 years, no answer)*
Southwest Kings GSA	1. Are you familiar with Sustainable Groundwater Management Act (SGMA) regulations? 2. Are you currently engaged in activity of discussions regarding groundwater management in this region? 3. Do you own or manage/operate land in this region? 4. Do you manage water resources? If yes, what is your role? 5. What is your primary interest in land or water resources management? 6. Do you have concerns about groundwater management? If so, what are they? 7. Do you have recommendations regarding groundwater management? If so, what are they?
Tri-County Water Authority GSA	Conducted verbal stakeholder survey discussions.

D.2 Tulare Lake Subbasin-Wide Outreach Efforts

The Tulare Lake Subbasin GSAs maintained a timeline of communication and outreach efforts completed throughout the GSA development and GSP development and public review phases, both on a subbasin-wide level and on the individual GSA level. Subbasin-wide public outreach meetings and presentations are shown in **Table 8**. **Figure 1**, **Figure 2** and **Figure 3** demonstrate a visual guide for consolidated subbasin and individual GSA stakeholder involvement completed since the GSAs were formed.

Table 8. Tulare Lake Subbasin-Wide Public Meetings, Notifications, Presentations & One-on-One Meetings

Event	Date
Kings County Water Commission Meeting – SGMA Update Presentation	May 21, 2018
Kings County Farm Bureau Board Meeting – SGMA Update Presentation	June 19, 2018
Kings County Ag/Water Commissions Joint Meeting – SGMA Update Presentation	March 25, 2019
Kings County Farm Bureau Meeting – GSP Public Review Presentation	August 20, 2019
Subbasin-Wide Public Review Outreach Meeting – Lakeside Community Church, Hanford	5:30 p.m., October 9, 2019
Subbasin-Wide Public Review Outreach Meeting – Lemoore Civic Auditorium, Lemoore	5:30 p.m., October 15, 2019
Subbasin-Wide Meeting regarding GSP with five GSA managers and County of Kings representatives (County Counsel SGMA liaison, CAO, Board of Supervisor Verboon)	November 6, 2019 at the TLBWSD office in Corcoran
Tulare Lake Subbasin GSP Public Hearing – Kings County Board of Supervisors Chambers	10 a.m., December 2, 2019

D.2.1 Public Noticing

I.D.2.1.1 Phase 1: GSA Formation and Coordination

During Phase 1: GSA Formation and Coordination, the five individual GSAs published public notices to notify stakeholders within their boundaries of the public hearings held prior to the official formation of the agencies. These notices are documented in **Table 9**.

Table 9. Public Notices for GSA Formation Public Hearings

GSA	Publication	Date Published	Date Public Hearing Held
El Rico GSA	The Corcoran Journal Visalia Times Delta The Bakersfield Californian	January 19, 2017; January 26, 2017 January 19, 2017; January 26, 2017 January 20, 2017; January 26, 2017	February 7, 2017
Mid-Kings River GSA	Hanford Sentinel	December 20, 2016; December 27, 2016	January 5, 2017
South Fork Kings GSA	Hanford Sentinel	February 15, 2017; February 22, 2017	March 8, 2017
Southwest Kings GSA	The Corcoran Journal	February 16, 2017; February 23, 2017; March 2, 2017	March 8, 2017
Tri-County Water Authority GSA	The Hanford Sentinel	January 17, 2017; January 24, 2017	January 31, 2017

I.D.2.1.2 Phase 3: GSP Review and Evaluation

A 90-day comment period was held the last quarter of 2019, with the GSP draft posted on the Tulare Lake Subbasin GSAs' websites for all stakeholders to conveniently download and review and provide comments. Public notices were published in local newspapers to notify stakeholders of the start of the public review period 90 days prior to the public hearing, and published again within 45 days of the public hearing (**Table 10**).

Table 10. Public Notices for GSP Public Review & Public Hearing

Publication	Date Published	Purpose of Notice
The Bakersfield Californian	September 3, 2019; September 10, 2019	Notice of Public Review of Tulare Lake Subbasin Draft GSP
The Corcoran Journal	September 5, 2019; September 12, 2019	
Hanford Sentinel	September 3, 2019; September 10, 2019	
Visalia Times Delta	September 3, 2019; September 10, 2019	
The Bakersfield Californian	October 19, 2019; October 25, 2019	Notice of Public Hearing on Tulare Lake Subbasin Draft GSP, scheduled for December 2, 2019
The Corcoran Journal	October 24, 2019; October 31, 2019	
Hanford Sentinel	October 18, 2019; October 25, 2019	
Visalia Times Delta	October 31, 2019; November 7, 2019	

D.2.2 Interbasin Coordination Efforts

Tulare Lake Subbasin GSAs and technical consultants met with surrounding subbasins throughout the development of the GSP to discuss how to achieve sustainability on a regional level, develop interbasin agreements, address boundary issues, discuss groundwater monitoring and groundwater modeling, and share data when possible. Between the five GSAs, meetings were held periodically with other GSAs within the Kern, Tule, Kaweah, Kings and Westside subbasins. GSA managers were also involved with other GSA boards and technical committees in other subbasins due to some member agencies' boundaries crossing into other subbasins. This allowed the managers to communicate a regional perspective in sustainability discussions, as their stakeholders hold interests in more than one subbasin.

While inter-basin issues were communicated and discussed during these numerous meetings, due to time constraints and each subbasin progressing at a different pace in the development of their GSPs, resolutions to conflicts are acknowledged but impractical to fully analyze prior to the GSP submittal deadline of January 31, 2020. These discussions will continue, and resolutions will be addressed in annual reports and/or the 2025 Tulare Lake Subbasin GSP Update.

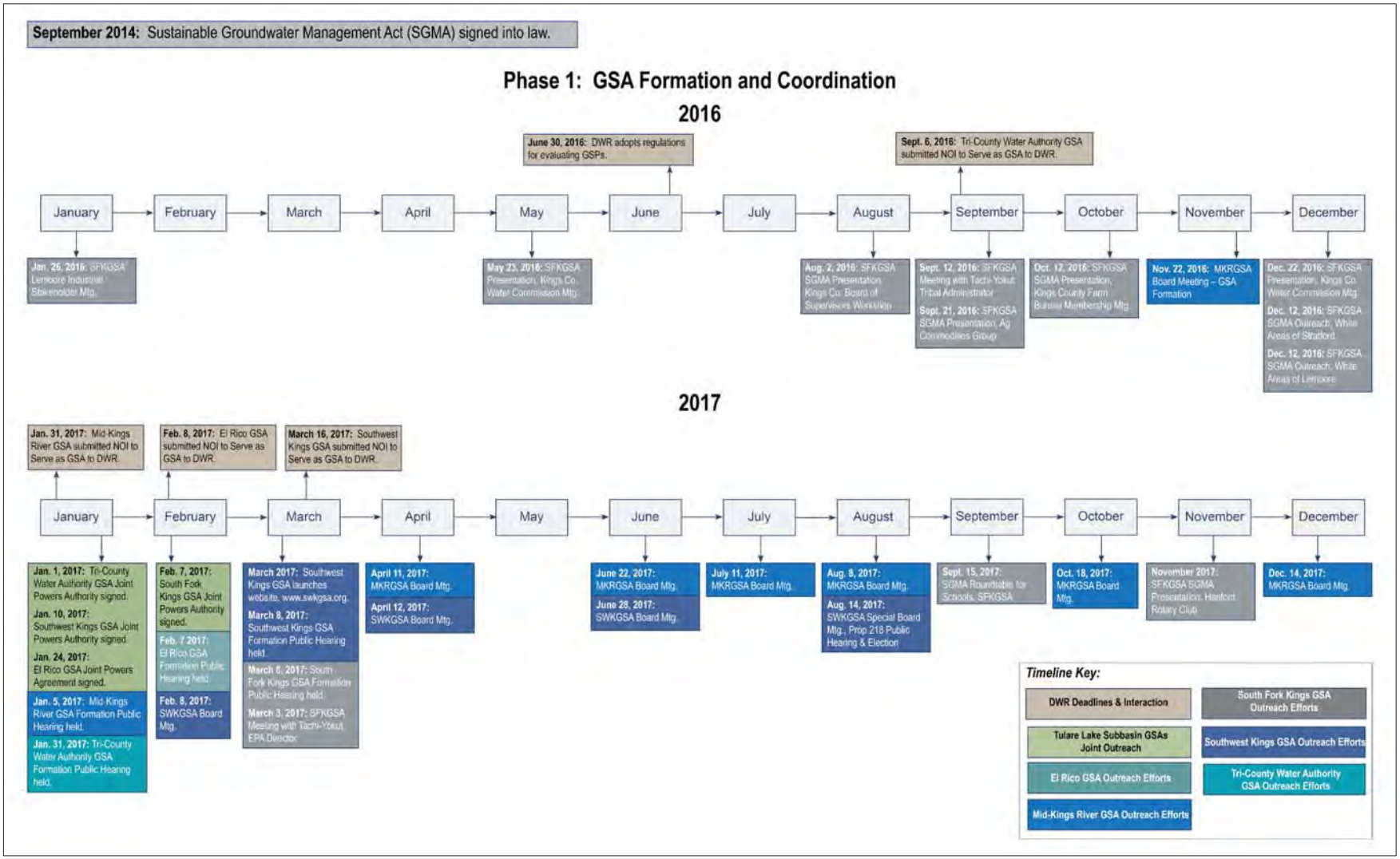


Figure 1. Tulare Lake Subbasin Communication & Engagement Timeline – Phase 1: GSA Formation and Coordination

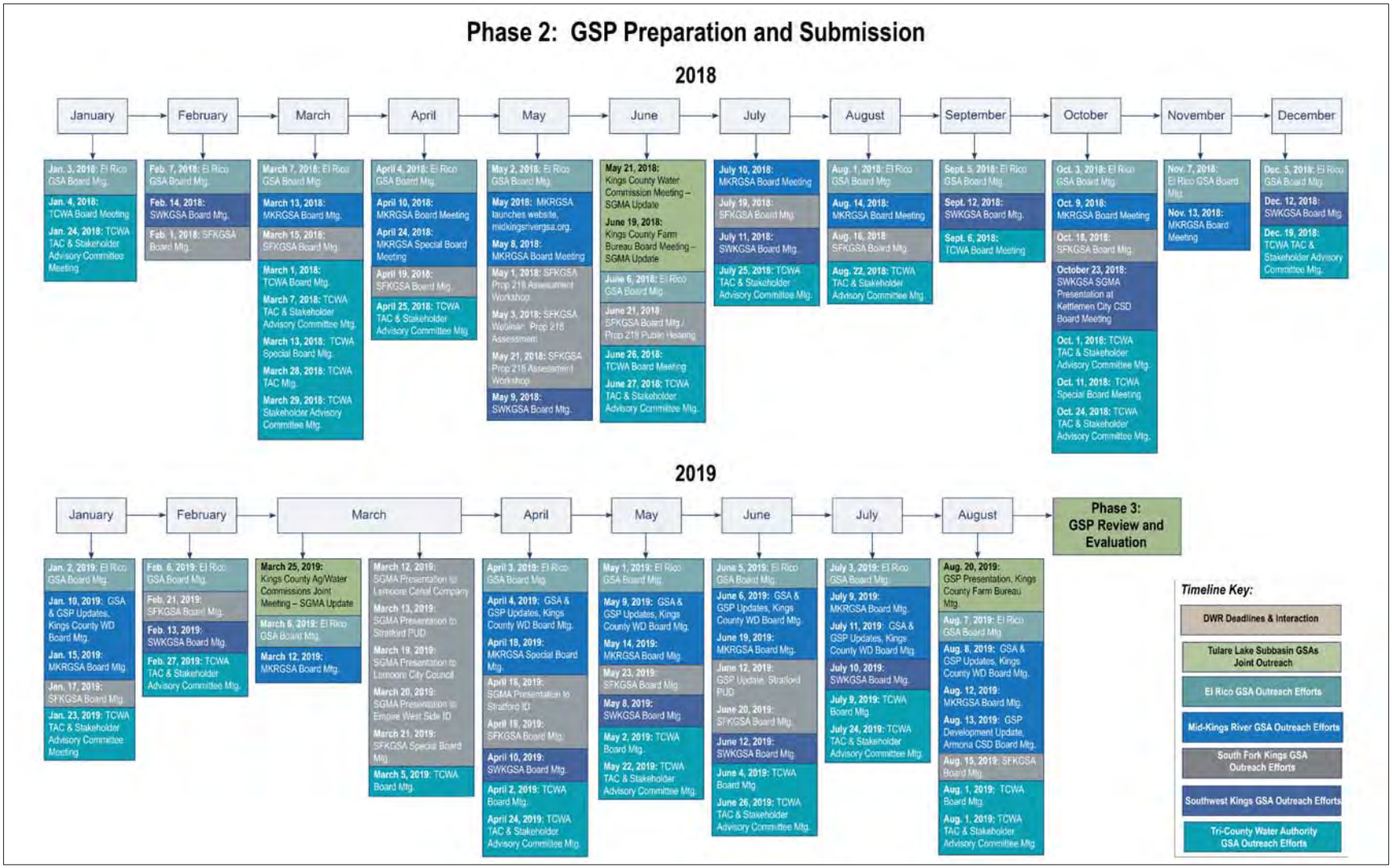


Figure 2. Tulare Lake Subbasin Communication & Engagement Timeline – Phase 2: GSP Preparation and Submission

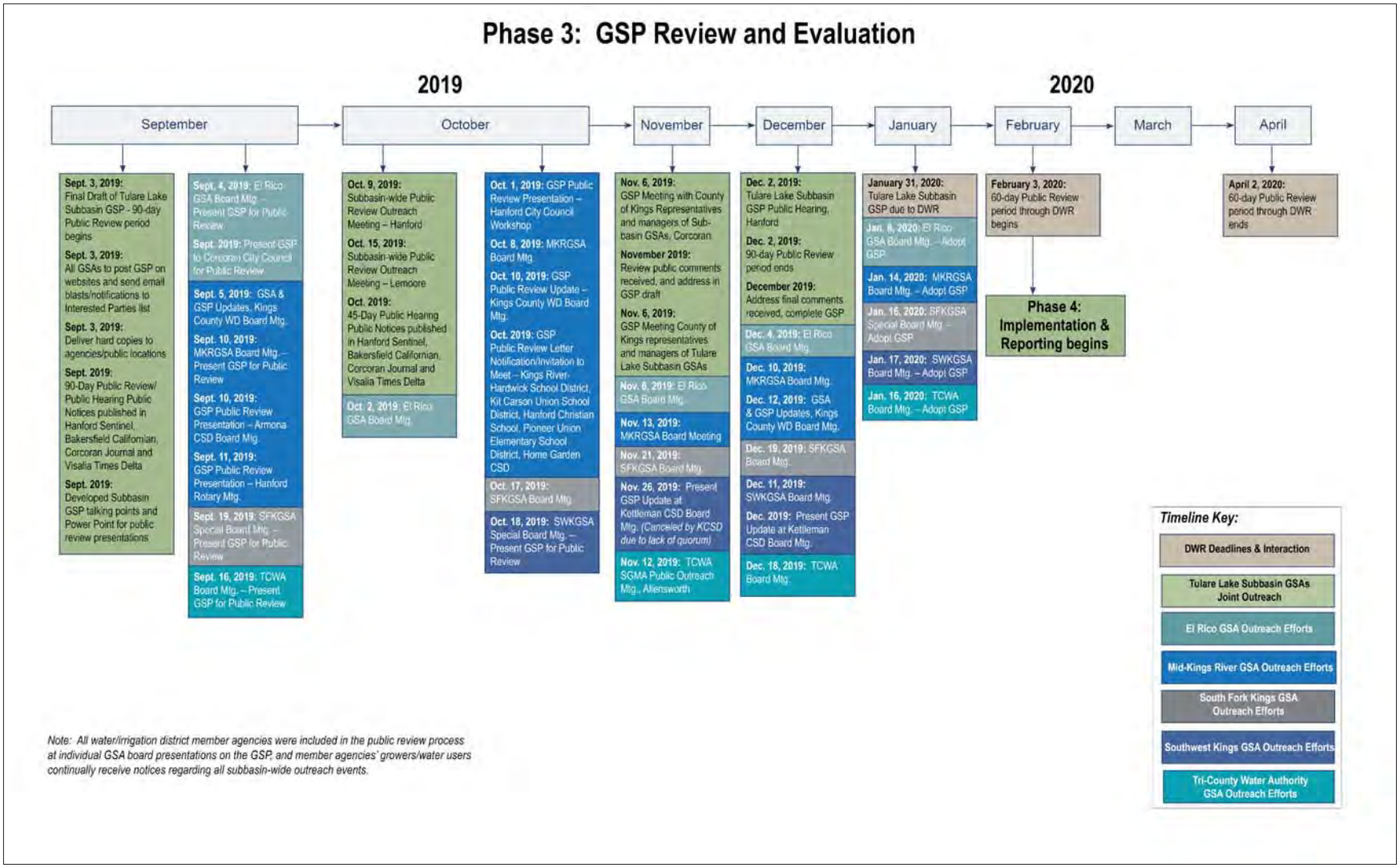


Figure 3. Tulare Lake Subbasin Communication & Engagement Timeline – Phase 3: GSP Review and Evaluation

D.3 El Rico GSA

Table 11. El Rico GSA Public Meetings, Presentations & One-on-One Meetings

Event	Date
One-on-one meetings with landowners of over 85 percent of the GSA area	Ongoing
SGMA & GSP Update meetings and negotiations with City of Corcoran personnel	Ongoing
GSA board meeting notices sent to all interested parties	Ongoing
Monthly meetings with "Un-districted Dairy Owners"	Ongoing
El Rico GSA Board Meeting	1 p.m., January 3, 2018
El Rico GSA Board Meeting	1 p.m., February 7, 2018
El Rico GSA Board Meeting	1 p.m., March 7, 2018
El Rico GSA Board Meeting	1 p.m., April 4, 2018
El Rico GSA Board Meeting	1 p.m., May 2, 2018
El Rico GSA Board Meeting	1 p.m., June 6, 2018
El Rico GSA Board Meeting	1 p.m., August 1, 2018
El Rico GSA Board Meeting	1 p.m., September 5, 2018
El Rico GSA Board Meeting	1 p.m., October 3, 2018
El Rico GSA Board Meeting	1 p.m., November 7, 2018
El Rico GSA Board Meeting	1 p.m., December 5, 2018
El Rico GSA Board Meeting	1 p.m., January 2, 2019
El Rico GSA Board Meeting	1 p.m., February 6, 2019
El Rico GSA Board Meeting	1 p.m., March 6, 2019
El Rico GSA Board Meeting	1 p.m., April 3, 2019
El Rico GSA Board Meeting	1 p.m., May 1, 2019
El Rico GSA Board Meeting	1 p.m., June 5, 2019
El Rico GSA Board Meeting	1 p.m., July 3, 2019
El Rico GSA Board Meeting	1 p.m., August 7, 2019
El Rico GSA Board Meeting	1 p.m., September 4, 2019
El Rico GSA Board Meeting	1 p.m., October 2, 2019
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Hanford	5:30 p.m., October 9, 2019
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Lemoore	5:30 p.m., October 15, 2019
El Rico GSA Board Meeting	1 p.m., November 6, 2019
GSP Meeting with County of Kings representatives and managers of Tulare Lake Subbasin GSAs	1:30 p.m., November 6, 2019
Tulare Lake Subbasin GSP Public Hearing – Hanford	10 a.m., December 2, 2019
El Rico GSA Board Meeting	1 p.m., December 4, 2019
El Rico GSA Board Meeting	1 p.m., January 8, 2020

D.4 Mid-Kings River GSA

D.4.1 Website – www.midkingsrivergsa.org

The Mid-Kings River GSA's website went live in May 2018 for the purpose of informing stakeholders about the GSA, public outreach opportunities, and as a resource with SGMA-related information. A site map is outlined below:

- **Homepage –** Introduction of Mid-Kings River GSA; GSA News
- **About Us –** Overview of SGMA; About the Mid-Kings River GSA; Member Agencies; Mid-Kings River GSA Information (links to Notice of Intent, JPA Members Agreement, GSA Boundary Map, Subbasin Boundary Map)
- **Board & Committees –** Board of Directors; (Agendas, Minutes, List of Board Members)
- **GSA Resources –** SGMA-Related Resources; Other Tulare Lake Subbasin GSAs (links); Partnering Agencies (links)
- **Contact Us –** Questions (telephone and email); Location/Mailing Address; Interested Parties List Sign-Up Form



Picture 1. Screenshot of www.midkingsrivergsa.org Homepage

D.4.2 Mid-Kings River GSA Outreach Tracking

Table 12. Mid-Kings River GSA Public Meetings, Notifications, Presentations & One-on-One Meetings

Event	Date
Landowner Meetings for requested updates on SGMA	Ongoing
Greater Kaweah GSA Collaboration – Updates to TAC and BOD on Tulare Lake Subbasin efforts	Ongoing
Participation in local DWR meetings	Ongoing
Coordination meetings with other subbasins and South Valley Practitioners Group	Ongoing
MKRGSA Board Meeting – GSA Formation	1 p.m., December 13, 2016
MKRGSA Board Meeting & Public Hearing to Become GSA	10 a.m., January 5, 2017
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., April 11, 2017
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., June 22, 2017
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., July 11, 2017
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., August 8, 2017
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., October 18, 2017
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., December 14, 2017
MKRGSA Board Meeting – SGMA and GSP Development Updates	3 p.m., March 13, 2018
MKRGSA Board Meeting – SGMA and GSP Development Updates	3 p.m., April 10, 2018
MKRGSA Special Board Meeting	9:30 a.m., April 24, 2018
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., May 8, 2018
Kings County Water Commission Meeting – SGMA Update	May 21, 2018
Kings County Farm Bureau Board Meeting – SGMA Update	June 19, 2018
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., July 10, 2018
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., August 14, 2018
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., October 9, 2018
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., November 13, 2018
GSA & GSP Development Updates – Kings County Water District Board Meeting	1:30 p.m., January 10, 2019
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., January 15, 2019
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., March 12, 2019
GSA & GSP Development Updates – Kings County Water District Board Meeting	1:30 p.m., April 4, 2019
MKRGSA Special Board Meeting – SGMA and GSP Development Updates	1 p.m., April 18, 2019
GSA & GSP Development Updates – Kings County Water District Board Meeting	1:30 p.m., May 9, 2019
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., May 14, 2019
GSA & GSP Development Updates – Kings County Water District Board Meeting	1:30 p.m., June 6, 2019
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., June 19, 2019
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., July 9, 2019
GSA & GSP Development Updates – Kings County Water District Board Meeting	1:30 p.m., July 11, 2019
GSA & GSP Development Updates – Kings County Water District Board Meeting	1:30 p.m., August 8, 2019
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., August 12, 2019
Armona CSD Board Meeting Presentation – SGMA and GSP Development Updates	6 p.m., August 13, 2019
GSA & GSP Development Updates – Kings County Water District Board Meeting	1:30 p.m., September 5, 2019

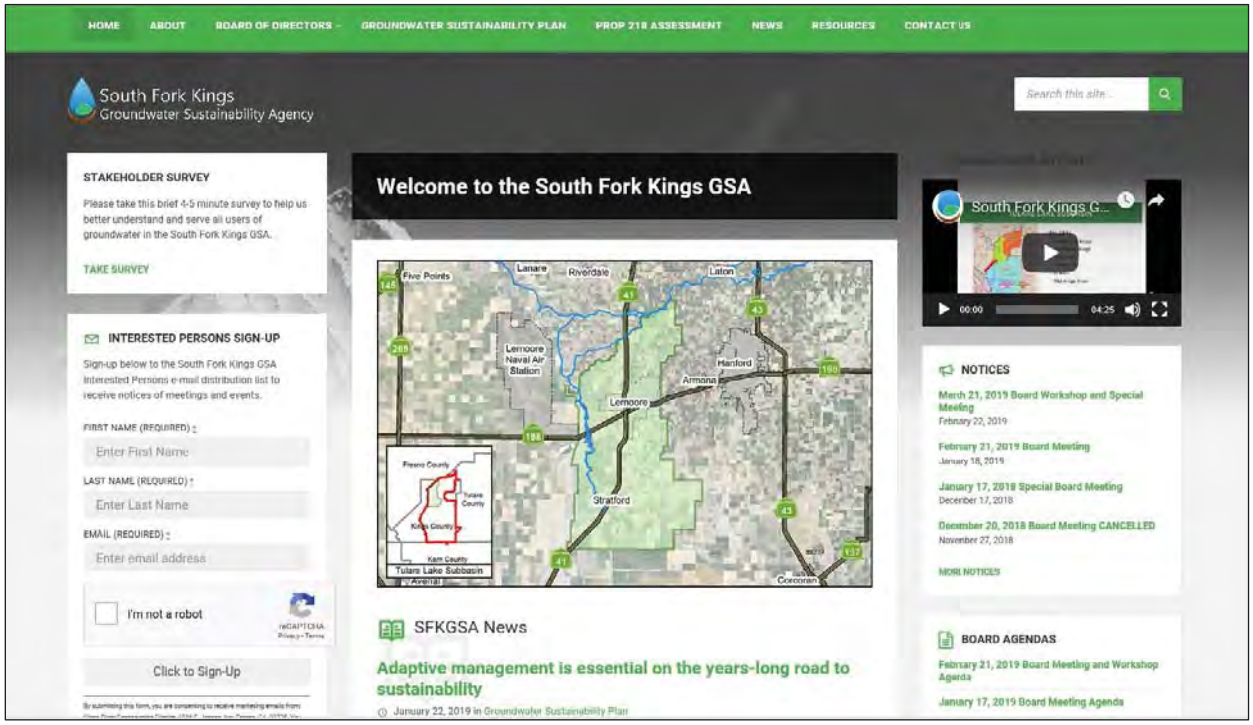
Event	Date
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., September 10, 2019
GSP Public Review Presentation at Armona CSD Board Meeting	6 p.m., September 10, 2019
GSP Public Review Presentation at Hanford Rotary Meeting	5:30 p.m., September 11, 2019
GSP Public Review Update – Kings County Water District Board Meeting	1:30 p.m., October 10, 2019
GSP Public Review Presentation at Hanford City Council Workshop	5:30 p.m., October 1, 2019
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., October 8, 2019
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Hanford	5:30 p.m., October 9, 2019
Home Garden CSD – Draft Tulare Lake Subbasin Groundwater Sustainability Plan Public Review Letter Notification & Invitation to Meet	Mailed via USPS and emailed October 11, 2019
Kings River-Hardwick School District – Draft Tulare Lake Subbasin Groundwater Sustainability Plan Public Review Letter Notification & Invitation to Meet	Mailed via USPS and emailed October 11, 2019
Kit Carson Union School District – Draft Tulare Lake Subbasin Groundwater Sustainability Plan Public Review Letter Notification & Invitation to Meet	Mailed via USPS and emailed October 11, 2019
Hanford Christian School – Draft Tulare Lake Subbasin Groundwater Sustainability Plan Public Review Letter Notification & Invitation to Meet	Mailed via USPS and emailed October 11, 2019
Pioneer Union Elementary School District – Draft Tulare Lake Subbasin Groundwater Sustainability Plan Public Review Letter Notification & Invitation to Meet	Mailed via USPS and emailed October 11, 2019
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Lemoore	5:30 p.m., October 15, 2019
GSP Meeting with County of Kings representatives and other GSA managers, Corcoran	1:30 p.m., November 6, 2019
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., November 13, 2019
Tulare Lake Subbasin GSP Public Hearing – Hanford	10 a.m., December 2, 2019
MKRGSA Board Meeting – SGMA and GSP Development Updates	1 p.m., December 10, 2019
GSA & GSP GSP Public Review Update – Kings County Water District Board Meeting	1:30 p.m., December 12, 2019
MKRGSA Board Meeting – Adoption of GSP	1 p.m., January 14, 2020

D.5 South Fork Kings GSA

D.5.1 Website – https://southforkkings.org/

The South Fork Kings GSA's website is a solid source of information for SGMA and the impacts within the GSA boundary. A site map is outlined below:

- **Homepage –** Welcome page with quick links to Stakeholder Survey, Interested Persons Sign-Up, GSA News, Notices, Board Agendas/Minutes, Proposition 218 Groundwater Assessment Resources
- **About Us –** About the South Fork Kings GSA; Quick links to Stakeholder Survey, Interested Persons Sign-Up, Board Agendas/Minutes, Documents
- **Board of Directors –** Board of Directors; Quick links to Stakeholder Survey, Interested Persons Sign-Up, Board Agendas/Minutes, Documents; Upcoming Events
- **Groundwater Sustainability Plan Portal –** Calendar, Projects, Coordination, Resources; Groundwater Sustainability Plan Development; GSP Implementation Roles (GSA, Stakeholder, DWR, SWRCB); GSP Schedule
- **Proposition 218 Assessment –** Election Results; Prop 218 Frequently Asked Questions; Prop 218 Election Documents; Overview of Groundwater Assessment
- **News**
- **Resources**
- **Contact Us –** Contact Us Inquiry Form; SGMA Update E-News Sign-Up; Quick links to Stakeholder Survey and Interested Persons Sign-Up



Picture 2. Screenshot of https://southforkkings.org/ Homepage

Table 13. 2017 SFKGSA Website Views

Month	Views
January	N/A
February	N/A
March	N/A
April	N/A
May	N/A
June	355
July	203
August	126
September	231
October	134
November	98
December	84

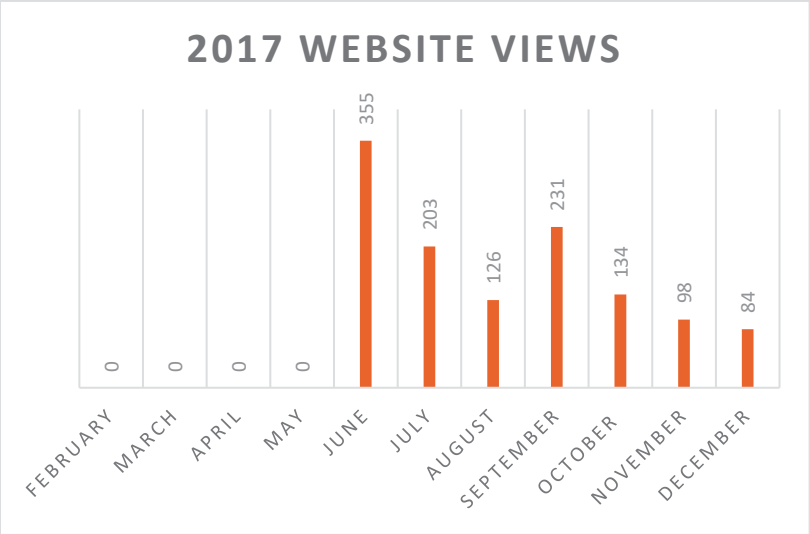


Table 14. 2018 SFKGSA Website Views

Month	Views
January	197
February	203
March	158
April	302
May	418
June	332
July	359
August	248
September	216
October	373
November	182
December	237

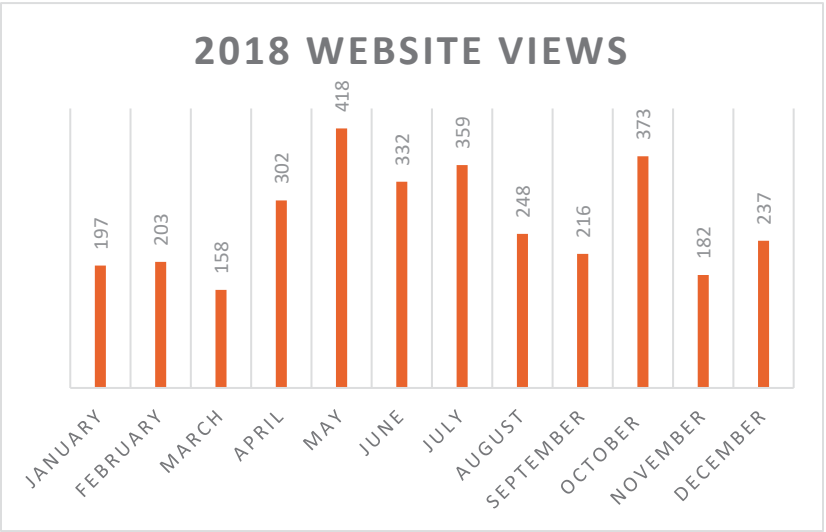
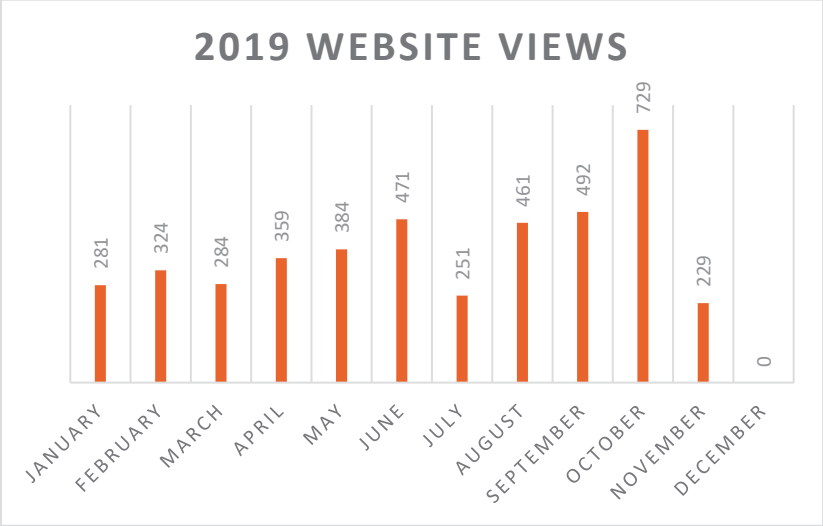


Table 15. 2019 SFKGSA Website Views

Month	Views
January	281
February	324
March	284
April	359
May	384
June	471
July	251
August	461
September	492
October	729
November	458
December	318



D.5.2 South Fork Kings GSA Outreach Tracking

Table 16. South Fork Kings GSA Public Meetings, Presentations & One-on-One Meetings

Event	Date	Attendance	Audience
Lemoore City Council Study Session	4/22/2015	15	Stakeholders
Empire Westside Water District Board Meeting	9/16/2015	7	Stakeholders
Stratford PUD Board Meeting	11/18/2015		Stakeholders (DAC)
Kings County Water Commission Meeting	11/23/2015	20	Stakeholders
Lemoore Industrial Stakeholder Meeting	1/26/2016	9	Stakeholders
Kings County Water Commission Meeting	5/23/2016	20	Stakeholders
Kings County Board of Supervisors Workshop	8/2/2016	30	Stakeholders
Janice Cuara, Tribal Administrator Tachi-Yokut	9/12/2016		Stakeholders – Native American
Ag Commodities Group Update	9/21/2016	8	
Kings County Farm Bureau Membership	10/12/2016	30	Stakeholders, Landowners
SFK White Areas – Stratford	12/12/2016		Stakeholders (DAC)
SFK White Areas – Lemoore	12/12/2016	35	Stakeholders
Kings County Water Commission Meeting	12/22/2016		Stakeholders
Noah Ignacio, EPA Director Tachi-Yokut	3/3/2017		Stakeholders – Native American
SGMA Roundtable for Schools SFK	9/15/2017	30	Stakeholders
SGMA Presentation, Hanford Rotary Club	11/2017	40	Stakeholders
Board Meeting, Lemoore City Council Chambers	02/1/2018	20	Stakeholders
Board Meeting, Lemoore City Council Chambers	3/15/2018	10	Stakeholders
Board Meeting, Lemoore City Council Chambers	4/19/2018	13	Stakeholders
Proposition 218 Assessment Workshop, Lemoore	5/1/2018	20	Landowners, City of Lemoore residents
Webinar: Proposition 218 Assessment	5/3/2018	1	Landowners

Event	Date	Attendance	Audience
Prop 218 Assessment Workshop, Lemoore	5/21/2018	21	Landowners, City of Lemoore residents
Board Meeting/Public Hearing for Proposition 218 Election	6/21/2018	25	Landowners, stakeholders
Board Meeting, Lemoore City Council Chambers	7/19/2018	19	Stakeholders
Board Meeting, Lemoore City Council Chambers	8/16/2018	16	Stakeholders
Board Meeting, Lemoore City Council Chambers	10/18/2018	19	Stakeholders
Board Meeting, Lemoore City Council Chambers	01/17/2019	24	Stakeholders
Board Meeting, Lemoore City Council Chambers	02/21/2019	14	Stakeholders
Presentation to Lemoore Canal Company	03/12/2019		Stakeholders
Presentation to Stratford Public Utility District	03/13/2019		Stakeholders
Presentation to Lemoore City Council	03/19/2019		Stakeholders
Presentation to Empire West Side Irrigation District	03/20/2019		Stakeholders
Special Board Meeting, Lemoore City Council Chambers	03/21/2019	19	Stakeholders
Presentation to Stratford Irrigation District	04/18/2019		Stakeholders
Board Meeting, Lemoore City Council Chambers	04/18/2019	13	Stakeholders
Board Meeting, Lemoore City Council Chambers	05/23/2019	14	Stakeholders
GSP Update, Stratford Public Utility District	06/12/2019		Stakeholders
Board Meeting, Lemoore City Council Chambers	06/20/2019	12	Stakeholders
Board Meeting, Lemoore City Council Chambers	08/15/2019	18	Stakeholders
Board Meeting – Lemoore City Council Chambers	09/19/2019	14	Stakeholders
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Hanford	10/9/2019	27	Stakeholders
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Lemoore	10/15/2019	35	Stakeholders
Board Meeting, Lemoore City Council Chambers	10/17/2019	12	Stakeholders
Board Meeting, Lemoore City Council Chambers	11/21/2019	13	Stakeholders
Tulare Lake Subbasin GSP Public Hearing – Hanford	12/2/2019		Stakeholders
Board Meeting, Lemoore City Council Chambers	12/19/2019		Stakeholders
Special Board Meeting – Adoption of GSP, Lemoore City Council Chambers	01/16/2020		Stakeholders

Table 17. South Fork Kings GSA Website Articles

Title/Topic	Date	Views
Kings County Farm Bureau newsletter article	Jul-15	N/A
SFK Board Approves Contract with Hydrogeological Consultant	6/20/2017	26
Board Supports Effort to Develop a Single GSP for the Tulare Lake Subbasin	7/20/2017	16
Contract Approved with Geosyntec Consultants	8/21/2017	28
Board Approves Preparation of Engineering Report for 218 Election	9/25/2017	23
Board Approves Data Sharing Agreements with North Fork Kings GSA, Westlands Water District	2/9/2018	17
The Model, the Data and Groundwater Sustainability	2/9/2018	225
Board Approves Engineer's Report, Moves Forward with Prop 218 Assessment	3/27/2018	84
Proposition 218 Election to Fund Local Groundwater Management Passes	6/22/2018	29
Consultants update Board on the groundwater model, a Groundwater Sustainability Plan foundation	7/24/2019	31
Groundwater Sustainability Plan schedule update	10/11/2018	28
Project and management action concepts discussed at Board workshop	10/22/2018	76
Adaptive management is essential on the years-long road to sustainability	1/22/2019	46
Preliminary Monitoring Network Identified	3/15/2019	49
Creativity and adaptive management will reduce 45,000 AF of estimated overdraft in the South Fork Kings	4/24/2019	70
Twelve Wells will Monitor Groundwater	6/7/2019	67
Board Approves $9.80 Assessment	6/25/2019	25

Table 18. Email Correspondence with Interested Persons List - Email Blasts

Message/Topic	Date Sent	Open Rate	Click Rate	Reach/Quantity
Board Agenda Packet	6/20/2017	43.5%	20.0%	24
Board Agenda Packet	7/21/2017	60.7%	5.9%	29
Board Agenda Packet	8/21/2017	46.4%	7.7%	30
Board Agenda Packet	9/25/2017	46.7%	7.1%	32
Board Agenda Packet	11/3/2017	53.3%	56.3%	32
Model, Data, Sustainability Tech Consultant; Data-Sharing Agreements Approved	2/9/18	49.2%	51.6%	67
Model, Data, Sustainability tech consultant; data sharing agreements approved	3/12/18	49%	51%	67
Board Agenda Packet	3/27/18	46%	50%	65
Engineer's Report Adopted; Prop 218 Election; Board meeting schedule update	4/16/18	44%	27%	68
Board Agenda Packet	5/2/18	48%	57%	76
Prop 218 Workshop Highlight, State Intervention, Groundwater Fee	5/7/18	N/A	N/A	0
Ballots mailed, local vs. state control, prop 218 resources, public hearing date	5/31/18	60%	33%	91
Submit your ballot by June 21 hearing date	7/27/18	47%	34%	106

Message/Topic	Date Sent	Open Rate	Click Rate	Reach/Quantity
Update to landowner on the overdraft number for the Tulare Lake Subbasin	7/16/18	N/A	N/A	1
Board Agenda Packet	7/24/18	57%	57%	113
Groundwater Model, Technical Services Continued with Geosyntec	8/13/18	52%	33%	117
Board Agenda Packet	10/15/18	54%	46%	119
Board Agenda Packet	10/23/18	46%	33%	120
Project and management actions discussed at workshop, DWR funding opportunity, Tulare Lake Subbasin Communication & Engagement Plan adopted, Stakeholder Survey, #SGMAMadeSimple	12/13/18	47%	42%	121
Meeting Cancellation Notice	12/17/18	44%	N/A	126
Board Agenda	1/17/2019	56%	44%	126
Adaptive management for sustainability, GSP Portal Updates, Stakeholder Survey, Water Budget video	1/23/2019	54%	35%	128
Board Agenda	2/15/2019	52%	33%	134
Meeting notice	2/22/2019	40%	8%	N/A
Timeline to GSP completion, Board appoints officers, monitoring network identified, water quality infographic	3/15/2019	50%	28%	141
Board Agenda	3/18/2019	44%	34%	141
Board Agenda	4/15/2019	43%	28%	142
Creativity and adaptive management will reduce overdraft, land subsidence infographic, board workshop slides	4/25/2019	51%	28%	142
Board Agenda, Budget Committee Agenda	5/20/2019	43%	24%	154
Twelve Wells will monitor groundwater, groundwater storage infographic	6/7/2019	41%	37%	153
Board Agenda	6/17/2019	39%	27%	152
Board approves &9.80 assessment, SGMA Made Simple video, June 20th workshop presentation	6/25/2019	35%	37%	153
Board Agenda	8/12/2019	51%	43%	209
Board Agenda	9/16/2019	45%	40%	218
GSP available for download, upcoming GSP workshops	10/2/2019	41%	18%	219
Board Agenda	10/14/2019	41%	24%	222
Upcoming GSP workshop promo	11/5/2019	42%	22%	222
Upcoming Irrigation Technology event at CSU Fresno	11/5/2019	36%	7%	224

Table 19. Direct Mailings to Stakeholders

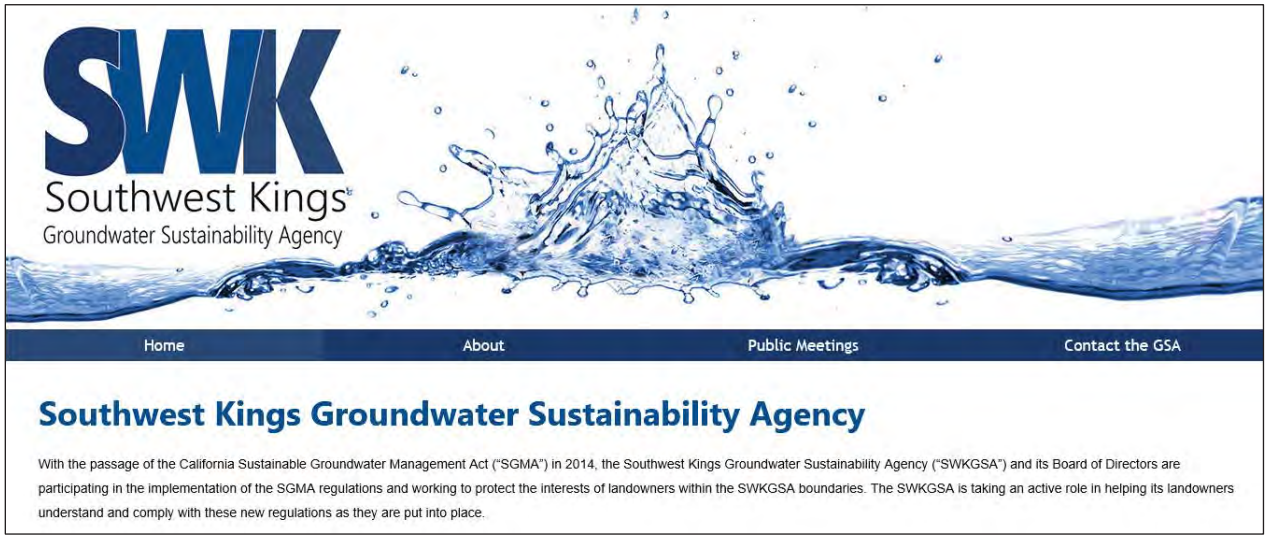
Date	Title	Audience	Quantity
April 2018	Prop 218 Informational Mailer	Landowners	897
April 2018	Prop 218 Informational Mailer (Spanish)	Residents	317
May 2018	Postcard: Final Workshop notice	Landowners	897
May 2018	Postcard: Final Workshop notice (Spanish)	Residents	317
June 2018	Postcard: final ballot reminder	Landowners	897
June 2018	Postcard: final ballot reminder (Spanish)	Residents	317
October 2018	Fall Mailer: Prop 28 results and GSP update	Landowners	897
October 2018	Fall Mailer: Prop 28 results and GSP update (Spanish)	Residents	317
July 2019	Contact Form and GSP education mailer	Landowners	1,089
July 2019	Contact Form and GSP education mailer (Spanish)	Residents	Online
October 2019	GSP Workshop promo mailer	Landowners	1,089
October 2019	GSP Workshop promo mailer (Spanish)	Residents	Online

D.6 Southwest Kings GSA

D.6.1 Website – www.swkgsa.org

The Southwest Kings GSA launched a website in March 2017 as a key avenue to inform stakeholders about the GSA, public outreach opportunities, and as a resource with SGMA-related information. A site map is outlined below:

- **Homepage –** Introduction of Southwest Kings GSA; Important Dates; News & Press Releases; and Quick Links to GSA Boundary Map and SGMA-Related Resources
- **About SGMA & SWKGSA –** What is SGMA?; SGMA and the Southwest Kings GSA; SWKGSA Information (links to boundary map, Bylaws & Policies, JPA Members Agreement, Cost-Sharing Agreement); Governance (Board of Directors, Alternate Directors, GSA Members, Management/Consultant Team)
- **Public Meetings –** Public Hearings; Board Meetings (agendas and minutes); Public Outreach Workshops
- **Contact the GSA –** Questions; Location; Interested Parties List Sign-Up Form



Picture 3. Screenshot of www.swkgsa.org Homepage

D.6.2 Outreach Tracking

Table 20. Southwest Kings GSA Public Meetings, Presentations & One-on-One Meetings

Meeting/Event	Date
Southwest Kings GSA Board Meeting – SGMA and GSA Formation	3 p.m., February 8, 2017
Southwest Kings GSA Board Meeting – SGMA and GSA Formation	3 p.m., March 8, 2017
Southwest Kings GSA Board Meeting – SGMA and GSP Development	3 p.m., April 12, 2017
Southwest Kings GSA Board Meeting – SGMA and GSP Development Updates	3 p.m., June 28, 2017
Southwest Kings GSA Special Board Meeting – Proposition 218 Public Hearing & Election	10 a.m., August 14, 2017
Southwest Kings GSA Board Meeting – SGMA and GSP Development Updates	3 p.m., February 14, 2018
Southwest Kings GSA Board Meeting – SGMA and GSP Development Updates	3 p.m., May 9, 2018
Southwest Kings GSA Board Meeting with special presentation on Preliminary Water Budget	3 p.m., July 11, 2018
Southwest Kings GSA Board Meeting – SGMA and GSP Development Updates	3 p.m., September 12, 2018
Kettleman City Community Services District Board Meeting – SGMA/GSA Presentation	6 p.m., October 23, 2018
Southwest Kings GSA Board Meeting – SGMA and GSP Development Updates	3 p.m., December 12, 2018
Southwest Kings GSA Board Meeting – SGMA and GSP Development Updates	3 p.m., February 13, 2019
Southwest Kings GSA Board Meeting – SGMA and GSP Development Updates	3 p.m., May 8, 2019
Southwest Kings GSA Board Meeting – SGMA and GSP Development Updates	3 p.m., July 10, 2019
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Hanford	5:30 p.m., October 9, 2019
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Lemoore	5:30 p.m., October 15, 2019
Southwest Kings GSA Special Board Meeting – GSP Public Review Update	3 p.m., October 18, 2019
GSP Meeting with County of Kings representatives and other GSA managers	1:30 p.m., November 6, 2019
GSP Public Review Presentation – Kettleman Community Services District Board Meeting *(Note: Presentation scheduled for Nov. 19, rescheduled for Nov. 26, but board meeting canceled by KCSD both dates due to lack of quorum)*	6 p.m., November 26, 2019
Tulare Lake Subbasin GSP Public Hearing – Hanford	10 a.m., December 2, 2019
Southwest Kings GSA Board Meeting – SGMA and GSP Development Updates	3 p.m., December 11, 2019
Special Board Meeting – Adoption of GSP	9 a.m., January 17, 2020

D.7 Tri-County Water Authority

D.7.1 Website – http://tcwater.org

The Tri-County Water Authority launched a website to aid in achieving the Authority's goal of world class groundwater management in the Tulare Lake Hydrologic Region. A site map of the website is outlined below:

- **Homepage –** Primary goal of Tri-County Water Authority; Updates/Reports; Notifications; Quick Links to SGMA Overview; Tri-County Water Authority Map; News; Calendar; About the Water Authority
- **SGMA –** What is The SGMA?; SGMA Purpose; What Are Your Rights?; Overview of The Water Problem; Frequently Asked Questions; Tri-County Water Authority Territory
- **About Us –** About Us Overview; Board of Directors; Trusted News Sources Links – http://tcwater.org/news/ ; Calendar – http://tcwater.org/events/
- **Contact the GSA**



Picture 4. Screenshot of http://tcwater.org Homepage

D.7.2 Outreach Tracking

Table 21. Tri-County Water Authority Public Meetings, Presentations & One-on-One Meetings

Tri-County Water Authority Meetings/Presentations/One-on-One Discussions	
Meeting/Event	Date
TCWA Board Meeting	1 p.m., January 4, 2018
TCWA Technical Advisory Committee Meeting	10 a.m., January 24, 2018
TCWA Stakeholder Advisory Committee Meeting	1 p.m., January 24, 2018
TCWA Board Meeting	1 p.m., March 1, 2018
TCWA Technical Advisory Committee Meeting	10 a.m., March 7, 2018

Tri-County Water Authority Meetings/Presentations/One-on-One Discussions	
Meeting/Event	Date
TCWA Stakeholder Advisory Committee Meeting	1 p.m., March 7, 2018
TCWA Special Board Meeting	1 p.m., March 13, 2018
TCWA Technical Advisory Committee Meeting	10 a.m., March 28, 2018
TCWA Stakeholder Advisory Committee Meeting	1 p.m., March 29, 2018
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., April 25, 2018
TCWA Board Meeting	1 p.m., June 26, 2018
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., June 27, 2018
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., July 25, 2018
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., August 22, 2018
TCWA Board Meeting	1 p.m., September 6, 2018
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., October 1, 2018
TCWA Special Board Meeting	1 p.m., October 11, 2018
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., October 24, 2018
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	9 a.m., December 19, 2018
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., January 23, 2019
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., February 27, 2019
TCWA Board Meeting	1 p.m., March 5, 2019
TCWA Board Meeting	1 p.m., April 2, 2019
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., April 24, 2019
TCWA Board Meeting	1 p.m., May 2, 2019
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., May 22, 2019
TCWA Board Meeting	1 p.m., June 4, 2019
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., June 26, 2019
TCWA Board Meeting	1 p.m., July 9, 2019
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., July 24, 2019
TCWA Technical Advisory Committee/Stakeholder Advisory Committee Meeting	10 a.m., August 1, 2019
TCWA Board Meeting	1 p.m., August 1, 2019
TCWA Board Meeting – Public Review of GSP Presentation	1 p.m., September 16, 2019
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Hanford	5:30 p.m., October 9, 2019
Tulare Lake Subbasin-Wide Public Outreach Meeting: GSP for the Subbasin, Lemoore	5:30 p.m., October 15, 2019
GSP Meeting with County of Kings representatives and other GSA managers	1:30 p.m., November 6, 2019
TCWA & SGMA – Public Outreach Meeting, Allensworth	2 p.m., November 12, 2019
Tulare Lake Subbasin GSP Public Hearing – Hanford	10 a.m., December 2, 2019
TCWA Board Meeting	1 p.m., December 18, 2019
TCWA Board Meeting – Adoption of GSP	1 p.m., January 16, 2020

APPENDIX C

STAKEHOLDER COMMENTS AND RESPONSES

APPENDIX C – PUBLIC COMMENTS ON THE DRAFT GSP

The Groundwater Sustainability Agencies (GSAs) solicited public and stakeholder comments on the draft Tulare Lake Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) from September 6, 2019, to December 2, 2019. During this period, the GSAs received comments transmitted to them in six letters and in one email. During the Public Hearing on December 2, 2019, one verbal comment was received. This section provides summaries of the comments contained in the letters and email and as presented verbally on the draft GSP and the responses to each comment.

Each letter, email, and verbal comment received is listed in Table C-1 and identified by comment author and date received by the GSAs.

Table C-1. List of Commenters

Comment ID	Comment Author	Comment Date
Organizations		
0-1	The Nature Conservancy	November 26, 2019
0-2	California Poultry Federation	November 27, 2019
0-3	Clean Water Action/Clean Water Fund; Local Government Commission; Audubon/California; The Nature Conservancy	December 2, 2019
0-4	Westlands Water District	December 2, 2019
0-5	Westlands Water District	December 2, 2019
Individuals		
I-1	Colleen Courtney	October 11,2019
I-2	Bill Miguel	October 15,2019
I-3	Bill Toss	December 2, 2019
I-4	Doug Verboon	December 2, 2019

Each of the comments is summarized below followed by responses from the GSAs. Hard copies of the comment correspondence received by the GSAs and a written summary of the verbal comment are compiled and presented following the comments and responses section.

Comment O-1

In The Nature Conservancy's letter to the South Fork Kings (SFK) GSA, they address the GSP's consideration of the beneficial uses and users of groundwater including environmental uses and users. The comment letter states:

> *Although there is a robust description of the confined (lower) and unconfined/semiconfined (upper) aquifers there is no explicit description with supporting data and information of how groundwater above the A- and C- clays in the upper aquifer interacts with the unconfined aquifer or is influenced by pumping in the unconfined portion of the aquifer. DWR's definition of a principal aquifer, is defined as an "aquifer of aquifer system that stores, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems."*
>
> *These shallow and perched areas within the upper aquifer range from near surface to 30 feet below ground surface and likely provide water supply to GDEs and ISWs. As such, they yield significant quantities of groundwater to surface water systems and beneficial users, and should not be dismissed because they do not yield groundwater for human use.*

These statements are the basis for the other resulting comments in their letter that request additional data and information, suggest that the GSA's and GSP recognize groundwater dependent ecosystems (GDEs) and interconnected surface water (ISW), and suggest a need for monitoring of these potential areas.

Response: Thank you for your letter and comments. Related to the Hydrologic Conceptual Model as presented in Section 3.1.8 of the draft GSP, there are geologic deposits in the Subbasin that are lacustrine clays named the A- through F-Clays. The A- through D-Clays may be more important locally in restricting the downward movement of groundwater. Figure 3-17 shows the areal extent of the A-Clay and the depth to groundwater above the A-Clay. Comparing this figure with your web-based GDE Pulse indicates an area along the South Fork Kings River where there would be the most interest in evaluating whether GDEs and ISWs occur.

From Section 4.0 of the draft GSP "Indicators for the sustainable management of groundwater were established under Sustainable Groundwater Management Act of 2014 (SGMA) based on factors that have the potential to impact the health and general well-being of the public. The following indicators were evaluated within the Subbasin: groundwater levels, groundwater storage volume, land subsidence, water quality, interconnected surface water, and seawater intrusion." ISW and seawater intrusion are not present within the Subbasin and were omitted from further consideration in the draft GSP. GDEs are not one of the sustainability indicators but rather dependent on ISW systems. Section 3.2.8 describes more fully the conditions found within the plan area.

It is also recognized that the GSP is adaptive in nature and will be updated as more information becomes available. It is noted in Section 5.4.1.2 that the ability to add and/or alter the existing monitor programs is envisioned. The individual GSAs will determine if or when additional

attempts will be made to collect that data. Temporal adjustments may be made for the different aquifer zones or in certain areas. For example, semi-annual water level readings in above the A-Clay wells is probably sufficient to capture seasonal and long-term trends in most of that aquifer zone because water levels in the aquifer are relatively stable in most of the area. Near the Kings River it may be desirable to collect more frequent data from above the A-Clay to better understand the relationship between the river and shallow groundwater.

Comment O-2

The California Poultry Federation (CPF) is the trade association for California's poultry industry. In their letter to the Southwest Kings (SWK) GSA, they expressed their support for effective measures to assure reliable water supplies. CPF's comments largely focused on 2 main issues:

1. Supply augmentation should be a top priority of the GSP.
2. Regarding demand management, the GSP does not explain precisely how it will be done and the public will need to have opportunities to participate in the development of demand management measures. Also, the GSAs should do their best to ameliorate economic impacts by adopting demand management measures that are cost-effective.

Response: Thank you for your letter and comments. The GSAs agree that supply augmentation should be a top priority for this Subbasin. Several supply augmentation projects and their implementation are described in Chapters 6 and 7.

The draft GSP has been revised to remove demand management or demand reduction as a definitive programmatic action. The potential for demand management is described in Section 6.4 only as an option for the GSAs should it be needed to meet the Sustainability Goal. If implementation is necessary, the GSAs are committed to executing such programs in a cost effective manner and with the input of the local communities.

Comment O-3

This letter was submitted to the Tri-County Water Authority GSA on behalf of the Clean Water Action/Clean Water Fund, Local Government Commission, Audubon/California, and The Nature Conservancy in the interests of disadvantaged communities (DACs), drinking water, and the environment. The letter presented a checklist of GSP review criteria and summary comments addressing 9 elements as indicated in the response.

Response: Thank you for your letter and comments. Responses to the summary comments in the letter are provided below.

1. **How the DACs were determined and engaged in the GSP development process.**
   DACs were identified using the California Department of Water Resources (DWR) DAC online mapping tool and associated Geographic Information System data (2018) and the Tulare Lake Basin DAC Water Study (published 2013). The GSAs conducted a substantial amount of stakeholder engagement, including outreach to DACs, during the development of the GSP. These efforts are described in detail in Appendix B.

2. **Financial assistance for DACs.**
   SGMA did not intend for the GSAs to provide financial assistance to entities in the Subbasin. Representatives of the GSAs will reasonably assist entities in identifying potential sources of financial assistance, if requested and necessary, and will provide other non-financial assistance to the extent that it is required in the SGMA regulations and the GSAs have the resources to do so.

3. **The development of Measurable Objectives and Minimum Thresholds Sustainable Management Criteria needs to be explained.**
   The development of Measurable Objectives and Minimum Thresholds are described in Chapter 4 of the draft GSP. The methods used and the rational for selecting these criteria are described in this chapter.

4. **There should be stakeholder engagement during GSP implementation.**
   The GSAs conducted a substantial amount of stakeholder engagement during the development of the GSP. These efforts are described in detail in Appendix B. The GSAs intend to continue stakeholder engagement efforts through GSP implementation.

5. **The potential for impacts to domestic water supply wells from GSP implementation.**
   Domestic water supply wells in the Subbasin typically are the shallowest wells in the Subbasin and have historically been subject to a dynamic groundwater system whereby water levels change frequently due to seasonal fluctuations and climatic changes (such as drought). Prior to SGMA, these wells also experienced gradual long-term decline of water levels due to the curtailment of federal and state surface water deliveries to the Subbasin. In this environment, owners of these wells have successfully adjusted by modifying the wells or drilling new wells. Under SGMA, water levels will continue to change frequently due to seasonal fluctuations and climatic changes and until the GSP is fully implemented, the wells may also experience gradual decline of water levels. However, as the GSP is

implemented, shallow water levels are expected to stabilize, thereby providing a positive benefit to domestic well owners.

6. **Groundwater Dependent Ecosystems should be addressed.**
   From Section 4.0 of the draft GSP "Indicators for the sustainable management of groundwater were established under SGMA based on factors that have the potential to impact the health and general well-being of the public. The following indicators were evaluated within the Subbasin: groundwater levels, groundwater storage volume, land subsidence, water quality, interconnected surface water, and seawater intrusion." Interconnected surface water and seawater intrusion are not present within the Subbasin and were omitted from further consideration in the draft GSP. GDEs are not one of the sustainability indicators but rather dependent on interconnected surface water systems. Section 3.2.8 describes more fully the conditions found within the plan area.

   It is also recognized that the GSP is adaptive in nature and will be updated as more information becomes available. It is noted in Section 5.4.1.2 that the ability to add and/or alter the existing monitor programs is envisioned. The following is offered; "The individual GSAs will determine if or when additional attempts will be made to collect that data. Temporal adjustments may be made for the different aquifer zones or in certain areas. For example, semi-annual water level readings in above the A-Clay wells is probably sufficient to capture seasonal and long-term trends in most of that aquifer zone because water levels in the aquifer are relatively stable in most of the area. Near the Kings River it may be desirable to collect more frequent data from above the A-Clay to better understand the relationship between the river and shallow groundwater."

7. **Climate change must be considered in development of the GSP.**
   As required by DWR, climate change is accounted for in the groundwater model (Appendix D) using assumptions and parameters provided by DWR.

8. **Drinking water should be considered in the water budget.**
   Municipal water use throughout the Subbasin is accounted for in the water budget. Water use from private domestic wells is not known nor is well construction known. The amount of water from domestic wells is estimated to be a *de minimis* amount in the overall water budget.

9. **Continued groundwater level decline during GSP implementation.**
   Per SGMA requirements, the GSAs have developed a GSP the implementation of which will result in groundwater sustainability for the Subbasin by 2040. At that point, average groundwater levels will become stable.

Comments O-4 and 0-5

Westlands Water District (Westlands) occupies the Westside Subbasin located to the southwest and adjacent to the Subbasin and is the GSA for this subbasin. In Westland's letters to the SWK GSA and SFK GSA (which are identical), they commented on 7 findings presented in the GSP, identified 3 discrepancies within the text, and offered 1 general comment.

Thank you for your letter and comments. Responses are provided below.

Finding 1 Comment
Finding 1 is in regard to groundwater flows into and out of the Subbasin and adjoining subbasins as described in Section 3.2.2 of the draft GSP. The letter states "*there is no substantial evidence to support the statements regarding groundwater flow directions out of the Subbasin to the Westside Subbasin.*"

Response: Potentiometric surface maps prepared by DWR from 1990 through 2016 clearly show that heads in the unconfined aquifer in the SFK GSA area are decreasing towards the southwest from the Subbasin into the Westside Subbasin. The winter 2014/2015 potentiometric surface map for the lower (confined) aquifer provided by Westlands in the comment letter also shows that groundwater from the SWK GSA is flowing towards the northwest towards a pumping depression southeast of Huron and to the southeast towards what appears to be a pumping center at the border between SFK GSA and SWK GSA with a contour of -160 feet. A review of the available water level elevation data for lower aquifer monitoring wells (some of it provided by Westlands) in this area of the Subbasin show between 1990 and 2016 the heads typically ranged from -100 feet to +100 feet. During this same period, wells in the Westside Subbasin typically ranged from -130 to +100 feet, generally lower than the wells in the Subbasin. A few new deep El Rico GSA wells started pumping in the 2014/2015 time range and had water level elevation in the -230 feet range, and may possibly be the source for the -160 foot contour shown on the map. However, these wells only operated in the last couple of years and are not representative of the long-term groundwater levels along the boundary between Subbasin and Westside Subbasin. In summary, there is evidence that between 1990 and 2016, the general direction of groundwater flow was from the Subbasin towards the Westside Subbasin both in the unconfined and confined aquifers.

Finding 2 Comment

The letter states *Figures 3-28b to 3-28d shows long term hydrographs for wells within the Tulare Lake Subbasin. Unfortunately, the data displayed by the hydrographs is pixelated, therefore unreviewable. Westlands GSA recommends revising the mentioned figures to display hydrographs using a higher resolution to allow the public to review.*

Response: These figures have been revised to show the hydrographs at a higher resolution.

Finding 3 Comment

Finding 3 is in regard to groundwater quality, as described in Section 3.2.5 in the draft GSP and shown on Figures 3-30 through 32. The letter states *We recommend that the draft GSP be revised to accurately convey groundwater quality data by aquifer and by the timeframe the data represents. In addition, we recommend that the groundwater quality data be reviewed for accuracy.*

Response: The groundwater quality data have been reviewed for accuracy and have been corrected where needed. Figures 3-30, 3-31, 3-32, and 3-33 have been revised to show the highest concentration of the constituents reported and the most recent concentrations. The source for the groundwater quality data used in these figures does not indicate the aquifer from which the data were collected.

Finding 4 Comment

The letter states *Figures 3-34 contains a legend that is incomplete and is unable to be reviewed. Westlands GSA recommends applying the corresponding color scheme to the vertical displacement legend to allow readers to be able to review the presented information.*

Response: The figure has been revised as recommended.

Finding 5 Comment

Finding 5 is in regard to the Sustainable Management Criteria presented in the draft GSP, specifically with respect to future water level decline. The letter states *The potential for curtailing historic underflow into the Westside Subbasin may be a substantial factor in contributing to significant and unreasonable subsidence and frustrate the Westlands' GSA ability to achieve the sustainability goal.*

Response: Thank you for your comment.

To evaluate your concern, the data developed within the draft GSP's was placed on a map showing the location of representative wells, aquifer representation, measurable objective, and

minimum thresholds. It should be noted that within the Tulare Lake GSP, there is a shallow zone above the A-Clay that is an additional aquifer that was not identified in the Westside Subbasin GSP. Thus the above E-Clay and Below E-Clay values were identified. Upon comparison for the above E-Clay designation, there are few wells in this zone in the westside basin. From the information, the data suggest that flow is from the Subbasin to the Westside Subbasin. For the below E-Clay aquifer, the data also suggest that the flow is from the Subbasin to the Westside Subbasin. So your initial suggestion that continued lowering of groundwater levels in the Tulare Lake GSP allows groundwater levels to become lower than levels established at 2015 is not supported. With the gradients that would result from these levels, it is recognized that groundwater outflow would continue to the Westside Subbasin. Per your point in your comment letter "The department shall evaluate whether a groundwater sustainability plan adversely affects the ability of an adjacent basin to implement their groundwater sustainability plan or impedes achievement of sustainability goals in an adjacent basin".

As to historical underflow that you mention in your comments, we would refer you to Figures 3-23 and 3-24. Historical groundwater flows have historically flown from the Westside Subbasin into the Subbasin. It is believed that groundwater pumping from within the Westside Subbasin has altered these flow paths and it appears that the Westlands GSP is proposing to continue this practice. As you stated, overlying and appropriative uses of groundwater within the Subbasin are entitled to legal and equitable protection against infringement by an action that deprives them of their historical inflows. More coordination is warranted between our subbasins to reach a resolution. We look forward to discussing with you more thoroughly these boundary conditions and how we might develop a solution.

Finding 6 Comment

Finding 6 is in regard to the Sustainable Management Criteria presented in the draft GSP, specifically with respect to future subsidence. The letter states *Westlands GSA is concerned that allowing subsidence rates as proposed may impact critical infrastructure such as roads, railroads, and may increase flood risks to existing land uses, especially near Corcoran where subsidence rates are critical, in the Westside Subbasin and other neighboring subbasins.*

Response: Thank you for your comment. The GSA's within the Subbasin are concerned about lowering of groundwater levels as well as land subsidence. To this end, it is recognized that land subsidence is a regional concern and based upon historical information, is thought to be a result of groundwater pumping beneath the Corcoran Clay. The historical data and model developed for the basin suggests that regionally the largest change in land subsidence is located Southeast of the Subbasin and within the Tule Subbasin. The rate of subsidence continues into the Subbasin with rates experienced in Lemoore being approximately half of the rate at the Corcoran site.

Section 4.4.1.3 has been revised to reflect this historic information and set a minimum threshold of 8 feet of subsidence at the Lemoore site. To quote from the revised GSP, "These values have been selected using historical subsidence data. There has been no information suggesting that there has been local significant damage to infrastructure in both these areas. At each five-year milestone, information from the groundwater model suggests subsidence will continue for the first five years until project and management actions are fully implemented."

Finding 7 Comment

Finding 7 is in regard to analysis in the groundwater model report presented in Appendix D of the draft GSP indicate the General Head Boundary (GHB) is driving groundwater flow out of the Westside Subbasin and into the Subbasin. The letter states *Westlands recommends reanalyzing the water level contour data from the numerical model and GSP.*

Response: The GHBs in the Westside Subbasin basically follows the boundary between Fresno and Kings Counties. The GHB heads were interpolated from water level elevation data provided by DWR and Westlands for wells near the edge of the model on both side of the county line. The resulting GHB heads have historically tended to decrease from north and southwest to a low area near the bend in the county line. The winter 2014/2015 potentiometric surface map for the lower (confined) aquifer provided by Westlands in the comment letter also shows that the water level elevation contours along the county (GHB) line are also converging towards a low area near the bend in the county line. We believe the GHBs heads utilized in the Westside Subbasin are a reasonable interpretation of historical water level elevation in the area.

Reporting Discrepancy #1

The letter states *Total lateral subsurface inflow into the Westside Subbasin shown in Figure D5-5 averages 72,296 AFY (67,347 from the Tulare Lake Subbasin and 4,948 AFY from the Kings Subbasin). Table 3-6 of the GSP shows average annual subsurface flow from the Tulare Lake Subbasin to the Westside Subbasin of 41,390. What is the source of this discrepancy?*

Response: The figure was referencing an incorrect cell and has been corrected.

Reporting Discrepancy #2

The letter states *In the graphic depicting aquifer specific fluxes in Figure D5-5, the sum of the "Net GW Flux" (which presumably is lateral subsurface flow between adjacent subbasins) totals 4,936 AFY while the total in the table shown in Figure D5-5 is 72,296 AFY. What is the source of this discrepancy?*

Response: The figure was referencing an incorrect cell and has been corrected.

Reporting Discrepancy #3

The letter states *Figure numbers in the Appendix D text do not correspond to the correct figures. Figure DS-10 is titled "Simulated Subsidence 1990-2016". Figure D5-8 shows "Groundwater Mass Balance Tule Subbasin".*

Response: The figure numbers have been corrected.

General Comment

Westlands recommended that GSA representatives from the two subbasins meet and confer at the earliest opportunity to determine whether an interbasin agreement can be reached. The agreement would be used to reach a cooperative resolution of important issues that will enable coordinated sustainable management in our GSAs.

Response: The GSAs in the Subbasin agree that efforts should be made to develop and interbasin agreement and look forward to the opportunity following submittal of the respective GSPs.

Comment I-1

In her email of October 11, 2019, Ms. Courtney made clear her opposition to the GSP and using groundwater for agriculture.

Response: Thank you for your email and comments. The comments do not pertain to the GSP's analysis. Opposition to the GSP has been noted and the email is included in full herein and will be forwarded to the DWR for consideration.

Comment I-2

The comment letter from Mr. Miguel has a number of points related to surface water supplies and the Kings River Water Association. While the letter recognizes that the GSP and GSA's have no authority, he goes on to assert that the GSP could be used to be a proponent of change and public awareness. The letter suggests that there has been an opportunity missed in the capture and use of surface water flows from the Kings River and that storage contemplated and permitted has not been fully utilized.

Response: Thank you for your letter and comments. As is recognized in the letter, the GSA's and GSP have no authority of surface water rights, diversion and beneficial uses of these rights. These surface water rights have historic origins, were initially exercised in the 1800s, predate statehood and more recently have been permitted by the State Water Resources Control Board. A watermaster has been charged with oversight of the river and assuring that the surface water diversions are in accordance with the licenses for diversion. As to your suggestion that additional

surface supplies could be utilized to offset overdraft, that is the plan. Please review Section 6.0 that identifies the projects envisioned to increased surface diversion and use. You will note that all the GSA's are planning on projects to divert and either recharge (where possible and the geologic conditions allow) or storage and reregulation of supply. These are most notable in the SFK, and El Rico, and Tri-County Water Agency GSA's. We look forward to the planning and implementation of these projects to allow for the continued farming and prosperity for the area.

Comment I-3

Mr. Toss provided a verbal comment at the Public Hearing on December 2, 2019, in which he stated that the demand reduction presented in Chapter 6 of the GSP as a management action to help achieve groundwater sustainability in the subbasin would be very damaging to Kings County and its growers. He requested that this management action be changed.

Response: Thank you for your comment. The draft GSP has been revised to remove demand management or demand reduction has a definitive programmatic action. The potential for demand management is described in Section 6.4 only as an option for the GSAs should it be needed to meet the Sustainability Goal. If implementation is necessary, the GSAs are committed to executing such programs in a cost effective manner and with the input of the local communities.

Comment I-4

Mr. Verboon is a Kings County Supervisor, but clarified that his comments were from him individually and "not on behalf of the Board of Supervisors". In his letter to the five GSAs, Mr. Verboon, on behalf of other signatories to the letter, made 3 main comments:

Comment 1: There were procedural defects that limited Kings County and its water uses in their opportunity to review and comment on the draft GSP.

Response: Thank you for your letter and comments. The GSAs understand that they have met their notice and other obligations to Kings County under Section 10728.4. The GSAs view that there were no procedural defects in the notice provided to the County. Consultation with Kings County took place at a meeting on November 6, 2019, roughly a month prior to the comment period close. Kings County chose to not submit any written or verbal comments on the draft GSP.

Comment 2: The projects presented in the draft GSP are too vague and non-committal.

Response: The draft GSP indicates that there exist a number of legal and practical uncertainties regarding project identification and adoption. Projects referenced in the draft GSP, and possibly others, will be identified and adopted by the GSAs, but only after sufficient data are collected, adequate analysis conducted, and funds are appropriated for the projects. Refer to Chapter 7 for further details on project implementation.

Comment 3: Land fallowing should be used as a demand reduction management action only as a last resort and after other demand reduction strategies and water recharge projects have been implemented.

Response: It appears that Mr. Verboon has interpreted the details of some groundwater model evaluations as planned GSA management strategies, and that is incorrect. Also, upon review, there were descriptions of land fallowing that were misleading and likely added to the confusion. These portion of the GSP have been revised. Also, the GSAs agree that supply augmentation should be a top priority for this Subbasin. Several supply augmentation projects and their implementation are described in Chapters 6 and 7.

Public Comment Letters

From: Colleen Courtney <colleencourtney66@gmail.com>

Sent: Saturday, October 12, 2019 1:01 AM

To: Colleen Courtney <colleencourtney66@gmail.com>; comments@southforkkings.org; jwyrick@jgboswell.com; kcwdh20@sbcglobal.net

Subject: GSAS-Kings County Resident STATES NO ON GROUND WATER FOR AGRICULTURAL PURPOSES!

Colleen Courtney
14234 16th Avenue
Lemoore, CA 93245-9517
Email: colleencourtney66@gmail.com

October 11,2019

To: GSAS Commissioners Board;

HELL NO! These sod Busters DO NOT DRAIN the Valleys Ground Water for their crops that ships out of State or over seas for your personal Padding Their wallets!

NOT AT this Valleys populations expense for their personal gains!

We need that water for drinking for people, animales we eat and other business endeavors other than these Sod Busters causing our lungs to fill with their crop dirt, pesticides from those dam planes or choppers that keep sprayers on to do a turns. Bull shit!

You sod Busters use your homes water well resource to water your acreages! Or drill more water wells on your own property or truck in tankers of water from the Rockies or Serras!

Or tap into your local City water line. Their water line is petty much secured source for your crop of your own choice of Occupational decision of becoming a FATCAT Farmer! At the other people's thirst expense!

We are already breathing your property's dirt and pesticides! Your surface soil covers our house and vechicals in one month! And pushing your sludge mixed with our water down that dam drive away!

I am about to phone the Sheriffs Department on that sod buster's property that constantly trespasses and squats on our property and buries everything!
We accumulated more of his farm land than he actually possesses!

These sodbusters are like city slumlords just purchased cheap property sell high, cut costs, don't maintain, rape the earth, suck it out of every earthly nutrients, minerals possible drain others water for your sole purposes to pad your wallets. And in the end abandon the worthless property your raped the hell out of. To go to another place to fu ck up for the next generation to overhaul that damage you caused in the first place!

NO GROUND WATER To SOD BUSTERS!
And SOD BUSTERS are NOT in the
AGRICULTURAL COMMUNITIES!

The Real Farmers know how to take care of the earth and would not ever think of asking people to give up their drinking water for themselves and their animals. For his crops. This Farmer would sacrifice his crops for those people when it came to water rights. And not directed by padding his wallet!

VOTE NO ON GROUND WATER! Let these sod busters truck in their water from Rockies or Serras! Just a cheap expense compared to Shipping crops to New York or Over Seas!

Cheap son of a bitches! Go dry up!

Colleen Courtney

RECEIVED K.R.C.D.

OCT 15 2019

File No. _____

South Fork Kings Groundwater Sustainability Agency
4886 E Jensen Avenue
Fresno, CA 93725

TO: SFKGSA Board Members and members of the Public.

RE: Response to SFKGSA Sustainability Plan.

I use this opportunity to respond to the South Fork Kings Groundwater Sustainability Plan. I understand that the SFKGSA is limited in its scope of responsibility and governance, however I feel the SFKGSA can become a useful proponent and informational resource for public awareness.

The primary source of groundwater recharge is the sandy bottom of the Kings River. Domestic wells, agriculture wells, groundwater dependent ecosystems, and other beneficial users are dependent upon the river's natural surface water flows to recharge underground aquifers. These surface water flows are managed by the Kings River Water Association (KRWA) whose 28 member districts receive water from a designated "point of diversion" on the Kings River. It has become common practice to divert surface water from lower stream points of diversion to upper stream diversion points to reduce what is commonly termed "channel loss". However, channel loss is also groundwater recharge. These diversions have a direct and negative impact on holders of overlying groundwater rights by diminishing groundwater recharge and adding to groundwater overdraft.

PART 1.

GROUNDWATER RIGHT HOLDERS:

SUSTAINABLE GROUNDWATER MANAGEMENT ACT: 10723.2.

"The groundwater sustainability agency shall consider the interests of all beneficial uses and users of groundwater, as well as those responsible for implementing groundwater sustainability plans. These interests include, but are not limited to, all of the following:"

(a) Holders of overlying groundwater rights, including:

(1) Agricultural users.

(2) Domestic well owners.

(b) Municipal well operators.

(c) Public water systems.

(d) Local land use planning agencies.

(e) Environmental users of groundwater.

Excerpts from CALIFORNIA WATER CODE:

§ 1706. The person entitled to the use of water by virtue of an appropriation other than under the Water Commission Act or this code may change the point of diversion, place of use, or purpose of use if others are not injured by such change...

§ 1707. (a) (1) Any person entitled to the use of water, whether based upon an appropriative, riparian, or other right, may petition the board pursuant to this chapter, Chapter 6.6 (commencing with Section 1435) or Chapter 10.5 (commencing with Section 1725) for a change for purposes of preserving or enhancing wetlands habitat, fish and wildlife resources, or recreation in, or on, the water.

Being a public entity, it is incumbent on the SFKGSA monitor and quantify the amount of groundwater recharge lost due to points of diversion changes. Further, it is an inherent responsibility of the SFKGSA to challenge any such diversions per California Water Code Sections 1706 and 1707, and by other codes sections not mentioned, and to advocate on behalf of those harmed by such diversions.

PART 2.

DECISION 1290

In 1967 the State of California State Water Rights Board issued its Decision 1290, a pivotal benchmark for Kings River water management. The following are excerpts from the Decision:

Page 16: "The primary source of all ground water in the Kings River service area is the river and its distributaries...".

Page 21: "The contracts with members of the KRWA result in the controlled release of water from these reservoirs* (Courtright, Wishon, Pine Flat) *to satisfy downstream requirements for irrigation and ground-water recharge."

Page 35-36: "...the association* (KRWA) *members have planned their overall project to take maximum advantage of all storage facilities available to them. This includes recharge of ground water and underground storage as well as the storage of flood waters in Tulare Lake Basin and maximum retention in Pine Flat Reservoir. Consulting Engineer Henry Karrer testified to the effect that under certain ideal conditions, about 2,000,000 acre-feet could be stored and regulated in Pine Flat Reservoir in any one year (RT192). He also said that up to 1,000,000 acre-feet of water could be stored in the cellular dyke system in Tulare Lake Basin (RT 192)."

This position was reaffirmed in a July 30, 2019 letter to Mitchell Moody of the State Water Resource Control Board when stating; "Decision 1290 expressly recognized the KRWA member units planned their overall project to take maximum advantage of all available storage facilities...".

Present estimate of King River Basin groundwater overdraft is 120,000 acre-feet per year, while average annual floodwater diverted to the San Joaquin River is 100,000 acre-feet. Opportunities of using Tulare Lake as a storage facility have been repeatedly missed as it has become common practice to redirect flood release water away from the ***cellular dyke system in Tulare Lake Basin*** to the San Joaquin. The beneficial use of this un-stored water is then lost to all.

It is understandable that stakeholders who would be harmed by the flooding of the Tulare Lake Basin would wish that flood release waters be diverted. The flooding of the Tulare Lake Basin would cause economic hardship to business interests. However, as noted in Decision 1290 and empirically known, the Kings River waters do naturally flow to the Tulare Lake Basin, into what is known as Tulare Lake.

It is likewise understandable that this diversion of flood release water comes at an equal price to stakeholders outside the Tulare Lake Basin. Water diverted away from the dyke system storage facility is water waisted and unused for negating groundwater overdraft and recharge. If full usage of the cellular dyke system were utilized as stated in Decision 1290, groundwater overdraft could be diminished by as much as 100,000 per year.

With SGMA deadlines approaching, stakeholders up-stream of the Tulare Lake Basin find themselves mired in a groundwater overdraft problem. They face the economic consequence of fallowed land and tax surcharges for groundwater pumping, while 100,000 acre-feet of Kings River surface water is re-routed to the San Joaquin River. Simply put; until the cellular dyke system in Tulare Lake Basin is fully utilized as intended, upstream right-holders and stakeholders a will pay the price for the problem Tulare Lake Basin interests pass on.

As stated, SFKGSA is a public entity and has an inherent responsibility to monitor, quantify and make publicly known the amount of groundwater recharge lost and the groundwater overdraft resulting from the non-use of the cellular dyke storage system as stated in Decision 1290. Additionally, it is requested that the SFKGSA study and make known the impact changes in points of diversion (Part 1) and non-use of the cellular dyke storage system in Tulare Lake Basin (Part 2) have upon groundwater recharge and overdraft prior to implementation of overdraft enforcement procedures.

Thank you for your consideration.

Bill Miguel
21425 Grangeville Blvd
Lemoore, California
October 11, 2019

The Nature Conservancy
Protecting nature. Preserving life.

CALIFORNIA WATER | **GROUNDWATER**

555 Capitol Mall, Suite 1290
Sacramento, California 95814
[916] 449-2850

nature.org
GroundwaterResourceHub.org

November 26, 2019

South Fork Kings Groundwater Sustainability Agency
4886 E. Jensen Avenue
Fresno, CA 93725
comments@southforkkings.org

Submitted online via: https://southforkkings.org/wp-content/uploads/2019/09/2019-0906-tulare-lake-subbasin-gsp-prelim-draft_for-upload.pdf

Re: Tulare Lake Subbasin Groundwater Sustainability Plan, Preliminary Draft

Dear Agency Staff,

The Nature Conservancy (TNC) appreciates the opportunity to comment on the Groundwater Sustainability Plan (GSP) for the Tulare Lake Subbasin that is being prepared under the Sustainable Groundwater Management Act (SGMA).

TNC as a Stakeholder Representative for the Environment

TNC is a global, nonprofit organization dedicated to conserving the lands and waters on which all life depends. We seek to achieve our mission through science-based planning and implementation of conservation strategies. For decades, we have dedicated resources to establishing diverse partnerships and developing foundational science products for achieving positive outcomes for people and nature in California. TNC was part of a stakeholder group formed by the Water Foundation in early 2014 to develop recommendations for groundwater reform and actively worked to shape and pass SGMA.

Our reason for engaging is simple: California's freshwater biodiversity is highly imperiled. We have lost more than 90 percent of our native wetland and river habitats, leading to precipitous declines in native plants and the populations of animals that call these places home. These natural resources are intricately connected to California's economy providing direct benefits through industries such as fisheries, timber and hunting, as well as indirect benefits such as clean water supplies. SGMA must be successful for us to achieve a sustainable future, in which people and nature can thrive within the Tulare Lake Groundwater Subbasin and California.

We believe that the success of SGMA depends on bringing the best available science to the table, engaging all stakeholders in robust dialog, providing strong incentives for beneficial outcomes and rigorous enforcement by the State of California.

Given our mission, we are particularly concerned about the inclusion of nature, as required, in GSPs. TNC has developed a suite of tools based on best available science to help Groundwater Sustainability Agencies (GSAs), consultants, and stakeholders efficiently incorporate nature into GSPs. These tools and resources are available online at

GroundwaterResourceHub.org. TNC's tools and resources are intended to reduce costs, shorten timelines, and increase benefits for both people and nature.

Addressing Nature's Water Needs in GSPs

SGMA requires that all beneficial uses and users, including environmental users of groundwater, be considered in the development and implementation of GSPs (Water Code § 10723.2).

The GSP Regulations include specific requirements to identify and consider groundwater-dependent ecosystems (GDEs) [23 CCR §354.16(g)] when determining whether groundwater conditions are having potential effects on beneficial uses and users. GSAs must also assess whether sustainable management criteria may cause adverse impacts to beneficial uses and users, which include environmental uses, such as plants and animals. TNC has identified each part of GSPs where consideration of beneficial uses and users are required. That list is available here: https://groundwaterresourcehub.org/importance-of-gdes/provisions-related-to-groundwater-dependent-ecosystems-in-the-groundwater-s. Please ensure that environmental beneficial users are addressed accordingly throughout the GSP. Adaptive management is embedded within SGMA and provides a process to work toward sustainability over time by beginning with the best available information to make initial decisions, monitoring the results of those decision, and using data collected through monitoring to revise decisions in the future. Over time, GSPs should improve as data gaps are reduced and uncertainties addressed.

To help ensure that GSPs adequately address nature as required under SGMA, TNC has prepared a checklist (**Attachment A**) for GSAs and their consultants to use. TNC believes the following elements are foundational for 2020 GSP submittals. For detailed guidance on how to address the checklist items, please also see our publication, *GDEs under SGMA: Guidance for Preparing GSPs*[1].

1. Environmental Representation

SGMA requires that GSAs consider the interests of all beneficial uses and users of groundwater. To meet this requirement, we recommend actively engaging environmental stakeholders by including environmental representation on the GSA board, technical advisory group, and/or working groups. This could include local staff from state and federal resource agencies, nonprofit organizations and other environmental interests. By engaging these stakeholders, GSAs will benefit from access to additional data and resources, as well as a more robust and inclusive GSP.

2. Basin GDE and ISW Maps

SGMA requires that GDEs and interconnected surface waters (ISWs) be identified in the GSP. We recommend using the Natural Communities Commonly Associated with Groundwater Dataset (NC Dataset) provided online[2] by the Department of Water Resources (DWR) as a starting point for the GDE map. The NC Dataset was developed through a collaboration between DWR, the California Department of Fish and Wildlife (CDFW) and TNC. We also recommend using GDE Pulse, which is also available on the internet at https://gde.codefornature.org/#/home. We also recommend using the California Natural

[1]GDEs under SGMA: Guidance for Preparing GSPs is available at: https://groundwaterresourcehub.org/public/uploads/pdfs/GWR_Hub_GDE_Guidance_Doc_2-1-18.pdf

[2] The Department of Water Resources' Natural Communities Commonly Associated with Groundwater dataset is available at: https://gis.water.ca.gov/app/NCDatasetViewer/

Diversity Database (CNDDB) provided by CDFW to look up species occurrences within your area.

3. Potential Effects on Environmental Beneficial Users

SGMA requires that potential effects on GDEs and environmental surface water users be described when defining undesirable results. In addition to identifying GDEs in the basin, TNC recommends identifying beneficial users of surface water, which include environmental users. This is a critical step, as it is impossible to define "significant and unreasonable adverse impacts" without knowing *what* is being impacted. For your convenience, we've provided a list of freshwater species within the boundary of the Tulare Lake Groundwater Subbasin (Subbasin) in **Attachment C**. Our hope is that this information will help your GSA better evaluate the impacts of groundwater management on environmental beneficial users of surface water. We recommend that after identifying which freshwater species exist in your basin, especially federal- and state-listed species, that you contact staff at CDFW, United States Fish and Wildlife Service (USFWS) and/or National Marine Fisheries Services (NMFS) to obtain their input on the groundwater and surface water needs of the organisms on the GSA's freshwater species list. We also refer you to the Critical Species Lookbook[3] prepared by TNC and partner organizations for additional background information on the water needs and groundwater reliance of critical species. Since effects to plants and animals are difficult and sometimes impossible to reverse, we recommend erring on the side of caution to preserve sufficient groundwater conditions to sustain GDEs and ISWs.

4. Biological and Hydrological Monitoring

If sufficient hydrological and biological data in and around GDEs is not available in time for the 2020/2022 plan, data gaps should be identified along with actions to reconcile the gaps in the monitoring network.

TNC has reviewed the Tulare Lake Preliminary Draft GSP and appreciates the use of some our relevant resources in addressing GDE-related topics. However, we consider it to be **inadequate** under SGMA since key environmental beneficial uses and users are not adequately identified and considered. In particular, 1) ISWs and GDEs are not adequately identified and evaluated for ecological importance or adequately considered in the basin's sustainable management criteria, and 2) connectivity and extent of the of ISWs and GDEs with the shallow / perched zones of the unconfined / semiconfined aquifer were not characterized. **Please present a more thorough analysis of the 1) connectivity of the shallow and perched portions of the unconfined aquifer, 2) extent of the perched and shallow areas within the aquifer, and 3) identification and evaluation of ISWs and GDEs in subsequent drafts of the GSP. Once potential GDEs and ISWs are identified, they must be considered when defining undesirable results and evaluated for further monitoring needs until data gaps are filled in the future. If they are not adequately defined, then they need to be identified as a data gap in the interim.**

Our specific comments related to the Tulare Lake GSP are provided in detail in **Attachment B** and are in reference to the numbered items in **Attachment A. Attachment C** provides a list of the freshwater species located in the Subbasin. **Attachment D** describes six best practices that GSAs and their consultants can apply when using local groundwater data to confirm a connection to groundwater for DWR's NC Dataset. **Attachment E** provides an overview of a new, free online tool (i.e., GDE Pulse) that allows GSAs to assess changes in GDE health using satellite, rainfall, and groundwater data.

[3] Available online at: https://groundwaterresourcehub.org/sgma-tools/the-critical-species-lookbook/

Thank you for fully considering our comments as you develop your GSP.

Best Regards,



Sandi Matsumoto
Associate Director, California Water Program
The Nature Conservancy

Attachment A

Environmental User Checklist

The Nature Conservancy is neither dispensing legal advice nor warranting any outcome that could result from the use of this checklist. Following this checklist does not guarantee approval of a GSP or compliance with SGMA, both of which will be determined by DWR and the State Water Resources Control Board.

GSP Plan Element*		GDE Inclusion in GSPs: Identification and Consideration Elements	Check Box
Admin Info	**2.1.5 Notice & Communication** *23 CCR §354.10*	**Description of the types of environmental beneficial uses of groundwater that exist within GDEs and a description of how environmental stakeholders were engaged throughout the development of the GSP.**	1
Planning Framework	**2.1.2 to 2.1.4 Description of Plan Area** *23 CCR §354.8*	**Description of jurisdictional boundaries, existing land use designations, water use management and monitoring programs; general plans and other land use plans relevant to GDEs and their relationship to the GSP.**	2
		Description of instream flow requirements, threatened and endangered species habitat, critical habitat, and protected areas.	3
		Summary of process for permitting new or replacement wells for the basin, and how the process incorporates any protection of GDEs	4
Basin Setting	**2.2.1 Hydrogeologic Conceptual Model** *23 CCR §354.14*	**Basin Bottom Boundary:** Is the bottom of the basin defined as at least as deep as the deepest groundwater extractions?	5
		Principal aquifers and aquitards: Are shallow aquifers adequately described, so that interconnections with surface water and vertical groundwater gradients with other aquifers can be characterized?	6
		Basin cross sections: Do cross-sections illustrate the relationships between GDEs, surface waters and principal aquifers?	7
	2.2.2 Current & Historical Groundwater Conditions *23 CCR §354.16*	**Interconnected surface waters:**	8
		Interconnected surface water maps for the basin with gaining and losing reaches defined (included as a figure in GSP & submitted as a shapefile on SGMA portal).	9
		Estimates of current and historical surface water depletions for interconnected surface waters quantified and described by reach, season, and water year type.	10
		Basin GDE map included (as figure in text & submitted as a shapefile on SGMA Portal).	11

		If NC Dataset *was* used:	Basin GDE map denotes which polygons were kept, removed, and added from NC Dataset (Worksheet 1, can be attached in GSP section 6.0).	12
			The basin's GDE shapefile, which is submitted via the SGMA Portal, includes two new fields in its attribute table denoting: 1) which polygons were kept/removed/added, and 2) the change reason (e.g., why polygons were removed).	13
			GDEs polygons are consolidated into larger units and named for easier identification throughout GSP.	14
		If NC Dataset *was not* used:	Description of why NC dataset was not used, and how an alternative dataset and/or mapping approach used is best available information.	15
		Description of GDEs included:		16
		Historical and current groundwater conditions and variability are described in each GDE unit.		17
		Historical and current ecological conditions and variability are described in each GDE unit.		18
		Each GDE unit has been characterized as having high, moderate, or low ecological value.		19
		Inventory of species, habitats, and protected lands for each GDE unit with ecological importance (Worksheet 2, can be attached in GSP section 6.0).		20
	2.2.3 Water Budget *23 CCR §354.18*	Groundwater inputs and outputs (e.g., evapotranspiration) of native vegetation and managed wetlands are included in the basin's historical and current water budget.		21
		Potential impacts to groundwater conditions due to land use changes, climate change, and population growth to GDEs and aquatic ecosystems are considered in the projected water budget.		22
Sustainable Management Criteria	**3.1 Sustainability Goal** *23 CCR §354.24*	**Environmental stakeholders / representatives were consulted.**		23
		Sustainability goal mentions GDEs or species and habitats that are of particular concern or interest.		24
		Sustainability goal mentions whether the intention is to address pre-SGMA impacts, maintain or improve conditions within GDEs or species and habitats that are of particular concern or interest.		25
	3.2 Measurable Objectives *23 CCR §354.30*	**Description of how GDEs were considered and whether the measurable objectives and interim milestones will help achieve the sustainability goal as it pertains to the environment.**		26
	3.3 Minimum Thresholds *23 CCR §354.28*	**Description of how GDEs and environmental uses of surface water were considered when setting minimum thresholds for relevant sustainability indicators:**		27
		Will adverse impacts to GDEs and/or aquatic ecosystems dependent on interconnected surface waters (beneficial user of surface water) be avoided with the selected minimum thresholds?		28
		Are there any differences between the selected minimum threshold and state, federal, or local standards relevant to the species or habitats residing in GDEs or aquatic ecosystems dependent on interconnected surface waters?		29
	3.4 Undesirable Results *23 CCR §354.26*	**For GDEs, hydrological data are compiled and synthesized for each GDE unit:**		30
		If hydrological data *are available* within/nearby the GDE	Hydrological datasets are plotted and provided for each GDE unit (Worksheet 3, can be attached in GSP Section 6.0).	31
			Baseline period in the hydrologic data is defined.	32

			GDE unit is classified as having high, moderate, or low susceptibility to changes in groundwater.	33
			Cause-and-effect relationships between groundwater changes and GDEs are explored.	34
		If hydrological data *are not available* within/nearby the GDE	Data gaps/insufficiencies are described.	35
			Plans to reconcile data gaps in the monitoring network are stated.	36
		For GDEs, biological data are compiled and synthesized for each GDE unit:		37
		Biological datasets are plotted and provided for each GDE unit, and when possible provide baseline conditions for assessment of trends and variability.		38
		Data gaps/insufficiencies are described.		39
		Plans to reconcile data gaps in the monitoring network are stated.		40
		Description of potential effects on GDEs, land uses and property interests:		41
		Cause-and-effect relationships between GDE and groundwater conditions are described.		42
		Impacts to GDEs that are considered to be "significant and unreasonable" are described.		43
		Known hydrological thresholds or triggers (e.g., instream flow criteria, groundwater depths, water quality parameters) for significant impacts to relevant species or ecological communities are reported.		44
		Land uses include and consider recreational uses (e.g., fishing/hunting, hiking, boating).		45
		Property interests include and consider privately and publicly protected conservation lands and opens spaces, including wildlife refuges, parks, and natural preserves.		46
Sustainable Management Criteria	**3.5 Monitoring Network** *23 CCR §354.34*	Description of whether hydrological data are spatially and temporally sufficient to monitor groundwater conditions for each GDE unit.		47
		Description of how hydrological data gaps and insufficiencies will be reconciled in the monitoring network.		48
		Description of how impacts to GDEs and environmental surface water users, as detected by biological responses, will be monitored and which GDE monitoring methods will be used in conjunction with hydrologic data to evaluate cause-and-effect relationships with groundwater conditions.		49
Projects & Mgmt Actions	**4.0. Projects & Mgmt Actions to Achieve Sustainability Goal** *23 CCR §354.44*	Description of how GDEs will benefit from relevant project or management actions.		50
		Description of how projects and management actions will be evaluated to assess whether adverse impacts to the GDE will be mitigated or prevented.		51

* In reference to DWR's GSP annotated outline guidance document, available at: https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/GD_GSP_Outline_Final_2016-12-23.pdf

Attachment B

TNC Evaluation of the
Tulare Lake Subbasin Groundwater Sustainability Plan, Preliminary Draft

A complete draft of the Tulare Lake Subbasin GSP is available at https://southforkkings.org/wp-content/uploads/2019/09/2019-0906-tulare-lake-subbasin-gsp-prelim-draft_for-upload.pdf for public review and comment and is dated August 2019. This attachment summarizes our comments on the complete public draft GSP. Comments are provided in the order of the checklist items included as Attachment A.

Checklist Item 1 - Notice & Communication (23 CCR §354.10)

[Section 2.5.3 Beneficial Uses and Users (p. 2-28)]

- The flow chart on p. 2-28 shows the engagement process with groundwater users during the development and implementation of the GSP. Table 2-4 (pp. 2-47 to 2-49) identifies all the beneficial uses and users of groundwater within the Subbasin by GSA in greater detail, but does not include environmental uses and users. Users identified include agricultural, public water systems, domestic well owners, municipal water systems, planning agencies, Native American Tribes, Disadvantaged Communities, monitoring entities, and surface water users (as represented by GSA members). California Water Code §1305(f) defines that beneficial uses of waters of the State include "preservation and enhancement of fish, wildlife, and other aquatic resources and preserves". **Please expand Table 2-4 to include environmental uses and users that are present in the Subbasin, such as:**
    - **ecological areas; preserves; potential ISWs and GDEs; managed wetlands;**
    - **Protected Lands, including conservation areas; and**
    - **Public Trust Uses including wildlife, aquatic habitat, fisheries, and recreation.**

Checklist Items 2 to 4 - Description of the Plan Area (23 CCR §354.8)

[Section 2.0 Plan Area (pp. 2-1 to 2-2)]

- The types and locations of environmental uses, species and habitats supported, and the designated beneficial environmental uses and users of surface waters that may be affected by groundwater extraction in the Subbasin should be specified in the section and in Table 2-4. **Please elaborate on the "surface water uses and users" by identifying the environmental uses and users of surface water for all GSAs in Table 2-4. Please explicitly identify the environmental users and take particular note of the species with protected status and any critical habitat that exists within the Subbasin.** The following are resources that can be used:
    - Natural Communities Commonly Associated with Groundwater dataset (NC Dataset) - https://gis.water.ca.gov/app/NCDatasetViewer/

    - The list of freshwater species located in the Tulare Lake Subbasin in Attachment C of this letter.
    - The California Department of Fish and Wildlife's California Natural Diversity Database (CNDDB) for species occurrences.
    - The USFWS's Environmental Conservation Online System (ECOS) for mapping critical habitat, wildlife and contaminants - https://ecos.fws.gov/ecp/
- The GSP addresses state and federal land ownership to some degree, but there is no mention of uses related to open space areas, managed wetlands, natural preserve areas, or other protected lands that contain natural resources. Per the USFWS ECOS website the Kern National Wildlife Refuge Complex, Tulare Basin Wildlife Management Area (on southern boundary), and Pixley National Wildlife Refuge (to the east of Highway 43) abut the GSP area. Within these areas there is critical habitat mapped for the Buena Vista Lake ornate shrew (*Sorex ornatus relictus*) near the Lemoore Naval Air Station and in the Kern National Wildlife Refuge, and the vernal pool fairy shrimp (*Branchinecta lynchyi*) in the Pixley National Wildlife Refuge. These habitat areas or species are not addressed in the description of the plan area, nor are sensitive habitats within the plan area acknowledged.
    - **Please identify the natural resources within the plan area and elaborate on any and all state, federal or other land ownership that exists within the plan area that provide protection of natural resources.**
    - **Please address how the GSP will address natural resource management on a regional scale since management within the GSP could affect neighboring sensitive resources.**
- The GSP goes on to state on p. 2-2 that the primary land use designations are for agricultural, urban, residential, commercial and industrial lands; however, the figure on that page shows riparian vegetation and water surface land use classifications that amount to more than residential and semi-agricultural. **Please revise the statement concerning primary land use designations to accurately reflect the percentages on the chart (i.e., agricultural, urban, riparian vegetation, water surface, etc.). Please identify the natural resources within the plan area and elaborate on any and all state, federal or other land ownership that exists within the plan area that provide protection of natural resources.**
- On page 2-2, it is stated that it was not possible to differentiate types of well uses between irrigation and domestic extractors because DWR does not have that data. However, these data are available on well completion reports which may be accessed on line through the GeoTracker GAMA website (https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/Default.asp). This is the approach taken in almost every other GSP we have reviewed and is an important distinction of use as it relates to prioritization of project needs and management decisions. **Please either address this issue or identify this as a data gap to reconcile in the 5-year GSP update.**

[Section 2.1 Summary of Jurisdictional Areas and Other Features (pp. 2-3 to 2-10)]

- The Plan summarizes the GSP Area and describes the jurisdictional areas and entities of the GSAs, but does not say anything about the jurisdictional areas of the resource agencies. **Please elaborate on the jurisdictional areas of the resource agencies and what resources they are in place to protect.**
- With exception of a short description of the Kings River Fisheries Management Program in Section 2.2.2.4, the GSP does not provide a description of other instream flow requirements, if any, or how the water infrastructure is in compliance with regulatory requirements set to protect species of concern. **Please provide a description of any current and planned instream flow requirements for Tulare Subbasin streams / rivers including Kings, Tule, White, Kaweah, and St. John's Rivers; and undammed streams including Deer, Dry, Mill, Cottonwood, and Poso Creeks. If there are no other instream flow requirements in place or planned, then please state that in the document.**

[Section 2.2.1 Monitoring and Management Programs (pp. 2-11 to 2-12)]

- This section addresses the water resources management actions that are being undertaken to monitor groundwater level, extraction and quality; subsidence; irrigated lands; and surface water. Management of natural resources is not considered in this section but should be described in order to provide a context for how groundwater management actions will be coordinated with environmental requirements to prevent undesirable results. **Please include a description of the natural resource management and monitoring programs occurring within the GSP area that affects instream, wetland and riparian ecosystems that have the potential to be groundwater dependent (i.e., interconnected surface water [ISWs] and groundwater dependent ecosystems [GDEs]).**

[Section 2.3 Relation to General Plans (pp. 2-14 to 2-17)]

- The GSP includes a very short description of the general plans within the GSP area but fails to specifically elaborate on the goals and policies outlined in the plans, and how the GSP will fit in with or affect the general plans' goals and policies related to the protection and management of GDEs, ISWs and aquatic resources that could be affected by groundwater withdrawals. **Please include a discussion of how implementation of the GSP may affect and be coordinated with General Plan policies and procedures regarding the protection of wetlands, aquatic resources, other GDEs and ISWs, and related threatened or endangered species.**
- This section should identify other land use plans, including Habitat Conservation Plans (HCPs) or Natural Community Conservation Plans (NCCPs) within the Subbasin and if they are associated with areas with instream flow requirements; or critical, GDE or ISW habitats. **Please identify all relevant HCPs and NCCPs within the Subbasin, and any reaches with instream flow and critical habitat requirements. Please elaborate on the natural resources within the Subbasin and address how GSP implementation will coordinate with the**

goals of these plans and requirements. If there are no HCPs, NCCPs, or preservation areas that could be affected, then that should be stated. The Critical Species Lookbook[4] includes the potential groundwater reliance of critical species in the basin. **Please include a discussion regarding the management of critical species and their habitats for these aquatic ecosystems and its relationship to the GSP.**

- **Please describe how the GSP will coordinate with the General Plan elements within the GSP area. Specifically, please elaborate on conservation, recreation and open space elements.**
- This section states (p. 2-15) that "It is considered unlikely that any Kern County General Plan Policies have any practical relevance to the plan area". The Kern National Wildlife Refuge Complex abuts the GSP area and it is difficult to understand that the General Plan for Kern County does not address habitat concerns and conservation that could be directly or indirectly affected by potential groundwater management actions within and adjacent to the Kern Subbasin. **Please 1) elaborate on the Kern County General Plan's conservation elements, 2) how the Tulare Lake Subbasin's GSP will comply with or not impact conservation elements being employed within protected habitat areas adjacent to the Tulare Subbasin, and 3) expand this conversation to include other neighboring habitat areas, such as Pixley National Wildlife Refuge.**

[Section 2.3.4 Permitting Process for New or Replacement Wells (pp. 2-17 to 2-19)]

- This section summarizes well permitting requirements and county ordinances for the counties of Kings, Kern and Tulare. **Please include a discussion of the following in this section:**
    - Future well permitting must be coordinated with the GSP to assure achievement of the Plan's sustainability goals.
    - How the well permitting process incorporates protection of GDEs within the Subbasin.
    - The State Third Appellate District recently found that Counties have a responsibility to consider the potential impacts of groundwater withdrawals on public trust resources when permitting new wells near streams with public trust uses (ELF v. SWRCB and Siskiyou County, No. C083239). **The need for well permitting programs to comply with this requirement should be stated in the text.**

<u>Checklist Items 5 to 7 – Hydrogeologic Conceptual Model (23 CCR §354.14)</u>

[Section 3.1.7 Definable Bottom of the Basin (pp. 3-16 to 3-19)]

- The GSP uses two methods (Water Quality and Geologic) to define the bottom of the basin but which method, or combination of the methods, that is being relied on for this GSP is not clearly stated. **Please explicitly state the final decision on how the bottom of the basin was determined, and what it was determined to be.**

[4] Available online at: https://groundwaterresourcehub.org/sgma-tools/the-critical-species-lookbook/

- Defining the bottom of the Subbasin based on geochemical properties is a suitable approach for defining the base of freshwater, however, as noted on page 9 of DWR's Hydrogeologic Conceptual Model BMP (https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_HCM_Final_2016-12-23.pdf) "the definable bottom of the basin should be at least as deep as the deepest groundwater extractions". **Thus, groundwater extraction well depth data should also be included in the determination of the basin bottom.** This will prevent the possibility of extractors with wells deeper than the basin boundary (defined by the base of freshwater) from claiming exemption of SGMA due to their well residing outside the vertical extent of the basin boundary. **Please characterize groundwater well extractions from the deepest wells in relation to defining the basin bottom**.

[Section 3.1.8 Hydrogeologic Setting: Principal Groundwater Aquifers and Aquitards (pp. 3-19 to 3-23)]

- Although there is robust description of the confined (lower) and unconfined / semi-confined (upper) aquifers there is no explicit description with supporting data and information of how groundwater above the A- and C-clays in the upper aquifer interacts with the unconfined aquifer, or is influenced by pumping in the unconfined portion of the upper aquifer. DWR's definition of a principal aquifer, is defined as an "aquifer or aquifer system that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems" [*23 CCR §351(aa)*]. These shallow and perched areas within the upper aquifer range from near surface to 30 feet below ground surface (bgs) (Figure 3-17, p. 3-74) and likely provide water supply to GDEs and ISWs. As such, they yield significant quantities of groundwater to surface water systems and beneficial users, and should not be dismissed because they do not yield groundwater for human use. **Please expand the description of the upper aquifer to include the interaction of the unconfined and shallow areas of the upper aquifer. Include cross-sections to show their connectivity and relationship to potential ISWs and GDEs.**
- Regional geologic cross sections are provided in Figures 3-14a, 3-14b and 3-14c (pp. 3-69 to 3-71). These cross-sections do not include a graphical representation of the shallow groundwater-bearing zones that may be connected to GDEs and ISWs in the GSP area, and how they are connected to the upper aquifer system. **Please include example near-surface cross section details that depict the conceptual understanding of shallow groundwater and stream interactions at different locations, including the shallow zones, any perched aquifers, and the unconfined / semi-confined upper aquifer**.
- Based on the information provided in the GSP, it appears that the confined lower aquifer is being considered a principal aquifer because of the large amount of consumption for agriculture and municipal water supply, but this is not explicitly stated. The unconfined / semi-confined aquifer is stated to have limited use because of water quality. On pages 3-18 and 3-19, there is a discussion of water quality and although water with TDS higher than 3,000 is not considered suitable for water supply or most agriculture, it is potentially suitable for livestock and production of crops with higher tolerance to salinity. Conversely, in Section 3.1.11 (pages 3-25

and 3-26), the GSP states that the upper aquifer is primarily used for domestic and municipal supplies, and agricultural pumping does occur in the deeper portion of the upper aquifer. Also, if water in the unconfined aquifer is significantly supporting GDEs and ISWs, production of salt tolerant crops, or livestock operations, then it should also be identified as a principal aquifer. Even if ultimately the GSA doesn't define shallow groundwater as a principal aquifer, the text indicates current or future use that could impact ISWs and GDEs. **Thus, disregarding this shallow groundwater as a principal aquifer due to its water quality is not supported by the data and is inadequate.** SGMA requires GSAs to sustainably manage groundwater resources in all aquifers, especially if groundwater use and management can result in impacts to beneficial uses and users. Please refer to Best Practice #1 in Attachment D for further explanation and accompanying graphics. **Please explicitly enumerate the principal aquifer(s) and intervening aquitards, their relationship to each other, and their role in supplying groundwater to all beneficial uses and users of groundwater (including environmental).**

[Section 3.2 Groundwater Conditions (pp. 3-26 to 3-28)]

- Groundwater elevation contours are shown for 1905-1907, 1952, 1990, 1995, 2000, 2005, 2010 and 2016 on Figures 3-24 through 3-27 with respect to mean sea level. However, the wells used to contour groundwater levels in the upper aquifer do not necessarily monitor shallow or perched groundwater that may be in communication with GDEs and ISWs. In addition, depth to groundwater cannot be readily assessed from the maps because they are presented with respect to sea level. **Please provide the following:**
    1) **Groundwater level contour maps representative of the uppermost aquifer where GDEs and ISWs may be reliant. If this data does not exist, then identify it as a data gap that will be addressed in the GSP when the GSP is updated.**
    2) **Depth to water contour maps that allow interpretation of beneficial groundwater uses by environmental users.**
    3) **If these data are not available, please identify this as a data gap and outline measures to address the data gap in subsequent sections of the GSP.**

[Section 3.2.5 Groundwater Quality (pp. 3-30 to 3-31)]

- There is water quality information for the upper aquifer and a statement that increases in TDS concentrations, arsenic, nitrate and volatile organic chemicals (VOCs) are largely due to agricultural practices and pumping, but there is no information regarding water quality of the perched water or other areas of the upper aquifer to understand how water quality may affect GDEs, ISWs and associated aquatic species. **Please modify this section of the GSP to include data about water quality in the zones where GDEs are present. If there are no data available, then please recognize this as a data gap and specify that additional data will be collected and analyzed for the GSP update.**

Checklist Items 8 to 10 – Interconnected Surface Waters (ISWs) (23 CCR §354.16)

[Figure 3.1.10 Groundwater Recharge and Discharge Areas (p. 3-25)]

- The text states that "Some discharge is impacted by direct soil evaporation and evapotranspiration, particularly in areas where groundwater is less than 10 feet bgs." Elsewhere the text states that agricultural drainage must be provided in some areas, indicating very shallow groundwater, or makes reference to deeper groundwater levels of about 30 feet for groundwater above the A-Clay. Earlier in this comment letter we pointed out the discrepancy between the various shallow groundwater levels that are presented (see Section 3.2 Groundwater Conditions [pp. 3-26 to 3-28]). This GSP also states that riparian and emergent marsh ecosystems are prevalent in certain areas where they have not already been degraded by land development. **Please 1) rectify the discrepancies in groundwater levels, particularly as they pertain to ISWs and GDEs; and 2) include the locations of phreatophytes and other GDEs to provide a complete representation of evapotranspiration within all groundwater discharge areas. If the regional groundwater connection of phreatophytes and other GDEs is not known, 1) please identify this data gap, 2) provide an approach to address it, and 3) include the ISWs and GDEs as potential features on a figure until they can be more conclusively evaluated.**

[Section 3.2.8 Interconnected Surface Water and Groundwater Systems (pp. 3-33 to 3-34)]

- The regulations [23 CCR §351(o)] define ISWs as "surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted". "At any point" has both a spatial and temporal component. Even short durations of interconnections of groundwater and surface water can be crucial for surface water flow and supporting environmental users of groundwater and surface water. ISWs can be either gaining or losing. The GSP disregards IWSs by stating that hydrologic conditions have been so altered that the ISWs that were historically connected are not any longer. There are inconsistencies throughout this GSP in regard to ISWs. The GSP states:
    - Section 3.1.10 (p. 3-25, also see the comment directly above): "Groundwater recharge in the Subbasin occurs primarily by two methods: 1) infiltration of surface water from the Kings River and unlined conveyances; and 2) infiltration of applied water for irrigation of crops." **ISWs can be either gaining or losing (see the definition above). If recharge primarily occurs through infiltration from rivers and streams, then these features must be included as an ISW with gaining and losing reaches defined on a map.**
    - Section 3.2.8 (p. 34): "A persistent, shallow perched water table at a depth of about 30 feet bgs is often present above the A-clay in the vicinity of surface water conveyances and below recharge facilities; however, this shallow perched zone is disconnected from the regional unconfined aquifer. Other localized shallow perched zones may exist elsewhere in the Subbasin, but these are not considered a significant source of groundwater." Section 3.1.8

states (p. 3-21) that the perched water is as shallow as 15 feet in some areas, and the groundwater elevation contour maps show it ranging from 0-20 feet AMSL. Data to support the claims about the nature of the perched aquifers is conflicting and the claims that perched units are disconnected or insignificant are not supported by data. **Please clarify the discrepancy between groundwater depths reported for the shallow perched water table that are provided in the text and on figures. If the location and size of other shallow perched zones is unknown, this information needs to be identified as a data gap, rather than a reason to completely disregard the features.** It is inadequate to assume that shallow perched zones are not a significant source of groundwater if they have not been fully characterized, and could be a significant source for GDEs and ISWs. **Please reconcile data gaps (shallow monitoring wells, stream gauges, and nested/clustered wells) along surface water features in the Monitoring Network section of the GSP to improve identification of ISWs prior to disregarding them in the GSP.**

Checklist Items 11 to 15 – Identifying and Mapping GDEs (23 CCR §354.16)

[Section 3.2.8.1 Groundwater Dependent Ecosystems (GDEs) (p. 3-34 to 3-35)]

- The text states (p. 3-35): "Groundwater pumping from the principal aquifer system is not likely to impact the occurrence of perched groundwater because the two systems are separated by the A-Clay aquitard. Perched groundwater above the A-Clay is not directly interconnected with the underlying unconfined / semiconfined aquifer in that pumping from the unconfined / semiconfined aquifer does not induce increased leakage through the A-Clay aquitard." This statement is not supported by the data provided in the GSP (see comments above) and is not a valid reason to disregard potential GSPs without further evidence. The A-Clay is reported to vary significantly in thickness and to contain permeable sands in some locations. **Please:**
    1) **Explicitly identify the principal aquifers;**
    2) **Provide data regarding the competence of the A-Clay as an aquitard**
    3) **Evaluate the potential degree of connection between the perched and unconfined aquifer based on objective data;**
    4) **Acknowledge the extent of the perched aquifers throughout the Subbasin as a data gap;**
    5) **Address data gaps associated with the interconnectivity with the unconfined / semiconfined aquifer to be reconciled in the GSP update; and**
    6) **Acknowledge the potential for GDEs and ISWs to be dependent on these groundwater resources.**
- Although this GSP did use the NCCAG database to preliminarily identify GDEs (p. 3-34), all were disregarded without acknowledgment of data gaps and further characterization of the natural communities in association with potential perched aquifers, and disparities in groundwater levels that have not yet been characterized. This evaluation potentially misses GDEs due to the potential for GDEs to utilize the

shallow and perched areas of the unconfined / semi-confined aquifer. The following comments apply:

- While depth to groundwater levels within 30 feet are generally accepted as being a proxy for deciding if polygons in the NC dataset are connected to groundwater, it is highly advised that seasonal and interannual groundwater fluctuations in the groundwater regime are taken into consideration. Utilizing groundwater data from one point in time or during a discrete season can misrepresent groundwater levels required by GDEs, and inadvertently result in adverse impacts to the GDEs. Based on a study we recently submitted to *Frontiers in Environmental Science*, we've observed riparian forests along the Cosumnes River to experience a range in groundwater levels between 1.5 and 75 feet over seasonal and interannual timescales. Seasonal fluctuations in the regional water table can support perched groundwater near an intermittent river that seasonally runs dry due to such fluctuations. While perched groundwater itself cannot directly be managed due to its position in the vadose zone, the water table position within the regional aquifer (via pumping rate restrictions, restricted pumping at certain depths, restricted pumping around GDEs, well density rules, etc.) and its interactions with surface water (e.g., timing and duration) can be managed to prevent adverse impacts to ecosystems due to changes in groundwater quality and quantity under SGMA. **We highly recommend using depth to groundwater data from multiple seasons and water year types (e.g., wet, dry, average, drought) to determine the range of depth to groundwater around NC dataset polygons. Please refer to Attachment D of this letter for best practices for using local groundwater data to verify whether polygons in the NC Dataset are supported by groundwater in an aquifer. If insufficient data are available to describe groundwater conditions within or near polygons from the NC dataset seasonally and interannually, or to determine conclusively whether shallow groundwater is hydraulically connected (directly or indirectly) to underlying aquifers, include those polygons in the GSP until data gaps are reconciled in the monitoring network, and include specific measures and time tables to address the data gaps.**
- If there are insufficient groundwater level data in the shallow and perched zones, then the NCCAGs in these areas should be included as GDEs in the GSP until data gaps are reconciled in the monitoring network. **Confirmation of GDEs should be based on depth to groundwater in the shallow and perched areas. Please revise the GDE analysis in the GSP to include a complete analysis and identification of data gaps.**
- **Please provide depth to groundwater contour maps and note the following best practices for doing so:**
  - Are the wells used for interpolating depth to groundwater sufficiently close (<5km) to NC Dataset polygons to reflect local conditions relevant to ecosystems?

- Are the wells used for interpolating depth to groundwater screened within the surficial unconfined aquifer and capable of measuring the true water table?
- Is depth to groundwater contoured using groundwater elevations at monitoring wells to get groundwater elevation contours across the landscape? This layer can then be subtracted from land surface elevations from a Digital Elevation Model (DEM) to estimate depth-to-groundwater contours across the landscape. This will provide much more accurate contours of depth to groundwater along streams and other land surface depressions where GDEs are commonly found. Depth to groundwater contours developed from depth to groundwater measurements at wells assumes that the land surface is constant, which is a poor assumption to make. It is better to assume that water surface elevations are constant in between wells, and then calculate depth to groundwater using a DEM of the land surface to contour depth to groundwater.

o Groundwater requirements of GDEs vary with vegetation types and rooting depths. In identifying GDEs, care should be taken to consider rooting depths of vegetation. **Please indicate what vegetation is present in the potential GDEs, and whether the GDE was eliminated or retained based solely on a specified depth limit.** While Valley Oak (*Quercus lobata*) have been observed to have a maximum rooting depth of ~24 feet (https://groundwaterresourcehub.org/gde-tools/gde-rooting-depths-database-for-gdes/), rooting depths vary spatially and temporally based on local hydrologic conditions. Also, maximum rooting depths do not take capillary action into consideration, which will vary with soil type and is an important consideration since woody phreatophytes generally do not prefer to have their roots submerged in groundwater for extended periods of time, and hence effectively redistribute their root systems to straddle the water table as it fluctuates. Hence, many riparian, floodplain and desert ecosystem species are highly capable of accessing groundwater at much deeper depths when needed.

o Rohde, Froend and Howard (2017) acknowledged GDEs as ecosystems that can rely on groundwater for some or all their requirements. This publication can be found at: https://ngwa.onlinelibrary.wiley.com/doi/pdf/10.1111/gwat.12511. GDEs can rely on multiple water sources simultaneously and at different temporal and / or spatial scales (e.g., precipitation, river water, reservoir water, soil moisture in the vadose zone, groundwater, applied water, treated wastewater effluent, urban stormwater, irrigated return flow). SGMA (Section 351.0) defines GDEs as "ecological communities and species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface". **Hence, we recommend using depth to groundwater contour maps derived from subtracting groundwater levels from a DEM, as described above, to identify whether a connection to groundwater exists for the wetlands mapped in Figure 3-38 in the Subbasin.**

Please refer to Attachments D and E of this letter for best practices for using local groundwater data to 1) verify whether polygons in the NC Dataset are supported by groundwater in an aquifer, and 2) verify ecosystem decline or recovery is correlated with groundwater levels.

- The GSP states (p. 3-35), "Most of these vegetation types/plant species [identified in the NCCGA] are associated with riparian habitat that rely on surface water", and goes on to disregard them because they are primarily located on the perched areas above the A-Clay layer and the " A-Clay is not directly interconnected with the underlying unconfined / semi-confined aquifer". Section 354.16 of the California Code of Regulations states that "each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes…GDEs". Just because GDEs are thought to rely on surface water and the perched areas are thought to not be directly connected to the unconfined aquifer, does not make them insignificant to the environment. Many data gaps exist that could clarify these statements, for example: 1) indirect and direct connection of perched aquifers have not been fully characterized, 2) the location and extent of perched areas have not been fully characterized, and 3) species composition and potential max rooting depths have not be tabulated. Many rare and protected species reside in GDEs since they are very unique ecosystems. **Please provide further information on the analysis of GDEs and potential ISWs, including citing field studies or modeling studies that show the hydrologic nature of these systems. Specifically indicate 1) which streams and GDE polygons were excluded, 2) identify any data gaps, and 3) ensure that GDE polygons are retained until data gaps are reconciled.**

Checklist Items 16 to 20 - Describing GDEs (23 CCR §354.16)

[Section 3.2.8.1 Groundwater Dependent Ecosystems (GDEs) (p. 3-34 to 3-35)]

- **Please provide information on the historical or current groundwater conditions specifically near the GDEs or the ecological conditions present**. **If data gaps exist, please acknowledge them and state how they may be reconciled in the future.** Refer to GDE Pulse (https://gde.codefornature.org; See Attachment E of this letter for more details) or any other locally available data (e.g., leaf area index, evapotranspiration or other data) to describe depth to groundwater trends in and around GDE areas, as well as trends in plant growth (e.g., NDVI) and plant moisture (e.g., NDMI). Below is a screenshot example of data available in GDE Pulse for NC dataset polygons found in the Tulare Lake GSP Area.



- **Please provide an ecological inventory (see Appendix III, Worksheet 2 of the GDE Guidance) for all potential GDEs that includes vegetation or habitat types and rank the GDEs as having a high, moderate or low value. Explain how each rank was characterized.**
- **Please identify whether any endangered or threatened freshwater species of animals and plants, or areas with critical habitat were found in or near any of the GDEs since some organisms rely on uplands and wetlands during different stages of their lifecycle**. Resources for this include the list of freshwater species located in the Subbasin that can be found in Attachment C of this letter, the Critical Species Lookbook, and the USFWS's ECOS and CDFW's CNDDB databases / mapping tools.

<u>Checklist Items 21 and 22 – Water Budget (23 CCR §354.18)</u>

[Section 3.3.1.2 Outflows (pp. 3-39 to 3-40)]

- Evapotranspiration (ET) is included as an outflow category in the water budget; however, it is only included as it pertains to crop water requirements. Groundwater outflow to the ET of natural ecosystems (i.e., GDEs, riparian areas, etc.) should be identified as a groundwater budget component. If the outflow is not known, it should be identified as a data gap and provisional information should be provided until an analysis can be performed to address the data gap. **Since natural ecosystems may be beneficial users of groundwater: 1) please provide a breakdown of ET for all land-cover types, including native and riparian vegetation (such as wetlands, riparian vegetation, phreatophytes and other communities); 2) identify any data gaps; 3) outline the actions needed to address them; 4) and the schedule for their implementation.**

Checklist Item 23-26 Sustainability Goal (23 CCR §354.24)

[Section 4.0 Sustainable Management Criteria (p. 4-1)]

- The GSP states that there is no ISW connectivity within the entire Subbasin, but data to support this broad assertion are insufficient to dismiss this sustainability indicator. It is acknowledged earlier in the GSP that recharge primarily occurs through surface streams / rivers and unlined canals; however, there isn't any quantitative analysis, monitoring data, or other information provided to support that ISWs are not present, and statements within the GSP are contradictory. **Please address ISWs in the Sustainable Management Criteria and the Sustainability Goal until sufficient data is available to conclude the status of ISWs.**
- The GSP states "Indicators for the sustainable management of groundwater were determined by SGMA based on factors that have the potential to impact the health and general well-being of the public." This chapter starts off by disregarding the environmental use and users of groundwater. Sweeping statements like this should be modified throughout the chapter to acknowledge all beneficial users. **Since GDEs and ISWs may be present in and near the GSP area due to the prevalence of shallow groundwater (please see comments under Checklist Items 16-20) they should be explicitly recognized in the establishment of sustainable management criteria for the groundwater level decline and ISW sustainability indicators. Please also update this section to recognize environmental beneficial groundwater uses as a component of the sustainable management goals.**

[Section 4.1 Sustainability Goal (pp. 4-1 to 4-3)]

- The Sustainability Goal states that "…the sustainability goal works as a tool for managing groundwater, basin-wide, on a long-term basis to protect quality of life through the continuation of existing economic industries in the area, including but not limited to agriculture". The overall theme is to protect groundwater resources for developed water users, particularly agriculture. **The narrative discussion of the sustainability goal should be expanded to include other beneficial uses and users of groundwater including environmental uses and users of groundwater.**
- The Discussion of Measures states that "management actions will be implemented to help mitigate overdraft based on the demand from beneficial uses and users", but developed users are the only parties identified in this chapter. Criteria used to evaluate the priority given to beneficial users during overdraft periods is not described. **Please update this section to provide a discussion of how human and environmental beneficial uses will be balanced in the implementation of management actions during periods of drought and overdraft.**
- **Since GDEs and ISWs may be present in the Subbasin (please see comments under Checklist Items 16-20) they should be recognized as beneficial users of groundwater and should be included in the Sustainability Goal and Discussion of Measures. In addition, a statement about any intention to address pre-SGMA impacts should be included.**

- GDEs are dependent, in part, on suitable water quality; however, the GSP focuses on subsidence, groundwater levels and changes in groundwater storage; and only considers water quality for irrigation and domestic use. **Given that there are potential GDEs and ISWs in the Subbasin, and they may be affected by water quality they should be included in the Sustainability Goal and addressed in the Sustainable Management Criteria established for the Water Quality Sustainability Indicator.**

[Section 4.2.4 Groundwater Quality Indicator (pp. 4-5 to 4-6)]

- The GSP states that the GSAs will rely on the existing programs in place for monitoring groundwater quality, and the "local GSAs will focus on water quality issues that are related to groundwater pumping rather than on issues related to contamination". However, since much of the groundwater is being used for irrigation, which then leaches back into the soil or drains elsewhere and carries nutrients and other solutes with it, the GSA should monitor constituents related to agriculture in addition to those related to pumping, such as arsenic. This includes nitrates, phosphates, salts, sodium, boron, chloride and acidification from carbonic acid which affects soil biota, structure, geochemistry, GDEs and ISWs. **Please consider revising this section to include monitoring for agricultural constituents.**

Checklist Item 26 – Measurable Objectives (23 CCR §354.30)

[Section 4.5 Measurable Objectives (pp. 4-18 to 4-20)]

- This Measurable Objectives do not consider the water quality needs of GDEs and ISWs. **Please modify this section to include impacts from degraded water quality on the plant and wildlife communities, and species they support within these habitats**.
- This GSP states that "ISWs do not exist within the Subbasin". However, this conclusion was based on well groundwater levels that are not reasonably close to the drainages, shallow or nested monitoring wells to assess potential interaction with surface water and GDEs and connectivity to underlying aquifers, or hydrogeologic data that does not fully characterize the location and extent of perched and shallow zones within the upper aquifer. In addition, there are no supporting data and information that demonstrates shallow groundwater near the streams and rivers is not supporting ISWs or GDEs. As such, the data are insufficient to dismiss this sustainability indicator under the GSP regulations. **Please modify this section of the GSP to retain ISWs as a sustainability indicator, pending the characterization of the shallow / perched zones and analysis of monitoring data or monitoring from additional wells to be installed in the future.**
- Since there are wildlife refuges and protected wildlife area that contain critical habitat directly adjacent to the GSP area, the GSP needs to address these areas, whether there are potential GDEs or ISWs, and how management actions within the Subbasin would affect these sensitive habitats. **Please explain how the measurable objectives will benefit adjacent subbasins and not hinder the**

ability of adjacent subbasins to be sustainable; and how the measurable objectives would benefit adjacent critical habitat areas. What are the mechanisms for this benefit?

- Sweeping statements, such as (p. 4-20) "interconnected surface waters do not exist within the Subbasin, so this indicator will not be further discussed in terms of Measurable Objectives" are completely dismissive with disregard for data gaps. There is not enough evidence to make statements like these. Many of the wells are screened too deep, not in the proper location to make comparisons, and / or nested wells have not been installed to inform how shallow groundwater interacts with potential ISWs, GDEs or the unconfined aquifer. **Please include all potential ISWs in the analysis and develop measurable objectives and minimum thresholds for these, to be managed until data gaps prove they are not interconnected.**

Checklist Item 27-29 – Minimum Thresholds (23 CCR §354.28)

[Section 4.4.1.2 Description of Minimum Thresholds and Processes to Establish [for Groundwater Level Indicator (p. 4-13), Section 4.4.1.4 Description of Minimum Thresholds and Processes to Establish [for Groundwater Quality Indicator (p. 4-14), and Section 4.4.1.5 Description of Minimum Thresholds and Processes to Establish [for Interconnected Surface Water Intrusion (p. 4-14)]

- These Minimum Thresholds do not consider GDEs and ISWs. **Please include GDEs (see comments under checklist items 8-20) in this section and whether the minimum thresholds and interim milestones will help achieve the potential sustainability goal as it pertains to the environment.**
- Section 4.4.1.5 (p. 4-14) states that "Interconnected surfaces waters are not considered present in the Subbasin are; therefore, no further discussion will occur on this indictor in terms of MTs". However, the GSP fails to provide any monitoring data, analysis or other information to substantiate this position. Based on the inconsistencies in groundwater levels presented previously in the GSP and this letter, and the unknowns associated with the extent and location of shallow and/or perched zones in the upper aquifer, it is possible that rivers, streams and GDEs may be hydraulically connected to the regional aquifer system. Minimum thresholds must be established for ISWs and GDEs unless and until sufficient data are provided to eliminate them from consideration. **Please modify this section of the GSP to 1) develop minimum thresholds for possible ISWs, including GDEs, and 2) include a statement that a data gap exists related to the interconnectedness of the of the Tulare Lakebed, rivers / streams, and shallow groundwater zones.**

[Section 4.4.4 Potential Effects to Beneficial Uses and Users (p. 4-17 to 4-18)]

- The evaluation of minimum thresholds completely disregards consideration of environmental beneficial users, such as ISWs, GDEs or the species they support. Effects to beneficial uses and users is focused on well capacity, pumping costs, extraction, and impacts from subsidence on infrastructure. There is no mention about potential impacts to GDEs or ISWs that could be affected by lowering of the

shallow portions of the unconfined or semi-confined portions of the upper aquifer since a continuity / discontinuity between the two is a data gap. Although there are many data gaps associated with ISWs and GDEs, it must be assumed that potential significant and unreasonable impacts to these beneficial users could occur. As such, they should be addressed in the evaluation of minimum thresholds. Section 4.4.4 should be modified to address how potential ISWs and GDEs would be affected by further lowering of groundwater levels. **Please address how 1) potential ISWs and GDEs would be affected by further lowering of groundwater levels, 2) these beneficial users will be protected / managed in the interim until data gaps are filled, and 3) what measures will be employed to protect GDEs and ISWs that are confirmed after data gaps are filled.**

- This Section does not include the required analysis of how the selected minimum thresholds for decline in groundwater levels could affect potential ISWs and GDEs within and near the GSP area. **Please include an analysis of the potential effect of the established minimum thresholds on ISWs and GDES within and near the GSP area, particularly in adjacent wildlife preserves / refuges.**
- Although agricultural and domestic water quality concerns have been articulated, similar concerns were not identified for environmental users. Degradation of water quality can impact terrestrial and aquatic wildlife that live in or near these ecosystems during at least part of the year even if the water is not a concern from an agricultural or municipal standpoint. **Please include a discussion about GDEs and water quality and whether the minimum thresholds and interim milestones will help achieve sustainability for environmental users.**

Checklist Item 30-46 – Undesirable Results (23 CCR §354.26)

[Section 4.3 Undesirable Results (pp. 4-6 to 4-12), and Subsection 4.3.3 Potential Effects to Beneficial Uses and Users (pp. 4-11 to 4-12)]

- The GSP states that there are no ISWs; however, this is largely based on assumptions and there are no monitoring data, analyses or other information to support this statement. In addition, the GSP indicates that 1) streams and rivers are the primary source of recharge; 2) a connection may exist between shallow and perched groundwater, but the extent and location of perched groundwater is unknown; and 3) surface and groundwater may be periodically connected in Tulare Lake. Furthermore, GDEs may exist within and near the GSP area. This is a data gap that needs to be identified and rectified by employing a monitoring network to verify the status of ISWs prior to complete dismissal of ISWs from the GSP. **Please modify this section of the GSP to include:**
    1) **A statement that there are potential ISWs and GDEs, unless adequate data can be provided to dismiss them.**
    2) **An assessment of the nature of potential undesirable results to ISWs and GDEs.**
    3) **A statement that the aquifers will be managed such there will be no depletion of ISWs that results in a significant and unreasonable impacts to ISWs or GDEs.**

4) **Data gaps and specific steps to verify the presence or absence of ISWs and GDEs with monitoring wells screened at the appropriate depths.**

- This section only describes undesirable results relating to human beneficial uses of groundwater and neglects environmental beneficial uses / users that could be adversely affected by chronic groundwater level decline or depletion of ISWs. **Please add "possible adverse impacts to potential GDEs and ISWs" to the list of potential undesirable results.**
- The GDE Pulse web application developed by TNC provides easy access to 35 years of satellite data to view trends of vegetation metrics, groundwater depth (where available), and precipitation data. This satellite imagery can be used to observe trends for NC dataset polygons within and near the GSA. Over the past 10 years (2009-2018), some NC dataset vegetation polygons have experienced adverse impacts to vegetation growth and moisture. An example screen shot of GDEs near Lemoore, California from the GDE Pulse tool is presented under Checklist items 16 to 20 above.
    - **For each potential GDE unit with supporting hydrological datasets please include the following:**
        - Plot and provide hydrological datasets for each GDE.
        - Define the baseline period in the hydrologic data.
        - Classify GDE units as having high, moderate, or low susceptibility to changes in groundwater.
        - Explore cause-and-effect relationships between groundwater changes and GDEs.
    - **For each identifiable GDE unit without supporting hydrological datasets please describe data gaps and / or insufficiencies.**
    - **Compile and synthesize biological data from CDFW's CNDDB, USFWS' ECOS Mapper, NC dataset, and / or the GDE Pulse tool (as applicable) for each GDE unit by:**
        - Characterizing biological resources for each GDE unit, and when possible provide baseline conditions for assessment of trends and variability.
        - Describing data gaps / insufficiencies.
    - **Describe possible effects on potential ISWs, GDEs, land uses, and property interests, including:**
        - Cause-and-effect relationships between potential ISWs and GDEs with groundwater conditions.
        - Impacts to potential ISWs and GDEs that are considered to be "significant and unreasonable".
        - Report known hydrological thresholds or triggers (e.g., instream flow criteria, groundwater depths, water quality parameters) for significant impacts to relevant species or ecological communities.
        - Land uses should include recreational uses (e.g., fishing/hunting, hiking, boating).
        - Property interests should include and consider privately and publicly protected conservation lands and opens spaces, including wildlife refuges, parks, and natural preserves.

- This section discusses water quality with respect to agricultural and municipal use but does not include a discussion of potential undesirable results for GDEs and ISWs. **Please modify this section to address how degraded water quality could affect vegetation and wildlife species that rely on GDEs and ISWs. Although arsenic is mentioned in this GSP, please consider adding a statement that over-pumping and dewatering of aquitards has been identified as a potential source of elevated arsenic concentrations above drinking water standards in San Joaquin Valley aquifers.** The following is a link to a paper by Smith, Knight and Fendorf (2018) titled "Overpumping leads to California groundwater arsenic threat": https://www.nature.com/articles/s41467-018-04475-3

Checklist Items 47-49 – Monitoring Network (23 CCR §354.34)

[Chapter 5 Monitoring Network (pp. 5-1 to 5-3), and Section 5.1 Description of Monitoring Network (pp. 5-3 to 5-15)]

- The GSP describes groundwater monitoring locations and states that groundwater monitoring in areas de-designated by the Tulare Lake Basin Plan amendment and associated aquifer zones is not proposed as decided by the GSAs. Although these areas (designated Management Area A and B) are not designated for municipal and agricultural uses in the Basin Plan, the groundwater could still potentially be used or is being used for livestock, crops with a higher tolerance to salt, domestic supply, public supply, and potentially other uses in the future. Since it is currently unclear how withdrawals within the unconfined aquifer will affect the perched and shallow areas of the aquifer (as associated with the A-Clay and C-Clay layers), Management Areas A and B still need to be monitored to assess effects to the unconfined aquifer as a whole. As stated above in the comments for other Checklist Items, **please reconcile data gaps (shallow monitoring wells, stream gauges, and nested/clustered wells, GDE and ISW responses to groundwater levels) along rivers, creek and the Tulare Lakebed in this section of the GSP to improve ISW and GDE mapping in future GSPs**.
- It is not acceptable to completely disregard these Management Areas based purely on a de-designation from municipal and agricultural uses only when there are still current and potential environmental uses of this groundwater. In addition, there is much uncertainty how the shallow aquifers are interacting with GDEs and ISWs. **Please add Representative Monitoring Sites (RMS) for these areas in order to better understand the interaction of the A-Clay and C-Clay layers with the unconfined aquifer, and potential GDEs and ISWs.**
- This section lists the proposed facilities for monitoring groundwater levels, storage and quality, and subsidence on pp. 5-9 through 5-15. This section proposes to use groundwater level monitoring to assess potential groundwater level and storage declines, existing programs to monitor water quality, and monitored surface conditions to evaluate land subsidence. It may acceptable to use groundwater level [in combination with assessment of vegetation response, for example by remote sensing] as a proxy for assessing potential effects on ISWs and GDEs, but the data gaps associated with the A-Clay, C-Clay, and shallow water tables need to be addressed. A set of representative wells have been selected to monitor the upper

and lower aquifer (Figures 5-1 to 5-3). There are only five wells that represent the "Above A-Clay and Shallow Groundwater Levels (i.e., Zone A)", and there are three data gaps areas identified (Figure 5-1). **Please describe 1) how these five wells are considered representative of the entire GSP Area, 2) how those data gap areas were selected, and 3) what methodologies would be used to extrapolate results to other areas where there are no wells or identified data gaps.**

- Many of the monitoring wells are not screened in the upper portion of the unconfined aquifer, where environmental beneficial users would obtain the groundwater on which they rely. Finally, there are currently no plans to monitor groundwater level declines to assess the potential for significant and unreasonable impacts to ISWs or GDEs in response to groundwater level declines. **Please modify the description of the new well network in the Proposed Facilities Section (Sections 5.1.4, p. 5-9) and Groundwater Levels Section (Section 5.1.4, p.5-9 to 5-11) to provide methodologies, data and other information to support the monitoring of GDEs and ISWs so as to assess and prevent potential significant and unreasonable impacts. This modification should include 1) locating new wells that are appropriately screened to detect connectivity of GDEs and ISWs with the unconfined aquifer and 2) identifying or installing additional stream gages in areas where there is potential for ISWs and GDEs. In addition, monitoring GDE responses to groundwater level declines should be included. GDE Pulse represents an example of how remote sensing can be used to achieve this objective. Please expand on the discussion of how the new well, stream and other data will be used to improve ISW mapping and inform an adequate analysis, and how the data will be used to verify possible GDEs and their sensitivity to groundwater level declines.**

[Section 5.1.1 Monitoring Network Objectives (p. 5-6)]

- The monitoring objectives listed include developing data to evaluate impacts to beneficial uses and users of groundwater but does not include filling data gaps as they specifically pertain to environmental users of groundwater. **Please expand this list to include monitoring to inform data gaps associated with groundwater use by potential GDEs, ISWs and the species that they support.**

[Section 5.4.1.4 Site Selection (p. 5-23)]

- This section includes the scientific rationale for the groundwater level monitoring network and the rationale used to add new wells to the monitoring system. However, evaluation and monitoring of potential GDEs and ISWs were not considered in new well site selection. **Please modify the site selection criteria to include the potential to install new wells that will provide information to support the investigation of GDEs and ISWs. This modification should include locating new / existing wells that are appropriately screened to detect connectivity of GDEs and ISWs with the shallow zones of the unconfined**

aquifer, and 2) expanding information on the extent and location of shallow / perched areas within the unconfined aquifer.

[Section 5.5 Data Storage and Reporting (pp. 5-31 to 5-32)]

- The data management system (DMS) described in this section allows for upload and storage of information related to the development and implementation of the GSP. The types of information that will be stored in the DMS are listed. Other than groundwater elevations, quality, and site information, there is no information being stored specific to the monitoring and evaluation of GDEs or ISWs. **We recommend adding remote sensing information to this list to evaluate possible correlations of ecosystem response to potential declines in groundwater level or quality due to pumping. This can be accomplished by incorporating the GDE pulse tool, Sentinel data, evapotranspiration, or leaf area index.**

Checklist Items 50 and 51 – Projects and Management Actions to Achieve Sustainability Goal (23 CCR §354.44)

[Chapter 6 Projects and Management Actions to Achieve Sustainability (pp. 6-1 to 6-21)]

- **This chapter should identify the specific actions and schedules proposed to address data gaps in the hydrogeologic conceptual model, water budget and monitoring network.**

[Section 6.3 Projects (pp. 6-4 to 6-17)]

- This section identifies many important types of projects, including conveyance facilities modifications and construction of new facilities, above-ground surface water storage, intentional recharge basins, on-farm recharge, and aquifer storage and recovery through injection. However, the descriptions of Measurable Objectives for these projects only identifies benefits to water level and storage through changes in allocation, imports, surface water diversions, pumping allowances; and adding recharge projects or water banking. Since maintenance or recovery of groundwater levels, or construction of recharge facilities, may have potential environmental benefits it would be advantageous to demonstrate multiple benefits from a funding and prioritization perspective.
    - **For the projects already identified, please consider stating how ISWs and GDEs will benefit or be protected, or what other environmental benefits will accrue.**
    - If ISWs will not be adequately protected by those listed, **please include and describe additional management actions and projects targeted for protecting potential ISWs.**
    - Storage and recharge projects can be designed as multiple-benefit projects to include elements that act functionally as wetlands and provide a benefit for wildlife and aquatic species. In some cases, such facilities have been incorporated into local HCPs and NCCPs, more fully recognizing the value of the habitat that they provide and the species they support. On-farm recharge may benefit waterfowl during migration, and recreational hunting and birdwatching depending on the time of year that fields are flooded. For

recharge projects, **please consider identifying if there is habitat value incorporated into the design and how the recharge ponds can be managed as multiple-benefit projects to benefit environmental users. Grant and funding opportunities for SGMA-related work may be available for multi-benefit projects that can address water quantity as well as provide environmental benefits. Please include environmental benefits and multiple benefits as criteria for assessing project priorities.**

- The GSP states that recharged water typically remains in the unconfined aquifer, above the A-Clay, C-Clay and E-Clay; and that existing wells in the area will be used for extraction of stored water. There appear to be many unknowns as to the extent and location of perched and shallow areas in the unconfined aquifer, and the connectivity of those areas with the aquifer. In addition, there are currently only five wells that will be used to monitor shallow zones throughout the entire GSP area. There remains a fair amount of uncertainty as to how this would operate or affect potential GDEs and ISWs. **Please acknowledge these uncertainties and address 1) how these recharge operations could affect environmental beneficial users, 2) how ecosystems that could be affected by recharge in the unconfined aquifer, particularly above the A- and C-Clay layers will be monitored if there are only five wells.**
- For examples of case studies on how to incorporate environmental benefits into groundwater projects, please visit our website: https://groundwaterresourcehub.org/case-studies/recharge-case-studies/

[Section 6.5 GSA Sustainable Methods (pp. 6-18 to 6-21)]

- The Subbasin potentially includes GDEs and ISWs (see our comments under Checklist Items 8-10 and 16-20 above) that are beneficial uses and users of groundwater and may include sensitive and protected resources. Protection of these environmental users and uses should be considered in establishing project priorities. In addition, and consistent with existing grant and funding guidelines for SGMA-related work, **priority should be given to multi-benefit projects that can address water quantity and quality as well as providing environmental benefits or benefits to disadvantaged communities.**

Attachment C

Freshwater Species Located in the Tulare Lake Subbasin

To assist in identifying the beneficial users of surface water necessary to assess the undesirable result "depletion of interconnected surface waters", Attachment C provides a list of freshwater species located within the Tulare Lake Subbasin. To produce the freshwater species list, we used ArcGIS to select features within the California Freshwater Species Database version 2.0.9 within the GSA's boundary. This database contains information on ~4,000 vertebrates, macroinvertebrates and vascular plants that depend on fresh water for at least one stage of their life cycle. The methods used to compile the California Freshwater Species Database can be found in Howard et al. 2015[5]. The spatial database contains locality observations and/or distribution information from ~400 data sources. The database is housed in the California Department of Fish and Wildlife's BIOS[6] as well as on TNC's science website[7].

		Legally Protected Status		
Scientific Name	**Common Name**	**Federal**	**State**	**Other**
BIRDS				
Actitis macularius	Spotted Sandpiper			
Aechmophorus clarkii	Clark's Grebe			
Aechmophorus occidentalis	Western Grebe			
Agelaius tricolor	Tricolored Blackbird	BCC	SSC	BSSC - First priority, BLM
Aix sponsa	Wood Duck			
Anas acuta	Northern Pintail			
Anas americana	American Wigeon			
Anas clypeata	Northern Shoveler			
Anas crecca	Green-winged Teal			
Anas cyanoptera	Cinnamon Teal			
Anas discors	Blue-winged Teal			
Anas platyrhynchos	Mallard			
Anas strepera	Gadwall			
Anser albifrons	Greater White-fronted Goose			
Ardea alba	Great Egret			
Ardea herodias	Great Blue Heron			
Aythya affinis	Lesser Scaup			
Aythya americana	Redhead		SSC	BSSC - Third priority
Aythya collaris	Ring-necked Duck			

[5] Howard, J.K. et al. 2015. Patterns of Freshwater Species Richness, Endemism, and Vulnerability in California. PLoSONE, 11(7). Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0130710
[6] California Department of Fish and Wildlife BIOS: https://www.wildlife.ca.gov/data/BIOS
[7] Science for Conservation: https://www.scienceforconservation.org/products/california-freshwater-species-database

Aythya marila	Greater Scaup			
Aythya valisineria	Canvasback		SSC	
Botaurus lentiginosus	American Bittern			
Bucephala albeola	Bufflehead			
Bucephala clangula	Common Goldeneye			
Butorides virescens	Green Heron			
Calidris alpina	Dunlin			
Calidris mauri	Western Sandpiper			
Calidris minutilla	Least Sandpiper			
Chen caerulescens	Snow Goose			
Chen rossii	Ross's Goose			
Chlidonias niger	Black Tern		SSC	BSSC - Second priority
Chroicocephalus philadelphia	Bonaparte's Gull			
Cistothorus palustris palustris	Marsh Wren			
Cygnus columbianus	Tundra Swan			
Dendrocygna bicolor	Fulvous Whistling-Duck		SSC	BSSC - First priority
Egretta thula	Snowy Egret			
Empidonax traillii	Willow Flycatcher	BCC	Endangered	USFS
Fulica americana	American Coot			
Gallinago delicata	Wilson's Snipe			
Gallinula chloropus	Common Moorhen			
Grus canadensis	Sandhill Crane			
Himantopus mexicanus	Black-necked Stilt			
Icteria virens	Yellow-breasted Chat		SSC	BSSC - Third priority
Limnodromus scolopaceus	Long-billed Dowitcher			
Lophodytes cucullatus	Hooded Merganser			
Megaceryle alcyon	Belted Kingfisher			
Mergus merganser	Common Merganser			
Mergus serrator	Red-breasted Merganser			
Numenius americanus	Long-billed Curlew			
Numenius phaeopus	Whimbrel			
Nycticorax nycticorax	Black-crowned Night-Heron			
Oxyura jamaicensis	Ruddy Duck			

Pelecanus erythrorhynchos	American White Pelican		SSC	BSSC - First priority
Phalacrocorax auritus	Double-crested Cormorant			
Phalaropus tricolor	Wilson's Phalarope			
Plegadis chihi	White-faced Ibis		Watch list	
Pluvialis squatarola	Black-bellied Plover			
Podiceps nigricollis	Eared Grebe			
Podilymbus podiceps	Pied-billed Grebe			
Porzana carolina	Sora			
Rallus limicola	Virginia Rail			
Recurvirostra americana	American Avocet			
Riparia riparia	Bank Swallow		Threatened	
Setophaga petechia	Yellow Warbler			BSSC - Second priority
Tachycineta bicolor	Tree Swallow			
Tringa melanoleuca	Greater Yellowlegs			
Tringa semipalmata	Willet			
Tringa solitaria	Solitary Sandpiper			
Xanthocephalus xanthocephalus	Yellow-headed Blackbird		SSC	BSSC - Third priority
CRUSTACEANS				
Branchinecta lindahli	Versatile Fairy Shrimp			
HERPS				
Actinemys marmorata marmorata	Western Pond Turtle		SSC	ARSSC, BLM, USFS
Ambystoma californiense californiense	California Tiger Salamander	Threatened	Threatened	ARSSC
Anaxyrus boreas boreas	Boreal Toad			
Spea hammondii	Western Spadefoot	Under Review in the Candidate or Petition Process	SSC	ARSSC, BLM
Thamnophis sirtalis sirtalis	Common Gartersnake			
INSECTS AND OTHER INVERTEBRATES				
Ameletus amador	A Mayfly			
Ameletus spp.	Ameletus spp.			

Anax walsinghami	Giant Green Darner			
Archilestes californica	California Spreadwing			
Argia emma	Emma's Dancer			
Baetis adonis	A Mayfly			
Baetis spp.	Baetis spp.			
Caudatella columbiella				Not on any status lists
Caudatella spp.	Caudatella spp.			
Cinygmula gartrelli	A Mayfly			
Cinygmula spp.	Cinygmula spp.			
Doroneuria baumanni	Cascades Stone			
Drunella coloradensis	A Mayfly			
Drunella doddsii	A Mayfly			
Drunella spinifera	A Mayfly			
Drunella spp.	Drunella spp.			
Enallagma carunculatum	Tule Bluet			
Enallagma civile	Familiar Bluet			
Epeorus albertae	A Mayfly			
Epeorus spp.	Epeorus spp.			
Ephemerella tibialis	A Mayfly			
Erythemis collocata	Western Pondhawk			
Hetaerina americana	American Rubyspot			
Heterlimnius corpulentus				Not on any status lists
Ischnura barberi	Desert Forktail			
Ischnura cervula	Pacific Forktail			
Ischnura denticollis	Black-fronted Forktail			
Libellula saturata	Flame Skimmer			
Malenka bifurcata				Not on any status lists
Malenka spp.	Malenka spp.			
Optioservus canus	Pinnacles Optioservus Riffle Beetle		SSC	
Optioservus spp.	Optioservus spp.			
Oroperla barbara	Gilltail Springfly			
Pachydiplax longipennis	Blue Dasher			
Pantala flavescens	Wandering Glider			
Pantala hymenaea	Spot-winged Glider			
Parapsyche almota	A Caddisfly			
Parapsyche elsis	A Caddisfly			

Parapsyche spp.	Parapsyche spp.			
Rhionaeschna multicolor	Blue-eyed Darner			
Rhithrogena decora	A Mayfly			
Rhithrogena spp.	Rhithrogena spp.			
Rhyacophila acuminata	A Caddisfly			Not on any status lists
Rhyacophila spp.	Rhyacophila spp.			
Simulium anduzei				Not on any status lists
Simulium spp.	Simulium spp.			
Skwala americana	American Springfly			
Skwala spp.	Skwala spp.			
Sperchon spp.	Sperchon spp.			
Sperchon stellata				Not on any status lists
Sweltsa adamantea				Not on any status lists
Sweltsa spp.	Sweltsa spp.			
Telebasis salva	Desert Firetail			
Tramea lacerata	Black Saddlebags			
Zapada columbiana	Columbian Forestfly			
MAMMALS				
Castor canadensis	American Beaver			Not on any status lists
Ondatra zibethicus	Common Muskrat			Not on any status lists
MOLLUSKS				
Anodonta californiensis	California Floater		SSC	USFS
PLANTS				
Cephalanthus occidentalis	Common Buttonbush			
Cirsium crassicaule	Slough Thistle		SSC	CRPR - 1B.1, BLM
Cyperus erythrorhizos	Red-root Flatsedge			
Cyperus squarrosus	Awned Cyperus			
Eragrostis hypnoides	Teal Lovegrass			
Euthamia occidentalis	Western Fragrant Goldenrod			
Galium trifidum	Small Bedstraw			
Juncus effusus effusus	NA			
Lasthenia ferrisiae	Ferris' Goldfields		SSC	CRPR - 4.2

Ludwigia peploides peploides	NA			Not on any status lists
Myosurus minimus	NA			
Persicaria lapathifolia				Not on any status lists
Rorippa palustris palustris	Bog Yellowcress			
Salix gooddingii	Goodding's Willow			
FISHES				
Catostomus occidentalis occidentalis	Sacramento sucker			Least Concern - Moyle 2013
Cottus asper ssp. 1	Prickly sculpin			Least Concern - Moyle 2013
Lavinia exilicauda exilicauda	Sacramento hitch		SSC	Near-Threatened - Moyle 2013
Oncorhynchus mykiss irideus	Coastal rainbow trout			Least Concern - Moyle 2013
Oncorhynchus tshawytscha - CV fall	Central Valley fall Chinook salmon	SSC	SSC	Vulnerable - Moyle 2013
Oncorhynchus tshawytscha - CV late fall	Central Valley late fall Chinook salmon	SSC		Endangered - Moyle 2013
Orthodon microlepidotus	Sacramento blackfish			Least Concern - Moyle 2013
Ptychocheilus grandis	Sacramento pikeminnow			Least Concern - Moyle 2013

Notes:
ARSSC = At-Risk Species of Special Concern
BCC = Bird of Conservation Concern
BSSC = Bird Species of Special Concern
CRPR = California Rare Plant Rank
CS = Currently Stable
IUCN = International Union for Conservation of Nature
SSC = Species of Special Concern

Attachment D

The Nature Conservancy

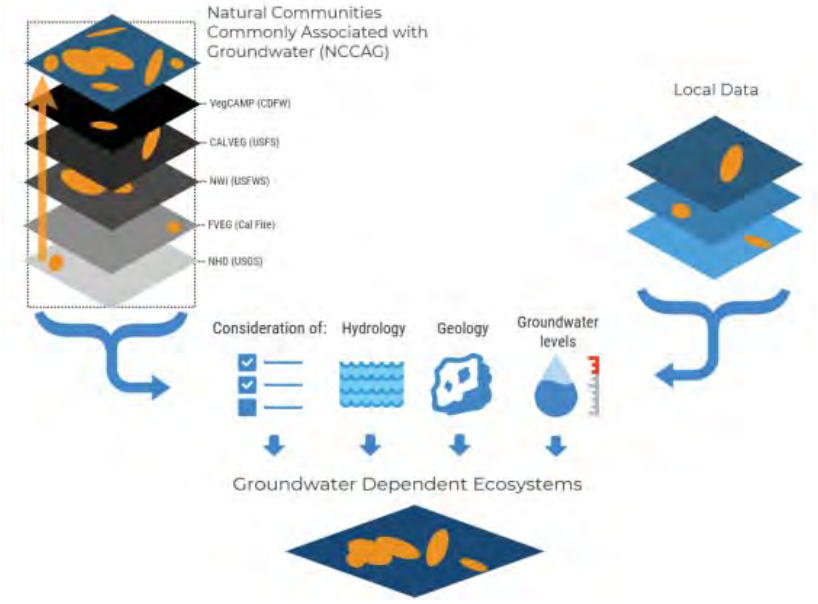
July 2019



IDENTIFYING GDEs UNDER SGMA

Best Practices for using the NC Dataset

The Sustainable Groundwater Management Act (SGMA) requires that groundwater dependent ecosystems (GDEs) be identified in Groundwater Sustainability Plans (GSPs). As a starting point, the Department of Water Resources (DWR) is providing the Natural Communities Commonly Associated with Groundwater Dataset (NC Dataset) online[8] to help Groundwater Sustainability Agencies (GSAs), consultants, and stakeholders identify GDEs within individual groundwater basins. To apply information from the NC Dataset to local areas, GSAs should combine it with the best available science on local hydrology, geology, and groundwater levels to verify whether polygons in the NC dataset are likely supported by groundwater in an aquifer (Figure 1)[9]. This document highlights six best practices for using local groundwater data to confirm whether mapped features in the NC dataset are supported by groundwater.



[8] *NC Dataset Online Viewer:* https://gis.water.ca.gov/app/NCDatasetViewer/

[9] California Department of Water Resources (DWR). 2018. Summary of the "Natural Communities Commonly Associated with Groundwater" Dataset and Online Web Viewer. Available at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Statewide-Reports/Natural-Communities-Dataset-Summary-Document.pdf

The NC Dataset identifies vegetation and wetland features that are good indicators of a GDE. The dataset is comprised of 48 publicly available state and federal datasets that map vegetation, wetlands, springs, and seeps commonly associated with groundwater in California[10]. It was developed through a collaboration between DWR, the Department of Fish and Wildlife, and The Nature Conservancy (TNC). TNC has also provided detailed guidance on identifying GDEs from the NC dataset[11] on the Groundwater Resource Hub[12], a website dedicated to GDEs.

BEST PRACTICE #1. Establishing a Connection to Groundwater

Groundwater basins can be comprised of one continuous aquifer (Figure 2a) or multiple aquifers stacked on top of each other (Figure 2b). In unconfined aquifers (Figure 2a), using the depth-to-groundwater and the rooting depth of the vegetation is a reasonable method to infer groundwater dependence for GDEs. If groundwater is well below the rooting (and capillary) zone of the plants and any wetland features, the ecosystem is considered disconnected and groundwater management is not likely to affect the ecosystem (Figure 2d). However, it is important to consider local conditions (e.g., soil type, groundwater flow gradients, and aquifer parameters) and to review groundwater depth data from multiple seasons and water year types (wet and dry) because intermittent periods of high groundwater levels can replenish perched clay lenses that serve as the water source for GDEs (Figure 2c). Maintaining these natural groundwater fluctuations are important to sustaining GDE health.

Basins with a stacked series of aquifers (Figure 2b) may have varying levels of pumping across aquifers in the basin, depending on the production capacity or water quality associated with each aquifer. If pumping is concentrated in deeper aquifers, SGMA still requires GSAs to sustainably manage groundwater resources in shallow aquifers, such as perched aquifers, that support springs, surface water, domestic wells, and GDEs (Figure 2). This is because vertical groundwater gradients across aquifers may result in pumping from deeper aquifers to cause adverse impacts onto beneficial users reliant on shallow aquifers or interconnected surface water. The goal of SGMA is to sustainably manage groundwater resources for current and future social, economic, and environmental benefits. While groundwater pumping may not be currently occurring in a shallower aquifer, use of this water may become more appealing and economically viable in future years as pumping restrictions are placed on the deeper production aquifers in the basin to meet the sustainable yield and criteria. Thus, identifying GDEs in the basin should done irrespective to the amount of current pumping occurring in a particular aquifer, so that future impacts on GDEs due to new production can be avoided. A good rule of thumb to follow is: *if groundwater can be pumped from a well - it's an aquifer*.

---

[10] *For more details on the mapping methods, refer to: Klausmeyer, K., J. Howard, T. Keeler-Wolf, K. Davis-Fadtke, R. Hull, A. Lyons. 2018. Mapping Indicators of Groundwater Dependent Ecosystems in California: Methods Report. San Francisco, California. Available at: https://groundwaterresourcehub.org/public/uploads/pdfs/iGDE_data_paper_20180423.pdf*

[11] "Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans" is available at: https://groundwaterresourcehub.org/gde-tools/gsp-guidance-document/

[12] *The Groundwater Resource Hub: www.GroundwaterResourceHub.org*

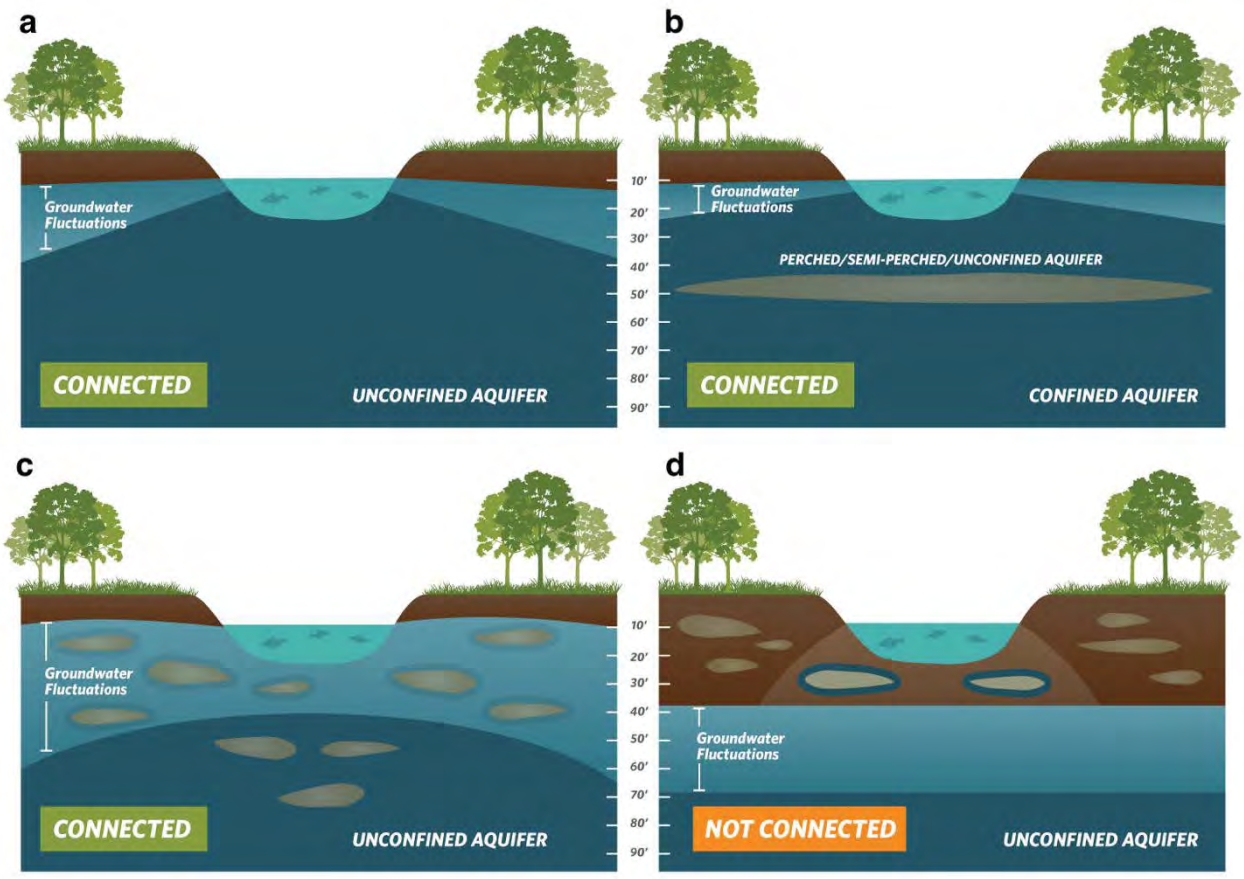


Figure 2. Confirming whether an ecosystem is connected to groundwater. Top: (a) Under the ecosystem is an unconfined aquifer with depth-to-groundwater fluctuating seasonally and interannually within 30 feet from land surface. **(b)** Depth-to-groundwater in the shallow aquifer is connected to overlying ecosystem. Pumping predominately occurs in the confined aquifer, but pumping is possible in the shallow aquifer. **Bottom: (c)** Depth-to-groundwater fluctuations are seasonally and interannually large, however, clay layers in the near surface prolong the ecosystem's connection to groundwater. **(d)** Groundwater is disconnected from surface water, and any water in the vadose (unsaturated) zone is due to direct recharge from precipitation and indirect recharge under the surface water feature. These areas are not connected to groundwater and typically support species that do not require access to groundwater to survive.

BEST PRACTICE #2. Characterize Seasonal and Interannual Groundwater Conditions

SGMA requires GSAs to describe current and historical groundwater conditions when identifying GDEs [23 CCR §354.16(g)]. Relying solely on the SGMA benchmark date (January 1, 2015) or any other single point in time to characterize groundwater conditions (e.g., depth-to-groundwater) is inadequate because managing groundwater conditions with data from one time point fails to capture the seasonal and interannual variability typical of California's climate. DWR's Best Management Practices document on water budgets[13] recommends using 10 years of water supply and water budget information to describe how historical conditions have impacted the operation of the basin within sustainable yield, implying that a baseline[14] could be determined based on data between 2005 and 2015. Using this or a similar time period, depending on data availability, is recommended for determining the depth-to-groundwater.

GDEs depend on groundwater levels being close enough to the land surface to interconnect with surface water systems or plant rooting networks. The most practical approach[15] for a GSA to assess whether polygons in the NC dataset are connected to groundwater is to rely on groundwater elevation data. As detailed in TNC's GDE guidance document[4], one of the key factors to consider when mapping GDEs is to contour depth-to-groundwater in the aquifer that is supporting the ecosystem (see Best Practice #5).

Groundwater levels fluctuate over time and space due to California's Mediterranean climate (dry summers and wet winters), climate change (flood and drought years), and subsurface heterogeneity in the subsurface (Figure 3). Many of California's GDEs have adapted to dealing with intermittent periods of water stress, however if these groundwater conditions are prolonged, adverse impacts to GDEs can result. While depth-to-groundwater levels within 30 feet[4] of the land surface are generally accepted as being a proxy for confirming that polygons in the NC dataset are supported by groundwater, it is highly advised that fluctuations in the groundwater regime be characterized to understand the seasonal and interannual groundwater variability in GDEs. Utilizing groundwater data from one point in time can misrepresent groundwater levels required by GDEs, and inadvertently result in adverse impacts to the GDEs. Time series data on groundwater elevations and depths are available on the SGMA Data Viewer[16]. However, if insufficient data are available to describe groundwater conditions within or near polygons from the NC dataset, include those polygons in the GSP until data gaps are reconciled in the monitoring network (see Best Practice #6).

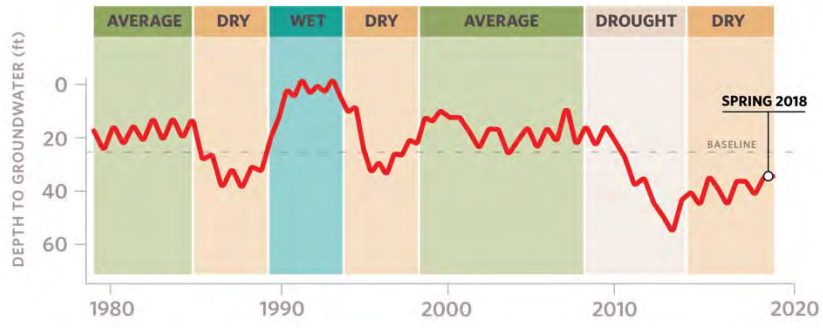


Figure 3. Example seasonality and interannual variability in depth-to-groundwater over time. Selecting one point in time, such as Spring 2018, to characterize groundwater conditions in GDEs fails to capture what groundwater conditions are necessary to maintain the ecosystem status into the future so adverse impacts are avoided.

[13] DWR. 2016. Water Budget Best Management Practice. Available at: https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_Water_Budget_Final_2016-12-23.pdf

[14] *Baseline is defined under the GSP regulations as "historic information used to project future conditions for hydrology, water demand, and availability of surface water and to evaluate potential sustainable management practices of a basin." [23 CCR §351(e)]*

[15] Groundwater reliance can also be confirmed via stable isotope analysis and geophysical surveys. For more information see The GDE Assessment Toolbox (Appendix IV, GDE Guidance Document for GSPs[4]).

[16] *SGMA Data Viewer: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer*

BEST PRACTICE #3. Ecosystems Often Rely on Both Groundwater and Surface Water

GDEs are plants and animals that rely on groundwater for all or some of its water needs, and thus can be supported by multiple water sources. The presence of non-groundwater sources (e.g., surface water, soil moisture in the vadose zone, applied water, treated wastewater effluent, urban stormwater, irrigated return flow) within and around a GDE does not preclude the possibility that it is supported by groundwater, too. SGMA defines GDEs as "ecological communities and species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" [23 CCR §351(m)]. Hence, depth-to-groundwater data should be used to identify whether NC polygons are supported by groundwater and should be considered GDEs. In addition, SGMA requires that significant and undesirable adverse impacts to beneficial users of surface water be avoided. Beneficial users of surface water include environmental users such as plants or animals[17], which therefore must be considered when developing minimum thresholds for depletions of interconnected surface water.

GSAs are only responsible for impacts to GDEs resulting from groundwater conditions in the basin, so if adverse impacts to GDEs result from the diversion of applied water, treated wastewater, or irrigation return flow away from the GDE, then those impacts will be evaluated by other permitting requirements (e.g., CEQA) and may not be the responsibility of the GSA. However, if adverse impacts occur to the GDE due to changing groundwater conditions resulting from pumping or groundwater management activities, then the GSA would be responsible (Figure 4).

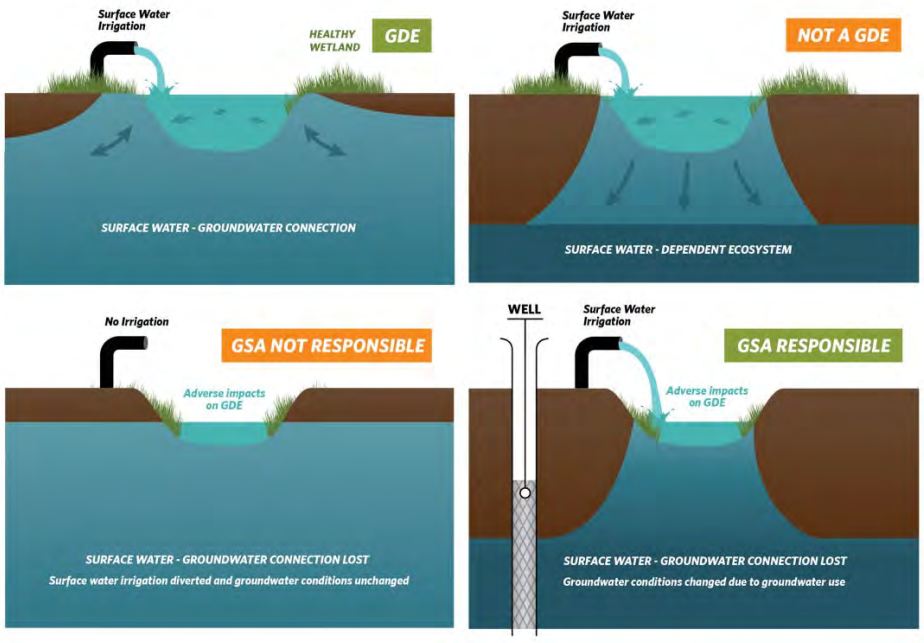


Figure 4. Ecosystems often depend on multiple sources of water. Top: (Left) Surface water and groundwater are interconnected, meaning that the GDE is supported by both groundwater and surface water. **(Right)** Ecosystems that are only reliant on non-groundwater sources are not groundwater-dependent. **Bottom: (Left)** An ecosystem that was once dependent on an interconnected surface water, but loses access to groundwater solely due to surface water diversions may not be the GSA's responsibility. **(Right)** Groundwater dependent ecosystems once dependent on an interconnected surface water system, but loses that access due to groundwater pumping is the GSA's responsibility.

[17] *For a list of environmental beneficial users of surface water by basin, visit: https://groundwaterresourcehub.org/gde-tools/environmental-surface-water-beneficiaries/*

BEST PRACTICE #4. Select Representative Groundwater Wells

Identifying GDEs in a basin requires that groundwater conditions are characterized to confirm whether polygons in the NC dataset are supported by the underlying aquifer. To do this, proximate groundwater wells should be identified to characterize groundwater conditions (Figure 5). When selecting representative wells, it is particularly important to consider the subsurface heterogeneity around NC polygons, especially near surface water features where groundwater and surface water interactions occur around heterogeneous stratigraphic units or aquitards formed by fluvial deposits. The following selection criteria can help ensure groundwater levels are representative of conditions within the GDE area:

- Choose wells that are within 5 kilometers (3.1 miles) of each NC Dataset polygons because they are more likely to reflect the local conditions relevant to the ecosystem. If there are no wells within 5km of the center of a NC dataset polygon, then there is insufficient information to remove the polygon based on groundwater depth. Instead, it should be retained as a potential GDE until there are sufficient data to determine whether or not the NC Dataset polygon is supported by groundwater.

- Choose wells that are screened within the surficial unconfined aquifer and capable of measuring the true water table.

- Avoid relying on wells that have insufficient information on the screened well depth interval for excluding GDEs because they could be providing data on the wrong aquifer. This type of well data should not be used to remove any NC polygons.

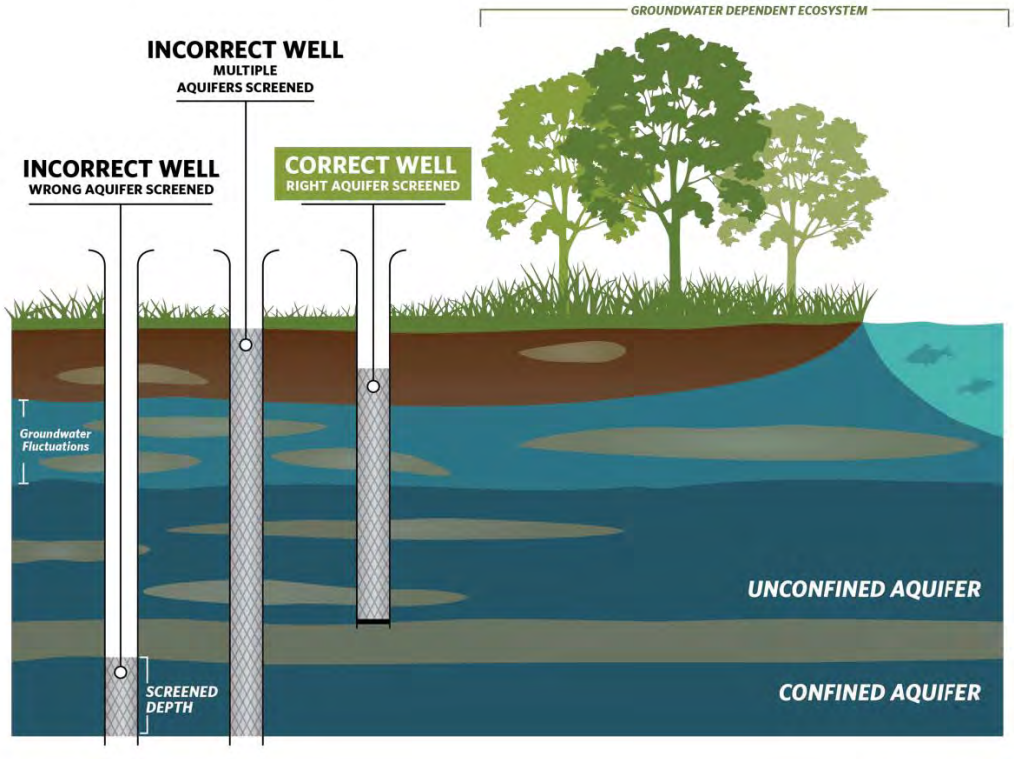


Figure 5. Selecting representative wells to characterize groundwater conditions near GDEs.

BEST PRACTICE #5. Contouring Groundwater Elevations

The common practice to contour depth-to-groundwater over a large area by interpolating measurements at monitoring wells is unsuitable for assessing whether an ecosystem is supported by groundwater. This practice causes errors when the land surface contains features like stream and wetland depressions because it assumes the land surface is constant across the landscape and depth-to-groundwater is constant below these low-lying areas (Figure 6a). A more accurate approach is to interpolate **groundwater elevations** at monitoring wells to get groundwater elevation contours across the landscape. This layer can then be subtracted from land surface elevations from a Digital Elevation Model (DEM)[18] to estimate depth-to-groundwater contours across the landscape (Figure b; Figure 7). This will provide a much more accurate contours of depth-to-groundwater along streams and other land surface depressions where GDEs are commonly found.

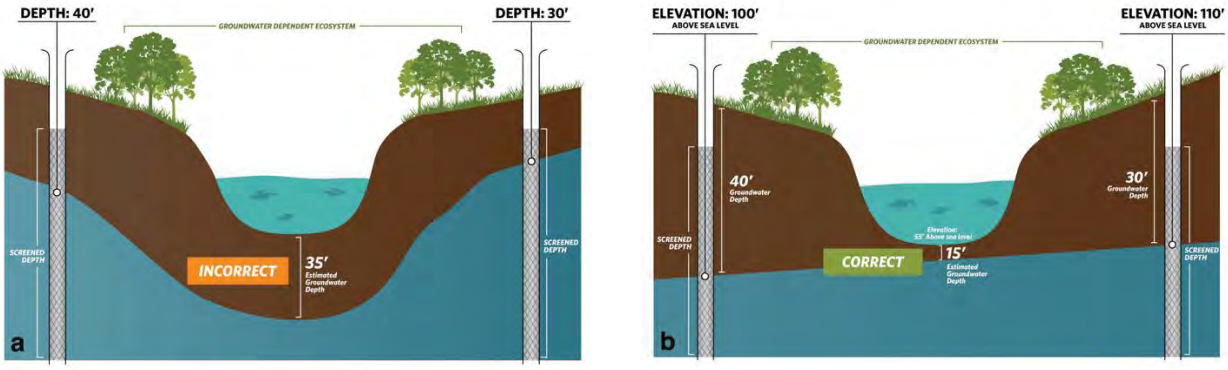


Figure 6. Contouring depth-to-groundwater around surface water features and GDEs. (a) Groundwater level interpolation using depth-to-groundwater data from monitoring wells. **(b)** Groundwater level interpolation using groundwater elevation data from monitoring wells and DEM data.

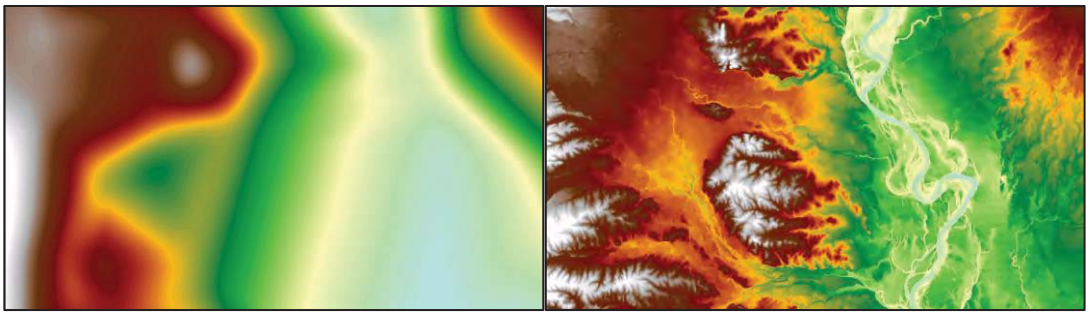


Figure 7. Depth-to-groundwater contours in Northern California. (Left) Contours were interpolated using depth-to-groundwater measurements determined at each well. **(Right)** Contours were determined by interpolating groundwater elevation measurements at each well and superimposing ground surface elevation from DEM spatial data to generate depth-to-groundwater contours. The image on the right shows a more accurate depth-to-groundwater estimate because it takes the local topography and elevation changes into account.

[18] USGS Digital Elevation Model data products are described at: https://www.usgs.gov/core-science-systems/ngp/3dep/about-3dep-products-services and can be downloaded at: https://iewer.nationalmap.gov/basic/

BEST PRACTICE #6. Best Available Science

Adaptive management is embedded within SGMA and provides a process to work toward sustainability over time by beginning with the best available information to make initial decisions, monitoring the results of those decisions, and using the data collected through monitoring programs to revise decisions in the future. In many situations, the hydrologic connection of NC dataset polygons will not initially be clearly understood if site-specific groundwater monitoring data are not available. If sufficient data are not available in time for the 2020/2022 plan, **The Nature Conservancy strongly advises that questionable polygons from the NC dataset be included in the GSP until data gaps are reconciled in the monitoring network.** Erring on the side of caution will help minimize inadvertent impacts to GDEs as a result of groundwater use and management actions during SGMA implementation.

KEY DEFINITIONS

Groundwater basin is an aquifer or stacked series of aquifers with reasonably well-defined boundaries in a lateral direction, based on features that significantly impede groundwater flow, and a definable bottom. *23 CCR §341(g)(1)*

Groundwater dependent ecosystem (GDE) are ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. *23 CCR §351(m)*

Interconnected surface water (ISW) surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted. *23 CCR §351(o)*

Principal aquifers are aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems. *23 CCR §351(aa)*

ABOUT US

The Nature Conservancy is a science-based nonprofit organization whose mission is *to conserve the lands and waters on which all life depends*. To support successful SGMA implementation that meets the future needs of people, the economy, and the environment, TNC has developed tools and resources (www.groundwaterresourcehub.org) intended to reduce costs, shorten timelines, and increase benefits for both people and nature.

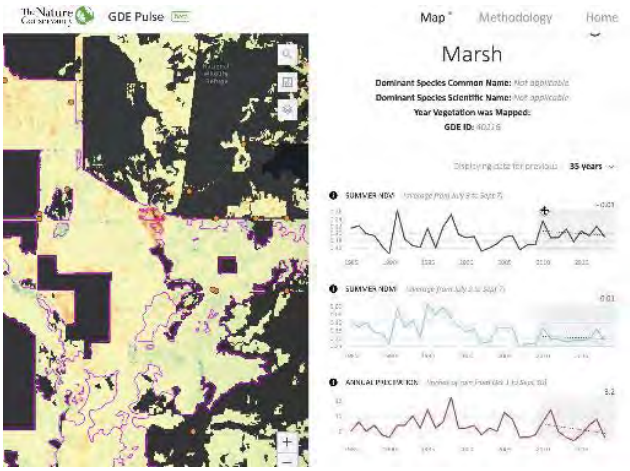
Attachment E

GDE Pulse

A new, free online tool that allows Groundwater Sustainability Agencies to assess changes in groundwater dependent ecosystem (GDE) health using satellite, rainfall, and groundwater data.

The Nature Conservancy
Protecting nature. Preserving life.

Visit
https://gde.codefornature.org/



Remote sensing data from satellites has been used to monitor the health of vegetation all over the planet. GDE pulse has compiled 35 years of satellite imagery from NASA's Landsat mission for every polygon in the Natural Communities Commonly Associated with Groundwater Dataset[19]. The following datasets are included:

Normalized Difference Vegetation Index (NDVI) is a satellite-derived index that represents the greenness of vegetation. Healthy green vegetation tends to have a higher NDVI, while dead leaves have a lower NDVI. We calculated the average NDVI during the driest part of the year (July - Sept) to estimate vegetation health when the plants are most likely dependent on groundwater.

Normalized Difference Moisture Index (NDMI) is a satellite-derived index that represents water content in vegetation. NDMI is derived from the Near-Infrared (NIR) and Short-Wave Infrared (SWIR) channels. Vegetation with adequate access to water tends to have higher NDMI, while vegetation that is water stressed tends to have lower NDMI. We calculated the average NDVI during the driest part of the year (July–September) to estimate vegetation health when the plants are most likely dependent on groundwater.

Annual Precipitation is the total precipitation for the water year (October 1st – September 30th) from the PRISM dataset[20]. The amount of local precipitation can affect vegetation with more precipitation generally leading to higher NDVI and NDMI.

Depth to Groundwater measurements provide an indication of the groundwater levels and changes over time for the surrounding area. We used groundwater well measurements from nearby (<1km) wells to estimate the depth to groundwater below the GDE based on the average elevation of the GDE (using a digital elevation model) minus the measured groundwater surface elevation.

[19] The Natural Communities Commonly Associated with Groundwater Dataset is hosted on the California Department of Water Resources' website: https://gis.water.ca.gov/app/NCDatasetViewer/#

[20] The PRISM dataset is hosted on Oregon State University's website: http://www.prism.oregonstate.edu/

California Poultry FEDERATION
4640 SPYRES WAY, SUITE 4 | MODESTO, CA 95356 | PHONE: (209) 576-6355 | FAX: (209) 576-6119 | WWW.CPIF.ORG

VIA E-MAIL (lsales@ppeng.com)

November 27, 2019

Members of the Tulare Lake Subbasin Board
of Directors
c/o Laurie Sales, Project Administrator
Southwest Kings GSA
286 West Cromwell Avenue
Fresno, California 93711

Re: Tulare Lake Subbasin GSP

Dear Board Members:

The California Poultry Federation ("CPF") appreciates the opportunity to comment on the draft Tulare Lake Subbasin Groundwater Sustainability Plan (the "Draft GSP"). CPF is the trade association for California's diverse and dynamic poultry industry. Our members include growers, hatchers, breeders, and processors that work with chickens, turkeys, ducks, game birds, and squab. Water is essential for all of them—both for nutrition and for maintaining sanitary conditions. CPF therefore supports effective measures to assure reliable water supplies.

In this regard, CPF recommends that each Tulare Lake Subbasin Groundwater Sustainability Agency ("GSA") make supply augmentation its top priority. We were encouraged to see that the Draft GSP incorporated storage, recharge, and conveyance projects and that Table 7-1 listed consideration of incentives as a means of encouraging participation in augmentation. Additional extraction rights in particular would be an excellent method of increasing landowner support for supply projects.

But we are concerned that the Draft GSP also emphasized substantial demand management without explaining precisely how that would be done. The listed management actions are "conceptual" (Draft GSP page 6-2) and Appendix E, which is to contain GSA appendices, is blank. Nor does the Draft GSP appear to set out any principles—which should include minimizing economic impact, maintaining established water rights, and incentivizing investment in water supply infrastructure—for developing demand management measures. The public will need to have meaningful opportunities to participate in the development of any specific demand management measures, which means that there must be sufficient time to evaluate supporting information and submit written comments. That is especially important in light of the finding (at Draft GSP page 7-7) that "[a]t this time there is not sufficient information to develop a financial

EXECUTIVE COMMITTEE MEMBERS AND OFFICERS
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DALTON RASMUSSEN, SQUAB PRODUCERS OF CALIFORNIA - SECRETARY/TREASURER | DAVID RUBENSTEIN, PITMAN FAMILY FARMS
BILL MATTOS, CALIFORNIA POULTRY FEDERATION - PRESIDENT

impact due to demand reduction." CPF expects all the Subbasin GSAs to do their best to ameliorate economic impacts by adopting implementation measures that are cost-effective.

One other point about public comment deserves mention. It was difficult to ascertain when written comments on the Draft GSP were due and where they should be sent. The Subbasin GSAs should establish, utilize, and publicize one central clearinghouse available through the Internet for disseminating information about further proposed actions in the Subbasin and receiving written comments.

Please contact me if you need any further information about these comments.

Very truly yours,

Bill Mattos

Bill Mattos
President

December 1, 2019

Sent via email to djackson@tcwater.org and dmelville@ppeng.com

Re: Comments on Draft Groundwater Sustainability Plan for Tri County Water Authority Tulare Lake Groundwater Basin

To Whom It May Concern,

On behalf of the above-listed organizations, we would like to offer the attached comments on the draft Groundwater Sustainability Plan for the Tri County Water Authority Tulare Lake Groundwater Basin. Our organizations are deeply engaged in and committed to the successful implementation of the Sustainable Groundwater Management Act (SGMA) because we understand that groundwater is a critical piece of a resilient California water portfolio, particularly in light of our changing climate. Because California's water and economy are interconnected, the sustainable management of each basin is of interest to both local communities and the state as a whole. This letter adopts by reference the comments and recommendations submitted by The Nature Conservancy on this draft plan.

Our organizations have significant expertise in the environmental needs of groundwater and the needs of disadvantaged communities.

- The Nature Conservancy, in collaboration with state agencies, has developed several tools[1] for identifying groundwater dependent ecosystems in every SGMA groundwater basin and has made that tool available to each Groundwater Sustainability Agency.
- Local Government Commission supports leadership development, performs community engagement, and provides technical assistance dealing with groundwater management and other resilience-related topics at the local and regional scales; we provide guidance and resources for statewide applicability to the communities and GSAs we are working with directly in multiple groundwater basins.
- Audubon California is an expert in understanding wetlands and their role in groundwater recharge and applying conservation science to develop multiple-benefit solutions for sustainable groundwater management.
- Clean Water Action and Clean Water Fund are sister organizations that have deep expertise in the provision of safe drinking water, particularly in California's small disadvantaged communities, and co-authored a report on public and stakeholder engagement in SGMA[2].

[1] https://groundwaterresourcehub.org/

[2] https://www.cleanwater.org/publications/collaborating-success-stakeholder-engagement-sustainable-groundwater-management-act

Because of the number of draft plans being released and our interest in reviewing every plan, we have identified key plan elements that are necessary to ensure that each plan adequately addresses essential requirements of SGMA. A summary review of your plan using our evaluation framework is attached to this letter as Appendix A. Our hope is that you can use our feedback to improve your plan before it is submitted in January 2020.

This review does not look at data quality but instead looks at how data was presented and used to identify and address the needs of disadvantaged communities (DACs), drinking water and the environment. In addition to informing individual groundwater sustainability agencies of our analysis, we plan to aggregate the results of our reviews to identify trends in GSP development, compare plans and determine which basins may require greater attention from our organizations.

Key Indicators

Appendix A provides a list of the questions we posed, how the draft plan responds to those questions and an evaluation by element of major issues with the plan. Below is a summary by element of the questions used to evaluate the plan.

1. Identification of Beneficial Users. This element is meant to ascertain whether and how DACs and groundwater-dependent ecosystems (GDEs) were identified, what standards and guidance were used to determine groundwater quality conditions and establish minimum thresholds for groundwater quality, and how environmental beneficial users and stakeholders were engaged through the development of the draft plan.
2. Communications plan. This element looks at the sufficiency of the communications plan in identifying ongoing stakeholder engagement during plan implementation, explicit information about how DACs were engaged in the planning process and how stakeholder input was incorporated into the GSP process and decision-making.
3. Maps related to Key Beneficial Uses. This element looks for maps related to drinking water users, including the density, location and depths of public supply and domestic wells; maps of GDE and interconnected surface waters with gaining and losing reaches; and monitoring networks.
4. Water Budgets. This element looks at how climate change is explicitly incorporated into current and future water budgets; how demands from urban and domestic water users were incorporated; and whether the historic, current and future water demands of native vegetation and wetlands are included in the budget.
5. Management areas and Monitoring Network. This element looks at where, why and how management areas are established, as well what data gaps have been identified and how the plan addresses those gaps.
6. Measurable Objectives and Undesirable Results. This element evaluates whether the plan explicitly considers the impacts on DACs, GDEs and environmental beneficial users in the development of Undesirable Results and Measurable Objectives. In addition, it examines whether stakeholder input was solicited from these beneficial users during the development of those metrics.
7. Management Actions and Costs. This element looks at how identified management actions impact DACs, GDEs and interconnected surface water bodies; whether mitigation for impacts to DACs is discussed or funded; and what efforts will be made to fill identified data gaps in the first five years of the plan. Additionally, this element asks whether any changes to local ordinances or land use plans are included as management actions.

Conclusion

We know that SGMA plan development and implementation is a major undertaking, and we want every basin to be successful. We would be happy to meet with you to discuss our evaluation as you finalize your Plan for submittal to DWR. Feel free to contact Suzannah Sosman at suzannah@aginnovations.org for more information or to schedule a conversation.

Sincerely,



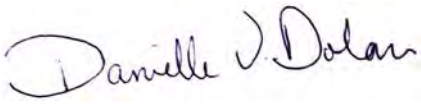
Jennifer Clary
Water Program Manager
Clean Water Action/Clean Water Fund



Samantha Arthur
Working Lands Program Director
Audubon California



Sandi Matsumoto
Associate Director, California Water Program
The Nature Conservancy



Danielle V. Dolan
Water Program Director
Local Government Commission

Appendix A
Review of Public Draft GSP

Groundwater Basin/Subbasin: Tulare Lake Subbasin (DWR 5-22-12)
GSA: Five GSAs (Mid-Kings River, South Fork Kings, Southwest Kings, El Rico, and the Tri-County Water Authority GSAs)
GSP Date: August 2019 Public Review Draft

1. Identification of Beneficial Users

Were key beneficial users identified and engaged?

Selected relevant requirements and guidance:
GSP Element 2.1.5, "Notice & Communication" (§354.10):
(a) A description of the beneficial uses and users of groundwater in the basin, including the land uses and property interests potentially affected by the use of groundwater in the basin, the types of parties representing those interests, and the nature of consultation with those parties.
GSP Element 2.2.2, "Groundwater Conditions" (§354.16):
(d) Groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes.
(f) Identification of interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems, utilizing data available from the Department, as specified in Section 353.2, or the best available information.
(g) Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or the best available information.
GSP Element 3.3, "Minimum Thresholds" (§354.28):
(4) How minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests.

Review Criteria		Yes	No	N/A	Relevant Info per GSP	Location (Section, Page[1])
1. Do beneficial users (BUs) identified within the GSP area include:	a. Disadvantaged Communities (DACs)	X			From Table 2-4, DACs include Armona, Home Garde, Hardwick, Community of Stratford, Kettleman City, and City of Corcoran.	Table 2-4, Page 94
	b. Tribes	X			"The only Native American Tribe within the Tulare Lake Subbasin boundary is the Santa Rosa Rancheria Tachi-Yokut Tribe. The Tachi-Yokut Tribe was invited to participate in GSP development via a letter sent on June 28, 2016 by the then Upper Tulare Lake GSA MOU Group (now known as the South Fork Kings GSA). A copy of the letter is included in the Appendix A of the Tulare Lake Subbasin GSAs' Communication & Engagement Plan. The Tribe's EPA director attended one of the South Fork Kings GSA's board meetings, and has been on their Interested Parties List since April 2017, receiving regular updates about GSP development within the SFKGSA and the Tulare Lake Subbasin. In addition, a Sacred Lands File & Native American Contacts List Request was also sent to the Native American Heritage Commission."	Appendix B, Page 373
	c. Small community public water systems (<3,300 connections)	X			Public water systems such as Armona CSD and Home Garden CSD are included in Table 2-4. It is not clear from the GSP which systems have fewer than 3,300 connections.	Table 2-4, Page 94
2. What data were used to identify presence or absence	d. DWR DAC Mapping Tool[2]		X		Data source is not clear from the GSP.	
	i. Census Places		X			

[1] Page numbers refer to the page of the PDF.
[2] DWR DAC Mapping Tool: https://gis.water.ca.gov/app/dacs/

	of DACs?	ii. Census Block Groups		X			
		iii. Census Tracts		X			
		e. Other data source		X			
3.	Groundwater Conditions section includes discussion of:	f. Drinking Water Quality	X			"Currently, as described in Section 5.4.3, groundwater quality in the northern portion of the Subbasin encompassing the Mid-Kings River GSA and South Fork Kings GSA is generally excellent for irrigation and satisfactory for municipal and industrial use (KCWD 2011). South of Stratford and Corcoran, groundwater quality diminishes, and portions of the Tulare Lakebed have been undesignated from being suitable for municipal, domestic, agricultural irrigation, and stock watering supply. Shallow groundwater contamination from fuel hydrocarbons, agricultural chemicals, or solvents are localized in the urbanized areas of Lemoore and Hanford and some smaller communities. Limited regional data is available for determining current nutrient concentrations based on groundwater depth and location. As discussed in Section 3.2.5, shallow groundwater can have elevated concentrations of nitrates and TDS, but the majority of the region is generally below Maximum Contaminant Levels (MCLs)."	4.4.1.4, Page 248
		g. California Maximum Contaminant Levels (CA MCLs)[3] (or Public Health Goals where MCL does not exist, e.g. Chromium VI)		X		See above. MCLs are only briefly discussed.	4.4.1.4, Page 248
4.	What local, state, and federal standards or plans were used to assess drinking water BUs in the development of Minimum Thresholds (MTs)?	h. Office of Environmental Health Hazard Assessment Public Health Goal (OEHHA PHGs)[4]		X			
		i. CA MCLs[3]	X			"The basic authority of the GSAs is to locally determine the sustainable amount of groundwater that can be pumped and to manage the transition from the current groundwater usage to a groundwater usage that is sustainable. Also, GSAs do not have the authority to modify surface water rights. Federal and state agencies provide direct oversight of quality and set their own appropriate thresholds such as Maximum Contaminant Levels for drinking water. These will be utilized by the Subbasin for MOs and MTs. For these reasons, the local GSAs will focus on water quality issues that are related to groundwater pumping rather than on issues related to contamination." "MTs will follow the state, federal, and local standards related to the relevant sustainability indicators set by the coalitions."	4.2.4, Page 239 4.4.2.4, Page 249
		j. Water Quality Objectives (WQOs) in Regional Water Quality Control Plans		X			
		k. Sustainable Communities Strategies/ Regional Transportation Plans[5]		X			

[3] CA MCLs: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/MCLsandPHGs.html
[4] OEHHA PHGs: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/MCLsandPHGs.html
[5] CARB: https://ww2.arb.ca.gov/resources/documents/scs-evaluation-resources

	l. County and/or City General Plans, Zoning Codes and Ordinances[6]		X			

Summary/ Comments
It is recommended that the GSP clearly identify the data sources that were used to identify the presence of DACs, and include as maps showing the locations of DACs. The representative monitoring networks should be shown on maps that include the location of DACs so that one can assess the networks' ability to monitor potential impacts to these sensitive beneficial users.

The GSP should provide much more thorough information on what the water quality MTs/MOs are and what standards were used in the development of MTs/MOs. Such information is crucial to the drinking water beneficial users in the subbasin.

[6] OPR General Plan Guidelines: http://www.opr.ca.gov/planning/general-plan/

2. Communications Plan

How were key beneficial users engaged and how was their input incorporated into the GSP process and decisions?

Selected relevant requirements and guidance:
GSP Element 2.1.5, "Notice & Communication" (§354.10):
Each Plan shall include a summary of information relating to notification and communication by the Agency with other agencies and interested parties including the following:
(c) Comments regarding the Plan received by the Agency and a summary of any responses by the Agency.
(d) A communication section of the Plan that includes the following:
(1) An explanation of the Agency's decision-making process.
(2) Identification of opportunities for public engagement and a discussion of how public input and response will be used.
(3) A description of how the Agency encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin.
(4) The method the Agency shall follow to inform the public about progress implementing the Plan, including the status of projects and actions.

DWR Guidance Document for GSP Stakeholder Communication and Engagement[7]

Review Criteria	Yes	No	N/A	Relevant Info per GSP	Location (Section, Page)
1. Is a Stakeholder Communication and Engagement Plan (SCEP) included?	X			Appendix B: Stakeholder Communication and Engagement Plan (no date)	Appendix B, Page 368
2. Does the SCEP or GSP identify that ongoing engagement will be conducted during GSP implementation?	X			"During the implementation phase, communication and engagement efforts focus on educational and informational awareness of the requirements and processes for reaching groundwater sustainability as set forth in the submitted GSP. Active involvement of all stakeholders is encouraged during implementation, and public notices are required for any public meetings, as well as prior to imposing or increasing any fees. Public outreach is also completed by the individual GSAs with collaborative efforts when target audiences span more than one GSA boundary."	2.5.1, Page 73
3. Does the SCEP or GSP specifically identify how DAC beneficial users were engaged in the planning process?	X			"Communication and educational outreach efforts with disadvantaged communities (DAC) and severely disadvantaged communities (SDAC) was needed for the development and implementation of the Tulare Lake Subbasin's GSP according to the Department of Water Resources' Best Management Practices. Information used to communicate to and engage the DACs in the GSP process, included an explanation of SGMA and soliciting feedback. GSA representatives regularly communicated with DACs and gave presentations on SGMA to community representatives, while gathering their feedback and input. By including DACs and SDACs in communication efforts during the development, public review and implementation phases of the GSP, residents were more likely to participate and provide feedback that could be crucial to long-term solutions for groundwater sustainability within their communities.	Appendix B, Page 374, 377

[7] DWR Guidance Document for GSP Stakeholder Communication and Engagement
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Guidance-Document-for-Groundwater-Sustainability-Plan---Stakeholder-Communication-and-Engagement.pdf

				Any feedback received from DAC/SDAC residents was reviewed and evaluated by the Tulare Lake Subbasin GSAs during the GSP development and public review phases." "For outreach to DACs/SDACs, fliers were available in both English and Spanish languages."	
4. Does the SCEP or GSP explicitly describe how stakeholder input was incorporated into the GSP process and decisions?	X			"As active stakeholders, members of the Boards of Directors and Stakeholder/Advisory Committees are direct representatives of their districts, communities and industries, and they continually gather feedback/input, and the concerns/needs of their constituents and report back to their respective meetings. Any stakeholder input received was reviewed by the GSA and Subbasin technical teams and taken into consideration during GSP development." "Stakeholder input was utilized during the GSA formation phase, as beneficial users and stakeholders with interests in groundwater usage within the GSAs' boundaries were notified via public meeting notices as soon as the process began." "With the goal of having the draft GSP before the end of the third quarter in 2019, 2018 was primarily the technical development of the plan, while working with GSA Boards of Directors, technical teams/committees, and GSA management at the subbasin level, as well as stakeholders for feedback and input. During the last quarter of 2018, the first round of public outreach meetings and interaction with stakeholder groups and other community organizations and entities was held with the purpose of educating and informing stakeholders about SGMA and the GSP process, while also soliciting feedback and input from these groups to consider and possibly include feedback and input into the GSP. Public outreach for this phase was completed by the individual GSAs." "Once the draft of the GSP was completed in September 2019, the public review process began. A 90-day comment period was held, with the GSP draft posted on the Tulare Lake Subbasin GSAs' websites for all stakeholders to conveniently download and review and provide comments. Outreach meetings were held during this phase both on subbasin-wide level, as well as by individual GSAs. These meetings focused on an overview of the GSP content, while giving stakeholders a public forum to provide their feedback and comments." Outreach tracking is also presented in tables by each GSA in Appendix D.	Appendix B, Page 370
Summary/ Comment It is important that stakeholder engagement be maintained through the development of future projects and management actions and other SGMA compliance and implementation steps.					

3. Maps Related to Key Beneficial Uses

Were best available data sources used for information related to key beneficial users?

Selected relevant requirements and guidance:
GSP Element 2.1.4 "Additional GSP Elements" (§354.8):
Each Plan shall include a description of the geographic areas covered, including the following information:
(a) One or more maps of the basin that depict the following, as applicable:
(5) The density of wells per square mile, by dasymetric or similar mapping techniques, showing the general distribution of agricultural, industrial, and domestic water supply wells in the basin, including de minimis extractors, and the location and extent of communities dependent upon groundwater, utilizing data provided by the Department, as specified in Section 353.2, or the best available information.

GSP Element 3.5 Monitoring Network (§354.34)
(b) Each Plan shall include a description of the monitoring network objectives for the basin, including an explanation of how the network will be developed and implemented to monitor groundwater and related surface conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial density to evaluate the affects and effectiveness of Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:
(c) Each monitoring network shall be designed to accomplish the following for each sustainability indicator:
(1) Chronic Lowering of Groundwater Levels. Demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features by the following methods:
(A) A sufficient density of monitoring wells to collect representative measurements through depth-discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer.
(4) Degraded Water Quality. Collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues.
(6) Depletions of Interconnected Surface Water. Monitor surface water and groundwater, where interconnected surface water conditions exist, to characterize the spatial and temporal exchanges between surface water and groundwater, and to calibrate and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. The monitoring network shall be able to characterize the following:
(A) Flow conditions including surface water discharge, surface water head, and baseflow contribution.
(B) Identifying the approximate date and location where ephemeral or intermittent flowing streams and rivers cease to flow, if applicable.
(C) Temporal change in conditions due to variations in stream discharge and regional groundwater extraction.
(D) Other factors that may be necessary to identify adverse impacts on beneficial uses of the surface water.
(f) The Agency shall determine the density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends based upon the following factors:
(3) Impacts to beneficial uses and users of groundwater and land uses and property interests affected by groundwater production, and adjacent basins that could affect the ability of that basin to meet the sustainability goal.

Review Criteria		Yes	No	N/A	Relevant Info per GSP	Location (Section, Page)
1. Does the GSP Include Maps Related to Drinking Water Users?	a. Well Density		X		No maps are provided. Page 47 indicates that there are 75 public supply wells in the Subbasin and the total number of wells is about 3,871.	Section 2, Page 47
	b. Domestic and Public Supply Well Locations & Depths		X		The GSP does not appear to include information on domestic and public supply well locations and depths.	
	i. Based on DWR Well Completion Report Map Application[8]?			X		

[8] DWR Well Completion Report Map Application: https://www.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37

	ii. Based on Other Source(s)?				X		
2. Does the GSP include maps of monitoring networks?	a. Existing Monitoring Wells		X			Existing monitoring wells for subsidence and water quality can be found in Figure 5-4 and 5-5.	Figure 5-4, Page 301 Figure 5-4, Page 302
	b. Existing Monitoring Well Data sources:	i. California Statewide Groundwater Elevation Monitoring (CASGEM)	X			"Groundwater levels are measured in the various networks and types of wells including: […] CASGEM Wells: DWR collects groundwater levels reported by local agencies and reports them through the CASGEM program. There are currently 17 CASGEM wells in the Subbasin."	5.1.5, Page 276
		ii. Water Board Regulated monitoring sites	X			"Water quality data will be obtained from the below-mentioned coalitions: […] RWQCB - Regional Water Quality Control Board" "Though water quality has been periodically analyzed within the Subbasin for irrigation suitability, monitoring programs are generally not in place with defined temporal and spatial distribution, except for municipal water suppliers, RWQCB sites with WDRs, and monitoring at evaporation ponds."	4.4.2.4, Page 250 5.4.3, Page 291
		iii. Department of Pesticide Regulation (DPR) monitoring wells	X			"The California Department of Pesticide Regulation (DPR) maintains a Surface Water Database (SURF) containing data from a wide variety of environmental monitoring studies designed to test for the presence or absence of pesticides in California surface waters. As part of DPR's effort to provide public access to pesticide information, this database provides access to data from DPR's SURF (DPR 2019)."	2.4.3.3, Page 68
	c. SGMA-Compliance Monitoring Network		X			Figure 5-1 to Figure 5-5	Figure 5-1 to Figure 5-5, Page298-302
	i. SGMA Monitoring Network map includes identified DACs?			X		DACs are not included. However, public water systems are shown on the maps.	
	ii. SGMA Monitoring Network map includes identified GDEs?			X		GDEs are not included.	

Summary/ Comments

The draft GSP does not provide maps showing "The density of wells per square mile, by dasymetric or similar mapping techniques, showing the general distribution of agricultural, industrial, and domestic water supply wells in the basin, including de minimis extractors, and the location and extent of communities dependent upon groundwater, utilizing data provided by the Department, as specified in Section 353.2, or the best available information" as required by 23 CCR § 354.8.(a)(5). The GSP should include the density, location and depths of all domestic and public supply wells in the GSA area using the best available information, and present this information on maps along with the proposed SGMA-compliance monitoring network so that the public can evaluate how well the monitoring network addresses these key beneficial users.

Providing maps of the monitoring network overlaid with location of DACs, GDEs, and any other sensitive beneficial users will also allow the reader to evaluate adequacy of the network to monitor conditions near these beneficial users.

4. Water Budgets

How were climate change projections incorporated into projected/future water budget and how were key beneficial users addressed?

Selected relevant requirements and guidance:
GSP Element 2.2.3 "Water Budget Information" (Reg. § 354.18)
Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form.

*Projected water budgets shall be used to estimate future baseline conditions of supply, **demand**, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components. The projected water budget shall utilize the following methodologies and assumptions to estimate future baseline conditions concerning hydrology, water demand and surface water supply availability or reliability over the planning and implementation horizon:*
(b) The water budget shall quantify the following, either through direct measurements or estimates based on data:
(5) If overdraft conditions occur, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.
(6) The water year type associated with the annual supply, demand, and change in groundwater stored.
(c) Each Plan shall quantify the current, historical, and projected water budget for the basin as follows:
*(1) Current water budget information shall quantify current inflows and outflows for the basin using the most recent hydrology, water supply, **water demand**, and land use information.*

DWR Water Budget BMP[9]
DWR Guidance for Climate Change Data Use During GSP Development and Resource Guide[10]

Review Criteria	Yes	No	N/A	Relevant Info per GSP	Location (Section, Page)
1. Are climate change projections explicitly incorporated in future/ projected water budget scenario(s)?	X			"The projected water budget for the Subbasin represents a hypothetical forecast for the 54-year period from 2017 through 2070 based on an assumed "normal hydrology" period and estimated future climate change impacts."	3.3.7, Page 141
2. Is there a description of the methodology used to include climate change?	X			"In a climate period analysis, climate change is modeled as a shift from a baseline condition, usually historically observed climate where every year or month of the simulation it is shifted in a way that represents the climate change signal at a future 30-year climate period. Climate period analysis provides advantages in this situation because it isolates the climate change signal independent of the monthly variability signal. In a climate period analysis, monthly variability is based on the reference period from which change is being measured, meaning that all differences between the future	3.3.7.3, Page 142-143

[9] DWR BMP for the Sustainable <management of Groundwater Water Budget:
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-4-Water-Budget.pdf
[10] DWR Guidance Document for the Sustainable Management of Groundwater Guidance for Climate Change Data Use During GSP Development:
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Climate-Change-Guidance_Final.pdf

						simulation and the reference period are the result of the climate change signal alone. Climate period analysis was utilized to modify the 54-year forecast of "normal hydrology" to account for future climate change. The 2017-2070 forecast incorporates climate period analysis using the 2030 and 2070 monthly change factors (CNRA 2018) for each forecast analog month (Figure 3-52). The 2030 monthly change factors were applied to the forecast months January 2017 through December 2030. The 2070 monthly change factors were applied to the forecast months January 2031 through December 2070. There is a notable increase in magnitude of the 2070 change factors compared to the 2030 change factors."	
3. What is used as the basis for climate change assumptions?	a. DWR-Provided Climate Change Data and Guidance[11]		X			"The DWR provides guidance on how to incorporate climate change into hydrology forecasts. There are two basic approaches that have been used to simulate climate change in water resource modeling: 1) transient analysis; and 2) climate period analysis (DWR 2018)."	3.3.7.3, Page 142
	b. Other			X			
4. Does the GSP use multiple climate scenarios?				X			
5. Does the GSP quantitatively incorporate climate change projections?			X			Based on the information presented in Figure 3-53, the GSP appears to have quantitatively incorporated climate change projections. However, no descriptions or tables are provided regarding the quantitative results of the climate change projections.	Figure 3-53, Page 219
6. Does the GSP explicitly account for climate change in the following elements of the future/projected water budget?	a. Inflows:	i. Precipitation	X			"The climate change factors were also applied to 54-year forecasts of monthly inflows (effective precipitation, surface water deliveries, lake bottom storage, and canal and river seepage) and outflows (agricultural demand) for the "normal hydrology" forecast."	3.3.7.4, Page 143
		ii. Surface Water	X				
		iii. Imported Water	X				
		iv. Subsurface Inflow	X				
	b. Outflows:	i. Evapotranspiration	X				
		ii. Surface Water Outflows (incl. Exports)			X		
		iii. Groundwater Outflows (incl. Exports)	X				
7. Are demands by these sectors (drinking water users) explicitly included in the future/projected	a. Domestic Well users (<5 connections)		X			"Municipal and domestic groundwater pumping are estimated upward based on projected population growth at an annual rate of 0.03%." It is not clear from the GSP if demands by some or all of these community and non-community water systems were considered. The GSP also does not identify the number of connections of the various	3.3.7.4, Page 143
	b. State Small Water systems (5-14 connections)			X			
	c. Small community water systems (<3,300 connections)			X			

[11] DWR Guidance Document for the Sustainable Management of Groundwater Guidance for Climate Change Data Use During GSP Development: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Climate-Change-Guidance_Final.pdf
DWR Resource Guide DWR-Provided Climate Change Data and Guidance for Use During GSP Development: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Resource-Guide-Climate-Change-Guidance_v8.pdf

water budget?	d. Medium and Large community water systems (> 3,300 connections)		X		public water systems present in the basin.	
	e. Non-community water systems		X			

Summary/ Comments

Given the uncertainties of climate change, the GSP should include and analyze the effects of multiple climate change scenarios.

The GSP should present the results of the projected water budget in a tabulated, transparent format. The GSP should also clearly identify and quantify water demands of all drinking water users in the projected water budget, including the small and large public water systems. Such information is necessary for the public to assess whether drinking water demands were fully and appropriately considered in the GSP.

5. Management Areas and Monitoring Network

How were key beneficial users considered in the selection and monitoring of Management Areas and was the monitoring network designed appropriately to identify impacts on DACs and GDEs?

Selected relevant requirements and guidance:
GSP Element 3.3, "Management Areas" (§354.20):

(b) A basin that includes one or more management areas shall describe the following in the Plan:
(2) The minimum thresholds and measurable objectives established for each management area, and an explanation of the rationale for selecting those values, if different from the basin at large.
(3) The level of monitoring and analysis appropriate for each management area.
(4) An explanation of how the management area can operate under different minimum thresholds and measurable objectives without causing undesirable results outside the management area, if applicable.
(c) If a Plan includes one or more management areas, the Plan shall include descriptions, maps, and other information required by this Subarticle sufficient to describe conditions in those areas.

CWC Guide to Protecting Drinking Water Quality under the SGMA[12]
TNC's Groundwater Dependent Ecosystems under the SGMA, Guidance for Preparing GSPs[13]

Review Criteria	Yes	No	N/A	Relevant Info per GSP	Location (Section, Page)
1. Does the GSP define one or more Management Area?	X			"In order to facilitate implementation of the GSP, management areas have been created for the Subbasin. There are five Primary Management Areas and two Secondary Management Areas."	3.4, Page 144 Figure 3-54, Page 220
2. Were the management areas defined specifically to manage GDEs?		X		"Primary Management Areas have been formed from each of the five GSAs." "Two Secondary Management Areas have been formed for the Subbasin. These two Secondary Management Areas are different from the Primary Management Areas and each other due to distinctly different groundwater conditions in each area."	3.4, Page 144
3. Were the management areas defined specifically to manage DACs?		X			
a. If yes, are the Measurable Objectives (MOs) and MTs for GDE/DAC management areas more restrictive than for the basin as a whole?			X		
b. If yes, are the proposed management actions for GDE/DAC management areas more restrictive/ aggressive than for the basin as a whole?			X		
4. Does the GSP include maps or descriptions indicating what DACs are located in each Management Area(s)?	X			Table 2-4 describes DACs in each GSA area.	Table 2-4, Page 94
5. Does the GSP include maps or descriptions indicating what GDEs are located in each Management Area(s)?	X			Figure 3-38. Distribution of Wetlands and Phreatophyte Vegetation	Figure 3-38, Page 198

[12] CWC Guide to Protecting Drinking Water Quality under the SGMA: https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1559328858/Guide_to_Protecting_Drinking_Water_Quality_Under_the_Sustainable_Groundwater_Management_Act.pdf?1559328858
[13] TNC's Groundwater Dependent Ecosystems under the SGMA, Guidance for Preparing GSPs: https://www.scienceforconservation.org/assets/downloads/GDEsUnderSGMA.pdf

Summary/ Comments
It is recommended that the GSP includes maps of the identified DACs located within each Management Area.

Care should be taken so that the management areas and the associated monitoring network are designed to adequately assess and protect against impacts to all beneficial users, including GDEs and DACs.

6. Measurable Objectives, Minimum Thresholds, and Undesirable Results

How were DAC and GDE beneficial uses and users considered in the establishment of Sustainable Management Criteria?

Selected relevant requirements and guidance:
GSP Element 3.4 "Undesirable Results" (§ 354.26):
(b) The description of undesirable results shall include the following:
(3) Potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results

GSP Element 3.2 "Measurable Objectives" (§ 354.30)
(a) Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.

Review Criteria	Yes	No	N/A	Relevant Info per GSP	Location (Section, Page)
1. Are DAC impacts considered in the development of Undesirable Results (URs), MOs, and MTs for groundwater levels and groundwater quality?		X		The impacts to DACs are not explicitly considered. Water Level URs: "Exceedance of MTs leading to undesirable results related to groundwater level in the Subbasin would cause a diminished level of groundwater supplies for agricultural and municipal needs. Groundwater levels are anticipated to continue to decrease at current rates in the next several years before implemented programs have a positive effect on the stabilization of groundwater levels based on the variability of hydrology and availability of flood water. As stated above, agriculture is the main economic enterprise of the Subbasin, so effective management of groundwater for sustainable future use is critical to the continuation of current economic interests, which add value to the Subbasin's communities. Decreases in groundwater levels will continue to increase the cost of energy for pumping. If MT levels are reached or exceeded, wells have the potential to go dry and require deepening to reach the lowered water table. Alternatively, pumps may be lowered if the existing well casing is sufficiently deeper. However, once the Subbasin reaches sustainability in the future, the depth of the wells will be known and can be designed to meet those depths to prevent future wells from becoming dry." Water Level MTs: "Due to the timely process of infrastructure development and program implementation, and variability in hydrology and the availability of flood water, groundwater levels are expected to continue to decrease in the next several years before programs have a positive effect on the stabilization of groundwater levels. Decreases in groundwater levels will continue to increase the cost of energy for pumping. If MT levels are reached, there may be some wells that go dry and require deepening to reach the water table. Alternatively, pumps may be lowered if the existing well casing is sufficiently deeper. However, once the Subbasin reaches sustainability in the future, the design depth for wells will be known and will be used in planning of future	4.3.3, Page 245 4.4.4, Page 251

					well construction to minimize future wells from becoming dry." Water Quality MTs: "If water quality is allowed to deteriorate to levels set by MTs, agricultural producers may experience a decrease in crop yield and/or crop quality. Poor water quality would cause a buildup of salts and nitrates in the surface layers of soil. The best way to treat nutrient build up is by leaching or over-irrigating enough to push soluble contaminants through the soil column."	
2.	Does the GSP explicitly discuss how stakeholder input from DAC community members was considered in the development of URs, MOs, and MTs?		X		The GSP does not explicitly discuss how stakeholder input from DACs was considered.	
3.	Does the GSP clearly identify and detail the anticipated degree of water level decline from current elevations to the water level MOs and MTs?		X		The GSP does not clearly identify the anticipated degree of water level decline. However, current water levels and MOs/MTs are presented in Table 4-1. Based on this if water levels reach MTs, this will represent an average decline of approx. 100 feet below 2017 conditions, and over 200 feet below current conditions in some parts of the subbasin (i.e., wells SFK_B_1920E19A001M, SFK_C_20S20E07H001M, and SFK_C_LEM_12). Even MOs represent over 100 feet of decline below 2017 water levels in many areas of the Subbasin.	Table 4-1, Page 262
4.	If yes, does it include:	a. Is this information presented in table(s)?	X			
		b. Is this information presented on map(s)?	X			
		c. Is this information presented relative to the locations of DACs and domestic well users?	X			
		d. Is this information presented relative to the locations of ISW and GDEs?	X			
5.	Does the GSP include an analysis of the anticipated impacts of water level MOs and MTs on drinking water users?		X		"Due to the timely process of infrastructure development and program implementation, and variability in hydrology and the availability of flood water, groundwater levels are expected to continue to decrease in the next several years before programs have a positive effect on the stabilization of groundwater levels. Decreases in groundwater levels will continue to increase the cost of energy for pumping. If MT levels are reached, there may be some wells that go dry and require deepening to reach the water table. Alternatively, pumps may be lowered if the existing well casing is sufficiently deeper. However, once the Subbasin reaches sustainability in the future, the design depth for wells will be known and will be used in planning of future well construction to minimize future wells from becoming dry." Impacts on drinking water users are not explicitly considered. Based on the water level declines identified above, it would be expected that such impacts could be significant.	4.4.4, Page 251
6.	If yes:	a. On domestic well users?	X			
		b. On small water system production wells?	X			
		c. Was an analysis conducted and clearly illustrated (with maps) to identify what wells would be expected to be partially and fully dewatered at the MOs?	X			
		d. Was an analysis conducted and clearly illustrated (with maps) to identify what wells would be expected to be partially and fully dewatered at the MTs?	X			
		e. Was an economic analysis performed to assess the increased operation costs associated with increased lift as a result of water level decline?	X			
9.	Does the sustainability goal explicitly include drinking water and nature?		X		"This GSP aims to manage groundwater resources to continue to provide an adequate water supply for existing beneficial uses and users in accordance with counties and cities general plans while meeting established measurable objectives (MO) to maintain a sustainable yield. This goal aims to continue to provide adequate water supply for existing beneficial uses and users while ensuring the future, sustainable use of groundwater. Additionally, the sustainability goal works as a tool for managing groundwater, basin-wide, on a long-term basis to protect quality of life through the continuation of existing economic industries in the area including but not limited to agriculture."	1.3.1, Page 40 Table 2-4, Page 94

				Table 2-4. Beneficial Uses and Users by GSA The sustainability goal does not include nature.	

Summary/ Comments

Based on the presented information, impacts to DACs are not explicitly considered in the discussion of URs, MOs, and MTs. More detail and specifics regarding DACs, including those that rely on smaller community drinking water systems and domestic wells, is necessary to demonstrate that these beneficial users were adequately considered. It is recommended that the GSP present a thorough and robust analysis, supported by maps, that identifies: (1) what domestic wells are likely to be impacted (including partially dewatered) at the MTs and at the MOs and (2) the location of the likely impacted wells with respect to DACs and other communities and systems dependent on groundwater.

Based on the information presented in Table 4-1 of the draft GSP, if water levels reach MTs, this will represent an average decline of approx. 100 feet below 2017 water levels, and over 200 feet below current conditions in some parts of the subbasin (i.e., wells SFK_B_1920E19A001M, SFK_C_20S20E07H001M, and SFK_C_LEM_12). Even MOs represent an average decline of over 50 feet below current conditions and over 100 feet of decline in many areas of the Subbasin. The GSP needs to explain how such water level declines represent sustainable conditions and are protective of beneficial uses and users in the Subbasin.

A proactive assistance program should be developed for potentially impacted beneficial users, including DACs, small water systems, and domestic wells, to mitigate potential future adverse impacts.

The GSP should also explicitly demonstrate whether and how the stakeholder input from DACs was considered in the development of URs, MOs, and MTs.

We recommend that the sustainability goal explicitly includes environmental beneficial uses of groundwater.

7. Management Actions and Costs

What does the GSP identify as specific actions to achieve the MOs, particularly those that affect the key BUs, including actions triggered by failure to meet MOs? What funding mechanisms and processes are identified that will ensure that the proposed projects and management actions are achievable and implementable?

Selected relevant requirements and guidance

GSP Element 4.0 Projects and Management Actions to Achieve Sustainability Goal (§ 354.44)

(a) Each Plan shall include a description of the projects and management actions the Agency has determined will achieve the sustainability goal for the basin, including projects and management actions to respond to changing conditions in the basin.

(b) Each Plan shall include a description of the projects and management actions that include the following:

(1) A list of projects and management actions proposed in the Plan with a description of the measurable objective that is expected to benefit from the project or management action.

Review Criteria	Yes	No	N/A	Relevant Info per GSP	Location (Section, Page)
1. Does the GSP identify benefits or impacts to DACs as a result of identified management actions?		X		The impacts to DACs are not explicitly discussed in the GSP. Recharge projects are noted in the GSP as expected to improve water quality.	6.3.3, Page 323
2. If yes: a. Is a plan to mitigate impacts on DAC drinking water users included in the proposed Projects and		X			

		Management Actions?					
	b.	Does the GSP identify costs to fund a mitigation program?		X			
	c.	Does the GSP include a funding mechanism to support the mitigation program?		X			
3.	Does the GSP identify any demand management measures in its projects and management actions?		X			Section 6.3 and 6.4 provide potential P/MAs options that may be utilized by the GSAs. Table 6-1 to 6-4 in Section 6.5 list the P/MAs chosen for each GSA.	6.3, Page 317-330 6.4, Page 330-331 6.5, Page 331-334
4.	If yes, does it include:	a. Irrigation efficiency program		X			
		b. Ag land fallowing (voluntary or mandatory)	X			Fallowing programs are identified by Mid-Kings River GSA, El Rico GSA, and South Fork Kings GSA. "The Subbasin may adopt a policy to incentive farmers to permanently fallow land. Policy will solicit volunteers first then look towards mandatory fallowing based on percentage reductions possibly on a rotation basis."	
		c. Pumping allocation/restriction	X			Groundwater allocation is listed as a potential management action in Section 6.4.	
		d. Pumping fees/fines	X			Pumping fees for groundwater allocation exceedances and groundwater extractions are listed as potential management actions in Section 6.4.	
		e. Development of a water market/credit system	X			Groundwater marketing and trade is listed as a potential management action in Section 6.4.	
		f. Prohibition on new well construction		X			
		g. Limits on municipal pumping		X		It is not clear if there would be limits on municipal pumping.	
		h. Limits on domestic well pumping		X		It is not clear if there would be limits on domestic well pumping.	
		i. Other	X			"Require new developments (non-de minimis extractors) to prove sustainable water supplies if land use conversion is not a conservation measure"	
5.	Does the GSP identify water supply augmentation projects in its projects and management actions?		X			Section 6.3 and 6.4 provide potential P/MAs options that may be utilized by the GSAs. Table 6-1 to 6-4 in Section 6.5 list the P/MAs chosen for each GSA.	6.3, Page 317-330 6.4, Page 330-331 6.5, Page 331-334
6.	If yes, does it include:	a. Increasing existing water supplies	X			"Each GSA is proposing to use their existing contract and rights for surface water as access to import more surface water into the Subbasin."	
		b. Obtaining new water supplies		X			
		c. Increasing surface water storage	X			Storage projects are identified by South Fork Kings GSA, El Rico GSA, and Tri-County Water GSA.	
		d. Groundwater recharge projects – District or Regional level	X			Recharge projects are identified by Mid-Kings River GSA and South Fork Kings GSA.	
		e. On-farm recharge	X			On-Farm Improvements project is identified by South Fork Kings GSA.	
		f. Conjunctive use of surface water	X			The recharge projects also involve conjunctive use of surface water.	
		g. Developing/utilizing recycled water		X			

	h. Stormwater capture and reuse		X			
	i. Increasing operational flexibility (e.g., new interties and conveyance)	X			The Mid-Kings River GSA plans to pursue improvement to conveyance systems and expanded surface water delivery system.	
	j. Other		X			
7. Does the GSP include plans to fill identified data gaps by the first five-year report?		X			Section 5.4.1.3 discusses plans to fill data gaps in groundwater level monitoring network, including plans to collect well completion reports, perform a video inspection of wells to obtain construction information, construct a dedicated monitoring well, and replace monitor point with another alternate private well. Some P/MAs in Table 7-1 are also noted in the GSP as expected to help fill data gaps, including (1) Flood Flows (Spills into the Subbasin), include, Tule River, Deer Creek, Cross-Creeks and Kings River; (2) Registration of extraction facilities; (3) Require self-reporting of groundwater extraction, water level, and water quality data; and (4) Require well meters, sounding tubes, and water quality sample ports.	5.4.1.3, Page 286 Table 7-1, Page 343
8. Do proposed management actions include any changes to local ordinances or land use planning?		X			"Require new developments (non-de minimis extractors) to prove sustainable water supplies if land use conversion is not a conservation measure"	6.4, Page 330
9. Does the GSP identify additional/contingent actions and funding mechanisms in the event that MOs are not met by the identified actions?			X		"This section identifies the proposed project and management action targets envisioned to achieve sustainability. These preliminary amounts will be reevaluated, and conditions monitored while efforts are implemented. This will allow the GSA to compare the anticipated versus resulting change in groundwater levels as well as other sustainability criteria to determine if additional measures need to be employed to achieve sustainability." However, the GSP does not provide details on what projects and management actions will be implemented as additional measures.	6.5, Section 331
10. Does the GSP provide a plan to study the interconnectedness of surface water bodies?			X		"As discussed in Section 3.2.8, Interconnected Surface Water and Groundwater Systems, the Subbasin does not contain interconnected surface and groundwater systems based on review of groundwater potentiometric surface maps. Groundwater contours indicate the Kings River, Cross Creek, and Mill Creek are losing streams that directly recharge groundwater. Groundwater is not in contact with these streams and cannot contribute any base flow to them. Due to the lack of connected water systems, interconnected surface water will not be monitored or considered when making management decisions."	4.2.5, Page 240
11. If yes:	a. Does the GSP identify costs to study the interconnectedness of surface water bodies?			X		
	b. Does the GSP include a funding mechanism to support the study of interconnectedness surface water bodies?			X		

Summary/ Comments

The GSP should identify the potential impacts of the proposed projects or management actions on DACs. If impacts are expected, the GSP should include plans to monitor for, prevent, and/or mitigate against such impacts, provide the estimated costs, and identify the funding sources.

The GSP does not appear to include any plans to address impacts to domestic well users if water quality in these wells is degraded in the future. The GSP should include plan to

monitor for and mitigate impacts to DAC drinking water users.

Westlands Water District
3130 N. Fresno Street, P.O. Box 6056, Fresno, California 93703-6056, (559) 224-1523, FAX (559) 241-6277

December 2, 2019

Southwest Kings Groundwater Sustainability Agency
Kings Subbasin
Basin Number 5-22.08
Transmitted via online submission at: info@swkgsa.org

Subject: Tulare Lake Subbasin Draft Groundwater Sustainability Plan

Dear Southwest Kings GSA Group:

Westlands Water District ("Westlands GSA") appreciates the opportunity to provide comments on the Tulare Lake Subbasin Draft Groundwater Sustainability Plan ("Draft GSP"). The Westlands Groundwater Sustainability Agency ("GSA") respectfully submits the following comments.

Finding 1 (Page 3-27): Figures 3-26 and 3-27, Table 3-6, and Section 3.2.2 of the GSP states with respect to groundwater flow in the unconfined aquifer that, "[i]n general, groundwater flowed into the Subbasin from the Kings, Kaweah, and Tule Subbasins and out of the Subbasin to the Westside Subbasin." This statement is supplemented by contours of unconfined potentiometric head developed by DWR from 1990 through 2016.

Westlands' Comment: The unconfined water level data are used to make inferences about general groundwater flow directions. As stated in Section 3.2.3 of the GSP, vertical gradients can exceed 50 feet per 100 feet suggesting that flow directions can be heavily dependent on the depth horizons that are selected and therefore, change considerably with depth. Model results provided in Appendix D also highlight how groundwater flow directions vary with depth.

DWR does not provide groundwater contours for the majority of the boundary shared between the Westside and Tulare Lake Subbasin. In fact, contours from 2005, 2010 and 2016 provide almost no overlap with the shared Subbasin boundary. As a result, there is no substantial evidence to support the statements regarding groundwater flows "out of the Subbasin to the Westside Subbasin."

The spatial information for wells used to develop the DWR water level contours are readily available for 2016 (DWR, 2019). Review of these data reveals that the majority of wells used by DWR to develop contours of unconfined potentiometric head within the Westside Subbasin are screened in the Lower Aquifer (**WWD Attachment: Figure 1**). Given that groundwater level readings can vary considerably between the Upper Aquifer and Lower Aquifer, water levels from the Lower Aquifer are unlikely to be representative of unconfined water levels (even in the Spring) and should not be used to support the GSP conclusions of subsurface flow in the unconfined aquifer between the Westside and Tulare Lake Subbasins.

Therefore, the analysis is not supported by substantial evidence and we respectfully disagree with the conclusion set forth in the GSP relating to groundwater conditions in the unconfined aquifer.

Finding 2 (Page 3-87): Figures 3-28b, 3-28c and 3-28d display wells within the Tulare Lake Subbasin with long term hydrographs.

Westlands' Comment: Figures 3-28b to 3-28d shows long term hydrographs for wells within the Tulare Lake Subbasin. Unfortunately, the data displayed by the hydrographs is pixelated, therefore unreviewable. Westlands GSA recommends revising the mentioned figures to display hydrographs using a higher resolution to allow the public to review.

Finding 3 (Page 3-93): Figures 3-30 through 3-32, and Section 3.2.5 describes groundwater quality data in the Tulare Lake and Westside Subbasins. With respect to TDS, the GSP cites reports from Davis et al., 1956 and Hansen et al., 2018.

Westlands Comments: Both reports highlight how depth significantly influences TDS concentrations. However, Figure 3-30 does not report the depth of the wells or the aquifer the TDS sample represents which can substantially influence how data is interpreted. Furthermore, none of the maps shows the time period being represented. With respect to the concentration of arsenic in groundwater, neither the most recent nor the maximum arsenic concentration in the data available from GeoTracker is as high as those shown in Figure 3-31 (**WWD Attachment: Figure 2 and 3**). Furthermore, the density of wells with available arsenic data in the Geotracker GAMA database is substantially less than that shown in Figure 3-31.

The concentration of nitrate in groundwater is shown in Figure 3-32. This map shows nitrate concentration exceeding the MCL in four locations adjacent to the Westside Subbasin boundary. A review of data available from Geotracker GAMA show that samples exceeding the MCL were measured in the mid to late-1980's and likely do not reflect the current ambient nitrate concentration at these locations.

We recommend that the draft GSP be revised to accurately convey groundwater quality data by aquifer and by the timeframe the data represents. In addition, we recommend that the groundwater quality data be reviewed for accuracy.

Finding 4 (Page 3-87): Figures 3-34 displaying historical subsidence in the San Joaquin Valley from 1949 – 2005.

Westlands' Comment: Figures 3-34 contains a legend that is incomplete and is unable to be reviewed. Westlands GSA recommends applying the corresponding color scheme to the vertical displacement legend to allow readers to be able to review the presented information.

Finding 5 (Page 4-18): Section 4.5.1.1 introduces the following sustainable management criteria for Groundwater Levels paraphrased as follows: The Sustainable Management Criteria for Groundwater Level (Section 4.5.1.1) proposes the Measurable Objective to be set at a groundwater level using Method 4, which forecasts water levels to 2035 and sets the 2035 water level as the Measurable Objective. Minimum Thresholds were based on assumed stability of groundwater levels between 2035 and 2040 and are designed to be a last-resort warning before more severe measures must be taken to protect groundwater resources. Section 4.4.3 (Selection Process of Minimum Thresholds to Avoid

Undesirable Results) establishes the Minimum Thresholds as "one standard deviation of all observed head data in compliance wells or modeled forecasted data." Figure 4-2 through 4-6 describe establishment of the Minimum Thresholds as "one standard deviation or 50 feet, whichever is greater."

Westlands' Comment: Sustainable Management Criteria, which includes the measurable objectives and the minimum thresholds, allows groundwater levels in the aquifer to decline past the Westside Subbasin's Measurable Objectives and Minimum Thresholds, set at 2015 groundwater levels, and may negatively impact the Westside Subbasin's ability to achieve sustainability by reducing net inflow into the Westside Subbasin and/or reversing the groundwater flow direction. More specifically, the proposed decline of groundwater levels in the Southwest Kings GSA may alter the groundwater conditions near the boundary between the Westside Subbasin and the Kings Subbasin and result in a lowering of groundwater levels in the Westside Subbasin. This action would have the effect of shifting the burden of SGMA compliance from the Southwest Kings GSA to Westlands GSA. This is not permissible. The GSP is devoid of substantial evidence and any explanation as to how the Minimum Thresholds will avoid a significant and unreasonable reduction in groundwater storage and significant and unreasonable land subsidence contributing to the impairment of surface uses within the Westside Subbasin.

Water Code section 10733, subdivision (c) provides in relevant part:

> "The department shall evaluate whether a groundwater sustainability plan adversely affects the ability of an adjacent basin to implement their groundwater sustainability plan or impedes achievement of sustainability goals in an adjacent basin"

Further, we respectfully call your attention to Code of Regulations, title 23, section 355.4, subdivision (b)(7):

> "When evaluating whether a Plan is likely to achieve the sustainability goal for the basin, the Department shall consider . . . whether the Plan *will adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of its sustainability goal.*" (emphasis added)

and Code of Regulations, title 23, section 354.28, subdivision (b)(3):

> "The description of minimum thresholds shall include . . . how minimum thresholds have been selected to *avoid causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals*." (emphasis added)

Moreover, the implementation of SGMA and a GSP cannot be used to override the protections afforded common law water rights. Overlying and appropriative uses of groundwater within the Westside Subbasin are entitled to legal and equitable protection against infringement by an action that deprives them of their historical subsurface inflows. (*City of Lodi v. East Bay Municipal Utility District* (1936) 7 Cal.2d 316, 344 [protecting groundwater levels against lowering from another party's pumping]; *Trussell v. City of San Diego* (1959) 172 Cal.App.2d 593, 611 [enjoining a party for lowering water table by interrupting surface flow].)

Practically speaking, proposing a continued decline of groundwater levels in the Lower Aquifer is not supported by substantial evidence because the GSP acknowledges that it does not have enough data to support its finding that there will be no impact to historical boundary flow conditions between the

Subbasins. The potential for curtailing historic underflow into the Westside Subbasin may be a substantial factor in contributing to significant and unreasonable subsidence and frustrate the Westlands' GSA ability to achieve the sustainability goal.

Finding 6 (Page 4-21): Section 4.5.33 Land Subsidence references Table 4-2: *Lemoore-Average Land Subsidence Interim Milestones based on Measurable Objectives for the Subbasin,* which displays modeled subsidence rates and interim milestones for those subsidence rates. The Tulare Lake Subbasin also proposes a minimum threshold of 16 ft by 2040 in Section 4.4.1.3.

Westlands' Comment: Westlands GSA is concerned that allowing subsidence rates as proposed may impact critical infrastructure such as roads, railroads, and may increase flood risks to existing land uses, especially near Corcoran where subsidence rates are critical, in the Westside Subbasin and other neighboring subbasins. Westlands GSA strongly recommend selecting Measurable Objectives and Minimum Thresholds to subsidence rates that will not negatively impact infrastructure in neighboring subbasins. The GSP fails to reference any substantial evidence that the minimum threshold will avoid significant and unreasonable land subsidence that impairs surface uses in the Westside Subbasin.

Finding 7 (Appendix D): The information provided in the GSP suggests a conceptual error leading to flows between the Westside Subbasin and Tulare Lake Subbasin to be misrepresented in the numerical model and GSP. Figure D5-5 in Appendix D shows the average model simulated net lateral subsurface flow of 158,405 AFY from the Lower Aquifer to the general head boundary (GHB) in the Westside Subbasin. Contours of simulated Lower Aquifer groundwater levels from 2015 in Figure D5-3 show a cone of depression along the GHB in the Westside Subbasin. Figure D5-5 shows pumping from the Lower Aquifer is a net positive suggesting that intraborehole flow from the Upper Aquifer to the Lower Aquifer is greater than the amount extracted from wells, suggesting the GHB is driving the flow across the boundary between the Westside and Tulare Lake Subbasins and out of the Westside Subbasin.

Westlands' Comment:
Lower Aquifer contours developed from water level data at the end of the 2014 irrigation year (one year before the simulated contour data provided) do not show a cone of depression in the location of the GHB (**WWD Attachment: Figure 4**). These contours also cannot be interpreted to suggest that groundwater flow is from the Tulare Lake Subbasin to the Westside Subbasin. Furthermore, it is unclear what physical process would cause a localized cone of depression to form in this location, especially considering that the groundwater model simulates positive net pumping from the Lower Aquifer in the Westside Subbasin.

The analysis is not supported by substantial evidence and for the reasons set forth above, Westlands recommends reanalyzing the water level contour data from the numerical model and GSP.

Lastly, the Westlands GSA identified the following reporting discrepancies within the text of the GSP and Appendix D that should be reviewed:

1. Total lateral subsurface inflow into the Westside Subbasin shown in Figure D5-5 averages 72,296 AFY (67,347 from the Tulare Lake Subbasin and 4,948 AFY from the Kings Subbasin). Table 3-6 of the GSP shows average annual subsurface flow from the Tulare Lake Subbasin to the Westside Subbasin of 41,390. What is the source of this discrepancy?

2. In the graphic depicting aquifer specific fluxes in Figure D5-5, the sum of the "Net GW Flux" (which presumably is lateral subsurface flow between adjacent subbasins) totals 4,936 AFY while the total in the table shown in Figure D5-5 is 72,296 AFY. What is the source of this discrepancy?

3. Figure numbers in the Appendix D text do not correspond to the correct figures. Figure D5-10 is titled "Simulated Subsidence 1990-2016". Figure D5-8 shows "Groundwater Mass Balance Tule Subbasin".

Westlands' General Comment: The GSP Regulations include a provision authorizing GSAs in adjacent basins to enter into interbasin agreements. The interbasin agreements can "establish compatible sustainability goals" and be included in GSPs to "support a finding that implementation of the Plan will not adversely affect an adjacent basin's ability to implement its Plan or impede the ability to achieve its sustainability goal." (Code Regs., tit. 23, § 357.2.)[1] The interbasin agreements may also address: (1) "an estimate of groundwater flow across basin boundaries;" (2) how the GSAs will reconcile differing minimum thresholds and measurable objectives in the basins to avoid undesirable results; and (3) a process for resolving conflicts between the GSAs. (*Id.*) Given the potential reduction of historical cross-boundary flow attributable to the planned operation with the Tulare Lake Subbasin Draft GSP, Westlands strongly recommends that we meet and confer at the earliest opportunity to determine whether an interbasin agreement can be reached. Our intention is to reach a cooperative resolution of these important issues that will enable coordinated sustainable management in our GSAs.

If you have any questions or concerns, regarding these comments, please contact Kiti Campbell by email at kcampbell@wwd.ca.gov or by phone at (559) 241-6226. Thank you for the opportunity to provide comments on the Tulare Lake Subbasin Draft GSP.

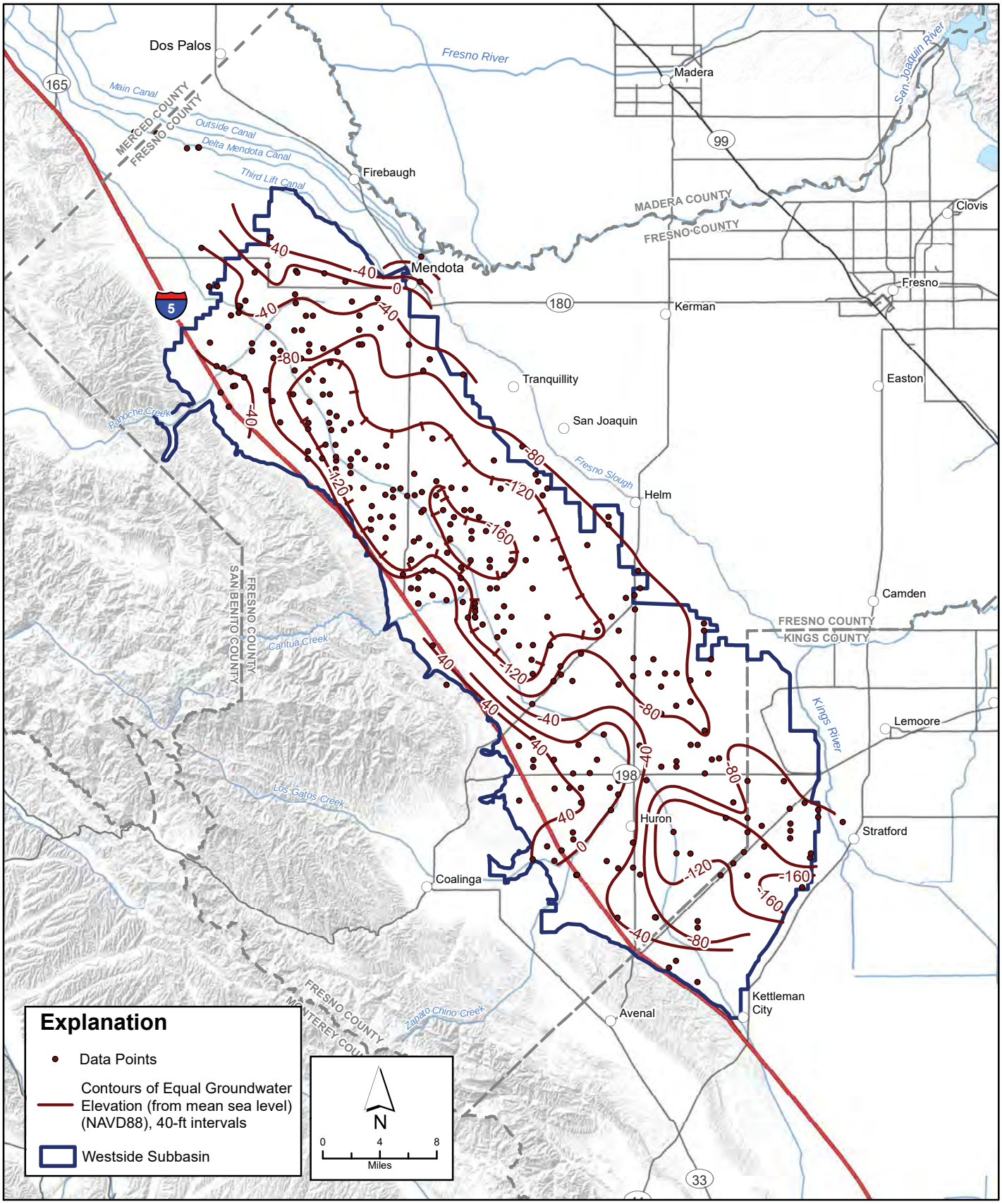
Sincerely,

Russ Freeman

Russ Freeman, P.E.
Deputy General Manager – Resources
Westlands Water District

[1] See Appendix A for the complete text of the provisions of SGMA and the GSP Regulations (Code Regs., tit. 23, § 350, *et seq.*) cited herein.

Figure 4

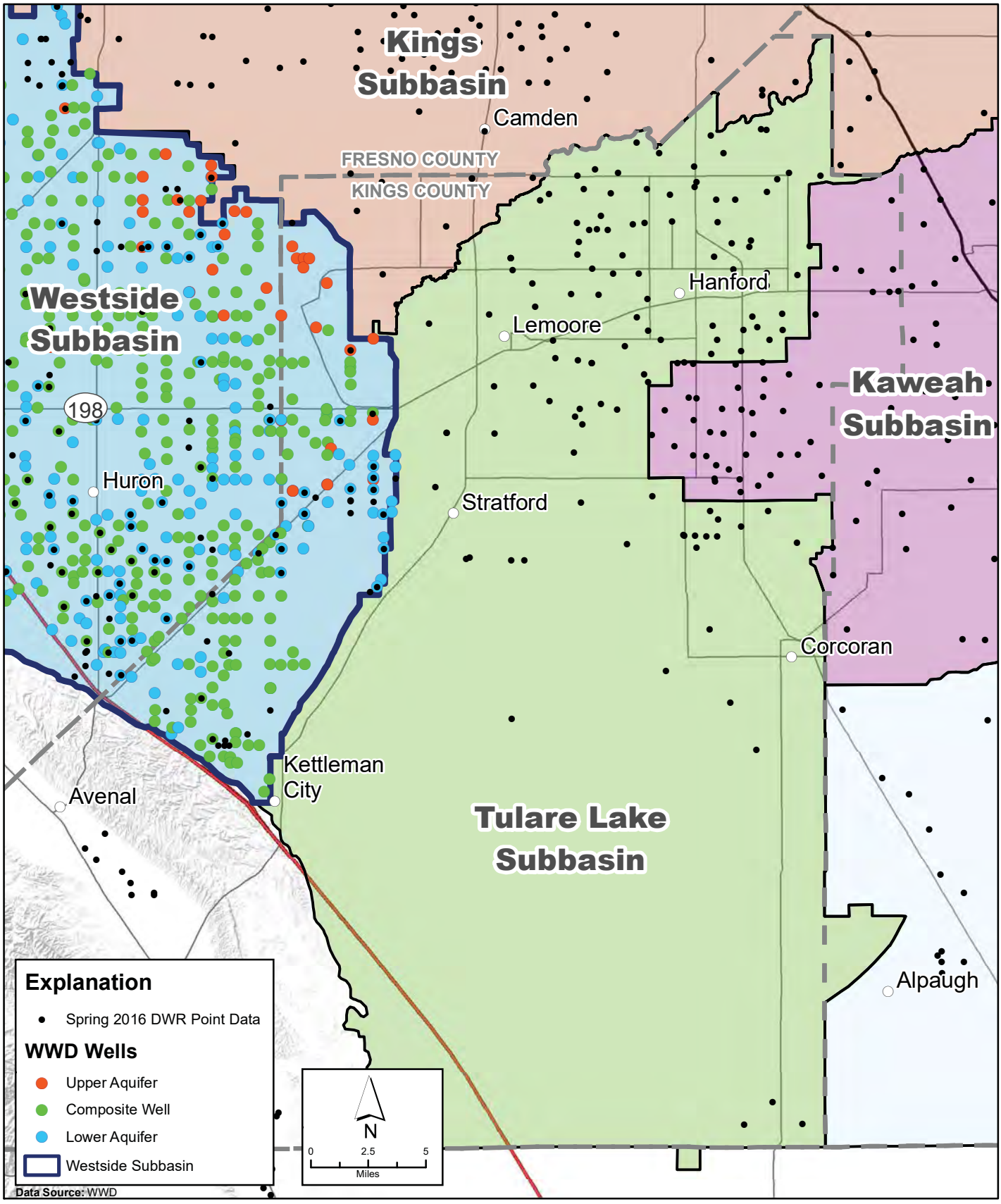


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Luhdorff & Scalmanini
Consulting Engineers

FIGURE 2-40
Contours of Equal Groundwater Elevation
Lower Aquifer, Winter 2014/2015

Groundwater Sustainability Plan
Westside Subbasin



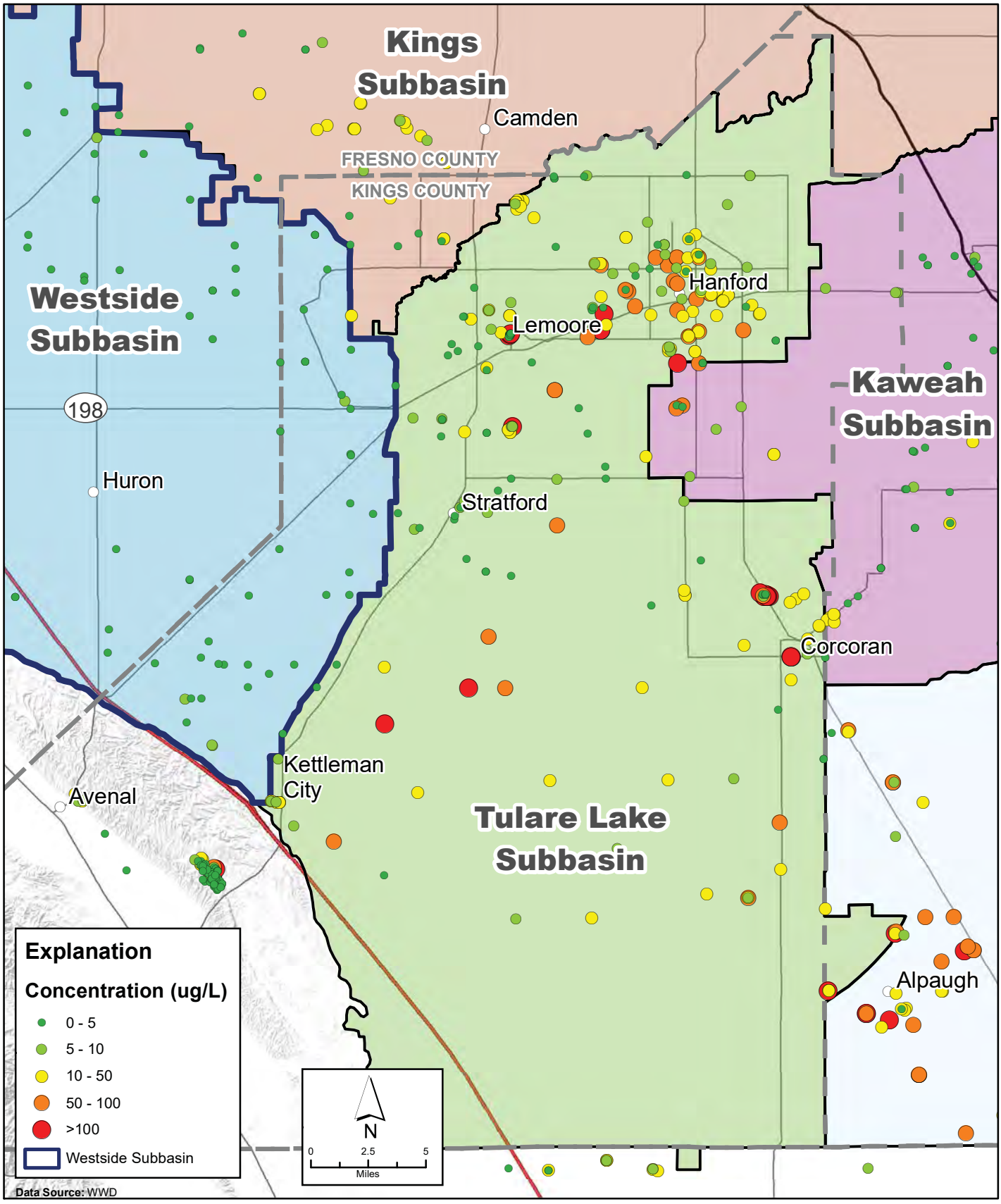
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Luhdorff & Scalmanini Consulting Engineers

FIGURE 1

DWR Point Data Used to Develop Contours of the Unconfined Aquifer vs Westlands Well Construction

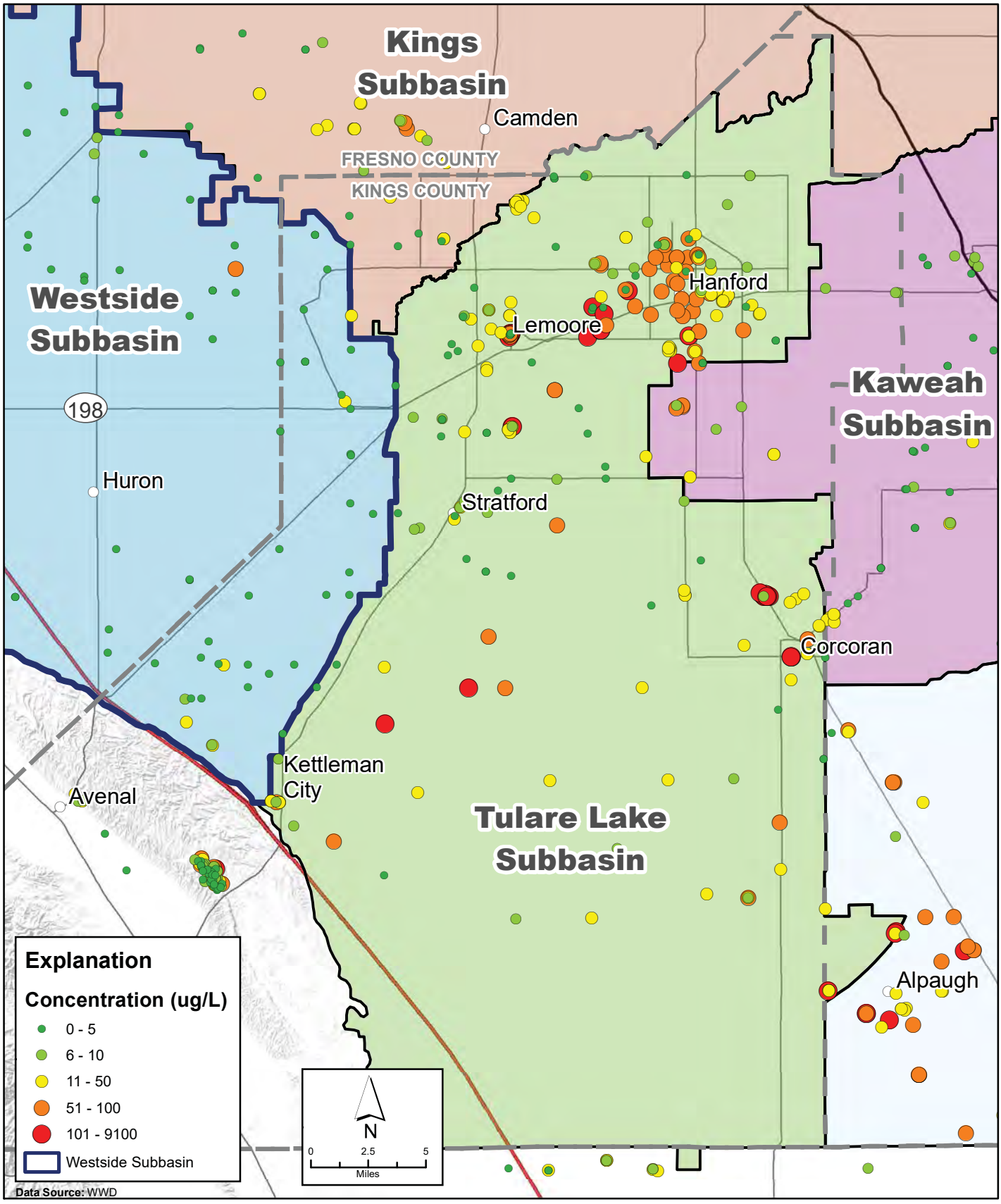
Groundwater Sustainability Plan
Westside Subbasin



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Luhdorff & Scalmanini
Consulting Engineers

FIGURE 2
Arsenic Concentration in Groundwater Wells
Most Recent Reported Value
Groundwater Sustainability Plan
Westside Subbasin



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Luhdorff & Scalmanini
Consulting Engineers

FIGURE 3
Arsenic Concentration in Groundwater Wells
Maximum Reported Value
Groundwater Sustainability Plan
Westside Subbasin

Westlands Water District
3130 N. Fresno Street, P.O. Box 6056, Fresno, California 93703-6056, (559) 224-1523, FAX (559) 241-6277

December 2, 2019

South Fork Kings Groundwater Sustainability Agency
Kings Subbasin
Basin Number 5-22.08
Transmitted via online submission at: comments@southforkkings.org

Subject: Tulare Lake Subbasin Draft Groundwater Sustainability Plan

Dear South Fork Kings GSA Group:

Westlands Water District ("Westlands GSA") appreciates the opportunity to provide comments on the Tulare Lake Subbasin Draft Groundwater Sustainability Plan ("Draft GSP"). The Westlands Groundwater Sustainability Agency ("GSA") respectfully submits the following comments.

Finding 1 (Page 3-27): Figures 3-26 and 3-27, Table 3-6, and Section 3.2.2 of the GSP states with respect to groundwater flow in the unconfined aquifer that, "[i]n general, groundwater flowed into the Subbasin from the Kings, Kaweah, and Tule Subbasins and out of the Subbasin to the Westside Subbasin." This statement is supplemented by contours of unconfined potentiometric head developed by DWR from 1990 through 2016.

Westlands' Comment: The unconfined water level data are used to make inferences about general groundwater flow directions. As stated in Section 3.2.3 of the GSP, vertical gradients can exceed 50 feet per 100 feet suggesting that flow directions can be heavily dependent on the depth horizons that are selected and therefore, change considerably with depth. Model results provided in Appendix D also highlight how groundwater flow directions vary with depth.

DWR does not provide groundwater contours for the majority of the boundary shared between the Westside and Tulare Lake Subbasin. In fact, contours from 2005, 2010 and 2016 provide almost no overlap with the shared Subbasin boundary. As a result, there is no substantial evidence to support the statements regarding groundwater flows "out of the Subbasin to the Westside Subbasin."

The spatial information for wells used to develop the DWR water level contours are readily available for 2016 (DWR, 2019). Review of these data reveals that the majority of wells used by DWR to develop contours of unconfined potentiometric head within the Westside Subbasin are screened in the Lower Aquifer (**WWD Attachment: Figure 1**). Given that groundwater level readings can vary considerably between the Upper Aquifer and Lower Aquifer, water levels from the Lower Aquifer are unlikely to be representative of unconfined water levels (even in the Spring) and should not be used to support the GSP conclusions of subsurface flow in the unconfined aquifer between the Westside and Tulare Lake Subbasins.

Therefore, the analysis is not supported by substantial evidence and we respectfully disagree with the conclusion set forth in the GSP relating to groundwater conditions in the unconfined aquifer.

Finding 2 (Page 3-87): Figures 3-28b, 3-28c and 3-28d display wells within the Tulare Lake Subbasin with long term hydrographs.

Westlands' Comment: Figures 3-28b to 3-28d shows long term hydrographs for wells within the Tulare Lake Subbasin. Unfortunately, the data displayed by the hydrographs is pixelated, therefore unreviewable. Westlands GSA recommends revising the mentioned figures to display hydrographs using a higher resolution to allow the public to review.

Finding 3 (Page 3-93): Figures 3-30 through 3-32, and Section 3.2.5 describes groundwater quality data in the Tulare Lake and Westside Subbasins. With respect to TDS, the GSP cites reports from Davis et al., 1956 and Hansen et al., 2018.

Westlands Comments: Both reports highlight how depth significantly influences TDS concentrations. However, Figure 3-30 does not report the depth of the wells or the aquifer the TDS sample represents which can substantially influence how data is interpreted. Furthermore, none of the maps shows the time period being represented. With respect to the concentration of arsenic in groundwater, neither the most recent nor the maximum arsenic concentration in the data available from GeoTracker is as high as those shown in Figure 3-31 (**WWD Attachment: Figure 2 and 3**). Furthermore, the density of wells with available arsenic data in the Geotracker GAMA database is substantially less than that shown in Figure 3-31.

The concentration of nitrate in groundwater is shown in Figure 3-32. This map shows nitrate concentration exceeding the MCL in four locations adjacent to the Westside Subbasin boundary. A review of data available from Geotracker GAMA show that samples exceeding the MCL were measured in the mid to late-1980's and likely do not reflect the current ambient nitrate concentration at these locations.

We recommend that the draft GSP be revised to accurately convey groundwater quality data by aquifer and by the timeframe the data represents. In addition, we recommend that the groundwater quality data be reviewed for accuracy.

Finding 4 (Page 3-87): Figures 3-34 displaying historical subsidence in the San Joaquin Valley from 1949 – 2005.

Westlands' Comment: Figures 3-34 contains a legend that is incomplete and is unable to be reviewed. Westlands GSA recommends applying the corresponding color scheme to the vertical displacement legend to allow readers to be able to review the presented information.

Finding 5 (Page 4-18): Section 4.5.1.1 introduces the following sustainable management criteria for Groundwater Levels paraphrased as follows: The Sustainable Management Criteria for Groundwater Level (Section 4.5.1.1) proposes the Measurable Objective to be set at a groundwater level using Method 4, which forecasts water levels to 2035 and sets the 2035 water level as the Measurable Objective. Minimum Thresholds were based on assumed stability of groundwater levels between 2035 and 2040 and are designed to be a last-resort warning before more severe measures must be taken to protect groundwater resources. Section 4.4.3 (Selection Process of Minimum Thresholds to Avoid

Undesirable Results) establishes the Minimum Thresholds as "one standard deviation of all observed head data in compliance wells or modeled forecasted data." Figure 4-2 through 4-6 describe establishment of the Minimum Thresholds as "one standard deviation or 50 feet, whichever is greater."

Westlands' Comment: Sustainable Management Criteria, which includes the measurable objectives and the minimum thresholds, allows groundwater levels in the aquifer to decline past the Westside Subbasin's Measurable Objectives and Minimum Thresholds, set at 2015 groundwater levels, and may negatively impact the Westside Subbasin's ability to achieve sustainability by reducing net inflow into the Westside Subbasin and/or reversing the groundwater flow direction. More specifically, the proposed decline of groundwater levels in the South Fork Kings GSA may alter the groundwater conditions near the boundary between the Westside Subbasin and the Kings Subbasin and result in a lowering of groundwater levels in the Westside Subbasin. This action would have the effect of shifting the burden of SGMA compliance from the South Fork Kings GSA to Westlands GSA. This is not permissible. The GSP is devoid of substantial evidence and any explanation as to how the Minimum Thresholds will avoid a significant and unreasonable reduction in groundwater storage and significant and unreasonable land subsidence contributing to the impairment of surface uses within the Westside Subbasin.

Water Code section 10733, subdivision (c) provides in relevant part:

> "The department shall evaluate whether a groundwater sustainability plan adversely affects the ability of an adjacent basin to implement their groundwater sustainability plan or impedes achievement of sustainability goals in an adjacent basin"

Further, we respectfully call your attention to Code of Regulations, title 23, section 355.4, subdivision (b)(7):

> "When evaluating whether a Plan is likely to achieve the sustainability goal for the basin, the Department shall consider . . . whether the Plan *will adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of its sustainability goal.*" (emphasis added)

and Code of Regulations, title 23, section 354.28, subdivision (b)(3):

> "The description of minimum thresholds shall include . . . how minimum thresholds have been selected to *avoid causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals.*" (emphasis added)

Moreover, the implementation of SGMA and a GSP cannot be used to override the protections afforded common law water rights. Overlying and appropriative uses of groundwater within the Westside Subbasin are entitled to legal and equitable protection against infringement by an action that deprives them of their historical subsurface inflows. (*City of Lodi v. East Bay Municipal Utility District* (1936) 7 Cal.2d 316, 344 [protecting groundwater levels against lowering from another party's pumping]; *Trussell v. City of San Diego* (1959) 172 Cal.App.2d 593, 611 [enjoining a party for lowering water table by interrupting surface flow].)

Additionally, proposing a continued decline of groundwater levels in the Lower Aquifer is not supported by substantial evidence because the GSP acknowledges that it does not have enough data to support its finding that there will be no impact to historical boundary flow conditions between the

Subbasins. The potential for curtailing historic underflow into the Westside Subbasin may be a substantial factor in contributing to significant and unreasonable subsidence and frustrate the Westlands' GSA ability to achieve the sustainability goal.

Finding 6 (Page 4-21): Section 4.5.33 Land Subsidence references Table 4-2: *Lemoore-Average Land Subsidence Interim Milestones based on Measurable Objectives for the Subbasin,* which displays modeled subsidence rates and interim milestones for those subsidence rates. The Tulare Lake Subbasin also proposes a minimum threshold of 16 ft by 2040 in Section 4.4.1.3.

Westlands' Comment: Westlands GSA is concerned that allowing subsidence rates as proposed may impact critical infrastructure such as roads, railroads, and may increase flood risks to existing land uses, especially near Corcoran where subsidence rates are critical, in the Westside Subbasin and other neighboring subbasins. Westlands GSA strongly recommend selecting Measurable Objectives and Minimum Thresholds to subsidence rates that will not negatively impact infrastructure in neighboring subbasins. The GSP fails to reference any substantial evidence that the minimum threshold will avoid significant and unreasonable land subsidence that impairs surface uses in the Westside Subbasin.

Finding 7 (Appendix D): The information provided in the GSP suggests a conceptual error leading to flows between the Westside Subbasin and Tulare Lake Subbasin to be misrepresented in the numerical model and GSP. Figure D5-5 in Appendix D shows the average model simulated net lateral subsurface flow of 158,405 AFY from the Lower Aquifer to the general head boundary (GHB) in the Westside Subbasin. Contours of simulated Lower Aquifer groundwater levels from 2015 in Figure D5-3 show a cone of depression along the GHB in the Westside Subbasin. Figure D5-5 shows pumping from the Lower Aquifer is a net positive suggesting that intraborehole flow from the Upper Aquifer to the Lower Aquifer is greater than the amount extracted from wells, suggesting the GHB is driving the flow across the boundary between the Westside and Tulare Lake Subbasins and out of the Westside Subbasin.

Westlands' Comment:
Lower Aquifer contours developed from water level data at the end of the 2014 irrigation year (one year before the simulated contour data provided) do not show a cone of depression in the location of the GHB (**WWD Attachment: Figure 4**). These contours also cannot be interpreted to suggest that groundwater flow is from the Tulare Lake Subbasin to the Westside Subbasin. Furthermore, it is unclear what physical process would cause a localized cone of depression to form in this location, especially considering that the groundwater model simulates positive net pumping from the Lower Aquifer in the Westside Subbasin.

The analysis is not supported by substantial evidence and for the reasons set forth above, Westlands recommends reanalyzing the water level contour data from the numerical model and GSP.

Lastly, the Westlands GSA identified the following reporting discrepancies within the text of the GSP and Appendix D that should be reviewed:

1. Total lateral subsurface inflow into the Westside Subbasin shown in Figure D5-5 averages 72,296 AFY (67,347 from the Tulare Lake Subbasin and 4,948 AFY from the Kings Subbasin). Table 3-6 of the GSP shows average annual subsurface flow from the Tulare Lake Subbasin to the Westside Subbasin of 41,390. What is the source of this discrepancy?

2. In the graphic depicting aquifer specific fluxes in Figure D5-5, the sum of the "Net GW Flux" (which presumably is lateral subsurface flow between adjacent subbasins) totals 4,936 AFY while the total in the table shown in Figure D5-5 is 72,296 AFY. What is the source of this discrepancy?

3. Figure numbers in the Appendix D text do not correspond to the correct figures. Figure D5-10 is titled "Simulated Subsidence 1990-2016". Figure D5-8 shows "Groundwater Mass Balance Tule Subbasin".

Westlands' General Comment: The GSP Regulations include a provision authorizing GSAs in adjacent basins to enter into interbasin agreements. The interbasin agreements can "establish compatible sustainability goals" and be included in GSPs to "support a finding that implementation of the Plan will not adversely affect an adjacent basin's ability to implement its Plan or impede the ability to achieve its sustainability goal." (Code Regs., tit. 23, § 357.2.)[1] The interbasin agreements may also address: (1) "an estimate of groundwater flow across basin boundaries;" (2) how the GSAs will reconcile differing minimum thresholds and measurable objectives in the basins to avoid undesirable results; and (3) a process for resolving conflicts between the GSAs. (*Id.*) Given the potential reduction of historical cross-boundary flow attributable to the planned operation with the Tulare Lake Subbasin Draft GSP, Westlands strongly recommends that we meet and confer at the earliest opportunity to determine whether an interbasin agreement can be reached. Our intention is to reach a cooperative resolution of these important issues that will enable coordinated sustainable management in our GSAs.

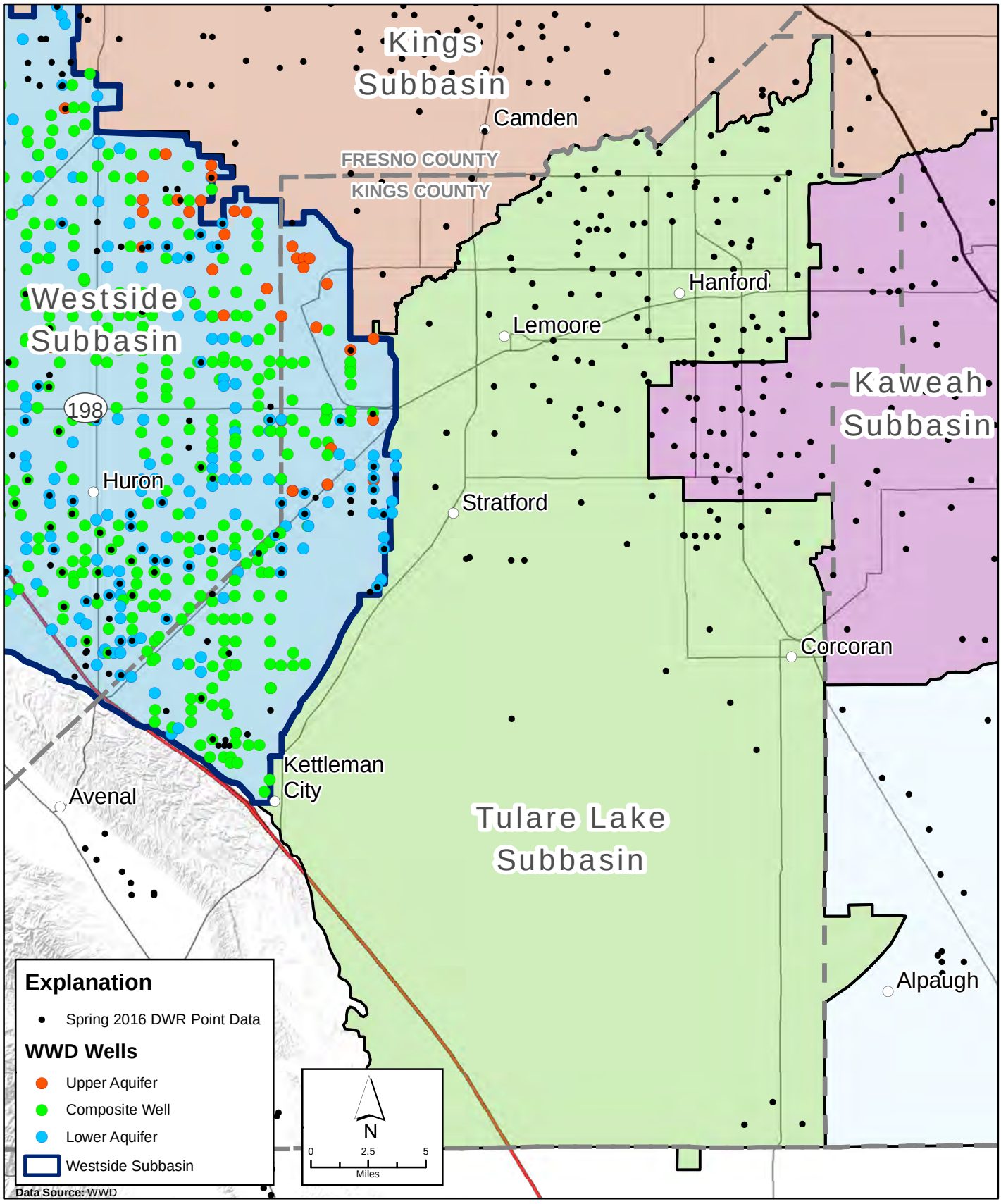
If you have any questions or concerns, regarding these comments, please contact Kiti Campbell by email at kcampbell@wwd.ca.gov or by phone at (559) 241-6226. Thank you for the opportunity to provide comments on the Tulare Lake Subbasin Draft GSP.

Sincerely,

Russ Freeman

Russ Freeman, P.E.
Deputy General Manager – Resources
Westlands Water District

[1] See Appendix A for the complete text of the provisions of SGMA and the GSP Regulations (Code Regs., tit. 23, § 350, *et seq.*) cited herein.



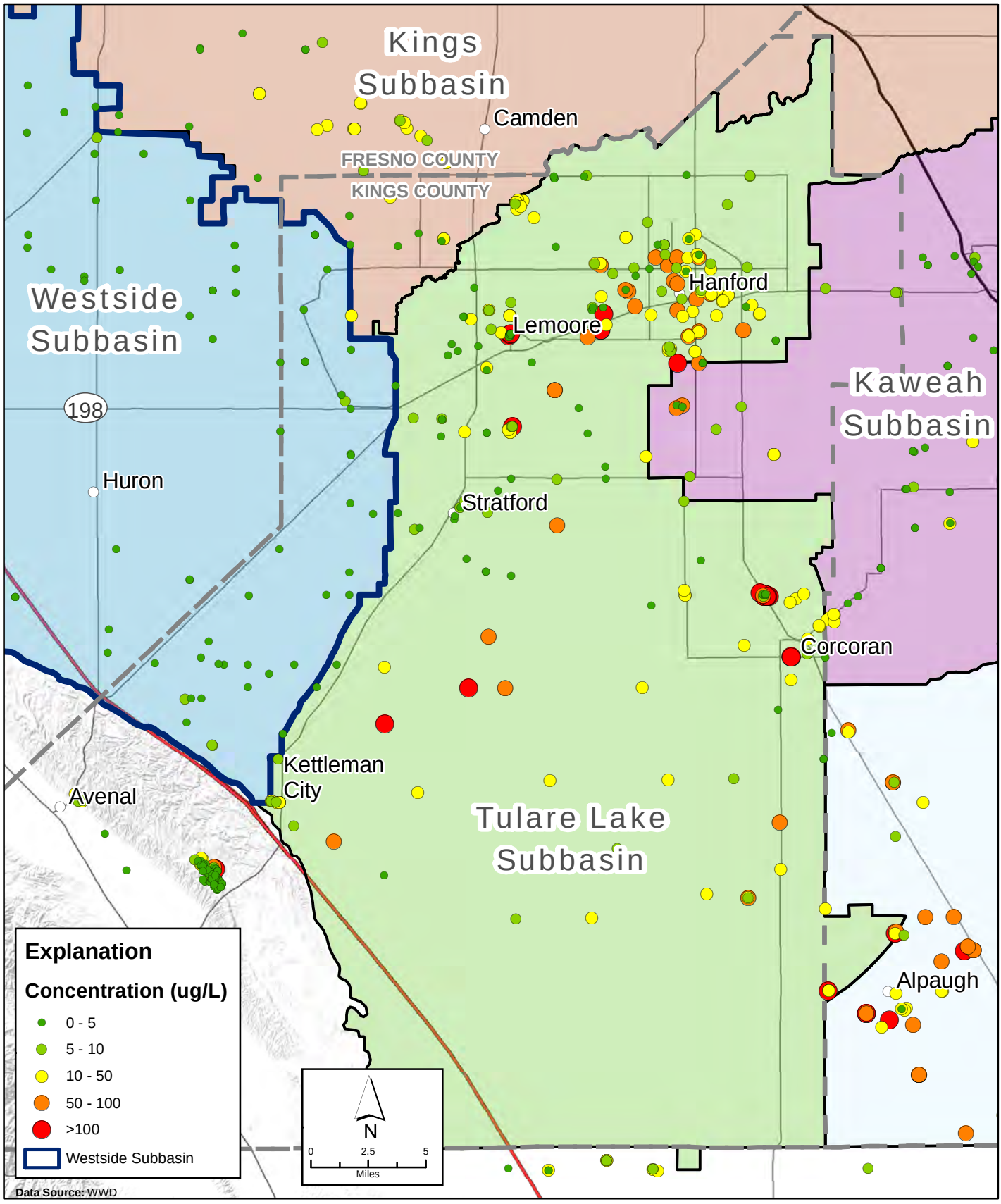
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Luhdorff & Scalmanini
Consulting Engineers

FIGURE 1

DWR Point Data Used to Develop Contours of the Unconfined Aquifer vs Westlands Well Construction

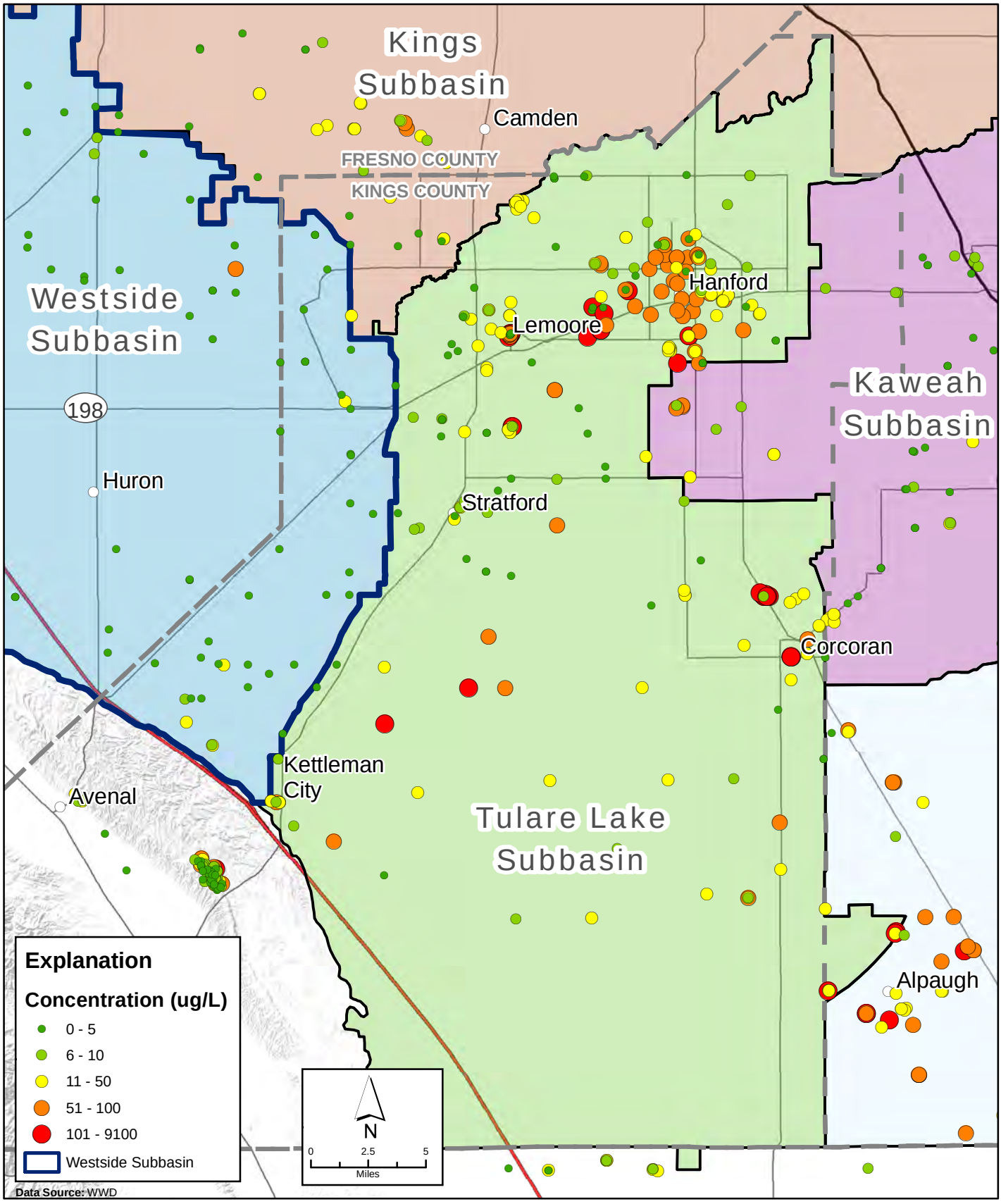
Groundwater Sustainability Plan
Westside Subbasin



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Luhdorff & Scalmanini
Consulting Engineers

FIGURE 2
Arsenic Concentration in Groundwater Wells
Most Recent Reported Value
Groundwater Sustainability Plan
Westside Subbasin

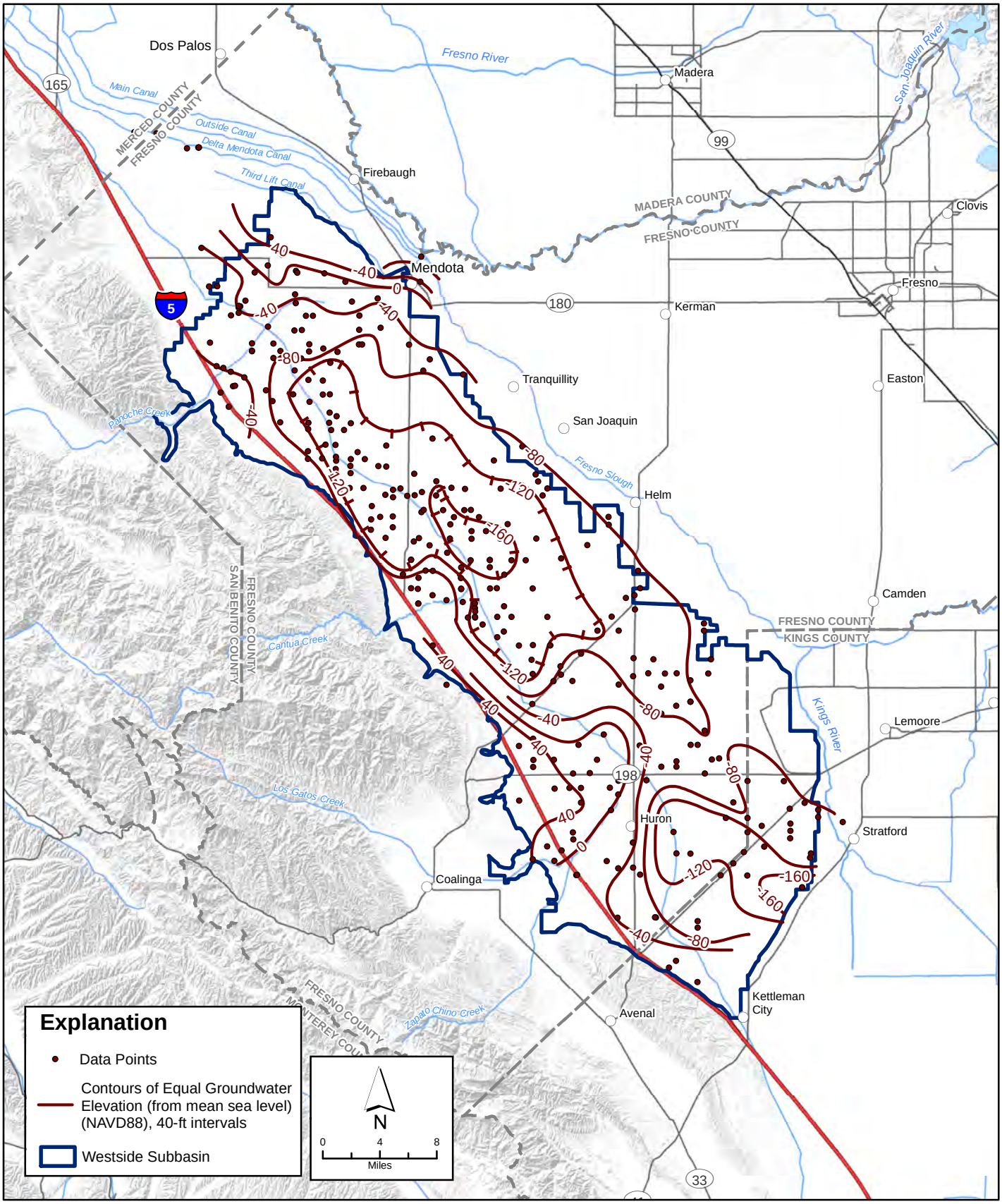


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Luhdorff & Scalmanini
Consulting Engineers

FIGURE 3
Arsenic Concentration in Groundwater Wells
Maximum Reported Value
Groundwater Sustainability Plan
Westside Subbasin

Figure 4



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Luhdorff & Scalmanini
Consulting Engineers

FIGURE 2-40
Contours of Equal Groundwater Elevation
Lower Aquifer, Winter 2014/2015

Groundwater Sustainability Plan
Westside Subbasin

DOUG VERBOON
Supervisor
District 3

BOARD OF SUPERVISORS
Kings County Government Center
Hanford, CA 93230
Phone (559) 852-2366
Fax (559) 585-8047

December 2, 2019

Via Hand Delivery

Dennis Mills
Mid-Kings River GSA
200 N. Campus Drive
Hanford, CA 93230

Charlotte Gallock
South Fork Kings GSA
4886 East Jensen Avenue
Fresno, CA 93725

Jeof Wyrick
El Rico GSA
101 W. Walnut Street
Pasadena, CA 91103

Dale Melville
Southwest Kings GSA
c/o Provost & Pritchard Consulting Group
286 W. Cromwell Avenue
Fresno, CA 93711

Deanna Jackson
Tri-County Water Authority GSA
944 E. Whitley Avenue, Suite E
Corcoran, CA 93212

Re: Comments on the Tulare Lakes Subbasin Groundwater Sustainability Plan

Dear Messrs. and Madams:

I am writing as a duly elected Supervisor for the County of Kings (the "County") and not on behalf of the Board of Supervisors. I am also writing on behalf of the other signatories to this letter, who care as deeply as I do about the issues raised in the Tulare Lakes Subbasin Groundwater Sustainability Plan (the "GSP") that has been proposed and is subject to this public hearing. I am submitting my comments and proposed changes in writing so that they may be incorporated into the GSP prior to its submission to the State Department of Water Resources ("DWR") by January 31, 2020.

Procedural Defects

The Groundwater Sustainability Agencies addressed above ("GSAs") issued a notice on September 3, 2019 for the December 2, 2019 public hearing to comment on the GSP. The narrative part of the GSP – approximately 500 pages – was not issued until three days later, on September 6, 2019. The Appendix D to the GSP – the Water Modeling Report – and the Water Model itself were not released to the public for review until October 17th, 2019, a month and half later. Even though the County requested to, and did, coordinate with the GSAs on Wednesday, November 6th, the GSAs' delay in getting the complete GSP out for the full 90-day review period set out in Section 10728.4 of the Water Code impeded any serious review and feedback on the GSP.

Under Section 10728.4, you were required to provide the County – and, consequently, the public – with at least 90-days written notice of the public hearing at which you planned to adopt the GSP. When the GSAs were told their "notice" was inadequate because of the lengthy delay in issuing the entire GSP, the responses have typically been two-fold: First, they claim the statute is ambiguous as to what it meant by "notice" of the public hearing. In other words, the statute does not say with specificity that the GSP had to be released at the same time as the notice. The second response has been, "Well, you'll get to comment at the State level once the GSP is lodged with the State in January, so it shouldn't matter whether you had adequate opportunity to comment now." Neither of these responses excuses the GSAs from giving the County and its water users a full opportunity to review and comment on the draft GSP.

For public notice to be effective, it must satisfy the requirements of administrative due process. Federal and California courts have ruled over the last half-century that adequate notice must be "reasonably calculated, under all the circumstances, to apprise the interested parties of the pendency of the action and afford them an opportunity to present their objections . . . ." (*Mullane v. Cent. Hanover Bank & Trust Co.* (1950) 339 U.S. 306, 314.) Furthermore, the notice must "convey the required information" within "a reasonable time for those interested" to be heard "at a meaningful time and in a meaningful manner." (See *id;* see also *Mathews v. Eldridge* (1976) 424 U.S. 319, 333.) From these cases and others, it is clear that the September 3rd notice needed to include at least 90-days written notice of the date, time, and location of the public hearing, as well as service of the entire GSP.

Second, regardless of whether the County or anyone else has an opportunity to comment to the State on the final GSP submission, it was the legislature's intent that all interested parties have a meaningful opportunity to comment *before* it was submitted to the State. At least the legislature believed that the GSAs should be given the benefit of substantive input on the GSP before they submitted it. Unfortunately, the GSAs' delay in getting the draft GSP prepared in time for any substantive review, feedback and opportunity to revise the draft GSP in response to the public's comments has compromised the successful adoption and implementation of the GSP.

Project Vagueness

One of the most important parts, in my view, of a successful GSP is convincing the State that the GSAs are committed to creating a sustainable source of groundwater for the region and that they can be trusted to implement an approved GSP. I am concerned that the purported "projects" set out in the GSP are too vague and non-committal and, consequently, won't convince the State to defer to the GSAs when it comes to groundwater sustainability. If the State rejects the GSP as being too vague – or for any other reason – the Sustainable Groundwater Management Act ("SGMA") makes clear that the State will take over our groundwater management and local control of that essential water resource will be history.

I attended the October 22nd, 2019, Board of Supervisors meeting when Dennis Mills addressed the Board and stated openly that the GSAs had made a judgment decision to keep the description of the GSP's proposed projects vague; he said the GSAs didn't want to commit to any specific projects in case, on further review, it was determined a project was not viable. I was also part of the delegation from the County that met with the GSAs on November 6th to consult on the draft GSP. As we discussed whether the GSAs had considered certain elements of certain projects,

such as CEQA requirements, Dennis stated that none of the GSA Boards had committed to any of the projects in the GSP. The fact that the GSA Boards haven't committed to doing anything (other than perhaps a groundwater monitoring program) as part of the GSP process is not going to instill confidence in the State and I'm concerned it could lead to the State's rejection of the GSP. The "projects" that have been proposed in the GSP should be firmed up as much as possible before the plan is submitted in January.

Land Fallowing Project

Finally, and most importantly, I am very concerned about the GSP proposal to fallow significant amounts of land within the County so as to cut agricultural demand for groundwater by at least 25 percent in 12 years. When we spoke with the GSAs during the November 6th consultation meeting, Jeof Wyrick confirmed that the GSP model incorporated an assumption that two percent (2%) of the land in the subbasin – not even spread out over the entire County – would be fallowed each year until we met the 2040 compliance deadline. If that is pursued, it would result in approximately 220,000 acres of agricultural land being fallowed. A good portion of that fallowed land would have to be permanent tree crops, which would result in the destruction of a significant amount of the value of the land (as they have to be irrigated every year) as well as the County's tax base.

During our consultation meeting, Jeof said that the water model consultants had erroneously incorporated the two percent (2%) assumption into the model, thus, overstating the amount of land to be fallowed as a result of GSP implementation. He said the GSP was going to be revised to incorporate an assumption of one percent (1%) per year fallowing that would result in "only approximately 100,000 acres" in the GSAs' boundaries being fallowed. I have no idea whether that has been done already or if it actually will be done before the GSP is submitted to the State. That amount of fallowed land is certainly less by half than what was previously projected, but when there are only approximately 420,000 acres of agricultural land within the GSAs' boundaries, that is an unacceptable level of fallowing both to the farmers whose land would be fallowed and, I believe, to the residents of the County. This 25 percent of total agricultural land fallowing is consistent with representations that the GSAs made publicly at the public outreach meeting in Lemoore, California, on October 15, 2019.

I was also surprised when Jeof said at our consultation meeting that implementation of the GSP was really "farmer versus farmer warfare" and that what was going to happen is "private adjudication of water rights in a public forum" (*i.e.*, before the GSAs). We all know what's going to happen when the few large farm and agricultural interests in the County go after the small, family-owned farms: The small farms are going to lose. I'm going to do everything in my power as a member of the Board of Supervisors to make sure that doesn't happen.

For this reason alone, the GSP should be revised to clarify that land fallowing in Kings County will be deployed only as a last resort after every other possible means of demand reduction and water recharge have been fully implemented and only at the minimal levels absolutely necessary to achieve sustainability. It is important to have survivability for the small farmer so that he can be competitive with the large corporate famers when it comes to ground water pumping. The Tulare Lake Subbasin will never achieve sustainability if the exported ground water from the subbasin to surrounding areas in the region is left unaddressed.

I am available to answer questions and discuss these concerns.

Sincerely,

DOUG VERBOON
Supervisor

Name: Jerome Vanderlaan
Business: Wasmerdam Walnut Co.

Name:
Business: Casaca Vineyards

Name: Stanley Neves
Business: Golden Valley Farms

Name: Eddie Warmerdam
Business: Warmerdam Farms

Name:
Business: Trinity Ranches LLC

Name: Cornelius Warmerdam
Business:

Name: Rocky Silveira
Business: 4-B Farms

Name:
Business: Simba Farms

Name: Eddie N. Warmerdam
Business: ENW Farms Inc

Name:
Business: Millers Rentaland Inc

Name: Tim Parolini
Business: Parolini Farms

Name: Doug Wisecarver
Business: Wisecarver Farms

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Memorandum

To:	Tulare Lake Subbasin GSAs' Managers and Technical Team
From:	Trilby Barton, Public Outreach Coordinator, Provost & Pritchard
Subject:	Tulare Lake Subbasin GSAs' Groundwater Sustainability Plan Public Hearing Comments
Date:	December 2, 2019

December 2, 2019 Draft GSP Public Hearing Recap

The Tulare Lake Subbasin Groundwater Sustainability Agencies (GSAs) held a public hearing on the Draft Groundwater Sustainability Plan (GSP) on December 2, 2019. The hearing was held in the County of Kings Board of Supervisors' Chambers, and was called to order at 10:01 a.m. by Mid-Kings River GSA Manager, Dennis Mills.

Mr. Mills introduced himself and the other four GSA managers: Deanna Jackson with Tri-County Water Authority, Dale Melville with Southwest Kings GSA, Jeof Wyrick with El Rico GSA, and Charlotte Gallock with South Fork Kings GSA. Mr. Mills also introduced Trilby Barton, public outreach consultant with Provost & Pritchard Consultant Group. Mr. Mills and Ms. Barton explained the process for the public hearing, and Mr. Mills opened the floor for public comments.

Twenty stakeholders were in attendance, and one public comment was provided:

- **Bill Toss, Grower in Mid-Kings River GSA**
  "Reading through the plan that is available, the only thing that really struck out to me was the 25 percent set aside for reduction. That of course is most likely very damaging, and would not be sustainable economically here for Kings County or for us as growers. I hope that there is a change to that, and to make sure that is not the status quo."

Upon seeing that no other stakeholders wanted to provide oral comments, Mr. Mills thanked everyone for attending and closed the public hearing at 10:06 a.m.

APPENDIX D

GROUNDWATER MODEL REPORT

Tulare Lake Subbasin Hydrologic Model for Groundwater Sustainability Plan Development: Calibration and Predictive Simulations

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Prepared for:
Mid-Kings River Groundwater Sustainability Agency
Hanford, California

January 8, 2020
Project FR18161220

Tulare Lake Subbasin Hydrologic Model for Groundwater Sustainability Plan Development: Calibration and Predictive Simulations

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Prepared for:

Mid-Kings River Groundwater Sustainability Agency
200 North Campus Drive
Hanford, California 93230

Prepared by:

Wood Environment & Infrastructure Solutions, Inc.
1281 East Alluvial Avenue, Suite 101
Fresno, California 93720
T: 559-264-2535

January 8, 2020
Project FR18161220

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David M. Bean, PG, CHg
Principal Hydrogeologist



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Abbreviations and Acronyms

%	percent
AF	acre-feet
AF/D	acre-feet per day
AF/M	acre-feet per month
AF/Y	acre-feet per year
bgs	below ground surface
CID	Corcoran Irrigation District
CT	Critical Thresholds
CVHM	United States Geological Survey Central Valley Hydrologic Model
CVP	Central Valley Project
DWR	California Department of Water Resources
ER GSA	El Rico Groundwater Sustainability Agency
ETc	Crop Evapotranspiration
ft/d	feet per day
ft^2/d	square feet per day
ft/m	feet per month
GHB	General Head Boundary
GSAs	groundwater sustainability agencies
GSP	Groundwater Sustainability Plan
GUI	Graphic User Interface
GWV	Environmental Simulations Inc.'s Groundwater Vistas™ Version 7 simulation code GUI
HCM	hydrogeologic conceptual model
K	hydraulic conductivity
f_c	coarse fraction
KCWD	Kings County Water District
K_h	horizontal hydraulic conductivity
K_v	vertical hydraulic conductivity
MKR GSA	Mid-Kings River Groundwater Sustainability Agency
MO	Monitoring Objective
MODFLOW	USGS Modular finite-difference family of numerical simulation codes
NRMS	Normalized root mean square error
MNW2	Version 2 of the MODFLOW multi-node well package
msl	mean sea level
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RMS	root mean square
SFK GSA	South Fork Kings Groundwater Sustainability Agency
SSR	sum of the square of the residuals
S_s	specific storage
S_y	specific yield
Subbasin	Tulare Lake Subbasin
SGMA	Sustainable Groundwater Management Act of 2014
SWK GSA	Southwest Kings Groundwater Sustainability Agency
SWP	State Water Project
TCWA GSA	Tri-County Water Authority Groundwater Sustainability Agency
TLSBHM	Tulare Lake Subbasin Hydrologic Model
USGS	United States Geological Survey
WD	Water District
Wood	Wood Environment & Infrastructure Solutions, Inc.

1.0 Introduction

Wood Environment & Infrastructure Solutions, Inc. (Wood), has been retained by the Mid-Kings River Groundwater Sustainability Agency to prepare and document a hydrologic flow model of the Tulare Lake Subbasin (Subbasin) to aid local agencies in compliance with the Sustainable Groundwater Management Act of 2014 (SGMA). The Subbasin is located primarily in Kings County, within the Tulare Lake Hydrologic Region of the San Joaquin Valley, California (Figure D1-1). This project is a cooperative effort among five Groundwater Sustainability Agencies (GSAs) within the Subbasin including: Mid-Kings River GSA (MKR GSA), El Rico GSA (ER GSA), South Fork Kings GSA (SFK GSA), Southwest Kings GSA (SWK GSA), and Tri-County Water Authority GSA (TCWA GSA). Although the Subbasin is the primary focus of this modeling study, the modeling effort encompasses portion of adjacent California Department of Water Resources (DWR)-defined groundwater subbasins including the Kings, Kaweah, Tule, Kern, and Westside subbasins.

1.1 Background

Included as part of SGMA was a requirement that the DWR identify groundwater basins and subbasins in conditions of critical overdraft. As defined by DWR, overdraft occurs where the average annual amount of groundwater extraction exceeds the long-term average annual supply of water to the basin. Effects of overdraft can include land subsidence, groundwater depletion, and/or chronic lowering of groundwater levels. DWR Bulletin 118 defines critical overdraft as "when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts."

Based on this criterion and a formal evaluation of groundwater basins across the state, the DWR found much of the Tulare Lake Hydrologic Region to be one of the most critically over-drafted regions of the state. The Subbasin sits at the lowest point of the Tulare Lake Hydrologic Region and receives both surface water inflows from several rivers and streams (including Kings River, Kaweah River, Tule River, and Deer Creek) and the State Water Project (SWP), but also irrigation return flows (tailwater) draining from irrigated lands. Nonetheless, in most years, especially during frequent drought cycles, agricultural water demand exceeds the surface water inflows, leading to the drilling of wells to develop the groundwater resources to fulfill that unmet demand. In fact, under recent historical conditions, the average annual demand on groundwater resources significantly exceeds the average existing recharge to the groundwater system, leading the DWR to declare the Subbasin critically over drafted, triggering the need to develop a Groundwater Sustainability Plan (GSP) by January 31, 2020, per SGMA requirements.

The Tulare Lake Subbasin Hydrologic Model (TLSBHM) developed for this project provides a quantitative tool for development and evaluation of alternative water management scenarios considered for the GSP. Additional model development and calibration will occur throughout the implementation of the GSP as additional data are collected.

1.2 Modeling Objectives

The objectives of the current modeling efforts were to:

1. Prepare a three-dimensional numerical surface water/groundwater flow model of the Subbasin and portions of adjoining subbasins.

2. Calibrate the surface water/groundwater flow model for the period 1990-2016, with a focus on the "normal hydrology" period 1998 through 2010, for initial calibration using available groundwater elevation observations and stream flow observations.
3. Provide a Baseline Forecast from 2017-2070 assuming continued recent land use and continued 1998 through 2010 "normal hydrology" conditions modified to account for climate change. This forecast was utilized to establish Critical Thresholds (CT) and Monitoring Objectives (MO) throughout the Subbasin.
4. Provide a Projects Forecast from 2017-2070 assuming continued recent land use, continued 1998 through 2010 "normal hydrology" conditions as modified to account for climate change, and additional Surface Water Supply and Aquifer Recharge resulting from several projects assumed to be implemented throughout the Subbasin and adjoining subbasins.
5. Compare the Baseline and Projects forecasts and estimate what additional projects and management actions (such as land fallowing) may be required to obtain sustainability by 2040 and thereafter.

2.0 Hydrogeologic Conceptual Model

A hydrogeologic conceptual model (HCM) is a simplified description of the groundwater flow system, frequently in the form of a block diagram or cross-section with an accompanying narrative description of the function and interaction of the various components that comprise the hydrogeologic system (Anderson et al., 2015). The nature of the HCM determines the dimensions of the numerical model and the design of the grid, the distribution of the hydrogeologic properties, and the definition and distribution (over space and time) of external and internal stresses and boundary conditions. The purpose of the HCM is to establish an initial understanding of the groundwater system and organize the associated data and information so that the system can be analyzed more effectively.

Figure D2-1 presents block diagrams that schematically represents key aspects of the HCM for the TLSBHM under both pre-development and current conditions. Details related to this HCM for the project include: (1) description of the model domain, (2) delineation of the hydrostratigraphic units within the model domain, (3) definition of sources and sinks and estimation of the water budget, and (4) narrative description of the flow system. Each of these items are discussed in the following subsections.

2.1 Basin Location and Study Area

The Subbasin is located primarily in Kings County in the Tulare Lake Hydrologic Region of the San Joaquin Valley, California (Figure D2-2). The Subbasin covers an area of approximately 535,869 acres or about 837 square miles (DWR, 2016b). The Subbasin in bounded by the Kings Subbasin to the north, the Kaweah Subbasin to the northeast, the Tule Subbasin to the southeast, the Kern Subbasin to the south, the Kettleman Plain Subbasin to the southwest, and the Westside Subbasin to the northwest.

As shown on the figure, the study area extends beyond the official Subbasin boundaries (as delineated by the DWR) from 3 to 6 miles into adjacent subbasins to better evaluate interactions with groundwater in those adjacent areas. The study area includes approximately 151,880 acres (~237.3 square miles) of the Kaweah Subbasin, approximately 119,360 acres (~186.5 square miles) of the Kings Subbasin, approximately 126,600 acres (~197.8 square miles) of the Tule Subbasin, approximately 81,760 acres (~127.8 square miles) of the Westside Subbasin, and approximately 78,000 acres (~121.8 square miles) of the Kern Subbasin.

The vertical extent of the study area is the freshwater hydrogeologic system, based on the United States Geological Survey (USGS) Central Valley Hydrologic Model (CVHM; Faunt et al., 2009), and modified to be consistent with the findings of Tulare Lake Bed de-designation studies (RWQCB, 2017). The depth zones that comprise the freshwater hydrogeologic system extend to a depth of about 3,000 feet below ground surface (bgs), but not reaching down into the deeper confined saline groundwater below.

2.2 Topography

The Subbasin and surrounding area is generally located in the lowest portion of the San Joaquin Valley (Figure D2-3). Ground surface gently rises to the northeast from about 180 feet above mean sea level (msl) at the Tulare Lake bottom to about 300 feet above msl near Kingsburg. To the southwest, ground surface rises rapidly from the Tulare Lake bottom to about 500 feet near the Kettleman Hills. To the south, ground surface gently rises from the lake bottom to about 220 above msl at the Kern County line.

2.3 Geology

The Subbasin is located in the south-central portion of the greater San Joaquin Valley. The valley was formed generally as a structural trough subsiding between two uplifts: the tectonically driven tilted block of the Sierra Nevada and the thrust belts of the Coast Ranges created by crustal shortening east of the San Andreas fault.

Episodic intrusion of the Pacific Ocean through land gaps along the northern and southern boundaries of the San Joaquin Valley occurred during Miocene and Pliocene times, allowing deposition of marine sediments to accumulate in the subsiding shallow sea environment of the San Joaquin basin. These deposits were subjected to deformation as the Sierra Nevada rose on the east and Coastal Range rose to the west and the valley trough subsided. The marine deposits are exposed in the west-side thrust belts, which typically reach elevations of 2,000 feet or less. Beneath the San Joaquin Valley, the top of the marine deposits are typically 3,000 feet or more below the valley floor, rising on the southeastern portion of the valley to cap the igneous rocks of the uplifted Sierra foothills.

As the land gaps closed in the mid-Pliocene, the continued uplift of the Sierra Nevada and Coast Ranges shed continental deposits to the San Joaquin Valley. These continental deposits, typically assigned to the Plio-Pleistocene Tulare Formation, have filled the valley trough in places with more than 3,000 feet of sediments. Where Pleistocene geologic features periodically cut off the route of major rivers and tributaries to the sea, wide spread and sometimes extreme thicknesses of lacustrine sediments were deposited. Significant examples of these lacustrine deposits are the Tulare Lake Bed clays, the Buena Vista clays, and the Corcoran Clay (sometimes referred to as the E-Clay or modified E-Clay).

2.3.1 Tulare Formation – Continental Deposits

Various investigators in the San Joaquin Valley have assigned ages and names to what they have identified as formations in their respective study areas. The Plio-Pleistocene Tulare Formation, which has its type section on the eastern slope of the North Dome of the Kettleman Hills (Woodring et al., 1940), has been correlated stratigraphically with other valley formations such as the Laguna Formation in the northeast portion of the valley (Woodring et al., 1940) and Kern River formations in the southeast portion of the valley (Bartow, 1991).
In the Subbasin, the primary stratigraphic units containing usable groundwater include the Tulare Formation, older alluvium, and younger alluvium. The Tulare Formation is by far the thickest of these three. The bottom of the Tulare Formation has been defined by Woodring et al. (1940) as occurring just above the Mya interval of the primarily marine San Joaquin Formation, over which it conformably lies on

the North Dome, just northwest of the Tulare Lake bed. The Tulare Formation/San Joaquin Formation contact dips steeply eastward from the Kettleman Hills, lying more than 3,000 feet beneath the trough in the Tulare Lake area (Croft and Gordon, 1968). Woodring et al. (1940) have defined the Tulare as the uppermost continental deposits deformed by the folding associated with the Kettleman Hills. However, as noted by Davis et al. (1959), the upper contact of the Tulare Formation with younger continental deposits (older and younger alluvium) is not easily discerned because "at many places along the valley border the dips increase westward so gradually that only a rough separation can be effected between the valley alluvium and the Tulare Formation. Separation of the alluvium from the Tulare Formation beneath the valley is virtually impossible because of their lithologic similarity."

2.3.2 Lacustrine, Marsh, and Flood Deposits

In the Subbasin, Croft & Gordon (1968) identified a number of lacustrine clays in the subsurface that they correlated to lacustrine clays identified by Woodring et al. (1940) in the Tulare Formation in Kettleman Hills. Croft & Gordon (1968) identified these in geophysical logs and named them the A- through F-Clays, with the E-Clay being equivalent to the diatomaceous Corcoran Clay. Though the A- through D-Clays may be important locally in restricting downward movement of groundwater, by far the most important is the EC-Clay, which has been identified as a spatially extensive (about 3,500 square miles, Croft, 1972) and thick clay that separates regionally confined and unconfined groundwater zones in the southern San Joaquin Valley (Figure D2-4). The E-Clay has been age-dated as mid-Pleistocene and is considered part of the Tulare Formation (Croft & Gordon, 1968). Beneath the Tulare Lake bed, there is a thick, nearly homogeneous deposit of lacustrine clays from ground surface to the San Joaquin Formation, including the E-Clay. However, the E-Clay extends far beyond the shoreline of Tulare Lake (Croft, 1972).

2.3.3 Older and Younger Alluvium

The other continental deposits that have been identified in published reports as containing groundwater are the older and younger alluvium (Croft & Gordon, 1968). In the Tulare Lake area, these deposits are primarily Sierran in origin, being deposited by the major stream channels emanating from the Sierra Nevada. Some sediments may have Coast Range origin, but the axis of Tulare Lake bed is close to the Kettleman Hills, which leaves little room for Coast Range sediment deposition on the west side. The older alluvium is widespread throughout the San Joaquin Valley and in other areas represents deposition from both the Coast Ranges on the west side of the valley and the Sierra on the east. It typically overlies the Tulare Formation, though as mentioned earlier, there is no way to differentiate between the two in the subsurface. It is considered Pleistocene to Recent in age. Most of the groundwater withdrawn from the Subbasin comes from the older alluvium/Tulare Formation complex.

The younger alluvium is generally thinner than the older alluvium and is present in current stream channels and as a veneer over the older alluvium as the deposits stretch to the west. The younger alluvium is primarily arkosic and contains groundwater only ephemerally or where underlying clays tend to restrict downward movement of recharging water. It is considered of Recent age.

2.3.4 Tulare Lake Bed

The Tulare Lake bed is the prominent sedimentary feature in the Subbasin. It was a natural lake bed fed by streams from the east and south. Its elongate shape to the northwest reflects the subsidence of the valley trough east of the Kettleman Hills. Geologic cross sections through the Tulare Lake bed (Croft, 1972; Croft & Gordon, 1968; Davis et al., 1959) illustrate the thick and continuous nature of the clay deposits beneath the lake bed (Figure D2-5).

Cross-section A-A' (Plate 4, Croft & Gordon, 1968) indicates uninterrupted lacustrine deposits from the surface to at least 2,200 feet bgs beneath the central portion of the lake. Cross-sections B-B' and C-C' (Plates 5 and 6, Croft & Gordon, 1968) illustrate the interfingering of the coarser sediments and the thinner clay zones along the periphery of the lake with the thick clay deposits beneath the lake. Though Croft & Gordon (1968) did not carry the E-Clay through the lake deposits, Davis et al. (1959, Plate 10, Section G-G', Diatomaceous Clay) and Croft (1972, Plate 3, Section G-G', E-Clay) felt they had enough evidence to map it beneath the lake. Davis et al. (1959) show it as being warped downward along the axis of the lake with a maximum thickness of 150 to 175 feet. These cross sections indicate the Tulare Lake deposits form a clay "plug" across the center of the San Joaquin Valley that may be 15 miles wide, 8 miles long, and over ½ mile deep at its maximum dimensions.

2.4 Hydrogeology

The hydrogeology of the Subbasin is complex in that the only physical boundaries are the Kings River and the Kettleman Hills on the southwest edge of the Subbasin. The remaining edges of the Subbasin are based on political and water management areas. The Corcoran Clay under lies most of the Subbasin, and essentially subdivides the Subbasin into two aquifer systems: an unconfined to semi-confined aquifer system above the Corcoran Clay and a confined aquifer system below the Corcoran Clay.

The Kings River appears to be a natural groundwater divide separating the Subbasin and Kings Subbasin. The Kings River is also the primary source of surface water diversion into the Subbasin. As such, the Kings River hydrologic year has a significant influence on groundwater levels in the Subbasin. In the unconfined aquifer, groundwater outflow from the Kings Subbasin into the Subbasin is primarily due to leakage from the Kings River. However, this groundwater predominantly flows along the course of the Kings River and therefore does not remain exclusive to the Subbasin. In the confined aquifer, groundwater outflow from the Kings Subbasin into the Subbasin is also due to leakage from the Kings River in the northeast portion of the Subbasin where the Corcoran Clay is not present. This groundwater has a strong downward vertical component which creates steep southward hydraulic gradients beneath the Corcoran Clay. This groundwater tends to remain resident in the Subbasin confined aquifer.

The groundwater flow system for these two aquifer systems is summarized in the following subsections.

2.4.1 Unconfined Aquifer

The unconfined and semi-confined upper portion of the regional fresh-water aquifer are found above the Corcoran Clay. This upper portion of the regional freshwater aquifer is generally comprised of coarse- to medium-grained sediments (i.e., sand and gravel) with silt and clay interbeds.

Groundwater beneath the Subbasin and surrounding areas is typically found between depths from 30 to 250 feet bgs, depending on location and time. A review was conducted of available DWR groundwater elevation contour maps of the unconfined aquifer from 1960 to 2010 and briefly described below (DWR, 2018). The maps show a persistent, large data gap beneath the Tulare Lake bed where there are few observations of groundwater levels due to a lack of wells.

- In 1990, a dry hydrologic year on the Kings River, groundwater was at an elevation of about 260 feet msl near Kingsburg, decreasing toward the Tulare Lake bottom (Figure D2-6a). Groundwater elevations beneath Hanford were about 170 feet msl, and about 140 feet msl near Corcoran. There were several cones of depression in the water table near Hanford, north and south of Corcoran, and around Alpaugh. The Kings River appears to be a natural groundwater

divide. In general, the potentiometric surface map indicates that groundwater was flowing into the Subbasin from the Kern, Kings, Kaweah, and Tule subbasins and out of the Subbasin to the Westside Subbasin.

- In 1995, a wet hydrologic year on the Kings River, groundwater was at an elevation of about 260 feet msl near Kingsburg, decreasing toward the Tulare Lake bottom (Figure D2-6a). Groundwater elevations beneath Hanford were about 150 feet msl and about 110 feet msl near Corcoran. The cone of depression in the water table between Hanford and Corcoran has merged into a single large depression. The Kings River continues to be a natural groundwater divide. In general, the potentiometric surface map indicates that groundwater was flowing into the Subbasin from the Kern, Kings, Kaweah, and Tule subbasins and out of the Subbasin to the Westside Subbasin.

- In 2000, an average hydrologic year on the Kings River, groundwater was at an elevation of about 250 feet msl near Kingsburg, decreasing toward the Tulare Lake bottom (Figure D2-6a). Groundwater elevations beneath Hanford were about 150 feet msl and less than 100 feet msl near Corcoran. The Kings River continues to be a natural groundwater divide. In general, the potentiometric surface map indicates that groundwater was flowing into the Subbasin from the Kings, Kaweah, and presumably the Kern subbasins and out of the Subbasin to the Tule and Westside subbasins.

- In 2005, a wet hydrologic year on the Kings River, groundwater was at an elevation of about 260 feet msl near Kingsburg, decreasing toward the Tulare Lake bottom. Groundwater elevations beneath Hanford were about 140 feet msl, about 10 feet lower than in 2000 (Figure D2-6b). Throughout the Subbasin, groundwater levels were about 10 or more feet lower than in 2000. The Kings River continues to be a natural groundwater divide. In general, the potentiometric surface map indicates that groundwater was flowing into the Subbasin from the Kings, Kaweah, and Tule subbasins and out of the Subbasin to the Westside Subbasin.

- In 2010, an average hydrologic year on the Kings River, groundwater was at an elevation of about 250 feet msl near Kingsburg, decreasing toward the Tulare Lake bottom. Groundwater elevations beneath Hanford were about 130 feet msl and less than 10 feet msl near Corcoran (Figure D2-6b). Throughout the Subbasin, groundwater levels were about 10 or more feet lower than in 2005. The Kings River continues to be a natural groundwater divide. In general, the potentiometric surface map indicates that groundwater was flowing into the Subbasin from the Kings, Kaweah, Tule, and presumably the Kern subbasins and out of the Subbasin to the Westside Subbasin.

- In 2016, a dry hydrologic year on the Kings River, groundwater was at an elevation of about 230 feet msl near Kingsburg, decreasing toward the Tulare Lake bottom. In the Hanford area, groundwater levels were about 110 feet msl, about 20 feet lower than in 2010. Cones of depression in the water table west, north, and southeast of Corcoran are still present and becoming deeper (-40 feet msl). The Kings River no longer is a natural groundwater divide. In general, the potentiometric surface map indicates that groundwater was flowing into the Subbasin from the Kings and Kaweah subbasins and out of the Subbasin to the Kern, Tule, and Westside subbasins.

2.4.2 Confined Aquifer

The sediments below the Corcoran Clay comprise the lower confined portion of the regional fresh-water aquifer. This lower portion of the regional freshwater aquifer is generally comprised of clay, silt, sandy silt and clay, sand, silty/clayey sand, gravel, and sandy, silty and clayey gravel (Page, 1983).

There are few available maps showing groundwater elevations in the confined aquifer beneath the Subbasin and surrounding areas (Harder, 2017). In fall 1998 and spring 1999, a wet hydrologic year on the Kings River, groundwater was at an elevation of about 100 feet msl near Corcoran, decreasing to the south towards an apparent pumping center near Alpaugh. In general, the potentiometric surface map (Harder, 2017) indicates that groundwater was flowing into the Subbasin from the Kaweah Subbasin and out of the Subbasin to the Tule Subbasin.

In fall 2010, an average hydrologic year on the Kings River, groundwater was at an elevation of about -50 feet msl near Corcoran, decreasing towards an apparent pumping center southwest of Corcoran. In general, groundwater was flowing into the Subbasin from the Kaweah and Tule subbasins.

2.4.3 Subsidence

Land subsidence due to groundwater drawdown associated with heavy groundwater pumping has affected large areas of the San Joaquin Valley since the 1920s, including the Subbasin (AFW, 2018). Between 1926 and 1970, there was approximately 4 feet of cumulative subsidence near Corcoran, 4 to 6 feet of subsidence near Hanford, and as much as 12 feet of subsidence near Pixley (Figure D2-7). Following the completion of the SWP and Central Valley Project (CVP), surface water became readily available and groundwater extraction was reduced and subsidence due to groundwater drawdown was temporarily slowed or stopped.

In the past 10 to 25 years, groundwater pumping has once again been increasing, with associated resumption and acceleration of groundwater drawdown and associated subsidence. The subsidence was exacerbated during a moderate to severe drought from 2007 through 2009, and a severe to exceptional drought from 2012 through 2016. A Jet Propulsion Laboratory study of subsidence between June 2007 and December 2010 (JPL, 2012) indicated subsidence rates were as high as 8.5 inches per year in the vicinity of Corcoran (Figure D2-7). A more recent study by Jet Propulsion Laboratory (JPL, 2017) indicted that subsidence rates accelerated in some areas during the recent drought, with annual subsidence rates of 1 to 1.5 feet near Corcoran in 2015-2016 (Figure D2-8). Groundwater pumping and drawdown, and consequent subsidence, are anticipated to continue into the future at least until sustainable groundwater pumping is achieved. Due to inelastic soil behavior, subsidence is mostly irreversible even if groundwater pumping decreases and groundwater level recovers.

2.5 Surface Water Occurrence

Historically, river runoff from the Sierra Nevada collected in terminal lakes on the basin floor in the San Joaquin Basin creating vast regions of Tule marshes and woodland wetlands (Figure D2-9a). Tulare Lake, the largest terminal lake, received runoff from four major rivers, the South Fork Kings, Kaweah, Tule, and Kern Rivers (ECORP, 2007). These rivers formed broad deltaic and alluvial fans as they emerged from the Sierra foothills forming multiple channels and sloughs that shifted periodically especially during flooding events (ECORP, 2007). The natural hydrology of the Tulare Lake Basin has been extensively altered over the last 130 years for flood control, irrigation, land reclamation, and water conservation. Concerns about water supplies led to the construction of large dams and reservoirs on each of the four major rivers and channelization of the rivers for flood control and water banking have further modified the Tulare Basins

hydrography (ECORP, 2007). The surface water sources that supply the Subbasin are primarily from man-made canals and diverted rivers.

2.5.1 Tulare Lake

Tulare Lake was the largest freshwater lake west of the Mississippi River estimated to encompass 790 square miles at its highest overflow lever of 216 feet in 1862 and 1868 (Figure D2-9a) (ECORP, 2007). The lake was very shallow and had no natural outlet when the water levels was below 207 feet (ECORP, 2007). However, at 207 feet, the water could flow north into the San Joaquin River Basin. Increased diversion of water from the rivers and tributaries that previously flowed into Tulare Lake resulted in the lake drying up in the late 1800s except when occasionally flooded.

2.5.2 Kings River

The Kings River is a 133-mile-long river, the largest river draining the southern Sierra Nevada. The Kings River has three main tributaries, the North Fork, Middle Fork and South Fork, with the North and Middle forks flowing north to the San Joaquin River and the South Fork flowing south to the old Tulare Lake bed. Significant water development structures including the Pine Flat Dam were constructed in the last century to control and modified the rivers flow. The Kings River lies along the boundary between the Subbasin and Kings Subbasin, a portion of the boundary between the Subbasin and Westside Subbasin, and a portion of the boundary between the Subbasin and Kaweah Subbasin (Figure D2-9b). Leakage of water from the Kings River and distributary canals provides significant groundwater recharge in the Kings, Kaweah, Westside, and Tulare Lake subbasins, resulting in complex groundwater flow patterns between the subbasins.

2.5.3 Kaweah River

The Kaweah River is a 100-mile-long river in Tulare County and drains the southern Sierra Nevada (Figure D2-9a). The Kaweah River begins as four forks in Sequoia National Park, then flows in a southwest direction to Lake Kaweah – the only major reservoir on the river – and into the San Joaquin Valley, where it diverges into multiple channels across an alluvial plain around Visalia. The lower course of the river and its many distributaries – including the St. John's River and Mill Creek – form the Kaweah Delta, a productive agricultural region in the Kaweah Subbasin. Before the diversion of its waters for irrigation, the river flowed into Tulare Lake.

2.5.4 Tule River

The Tule River is a 71-mile-long river in Tulare County and drains the southern Sierra Nevada (Figure D2-8c). The Tule River has three main tributaries, the North Fork, Middle Fork and South Fork, that in the past flowed into Tulare Lake. Currently, water in the Tule River now flows into Lake Success, a reservoir constructed in 1961 near Porterville, California, and only in times of above normal precipitation or snow melt is water released onto the dry Tulare Lake bed.

2.5.5 Canals and Pipelines

There are 34 rivers, streams, canals, and diversions entering and within the Subbasin that deliver surface water to the Subbasin (Figures D2-9b-d).

Water is imported into the Subbasin using facilities of the SWP located west of the Subbasin and the CVP. Water can also be exported out of the Subbasin using the SWP and CVP facilities in combination with facilities developed by local water districts (ECORP, 2007). The CVP imports San Joaquin River water into

the Subbasin through the Friant-Kern Canal and Delta water through the Delta-Mendota and San Luis Canals.

The Friant-Kern Canal is operated and maintained by the Friant Water Authority and is used to convey water from the San Joaquin River to Kern County. The canal originates at the Friant Dam, which is operated by the United States Bureau of Reclamation. The Friant-Kern Canal flows southeasterly along the western flank of the Sierra Nevada foothills through Fresno, Tulare, and Kern counties. The Friant-Kern Canal has a capacity of approximately 5,300 cubic feet per second or about 10,510 acre-feet per day (AF/D), which decreases to about 2,500 cubic feet per second or about 4,960 AF/D as demand decreases toward its end in the Kern River, near Bakersfield, California (AFW, 2018).

2.6 Climate

The climate in the Subbasin is semi-arid characterized by hot, dry summers and cool moist winters and is classified as Mediterranean steppe climate (Köppen climate classification). The wet season occurs from November through March with 80 percent (%) of precipitation falling during this time frame (ECORP, 2007). The valley floor often receives little to no rainfall in the summer months. Precipitation typically occurs from storms that move in from the northwest off the Pacific Ocean and occasionally storms from the southwest that contain warm sub-tropical moisture can produce heavy rains especially during El Nino episodes.

Historical annual precipitation at the Hanford weather Station from 1899 to 2017 (Hanford, 2017) has ranged from a low of 3.37 inches in 1947 to a maximum of 15.57 inches in 1983 (Table D2-1). Monthly precipitation in the area ranges between 0 and 6.69 inches per month and averages about 8.28 inches per year. This results in an estimated 2 inches per year of infiltration into the unconfined aquifer. Figure D2-10 provides a chart of the annual precipitation at the Hanford station from 1940 to 2017.

2.7 Land Use

Land use in the Subbasin and surrounding areas is predominately agricultural with smaller urban areas. Land use was evaluated using DWR land use maps for 1990 through 2006 (DWR, 2016a) and annual CropScape maps from 2006 through 2016 (USDA, 2016). These maps were provided in Geographic Information System formats, allowing for aggregation of similar land uses (i.e., crop types) to simplify analysis (Figure D2-11a-d). A total of 33 land uses were identified and evaluated (Table D2-2). Of these land uses, 27 were assumed to be irrigated, while 6 land uses (open water, forests, etc.) were assumed to only receive precipitation.

The Subbasin covers an area of approximately 535,869 acres or about 837 square miles (DWR 2016b). Between 1990 and 2016, the Subbasin had an average of approximately 310,800 acres of crops, 7,110 acres of riparian or open water, 137,110 acres of fallow or non-developed land, and 22,130 acres of urban and industrial development (Table D2-2, Appendix D1). The mix of crops grown and fallow lands has changed over time as agricultural practices changed in response to agricultural markets and drought conditions. A chart of area by land use shows that fallow acreage increased significantly during the 2010-2016 drought, while riparian, cotton, and pasture acreage all decreased during the drought (Figure D2-12). Cotton showed the most change with a decrease of over 85,000 acres between 1995 and 2016. The data also show that the was an overall increase in permanent crops over time, with increases in young and mature almonds from approximately 7,680 acres in 1995 to 42,300 acres in 2016. The total acreage of pistachios also increased from 4,700 to 26,900 acres between 1995 and 2016; however, there was a loss of 4,220 acres of mature pistachios with a concurrent increase of 26,400 acres of young pistachios.

Annualized tables and charts of land use for the Subbasin GSAs and the portions of the Westside, Kings, Kaweah, Tule, and Kern subbasins within the model domain are presented in Appendix D1.

2.8 Basin Water Budget

The basin water budget describes the inflows to and outflows from the Subbasin hydrogeologic system. Inflow and outflow can occur from the hydraulic boundaries of the system, from various sources within the model domain such as rainfall, lakes, and leakage from rivers and canals, and from the exit points or sinks such as wells or drainage systems. The boundaries, sources, and sinks identified within the model domain are discussed below.

2.8.1 Inflows

Inflows consist of precipitation, surface water diversions for irrigation, imported groundwater for irrigation, intentional recharge, and leakage from streams and conveyances.

2.8.1.1 Precipitation

Precipitation can be a significant source of water to the Subbasin and surrounding area. Given the large areal extent of the Subbasin and surrounding area, it was determined that using a single weather station to estimate precipitation would be inadequate to represent the entire Subbasin. Instead, the Parameter-elevation Regression on Independent Slopes Model (PRISM) database maintained by the Oregon State University was used to estimate monthly precipitation from January 1990 through December 2016 across the model domain (PRISM, 2017). The PRISM database contains monthly total precipitation for the entire United States using a 4-kilometer grid. The monthly precipitation values are statistically derived values based on local weather stations and corrections for topographic variations. A total of 304 PRISM data sets were downloaded for the model domain. The monthly precipitation data were summed by Subbasin area to estimate the potential annual precipitation volume for each subbasin (Figure D2-13a). Maps of average monthly rainfall across the model domain for the months of January, March, May, July, September, and November shows that precipitation also varies spatially across the model domain (Figure D2-13b).

Not all rainfall is available for use by crops – some fall on impervious surface, some is taken up by dry soils, some is intercepted by foliage and on evaporates before it can infiltrate, and some deep percolates and recharges groundwater. Monthly effective precipitation was estimated by multiplying the monthly PRISM data sets by the Precipitation / Effective Precipitation ratios presented in FAO 56 (Chapter 3, Table 6; Allen et al., 1998) and shown on Figure D2-14. A table and chart summarizing annual effective precipitation by subbasin within the model domain is presented on Figure D2-15. This shows that between 1990 and 2016, effective precipitation provided as little as 9,320 acre-feet (AF) in a dry year (2013) to 501,030 AF in a wet year (2010) and averaged approximately 214,720 acre-feet per year (AF/Y) of water across the model domain.

2.8.1.2 Surface Water Diversions

Surface water diversion from external sources are the most significant source of water to the Subbasin and surrounding area. There are 34 rivers, streams, canals, and diversions entering and within the Subbasin that have recorded diversions (Figure D2-9a-c). Two primary data sources were employed for the surface water inflows and deliveries to the farms within the model domain:

- For lands within the Subbasin itself, surface water delivery and diversion records were obtained by via direct contacts with the various GSAs (and member water management agencies within the

GSAs) within the Subbasin proper (Table D2-3). Those records were relatively complete from 1990 through 2016 for diversions off the Kings system and SWP. As shown on Table D2-3, during the period 1998 through 2010, the Kings River had six below normal water years, four average water years, and three above average water years. Over the 1998-2010 period is Kings River water years average 96% of normal, making this a "normal hydrology" period.

- For deliveries to lands located within the model buffer area (between the boundaries of the Subbasin as defined by the DWR and the TLSBHM model domain boundaries), a combination of data gathered for GSAs whose footprint extended into the Subbasin proper, and data mined from the C2VSIM (Brush et al., 2016) model for those GSAs and water management districts that lay completely outside the official Subbasin boundary were utilized. The C2VSIM model surface water data covered from the beginning of the TLSBHM model period through the end of 2011 and was extended through the end of 2016 by correlation of those inflows with Kings River deliveries at Peoples weir. In general, inflows into this area from Kaweah and Tule Rivers, and Deer Creek were reconstructed from a variety of disparate data.

A table and chart summarizing annual surface water diversions by subbasin within the model domain is presented on Figure D2-16. Monthly surface water diversions by subbasin by GSA and subbasin are provide in Appendix D2. This shows that between 1990 and 2016, surface water diversions provided an average of 948,370 AF/Y of water across the model domain and as much as 1,696,540 AF of water in wet years.

The surface water diversions are not delivered uniformly across the model domain spatially or temporally (Figure D2-17). During the 1990-2016 period, there are several areas that historically have not received any surface water diversions or have received intermittent deliveries of surface water (Figure D2-17).

2.8.1.3 Imported Groundwater Supply

One unique feature of the Subbasin is the importation of groundwater supplies from adjacent subbasins. The ER GSA and TCWA GSA operated well fields in the adjacent Tule Subbasin and import the pumped groundwater into the Subbasin as an additional water supply. Between 1990 and 2016, ER GSA operated up to 52 wells in the Creighton Ranch well field, which delivered up to 68,730 AF in a dry year (2014) and as little as 0 AF in wet years (1996-1999) and averaged approximately 39,320 AF/Y in non-wet years (Table D2-4). The TCWA GSA operated up to 51 wells in the Angiola Water District (WD) well field, which delivered groundwater to TCWA GSA lands in both the Subbasin (about 60%) and Tule Subbasin (about 40%). Between 1990 and 2016, the Angiola WD well field delivered up to 23,100 AF in a dry year (2009) and as little as 0 AF in wet years (1996-1999) and averaged approximately 15,950 AF/Y in non-wet years (Table D2-4).

2.8.1.4 Lake Bottom Water Storage

Another unique feature of the Subbasin is the utilization of certain portions of the historical lake bottom for storage of the excess surface water inflows that were not diverted by others. This stored surface water is later used as an irrigation supply. In some years, sufficient water can be stored in the lake bottom to eliminate the need for supplemental groundwater pumping to meet the irrigation demand.

As observed in historical aerial imagery, the area occupied and the locations of water storage changes from year to year, although certain areas to the south appear to be more regularly utilized by storage (Figure D2-18). This can result in significant volumes of stored water in some years. Permanent lakebed storage facilities have the capacity to store approximately 70,000 AF at any given time. During flood events,

as an example of conjunctive use, some fields can be flooded allowing for the storage of significant volumes of water, in some years up to 450,000 AF in the ER GSA management area (Figure D2-18). When available, the storage water is typically utilized to supplement surface water deliveries in lieu of groundwater pumping. The importance of this conjunctive management capability is illustrated by the fact that the cumulative excess inflow stored in the lake bottom allowed lake bottom farmers to completely turn off their groundwater well fields between January 1995 and June 1999 (Table D2-4).

2.8.1.5 Intentional Recharge

Groundwater recharge in the Subbasin also occurs from intentional percolation of surface water in infiltration ponds and water banks. The Corcoran Irrigation District (CID) has operated nine intentional recharge basins covering approximately 2,760 acres since the 1980s (Figure D2-19). Aerial photograph analysis shows that only one or two basins are typically utilized each year between March and September when surface water is available, percolating an estimated average of 23,500 AF/Y of surface water. The other ponds are typically dry except in extremely wet years such as 2005-2006, 2010-2011, and 2017 when as much as 147,700 AF of water has been estimated to be percolated. During the 1990-2016 simulation period, the CID Ponds percolated an estimated 616,100 AF of excess surface water.

Kings County Water District (KCWD) has been infiltrating Kings River flood waters along the Old Kings River channel since the 1940s (referred to as Condition 8). Condition 8 water is surface water that naturally would have infiltrated along the Old Kings River channel during high river flow years had the river not been diverted for irrigation. Between 1990 and 2016, Condition 8 recharge has ranged from as little as 0 AF in most years and as much as 36,800 AF in flood years (1995) and averaged approximately 30,370 AF/Y in wet years (Figure D2-20).

In addition, KCWD operates 25 recharge basins totaling about 720 acres within the MKR GSA and also began operating a water bank on the Old Kings River Channel in 2002. Since 2002, approximately 73,600 AF of water has been recharged via percolation through approximately 50 acres of ponds through the water bank, and approximately 48,500 AF has been recovered utilizing five recovery wells. This leaves a positive balance of approximately 25,100 AF in the unconfined aquifer system as of 2016.

In the Chamberlain Ranch area of the ER GSA, 640 acres has been utilized for percolation basins. In 2017, approximately 5,000 AF was recharged. Immediately adjacent to the eastern boundary of the ER GSA in the Tule Subbasin, there are recharge basins that are operated by ER GSA landowners.

2.8.1.6 River and Canal Seepage

Seepage losses from river and canals provide another source of water to the Subbasin and surrounding areas. There are over 290 miles of major streams and canals within the Subbasin, in addition to many more miles of small distribution ditches on individual farms (Figures D2-9b-d). Most to the stream and canals are unlined and can have significant seepage losses. Ownership of canal and river seepage is to be determined. There was little available information on seepage losses in the Subbasin, although anecdotal reports indicate the Old River Channel, Peoples Ditch, and Lakeland Canal all have substantial losses near the head gates at Peoples Weir (personal communication, Dennis Mills).

2.8.2 Outflows

Outflows consist of evapotranspiration, agricultural pumping, municipal pumping, and agricultural drains.

2.8.2.1 Evapotranspiration

Crop evapotranspiration (ETc) or crop demand use is the largest outflow of water from the Subbasin. ETc data are based on spatial distributions of different types of crops, as well as estimated rates of evapotranspiration for the Subbasin area. Crop data comes from DWR data sets for the counties of Fresno, Kern, Kings, and Tulare (surveyed intermittently between 1990-2006) and from CropScape datasets (surveyed annually from 2007-2016). Monthly ETc varies by crop type and by season, typically peaking during the summer months. ETc rates were estimated from published ITRC rates (ITRC, 2003) under normal year conditions for the region (Table D2-5).

Annual crop demand was calculated for each crop type on a 40-acre basis as follows:

Annual Crop Acres (Acres) * *Annual Crop ETc* (Feet/Acre) = *Irrigated Crop Demand* (AF/Y)
(Table D2-2) (Table D2-5) (Table D2-6)

Note: some crop types do not receive irrigation water and thus have zero irrigated crop demand.

Between 1990 and 2016, the total irrigated crop demand in the Subbasin ranged from 564,120 AF in 2015 to 1,072,440 AF in 2007 and had an average irrigated crop demand of approximately 879,020 AF/Y (Table D2-6).

The mix of crops grown and fallow lands has changed over time as agricultural practices changed in response to agricultural markets and drought conditions. A chart of annual crop acreage shows that total crop acreage has generally decreased since 2010 (Figure D2-12). Crop demand shows a similar pattern, generally decreasing from 2009 through 2015 (Table D2-6). Cotton showed the most change with a decrease of crop demand over 50% between 1995 and 2016. The data also show that during the 2011-2016 drought, there was an overall increase in row crop demand including tomatoes, peppers, small vegetables, onion, garlic, grain, and hay. In addition, the data show a large increase in ETc demand from almonds, pistachios, and stone fruits. Annualized tables and charts of crop demand for the Subbasin GSAs and the portions of the Westside, Kings, Kaweah, Tule, and Kern subbasins within the model domain are presented in Appendix D3.

2.8.2.2 Specified Agricultural Well Field Pumping

Agricultural pumping is typically not recorded over much of California, including the Subbasin. However, there are 455 wells with reported production in 6 agricultural well fields within the model domain. A wellfield consists of a group of wells generally located in the same area and operated a single entity to provide a reliable groundwater supply. The agricultural wellfields include: ER GSA (99 wells), Creighton Ranch (52 wells), CID (98 wells), Angiola Water District (51 wells), Westlands Water District (150 wells), and Apex Ranch (5 wells) (Figure D2-21). The ER GSA and CID well fields service local areas in the Subbasin. The Creighton Ranch and Angola Water District well fields, located in the Tule Subbasin, service the Tule Subbasin and also export significant amounts of groundwater to the Subbasin. The Westlands Water District well field only services the Westside Subbasin. The specified pumping from the agricultural well fields has varied significantly over time, ranging from 23,470 AF (1998) to 370,880 AF (2016) and averaging about 202,750 AF/Y (Figure D2-22). The reduction in annual pumping coincides with the availability of surface flood waters (Figure D2-18). Appendix D4 presents an annualized summary of reported pumping by agricultural well fields within the model domain.

2.8.2.3 Specified Municipal Well Field Pumping

Municipal pumping of groundwater occurs in the Subbasin by the cities of Hanford, Lemoore, Stratford, and Corcoran (Figure D2-21). Specified pumping from the 30 identified municipal well fields has been slowly increasing over time but has remained relatively consistent (Figure D2-22). Between 1990 and 2016, reported municipal pumping has ranged from 9,110 AF (1991) to 26,700 AF (2002) and averaged 14,910 AF/Y over this 26-year period. The municipal pumping demand varies seasonally, peaking in the summer months. As noted in Section 2.4, municipal pump has created persistent cones of depression in the potentiometric surface near the cities of Hanford and Corcoran. Appendix D4 presents an annualized summary of pumping by municipal wells within the model domain as reported by the cities.

2.8.2.4 Estimated Agricultural Pumping

As noted above, agricultural pumping is typically not recorded over much of California, including the Subbasin. However, agricultural pumping by subbasin can be estimated using a simple water balance approach where:

Irrigated Crop Demand (AF/Y)- *Effective Precipitation* (AF/Y) */ Irrigation Efficiency* (%) = *Farm Demand* (AF/Y)

and

Farm Demand (AF/Y) – *Surface Water Supplies* (AF/Y) = *Estimated Agricultural Pumping Demand* (AF/Y) (Figure D2-23)

Note: Surface Water Supplies include Surface Water Deliveries, imported groundwater, and lake bottom water storage

Although this simple water balance approach does not account for subtleties in the areal distribution of effective precipitation, irrigation efficiency, and surface water deliveries, it does provide a reasonable gross estimate of agricultural pumping on the subbasin scale. Based on this analysis, gross agricultural pumping demand in the Subbasin from 1990 through 2016 has ranged from 24,730 AF (1995) to 785,260 AF (1991) and averaged approximately 469,560 AF/Y (Figure D2-23).

2.8.2.5 Agricultural Drains

Agricultural drains are used in several areas across the model domain to keep soil from becoming waterlogged in the root zone. Typically, a tile or French drain system is used, with tiles buried approximately 4 to 6 feet bgs draining to sumps. Subsurface drainage collected in the sumps is pumped via pipeline to evaporation basins. Figure D2-24 shows the approximate location of known subsurface drains within the Subbasin.

3.0 Simulation Code

In order to meet the model objectives discussed in Section 1.3, the groundwater flow model code must meet the following criteria:

- be able to simulate three-dimensional groundwater flow within the model domain,
- be well documented and verified against analytical solutions for specific flow scenarios,
- be accepted by regulatory agencies,
- be readily understandable and usable by others for simulation of future groundwater conditions, and
- have a readily available technical support structure.

The groundwater flow model codes MODFLOW2005-NWT (Niswonger et al., 2011) and MODFLOW-OWHM (Hanson et al., 2014) are two distinct versions from the well-known MODFLOW family of groundwater simulation codes. These codes were used to develop the Subbasin model.

MODFLOW is a modular, finite-difference computer code developed by the USGS to simulate three-dimensional groundwater flow (McDonald and Harbaugh, 1988, Harbaugh, A. W., 2005). The use of the MODFLOW family of codes is well documented in technical literature and is a de facto standard for groundwater flow modeling worldwide.

MODFLOW2005-NWT is a particular version of MODFLOW that implements the Newton method for handling non-linearities in flow equations, which allows for very efficient solution of the flow equation including complexities such as unsaturated zone flow, eliminated the cell draining and re-wetting problems of earlier versions of MODFLOW (Niswonger et al., 2011). MODFLOW-OWHM is a relatively new version of MODFLOW (still under development) specifically developed to provide a flexible and robust approach to simulate conjunctive management of surface water and groundwater resources in an agricultural crop production setting (Boyce et al., 2016).

3.1 Model Code Selection

Once the decision was made to develop a model using the MODFLOW family of codes, the initial plan was to develop both a MODFLOW2005-NWT model and a MODFLOW-OWHM model to provide independent, yet complementary, methods for model development. This was planned due to the fact that both codes will share many of the same input files, only differing in how the farm irrigation pumping is specified. For the NWT model, the farm irrigation pumping requirement would be calculated externally in a de-coupled modeling approach, whereas with OWHM, the farm irrigation pumping is calculated internally as a dynamic component.

The MODFLOW-NWT ("MF-NWT") code would be employed to develop a "de-coupled" model of conjunctive surface water – groundwater management in the Subbasin. In the de-coupled approach, the following four-step procedure is used to build surface boundary processes (irrigation, crop water use, return flows, etc.), build the irrigation well pumping file, and run the model to simulate system response:

- the crop ETc demand calculated externally on a model cell-by-cell basis based on cropping patterns, crop coefficients, and reference ETc;
- effective precipitation and specified surface water deliveries are also calculated on a model cell-by-cell basis, irrigation pumping demand is calculated as the ETc demand – effective precipitation - surface water supplies;
- the resulting cell-by-cell irrigation pumping demand is subsequently summed by area, and assigned to a hypothetical pumping well in the center of the area in the de-coupled model; and
- the model is run to simulate groundwater-system response (drawdown, loss of storage, subsidence) to the stresses (including municipal and irrigation pumping, natural recharge, intentional artificial recharge, recharge from stream and canal leakage, recharge from irrigation return flows.

The MODFLOW-OWHM ("MF-OWHM") code was investigated as a tool to dynamically simulate conjunctive management of surface water and groundwater resources in the Subbasin. The MF-OWHM model employs basically the same input data sets used to calculate the ETc and irrigation pumping

demands externally for the de-coupled MF-NWT model, but the MF-OWHM simulations are dynamic in the sense that the ETc and irrigation pumping are calculated internally within the model allowing for "feedback loops" between these two key stressors on the groundwater system. The MF-NWT de-coupled model does not address these types of feedback loops that actually can be occurring in the field.

The MF-OWHM, the code is currently undergoing enhancements (from to its capabilities and numerical methods. In January 2019, the USGS indicated that updated version of the model code (OWHM v2) would be available in March 2019. The most recent communication with the USGS indicated that the updated model code might not be ready until the end of October 2019, too late for the GSP schedule. Thus, further development of the OWHM was suspended at the end of March and efforts were directed at completing the de-coupled MF-NWT model for the Subbasin within the project schedule. The remainder of this report focusses on the de-coupled model development, application, and results.

3.2 Code Assumptions and Limitations

There are certain model code assumptions and limitations that must be considered when developing, applying, and interpreting a numerical model. Some key assumptions and limitations that may affect the site models are briefly discussed below.

Porous Media: The MODFLOW family of codes is limited simulation of saturated and unsaturated flow in porous media. It does not simulate flow through fractures or relatively impermeable bedrock.

Layer Continuity: MODFLOW requires that all layer extend from edge-to-edge of the model domain. This limits the ability to explicitly simulate formation pinch-outs or unconformities. Instead these features may be simulated using a hydraulic conductivity contrast.

Unsaturated Flow: The MODFLOW Unsaturated Zone Flow (UZF1) package can simulate flow in the unsaturated zone using an approximation to Richards' equation to simulate vertical unsaturated flow. The approach is limited in that unsaturated flow occurs in response to gravity, and there must be uniform hydraulic properties in the unsaturated zone for each vertical column of model cells. This limits the ability of the MODFLOW to simulate different properties of the thick unsaturated zone. The Brooks-Corey function is used to define the relation between unsaturated hydraulic conductivity and water content. Variables used by the UZF1 Package include initial and saturated water contents, saturated vertical hydraulic conductivity (Kv), and an exponent in the Brooks-Corey function. Residual water content is calculated internally by the UZF1 Package on the basis of the difference between saturated water content and specific yield (Sy).

The UZF1 Package is also substitution for the Recharge (RCH) and Evapotranspiration (ET) Packages of MODFLOW-2005. The UZF1 Package differs from the RCH Package in that an infiltration rate is applied at land surface instead of a specified recharge rate directly to ground water. The applied infiltration rate is further limited by the saturated Kv. The UZF1 Package differs from the ET Package in that evapotranspiration losses are first removed from the unsaturated zone above the evapotranspiration extinction depth, and if the demand is not met, water can be removed directly from ground water whenever the depth to ground water is less than the extinction depth. The UZF1 Package also differs from the ET Package in that water is discharged directly to land surface whenever the altitude of the water table exceeds land surface. Water that is discharged to land surface, as well as applied infiltration in excess of the saturated Kv, may be routed directly as inflow to specified streams or lakes if these packages are active; otherwise, this water is removed from the model similar to the Drain (DRN) Package.

Stress Periods: MODFLOW requires that temporally variable data be consistent within each stress period. This results in some temporally averaging of data. For example, stream flow or municipal pumping may vary hourly or daily in response to demand, while agricultural well field may pump nearly continuously for several months in a row. The averaging of transient stress into consistent monthly stress period tends to smooth out the hydraulic impacts of the transient stresses.

3.3 Graphic Pre/Post-Processor

To facilitate the preparation and evaluation of each model simulation, Wood utilized the graphics pre/post processor GWVistas® Version 7 (GWV) by Environmental Simulations, Inc. (ESI, 2017). GWV is a Windows® program that utilizes a graphic user interface (GUI) to build and modify a database of model parameters. The model grid, hydraulic properties, and boundary conditions are input using the GUI, and then GWV creates the necessary MODFLOW and MT3DMS data input files. The input files generated by GWV are generic (standard) files compatible with USGS MODFLOW-NWT and MT3DMS. Wood also utilized some in-house utilities and Microsoft EXCEL spreadsheets to generate standard MODFLOW data input files for selected simulations and for post-processing simulation results. For example, PYTHON scripts were utilized to add and subtract the large matrices containing 27 years of monthly data worth of effective precipitation, surface water deliveries, and crop demand to estimate agricultural pumping. Similarly, an Excel spreadsheet was created to allocate the estimated agricultural pumping demand to hypothetical wells, and export file formatted for importation into GWV.

GWV was also utilized to post-process the model simulations. GWV can display the simulated head results as plan views and cross-sections. In plan view, the contour intervals and labels specified by the user and dry cells are denoted by a different color. In cross-section view, the water table surface is also plotted. Most outputs to the screen can be saved in a number of formats (DXF, WMF, PCX, SURFER, etc.) for utilization in other graphics programs.

4.0 Model Design

The following sections describe the numerical groundwater flow model for the TLSBHM. The model construction was based on the HCM presented in Section 2.0, with each of the key features described in that Section represented numerically in the TLSBHM. This modeling effort is a revision to the preliminary groundwater model of the Subbasin (Kings Model) developed in 2016-2018 on behalf of the Kings County Community Development Agency (AFW, 2018).

4.1 Model Domain/Grid

As described in Section 2.1, the TLSBHM model domain is centered on the Subbasin and extends beyond the Subbasin several miles, overlapping adjacent subbasins within the Tulare Lake Hydrologic Region (Figure D2-2). The model domain was extended beyond the Subbasin so that model boundary conditions are sufficiently far away the area of interest in the Subbasin; these areas beyond the extent of the Subbasin henceforth are referred to as the "buffer areas" (Figure D2-2). The buffer areas extend approximately 3 miles beyond the DWR-defined Subbasin boundaries on the north, south, and east sides; on the west and southwest sides, however, a large buffer area is not included because the alluvial groundwater basin is truncated by low-permeability geologic units on those side. The active model grid covers an area of approximately 1,091,320 acres (about 1,705 square miles) and is orientated due north to align the model grid with the predominant direction State Plane coordinate system of Township/Range/Sections.

The preliminary Kings Model (AFW, 2018) exhibited some boundary condition interference along the eastern edge of the model. Hence the TLSBHM model grid was extended further east approximately

2.5 miles. In addition, some of the active model grid edges were modified to yield straighter lines to simplify specified boundary conditions. The resulting TLSBHM model grid consists of 281,750 active cells with uniform dimensions of 1,320 x 1,320 feet (¼ mile x ¼ mile, or 40-acres) (Figure D4-1). The complete model grid consists of 230 rows, 175 columns, and 7 layers.

4.2 Model Layers

The purpose of model layers is to represent the hydraulic influence of stratigraphy at a scale appropriate to the model objectives. One way to think of "hydraulic influence" is how finer-grained deposits present resistance to flow, both laterally and vertically, and it is only through multiple model layers that one can simulated the vertical resistance to flow. It is understood that stratigraphic variations occur at scales that are both smaller and larger than that characterized for this model.

- Those hydrostratigraphic variations that are of the same scale or larger than the numerical grid cell size, for example the Corcoran Clay, are captured explicitly in model property variations.
- Those hydrostratigraphic variations that are much smaller than the model cell size are not treated explicitly in the model, but rather their effect is incorporated into the model via appropriate assignment of large scale "effective" properties for the model cell as described above in Section 2.1.1. For example, say three 1- to 2- foot thick clay layer or lenses extend across a large portion of the 1,320-foot x 1,320-foot plan view area of a 50-foot thick model cell. To capture the hydraulic effect of those layers in the 50-foot thick model cell requires significantly reducing the Kv as guided by this conceptual model and application of the harmonic average as a lower bracket for significantly reducing Kv compared to what is in the CVHM model data that was provided to the TLSBHM modeling team by the USGS.

In addition to direct import of the CVHM hydraulic conductivity fields (based on the USGS sediment texture study) as the starting point for the model, refinements to the conceptual and numerical models of the site were based on consideration of several types of information. Supplement information considered included both recent and older USGS literature (Croft, 1972; Page, 1986), monitoring well perforation intervals in sub-areas of the site, and qualitative and quantitative information obtained directly from the GSAs.

The initial basis for the TLSBHM model layering scheme was based on a modified version of the CVHM (AFW, 2018). The modified CVHM model had 13 layers including 5 layers above the Corcoran Clay, 3 layers representing the Corcoran Clay, and 5 layers below the Corcoran Clay. The TLSBHM layering scheme was reduced from 13 layers to 7 layers to simplify the model and make it more consistent with the 3- to 4-layer models being developed for the Tule and Kaweah subbasins. The TLSBHM layer count was reduced by combining several thin layers into a single, thicker layer. For example, the 3 layers representing the Corcoran Clay in the CVHM model were combined into a single layer in the TLSBHM. Layer elevations and thicknesses were also modified in some areas based on local information. The resulting Cross-sections showing the model layering scheme and initial hydraulic conductivity distribution are shown on Figures D4-2 and D4-3.

4.3 Model Duration and Stress Periods

The TLSBHM simulates the period from 1990 through 2016 using 324 monthly stress periods (Table D4-1). The model simulates the period from 1990 to 1995 as a "run-up" period to stabilize the model hydraulics

prior to the 1998-2010 focused calibration period. The model continues from 2010 through 2016 to bring the model up to date with current hydraulic conditions as required under SGMA.

4.4 Model Hydraulic Parameters

The initial hydraulic properties assigned to the TLSBHM were extracted from CVHM. The hydraulic parameters were only modified as necessary during the model calibration process to improve the fit between simulated and observed heads. As such, the model contains no more complexity than is justified by the available data, the model objectives, and the model results to date. Section 4.4.1 briefly describes how the USGS used textural information from thousands of boring logs to develop three-dimensional maps of the hydraulic properties.

The range of final hydraulic properties, hydraulic conductivity, Kv, storage, Sy, and porosity used as a result of the calibration process are briefly summarized in the following subsections.

4.4.1 Hydraulic Conductivity

Geologically speaking, the Central Valley is a large structural trough filled with sediments of Jurassic to Holocene age. These sediments reach thicknesses on the order of 15,000 feet in the San Joaquin Valley, and as much as 30,000 feet in the Sacramento Valley. In general, the Sacramento Valley is predominantly fine-grained and reflects more fine-grained volcanic-derived sediments, and in the San Joaquin Valley the areas of coarse-grained texture are more widespread than the areas of fine-grained texture and occur along the major rivers, especially on the eastern side.

The texture (particle size) of these sediments and how that texture varies spatially strongly impacts how groundwater flows in response to recharge and discharge stresses on the system. Therefore, the textural distribution of the basin-fill sediments was used to define the initial vertical and lateral hydraulic conductivity and storage property distributions for the TLSBHM domain.

To characterize the Central Valley basin-fill deposits, scientists from the USGS developed a geologic texture model to describe the coarseness or fineness of basin-fill materials that make up the hydrogeologic system, and then used it to estimate hydraulic properties (hydraulic conductivity and storage properties) for every cell in the model grid. To create a sediment texture model for the Central Valley, the USGS compiled and analyzed data and information from approximately 8,500 drillers' logs of boreholes ranging in depth from 12 to 3,000 feet below land surface (Faunt el al., 2009). The textural characterization focused on the variability and spatial distribution of the fraction of coarse sediments (f_c) over 50-foot depth intervals. Figure D4-4 presents the f_c for several of the model layers, and Figure D4-5 presents an oblique view of f_c for the San Joaquin Valley, with the TLSBHM study area outlined in red. In general, there are two key aquifer systems, the upper unconfined and semi-confined aquifer and the deeper confined aquifer system, separated by the Corcoran Clay aquitard. On Figures D4-4 and D4-5, the Corcoran Clay horizon is found in model layers 6 through 8, with the unconfined and semi-confined shallow aquifer system in model layers 1 through 5 and the deeper confined aquifers in model layers 9 through 13.

The USGS generated estimates of hydraulic properties from their texture model developed for the CVHM. These values were imported directly into the TLSBHM to use as initial values prior to beginning model calibration. The initial hydraulic conductivity distribution utilized in the TLSBHM is shown on Figure D4-6.

Beneath the Subbasin study area, previous studies have identified extensive deposits of fine-grained materials consisting of lacustrine and marsh sediments (Croft and Gordon, 1968; Croft, 1972; Page, 1986, Williamson et.al., 1989). A cumulative thickness of as much as 3,000 feet of these fine- grained deposits have been identified and include laterally extensive clay layers (A – F Clays). The A-, C-, and E-Clays (i.e., Corcoran Clay) cover much of the TLSBHM domain. During the calibration process, these studies and input from the GSAs were utilized to adjust hydraulic properties derived from the USGS texture model to be more representative of the Tulare Lake bed and surrounding area (Figure D4-7). The following subsections provide a summary of the hydraulic properties for each of these depth intervals.

4.4.1.1 Unconfined and Semi-Confined Aquifer Zones above the Corcoran Clay

Above the Corcoran Clay is the unconfined to semi-confined upper portion of the regional fresh-water aquifer. This upper portion of the regional freshwater aquifer is generally comprised of coarse- to medium-grained sediments (i.e., sand and gravel) with silt and clay interbeds.

According to the USGS CVHM, the grid-block-scale horizontal hydraulic conductivity (K_h), ranges from 8 to 75 feet per day (ft/d). These values span the lower range of a "good aquifer" as defined by Bear (1972). Figure D4-4 presents the K_h distribution derived from the USGS texture study for selected model layers. On Figure D4-4 (as well as Figure D4-6), a broad swath of lower permeability (low sand fraction) deposits is evident that run from the northwest side of the model domain trending to the southeast toward the southeast corner of the model domain. In this zone, the hydraulic conductivities derived from the CVHM are in the 5 to 25 ft/d range, which is closer to the range of a "poor aquifer" (Bear, 1972), and which appear to be lower than values obtained from pumping tests in these areas (P&P, 2009). In fact, the averaging of sediment texture (f_c) over 50-foot depth intervals leads to "smoothing out" of permeability contrasts.

As described previously, it is important to recognize that even in the zones with a higher fraction of coarse textured sediments, clayey layers and lenses are found throughout the profile. This is especially important for estimating effective horizontal-to-vertical anisotropy of hydraulic conductivity for a numerical model layer thickness of 50 feet, which is the scale of vertical averaging that the USGS employed in their sediment texture study. For example, say the fraction of coarse-materials over a 50-foot depth interval is 90%; if the remaining 10% consists of a fine fraction that is concentrated in a few clay layers on the order of a foot thickness, then the effective K_v should tend toward the harmonic average of a clay and a sand (Freeze and Cherry, 1979). If the sand has a K_h of 90 ft/d and the clay layers have a K_h of 0.01 ft/d, then the effective K_v for that grid cell could be estimated using a layer-thickness weighted harmonic average as:

$$K_v \approx [50 / ((5/0.01) + (45/90))] = [50/500.5] \approx 0.1 \text{ ft/d}$$

The effective K_h can be estimated as the layer-thickness weighted arithmetic average:

$$K_h \approx [(45x90) + (5x0.01)] / 50 \approx 90* (45/50) = 81 \text{ ft/d}$$

These simple calculations indicate that it would be reasonable to expect very high anisotropy ratios (very low effective K_v), and indeed that is what was found during the model calibration process (see Section 5.0).

The storage properties above the Corcoran Clay do not vary nearly as much as the hydraulic conductivity in this portion of the aquifer. The S_y of the sediments above the Corcoran Clay (Layers 1 through 3) range from 0.08 to 0.3, while the specific storage (S_s) ranges between 1.5x10-5/feet and 7.3x10-3/feet.

4.4.1.2 Corcoran Clay Aquitard

The lateral extent and thickness of the Corcoran Clay are shown on Figure D2-4. While it is sometimes considered a continuous layer of low permeability sediments spanning across the San Joaquin Valley, in fact comparing these figures to the CVHM hydraulic conductivity maps for model layers 4 through 10 (Figures D4-4 through D4-6) clearly shows that the Corcoran Clay grades into coarse materials laterally, as well as above and below. They also show that some clay lenses exist above and throughout areas characterized as relatively "coarser" in the USGS texture study. Recognizing that the texture maps were developed from averaging f_c over 50-foot depth intervals, this impacts the effective Kv used in the TLSBHM as described in the previous section.

This is consistent with recent investigations by the USGS in the San Joaquin Valley, which indicate that the groundwater conditions grade from unconfined, or water-table, at the shallowest depths to semi-confined with increasing depth, eventually grading into fully confined conditions beneath the Corcoran Clay. Geophysical well logs indicate that the Corcoran Clay, although probably the largest single confining bed, constitutes only a small percentage of the total cumulative thickness of clay layers in the fresh-water bearing unconsolidated sediments in the Subbasin. Thus, it is more accurate to consider the confinement as the result of numerous overlapping clay lenses and beds. Further, the difference in hydraulic head directly above and below the Corcoran Clay is relatively small when compared to head differences between larger intervals of the deeper parts of the aquifer system. Again, rather than to explicitly simulate each of these thin clay layers and lenses discretely in the model, their impact on the flow system is simulated through the high anisotropy in hydraulic conductivity (very low Kv).

Hydraulic conductivity (K_h) values of the Corcoran Clay cells in the model domain from the USGS CVHM range from 0.5 to 10 ft/d, which is rather high for an aquitard material, and especially high considering that the harmonic average should be the guide for effective K_v. As mentioned in Section 4.4.1, hydraulic conductivity values at the depth horizon of the Corcoran Clay were adjusted during model calibration to improve the fit between the simulated and observed hydraulic heads over time.

In addition, as discussed in Section 2.3.4, Croft & Gordon (1968) identified uninterrupted lacustrine (clay) deposits from the surface to at least 2,200 feet bgs beneath the central portion of the Tulare Lake bed (Figure D2-5). These lacustrine deposits interfinger with coarser sediments and the thinner clay zones along the periphery of the lake with the thick clay deposits beneath the lake bed itself. The Corcoran Clay (E-Clay) has been identified as extending beneath the lake bed (Davis et al., 1959). show it as being warped downward along the axis of the lake with a maximum thickness of 150 to 175 feet. These cross sections indicate the Tulare Lake deposits form a clay "plug" across the center of the San Joaquin Valley that may be 15 miles wide, 8 miles long, and ½ mile deep at its maximum dimensions. This was incorporated into the TLSBHM (Figure D4-7).

Again, the storage properties do not vary as much as the hydraulic conductivity, with S_s of the Corcoran Clay and other sediments in this depth horizon ranging between 4.5x10-4/feet and 1.2x10-3/feet, with the S_y ranging from 0.10 to 0.15 where unconfined. Storage values were adjusted during model calibration to improve the fit between the simulated and observed hydraulic heads over time.

4.4.1.3 Confined Aquifer Beneath the Corcoran Clay

Hydraulic conductivities initially assigned to the model layers beneath the Corcoran Clay horizon were derived from the USGS CVHM. Conductivity values generally ranged from 20 to 40 ft/d, except for two broad regions of lower permeability. One of the areas with a predominance of low-K_h materials at depth is in the Westside Subbasin to the west, and the other is beneath the southeast buffer areas near where Deer Creek

enters the model domain. Again, the storage properties do not vary as much as the hydraulic conductivity, with Ss of the sediments below the Corcoran Clay ranging between $6.8x10^{-4}$/feet and $1.5x10^{-3}$/feet. Storage values were adjusted during model calibration to improve the fit between the simulated and observed hydraulic heads over time.

The TLSBHM groundwater model was initially assigned variable K_h values that ranged between $4.0x10^{-4}$ ft/d for aquitard clay units to 91 ft/d for aquifers, with the spatial distribution of the properties derived from the CVHM. These values were modified as necessary during the calibration process to improve the model fit to observed groundwater elevations (Figure D4-7).

4.4.2 Storage

The TLSBHM groundwater model was initially assigned S_s values from the USGS CVHM. Initial S_s values ranged between $1.5x10^{-5}$ to $7.3x10^{-3}$ feet-1. These values are within the published range of values for the silty to sandy sediment types (Spitz and Moreno, 1996). S_s values were modified over a limited range during the model calibration process.

4.4.3 Specific Yield

The TLSBHM groundwater model was initially assigned S_y values from the USGS CVHM. Initial S_y values ranged between $7.9x10^{-2}$ to $3.0x10^{-1}$. These values are within the published range of values for the silty to sandy sediment types (Spitz and Moreno, 1996). S_y values were modified over a limited range during the model calibration process.

4.4.4 Porosity

The TLSBHM groundwater model was initially assigned porosity values from the USGS CVHM. Initial porosity values ranged between $9.1x10^{-2}$ to $2.9x10^{-1}$. These values are within the published range of values for the silty to sandy sediment types (Spitz and Moreno, 1996). Porosity values were modified over a limited range during the model calibration process.

4.5 Model Boundary Conditions

Significant hydraulic boundaries (sources and sinks) within the model domain that must be considered in the site numerical model include the inflows and outflows from surrounding subbasins, inflows and outflows of surface water, return flows and intentional recharge, and groundwater pumping. These boundaries are discussed in the following subsections.

4.5.1 General Head Boundaries

The MODFLOW General Head Boundary (GHB) package was utilized to simulate the north, south, and east edges of the model domain and represent the aquifer system beyond the model domain (Figure D4-8). For the TLSBHM, the GHBs were developed based on historical water level observations in well located within 2 miles of the model domain boundary. Figure D4-8 shows the locations of wells evaluated to develop the GHB boundary conditions. The GHBs were developed as a series of 20 GHB reaches. The GHB heads at the ends of each reach were interpolated on a monthly basis from the available hydrograph data. The GHB heads for each cell within a reach were then linearly interpolated between the end points. This resulted in a relative smooth variation in GHB heads along the length of each reach.

The GHB conductance term, which governs how much water can flow through the GHB, was calculated as:

Conductance = KLW/M in square feet per day (ft^2/d), where:

K is the hydraulic conductivity of the sediments (assumed to be 25 ft/d),
L is the GHB length or distance to the head value (assumed to be 1,320 feet),
W is the GHB width (assumed to be 1,320 feet), and
M is the saturated thickness of GHB layer (assumed to be 100 feet).

4.5.2 River and Canal Boundaries

As noted above, several rivers and streams deliver surface water to irrigated lands within the model domain. The most important of these is the Kings River, which enters the model domain on the northeast side, and it flows westward near the top of the model domain before turning southwest then southward in the western portion of the model domain. Other major surface water inflows are provided by the Kaweah River, the Tule River, Deer Creek, and Poso Creek. Figure D4-9 shows the locations of each of these surface water features; also shown are the major distributary canals that take the deliveries from the streams and rivers and distribute that water to the irrigation farmlands.

The MODFLOW River (RIV) package was utilized to simulate all the stream and canals that deliver water to irrigated lands. The streams were developed as a series of 23 RIV reaches, where each RIV reach is composed on many model cells. The RIV package is a head dependent boundary and will allow water to enter groundwater via seepage (losing stream) or exit groundwater (gaining stream) based on river stage (Head) and a steam bed conductance term:

Conductance = KLW/M in ft^2/d, where:

K is the hydraulic conductivity of the sediments (assumed to be 1 to 10 ft/d),
L is the length of the river reach (variable in feet),
W is the river width (assumed to be 10 to 40 feet), and
M is the thickness of the river bed (assumed to be 10 feet).

The rivers were assumed to leak anytime there were surface water diversions down a particular river reach. Throughout the Subbasin, almost all river are disconnected from groundwater and are losing rivers. Appendix D2 presents an annualized summary of river flow by reach within the model domain.

4.5.3 Agricultural Drains

The MODFLOW Drain (DRN) package was utilized to simulate the agricultural drains within the model domain (Figure D2-24). The DRN package is a head dependent boundary condition that only collects groundwater above a specified elevation. Similar to GHBs, the rate of removal is governed by a conductance term:

Conductance = KLW/M in ft^2/d, where:

K is the hydraulic conductivity of the sediments (assumed to be 100 ft/d),
L is the length of the drain (assumed to be 1,320 feet),
W is the width of the drain (assumed to be 1,320 feet), and
M is the thickness of the drain bed (assumed to be 1 foot).

In areas where drains were simulated, if simulated groundwater rose to within 4 feet of ground surface, then groundwater was collected by the drains and assumed to be discharged to evaporation basins where it evaporated and was removed from the model domain.

4.5.4 Groundwater Extraction

Groundwater extraction for municipal, industrial, and agricultural demand was simulated using the MODFLOW Multi-Node Well (MNW2) package. The MNW2 package is a powerful enhancement to the original MODFLOW well package in that it allows for simulation of wells screened across multiple model layers (aquifers). Thus, the MNW2 package will calculate inflows from each model layer within the screened interval as well as the calculating flow within the well casing, including flows from one layer to another when the well is not being pumped. In addition, the MNW2 package will automatically increase pumping from deeper intervals as shallower aquifers become dewatered until the pumping level in the well approaches a specified elevation (such as a pump setting).

4.5.4.1 Specified Pumping Wells

As discussed in Sections 2.8.2.2 and 2.8.2.3, there are 485 known municipal, industrial, recovery, and agricultural wells that have data on well construction as well as reported pumping rates over time (Figure D2-21). The pumping rates were specified for the municipal wells based on monthly historical pumping data obtained from the cities of Corcoran, Hanford, Lemoore, and Stratford (Table D2-3), or reported monthly pumping data from irrigation districts such as CID, ER GSA, Westlands Water District, and reported pumping from well fields like Creighton Ranch and Angiola well fields (Table D2-6).

4.5.4.2 Hypothetical Agricultural Irrigation Wells

As discussed in Section 2.8.2.4, agricultural pumping is not typically recorded throughout most of the Subbasin. As such agricultural pumping had to be estimated based on available cropping data using a water balance method. Recognizing that many more wells exist in the Subbasin than those 485 known wells, an additional 1,091 hypothetical irrigation wells were uniformly distributed across the model domain on approximately 1-mile centers for those areas with unknown well completion intervals, resulting in the final well distribution as shown on Figure D4-10. The hypothetical wells were specified to be screened in the upper (above Corcoran) or lower (below Corcoran) aquifer zones based on statistics of well completions for 238 known irrigation wells in the Subbasin. In addition, approximately 25% of the hypothetical irrigation wells were specified to be completed across the Corcoran, producing groundwater from permeable intervals both above and below the aquitard, consistent with the completion statistics for the 238 known irrigation wells in the Subbasin.

Crop Evapotranspiration Rates

Field crops (alfalfa, row crops, corn, cotton, etc.) are assigned on an annual basis in the model. For example, if the annual DWR crop survey/CropScape data (DWR, 2016a) indicate that corn was present in a particular model cell, then it was assumed that corn was the only crop within that cell for the full calendar year (12 stress periods). The applied evapotranspiration rates for that cell were assigned based on the monthly ETc rates for corn.

Permanent crops including vineyards, almonds, pistachios, pomegranates, and stone fruit (tree crops) are assumed to be fully mature at the beginning of the simulation in 1990 (based on 1994-1996 DWR crop data). As the model progresses forward in time, the available crop data changed, and the spatial distribution of crops also changed, with a recent trend to more permanent tree crops being planted. As the permanent crop grows from seedling to full maturity, the evapotranspiration rate was assumed to

increase as well. The presence of a crop within a specific space in a cell was tracked over time by assigning crop IDs that reflect the number of years of maturity for each tree crop and using the intersect tool in ArcMap to see specific areas of overlap between year n tree crops and year n+1 tree crops. If an intersected area of the domain has almonds in year n and in year n+1, it is assumed that the almonds have matured in that particular portion of the cell.

The crop data for the Subbasin indicates that there was a substantial increase in the number of acres planted in tree crops during the 2010-2016 period (Section 2.8.2.1, Table D2-2). Rather than assuming full maturity and peak evapotranspiration rates for these new areas of tree crops, the ET rates for these areas are assumed to be a fraction of the mature ET rates.

For example, almonds are assumed to mature over a 5-year period, so the first year that almonds are present in a portion of a model cell they are assigned ET rates that are 1/5th of the mature rate. If those almonds are still in the same area the next year, then they are assigned an ET rate of 2/5^{ths} of the mature rate, and so on. If almonds are in the same spot for 5 years, they are assumed to have the full ET rates of a mature almond tree. Anything beyond 5 years, up to 25 years, uses the full maturity ET rates. For instances where almonds have been in a portion of a cell more than 25 years, the almond trees are assumed to have been replanted, and start over at the 1-year, 1/5th mature ET rates.

Almonds were assumed to mature over a 5-year period and were assumed to be replanted after 25 years. Pistachios were assumed to mature over a 13-year period and are assumed to remain in place for 100 years once they are planted. Pomegranates were assumed to mature over a 19-year period and were assumed to be replanted after 44 years. Stone fruits were assumed to mature over a 5-year period and were assumed to be replanted after 25 years.

Irrigated Areas/Irrigated Fractions

Area fractions within cells were used to compute an area-weighted average for crop ET values within each cell and to determine the irrigated areas of each cell for use with surface water delivery matrix processing. The crop distributions for each stress period were intersected with the active domain grid in ArcMap. Each cell containing crops was subdivided into multiple pieces, one for each crop type within the cell. The areas of each crop type within the cells were calculated for each stress period. The ET demand for a single cell is computed as the area of the crop type times the rate of ET for that crop, divided by the total area of the cell.

Irrigated areas also play a part in the surface water delivery preprocessing. Surface water deliveries were assumed to be spread evenly across the entire irrigated area of each GSA Area (or farm). Not all cells within a GSA may be fully irrigated; there may be a portion of a cell which is fallow, or contains non-irrigated land uses (winter wheat, native vegetation, urban areas). Therefore, the irrigated area of a cell can be used as a weighting factor against the full area of the cell to adjust the effective rates of surface water delivered within a specific cell in a GSA.

For example, if a GSA has a surface water delivery of 30,000 AF in the month of September and the total irrigated area of the GSA is 10,000 acres, then the nominal rate of surface water delivery is 30,000 AF / 30 days = 1,000 AF/D over an irrigated area of 10,000 acres. Going a step further, this becomes (1,000 AF/D) / (10,000 acres) = 0.1 ft/d rate of surface water delivery. For a cell where only half of the area is irrigated, the weighted surface water delivery rate for that cell would be 0.05 ft/d.

Agricultural Irrigation Pumping Demand

Monthly pumping rates for the hypothetical irrigation wells were computed based on crop ETc demand (Section 2.8.2.1) minus the sum of effective precipitation (Section 2.8.1.1), surface water deliveries (Section 2.8.1.2) and Lake Bottom Water Storage (Section 2.8.1.3). The logic behind the calculation of the hypothetical irrigation well pumping rates is summarized below.

For each monthly stress period and each 40-acre model cell:

- Area Weighted Crop Acreage (acres) x Crop ETc (feet per month [ft/m]) = ET Demand (acre-feet per month [AF/M])
- [-ET Demand (AF/M) + Effective Precipitation (ft/m)] / Irrigation Efficiency = -Farm Demand (AF/M)

  (*Note: over most of the model domain, Irrigation Efficiency was assumed to be 75% from 1990 to 2000 and then increase to 85% from 2000 through 2016. Irrigation Efficiency from the lake bottom area was assumed to be 95% from 1990 through 2016. Approximately 50% of excess Effective Precipitation was assumed to infiltrate and 50% was assumed lost to evaporation. Farm Demand is the volume of water needed to irrigate a field and meet crop demand due to inefficiencies in irrigation methods*)
- -Farm Demand (AF/M) + Surface Water Deliveries (AF/M) + Lake Bottom Storage Water (AF/M) = -Unmet Demand (AF/M) and +Tailwater Flow (AF/M)

  (Note: monthly Surface Water Deliveries were summed by GSA and applied to irrigated areas within each GSA. Lake Bottom Water Storage typically occurred only during and following very wet years and was an additional water supply for the ER GSA and TCWA GSA)
- -Unmet Demand (AF/M) + Avg Tailwater Flow/GSA (AF/M) = -Ag Pumping Demand (AF/M) and +Excess Applied Water (AF/M)

  (Note: Tailwater Flows were assumed to stay within each GSA. The monthly Average Tailwater Flow/GSA (AF/M) = Sum of Tailwater flow per GSA (AF/M) divided by GSA irrigated area. Approximately 75% of excess Applied Water was assumed to infiltrate and 25% was assumed lost to evaporation.)

Typically, each hypothetical agricultural irrigation well was assigned a service area (or farm) consisting of 16 model cells totaling 1-square mile (Figure D4-11). The sum of the monthly Ag Pumping Demand (AF/M) for the 16 model cells was assigned to each hypothetical agricultural irrigation well. For some hypothetical agricultural irrigation well the cell count was more or less than 16 model cells due to boundaries no-flow boundaries or to eliminate hypothetical wells servicing only 1 or 2 cells.

In addition, there are several large areas (ER GSA, CID, SWK GSA, TCWA GSA, and Westlands Water District) that were assumed to be operated as single service areas (or farms) with equal access to surface water and pumped groundwater within the service area. Several of the service areas supplied groundwater by wells located within the service area and/or by external well fields outside of the service area. For example, ER GSA is supplied groundwater from wells within the GSA and by the Creighton Ranch well field in the Tule Subbasin. Likewise, both SWK GSA and TCWA GSA are supplied groundwater from a few wells inside the GSAs and by the Angiola well field in the Tule Subbasin. CID and Westlands Water District are assumed to be supplied groundwater from the wells within each service area.

4.5.5 Deep Percolation and Intentional Recharge

Groundwater recharge occurs within the Subbasin from deep percolation of applied water and intentional recharge. Intentional recharge occurs at specific locations including Apex Ranch, CID ponds, and the Old Kings River (Section 2.8.1.4). Deep percolation of applied water occurs almost everywhere in the TLSBHM where there is active irrigation due to inefficient irrigation practices. There are three components to deep percolation including Farm Demand, Excess Applied Water, and Intentional Recharge. Deep percolation is estimated for each monthly stress period and each 40-acre model cell or farm as follows:

- [+Farm Demand (AF/M) / (1-1/Irrigation Efficiency)] + Excess Applied Water (AF/M) + APEX/CID/Condition 8 Intentional Recharge (AF/M) = Deep Percolation (AF/M)

  (*Note: over most of the model domain 75% of Excess Applied Water was assumed to percolate and 25% was assumed to evaporate*)

Deep percolation is applied to the TLSBHM for each stress period and each model cell using the RCH Package.

4.5.6 Subsidence

Land subsidence due to extraction of groundwater was simulated using the MODFLOW Subsidence (SUB) package. The SUB Package simulates elastic (recoverable) compaction and expansion, and inelastic (permanent) compaction of compressible fine-grained beds (interbeds) within the aquifers. The compaction of the interbeds is caused by head or pore-pressure changes (changes in effective stress) within the interbeds. If the stress is less than the pre-consolidation stress of the sediments, the deformation is elastic; if the stress is greater than the pre-consolidation stress, the deformation is inelastic.

The SUB package parameters of:

Sk_e skeletal storage elastic,

Sk_i skeletal storage in elastic,

b_{equiv} combine thickness of delay interbeds within a model layer, and

n_{equiv} combine thickness of non-delay interbeds within a model layer

were derived from CVHM and modified during calibration to approximate observed subsidence during the simulation period.

5.0 Model Calibration

Calibration of a groundwater flow model is a process through which the model is demonstrated to be capable of simulating the field-measured heads and flows that comprise the calibration targets. Calibration is accomplished by selecting a set of model parameters, boundary conditions, and stresses that produce simulated heads and fluxes that match field measurements within a pre-established range of error. Because of the multiplicity of parameters involved in the calibration process, a unique solution (e.g., one set of parameters) cannot be achieved. A brief discussion of the calibration of the groundwater flow model for the site is presented in the following subsections.

5.1 Model Calibration Criteria

The quantitative fit of the model to observed water level measurements is conducted through statistical analysis of the residuals, (the difference between observed and simulated water levels or heads) at specified observation locations, and in the case of transient calibration, with time. The residual is calculated as the observed value minus the simulated value; thus, a positive residual indicates that the simulated head value is less than the observed value, and vice-versa. The principal statistical measures of the residuals of all data points combined include the following:

- the mean of the residuals,
- the mean of the absolute value of the residuals,
- the standard deviation of the residuals,
- the sum of the square of the residuals (SSR),
- the root mean square (RMS) error of the residuals,
- the min and max of the residuals,
- the range of the observed values, and
- normalized root mean square error (NRMS) (e.g., the root mean square error divided by the range of observed values or the standard deviation divided by the range in observed values).

There is no industry standard for determining when a numerical model is adequately calibrated. However, a commonly used rule of thumb criterion for acceptable calibration is a normalized RMS error of less than 10% (Anderson et al., 2015). The RMS is the square root of the SSR divided by the number of observations throughout the model divided by the range of observed water level measurements. In addition, a plot of observed versus computed head values should track close to a 45-degree line and generally fall within one standard deviation of the mean error.

A common qualitative (visual) measure of goodness of fit in numerical modeling is a comparison of observe and simulated values using hydrographs for individual wells. In addition, a map view plot of the average residuals may be used to help identify targets or areas where the residuals in the model domain are largest. Clusters or patterns of gradation of positive or negative residuals may suggest areas where model parameters need to be adjusted further.

5.2 1990-2016 Transient Model Calibration

The transient TLSBHM simulated the period January 1990 through December 2016 using 324 monthly stress periods (Table D4-1). The TLSBHM was calibrated to two data sets, one data set covering the 1990-2016 period and a second data set limited to the 1998-2010 “normal hydrology” period.

The 1990-2016 calibration period included 16,468 groundwater level observations collected from 593 observation wells across the model domain. The 1998-2010 “normal hydrology” calibration period included 7,028 groundwater level observations collected from 544 observation wells across the model domain. Most of the observation wells had little or no completion interval information, making it difficult to assign the observations to a particular model layer. Wells with known completion intervals includes 81 wells above the Corcoran Clay and 69 wells below the Corcoran Clay. The other observation wells were assigned to model layers based on the similarity of observations with nearby known wells. Although additional observation wells with groundwater elevation measurements are available, many were

determined to have too short a record, too many spurious observations, or uncertain completion intervals and hence were not utilized.

Numerous model iterations were needed to calibrate the TLSBHM model. Various hydraulic parameters (K_h, K_v, S_s, S_y) and boundary conditions (RCH, GHB heads, RIV conductance) were incrementally modified using the manual trial and error method.

The calibration statistics for the entire 1990-2016 historical simulation period include a residual mean of -4.98 feet, a RMS error of 50.85 feet, a range of 575.33 feet, and a NRMS of 8.84 %, meeting the calibration criteria of a NRMS of <10% (Figure D5-1a). A scattergram of observed and simulated values shows that many values fall within one standard deviation of the perfect 45-degree fit. A residual distribution chart shows that the residual error approximates a gaussian distribution with a slight bias to over predicting heads.

The calibration statistics for 1998-2010 "normal hydrology" calibration period include a residual mean of 2.26 feet, a RMS error of 46.26 feet, a range of 545.16 feet, and a NRMS of 8.50 %, slightly better than for the 1990-2016 period, and meeting the calibration criteria of a NRMS of <10% (Figure D5-1b). A scattergram of observed and simulated values shows that most values are closer to the perfect 45-degree fit compared to the 1990-2016 period. A residual distribution chart shows that the residual error approximates a gaussian distribution with a slight bias to over predicting heads.

A qualitative comparison of observed and simulated heads in selected monitoring wells using hydrographs shows a reasonable fit for several wells, and poor fits for others (Figures D5-2a through D5-2g). In general, the hydrographs show that simulated heads are slightly under predicted above the Corcoran Clay (Figures D5-2a to D5-2c). Within the Corcoran Clay, the hydrographs show that simulated heads tend to start out lower than observed during the ramp-up period but end up with a relatively good fit after 1998 (Figure D5-2d). Below the Corcoran Clay, the hydrographs show that simulated heads are generally on trend with the observed, although seasonal variations are not simulated very well (Figures D5-2e to D5-2g). Observed and simulated heads in selected all monitoring wells used for model calibration are provided in Appendix D5.

Simulated potentiometric surface maps with groundwater flow vectors from above and below the Corcoran Clay show how the general direction of groundwater flow between the subbasins for December 2015 (Figure D5-3). In general, above the Corcoran Clay, simulated groundwater flow is entering the Subbasin from the north, east, and south, and leaving the Subbasin to the west. Below the Corcoran Clay, simulated groundwater flow is also entering the Subbasin from the north. The simulation results also show consistent cones of depression above the Corcoran Clay around pumping centers beneath the cities of Hanford, Lemoore, and Corcoran. There is also a large, persistent cones of depression beneath CID and lake bottom well fields southeast of the City of Corcoran and along the border between the Tulare Lake and Tule subbasins.

The maps also show that there is a large area in the lake bottom area where groundwater appears to be mounding slightly and the groundwater flow vectors show little movement of groundwater above and below the Corcoran Clay (Figure D5-3). This area has been described as being under lain by an extensive sequence of lacustrine and marsh deposits (i.e., Tulare Lake bed "clay plug") which are relatively impervious. Thus, the apparent mounding may result from a zone of residual high heads that are draining more slowly than surrounding areas as groundwater levels are being drawn down due to pumping, recharge to the lake bottom, or it could result as a combination of both.

5.3 1990-2016 Water Balance Calculations

The calibrated transient TLSBHM was used to estimate the groundwater flows that occur between the Subbasin and the adjoining subbasins (Figure D2-2). The following subsection present water balances 1990-2016 simulation period and the 1998-2010 "normal hydrology" period for the Subbasin itself, as well as for each adjoining subbasin, and net flows between the Subbasin can be extracted from these results. Note that the protrusion of the Kaweah Subbasin boundary into the Subbasin and the presence of large wellfields near subbasin boundaries complicate the assessment of inter-basin flows.

5.3.1 Tulare Lake Subbasin

The 1990-2016 annualized net water balance for the Subbasin shows that overall there is a long-term net outflow of groundwater from the Subbasin to the Kings, Kaweah and Tule subbasins (Table D5-1, Figure D5-4), while there is a long-term net inflow of groundwater from the Westside and Kern subbasins. These overall results can be disaggregated to subbasin interactions above and below the Corcoran Clay. Above the Corcoran Clay, there is a net outflow of groundwater from the Subbasin to the Kings, Kaweah, and Tule subbasins, and a net inflow of groundwater from the Westside and Kern subbasins. Below the Corcoran Clay, there is a net outflow of groundwater from the Subbasin to the Westside, Kings, Kaweah and Tule subbasins and a net inflow of groundwater from the Kern Subbasin. The inflows and outflows of groundwater from below the Corcoran Clay are greater than those from above the Corcoran Clay.

The change in storage in the Subbasin has varied from year to year depending on the water year type. Between 1990 and 2016, the estimated change in storage has ranged from -392,280 AF (2015) to 361,230 AF (2011) and averaged -85,690 AF/Y. During 1990-2016, the estimated cumulative change in storage was about -2,313,740 AF. During the 1998-2010 "normal hydrology" period, the estimated change in storage has ranged from about -220,650 AF (2006) to -296,280 AF (2008) and averaged -73,770 AF/Y. During the 1998-2010 period, the estimated cumulative change in storage was about -958,940 AF.

5.3.2 Westside Subbasin

Annualized net water balance for the portions of the Westside Subbasin within the model domain shows that there is a long-term net outflow from the Westside Subbasin to the Tulare Lake and Kings subbasins (Figure D5-5). In general, the long-term outflow from the Westside Subbasin to the Subbasin is greater than that from the Kings Subbasin above the Corcoran Clay, while the long-term inflow to the Westside Subbasin from the Subbasin is less than that from the Kings Subbasin below the Corcoran Clay. The potentiometric surface maps (Figure D5-3) show that the outflow of groundwater from the Subbasin is due to both pumping in the Westside Subbasin and leakage from the South Fork of the Kings River.

The change in storage for the portions of the Westside Subbasin within the model domain has varied from year to year depending on the water year type. Between 1990 and 2016 the estimated change in storage has ranged from -425,290 AF (1990) to 103,573 AF (1998) and averaged -84,070 AF/Y. During 1990-2016 the estimated cumulative change in storage was about -2,269,800 AF. During the 1998-2010 "normal hydrology" period the estimated change in storage has ranged from -177,600 AF (2008) to 103,573 AF (1998) and averaged about -47,080 AF/Y. During the 1998-2010 period the estimated cumulative change in storage was about -612,040 AF.

5.3.3 Kings Subbasin

Annualized net water balance for the portions of the Kings Subbasin within the model domain shows that there is a long-term net groundwater inflow to the Kings Subbasin from the Tulare Lake, Westside, and

Kaweah subbasins (Figure D5-6). In general, the groundwater inflow to the Kings Subbasin from the Tulare Lake and Kaweah subbasins is from both above and below the Corcoran Clay, while there is a net outflow from the Kings Subbasin to the Westside Subbasin below the Corcoran Clay. The potentiometric surface maps (Figure D5-3) show that above the Corcoran Clay, the outflow of groundwater from the Subbasin is primarily due to leakage from the Kings River. Below the Corcoran Clay, the outflow of groundwater from the Subbasin to the Kings Subbasin is due to leakage from the Kings River (where the Corcoran Clay is not present).

The change in storage for the portions of the Kings Subbasin within the model domain has varied from year to year depending on the water year type. Between 1990 and 2016, the estimated change in storage has ranged from -229,310 AF (2015) to 74,030 AF (1998) and averaged -68,220 AF/Y. During 1990-2016, the estimated cumulative change in storage was about -1,841,980 AF. During the 1998-2010 "normal hydrology" period, the estimated change in storage has ranged from -162,950 AF (2004) to 74,030 AF (1998) and averaged about -66,520 AF/Y. During the 1998-2010 period, the estimated cumulative change in storage was about -864,720 AF.

5.3.4 Kaweah Subbasin

Annualized net water balance for the portions of the Kaweah Subbasin within the model domain shows that there is a long-term net groundwater inflow to the Kaweah Subbasin from the Tulare Lake and Tule subbasins and a long-term net groundwater outflow to the Kings Subbasin (Figure D5-6). In general, the groundwater outflow from the Tule Subbasin is greater than that from the Subbasin above the Corcoran Clay, while the outflow from the Subbasin is greater than that from the Tule Subbasin below the Corcoran Clay. The potentiometric surface maps (Figure D5-3) show that a portion of the Kaweah Subbasin protrudes into the Subbasin. This complicates the calculation of inter-basin groundwater flow because there is both inflow and outflow between the Tulare Lake and Kaweah subbasins through this area. In addition, there is outflow of groundwater from the Kaweah Subbasin to the Subbasin due to well field pumping in the area near the City of Corcoran.

The change in storage for the portions of the Kaweah Subbasin within the model domain has varied from year to year depending on the water year type. Between 1990 and 2016, the estimated change in storage has ranged from -317,310 AF (2014) to 31,300 AF (2011) and averaged -156,640 AF/Y. During 1990-2016, the estimated cumulative change in storage was about -4,229,350 AF. During the 1998-2010 "normal hydrology" period, the estimated change in storage has ranged from -239,860 AF (2004) to -2,110 AF (1998) and averaged about -128,390 AF/Y. During the 1998-2010 period, the estimated cumulative change in storage was about -1,669,020 AF.

5.3.5 Tule Subbasin

Annualized net water balance for the portions of the Tule Subbasin within the model domain shows that there is a log-term net groundwater inflow to the Tule Subbasin from the Tulare Lake and Kern subbasins and a log-term net groundwater outflow from the Tule Subbasin to the Kaweah Subbasin (Figure D5-8). In general, the flow from the Subbasin is greater than that from the Kaweah Subbasin both above and below the Corcoran Clay, with greater groundwater flow below the Corcoran Clay. The potentiometric surface maps (Figure D5-8) show that the outflow of groundwater from the Subbasin is primarily due to pumping wellfields southeast of the City of Corcoran and a pumping center east of the model domain in the vicinity of the City of Pixley.

The change in storage for the portions of the Tule Subbasin within the model domain has varied from year to year depending on the water year type. Between 1990 and 2016, the estimated change in storage has ranged from -247,850 AF (1990) to -1,820 AF (2011) and averaged -143,770 AF/Y. During 1990-2016, the estimated cumulative change in storage was about -3,881,750 AF. During the 1998-2010 "normal hydrology" period, the estimated change in storage has ranged from -224,920 AF (2008) to -46,570 AF (2006) and averaged about -140,900 AF/Y. During the 1998-2010 period, the estimated cumulative change in storage was about -1,831,680 AF.

5.3.6 Kern Subbasin

Annualized net water balance for the portions of the Kern Subbasin within the model domain shows that there is a long-term net groundwater outflow from the Kern Subbasin to the Tulare Lake and Tule subbasins (Figure D5-9). In general, the outflow from the Kern Subbasin to the Subbasin is greater than that to the Tule Subbasin both above and below the Corcoran Clay, with greater groundwater flow below the Corcoran Clay. The potentiometric surface maps (Figure D5-3) show that the outflow of groundwater above the Corcoran Clay from the Subbasin to the Kern Subbasin. Starting in the mid-2000s, the groundwater flow filed above the Corcoran Clay reversed and there was a net inflow from the Kern Subbasin to the Subbasin. Below the Corcoran Clay, the water balance charts and potentiometric surface maps show a general decline in the outflow of groundwater from the Subbasin to the Kern Subbasin.

The change in storage for the portions of the Kern Subbasin within the model domain has varied from year to year depending on the water year type. Between 1990 and 2016, the estimated change in storage has ranged from -97,940 AF (2013) to 64,860 AF (2011) and averaged -17,490 AF/Y. During 1990-2016, the estimated cumulative change in storage was about -472,140 AF. During the 1998-2010 "normal hydrology" period, the estimated change in storage has ranged from -84,350 AF (2008) to 64,860 AF (1999) and averaged about -10,950 AF/Y. During the 1998-2010 period, the estimated cumulative change in storage was about -141,330 AF.

5.3.7 Groundwater Storage

The change in storage in the Subbasin has varied from year to year depending on the water year type. Between 1990 and 2016, the estimated change in storage has ranged from -392,280 AF (2015) to 361,230 AF (2011) and averaged -85,690 AF/Y. During the 26-year 1990-2016 simulation period, the estimated cumulative change in storage was about -2,313,740 AF (Table D5-1, Figure D5-4). During the 1998-2010 "normal hydrology" period, the estimated change in storage has ranged from about -220,650 AF (2006) to -296,280 AF (2008) and averaged -73,770 AF/Y. During the 13-year 1998-2010 "normal hydrology" period, the estimated cumulative change in storage was about -958,940 AF.

The simulated groundwater mass balance data were used to estimate the change in groundwater storage in the Subbasin on an annual basis for the simulation period. The simulation results indicate that between 1990 and 2016, the estimated annual change in storage averaged -85,690 AF/Y while during the 1998-2010 "normal hydrology" period, the estimated annual change in storage averaged -73,770 AF/Y or about 14 % less than the 1990-2016 period. Likewise, the estimated net cumulative change in storage for the 26-year 1990-2016 period was about -2,313,740 AF while the estimated net cumulative change in storage for the 13-year 1998-2010 period was about –958,940 AF or almost 60% less than during the 1990-2016 period. Note that following the wet years of 1995-1998, 2005-2006, and 2010-2011, there was a small net increase in groundwater storage in the Subbasin (Table D5-1, Figure D5-4). This indicates that the Subbasin is relatively sensitive to water year type, and that during wet years, there can be a significant

increase in the amount of groundwater in storage. Likewise, as shown on Figure D5-4, extended drought periods (like 2011-2016) can results in a significant loss of groundwater in storage.

5.3.8 Subsidence

Simulated cumulative land subsidence due to extraction of groundwater was simulated for the period 1990-2015 (Figure D5-10). Throughout most of the Subbasin, simulated cumulative subsidence was less than 2 feet. However, in the vicinity of the wellfields southeast of Corcoran in the Tule Subbasin, simulated subsidence was over 9 feet. The simulation results also indicate up to 4 feet of subsidence in the Westside, Kaweah, and Kern subbasins. Charts of simulated subsidence over time was also calculated for the major municipal and agricultural wellfields in the TLSBHM (Figure D5-11). These charts show that there was 1 to 2 feet of cumulative subsidence in the vicinity of Hanford, Lemoore, and Stratford, while there was about 5 feet of subsidence at Corcoran, and up to 9 feet of subsidence at the Angiola and Creighton Ranch well fields in Tule Subbasin. The charts also show a small seasonal pattern of elastic subsidence rebound. During the early simulation period (1990-1992), the simulated subsidence occurred at all locations and then stabilized from 1993 through 2001. Simulated subsidence at that time started to increase again after 2002 in a series of steps. Additional calibration of the model to subsidence is needed as more data are collected.

6.0 Sensitivity Analysis

A sensitivity analysis was conducted to evaluate the sensitivity of the model to a change in the estimated hydraulic conductivity and storage parameters. These values in the model were systematically modified over the plausible range of values for the sediment types present beneath the site, and the model was re-run. The sensitivity model run results were compared to the calibration model result to estimate the change in model calibration due to the change in the model parameter.

The sensitivity analysis results indicate that the aquifers above and below the Corcoran Clay are relatively sensitive to changes in K_h, while the Corcoran Clay is not sensitive, as shown by the change (delta) in the sum of square residual (Figure D6-1). The results indicate that little improvement in calibration could be expected by modifying the K_h parameters.

The model sensitivity is reversed with respect to K_v, with the Corcoran Clay heads relatively sensitive to changes in K_v, while the aquifers above and below the Corcoran Clay are relatively insensitive (Figure D6-1). The results indicate that a small improvement in calibration could be obtained by decreasing the K_v above the Corcoran Clay.

The sensitivity analysis results indicate that the model is also relatively sensitive to changes in aquifer S_s, with the change in sum of squares error increasing with lower values of storage (Figure D6-1). A small improvement in calibration could be obtained by decreasing the S_s above the Corcoran Clay.

The sensitivity analysis results indicate that the model is also relatively in sensitive to changes in the Sy of the unconfined aquifer above the Corcoran Clay, with the change in sum of squares error decreasing with lower values of S_y (Figure D6-1).

7.0 Predictive Simulations

The calibrated groundwater flow model was modified to develop two 54-year transient predictive simulations from 2017 through 2070: (1) a Baseline Forecast to evaluate potential undesirable impacts from maintaining the recent land use under “normal hydrology” conditions (i.e., the status quo); and

(2) a Projects Forecast to evaluate potential impacts of implementing alternative land uses and projects to obtain groundwater sustainability. Both forecast models consist of 649 monthly stress periods starting with December 2016 and ending with December 2070. The SGMA requires that any forecast model start with current conditions. The models were started in December 2016 to permit the importation of the calibration simulations results as the start for the forecast models. The forecast models assume multiple repeating 14-year cycles of "normal hydrology" (e.g., precipitation, stream flow, surface water deliveries, and boundary conditions) from 1998 to 2010 (Figure D7-1), starting with using 2011 hydrology as an analog for 2017, which was a wet year. A summary of the forecast year and associated "normal hydrology" analog year is presented on Table D7-1. The forecast models were developed as described in the following subsections.

7.1 Baseline Forecast Scenario

The TLSBHM Baseline Forecast model represents conditions that assume land use recovering from the 2010-2015 drought conditions to "normal hydrology" conditions in the first few years of the simulation and maintaining these "normal hydrology conditions for the duration of the simulations. The Baseline Forecast model were developed as described below.

7.1.1 Baseline Forecast Land Use

A review of historical land use shows that major cropping acreage patterns have changed significantly over the past decades (Table D2-6, Figure D2-12). Acreage of cotton, pasture, and dairy fodder decreased, especially during the 2011-2016 drought. During this same period, acreage of almonds, pistachios, pomegranates, and fallow land increased. Note that the more recent plantings of almonds, pistachios, pomegranates have not yet reached maturity and associated increased water demand (Section 4.5.4.2).

During this early Baseline Forecast stress period, the acreage of corn and cotton that had been fallowed during the drought was assumed to be replanted, except for the acreage that had been converted to permanent crops. In addition, the water demand of more recently planted acreage of almonds, pistachios, and pomegranates was assumed to increase as the trees matured as discussed in Section 4.5.4.2.

For crop maturation, tree crops are assumed to continue to mature on a 25-year cycle (except for pistachios which can produce for over 100 years) and continuously mature forward in time. All other crops/land use is assumed to revert to whatever the land use was in the seed year for that particular forecast year. For example, assume there is a new patch of almonds planted in 2016 (crop zone 201). In 2021, it will be in its sixth year of existence, so it's assigned the ET rate of 6-year old almonds (crop zone 206). The other crops around this patch of almonds will revert to whatever was planted there in 2001, since 2001 is the seed year for the forecast year 2021. Three years from then, the patch of almonds is now mature and assigned an ET rate for mature almonds (crop zone 209), while the nearby crops are represented by seed year 2004 (corresponding to 2024). Further into the forecast, the almonds will be in their 25th year of existence in 2041 (crop zone 225), while the surrounding crops will be represented by seed year 2007. That same patch of almonds will be replaced, cycle back to being represented by 1st year almond ET rates (crop zone 201), and since it is 2042, the other crops are represented by whatever was planted in 2008. A chart of Baseline Forecast crop acreage is presented on Figure D7-2. Note that the crop acreage chart shows a repeating cycle of replanting of permanent tree crops.

7.1.2 Baseline Forecast Municipal Pumping

Baseline Forecast municipal water demand for the cities of Hanford, Lemoore, and Corcoran were assumed to vary seasonally at the average of 2011-2015 pumping rates. Municipal pumping was assumed

to increase slowly with populations growth at a rate of 0.35% per year from about 25,060 AF (2017) to about 30,160 AF (2070).

7.1.3 Baseline Forecast Hypothetical Irrigation Pumping

As discussed in Section 4.5.4.2, the calibration model utilized the available groundwater pumping data for the individual wells and well fields servicing the ER GSA, CID, SWK GSA, TCWA GSA, and Westlands Water District, which allowed these areas to be treated as individual service area or "farms" (Figure D4-11). In the rest of the model domain, the agricultural pumping demand was calculated on approximately 40-acre spacing and assigned to hypothetical agricultural wells on approximately a 1-miles spacing. A similar process was utilized for the forecast models with a few modifications as described below.

For the forecast models, the service area or "farm" concept was extended throughout model domain by dividing the model by subbasin and GSAs into 10 services areas or "farms" (Figure D7-3). For each service area, the monthly agricultural pumping demand was calculated as follows:

- Service Area Weighted Crop Acreage (acres) x Crop ETc (ft/m) = Service Area ET Demand (AF/M)
- [-Service Area ET Demand (AF/M) + Effective Precipitation (ft/m)] / Irrigation Efficiency = -Service Area Farm Demand (AF/M)

  (*Note: over most of the model domain, Irrigation Efficiency was assumed to be 85% from 2017 to 2070. In the lake bottom area Irrigation Efficiency from was assumed to be 95% from 2017 through 2070. Approximately 50% of excess Effective Precipitation was assumed to infiltrate and 50% was assumed lost to evaporation).*
- -Service Area Farm Demand (AF/M) + Service Area Surface Water Deliveries (AF/M) + Service Area Lake Bottom Storage Water (AF/M) +Service Area Project Water (AF/M) = -Service Area Ag Pumping Demand (AF/M)

  (Note: when monthly Service Area water supplies exceeded monthly Service Area Farm Demand the excess water supply was assumed to carry over as available water supply in the following month).

The resulting service area agricultural pumping demand was then divided equally amongst the wells and well fields suppling groundwater to each servicing area. However, pumping from the Westlands Water District, CID, ER GSA, Creighton Ranch, and Angiola wells fields was limited to the maximum historical pumping from each well field (although not necessarily for each well). While this approach many not replicate the individual historical pumping from each well in a service area, it does provide a reasonable approach to allocate forecast groundwater agricultural pumping in each service area and thus a reasonable estimate of groundwater system demand.

7.1.4 Baseline Forecast GHBs

As shown on Table D7-1, the Baseline Forecast uses historical years as analogs for the hydrology conditions in the forecast. For example, 2019 is assumed to have hydrology similar to 1999. However, the GHB heads in 1999 are many feet higher than those in 2016 when the Baseline Forecast model starts. To correct for this head discrepancy, the general head boundaries for the Baseline Forecast model were developed by calculating the difference in monthly heads for each stress period of the calibration simulation, and then adding that difference to the forecast GHB head from the previous month. This allows the Baseline Forecast GHBs to have a similar change in heads between stress periods as the calibration model, but from a different initial (2016) elevation. For example, the Baseline Forecast GHB

heads for simulation year 2019 are based on the heads difference for the analog year 1999. If the head difference for GHB cell 1001 between December 1998-January 1999 was 0.55 feet in the calibration model, then 0.55 feet was added to the GHB cell 1001 head for the December 2018 to yield the January 2019 GHB head. Thus the resulting Baseline Forecast GHBs exhibit a change in heads similar to that for the calibration model analog year, but from a different initial condition.

7.1.5 Baseline Forecast of Climate Change

The SGMA guidelines require that climate change be considered in any forecasts of future land uses. The California Natural Resources Association (CNRA) has developed a set of tools that can apply change factors to historical precipitation, ET demand, and surface water delivery data to make historical data consistent with forecasted conditions under climate change. The CNRA has developed two climate change factor data sets, one for 2030 and one for 2070.

7.1.5.1 Effective Precipitation

The Baseline Forecast monthly effective precipitation data set was processed through the CNRA python script/ArcGIS tool. The tool takes monthly data and processes it using change factors, which vary temporally and spatially. For model cells that cross multiple change factor grid cells, an area-weighted average change factor is applied. The change factors for a 2030 forecast were used for the forecast period January 2017-Dececember 2030 (stress periods 2 – 169) while the change factors for a 2070 forecast were used for the forecast period January 2031-December 2070 (stress periods 170 – 649).

7.1.5.2 Crop Evapotranspiration

The Baseline Forecast monthly ETc data set was processed through the CNRA python script/ArcGIS tool. The tool takes monthly data and processes it using change factors, which vary temporally and spatially. Since the "normal hydrology" Baseline Forecast scheme rotates through a series of years from 1997 to 2010 (with a 2011-based year for 2017), each ET distribution for the Baseline Forecast is unique when accounting for tree crop maturation. For model cells that cross multiple change factor grid cells, an area-weighted average change factor is applied. The change factors for a 2030 forecast were used for the forecast period January 2017-December 2030 (stress periods 2 – 169) while the change factors for a 2070 forecast were used for the forecast period January 2031-December 2070 (stress periods 170 – 649).

7.1.5.3 Surface Water Deliveries

The Baseline Forecast surface water delivery data set incorporates a reduction in historical surface water allocations to SWK GSA and TCWA GSA due the sale of water rights. The Baseline Forecast surface water delivery data set all GSAs outside of the Subbasin were not modified. CNRA change factors for surface water deliveries do not vary spatially, and are simply a multiplier applied to the historical surface water delivery volume. Different change factors are available for 2030 and 2070 climate change forecasted conditions. Like the effective precipitation and ETc data sets, the 2030 change factors were used for the forecast period January 2017-December 2030 (stress periods 2 – 169) while the change factors for a 2070 forecast were used for the forecast period January 2031-December 2070 (stress periods 170 – 649).
The Baseline Forecast of surface water deliveries is shown on Figure D7-4.

7.1.6 Baseline Forecast Simulation Results

A comparison of simulated potentiometric surface maps from above and below the Corcoran Clay for December 2015 (Figure D5-3) with simulated Baseline Forecast potentiometric surface maps from above and below the Corcoran Clay for June 2040 (Figure D7-5) show that the groundwater elevations beneath

the Subbasin above and below the Corcoran clay are projected to decline about 25 feet and 50 feet, respectively during the 25-year simulation period. Dewatered areas in the upper aquifer on the east side of the model domain (mostly in the Kaweah and Tule subbasins) are projected to expanded and migrate into deeper intervals. The cones of depression above and below the Corcoran Clay in the Lemoore, Creighton Ranch, and Angiola Water District well field areas are projected to become more pronounced.

Simulated Baseline Forecast potentiometric surface maps from above and below the Corcoran Clay for December 2070 (Figure D7-6) show that the groundwater elevations beneath the Subbasin above and below the Corcoran clay are projected to decline about 50 feet and 150 feet, respectively, during the 54-year simulation period. Dewatered areas in the upper aquifer in the Kaweah and Tule subbasins are projected to expanded significantly and migrate into deeper intervals. The cones of depression above and below the Corcoran Clay in the Westside Subbasin, Creighton Ranch, and Angiola well field areas are projected to become much more pronounced.

Simulated Baseline Forecast hydrographs for selected compliance wells in the vicinity of the cities of Corcoran, Hanford, and Lemoore show a continued gradual decline in groundwater elevations in the unconfined aquifer above and below the Corcoran Clay, with seasonal variations much greater below the Corcoran Clay (Figure D7-7). Over the 54-year simulation period, the hydrographs above the Corcoran Clay show approximately 100 feet of decline in the Corcoran area, about 90 feet of decline in the Hanford area, and about 100 feet of decline in the Lemoore area. Over the same period, the hydrographs below the Corcoran Clay show about 100 feet of decline in the Corcoran area, about 100 feet of decline in the Hanford area, and about 100 feet of decline in the Lemoore area.

The Baseline Forecast simulation results indicate that subsidence will continue over the next 54 years under continued existing conditions. A map of cumulative subsidence from 2017-2040 shows that the is about 0 to 4 feet of additional subsidence over most of the Subbasin, with up to 6 feet of additional subsidence in the Lemoore area and Angiola and Creighton Ranch wells fields in the Tule Subbasin (Figure D7-8). Baseline Forecast subsidence in the lake bottom area are minimal. A map of cumulative subsidence from 2017-2070 shows that the is about 0 to 8 feet of additional subsidence over most of the Subbasin, with up to 10 feet of additional subsidence in the Lemoore area and over 10 feet of subsidence in the Angiola and Creighton Ranch wells fields in the Tule Subbasin (Figure D7-8).

Simulated Baseline Forecast subsidence hydrographs for continuous GPS compliance point near the cities of Corcoran and Lemoore wells show that under continued existing conditions, subsidence rate remain consistent during the forecast period (Figure D7-8). The minimum threshold for subsidence was specified as 11.5 feet, which was the maximum simulated subsidence within the TLSBHM domain in 2070.

The Baseline Forecast simulation groundwater mass balance data were used to estimate the change in groundwater storage in the Subbasin on an annual basis for the 54-year forecast simulation period (Figure D7-9). Similar to the 1998-2010 “normal hydrology” period in the calibration model, the period 2040-2048 represents a “normal” or “hydrologically balanced” period in the forecast model. Under the Baseline Forecast assumptions described above, the 2040-2408 “hydrologically balanced period” annual change in groundwater storage averaged about -149,430 AF/Y. During the 2017-2070 period, the annual change in groundwater storage averaged about -142,990 AF/Y, and as much as -7.72 million AF of cumulative storage depletion from the Subbasin.

In summary, the Baseline Forecast simulation results indicate continued overdraft conditions in the Subbasin, with chronic lowering of groundwater levels, continued reduction of groundwater in storage,

continued land subsidence, and possibly degraded groundwater quality. Thus, the Baseline Forecast indicates that sustainable groundwater conditions in the Subbasin cannot be achieved without changes in groundwater usage and management.

7.2 Forecast Project Simulations

Multiple Projects Forecast simulations were created iteratively by modifying the Baseline Forecast and incorporating various potential projects and management actions developed by the GSAs for the Subbasin and surrounding subbasins (see Section 7.6) (Figure D7-10). The objectives of the projects and management actions are to obtain groundwater sustainability (defined as stable groundwater elevations with minimal changes in storage, land subsidence, and water quality degradation over time) by 2040 through a combination of increase water supplies and demand reduction.

Potential projects and management actions considered include:

- Above ground surface water storage projects,
- Intentional recharge basins,
- On-Farm Recharge,
- Aquifer Storage and Recovery (ASR), and
- Agricultural pumping limits in surrounding subbasins.

The combined projects were assumed to provide an annual average of 40,500 AF/Y of increases water supply and 38,000 AF/Y of groundwater recharge for a total of about 78,500 AF/Y of new water supply (Table D7-2, Figure D7-11). This is slightly more than the average overdraft (-73,760 AF/Y) observed during the 1998-2010 "normal hydrology" period and about 92% of the 1990-2016 average overdraft (-85,690 AF/Y). In addition, land use changes resulting from construction of the projects are anticipated to reduce agricultural demand by approximately 26,900 AF/Y. In total, the proposed project may yield an average of up to 104,400 AF/Y of additional water supply to the Subbasin. The proposed projects are described below by Subbasin GSAs.

Mid-Kings River Groundwater Sustainability Agency

The Mid-Kinks River GSA has proposed constructing several 40-80 acre groundwater recharge facilities in the GSA. For modeling purposes, the proposed recharge facility was assumed to be constructed on about 1,500 acres of land in the northeast portion of the GSA (Figure D7-10). The simulated facility was implemented in four 5-year phases starting in 2020. Full build out would be completed in 2035. Due to conversion of irrigated crop land to recharge basins, the recharge facility construction is estimated to result in a permanent annual agricultural demand reduction of about 4,500 AF once completed. The facility was assumed to recharge Kings River flood waters with an assumed percolation rate of approximately 1-foot per day for a 150-day period from March through July when flood waters are typically available based on the historical hydrology cycles used to construct the forecast (Figure D7-11). Flood water were assumed to be available about every 6 to 7 years. Total recharge capacity would increase in 5-year phases from an initial 50,000 AF to an estimated 200,000 AF during flood years when fully built out. Annual average project yield is estimated to be about 38,000 AF/Y over the simulation period, and about 44,440 AF/Y over the hydrologically balanced 2040-2048 period (Table D7-2). Intentional recharge was simulated in the Projects Forecast using the RCH package.

El Rico Groundwater Sustainability Agency

The ER GSA has proposed constructing an intermittent surface water storage facility to store Kings River flood water when available (Figure D7-10). The proposed surface water storage facility was assumed to be constructed by 2030 using raised 6-foot berms to enclose approximately 6,400 acres of land. The land would continue to be farmed during non-flood years, so the net average agricultural demand reduction is estimated to be about 8,400 AF/Y. The surface water storage facility was assumed to store approximately 40,000 AF of Kings River flood waters at a rate of about 8,000 AF/M during a 150-day period from March through July when flood water are typically available based on the historical hydrology cycles used to construct the forecast (Figure D7-11). Because of the clayey nature of the Lake Bottom sediments, infiltration of storage water was assumed to be de minimis. Annual average project yield is estimated to be about 8,780 AF/Y over the simulation period, and 8,890 AF/Y over the hydrologically balanced 2040-2048 period (Table D7-2). This additional surface water supply was added to the Baseline Forecast surface water deliveries for the ER GSA.

South Fork Kings Groundwater Sustainability Agency

The SFK GSA has proposed a number of small projects including aquifer storage and recovery (ASR) wells, new surface water storage facilities, and land fallowing. The potential projects for SFK GSA were very conceptual in nature. The location of the potential ASR well field(s) and potential recharge and recovery rates has not been identified. The locations of potential surface water storage facilities and land fallowing areas were also undefined. Hence, for forecast modeling purposes, a single large surface water storage facility was assumed to be constructed in the southeast portion of the GSA (Figure D7-11). The simulated surface water storage facility was assumed to be constructed by 2030 using raised 6-foot berms to enclose approximately 10,000 acres of land. Approximately half of this land was assumed to already be fallow, so the net agricultural demand reduction is estimated to be about 15,000 AF/Y after 2030. Because of the clayey nature of the sediments in this area, infiltration of storage water was assumed to be de minimis. The surface water storage facility was assumed to store approximately 60,000 AF of Kings River flood waters at a rate of about 12,000 AF/M from March through July when flood water are typically available based on the historical hydrology cycles used to construct the forecast (Figure D7-11). Annual average project yield is estimated to be about 13,170 AF/Y over the simulation period, and 13,330 AF/Y over the hydrologically balanced 2040-2048 period (Table D7-2). This additional surface water supply was added to the Baseline Forecast surface water deliveries for the SFK GSA.

Tri-County Water Authority Groundwater Sustainability Agency

The TCWA GSA has proposed constructing a new surface water storage facility over the middle portion of the GSA (Figure D7-11). The simulated surface water storage facility was assumed to be constructed by 2030 using raised 6-foot berms to enclose approximately 13,340 acres of fallow land, so there was no net agricultural demand reduction. Because of the clayey nature of the sediments in this area, infiltration of storage water was assumed to be de minimis. The surface water storage facility was assumed to store approximately 80,000 AF of Kings River flood waters at a rate of about 16,000 AF/M from March through July when flood water are typically available based on the historical hydrology cycles used to construct the forecast (Figure D7-11). Annual average project yield is estimated to be about 17,561 AF/Y over the simulation period, and 17,780 AF/Y over the hydrologically balanced 2040-2048 period (Table 7-2). This additional surface water supply was added to the Baseline surface water deliveries for the TCWA GSA and SWK GSA.

Surrounding Subbasins Projects

As shown on Figure D2-2, the Subbasin is surround by the Westside, Kings, Kaweah, Tule, and Kern subbasins. It was assumed that these surrounding subbasins would also implement projects similar in scope and yield as those proposed for the Subbasin in order to obtain groundwater sustainability. Since all the surrounding subbasins were developing potential projects as part of their GSPs, there was insufficient time to coordinate with the surrounding subbasins and implement their proposed projects into the TLSBHM Projects Forecast model. Therefore, for simplicity, it was assumed that each surrounding subbasins would implement projects that would yield additional surface water supplies similar to what is proposed for the Subbasin, or approximately 75% of the 1990-2016 annual average change in storage estimated for that portion of each subbasin within the TLSBHM (Figures D5-4 through D5-9). It was further assumed, for simplicity, that the surrounding subbasin projects would be implement outside of the TLSBHM model domain and that the additional water supply would be imported into the TLSBHM domain as addition surface water deliveries. The assumed surrounding subbasin additional water supplies include:

- Westside Subbasin 60,330 AF/Y
- Kings Subbasin 50,960 AF/Y
- Kaweah Subbasin 114,400 AF/Y
- Tule Subbasin 104,220 AF/Y
- Kern Subbasin 35,720 AF/Y

This additional surface water supply was added to the Baseline surface water deliveries for each of the surrounding subbasins.

Surrounding Subbasins Pumping Limits

Another management option under consideration by the surrounding subbasins is a limitation of groundwater pumping to a prescribed number of acre-feet per acre of irrigated land. Based on review of draft GSPs and discussions with other GSA the pumping limits under consideration include:

Subbasin	GSA	Irrigated Acres in Model	Pumping Limit (af/ac)	Agricultural Pumping (AF/Y)
Kaweah	All	127,870	2.00	255,740
Kings	Central Kings	16,170	1.13	18,275
Kings	Kings River East	15,800	0.73	11,530
Kings	North Fork Kings	41,864	1.10	46,050
Kern	--	36,190	1.00	36,190
Tule	--	79,920	0.54	43,160
Westside	--	62,920	0.60	37,750

The prescribed pumping limit volumes were assumed to be uniformly distributed between all agricultural wells in each subbasin within the model domain.

7.2.1 Projects Forecast Land Use

Land use under the Projects Forecast is identical to that used in the Baseline Forecast with the exception that lands utilized for most of the Subbasin projects was assumed to go out of production as the projects are built out over time, resulting in a step-wise decrease in agricultural demand (Figure D7-10).

Land fallowing in the surrounding subbasins resulting from implementation of pumping limits was not explicitly simulated in the model. Only the reduction in agricultural pumping was specified in the forecast model.

7.2.2 Projects Forecast Municipal Pumping

The Project Forecast municipal water demand for the cities of Hanford, Lemoore, and Corcoran is identical to that used in the Baseline Forecast. Municipal pumping was assumed to increase slowly with populations growth at a rate of 0.35% per year from about 25,060 AF (2017) to about 30,160 AF (2070).

7.2.3 Projects Forecast Hypothetical Irrigation Pumping

The Projects Forecast of agricultural irrigation pumping was calculated in an identical manner as for the Baseline Forecast, assuming increased surface water deliveries from the projects and pumping limits in the surrounding subbasins. The available surface water supplies were increased by the proposed project yields as described in Section 7.2.1. During flood events, additional stored surface water was assumed to be available to supplement surface water deliveries the month following storage, less evaporative losses. For example, the volume of water stored in the proposed SFK GSA surface water pond during March 2031 (about 1.2 feet over 10,000 acres) would be available to be redistributed as additional surface water supply to SFK GSA in April 2013 minus open water evaporation for March (about 0.38 feet). This assumption allows the proposed project surface water storage to be depleted in a timely manner by both evaporation and re-use.

7.2.4 Projects Forecast GHBs

The Projects Forecast GHBs were calculated in an identical manner as for the Baseline Forecast with one modification. As described in Section 7.1.4, the general head boundaries for the Baseline Forecast model were developed by calculating the difference in monthly heads for each stress period of the calibration simulation, and then adding that difference to the forecast GHB head from the previous month. This allows the forecast GHBs to have a similar change in heads between stress periods as the calibration model, but from a different initial (2016) elevation. This same process was used for the Projects Forecast GHBs with the addition of a head change factor that assumes projects were implemented in the subbasins surrounding the Subbasin resulting in a gradual stabilization (or "soft landing") of heads around 2040. The head change factor had a value of 100% from 2017 through 2026, and then decreased by 5% per year until 2040 where the head change factor was fixed at 25% for the duration of the simulation. The resulting Projects Forecast GHBs show a more gradual decrease in the rate of decline compared to the Baseline GHBs (Figure D7-12).

7.2.5 Projects Forecast of Climate Change

The SGMA guidelines require that climate change be considered in any forecasts of future land uses. The same CNRA climate change factor data sets for 2030 and 2070 used in the Baseline Forecast were applied to the Projects Forecast ET demand, and surface water delivery data. The CNRA corrected effective precipitation results remained identical to the Baseline Forecast.

7.2.6 Projects Forecast Simulation Results

As discussed in Section 7.2, multiple Projects Forecast simulations were created iteratively by modifying the Baseline Forecast and incorporating various potential projects and management actions developed by the Subbasin GSAs and surrounding subbasins. The Projects Forecast scenarios evolved as follows:

1. Projects Forecast Scenario 1: The Baseline Forecast was modified by added projects and associated land fallowing in the Subbasin only (discussed below). The simulation results showed a continued lowering of groundwater levels, reduction of groundwater in storage, continued land subsidence, and increased outflow to surrounding subbasins.
2. Projects Forecast Scenario 2: The Projects Forecast was further modified with GHBs that caused an asymptotic flatting (i.e., soft landing) of the GHB heads in 2040, representing the effects of assumed projects in other subbasins. The modification of the GHBs simulation results showed only a slight reduction of groundwater level declines compared to Projects Forecast Scenario 1, with continued reduction of groundwater in storage, continued land subsidence, and continued outflow to surrounding subbasins.
3. Projects Forecast Scenario 3: The Projects Forecast was further modified by assuming each surrounding subbasin implemented projects that would yield additional surface water supplies similar to what is proposed for the Subbasin, or approximately 75% of the 1990-2016 annual average change in storage estimated for that portion of each subbasin within the TLSBHM. The simulation results showed a substantial reduction of groundwater level declines over time compared to Projects Forecast Scenarios 1 and 2, but with continued declining groundwater levels, reduction of groundwater in storage, continued land subsidence, and continued outflow to surrounding subbasins, after 2040.
4. Projects Forecast Scenario 4: The Projects Forecast was further modified by implementing agricultural pumping limits in the surrounding subbasins. The simulation results showed a substantial reduction of groundwater level declines over time compared to Projects Forecast Scenarios 1 through 3, resulting in stable groundwater elevations throughout most of the Subbasin and surrounding subbasins, with significantly reduced reduction of groundwater in storage, and significantly reduced land subsidence. These results are presented below.

A comparison of simulated potentiometric surface maps from above and below the Corcoran Clay for the Baseline Forecast for June 2040 (Figure D7-5) with simulated Projects Forecast Scenario 4 (hereafter referred to simply as the Projects Forecast) potentiometric surface maps from above the Corcoran Clay for June 2040 (Figure D7-13) show that the simulated groundwater elevations beneath the Subbasin above the Corcoran Clay are about 10 feet higher under the Projects Forecast compared to the Baseline Forecast. Simulated groundwater elevations in the surrounding subbasins are substantially higher with groundwater elevation increases ranging from 20 to 30 feet in Kaweah, Kings, and Tule subbasins. The Westside Subbasin showed groundwater elevations increases in the 10 to 20 foot range, while there was little increase in the Kern Subbasin.

Simulated groundwater elevations for June 2040 beneath the Subbasin below the Corcoran Clay are about 20 to 30 feet higher under the Projects Forecast compared to the Baseline Forecast. In the Kaweah and Kings subbasins, simulated heads are 20 to 40 feet higher compared to the Baseline Forecast. In the Tule Subbasin in Creighton Ranch and Angiola well field areas, simulated heads are as much as 130 feet higher compared to the Baseline Forecast. The Westside Subbasin showed groundwater elevations increases in the 40- to 100-foot range, while the heads in the Kern Subbasin increased as much as 50 feet.

A comparison of simulated potentiometric surface maps from above and below the Corcoran Clay for the Baseline Forecast for December 2070 (Figure D7-5) with simulated Projects Forecast potentiometric surface maps from above the Corcoran Clay for December 2070 (Figure D7-14) show that the simulated groundwater elevations beneath the Subbasin above the Corcoran Clay are about 10 to 30 feet higher under the Projects Forecast compared to the Baseline Forecast. Simulated groundwater elevations in the surrounding subbasins are substantially higher with groundwater elevation increases ranging from 20 to 40 feet in Kaweah and Kings subbasins, and as much as 80 feet in the Tule Subbasin. The Westside Subbasin showed groundwater elevations increases in the 10 to 20 to 60 foot range, while the heads in the Kern Subbasin increased as much as 40 feet.

Simulated groundwater elevations for December 2070 beneath the Subbasin below the Corcoran Clay are about 30 to 40 feet higher under the Projects Forecast compared to the Baseline Forecast. In the Kaweah and Kings subbasins, simulated heads are 30 to 60 feet higher compared to the Baseline Forecast. In the Tule Subbasin in Creighton Ranch and Angiola well field areas, simulated heads are as much as 160 feet higher compared to the Baseline Forecast. The Westside Subbasin showed groundwater elevations increases in the 50-to 130-foot range, while the heads in the Kern Subbasin increased as much as 90 feet.

Simulated Projects Forecast hydrographs for selected compliance wells in the vicinity of the cities of Corcoran, Hanford, and Lemoore show a gradual stabilization of groundwater elevations in the unconfined aquifer above and confined below the Corcoran Clay, with seasonal variations much greater below the Corcoran Clay (Figure D7-15). Over the 54-year simulation period, the hydrographs above the Corcoran Clay show approximately 15 feet of decline in the Corcoran area, about 25 feet of decline in the Hanford area, and about 60 feet of decline in the Lemoore area. Over the same period, the hydrographs below the Corcoran Clay show about 30 feet of decline in the Corcoran area, about 25 feet of decline in the Hanford area, and about 20 feet of decline in the Lemoore area.

The Projects Forecast simulation results indicate that subsidence will continue over the next 54 years under the assumed forecast conditions. A map of cumulative subsidence from 2017-2040 shows that the is about 0 to 2 feet of additional subsidence over most of the Subbasin, with up to 2 feet of additional subsidence in the Lemoore area (Figure D7-16). Subsidence in the Angiola and Creighton Ranch wells fields in the Tule Subbasin is significantly less compared to the Baseline Forecast (Figure D7-7). Projects Forecast subsidence in the lake bottom area in minimal. A map of cumulative subsidence from 2017-2070 shows that the is about 2 to 4 feet of additional subsidence over the northern portion of the Subbasin, with up to 2 feet of additional subsidence in the Angiola and Creighton Ranch wells fields in the Tule Subbasin (Figure D7-16).

Simulated Projects Forecast subsidence hydrographs for continuous GPS compliance point near the cities of Corcoran and Lemoore wells show that under project conditions, the subsidence continues to occur (Figure D7-17), but at significant reduced rates compared to the Baseline Forecast (Figure D7-8).

The Projects Forecast simulation groundwater mass balance data were used to estimate the change in groundwater storage in the Subbasin on an annual basis for the 54-year forecast simulation period (Figure D7-18). Under the Projects Forecast assumptions described above, between 2017 and 2070, there would continue to be an annual average of about -36,200 AF/Y of groundwater storage depletion (a reduction of 75% compared to the Baseline Forecast), and as much as -7.72 million AF of cumulative storage depletion from the Subbasin. Most of the remaining overdraft in the Subbasin appears to result from the continued outflow of groundwater to the surrounding subbasins, which average approximately -58,610 AF/Y over the 2017-2070 simulation periods (Figure D7-18).

As discussed in Section 7.2, for simulation purposes it was assumed that the surrounding subbasins would implement projects and management actions that would increase surface water supply and decrease agricultural demand. However, until the magnitude and timing of actual projects and management actions to be implemented in the surrounding subbasins can be incorporated into the TLSBHM, the model forecasts will have a degree of uncertainty regarding future water balance and overdraft estimates.

In summary, the Projects Forecast simulation results indicate that overdraft conditions in the Subbasin will be mostly eliminated, with stable groundwater levels by 2040. While there continues to be some reduction of groundwater in storage, the forecast that groundwater levels remain relatively stable through 2070 indicates that the continued reduction in groundwater in storage is also sustainable. Likewise, although some land subsidence will continue over time, the forecast that groundwater levels remain relatively stable through 2070 indicates that the continued subsidence is also sustainable. Thus, the Projects Forecast indicates that sustainable groundwater conditions in the Subbasin can be achieved by 2040 with implementation of the proposed projects and management actions in the Subbasin and assumed projects and management actions in the surrounding subbasins.

7.2.7 Historical vs. Projects Forecast Simulation Comparison

A comparison of the 1990-2016 historical model, 2017-2070 Baseline Forecast, and 2017-2070 Projects Forecast was made using the annual average groundwater balance data for each simulation (Table D7-3). The Baseline and Projects forecast models both assume that land fallowed during the 2011-2016 drought would be put back into production, and that overall crop demand would increase due to the maturation of permanent crop as described in Section 7.1.1. The increase in ET demand was also exacerbated by climate change. Furthermore, the forecasts also assume that groundwater levels would continue to decline at historical rates for 10 or more years prior to project implementation. As a result, for the even though the Baseline Forecast 2017-2070 average annual pumping, recharge, and river leakage are similar to the Calibration 1990-2016 average values, the net change in storage increased from -85,690 AF/Y to -142,990 AF/Y because there was more interbasin outflow from the Subbasin into the surrounding subbasins. The annual average values for 1998-2010 and 2040-2048 "normal hydrology" periods have similar results, where the net change in storage increased from -73,760 AF/Y to -149,430 AF/Y.

The Projects Forecast shows a different trend. With implementation of the projects, the 2017-2070 average annual pumping decreases, groundwater recharge increases, and interbasin flow decreases. As a result, the net change in storage decreased from -85,690 AF/Y to -36,200 AF/Y (nearly a 60% decrease). The results are similar for the 1998-2010 and 2040-2048 "normal hydrology" periods, where the net change in storage decreased from -73,760 AF/Y to -19,390 AF/Y.

The results of the Projects forecast simulation indicate that under the assumed forecast conditions, implementation of the proposed projects to increase surface water supply and recharge coupled with agricultural demand reductions in the surrounding subbasins can significantly reduce overdraft to sustainable levels in the Subbasin as evidenced by the stabilization of groundwater levels throughout most of the subbasins (Figure D7-15, GSP Appendix G) and the reduction of subsidence (Figure 7-17).

8.0 Data Limitations

Groundwater models are designed to estimate changes over time in groundwater levels, flow directions, and storage given a set of inflows (precipitation, surface water, under flow in, etc.) and outflows (evapotranspiration, pumping, underflow out, etc.). Prior to the SGMA there were no requirements to manage or report groundwater usage. As a result, most GSAs do know the location, construction, and

pumping history of many pumping wells within their GSAs. Furthermore, most GSAs often do not have a good historical accounting of which parcels have received surface waters and at what rates. Hence, these inputs and outputs need to be approximated by other means than direct measurement.

The data utilized for construction and calibration of the TLSBHM were provided by various private parties, public agencies, and data extracted from existing numerical models of the area including DWR's 2014 release of C2VSim in the Coarse Grid version, USGS CVHM, the Kaweah Delta Water Conservation District model (Fugro West, 2005), and the preliminary Tule Subbasin and Westside Subbasin models. Other numerical models adjacent to and/or covering portions of the TLSBHM are known to exist, but were unavailable for this effort. The data gathering effort also occurred before many GSAs were organized, so it is likely that some data were unavailable at the time the model was developed. It is anticipated that as the TLSBHM is reviewed and utilized that some corrections of input data will be necessary and that additional data, unavailable at the time, will need to be incorporated into the model.

Much of the hydrologic data used to construct and calibrate the TLSBHM are based on estimates or inferred from multiple data sources. As noted above, most GSAs do not know the historical delivery of surface water to various parcels within the GSAs. Hence it was necessary to assume that all irrigated parcels received some surface water allotment. Likewise, the location, construction, and pumping history of most of the irrigation wells in the TLSBHM domain are not known. Hence hypothetical irrigation well locations were assumed to be distributed with relatively uniform spacing across the model domain. The hypothetical irrigation wells were also assumed to have completion intervals and frequency similar to that of a small subset of wells with known constructions. Hypothetical irrigation wells pumping was estimated based on a water balance method using estimated agricultural demand based on reported crop type minus the assumed distribution of surface water supplies. While these simplifying assumptions and estimates are reasonable given the sparseness of measurements, they add uncertainty to the model.

Overtime, under the SGMA, more accurate spatial and temporal groundwater pumping, and surface water delivery data should be collected and utilized to construct and update groundwater models of the Subbasin. As the models are populated with actual measurement instead of estimate, the models will become more useful tool for managing groundwater in the Subbasin.

9.0 Summary of Model Reliability and Peer Review

The TLSBHM is an approximation of existing conditions beneath and in the vicinity of the Subbasin. It covers a large area with very dynamic hydrologic conditions that have significant changes over the simulation period. Due to a lack of historical data, much of the data utilized to construct the model had to be inferred from alternative data sets. Given the uncertainty of these estimates, the model can approximate on average, but not completely reproduce, all observations across the entire site area under all conditions. Overall, the TLSBHM can reliably predict groundwater elevations in response to various hydrologic conditions within the calibration period based on the available data and estimates. However, forecast simulations with extreme ranges in hydrologic conditions (i.e., severe drought conditions or extreme flooding) may produce less reliable results.

The TLSBHM was submitted for peer review to Dr James T McCord of GeoSystems Analysis, Inc. Dr. McCord has over 30 years of experience in hydrology, hydrogeology, and water resource investigations, with emphasis on characterization of groundwater and surface water systems, numerical modeling of hydrologic systems. He has authored numerous consulting reports and technical peer-reviewed papers, and co-authored the textbook, Vadose Zone Processes (CRC Press, 1999). He has served as an Adjunct Professor of Earth Science at New Mexico Technical University since 1991, as well as Adjunct

Professor of Civil Engineering at the University of New Mexico and of Civil and Environmental Engineering at New Mexico Tech since 2007. Dr. McCord's per review in include in Appendix D6.

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Table D2-1

Historical Precipitation - Hanford, California[1]

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1899	M	M	M	M	M	M	M	M	0	0.67	M	0.87	M
1900	1.38	0	1.18	1.04	M	M	M	M	M	M	M	M	M
1901	M	M	M	M	M	M	M	T	1.04	T	M	0.15	M
1902	0.4	2	1.78	0.47	0.09	M	0	M	0	0.36	1.67	0.56	M
1903	1.31	0.38	1.71	0.5	0	0	0	0	0	0.05	0.47	0.15	4.57
1904	0.52	2.03	2.05	0.72	0	0	0	0	2.48	0.84	0.31	1.16	10.11
1905	1.28	1.09	2.1	0.56	0.65	0	0	0	0.07	0	1.16	0.23	7.14
1906	1.59	1.92	4.05	0.62	2.06	0.02	0	0	0	0	M	M	M
1907	M	M	M	M	M	M	M	M	M	M	M	M	M
1908	M	M	M	M	M	M	M	M	M	M	M	0.31	M
1909	M	M	M	M	M	M	M	M	M	M	M	M	M
1910	M	M	M	M	M	M	M	M	M	M	M	M	M
1911	M	M	M	M	M	M	M	M	M	M	M	M	M
1912	M	0.02	3.24	1.52	0.27	0	0	0	0	0	0.61	0.21	M
1913	1.26	1.55	0.34	0.78	0.76	0.06	0.08	0	M	M	M	1.35	M
1914	4.36	1.25	0.37	0.11	M	1.06	0	0	0	0	0.02	M	M
1915	M	M	0.3	1.37	M	M	M	M	M	M	M	M	M
1916	4.68	M	M	M	0.16	M	M	0.28	0.47	1.09	M	1.35	M
1917	M	M	M	M	0.31	M	M	M	M	M	M	M	M
1918	M	4.5	3.43	M	M	M	M	M	0.88	0.12	M	M	M
1919	M	M	1.01	0.15	0.1	M	M	M	M	M	M	M	M
1920	M	2.72	3.05	0.24	M	M	M	M	M	M	M	M	M
1921	M	0.89	M	M	0.87	M	M	M	M	M	M	M	M
1922	M	M	M	M	M	M	M	T	M	M	M	M	M
1923	M	M	M	2.43	M	M	M	M	M	M	M	0.22	M
1924	M	M	1.86	M	0	M	M	T	0	0.65	M	2.12	M
1925	M	M	1.58	M	M	M	0	M	0	M	M	M	M
1926	0.82	1.44	0.2	2.67	T	0	0	0	0	0.76	3.67	0.65	10.21
1927	1.33	2.52	2.04	0.18	0.06	T	0	0.04	T	1.67	1.63	0.78	10.25
1928	0.09	0.96	1.55	0.08	0.1	0	0	0	0	T	1.47	1.69	5.94
1929	0.81	0.61	1.4	0.81	0	0.24	T	0	0.03	0	0	0.42	4.32
1930	1.66	1	1.66	0.15	0.37	0	0	0.02	0.38	0.07	0.67	0.3	6.28
1931	2.32	0.72	0.07	0.91	0.2	1.12	0	0.08	0.08	0	1.36	2.54	9.4
1932	1.85	1.52	0.47	0.71	0.13	0	0	0	0	0	0.28	0.93	5.89
1933	3.12	0.16	0.72	0.28	0.41	0.07	0	0	0	0.15	0	1.01	5.92
1934	0.17	1.53	0.05	0	0.22	0.14	0	0	0	1.06	2.15	1.84	7.16
1935	2.5	1.77	2	2.05	0	0	0.03	0	0.06	0.51	0.4	0.89	10.21
1936	0.66	4.7	0.97	0.55	T	T	0	0	0	1.84	0	2.87	11.59
1937	1.95	2.46	2.23	0.22	0	0	0	0	0	0.11	0.21	2.16	9.34
1938	1.76	3.51	4.59	1.15	0.11	0.17	0.07	0	0.13	0.19	0.19	1.42	13.29
1939	1.54	0.77	1.44	0.82	T	0.12	0	0	0.04	0.57	0.06	0.22	5.58
1940	3.53	3.61	0.99	0.18	T	T	0	0	0	0.85	T	3.61	12.77

Table D2-1

Historical Precipitation - Hanford, California[1]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1941	1.51	3.9	2.05	2.41	T	T	0	T	0	0.9	0.57	3.11	14.45
1942	1.21	0.88	0.94	1.19	0.16	0	0	M	0	0	0.43	1.1	M
1943	2.73	1.14	3.35	0.87	0	0	0	0	0	0.03	0.22	1.03	9.37
1944	1.28	2.97	0.22	0.86	0.28	0.23	0	0	0.02	0.23	2.25	0.97	9.31
1945	0.26	2.71	1.81	0.16	0.1	0.17	0	0	T	0.71	1.15	1.51	8.58
1946	0.34	1.53	2.56	0.07	0.41	0	0.11	0	0	1.33	1.1	2.06	9.51
1947	0.41	0.49	0.56	0.11	0.41	0	0	0	T	0.59	0.29	0.51	3.37
1948	0	0.44	1.46	1.55	0.54	0	0	0	0	0.03	0.01	0.99	5.02
1949	0.51	0.85	1.94	0.07	0.53	0	0	T	0	0	0.6	0.68	5.18
1950	1.93	1.13	1.1	0.4	0	0	0.08	0	0	0.34	0.63	1.06	6.67
1951	1.24	0.76	0.22	1.17	0.07	0	0	0	0	0.08	1.11	2.39	7.04
1952	3.08	0.27	2.18	0.79	0.01	0.02	T	0	0.17	0.05	0.65	2.96	10.18
1953	1.1	0.27	0.34	0.83	0.29	0.02	T	0	0	0.02	1.01	0.09	3.97
1954	1.89	0.78	2.21	0.52	0.34	0.08	0	0	0	0	0.66	1.61	8.09
1955	3.25	1.31	M	M	0.9	0	0	M	0	0.02	0.92	4.67	M
1956	1.2	0.38	0.1	0.73	0.83	0	0	0	0	0.72	0	0.15	4.11
1957	1.39	1.17	0.56	0.67	0.63	0	0	0	0	0.2	1.39	1.41	7.42
1958	1.85	2.3	3.92	2.04	0.24	0	0	T	0.88	0	0.23	0.16	11.62
1959	0.86	1.9	0.11	0.52	T	0	0	T	0.11	0	0	0.17	3.67
1960	0.8	1.71	0.61	0.57	0	0	0.02	0	0	0.53	2.61	0.03	6.88
1961	1.34	0.22	0.67	0.22	0.37	0	0	0	0	0	1.11	1.28	5.21
1962	0.71	4.88	1.06	0	0.11	0	0	0	0.01	0.1	0	0.19	7.06
1963	1.19	1.68	1.37	2.88	0.56	0.17	0	0	0.33	0.75	1.23	0.29	10.45
1964	0.61	0.02	0.94	0.64	0.2	0	0	0.34	0	0.95	1.31	1.44	6.45
1965	1.18	0.33	0.33	1.6	0	0	0	0.05	0.07	0.05	2.15	1.97	7.73
1966	0.63	0.71	0.1	0	0.07	0.06	0.04	0	0.29	0	1.28	2.57	5.75
1967	1.41	0.05	2.42	2.95	0.07	0.23	0	0	0.31	0	1.99	0.5	9.93
1968	0.57	0.64	1	0.5	0.08	0	0	0	0	1.33	0.98	1.64	6.74
1969	6.69	4.54	0.79	0.85	0.32	0.21	0.07	0	0.15	0.05	0.51	0.7	14.88
1970	1.6	1.33	1.42	0.16	0	T	T	0	0	T	2.4	1.23	8.14
1971	0.35	0.19	0.23	0.4	1.44	0	0	T	0.04	0.06	0.41	1.87	4.99
1972	0.04	0.35	0	0.23	0	0	0	0	0.24	0.21	2.9	0.65	4.62
1973	M	2.29	2.2	0.12	M	M	0	0	0	M	M	M	M
1974	2.97	0.11	1.75	0.03	0	0	0	0	0	0.65	0.24	1.4	7.15
1975	0.09	2.26	M	0.49	0	0	0	0	0.96	M	0.05	0.22	M
1976	T	2.94	0.19	1.47	0.03	0.51	0	0.22	1.47	0	1.15	0.96	8.94
1977	0.59	0.03	0.43	0	0.91	0.07	0	0	0	0.05	0.66	2.85	5.59
1978	2.22	5.05	4.12	1.71	0	0	0	0	1.1	0	0.79	0.5	15.49
1979	2.19	1.61	1.16	0.03	0	0	0.04	0	0.08	0.41	0.62	0.41	6.55
1980	2.9	2.71	1.28	0.05	0.04	0	0	0	0	0.09	0	0.2	7.27
1981	1.77	0.86	2.1	0.68	0.17	0	0	0	0	0.76	1.08	0.29	7.71
1982	0.84	0.38	3.52	1.75	0	0.45	0.18	0	0.64	1.03	2.15	0.71	11.65
1983	3.74	2.59	3.39	1.63	0.04	0	0	0.05	0.82	0.43	1.66	1.22	15.57
1984	0.01	0.42	0.27	0.18	0	0	0	0	0	M	M	M	M
1985	0.59	M	0.7	0.12	0	0	M	0	T	M	2.11	0.66	M

Table D2-1

Historical Precipitation - Hanford, California[1]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	1.46	2.6	3.43	0.5	0	0	T	T	0.15	0	0.21	0.77	9.12
1987	1.77	2.07	2.02	0.06	0.13	0.05	0	0	0	0.58	0.47	1.7	8.85
1988	1.37	0.4	0.93	1.99	0.07	0	0	0	0	0	1.31	2.29	8.36
1989	0.17	1.04	0.85	0.02	0.39	0	0	T	0.67	0.32	0.2	0	3.66
1990	1.66	1.1	0.3	0.97	0.87	0	T	T	T	0.01	0.22	0.15	5.28
1991	0.31	0.12	6.62	0.19	T	0.12	0	0	0.11	0.41	0.14	M	M
1992	1.4	2.82	0.85	0.1	T	0	0.01	0.01	T	0.58	T	2.62	8.39
1993	3.88	2.48	2.16	0.07	0.08	0.3	0	0	0	0.24	0.64	0.66	10.51
1994	0.94	1.45	1.02	0.72	0.66	0	T	0	1.06	0.35	1.54	0.33	8.07
1995	4.7	0.51	4.77	0.65	0.87	0.04	T	0	T	0	T	1.59	13.13
1996	1.68	2.89	2.27	0.85	0.1	T	0	0	0	2.43	0.69	3.27	14.18
1997	3.02	0.12	0.21	0	0	T	T	0	0.06	0.09	1.96	1.8	7.26
1998	2	4.05	2.63	1.68	1.31	0.44	0	0	T	0.68	0.63	0.65	14.07
1999	3.01	0.56	0.43	1.37	0	0	0	T	0.01	0	0.15	T	5.53
2000	1.8	3.28	1.59	0.97	0.48	0.35	0	0	0.03	1.31	T	0.05	9.86
2001	1.98	1.48	1.24	1.12	0	0	0.09	0	T	0.18	1.84	1.99	9.92
2002	0.87	0.31	1.04	0.03	0.01	0.82	0	0	0	0	1.42	1.14	5.64
2003	0.24	1.08	1.01	1.5	0.62	0	T	0.07	0	0	0.49	2	7.01
2004	2	2.18	0.29	0.02	0.01	0	0	0	0	2.06	0.52	2.23	9.31
2005	2.63	1.58	2.24	0.71	0.83	0	0	T	0.01	0.01	0.19	2.07	10.27
2006	3.54	0.55	2.72	3.39	0.53	0	0	0	0	0.06	0.22	1.01	12.02
2007	0.65	0.89	0.26	0.33	0.01	0	0	0.12	0.37	0.35	0.12	1.32	4.42
2008	2.18	1.18	T	0	0.11	0	0	0	0	0.15	1.04	1.49	6.15
2009	0.8	1.86	0.2	0.02	0.41	0.22	0	0	0.18	1.32	0.28	1.42	6.71
2010	2.64	1.91	0.34	1.65	0.17	0	0	0	0	0.64	1.32	6.46	15.13
2011	1.52	1.53	2.87	0.3	0.4	1.04	0	0.08	0.01	0.55	0.8	0.06	9.16
2012	M	M	M	1.39	0.03	M	T	0	0	0.28	0.49	1.9	M
2013	0.22	0.48	0.79	0.08	0.17	0	0	0	0.01	T	0.33	0.16	M
2014	0.3	1.38	0.27	0.35	T	0	0	0	0.03	0	0.94	2.52	5.79
2015	0.08	0.72	0.02	0.77	0.1	0	0.45	0	0	0.38	0.91	1.4	4.83
2016	2.56	0.58	1.99	0.57	0.02	0.09	0	0	0	0.76	0.4	1.6	8.57
2017	3.7	2.8	0.31	1.02	0.36	0.01	0	0.01	0.17	0.06	0.21	0.08	8.73
Mean	1.59	1.5	1.47	0.75	0.25	0.09	0.01	0.01	0.15	0.38	0.82	1.24	8.28
Min	6.69 1969	5.05 1978	6.62 1991	3.39 2006	2.06 1906	1.12 1931	0.45 2015	0.34 1964	2.48 1904	2.43 1996	3.67 1926	6.46 2010	15.57 1983
Max	0 1948	0 1900	0 1972	0 2008	0 2018	0 2015	0 2017	0 2016	0 2016	0 2014	0 1980	0 1989	3.37 1947

1. From: https://w2.weather.gov/climate/xmacis.php?wfo=hnx
   M = missing data and T = trace amount of precipitation.

Table D2-2
Historical Land Use

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Tulare Lake Subbasin[1]	1990-1995 (acres)	1996-1998 (acres)	1999-2006 (acres)	2007 (acres)	2008 (acres)	2009 (acres)	2010 (acres)	2011 (acres)	2012 (acres)	2013 (acres)	2014 (acres)	2015 (acres)	2016 (acres)	Average (acres)
Alfalfa Hay and Clover	41,604	32,564	54,301	72,459	80,600	71,504	69,685	38,789	42,131	49,318	35,820	29,665	24,245	**45,987**
Almonds (Adolescent)			2,908			5,127	7,927	3,222	4,464	7,476	6,526	6,222	5,365	**2,470**
Almonds (Mature)	7,682	5,241	4,550	12,897	11,825	9,826	8,374	10,140	10,818	11,441	12,876	15,046	15,105	**7,852**
Almonds (Young)		3,278	9,290	16,538	25,966	14,678	20,887	13,968	14,564	20,341	17,678	16,983	21,576	**9,557**
Berries	20								1	2		0		**5**
Carrot Single Crop								11	5	12	2	2	16	**2**
Citrus (no ground cover)			25		13	14	4	120	29	100	89	22	9	**21**
Corn and Grain Sorghum	14,280	38,896	29,349	39,271	31,762	34,643	23,031	33,780	29,175	27,566	22,638	18,826	17,400	**25,404**
Cotton	159,534	180,960	124,764	109,605	88,304	72,441	98,167	105,541	88,993	89,317	63,385	44,532	73,720	**118,794**
Dairy Single Crop*	3,816	4,077	4,385											**2,438**
Fallow Land*	193,695	138,392	89,606	65,169	85,144	99,688	90,192	152,391	172,697	172,486	195,172	237,790	200,972	**136,159**
Forest*	420	809	2,955	6	5	46	5			1		4	0	**952**
Grain and Grain Hay	28,708	48,533	62,962	19,266	27,870	27,406	25,980	7,758	9,968	11,194	12,213	21,196	19,069	**34,833**
Melons	250	56	284				14	2	11	7	797	18	86	**170**
Misc. field crops	17,116	12,819	51,311		2			0			2			**18,531**
Onions and Garlic	457	479	770			7	1,358	411	302	94	502	149	644	**483**
Open Water*	5,568	9,092	8,968	5,576	4,296	4,049	5,434	7,703	5,443	5,045	6,824	5,919	5,435	**6,637**
Pasture and Misc. Grasses	2,500	5,029	5,615	50,688	44,232	66,944	53,080	14,680	13,368	15,355	33,551	15,744	13,743	**14,473**
Pistachio (Adolescent)								170	218	370	882	3,575	3,836	**335**
Pistachio (Mature)	4,694	3,808	3,804	6,096	1,907	934	404	394	380	348	330	485	469	**2,888**
Pistachio (Young)		1,580	4,390	4,351	4,259	8,527	8,083	12,985	14,676	15,878	19,195	22,678	22,570	**6,247**
Pomegranates (Adolescent)											3	16	27	**2**
Pomegranates (Young)				61	1,705	545	256	5,012	804	1,395	2,207	1,312	3,111	**608**
Potatoes, Sugar beets, Turnip etc..	5,736	1	209	6		3		9		41		2	2	**1,331**
Riparian*		668	1,120	517	134	398	615	226	138	313	239	248	194	**477**
Small Vegetables	1,599	647	4,518	20	2	13	212	142	133	244	165	78	198	**1,643**
Stone Fruit (Adolescent)			1,478			14	66	100	125	69	47	191	170	**412**
Stone Fruit (Mature)	7,070	4,985	3,854	1,314	544	168	18	3	23	41	23	27	39	**3,206**
Stone Fruit (Young)		1,827	4,185	672	1,609	1,573	2,502	1,077	712	1,641	1,340	1,183	713	**1,770**
Tomatoes and Peppers	5,634	1,627	14,676	117	2	110	12	21,482	23,670	7,114	11,922	19,211	23,420	**9,203**
Urban, Industrial*	12,654	17,391	19,875	33,427	34,711	44,471	32,218	32,091	28,576	29,366	33,901	30,530	30,930	**22,128**
Wine Grapes with 80% canopy	2,948	3,226	5,779	5,588	3,499	2,240	2,746	5,361	9,228	4,655	6,472	4,672	10,985	**4,565**
Winter Wheat*				72,238	67,458	50,451	64,526	48,212	45,118	44,530	30,950	19,420	21,690	**17,207**
Tulare Lake Subbasin Irrigated Crop Acreage	**299,832**	**345,557**	**389,021**	**338,951**	**324,102**	**316,717**	**322,806**	**275,156**	**263,796**	**264,018**	**248,665**	**221,837**	**256,519**	**310,792**
Tulare Lake Subbasin Total Crop Acreage	**515,986**	**515,986**	**515,931**	**515,883**	**515,849**	**515,821**	**515,796**	**515,779**	**515,768**	**515,759**	**515,751**	**515,747**	**515,741**	**496,788**

1. Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year

Table D2-3
Historical Kings River Diversions

Tulare Lake Subbasin Hydrologic Model
Kings County, California

	GSA	Mid-Kings River					South Fork Kings							Southwest Kings									
	Agency	Peoples Ditch Company	Last Chance Water Ditch Company				Stratford Irrigation District	Empire West Side Irrigation District			Lemoore Canal & Irrigation Company			Dudley Ridge Water District-Monthly Diversions Assumed									
Kings River Water Years	Diversion	*Peoples Canal- MKRGSA Total*	*Last Chance Canal- MKRGSA Total*	*Lakeside IWD*	Imported Water	Mid Kings	Stratford Canal	Empire West Side ID total from SWP	Empire West Side Canal	Westlake Canal	Lemoore Canal	Imported Water	South Fork Kings River	*Blakeley Canal-Kings River & Lateral A*	TLBWSD Lateral C, T203	Dudley Ridge State Turnout (DR-1), T201	Dudley Ridge State Turnout (DR-1B), T202	Dudley Ridge State Turnout (DR-1A), T204	Dudley Ridge State Turnout (DR-2), T205	Dudley Ridge State Turnout (Paramount), T207	Dudley Ridge State Turnout (DR-3), T208	Imported Water, Angiola/Green Valley Well Fields, City of Lemoore and Westlands RD 761	Southwest Kings
		(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)
71%	1966	107,763	50,356	-	-	158,119	2,158	-	4,770	3,604	96,079	-	106,612	20,559	-	-	-	-	-	-	-	-	20,559
197%	1967	136,889	78,468	-	-	215,358	3,947	-	9,622	5,861	109,323	-	128,753	29,187	-	-	-	-	-	-	-	-	29,187
49%	1968	75,809	31,878	-	-	107,688	3,540	1,780	13,636	12,718	91,478	-	123,153	19,692	0	3,312	949	2,372	11,388	9	5,694	-	43,416
256%	1969	107,636	61,339	-	-	168,975	1,139	50	2,878	6,056	87,537	-	97,659	534	0	3,942	1,130	2,824	13,554	11	6,777	-	28,771
78%	1970	76,723	38,772	-	-	115,495	1,884	3,548	5,359	7,305	93,441	-	111,538	0	0	5,077	1,455	3,637	17,456	15	8,728	-	36,366
69%	1971	86,815	35,321	-	-	122,137	4,376	5,391	4,665	10,280	96,498	-	121,210	10,521	0	5,158	1,478	3,695	17,735	15	8,867	-	47,469
50%	1972	51,631	38,190	-	-	89,820	4,062	5,216	6,188	5,133	80,465	-	101,065	20,920	0	5,333	1,528	3,820	18,335	15	9,168	-	59,119
125%	1973	139,667	62,672	-	-	202,339	4,411	5,233	5,964	6,543	86,382	-	108,534	22,249	0	4,429	1,269	3,172	15,228	13	7,614	-	53,973
122%	1974	137,406	68,454	-	-	205,860	4,082	4,085	9,291	10,508	102,115	-	130,081	37,966	0	8,390	2,404	6,010	28,849	24	14,425	-	98,069
92%	1975	109,458	43,937	-	-	153,395	4,570	5,803	8,763	10,939	104,388	-	134,463	36,603	0	10,191	2,920	7,300	35,040	29	17,520	-	109,602
32%	1976	37,828	2,255	-	-	40,083	4,284	5,811	5,915	5,004	70,925	-	91,940	22,247	0	7,770	2,226	5,566	26,716	22	13,358	-	77,906
23%	1977	43,393	9,542	-	-	52,935	2,203	2,120	1,598	557	42,067	-	48,545	8,903	0	3,633	1,041	2,603	12,493	10	6,246	-	34,930
201%	1978	125,769	71,577	-	-	197,346	2,859	409	10,627	9,312	80,567	-	103,774	26,094	0	7,455	2,136	5,340	25,632	21	12,816	-	79,494
101%	1979	125,680	64,463	-	-	190,143	6,434	1,565	15,449	9,523	107,578	-	140,549	52,496	0	9,685	2,775	6,938	33,302	28	16,651	-	121,876
178%	1980	101,388	64,365	-	-	165,753	3,981	805	16,100	11,566	103,714	-	136,165	53,639	0	10,061	2,883	7,207	34,594	29	17,297	-	125,710
61%	1981	89,091	47,482	-	-	136,572	4,435	7,966	7,841	9,437	89,111	-	118,790	42,806	0	9,213	2,640	6,599	31,677	26	15,839	-	108,800
181%	1982	127,200	65,413	-	-	192,613	4,479	4,379	9,396	20,983	100,153	-	139,389	41,213	0	6,968	1,997	4,992	23,960	20	11,980	-	91,130
261%	1983	60,994	48,013	-	-	109,007	3,808	0	6,097	10,389	58,631	-	78,926	22,250	0	7,026	2,013	5,033	24,157	20	12,078	-	72,577
115%	1984	97,831	53,649	-	-	151,480	2,533	0	2,801	3,800	99,362	-	108,496	10,003	0	8,116	2,326	5,814	27,907	23	13,954	-	68,144
73%	1985	105,362	39,583	-	-	144,944	4,869	4,677	5,209	6,827	103,148	-	124,731	34,288	0	7,791	2,232	5,581	26,788	22	13,394	-	90,096
190%	1986	111,962	62,457	-	-	174,419	7,329	2,070	7,345	16,723	87,761	-	121,227	27,361	0	6,427	1,841	4,604	22,098	18	11,049	-	73,398
45%	1987	70,406	24,792	-	-	95,198	5,177	3,961	4,959	10,982	90,541	-	115,620	28,582	0	5,816	1,666	4,166	19,996	17	9,998	-	70,242
48%	1988	60,312	21,844	-	-	82,156	3,953	3,128	4,457	2,949	76,554	-	91,041	21,261	0	6,030	1,728	4,319	20,733	17	10,367	-	64,456
53%	1989	60,579	19,935	-	-	80,514	0	2,700	0	-	56,519	-	59,219	13,458	0	7,168	2,054	5,134	24,645	21	12,323	-	64,802
40%	1990	53,292	9,909	-	-	63,201	0	2,979	0	-	34,465	-	37,444	6,485	0	4,606	1,320	3,299	15,836	13	7,918	14,540	54,016
63%	1991	45,654	18,622	-	-	64,276	1,760	199	1,006	964	31,492	-	35,420	5,941	0	1,670	479	1,196	5,743	5	2,871	8,181	26,085
41%	1992	49,394	9,361	-	-	58,755	1,759	1,219	0	0	37,968	-	40,945	6,003	0	1,696	486	1,215	5,831	5	2,915	6,095	24,245
149%	1993	147,363	53,498	-	-	200,860	5,070	2,467	4,314	8,612	91,166	-	111,629	30,546	0	2,917	836	2,090	10,031	8	5,016	6,480	57,925
50%	1994	69,510	30,738	-	-	100,248	2,997	1,499	3,808	6,811	76,550	-	91,666	26,295	0	3,834	1,099	2,747	13,184	11	6,592	11,642	65,404
202%	1995	143,785	102,300	-	-	246,085	6,123	1,468	6,419	1,410	85,049	-	100,469	34,039	0	5,715	1,637	4,094	19,650	16	9,825	8,131	83,107
122%	1996	166,765	95,338	-	-	262,103	6,774	1,681	5,576	5,778	105,398	-	125,206	41,813	0	6,886	1,973	4,933	23,677	20	11,839	14,505	105,645
155%	1997	133,158	85,505	20,657	-	239,321	7,460	0	8,239	2,079	89,117	-	106,896	25,259	0	7,895	2,262	5,655	27,146	23	13,573	11,319	93,132
181%	1998	141,107	77,863	29,871	-	248,841	5,578	488	4,596	8,447	75,590	-	94,698	17,157	3,528	6,955	1,993	4,982	23,916	20	11,958	11,348	81,857
74%	1999	101,773	62,938	12,119	-	176,830	4,971	2,858	6,135	3,624	95,504	-	113,092	25,132	0	7,958	2,280	5,701	27,363	23	13,681	10,280	92,418
90%	2000	108,835	82,526	13,181	-	204,541	4,598	1,619	2,184	4,566	99,074	-	112,041	21,426	0	7,397	2,119	5,299	25,433	21	12,717	10,299	84,711
59%	2001	73,419	31,031	7,017	-	111,467	4,959	1,674	1,993	2,680	58,979	-	70,285	11,377	0	6,030	1,728	4,319	20,732	17	10,366	10,306	64,875
67%	2002	99,376	52,020	5,354	-	156,751	4,104	1,265	1,364	2,202	74,196	-	83,131	13,083	0	6,930	1,986	4,964	23,828	20	11,914	10,291	73,016
83%	2003	104,545	54,735	13,325	-	172,605	4,356	1,292	752	3,362	63,511	-	73,273	8,256	0	6,657	1,907	4,768	22,888	19	11,444	10,359	66,299
61%	2004	79,743	27,306	5,667	-	112,717	2,019	3,206	1,650	1,480	58,257	-	66,611	12,382	0	6,383	1,829	4,572	21,946	18	10,973	10,072	68,176
148%	2005	131,193	54,799	24,547	-	210,539	5,619	3,451	2,664	1,946	98,279	-	111,958	24,480	0	7,366	2,111	5,276	25,327	21	12,663	11,115	88,360
172%	2006	129,571	65,459	24,718	-	219,748	6,065	2,954	5,417	2,368	96,857	-	113,661	34,147	0	7,766	2,225	5,563	26,702	22	13,351	11,115	100,891
40%	2007	84,144	20,918	3,312	-	108,374	4,836	1,876	3,810	4,727	70,288	-	85,536	25,308	0	6,090	1,745	4,363	20,940	17	10,470	9,975	78,909
72%	2008	81,364	29,000	6,764	-	117,128	2,037	852	1,470	1,081	59,988	-	65,428	10,209	0	5,292	1,516	3,791	18,195	15	9,097	10,016	58,131
79%	2009	85,743	30,617	5,829	-	122,189	2,047	148	1,811	1,771	49,297	-	55,074	7,997	0	3,982	1,141	2,852	13,691	11	6,846	12,178	48,699
121%	2010	113,146	42,817	16,103	-	172,066	4,318	2,545	3,644	2,900	90,694	-	104,101	17,655	0	4,144	1,187	2,969	14,249	12	7,125	42,300	89,641
180%	2011	163,801	79,589	23,764	-	267,154	4,979	1,364	4,625	4,947	109,605	-	125,519	43,781	0	3,373	966	2,416	11,597	10	5,799	34,012	101,953
49%	2012	80,025	30,309	4,595	-	114,929	4,203	1,151	4,594	2,289	71,207	-	83,443	22,689	0	2,775	795	1,988	9,543	8	4,771	51,435	94,006
41%	2013	49,246	12,881	110	-	62,236	0	536	0	0	43,206	-	43,741	3,284	0	3,591	1,029	2,572	12,346	10	6,173	19,602	48,606
32%	2014	27,801	8,824	0	-	36,626	0	158	0	0	17,905	-	18,062	567	0	2,136	612	1,530	7,345	6	3,672	23,852	39,720
21%	2015	12,430	-	0	-	12,430	0	326	0	0	14,759	-	15,085	184	0	3,271	937	2,343	11,247	9	5,623	31,718	55,333
75%	2016	67,310	20,567	2,986	-	90,863	0	-	0	0	42,532	-	42,532	-	-	-	-	-	-	-	-	34,248	34,248
204%	2017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Annual Averages	93,943	44,985	4,312		143,240	3,669	2,156	4,804	5,315	77,554		93,499	20,737	68	5,535	1,586	3,965	19,033	16	9,516	8,734	69,598

Table D2-3
Historical Kings River Diversions

Tulare Lake Subbasin Hydrologic Model
Kings County, California

	GSA	El Rico												Tri-County											
	Agency																								
Kings River Water Years	Diversion	Empire Weir No. 2 (over #2 weir to river extension, River Water) Modified Total: (Empire Weir No. 2 minus Tri County Kings River Water)	TLBWSD Lateral B, T206 (State Water)-Modified Total:(SWP Total for Lateral B minus Tri County Entitlement)	Lakelands Canal-Total	Tulare Lake Canal	Melga Canal-Diversion of Peoples Canal, El Rico GSA Total	Kern River	Deer Creek-30% of Deer Creek Total	Tule River-El Rico	Kaweah River	Loan Oak/New Deal- Diversion of Last Chance, El RicoGSA Total	Imported Water	El Rico	Poso Creek	TLBWSD Lateral A, T200 (State Water)-Assumed Full Entitlement-25% to Lateral A	TLBWSD Lateral B, T206 (State Water)-Assumed Full Entitlement-75% to Lateral B	Tule River-Tri County	Deer Creek-70% of Deer Creek Total	White River	Kings River-Tri County	Other Water	Imported Water	Tri-County	Annual Totals
		(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)	(AF/Y)
71%	1966	2,404	-	14,225	17,831	71,842	-	-	-	-	21,581	-	127,884	-	-	-	-	-	-	-	-	-	0	413,173
197%	1967	82,883	-	71,671	42,476	91,260	-	-	-	-	33,629	-	321,919	-	-	-	-	-	-	-	-	-	0	695,217
49%	1968	4,673	10,256	17,218	49,218	50,540	-	-	-	-	13,662	-	151,775	-	923	2,768	-	-	-	-	-	-	3,690	429,722
256%	1969	196,219	2,893	40,568	0	71,757	-	-	-	-	26,288	-	339,477	-	260	781	-	-	-	-	-	-	1,041	635,924
78%	1970	0	0	52,483	0	51,149	-	-	-	-	16,617	-	120,248	-	0	0	-	-	-	-	-	-	0	383,648
69%	1971	0	47,329	28,610	490	57,877	-	-	-	-	15,138	-	178,091	-	4,257	12,771	-	-	-	-	-	-	17,028	485,935
50%	1972	1,099	103,195	0	7,305	34,420	-	-	-	-	16,367	-	224,849	-	9,282	27,846	-	-	-	-	-	-	37,128	511,981
125%	1973	530	45,583	19,101	31,948	93,111	-	-	-	-	26,860	-	244,723	-	4,100	12,300	-	-	-	-	-	-	16,400	625,968
122%	1974	14,906	56,123	55,482	28,336	91,604	-	0	-	-	29,337	-	309,845	0	5,157	15,472	1,402	0	0	0	-	-	22,032	765,886
92%	1975	11,905	89,737	41,833	53,125	72,972	-	0	-	-	18,830	-	342,042	0	7,224	21,671	224	0	0	2,642	0	-	31,760	771,261
32%	1976	0	47,863	3,493	45,170	25,219	-	0	-	-	967	-	151,071	0	3,541	10,624	0	0	0	9,154	0	-	23,320	384,320
23%	1977	1,732	21,197	0	4,003	28,929	-	0	-	-	4,090	-	71,762	0	635	1,905	0	0	0	950	0	-	3,490	211,662
201%	1978	33,029	3,073	31,904	49,511	83,846	-	3,000	-	-	30,676	-	237,179	1,500	624	1,873	2,476	7,000	1,000	11,956	0	-	26,430	644,222
101%	1979	2,523	97,690	34,336	32,856	83,787	-	0	-	-	27,627	-	334,337	0	4,271	12,814	185	0	0	6,575	0	-	23,846	810,750
178%	1980	41,353	34,131	37,277	29,258	67,592	-	1,800	-	-	27,585	-	259,729	900	3,163	9,488	2,611	4,200	600	2,819	0	-	23,780	711,136
61%	1981	8,761	140,237	9,180	19,710	59,394	-	0	742	78,485	20,349	-	415,677	0	5,033	15,099	223	0	0	8,983	0	-	29,338	809,178
181%	1982	45,602	36,788	54,659	77,268	84,800	-	5,660	63,476	171,808	28,034	-	589,793	2,830	2,598	7,793	3,090	13,207	1,887	12,547	0	-	43,951	1,056,876
261%	1983	238,616	522	21,919	1,333	40,663	-	12,150	193,800	114,301	20,577	-	644,159	6,075	0	0	340	28,350	4,050	0	0	-	38,815	943,484
115%	1984	17,704	1,917	42,516	0	65,220	-	19,804	17,566	120,846	22,992	-	309,830	9,902	303	909	0	46,210	6,601	0	0	-	63,925	701,875
73%	1985	16,118	84,042	20,108	29,821	70,241	-	0	367	73,859	16,964	-	361,048	0	5,881	17,644	826	0	0	1,586	0	-	25,937	746,756
190%	1986	28,395	41,528	50,896	51,205	74,641	-	5,144	43,384	71,918	26,767	-	417,043	2,572	1,269	3,806	1,701	12,004	1,715	11,054	0	-	34,121	820,207
45%	1987	18,250	60,441	27,104	57,023	46,938	-	0	0	44,445	10,625	-	299,874	0	3,517	10,550	0	0	0	9,366	0	-	23,432	604,366
48%	1988	8,209	40,544	18,863	17,816	40,208	-	0	0	25,873	9,362	-	184,264	0	2,207	6,622	0	0	0	984	0	-	9,814	431,730
53%	1989	0	75,859	7,458	0	40,386	-	0	0	24,550	8,544	-	200,939	0	4,605	13,814	150	0	0	0	1,580	-	20,149	425,623
40%	1990	0	37,168	15,114	0	35,528	-	0	0	39,853	4,247	-	153,181	0	1,810	5,430	0	0	0	0	4,556	-	11,796	319,638
63%	1991	344	2,855	6,143	2,870	30,436	-	0	0	28,897	7,981	-	81,060	0	16	49	604	0	0	1,604	0	-	2,274	209,115
41%	1992	0	35,181	0	0	32,930	-	279	0	23,442	4,012	-	115,532	140	1,156	3,469	0	652	93	0	0	-	5,510	244,987
149%	1993	25,174	58,745	66,990	44,555	68,050	-	101	0	108,379	22,928	-	426,703	50	565	1,694	1,155	235	34	6,919	2,575	-	13,226	810,344
50%	1994	15,625	28,204	0	49,718	38,072	-	0	0	28,376	-	-	175,829	0	990	2,970	0	0	0	6,098	0	-	10,058	443,205
202%	1995	51,722	59,720	52,969	48,240	75,670	-	2,285	13,777	149,232	-	-	487,891	1,142	3,032	9,095	6,040	5,331	762	4,902	0	-	30,303	947,854
122%	1996	33,027	107,966	61,767	36,006	81,522	-	1,847	236	139,238	-	-	521,635	924	3,055	9,165	1,913	4,311	616	2,219	0	-	22,202	1,036,790
155%	1997	19,089	2,107	32,557	25,047	65,232	-	9,220	40,122	66,638	-	-	265,690	4,610	1,895	5,684	1,701	21,513	3,073	4,729	0	-	43,206	748,244
181%	1998	4,514	17,487	32,918	16,707	75,570	-	5,590	26,731	58,340	-	-	243,601	2,795	1,057	3,171	2,083	13,042	1,863	50	0	-	24,061	693,058
74%	1999	4,359	140,451	8,184	13,492	49,810	-	0	2,235	51,184	-	-	329,217	0	95	286	274	0	0	167	0	-	822	712,379
90%	2000	16,796	86,346	35,062	33,304	56,416	-	871	2,900	48,050	-	-	319,674	435	3,935	11,804	1,166	2,032	290	0	0	-	19,663	740,630
59%	2001	21,146	39,067	2,122	38,045	38,433	-	0	8	20,131	-	-	180,610	0	1,027	3,082	0	0	0	3,044	3,000	-	10,154	437,390
67%	2002	14,150	33,324	46,842	7,942	45,043	-	0	490	73,770	-	-	242,267	0	2,004	6,011	124	0	0	0	190	-	8,329	563,493
83%	2003	13,153	44,894	36,750	45,168	48,228	-	0	1,748	49,413	-	-	254,241	0	2,152	6,455	790	0	0	6,652	160	-	16,209	582,626
61%	2004	17,145	42,460	40,917	16,768	40,719	-	0	1,106	59,030	-	-	241,003	0	265	795	559	0	0	0	5,293	-	6,912	495,419
148%	2005	73,872	75,546	42,290	64,243	67,430	-	1,767	2,372	86,750	-	-	442,024	884	116	347	1,680	4,123	589	10,632	1,235	-	19,605	872,486
172%	2006	70,800	52,463	80,614	74,920	69,623	-	2,392	17,135	171,601	-	-	561,992	1,196	126	378	795	5,581	797	14,253	0	-	23,126	1,019,418
40%	2007	21,586	39,927	17,889	31,676	46,218	-	0	153	39,474	-	-	217,420	0	50	149	0	0	0	18,083	63	-	18,345	508,584
72%	2008	9,553	11,833	8,051	5,282	41,851	-	0	158	37,662	-	-	123,545	0	156	468	828	0	0	4,756	0	-	6,208	370,440
79%	2009	855	13,750	22,036	99	43,482	-	0	1,383	62,389	-	-	152,859	0	7	21	0	0	0	0	0	-	28	378,849
121%	2010	34,789	32,026	38,210	37,297	55,771	-	0	5,059	102,754	-	-	315,091	0	2	7	1,676	0	0	10,587	282	-	12,555	693,453
180%	2011	89,121	25,964	88,052	78,409	83,250	-	0	11,316	140,553	-	-	530,567	0	68	205	-	0	0	0	-	-	273	1,025,466
49%	2012	24,964	43,921	3,483	15,977	39,616	-	0	200	60,683	-	-	205,755	0	57	170	-	0	0	0	-	-	227	498,360
41%	2013	0	13,062	58,140	0	27,281	-	-	-	-	-	-	109,253	0	58	174	-	0	0	0	-	-	232	264,069
32%	2014	0	3,681	41,472	0	12,461	-	-	-	-	-	-	59,473	0	38	115	-	0	0	0	-	-	154	154,035
21%	2015	0	0	21,076	0	2,493	-	-	-	-	-	-	24,175	0	45	0	-	0	0	0	-	-	45	107,068
75%	2016	0	-	32,114	0	27,677	-	-	-	-	-	-	59,791	0			-	0	0	0	-	-	0	227,433
204%	2017	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Annual Averages	26,210	40,175	31,229	26,107	54,847	0	1,383	8,586	45,614	10,052		268,189	705	1,816	5,446	666	3,227	470	3,333	364		16,175	590,701

Table D2-3
Historical Kings River Diversions

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Notes:
1. Values highlighted have been modified.
2. Values with "0" indicate no surface water delivery to the best of our knowledge.
3. Values with "-" have no verified data.
4. Total flow from Peoples Canal is split 60% to Mid-Kings, 40% to Melga.
5. Last Chance Diversion is split 50% between Mid-Kings and El Rico.
6. Blakeley has added State Water from Lateral A for Southwest.
7. Total flow from Deer Creek split 30% to El Rico, 70% to Tri-County.
8. Tule River for El Rico includes the total of Elk Bayou and TID Spill.
9. SWP from TLBWSD Split Through out Tri-County and Southwest Kings.
10. Kings River water in Tri-County was subtracted from the total in Empire Weir No. 2. 1976 and 2010 are 0 for Empire Weir No. 2 because of negative values.
11. Lakeside is a portion of Kaweah River, Reduced Total Kaweah River between Mid-Kings and El Rico.
12. Additional Tule River flow data added for Tri-County.
13. Empire Westside Irrigation District total from SWP reduce annual totals by 10%.
14. Dudley Ridge Water District reduce annual totals by 10%.
15. Lateral A (T200) & Lateral B (T206) reduce annual totals by 18% for El Rico & Tri-County.
16. Modifications to Peoples Canal and Last Chance as a result of discussions with Mid-Kings River GSA on 2/14/19.

Key

Wet Year
Dry Year
Average Precipitation
GSA Annual Totals
Kings River Watershed Total

Average Annual
690,714
494,326
649,938

Reduction in Entitlement	
Empire West Side ID Total from SWP	10%
Dudley Ridge State Turnouts	10%
Lateral A & B for El Rico & Tri County	18%

Table D2-4

Annual Specified Well Field Pumping[1]

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Date	El Rico GSA Well Field (AF/Y)	Creighton Ranch Well Field (AF/Y)	Corcoran ID Well Field (AF/Y)	Angiola Well Field (AF/Y)	Westlands Well Field (AF/Y)	Municipal Well Fields (AF/Y)	Apex Ranch Well Field (AF/Y)
1990	70,716	27,222	87,977	34,500	67,131	9,370	--
1991	57,509	38,484	84,438	23,396	98,656	9,109	--
1992	80,012	27,255	72,348	33,494	98,344	9,666	--
1993	11,395	4,035	14,248	5,956	44,056	10,208	--
1994	48,043	17,986	78,297	16,389	72,674	10,928	--
1995	2,897	905	7,145	-	27,589	10,775	--
1996	-	-	20,261	-	28,516	12,719	--
1997	-	-	15,586	-	27,000	12,775	--
1998	-	-	2,484	-	20,988	11,555	--
1999	-	-	33,406	-	37,185	13,087	--
2000	14,910	2,849	40,672	6,784	43,392	13,421	--
2001	89,799	41,120	64,353	23,244	65,947	13,895	--
2002	68,933	35,843	64,736	26,537	66,530	26,701	--
2003	32,420	10,856	62,246	22,429	40,841	19,349	526
2004	82,875	47,511	74,007	26,805	42,115	18,777	912
2005	-	468	20,138	662	14,744	16,536	--
2006	-	72	14,034	141	16,526	15,822	6,939
2007	69,863	40,266	85,434	32,894	40,373	17,221	6,319
2008	92,269	52,980	79,362	32,502	63,519	18,432	5,435
2009	78,097	45,292	81,493	37,798	69,904	16,354	7,677
2010	36,129	17,740	29,669	22,568	34,895	15,271	6,345
2011	606	314	7,328	11,336	15,509	17,042	--
2012	95,154	52,325	70,008	19,388	55,298	17,467	9,044
2013	100,275	66,005	78,175	30,528	70,940	18,411	4,970
2014	108,976	68,726	69,880	27,695	94,077	16,930	298
2015	116,254	61,050	67,982	30,220	90,723	16,146	--
2016	126,886	53,113	67,982	29,047	93,853	14,555	--
1990-2016 Average	**51,260**	**26,386**	**51,618**	**18,308**	**53,382**	**14,908**	**4,847**
1998-2010 Average	**43,484**	**22,692**	**50,156**	**17,874**	**42,843**	**16,648**	**4,879**
Well Count	**99**	**52**	**98**	**51**	**150**	**30**	**5**

1. GSA = Groundwater Sustainability Agency, ID = Irrigation District, and AF/Y = acre-feet per year.

Table D2-5

Reference Crop Evapotranspiration Values[1]

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Crop Evapotranspiration	January (inches)	February (inches)	March (inches)	April (inches)	May (inches)	June (inches)	July (inches)	August (inches)	September (inches)	October (inches)	November (inches)	December (inches)
Reference ETo	0.82	2.22	4.5	6.73	8.52	8.23	8.34	7.62	5.8	4.2	1.28	0.84
Fallow Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Almonds	0.83	0.85	2.71	3.91	6.75	6.39	6.58	6.08	3.92	2.25	0.75	0.83
Pistachio	0.83	0.66	1.92	1.13	2.77	5.91	8.17	7.65	5.26	2.99	0.81	0.83
Grain and Grain Hay	0.89	2.09	4.67	6.86	3.84	0.14	0.20	0.09	0.08	0.38	0.84	0.89
Cotton	0.88	0.64	1.88	0.75	1.62	4.68	8.17	7.70	5.35	1.52	0.78	0.87
Corn and Grain Sorghum	0.88	0.64	2.89	1.16	2.83	7.00	8.06	5.12	0.38	0.38	0.78	0.87
Misc. field crops	0.88	0.64	2.89	1.16	2.77	7.32	7.56	3.03	0.08	0.38	0.78	0.87
Alfalfa Hay and Clover	0.88	2.12	4.31	5.78	7.25	7.02	7.01	6.34	4.80	2.01	1.33	0.91
Pasture and Misc. Grasses	0.89	1.64	3.37	5.17	7.83	7.64	7.74	7.00	5.32	3.25	1.18	0.87
Small Vegetables	0.88	1.29	4.07	1.25	0.02	0.11	0.18	1.08	1.54	1.84	1.61	0.90
Potatoes, Sugar beets, Turnip etc.	0.88	0.92	3.13	6.72	8.84	8.58	7.58	0.18	0.08	0.37	0.77	0.86
Onions and Garlic	0.88	1.88	4.10	5.48	4.80	0.56	0.18	0.08	0.08	0.37	1.34	0.88
Citrus (no ground cover)	0.83	1.98	3.96	4.69	5.54	5.76	5.72	5.24	3.91	3.14	1.47	0.86
Tomatoes and Peppers	0.88	0.63	2.57	0.70	4.39	8.12	7.42	0.78	0.08	0.37	0.77	0.86
Wine Grapes with 80% canopy	0.84	0.66	2.17	1.42	4.18	6.06	6.00	4.82	2.74	0.40	0.75	0.84
Dairy Single Crop	1.03	1.94	3.48	4.67	4.50	6.71	7.72	6.32	3.91	2.27	1.24	1.14
Carrot Single Crop	1.02	1.60	3.14	5.95	4.79	5.75	6.16	4.36	3.70	2.85	1.77	1.19
Carrot Double Cropping	0.54	1.40	2.93	4.41	5.84	3.59	2.71	3.53	3.12	2.60	1.41	1.12
Dairy Double Cropping	0.59	1.59	3.26	4.65	3.57	5.27	7.87	6.81	3.71	0.77	0.59	0.67
Urban, Commercial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban, Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Riparian	0.00	0.01	3.49	6.13	8.33	8.23	8.34	7.62	5.74	3.91	1.02	0.10
Open Water	0.82	2.22	4.50	6.73	8.52	8.23	8.34	7.62	5.80	4.20	1.58	0.84
Average All Crops	0.85	1.29	3.19	3.66	4.56	5.37	5.84	4.23	2.67	1.56	1.05	0.90

Table D2-5

Reference Crop Evapotranspiration Values[1]

Crop Evapotranspiration	January (ft/d)	February (ft/d)	March (ft/d)	April (ft/d)	May (ft/d)	June (ft/d)	July (ft/d)	August (ft/d)	September (ft/d)	October (ft/d)	November (ft/d)	December (ft/d)
Reference ETo	0.00220	0.00661	0.01210	0.01869	0.02290	0.02286	0.02242	0.02048	0.01611	0.01129	0.00356	0.00226
Fallow Land	0	0	0	0	0	0	0	0	0	0	0	0
Almonds	0.00223	0.00253	0.00728	0.01086	0.01815	0.01775	0.01769	0.01634	0.01089	0.00605	0.00208	0.00223
Pistachio	0.00223	0.00196	0.00516	0.00314	0.00745	0.01642	0.02196	0.02056	0.01461	0.00804	0.00225	0.00223
Grain and Grain Hay	0.00239	0.00622	0.01255	0.01906	0.01032	0.00039	0.00054	0.00024	0.00022	0.00102	0.00233	0.00239
Cotton	0.00237	0.00190	0.00505	0.00208	0.00435	0.01300	0.02196	0.02070	0.01486	0.00409	0.00217	0.00234
Corn and Grain Sorghum	0.00237	0.00190	0.00777	0.00322	0.00761	0.01944	0.02167	0.01376	0.00106	0.00102	0.00217	0.00234
Misc. field crops	0.00237	0.00190	0.00777	0.00322	0.00745	0.02033	0.02032	0.00815	0.00022	0.00102	0.00217	0.00234
Alfalfa Hay and Clover	0.00237	0.00631	0.01159	0.01606	0.01949	0.01950	0.01884	0.01704	0.01333	0.00540	0.00369	0.00245
Pasture and Misc. Grasses	0.00239	0.00488	0.00906	0.01436	0.02105	0.02122	0.02081	0.01882	0.01478	0.00874	0.00328	0.00234
Small Vegetables	0.00237	0.00384	0.01094	0.00347	0.00005	0.00031	0.00048	0.00290	0.00428	0.00495	0.00447	0.00242
Potatoes, Sugar beets, Turnip etc.	0.00237	0.00274	0.00841	0.01867	0.02376	0.02383	0.02038	0.00048	0.00022	0.00099	0.00214	0.00231
Onions and Garlic	0.00237	0.00560	0.01102	0.01522	0.01290	0.00156	0.00048	0.00022	0.00022	0.00099	0.00372	0.00237
Citrus (no ground cover)	0.00223	0.00589	0.01065	0.01303	0.01489	0.01600	0.01538	0.01409	0.01086	0.00844	0.00408	0.00231
Tomatoes and Peppers	0.00237	0.00188	0.00691	0.00194	0.01180	0.02256	0.01995	0.00210	0.00022	0.00099	0.00214	0.00231
Wine Grapes with 80% canopy	0.00226	0.00196	0.00583	0.00394	0.01124	0.01683	0.01613	0.01296	0.00761	0.00108	0.00208	0.00226
Dairy Single Crop	0.00276	0.00578	0.00936	0.01296	0.01211	0.01863	0.02076	0.01698	0.01085	0.00611	0.00344	0.00305
Carrot Single Crop	0.00274	0.00476	0.00844	0.01652	0.01288	0.01598	0.01657	0.01173	0.01027	0.00765	0.00490	0.00320
Carrot Double Cropping	0.00144	0.00416	0.00788	0.01226	0.01570	0.00998	0.00729	0.00950	0.00867	0.00700	0.00393	0.00301
Dairy Double Cropping	0.00158	0.00474	0.00877	0.01291	0.00958	0.01463	0.02115	0.01831	0.01029	0.00207	0.00165	0.00180
Urban, Commercial	0	0	0	0	0	0	0	0	0	0	0	0
Urban, Industrial	0	0	0	0	0	0	0	0	0	0	0	0
Riparian	0.00000	0.00004	0.00938	0.01703	0.02240	0.02286	0.02242	0.02048	0.01595	0.01052	0.00284	0.00026
Open Water	0.00220	0.00661	0.01210	0.01869	0.02290	0.02286	0.02242	0.02048	0.01611	0.01129	0.00439	0.00226
Average All Crops	0.00229	0.00383	0.00858	0.01016	0.01227	0.01491	0.01569	0.01138	0.00742	0.00420	0.00293	0.00243

1. Grass reference ETo based on typical year, CIMIS Zone 16 monthly evapotranspiration. Irrigation Training and Research Center, California Polytechnic State University, San Luis Obispo. ft/d = feet per day.

Table D2-6
Historical Evapotranspiration Demand

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Tulare Lake Subbasin[1]	1990-1995 (AF/Y)	1996-1998 (AF/Y)	1999-2006 (AF/Y)	2007 (AF/Y)	2008 (AF/Y)	2009 (AF/Y)	2010 (AF/Y)	2011 (AF/Y)	2012 (AF/Y)	2013 (AF/Y)	2014 (AF/Y)	2015 (AF/Y)	2016 (AF/Y)	Average (AF/Y)
Alfalfa Hay and Clover	172,519	135,032	225,167	300,041	333,752	296,086	288,555	160,621	174,457	204,219	148,325	122,839	100,395	**190,580**
Almonds (Adolescent)			8,113			11,218	19,864	8,127	10,631	18,529	16,937	15,155	13,714	**6,332**
Almonds (Mature)	26,791	18,278	15,869	47,030	43,122	35,832	30,537	36,976	39,450	41,720	46,956	54,869	55,084	**28,083**
Almonds (Young)		2,287	6,480	12,062	26,125	15,445	17,964	13,431	14,580	18,458	17,621	15,779	20,206	**8,292**
Berries	47								2	6		1		**11**
Carrot Single Crop								37	16	41	7	6	56	**6**
Citrus (no ground cover)			91		42	46	14	405	99	335	300	74	32	**74**
Corn and Grain Sorghum	36,877	100,450	75,793	101,418	82,027	89,467	59,478	87,236	75,344	71,190	58,462	48,619	44,935	**65,605**
Cotton	463,179	525,386	362,232	320,870	258,511	212,071	287,383	308,970	260,527	261,476	185,559	130,368	215,815	**345,645**
Dairy Single Crop*	14,290	15,268	16,421											**9,129**
Fallow Land*														**-**
Forest*														**-**
Grain and Grain Hay	50,167	84,811	110,025	33,572	48,563	47,755	45,271	13,518	17,369	19,505	21,282	36,934	33,228	**60,837**
Melons	413	92	468				21	3	16	10	1,182	27	128	**275**
Misc. field crops	40,450	30,296	121,265		5			1			4			**43,795**
Onions and Garlic	807	846	1,359			12	2,417	731	538	167	893	266	1,146	**854**
Open Water*														**-**
Pasture and Misc. Grasses	10,799	21,726	24,256	218,974	191,082	289,198	229,306	63,417	57,751	66,333	144,942	68,014	59,370	**62,524**
Pistachio (Adolescent)								213	315	559	1,290	4,713	5,704	**474**
Pistachio (Mature)	15,229	12,354	12,341	17,831	5,680	2,825	1,236	1,283	1,237	1,135	1,075	1,412	1,374	**9,256**
Pistachio (Young)		394	2,265	1,091	1,370	2,454	2,395	3,729	5,770	7,498	8,281	8,231	9,024	**2,477**
Pomegranates (Adolescent)											5	23	41	**3**
Pomegranates (Young)				11	303	99	52	901	210	376	537	567	746	**141**
Potatoes, Sugar beets, Turnip etc.	18,604	4	676	19		10		29		127		7	7	**4,317**
Riparian*														**-**
Small Vegetables	2,835	1,147	8,009	33	3	20	340	227	212	390	264	126	317	**2,905**
Stone Fruit (Adolescent)			4,238			28	138	232	291	171	106	414	425	**1,166**
Stone Fruit (Mature)	25,350	17,875	13,818	4,560	1,886	584	64	11	80	141	79	95	136	**11,485**
Stone Fruit (Young)		1,310	3,001	466	1,234	1,217	1,879	1,010	547	1,250	1,186	913	667	**1,308**
Tomatoes and Peppers	12,971	3,747	33,791	261	5	246	26	47,851	52,725	15,847	26,555	42,793	52,168	**20,892**
Urban, Industrial*														**-**
Wine Grapes with 80% canopy	7,586	8,301	14,872	14,203	8,893	5,692	6,980	13,625	23,455	11,832	16,450	11,874	27,920	**11,683**
Winter Wheat*														**-**
Tulare Lake Subbasin Irrigated ET Demand	**884,626**	**964,336**	**1,044,130**	**1,072,442**	**1,002,603**	**1,010,305**	**993,918**	**762,584**	**735,624**	**741,315**	**698,299**	**564,117**	**642,636**	**879,019**
Tulare Lake Subbasin GSA Total ET Demand	**898,916**	**979,604**	**1,060,551**	**1,072,442**	**1,002,603**	**1,010,305**	**993,918**	**762,584**	**735,624**	**741,315**	**698,299**	**564,117**	**642,636**	**888,148**

1. Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year. AF/Y = acre-feet per year, GSA = Groundwater Sustainability Agency, and ET = evapotranspiration.

Table D2-7

Historical Farm Demand[1]

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Date	Other SB (AF/Y)	TLSB (AF/Y)	Westside (AF/Y)	Kings (AF/Y)	Kaweah (AF/Y)	Tule (AF/Y)	Kern (AF/Y)	Mid-Kings (AF/Y)	El Rico (AF/Y)	South Fork (AF/Y)	Southwest (AF/Y)	TCWA (AF/Y)
Jan-90	1,728,732	1,065,856	379,829	425,121	552,538	256,615	114,629	325,993	417,055	166,690	114,789	41,329
Jan-91	1,614,099	994,832	358,828	401,725	514,334	233,176	106,035	306,828	388,094	155,314	107,036	37,561
Jan-92	1,628,359	1,012,909	343,450	406,535	528,115	241,481	108,779	313,628	395,489	156,526	108,443	38,824
Jan-93	1,625,686	1,008,709	347,335	404,875	524,762	240,425	108,288	310,417	394,078	156,684	108,853	38,677
Jan-94	1,667,754	1,047,937	339,746	419,143	544,830	251,521	112,514	321,367	409,642	163,677	112,809	40,442
Jan-95	1,518,505	973,503	292,869	389,226	502,007	229,979	104,424	298,503	382,014	151,236	104,578	37,172
Jan-96	1,576,024	1,067,962	313,585	344,546	482,623	304,804	130,465	274,763	432,798	171,197	134,163	55,041
Jan-97	1,680,694	1,123,726	337,872	377,306	511,503	317,630	136,383	296,047	449,362	180,958	139,428	57,931
Jan-98	1,549,840	1,059,009	286,711	361,492	480,381	294,124	127,132	282,666	424,886	167,423	132,138	51,896
Jan-99	1,691,385	1,232,448	339,665	407,814	535,160	327,150	81,596	286,433	535,576	191,560	148,842	70,039
Jan-00	1,445,415	1,127,412	284,814	349,602	457,426	279,949	73,623	251,153	506,236	164,195	141,354	64,475
Jan-01	1,448,592	1,111,506	309,426	344,390	447,420	273,032	74,325	252,107	492,321	161,311	143,460	62,308
Jan-02	1,541,594	1,201,455	318,210	370,000	480,162	290,750	82,471	275,691	524,619	174,107	159,485	67,554
Jan-03	1,555,120	1,198,411	341,139	366,586	474,349	288,517	84,529	276,879	519,352	171,951	163,815	66,414
Jan-04	1,505,353	1,162,011	319,587	357,269	463,075	281,525	83,897	267,176	504,557	165,885	160,028	64,366
Jan-05	1,470,433	1,155,548	293,659	353,639	461,355	278,436	83,344	266,036	503,020	165,545	157,409	63,538
Jan-06	1,423,773	1,129,741	281,543	345,256	445,626	268,596	82,751	260,555	488,753	162,180	156,955	61,299
Jan-07	1,645,495	1,183,096	324,200	294,958	447,694	338,016	240,627	248,586	542,967	168,715	157,357	65,471
Jan-08	1,618,955	1,083,093	307,929	286,930	474,164	335,571	214,361	252,038	499,213	157,222	99,089	75,531
Jan-09	1,579,778	1,091,697	349,701	288,327	381,416	286,941	273,394	222,909	473,147	141,969	186,010	67,662
Jan-10	1,563,995	1,016,725	297,419	297,831	370,133	326,713	271,898	197,569	442,224	138,271	178,015	60,646
Jan-11	1,145,135	791,090	287,744	234,224	382,183	166,368	74,617	190,992	384,027	114,892	65,595	35,584
Jan-12	1,254,900	776,133	330,525	245,767	397,981	200,454	80,173	191,423	373,845	122,949	65,986	21,930
Jan-13	1,322,113	826,405	371,025	237,221	406,748	194,551	112,569	199,812	420,487	105,696	73,137	27,273
Jan-14	1,422,271	757,265	413,917	266,385	385,588	218,818	137,564	199,827	289,182	112,733	97,591	57,932
Jan-15	1,335,608	624,647	428,797	253,146	362,160	194,523	96,982	196,099	250,843	101,691	46,314	29,700
Jan-16	1,285,028	677,936	417,581	260,622	348,283	168,493	90,048	188,850	320,298	97,905	47,386	23,497
1990-2016 Average	**1,512,764**	**1,018,558**	**333,967**	**336,664**	**457,853**	**262,524**	**121,756**	**257,568**	**435,707**	**151,425**	**122,595**	**51,263**
1998-2010 Average	**1,541,517**	**1,134,781**	**311,846**	**340,315**	**455,259**	**297,640**	**136,457**	**256,907**	**496,682**	**163,872**	**152,612**	**64,707**

1. SB = subbasin, TLSB = Tulare Lake Subbasin, TCWA = Tri-County Water Agency, AF/Y = acre-feet per year.

Table D4-1
Tulare Lake Subbasin Hydrologic Model Stress Periods

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Date	Stress Period	Days	Date	Stress Period	Days
Jan-90	1	31	Mar-93	39	31
Feb-90	2	28	Apr-93	40	30
Mar-90	3	31	May-93	41	31
Apr-90	4	30	Jun-93	42	30
May-90	5	31	Jul-93	43	31
Jun-90	6	30	Aug-93	44	31
Jul-90	7	31	Sep-93	45	30
Aug-90	8	31	Oct-93	46	31
Sep-90	9	30	Nov-93	47	30
Oct-90	10	31	Dec-93	48	31
Nov-90	11	30	Jan-94	49	31
Dec-90	12	31	Feb-94	50	28
Jan-91	13	31	Mar-94	51	31
Feb-91	14	28	Apr-94	52	30
Mar-91	15	31	May-94	53	31
Apr-91	16	30	Jun-94	54	30
May-91	17	31	Jul-94	55	31
Jun-91	18	30	Aug-94	56	31
Jul-91	19	31	Sep-94	57	30
Aug-91	20	31	Oct-94	58	31
Sep-91	21	30	Nov-94	59	30
Oct-91	22	31	Dec-94	60	31
Nov-91	23	30	Jan-95	61	31
Dec-91	24	31	Feb-95	62	28
Jan-92	25	31	Mar-95	63	31
Feb-92	26	29	Apr-95	64	30
Mar-92	27	31	May-95	65	31
Apr-92	28	30	Jun-95	66	30
May-92	29	31	Jul-95	67	31
Jun-92	30	30	Aug-95	68	31
Jul-92	31	31	Sep-95	69	30
Aug-92	32	31	Oct-95	70	31
Sep-92	33	30	Nov-95	71	30
Oct-92	34	31	Dec-95	72	31
Nov-92	35	30	Jan-96	73	31
Dec-92	36	31	Feb-96	74	29
Jan-93	37	31	Mar-96	75	31
Feb-93	38	28	Apr-96	76	30

Table D4-1
Tulare Lake Subbasin Hydrologic Model Stress Periods

Date	Stress Period	Days	Date	Stress Period	Days
May-96	77	31	Oct-99	118	31
Jun-96	78	30	Nov-99	119	30
Jul-96	79	31	Dec-99	120	31
Aug-96	80	31	Jan-00	121	31
Sep-96	81	30	Feb-00	122	29
Oct-96	82	31	Mar-00	123	31
Nov-96	83	30	Apr-00	124	30
Dec-96	84	31	May-00	125	31
Jan-97	85	31	Jun-00	126	30
Feb-97	86	28	Jul-00	127	31
Mar-97	87	31	Aug-00	128	31
Apr-97	88	30	Sep-00	129	30
May-97	89	31	Oct-00	130	31
Jun-97	90	30	Nov-00	131	30
Jul-97	91	31	Dec-00	132	31
Aug-97	92	31	Jan-01	133	31
Sep-97	93	30	Feb-01	134	28
Oct-97	94	31	Mar-01	135	31
Nov-97	95	30	Apr-01	136	30
Dec-97	96	31	May-01	137	31
Jan-98	97	31	Jun-01	138	30
Feb-98	98	28	Jul-01	139	31
Mar-98	99	31	Aug-01	140	31
Apr-98	100	30	Sep-01	141	30
May-98	101	31	Oct-01	142	31
Jun-98	102	30	Nov-01	143	30
Jul-98	103	31	Dec-01	144	31
Aug-98	104	31	Jan-02	145	31
Sep-98	105	30	Feb-02	146	28
Oct-98	106	31	Mar-02	147	31
Nov-98	107	30	Apr-02	148	30
Dec-98	108	31	May-02	149	31
Jan-99	109	31	Jun-02	150	30
Feb-99	110	28	Jul-02	151	31
Mar-99	111	31	Aug-02	152	31
Apr-99	112	30	Sep-02	153	30
May-99	113	31	Oct-02	154	31
Jun-99	114	30	Nov-02	155	30
Jul-99	115	31	Dec-02	156	31
Aug-99	116	31	Jan-03	157	31
Sep-99	117	30	Feb-03	158	28

Table D4-1
Tulare Lake Subbasin Hydrologic Model Stress Periods

Date	Stress Period	Days	Date	Stress Period	Days
Mar-03	159	31	Aug-06	200	31
Apr-03	160	30	Sep-06	201	30
May-03	161	31	Oct-06	202	31
Jun-03	162	30	Nov-06	203	30
Jul-03	163	31	Dec-06	204	31
Aug-03	164	31	Jan-07	205	31
Sep-03	165	30	Feb-07	206	28
Oct-03	166	31	Mar-07	207	31
Nov-03	167	30	Apr-07	208	30
Dec-03	168	31	May-07	209	31
Jan-04	169	31	Jun-07	210	30
Feb-04	170	29	Jul-07	211	31
Mar-04	171	31	Aug-07	212	31
Apr-04	172	30	Sep-07	213	30
May-04	173	31	Oct-07	214	31
Jun-04	174	30	Nov-07	215	30
Jul-04	175	31	Dec-07	216	31
Aug-04	176	31	Jan-08	217	31
Sep-04	177	30	Feb-08	218	29
Oct-04	178	31	Mar-08	219	31
Nov-04	179	30	Apr-08	220	30
Dec-04	180	31	May-08	221	31
Jan-05	181	31	Jun-08	222	30
Feb-05	182	28	Jul-08	223	31
Mar-05	183	31	Aug-08	224	31
Apr-05	184	30	Sep-08	225	30
May-05	185	31	Oct-08	226	31
Jun-05	186	30	Nov-08	227	30
Jul-05	187	31	Dec-08	228	31
Aug-05	188	31	Jan-09	229	31
Sep-05	189	30	Feb-09	230	28
Oct-05	190	31	Mar-09	231	31
Nov-05	191	30	Apr-09	232	30
Dec-05	192	31	May-09	233	31
Jan-06	193	31	Jun-09	234	30
Feb-06	194	28	Jul-09	235	31
Mar-06	195	31	Aug-09	236	31
Apr-06	196	30	Sep-09	237	30
May-06	197	31	Oct-09	238	31
Jun-06	198	30	Nov-09	239	30
Jul-06	199	31	Dec-09	240	31

Table D4-1
Tulare Lake Subbasin Hydrologic Model Stress Periods

Date	Stress Period	Days	Date	Stress Period	Days
Jan-10	241	31	Jul-13	283	31
Feb-10	242	28	Aug-13	284	31
Mar-10	243	31	Sep-13	285	30
Apr-10	244	30	Oct-13	286	31
May-10	245	31	Nov-13	287	30
Jun-10	246	30	Dec-13	288	31
Jul-10	247	31	Jan-14	289	31
Aug-10	248	31	Feb-14	290	28
Sep-10	249	30	Mar-14	291	31
Oct-10	250	31	Apr-14	292	30
Nov-10	251	30	May-14	293	31
Dec-10	252	31	Jun-14	294	30
Jan-11	253	31	Jul-14	295	31
Feb-11	254	28	Aug-14	296	31
Mar-11	255	31	Sep-14	297	30
Apr-11	256	30	Oct-14	298	31
May-11	257	31	Nov-14	299	30
Jun-11	258	30	Dec-14	300	31
Jul-11	259	31	Jan-15	301	31
Aug-11	260	31	Feb-15	302	28
Sep-11	261	30	Mar-15	303	31
Oct-11	262	31	Apr-15	304	30
Nov-11	263	30	May-15	305	31
Dec-11	264	31	Jun-15	306	30
Jan-12	265	31	Jul-15	307	31
Feb-12	266	29	Aug-15	308	31
Mar-12	267	31	Sep-15	309	30
Apr-12	268	30	Oct-15	310	31
May-12	269	31	Nov-15	311	30
Jun-12	270	30	Dec-15	312	31
Jul-12	271	31	Jan-16	313	31
Aug-12	272	31	Feb-16	314	29
Sep-12	273	30	Mar-16	315	31
Oct-12	274	31	Apr-16	316	30
Nov-12	275	30	May-16	317	31
Dec-12	276	31	Jun-16	318	30
Jan-13	277	31	Jul-16	319	31
Feb-13	278	28	Aug-16	320	31
Mar-13	279	31	Sep-16	321	30
Apr-13	280	30	Oct-16	322	61
May-13	281	31	Nov-16	323	30
Jun-13	282	30	Dec-16	324	31

Table D5-1

Tulare Lake Subbasin Historical and Current Water Balance[1]

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Land Surface Water Budget													
			Inflows						Outflows				Net
Year	Kings River Flows	Year Type	Effective Precipitation (AF)	Applied Surface Water (AF)	Applied Pond Water (AF)	Imported Groundwater (AF)	Applied Groundwater (AF)	Total Inflows (AF)	Drain Outflow (AF)	Farm Demand Evapotranspiration (AF)	Deep Percolation (AF)	Total Outflows (AF)	Inflow-Outflow (AF)
1990	40%	D	19,958	319,870	10,310	48,885	609,474	1,008,496	0	1,065,856	132,933	1,198,789	-190,293
1991	63%	D	78,722	209,568	3,793	52,225	568,130	912,439	0	994,832	125,674	1,120,507	-208,068
1992	41%	D	64,818	245,345	8,619	46,926	587,328	953,036	0	1,012,909	126,365	1,139,274	-186,238
1993	149%	W	67,191	811,312	31,153	7,533	238,616	1,155,805	0	1,008,709	124,472	1,133,181	22,624
1994	50%	D	34,514	443,731	4,237	27,612	481,028	991,122	26	1,047,937	129,432	1,177,394	-186,272
1995	202%	W	95,479	948,773	42,079	905	177,847	1,265,083	82	973,503	116,897	1,090,481	174,601
1996	122%	N	100,745	1,038,046	26,566	0	182,868	1,348,225	251	1,067,962	127,604	1,195,817	152,408
1997	155%	W	58,885	749,117	54,380	0	265,952	1,128,333	1,392	1,123,726	143,342	1,268,459	-140,126
1998	181%	W	116,167	693,908	49,104	0	237,530	1,096,709	1,870	1,059,009	128,533	1,189,412	-92,703
1999	74%	D	34,039	713,206	39,371	0	325,154	1,111,771	7,376	1,232,448	151,647	1,391,471	-279,701
2000	90%	N	70,413	741,494	35,618	6,833	247,306	1,101,664	17,343	1,127,412	95,624	1,240,379	-138,714
2001	59%	D	94,963	437,871	8,911	54,771	453,432	1,049,949	13,351	1,111,506	90,933	1,215,791	-165,841
2002	67%	D	26,034	564,134	21,817	51,428	408,568	1,071,981	10,253	1,201,455	85,417	1,297,125	-225,143
2003	83%	N	40,108	583,124	4,687	24,029	366,253	1,018,201	8,170	1,198,411	95,332	1,301,914	-283,713
2004	61%	D	74,858	495,764	25,863	63,254	475,486	1,135,226	20,849	1,162,011	86,876	1,269,736	-134,510
2005	148%	W	80,390	873,425	36,085	857	200,953	1,191,709	5,413	1,155,548	101,553	1,262,513	-70,804
2006	172%	W	104,703	1,020,922	37,530	154	189,607	1,352,916	9,651	1,129,741	108,496	1,247,887	105,029
2007	40%	D	14,800	508,886	4,613	60,608	456,931	1,045,839	14,999	1,183,096	97,935	1,296,030	-250,191
2008	72%	D	35,836	371,231	9,331	72,842	497,113	986,354	13,795	1,083,093	89,622	1,186,511	-200,157
2009	79%	N	32,367	379,590	16,632	68,391	440,286	937,266	4,295	1,091,697	94,173	1,190,165	-252,899
2010	121%	N	88,203	694,592	51,406	31,531	234,505	1,100,238	2,440	1,016,725	78,915	1,098,080	2,158
2011	180%	W	52,937	1,026,568	21,035	7,241	60,638	1,168,420	4,486	791,090	83,959	879,535	288,885
2012	49%	D	45,317	498,937	20,785	64,173	339,834	969,046	3,226	776,133	62,058	841,417	127,629
2013	41%	D	2,800	264,515	1,725	84,661	437,315	791,017	8,381	826,405	65,687	900,473	-109,456
2014	32%	D	30,586	154,346	0	85,650	491,323	761,906	3,579	757,265	62,755	823,599	-61,693
2015	21%	D	15,085	107,212	0	79,517	508,193	710,008	829	624,647	49,756	675,231	34,777
2016	75%	D	41,890	227,755	0	70,864	413,868	754,377	2,497	677,936	53,544	733,977	20,400
1990-2016 Avg	**91%**	**--**	**56,363**	**560,120**	**20,950**	**37,440**	**366,501**	**1,041,375**	**5,724**	**1,018,558**	**100,353**	**1,124,635**	**-83,260**
1998-2010 Avg	**96%**	**--**	**62,529**	**621,396**	**26,228**	**33,438**	**348,702**	**1,092,294**	**9,985**	**1,134,781**	**100,389**	**1,245,155**	**-152,861**

Subsurface Water Budget															
			Inflows							Outflows				Annual Change in Storage		
			Deep Percolation				Interbasin Inflow			Groundwater Pumping		Interbasin Outflow				
Year	Kings River Flows	Year Type	Precipitation Infiltration (AF)	Applied Water Infiltration (AF)	Stream Leakage (AF)	Intentional Recharge (AF)	Upper Aquifer (AF)	Lower Aquifer (AF)	Total Inflows (AF)	Upper Aquifer (AF)	Lower Aquifer (AF)	Upper Aquifer (AF)	Lower Aquifer (AF)	Total Outflows (AF)	Upper Aquifer (AF)	Lower Aquifer (AF)	Total Aquifer (AF)
1990	40%	D	17,012	132,933	222,466	1,021	60,944	120,265	554,640	363,970	254,873	52,493	58,787	730,124	-392,438	206,512	-185,926
1991	63%	D	10,310	125,674	149,106	0	59,832	104,657	449,578	351,785	225,455	44,466	68,123	689,829	-379,415	154,951	-224,464
1992	41%	D	13,215	126,365	122,515	0	58,304	102,535	422,934	345,307	251,686	43,733	75,762	716,488	-379,874	89,485	-290,389
1993	149%	W	43,499	124,472	178,243	61	51,892	77,023	475,190	239,755	9,069	42,526	80,157	371,507	-117,785	275,064	157,279
1994	50%	D	20,701	129,432	121,447	23,540	52,755	83,154	431,028	310,055	181,901	44,438	80,974	617,368	-255,820	87,113	-168,707
1995	202%	W	58,569	116,897	160,315	60,372	45,868	68,012	510,032	205,637	17,015	50,708	79,891	353,250	-23,977	255,398	231,421
1996	122%	N	78,864	127,604	161,750	32,081	42,064	60,065	502,429	184,321	11,265	47,154	88,966	331,705	-4,023	190,504	186,481
1997	155%	W	65,946	143,342	153,373	42,787	40,618	63,597	509,662	204,969	73,758	50,417	89,192	418,336	-15,247	116,032	100,786
1998	181%	W	75,095	128,533	152,395	61,425	38,754	67,063	523,264	191,289	57,797	55,626	78,577	383,288	17,175	136,362	153,536
1999	74%	D	47,885	151,647	180,710	0	41,389	79,296	500,928	227,049	111,192	47,970	93,144	479,355	-71,374	71,897	522
2000	90%	N	51,238	95,624	159,781	23,540	41,391	75,001	446,574	201,799	58,927	44,741	85,312	390,779	-76,900	120,539	43,638
2001	59%	D	26,775	90,933	124,376	0	44,167	84,217	370,468	264,888	202,438	45,556	85,202	598,085	-222,719	-20,340	-243,059
2002	67%	D	41,347	85,417	164,069	0	46,006	76,591	413,429	272,312	162,957	45,147	97,839	578,256	-174,685	-3,708	-178,393
2003	83%	N	36,128	95,332	174,955	23,540	45,798	78,735	454,487	255,270	130,332	46,552	94,198	526,352	-133,547	32,464	-101,083
2004	61%	D	40,008	86,876	148,458	10,700	46,099	79,299	411,440	279,593	214,670	46,854	90,221	631,339	-181,729	-49,393	-231,122
2005	148%	W	64,268	101,553	185,872	58,945	41,121	60,617	512,376	194,492	22,996	48,908	89,165	355,562	516	120,500	121,017
2006	172%	W	57,791	108,496	169,501	170,266	37,534	56,625	600,213	174,179	31,250	56,025	86,840	348,293	117,742	102,907	220,649
2007	40%	D	23,538	97,935	174,019	0	42,192	67,360	405,044	264,654	209,499	52,530	90,375	617,057	-177,972	-70,518	-248,490
2008	72%	D	26,373	89,622	137,369	0	43,266	76,606	373,236	283,431	232,114	49,766	93,253	658,564	-210,701	-85,575	-296,277
2009	79%	N	29,563	94,173	167,126	10,700	43,877	74,501	419,939	268,843	187,798	49,818	92,397	598,856	-170,773	-42,237	-213,010
2010	121%	N	67,953	78,915	145,364	23,540	37,974	63,446	417,193	187,770	62,006	47,711	91,016	388,504	-56,332	69,461	13,129
2011	180%	W	88,853	83,959	180,036	180,066	32,182	51,038	616,133	126,313	48,633	58,840	85,781	319,567	197,345	163,884	361,228
2012	49%	D	46,276	62,058	126,057	10,700	34,819	64,180	344,090	205,013	152,288	52,627	89,367	499,295	-137,135	-32,812	-169,947
2013	41%	D	23,005	65,687	123,434	0	38,673	66,410	317,209	252,639	203,087	50,934	92,285	598,945	-222,003	-83,604	-305,607
2014	32%	D	20,546	62,755	92,469	23,320	41,277	69,232	309,598	276,394	231,859	51,497	100,472	660,223	-247,305	-113,047	-360,352
2015	21%	D	25,814	49,756	74,156	23,540	41,875	72,128	287,269	283,699	240,639	50,653	90,840	665,831	-286,779	-105,501	-392,279
2016	75%	D	26,426	53,544	32,070	42,659	36,829	65,273	256,801	248,557	179,866	60,070	100,280	588,773	-234,011	-60,314	-294,325
1990-2016 Avg	**91%**	**--**	**41,740**	**100,353**	**147,460**	**30,474**	**43,981**	**74,331**	**438,340**	**246,814**	**139,458**	**49,547**	**86,978**	**522,797**	**-142,214**	**56,519**	**-85,694**
1998-2010 Avg	**96%**	**--**	**45,228**	**100,389**	**160,307**	**29,435**	**42,274**	**72,258**	**449,892**	**235,813**	**129,537**	**49,016**	**89,811**	**504,176**	**-103,177**	**29,412**	**-73,765**

1. AF = acre-feet, D = dry, W = wet, and N = normal.

Table D7-1

2017 – 2070 Forecast Model Hydrology Sequence[1]

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Stress Period	Forecast Year	Hydrology Conditions	Normal Kings River Flow (AF)	CNRA Change Factor	Kings River Flow CNRA (AF)
1	2017	2011	1,037,113	1.004167	1,041,434
2	2018	2010	706,083	1.016667	717,851
3	2019	1999	763,007	0.998333	761,735
4	2020	2000	777,871	1.010833	786,298
5	2021	2001	456,607	1.013333	462,695
6	2022	2002	582,769	1.015000	591,510
7	2023	2003	603,080	1.014167	611,624
8	2024	2004	515,426	1.038333	535,184
9	2025	2005	901,509	1.001667	903,011
10	2026	2000	777,871	1.010833	786,298
11	2027	2007	526,947	1.008333	531,338
12	2028	2008	379,491	1.001667	380,123
13	2029	2009	387,005	1.015000	392,810
14	2030	2010	706,083	1.016667	717,851
15	2031	1997	757,901	0.983333	745,269
16	2032	1998	704,676	0.989167	697,042
17	2033	1999	763,007	0.996667	760,463
18	2034	2000	777,871	1.021667	794,725
19	2035	2001	456,607	1.016667	464,217
20	2036	2002	582,769	0.974167	567,714
21	2037	2003	603,080	0.974167	587,500
22	2038	2004	515,426	1.002500	516,714
23	2039	2005	901,509	0.993333	895,499
24	2040	2000	777,871	1.021667	794,725
25	2041	2007	526,947	1.000833	527,386
26	2042	2008	379,491	1.002500	380,440
27	2043	2009	387,005	0.991667	383,780
28	2044	2010	706,083	1.012500	714,909
29	2045	1997	757,901	0.983333	745,269
30	2046	1998	704,676	0.989167	697,042
31	2047	1999	763,007	0.996667	760,463
32	2048	2000	777,871	1.021667	794,725
33	2049	2001	456,607	1.016667	464,217
34	2050	2002	582,769	0.974167	567,714
35	2051	2003	603,080	0.974167	587,500
36	2052	2004	515,426	1.002500	516,714

Table D7-1

2017 – 2070 Forecast Model Hydrology Sequence[1]

Stress Period	Forecast Year	Hydrology Conditions	Normal Kings River Flow (AF)	CNRA Change Factor	Kings River Flow CNRA (AF)
37	2053	2005	901,509	0.993333	895,499
38	2054	2000	777,871	1.021667	794,725
39	2055	2007	526,947	1.000833	527,386
40	2056	2008	379,491	1.002500	380,440
41	2057	2009	387,005	0.991667	383,780
42	2058	2010	706,083	1.012500	714,909
43	2059	1997	757,901	0.983333	745,269
44	2060	1998	704,676	0.989167	697,042
45	2061	1999	763,007	0.996667	760,463
46	2062	2000	777,871	1.021667	794,725
47	2063	2001	456,607	1.016667	464,217
48	2064	2002	582,769	0.974167	567,714
49	2065	2003	603,080	0.974167	587,500
50	2066	2004	515,426	1.002500	516,714
51	2067	2005	901,509	0.993333	895,499
52	2068	2000	777,871	1.021667	794,725
53	2069	2007	526,947	1.000833	527,386
54	2070	2008	379,491	1.002500	380,440

1. AF = acre-feet and CNRA = California Natural Resources Agency.

Table D7-2

2017 – 2070 Projects Forecast Model Project Development and Yields[1]

Tulare Lake Subbasin Hydrologic Model
Kings County, California

Year	Kings River Hydrology		Project Descriptions	Mid-Kings GSA	El Rico GSA		South Fork Kings GSA	TCWA GSA	New Project
	% Normal Flows	Flood Years		Proposed Recharge (AF)	Existing Ponds (AF)	Proposed 6,400 AC SW Pond (AF)	Proposed 10,000 AC SW Pond (AF)	Proposed 13,340 AC SW Pond (AF)	Total SW Supply (AF)
2017	180%			0	0	0	0	0	0
2018	121%			0	0	0	0	0	0
2019	74%			0	0	0	0	0	0
2020	90%		Construct 340 acres of Perc Basins	0	0	0	0	0	0
2021	59%			0	0	0	0	0	0
2022	67%			0	0	0	0	0	0
2023	83%			0	0	0	0	0	0
2024	61%			0	0	0	0	0	0
2025	148%	Flood		50,000	71,000	0	0	0	0
2026	90%		Construct 340 acres of Perc Basins	0	0	0	0	0	0
2027	40%			0	0	0	0	0	0
2028	72%		Construct 6,400, 10,000, and 13,400	0	0	0	0	0	0
2029	79%		acres of SW Ponds	0	0	0	0	0	0
2030	121%		Construct 340 acres of Perc Basins	0	0	0	0	0	0
2031	155%	Flood		150,000	71,000	40,000	60,000	80,000	180,000
2032	181%	Flood		150,000	71,000	40,000	60,000	80,000	180,000
2033	74%			0	0	0	0	0	0
2034	90%			0	0	0	0	0	0
2035	59%		Construct 340 acres of Perc Basins	0	0	0	0	0	0
2036	67%			0	0	0	0	0	0
2037	83%			0	0	0	0	0	0
2038	61%			0	0	0	0	0	0
2039	148%	Flood		200,000	71,000	40,000	60,000	80,000	180,000
2040	90%			0	0	0	0	0	0
2041	40%			0	0	0	0	0	0
2042	72%			0	0	0	0	0	0
2043	79%			0	0	0	0	0	0
2044	121%			0	0	0	0	0	0
2045	155%	Flood		200,000	71,000	40,000	60,000	80,000	180,000
2046	181%	Flood		200,000	71,000	40,000	60,000	80,000	180,000
2047	74%			0	0	0	0	0	0
2048	90%			0	0	0	0	0	0
2049	59%			0	0	0	0	0	0
2050	67%			0	0	0	0	0	0
2051	83%			0	0	0	0	0	0
2052	61%			0	0	0	0	0	0
2053	148%	Flood		200,000	71,000	40,000	60,000	80,000	180,000
2054	90%			0	0	0	0	0	0
2055	40%			0	0	0	0	0	0
2056	72%			0	0	0	0	0	0
2057	79%			0	0	0	0	0	0
2058	121%			0	0	0	0	0	0
2059	155%	Flood		200,000	71,000	40,000	60,000	80,000	180,000
2060	181%	Flood		200,000	71,000	40,000	60,000	80,000	180,000
2061	74%			0	0	0	0	0	0
2062	90%			0	0	0	0	0	0
2063	59%			0	0	0	0	0	0
2064	67%			0	0	0	0	0	0
2065	83%			0	0	0	0	0	0
2066	61%			0	0	0	0	0	0
2067	148%	Flood		200,000	71,000	40,000	60,000	80,000	180,000
2068	90%			0	0	0	0	0	0
2069	40%			0	0	0	0	0	0
2070	72%			0	0	0	0	0	0
			Project Annual Average	**38,043**	**15,435**	**8,780**	**13,171**	**17,561**	**40,500**
			2040-2048 Average	**44,444**	**15,778**	**8,889**	**13,333**	**17,778**	**40,000**

1. GSA = Groundwater Sustainability Agency, TCWA = Tri-County Water Authority, AC = acre, SW = southwest, SF = surface water, and AF = acre-feet.

Table D7-3

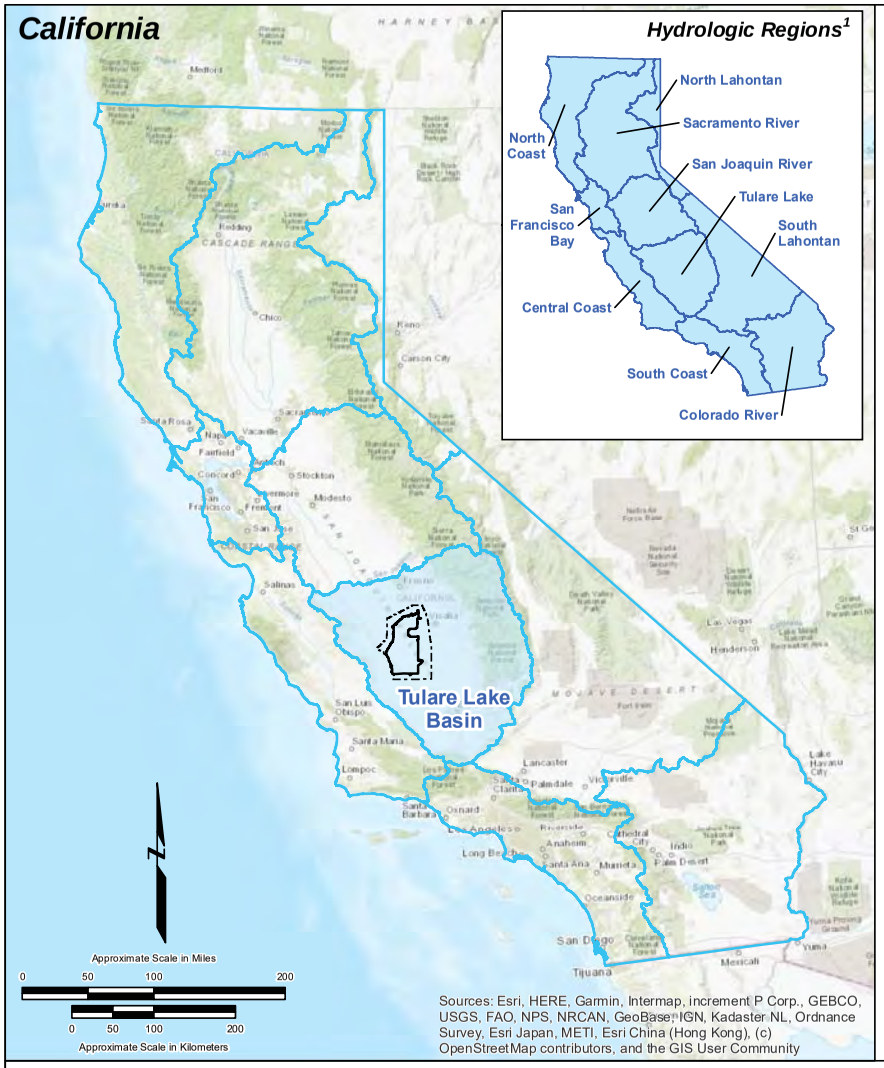
Historical and Forecasts Groundwater Balance Comparison[1]

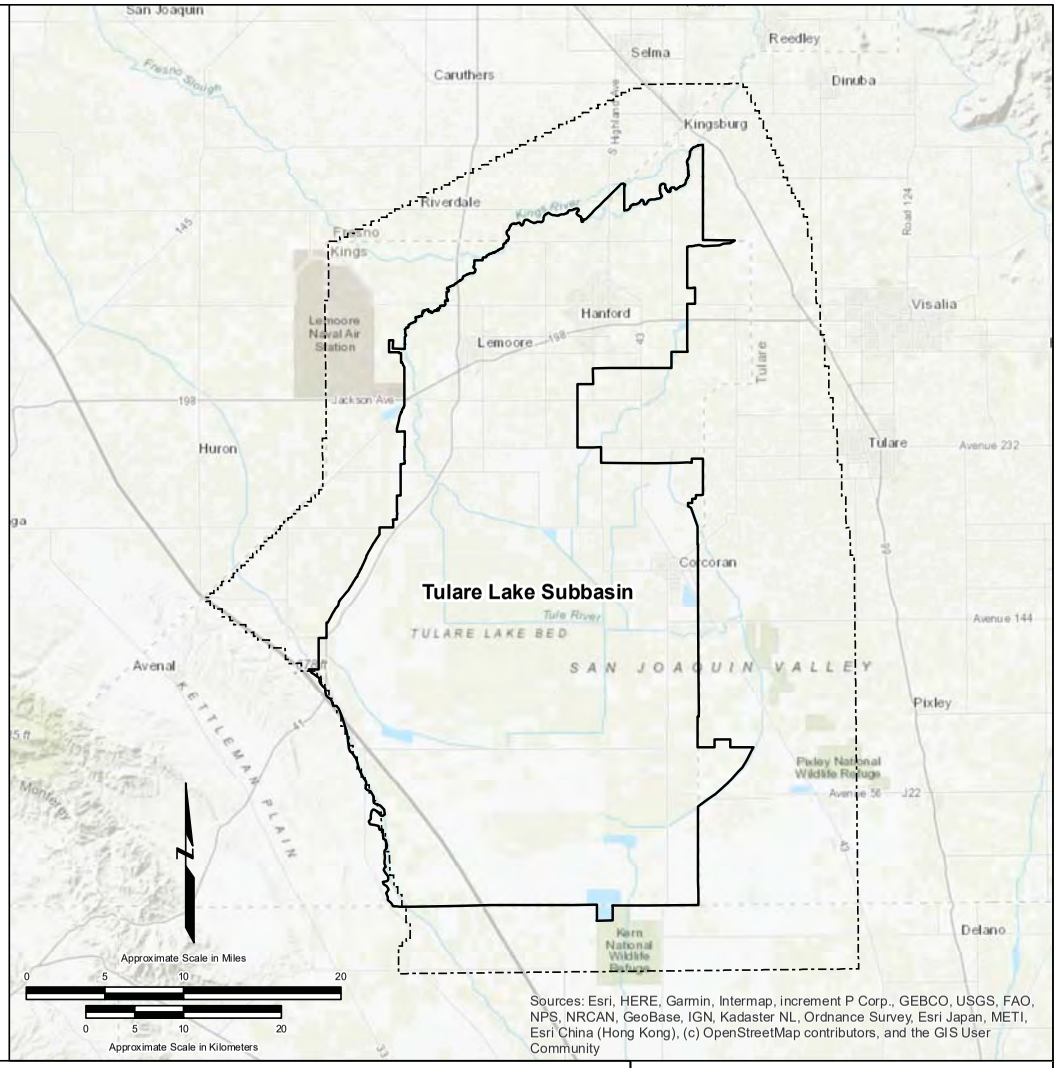
Tulare Lake Subbasin Hydrologic Model
Kings County, California

Simulation	Total Simulation Period	Tulare Lake Drain Net (AF/Y)	Tulare Lake Well Net (AF/Y)	Tulare Lake River Net (AF/Y)	Tulare Lake Recharge Net (AF/Y)	Tulare Lake Storage Net (AF/Y)	Tulare Lake Net Interbasin Flow (AF/Y)	Tulare Lake - Westside Net (AF/Y)	Tulare Lake - Kings Net (AF/Y)	Tulare Lake - Kaweah Net (AF/Y)	Tulare Lake - Tule Net (AF/Y)	Tulare Lake - Kern Net (AF/Y)
Above Corcoran Clay												
Calibration	1990-2016 Average	-5,724	-246,814	141,361	173,756	-142,214	-5,565	5,230	-5,566	-64	-6,678	1,514
Baseline Forecast	2017-2070 Average	-2,915	-233,018	148,209	172,329	-91,547	-30,438	1,288	-8,263	-8,955	-13,336	-1,172
Projects Forecast	2017-2070 Average	-3,919	-196,130	109,294	200,120	-29,931	-16,363	1,707	-4,390	-6,625	-6,988	-67
Below Corcoran Clay												
Calibration	1990-2016 Average	0	-134,595	0	0	56,519	-12,648	-1,269	-8,259	-19,363	-11,700	27,943
Baseline Forecast	2017-2070 Average	0	-90,714	0	0	-51,440	-108,636	-24,350	-25,894	-44,226	-35,198	21,032
Projects Forecast	2017-2070 Average	0	-89,353	0	0	-6,269	-42,250	-11,794	-4,500	-27,202	-6,599	7,845
Total Aquifer												
Calibration	1990-2016 Average	-5,724	-381,410	141,361	173,756	-85,694	-18,213	3,961	-13,826	-19,427	-18,379	29,457
Baseline Forecast	2017-2070 Average	-2,915	-323,732	148,209	172,329	-142,987	-139,074	-23,062	-34,157	-53,181	-48,534	19,860
Projects Forecast	2017-2070 Average	-3,919	-285,483	109,294	200,120	-36,200	-58,613	-10,086	-8,890	-33,827	-13,587	7,778

Simulation	Normal Hydrology Period	Tulare Lake Drain Net (AF/Y)	Tulare Lake Well Net (AF/Y)	Tulare Lake River Net (AF/Y)	Tulare Lake Recharge Net (AF/Y)	Tulare Lake Storage Net (AF/Y)	Tulare Lake Net Interbasin Flow (AF/Y)	Tulare Lake - Westside Net (AF/Y)	Tulare Lake - Kings Net (AF/Y)	Tulare Lake - Kaweah Net (AF/Y)	Tulare Lake - Tule Net (AF/Y)	Tulare Lake - Kern Net (AF/Y)
Above Corcoran Clay												
Calibration	1998-2010 Average	-9,985	-235,813	140,827	176,936	-103,177	-6,741	4,658	-5,640	-244	-7,131	1,616
Baseline Forecast	2040-2048 Average	-1,986	-231,248	141,765	170,054	-104,055	-34,749	965	-10,192	-9,468	-13,930	-2,124
Projects Forecast	2040-2048 Average	-3,288	-182,304	89,564	210,859	-25,079	-19,005	1,572	-6,346	-7,148	-6,743	-341
Below Corcoran Clay												
Calibration	1998-2010 Average	0	-129,537	0	0	29,412	-17,552	1,173	-10,299	-20,331	-14,158	26,063
Baseline Forecast	2040-2048 Average	0	-72,702	0	0	-45,379	-121,729	-29,706	-29,475	-46,470	-36,501	20,423
Projects Forecast	2040-2048 Average	0	-62,943	0	0	5,687	-53,972	-15,058	-8,292	-31,963	-6,195	7,536
Total Aquifer												
Calibration	1998-2010 Average	-9,985	-365,350	140,827	176,936	-73,765	-24,294	5,830	-15,939	-20,575	-21,289	27,680
Baseline Forecast	2040-2048 Average	-1,986	-303,950	141,765	170,054	-149,434	-156,477	-28,740	-39,667	-55,938	-50,431	18,299
Projects Forecast	2040-2048 Average	-3,288	-245,247	89,564	210,859	-19,392	-72,977	-13,485	-14,638	-39,111	-12,938	7,195

1. AF/Y = acre-feet per year.





Explanation

- Hydrologic region
- Subbasin boundary
- Model Domain

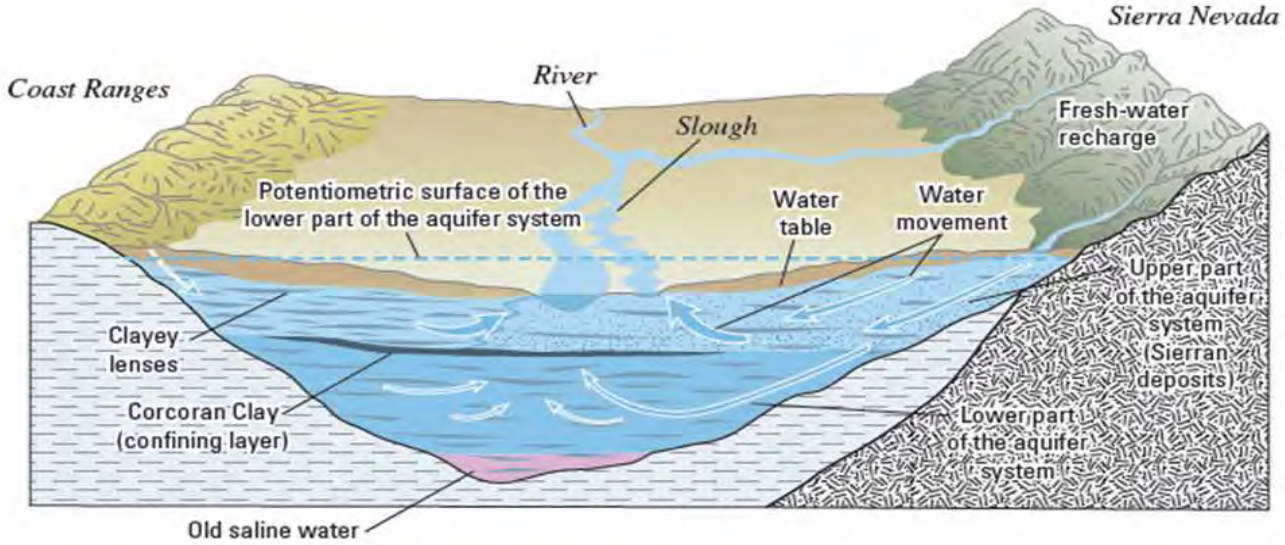
Note:
1) Hydrologic region dataset obtained from California Department of Water Resources (CA DWR), September 12, 2018. https://data.ca.gov/dataset/hydrologic-regions

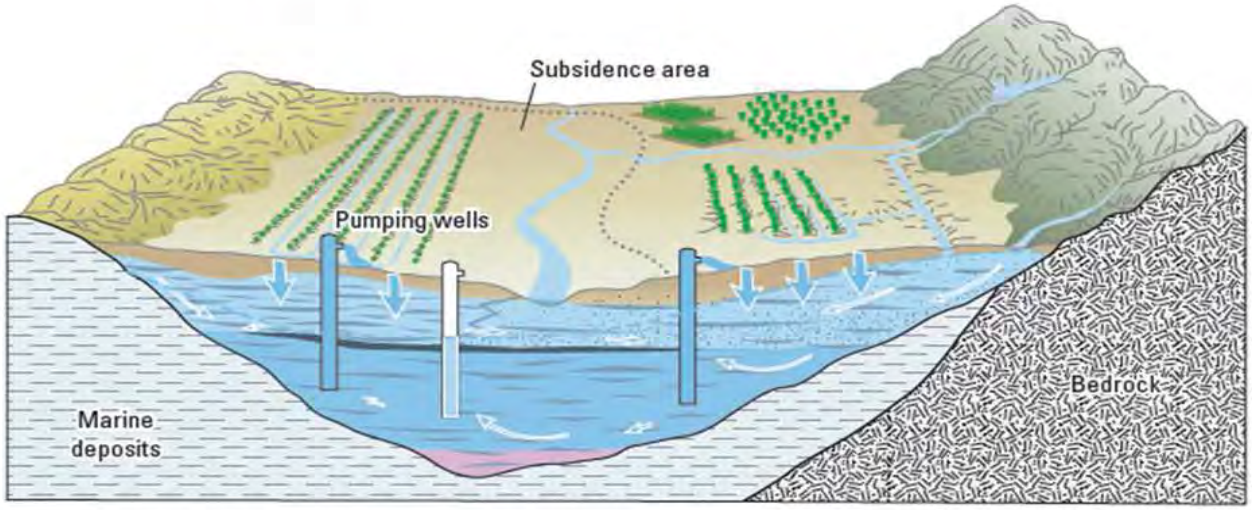
Site Location Map
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/12/2019	Project No.: FR18161220
		Figure **D1-1**

Date: 12/12/2019 Printed by: shaina.price
Path: N:_FR_projects\FR18xFR18161220\gis\maps\2019\Basin_Setting_fig3-1_SiteLocationMap.mxd

Pre-Development





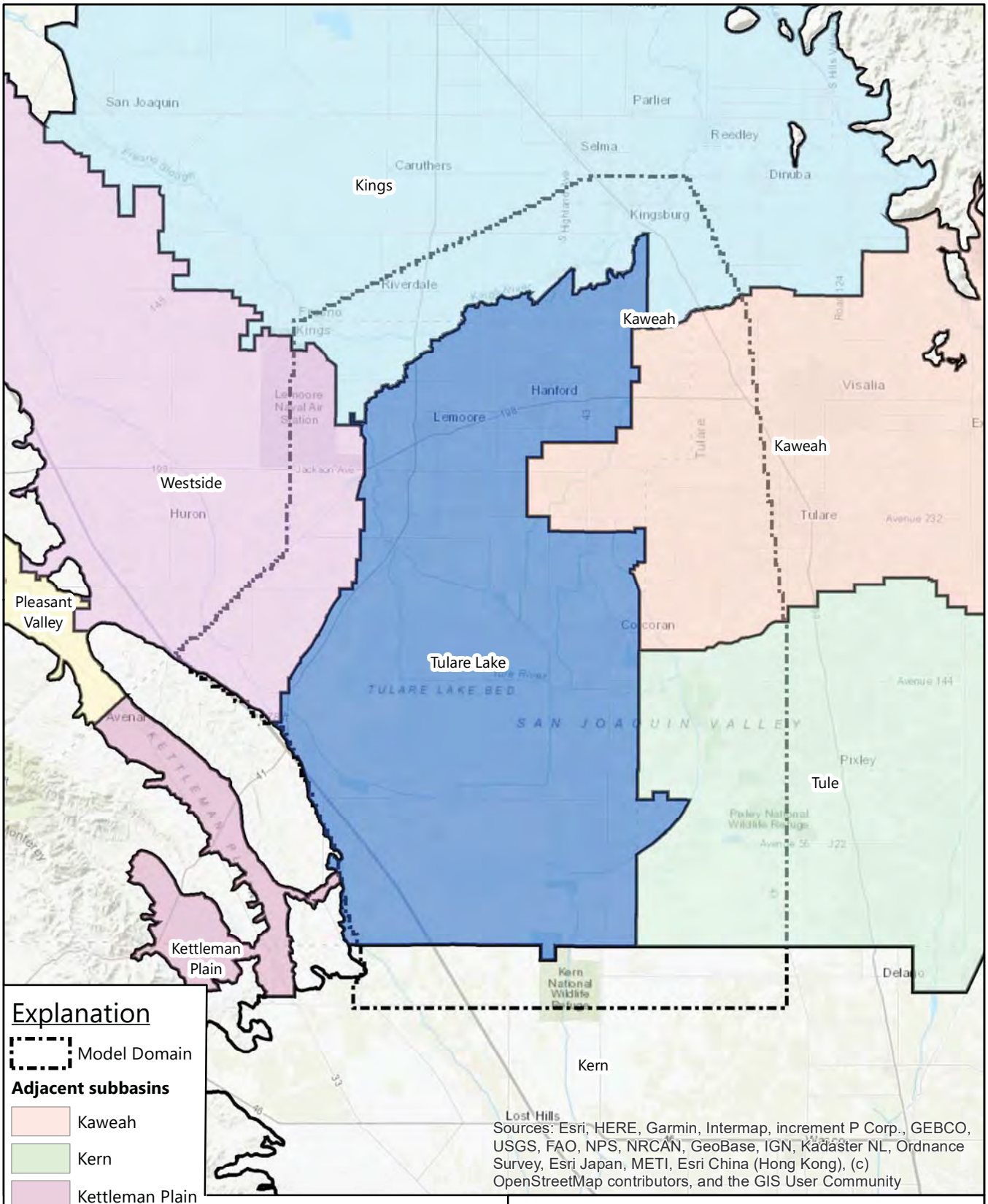
Post-Development

adapted from Fig. A9, USGS Prof. Paper 1766

Pre-Development and Post-Development Hydrogeologic Conceptual Model for the San Joaquin Valley

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 08/26/2019	Project No.: FR18161220
		Figure **D2-1**

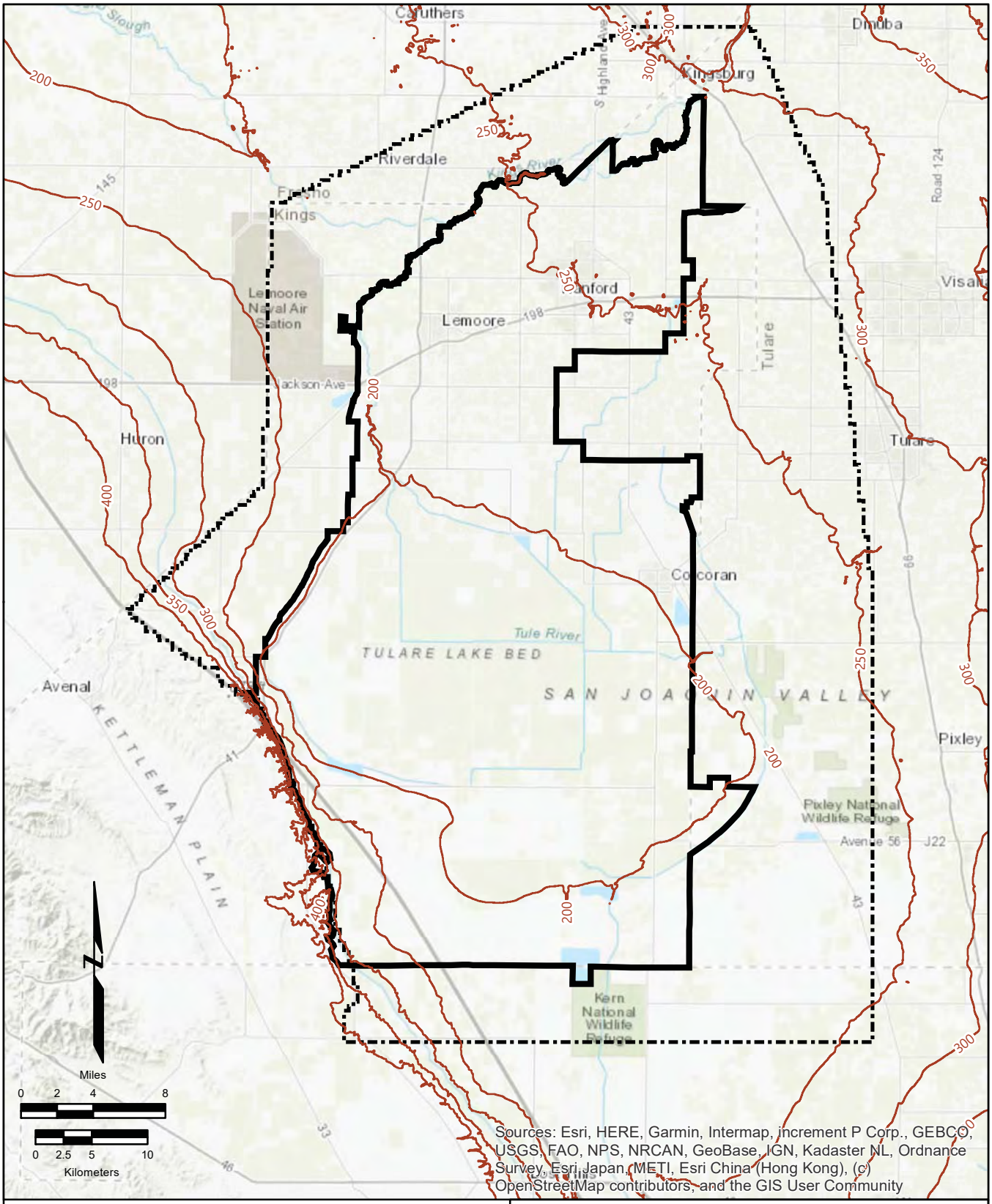


Subbasins Bounding The Tulare Lake Subbasin

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/7/2020	Project No.: FR18161220
		Figure **D2-2**

Date: 1/7/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\AppendixD_figD2-2_ModelDomain.mxd



Explanation

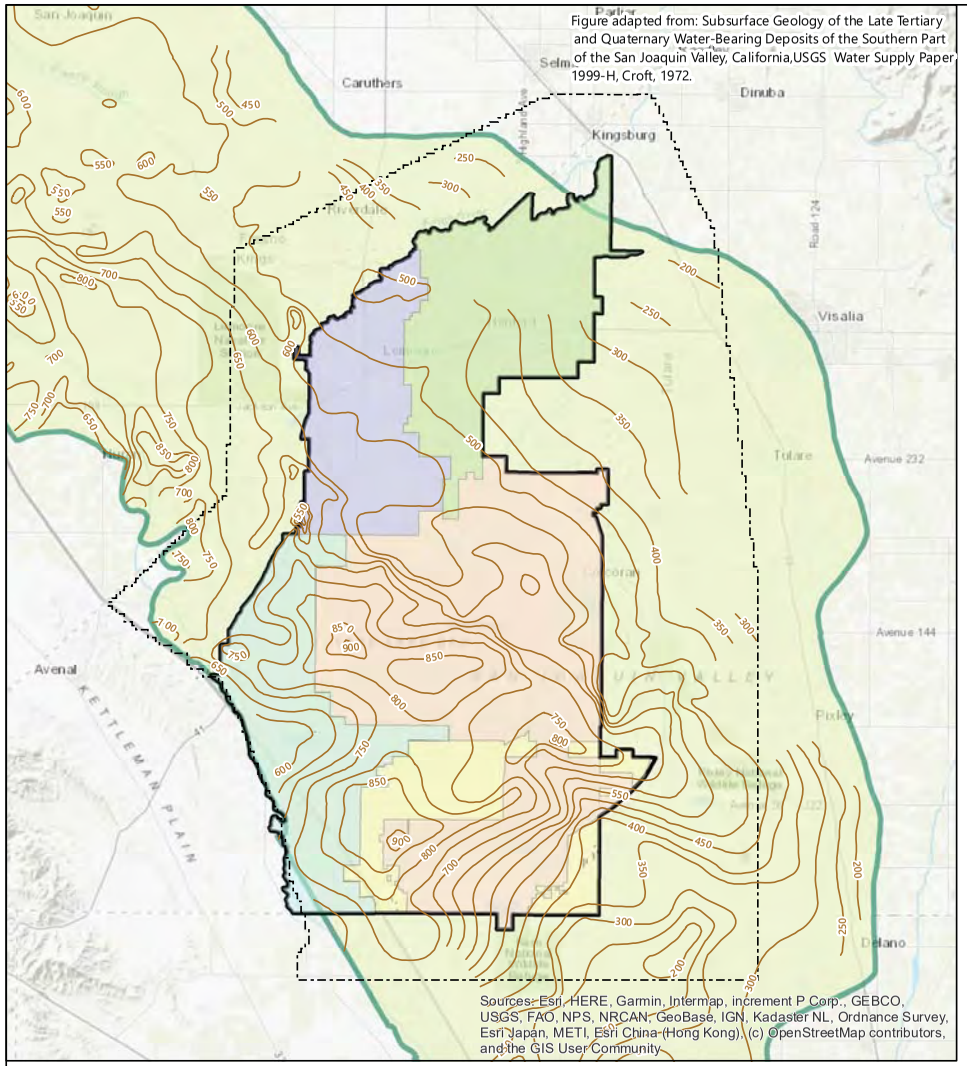
- 50ft elevation contour
- Subbasin boundary
- Model domain

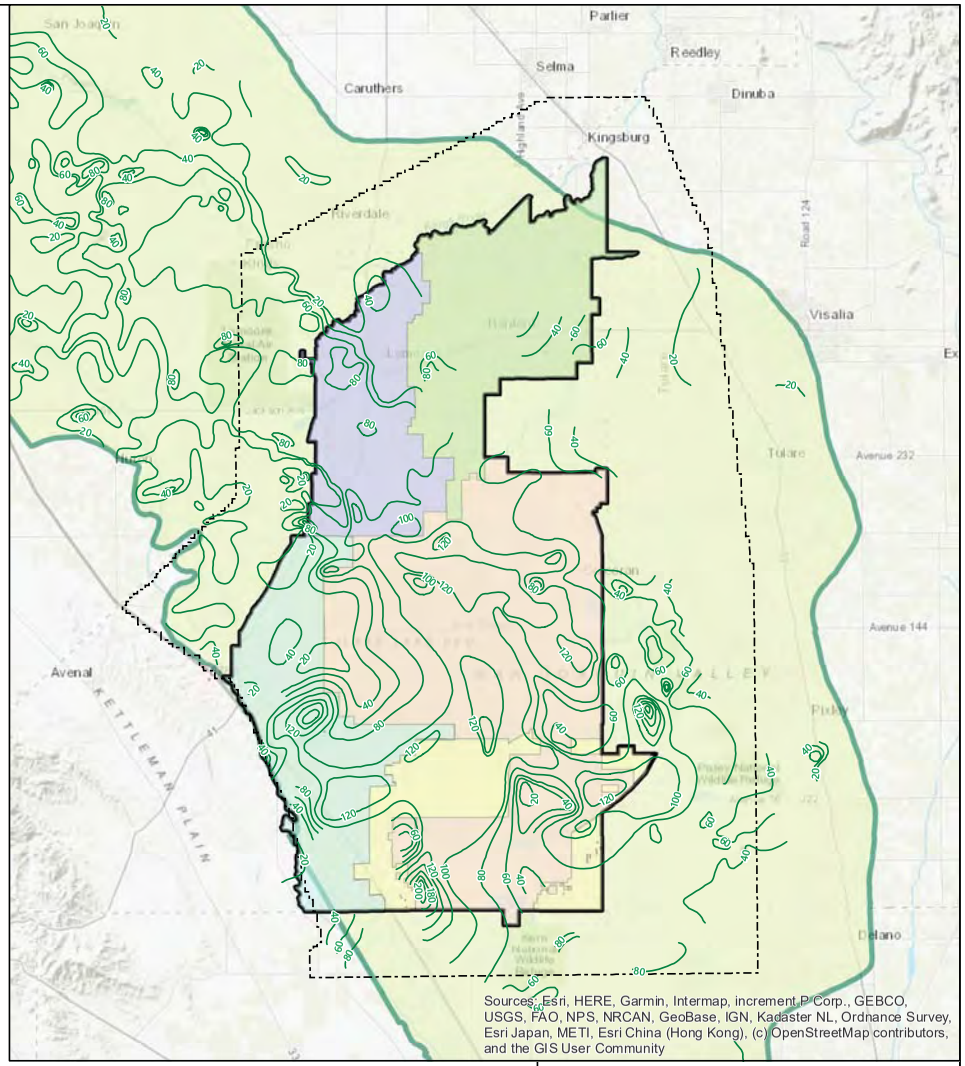
Surface Topography

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/12/2019	Project No.: FR18161220
		Figure **D2-3**

Date: 12/12/2019 Printed by: shaina.price
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\AppendixD_figD2-3_Topography.mxd





Explanation

- Depth to top of E-Clay in feet
- Thickness of E-Clay in feet
- Model domain
- Subbasin boundary
- Extent of E-Clay

Groundwater Sustainability Areas (GSAs)

- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

Approximate Scale in Miles
0 4 8 16

Approximate Scale in Kilometers
0 4 8 16

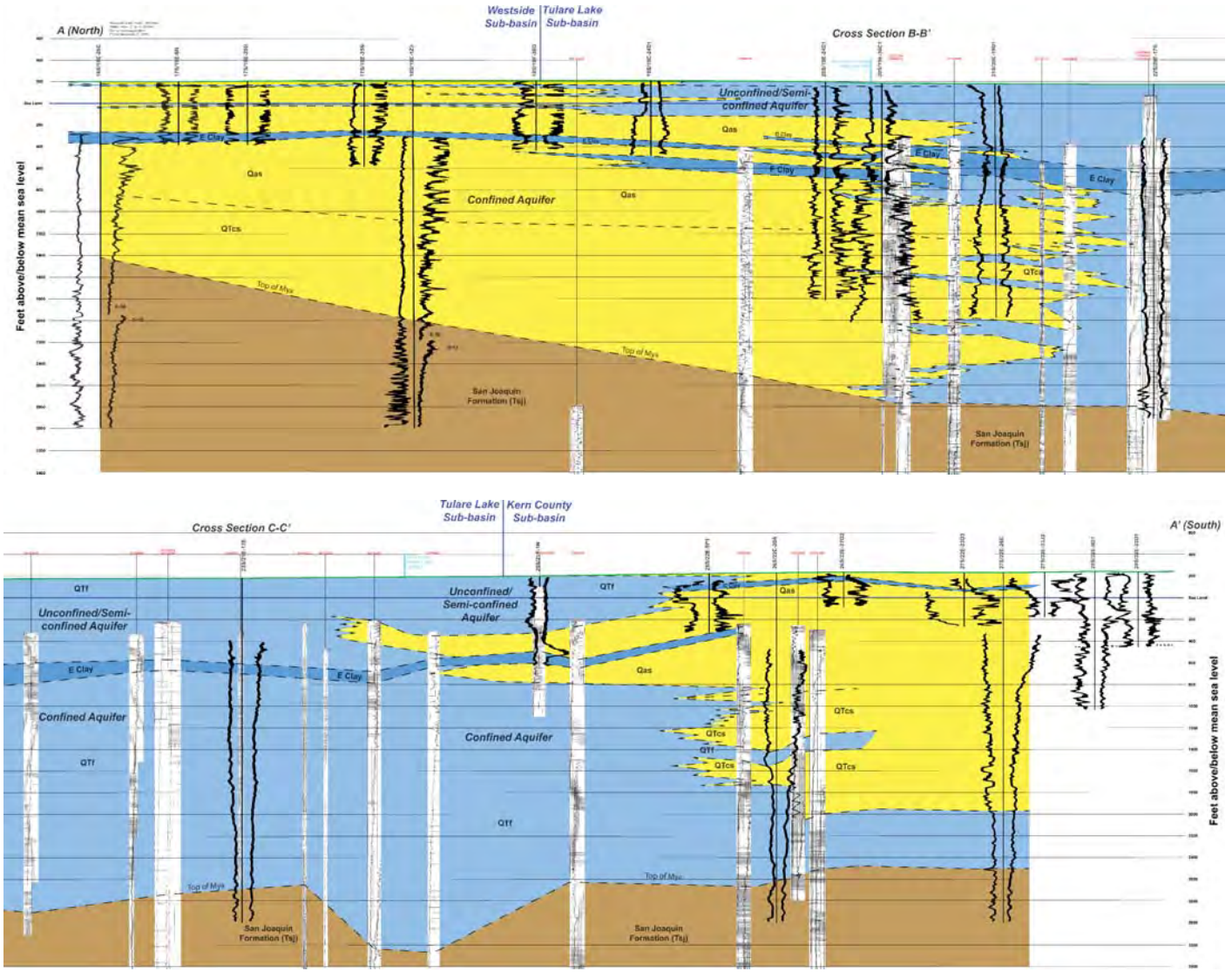
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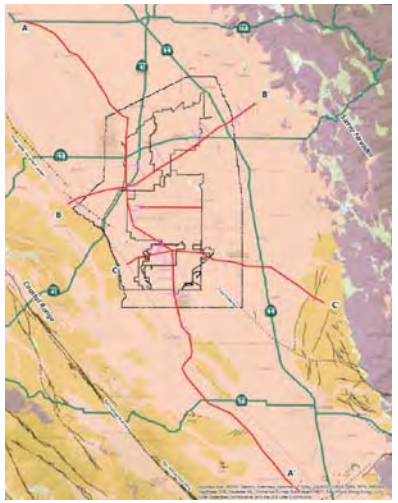
Lateral Extent Elevation and Thickness of E-Clay

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/7/2020	Project No.: FR16181220
		Figure **D2-4**

Date: 1/7/2020 Printed by: elizabeth.chapman
Path: N:_PR_projects\FR\BSR\16181220\gis\maps\2019\AppendixD_figD2-4_Corcoran Clay.mxd





Explanation

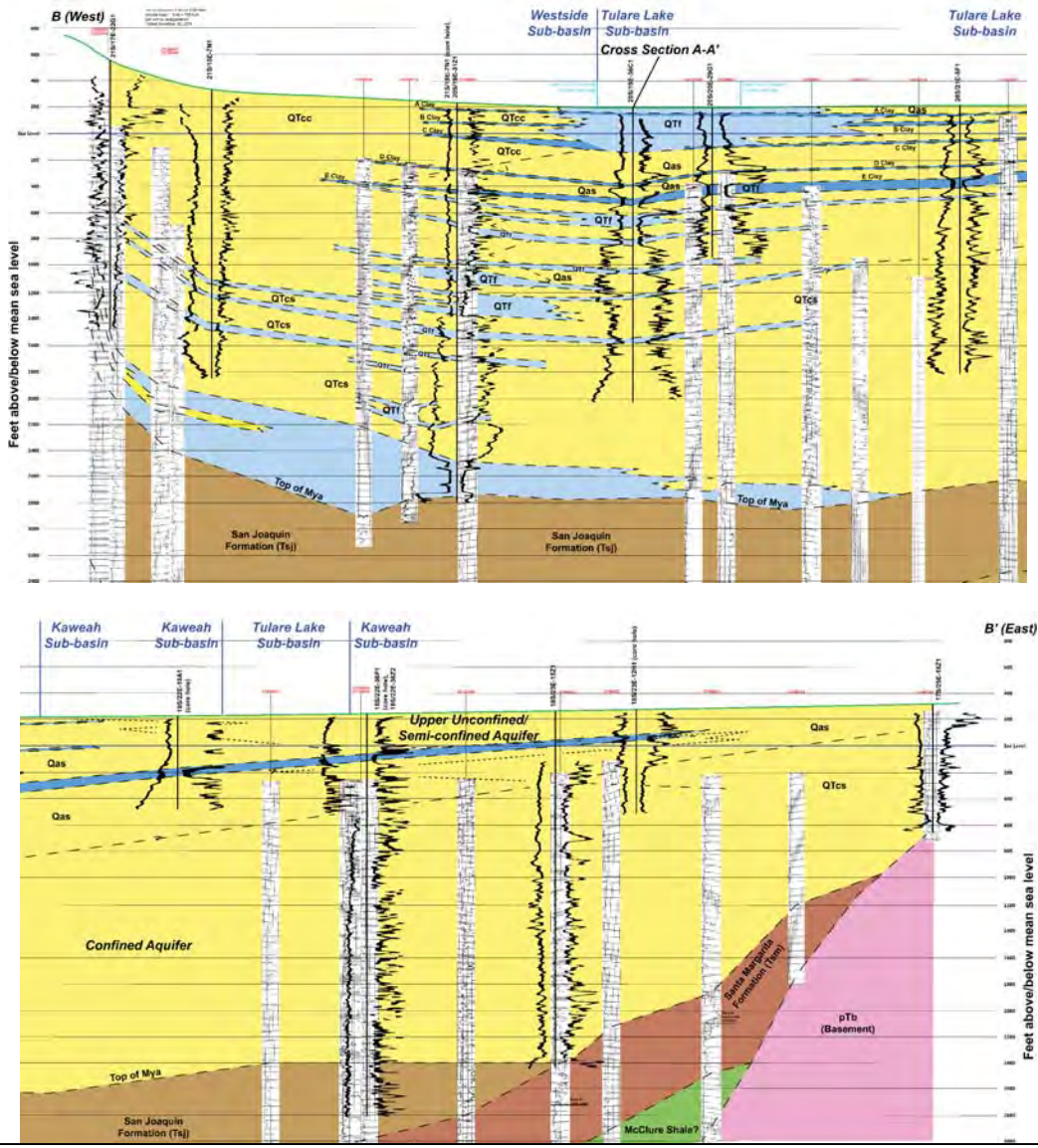
- Coarse-grained alluvium / Tulare Formation
- San Joaquin Formation
- Alluvium / Tulare Formation lacustrine sediments
- Regional clay marker beds as defined by Croft (1972)
- **25S/21E-1N** — CA DWR well name
- **03120281** — CA DOGGR well APN
- 0 30 — Electric log resistivity scale (ohmmeters)

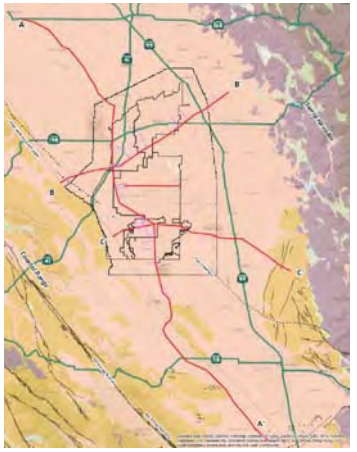
Notes:
1) Contacts dashed where inferred.
2) CA DWR = California Department of Water Resources.
2) CA DOGGR = Division of Oil, Gas, and Geothermal Resources, California Department of Conservation.

North-South Geologic Cross-Section A-A'
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings county, California

By: EMC	Date: 12/13/2019	Project No.: FR18161220
		Figure **D2-5a**

Date: 12/13/2019 Printed by: shaina.price
Path: N:_PA_projects\FR18xx\FR18161220\gis\maps\2019\AppendixD_figD2-5a_ North-South Geologic Cross Section A-A'.mxd





Explanation

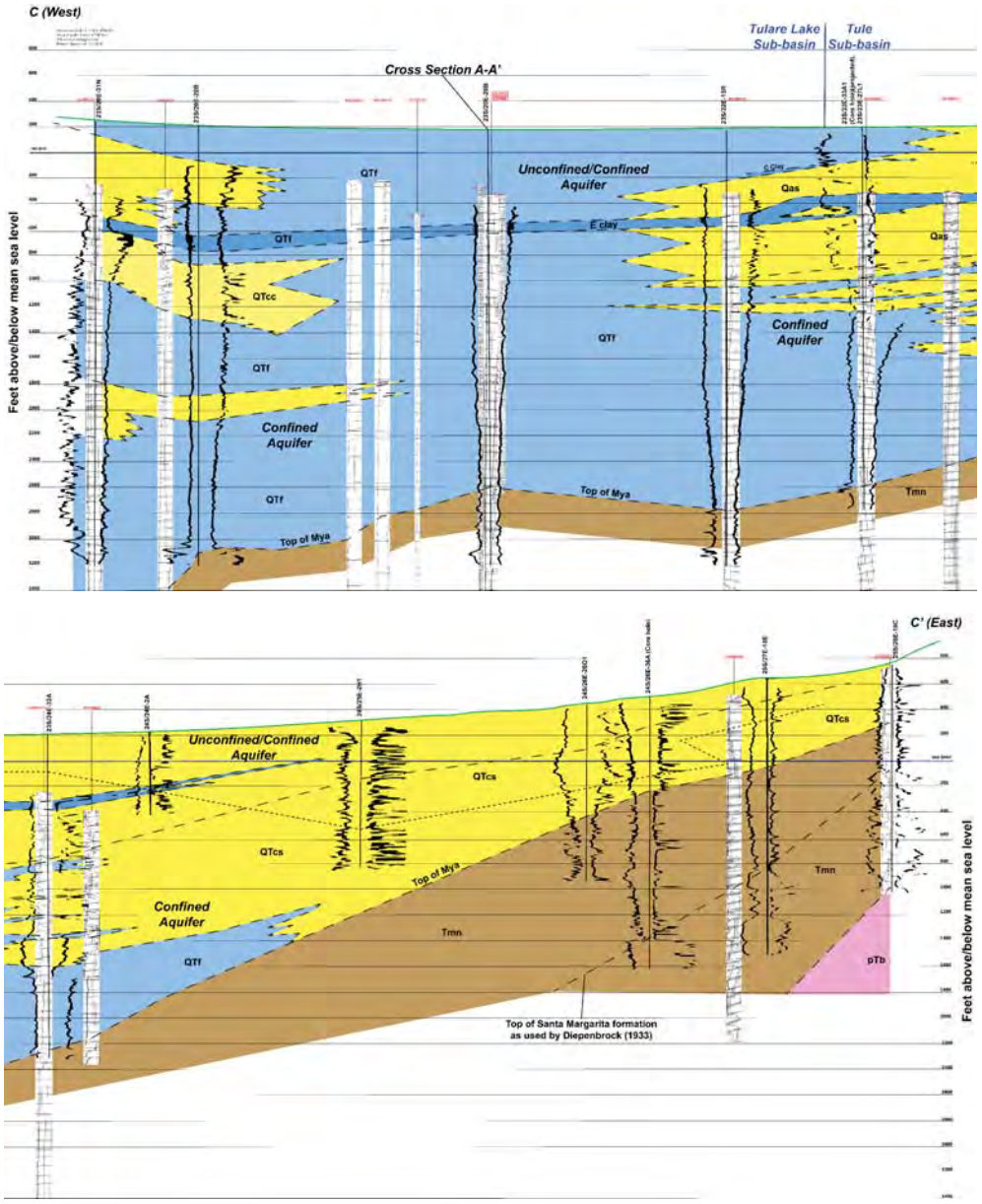
- Coarse-grained alluvium / Tulare Formation
- San Joaquin Formation
- Etchegoin Formation
- Santa Margarita Formation
- Alluvium / Tulare Formation lacustrine sediments
- Regional clay marker beds as defined by Croft (1972)
- Crystalline basement
- **25S/21E-1N** — CA DWR well name
- **03120281** — CA DOGGR well APN
- 0 30 — Electric log resistivity scale (ohmmeters)

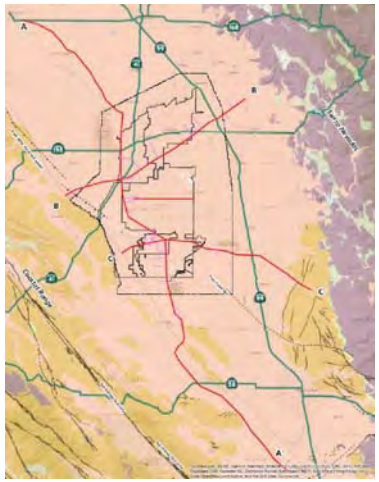
Notes:
1) Contacts dashed where inferred.
2) CA DWR = California Department of Water Resources.
2) CA DOGGR = Division of Oil, Gas, and Geothermal Resources, California Department of Conservation.

West-East Geologic Cross-Section B-B'
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/13/2019	Project No.: FR18161220
		Figure **D2-5b**

Date: 12/13/2019 Printed by: shaina.price
Path: N:_PR_projects\FR18xx\FR18161220\gis\maps\2019\AppendixD_figD2-5b_West-East Geologic Cross-Section B-B'.mxd





Explanation

- Coarse-grained alluvium / Tulare Formation
- San Joaquin Formation
- Alluvium / Tulare Formation lacustrine sediments
- Regional clay marker beds as defined by Croft (1972)
- Crystalline basement
- **25S/21E-1N** — CA DWR well name
- **03120281** — CA DOGGR well APN
- 0 30 — Electric log resistivity scale (ohmmeters)

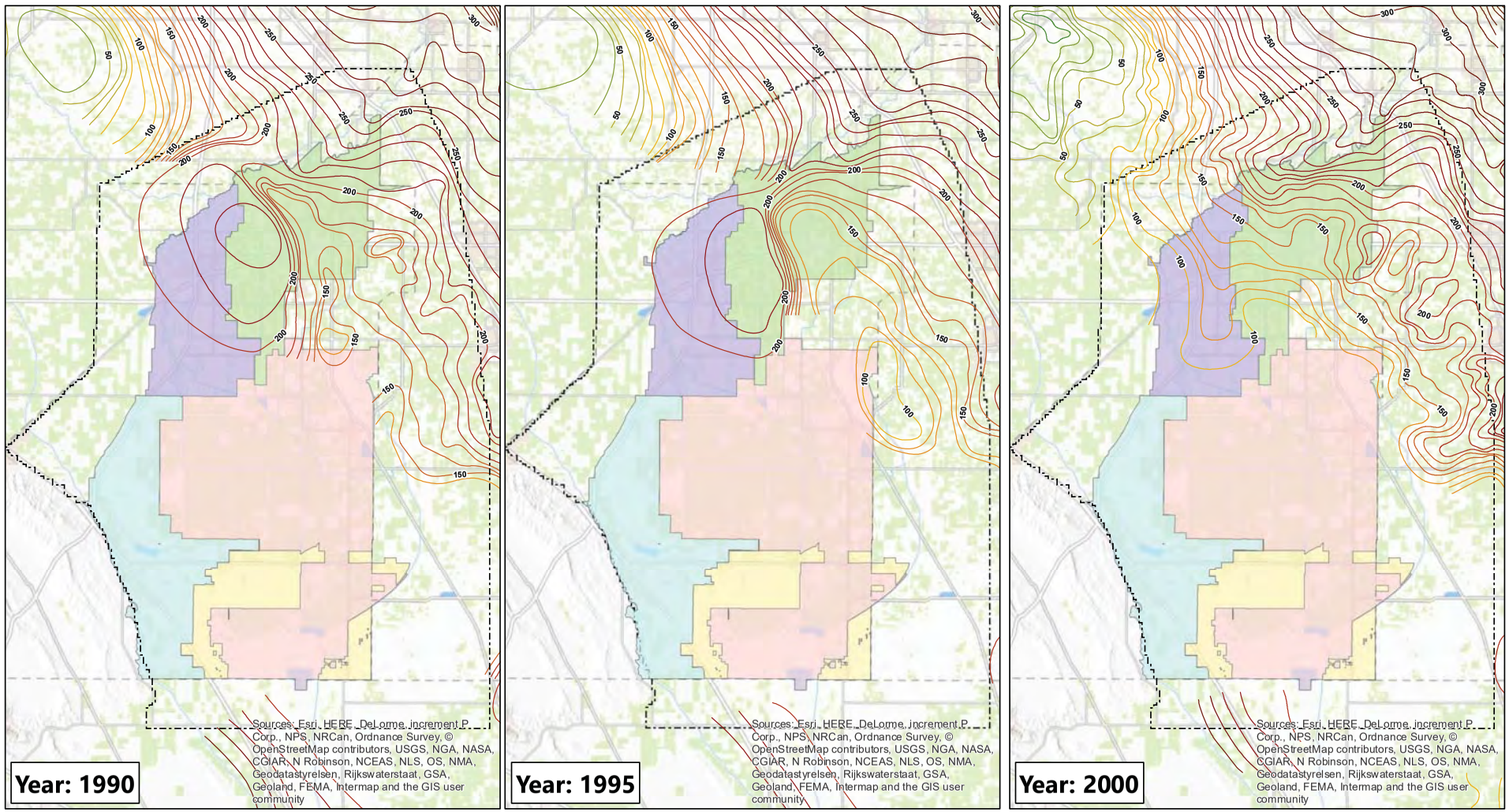
Notes:
1) Contacts dashed where inferred.
2) CA DWR = California Department of Water Resources.
2) CA DOGGR = Division of Oil, Gas, and Geothermal Resources, California Department of Conservation.

North - South Geologic Cross-Section Through the Tulare Lake Bed

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/13/2019	Project No.: FR18161220
		Figure **D2-5c**

Date: 12/13/2019 Printed by: shaina.price
Path: N:_PA_projects\FR18\s\FR18161220\gis\maps\2019\AppendixD_figD2-5c_West-East Geologic Cross-Section C-C'.mxd



Explanation

- Model domain
- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

Groundwater elevation (FMSL)
700
-350

APPROXIMATE SCALE IN MILES
0 5 10 20
0 5 10 20
APPROXIMATE SCALE IN KILOMETERS

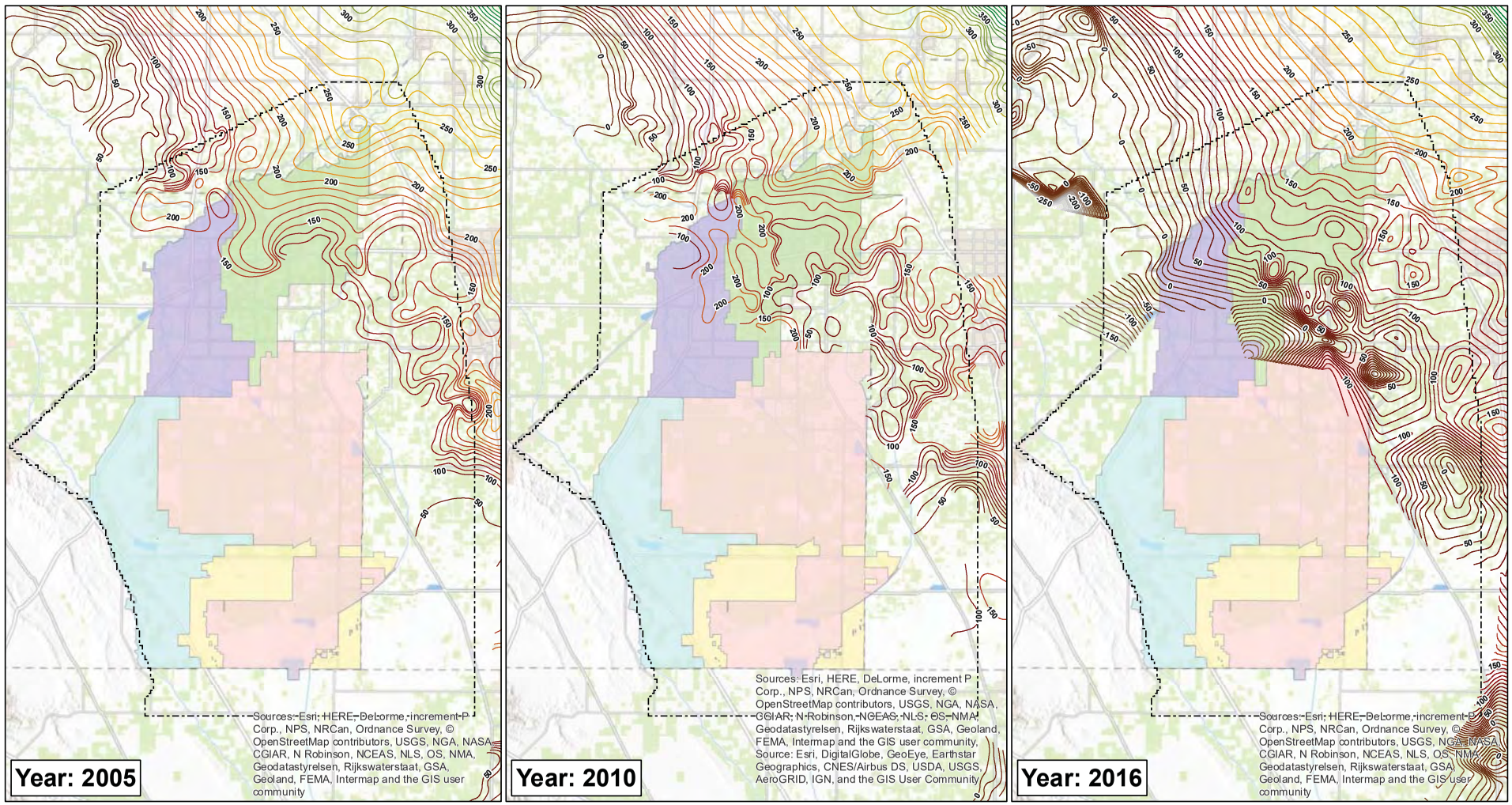
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Historical DWR Groundwater Elevation Maps Unconfined Aquifer

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/8/2020	Project No.: FR18161220
		Figure **D2-6a**

Date: 1/8/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18\FR18161220\gis\maps\2019\Appendix D_fig\D2-6a_RecentGroundwaterConditions_1990_1995_2000.mxd



Explanation

- Model domain
- El Rico Groundwater Sustainability Agency
- Mid-Kings River Groundwater Sustainability Agency
- South Fork Kings Groundwater Sustainability Agency
- Southwest Kings Groundwater Sustainability Agency
- Tri-County Water Authority

Groundwater elevation (FMSL)

-700

-350

APPROXIMATE SCALE IN MILES

0 5 10 20

0 5 10 20

APPROXIMATE SCALE IN KILOMETERS

N

NOTE:

1) Groundwater elevation data obtained from California Department of Water Resources (CA DWR), June 2018: https://databasin.org/datasets/b05820cda86b4921a515065fa1deffcc

2) FMSL = Feet above mean sea level.

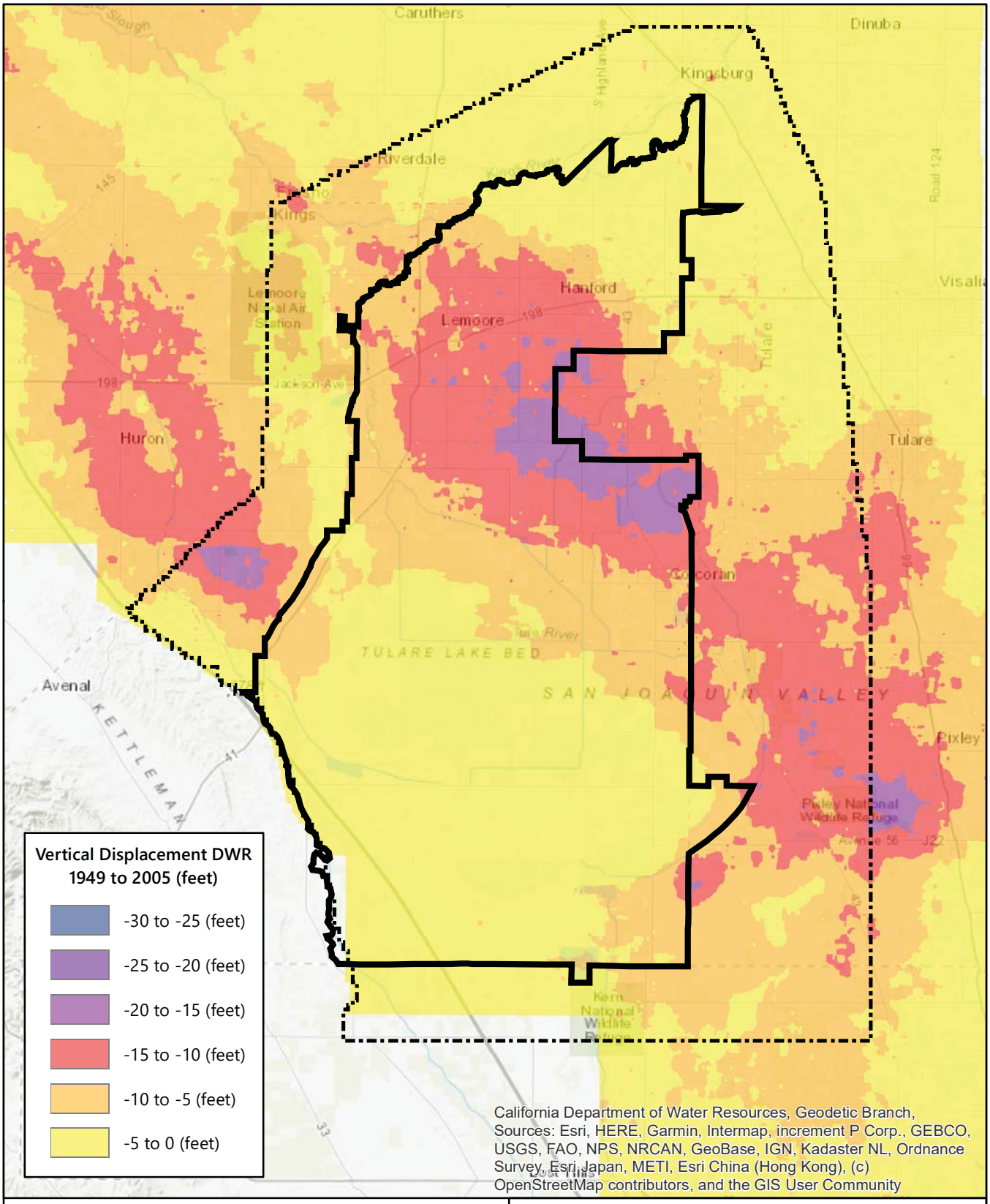
Historical DWR Groundwater Elevation Maps, Unconfined Aquifer

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/13/2019	Project No.: FR18161220

Figure **D2-6b**

Date: 12/13/2019 Printed by: shaina.price
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\AppendixD_fig\D2-6b_RecentGroundwaterConditions_2005_2010_2016.mxd



Explanation

Model domain

Subbasin boundary

Miles
0 2 4 8
0 2.5 5 10
Kilometers

Notes:

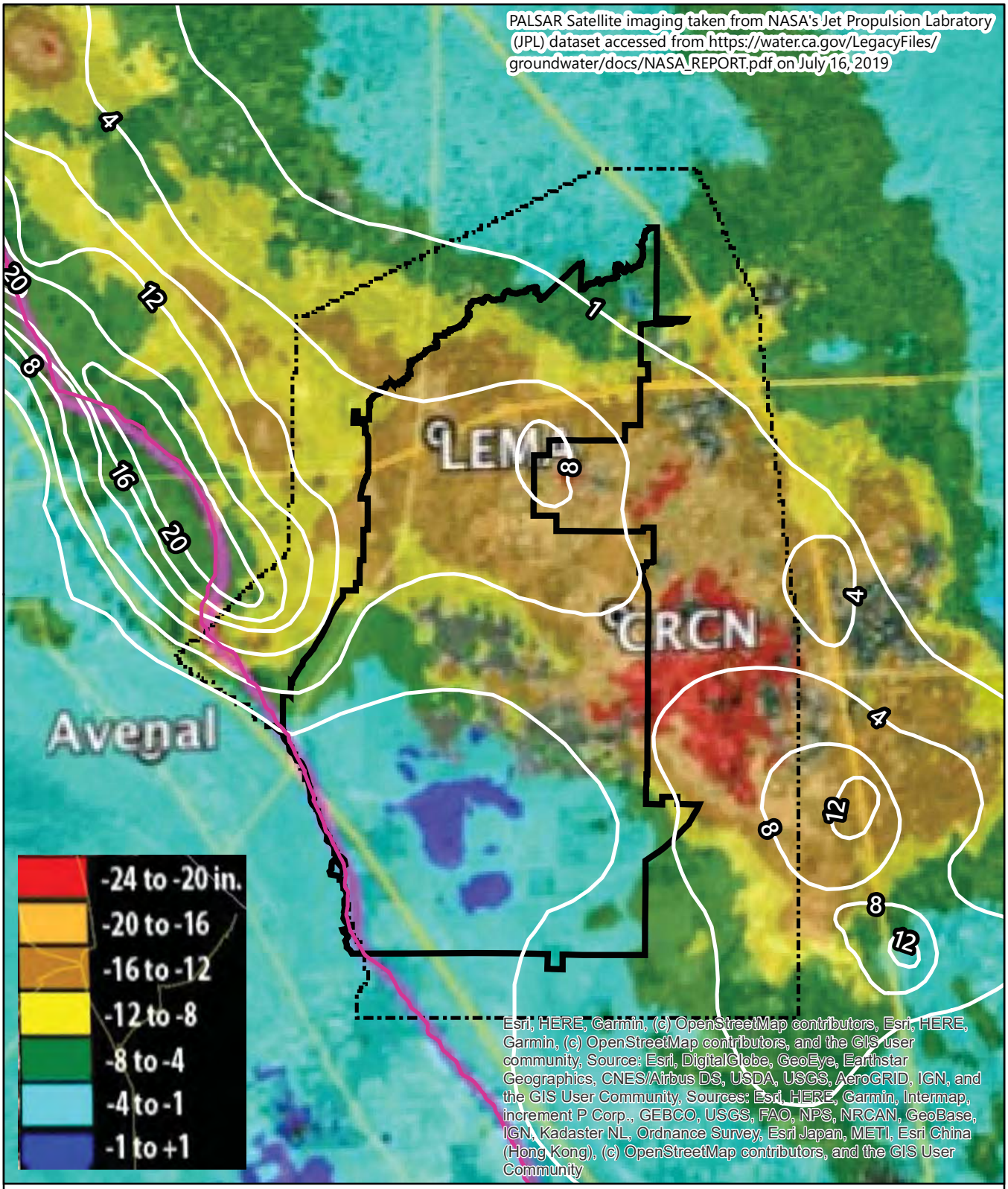
1. Vertical Displacement dataset taken from California Department of Water Resources (DWR) https://sgma.water.ca.gov/webgis. Accessed July 9, 2019.

Historical Subsidence of the Tulare Lake Subbasin

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/13/2019	Project No.: FR18161220
		Figure **D2-7**

Date: 12/13/2019 Printed by: shaina.price
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\AppendixD_figD2-7_Historical Subsidence TLSB8x11.mxd



Explanation

Subbasin boundary

Model domain

Edmund G. Brown California Aqueduct

White line shows historical subsidence data from 1926-1970 (ft.)

Miles
0 2 4 8
0 2.5 5 10
Kilometers

N

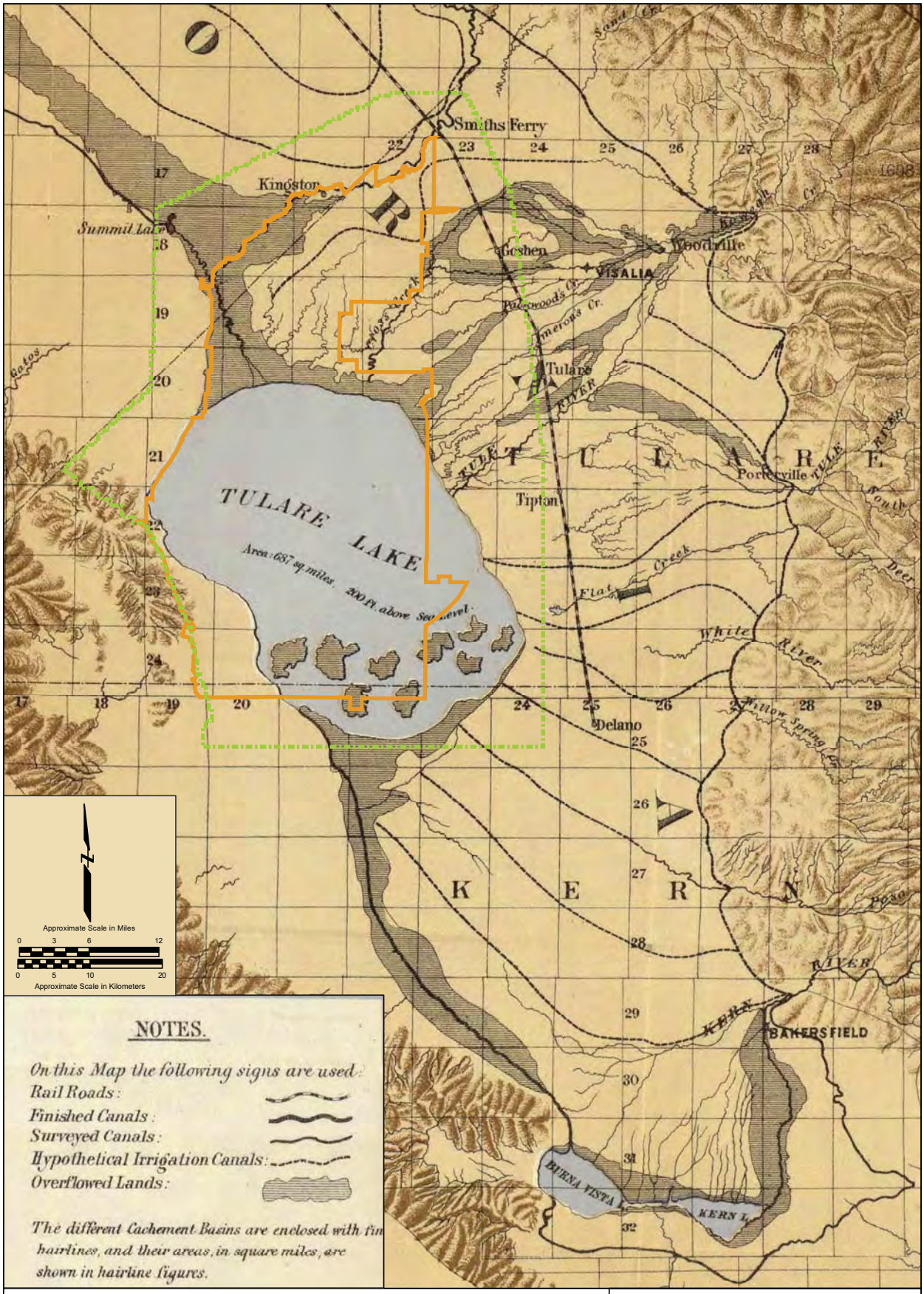
Subsidence in the Tulare Lake Subbasin 2007 to 2010

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/13/2019	Project No.: FR18161220
		Figure **D2-8**

Date: 12/13/2019 Printed by: shaina.price
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\AppendixD_figD2-8_Historical Subsidence TLSB8x11.mxd

Date: 12/12/2019 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\AppendixD_figD2-9a_Historic Surface Water Systems San Joaquin Valley.mxd



Explanation

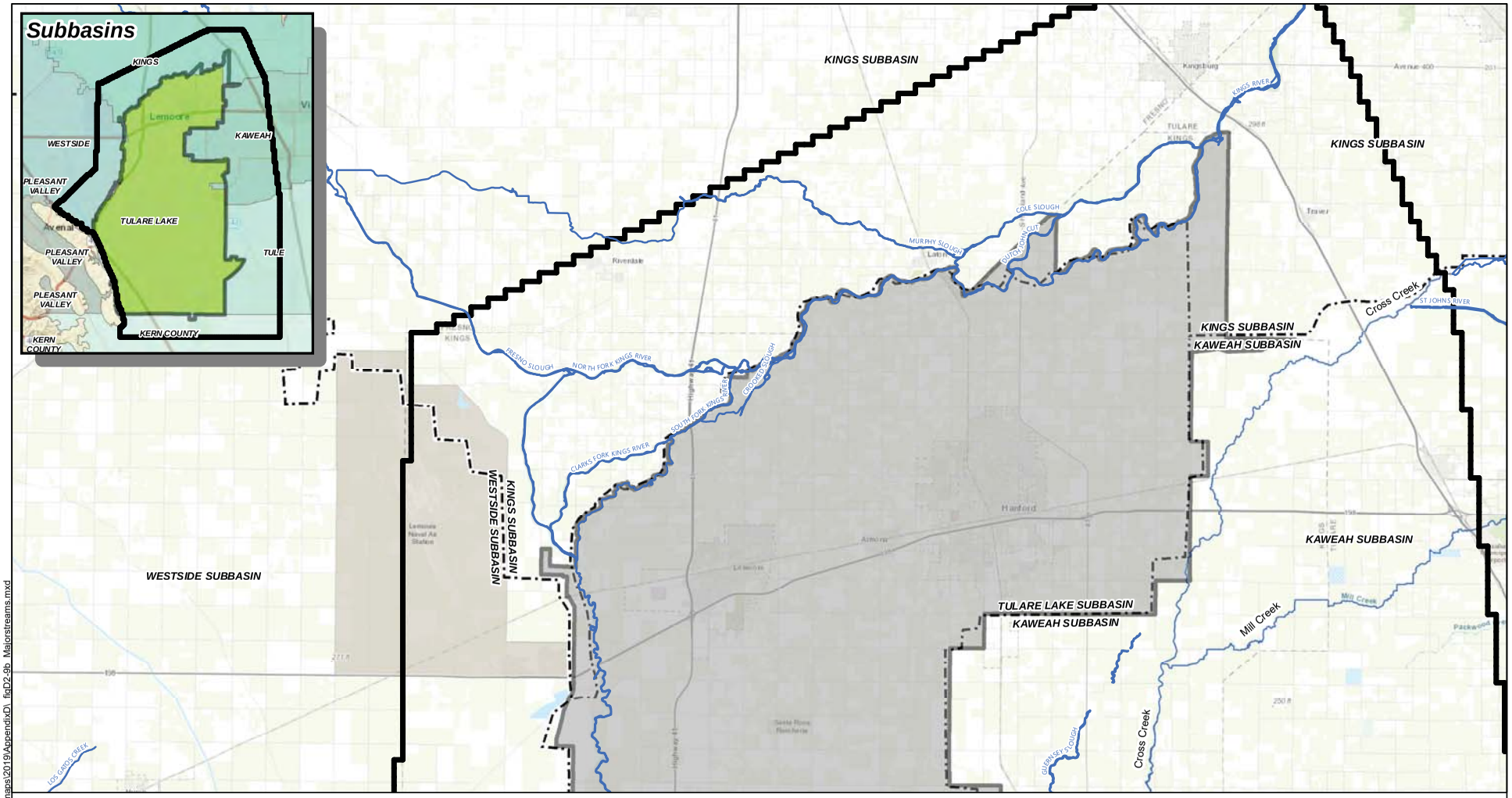
Model domain

Subbasin boundary

Note:
Adapted from "Map of the San Joaquin, Sacramento and Tulare Valleys, State of California, Prepared Under The Direction of the Board of Commissioners on Irrigation, 1873"

Historic Drainage System
Tulare Lake Basin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: GLK	Date: 12/12/2019	Project No.: FR16181220
		Figure **D2-9a**



N:_FR_projects\FR18s\FR18161220\gis\maps\2019\AppendixD_figD2-9b_Majorstreams.mxd

Explanation

- River/Lake [1]
- Model Domain
- Tulare Lake subbasin boundary
- Boundaries of adjacent subbasins

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

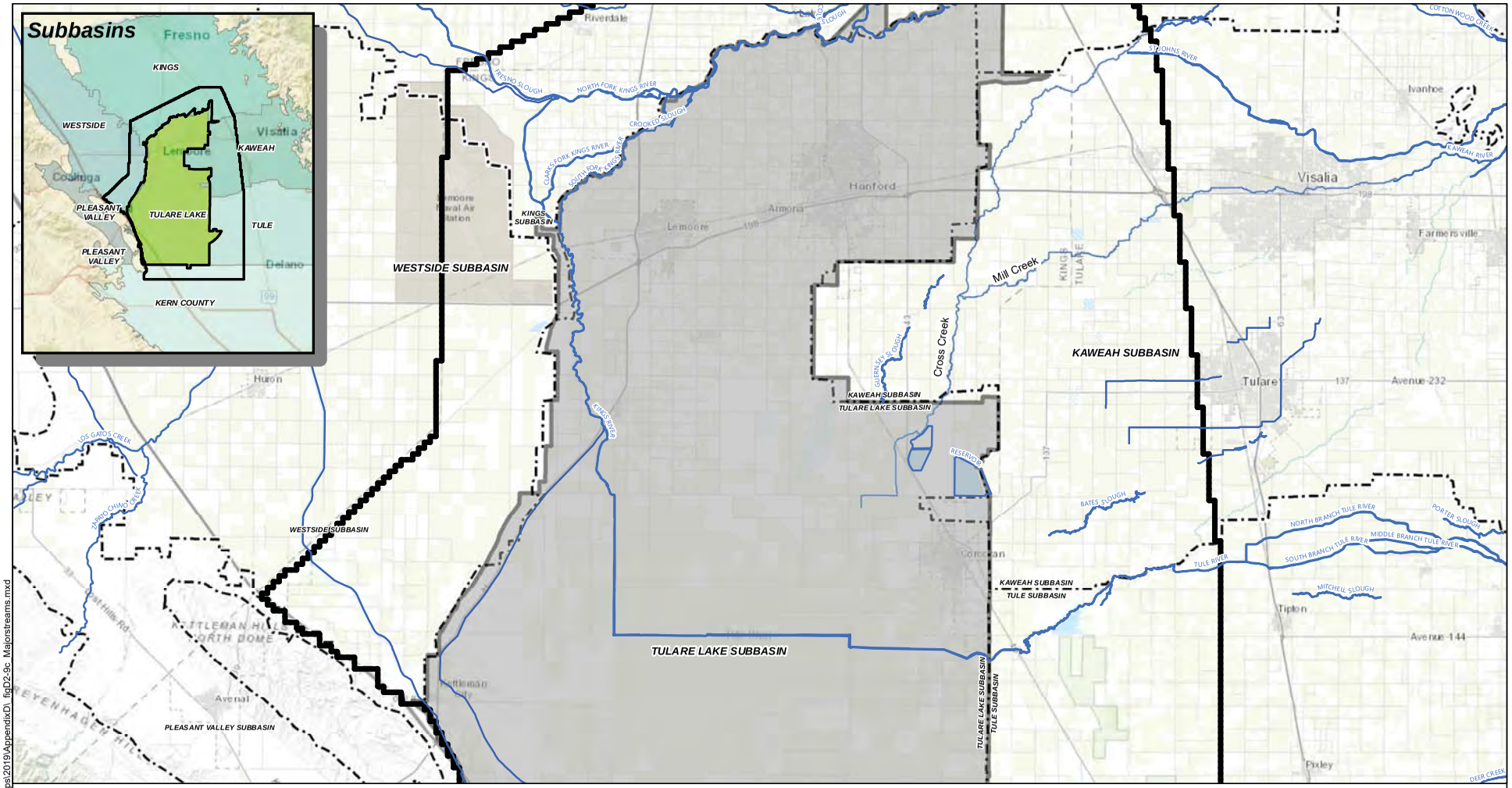
APPROXIMATE SCALE IN MILES
0 1 2 4
0 1 2 4
APPROXIMATE SCALE IN KILOMETERS

N

Notes:
1. Data accessed from the National Hydrography Dataset (2018)

Simulated Major Streams and Distribution Channels
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 12/13/2019	Project No.: FR18161220
		Figure **D2-9b**



Explanation

- River/Lake [1]
- Model Domain
- Tulare Lake subbasin boundary
- Boundaries of adjacent subbasins

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

APPROXIMATE SCALE IN MILES
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0 1 2 4
APPROXIMATE SCALE IN KILOMETERS

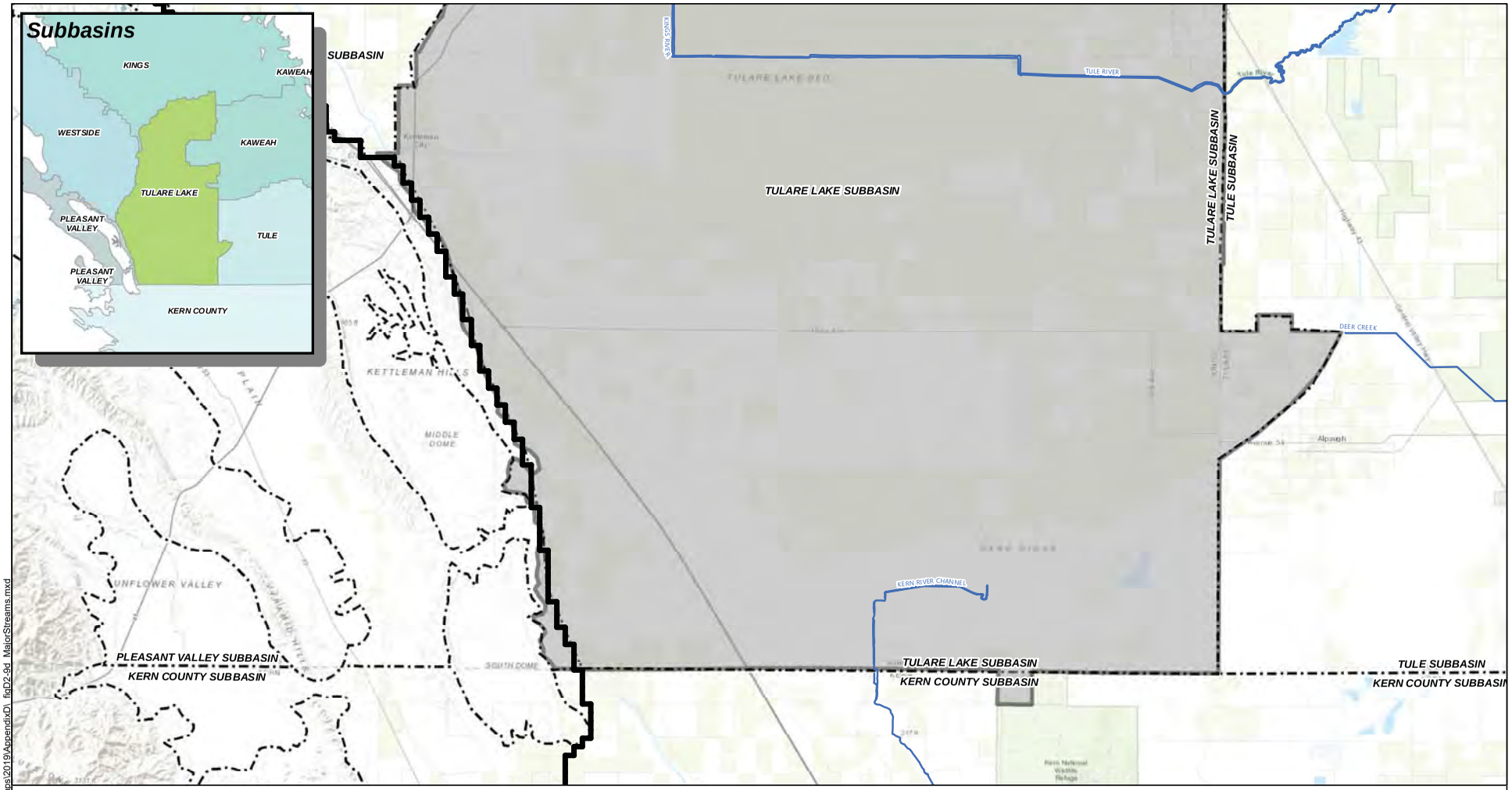
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Notes:
1. Data accessed from the National Hydrography Dataset (2018)

Major Streams and Distribution Channels
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/2/2020	Project No.: FR18161220
		Figure **D2-9c**

N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Appendix\D_figD2-9c_MajorsStreams.mxd



N:_FR_projects\FR18s\FR18161220\gis\maps\2019\Appendix\D_figD2-9d_MajorStreams.mxd

Explanation

- River/Lake [1]
- Model domain
- Subbasin boundary
- Boundaries of adjacent subbasins

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

APPROXIMATE SCALE IN MILES
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APPROXIMATE SCALE IN KILOMETERS
0 1 2 4

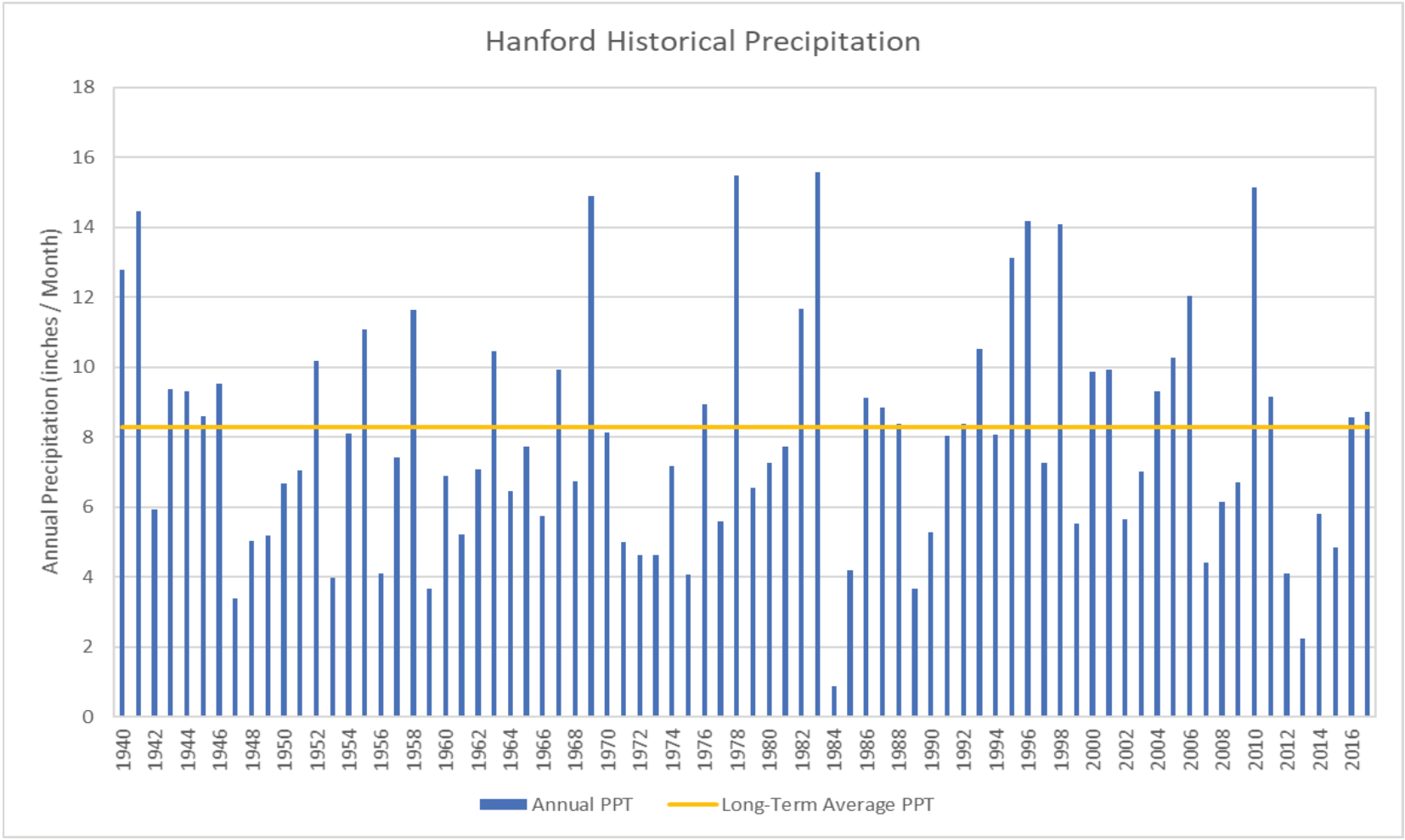
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Notes:
1. Data accessed from the National Hydrography Dataset (2018)

Major Streams and Distribution Channels
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

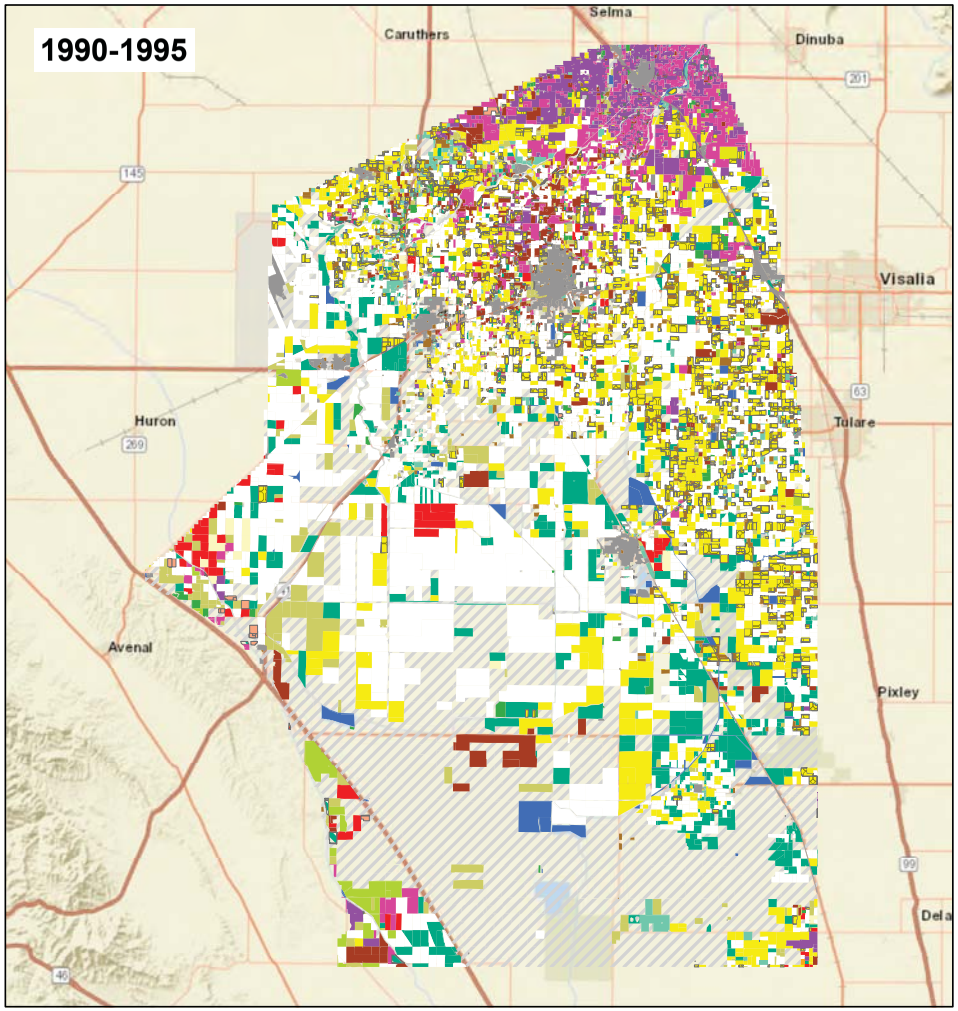
By: EMC	Date: 12/13/2019	Project No.: FR18161220
		Figure **D2-9d**

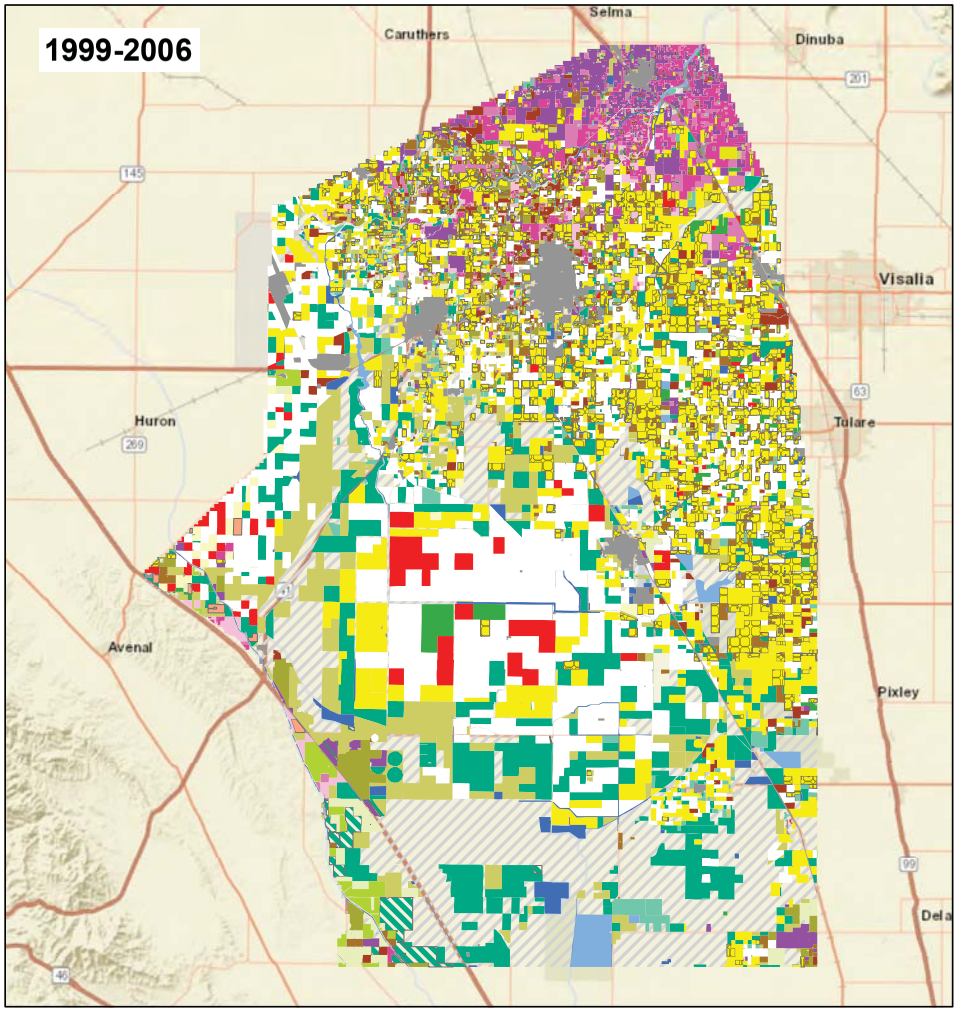
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\3-BasinSe□ing\Figures\DAV□S FOLD□R\DRAFT_TLSB_SGMA_GWModel_Figures_v3Fig D2-10 □an□ord PPT 12□13□2019



Historical Annual Precipitation
Hanford, California
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure D□□□□





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Explanation

- Alfalfa Hay and Clover
- Almonds (Young)
- Almonds (Adolescent)
- Almonds (Mature)
- Berries
- Carrot Single Crop
- Citrus (no ground cover)
- Corn and Grain Sorghum
- Cotton
- Dairy Single Crop
- Fallow Land
- Forest
- Grain and Grain Hay
- Melons
- Misc. field crops
- Onions and Garlic
- Open Water
- Pasture and Misc. Grasses
- Pistachio (Young)
- Pistachio (Adolescent)
- Pistachio (Mature)
- Pomegranates (Young)
- Pomegranates (Adolescent)
- Potatoes, Sugar beets, Turnip etc..
- Riparian
- Small Vegetables
- Stone Fruit (Young)
- Stone Fruit (Adolescent)
- Stone Fruit (Mature)
- Tomatoes and Peppers
- Urban, Commercial
- Urban, Industrial
- Wine Grapes with 80% canopy
- Winter Wheat

N

0 20,000 40,000

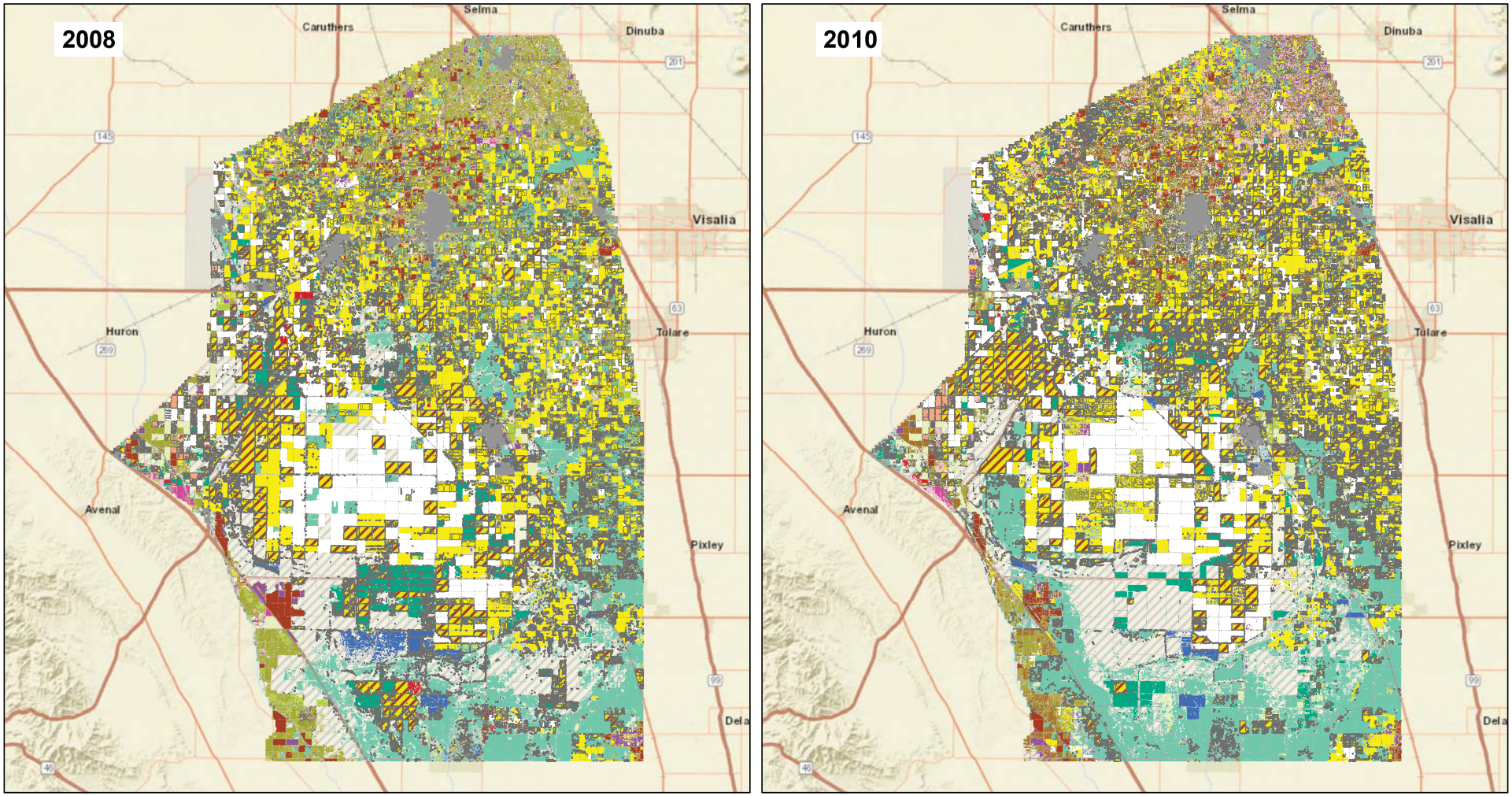
APPROXIMATE SCALE IN FEET

Crop Distributions

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: jmp	Date: 3/26/2019	Project No.: FR18161220
		Figure **D2-11a**

\\fsn-fs1\Graphics_FR_projects\FR18s\FR18161220\gis\maps\2018\Hydrogeologic_Conceptual_Model\Arcmap 10.4\ fig3-8a_CropDistributions_rev.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community

Explanation

- Alfalfa Hay and Clover
- Almonds (Young)
- Almonds (Adolescent)
- Almonds (Mature)
- Berries
- Carrot Single Crop
- Citrus (no ground cover)
- Corn and Grain Sorghum
- Cotton
- Dairy Single Crop
- Fallow Land
- Forest
- Grain and Grain Hay
- Melons
- Misc. field crops
- Onions and Garlic
- Open Water
- Pasture and Misc. Grasses
- Pistachio (Young)
- Pistachio (Adolescent)
- Pistachio (Mature)
- Pomegranates (Young)
- Pomegranates (Adolescent)
- Potatoes, Sugar beets, Turnip etc..
- Riparian
- Small Vegetables
- Stone Fruit (Young)
- Stone Fruit (Adolescent)
- Stone Fruit (Mature)
- Tomatoes and Peppers
- Urban, Commercial
- Urban, Industrial
- Wine Grapes with 80% canopy
- Winter Wheat

N

0 20,000 40,000

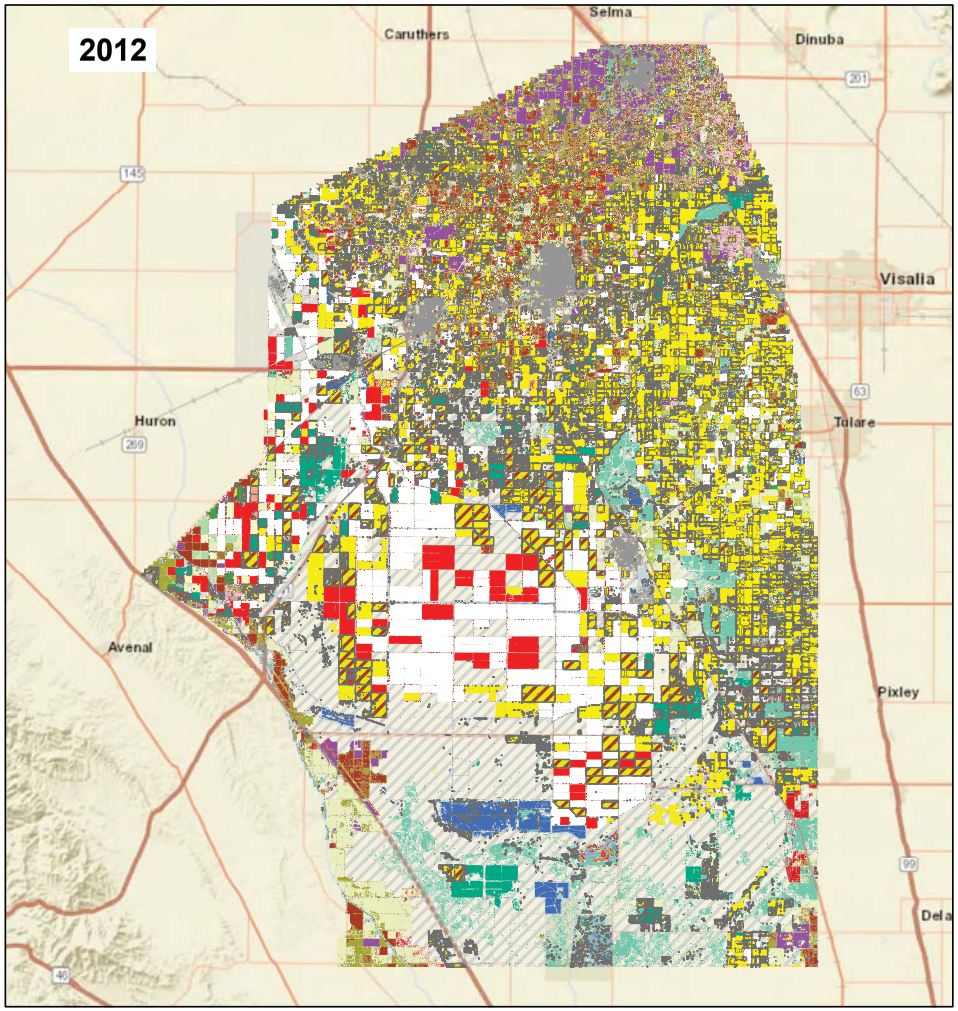
APPROXIMATE SCALE IN FEET

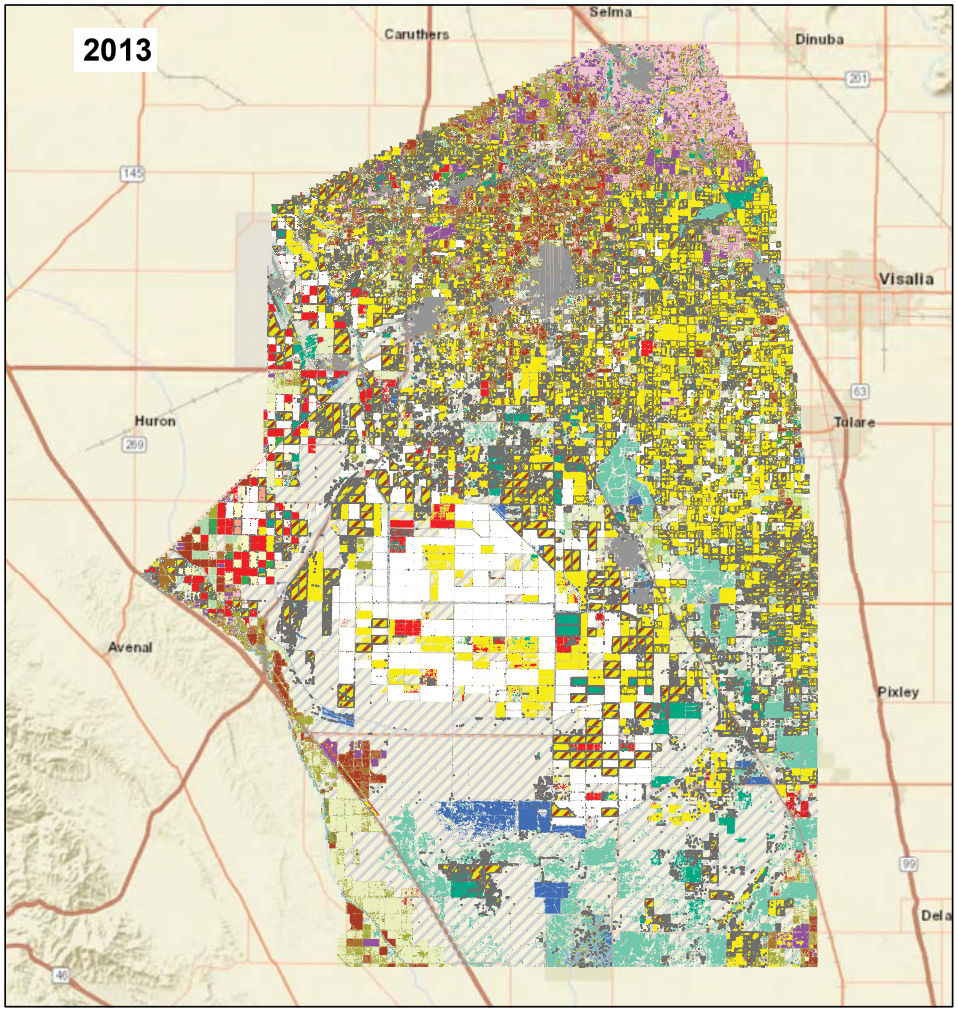
Crop Distributions

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: jmp	Date: 3/26/2019	Project No.: FR18161220
		Figure D2-11b

\\fsn-fs1\Graphics_FR_projects\FR18s\FR18161220\gismaps\2018\Hydrogeologic_Conceptual_Model\Arcmap 10.4_fig3-8b_CropDistributions_rev.mxd





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Explanation

- Alfalfa Hay and Clover
- Almonds (Young)
- Almonds (Adolescent)
- Almonds (Mature)
- Berries
- Carrot Single Crop
- Citrus (no ground cover)
- Corn and Grain Sorghum
- Cotton
- Dairy Single Crop
- Fallow Land
- Forest
- Grain and Grain Hay
- Melons
- Misc. field crops
- Onions and Garlic
- Open Water
- Pasture and Misc. Grasses
- Pistachio (Young)
- Pistachio (Adolescent)
- Pistachio (Mature)
- Pomegranates (Young)
- Pomegranates (Adolescent)
- Potatoes, Sugar beets, Turnip etc..
- Riparian
- Small Vegetables
- Stone Fruit (Young)
- Stone Fruit (Adolescent)
- Stone Fruit (Mature)
- Tomatoes and Peppers
- Urban, Commercial
- Urban, Industrial
- Wine Grapes with 80% canopy
- Winter Wheat

N

0 20,000 40,000

APPROXIMATE SCALE IN FEET

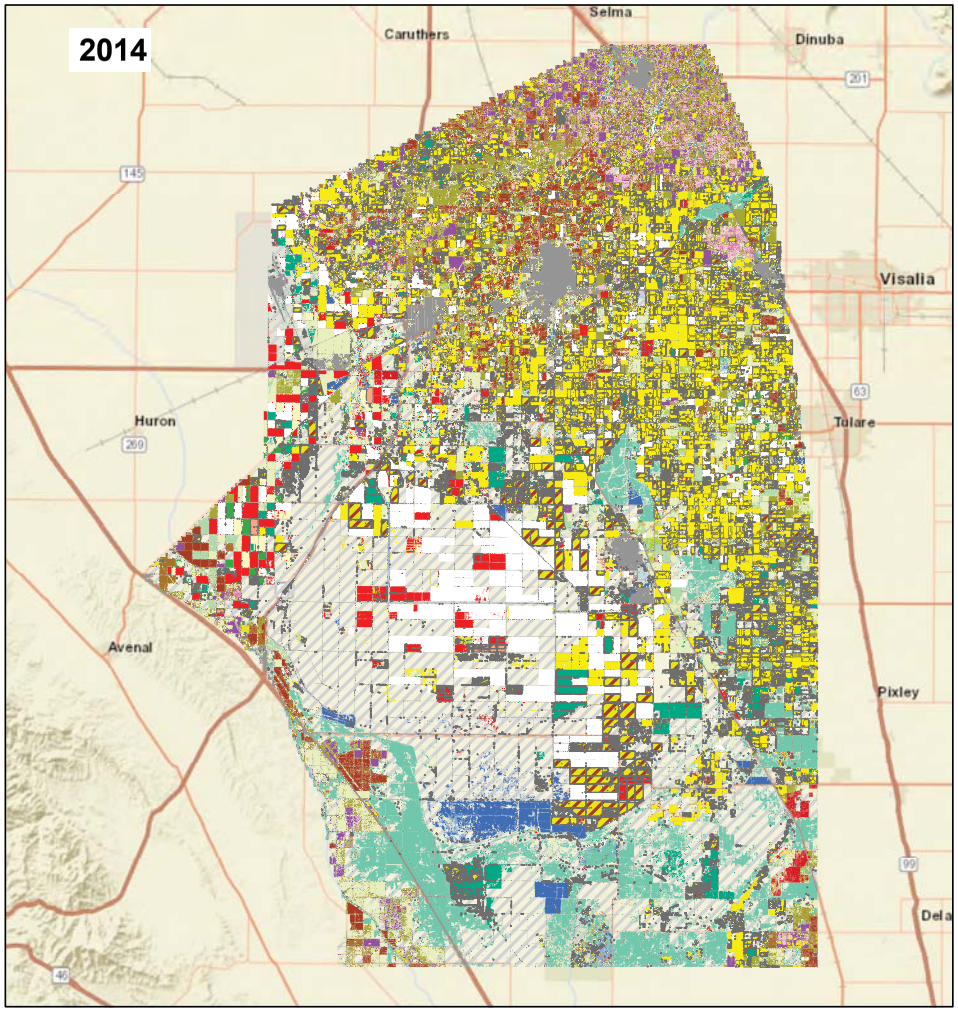
Crop Distributions

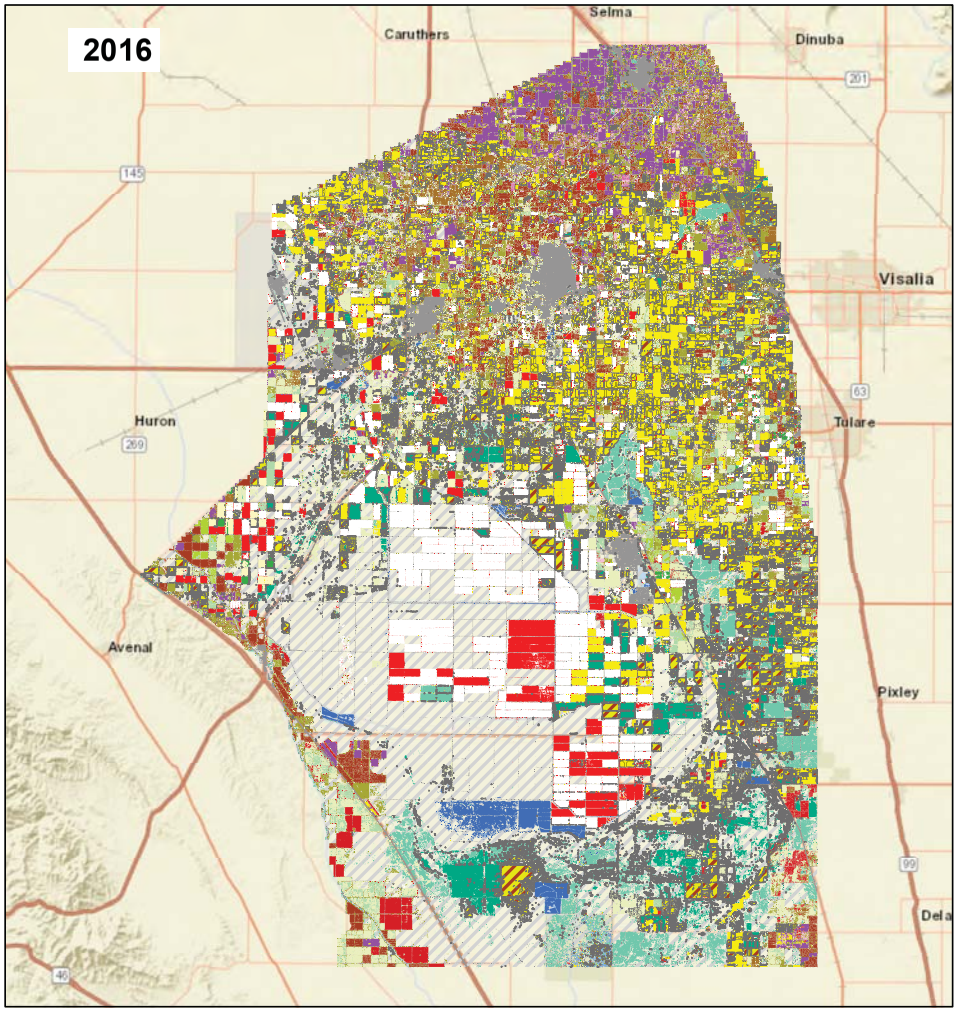
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: jmp	Date: 3/26/2019	Project No.: FR18161220

Figure **D2-11c**

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Explanation

- Alfalfa Hay and Clover
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- Small Vegetables
- Stone Fruit (Young)
- Stone Fruit (Adolescent)
- Stone Fruit (Mature)
- Tomatoes and Peppers
- Urban, Commercial
- Urban, Industrial
- Wine Grapes with 80% canopy
- Winter Wheat

N

0 20,000 40,000

APPROXIMATE SCALE IN FEET

Crop Distributions

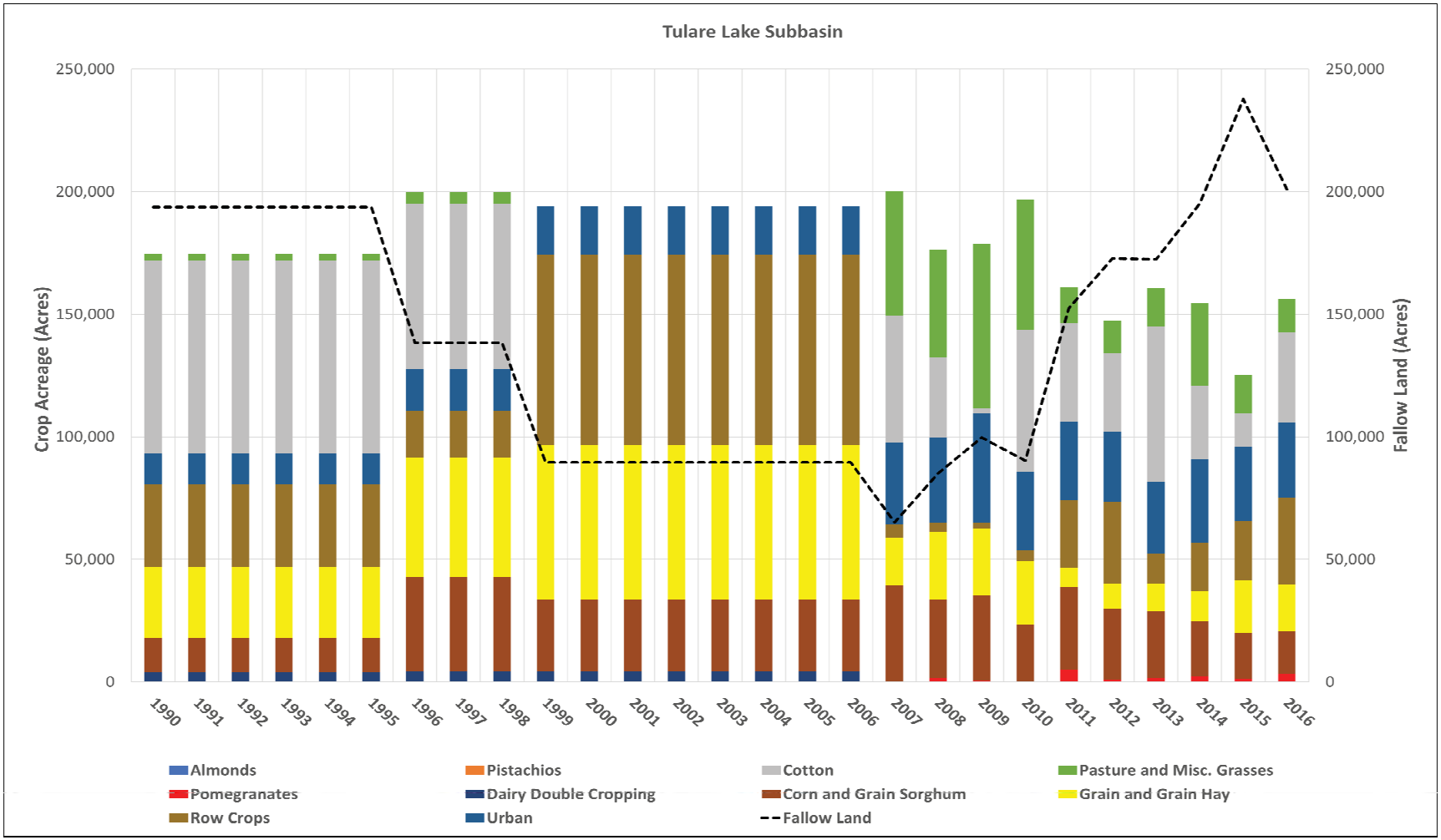
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: jmp	Date: 3/26/2019	Project No.: FR18161220

Figure **D2-11d**

\\fsn-fs1\Graphics_FR_projects\FR18s\FR18161220\gis\maps\2018\Hydrogeologic_Conceptual_Model\Arcmap 10.4_fig3-8d_CropDistributions_rev.mxd

N:_FR_projects\FR18s\FR18161220\temp\DBean_Hydro_\Wood Figure TemplatesFig 2-12 HstoricalCrop Acreage 9/7/2019



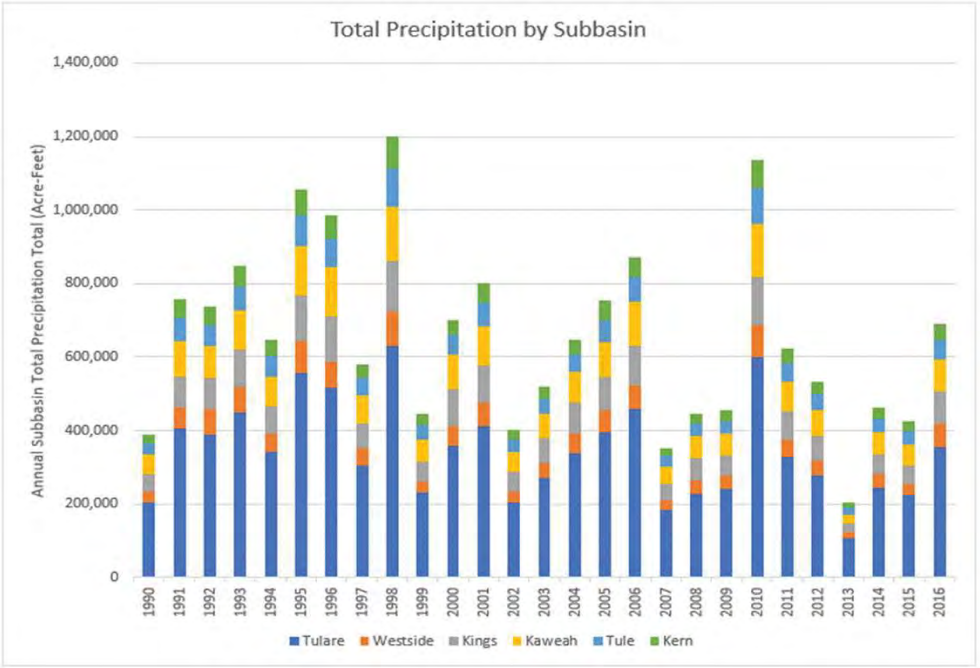
Historical Crop Acreage in Model Domain

Tulare Lake Subbasin Groundwater Sustainabilty Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-12**

ANNUAL TOTAL PRECIPITATION (ACRE-FEET)

SP	Tulare	Westside	Kings	Kaweah	Tule	Kern	Total
1990	205,446	28,212	48,930	51,309	30,947	24,023	388,867
1991	405,080	57,267	83,913	96,137	63,627	50,916	756,939
1992	390,074	67,498	84,716	87,700	57,619	48,389	735,997
1993	447,720	71,443	101,727	105,426	65,907	54,792	847,015
1994	340,437	50,626	75,966	80,699	54,192	45,398	647,318
1995	556,440	85,801	126,208	134,572	83,809	68,943	1,055,774
1996	517,621	70,468	123,183	132,981	78,164	62,576	984,993
1997	304,204	46,045	70,190	75,198	46,704	38,101	580,442
1998	628,620	94,415	137,547	149,223	102,104	88,545	1,200,453
1999	231,988	30,280	53,202	60,123	39,033	32,569	447,196
2000	358,410	53,273	99,777	96,159	51,600	40,115	699,334
2001	411,922	63,322	101,366	106,449	63,662	52,859	799,578
2002	205,011	30,798	53,013	53,586	32,171	26,641	401,219
2003	270,548	40,570	66,233	68,593	40,425	33,269	519,638
2004	339,269	53,188	82,590	83,239	49,381	40,603	648,271
2005	394,033	61,121	90,935	93,355	60,700	53,816	753,960
2006	457,938	64,091	108,085	119,504	69,821	52,995	872,434
2007	184,578	26,460	44,432	46,579	29,322	21,777	353,148
2008	228,631	37,419	58,349	59,869	35,246	27,247	446,762
2009	240,260	36,916	55,236	59,739	34,814	29,497	456,461
2010	598,897	88,582	130,029	144,182	96,270	80,046	1,138,006
2011	328,748	46,550	76,276	80,288	51,437	40,143	623,442
2012	277,729	39,653	66,630	72,324	43,489	33,195	533,019
2013	108,142	15,048	22,376	25,747	19,794	14,606	205,713
2014	243,088	37,368	54,143	61,105	38,200	29,654	463,558
2015	223,458	29,592	51,681	58,217	35,773	25,262	423,982
2016	356,639	60,978	87,691	88,184	53,105	44,307	690,904
min	108,142	15,048	22,376	25,747	19,794	14,606	205,713
max	628,620	94,415	137,547	149,223	102,104	88,545	1,200,453
mean	342,775	51,370	79,793	84,833	52,864	42,973	654,608

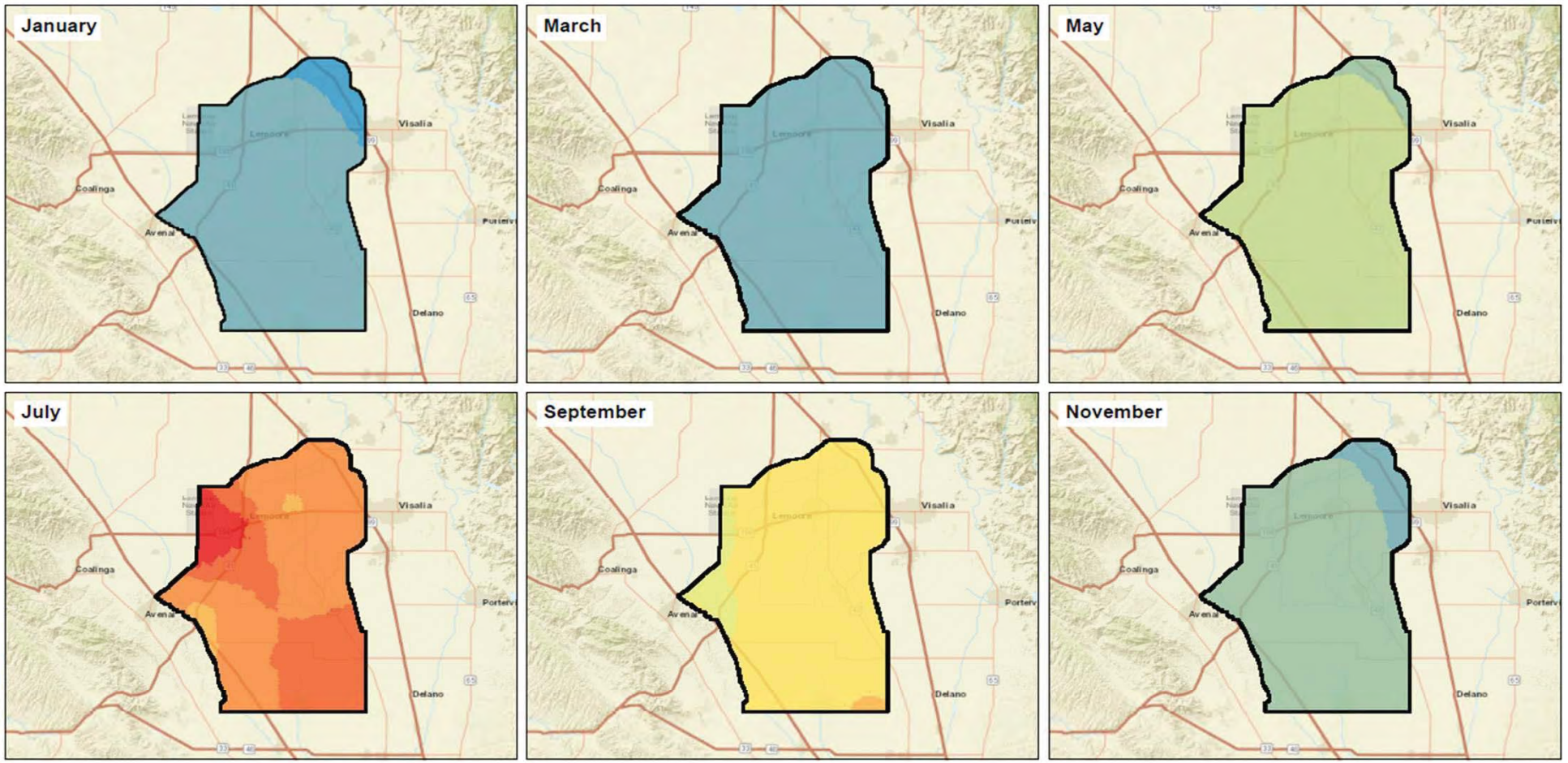


Note:
Annual precipitation totals are based on 4-kilometer grids of precipitation from the Oregon State University PRISM database. Monthly totals taken from January 1990 to December 2016

Estimated Annual Total Precipitation by Subbasin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-13a**

N:_FR_projects\FR18s\FR18161220\temp\DBean_Hydro_\Wood Figure TemplatesFig 2-13b Month Avg PPT_9/7/2019



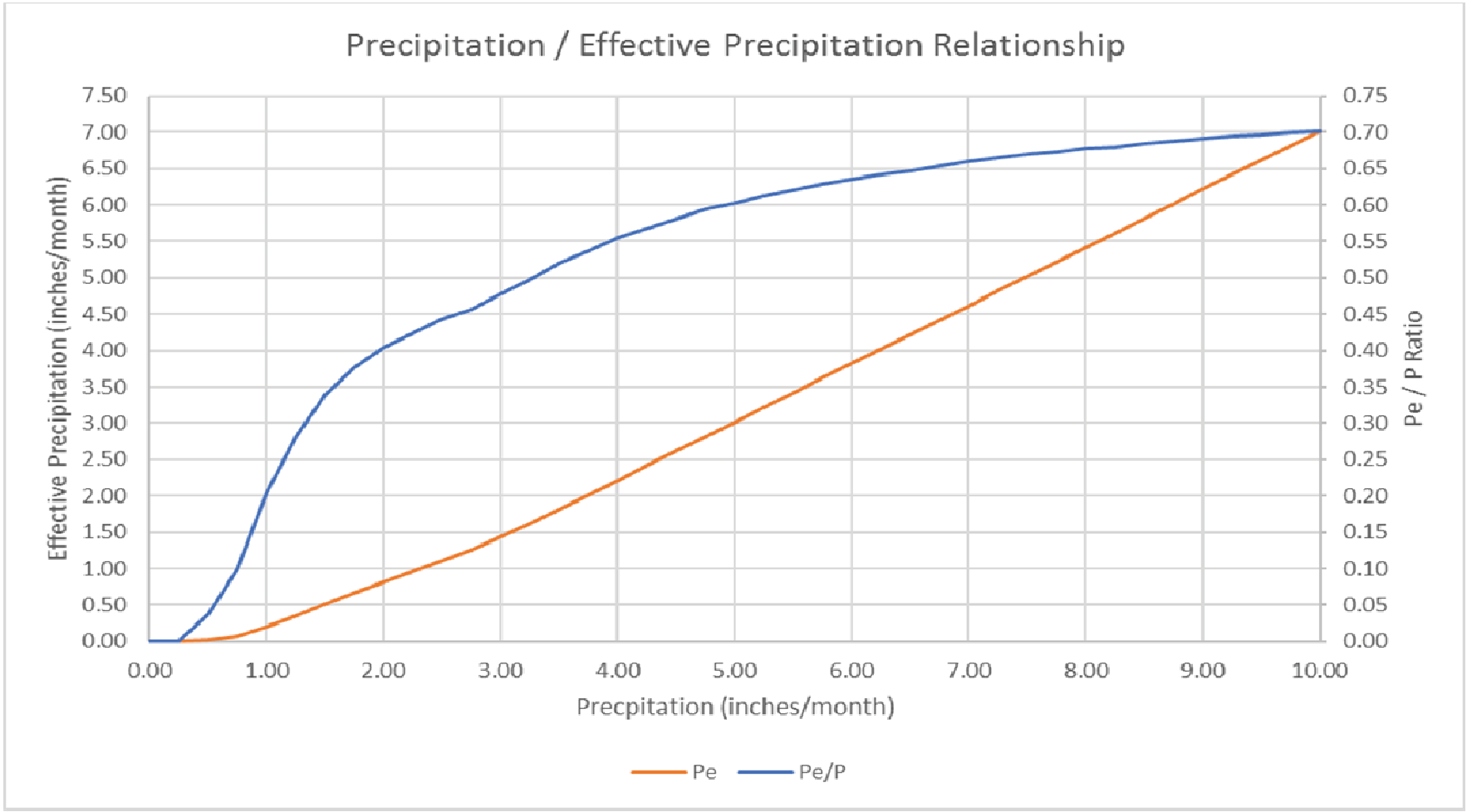
Average Monthly Precipitation Across Model Domain 1990-2016

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 09/07/19	Project No.: FR18161220
		Figure **D2-13b**

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I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D2-14 PPT-Pe
12/19/2019



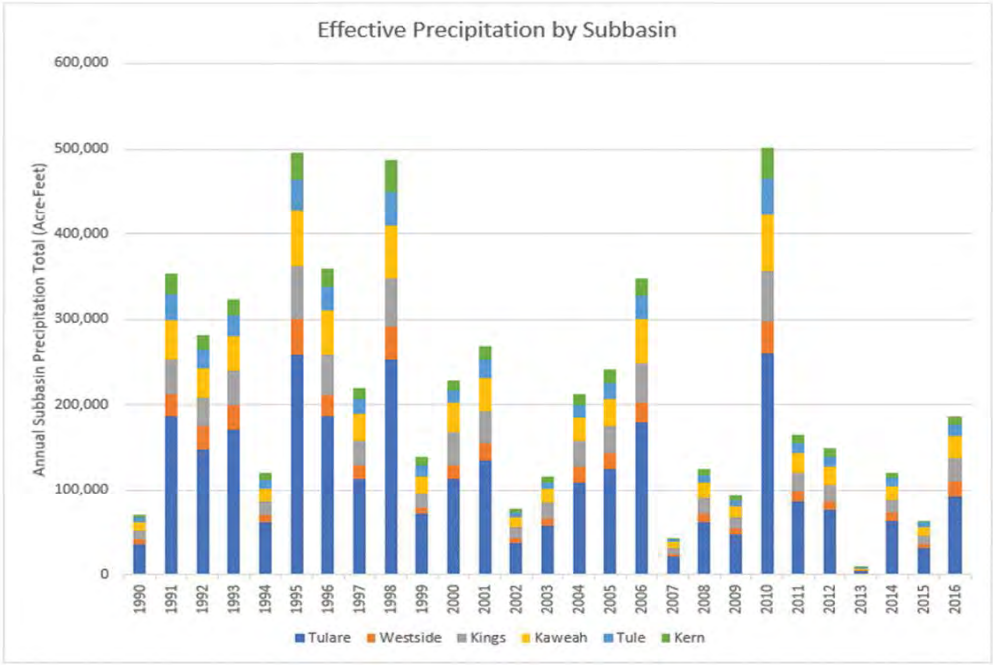
Modified from:
United Nations Food and Agricultre Organization (FAO)
FAO 56, Chapter 3 Table 6
Precipitation (P) and Effective Precipitation (Pe) in mm/month

Precipitation Versus Effective Precipitation
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-14**

ANNUAL EFFECTIVE PRECIPITATION (ACRE-FEET)

Date	Tulare	Westside	Kings	Kaweah	Tule	Kern	Total
1990	35,788	5,208	10,921	10,176	4,812	3,714	70,619
1991	187,134	25,313	40,273	46,723	29,809	23,715	352,967
1992	148,073	27,645	33,148	33,386	21,388	17,350	280,990
1993	170,267	29,369	40,873	40,049	23,350	19,250	323,158
1994	61,232	8,593	15,645	16,141	10,127	8,240	119,978
1995	259,175	41,208	62,347	64,874	37,212	30,391	495,207
1996	186,149	24,278	48,754	51,487	27,483	21,442	359,593
1997	113,642	15,748	28,680	30,918	17,369	13,352	219,710
1998	252,323	38,854	56,898	60,724	41,542	36,341	486,681
1999	71,917	7,632	16,648	20,114	13,016	10,619	139,945
2000	113,113	16,314	38,555	34,058	15,532	11,155	228,726
2001	134,333	20,616	37,779	38,654	20,766	17,000	269,148
2002	37,068	5,535	12,943	11,666	5,956	4,445	77,613
2003	57,809	8,545	17,995	17,097	8,207	6,806	116,460
2004	109,787	18,411	29,462	28,012	14,496	12,064	212,232
2005	124,268	19,089	31,607	31,363	18,469	16,100	240,896
2006	179,592	23,246	45,635	51,807	27,290	19,450	347,021
2007	20,953	2,745	7,604	7,072	3,259	1,764	43,397
2008	61,111	11,105	18,873	18,211	9,119	6,389	124,809
2009	47,768	7,417	12,492	13,028	6,456	5,711	92,872
2010	260,214	37,095	58,830	65,701	43,440	35,754	501,035
2011	86,495	12,603	22,107	21,802	12,693	9,244	164,943
2012	75,839	10,048	19,758	21,768	12,555	8,764	148,732
2013	4,721	561	939	1,214	1,153	735	9,322
2014	63,051	9,701	14,375	17,224	9,896	6,761	121,008
2015	30,969	4,190	10,169	11,275	5,114	1,900	63,617
2016	92,375	18,143	27,302	25,956	12,925	10,086	186,788
min	4,721	561	939	1,214	1,153	735	9,322
max	260,214	41,208	62,347	65,701	43,440	36,341	501,035
mean	110,562	16,638	28,171	29,278	16,794	13,279	214,721



Note:
Annual effective precipitation totals are based on 2 kilometer grids of precipitation from the Oregon State University PRISM database and Effective Precipitation Chart

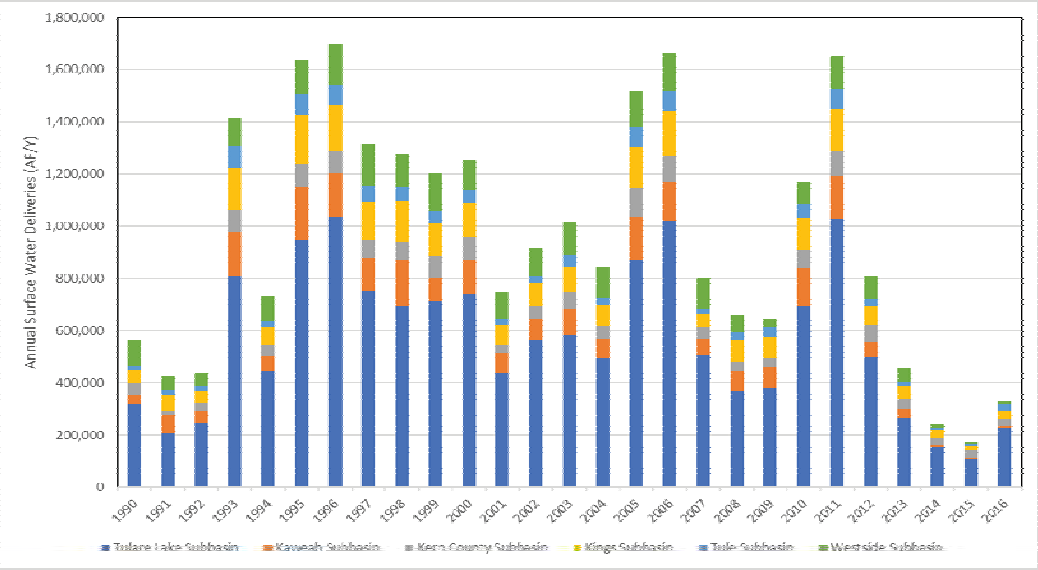
Estimated Annual Effective Precipitation by Subbasin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-15**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D2-16 SW Diversions 12/19/2019

Annual Surface Water Deliveries (Acre-Feet / Year)

Date	Tulare Lake Subbasin	Kaweah Subbasin	Kern County Subbasin	Kings Subbasin	Tule Subbasin	Westside Subbasin	Total Model Domain
1990	319,638	34,691	46,977	47,706	14,494	101,753	565,259
1991	209,115	66,976	16,670	60,707	20,365	50,314	424,147
1992	244,988	48,175	29,248	47,266	18,257	51,537	439,472
1993	810,344	165,910	83,835	160,515	85,065	109,771	1,415,439
1994	443,205	56,606	44,535	69,284	22,852	94,931	731,414
1995	947,855	199,690	91,209	186,720	82,330	127,670	1,635,474
1996	1,036,790	163,574	87,848	177,280	75,768	155,283	1,696,544
1997	748,244	131,645	68,613	142,094	63,303	162,313	1,316,212
1998	693,058	179,630	69,486	153,596	54,029	127,191	1,276,990
1999	712,379	90,346	82,217	123,948	49,408	147,138	1,205,436
2000	740,630	131,085	85,279	129,655	53,811	114,126	1,254,586
2001	437,390	75,793	31,430	73,740	27,230	100,268	745,851
2002	563,492	79,353	51,035	87,765	28,672	107,362	917,680
2003	582,626	100,822	63,030	96,972	46,562	125,166	1,015,176
2004	495,419	71,381	49,475	80,158	28,180	120,407	845,020
2005	872,486	161,327	109,892	158,076	78,061	139,083	1,518,926
2006	1,019,418	150,216	100,573	170,799	74,941	147,368	1,663,316
2007	508,584	60,204	44,265	51,185	21,408	118,138	803,785
2008	370,440	74,103	34,343	83,836	29,913	64,483	657,118
2009	378,849	81,144	34,414	79,124	39,295	33,190	646,016
2010	693,453	145,197	71,837	120,646	54,005	81,772	1,166,909
2011	1,025,466	165,643	97,315	159,548	78,345	125,949	1,652,265
2012	498,360	56,953	65,646	72,022	26,220	90,518	809,719
2013	264,069	33,712	41,542	46,333	17,950	51,684	455,291
2014	154,035	8,482	24,232	31,689	7,799	15,092	241,330
2015	107,068	7,140	24,818	18,233	7,799	9,836	174,894
2016	227,433	8,482	24,232	31,689	24,908	15,092	331,837
1990-2016 Average	**559,438**	**94,381**	**58,296**	**98,540**	**41,888**	**95,831**	**948,374**
1998-2010 Average	**620,633**	**107,739**	**63,637**	**108,423**	**45,039**	**109,669**	**1,055,139**

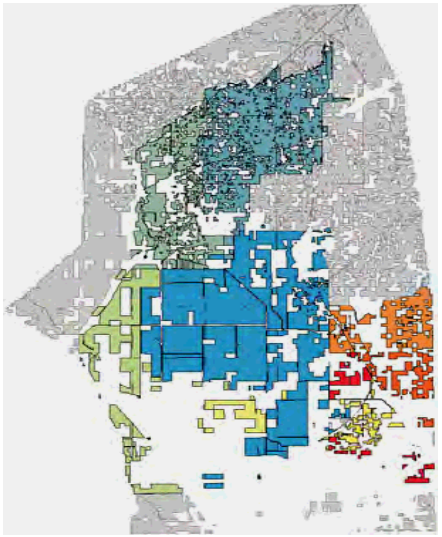


Estimated Annual Surface Water Diversions by Subbasin

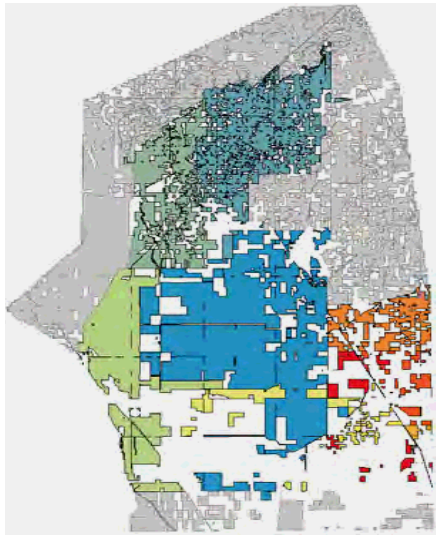
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-16**

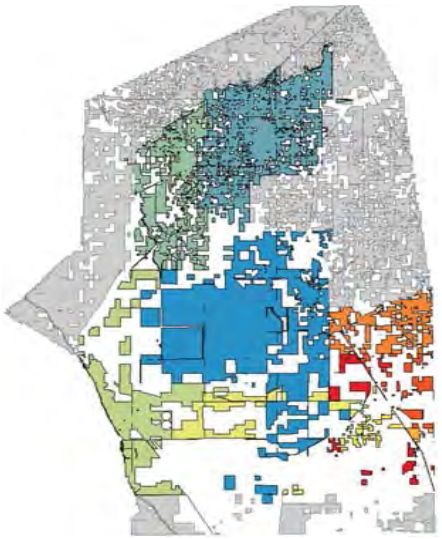
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D2-17 SW Delivery Areas 12/19/2019



1990 - 1995



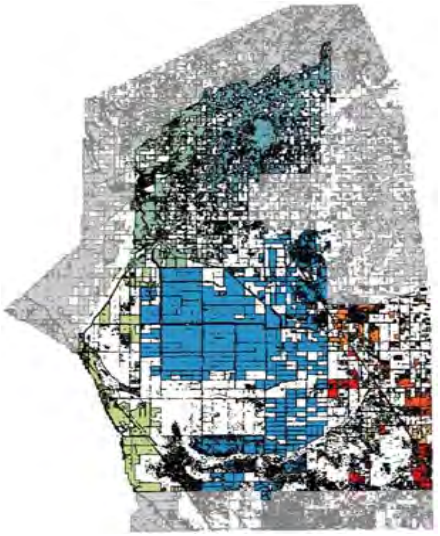
1996 - 1998



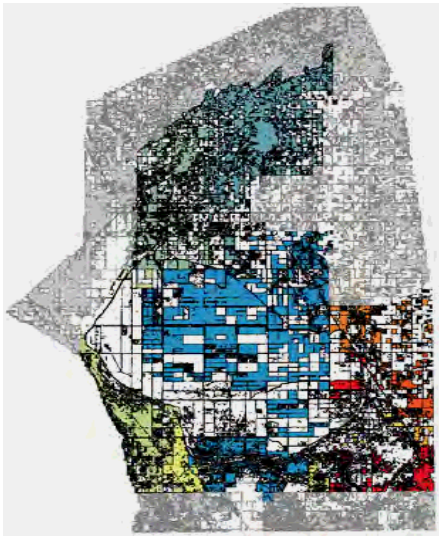
1999 - 2006



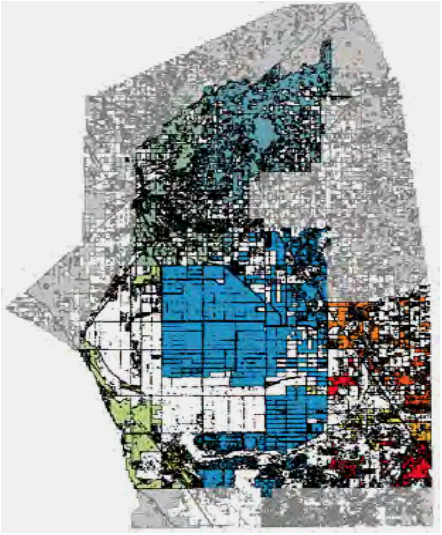
2009



2012



2014



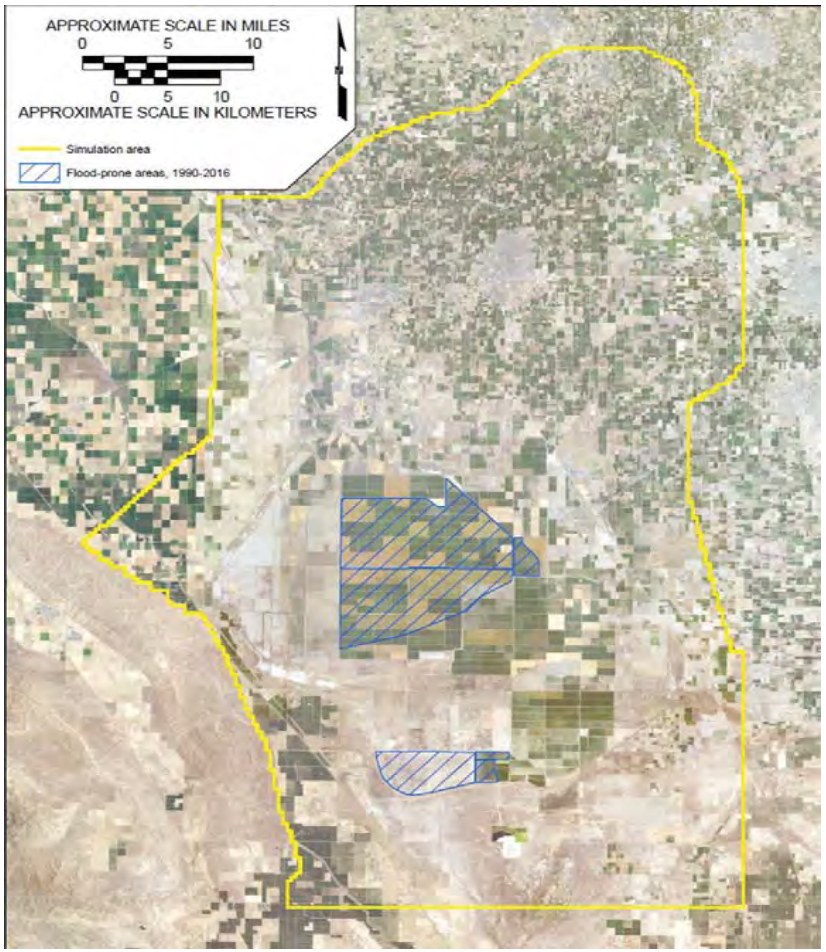
2016

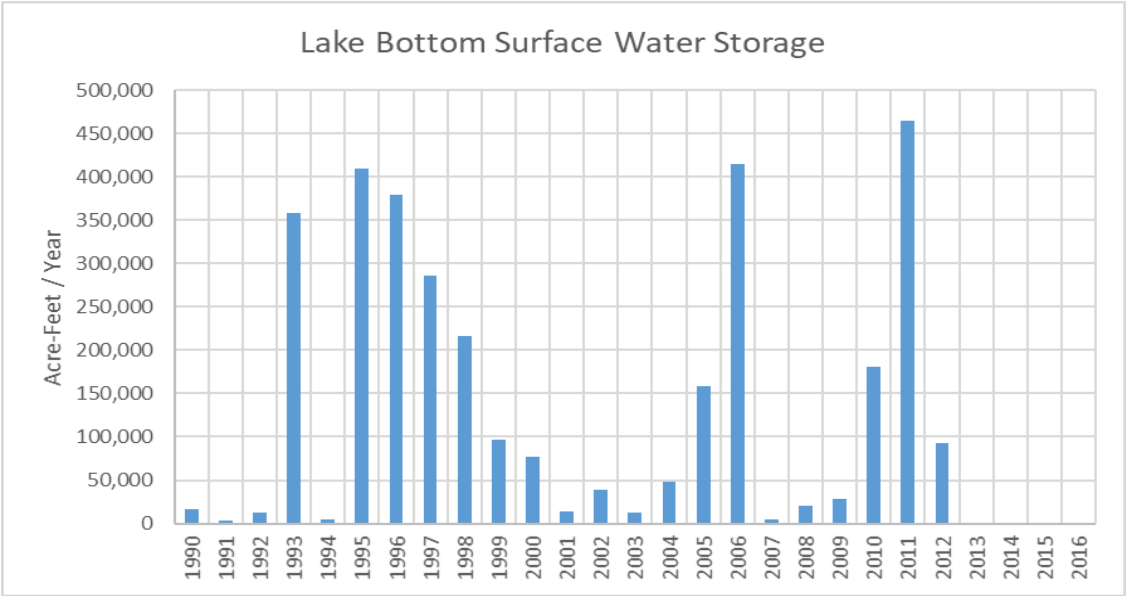
- Kaweah Subbasin, Greater Kaweah GSA
- Kaweah Subbasin, Mid-Kaweah GSA
- Kern County Subbasin, Kern Groundwater Authority GSA
- Kern County Subbasin, Semitropic
- Kings Subbasin, Central Kings GSA
- Kings Subbasin, Kings River East GSA
- Kings Subbasin, North Fork Kings GSA
- Kings Subbasin, South Kings GSA
- Tulare Lake Subbasin, Alpaugh GSA
- Tulare Lake Subbasin, El Rico GSA
- Tulare Lake Subbasin, Mid-Kings River GSA
- Tulare Lake Subbasin, South Fork Kings GSA
- Tulare Lake Subbasin, Southwest Kings GSA
- Tulare Lake Subbasin, Tri-County Water Authority GSA
- Tule Subbasin, Alpaugh GSA
- Tule Subbasin, Delano-Earlmart Irrigation District GSA
- Tule Subbasin, Lower Tule River ID GSA
- Tule Subbasin, Pixley ID GSA
- Tule Subbasin, Tri-County Water Authority GSA
- Westside Subbasin, Westlands Water District

Location of Surface Water Delivery Areas by Subbasin

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-17**





Explanation

Model Area

Surface Water Ponds

Location of Surface Water Storage Areas and Estimated Annual Lake Bottom Storage

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-18**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D2-19 CID Int RCH 12/19/2019



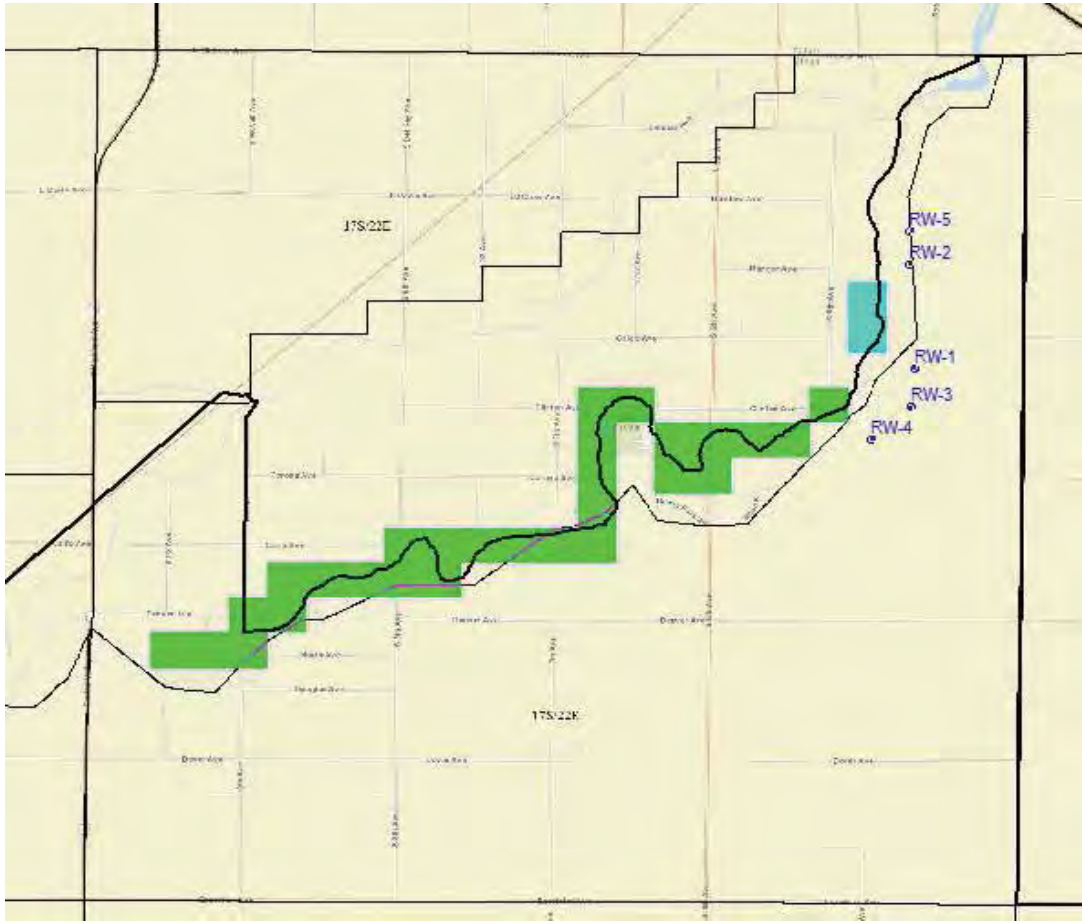
Date	Pond 1 (AF/Y)	Pond 2 (AF/Y)	Pond 3 (AF/Y)	Pond 4 (AF/Y)	Pond 5 (AF/Y)	Pond 6 (AF/Y)	Pond 7 (AF/Y)	Pond 8 (AF/Y)	Pond 9 (AF/Y)	Total (AF/Y)
1990	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0
1994	10,700	12,840	0	0	0	0	0	0	0	23,540
1995	10,700	12,840	0	0	0	0	0	0	0	23,540
1996	10,700	12,840	0	0	0	0	0	0	0	23,540
1997	10,700	12,840	0	0	0	0	0	0	0	23,540
1998	10,700	12,840	0	0	0	0	0	0	0	23,540
1999	0	0	0	0	0	0	0	0	0	0
2000	10,700	12,840	0	0	0	0	0	0	0	23,540
2001	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0
2003	10,700	12,840	0	0	0	0	0	0	0	23,540
2004	10,700	0	0	0	0	0	0	0	0	10,700
2005	10,700	12,840	14,980	14,980	0	0	0	0	0	53,500
2006	10,700	12,840	14,980	14,980	21,400	25,680	12,840	23,540	10,700	147,660
2007	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0
2009	10,700	0	0	0	0	0	0	0	0	10,700
2010	10,700	12,840	0	0	0	0	0	0	0	23,540
2011	10,700	12,840	14,980	14,980	21,400	25,680	12,840	23,540	10,700	147,660
2012	10,700	0	0	0	0	0	0	0	0	10,700
2013	0	0	0	0	0	0	0	0	0	0
2014	10,600	12,720	0	0	0	0	0	0	0	23,320
2015	10,700	12,840	0	0	0	0	0	0	0	23,540
2016	0	0	0	0	0	0	0	0	0	0
Total	171,100	166,800	44,940	44,940	42,800	51,360	25,680	47,080	21,400	616,100

Estimated Annual Intentional Recharge - Corcorian Irrigation District

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-19**

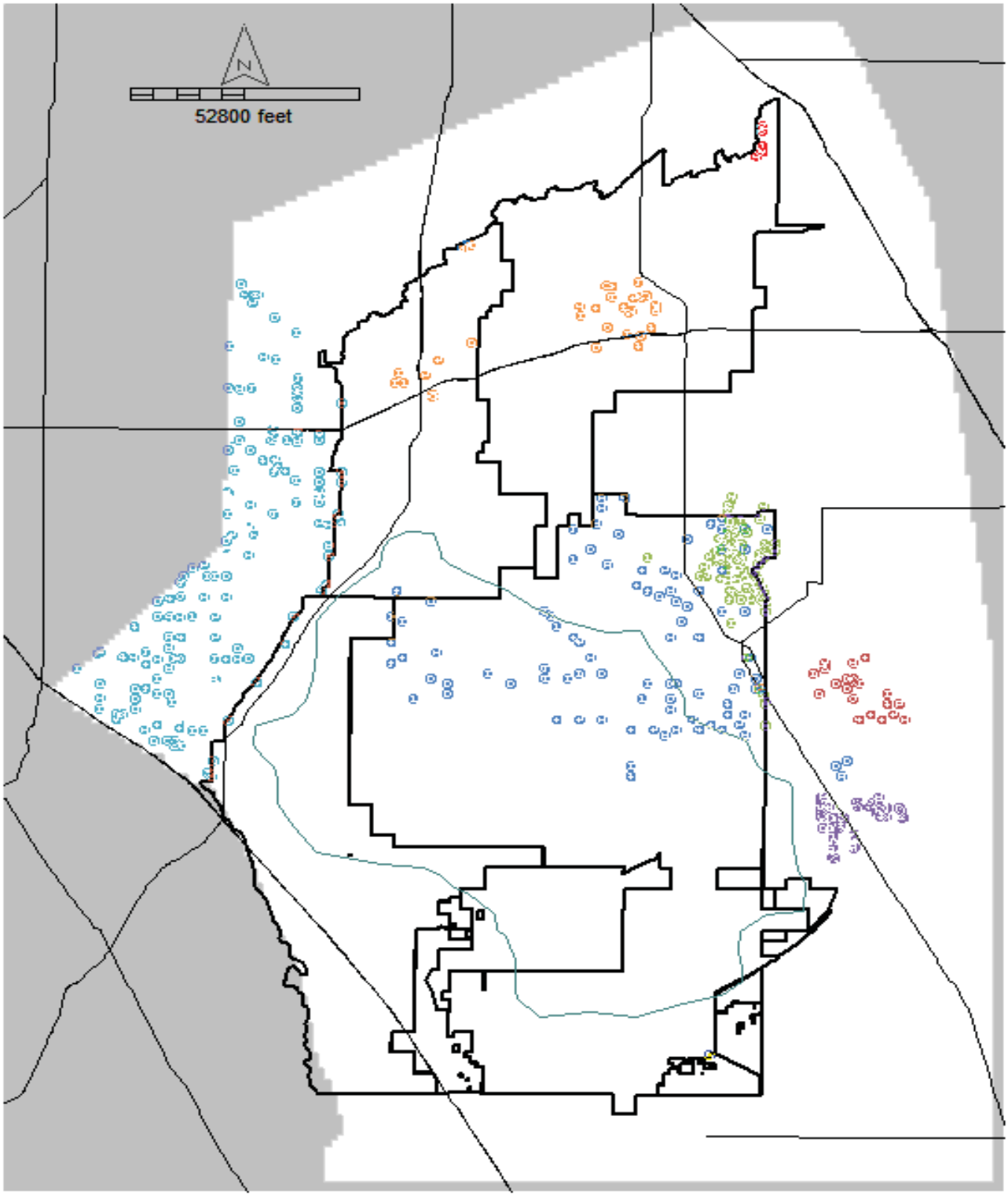
Date	Cond 8 Recharge (AF/Y)	APEX Recharge (AF/Y)	APEX Recovery (AF/Y)	APEX Storage (AF/Y)
1990	1,021	--	--	--
1991	0	--	--	--
1992	0	--	--	--
1993	61	--	--	--
1994	0	--	--	--
1995	36,806	--	--	--
1996	8,541	--	--	--
1997	19,259	--	--	--
1998	37,879	--	--	--
1999	0	--	--	--
2000	0	--	--	--
2001	0	--	--	--
2002	0	225	0	225
2003	0	3,742	526	3,216
2004	0	0	912	-912
2005	5,442	10,994	0	10,994
2006	22,611	12,152	6,939	5,213
2007	0	3,630	6,319	-2,689
2008	0	2,792	5,435	-2,643
2009	0	9,514	7,677	1,837
2010	0	9,154	6,345	2,809
2011	32,441	10,292	0	10,292
2012	0	3,692	9,044	-5,352
2013	0	6,962	4,970	1,992
2014	0	441	298	143
2015	0	0	0	0
2016	42,672	0	0	0
Total	206,732	73,590	48,465	25,125



Condition 8 Recharge Area
APEX Ranch Water Bank Recharge Pond
APEX Ranch Recover Well

Estimated Annual Intentional Recharge - Condition 8 and APEX Ranch
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-20**



- Municipal
- Westlands Water District
- Corcoran Irrigation District
- El Rico GSA
- Creighton Ranch
- Angiola Well Field
- Apex Ranch

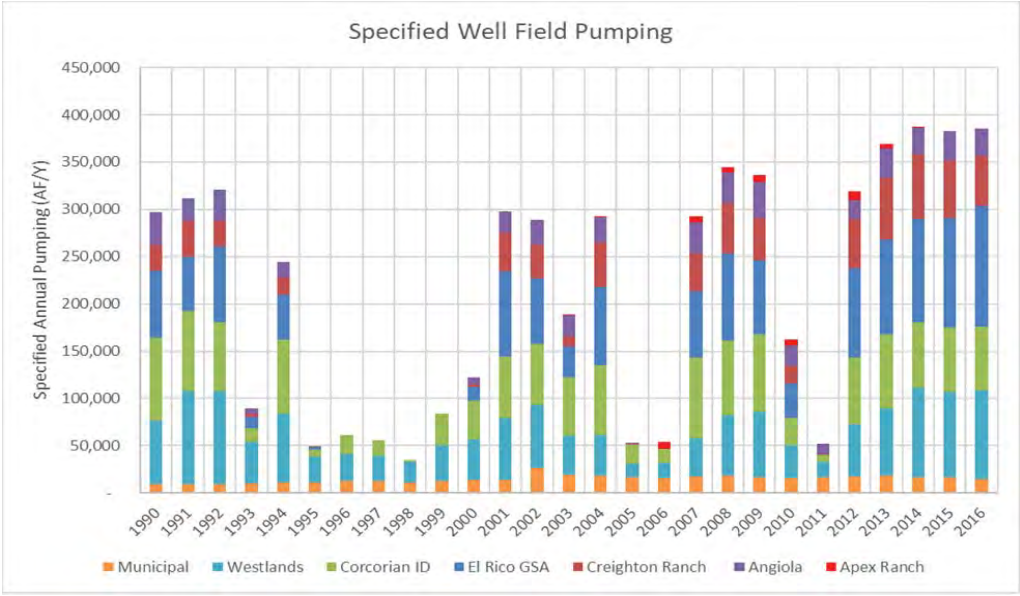
Location of Wells with Specified Pumping and Known Construction

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-21**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D2-21 Specified Well Map 12/19/2019

Date	El Rico GSA Well Field (AF/Y)	Creighton Ranch Well Field (AF/Y)	Corcorian ID Well Field (AF/Y)	Angiola Well Field (AF/Y)	Westlands Well Field (AF/Y)	Municipal Well Fields (AF/Y)	Apex Ranch Well Field (AF/Y)
1990	70,716	27,222	87,977	34,500	67,131	9,370	--
1991	57,509	38,484	84,438	23,396	98,656	9,109	--
1992	80,012	27,255	72,348	33,494	98,344	9,666	--
1993	11,395	4,035	14,248	5,956	44,056	10,208	--
1994	48,043	17,986	78,297	16,389	72,674	10,928	--
1995	2,897	905	7,145	-	27,589	10,775	--
1996	-	-	20,261	-	28,516	12,719	--
1997	-	-	15,586	-	27,000	12,775	--
1998	-	-	2,484	-	20,988	11,555	--
1999	-	-	33,406	-	37,185	13,087	--
2000	14,910	2,849	40,672	6,784	43,392	13,421	--
2001	89,799	41,120	64,353	23,244	65,947	13,895	--
2002	68,933	35,843	64,736	26,537	66,530	26,701	-
2003	32,420	10,856	62,246	22,429	40,841	19,349	526
2004	82,875	47,511	74,007	26,805	42,115	18,777	912
2005	-	468	20,138	662	14,744	16,536	-
2006	-	72	14,034	141	16,526	15,822	6,939
2007	69,863	40,266	85,434	32,894	40,373	17,221	6,319
2008	92,269	52,980	79,362	32,502	63,519	18,432	5,435
2009	78,097	45,292	81,493	37,798	69,904	16,354	7,677
2010	36,129	17,740	29,669	22,568	34,895	15,271	6,345
2011	606	314	7,328	11,336	15,509	17,042	-
2012	95,154	52,325	70,008	19,388	55,298	17,467	9,044
2013	100,275	66,005	78,175	30,528	70,940	18,411	4,970
2014	108,976	68,726	69,880	27,695	94,077	16,930	298
2015	116,254	61,050	67,982	30,220	90,723	16,146	-
2016	126,886	53,113	67,982	29,047	93,853	14,555	-



Notes:
1. El Rico Groundwater Sustainability Agency (GSA), Corcoran Irrigation District, and Creighton Ranch pumping provided by the El Rico GSA
2. Angiola Well Field pumping data provided by Angiola Water District
3. Westlands pumping provided by Westlands Water District
4. Municipal pumping and Apex pumping provided by various municipalities and Kings River Water District

Annual Specified Pumping by Well Field
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-22**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D2-23 Gross Water Balance 12/19/2019

Annual Crop Demand (AF/Y)

Date	TLSB	Westside	Kings	Kaweah	Tule	Kern	Total
1990	901,131	291,990	328,863	424,556	197,637	87,217	2,231,393
1991	901,119	288,262	328,849	424,556	197,637	87,217	2,227,639
1992	902,016	284,489	329,148	424,998	197,921	87,318	2,225,890
1993	901,095	283,147	328,833	424,556	197,637	87,217	2,222,484
1994	900,719	263,495	328,833	424,556	197,637	87,217	2,202,456
1995	900,633	243,070	328,775	424,556	197,637	87,217	2,181,887
1996	982,820	257,687	292,187	406,852	254,257	107,481	2,301,283
1997	985,893	268,823	300,664	408,439	253,933	108,406	2,326,158
1998	989,781	243,239	309,316	410,462	254,000	109,483	2,316,281
1999	1,062,749	263,950	316,538	415,430	253,992	63,054	2,375,713
2000	1,079,872	258,530	324,230	418,470	254,108	66,574	2,401,785
2001	1,089,515	283,910	325,407	419,045	253,769	69,132	2,440,778
2002	1,100,326	277,743	326,810	420,081	253,820	71,790	2,450,569
2003	1,111,248	299,919	328,199	421,117	253,870	74,447	2,488,801
2004	1,113,509	289,665	328,509	422,104	254,310	75,582	2,483,679
2005	1,113,269	268,262	328,310	422,163	253,971	76,507	2,462,481
2006	1,114,369	261,146	328,236	422,685	254,021	77,537	2,457,995
2007	1,074,260	280,336	257,665	387,633	290,933	205,928	2,496,756
2008	1,004,624	273,945	256,884	421,390	296,194	186,808	2,439,846
2009	1,012,322	305,821	256,214	336,797	250,674	237,356	2,399,183
2010	995,249	278,025	281,457	346,870	301,120	247,643	2,450,365
2011	764,558	257,795	219,117	346,680	152,303	67,393	1,807,847
2012	738,639	292,444	227,094	361,650	182,653	73,426	1,875,904
2013	743,729	318,593	202,452	346,907	166,566	96,210	1,874,457
2014	701,059	365,392	239,018	343,552	193,931	120,344	1,963,297
2015	566,898	370,658	223,336	318,118	170,463	83,566	1,733,039
2016	646,034	371,623	241,082	317,784	152,776	80,645	1,809,944
Min	566,898	243,070	202,452	317,784	152,303	63,054	1,733,039
Max	1,114,369	371,623	329,148	424,998	301,120	247,643	2,496,756
1990-2016 Average	940,646	286,739	292,075	394,889	227,325	104,545	2,246,219
1998-2010 Average	1,066,238	275,730	305,213	404,942	263,445	120,142	2,435,710

Annual Effective Precipitation Utilized by Crops (AF/Y)

Date	TLSB	Westside	Kings	Kaweah	Tule	Kern	Total
1990	19,958	4,318	9,898	10,134	4,021	1,244	49,574
1991	78,722	16,428	27,444	38,793	21,719	7,694	190,800
1992	64,818	24,269	24,144	28,899	15,747	5,740	163,617
1993	67,191	20,008	25,068	30,973	16,254	6,004	165,498
1994	34,514	6,123	14,367	15,929	7,877	2,828	81,637
1995	95,479	21,157	36,745	48,040	24,113	8,897	234,430
1996	100,745	20,047	33,683	44,875	24,361	9,632	233,344
1997	58,885	12,805	17,579	24,815	14,337	6,118	134,539
1998	116,167	25,963	38,123	50,183	32,155	14,137	276,727
1999	34,039	6,590	10,459	14,066	7,218	1,858	74,231
2000	70,413	13,814	26,881	29,672	15,472	3,995	160,246
2001	94,963	18,024	32,490	38,749	21,039	5,954	211,219
2002	26,034	4,299	12,099	11,948	5,990	1,685	62,054
2003	40,108	7,125	16,388	17,922	7,930	2,591	92,063
2004	74,858	15,360	24,636	28,506	14,362	4,272	161,995
2005	80,390	16,208	27,519	30,024	16,637	5,669	176,448
2006	104,703	19,345	34,578	43,910	25,059	7,201	234,795
2007	14,800	1,940	6,669	7,093	3,456	1,379	35,337
2008	35,836	9,454	12,655	18,355	10,733	4,599	91,630
2009	32,367	5,698	10,965	12,592	6,666	4,957	73,244
2010	88,203	22,750	27,939	32,256	23,244	16,507	210,899
2011	52,937	10,835	19,879	21,821	10,643	3,971	120,086
2012	45,317	8,817	17,930	23,369	12,074	5,282	112,788
2013	2,800	326	525	1,175	893	527	6,246
2014	30,586	10,563	12,275	15,813	7,632	3,413	80,282
2015	15,085	3,280	7,920	10,283	4,837	1,131	42,536
2016	41,890	13,881	19,341	21,746	9,312	4,102	110,272
Min	2,800	326	525	1,175	893	527	6,246
Max	116,167	25,963	38,123	50,183	32,155	16,507	276,727
1990-2016 Average	56,363	12,571	20,304	24,887	13,473	5,237	132,835
1998-2010 Average	62,529	12,813	21,646	25,790	14,612	5,754	143,145

Annual Farm Demand (AF/Y)

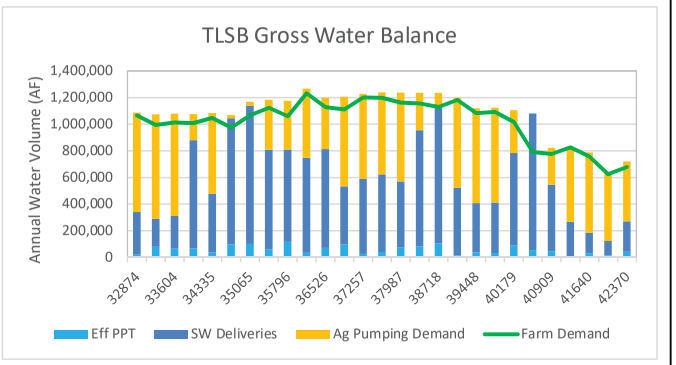
Date	TLSB	Westside	Kings	Kaweah	Tule	Kern	Total
1990	1,065,856	379,829	425,121	552,538	256,615	114,629	2,794,588
1991	994,832	358,828	401,725	514,334	233,176	106,035	2,608,931
1992	1,012,909	343,450	406,535	528,115	241,481	108,779	2,641,268
1993	1,008,709	347,335	404,875	524,762	240,425	108,288	2,634,395
1994	1,047,937	339,746	419,143	544,830	251,521	112,514	2,715,691
1995	973,503	292,869	389,226	502,007	229,979	104,424	2,492,007
1996	1,067,962	313,585	344,546	482,623	304,804	130,465	2,643,985
1997	1,123,726	337,872	377,306	511,503	317,630	136,383	2,804,420
1998	1,059,009	286,711	361,492	480,381	294,124	127,132	2,608,849
1999	1,232,448	339,665	407,814	535,160	327,150	81,596	2,923,833
2000	1,127,412	284,814	349,602	457,426	279,949	73,623	2,572,827
2001	1,111,506	309,426	344,390	447,420	273,032	74,325	2,560,098
2002	1,201,455	318,210	370,000	480,162	290,750	82,471	2,743,049
2003	1,198,411	341,139	366,586	474,349	288,517	84,529	2,753,532
2004	1,162,011	319,587	357,269	463,075	281,525	83,897	2,667,364
2005	1,155,548	293,659	353,639	461,355	278,436	83,344	2,625,980
2006	1,129,741	281,543	345,256	445,626	268,596	82,751	2,553,513
2007	1,183,096	324,200	294,958	447,694	338,016	240,627	2,828,591
2008	1,083,093	307,929	286,930	474,164	335,571	214,361	2,702,048
2009	1,091,697	349,701	288,327	381,416	286,941	273,394	2,671,475
2010	1,016,725	297,419	297,831	370,133	326,713	271,898	2,580,720
2011	791,090	287,744	234,224	382,183	166,368	74,617	1,936,226
2012	776,133	330,525	245,767	397,981	200,454	80,173	2,031,033
2013	826,405	371,025	237,221	406,748	194,551	112,569	2,148,518
2014	757,265	413,917	266,385	385,588	218,818	137,564	2,179,536
2015	624,647	428,797	253,146	362,160	194,523	96,982	1,960,255
2016	677,936	417,581	260,622	348,283	168,493	90,048	1,962,964
Min	624,647	281,543	234,224	348,283	166,368	73,623	1,936,226
Max	1,232,448	428,797	425,121	552,538	338,016	273,394	2,923,833
1990-2016 Average	1,018,558	333,967	336,664	457,853	262,524	121,756	2,531,322
1998-2010 Average	1,134,781	311,846	340,315	455,259	297,640	136,457	2,676,298

Annual SW Deliveries (AF/Y)

Date	TLSB	Westside	Kings	Kaweah	Tule	Kern	Total
1990	319,870	101,619	47,539	34,733	14,511	46,975	565,248
1991	209,568	50,258	60,256	67,030	20,368	16,662	424,142
1992	245,345	51,466	46,973	48,204	18,265	29,256	439,510
1993	811,312	109,501	159,335	166,035	85,071	83,829	1,415,083
1994	443,731	94,821	68,919	56,681	22,866	44,530	731,548
1995	948,773	127,445	185,554	199,827	82,318	91,195	1,635,112
1996	1,038,046	155,077	176,089	163,768	75,817	87,846	1,696,643
1997	749,117	162,214	141,157	131,813	63,410	68,603	1,316,314
1998	693,908	127,058	152,543	179,774	54,049	69,486	1,276,818
1999	713,206	147,012	123,314	90,454	49,410	82,217	1,205,613
2000	741,494	114,048	128,808	131,211	53,836	85,257	1,254,654
2001	437,871	100,121	73,383	75,856	27,236	31,432	745,899
2002	564,134	107,249	87,249	79,437	28,684	51,013	917,765
2003	583,124	124,958	96,413	100,930	46,590	63,012	1,015,028
2004	495,764	120,232	79,759	71,463	28,189	49,469	844,876
2005	873,425	138,809	157,030	161,487	78,104	109,872	1,518,728
2006	1,020,922	147,160	169,818	150,345	74,983	100,583	1,663,811
2007	508,886	117,825	51,225	60,221	21,430	44,262	803,848
2008	371,231	64,289	83,113	74,197	29,911	34,341	657,082
2009	379,590	33,075	78,392	81,233	39,292	34,417	645,999
2010	694,592	81,618	119,468	145,326	54,007	71,839	1,166,851
2011	1,026,568	125,783	158,177	165,812	78,345	97,317	1,652,002
2012	498,937	90,342	71,505	57,021	26,222	65,649	809,676
2013	264,515	51,613	45,947	33,756	17,953	41,540	455,323
2014	154,346	15,048	31,361	8,517	7,799	24,232	241,303
2015	107,212	9,806	18,103	7,154	7,800	24,819	174,894
2016	227,755	15,061	31,385	8,505	24,909	24,233	331,849
Min	107,212	9,806	18,103	7,154	7,799	16,662	174,894
Max	1,038,046	162,214	185,554	199,827	85,071	109,872	1,696,643
1990-2016 Average	560,120	95,685	97,882	94,474	41,903	58,292	948,356
1998-2010 Average	621,396	109,497	107,732	107,841	45,055	63,631	1,055,152

Annual Agricultural Pumping Demand (AF/Y)

Date	TLSB	Westside	Kings	Kaweah	Tule	Kern	Total
1990	-745,986	-278,210	-377,582	-517,805	-242,104	-67,654	-2,229,341
1991	-785,264	-308,570	-341,469	-447,304	-212,809	-89,372	-2,184,789
1992	-767,564	-291,984	-359,561	-479,910	-223,216	-79,523	-2,201,759
1993	-197,397	-237,834	-245,540	-358,728	-155,354	-24,459	-1,219,312
1994	-604,206	-244,926	-350,224	-488,149	-228,655	-67,983	-1,984,143
1995	-24,730	-165,424	-203,672	-302,179	-147,661	-13,229	-856,896
1996	-29,915	-158,508	-168,457	-318,855	-228,987	-42,619	-947,342
1997	-374,608	-175,659	-236,149	-379,690	-254,220	-67,780	-1,488,105
1998	-365,102	-159,653	-208,949	-300,607	-240,074	-57,645	-1,332,031
1999	-519,242	-192,653	-284,500	-444,706	-277,739	621	-1,718,220
2000	-385,918	-170,767	-220,794	-326,215	-226,113	11,634	-1,318,173
2001	-673,635	-209,305	-271,007	-371,563	-245,796	-42,893	-1,814,199
2002	-637,322	-210,961	-282,751	-400,725	-262,067	-31,459	-1,825,285
2003	-615,287	-216,181	-270,173	-373,419	-241,927	-21,516	-1,738,504
2004	-666,247	-199,354	-277,510	-391,613	-253,336	-34,428	-1,822,488
2005	-282,123	-154,850	-196,609	-299,869	-200,331	26,529	-1,107,252
2006	-108,819	-134,383	-175,438	-295,282	-193,614	17,832	-889,703
2007	-674,210	-206,375	-243,733	-387,473	-316,586	-196,365	-2,024,743
2008	-711,862	-243,641	-203,818	-399,968	-305,659	-180,020	-2,044,967
2009	-712,107	-316,626	-209,935	-300,183	-247,649	-238,977	-2,025,477
2010	-322,133	-215,801	-178,363	-224,807	-272,706	-200,059	-1,413,869
2011	0	-161,961	-76,046	-216,371	-88,024	22,700	-519,702
2012	-277,196	-240,183	-174,262	-340,959	-174,232	-14,524	-1,221,356
2013	-561,890	-319,412	-191,274	-372,992	-176,598	-71,029	-1,693,195
2014	-602,919	-398,869	-235,024	-377,071	-211,018	-113,332	-1,938,233
2015	-517,434	-418,991	-235,043	-355,006	-186,723	-72,163	-1,785,361
2016	-450,181	-402,520	-229,237	-339,778	-143,584	-65,815	-1,631,116
Min	-785,264	-418,991	-377,582	-517,805	-316,586	-238,977	-2,229,341
Max	0	-134,383	-76,046	-216,371	-88,024	26,529	-519,702
1990-2016 Average	-467,159	-238,282	-238,782	-363,379	-220,622	-63,464	-1,591,687
1998-2010 Average	-513,385	-202,350	-232,583	-347,418	-252,584	-72,827	-1,621,147



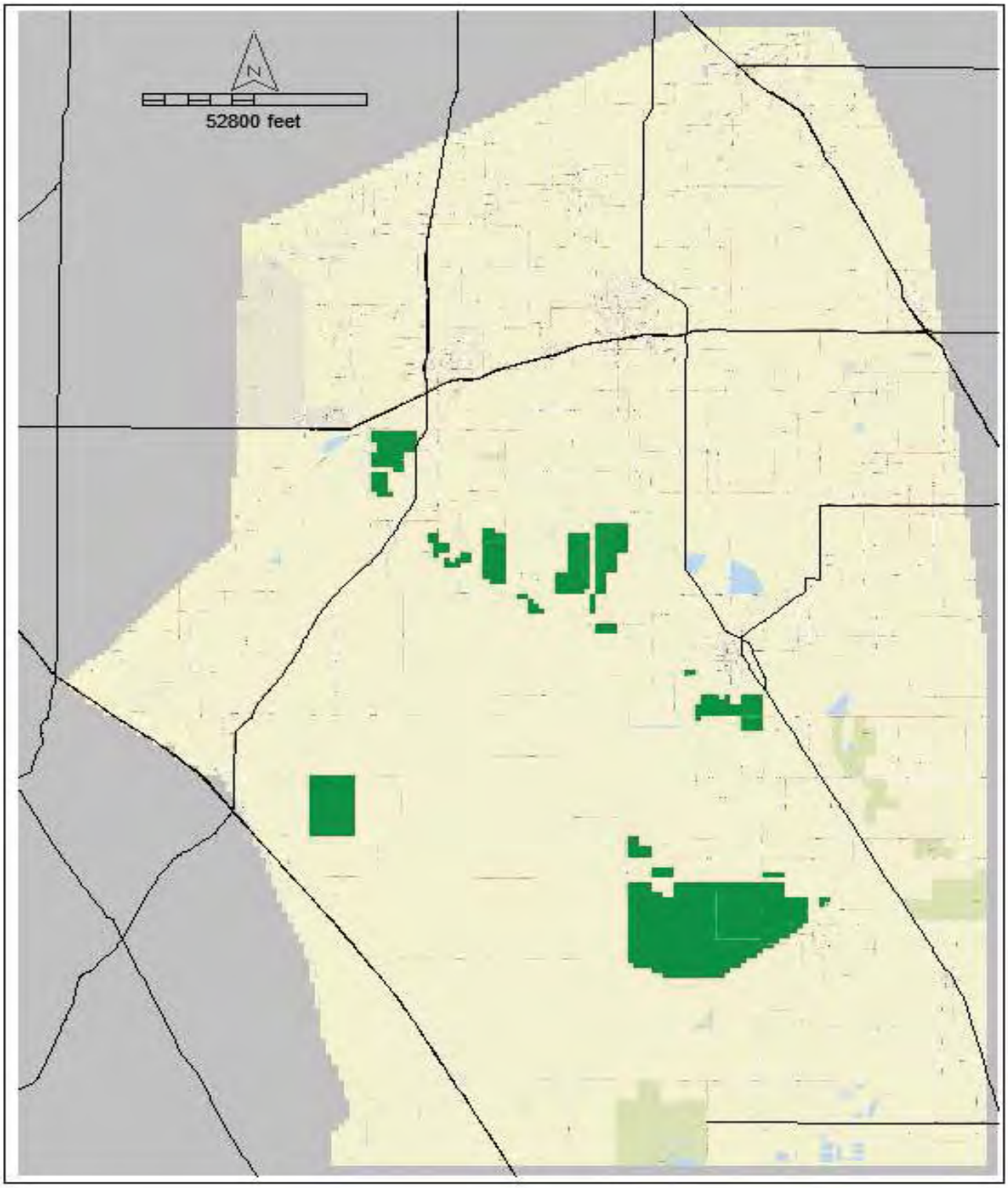
Gross Annual Water Balance

Tulare Lake Subbasin Groundwater Sustainability Plan

Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-23**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D2-24 Ag Drains



Legend

Model Area

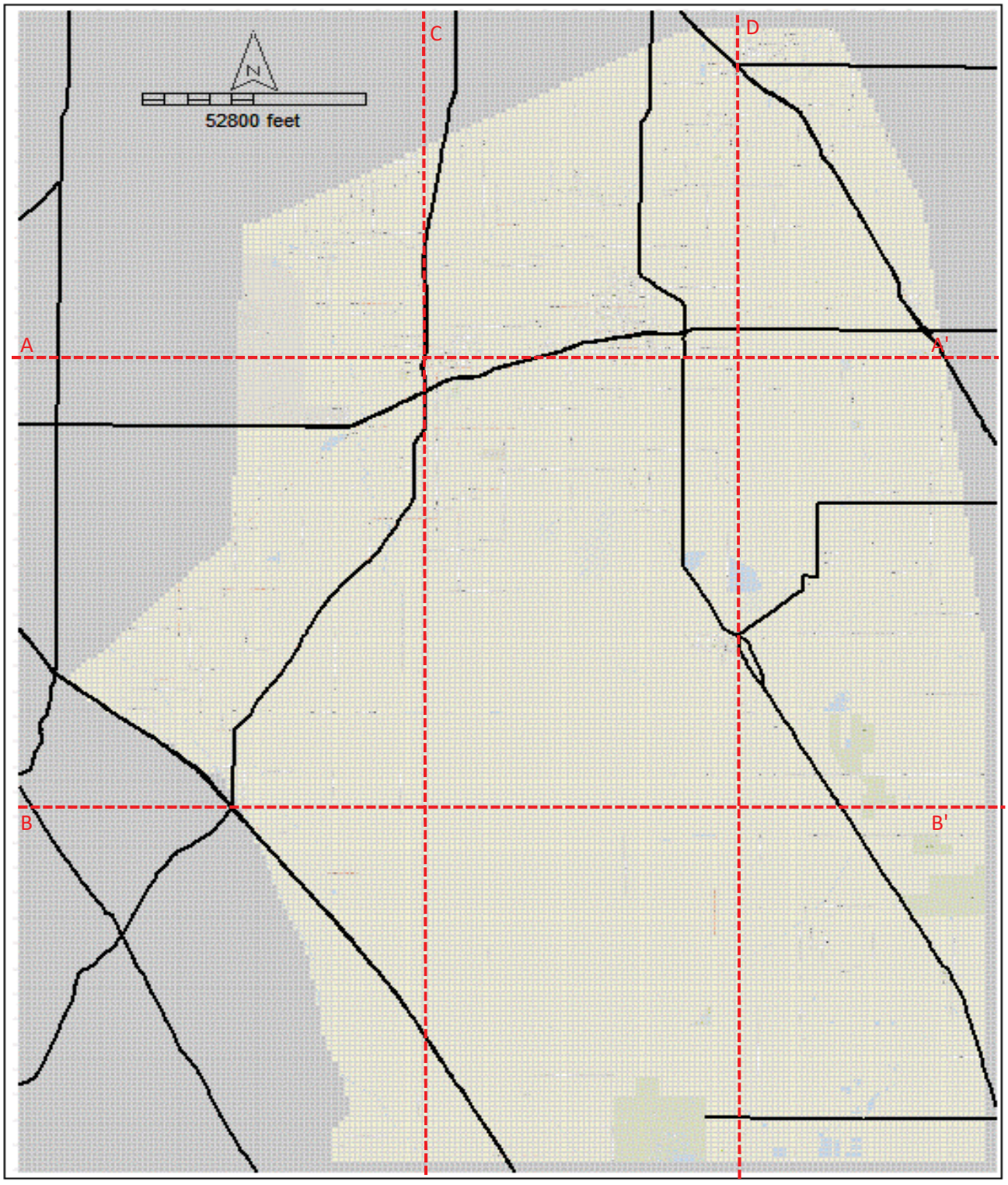
Sub-Surface Drains

Approximate Location of Sub-Surface Drainage Systems

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D2-24**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D4-1 Model Grid



Explanation

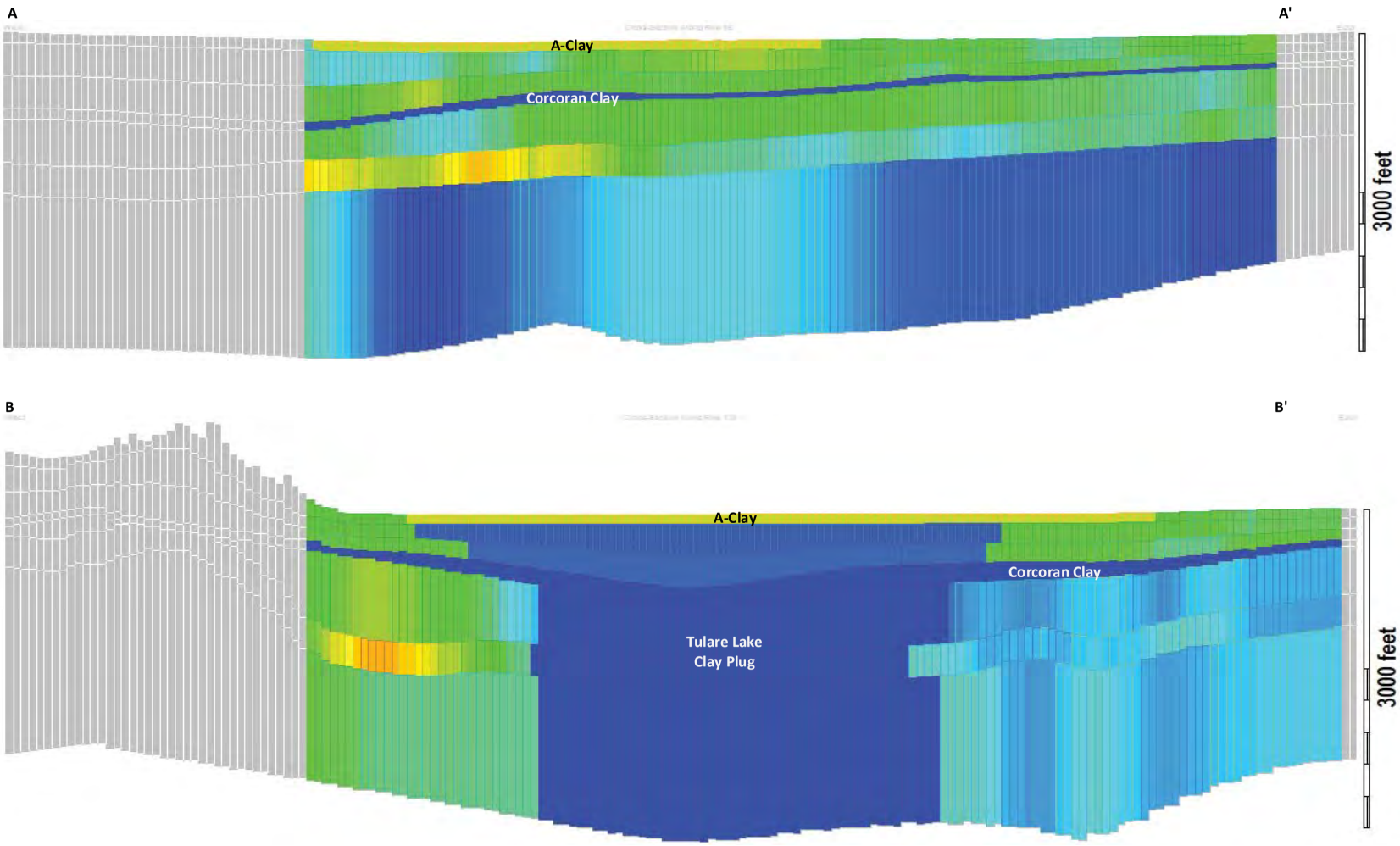
- Cross Section
- Major Roads
- No Flow

Tulare Lake Subbasin Hydrologic Model Domain and Grid

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D4-1**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D4-2 E-W X-Sections 12/19/2019



Vertical Exaggeration 20 X

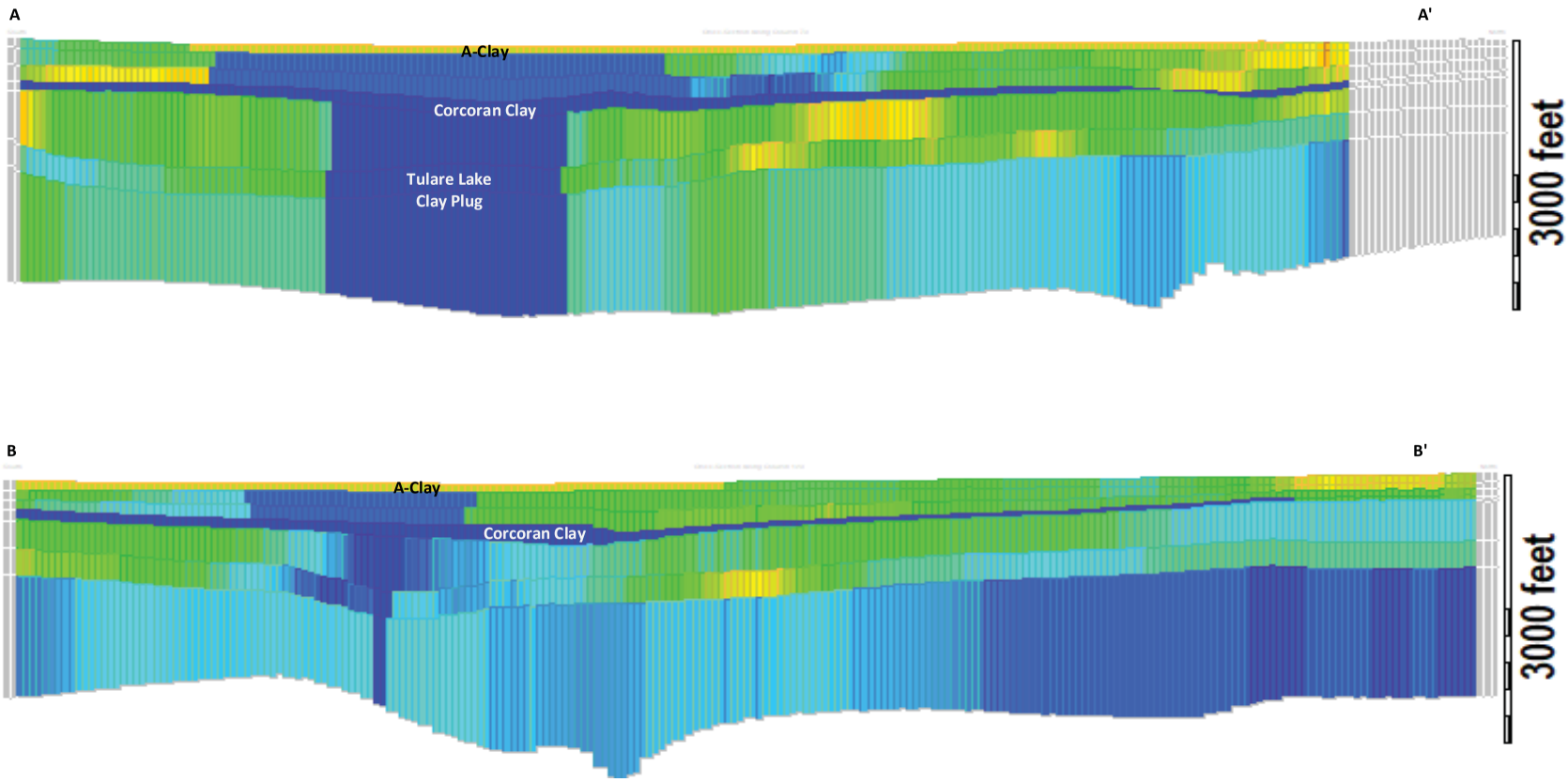
Hydraulic Conductivity in Feet per day (ft/d)

0.01 5 10 15 20 25 30 35 40

Model Layers and East-West Cross-Sections A-A' and B-B'

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D4-2**



Vertical Exaggeration 20 X

Hydraulic Conductivity in Feet per day (ft/d)

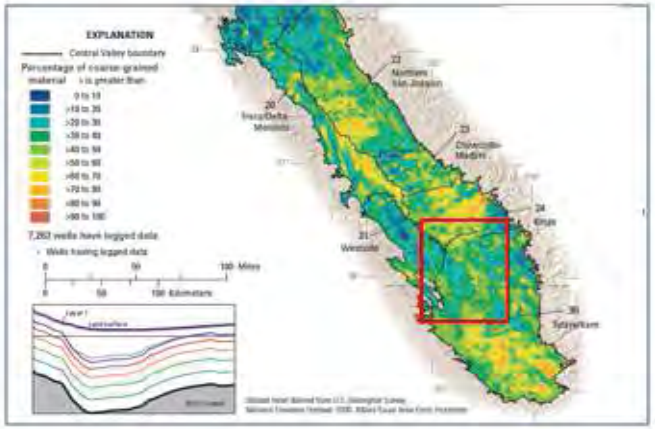
0.01 5 10 15 20 25 30 35 40

Model Layers and North-South Cross-Sections C-C' and D-D'

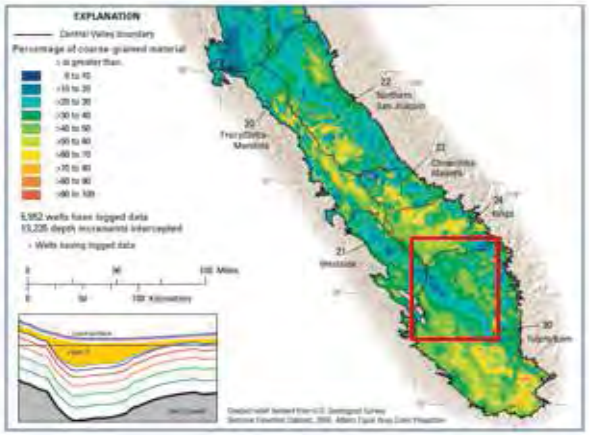
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D4-3**

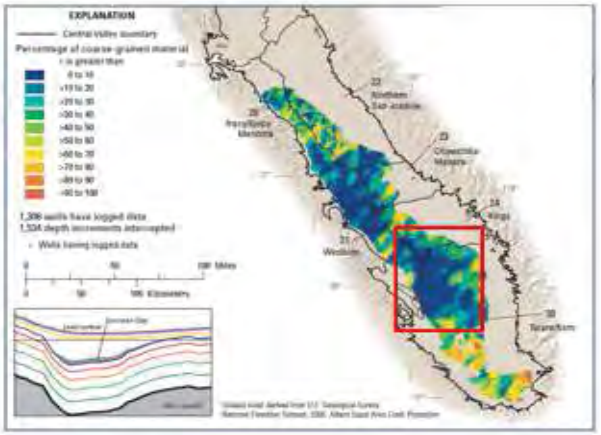
a. 0 - 50 foot depth interval



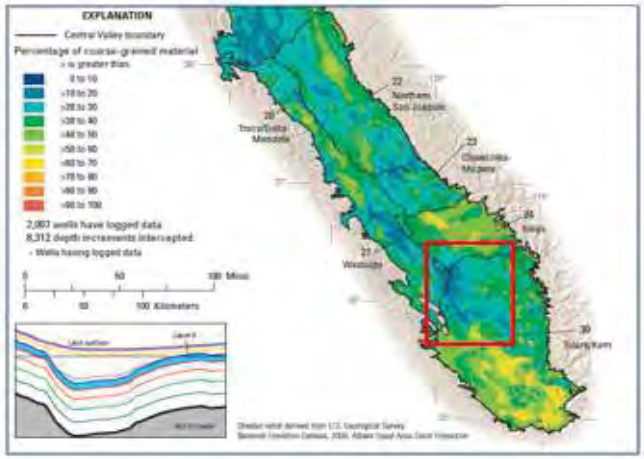
b. 50 - 200 foot depth interval



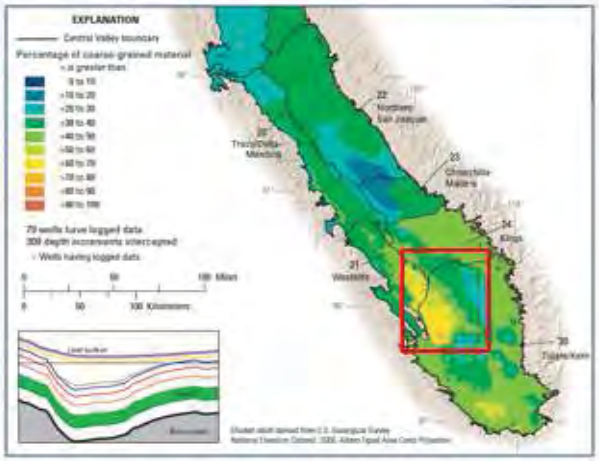
c. Corcoran Clay Depth interval



d. 100 foot depth interval immediately below Corcoran Clay



e. 200 foot depth interval from 400 to 700 feet bgs



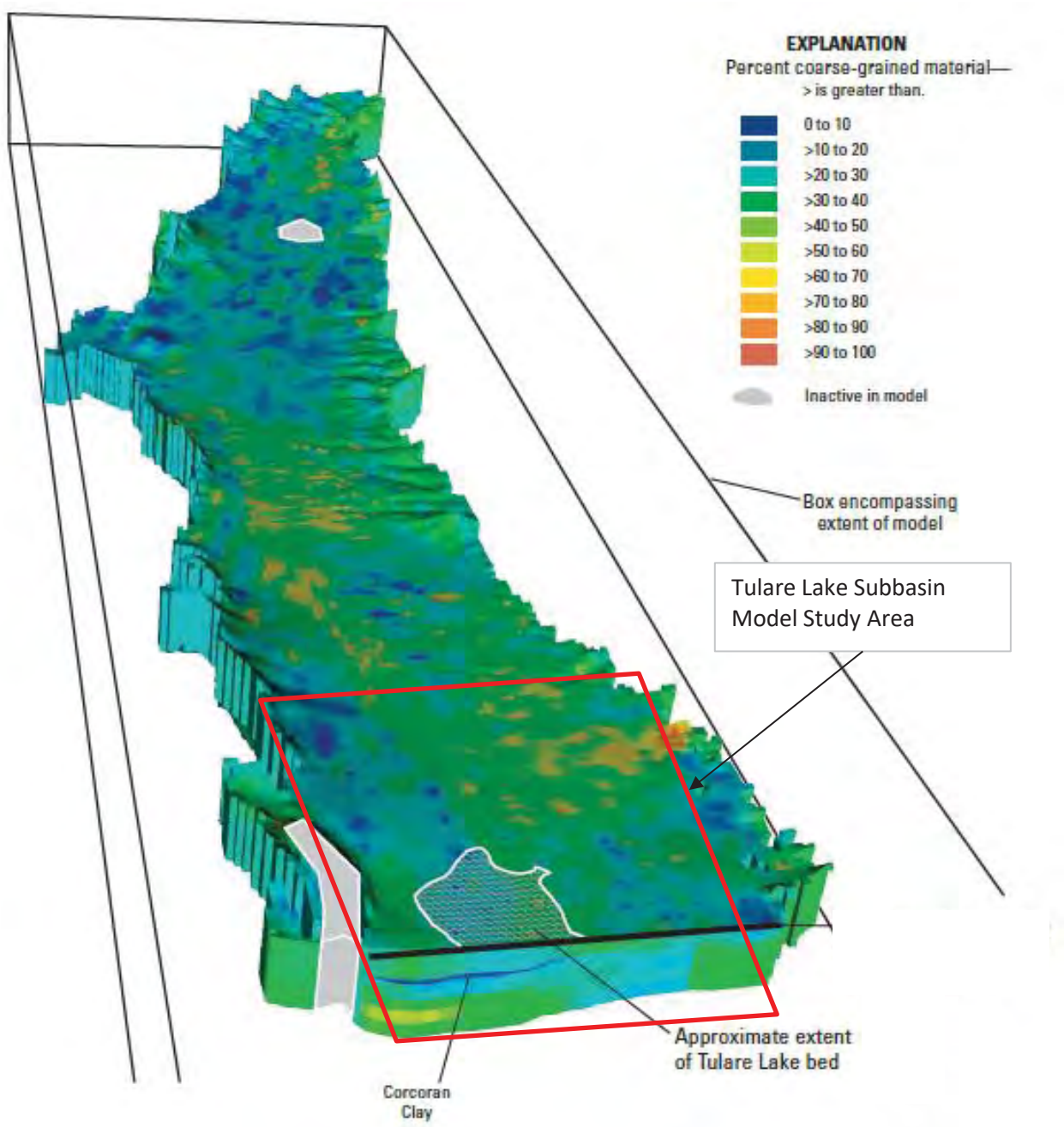
Tulare Lake Subbasin Hydrologic Model study area

*adapted from Fig. A12, USGS Prof. Paper 1766

Kriged Distribution of Coarse Fraction For San Joaquin Valley Basin-Fill Sediments at Five Depth Intervals

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D4-4**



Modified from USGS Pro Paper 1766

3D Oblique Image of San Joaquin Valley Coarse Fraction Percentage Estimated by USGS Sediment Texture Study

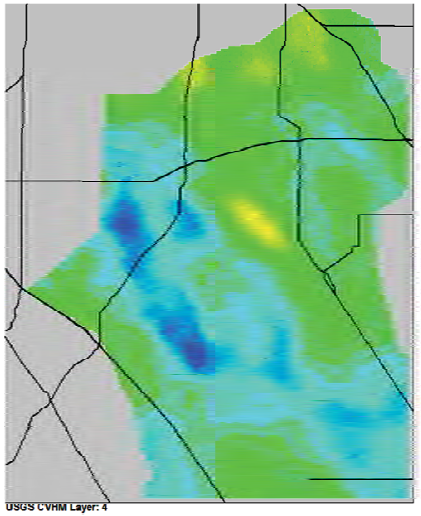
Tulare Lake Subbasin Groundwater Sustainability Plan

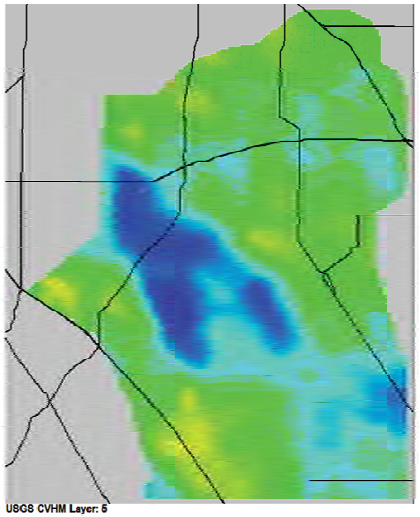
Kings County, California

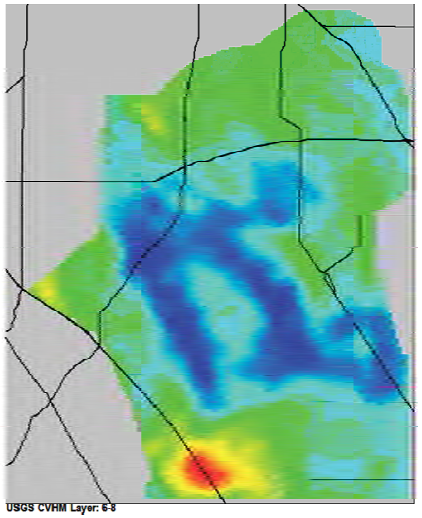
By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure D4-6

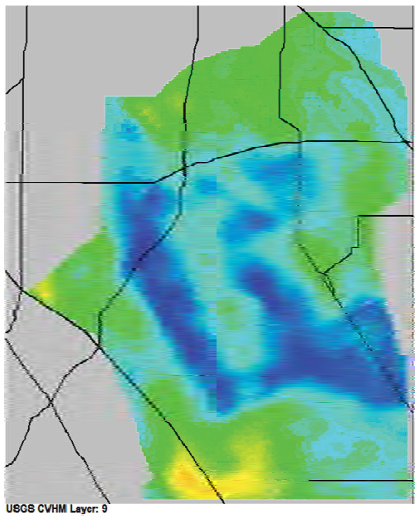
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\3-BasinSetting\Figures\DAVIS FOLDER\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig 3-6 Oblique Texture Model 12/2020

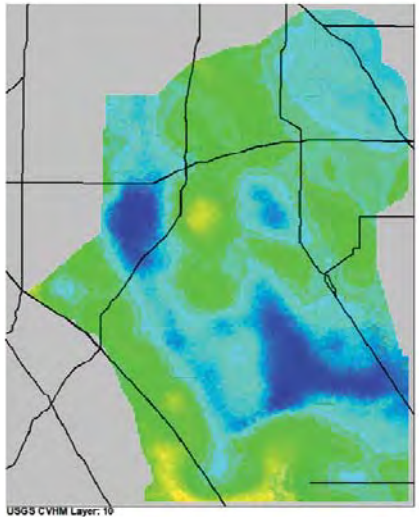
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\3-BasinSetting\Figures\DAVES FOLDER\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig 4-6 USCS CVHM Kh 1/6/2020

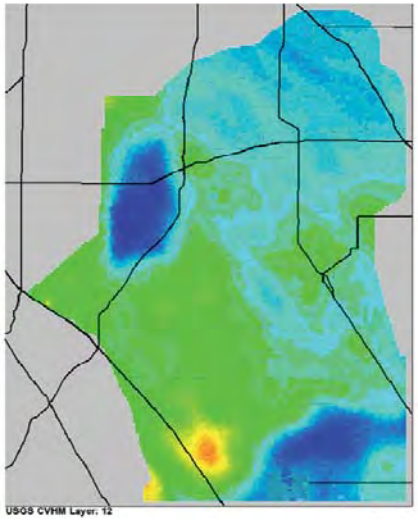


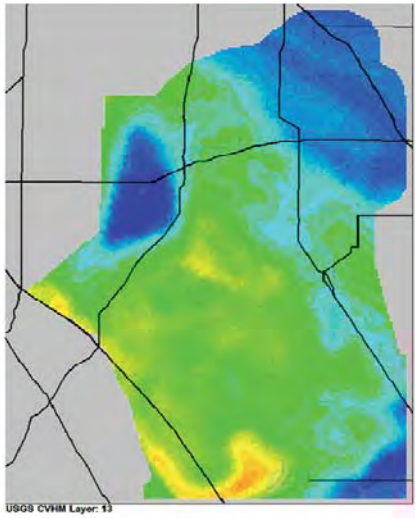




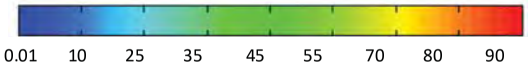








Hydraulic Conductivity in feet per day (ft/d)

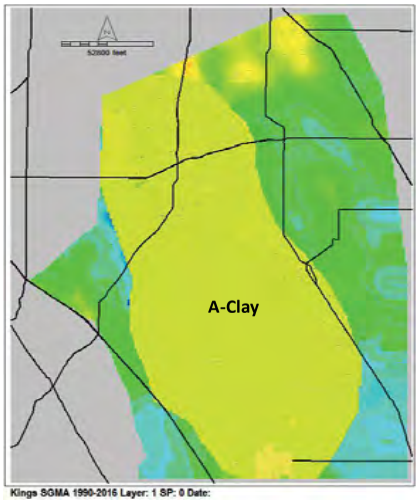


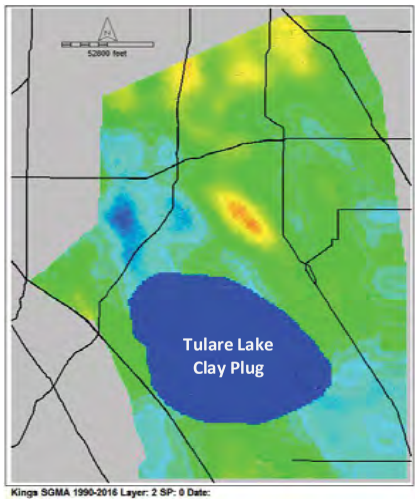
USGS CVHM Hydraulic Conductivity Distribution

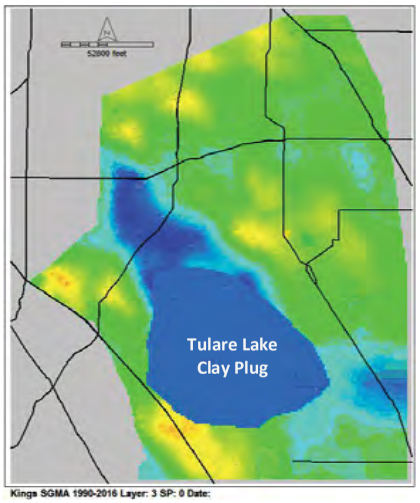
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

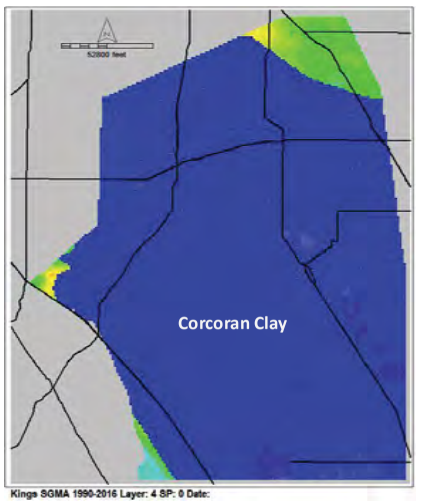
By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D4-6**

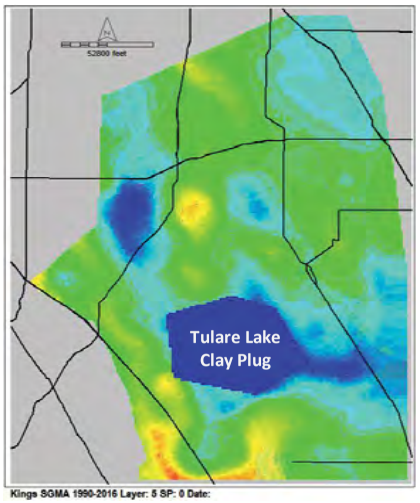
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\3-BasinSetting\Figures\DAVES FOLDER\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig 4-7 Calibrated Model Kh 1/6/2020

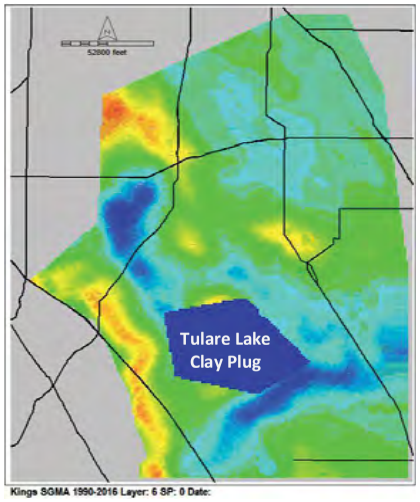


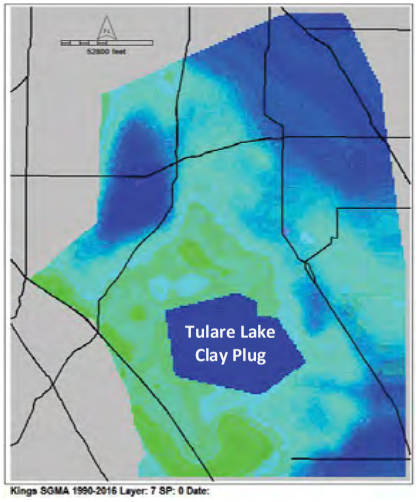


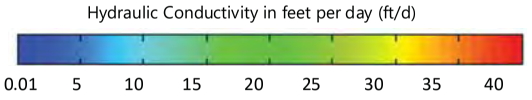








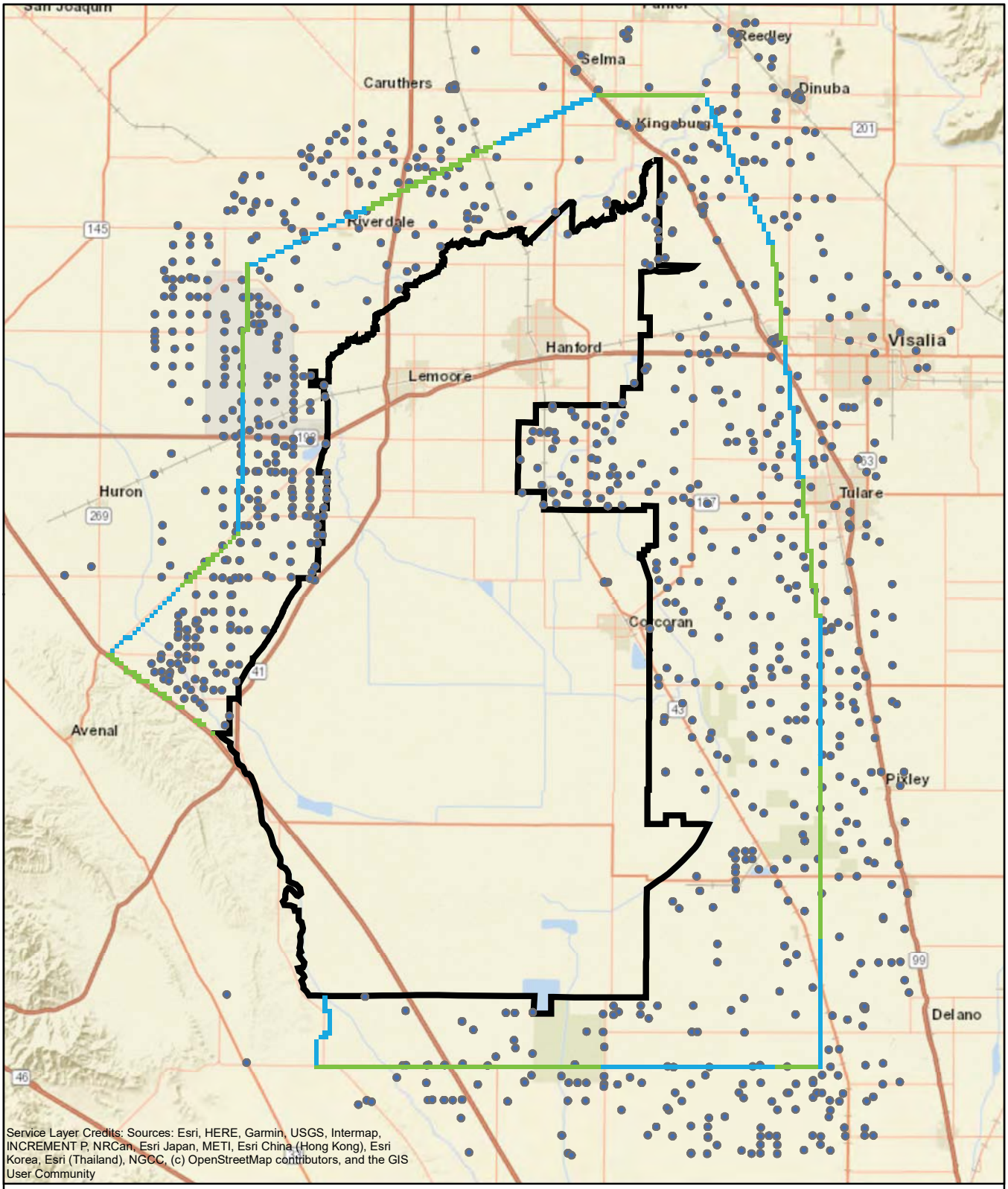




Calibrated Model Layer Hydraulic Conductivity Distribution

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D4-7**



Explanation

- Evaluated wells
- General head boundaries

Miles
0 2 4 8
0 2.5 5 10
Kilometers

N

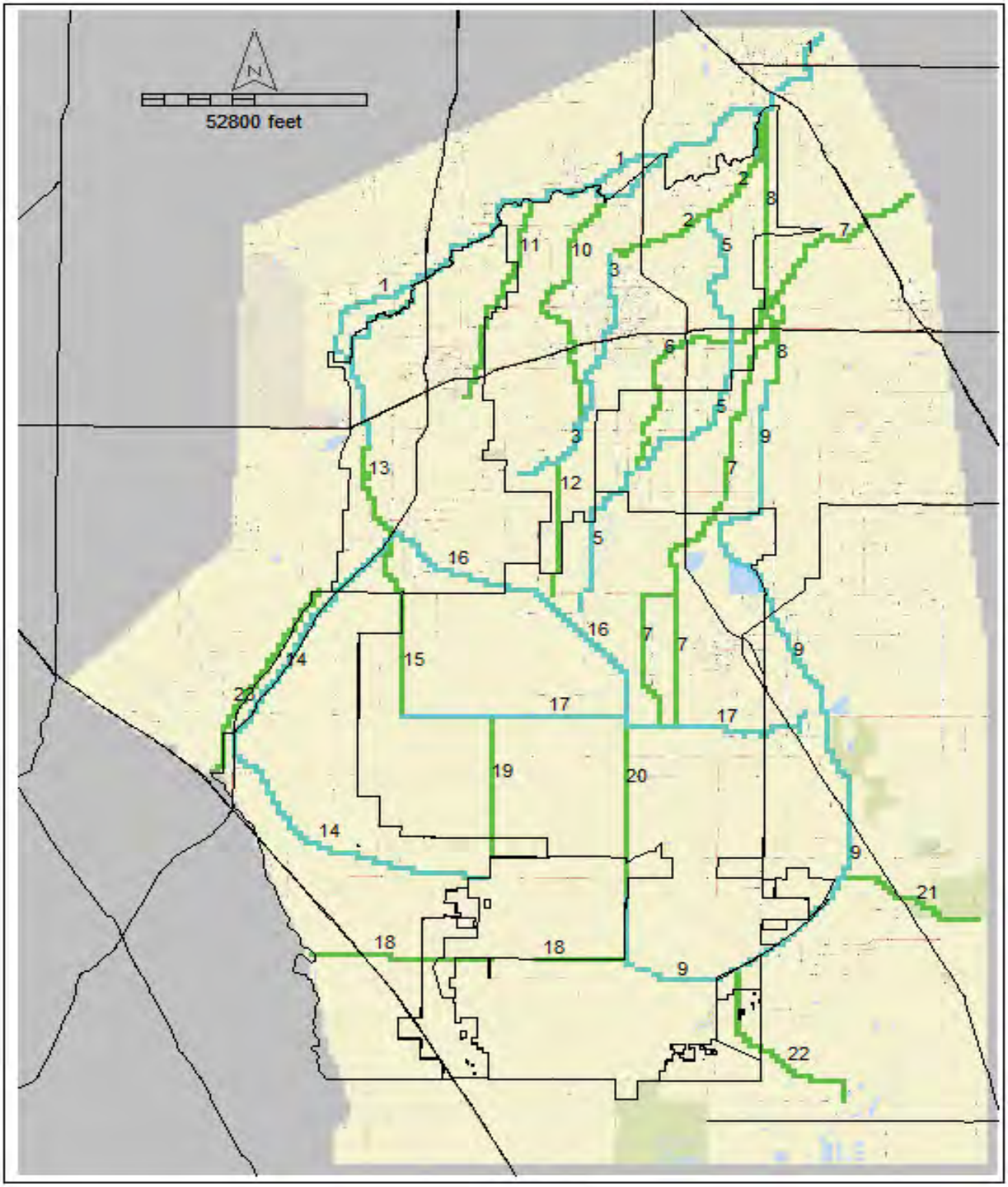
Location of Wells Evaluated for General Head Boundaries

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: EMC	Date: 1/7/2020	Project No.: FR18161220
		Figure **D4-8**

Date: 1/7/2020 Printed by: elizabeth.chapman
Path: N:_FR_projects\FR18s\FR18161220\gis\maps\2019\AppendixD_figD4-8_wellsandGHBs.mxd

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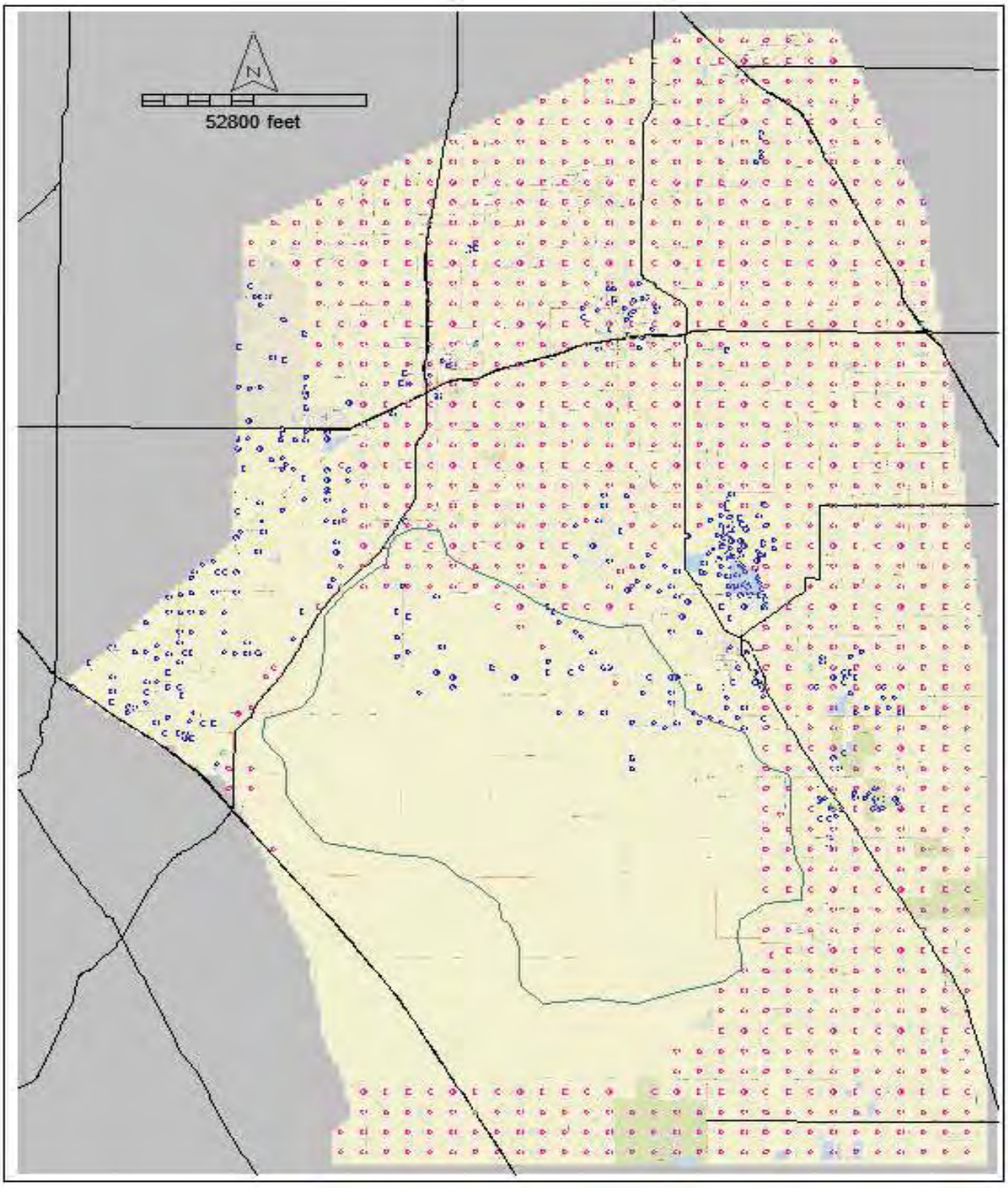
Notes:
1) Numbers shown are River Reaches
2) Colors delinate different reaches

Location of Rivers, Streams, and Canals for River Boundaries

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D4-9**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D4-10 All Wells



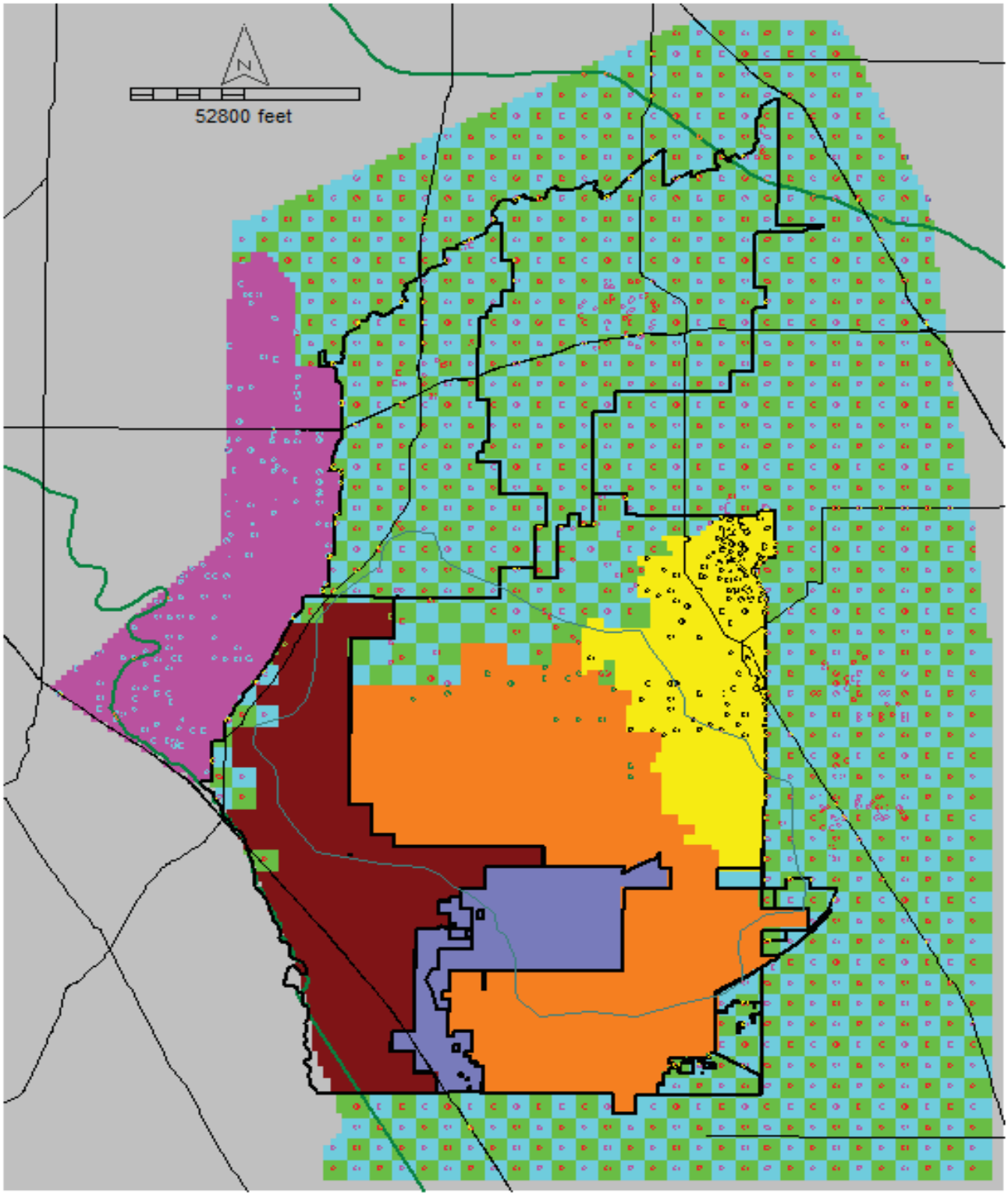
Location of Existing and Hypothetical Pumping Well within Model Domain

Tulare Lake Subbasin Groundwater Sustainability Plan

Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D4-10**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D4-11 Ag Demand Areas



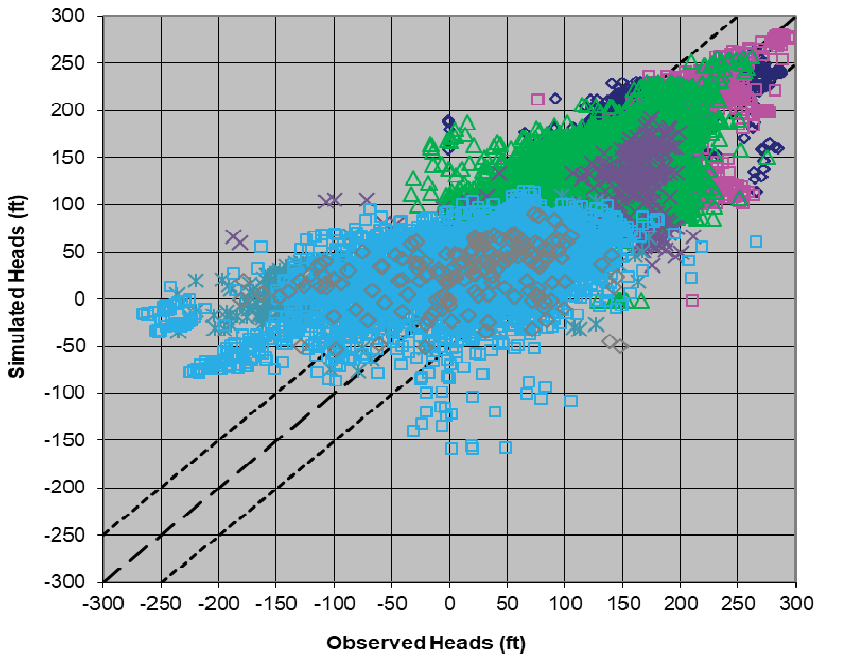
- Hypothetical Agricultural Well Service Area
- Hypothetical Agricultural Well Service Area
- Corcorain ID Service Area
- El Rico GSA Service Area
- Westlands Water District Service Area
- SouthWest Kings GSA Service Area
- Tri County Water Authority Service Area

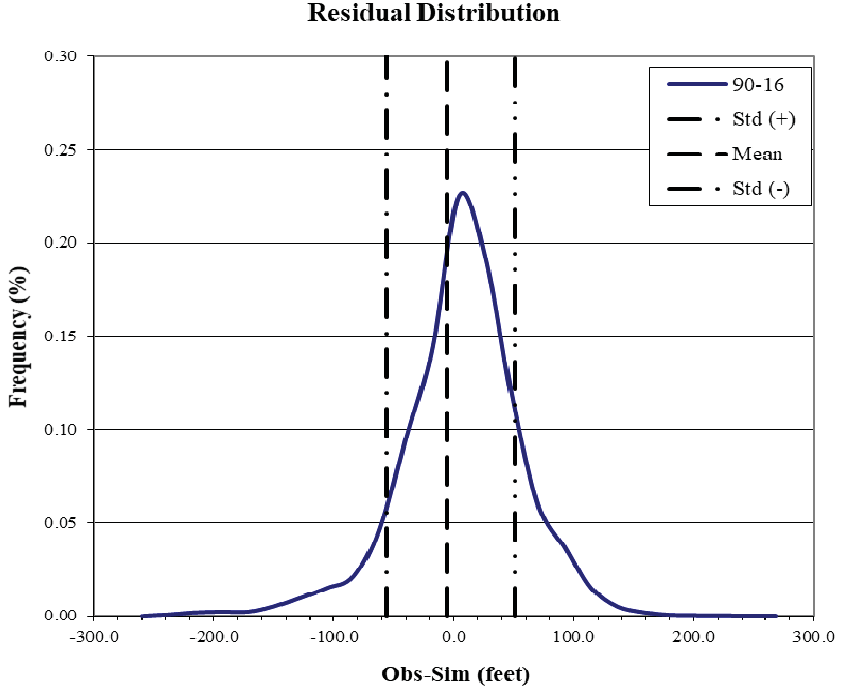
Location of Hypothetical Irrigation Well Service Areas within Model Domain

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D4-11**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D5-1a 1990-2016 Calib Stats 12/19/2019





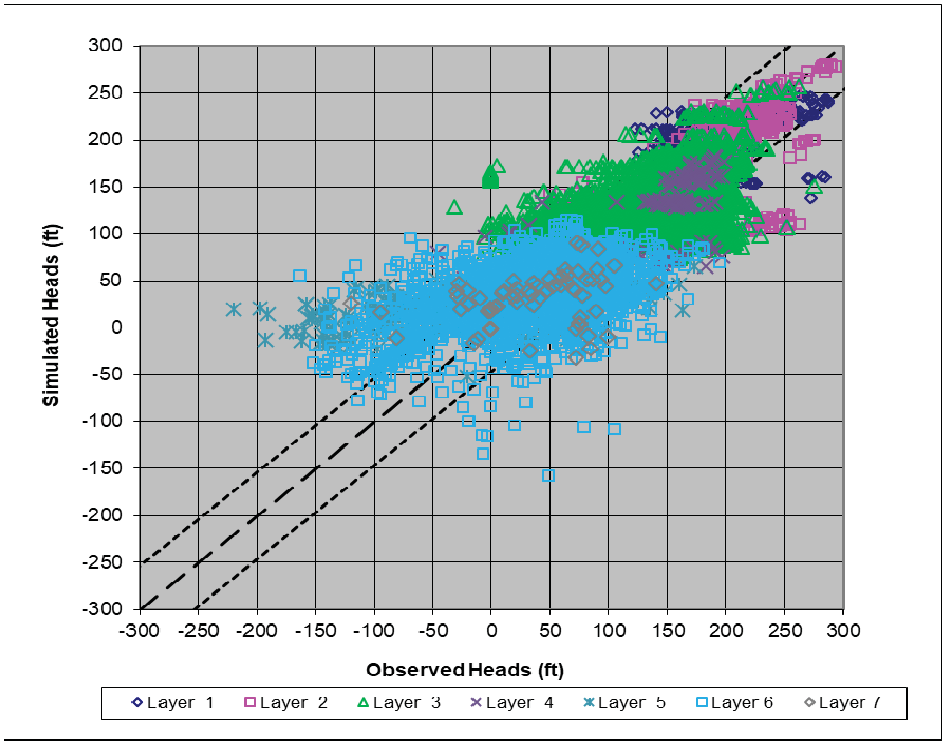
Statistics	Layer 1 - 7		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7
Residual Mean	-4.98	ft	-9.30	185.26	-1.18	25.67	-35.43	-11.66	-11.45
Absolute Residual Mean	37.03	ft	26.33	38.80	30.55	36.38	64.09	49.81	45.61
Residual Std. Deviation	50.61	ft	34.84	44.84	39.78	53.49	75.82	63.58	63.42
Sum of Squares	42586112	ft^2	1733398	45812399	12887543	1291708	5743049	18228849	780823
RMS Error	50.85	ft	34.84	44.84	39.78	53.49	75.82	63.58	63.42
Min. Residual	-255.01	ft	-179.50	-1.00	-180.93	-252.97	-240.51	-255.01	-197.45
Max. Residual	213.28	ft	152.58	280.01	143.90	151.42	154.06	213.28	197.53
Number of Observations	16468		1333	1261	8136	367	820	4363	188
Range in Observations	575.33	ft	332.09	281.01	324.83	404.39	394.58	468.29	394.98
Scaled Residual Std. Deviation	8.80%		10.49%	15.96%	12.25%	13.23%	19.22%	13.58%	16.06%
Scaled Absolute Residual Mean	6.44%		7.93%	13.81%	9.40%	9.00%	16.24%	10.64%	11.55%
Scaled RMS Error	8.84%		10.49%	15.96%	12.25%	13.23%	19.22%	13.58%	16.06%
Scaled Residual Mean	-0.87%		-2.80%	65.92%	-0.36%	6.35%	-8.98%	-2.49%	-2.90%
Correlation Coefficient	82%		66%	64%	74%	76%	92%	82%	82%

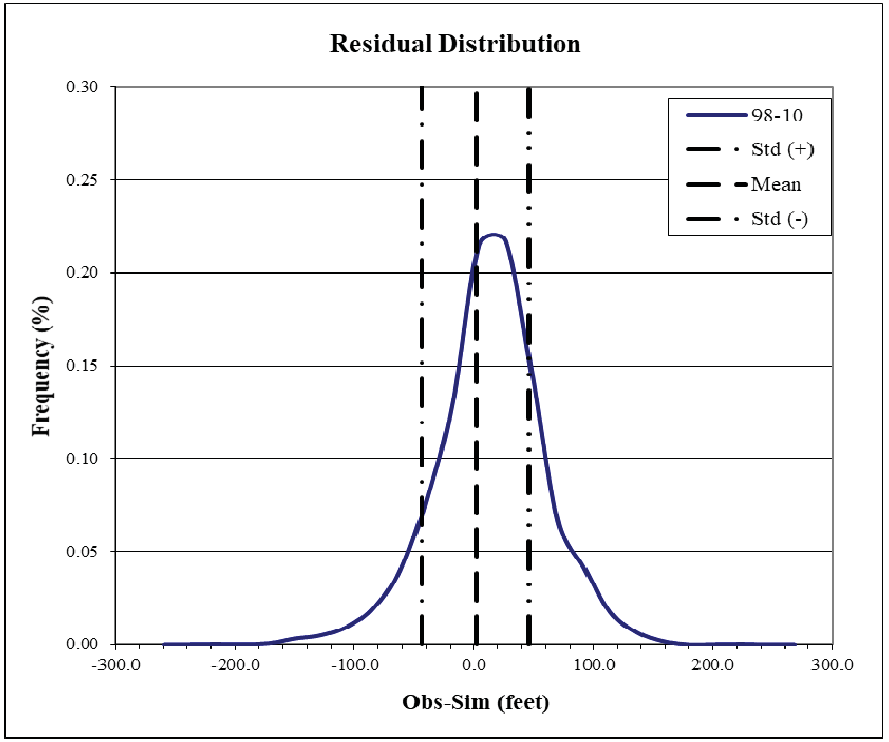
1990 - 2016 Calibration Statistics and Scattergram

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 11/20/19	Project No.: FR18161220
		Figure **D5-1a**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D5-1b 1998-2010 Calib Stats 12/19/2019





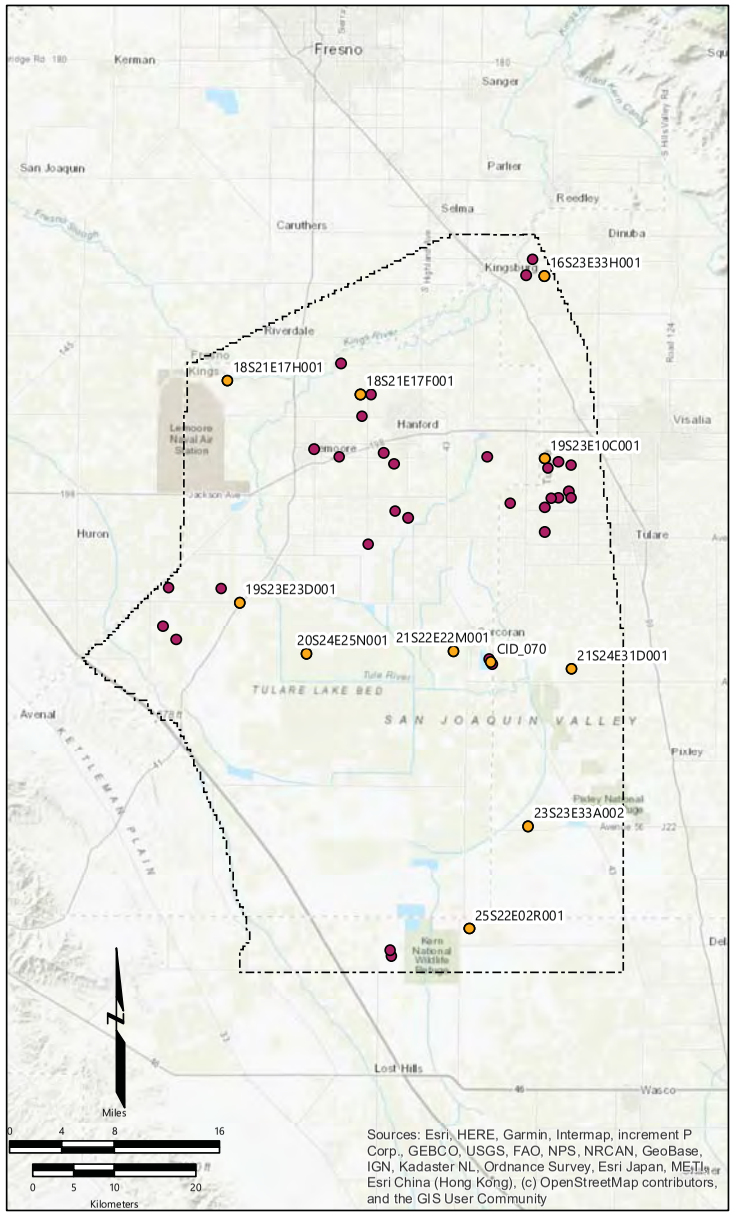
Statistics	Layer 1 - 7		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7
Residual Mean	2.26	ft	-3.24	185.61	5.32	20.05	-26.55	-1.71	4.83
Absolute Residual Mean	34.78	ft	23.78	40.69	29.78	28.23	61.79	44.63	35.33
Residual Std. Deviation	46.26	ft	32.01	47.25	38.69	40.99	73.64	55.32	48.41
Sum of Squares	15075869	ft^2	561933	19148686	5416707	316496	2009708	5707709	160941
RMS Error	46.32	ft	32.01	47.25	38.69	40.99	73.64	55.32	48.41
Min. Residual	-240.16	ft	-89.83	-1.00	-167.94	-125.53	-240.16	-219.41	-145.72
Max. Residual	213.28	ft	133.86	280.01	143.40	121.24	144.32	213.28	108.57
Number of Observations	7028		543.00	522.00	3552.00	152.00	328.00	1863.00	68.00
Range in Observations	545.16	ft	223.69	281.01	311.34	246.77	384.47	432.70	254.29
Scaled Residual Std. Deviation	8.49%		14.31%	16.81%	12.43%	16.61%	19.15%	12.79%	19.04%
Scaled Absolute Residual Mean	6.38%		10.63%	14.48%	9.57%	11.44%	16.07%	10.31%	13.89%
Scaled RMS Error	8.50%		14.31%	16.81%	12.43%	16.61%	19.15%	12.79%	19.04%
Scaled Residual Mean	0.41%		-1.45%	66.05%	1.71%	8.12%	-6.91%	-0.39%	1.90%
Correlation Coefficient	82%		58%	62%	77%	66%	91%	79%	78%

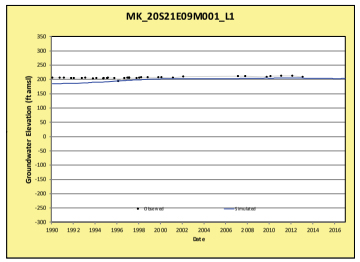
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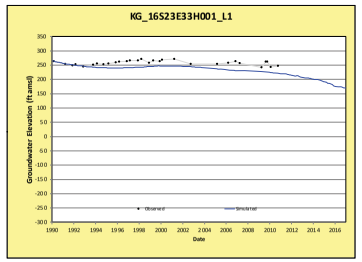
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

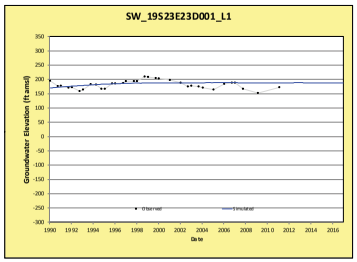
By: dmb	Date: 07/30/19	Project No.: FR18161220

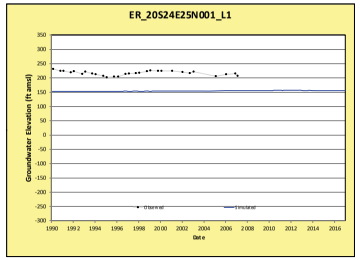
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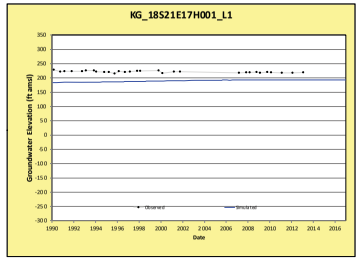


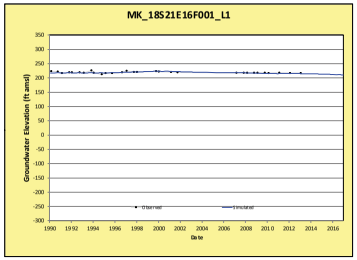


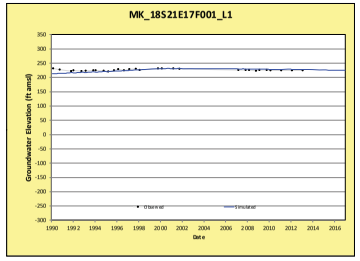


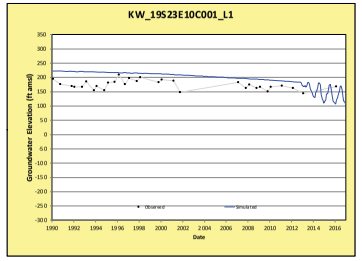


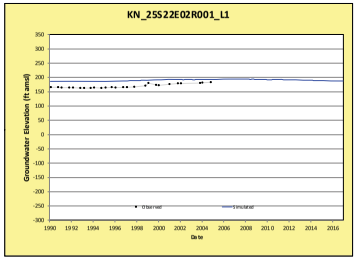


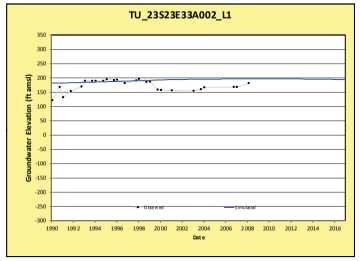


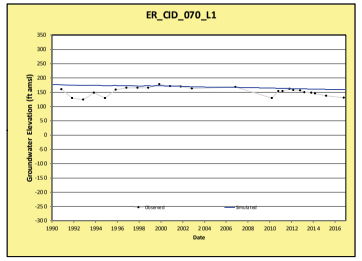












Explanation

- Target well with hydrograph shown
- Target well
- Model domain

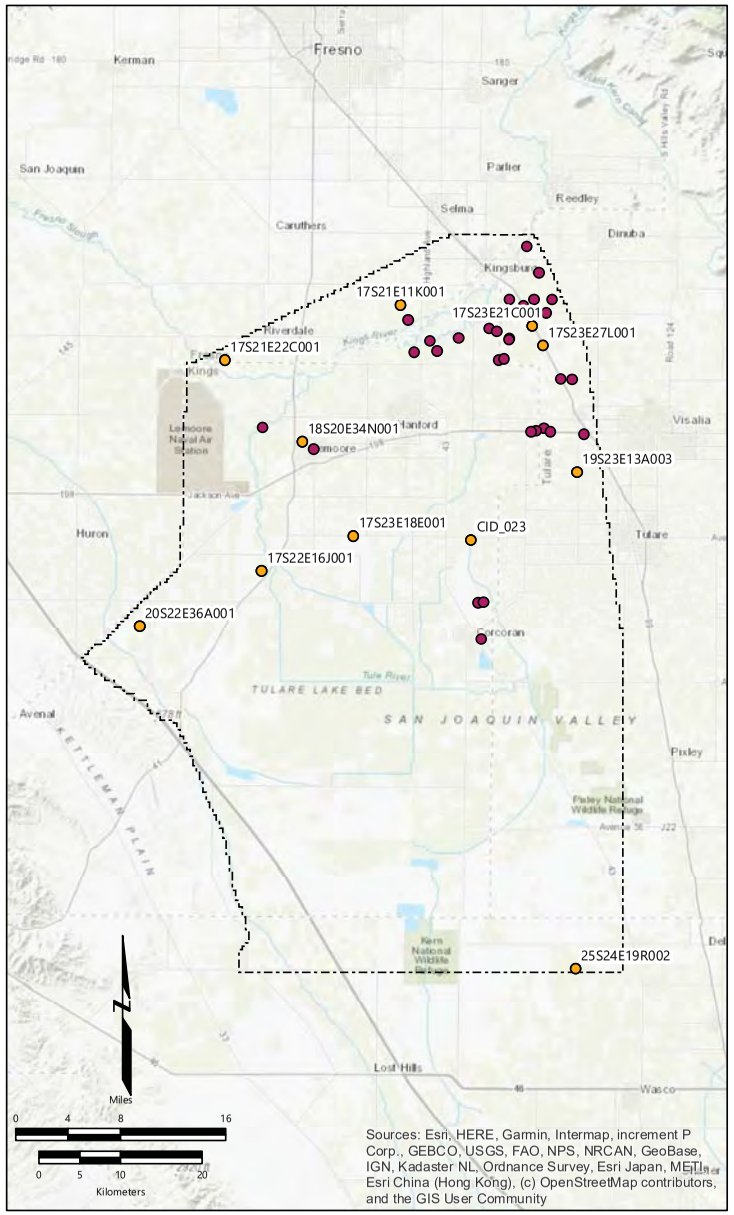
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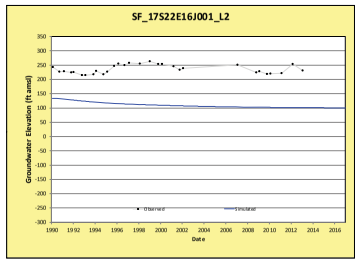
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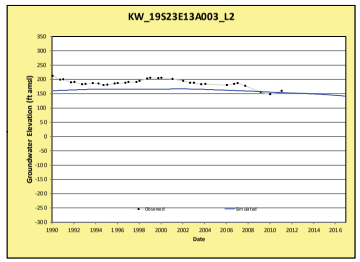
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

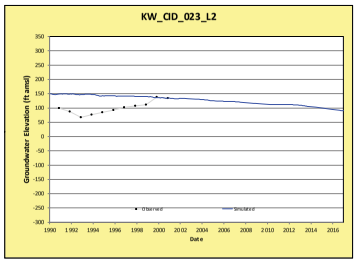
By: EMC	Date: 1/8/2020	Project No.: FR18161220
		Figure **D5-2a**

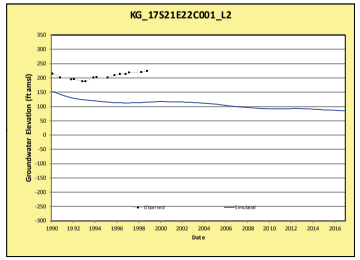
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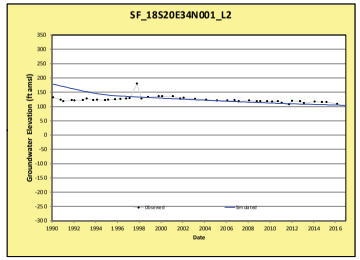


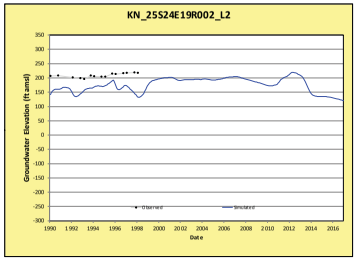


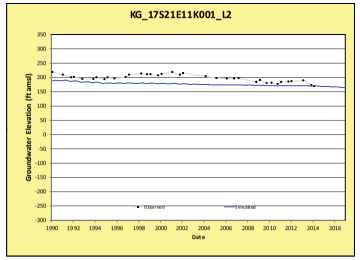


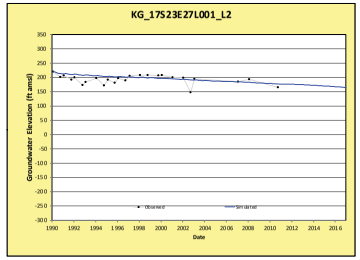


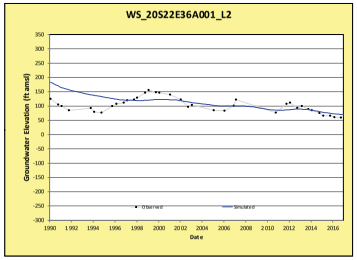


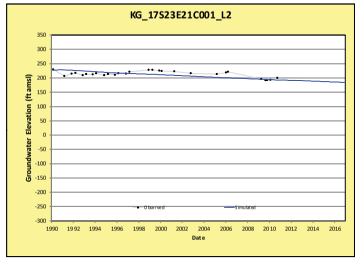


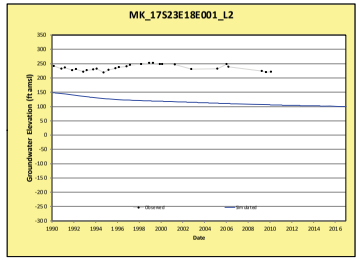












Explanation

- Target wells with hydrograph shown
- Target well
- Model domain

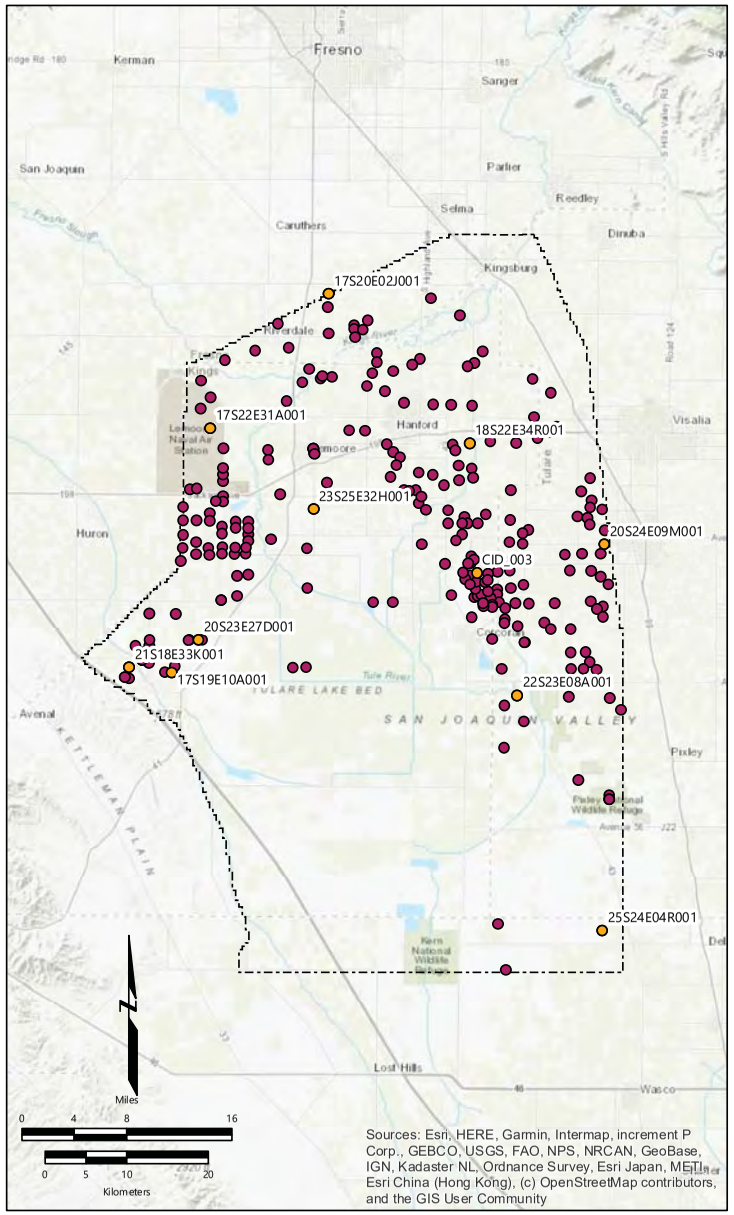
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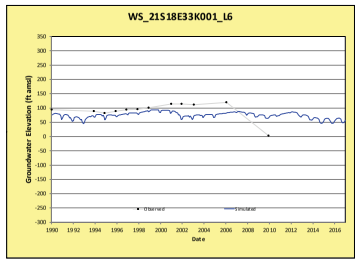
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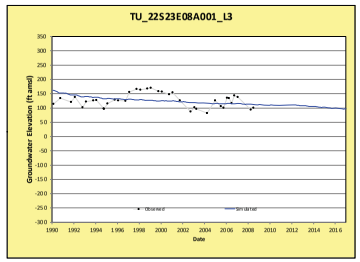
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

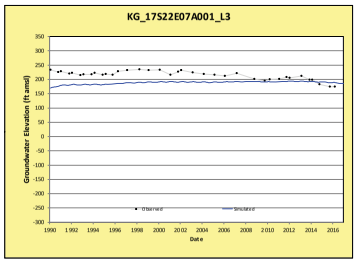
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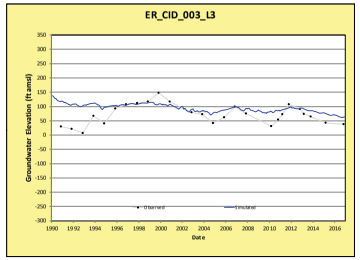
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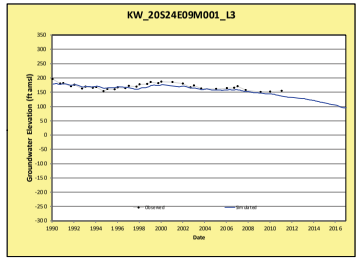


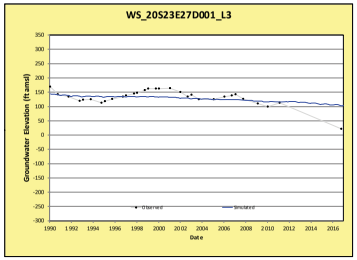


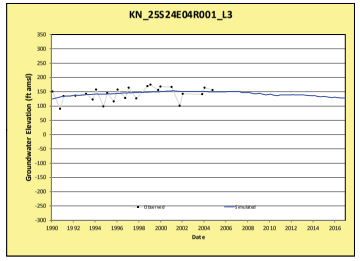


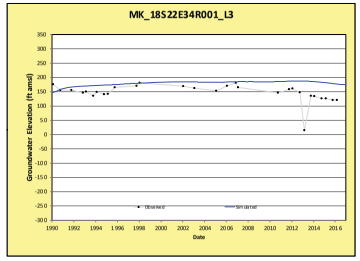


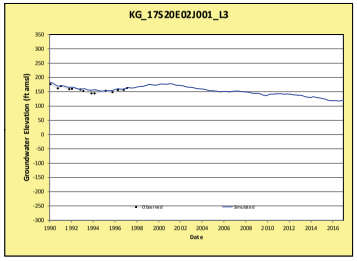


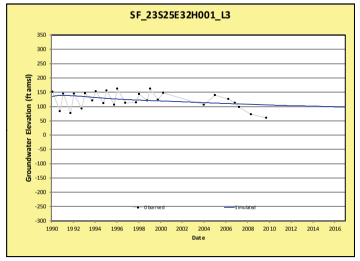


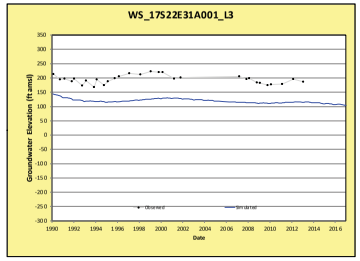












Explanation

- Target wells with hydrograph shown
- Target well
- Model domain

Well ID — Layer

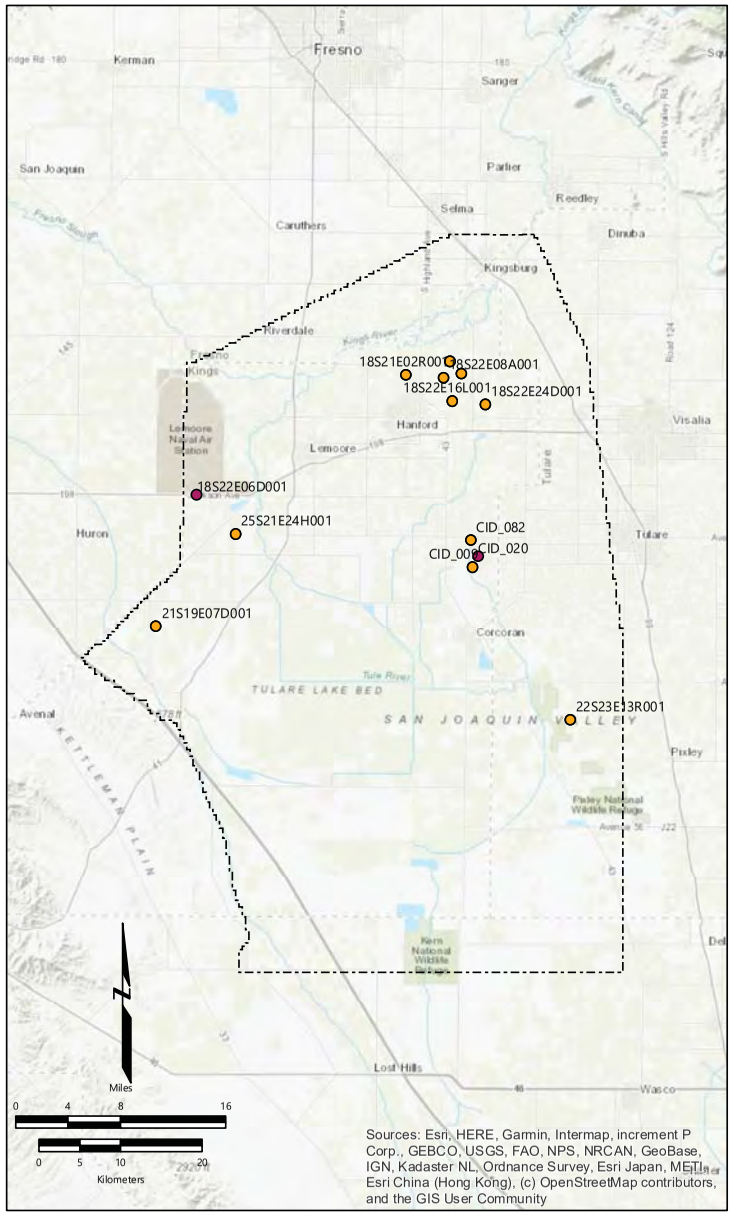
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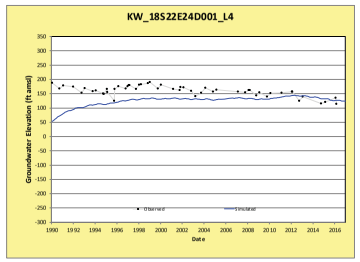
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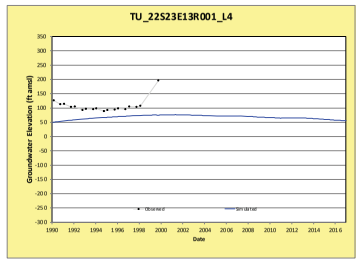
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

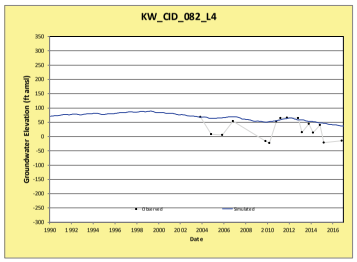
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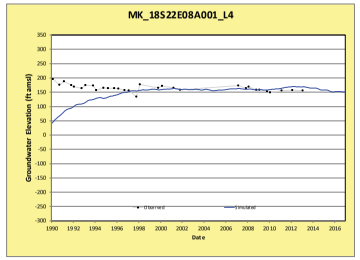
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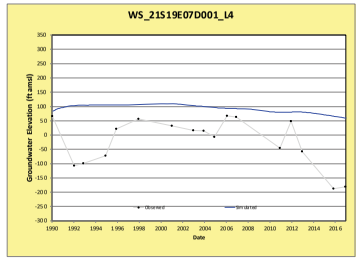


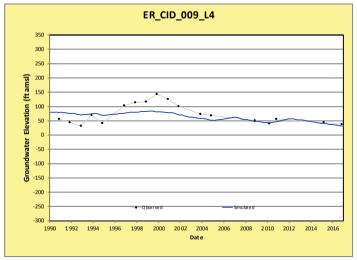


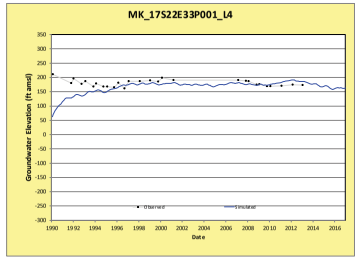


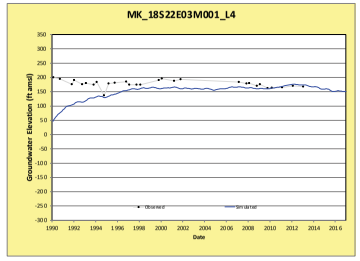


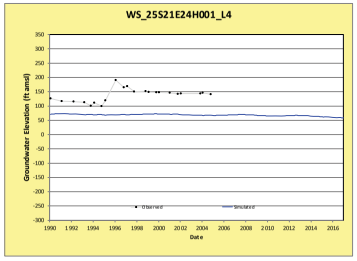


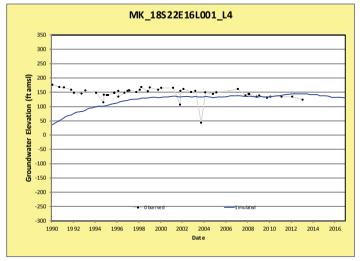


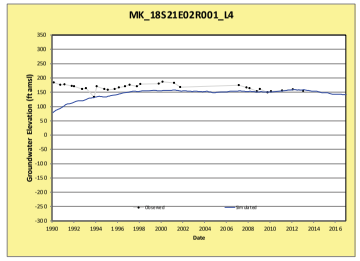












Explanation

- Target well with hydrograph shown
- Target well
- Model domain

Well ID / Layer

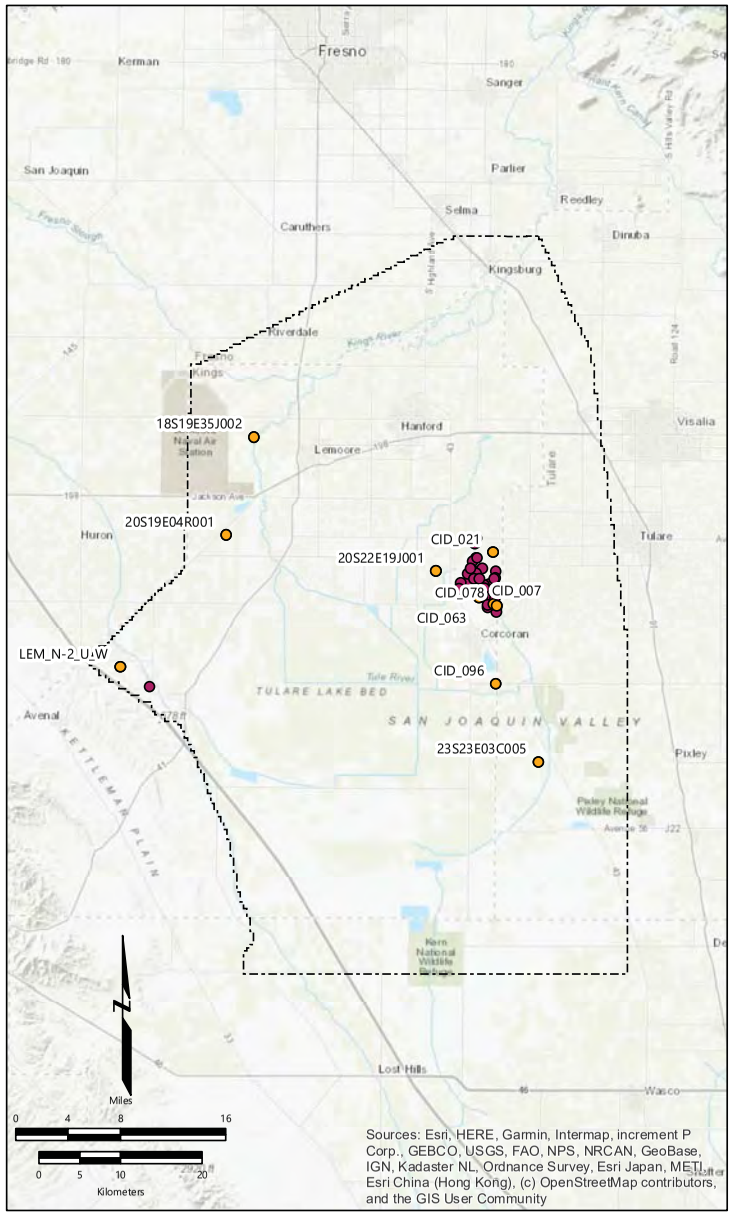
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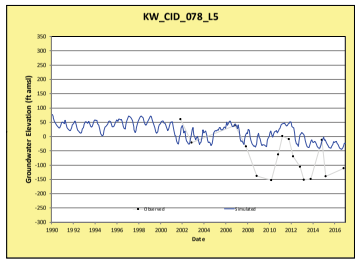
Layer 4 Observed and Simulated Hydrographs

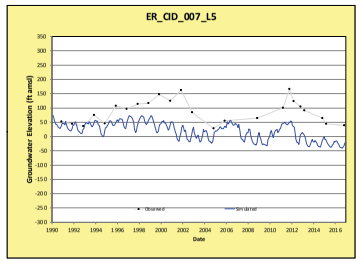
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

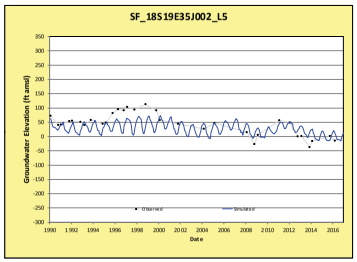
By: EMC	Date: 1/8/2020	Project No.: FR18161220
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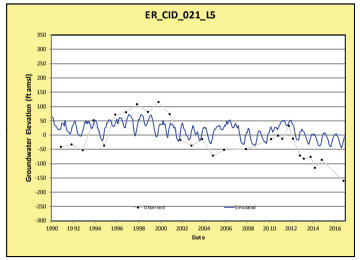
Date: 1/8/2020 Printed by: elizabeth.chapman
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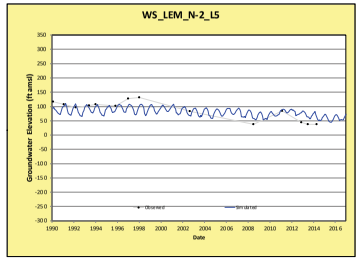


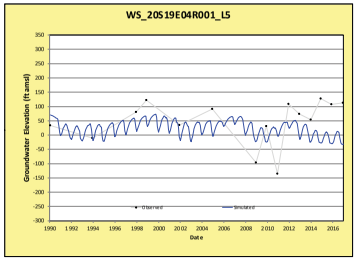


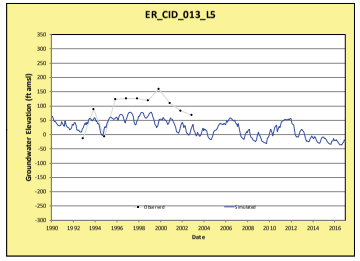


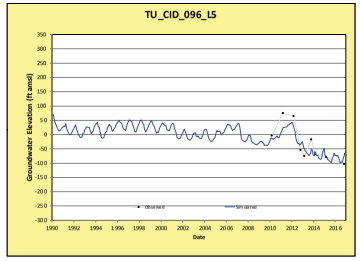


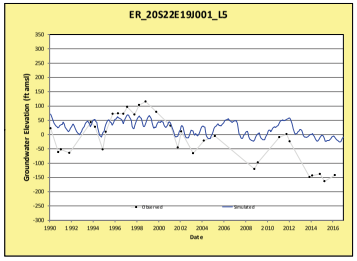


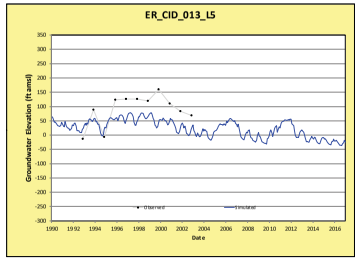


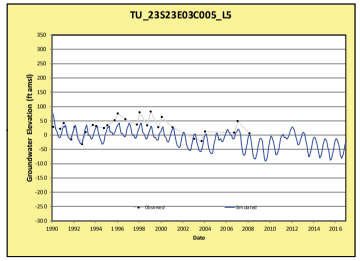












Explanation

- Target well with hydrograph shown
- Target well
- Model domain

Well ID — Layer

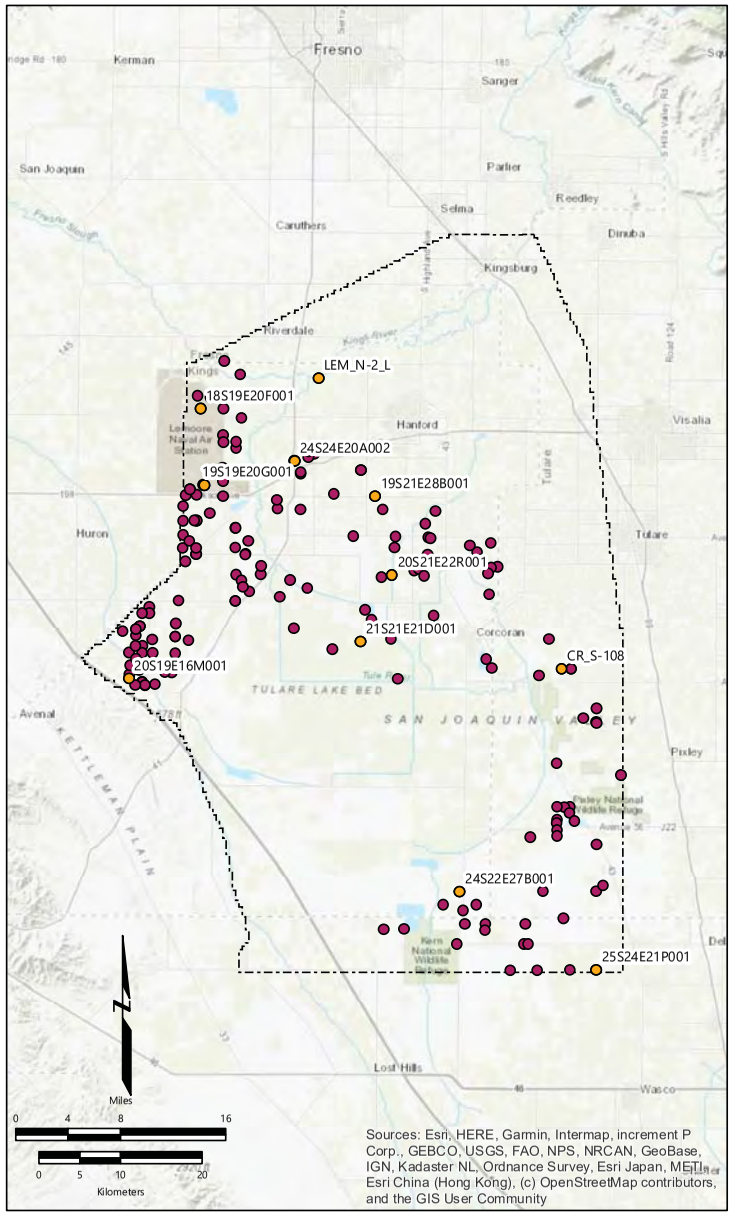
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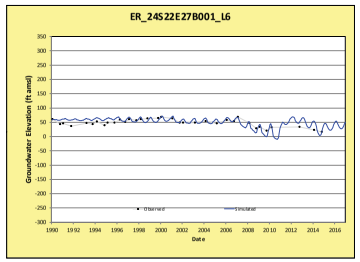
Layer 5 Observed and Simulated Hydrographs

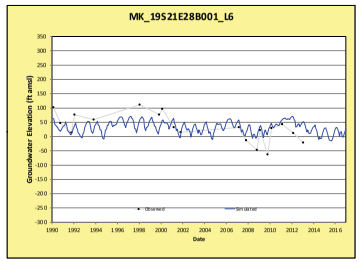
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

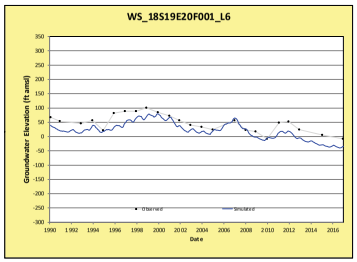
By: EMC	Date: 1/8/2020	Project No.: FR18161220
		Figure **D5-2e**

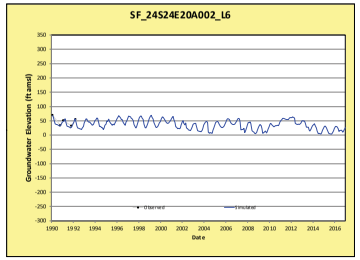
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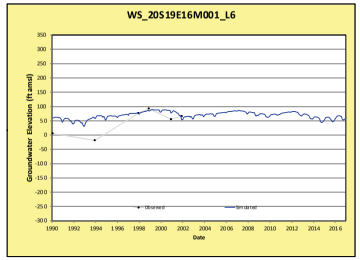


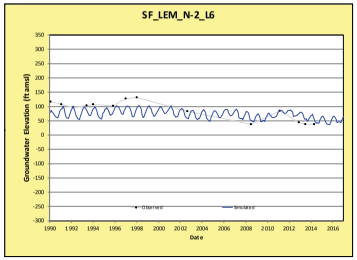


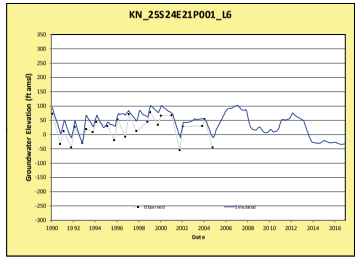


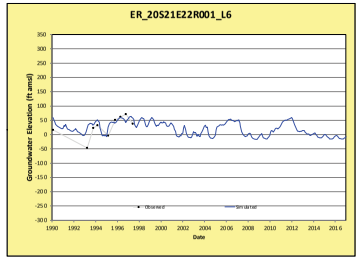


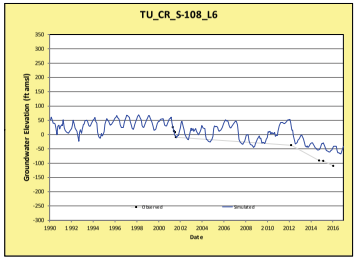


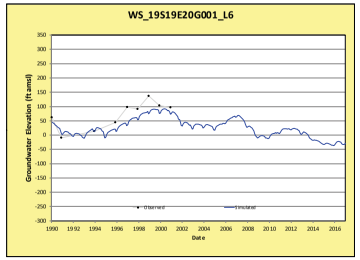


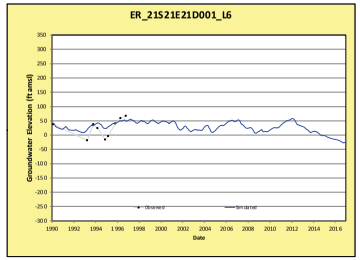












Explanation

- Target wells with hydrograph shown
- Target well
- Model domain

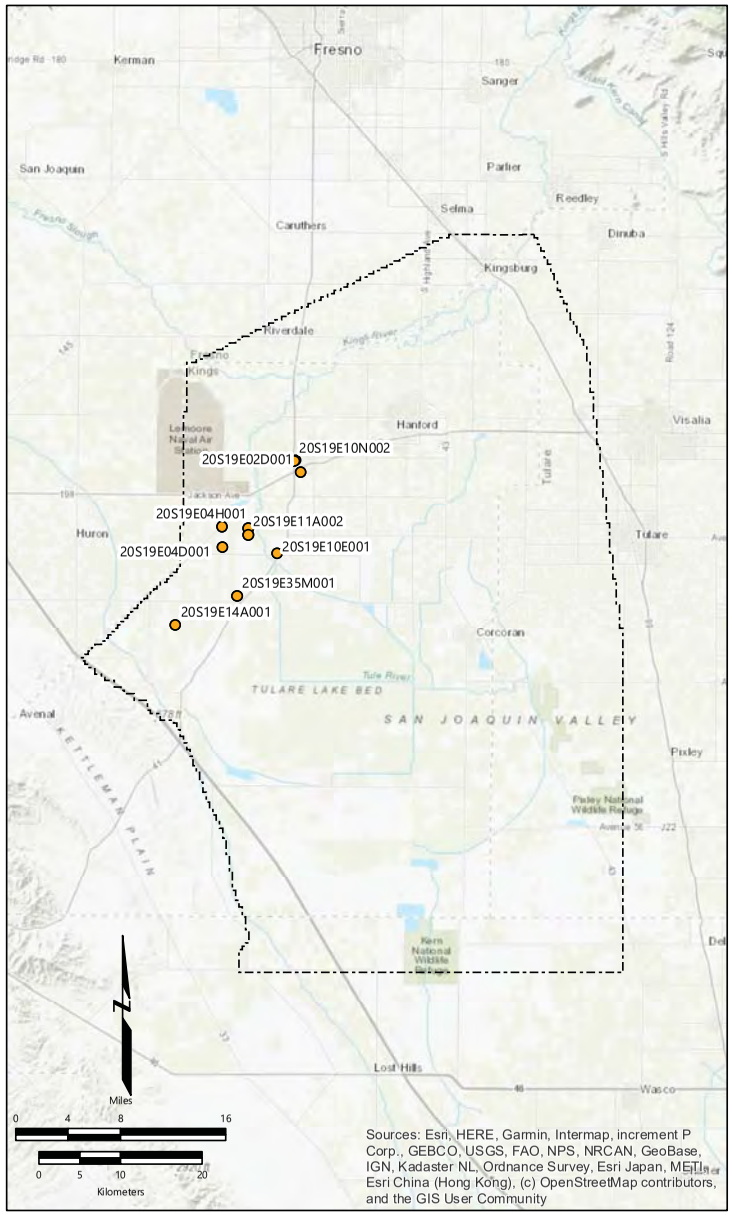
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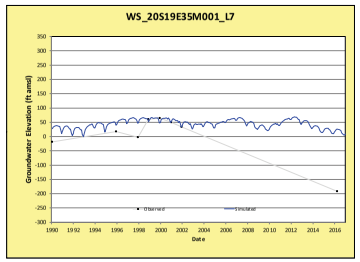
Layer 6 Observed and Simulated Hydrographs

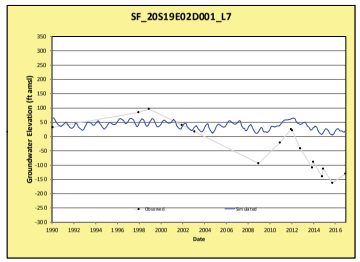
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

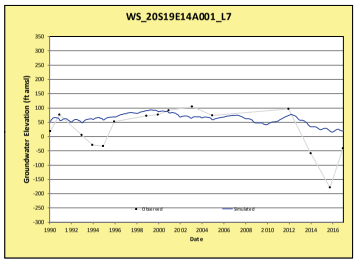
By: EMC	Date: 1/8/2020	Project No.: FR18161220
		Figure **D5-2f**

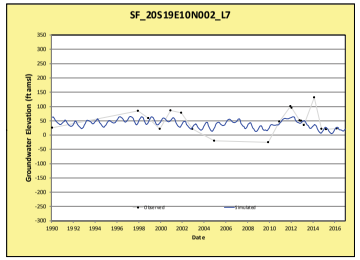
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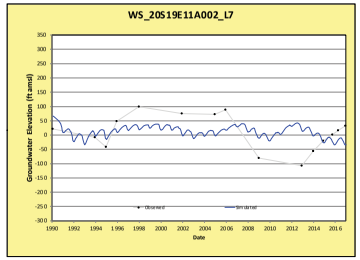


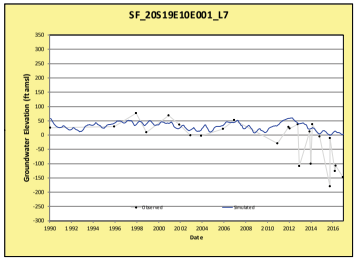


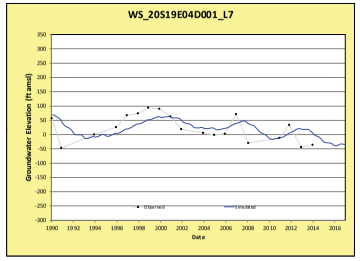


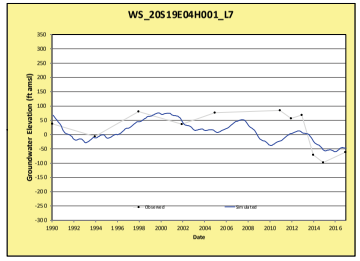


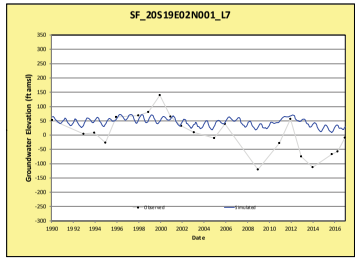


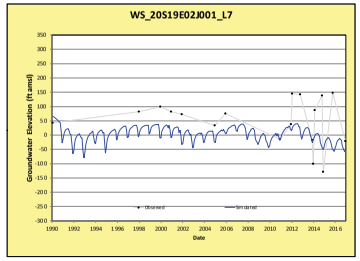












Explanation

- Target well with hydrograph shown
- Target well
- Model domain

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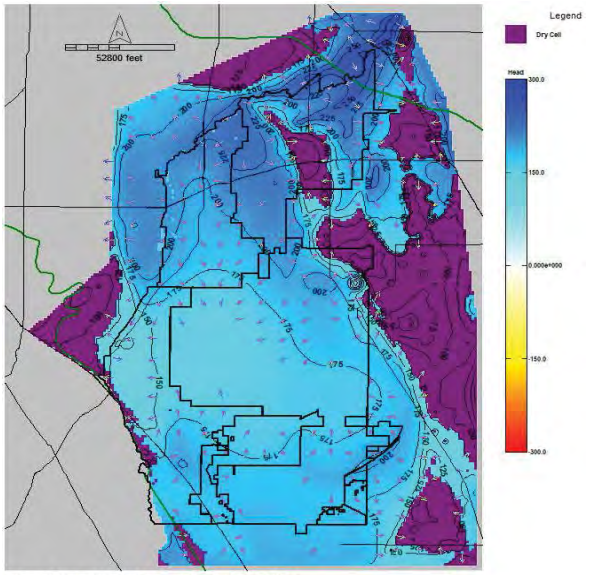
Layer 7 Observed and Simulated Hydrographs

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

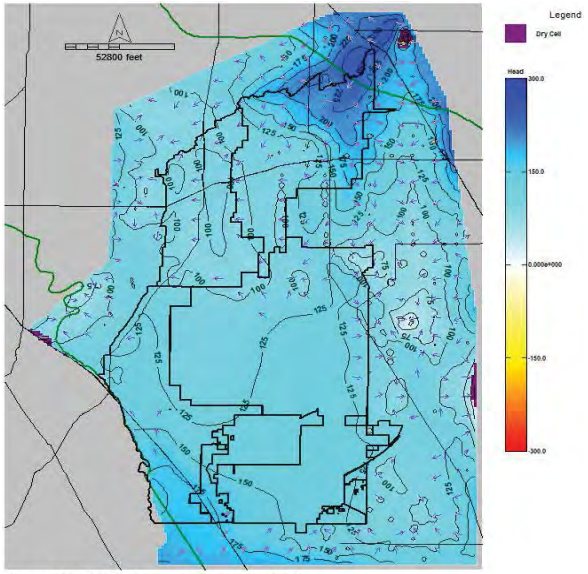
By: EMC	Date: 1/8/2020	Project No.: FR18161220
		Figure **D5-2g**

Date: 1/8/2020 Printed by: elizabeth.chapman
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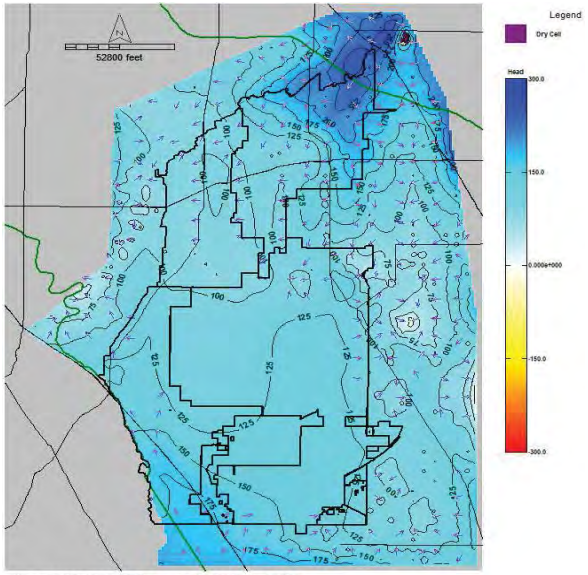
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D5-3 Calib Potentiometrics 12/19/2019



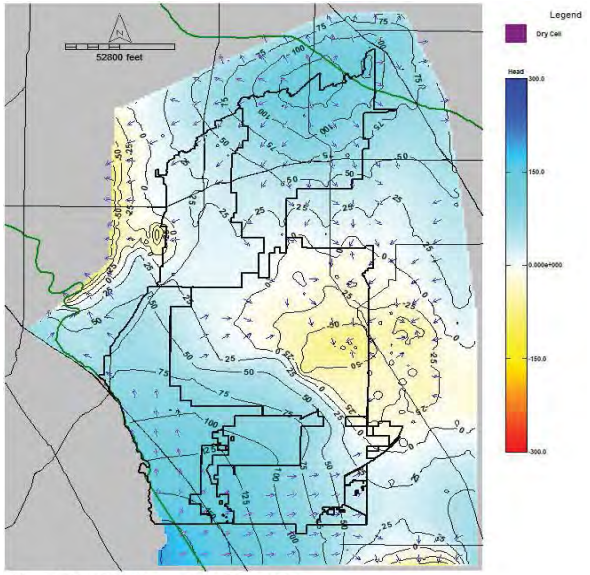
Kings SGMA 1990-2016 Layer: 1 SP: 312 Date: 2016.0



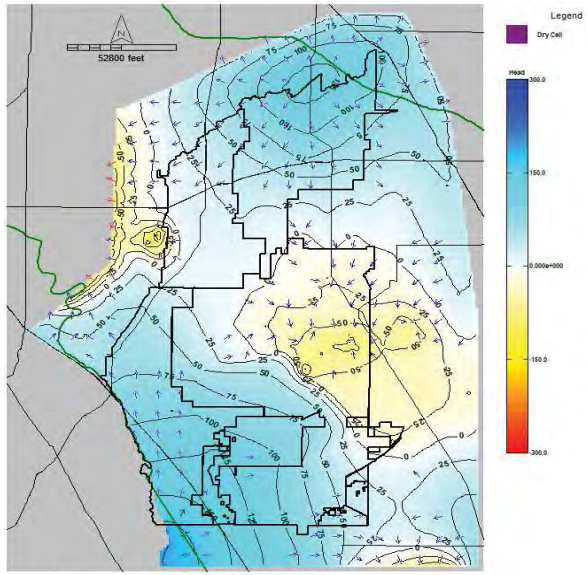
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Kings SGMA 1990-2016 Layer: 3 SP: 312 Date: 2016.0



Kings SGMA 1990-2016 Layer: 5 SP: 312 Date: 2016.0



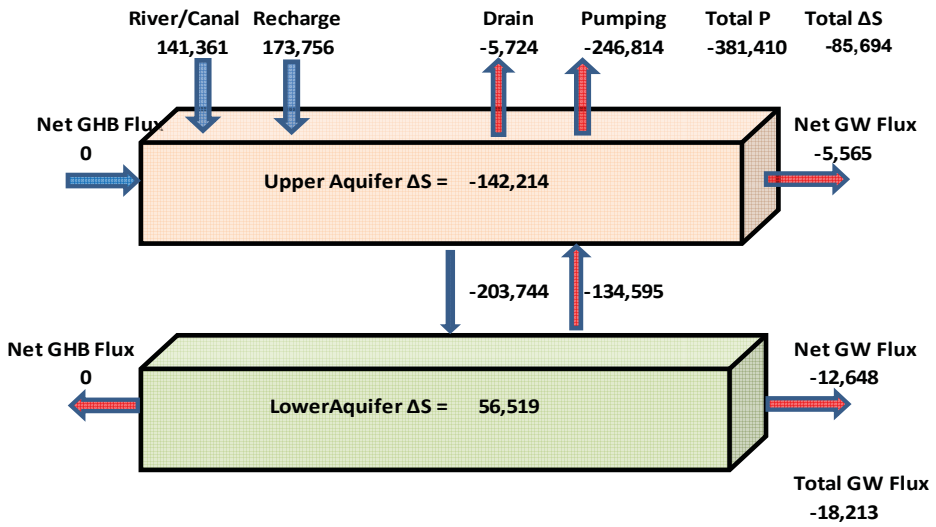
Kings SGMA 1990-2016 Layer: 6 SP: 312 Date: 2016.0

Simulated December 2015 Groundwater Elevations and Groundwater Flow Vectors

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

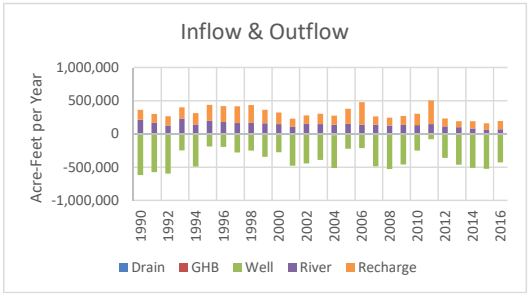
By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D5-3**

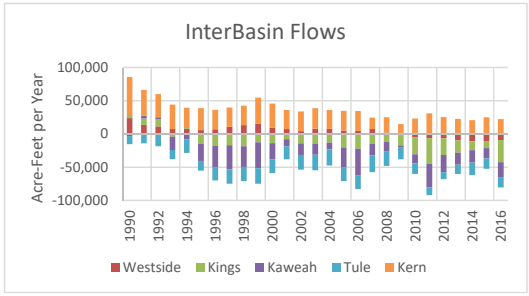
1990-2016
Average Groundwater Balance
Tulare Lake SB

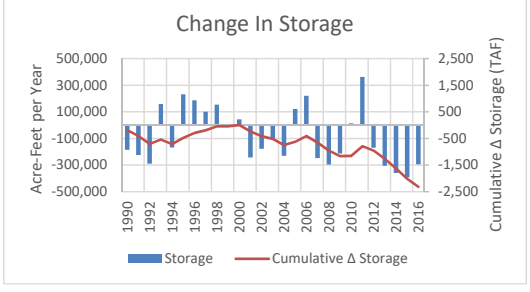


1990 - 2016
Tulare Lake Subbasin

TulareLake Date	Net Drain	Net GHB	Net Well	Net River	Net Recharge	Net Storage	TulareLake Interbasin	Westside Interbasin	Kings Interbasin	Kaweah Interbasin	Tule Interbasin	Kern Interbasin
1990	0	0	-618,843	212,023	150,920	-185,926	69,929	23,632	4,815	-3,467	-12,024	56,971
1991	0	0	-577,240	164,892	135,941	-224,464	51,899	13,271	9,747	4,376	-14,187	38,693
1992	0	0	-596,994	125,681	139,491	-290,389	41,344	11,225	10,812	2,987	-18,583	34,904
1993	0	0	-248,824	231,839	167,981	157,279	6,232	7,344	-4,219	-20,133	-13,496	36,736
1994	-26	0	-491,956	139,080	173,457	-168,707	10,497	7,647	1,210	-8,114	-20,670	30,426
1995	-82	0	-188,622	200,925	235,917	231,421	-16,719	5,564	-14,724	-26,071	-14,705	33,217
1996	-251	0	-195,586	177,508	238,753	186,481	-33,990	6,788	-17,826	-32,867	-19,334	29,250
1997	-1,392	0	-278,726	162,833	252,651	100,786	-35,395	10,524	-17,146	-36,466	-21,396	29,090
1998	-1,870	0	-249,086	165,955	266,380	153,536	-28,386	13,146	-18,649	-31,067	-21,177	29,362
1999	-7,376	0	-338,241	159,660	201,878	522	-20,428	15,099	-12,823	-38,853	-23,234	39,384
2000	-17,343	0	-260,727	147,624	172,534	43,638	-13,661	9,202	-14,008	-24,256	-20,878	36,279
2001	-13,351	0	-467,326	108,934	119,202	-243,059	-2,375	7,046	-8,208	-10,602	-19,402	28,791
2002	-10,253	0	-435,270	150,502	128,082	-178,393	-20,389	4,116	-14,310	-17,484	-22,160	29,448
2003	-8,170	0	-385,602	145,737	157,010	-101,083	-16,217	7,968	-14,505	-16,849	-23,580	30,749
2004	-20,849	0	-494,263	137,236	138,732	-231,122	-11,678	7,475	-13,320	-9,952	-24,296	28,416
2005	-5,413	0	-217,488	150,074	227,638	121,017	-36,335	4,993	-20,418	-30,344	-20,294	29,728
2006	-9,651	0	-205,429	138,230	339,860	220,649	-48,705	4,446	-22,451	-40,403	-20,192	29,895
2007	-14,999	0	-474,153	137,542	123,827	-248,490	-33,353	7,330	-14,948	-17,451	-25,274	16,990
2008	-13,795	0	-515,546	126,421	117,419	-296,277	-23,147	1,856	-12,181	-14,428	-21,584	23,191
2009	-4,295	0	-456,641	133,032	135,636	-213,010	-23,837	-1,793	-15,575	-2,407	-18,590	14,527
2010	-2,440	0	-249,776	129,805	171,969	13,129	-37,307	-5,091	-25,818	-13,379	-16,097	23,078
2011	-4,486	0	-77,680	147,432	355,590	361,228	-61,401	-6,641	-38,331	-35,573	-11,696	30,840
2012	-3,226	0	-357,301	111,314	120,601	-169,947	-42,994	-6,733	-25,065	-25,720	-10,775	25,299
2013	-8,381	0	-455,726	99,564	90,038	-305,607	-38,136	-9,909	-18,283	-18,315	-13,933	22,304
2014	-3,579	0	-508,253	82,742	107,427	-360,352	-41,461	-11,151	-13,313	-18,684	-18,842	20,529
2015	-829	0	-524,338	60,439	99,444	-392,279	-27,490	-10,951	-10,641	-15,502	-15,383	24,986
2016	-2,497	0	-428,423	69,718	123,037	-294,325	-58,248	-9,455	-33,115	-23,497	-14,438	22,257
1990-2016 Average	**-5,724**	**0**	**-381,410**	**141,361**	**173,756**	**-85,694**	**-18,213**	**3,961**	**-13,826**	**-19,427**	**-18,379**	**29,457**
1998-2010 Average	**-9,985**	**0**	**-365,350**	**140,827**	**176,936**	**-73,765**	**-24,294**	**5,830**	**-15,939**	**-20,575**	**-21,289**	**27,680**



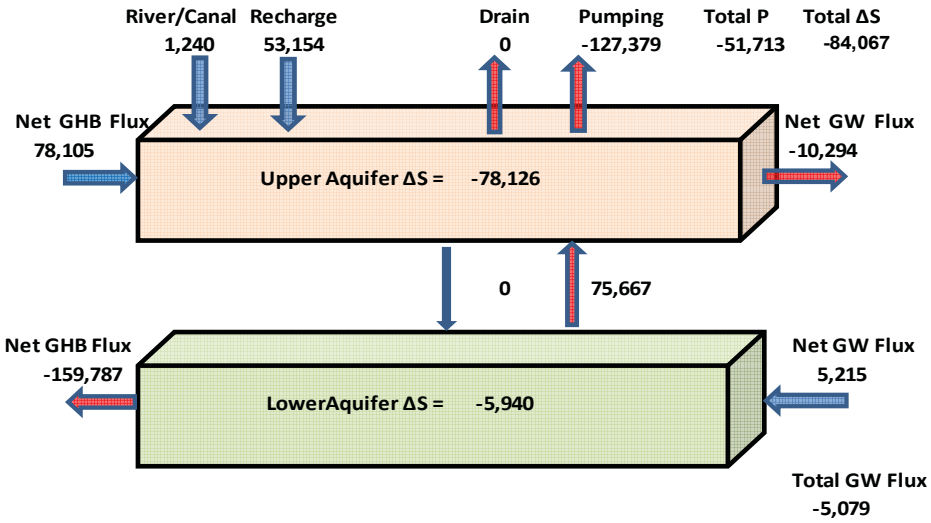




Groundwater Mass Balance
Tulare Lake Subbasin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

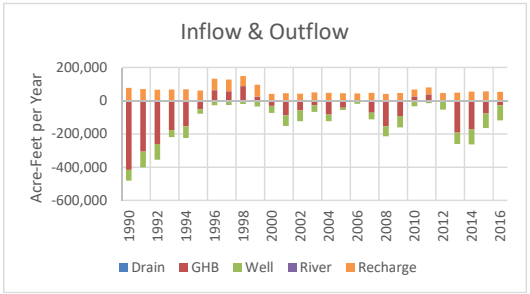
By: dmb	Date: 12/15/19	Project No.: FR18161220
		Figure **D5-4**

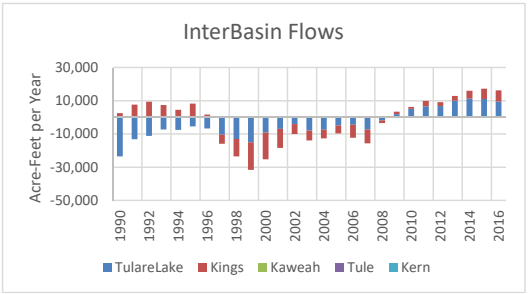
1990-2016
Average Groundwater Balance
Westside SB

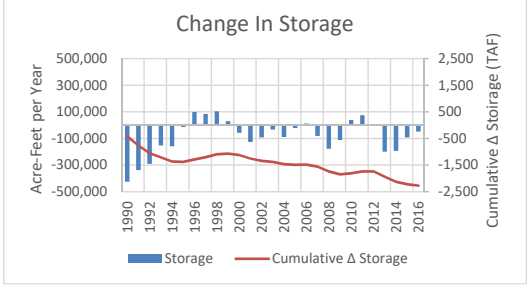


1990 - 2016
Westside Subbasin

TulareLake Date	Net Drain	Net GHB	Net Well	Net River	Net Recharge	Net Storage	Interbasin TulareLake	Interbasin Westside	Interbasin Kings	Interbasin Kaweah	Interbasin Tule	Interbasin Kern
1990	0	-416,613	-64,299	1,305	75,411	-425,294	-23,632	0	2,518	0	0	0
1991	0	-306,833	-94,899	1,315	67,929	-338,123	-13,271	0	7,580	0	0	0
1992	0	-260,820	-94,233	1,297	64,558	-291,005	-11,225	0	9,334	0	0	0
1993	0	-177,022	-42,742	1,275	65,909	-152,615	-7,344	0	7,293	0	0	0
1994	0	-154,444	-69,800	1,262	67,284	-158,845	-7,647	0	4,416	0	0	0
1995	0	-51,451	-26,944	1,258	59,364	-15,122	-5,564	0	8,215	0	0	0
1996	0	61,385	-27,841	1,253	69,011	98,671	-6,788	0	1,651	0	0	0
1997	0	55,068	-26,074	1,249	69,862	84,080	-10,524	0	-5,501	0	0	0
1998	0	86,377	-20,708	1,252	60,275	103,573	-13,146	0	-10,476	0	0	0
1999	0	22,760	-35,621	1,250	71,595	28,355	-15,099	0	-16,531	0	0	0
2000	0	-31,098	-42,612	1,262	38,891	-58,827	-9,202	0	-16,069	0	0	0
2001	0	-88,368	-64,117	1,269	42,859	-126,795	-7,046	0	-11,392	0	0	0
2002	0	-59,530	-64,657	1,278	40,823	-92,170	-4,116	0	-5,977	0	0	0
2003	0	-28,132	-39,554	1,283	47,458	-32,937	-7,968	0	-6,025	0	0	0
2004	0	-83,841	-40,547	1,290	46,023	-89,837	-7,475	0	-5,288	0	0	0
2005	0	-42,330	-14,695	1,291	43,362	-22,114	-4,993	0	-4,750	0	0	0
2006	0	-2,135	-16,480	1,294	41,476	11,768	-4,446	0	-7,942	0	0	0
2007	0	-73,077	-39,686	1,296	45,543	-81,676	-7,330	0	-8,423	0	0	0
2008	0	-153,303	-61,382	1,307	39,326	-177,598	-1,856	0	-1,697	0	0	0
2009	0	-92,631	-68,431	1,308	44,595	-111,863	1,793	0	1,497	0	0	0
2010	0	24,802	-34,671	1,310	40,459	38,085	5,091	0	1,094	0	0	0
2011	0	37,267	-15,329	1,312	40,675	73,785	6,641	0	3,219	0	0	0
2012	0	-449	-54,215	1,318	44,354	99	6,733	0	2,358	0	0	0
2013	0	-191,800	-68,720	1,316	47,308	-199,093	9,909	0	2,894	0	0	0
2014	0	-173,365	-90,404	1,313	52,774	-193,733	11,151	0	4,762	0	0	0
2015	0	-77,549	-87,385	1,313	54,676	-91,693	10,951	0	6,279	0	0	0
2016	0	-28,273	-90,193	0	53,365	-48,877	9,455	0	6,768	0	0	0
1990-2016 Average	**0**	**-81,682**	**-51,713**	**1,240**	**53,154**	**-84,067**	**-3,961**	**0**	**-1,118**	**0**	**0**	**0**
1998-2010 Average	**0**	**-40,039**	**-41,782**	**1,284**	**46,360**	**-47,080**	**-5,830**	**0**	**-7,075**	**0**	**0**	**0**



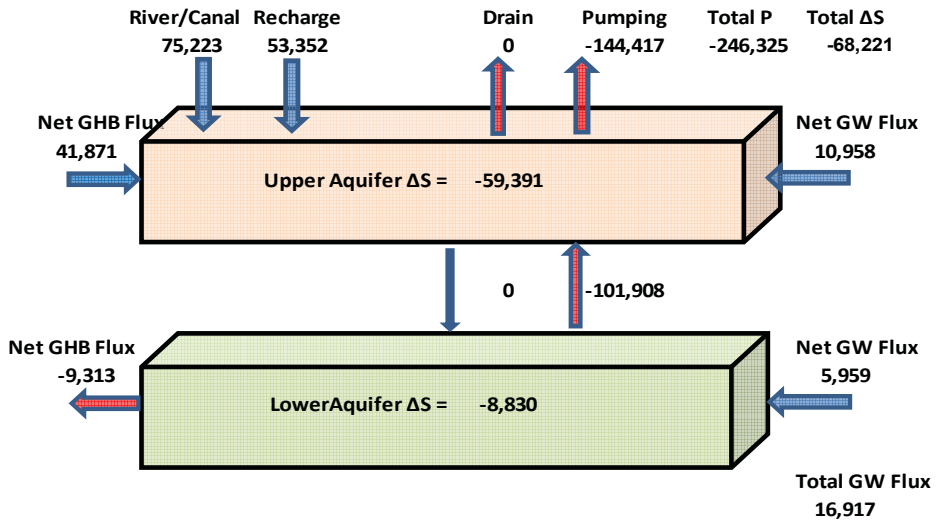




Groundwater Mass Balance
Westside Subbasin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

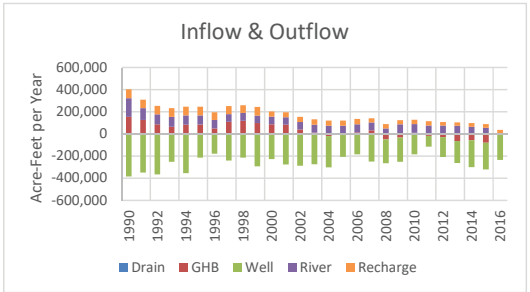
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		Figure **D5-5**

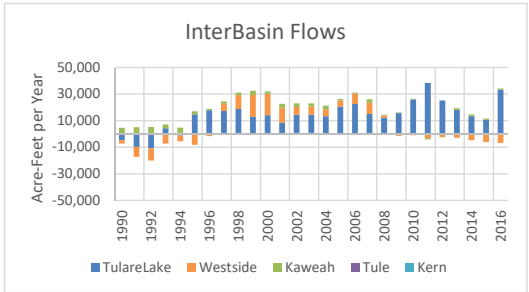
1990-2016
Average Groundwater Balance
Kings SB

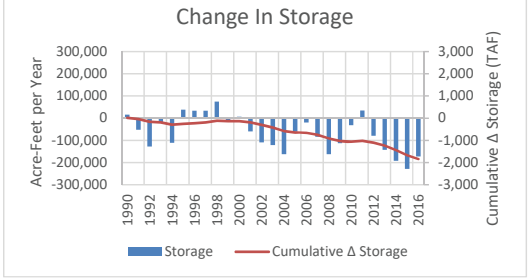


1990 - 2016
Kings Subbasin

TulareLake Date	Net Drain	Net GHB	Net Well	Net River	Net Recharge	Net Storage	Interbasin TulareLake	Interbasin Westside	Interbasin Kings	Interbasin Kaweah	Interbasin Tule	Interbasin Kern
1990	0	153,507	-384,337	169,046	79,741	15,208	-4,815	-2,518	0	4,504	0	0
1991	0	124,539	-348,796	107,577	75,776	-53,100	-9,747	-7,580	0	5,048	0	0
1992	0	85,636	-366,658	91,057	76,643	-128,172	-10,812	-9,334	0	5,220	0	0
1993	0	63,444	-251,847	90,672	77,740	-20,149	4,219	-7,293	0	2,874	0	0
1994	0	82,944	-355,512	83,133	78,922	-111,410	-1,210	-4,416	0	4,642	0	0
1995	0	84,637	-215,315	82,151	77,734	38,072	14,724	-8,215	0	2,339	0	0
1996	0	48,223	-178,362	77,072	68,853	32,844	17,826	-1,651	0	873	0	0
1997	0	107,723	-241,638	70,229	72,279	33,073	17,146	5,501	0	1,803	0	0
1998	0	118,175	-214,567	69,924	69,494	74,029	18,649	10,476	0	1,860	0	0
1999	0	96,736	-292,444	67,565	78,859	-16,762	12,823	16,531	0	3,100	0	0
2000	0	85,919	-227,760	68,455	47,204	5,842	14,008	16,069	0	1,936	0	0
2001	0	82,301	-277,276	67,448	45,197	-59,687	8,208	11,392	0	2,987	0	0
2002	0	38,507	-286,933	68,043	47,651	-109,739	14,310	5,977	0	2,634	0	0
2003	0	10,551	-275,240	72,558	47,606	-121,577	14,505	6,025	0	2,345	0	0
2004	0	-19,464	-283,587	72,500	46,386	-162,951	13,320	5,288	0	2,545	0	0
2005	0	-4,898	-203,108	72,979	47,504	-61,361	20,418	4,750	0	976	0	0
2006	0	13,674	-184,500	72,546	47,592	-19,644	22,451	7,942	0	614	0	0
2007	0	32,310	-250,493	70,241	37,723	-84,139	14,948	8,423	0	2,632	0	0
2008	0	-50,566	-214,765	49,586	38,416	-162,941	12,181	1,697	0	463	0	0
2009	0	-33,972	-217,422	85,755	37,471	-113,549	15,575	-1,497	0	479	0	0
2010	0	9,787	-185,133	78,260	39,636	-32,243	25,818	-1,094	0	459	0	0
2011	0	-17,920	-97,073	75,380	39,597	34,158	38,331	-3,219	0	-966	0	0
2012	0	-29,573	-179,351	74,885	31,796	-79,785	25,065	-2,358	0	-281	0	0
2013	0	-64,621	-198,165	72,788	30,437	-143,078	18,283	-2,894	0	1,051	0	0
2014	0	-57,537	-243,399	63,777	34,247	-193,050	13,313	-4,762	0	1,243	0	0
2015	0	-79,762	-242,398	55,138	32,307	-229,309	10,641	-6,279	0	958	0	0
2016	0	-1,216	-234,685	2,254	33,689	-172,561	33,115	-6,768	0	944	0	0
1990-2016 Average	**0**	**32,559**	**-246,325**	**75,223**	**53,352**	**-68,221**	**13,826**	**1,118**	**0**	**1,973**	**0**	**0**
1998-2010 Average	**0**	**29,159**	**-239,479**	**70,451**	**48,518**	**-66,517**	**15,939**	**7,075**	**0**	**1,771**	**0**	**0**



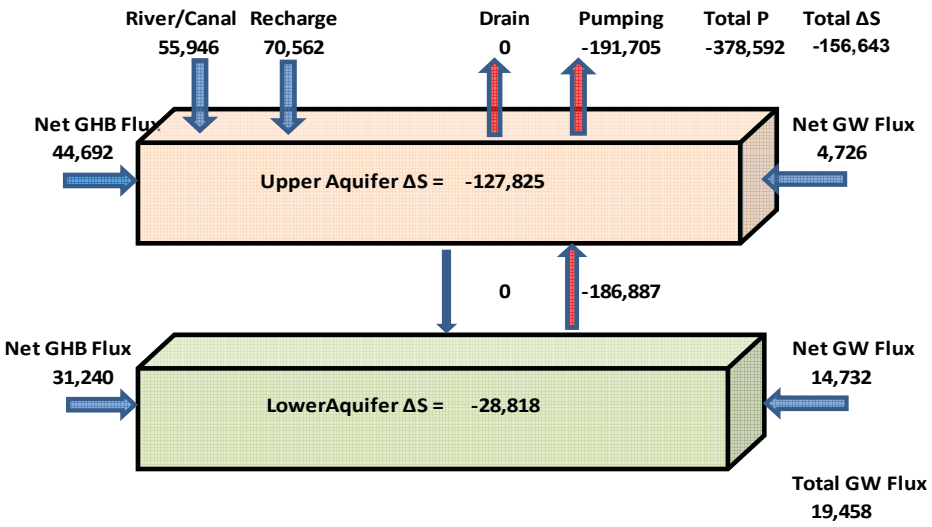




Groundwater Mass Balance
Kings Subbasin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

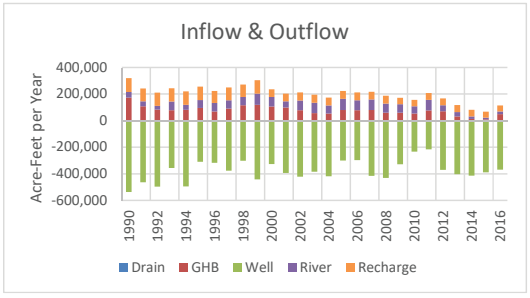
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		Figure **D5-6**

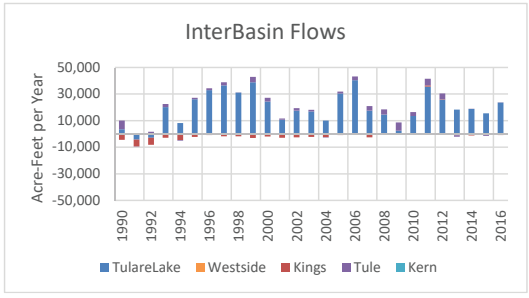
1990-2016
Average Groundwater Balance
Kaweah SB

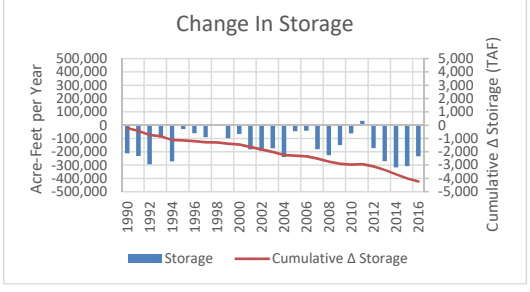


1990 - 2016
Kaweah Subbasin

TulareLake Date	Net Drain	Net GHB	Net Well	Net River	Net Recharge	Net Storage	Interbasin TulareLake	Interbasin Westside	Interbasin Kings	Interbasin Kaweah	Interbasin Tule	Interbasin Kern
1990	0	172,831	-537,159	42,496	103,609	-212,649	3,467	0	-4,504	0	6,568	0
1991	0	107,583	-463,728	36,764	96,709	-232,084	-4,376	0	-5,048	0	-11	0
1992	0	81,651	-497,528	29,290	99,060	-294,105	-2,987	0	-5,220	0	1,542	0
1993	0	77,286	-356,606	66,092	99,049	-94,514	20,133	0	-2,874	0	2,383	0
1994	0	80,902	-495,185	37,053	102,172	-272,016	8,114	0	-4,642	0	-549	0
1995	0	94,932	-309,662	59,838	100,083	-30,023	26,071	0	-2,339	0	1,054	0
1996	0	68,503	-317,375	63,686	91,031	-60,703	32,867	0	-873	0	1,443	0
1997	0	89,438	-377,453	63,327	96,295	-91,317	36,466	0	-1,803	0	2,354	0
1998	0	114,652	-301,969	63,291	92,691	-2,106	31,067	0	-1,860	0	22	0
1999	0	118,216	-442,308	84,491	100,527	-99,162	38,853	0	-3,100	0	4,070	0
2000	0	106,502	-327,865	70,296	58,536	-67,290	24,256	0	-1,936	0	2,897	0
2001	0	97,263	-394,189	48,197	57,101	-182,971	10,602	0	-2,987	0	972	0
2002	0	78,197	-422,360	72,804	61,265	-193,353	17,484	0	-2,634	0	1,815	0
2003	0	56,243	-384,827	77,120	60,606	-175,029	16,849	0	-2,345	0	1,236	0
2004	0	53,353	-419,713	60,149	59,185	-239,862	9,952	0	-2,545	0	-308	0
2005	0	78,649	-300,204	85,039	59,441	-46,176	30,344	0	-976	0	1,502	0
2006	0	77,866	-298,321	74,806	59,613	-43,395	40,403	0	-614	0	2,795	0
2007	0	79,789	-415,842	79,484	57,284	-180,937	17,451	0	-2,632	0	3,492	0
2008	0	58,458	-431,763	68,344	60,460	-226,521	14,428	0	-463	0	4,003	0
2009	0	58,932	-329,201	63,510	48,642	-150,022	2,407	0	-479	0	6,147	0
2010	0	52,112	-234,294	55,673	48,421	-62,200	13,379	0	-459	0	2,962	0
2011	0	76,346	-216,915	79,408	50,989	31,298	35,573	0	966	0	4,929	0
2012	0	70,075	-370,148	45,029	50,752	-173,616	25,720	0	281	0	4,380	0
2013	0	31,050	-403,265	33,241	51,860	-270,970	18,315	0	-1,051	0	-1,157	0
2014	0	12,193	-415,074	18,863	49,171	-317,311	18,684	0	-1,243	0	26	0
2015	0	9,525	-390,330	11,544	46,175	-309,136	15,502	0	-958	0	-619	0
2016	0	47,596	-368,704	20,716	44,451	-233,187	23,497	0	-944	0	174	0
1990-2016 Average	**0**	**75,931**	**-378,592**	**55,946**	**70,562**	**-156,643**	**19,427**	**0**	**-1,973**	**0**	**2,005**	**0**
1998-2010 Average	**0**	**79,249**	**-361,758**	**69,477**	**63,367**	**-128,386**	**20,575**	**0**	**-1,771**	**0**	**2,431**	**0**



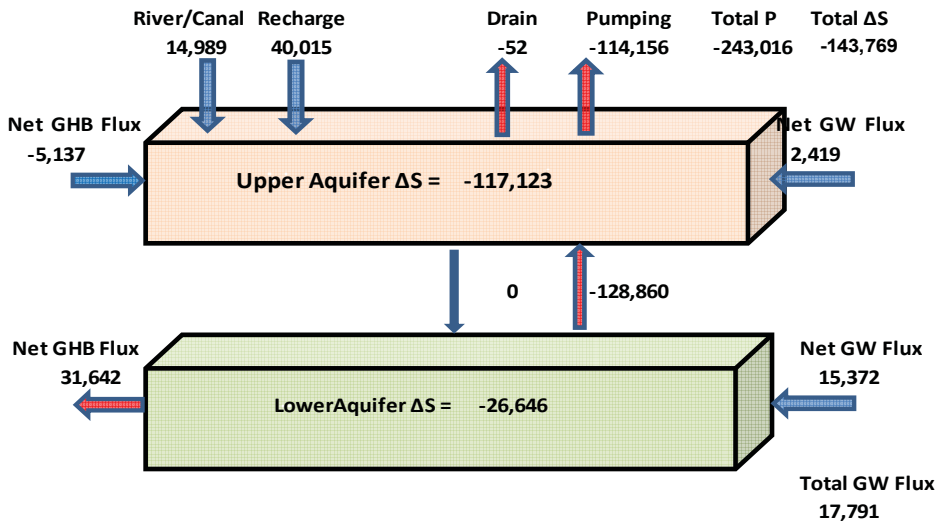




Groundwater Mass Balance
Kaweah Subbasin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

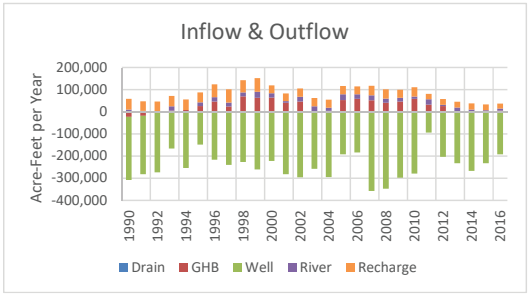
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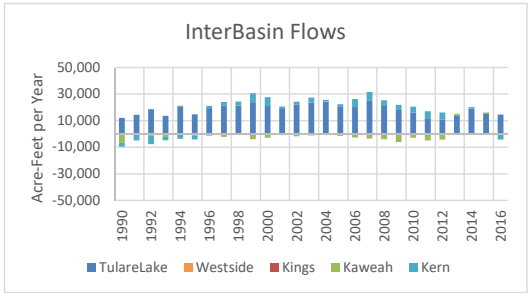
1990-2016
Average Groundwater Balance
Tule SB

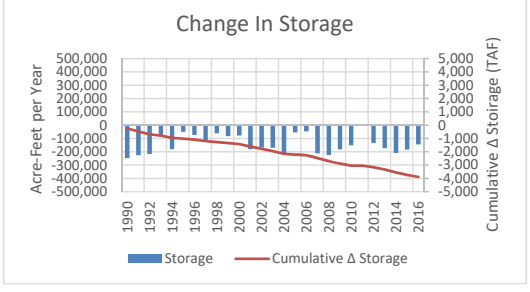


1990 - 2016
Tule Subbasin

TulareLake Date	Net Drain	Net GHB	Net Well	Net River	Net Recharge	Net Storage	Interbasin TulareLake	Interbasin Westside	Interbasin Kings	Interbasin Kaweah	Interbasin Tule	Interbasin Kern
1990	0	-23,566	-284,555	9,618	48,228	-247,845	12,024	0	0	-6,568	0	-3,025
1991	0	-18,667	-263,398	3,449	43,409	-225,953	14,187	0	0	11	0	-4,946
1992	0	-5,300	-268,690	684	45,275	-217,174	18,583	0	0	-1,542	0	-6,183
1993	0	4,326	-165,862	20,019	46,394	-86,494	13,496	0	0	-2,383	0	-2,484
1994	0	7,958	-253,837	0	46,982	-181,434	20,670	0	0	549	0	-3,757
1995	0	25,307	-148,402	16,882	44,943	-50,717	14,705	0	0	-1,054	0	-3,098
1996	0	45,820	-216,603	19,552	57,888	-73,711	19,334	0	0	-1,443	0	1,739
1997	0	23,106	-239,747	18,382	59,597	-116,961	21,396	0	0	-2,354	0	2,659
1998	0	68,956	-227,472	17,741	54,979	-61,553	21,177	0	0	-22	0	3,087
1999	-94	62,510	-260,854	27,404	61,127	-83,406	23,234	0	0	-4,070	0	7,338
2000	-82	63,667	-221,821	19,580	35,921	-78,068	20,878	0	0	-2,897	0	6,685
2001	-43	40,136	-282,286	7,462	34,734	-180,420	19,402	0	0	-972	0	1,148
2002	-77	45,471	-295,718	21,943	36,975	-169,024	22,160	0	0	-1,815	0	2,037
2003	-143	785	-257,704	23,994	36,852	-170,227	23,580	0	0	-1,236	0	3,644
2004	-88	3,599	-294,831	14,519	35,955	-215,230	24,296	0	0	308	0	1,012
2005	-174	52,654	-191,897	26,378	36,973	-55,320	20,294	0	0	-1,502	0	1,954
2006	-151	57,771	-184,092	20,669	35,792	-46,574	20,192	0	0	-2,795	0	6,040
2007	-209	51,182	-357,542	22,998	43,001	-212,594	25,274	0	0	-3,492	0	6,196
2008	-143	40,599	-347,405	18,133	42,686	-224,920	21,584	0	0	-4,003	0	3,628
2009	-103	46,193	-297,514	16,553	36,625	-182,508	18,590	0	0	-6,147	0	3,296
2010	-36	58,280	-279,500	10,122	41,904	-151,840	16,097	0	0	-2,962	0	4,255
2011	-58	32,131	-94,078	23,936	24,249	-1,823	11,696	0	0	-4,929	0	5,231
2012	-13	25,701	-203,630	4,825	26,348	-135,064	10,775	0	0	-4,380	0	5,310
2013	0	3,110	-232,680	16,090	25,641	-173,089	13,933	0	0	1,157	0	-340
2014	0	505	-266,921	8,515	28,447	-209,336	18,842	0	0	-26	0	1,301
2015	0	-1,136	-231,535	6,160	26,210	-184,562	15,383	0	0	619	0	-262
2016	0	4,541	-192,869	9,100	23,267	-145,904	14,438	0	0	-174	0	-4,209
1990-2016 Average	**-52**	**26,505**	**-243,016**	**14,989**	**40,015**	**-143,769**	**18,379**	**0**	**0**	**-2,005**	**0**	**1,417**
1998-2010 Average	**-103**	**45,523**	**-269,126**	**19,038**	**41,040**	**-140,899**	**21,289**	**0**	**0**	**-2,431**	**0**	**3,871**



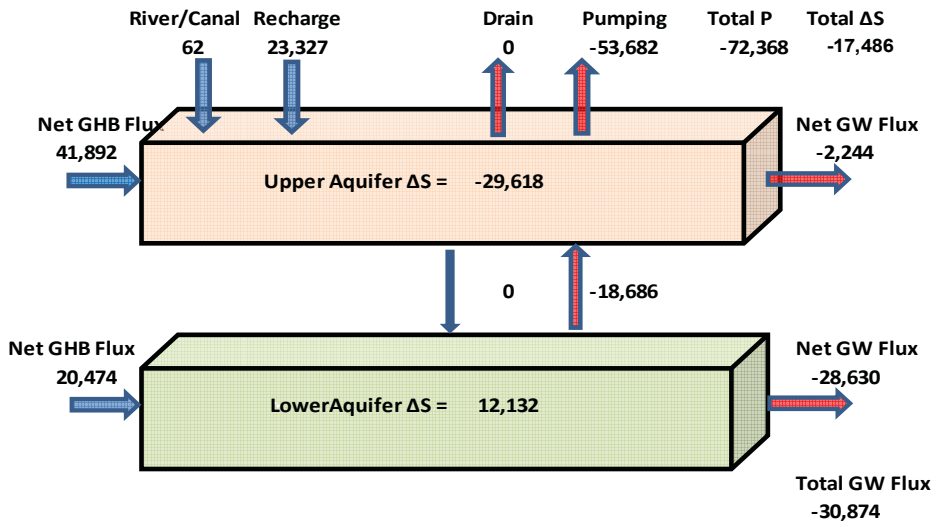




Groundwater Mass Balance
Tule Subbasin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

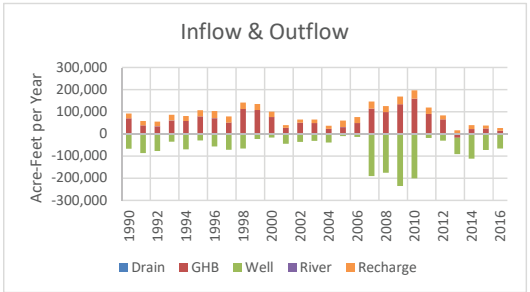
By: dmb	Date: 12/15/19	Project No.: FR18161220
		Figure **D5-8**

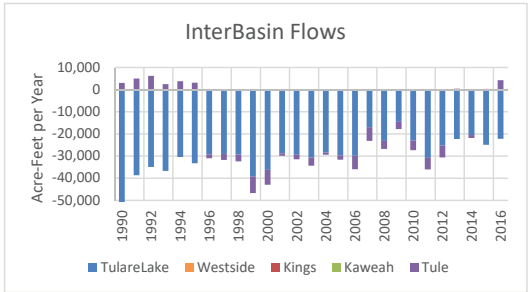
1990-2016
Average Groundwater Balance
Kern SB

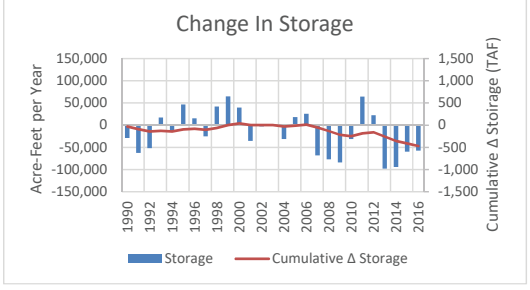


1990 - 2016
Kern Subbasin

TulareLake Date	Net Drain	Net GHB	Net Well	Net River	Net Recharge	Net Storage	Interbasin TulareLake	Interbasin Westside	Interbasin Kings	Interbasin Kaweah	Interbasin Tule	Interbasin Kern
1990	0	69,796	-67,231	0	22,116	-29,265	-56,971	0	0	0	3,025	0
1991	0	38,262	-87,211	0	20,006	-62,690	-38,693	0	0	0	4,946	0
1992	0	34,064	-77,917	187	20,626	-51,761	-34,904	0	0	0	6,183	0
1993	0	60,245	-35,270	185	26,026	16,935	-36,736	0	0	0	2,484	0
1994	0	57,842	-69,714	0	22,828	-15,712	-30,426	0	0	0	3,757	0
1995	0	78,149	-30,062	185	28,292	46,446	-33,217	0	0	0	3,098	0
1996	0	70,592	-56,706	187	31,895	14,979	-29,250	0	0	0	-1,739	0
1997	0	50,141	-72,084	185	28,287	-25,219	-29,090	0	0	0	-2,659	0
1998	0	111,858	-66,609	185	28,908	41,894	-29,362	0	0	0	-3,087	0
1999	0	107,107	-23,290	0	27,767	64,863	-39,384	0	0	0	-7,338	0
2000	0	75,337	-17,088	187	24,123	39,596	-36,279	0	0	0	-6,685	0
2001	0	27,538	-44,901	0	11,757	-35,545	-28,791	0	0	0	-1,148	0
2002	0	50,642	-36,158	0	13,888	-3,114	-29,448	0	0	0	-2,037	0
2003	0	48,468	-31,250	0	16,522	-652	-30,749	0	0	0	-3,644	0
2004	0	22,793	-39,107	0	14,192	-31,550	-28,416	0	0	0	-1,012	0
2005	0	30,314	-10,054	185	29,176	17,940	-29,728	0	0	0	-1,954	0
2006	0	48,548	-13,906	185	26,744	25,637	-29,895	0	0	0	-6,040	0
2007	0	114,520	-190,698	0	31,175	-68,188	-16,990	0	0	0	-6,196	0
2008	0	97,862	-175,605	0	27,362	-77,200	-23,191	0	0	0	-3,628	0
2009	0	133,803	-235,193	0	34,866	-84,347	-14,527	0	0	0	-3,296	0
2010	0	159,358	-200,492	0	36,801	-31,667	-23,078	0	0	0	-4,255	0
2011	0	89,684	-18,947	0	29,513	64,180	-30,840	0	0	0	-5,231	0
2012	0	65,311	-30,394	0	17,679	21,988	-25,299	0	0	0	-5,310	0
2013	0	-18,128	-73,820	0	15,969	-97,943	-22,304	0	0	0	340	0
2014	0	21,647	-111,701	0	17,652	-94,232	-20,529	0	0	0	-1,301	0
2015	0	24,001	-72,531	0	13,114	-60,141	-24,986	0	0	0	262	0
2016	0	14,125	-65,994	0	12,550	-57,368	-22,257	0	0	0	4,209	0
1990-2016 Average	**0**	**62,366**	**-72,368**	**62**	**23,327**	**-17,486**	**-29,457**	**0**	**0**	**0**	**-1,417**	**0**
1998-2010 Average	**0**	**79,088**	**-83,412**	**57**	**24,868**	**-10,949**	**-27,680**	**0**	**0**	**0**	**-3,871**	**0**



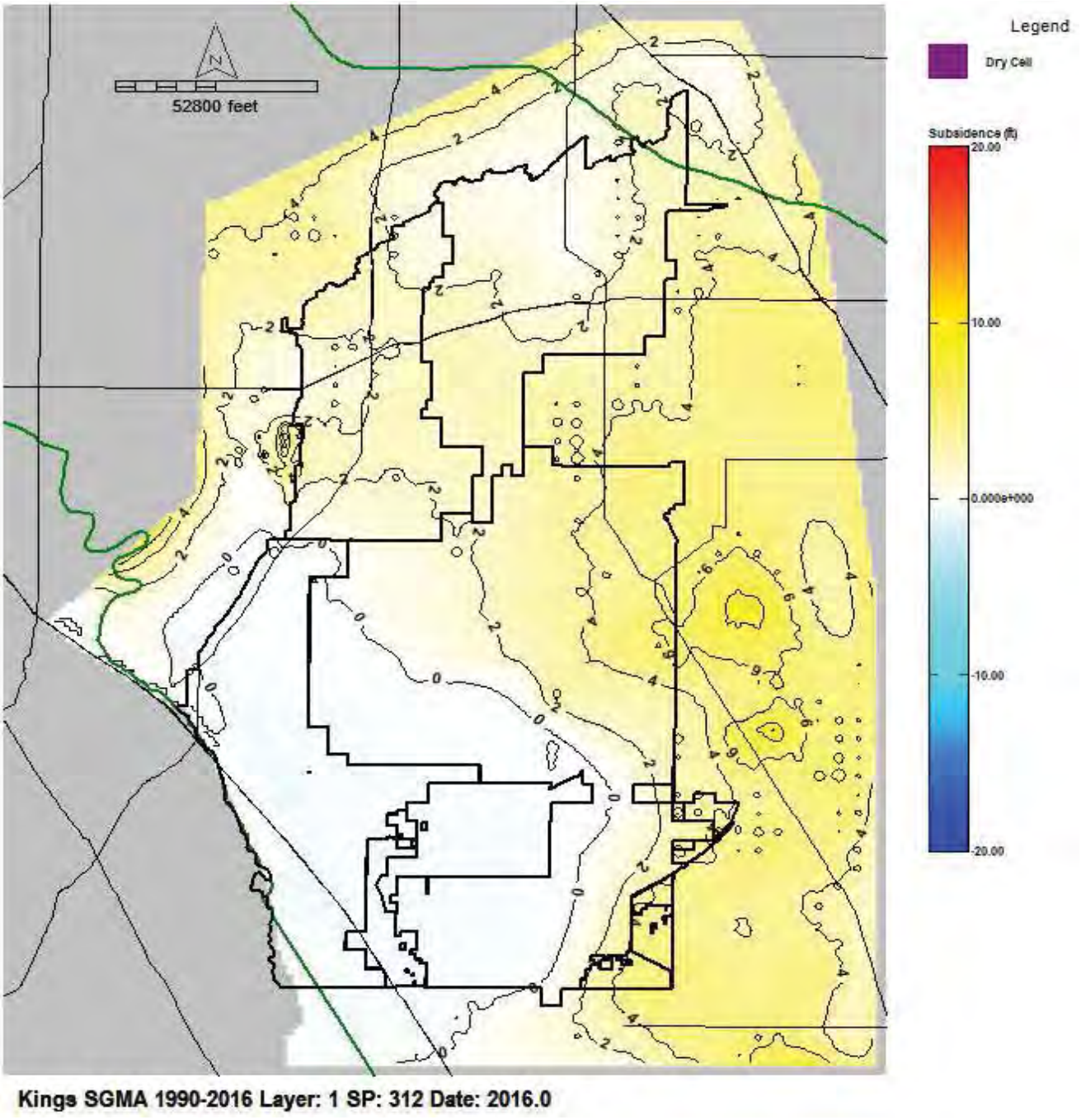




Groundwater Mass Balance
Kern Subbasin
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/15/19	Project No.: FR18161220
		Figure **D5-9**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D5-10 Subsidence

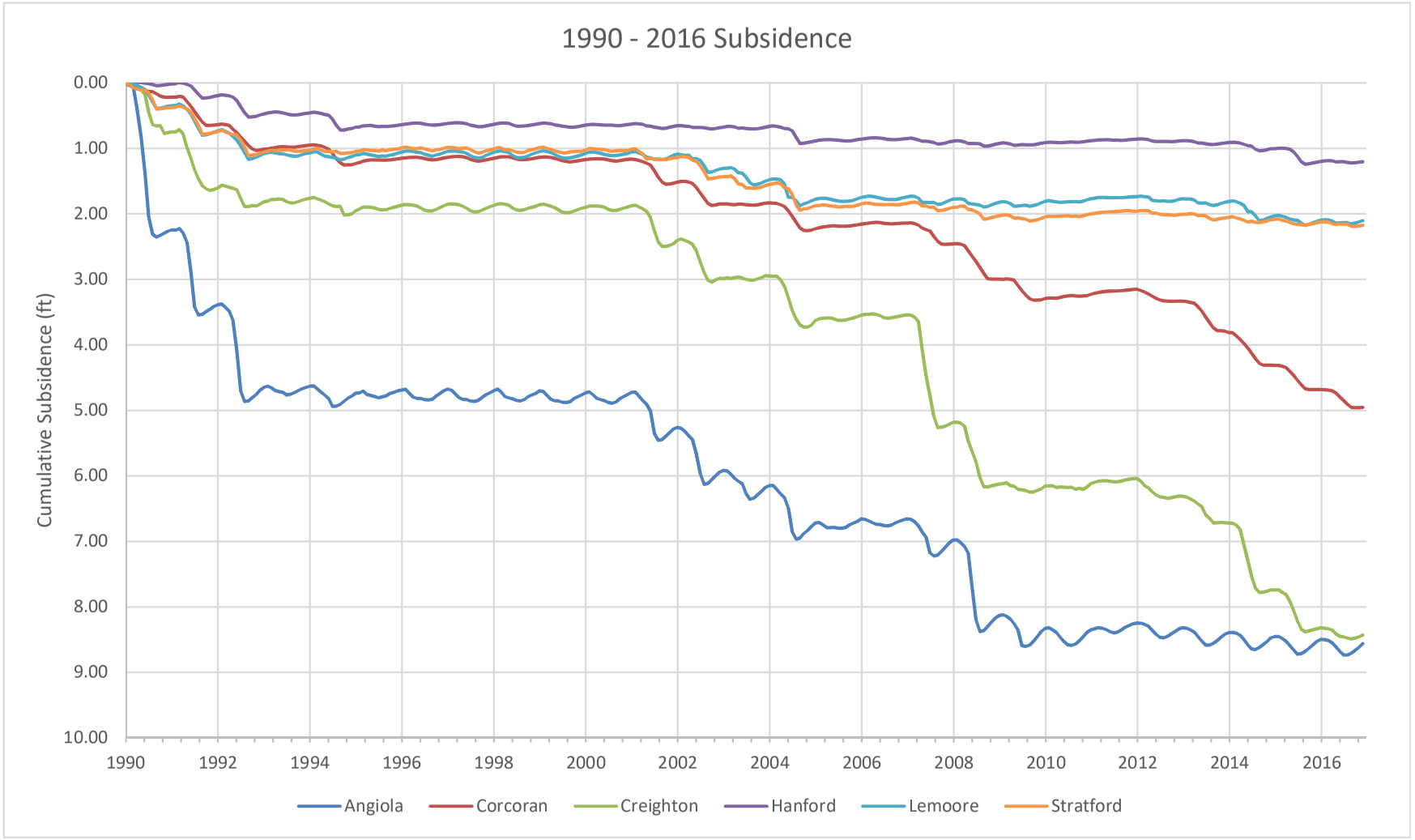


Simulated Subsidence 1990-2015

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

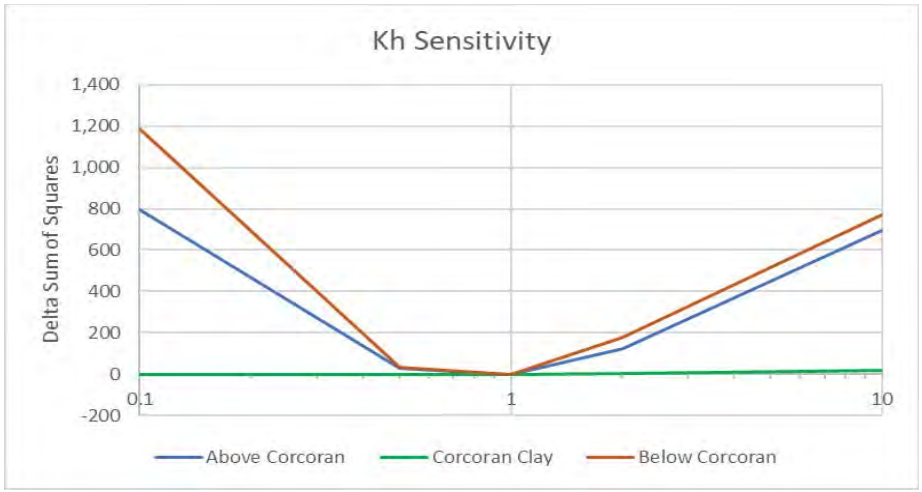
By: dmb	Date: 12/12/19	Project No.: FR18161220
		Figure **D5-10**

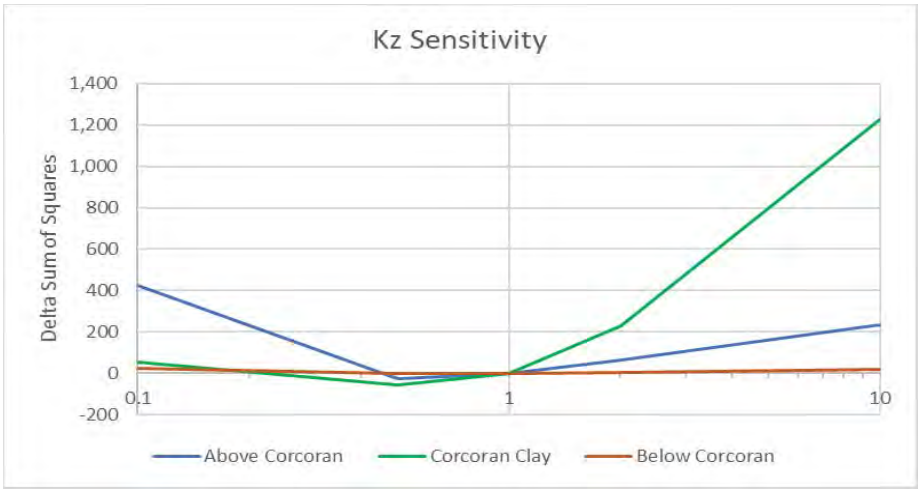
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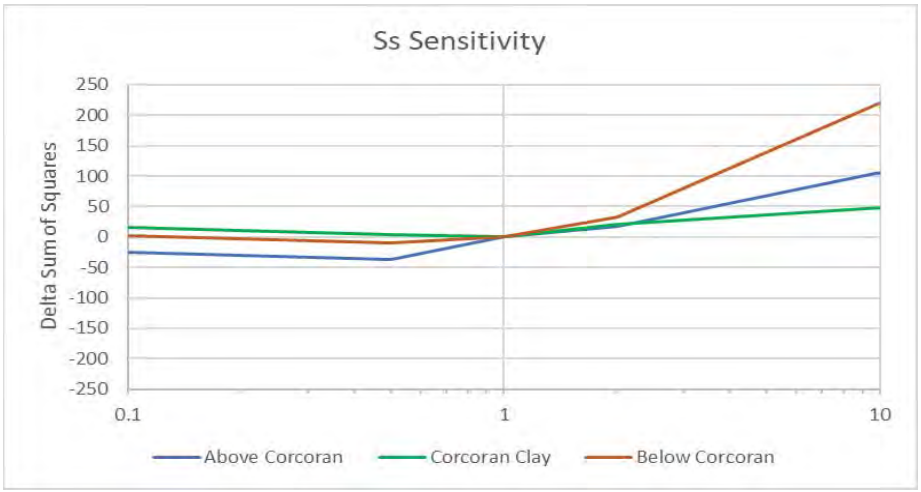


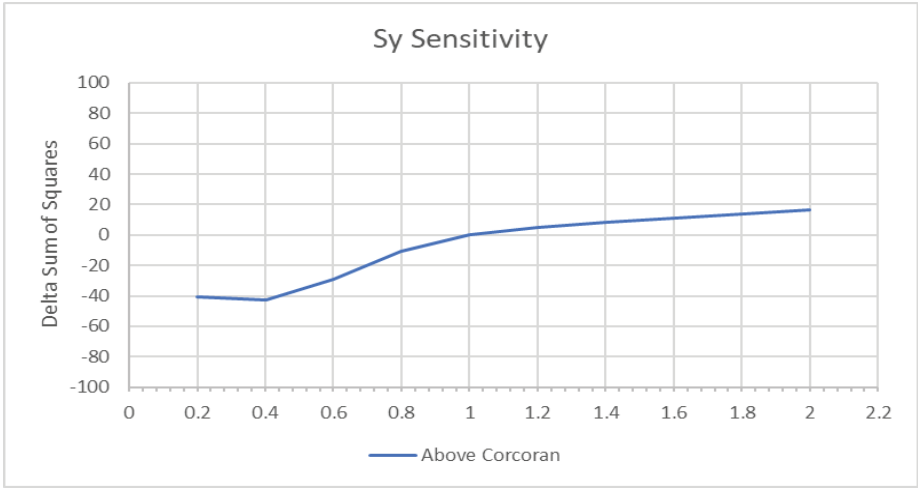
Simulated Cumulative Subsidence
Municipal and Agricultural Well Field
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/19	Project No.: FR18161220
		Figure **D5-11**





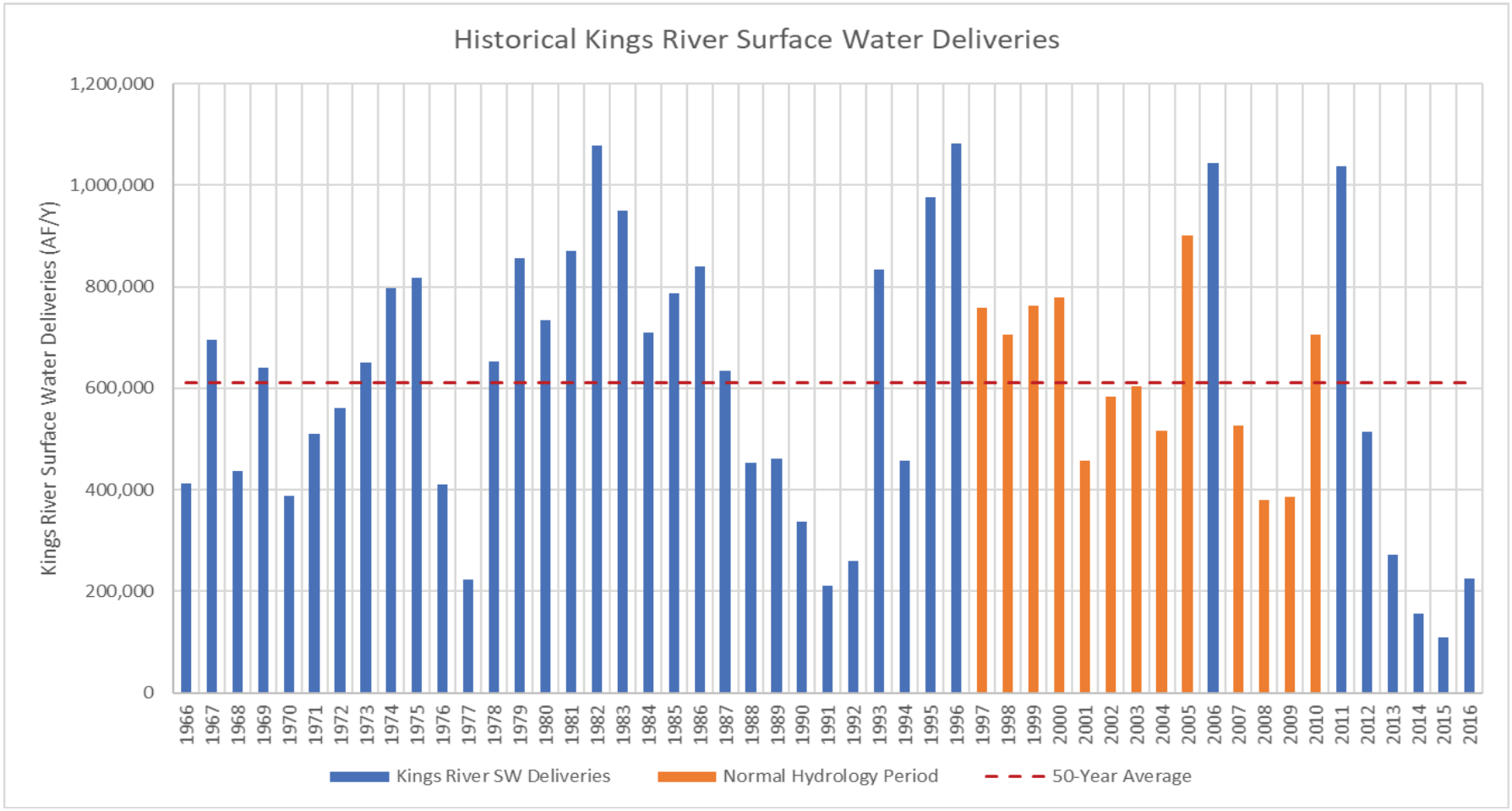




Model Hydraulic Parameter Sensitivity Anlysis

Tulare Lake Subbasin SGMA Model
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D6-1**



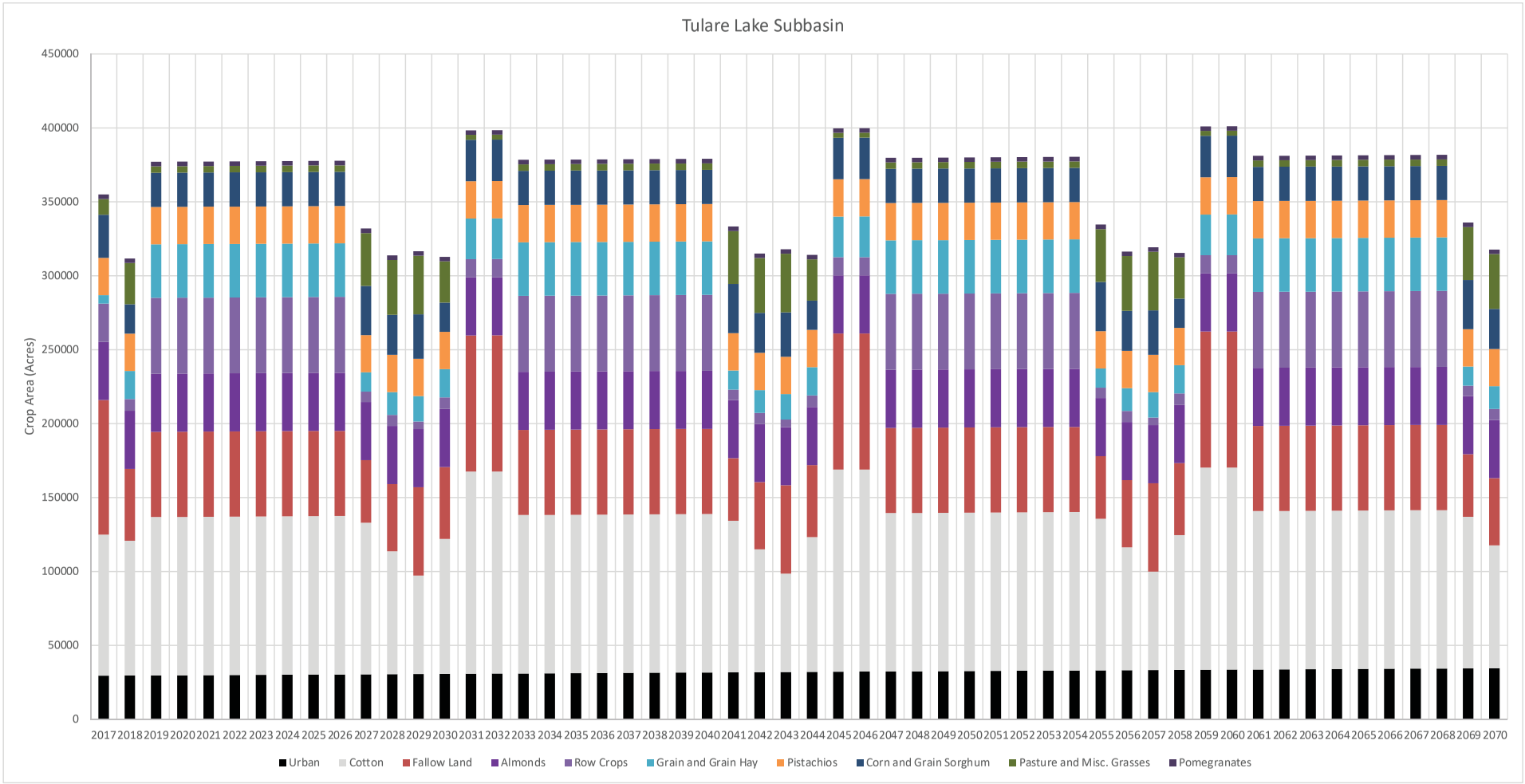
□o□e: □ormal □□drolog□c□cle included 199□ ins□ead o□2006 □o ma□c□ □□e □0-□ear average

Historical Kings River Surface Water Deliveries with Normal Hydrology

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure D□□

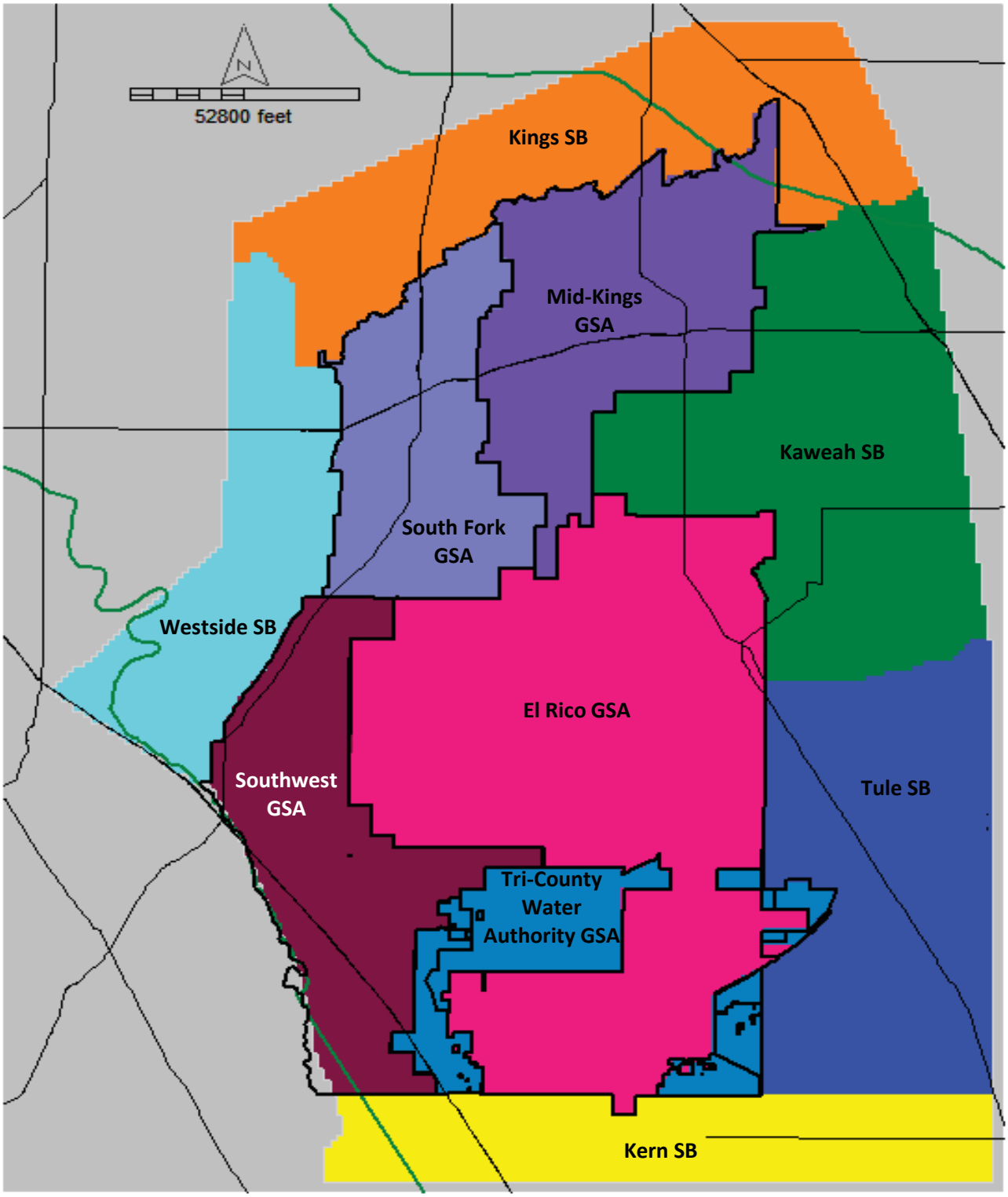
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D7-2 Baseline Crop Acres 12/19/2019



2017-2070 Baseline Forecast
Crop Acerage
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/2019	Project No.: FR18161220
		Figure **D7-2**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D7-3 Forecast Service Areas

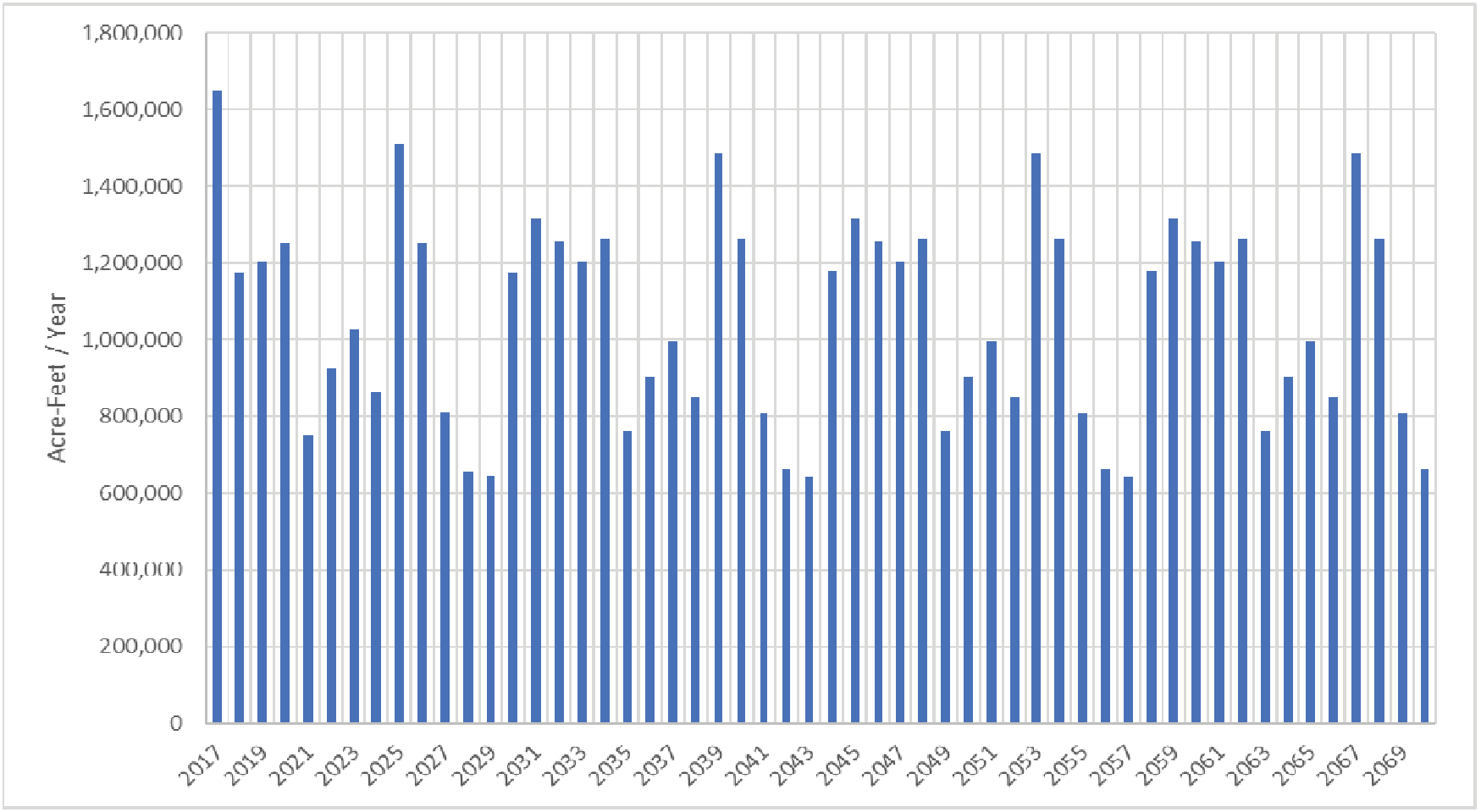


Forecast Model Service Areas

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/19	Project No.: FR18161220
		Figure **D7-3**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D7-4 Baseline SWD CNRA

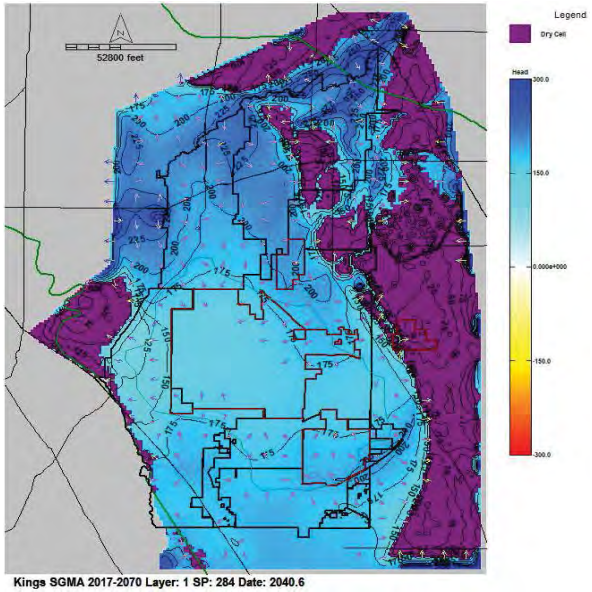


2017-2070 Baseline Forecast of Surface Water Deliveries with CNRA

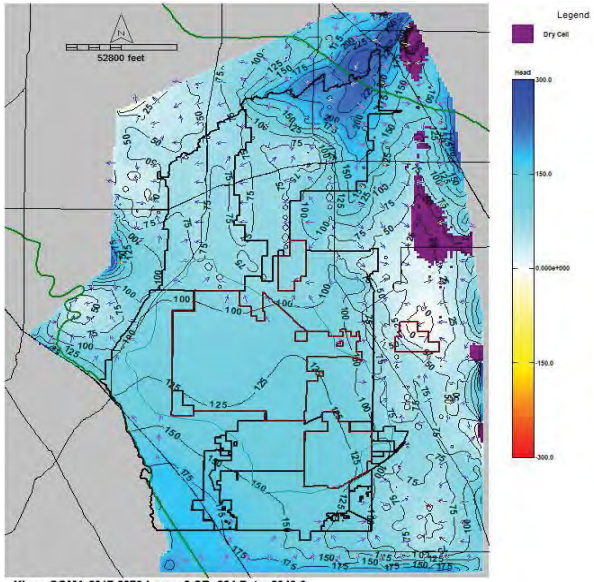
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/2019	Project No.: FR18161220
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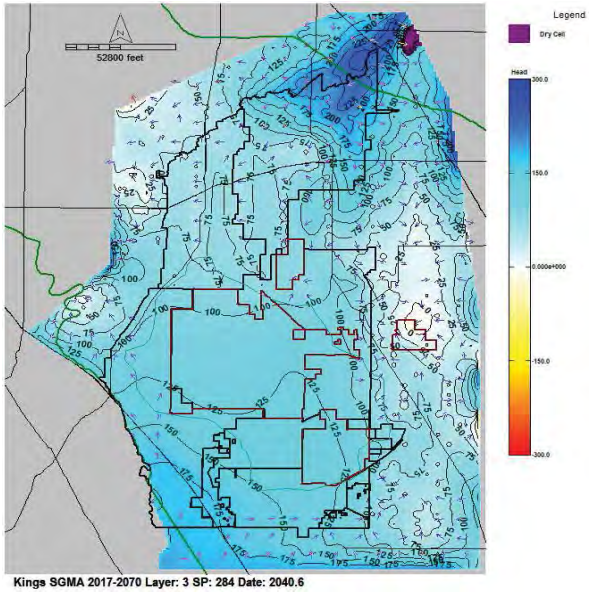
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D7-5 2040 Baseline Potentio 12/19/2019



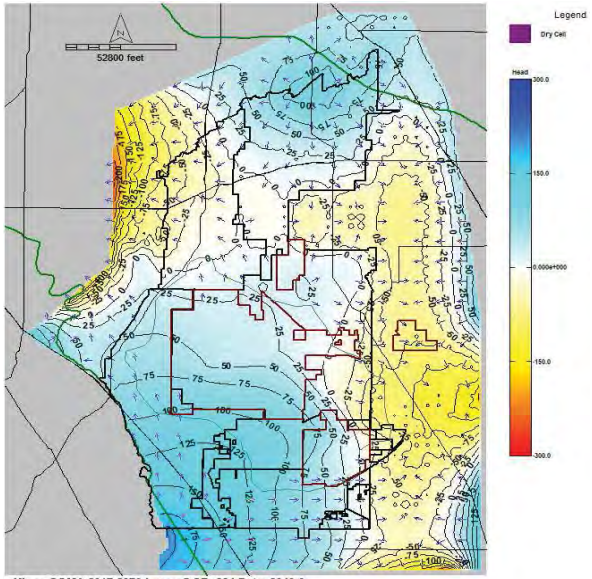
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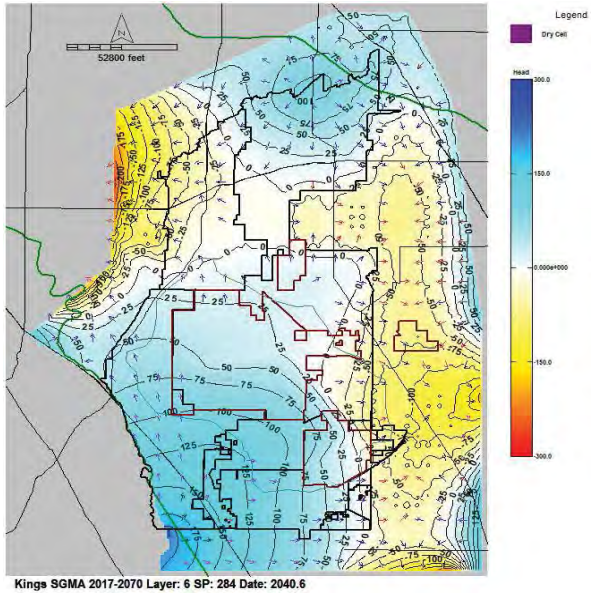
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Kings SGMA 2017-2070 Layer: 3 SP: 284 Date: 2040.6



Kings SGMA 2017-2070 Layer: 5 SP: 284 Date: 2040.6



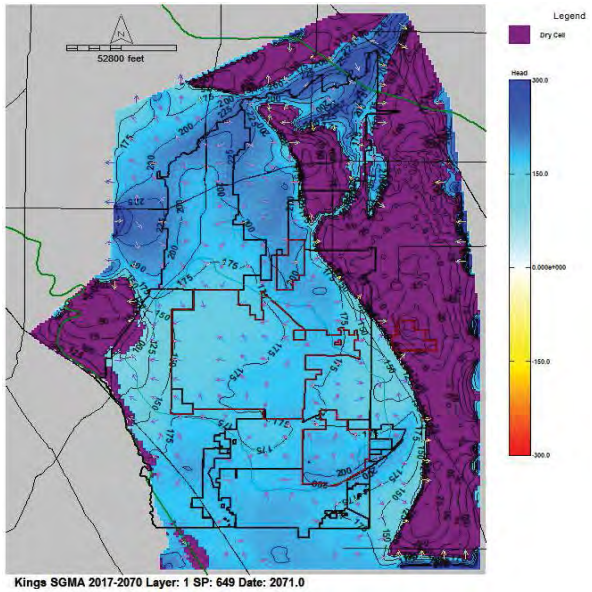
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2040 Baseline Forecast Groundwater Elevations and Groundwater Flow Vectors

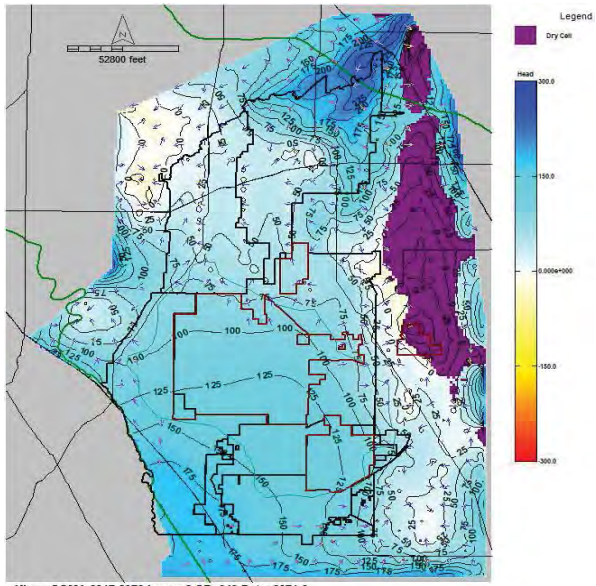
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/2019	Project No.: FR18161220
		Figure **D7-5a**

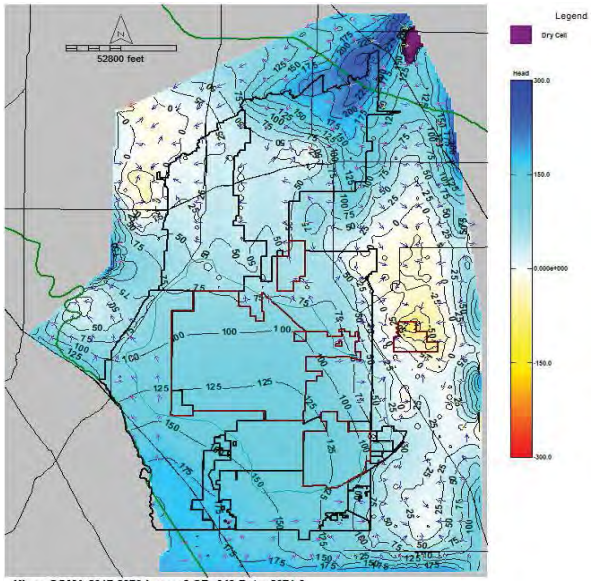
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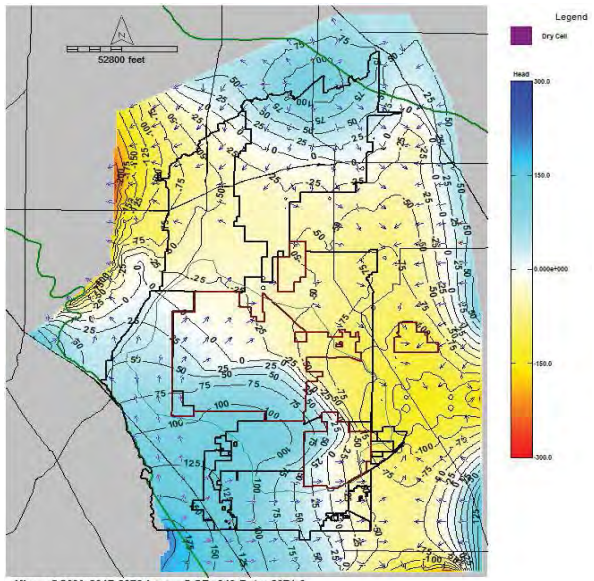
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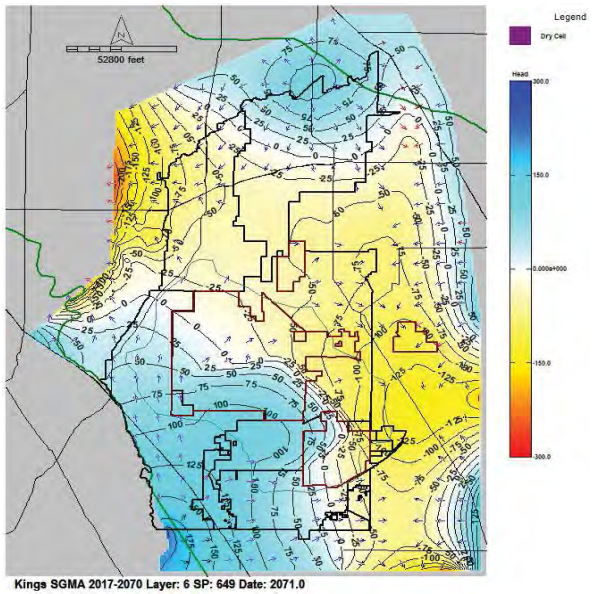
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Kings SGMA 2017-2070 Layer: 3 SP: 649 Date: 2071.0



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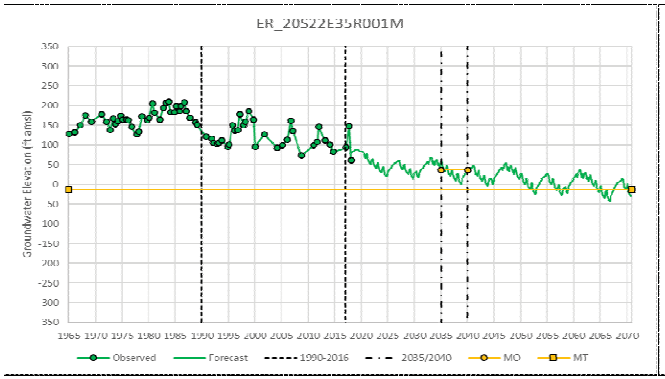
2070 Baseline Forecast Groundwater Elevations and Groundwater Flow Vectors

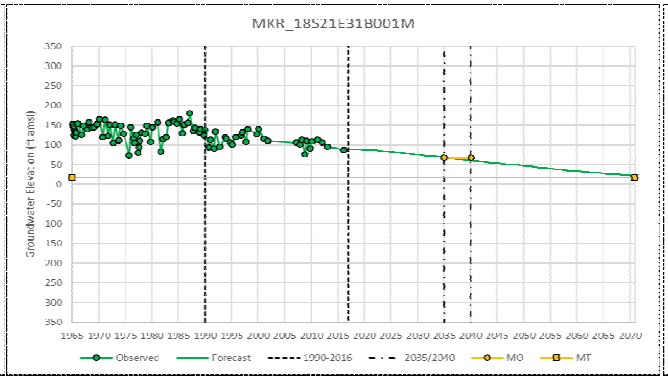
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

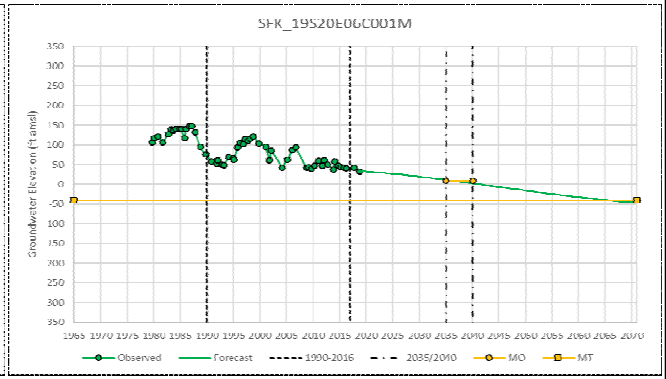
By: dmb	Date: 12/12/2019	Project No.: FR18161220
		Figure **D7-5b**

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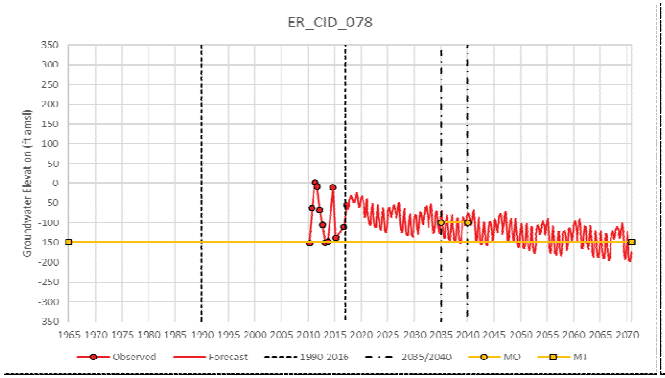
Above the Corcoran Clay



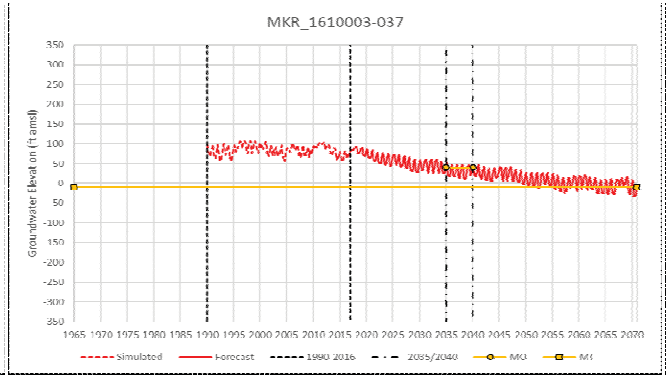




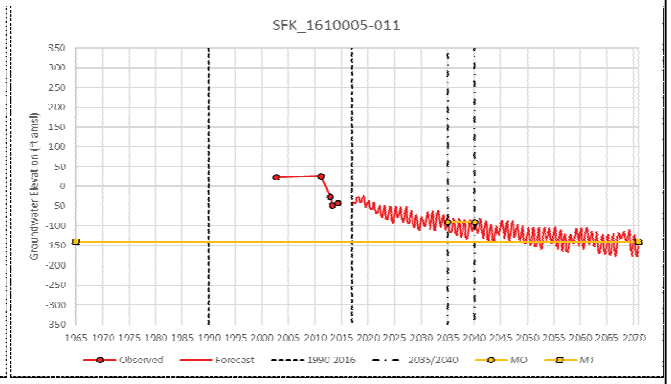
Corcoran



Hanford



Lemoore



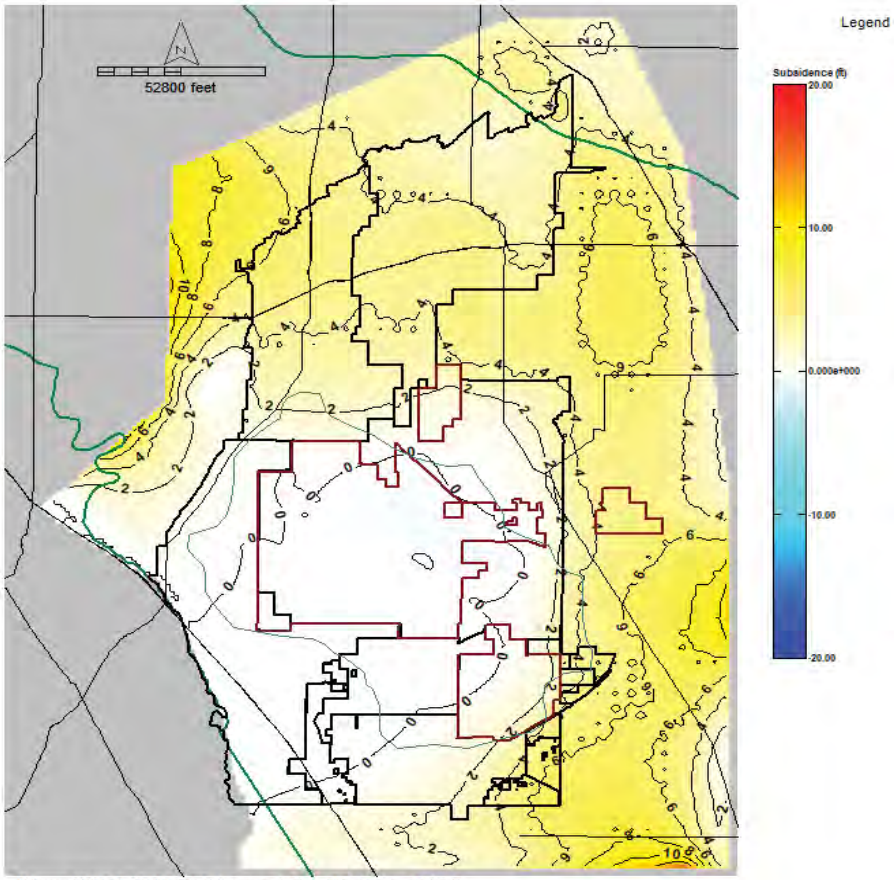
Below the Corcoran Clay

Baseline Forecast Hydrographs for Selected Compliance Wells

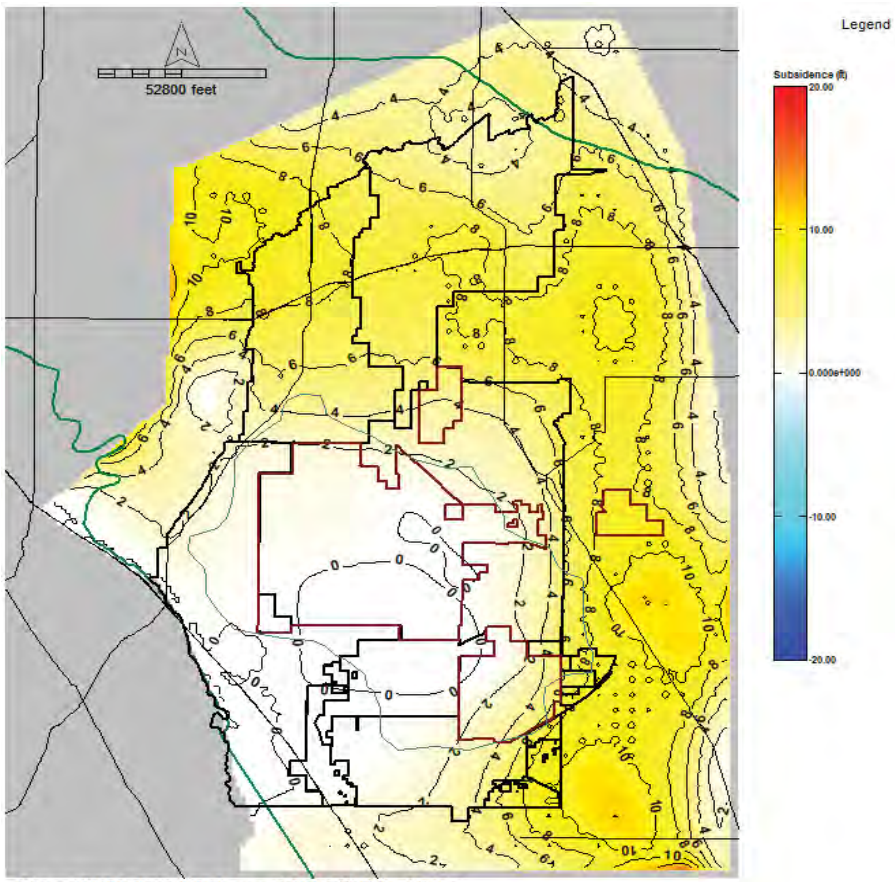
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/2019	Project No.: FR18161220
		Figure **D7-6**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D□-□ Baseline Subsidence 1□8:2020



Kings SGMA 2017-2070 Layer: 1 SP: 284 Date: 2040.6

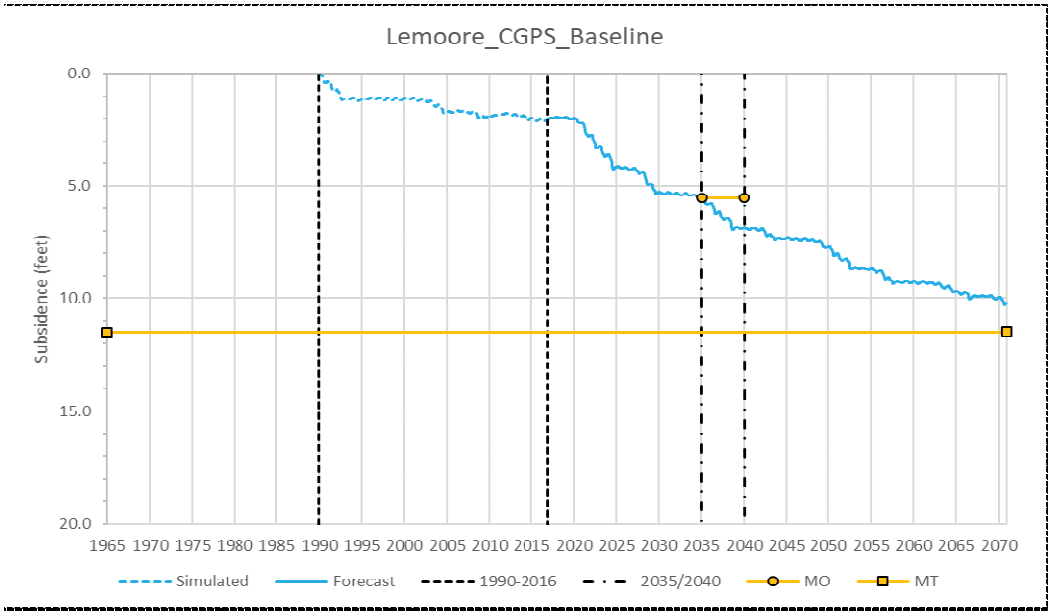


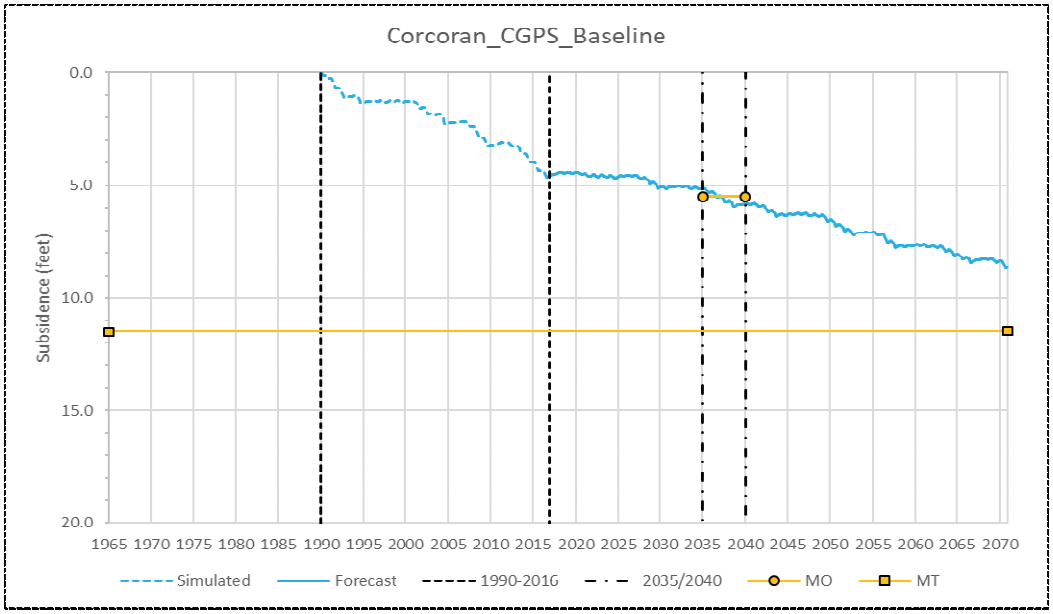
Kings SGMA 2017-2070 Layer: 1 SP: 649 Date: 2071.0

Cumulative Subsidence Since 2017
Baseline Forecast 2040 and 2070
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/2019	Project No.: FR18161220
		Figure **D7-7**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D7-8 BaselineSub Hydrograph



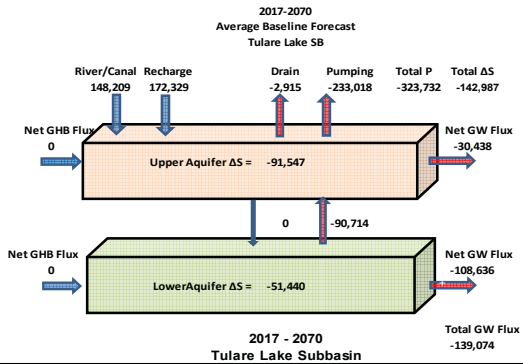


Baseline Forecast Cumulative Subsidence Compliance Monitoring Points

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

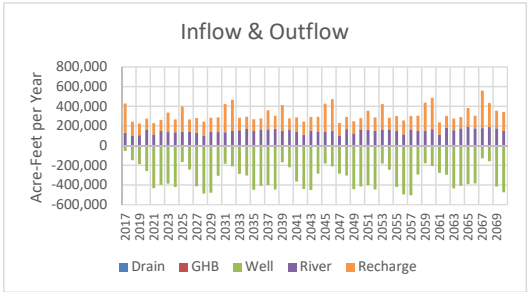
By: dmb	Date: 12/12/2019	Project No.: FR18161220
		Figure **D7-8**

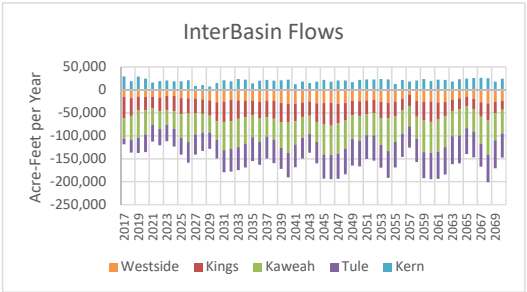
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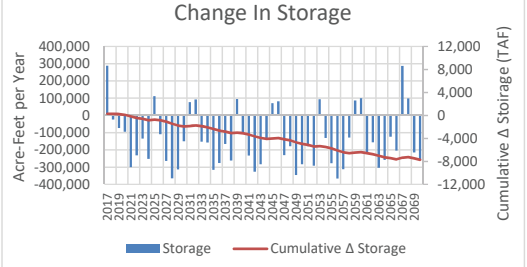


2017 - 2070
Tulare Lake Subbasin

TulareLake Date	Net Drain	Net GHB	Net Well	Net River	Net Recharge	Net Storage	Interbasin TulareLake	Interbasin Westside	Interbasin Kings	Interbasin Kaweah	Interbasin Tule	Interbasin Kern
2017	-3,292	0	-50,431	129,387	298,093	287,496	0	-15,464	-46,141	-45,027	-11,808	29,206
2018	-750	0	-148,570	103,459	138,862	-24,232	0	-17,988	-38,795	-51,760	-28,153	18,718
2019	-396	0	-188,615	104,781	118,404	-74,022	0	-15,131	-29,903	-59,520	-32,928	28,989
2020	-1,210	0	-257,766	157,370	117,021	-95,284	0	-15,775	-29,008	-52,335	-38,614	24,297
2021	-2,134	0	-431,121	113,552	113,998	-301,058	0	-14,764	-25,890	-35,441	-36,496	15,557
2022	-9,578	0	-389,656	148,571	110,833	-232,720	0	-16,726	-29,434	-38,896	-35,732	18,943
2023	-9,797	0	-377,216	144,092	191,118	-135,035	0	-13,681	-29,968	-32,679	-35,692	20,379
2024	-9,276	0	-411,385	134,798	130,845	-252,348	0	-13,684	-33,320	-37,721	-38,735	18,554
2025	-9,008	0	-159,588	141,173	253,920	111,310	0	-17,983	-35,252	-50,832	-36,944	18,440
2026	-9,295	0	-234,658	143,339	121,516	-109,828	0	-18,531	-31,998	-62,773	-45,480	20,936
2027	-3,084	0	-411,439	132,425	148,658	-264,518	0	-18,810	-31,605	-46,647	-44,056	8,731
2028	-4,347	0	-482,752	101,674	139,826	-365,116	0	-20,740	-31,663	-40,554	-40,011	10,437
2029	-6,207	0	-473,450	141,914	140,738	-313,258	0	-22,944	-33,514	-36,563	-35,540	7,245
2030	-5,243	0	-300,946	136,633	150,653	-150,025	0	-27,132	-41,551	-40,361	-40,522	14,791
2031	-1,757	0	-183,915	134,735	285,585	76,477	0	-25,861	-44,113	-61,335	-48,021	20,901
2032	-2,659	0	-210,461	147,907	316,900	92,627	0	-22,307	-46,545	-59,821	-49,298	18,382
2033	-6,860	0	-282,130	156,810	126,029	-152,839	0	-23,116	-40,010	-61,887	-49,937	23,404
2034	-3,818	0	-300,116	169,446	122,795	-157,549	0	-23,758	-36,466	-58,144	-50,904	22,083
2035	-8,633	0	-441,194	147,758	120,698	-315,937	0	-23,778	-32,290	-47,258	-51,696	13,843
2036	-2,844	0	-407,576	162,808	113,725	-277,090	0	-26,818	-35,974	-49,950	-50,780	19,653
2037	-6,973	0	-393,826	164,766	193,473	-165,962	0	-23,577	-36,481	-41,818	-47,739	21,758
2038	-23,724	0	-423,714	170,466	133,975	-261,844	0	-23,777	-39,306	-46,292	-50,188	20,025
2039	-8,671	0	-162,253	150,468	261,073	94,885	0	-28,683	-41,620	-56,396	-45,765	20,788
2040	-8,057	0	-212,170	157,556	119,233	-106,996	0	-30,546	-39,238	-67,365	-53,540	21,850
2041	-5,104	0	-361,502	144,072	142,798	-233,348	0	-29,977	-38,432	-50,504	-49,720	12,021
2042	-2,748	0	-438,341	110,385	133,689	-327,522	0	-27,427	-31,574	-45,003	-45,971	18,233
2043	-1,965	0	-450,808	154,853	135,856	-283,322	0	-25,454	-30,918	-39,388	-41,293	15,057
2044	0	0	-285,516	142,901	148,782	-136,357	0	-29,141	-40,661	-43,988	-46,473	17,555
2045	0	0	-183,727	141,152	284,955	70,430	0	-29,079	-46,558	-65,167	-52,607	21,462
2046	0	0	-211,949	154,734	316,279	81,644	0	-27,918	-50,088	-63,422	-53,666	17,673
2047	0	0	-285,777	102,969	125,867	-230,338	0	-30,204	-42,632	-66,180	-54,785	20,405
2048	0	0	-305,758	167,267	123,023	-179,098	0	-28,919	-36,899	-62,428	-55,825	20,440
2049	0	0	-444,243	125,538	120,150	-346,793	0	-24,332	-31,416	-51,824	-57,332	16,661
2050	0	0	-415,786	163,797	114,030	-283,289	0	-25,029	-31,754	-53,927	-56,321	21,685
2051	0	0	-404,556	159,642	194,042	-178,887	0	-23,093	-30,523	-44,967	-51,903	22,394
2052	0	0	-446,277	150,374	135,694	-291,833	0	-21,035	-29,966	-48,316	-54,946	22,494
2053	0	0	-183,305	159,180	263,059	93,063	0	-26,612	-35,116	-58,392	-49,382	23,630
2054	0	0	-244,986	159,110	123,386	-131,840	0	-28,062	-34,361	-71,317	-58,079	22,469
2055	0	0	-420,853	148,192	151,360	-277,705	0	-25,895	-31,453	-55,998	-55,894	12,657
2056	0	0	-496,998	114,335	140,360	-366,983	0	-19,449	-25,676	-50,048	-50,927	21,022
2057	0	0	-504,789	159,039	140,232	-312,851	0	-10,938	-24,080	-44,316	-46,355	17,853
2058	0	0	-294,759	152,165	150,384	-129,034	0	-24,334	-34,112	-48,062	-51,043	20,463
2059	0	0	-180,750	151,281	284,994	86,505	0	-26,011	-40,937	-68,809	-56,756	23,490
2060	0	0	-208,497	167,175	316,329	99,201	0	-25,369	-44,674	-67,186	-57,771	19,186
2061	0	0	-278,224	111,075	125,072	-214,084	0	-27,627	-37,207	-70,470	-58,722	21,985
2062	0	0	-295,518	179,447	121,650	-156,830	0	-26,398	-31,219	-67,227	-59,432	21,834
2063	0	0	-435,625	155,188	119,632	-304,744	0	-21,333	-24,539	-55,367	-60,737	17,855
2064	0	0	-410,660	176,101	112,798	-258,488	0	-18,537	-23,571	-57,476	-60,516	23,108
2065	0	0	-390,901	190,501	191,607	-124,017	0	-14,810	-21,614	-47,222	-56,154	24,170
2066	0	0	-385,749	175,809	126,968	-204,212	0	-19,675	-22,308	-48,698	-56,466	25,517
2067	0	0	-130,038	177,997	380,464	286,962	0	-27,089	-31,484	-59,206	-49,777	26,094
2068	0	0	-159,015	188,104	244,419	97,660	0	-29,769	-36,271	-75,275	-59,838	25,307
2069	0	0	-416,014	176,019	178,001	-215,012	0	-26,190	-25,091	-58,935	-60,557	17,413
2070	0	0	-475,674	149,023	191,903	-257,301	0	-24,047	-19,259	-51,309	-53,012	24,403
2017-2070 Average	**-2,915**	**0**	**-323,732**	**148,209**	**172,329**	**-142,987**	**0**	**-23,062**	**-34,157**	**-53,181**	**-48,534**	**19,860**
2040-2048 Average	**-1,986**	**0**	**-303,950**	**141,765**	**170,054**	**-149,434**	**0**	**-28,740**	**-39,667**	**-55,938**	**-50,431**	**18,299**



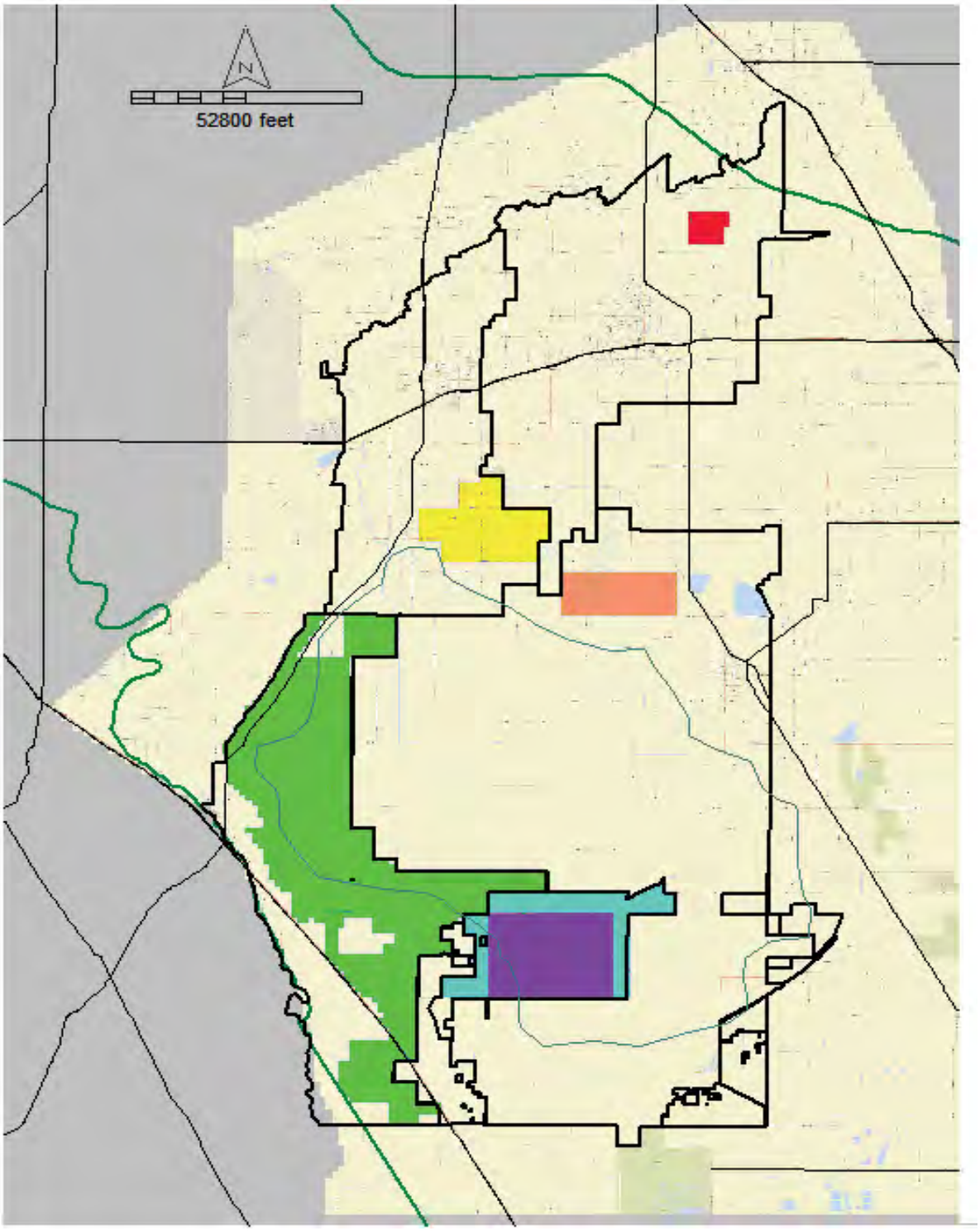




Baseline Forecast Groundwater Mass Balance Tulare Lake Subbasin

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/15/19	Project No.: FR18161220
		Figure **D7-9**



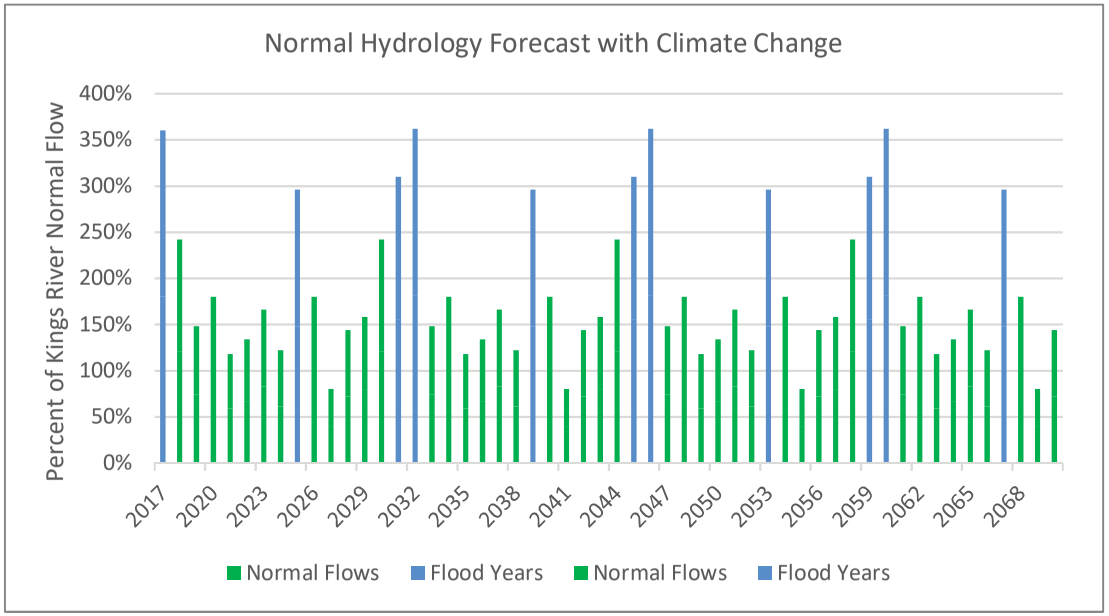
Explanation

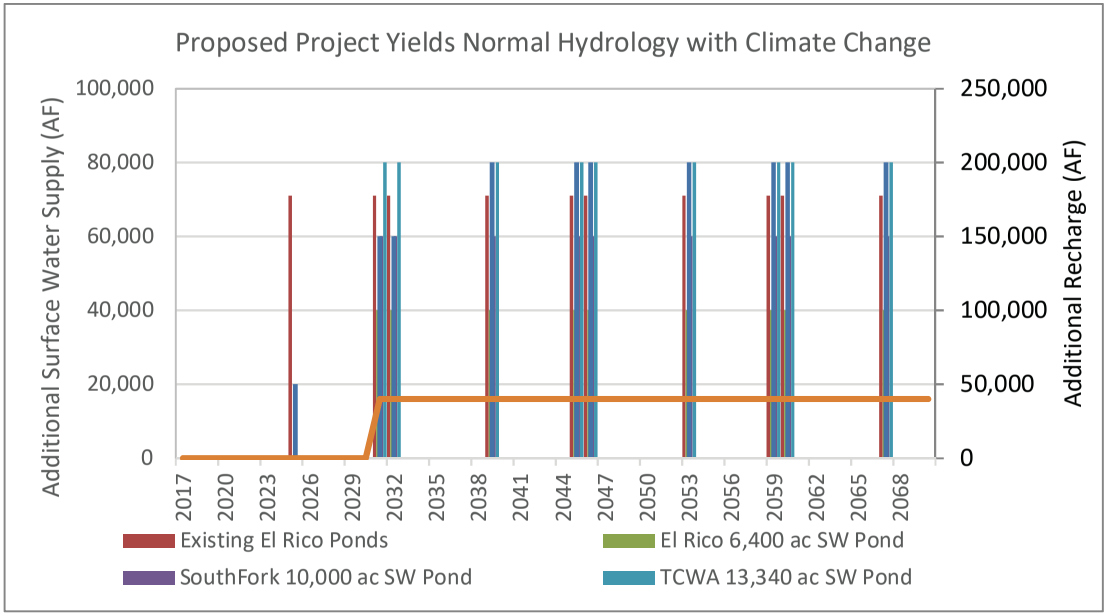
- Mid-Kings River GSA Intentional Recharge Basins
- El Rico GSA Intermittal Surface Water Storage Ponds
- South Fork Kings GSA Surface Water Storage Ponds
- TCWA GSA Surface Water Storage Ponds
- Southwest Kings GSA Land Fallowing
- TCWA GSA Land Fallowing

Forecast Project Areas

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D7-10**

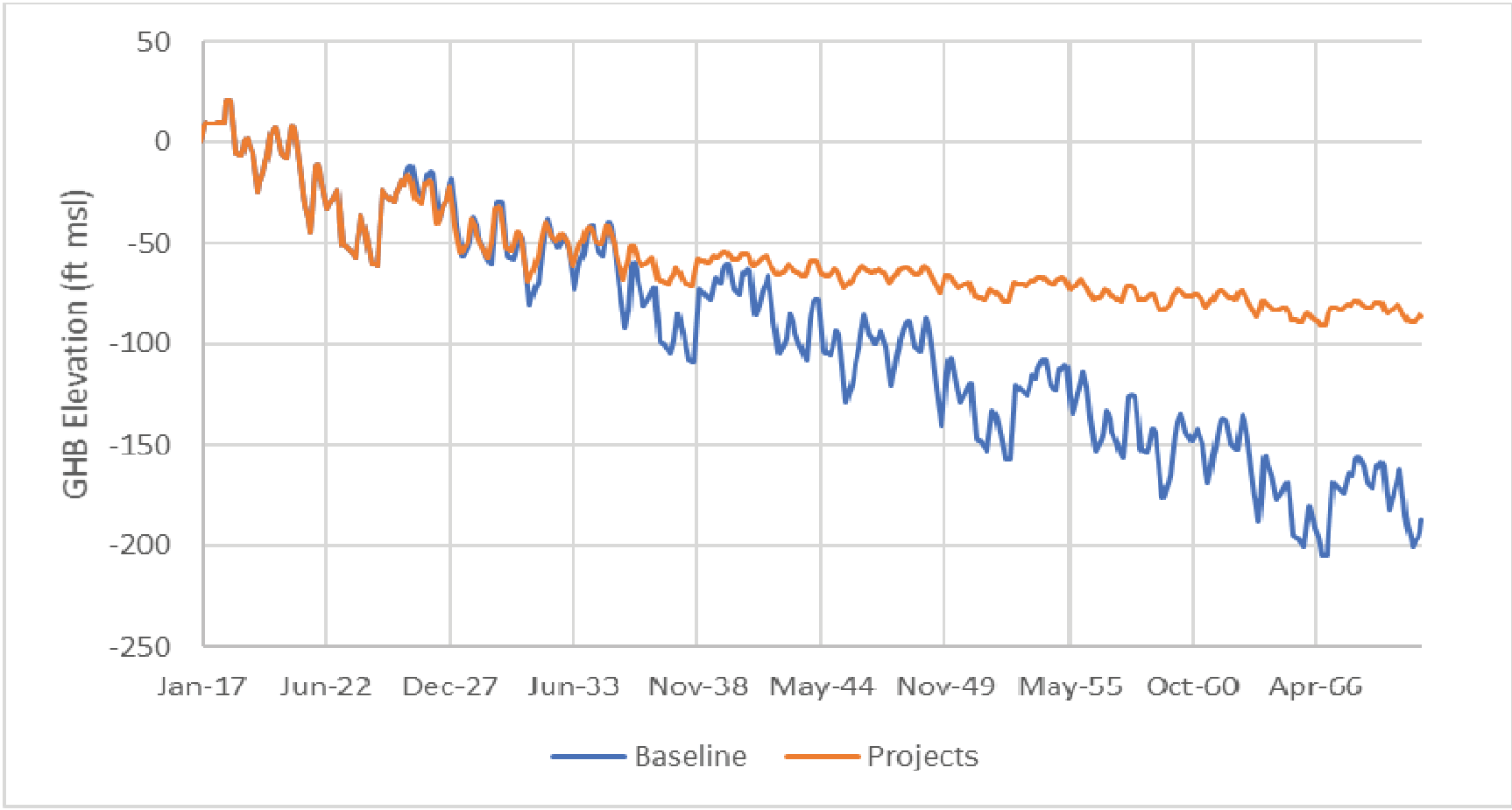




Project Forecast Flood Years and Project Performance

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D7-11**

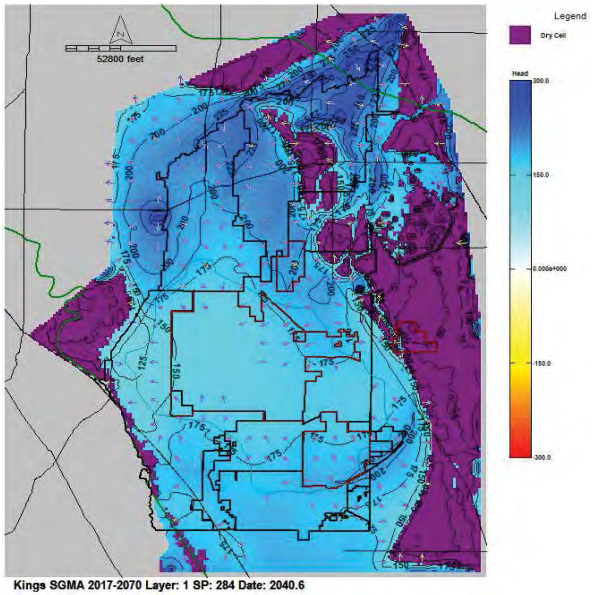


Project vs Baseline GHB Example

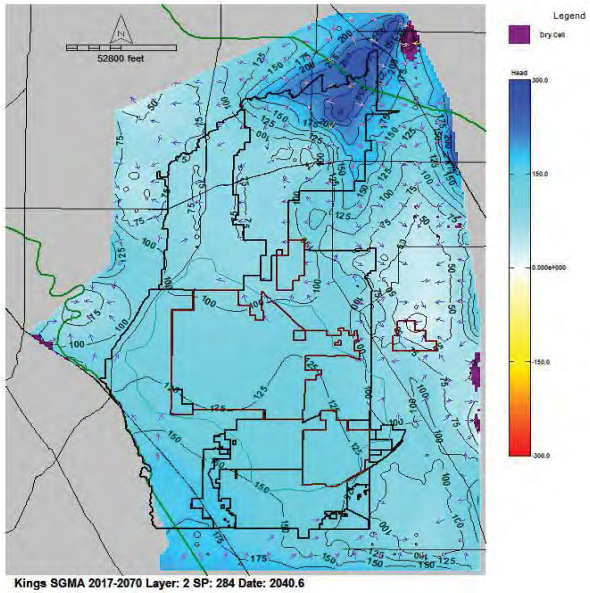
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 07/30/19	Project No.: FR18161220
		Figure **D7-12**

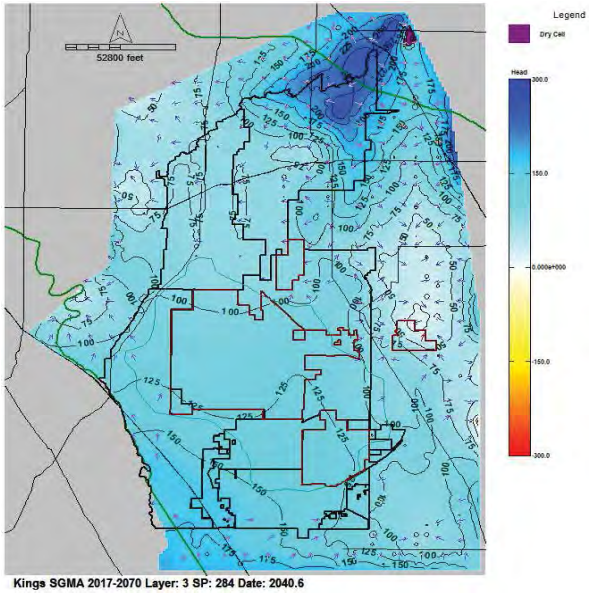
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D7-13 2040 Projects Potento 12/19/2019



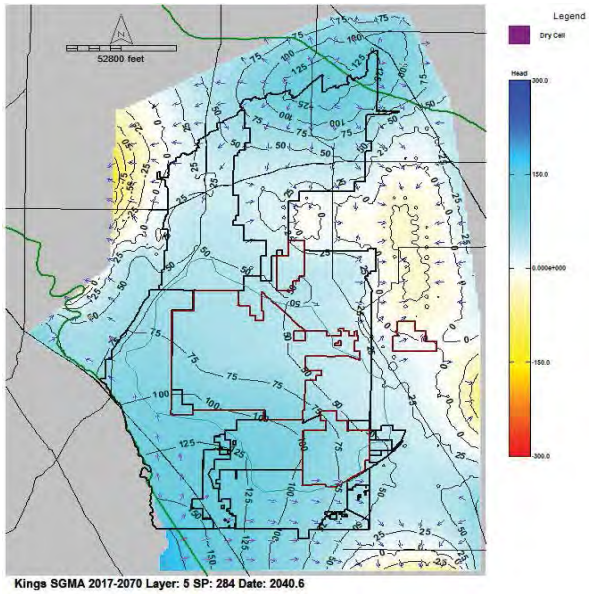
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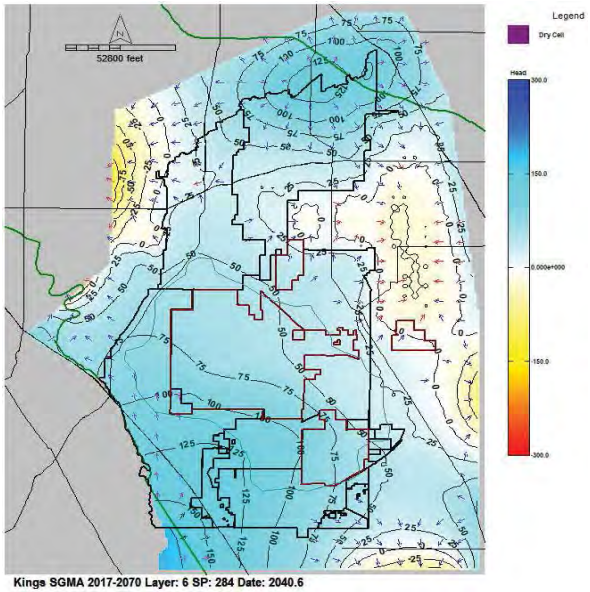
Kings SGMA 2017-2070 Layer: 2 SP: 284 Date: 2040.6



Kings SGMA 2017-2070 Layer: 3 SP: 284 Date: 2040.6



Kings SGMA 2017-2070 Layer: 5 SP: 284 Date: 2040.6



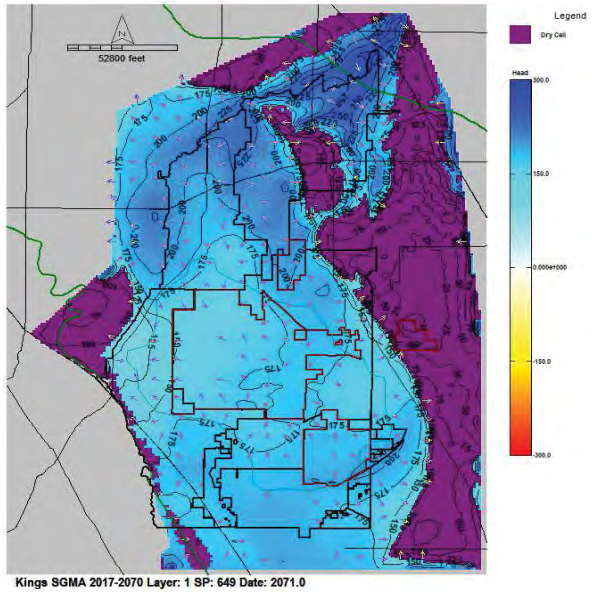
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2040 Project Forecast Groundwater Elevations and Groundwater Flow Vectors

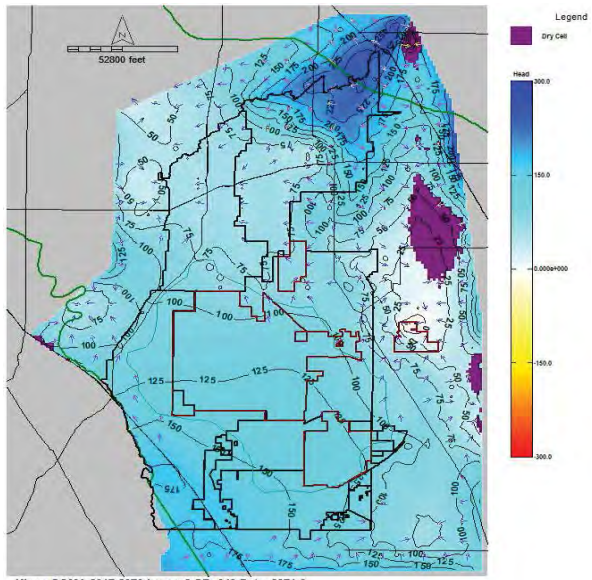
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/2019	Project No.: FR18161220
		Figure **D7-13**

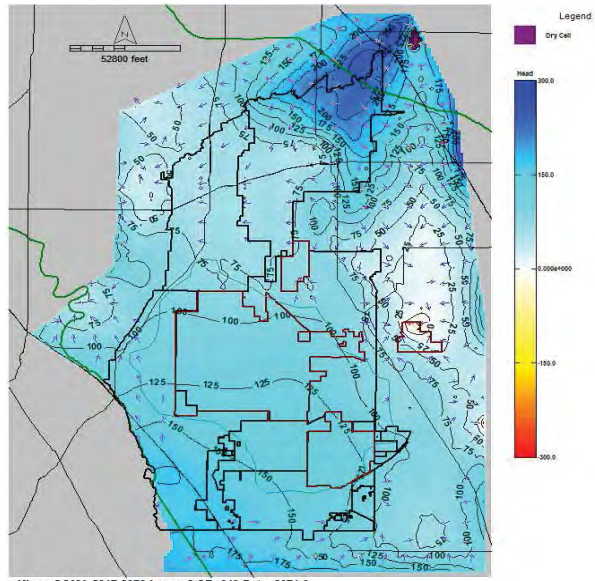
I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D7-14 2070 Project Potento 12/19/2019



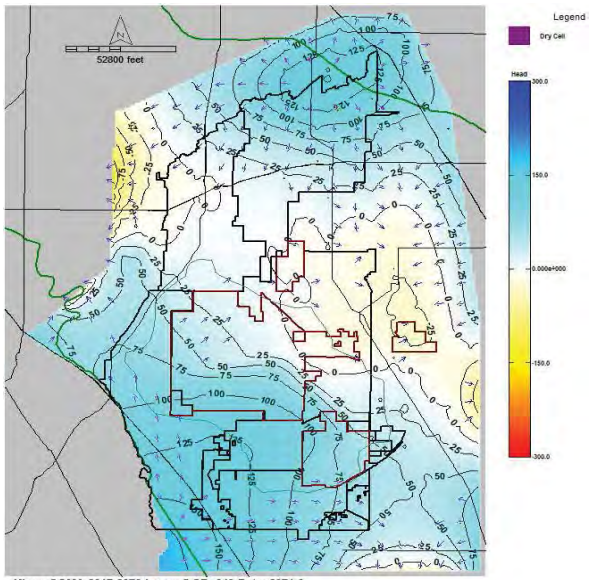
Kings SGMA 2017-2070 Layer: 1 SP: 649 Date: 2071.0



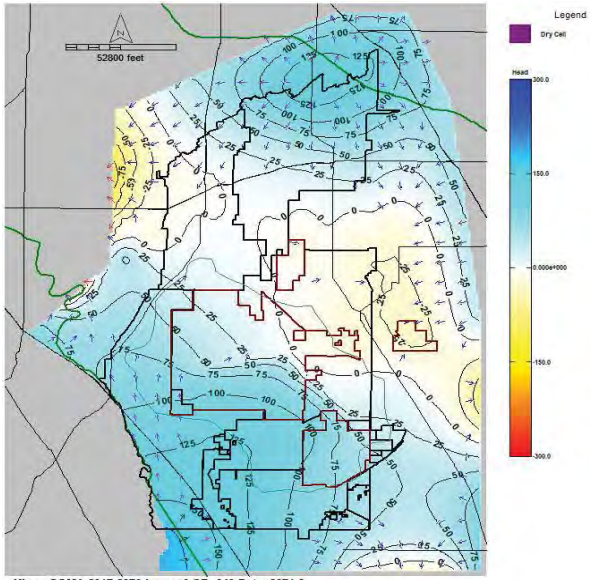
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Kings SGMA 2017-2070 Layer: 3 SP: 649 Date: 2071.0



Kings SGMA 2017-2070 Layer: 5 SP: 649 Date: 2071.0



Kings SGMA 2017-2070 Layer: 6 SP: 649 Date: 2071.0

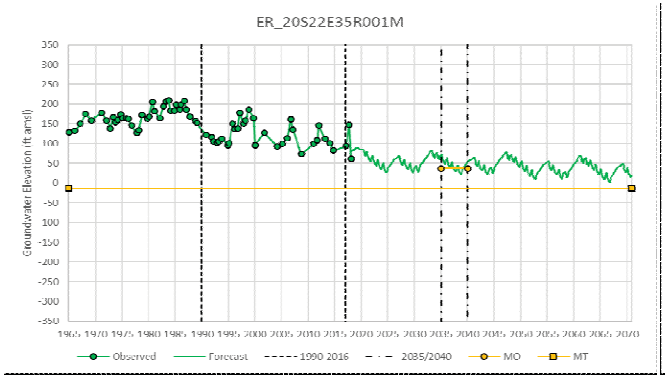
2070 Project Forecast Groundwater Elevations and Groundwater Flow Vectors

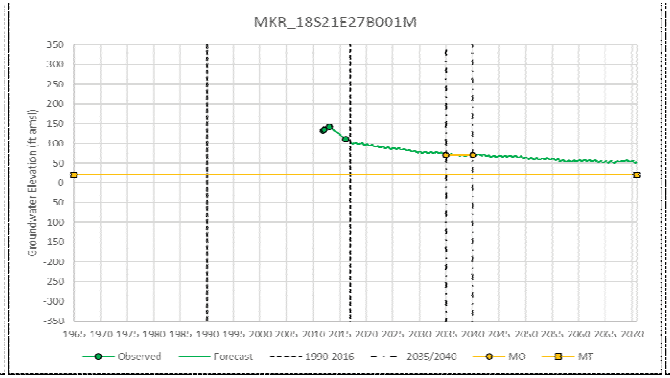
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

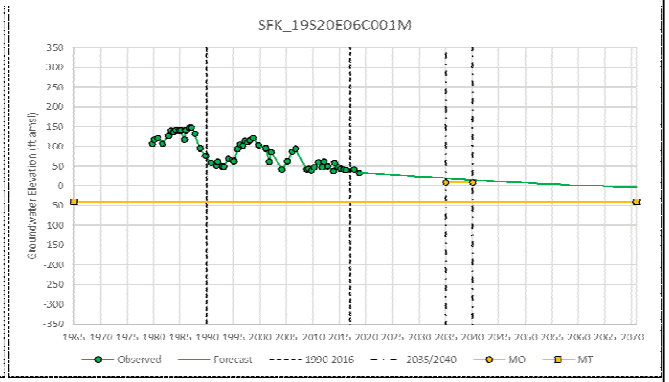
By: dmb	Date: 12/12/2019	Project No.: FR18161220
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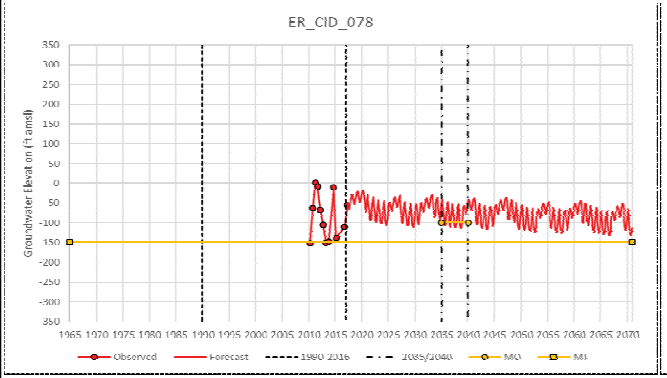
Above the Corcoran Clay



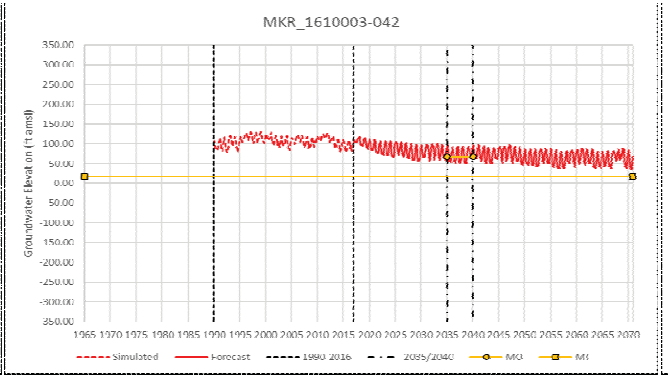




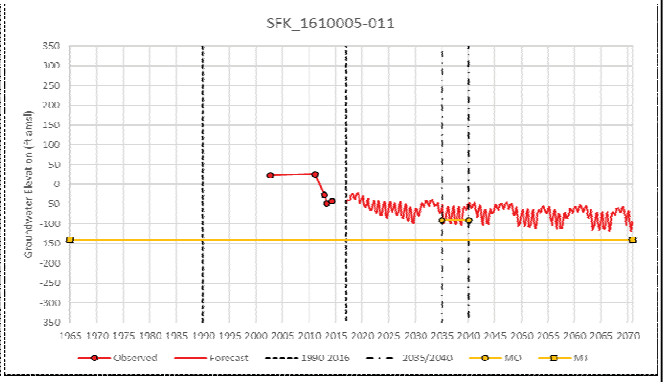
Corcoran



Hanford



Lemoore



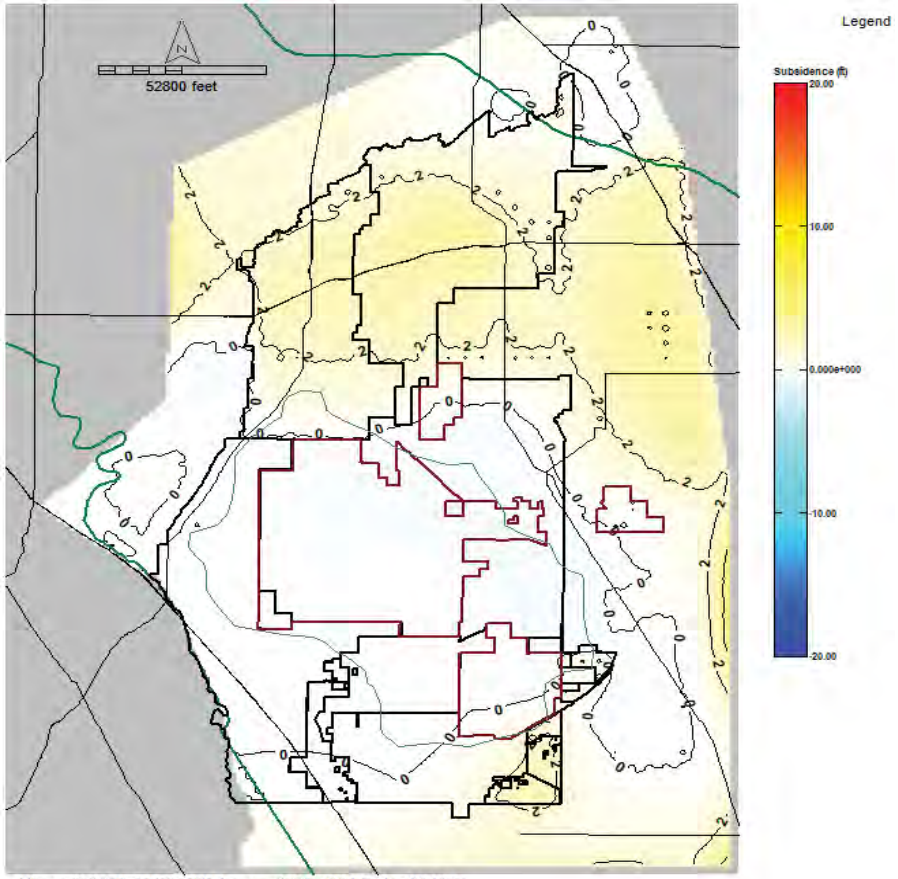
Below the Corcoran Clay

Project Forecast Hydrographs for Selected Compliance Wells

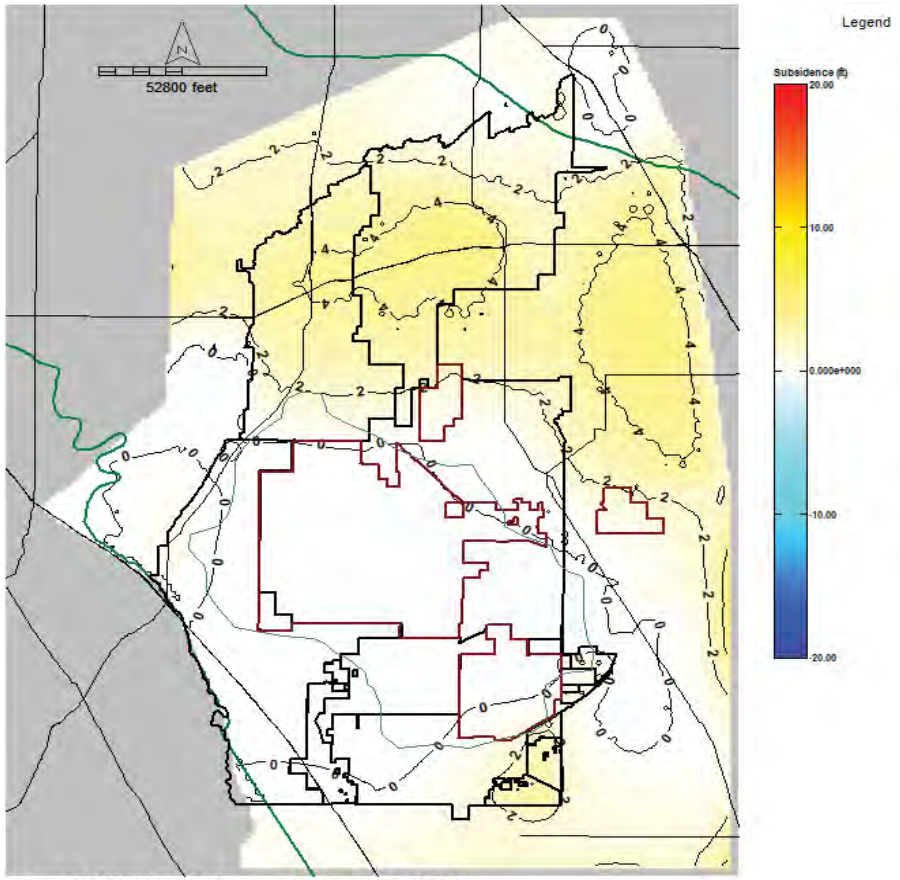
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/2019	Project No.: FR18161220
		Figure **D7-15**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D□-16 Pro@c□Subsidence



Kings SGMA 2017-2070 Layer: 1 SP: 284 Date: 2040.6



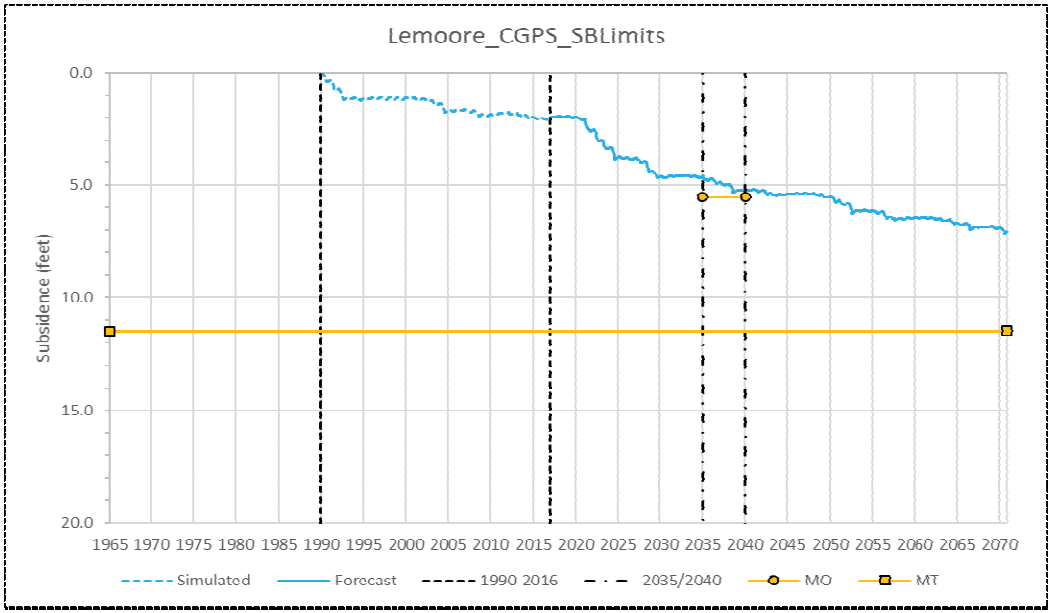
Kings SGMA 2017-2070 Layer: 1 SP: 649 Date: 2071.0

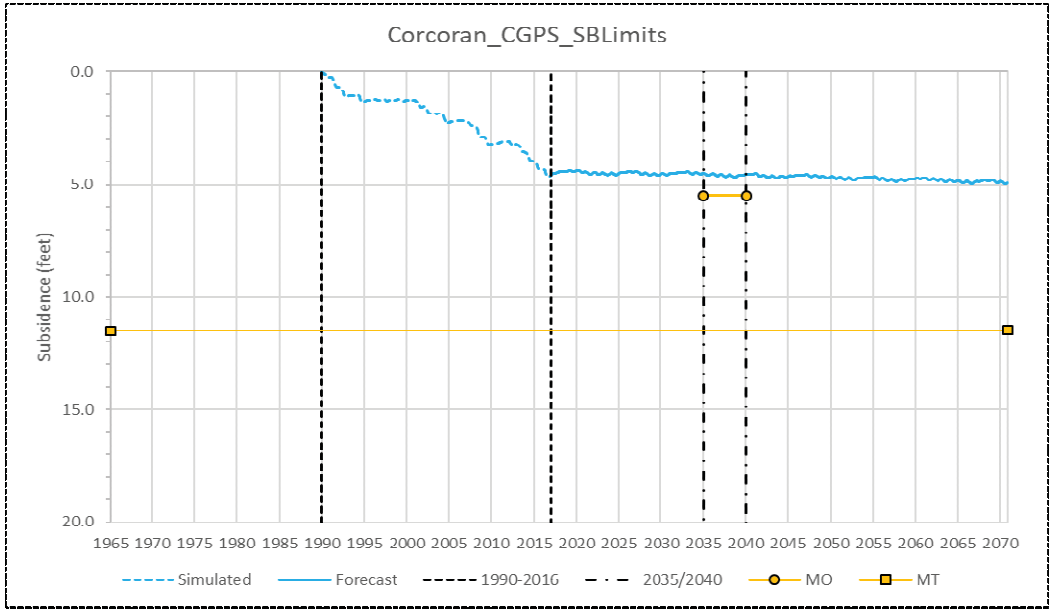
Cumulative Subsidence Since 2017
Project Forecast 2040 and 2070

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

By: dmb	Date: 12/12/2019	Project No.: FR18161220
		Figure **D7-16**

I:\FR18s\FR18161220 Tulare Lake GSP\Figures\8-Appendices\Figures\PendingReview\AppendixD\December2019\DRAFT_TLSB_SGMA_GWModel_Figures_v3.xlsxFig D7-17 Project Sub Hydros

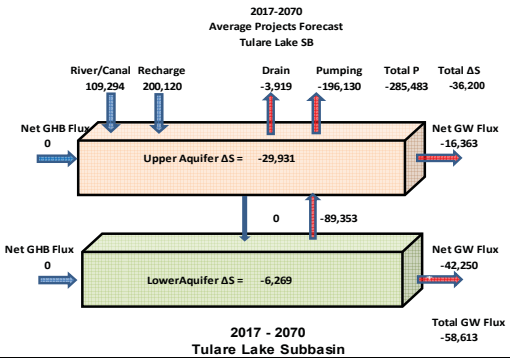




Project Forecast with Subbasin Pumping Limits Cumulative Subsidence Compliance Monitoring Points

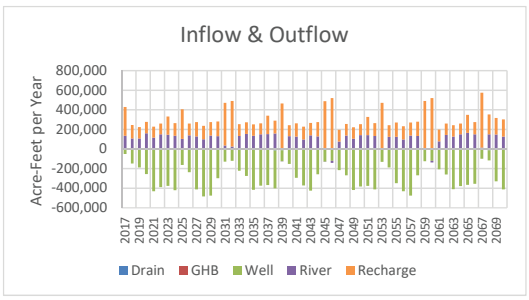
Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

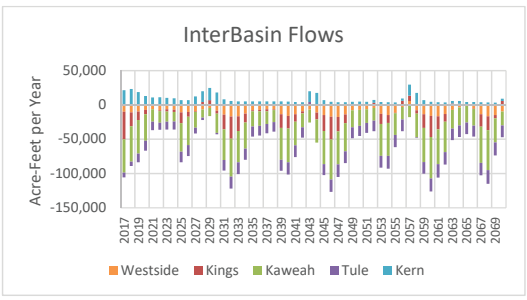
By: dmb	Date: 12/12/2019	Project No.: FR18161220
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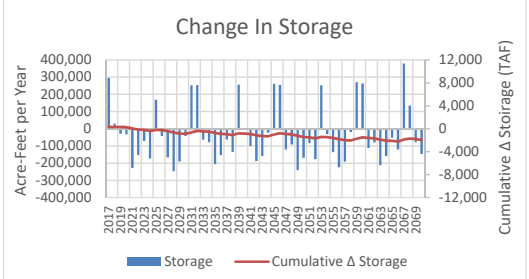


2017 - 2070
Tulare Lake Subbasin

TulareLake Date	Net Drain	Net GHB	Net Well	Net River	Net Recharge	Net Storage	Interbasin TulareLake	Interbasin Westside	Interbasin Kings	Interbasin Kaweah	Interbasin Tule	Interbasin Kern
2017	-768	0	-49,996	134,061	294,631	293,851	0	-9,992	-40,297	-48,598	-6,953	21,200
2018	-51	0	-147,931	106,461	137,333	29,785	0	-10,916	-20,328	-51,541	-6,322	23,003
2019	-69	0	-188,204	107,068	117,120	-29,333	0	-9,689	-12,439	-49,028	-12,606	18,498
2020	-751	0	-255,895	160,022	116,429	-33,567	0	-7,499	-6,200	-38,702	-14,321	12,890
2021	-2,567	0	-429,344	114,591	113,000	-228,163	0	-6,324	1,150	-18,147	-12,345	9,568
2022	-742	0	-387,832	149,597	110,391	-153,344	0	-8,036	-1,192	-16,819	-10,142	11,115
2023	-2,081	0	-375,607	144,279	186,092	-72,254	0	-6,559	-3,333	-14,772	-11,461	10,147
2024	-12,152	0	-409,790	134,618	129,097	-173,684	0	-6,923	-3,333	-14,122	-11,585	9,682
2025	-5,901	0	-158,066	103,591	300,300	167,712	0	-11,065	-15,504	-41,827	-15,388	6,934
2026	-6,425	0	-231,683	138,003	120,755	-42,544	0	-10,328	-7,050	-41,311	-15,866	6,838
2027	-4,097	0	-408,650	128,404	144,489	-166,792	0	-9,442	-924	-23,018	-8,481	12,393
2028	-3,806	0	-479,787	98,269	137,572	-247,432	0	-6,650	4,048	-12,008	-3,496	15,713
2029	-4,776	0	-470,493	136,664	136,267	-190,413	0	-4,525	6,786	-11,984	87	17,840
2030	-2,184	0	-296,843	131,230	148,799	-43,406	0	-8,521	-4,397	-27,797	-2,292	17,851
2031	-1,342	0	-128,244	34,194	435,214	252,338	0	-14,173	-21,527	-44,586	-15,432	8,110
2032	-2,135	0	-118,244	25,043	464,633	253,462	0	-16,860	-32,389	-55,308	-17,407	5,767
2033	-2,751	0	-219,926	132,336	120,754	-64,405	0	-16,851	-21,233	-45,466	-17,455	5,077
2034	-2,351	0	-273,863	153,223	119,220	-78,745	0	-12,647	-13,009	-38,118	-16,298	4,879
2035	-1,785	0	-414,804	134,016	116,897	-206,981	0	-7,842	-1,636	-21,888	-14,849	4,870
2036	-1,969	0	-372,544	149,859	110,501	-153,893	0	-7,391	-2,192	-21,086	-14,068	4,967
2037	-4,264	0	-363,305	152,162	186,307	-63,641	0	-6,467	-2,997	-18,447	-13,642	4,983
2038	-15,878	0	-386,782	158,310	129,519	-135,618	0	-6,736	-1,043	-17,305	-13,856	4,989
2039	-12,937	0	-112,427	-1,549	463,139	255,562	0	-13,698	-19,924	-46,314	-16,200	4,904
2040	-4,822	0	-147,191	129,532	113,179	-3,861	0	-15,971	-18,585	-49,122	-17,955	4,620
2041	-6,403	0	-288,654	125,667	136,255	-100,523	0	-13,749	-10,872	-34,353	-17,111	4,246
2042	-2,511	0	-369,213	97,116	129,325	-188,355	0	-9,518	-2,914	-20,346	-15,076	3,738
2043	-5,152	0	-419,146	138,244	128,118	-160,121	0	-7,192	1,016	-18,647	3,140	15,790
2044	-1,928	0	-256,990	128,874	144,339	-23,229	0	-11,233	-9,893	-34,027	233	17,141
2045	-1,615	0	-127,421	-2,607	487,733	260,886	0	-14,968	-23,284	-48,182	-15,906	6,928
2046	-2,192	0	-118,440	-22,036	518,991	254,254	0	-17,181	-33,280	-58,225	-18,145	4,513
2047	-1,846	0	-213,881	74,677	120,491	-120,887	0	-17,529	-21,199	-48,012	-18,486	3,949
2048	-3,121	0	-266,286	136,608	119,296	-92,692	0	-14,027	-12,735	-41,083	-17,137	3,833
2049	-955	0	-417,584	104,902	116,316	-241,563	0	-8,059	420	-24,754	-15,986	3,853
2050	-2,104	0	-380,556	141,874	110,770	-169,379	0	-7,332	852	-23,106	-14,955	3,988
2051	-2,151	0	-373,868	139,939	186,903	-85,094	0	-6,328	191	-20,161	-14,365	4,080
2052	-2,945	0	-409,066	132,768	131,240	-178,002	0	-4,743	2,951	-18,330	-15,302	4,171
2053	-1,757	0	-130,174	5,547	465,172	251,586	0	-13,057	-14,939	-46,488	-17,189	4,219
2054	-5,694	0	-182,931	124,170	117,298	-32,521	0	-14,787	-11,432	-48,072	-18,716	3,894
2055	-2,953	0	-346,167	123,932	144,789	-137,299	0	-11,714	-597	-31,503	-17,950	3,589
2056	-5,089	0	-426,442	96,606	136,007	-224,340	0	-3,053	5,860	-18,230	-17,157	3,278
2057	-2,832	0	-472,419	136,967	132,395	-192,493	0	5,515	7,767	-17,808	129	16,150
2058	-1,986	0	-265,982	132,665	145,904	-19,975	0	-8,004	-4,928	-34,531	-1,020	17,529
2059	-1,441	0	-124,741	1,848	487,775	270,056	0	-13,579	-19,998	-49,951	-16,865	6,926
2060	-5,248	0	-115,440	-16,351	519,068	263,398	0	-16,253	-30,525	-60,325	-19,196	4,327
2061	-878	0	-207,328	77,986	119,694	-112,695	0	-16,694	-19,066	-50,528	-19,593	3,699
2062	-6,177	0	-255,034	141,942	117,940	-79,683	0	-13,385	-11,283	-44,118	-18,210	3,559
2063	-2,104	0	-409,125	127,082	115,805	-213,067	0	-7,479	2,086	-27,132	-16,779	3,593
2064	-2,912	0	-375,558	149,053	109,563	-159,420	0	-3,670	1,802	-26,339	-16,899	3,789
2065	-4,655	0	-360,424	163,296	184,366	-52,779	0	-1,038	-312	-24,380	-16,820	4,124
2066	-4,273	0	-350,525	150,290	122,618	-121,655	0	-5,683	-471	-24,161	-15,961	4,244
2067	-5,939	0	-94,695	15,041	558,534	377,959	0	-13,561	-18,174	-52,954	-18,116	3,915
2068	-13,107	0	-102,855	148,782	203,000	133,847	0	-16,690	-20,384	-58,120	-19,784	3,545
2069	-7,533	0	-321,613	147,416	168,607	-78,689	0	-14,878	-4,800	-35,079	-19,070	3,256
2070	-7,539	0	-406,054	125,600	176,541	-146,985	0	-9,685	5,622	-20,423	-17,074	3,291
2017-2070 Average	**-3,919**	**0**	**-285,483**	**109,294**	**200,120**	**-36,200**	**0**	**-10,086**	**-8,890**	**-33,827**	**-13,587**	**7,778**
2040-2048 Average	**-3,288**	**0**	**-245,247**	**89,564**	**210,859**	**-19,392**	**0**	**-13,485**	**-14,638**	**-39,111**	**-12,938**	**7,195**







Projects Forecast Groundwater Mass Balance Tulare Lake Subbasin

Tulare Lake Subbasin Groundwater Sustainability Plan
Kings County, California

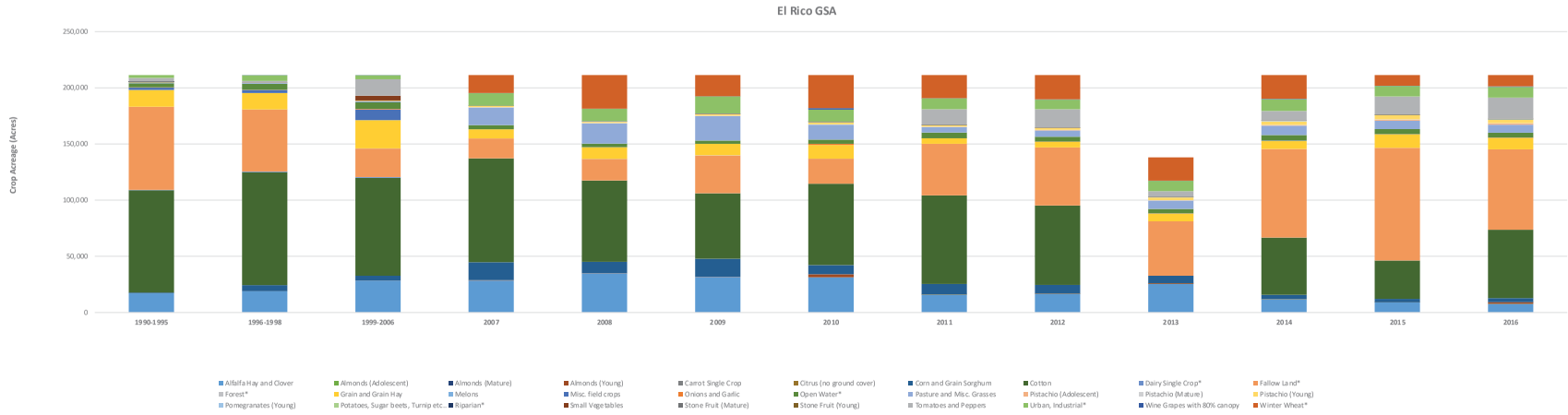
By: dmb	Date: 12/16/19	Project No.: FR18161220
		Figure **D7-18**

Appendix D1
Land Use and Crop Acreage

APPENDIX D1-1

Sum of Crop Acreage (Acres) Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
El Rico GSA													
Alfalfa Hay and Clover	17062	18882	28224	28550	34759	31625	31388	16035	16646	25428	11801	8919	7682
Almonds (Adolescent)	0	0	0	0	0	0	0	2	1	1	8	2	4
Almonds (Mature)	0	0	0	0	0	0	0	0	0	0	0	0	0
Almonds (Young)	0	0	0	258	180	197	2669	238	259	636	208	246	1546
Carrot Single Crop	0	0	0	0	0	0	0	6	2	0	0	0	4
Citrus (no ground cover)	0	0	0	0	0	0	0	5	0	2	0	1	1
Corn and Grain Sorghum	782	5521	4532	16009	10213	16088	8204	9059	7686	6589	3771	2958	3518
Cotton	91026	100576	87075	92487	72329	58241	72345	78989	70591	0	50987	34147	60879
Dairy Single Crop*	386	493	718	0	0	0	0	0	0	0	0	0	0
Fallow Land*	73850	55208	25343	17545	19197	33697	22362	45881	51731	48511	78767	100327	71667
Forest*	0	12	156	0	3	36	1	0	0	0	0	0	0
Grain and Grain Hay	15048	14737	25257	8152	10582	10260	12219	4876	5254	7028	7005	12142	10308
Melons	0	0	0	0	0	0	0	1	6	1	491	3	63
Misc. field crops	2012	2737	9414	0	2	0	0	0	0	0	0	0	0
Onions and Garlic	253	165	606	0	0	0	1031	26	59	28	43	82	62
Open Water*	3550	5363	5676	3742	3038	2939	3748	5020	4152	4064	4826	4456	4232
Pasture and Misc. Grasses	444	682	902	15534	17925	21653	13233	4887	5745	7242	8473	7506	7212
Pistachio (Adolescent)	0	0	0	0	0	0	0	168	188	225	433	732	931
Pistachio (Mature)	0	0	0	519	494	348	294	286	281	260	259	414	386
Pistachio (Young)	0	92	612	1286	1030	1613	2066	1148	1837	2468	3146	3862	3324
Pomegranates (Young)	0	0	0	3	518	237	24	460	92	425	541	324	292
Potatoes, Sugar beets, Turnip etc...	465	0	0	5	0	0	0	1	0	1	0	1	1
Riparian*	0	0	260	11	59	93	386	20	14	54	83	92	101
Small Vegetables	807	298	4282	0	0	2	58	14	18	67	64	5	73
Stone Fruit (Mature)	0	0	0	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	0	0	2	13	64	3	4	123	1	2	57	60
Tomatoes and Peppers	3069	1361	14625	5	1	67	0	13774	16185	4920	8549	16040	18943
Urban, Industrial*	2645	5070	3531	11025	10872	15246	10536	9841	8535	9304	10539	9274	9570
Wine Grapes with 80% canopy	0	196	130	160	142	18	1400	89	407	36	215	186	377
Winter Wheat*	0	0	0	16033	29951	18879	29123	20451	21465	20757	21059	9497	10032
El Rico GSA Irrigated Crop Acreage	**130966**	**145246**	**175658**	**162969**	**148189**	**140412**	**144935**	**130069**	**125380**	**128584**	**95998**	**87624**	**115666**
El Rico GSA Total Crop Acreage	**211398**	**211393**	**211342**	**211325**	**211311**	**211301**	**211291**	**211282**	**211278**	**211273**	**211272**	**211270**	**211268**

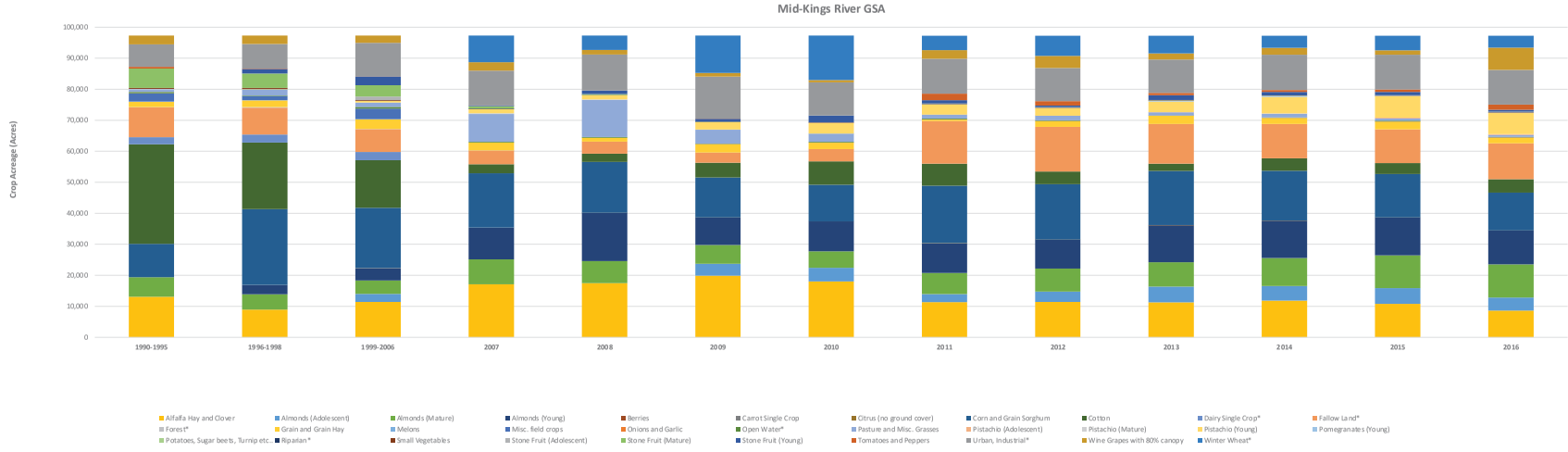
Notes: Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year



APPENDIX D1-2

Sum of Crop Acreage (Acres) Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Mid-Kings River GSA													
Alfalfa Hay and Clover	13077	8955	11390	17127	17455	19907	17997	11349	11422	11310	11841	10814	8641
Almonds (Adolescent)	0	0	2646	0	0	3787	4400	2615	3312	5048	4677	5026	4221
Almonds (Mature)	6279	4955	4272	8040	7115	6086	5356	6765	7410	7851	9051	10582	10643
Almonds (Young)	0	3000	4011	10240	15571	8903	9640	9566	9308	11916	12070	12231	10961
Berries	0	0	0	0	0	0	0	0	1	2	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	1	2	0	2	0	4
Citrus (no ground cover)	0	0	21	0	10	9	4	110	27	89	30	17	4
Corn and Grain Sorghum	10777	24410	19454	17506	16434	12857	11789	18456	17872	17415	16054	13966	12211
Cotton	32138	21479	15330	2895	2617	4746	7523	7128	4136	2391	4027	3536	4295
Dairy Single Crop*	2278	2624	2666	0	0	0	0	0	0	0	0	0	0
Fallow Land*	9607	8651	7329	4456	3877	3288	3992	13754	14408	12757	11022	10897	11563
Forest*	93	163	71	2	0	7	1	0	0	1	0	0	0
Grain and Grain Hay	1658	2181	3123	2539	1275	2690	2058	498	1815	2657	1915	2558	1776
Melons	151	56	27	0	0	0	0	1	3	4	0	0	13
Misc. field crops	2574	1297	3410	0	0	0	0	0	0	0	0	0	0
Onions and Garlic	58	0	0	0	0	1	20	36	71	4	61	7	118
Open Water*	457	209	560	246	228	121	274	280	177	103	122	203	212
Pasture and Misc. Grasses	860	1881	1360	8942	12009	4550	2646	1272	1468	1001	1177	750	595
Pistachio (Adolescent)	0	0	0	0	0	0	0	2	14	41	112	244	227
Pistachio (Mature)	99	78	74	244	95	46	27	25	17	16	14	14	19
Pistachio (Young)	0	137	452	1302	1386	2477	3444	3198	2521	3410	5367	6919	6844
Pomegranates (Young)	0	0	0	1	21	5	5	114	50	254	220	26	74
Potatoes, Sugar beets, Turnip etc...	0	1	0	2	0	2	0	0	0	0	0	0	1
Riparian*	0	20	20	178	18	20	4	66	9	29	69	10	38
Small Vegetables	336	348	236	15	1	2	98	99	64	102	87	29	92
Stone Fruit (Adolescent)	0	0	1183	0	0	3	60	100	124	69	46	191	166
Stone Fruit (Mature)	6217	4597	3662	793	345	29	7	3	23	41	23	27	39
Stone Fruit (Young)	0	1504	2816	342	1126	953	2187	1008	485	1549	1150	1093	612
Tomatoes and Peppers	589	132	48	1	0	35	0	2108	1412	788	603	763	1651
Urban, Industrial*	7209	7934	10796	11097	11599	13542	10655	11206	10679	10709	11395	11219	11192
Wine Grapes with 80% canopy	2868	2713	2368	2768	1506	1180	778	2768	3935	2023	2241	1448	7218
Winter Wheat*	0	0	0	8574	4606	12043	14313	4658	6509	5691	3894	4696	3835
Mid-Kings River GSA Irrigated Crop A	**77681**	**77725**	**75883**	**72754**	**76968**	**68269**	**68042**	**67222**	**65492**	**67981**	**70768**	**70242**	**70424**
Mid-Kings River GSA Total Crop Acre	**97326**	**97326**	**97325**	**97307**	**97296**	**97289**	**97282**	**97276**	**97273**	**97272**	**97269**	**97267**	**97265**

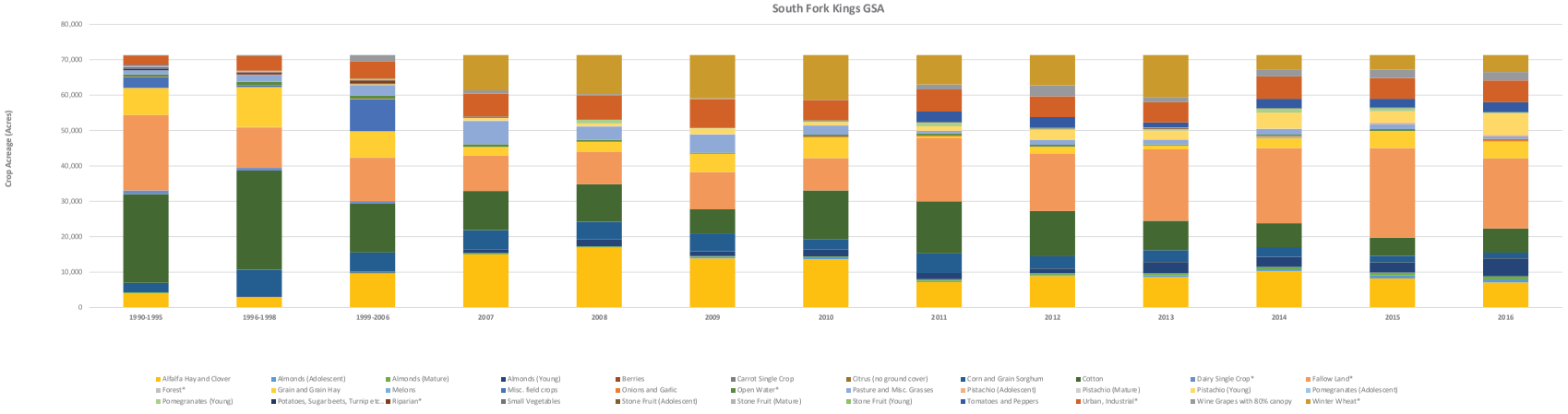
Notes: Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year



APPENDIX D1-3

Sum of Crop Acreage (Acres) Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
South Fork Kings GSA													
Alfalfa Hay and Clover	4030	2892	9546	14989	16927	13848	13603	7183	8911	8561	10328	8208	7048
Almonds (Adolescent)	0	0	172	0	0	431	605	301	272	538	469	857	905
Almonds (Mature)	213	143	135	383	332	259	221	507	522	584	651	818	829
Almonds (Young)	0	188	322	1113	1972	1328	1916	1794	1231	3147	2833	2825	5066
Berries	0	0	0	0	0	0	0	0	0	0	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	1	0	2	0	2	7
Citrus (no ground cover)	0	0	5	0	0	0	0	4	1	5	0	1	1
Corn and Grain Sorghum	2721	7461	5363	5344	4974	5058	2951	5499	3523	3375	2758	1893	1639
Cotton	25101	27984	13748	11091	10661	6816	13753	14685	12783	8294	6759	5136	6829
Dairy Single Crop*	998	761	781	0	0	0	0	0	0	0	0	0	0
Fallow Land*	21306	11422	12200	9929	9182	10491	9125	17821	16304	20156	21235	25318	19818
Forest*	6	106	97	4	1	4	3	0	0	0	0	1	0
Grain and Grain Hay	7688	11325	7401	2545	2791	5254	5903	570	1868	1073	2824	4829	4710
Melons	0	0	0	0	0	0	5	0	2	1	302	0	10
Misc. field crops	3029	537	9083	0	0	0	0	0	0	0	0	0	0
Onions and Garlic	146	0	164	0	0	4	278	262	63	61	316	40	446
Open Water*	568	944	770	707	508	239	479	505	493	289	363	435	314
Pasture and Misc. Grasses	1196	1992	3076	6612	3776	5167	2585	764	1385	1335	1598	1466	736
Pistachio (Adolescent)	0	0	0	0	0	0	0	0	15	20	45	388	391
Pistachio (Mature)	0	0	0	138	122	64	61	61	61	56	51	50	58
Pistachio (Young)	0	34	231	784	778	1662	903	1265	2756	2520	4547	3177	6029
Pomegranates (Adolescent)	0	0	0	0	0	0	0	0	0	0	3	16	27
Pomegranates (Young)	0	0	0	10	1005	102	188	996	411	467	1142	933	292
Potatoes, Sugar beets, Turnip etc...	468	0	209	0	0	2	0	0	0	38	0	1	0
Riparian*	0	648	841	190	14	66	27	101	22	212	32	124	43
Small Vegetables	430	2	0	5	0	8	11	14	30	43	4	38	28
Stone Fruit (Adolescent)	0	0	65	0	0	0	0	1	0	0	1	0	4
Stone Fruit (Mature)	408	316	192	3	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	94	245	38	53	95	229	61	94	86	85	32	40
Tomatoes and Peppers	287	51	0	93	2	8	12	2982	3060	1400	2605	2355	2749
Urban, Industrial*	2631	4086	4952	6415	6654	7933	5793	6213	5863	5729	6304	5928	6151
Wine Grapes with 80% canopy	80	317	1706	974	503	254	60	1408	3084	1481	1877	2279	2329
Winter Wheat*	0	0	0	9941	11051	12214	12590	8305	8551	11832	4173	4154	4807
South Fork Kings GSA Irrigated Crop	**45796**	**53338**	**51663**	**44120**	**43896**	**40359**	**43287**	**38359**	**40073**	**33087**	**39198**	**35344**	**40172**
South Fork Kings GSA Total Crop Acr	**71305**	**71305**	**71305**	**71305**	**71305**	**71305**	**71305**	**71305**	**71305**	**71305**	**71305**	**71305**	**71305**

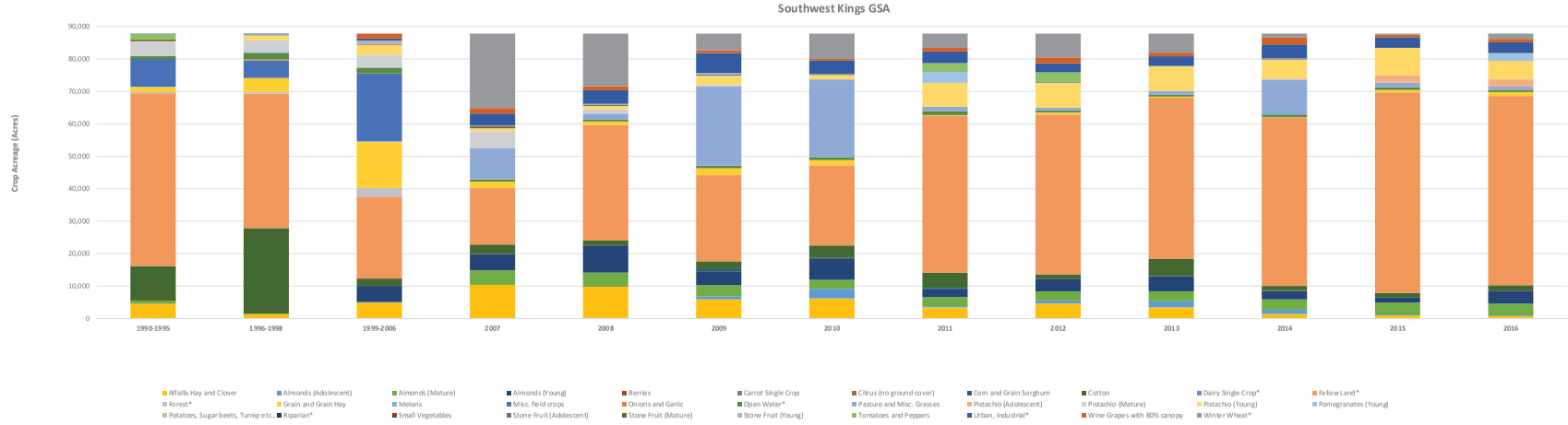
Notes: Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year



APPENDIX D1-4

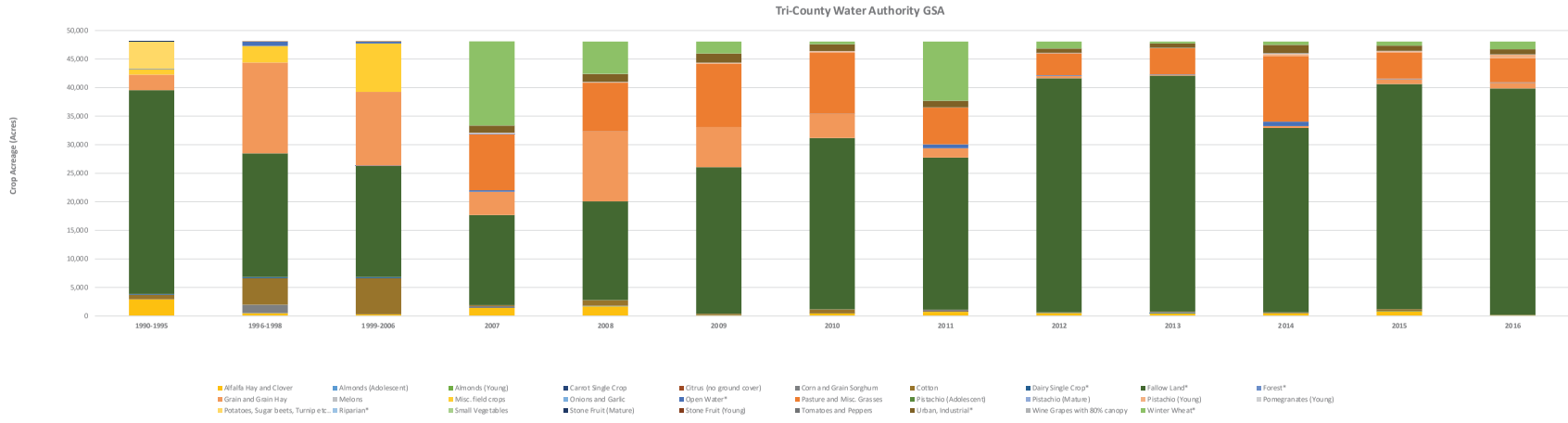
Sum of Crop Acreage (Acres) Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Southwest Kings GSA													
Alfalfa Hay and Clover	4524	1347	4850	10391	9787	5943	6228	3472	4626	3475	1381	960	715
Almonds (Adolescent)	0	0	90	0	0	908	2921	304	879	1889	1372	337	235
Almonds (Mature)	1190	143	143	4474	4377	3481	2797	2867	2887	3005	3175	3646	3633
Almonds (Young)	0	90	4957	4922	8214	4248	6657	2329	3744	4631	2555	1577	3997
Berries	20	0	0	0	0	0	0	0	0	0	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	0	0	0	0	0	0
Citrus (no ground cover)	0	0	0	0	3	4	0	0	2	3	59	4	4
Corn and Grain Sorghum	0	17	0	66	18	640	85	492	32	73	34	4	31
Cotton	10438	26255	2279	2960	1746	2428	3832	4690	1444	5300	1466	1388	1671
Dairy Single Crop*	39	0	15	0	0	0	0	0	0	0	0	0	0
Fallow Land*	53229	41443	25225	17464	35584	26521	24733	48292	49251	49716	51859	61821	58286
Forest*	321	527	2617	0	0	0	0	0	0	0	0	3	0
Grain and Grain Hay	1595	4379	14293	1981	1010	2189	1583	188	597	306	132	796	1251
Melons	100	0	257	0	0	0	9	0	0	0	4	0	1
Misc. field crops	8580	5377	20902	0	0	0	0	0	0	0	2	0	0
Onions and Garlic	0	314	0	0	0	2	25	64	104	2	80	20	15
Open Water*	902	1805	1657	606	473	737	891	1233	536	543	749	774	619
Pasture and Misc. Grasses	0	472	276	9716	1984	24511	23979	1343	898	1176	10802	1403	998
Pistachio (Adolescent)	0	0	0	0	0	0	0	0	1	84	293	2212	2288
Pistachio (Mature)	4595	3730	3730	5195	1195	476	21	21	20	17	6	6	6
Pistachio (Young)	0	1316	3094	829	1002	2610	1360	7358	7551	7459	5794	8509	5688
Pomegranates (Young)	0	0	0	49	147	166	16	3397	249	241	161	23	2448
Potatoes, Sugar beets, Turnip etc...	0	0	0	0	0	0	0	2	0	0	0	0	0
Riparian*	0	0	0	76	1	219	186	35	27	13	25	13	12
Small Vegetables	27	0	0	1	1	0	38	14	19	2	9	5	5
Stone Fruit (Adolescent)	0	0	229	0	0	11	6	0	0	0	0	0	0
Stone Fruit (Mature)	445	72	0	518	198	139	11	0	0	0	0	0	0
Stone Fruit (Young)	0	229	1124	289	416	462	83	4	10	4	102	0	2
Tomatoes and Peppers	1689	83	3	19	0	1	0	2601	3012	3	144	7	54
Urban, Industrial*	169	262	546	3643	4212	6157	4050	3619	2776	2885	4250	3199	3148
Wine Grapes with 80% canopy	0	0	1576	1684	1312	788	505	1093	1796	1113	2137	757	1060
Winter Wheat*	0	0	0	22975	16175	5212	7839	4436	7394	5913	1262	388	1688
Southwest Kings GSA Irrigated Crop	**33202**	**43824**	**57801**	**43094**	**31411**	**49008**	**50156**	**30239**	**27869**	**28783**	**29707**	**21654**	**24100**
Southwest Kings GSA Total Crop Acr	**87862**	**87862**	**87860**	**87858**	**87856**	**87855**	**87854**	**87854**	**87853**	**87853**	**87852**	**87852**	**87852**

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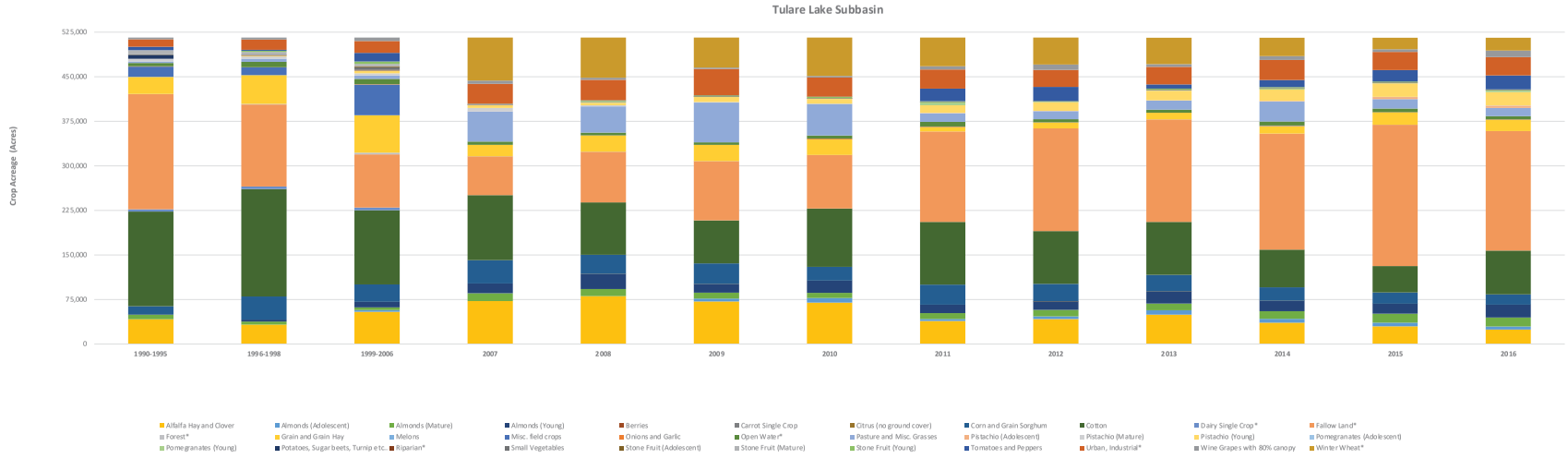
Sum of Crop Acreage (Acres) Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Tri-County Water Authority GSA													
Alfalfa Hay and Clover	2917	488	290	1402	1672	181	469	750	526	544	469	765	159
Almonds (Adolescent)	0	0	0	0	0	0	0	0	0	0	0	0	0
Almonds (Young)	0	0	0	5	28	2	6	42	21	11	12	104	7
Carrot Single Crop	0	0	0	0	0	0	0	2	0	9	0	0	0
Citrus (no ground cover)	0	0	0	0	0	0	0	1	0	0	0	0	0
Corn and Grain Sorghum	0	1486	0	347	123	0	2	274	62	114	20	5	1
Cotton	830	4665	6333	172	952	210	714	49	39	104	147	325	47
Dairy Single Crop*	116	199	205	0	0	0	0	0	0	0	0	0	0
Fallow Land*	35703	21667	19509	15775	17303	25691	29979	26643	41003	41346	32290	39427	39639
Forest*	0	0	14	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	2719	15911	12888	4050	12212	7013	4217	1625	433	130	336	872	1024
Melons	0	0	0	0	0	0	0	0	0	0	0	15	0
Misc. field crops	921	2871	8503	0	0	0	0	0	0	0	0	0	0
Onions and Garlic	0	0	0	0	0	0	3	22	5	0	1	0	2
Open Water*	90	771	305	274	49	13	42	665	86	45	764	51	58
Pasture and Misc. Grasses	0	1	1	9885	8538	11063	10637	6414	3873	4601	11501	4618	4202
Pistachio (Adolescent)	0	0	0	0	0	0	0	0	0	0	0	0	0
Pistachio (Mature)	0	0	0	0	0	0	0	0	0	0	0	0	0
Pistachio (Young)	0	1	1	151	63	164	309	16	11	22	342	212	685
Pomegranates (Young)	0	0	0	0	14	35	22	46	2	8	143	7	5
Potatoes, Sugar beets, Turnip etc...	4803	0	0	0	0	0	0	6	0	1	0	0	0
Riparian*	0	0	0	63	42	0	11	3	67	5	30	9	1
Small Vegetables	0	0	0	0	0	0	6	0	1	30	0	1	1
Stone Fruit (Mature)	0	0	0	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	0	0	1	0	0	0	0	0	0	1	0	0
Tomatoes and Peppers	0	0	0	0	0	0	0	17	1	4	20	46	24
Urban, Industrial*	0	39	50	1247	1374	1594	1184	1122	722	740	1413	910	868
Wine Grapes with 80% canopy	0	0	0	2	36	0	3	2	6	2	3	2	0
Winter Wheat*	0	0	0	14715	5675	2104	462	10361	1199	337	563	685	1327
Irrigated Crop Acreage	**12191**	**25423**	**28017**	**16014**	**23638**	**18668**	**16387**	**9267**	**4981**	**5582**	**12994**	**6971**	**6157**
Total Crop Acreage	**48099**	**48099**	**48099**	**48088**	**48081**	**48070**	**48064**	**48061**	**48059**	**48056**	**48053**	**48053**	**48051**

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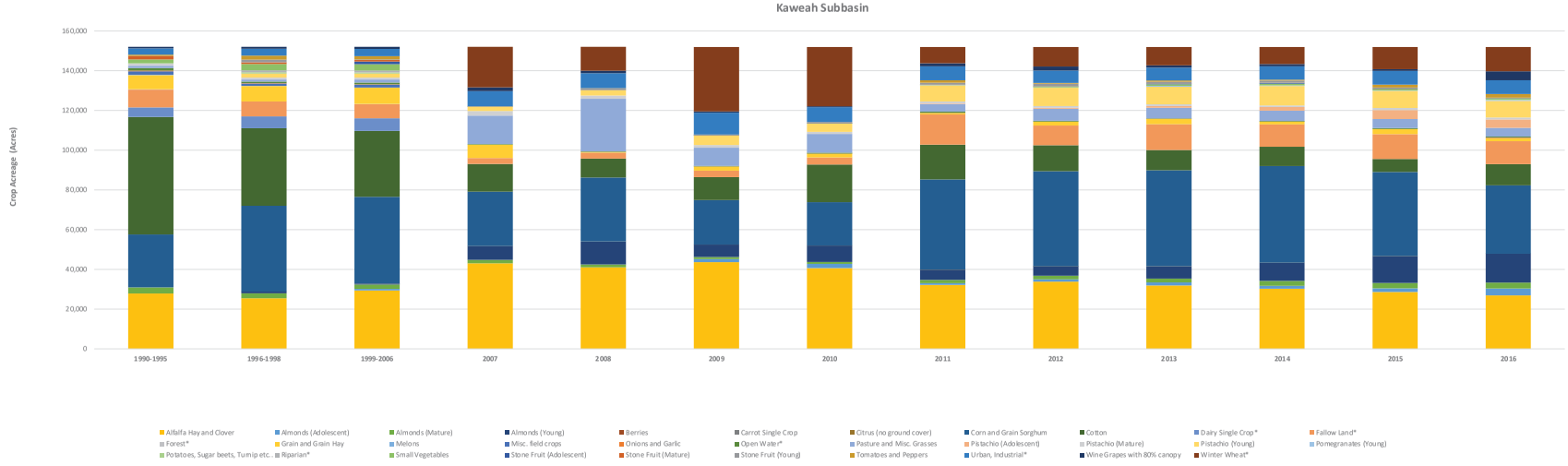
Sum of Crop Acreage (Acres) Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Tulare Lake Subbasin													
Alfalfa Hay and Clover	41604	32564	54301	72459	80600	71504	69685	38789	42131	49318	35820	29665	24245
Almonds (Adolescent)	0	0	2908	0	0	5127	7927	3222	4464	7476	6526	6222	5365
Almonds (Mature)	7682	5241	4550	12897	11825	9826	8374	10140	10818	11441	12876	15046	15105
Almonds (Young)	0	3278	9290	16538	25966	14678	20887	13968	14564	20341	17678	16983	21576
Berries	20	0	0	0	0	0	0	0	1	2	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	11	5	12	2	2	16
Citrus (no ground cover)	0	0	25	0	13	14	4	120	29	100	89	22	9
Corn and Grain Sorghum	14280	38896	29349	39271	31762	34643	23031	33780	29175	27566	22638	18826	17400
Cotton	159534	180960	124764	109605	88304	72441	98167	105541	88993	89317	63385	44532	73720
Dairy Single Crop*	3816	4077	4385	0	0	0	0	0	0	0	0	0	0
Fallow Land*	193695	138392	89606	65169	85144	99688	90192	152391	172697	172486	195172	237790	200972
Forest*	420	809	2955	6	5	46	5	0	0	1	0	4	0
Grain and Grain Hay	28708	48533	62962	19266	27870	27406	25980	7758	9968	11194	12213	21196	19069
Melons	250	56	284	0	0	0	14	2	11	7	797	18	86
Misc. field crops	17116	12819	51311	0	2	0	0	0	0	0	2	0	0
Onions and Garlic	457	479	770	0	0	7	1358	411	302	94	502	149	644
Open Water*	5568	9092	8968	5576	4296	4049	5434	7703	5443	5045	6824	5919	5435
Pasture and Misc. Grasses	2500	5029	5615	50688	44232	66944	53080	14680	13368	15355	33551	15744	13743
Pistachio (Adolescent)	0	0	0	0	0	0	0	170	218	370	882	3575	3836
Pistachio (Mature)	4694	3808	3804	6096	1907	934	404	394	380	348	330	485	469
Pistachio (Young)	0	1580	4390	4351	4259	8527	8083	12985	14676	15878	19195	22678	22570
Pomegranates (Adolescent)	0	0	0	0	0	0	0	0	0	0	3	16	27
Pomegranates (Young)	0	0	0	61	1705	545	256	5012	804	1395	2207	1312	3111
Potatoes, Sugar beets, Turnip etc...	5736	1	209	6	0	3	0	9	0	41	0	2	2
Riparian*	0	668	1120	517	134	398	615	226	138	313	239	248	194
Small Vegetables	1599	647	4518	20	2	13	212	142	133	244	165	78	198
Stone Fruit (Adolescent)	0	0	1478	0	0	14	66	100	125	69	47	191	170
Stone Fruit (Mature)	7070	4985	3854	1314	544	168	18	3	23	41	23	27	39
Stone Fruit (Young)	0	1827	4185	672	1609	1573	2502	1077	712	1641	1340	1183	713
Tomatoes and Peppers	5634	1627	14676	117	2	110	12	21482	23670	7114	11922	19211	23420
Urban, Industrial*	12654	17391	19875	33427	34711	44471	32218	32091	28576	29366	33901	30530	30930
Wine Grapes with 80% canopy	2948	3226	5779	5588	3499	2240	2746	5361	9228	4655	6472	4672	10985
Winter Wheat*	0	0	0	72238	67458	50451	64526	48212	45118	44530	30950	19420	21690
Tulare Lake Subbasin Irrigated Crop	**299832**	**345557**	**389021**	**338951**	**324102**	**316717**	**322806**	**275156**	**263796**	**264018**	**248665**	**221837**	**256519**
Tulare Lake Subbasin Total Crop Acr	**515986**	**515986**	**515931**	**515883**	**515849**	**515821**	**515796**	**515779**	**515768**	**515759**	**515751**	**515747**	**515741**

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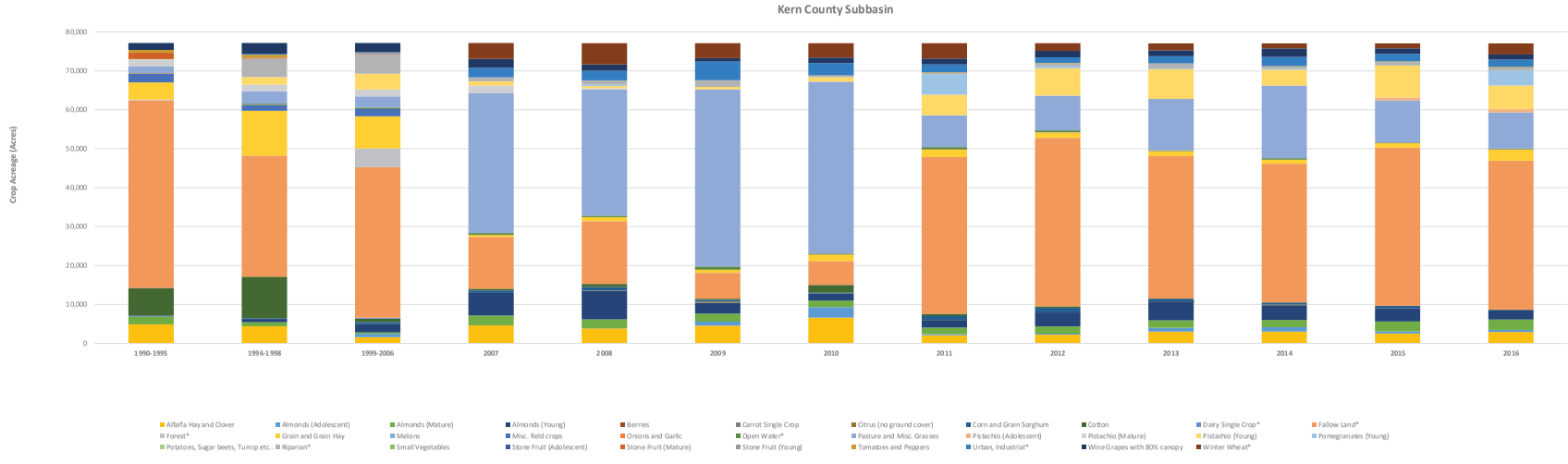
Sum of Crop Acreage (Acres) Kaweah Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Kaweah Subbasin													
Alfalfa Hay and Clover	27850	25488	29418	43095	41094	43668	40716	32231	33810	31880	30293	28662	26949
Almonds (Adolescent)	0	0	771	0	0	1532	2066	872	1229	1617	1456	1803	3445
Almonds (Mature)	3153	2535	2191	1736	1410	1077	921	1634	1819	1926	2456	2749	2995
Almonds (Young)	0	790	398	6870	11485	6194	8294	5130	4634	6064	9091	13550	14488
Berries	0	9	9	0	0	0	0	0	0	0	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	26	2	0	3	0	4
Citrus (no ground cover)	0	0	0	4	10	15	4	12	10	53	73	5	8
Corn and Grain Sorghum	26638	43219	43776	27456	32303	22468	21812	45387	47930	48395	48640	42286	34456
Cotton	59129	39071	33139	13910	9429	11494	18937	17481	13112	10144	9699	6535	10619
Dairy Single Crop*	4739	5962	6386	0	0	0	0	0	0	0	0	0	0
Fallow Land*	9002	7460	7147	2975	2992	3242	3633	15205	9874	13007	11274	12526	11575
Forest*	176	46	35	0	1	20	0	0	0	1	3	0	0
Grain and Grain Hay	7117	7703	8178	6799	501	2199	1849	745	1957	2730	1408	2541	1462
Melons	153	101	101	0	0	1	0	3	1	14	0	2	102
Misc. field crops	1745	1167	1439	0	1	1	0	0	0	0	0	0	0
Onions and Garlic	429	229	229	0	0	0	33	167	24	1	9	4	277
Open Water*	1210	726	866	246	233	247	516	579	378	199	277	492	424
Pasture and Misc. Grasses	1206	1112	1494	14364	26396	9090	9378	3711	6078	5345	5242	4515	4501
Pistachio (Adolescent)	0	0	0	0	0	0	0	336	493	880	1833	4513	4211
Pistachio (Mature)	1020	955	955	2307	1657	1343	1083	1034	886	794	771	1046	900
Pistachio (Young)	0	1985	2037	2026	2702	4762	4110	8081	9263	8907	9834	8573	8411
Pomegranates (Young)	0	0	0	4	155	10	3	89	52	430	128	102	395
Potatoes, Sugar beets, Turnip etc...	419	684	611	6	0	1	0	107	58	3	205	155	188
Riparian*	0	934	934	16	14	32	3	13	15	59	34	9	58
Small Vegetables	1749	3208	3163	89	1	5	2	175	490	782	766	780	725
Stone Fruit (Adolescent)	0	0	1320	0	0	22	26	20	128	382	403	82	30
Stone Fruit (Mature)	1645	883	762	125	24	5	0	19	3	7	70	94	17
Stone Fruit (Young)	0	1360	310	120	828	489	824	923	1191	818	1005	558	258
Tomatoes and Peppers	752	2013	1691	14	1	16	0	1188	384	697	546	1415	1750
Urban, Industrial*	3123	3412	3648	7583	7565	10932	7414	7056	6340	6453	6684	6941	6921
Wine Grapes with 80% canopy	801	1007	1036	1909	1183	630	547	1589	1944	1146	1170	862	4520
Winter Wheat*	0	0	0	20373	12023	32495	29802	8152	9855	9222	8580	11152	12262
Kaweah Subbasin Irrigated Crop Acr	**133807**	**133516**	**133027**	**120832**	**129180**	**105020**	**110604**	**120961**	**125498**	**123017**	**125103**	**120831**	**120710**
Kaweah Subbasin Total Crop Acreag	**152057**	**152057**	**152044**	**152025**	**152007**	**151987**	**151972**	**151966**	**151959**	**151957**	**151955**	**151951**	**151949**

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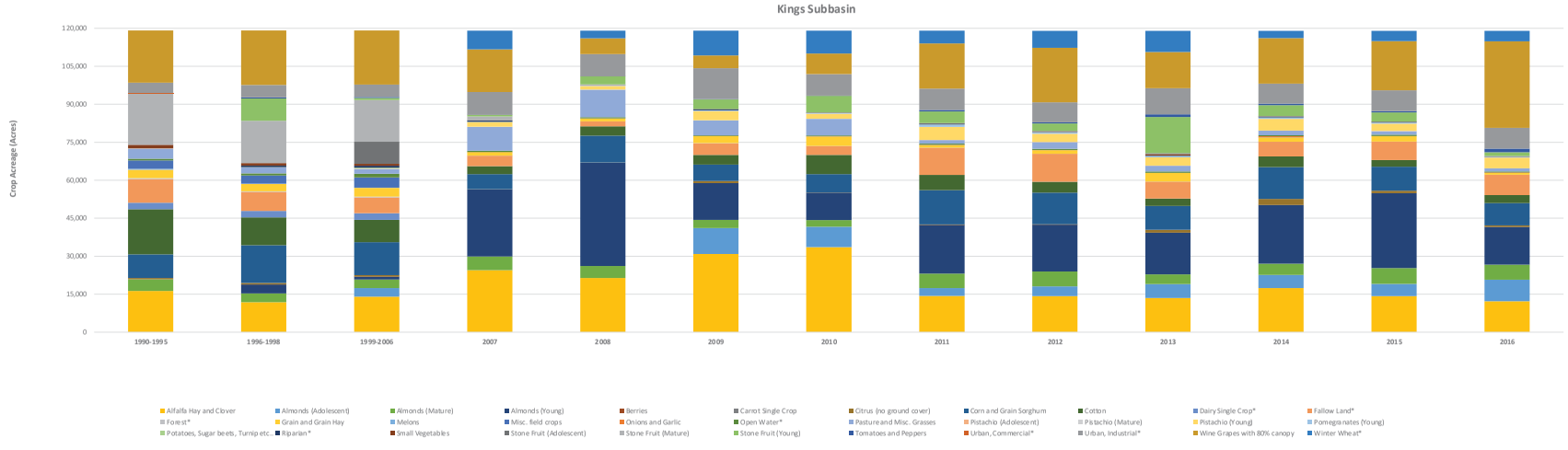
Sum of Crop Acreage (Acres) Kern County Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Kern County Subbasin													
Alfalfa Hay and Clover	4901	4407	1624	4680	3816	4559	6610	2076	2224	3033	3011	2533	2915
Almonds (Adolescent)	0	0	812	0	0	1015	2696	295	249	1001	1166	529	567
Almonds (Mature)	1966	1035	402	2459	2384	2079	1689	1674	1889	1875	1878	2559	2635
Almonds (Young)	0	835	2229	5818	7283	2776	1820	1994	3570	4715	3756	3421	2367
Berries	0	0	0	0	0	0	0	0	0	8	0	0	0
Carrot Single Crop	53	0	0	0	0	0	0	0	0	3	1	1	2
Citrus (no ground cover)	0	0	0	0	131	278	0	2	19	2	152	1	1
Corn and Grain Sorghum	234	184	439	635	878	504	218	964	1186	852	491	614	144
Cotton	7102	10686	800	474	798	283	1970	614	385	66	120	30	62
Dairy Single Crop*	1	0	331	0	0	0	0	0	0	0	0	0	0
Fallow Land*	48223	31069	38616	13275	16082	6615	6146	40232	43273	36573	35547	40594	38237
Forest*	168	3	4832	0	1	1	0	0	2	0	0	0	0
Grain and Grain Hay	4362	11541	8261	506	1043	838	1682	1944	1374	1267	1078	1121	2860
Melons	0	0	0	0	0	1	0	0	21	8	1	0	4
Misc. field crops	2316	1463	1842	0	0	0	0	0	0	0	0	0	0
Onions and Garlic	130	56	0	0	0	0	9	52	71	10	16	34	102
Open Water*	2	308	376	513	376	796	241	553	408	202	331	137	126
Pasture and Misc. Grasses	1641	3129	2856	35869	32488	45504	44155	8180	8962	13185	18668	10827	9311
Pistachio (Adolescent)	0	0	0	0	0	0	0	0	0	2	61	758	807
Pistachio (Mature)	1847	1786	1775	2013	207	1	0	0	0	0	0	0	0
Pistachio (Young)	0	1906	4110	1063	631	663	1182	5304	7047	7601	4011	8202	6088
Pomegranates (Young)	0	0	0	0	361	0	0	5246	486	199	188	59	3850
Potatoes, Sugar beets, Turnip etc...	84	0	0	0	0	1	0	0	1	0	2	5	1
Riparian*	0	4723	4997	1015	956	1662	470	406	748	1307	571	1029	788
Small Vegetables	22	0	50	0	2	0	12	4	12	9	6	11	12
Stone Fruit (Adolescent)	0	0	20	0	0	0	0	0	0	0	0	0	3
Stone Fruit (Mature)	1600	245	202	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	27	3	5	124	60	14	42	14	25	246	24	119
Tomatoes and Peppers	724	766	0	0	0	1	0	83	80	17	24	28	127
Urban, Industrial*	16	237	266	2445	2462	4764	3065	2002	1443	1807	2236	1848	1751
Wine Grapes with 80% canopy	1779	2764	2324	2284	1647	852	1439	1520	1657	1530	2223	1418	1343
Winter Wheat*	0	0	0	4077	5456	3860	3684	3907	1963	1781	1292	1290	2849
Kern County Subbasin Irrigated Crop	**28760**	**40830**	**27749**	**55826**	**51792**	**59414**	**63495**	**29994**	**29247**	**35407**	**37098**	**32174**	**33318**
Kern County Subbasin Total Crop Ac	**77170**	**77170**	**77168**	**77150**	**77125**	**77111**	**77102**	**77094**	**77084**	**77078**	**77074**	**77073**	**77070**

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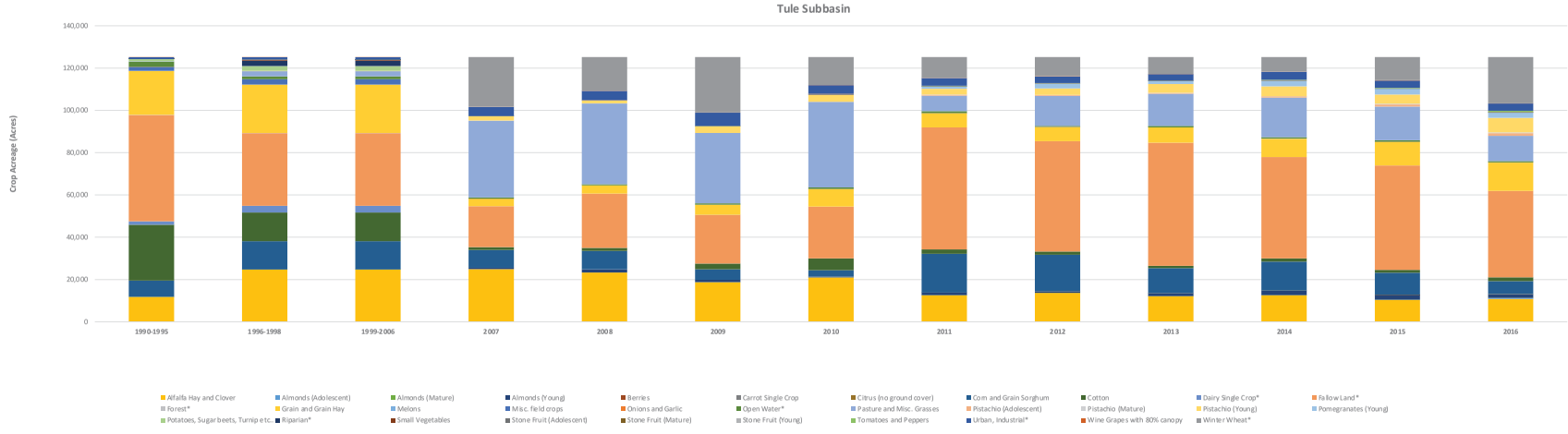
Sum of Crop Acreage (Acres)													
Kings Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Kings Subbasin													
Alfalfa Hay and Clover	16306	11835	14019	24478	21394	30890	33571	14356	14247	13523	17393	14242	12182
Almonds (Adolescent)	0	0	3414	0	0	10231	8066	3031	3819	5446	5193	4806	8502
Almonds (Mature)	4542	3495	3350	5386	4752	3247	2623	5737	5882	3838	4426	6262	5965
Almonds (Young)	0	3529	1164	26493	40739	14505	10844	19230	18486	16474	23168	29556	14910
Berries	0	3	3	0	0	0	0	0	2	16	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	14	1	2	36	0	8
Citrus (no ground cover)	532	557	557	74	93	851	57	206	148	1165	2395	975	570
Corn and Grain Sorghum	9363	14915	13000	5986	10644	6420	7212	13547	12495	9374	12586	9486	8811
Cotton	17806	11022	8861	3151	3700	3875	7667	6017	4335	2911	4225	2613	3156
Dairy Single Crop*	2549	2553	2615	0	0	0	0	0	0	0	0	0	0
Fallow Land*	9327	7519	6268	4149	1922	4614	3512	10692	11063	6697	5755	7343	8050
Forest*	413	229	266	17	9	22	9	2	11	2	2	4	16
Grain and Grain Hay	3299	2801	3445	1384	1109	2770	3757	987	1365	3407	1774	2054	677
Melons	407	180	130	0	3	18	4	1	10	33	7	9	29
Misc. field crops	3315	3204	3954	0	0	1	0	0	0	0	0	0	0
Onions and Garlic	0	0	106	27	58	91	38	175	73	65	389	107	236
Open Water*	671	893	1398	536	483	241	350	473	459	471	418	539	374
Pasture and Misc. Grasses	3833	2326	1914	9370	10809	5861	6552	1431	2665	2291	1789	1361	1172
Pistachio (Adolescent)	0	0	0	0	0	0	0	3	10	3	21	38	34
Pistachio (Mature)	172	109	109	96	73	66	59	59	58	58	56	56	34
Pistachio (Young)	0	9	121	1806	1466	3603	1931	5141	3223	3251	4585	2899	4214
Pomegranates (Young)	0	0	0	142	194	337	312	966	661	581	601	414	315
Potatoes, Sugar beets, Turnip etc...	0	31	233	1	0	2	0	9	0	0	0	2	0
Riparian*	0	584	821	417	54	454	44	280	110	147	219	75	67
Small Vegetables	1465	961	728	9	38	3	15	80	133	591	63	20	52
Stone Fruit (Adolescent)	0	0	8693	0	0	9	87	120	241	326	234	311	141
Stone Fruit (Mature)	20143	16740	16500	1663	324	64	42	12	15	12	32	24	14
Stone Fruit (Young)	0	8804	865	632	3153	3757	6595	4583	2872	14281	4299	3588	1501
Tomatoes and Peppers	51	450	309	15	4	147	23	632	484	1101	554	489	1483
Urban, Commercial*	234	0	0	0	0	0	0	0	0	0	0	0	0
Urban, Industrial*	4096	4846	4942	9013	8793	12129	8555	8395	7942	10273	7943	8218	8190
Wine Grapes with 80% canopy	20602	21532	21331	16829	6248	5113	8126	17826	21517	14294	17966	19448	34154
Winter Wheat*	0	0	0	7416	3009	9737	8988	5024	6696	8390	2883	4070	4153
Kings Subbasin Irrigated Crop Acreag	**101836**	**102501**	**102807**	**97542**	**104801**	**91860**	**97580**	**94163**	**92742**	**93040**	**101794**	**98762**	**98160**
Kings Subbasin Total Crop Acreage	**119125**	**119125**	**119116**	**119090**	**119071**	**119056**	**119038**	**119030**	**119023**	**119019**	**119014**	**119012**	**119009**

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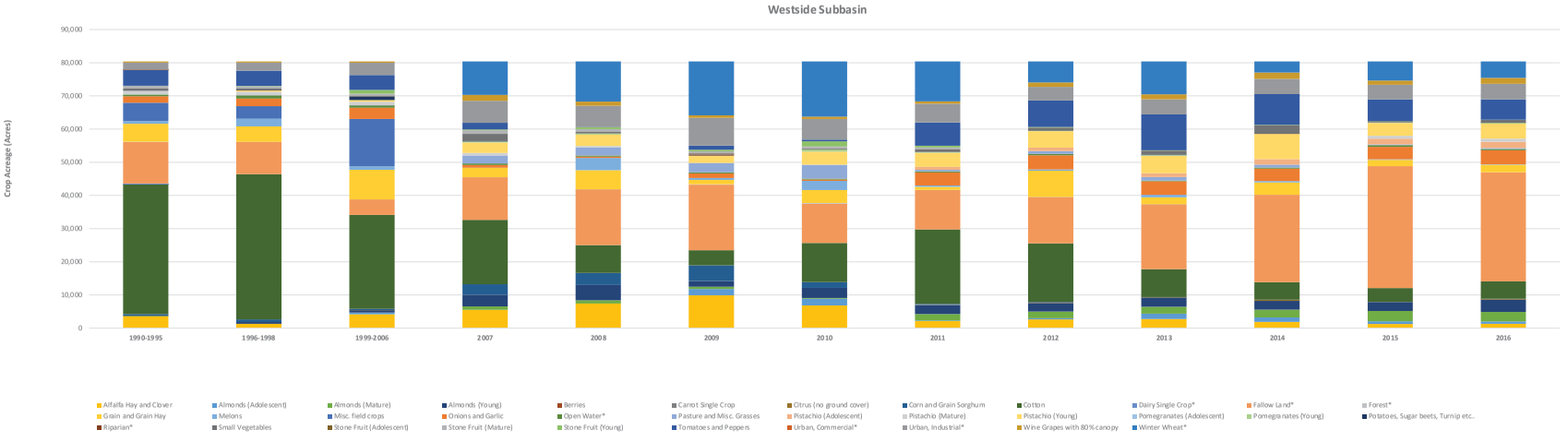
Sum of Crop Acreage (Acres) Tule Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Tule Subbasin													
Alfalfa Hay and Clover	11815	24766	24766	24935	23335	18778	21039	12659	13696	12191	12634	10375	10831
Almonds (Adolescent)	0	0	2	0	0	48	32	5	3	20	48	98	413
Almonds (Mature)	43	13	13	0	0	0	0	3	0	0	0	6	6
Almonds (Young)	0	2	0	656	1520	1020	306	1111	740	1320	2101	2193	1892
Berries	0	0	0	0	0	0	0	0	0	0	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	1	0	0	0	1	17
Citrus (no ground cover)	0	0	0	0	0	0	0	5	0	3	4	2	1
Corn and Grain Sorghum	7656	13330	13330	8428	8660	5049	3069	18412	17304	11863	13687	10594	6087
Cotton	26378	13577	13577	1320	1507	2684	5541	2100	1527	1080	1498	1346	1809
Dairy Single Crop*	1668	3213	3213	0	0	0	0	0	0	0	0	0	0
Fallow Land*	50291	34370	34370	19350	25634	23018	24491	57622	52185	58262	47946	49332	40907
Forest*	59	9	9	0	0	13	0	0	0	0	0	0	0
Grain and Grain Hay	20747	22935	22934	3486	3875	4813	8244	6775	6675	7204	8679	11225	13366
Melons	12	0	0	0	0	5	0	1	2	1	65	4	27
Misc. field crops	1909	2492	2494	0	0	0	0	0	0	0	0	0	0
Onions and Garlic	2	0	0	1	0	0	83	41	103	1	5	20	59
Open Water*	2437	1373	1373	686	547	653	788	935	437	716	654	700	650
Pasture and Misc. Grasses	238	2419	2419	36249	38175	33240	40465	7292	14196	15170	18730	15904	11931
Pistachio (Adolescent)	0	0	0	0	0	0	0	459	371	429	624	995	1192
Pistachio (Mature)	0	0	0	100	67	41	33	33	33	32	32	398	398
Pistachio (Young)	0	201	201	1954	1313	3170	3336	2747	3086	4184	4677	4328	6906
Pomegranates (Young)	0	0	0	2	98	67	17	1076	2311	1363	2648	2709	2393
Potatoes, Sugar beets, Turnip etc...	929	2278	2278	0	0	1	0	1	1	1	4	7	1
Riparian*	0	2509	2509	199	121	57	183	186	58	158	68	63	47
Small Vegetables	0	517	517	1	1	5	204	10	33	31	55	43	236
Stone Fruit (Adolescent)	0	0	20	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Mature)	9	0	0	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	20	0	7	72	9	2	35	31	1	43	41	6
Tomatoes and Peppers	2	18	18	1	0	2	0	105	108	72	268	233	658
Urban, Industrial*	950	1116	1116	4262	4258	6251	4117	3636	3116	3057	3771	3517	3402
Wine Grapes with 80% canopy	71	61	61	35	93	33	99	124	187	32	106	119	136
Winter Wheat*	0	0	0	23544	15937	26255	13161	9833	9005	8017	6859	10955	21832
Tule Subbasin Irrigated Crop Acreag	**69813**	**82629**	**82629**	**77175**	**78716**	**68963**	**82470**	**52997**	**60406**	**54997**	**65908**	**60640**	**58368**
Tule Subbasin Total Crop Acreage	**125218**	**125218**	**125218**	**125215**	**125214**	**125210**	**125209**	**125208**	**125207**	**125206**	**125206**	**125206**	**125205**

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Sum of Crop Acreage (Acres) Westside Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Westside Subbasin													
Alfalfa Hay and Clover	3565	1318	4209	5516	7401	9897	6821	2099	2614	2755	1895	1262	1284
Almonds (Adolescent)	0	0	485	0	0	1873	2016	183	381	1622	1309	802	736
Almonds (Mature)	152	0	0	1044	968	729	240	1962	2029	2068	2348	3129	2866
Almonds (Young)	0	492	680	3525	4619	1617	3064	2645	2375	2820	2693	2702	3720
Berries	12	9	11	0	0	0	0	0	194	0	0	0	30
Carrot Single Crop	0	0	0	0	0	0	0	52	0	1	3	28	2
Citrus (no ground cover)	8	7	18	0	37	16	0	72	0	128	276	27	146
Corn and Grain Sorghum	484	805	423	3151	3625	4814	1747	312	302	9	29	8	45
Cotton	39262	43751	28342	19395	8364	4552	11801	22437	17678	8400	5293	4097	5286
Dairy Single Crop*	95	0	0	0	0	0	0	0	0	0	0	0	0
Fallow Land*	12574	9781	4611	12872	16866	19744	11787	11910	13995	19578	26359	36778	32844
Forest*	47	0	0	11	3	112	206	0	0	11	0	0	0
Grain and Grain Hay	5433	4637	8954	2865	5720	1326	3954	952	7891	2061	3743	1900	2345
Melons	777	2323	1020	3	3702	556	2743	368	414	741	394	158	85
Misc. field crops	5520	3801	14307	0	0	0	14	0	0	0	0	0	0
Onions and Garlic	1997	2306	3392	767	381	1373	385	3942	4252	4107	3712	3762	4236
Open Water*	517	986	678	490	351	385	275	348	379	233	369	479	364
Pasture and Misc. Grasses	0	2	74	2414	2521	2822	4201	429	894	988	881	254	280
Pistachio (Adolescent)	0	0	0	0	0	0	0	900	1016	1184	1676	1740	1956
Pistachio (Mature)	1089	1048	1046	748	387	3	2	2	2	1	0	874	876
Pistachio (Young)	0	382	481	3177	3380	2036	3957	4225	4973	5282	7563	3854	4571
Pomegranates (Adolescent)	0	0	0	0	0	0	0	0	0	24	0	0	0
Pomegranates (Young)	0	0	0	259	395	136	645	251	168	210	13	168	239
Potatoes, Sugar beets, Turnip etc...	0	0	1051	106	0	0	0	30	0	0	0	0	2
Riparian*	0	0	0	19	8	348	39	11	2	17	10	6	8
Small Vegetables	651	537	281	2210	421	286	305	834	878	1259	2529	385	814
Stone Fruit (Adolescent)	0	0	67	0	0	87	42	50	40	13	53	0	0
Stone Fruit (Mature)	865	712	508	1081	867	605	494	435	1	0	6	0	0
Stone Fruit (Young)	0	101	1173	250	485	452	1600	520	127	114	86	2	60
Tomatoes and Peppers	4765	4606	4502	2001	77	1284	497	7045	8011	10820	9286	6558	6171
Urban, Commercial*	21	0	0	0	0	0	0	0	0	0	0	0	0
Urban, Industrial*	2219	2465	3683	6617	6463	8360	6217	5623	4131	4533	4628	4411	4697
Wine Grapes with 80% canopy	353	341	408	1780	1265	714	686	725	1333	1503	1881	1261	1756
Winter Wheat*	0	0	0	10100	12089	16257	16641	12017	6298	9893	3340	5724	4952
Westside Subbasin Irrigated Crop Ac	**64932**	**67173**	**71432**	**50291**	**44615**	**35179**	**45215**		**55572**	**46111**	**45668**	**32972**	**37506**
Westside Subbasin Total Crop Acrea	**80405**	**80405**	**80404**	**80400**	**80394**	**80386**	**80381**	**80378**	**80376**	**80375**	**80373**	**80371**	**80371**

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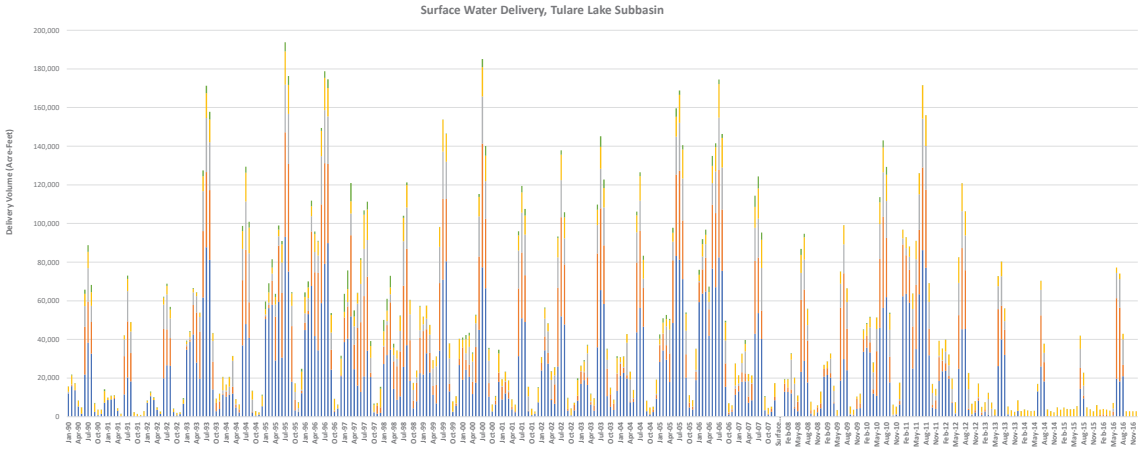
Appendix D2
Monthly Surface Water Deliveries by GSA and Subbasin

APPENDIX D2-1

Surface Water Delivery (Acre-Feet)						
	El Rico GSA	Mid-Kings River GSA	South Fork Kings GSA	Southwest Kings GSA	Tri-County Water Authority GSA	Tulare Lake Subbasin Total
Jan-90	12096	0	799	2753	12	15660
Feb-90	15780	532	389	4646	439	21787
Mar-90	13668	183	0	3383	136	17370
Apr-90	5311	0	0	3008	136	8454
May-90	1550	0	0	3191	159	4900
Jun-90	21777	24810	10647	6343	2198	65774
Jul-90	38337	21228	17294	8527	3431	88817
Aug-90	32604	16448	8315	7059	3826	68253
Sep-90	2580	0	0	4198	328	7106
Oct-90	788	0	0	2760	78	3626
Nov-90	1498	0	0	2048	164	3709
Dec-90	7192	0	0	6100	889	14181
Jan-91	8679	0	0	1104	181	9965
Feb-91	8930	0	0	1727	185	10843
Mar-91	9149	547	0	1291	182	11170
Apr-91	3017	45	0	1251	62	4375
May-91	114	0	0	1304	1	1420
Jun-91	11492	19825	8674	2059	6	42056
Jul-91	20315	29037	15627	6390	1621	72990
Aug-91	18326	14618	11119	4857	21	48941
Sep-91	329	202	0	1793	3	2328
Oct-91	58	0	0	1244	1	1303
Nov-91	111	0	0	725	1	837
Dec-91	540	0	0	2339	8	2888
Jan-92	7246	0	0	920	273	8440
Feb-92	10577	299	0	1569	546	12991
Mar-92	8589	0	0	1126	352	10067
Apr-92	3607	0	0	1104	175	4886
May-92	1444	0	0	1157	101	2702
Jun-92	19886	25477	12628	3649	434	62074
Jul-92	26610	18544	18112	4383	1222	68870
Aug-92	26266	14436	10146	4586	1475	56908
Sep-92	2425	0	17	1607	210	4260
Oct-92	733	0	0	1107	50	1890
Nov-92	1399	0	42	788	105	2334
Dec-92	6752	0	0	2247	568	9567
Jan-93	34635	1882	1061	1250	518	39346
Feb-93	38849	1049	1263	2577	606	44344
Mar-93	42588	15260	6536	1765	484	66632
Apr-93	27978	25934	8549	1783	190	64434
May-93	19683	24280	7672	2096	49	53781
Jun-93	61633	34418	20707	7760	2909	127427
Jul-93	87698	38923	27999	12806	3881	171307
Aug-93	81214	36099	24734	11805	3983	157835
Sep-93	14088	14353	10776	3878	252	43346
Oct-93	2877	4303	0	2120	24	9326
Nov-93	3993	3868	580	3408	51	11900
Dec-93	11465	490	1753	6678	277	20663
Jan-94	10334	2575	689	2961	7	16565
Feb-94	11346	324	3923	4813	240	20646
Mar-94	12003	3460	13518	2370	74	31425
Apr-94	4798	1453	468	2327	74	9121
May-94	2215	1617	63	2408	87	6390
Jun-94	36961	33759	16145	9249	2660	98774
Jul-94	48009	38368	25061	14823	3141	129403
Aug-94	40822	18407	25402	13274	2948	100854
Sep-94	2209	284	6397	4309	208	13407
Oct-94	589	0	0	2259	43	2891
Nov-94	1124	0	0	1123	90	2336
Dec-94	5419	0	0	5487	486	11392
Jan-95	50543	1489	872	2742	4002	59648
Feb-95	56193	1601	1274	5234	4718	69020
Mar-95	57904	12501	3713	3136	4209	81464
Apr-95	29106	22707	6177	3981	1644	63614
May-95	59386	29180	4786	3452	2211	98016
Jun-95	30642	33398	15773	9446	1637	90896
Jul-95	93097	54051	24738	17192	4769	193847
Aug-95	75149	55594	25997	14978	4617	176335
Sep-95	18055	28881	10439	6469	600	64444
Oct-95	3250	5460	4122	4404	130	17366
Nov-95	2410	0	1993	2751	275	7430
Dec-95	12155	1222	586	9321	1489	24773
Jan-96	44804	3917	4812	8505	2349	64387
Feb-96	53068	1691	6610	5587	3070	70027
Mar-96	67724	28082	7981	5191	2808	111787
Apr-96	41794	32997	10433	9367	1218	95808
May-96	34362	40058	8963	7192	410	90985
Jun-96	58752	51099	24996	13079	1533	149459
Jul-96	79092	52174	27425	16679	3469	178839
Aug-96	89843	40956	24649	14773	4495	174666
Sep-96	24394	10256	8963	9114	940	53668
Oct-96	2515	415	373	5858	131	9293
Nov-96	4276	0	0	1720	277	6274
Dec-96	21009	507	0	8581	1500	31597
Jan-97	38642	12784	0	2864	9282	63572
Feb-97	40362	16730	2192	6744	9729	75757
Mar-97	51972	41932	11303	6310	9411	120928
Apr-97	24596	12751	9437	5063	3232	55079
May-97	16136	29820	12593	5395	166	64110
Jun-97	12763	36157	19809	12465	842	82036
Jul-97	20865	41549	24488	17688	2223	106812
Aug-97	34090	38432	18975	15742	4045	111285
Sep-97	20520	2208	7805	6062	2594	39189
Oct-97	2187	0	294	3743	581	6804
Nov-97	1598	4010	0	1392	172	7173
Dec-97	1959	2947	0	9663	931	15499
Jan-98	27236	9019	488	7448	5942	50133
Feb-98	31844	15587	1993	5453	6191	61069
Mar-98	34696	24491	4235	3483	6014	72919
Apr-98	14460	14200	3219	3832	2058	37768
May-98	8776	17329	3981	4124	109	34318
Jun-98	10527	23256	10677	7449	401	52311
Jul-98	25767	42068	22992	12081	1124	104033
Aug-98	37026	49842	21467	11524	1358	121217
Sep-98	18449	21166	13410	7283	192	60500
Oct-98	4362	4005	5516	3488	45	17417
Nov-98	7941	9537	2820	3536	99	23932
Dec-98	22517	18341	3900	12154	528	57440
Jan-99	21858	22424	3602	3790	92	51766
Feb-99	32889	12418	5423	6632	105	57468
Mar-99	22875	10239	9343	4919	89	47466
Apr-99	11286	4682	8966	4310	35	29278
May-99	6892	9519	9693	5002	8	31114
Jun-99	34267	34956	18737	10197	60	98216
Jul-99	70847	41958	24375	16565	114	153859
Aug-99	80450	32271	19217	14414	173	146525
Sep-99	13128	3880	13204	7652	87	37951
Oct-99	2379	0	306	5179	4	7868
Nov-99	5597	1225	223	3566	9	10619
Dec-99	26748	3260	3	10193	47	40249
Jan-00	19168	16688	0	3981	1203	41040
Feb-00	24248	5154	3492	7221	2132	42247
Mar-00	20602	6407	9117	5813	1472	43410
Apr-00	11770	6319	10455	4060	687	33292
May-00	17655	18463	12305	3963	345	52732
Jun-00	44925	37946	20771	10132	1476	115251
Jul-00	77296	63999	24480	15187	4158	185120
Aug-00	66535	35841	19517	13197	5017	140108
Sep-00	10350	7067	11589	5866	714	35586
Oct-00	2705	0	0	3524	169	6399
Nov-00	6375	1920	167	1939	357	10757
Dec-00	18044	4739	148	9827	1933	34689
Jan-01	8961	6643	306	3439	7	19357
Feb-01	12104	5840	413	4738	249	23344
Mar-01	9359	3393	955	5022	77	18805
Apr-01	3836	1392	0	3725	77	9030
May-01	2267	621	0	3302	90	6280
Jun-01	31309	35031	19672	7838	2141	95991
Jul-01	50997	33980	20650	10499	3334	119460
Aug-01	49055	24248	20927	9909	3350	107488
Sep-01	2898	319	7363	4769	186	15535
Oct-01	808	0	0	3235	44	4088
Nov-01	1545	0	0	1047	93	2685
Dec-01	7472	0	0	7351	505	15328
Jan-02	23954	3915	0	2950	50	30869
Feb-02	34366	7194	9184	5270	523	56538
Mar-02	27523	5518	11211	3970	187	48409
Apr-02	8687	535	9845	4403	163	23633
May-02	6720	10074	4546	4164	176	25680
Jun-02	25952	40777	15782	9963	815	93288
Jul-02	51918	51345	19135	13258	2180	137837
Aug-02	47781	31068	13428	10907	2618	105802
Sep-02	3024	974	0	5499	364	9861
Oct-02	753	0	0	3507	86	4346
Nov-02	3255	2826	0	1030	182	7292
Dec-02	8335	2524	0	8095	984	19937
Jan-03	17035	6380	178	2599	251	26443
Feb-03	18975	3997	356	5205	759	29292
Mar-03	16464	3997	12382	4018	398	37259
Apr-03	6235	1332	536	3573	240	11916
May-03	3104	2694	180	3447	189	9614
Jun-03	35955	48545	14724	7872	2655	109751
Jul-03	65530	42356	20487	11279	5552	145204
Aug-03	58315	30398	19584	10022	4429	122748
Sep-03	10724	14051	4602	5418	390	35185
Oct-03	5060	6628	0	3235	93	15015
Nov-03	3534	3270	0	1849	195	8849
Dec-03	13310	8954	246	7783	1057	31349
Jan-04	21193	6202	887	2469	169	30920
Feb-04	22630	2751	421	5211	232	31245
Mar-04	19750	1700	16892	4331	188	42861
Apr-04	7463	567	11364	3817	76	23287
May-04	7649	1847	202	4028	23	13750
Jun-04	43669	36111	15703	8761	1864	106108
Jul-04	56276	39905	15616	12716	2044	126557
Aug-04	46550	20059	4869	9753	2102	83334
Sep-04	2893	0	0	5344	48	8285
Oct-04	1143	426	0	3106	11	4686
Nov-04	2473	1234	27	1335	24	5093
Dec-04	9313	1915	630	7305	130	19292
Jan-05	28328	8681	318	3073	2183	42584
Feb-05	34297	8543	211	5698	2211	50959
Mar-05	29485	7573	9716	3712	2191	52678
Apr-05	17953	14774	12322	4882	736	50667
May-05	48534	32390	9719	4539	2573	97756
Jun-05	83212	42082	19626	10292	4362	159573
Jul-05	81301	45958	24885	14477	2262	168883
Aug-05	71251	30263	21741	15052	2244	140551
Sep-05	20198	12158	12151	8680	770	53957
Oct-05	4823	2388	126	3795	5	11137
Nov-05	3751	1321	193	3261	10	8536
Dec-05	18891	4407	951	10899	57	35205
Jan-06	59292	10338	592	3257	2512	75991
Feb-06	63754	12505	6626	6422	2541	91849
Mar-06	64764	17538	6973	4837	2663	96774
Apr-06	41883	13691	3840	5137	2833	67383
May-06	76704	32999	11252	8857	5127	134938
Jun-06	67064	38328	21556	12485	2077	141510
Jul-06	82441	45232	27164	17302	2425	174563
Aug-06	75475	31743	21761	15341	2036	146355
Sep-06	15527	12043	11907	9365	807	49649
Oct-06	1262	853	149	4680	33	6977
Nov-06	2510	1310	156	1921	11	5908
Dec-06	11319	3168	1686	11288	62	27522
Jan-07	13171	2716	1406	4102	0	21395
Feb-07	18115	4927	4753	4776	12	32582
Mar-07	18252	4158	11450	3792	2061	39713
Apr-07	7207	3220	7950	3630	4	22010
May-07	8494	8585	313	3894	4	21291
Jun-07	42957	37657	17154	10846	5784	114397
Jul-07	53608	28757	20138	15667	6199	124370
Aug-07	40221	14702	22073	14551	3777	95325
Sep-07	3237	0	300	6629	473	10638
Oct-07	1095	474	0	2879	2	4449
Nov-07	2519	1514	0	1013	5	5050
Dec-07	8543	1666	0	7129	24	17363

APPENDIX D2-1 (Cont)

Surface Water Delivery (Acre-Feet)	El Rico GSA	Mid-Kings River GSA	South Fork Kings GSA	Southwest Kings GSA	Tri-County Water Authority GSA	Tulare Lake Subbasin Total
Jan-08	12877	4236	0	2158	249	19521
Feb-08	12794	2358	0	4154	286	19592
Mar-08	12030	2029	15452	3035	260	32806
Apr-08	4310	676	12129	2975	94	20185
May-08	2848	4804	280	2918	14	10863
Jun-08	23201	37252	14023	9327	3063	86866
Jul-08	28911	36960	15430	11570	1795	94666
Aug-08	17737	21618	8115	8066	321	55857
Sep-08	1686	1694	0	4266	28	7674
Oct-08	535	324	0	2614	7	3479
Nov-08	2311	2600	0	966	14	5891
Dec-08	4305	2578	0	6083	77	13042
Jan-09	20714	4035	0	1996	0	26745
Feb-09	21578	3528	0	3511	2	28619
Mar-09	20219	2386	7422	2559	1	32585
Apr-09	6912	583	5834	2571	1	15900
May-09	626	0	0	2805	1	3432
Jun-09	18684	37791	12420	6179	3	75077
Jul-09	29891	44375	14955	9897	7	99125
Aug-09	24119	21353	13859	7115	9	66454
Sep-09	992	0	583	3621	1	5197
Oct-09	662	513	0	2362	0	3537
Nov-09	4030	5151	0	1119	1	10300
Dec-09	4435	2475	0	4964	3	11878
Jan-10	33578	6591	0	4533	503	45205
Feb-10	35716	6121	0	6119	503	48460
Mar-10	33280	5202	7720	5041	503	51746
Apr-10	11965	2285	8767	4939	168	28125
May-10	10826	23142	11452	5874	0	51294
Jun-10	45995	35698	18042	11282	2611	113628
Jul-10	56367	47091	23080	12815	3684	143036
Aug-10	61845	30709	19039	13661	4026	129280
Sep-10	17793	13208	13979	8270	556	53806
Oct-10	417	0	736	5071	0	6224
Nov-10	1053	221	221	3629	0	5126
Dec-10	6255	1797	1065	8405	1	17524
Jan-11	62292	26805	3271	4336	0	96704
Feb-11	63568	19954	3729	5631	17	92899
Mar-11	58959	17047	6734	5266	5	88011
Apr-11	24884	21763	9084	8007	5	63744
May-11	34998	33281	13176	9466	6	90927
Jun-11	63404	33286	18476	10767	26	125958
Jul-11	86173	42788	25299	17245	72	171578
Aug-11	77137	40417	22548	15888	87	156077
Sep-11	31800	13857	13793	9652	12	69114
Oct-11	4824	1194	6244	4587	3	16851
Nov-11	4056	4435	2415	3445	6	14358
Dec-11	18473	12326	750	7661	34	39243
Jan-12	23492	5381	289	6088	0	35250
Feb-12	23705	4034	5923	6199	14	39875
Mar-12	19686	1379	5543	5520	4	32131
Apr-12	7287	460	6581	5292	4	19625
May-12	1402	0	454	5644	5	7504
Jun-12	24802	27755	16731	13201	21	82510
Jul-12	45234	42066	19057	14465	60	120883
Aug-12	45391	30434	18014	12409	72	106320
Sep-12	3441	840	9880	8366	10	22537
Oct-12	777	123	405	5250	2	6556
Nov-12	2219	1192	59	4525	5	8001
Dec-12	8318	1267	508	7047	28	17168
Jan-13	893	1266	330	2519	0	5009
Feb-13	2596	939	7	3906	14	7463
Mar-13	1013	33	8164	3040	4	12254
Apr-13	613	11	3540	3028	4	7196
May-13	717	0	0	3016	5	3738
Jun-13	26176	29510	11863	5136	22	72707
Jul-13	39994	17398	15372	7502	61	80327
Aug-13	31989	12980	4464	6522	74	56030
Sep-13	1222	0	0	4031	11	5264
Oct-13	371	0	0	2910	2	3284
Nov-13	665	0	0	1723	5	2393
Dec-13	3004	99	0	5274	29	8405
Jan-14	31	27	0	2773	0	2831
Feb-14	331	0	7	3338	9	3686
Mar-14	231	138	0	2791	3	3163
Apr-14	120	0	0	2745	3	2869
May-14	141	0	0	2816	3	2959
Jun-14	13183	0	0	3744	14	16941
Jul-14	25975	26500	13175	4647	41	70337
Aug-14	18326	9961	4790	4555	49	37681
Sep-14	246	0	90	3414	7	3757
Oct-14	71	0	0	2751	2	2824
Nov-14	138	0	0	2041	3	2182
Dec-14	681	0	0	4106	19	4806
Jan-15	4	0	0	3439	0	3443
Feb-15	32	0	0	4691	2	4725
Mar-15	45	0	31	3836	3	3915
Apr-15	27	0	11	3764	2	3804
May-15	32	0	0	3840	2	3874
Jun-15	55	0	65	5326	4	5451
Jul-15	14382	10880	9816	6779	10	41868
Aug-15	9458	1549	5162	6539	9	22718
Sep-15	23	0	0	4764	2	4788
Oct-15	17	0	0	3743	1	3761
Nov-15	25	0	0	2725	2	2752
Dec-15	75	0	0	5887	6	5968
Jan-16	0	896	0	2854	0	3750
Feb-16	116	1103	0	2854	0	4073
Mar-16	0	896	0	2854	0	3750
Apr-16	0	299	0	2854	0	3153
May-16	672	2004	1559	2854	0	7089
Jun-16	19693	41699	12988	2854	0	77234
Jul-16	18328	38082	14830	2854	0	74094
Aug-16	20982	5884	13154	2854	0	42874
Sep-16	0	0	0	2854	0	2854
Oct-16	0	0	0	2854	0	2854
Nov-16	0	0	0	2854	0	2854
Dec-16	0	0	0	2854	0	2854

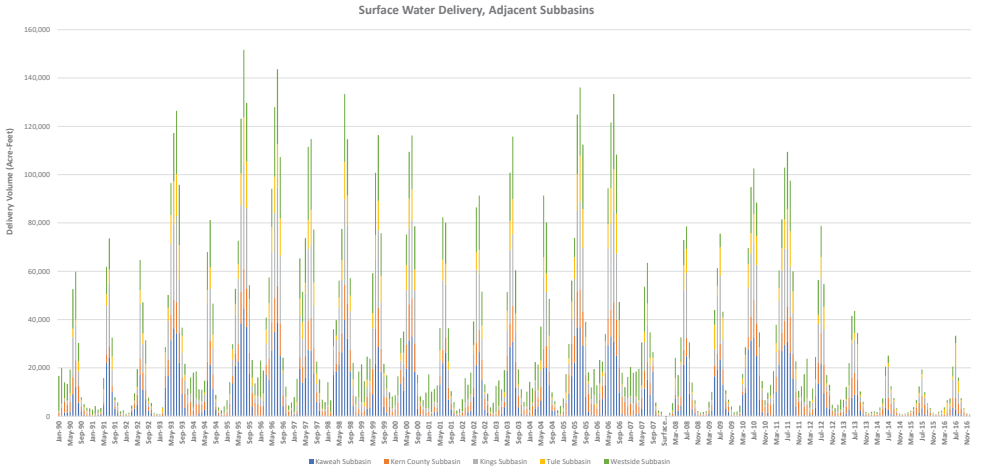


APPENDIX D2-2

Surface Water Delivery (Acre-Feet)	Kaweah Subbasin	Kern County Subbasin	Kings Subbasin	Tule Subbasin	Westside Subbasin
Jan-90	47	1371	641	98	14547
Feb-90	130	3377	1373	244	14780
Mar-90	1444	4469	1141	386	6613
Apr-90	1596	2992	1217	636	6917
May-90	1731	4044	2573	1121	9906
Jun-90	9129	7032	16562	3468	16410
Jul-90	12238	10939	14508	2300	19830
Aug-90	5593	6916	6048	4178	7587
Sep-90	2007	1975	1688	1038	1151
Oct-90	652	1725	781	670	1147
Nov-90	85	936	851	296	1291
Dec-90	41	1201	324	59	1575
Jan-91	8	307	94	53	2212
Feb-91	42	378	461	131	3188
Mar-91	605	178	324	159	1529
Apr-91	760	466	259	269	1647
May-91	4621	1175	2598	2722	4730
Jun-91	22007	3359	20363	4708	11412
Jul-91	24361	4596	25900	5856	12927
Aug-91	9982	2702	6574	5370	7908
Sep-91	3052	1040	1852	547	1387
Oct-91	1344	1418	1184	359	1441
Nov-91	53	485	336	159	972
Dec-91	143	566	763	32	960
Jan-92	7	103	99	82	508
Feb-92	55	251	386	204	558
Mar-92	1716	798	320	249	1368
Apr-92	3133	2152	715	429	3036
May-92	4802	4154	2222	941	7373
Jun-92	17030	6905	22629	5580	12539
Jul-92	10891	7189	11734	4545	12735
Aug-92	7065	3767	6252	4529	9834
Sep-92	2278	1713	1418	842	1429
Oct-92	1139	1486	843	560	1418
Nov-92	35	460	326	248	374
Dec-92	24	270	322	49	366
Jan-93	3	233	45	223	283
Feb-93	24	1115	327	1878	329
Mar-93	11765	4796	3525	6456	2058
Apr-93	16628	6952	15864	5452	5331
May-93	31394	10498	29534	11882	13180
Jun-93	36360	11963	31144	17772	19969
Jul-93	34332	12848	35642	17361	26255
Aug-93	22197	12206	21941	14504	24952
Sep-93	9298	6569	10424	6972	3412
Oct-93	3372	5814	5706	2284	4458
Nov-93	284	4976	3108	248	2854
Dec-93	253	5866	3255	31	6689
Jan-94	293	1859	1457	62	14391
Feb-94	235	4902	2052	154	11245
Mar-94	1174	3746	1735	187	4253
Apr-94	1700	3097	1026	352	4789
May-94	2645	3262	3119	733	4923
Jun-94	14876	7646	24290	5384	15762
Jul-94	21182	10130	21360	9021	19556
Aug-94	11467	5895	10842	5542	12822
Sep-94	2504	1525	2089	759	1917
Oct-94	455	1049	516	434	1230
Nov-94	27	623	151	187	1490
Dec-94	50	801	649	37	2553
Jan-95	62	1517	822	294	3945
Feb-95	107	5076	1466	2446	4999
Mar-95	13717	2946	6844	4178	2134
Apr-95	21008	4724	16379	4430	6216
May-95	22750	7162	26917	6118	9726
Jun-95	38495	12984	35898	13129	22645
Jul-95	44604	16411	43101	19611	27976
Aug-95	36972	16002	33223	19211	24260
Sep-95	17742	8571	13976	8283	5616
Oct-95	3822	5892	2839	3356	7384
Nov-95	171	5241	1991	1162	5016
Dec-95	241	4683	3265	112	7753
Jan-96	257	3830	3497	171	15241
Feb-96	227	4045	2233	2850	9564
Mar-96	17084	4212	8807	5755	4982
Apr-96	14994	8713	16632	6401	10742
May-96	27215	11626	29126	10291	15910
Jun-96	34883	14051	35248	14968	28780
Jul-96	38539	15436	40793	17823	31016
Aug-96	24891	13542	28073	15431	25341
Sep-96	4141	4517	9234	1028	5287
Oct-96	1268	3364	2693	684	4243
Nov-96	43	1779	492	306	1763
Dec-96	33	2734	452	60	2416
Jan-97	465	318	888	96	6174
Feb-97	780	1350	2277	1360	9686
Mar-97	19616	4778	17019	7234	16640
Apr-97	13855	6395	11696	7037	12485
May-97	15904	8934	25906	4524	18409
Jun-97	27570	11860	29858	11890	30312
Jul-97	27017	13740	30387	14320	29306
Aug-97	17755	10410	17428	9734	21987
Sep-97	5995	3886	3381	4308	5058
Oct-97	2392	3114	1834	2352	5550
Nov-97	209	1807	686	391	3755
Dec-97	86	2021	735	57	2950
Jan-98	40	4058	557	53	9421
Feb-98	16	1413	136	180	4800
Mar-98	17198	1462	8816	1500	6959
Apr-98	18553	3193	9764	1807	6464
May-98	21517	5380	17966	4202	7069
Jun-98	26476	7845	22139	8145	12919
Jul-98	39784	14518	35487	15503	28073
Aug-98	32219	14327	32359	12476	23258
Sep-98	18559	8841	16058	6449	7230
Oct-98	4207	4416	3715	2929	6783
Nov-98	184	1743	2377	583	3331
Dec-98	877	2290	4223	202	10884
Jan-99	270	1175	3687	554	15754
Feb-99	128	2220	1732	1655	8688
Mar-99	3039	5126	3462	3523	9463
Apr-99	3354	6552	3010	1742	9135
May-99	9147	10436	16776	6266	16579
Jun-99	21666	14488	28786	10130	25709
Jul-99	28645	16359	31931	12287	27148
Aug-99	18298	9651	19378	10795	17599
Sep-99	3892	4405	8003	1635	3740
Oct-99	1489	6242	3144	537	5503
Nov-99	233	3775	2670	237	2996
Dec-99	186	1789	1369	47	4824
Jan-00	183	2447	1682	75	4298
Feb-00	195	5584	2515	351	7826
Mar-00	13554	5723	3625	3107	6384
Apr-00	10637	5906	5303	4436	8766
May-00	19686	10031	22335	10465	12749
Jun-00	31336	15006	31244	12509	19346
Jul-00	33065	15694	32482	12724	22269
Aug-00	18279	11856	22034	8593	17887
Sep-00	3187	5443	4314	769	3424
Oct-00	618	3815	1001	512	2275
Nov-00	165	2624	1086	226	2571
Dec-00	181	1151	2033	45	6332
Jan-01	96	1721	1304	73	14080
Feb-01	79	836	681	182	8421
Mar-01	1619	2440	1699	222	5282
Apr-01	1845	1588	1697	375	7266
May-01	13061	3564	6552	4061	9234
Jun-01	22013	5679	28434	8687	17537
Jul-01	26342	6281	21764	8711	16982
Aug-01	6921	4870	7429	3397	13782
Sep-01	2808	2297	2379	753	2108
Oct-01	904	1182	867	501	2447
Nov-01	47	561	206	222	1305
Dec-01	58	412	728	44	1826
Jan-02	111	1242	555	77	5044
Feb-02	263	3354	1887	191	10078
Mar-02	1567	2679	2407	232	6151
Apr-02	2279	3694	2782	392	8934
May-02	8056	3793	14135	3426	9804
Jun-02	21134	9403	30090	7238	18587
Jul-02	26501	9237	23318	9796	22521
Aug-02	14993	8456	8492	5606	14048
Sep-02	2807	4270	2133	787	3193
Oct-02	1460	3142	1181	524	2963
Nov-02	54	1076	411	348	1778
Dec-02	127	689	375	57	4261
Jan-03	125	882	459	181	10900
Feb-03	103	2700	1212	218	10555
Mar-03	1043	2788	2060	266	4915
Apr-03	3767	2265	1936	1959	9139
May-03	18843	6246	10425	8209	7639
Jun-03	28702	9500	30798	11859	19955
Jul-03	30699	14946	29784	14417	25924
Aug-03	11713	10773	12405	7635	17902
Sep-03	3771	4893	3616	901	6180
Oct-03	1102	3625	2000	600	3883
Nov-03	224	2201	1216	265	2084
Dec-03	729	2211	1061	53	6090
Jan-04	205	1248	894	83	11775
Feb-04	127	4067	1213	207	5917
Mar-04	3259	7192	4015	252	7697
Apr-04	3828	3913	2446	426	10818
May-04	6348	5772	6833	4041	14128
Jun-04	20114	7846	29563	8286	25508
Jul-04	19954	9223	22297	7586	21170
Aug-04	12796	5486	9468	5573	15280
Sep-04	2383	2398	2093	855	2084
Oct-04	2235	1451	661	569	1365
Nov-04	96	485	345	252	1231
Dec-04	36	392	340	50	3433
Jan-05	37	1723	515	973	4077
Feb-05	142	5371	1397	2875	7664
Mar-05	9329	7917	4535	2312	5803
Apr-05	16557	13449	10234	7101	8779
May-05	22141	11096	23578	9012	7929
Jun-05	36488	14923	33535	15303	24589
Jul-05	36866	15534	36452	19067	28207
Aug-05	29242	14034	26373	16129	26623
Sep-05	7968	9057	11583	4196	6209
Oct-05	1790	7564	4348	715	3728
Nov-05	191	4929	1583	316	4856
Dec-05	574	4297	3944	63	10618
Jan-06	44	3048	619	1536	7565
Feb-06	498	6448	2851	3751	9719
Mar-06	7048	5619	3734	1916	4257
Apr-06	13024	5112	11080	1843	2963
May-06	29347	11068	29089	9981	14873
Jun-06	33094	11030	35571	14724	27155
Jul-06	30714	16449	38124	16978	31089
Aug-06	24962	15057	27330	16460	24540
Sep-06	9862	10336	12634	6849	7608
Oct-06	1096	6974	4504	591	4830
Nov-06	216	5659	1983	261	3936
Dec-06	311	3774	3280	52	8834
Jan-07	261	5025	2830	143	12097
Feb-07	306	2356	2228	298	12803
Mar-07	863	4484	2370	363	10386
Apr-07	985	2811	2165	612	13021
May-07	2965	4835	3624	1350	17784
Jun-07	11494	7256	11801	4407	18668
Jul-07	15168	7529	15169	8696	16893
Aug-07	8858	4901	7301	3060	10555
Sep-07	18477	2571	1890	1228	2441
Oct-07	713	1595	948	818	1590
Nov-07	57	536	396	361	1003
Dec-07	58	366	463	72	896

APPENDIX D2-2 (Cont)

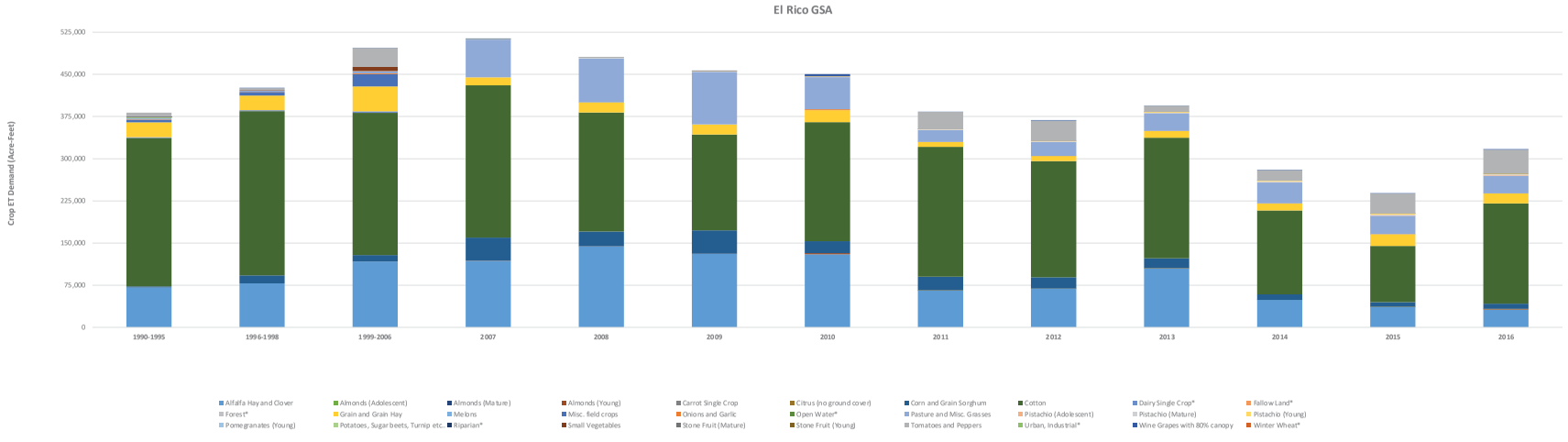
Surface Water Delivery (Acre-Feet)	Kaweah Subbasin	Kern County Subbasin	Kings Subbasin	Tule Subbasin	Westside Subbasin
Jan-08	18	152	246	83	902
Feb-08	76	852	802	552	3112
Mar-08	7172	1651	2476	4489	8384
Apr-08	2395	2361	2802	424	9010
May-08	4395	3761	13361	934	10147
Jun-08	21269	6219	24490	10546	10365
Jul-08	24815	7612	26919	9910	9325
Aug-08	9279	5128	8168	1262	6755
Sep-08	3121	3576	2429	849	3966
Oct-08	1277	2028	1254	566	1414
Nov-08	205	549	529	250	602
Dec-08	80	454	359	50	502
Jan-09	228	401	302	81	756
Feb-09	94	767	377	200	680
Mar-09	988	1077	1194	244	2448
Apr-09	2213	2440	1660	416	3365
May-09	16510	4280	6848	10204	6105
Jun-09	19393	6669	23889	3994	7381
Jul-09	23418	6562	28183	11783	5651
Aug-09	13001	6142	12501	9198	2372
Sep-09	3185	3051	2110	827	1515
Oct-09	1964	2051	1283	551	1004
Nov-09	98	627	533	1747	945
Dec-09	52	348	244	48	967
Jan-10	9	193	118	75	1524
Feb-10	91	784	555	203	2815
Mar-10	9084	1151	2912	2390	1932
Apr-10	9661	2259	8354	5168	3111
May-10	27630	5169	20455	9836	6608
Jun-10	31224	10058	26047	8433	19120
Jul-10	32344	15684	23806	11894	18808
Aug-10	24931	13524	24152	12023	13783
Sep-10	7017	9882	8430	3200	6138
Oct-10	1650	5379	3908	511	3096
Nov-10	55	3811	363	226	2129
Dec-10	1501	3942	1547	46	2707
Jan-11	199	4763	2695	829	4520
Feb-11	452	4746	1734	2065	9670
Mar-11	10065	6270	10124	3745	7657
Apr-11	21424	6019	20262	5438	7172
May-11	26993	7494	25764	9322	11941
Jun-11	29531	9935	29828	12067	21540
Jul-11	30783	14434	24313	16092	23798
Aug-11	26314	14932	20716	14640	20960
Sep-11	15663	10223	16679	9216	8234
Oct-11	3935	6062	4893	4634	3188
Nov-11	193	5978	1164	247	2826
Dec-11	101	6460	1375	49	4443
Jan-12	583	3300	1743	82	11629
Feb-12	260	4623	2325	204	16398
Mar-12	442	1161	1600	248	2847
Apr-12	441	2454	2814	1126	4631
May-12	3353	5228	5466	1221	9250
Jun-12	13499	8711	16026	3763	14397
Jul-12	21816	12788	26698	8687	12811
Aug-12	9476	11893	14638	9194	9482
Sep-12	3692	6552	2578	840	3343
Oct-12	3264	5333	1361	559	2483
Nov-12	108	2295	520	247	1604
Dec-12	18	1308	252	49	1642
Jan-13	36	1248	396	82	2969
Feb-13	152	1411	828	204	4297
Mar-13	574	1361	1343	248	3226
Apr-13	1043	2932	2598	419	5102
May-13	2885	4727	4167	923	9255
Jun-13	7655	8186	14386	1376	9966
Jul-13	8922	8924	13925	2653	9178
Aug-13	9089	5862	4616	10351	4590
Sep-13	2433	3503	2168	840	1332
Oct-13	782	2414	1215	559	963
Nov-13	82	597	423	247	375
Dec-13	59	378	269	49	431
Jan-14	109	361	701	82	559
Feb-14	22	840	299	204	616
Mar-14	18	523	202	248	704
Apr-14	63	1566	438	419	1138
May-14	269	2973	990	923	2222
Jun-14	3386	4293	7480	1376	3990
Jul-14	2612	4990	12797	1604	3047
Aug-14	940	4270	4563	1248	1399
Sep-14	647	2565	2645	840	729
Oct-14	287	1166	906	559	381
Nov-14	108	413	376	247	122
Dec-14	22	272	291	49	184
Jan-15	59	336	607	82	70
Feb-15	27	805	325	204	225
Mar-15	114	1076	416	248	433
Apr-15	154	1989	413	419	793
May-15	266	3394	693	923	1440
Jun-15	1336	4267	2704	1376	2637
Jul-15	3306	5141	7295	1604	1975
Aug-15	852	3915	2958	1248	937
Sep-15	610	2046	1250	840	528
Oct-15	287	1166	906	559	381
Nov-15	108	413	376	247	263
Dec-15	22	272	291	49	155
Jan-16	109	361	701	142	559
Feb-16	22	840	299	477	616
Mar-16	18	523	202	2211	704
Apr-16	63	1566	438	3442	1138
May-16	269	2973	990	923	2222
Jun-16	3386	4293	7480	1376	3990
Jul-16	2612	4990	12797	9836	3047
Aug-16	940	4270	4563	4806	1399
Sep-16	647	2565	2645	840	729
Oct-16	287	1166	906	559	381
Nov-16	108	413	376	247	122
Dec-16	22	272	291	49	184



Appendix D3
Summary of Crop Demand

Sum of Crop ET Demand (Acre-Feet/Year) Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
El Rico GSA													
Alfalfa Hay and Clover	70729	78296	117038	118221	143932	130955	129971	66396	68927	105292	48866	36930	31810
Almonds (Adolescent)	0	0	0	0	0	0	0	3	2	2	18	5	10
Almonds (Mature)	0	0	0	0	0	0	0	0	0	0	0	0	0
Almonds (Young)	0	0	0	188	146	145	1951	180	194	477	170	185	1163
Carrot Single Crop	0	0	0	0	0	0	0	19	8	1	0	0	16
Citrus (no ground cover)	0	0	0	0	0	0	0	16	0	7	0	2	4
Corn and Grain Sorghum	2018	14258	11703	41343	26375	41546	21187	23395	19850	17015	9740	7639	9086
Cotton	264279	292007	252807	270755	211744	170500	211791	231241	206654	214373	149263	99964	178223
Dairy Single Crop*	1445	1847	2688	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	26296	25753	44136	14205	18440	17878	21292	8497	9155	12247	12207	21158	17961
Melons	0	0	0	0	0	0	0	1	8	2	728	4	93
Misc. field crops	4755	6468	22248	0	4	0	0	0	0	0	0	0	0
Onions and Garlic	446	291	1070	0	0	0	1834	47	105	49	77	146	111
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	1917	2947	3895	67107	77436	93539	57165	21110	24818	31286	36605	32424	31157
Pistachio (Adolescent)	0	0	0	0	0	0	0	211	277	370	687	1003	1370
Pistachio (Mature)	0	0	0	1232	1293	983	897	932	917	847	842	1184	1122
Pistachio (Young)	0	23	221	322	376	619	698	392	735	1140	1492	1535	1315
Pomegranates (Young)	0	0	0	0	91	42	4	81	24	93	148	164	162
Potatoes, Sugar beets, Turnip etc...	1508	0	0	14	0	0	0	4	0	4	0	3	3
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Vegetables	1430	528	7590	0	0	3	94	23	29	107	103	8	116
Stone Fruit (Mature)	0	0	0	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	0	0	2	9	44	2	3	85	1	2	40	78
Tomatoes and Peppers	7067	3135	33674	11	2	150	0	30683	36052	10959	19043	35729	42194
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	0	503	334	407	362	47	3559	227	1035	92	546	472	958
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
El Rico GSA Irrigated ET Demand	**380445**	**424208**	**494716**	**513807**	**480209**	**456451**	**450445**	**383463**	**368875**	**394364**	**280539**	**238594**	**316952**
El Rico GSA Total ET Demand	**381890**	**426054**	**497404**	**513807**	**480209**	**456451**	**450445**	**383463**	**368875**	**394364**	**280539**	**238594**	**316952**

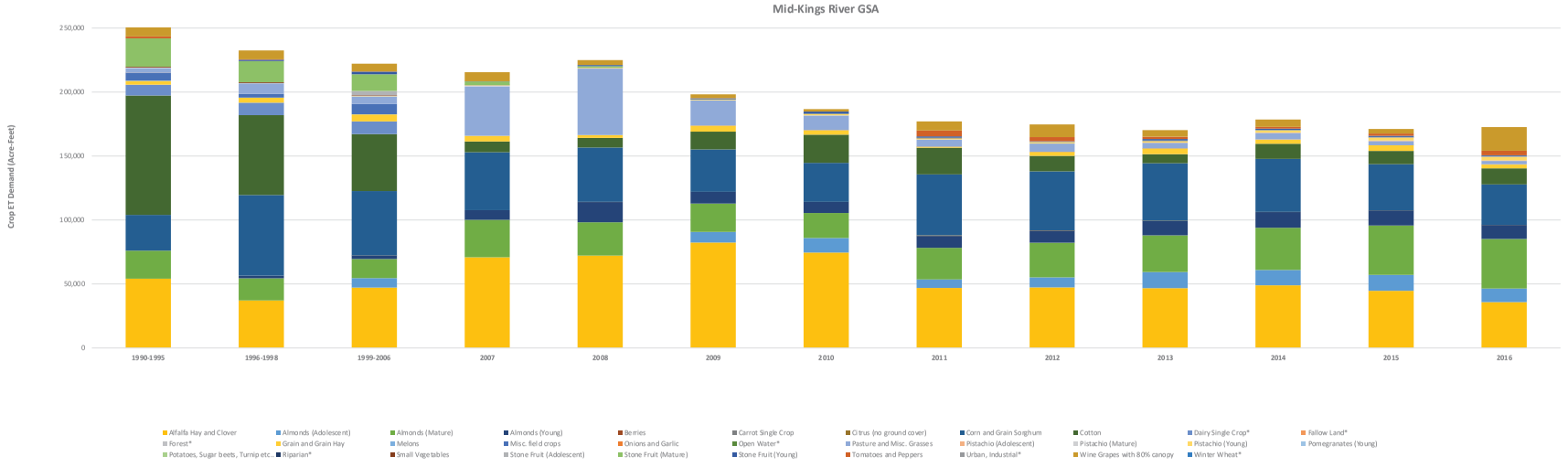
Notes: Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year



Sum of Crop ET Demand (Acre-Feet/Year)													
Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Mid-Kings River GSA													
Alfalfa Hay and Clover	54225	37134	47231	70920	72279	82432	74524	46996	47297	46833	49033	44781	35779
Almonds (Adolescent)	0	0	7382	0	0	8287	11414	6655	7948	12571	11964	12357	10700
Almonds (Mature)	21899	17282	14900	29318	25948	22195	19532	24669	27021	28629	33006	38590	38813
Almonds (Young)	0	2093	2798	7469	15899	9090	8694	9270	9515	11128	12224	11764	10892
Berries	0	0	0	0	0	0	0	0	1	6	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	4	7	1	7	0	14
Citrus (no ground cover)	0	0	75	0	32	31	14	370	89	299	102	56	12
Corn and Grain Sorghum	27832	63039	50239	45210	42440	33204	30445	47662	46154	44975	41460	36068	31535
Cotton	93307	62361	44507	8474	7660	13894	22023	20867	12109	7001	11789	10353	12573
Dairy Single Crop*	8529	9826	9984	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	2897	3811	5457	4423	2221	4688	3586	868	3163	4629	3337	4457	3095
Melons	248	92	45	0	0	0	0	2	5	6	0	0	20
Misc. field crops	6082	3065	8059	0	0	0	0	0	0	0	0	0	0
Onions and Garlic	102	0	0	0	0	1	36	65	126	7	109	13	210
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	3717	8128	5877	38630	51880	19656	11431	5495	6343	4322	5084	3241	2570
Pistachio (Adolescent)	0	0	0	0	0	0	0	2	18	55	152	343	350
Pistachio (Mature)	321	254	241	675	270	135	86	83	57	52	45	46	55
Pistachio (Young)	0	34	215	326	374	674	983	947	885	1156	1706	2353	2641
Pomegranates (Young)	0	0	0	0	4	1	1	20	10	46	40	5	13
Potatoes, Sugar beets, Turnip etc...	0	4	0	5	0	5	0	1	0	1	0	1	2
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Vegetables	595	617	418	24	2	4	158	159	103	164	139	46	147
Stone Fruit (Adolescent)	0	0	3393	0	0	5	126	230	290	171	105	414	416
Stone Fruit (Mature)	22291	16483	13130	2753	1199	102	26	11	80	141	79	95	136
Stone Fruit (Young)	0	1079	2020	237	879	730	1645	958	386	1186	1054	845	560
Tomatoes and Peppers	1355	304	110	2	0	77	0	4695	3145	1754	1343	1699	3679
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	7381	6981	6093	7034	3829	2999	1976	7037	10002	5141	5696	3681	18346
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
Mid-Kings River GSA Irrigated ET De	**242254**	**222759**	**212189**	**215500**	**224914**	**198211**	**186699**	**177065**	**174754**	**170274**	**178474**	**171208**	**172557**
Mid-Kings River GSA Total ET Dema	**250784**	**232585**	**222173**	**215500**	**224914**	**198211**	**186699**	**177065**	**174754**	**170274**	**178474**	**171208**	**172557**

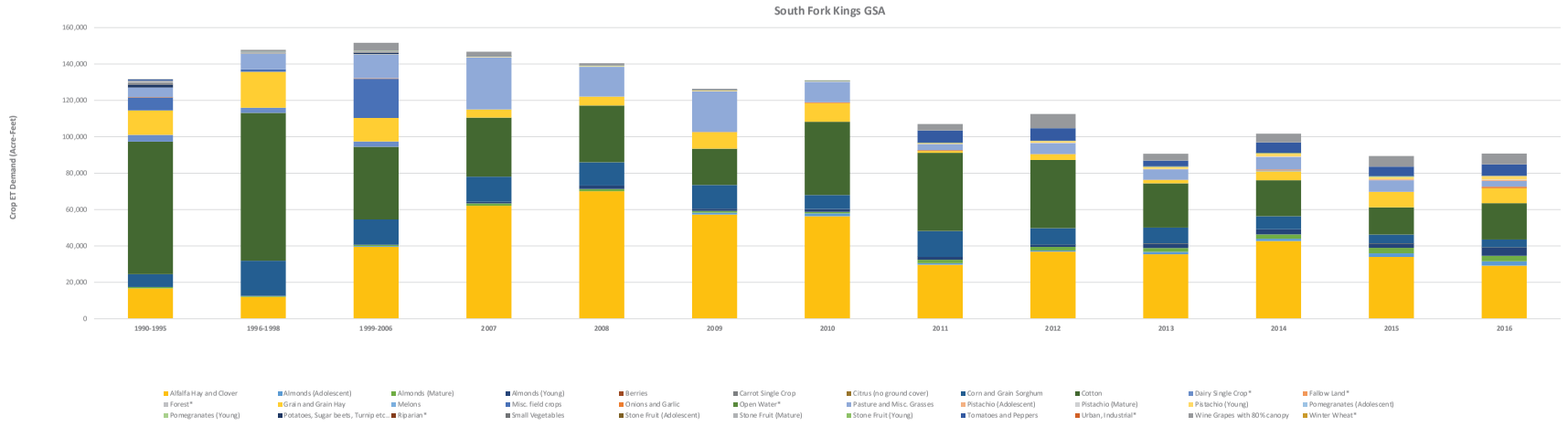
APPENDIX D3-2

Notes: Fields with an Asterisk (*) are not irrigated; Annual Total is by Calendar Year



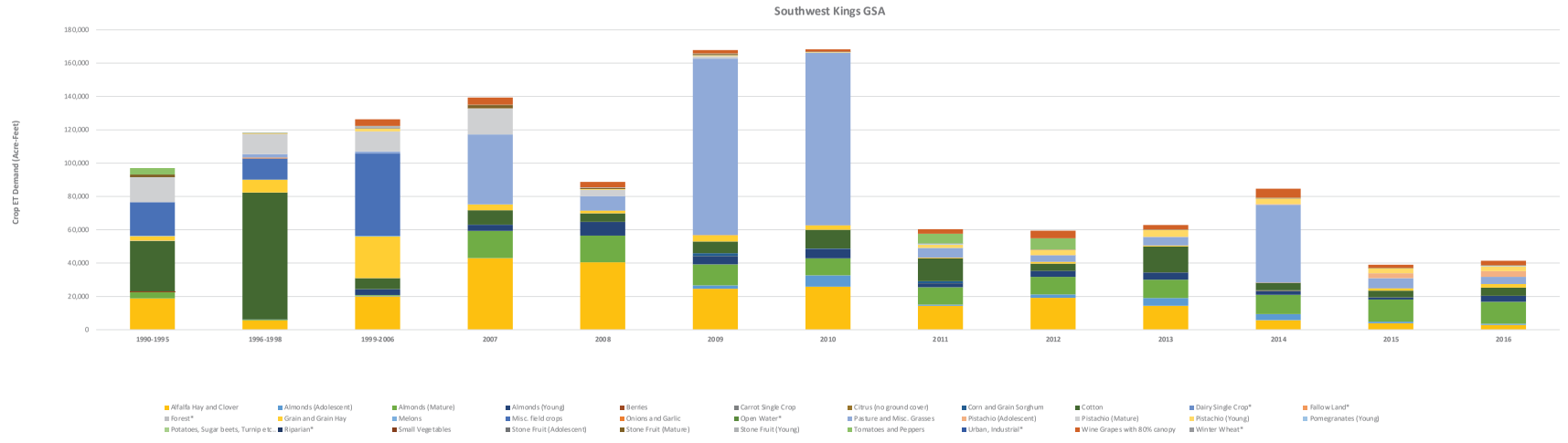
Sum of Crop ET Demand (Acre-Feet/Year)							APPENDIX D3-3						
Tulare Lake Subbasin	**1990-1995**	**1996-1998**	**1999-2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
South Fork Kings GSA													
Alfalfa Hay and Clover	16709	11994	39584	62068	70090	57340	56328	29744	36900	35451	42768	33986	29185
Almonds (Adolescent)	0	0	480	0	0	944	1576	777	652	1305	1236	1974	2399
Almonds (Mature)	743	499	472	1396	1211	944	805	1850	1903	2131	2373	2984	3024
Almonds (Young)	0	131	225	812	1861	1270	1646	1631	1226	2518	2843	2414	4672
Berries	0	0	0	0	0	0	0	0	1	0	0	1	0
Carrot Single Crop	0	0	0	0	0	0	0	4	2	7	0	6	26
Citrus (no ground cover)	0	0	17	0	0	0	0	14	3	18	0	2	2
Corn and Grain Sorghum	7027	19269	13851	13800	12846	13062	7622	14201	9097	8717	7123	4889	4232
Cotton	72878	81246	39915	32470	31210	19953	40263	42989	37422	24280	19786	15035	19992
Dairy Single Crop*	3737	2849	2925	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	13435	19790	12933	4435	4864	9156	10285	993	3255	1869	4921	8414	8207
Melons	0	0	0	0	0	0	8	1	2	2	448	0	15
Misc. field crops	7159	1270	21466	0	0	0	0	1	0	0	0	0	0
Onions and Garlic	258	0	289	0	0	8	495	467	112	108	563	71	795
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	5165	8608	13288	28562	16311	22322	11169	3302	5982	5766	6903	6334	3180
Pistachio (Adolescent)	0	0	0	0	0	0	0	0	19	29	64	504	585
Pistachio (Mature)	1	0	0	311	306	176	184	200	199	181	168	162	177
Pistachio (Young)	0	9	83	196	206	442	246	360	878	1028	1600	1130	1957
Pomegranates (Adolescent)	0	0	0	0	0	0	0	0	0	0	5	23	41
Pomegranates (Young)	0	0	0	2	176	19	41	196	121	161	294	393	140
Potatoes, Sugar beets, Turnip etc...	1518	0	676	0	0	5	0	0	0	119	0	3	1
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Vegetables	762	3	0	8	0	13	18	23	49	69	7	62	44
Stone Fruit (Adolescent)	0	0	188	0	0	0	0	1	1	0	2	0	9
Stone Fruit (Mature)	1463	1135	688	9	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	67	175	26	38	67	167	47	69	61	60	28	28
Tomatoes and Peppers	660	117	0	207	3	17	26	6642	6816	3119	5802	5246	6122
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	205	816	4390	2477	1278	644	153	3578	7838	3765	4771	5792	5920
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
South Fork Kings GSA Irrigated ET D	**127983**	**144955**	**148720**	**146777**	**140400**	**126381**	**131035**	**107022**	**112547**	**90701**	**101735**	**89454**	**90754**
South Fork Kings GSA Total ET Dem	**131720**	**147804**	**151645**	**146777**	**140400**	**126381**	**131035**	**107022**	**112547**	**90701**	**101735**	**89454**	**90754**

Notes: Fields with an Asterisk (*) are not irrigated; Annual Total is by Calendar Year



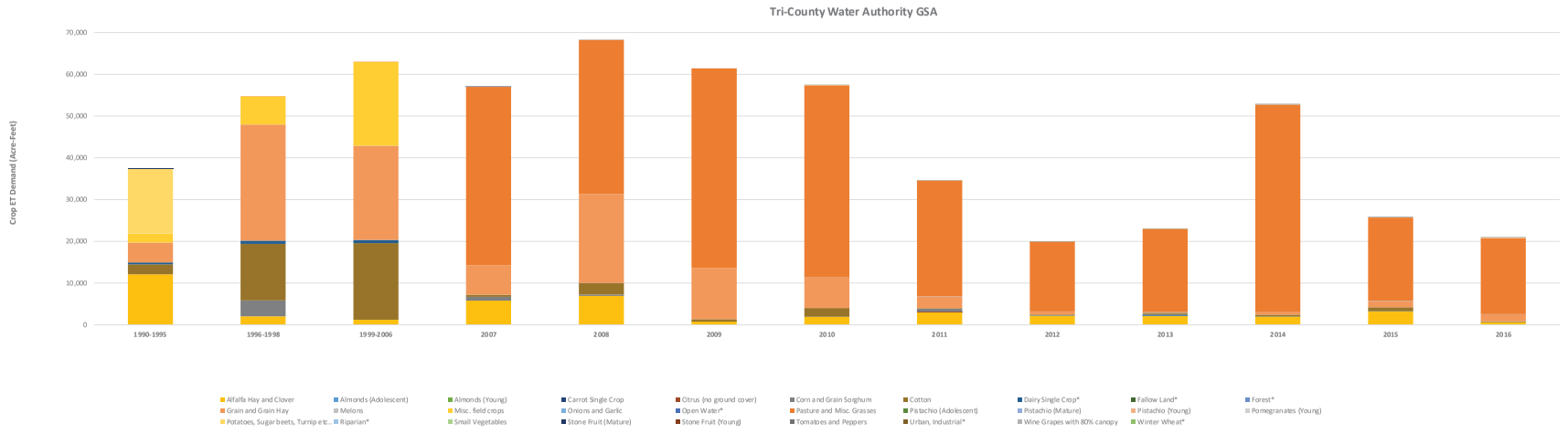
Sum of Crop ET Demand (Acre-Feet/Year)							APPENDIX D3-4						
Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Southwest Kings GSA													
Alfalfa Hay and Clover	18759	5587	20110	43026	40528	24609	25791	14378	19154	14389	5716	3975	2961
Almonds (Adolescent)	0	0	251	0	0	1987	6874	691	2030	4651	3718	819	604
Almonds (Mature)	4150	497	497	16316	15963	12694	10200	10456	10526	10960	11577	13295	13247
Almonds (Young)	0	63	3457	3590	8199	4939	5669	2319	3629	4328	2374	1340	3474
Berries	47	0	0	0	0	0	0	0	0	0	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	1	0	0	0	0	1
Citrus (no ground cover)	0	0	0	0	10	15	0	1	6	12	197	13	13
Corn and Grain Sorghum	0	45	0	170	47	1654	219	1271	82	188	89	10	80
Cotton	30305	76227	6616	8666	5111	7109	11217	13730	4226	15517	4291	4063	4891
Dairy Single Crop*	145	0	55	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	2788	7652	24977	3452	1759	3814	2758	328	1041	533	231	1387	2180
Melons	165	0	423	0	0	0	14	0	1	0	6	0	1
Misc. field crops	20277	12708	49397	0	1	0	0	0	0	0	4	0	0
Onions and Garlic	0	555	0	0	0	3	45	113	186	3	143	36	26
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	0	2040	1192	41974	8570	105889	103590	5801	3878	5081	46667	6062	4311
Pistachio (Adolescent)	0	0	0	0	0	0	0	1	105	387	2863	3399	
Pistachio (Mature)	14907	12101	12101	15614	3811	1532	68	68	64	55	20	20	20
Pistachio (Young)	0	328	1744	208	396	675	390	2026	3269	4168	3397	3156	2931
Pomegranates (Young)	0	0	0	9	30	30	3	596	56	74	30	5	430
Potatoes, Sugar beets, Turnip etc...	0	0	0	0	0	0	0	7	0	0	0	0	1
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Vegetables	47	0	0	1	1	0	61	23	30	2	14	8	8
Stone Fruit (Adolescent)	0	0	658	0	0	23	12	0	0	0	0	0	0
Stone Fruit (Mature)	1596	257	0	1799	688	482	38	0	0	0	0	0	0
Stone Fruit (Young)	0	164	806	200	307	376	64	3	7	3	70	0	1
Tomatoes and Peppers	3889	191	6	42	0	2	0	5793	6709	6	321	16	120
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	0	0	4055	4280	3334	2002	1284	2777	4565	2829	5430	1925	2694
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
Southwest Kings GSA Irrigated ET De	**96929**	**118416**	**126291**	**139347**	**88756**	**167834**	**168296**	**60381**	**59459**	**62904**	**84684**	**38993**	**41393**
Southwest Kings GSA Total ET Dema	**97074**	**118416**	**126346**	**139347**	**88756**	**167834**	**168296**	**60381**	**59459**	**62904**	**84684**	**38993**	**41393**

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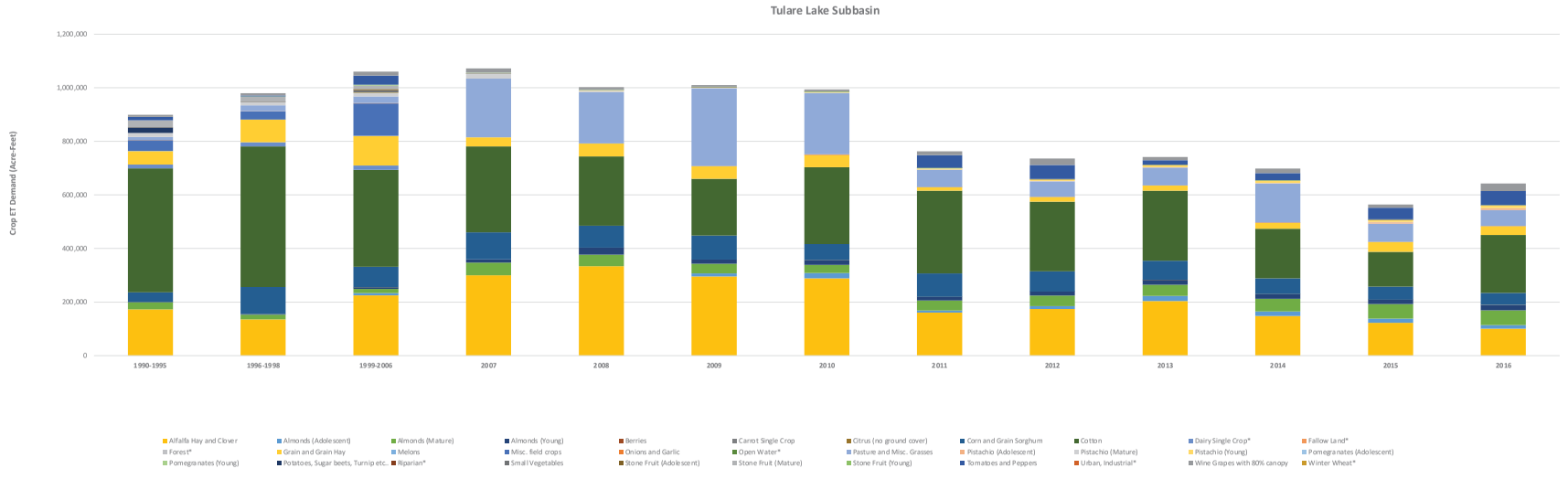
Sum of Crop ET Demand (Acre-Feet/Year) Tulare Lake Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Tri-County Water Authority GSA													
Alfalfa Hay and Clover	12097	2022	1204	5806	6923	750	1941	3106	2180	2254	1941	3166	659
Almonds (Adolescent)	0	0	0	0	0	0	0	0	0	0	0	0	0
Almonds (Young)	0	0	0	4	21	1	4	30	16	8	9	76	5
Carrot Single Crop	0	0	0	0	0	0	0	9	0	32	0	0	0
Citrus (no ground cover)	0	0	0	0	0	0	0	4	0	0	0	0	0
Corn and Grain Sorghum	0	3839	0	895	319	1	5	706	160	294	51	13	2
Cotton	2410	13544	18387	505	2786	616	2089	143	115	306	431	952	136
Dairy Single Crop*	433	747	768	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	4751	27805	22522	7057	21279	12220	7349	2832	755	227	585	1519	1785
Melons	0	0	0	0	0	0	0	0	0	0	0	22	0
Misc. field crops	2177	6785	20095	0	0	0	0	0	0	0	0	0	0
Onions and Garlic	0	0	0	0	0	0	6	40	9	0	1	0	4
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	0	4	4	42701	36886	47791	45951	27710	16730	19878	49684	19952	18152
Pistachio (Adolescent)	0	0	0	0	0	0	0	0	0	0	0	0	0
Pistachio (Mature)	0	0	0	0	0	0	0	0	0	0	0	0	0
Pistachio (Young)	0	0	1	38	18	44	78	4	3	5	87	57	180
Pomegranates (Young)	0	0	0	0	2	6	4	8	0	1	25	1	1
Potatoes, Sugar beets, Turnip etc...	15578	0	0	0	0	0	0	17	0	3	0	0	0
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Vegetables	0	0	0	0	0	0	10	1	1	48	1	2	2
Stone Fruit (Mature)	1	0	0	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	0	0	1	0	0	0	0	0	0	0	0	0
Tomatoes and Peppers	0	0	0	0	0	0	0	38	3	8	46	102	53
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	0	0	0	5	91	0	7	6	16	6	7	5	1
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
Irrigated ET Demand	**37015**	**53999**	**62214**	**57010**	**68324**	**61429**	**57443**	**34654**	**19988**	**23072**	**52867**	**25868**	**20980**
Total ET Demand	**37449**	**54746**	**62982**	**57010**	**68324**	**61429**	**57443**	**34654**	**19988**	**23072**	**52867**	**25868**	**20980**

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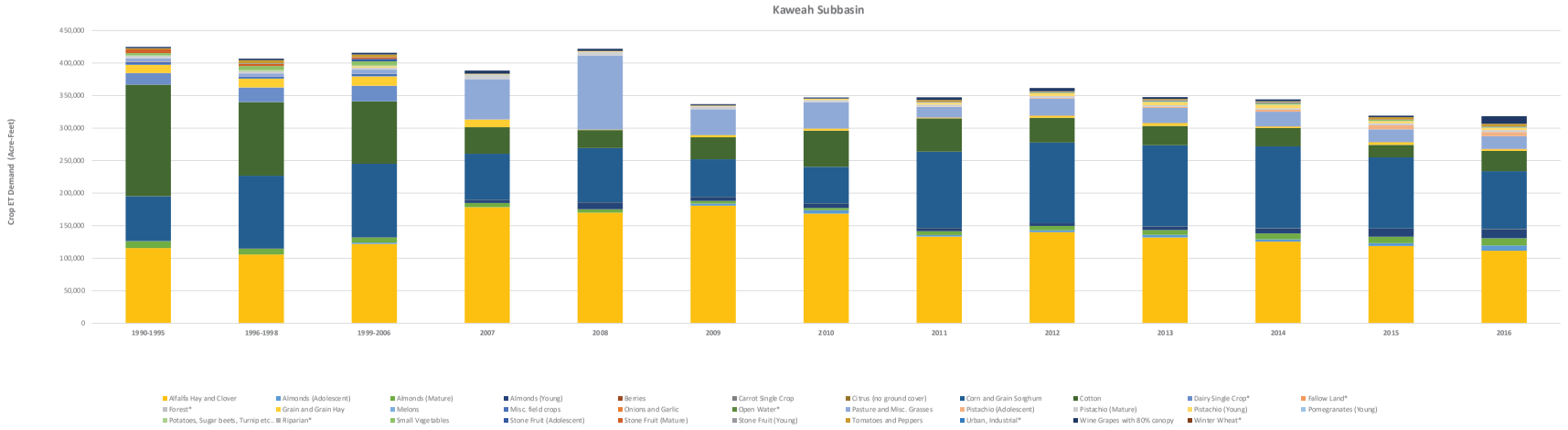
Sum of Crop ET Demand (Acre-Feet/Year)							APPENDIX D3-6						
Tulare Lake Subbasin	**1990-1995**	**1996-1998**	**1999-2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Tulare Lake Subbasin													
Alfalfa Hay and Clover	172519	135032	225167	300041	333752	296086	288555	160621	174457	204219	148325	122839	100395
Almonds (Adolescent)	0	0	8113	0	0	11218	19864	8127	10631	18529	16937	15155	13714
Almonds (Mature)	26791	18278	15869	47030	43122	35832	30537	36976	39450	41720	46956	54869	55084
Almonds (Young)	0	2287	6480	12062	26125	15445	17964	13431	14580	18458	17621	15779	20206
Berries	47	0	0	0	0	0	0	0	2	6	0	1	0
Carrot Single Crop	0	0	0	0	0	0	0	37	16	41	7	6	56
Citrus (no ground cover)	0	0	91	0	42	46	14	405	99	335	300	74	32
Corn and Grain Sorghum	36877	100450	75793	101418	82027	89467	59478	87236	75344	71190	58462	48619	44935
Cotton	463179	525386	362232	320870	258511	212071	287383	308970	260527	261476	185559	130368	215815
Dairy Single Crop*	14290	15268	16421	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	50167	84811	110025	33572	48563	47755	45271	13518	17369	19505	21282	36934	33228
Melons	413	92	468	0	0	0	21	3	16	10	1182	27	128
Misc. field crops	40450	30296	121265	0	5	0	0	1	0	0	4	0	0
Onions and Garlic	807	846	1359	0	0	12	2417	731	538	167	893	266	1146
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	10799	21726	24256	218974	191082	289198	229306	63417	57751	66333	144942	68014	59370
Pistachio (Adolescent)	0	0	0	0	0	0	0	213	315	559	1290	4713	5704
Pistachio (Mature)	15229	12354	12341	17831	5680	2825	1236	1283	1237	1135	1075	1412	1374
Pistachio (Young)	0	394	2265	1091	1370	2454	2395	3729	5770	7498	8281	8231	9024
Pomegranates (Adolescent)	0	0	0	0	0	0	0	0	0	0	5	23	41
Pomegranates (Young)	0	0	0	11	303	99	52	901	210	376	537	567	746
Potatoes, Sugar beets, Turnip etc...	18604	4	676	19	0	10	0	29	0	127	0	7	7
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	
Small Vegetables	2835	1147	8009	33	3	20	340	227	212	390	264	126	317
Stone Fruit (Adolescent)	0	0	4238	0	0	28	138	232	291	171	106	414	425
Stone Fruit (Mature)	25350	17875	13818	4560	1886	584	64	11	80	141	79	95	136
Stone Fruit (Young)	0	1310	3001	466	1234	1217	1879	1010	547	1250	1186	913	667
Tomatoes and Peppers	12971	3747	33791	261	5	246	26	47851	52725	15847	26555	42793	52168
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	7586	8301	14872	14203	8893	5692	6980	13625	23455	11832	16450	11874	27920
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
Tulare Lake Subbasin Irrigated ET De	**884626**	**964336**	**1044130**	**1072442**	**1002603**	**1010305**	**993918**	**762584**	**735624**	**741315**	**698299**	**564117**	**642636**
Tulare Lake Subbasin GSA Total ET D	**898916**	**979604**	**1060551**	**1072442**	**1002603**	**1010305**	**993918**	**762584**	**735624**	**741315**	**698299**	**564117**	**642636**

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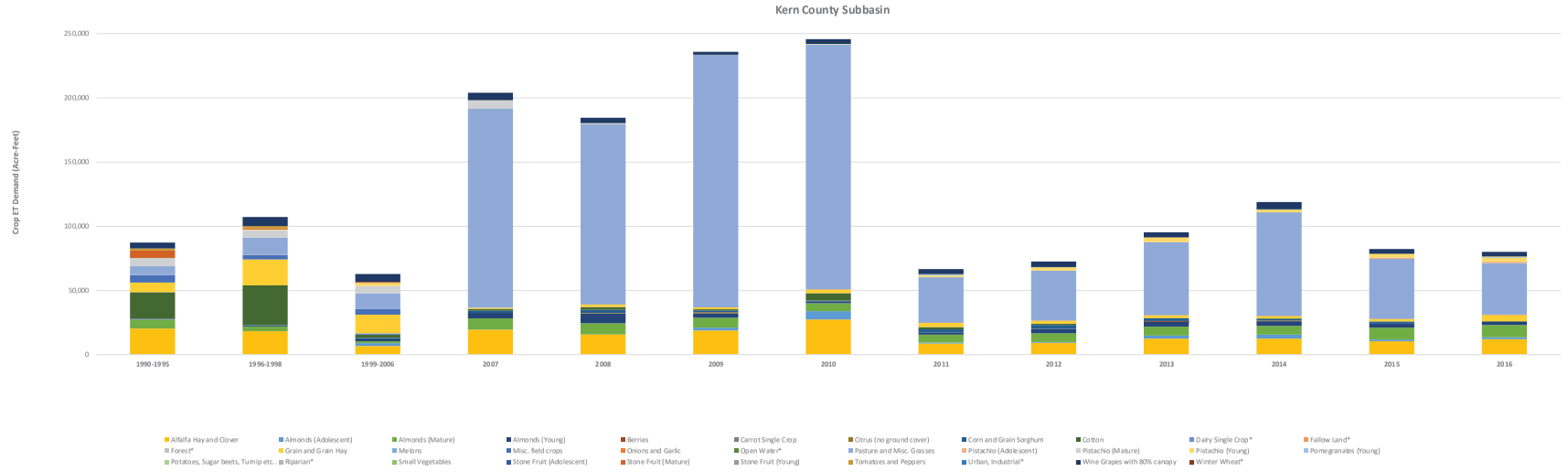
Sum of Crop Acreage (Acres)							APPENDIX D3-7						
Kaweah Subbasin	**1990-1995**	**1996-1998**	**1999-2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Kaweah Subbasin													
Alfalfa Hay and Clover	115486	105689	121989	178448	170164	180822	168599	133463	140002	132011	125440	118685	111593
Almonds (Adolescent)	0	0	2151	0	0	3352	5331	2218	2912	4107	3639	4441	8087
Almonds (Mature)	10994	8841	7642	6331	5140	3927	3359	5959	6632	7023	8956	10024	10922
Almonds (Young)	0	551	277	5010	10534	5981	7005	4784	4303	5354	7935	12728	14258
Berries	0	20	20	0	0	0	0	0	1	1	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	0	91	6	10	1	14
Citrus (no ground cover)	0	0	0	14	32	52	14	41	35	178	247	18	26
Corn and Grain Sorghum	68793	111613	113052	70905	83423	58024	56330	117213	123778	124980	125613	109204	88983
Cotton	171670	113435	96213	40721	27603	33648	55438	51177	38387	29695	28395	19132	31086
Dairy Single Crop*	17748	22327	23914	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	12438	13462	14290	11846	873	3831	3221	1298	3410	4757	2453	4427	2548
Melons	253	167	167	0	0	1	0	4	2	21	0	3	151
Misc. field crops	4124	2758	3400	0	2	2	0	0	0	0	0	0	0
Onions and Garlic	758	404	404	0	0	0	59	297	43	2	16	7	492
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	5210	4802	6452	62054	114029	39268	40513	16032	26257	23092	22644	19504	19446
Pistachio (Adolescent)	0	0	0	0	0	0	0	421	701	1303	2697	6183	6617
Pistachio (Mature)	3309	3097	3097	7106	5394	4376	3529	3368	2888	2586	2512	3113	2640
Pistachio (Young)	0	495	1990	508	928	1646	1688	2718	4237	5070	5543	3449	3661
Pomegranates (Young)	0	0	0	1	28	2	0	16	9	76	24	22	81
Potatoes, Sugar beets, Turnip etc...	1361	2217	1983	18	0	2	0	332	180	9	634	478	580
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Vegetables	3100	5686	5606	142	2	7	3	281	783	1251	1226	1248	1160
Stone Fruit (Adolescent)	0	0	3787	0	0	45	68	44	272	852	1000	191	70
Stone Fruit (Mature)	5897	3165	2730	433	84	18	0	66	9	25	244	328	60
Stone Fruit (Young)	0	975	222	83	602	359	606	770	1131	749	864	472	255
Tomatoes and Peppers	1732	4634	3894	31	2	36	0	2646	855	1553	1216	3151	3897
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	2062	2591	2667	4852	3006	1600	1390	4039	4940	2914	2975	2190	11487
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
Kaweah Subbasin Irrigated ET Dema	**407187**	**384603**	**392034**	**388504**	**421846**	**336999**	**347154**	**347277**	**361772**	**347610**	**344283**	**318999**	**318135**
Kaweah Subbasin Total ET Demand	**424935**	**406930**	**415948**	**388504**	**421846**	**336999**	**347154**	**347277**	**361772**	**347610**	**344283**	**318999**	**318135**

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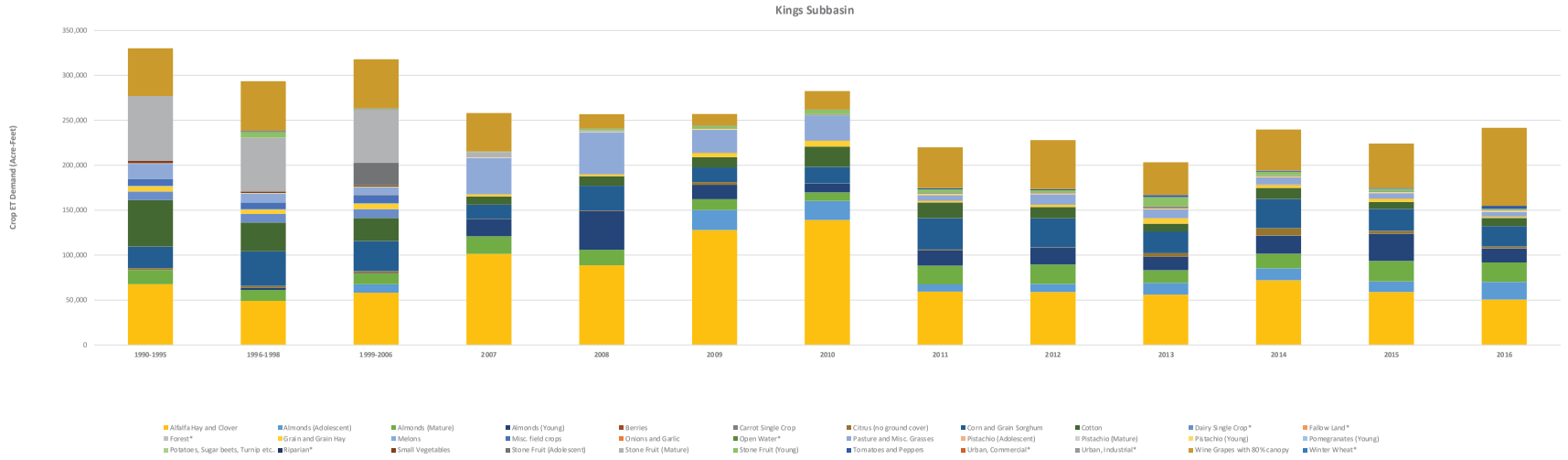
Sum of Crop ET Demand (Acre-Feet/Year)													
Kern County Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Kern County Subbasin													
Alfalfa Hay and Clover	20321	18273	6736	19380	15803	18878	27373	8596	9207	12561	12467	10488	12071
Almonds (Adolescent)	0	0	2266	0	0	2222	6474	833	571	2331	3094	1258	1413
Almonds (Mature)	6857	3611	1401	8966	8694	7583	6160	6105	6889	6838	6847	9333	9610
Almonds (Young)	0	583	1555	4243	7634	3583	1592	1620	3251	4381	3710	3081	2335
Berries	0	0	0	0	0	0	0	0	0	18	0	0	0
Carrot Single Crop	188	0	0	0	0	0	0	1	0	10	5	3	5
Citrus (no ground cover)	0	0	0	0	440	935	0	6	64	7	510	4	3
Corn and Grain Sorghum	603	475	1135	1640	2267	1302	562	2488	3062	2200	1269	1586	371
Cotton	20621	31026	2324	1387	2337	829	5767	1798	1127	192	351	89	181
Dairy Single Crop*	3	0	1239	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	7623	20168	14436	881	1817	1460	2931	3387	2394	2208	1878	1953	4984
Melons	0	0	0	0	0	1	0	0	31	12	2	0	6
Misc. field crops	5473	3458	4354	0	0	0	0	0	0	0	0	0	0
Onions and Garlic	230	99	0	0	0	1	16	92	127	18	28	60	181
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	7088	13517	12338	154954	140349	196576	190751	35338	38717	56959	80646	46771	40224
Pistachio (Adolescent)	0	0	0	0	0	0	0	0	2	0	77	966	1205
Pistachio (Mature)	5993	5796	5758	6465	674	2	0	0	0	0	0	0	0
Pistachio (Young)	0	476	2322	266	174	174	300	1350	2464	3525	2055	2939	2940
Pomegranates (Young)	0	0	0	0	63	0	0	921	158	42	35	16	679
Potatoes, Sugar beets, Turnip etc...	272	0	0	0	0	2	0	1	2	0	6	17	2
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Vegetables	38	0	88	0	2	0	19	6	19	14	9	17	19
Stone Fruit (Adolescent)	0	0	58	0	0	0	0	0	0	0	0	0	7
Stone Fruit (Mature)	5735	877	723	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	19	2	4	86	44	10	30	11	18	174	22	85
Tomatoes and Peppers	1667	1763	0	0	0	2	0	185	178	37	53	63	283
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	4578	7112	5979	5806	4185	2166	3657	3862	4212	3889	5651	3603	3413
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
Kern County Subbasin Irrigated ET D	**87287**	**107253**	**61474**	**203992**	**184526**	**235758**	**245611**	**66619**	**72486**	**95264**	**118867**	**82269**	**80017**
Kern County Subbasin Total ET Dem	**87290**	**107253**	**62713**	**203992**	**184526**	**235758**	**245611**	**66619**	**72486**	**95264**	**118867**	**82269**	**80017**

Notes: Fields with an Asterisk (*) are not irrigated; Annual Total is by Calendar Year



Sum of Crop ET Demand (Acre-Feet/Year) Kings Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Kings Subbasin													
Alfalfa Hay and Clover	67617	49074	58132	101357	88588	127908	139012	59444	58992	55996	72022	58974	50444
Almonds (Adolescent)	0	0	9525	0	0	22385	21317	7909	9004	13168	13348	11819	19720
Almonds (Mature)	15841	12188	11683	19642	17328	11842	9567	20922	21449	13995	16138	22835	21754
Almonds (Young)	0	2461	812	19323	43483	16082	9544	17088	18720	15125	20298	30152	15595
Berries	0	8	8	0	0	0	0	1	5	38	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	48	5	7	126	0	30
Citrus (no ground cover)	1912	2002	2002	249	313	2861	192	694	496	3915	8050	3278	1915
Corn and Grain Sorghum	24180	38518	33574	15458	27487	16580	18626	34985	32268	24209	32503	24496	22755
Cotton	51696	32000	25728	9225	10830	11344	22446	17615	12690	8521	12370	7650	9240
Dairy Single Crop*	9546	9561	9791	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	5766	4894	6019	2412	1933	4827	6546	1719	2379	5936	3092	3579	1179
Melons	671	297	215	0	5	27	6	1	15	48	11	14	42
Misc. field crops	7835	7572	9345	0	0	2	0	0	0	0	0	0	0
Onions and Garlic	0	0	188	47	103	162	67	312	130	116	692	190	420
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	16557	10047	8269	40480	46696	25318	28303	6182	11512	9898	7730	5879	5061
Pistachio (Adolescent)	0	0	0	0	0	0	0	4	13	4	27	50	50
Pistachio (Mature)	558	353	353	289	229	212	192	192	188	187	184	183	111
Pistachio (Young)	0	2	37	453	385	955	571	1349	1006	949	1302	943	1353
Pomegranates (Young)	0	0	0	25	38	67	71	189	187	119	107	97	60
Potatoes, Sugar beets, Turnip etc...	0	99	754	2	0	5	0	27	1	1	1	8	0
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Vegetables	2596	1703	1291	15	61	5	24	127	212	945	102	32	84
Stone Fruit (Adolescent)	0	0	24935	0	0	19	185	261	517	747	529	673	329
Stone Fruit (Mature)	72220	60018	59160	5770	1126	223	144	42	51	41	111	84	48
Stone Fruit (Young)	0	6313	620	439	2253	2798	4964	4060	2371	10498	4070	2798	1273
Tomatoes and Peppers	117	1037	711	33	9	327	51	1407	1078	2452	1235	1090	3304
Urban, Commercial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	53016	55408	54892	42775	15880	12995	20652	45308	54690	36332	45665	49431	86809
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
Kings Subbasin Irrigated ET Demand	**320581**	**283996**	**308252**	**257993**	**256747**	**256945**	**282481**	**219886**	**227981**	**203247**	**239711**	**224256**	**241575**
Kings Subbasin Total ET Demand	**330127**	**293556**	**318043**	**257993**	**256747**	**256945**	**282481**	**219886**	**227981**	**203247**	**239711**	**224256**	**241575**

Notes: Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year



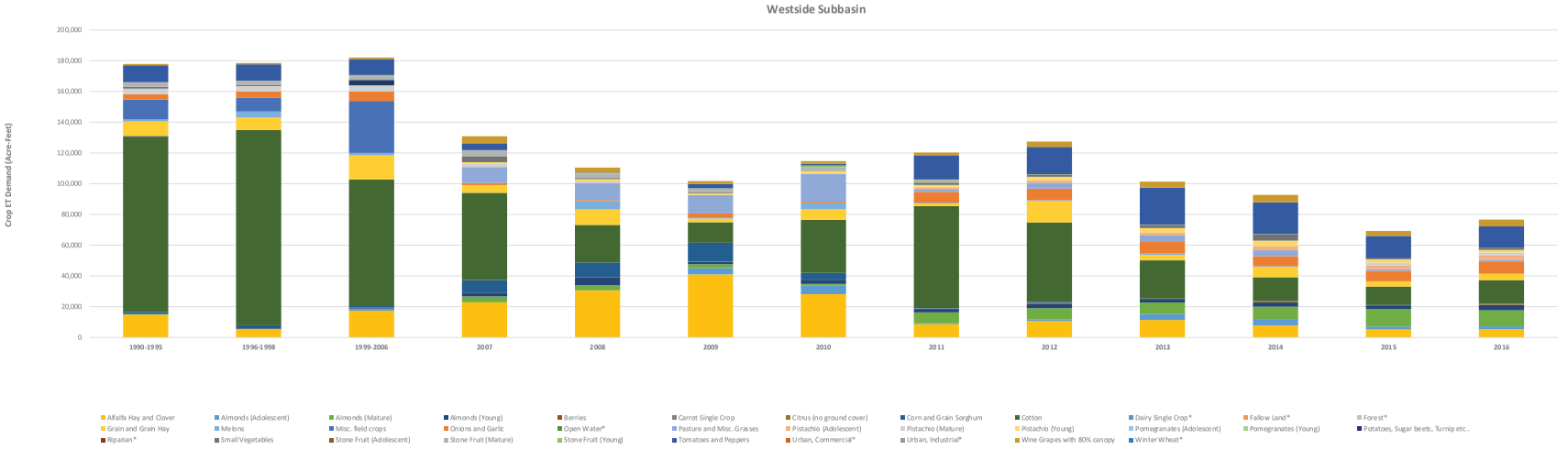
Sum of Crop ET Demand (Acre-Feet/Year)													APPENDIX D3-10
Tule Subbasin	**1990-1995**	**1996-1998**	**1999-2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Tule Subbasin													
Alfalfa Hay and Clover	48995	102696	102695	103253	96627	77757	87117	52421	56712	50482	52317	42961	44851
Almonds (Adolescent)	0	0	6	0	0	104	83	13	8	45	113	223	943
Almonds (Mature)	152	45	45	0	0	0	0	12	1	1	1	22	22
Almonds (Young)	0	2	0	479	1195	833	245	820	590	1052	1679	1995	1722
Berries	0	0	0	0	0	0	0	0	0	0	0	0	0
Carrot Single Crop	0	0	0	0	0	0	0	4	2	1	0	2	61
Citrus (no ground cover)	0	0	0	0	0	0	0	17	1	11	15	7	4
Corn and Grain Sorghum	19772	34425	34425	21765	22365	13040	7925	47549	44687	30636	35347	27359	15720
Cotton	76583	39418	39418	3865	4411	7859	16222	6149	4469	3160	4387	3940	5296
Dairy Single Crop*	6246	12030	12030	0	0	0	0	0	0	0	0	0	0
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain and Grain Hay	36255	40079	40077	6075	6753	8386	14365	11806	11631	12553	15122	19560	23291
Melons	20	0	0	0	0	7	0	2	4	2	96	5	40
Misc. field crops	4512	5890	5893	0	0	0	0	0	0	0	0	0	0
Onions and Garlic	4	0	0	1	0	0	147	73	183	1	9	36	105
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture and Misc. Grasses	1030	10450	10450	156596	164915	143596	174809	31502	61326	65535	80914	68705	51541
Pistachio (Adolescent)	0	0	0	0	0	0	0	575	558	722	1073	1324	1792
Pistachio (Mature)	0	0	0	301	218	135	108	107	106	106	105	929	1021
Pistachio (Young)	0	50	201	490	528	1184	1246	793	1182	1770	2221	1795	2525
Pomegranates (Young)	0	0	0	0	17	12	3	189	545	585	1024	1409	1596
Potatoes, Sugar beets, Turnip etc...	3015	7388	7388	0	0	2	0	4	3	2	11	21	3
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Vegetables	0	916	916	1	1	7	326	15	53	49	88	68	378
Stone Fruit (Adolescent)	0	0	58	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Mature)	33	0	0	0	0	0	0	0	0	0	0	0	0
Stone Fruit (Young)	0	15	0	5	50	6	1	25	22	1	30	29	5
Tomatoes and Peppers	4	40	40	3	0	5	0	234	239	159	597	518	1466
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
Wine Grapes with 80% canopy	183	157	157	88	237	83	252	314	476	81	269	304	346
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0
Tule Subbasin Irrigated ET Demand	**190557**	**241571**	**241770**	**292921**	**297316**	**253017**	**302850**	**152624**	**182797**	**169553**	**195419**	**171213**	**152727**
Tule Subbasin Total ET Demand	**196803**	**253600**	**253800**	**292921**	**297316**	**253017**	**302850**	**152624**	**182797**	**169553**	**195419**	**171213**	**152727**

Notes: Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year



Sum of Crop ET Demand (Acre-Feet/Year)														APPENDIX D3-11
Westside Subbasin	1990-1995	1996-1998	1999-2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Westside Subbasin														
Alfalfa Hay and Clover	14783	5463	17452	22840	30645	40982	28245	8690	10822	11407	7847	5227	5318	
Almonds (Adolescent)	0	0	1353	0	0	4098	5704	471	870	3772	3691	1847	1898	
Almonds (Mature)	530	0	0	3808	3528	2660	877	7155	7400	7542	8563	11411	10450	
Almonds (Young)	0	343	474	2571	5132	1461	2712	2247	2802	2334	2597	2396	3486	
Berries	29	22	27	0	0	0	0	0	462	0	0	0	71	
Carrot Single Crop	0	0	0	0	0	0	0	183	2	5	10	99	9	
Citrus (no ground cover)	30	23	64	0	124	53	0	241	0	430	927	90	491	
Corn and Grain Sorghum	1249	2078	1093	8137	9361	12433	4512	806	779	23	75	20	115	
Cotton	113990	127022	82287	56779	24486	13325	34546	65685	51753	24591	15497	11995	15476	
Dairy Single Crop*	354	0	0	0	0	0	0	0	0	0	0	0	0	
Fallow Land*	0	0	0	0	0	0	0	0	0	0	0	0	0	
Forest*	0	0	0	0	0	0	0	0	0	0	0	0	0	
Grain and Grain Hay	9494	8102	15647	4992	9968	2311	6890	1659	13750	3591	6523	3310	4086	
Melons	1280	3829	1681	4	5492	824	4069	545	615	1099	584	235	126	
Misc. field crops	13047	8983	33812	0	0	0	33	0	0	0	0	0	0	
Onions and Garlic	3528	4074	5993	1365	678	2444	685	7017	7569	7310	6608	6697	7539	
Open Water*	0	0	0	0	0	0	0	0	0	0	0	0	0	
Pasture and Misc. Grasses	0	7	320	10430	10890	12191	18149	1854	3863	4268	3807	1098	1211	
Pistachio (Adolescent)	0	0	0	0	0	0	0	1128	1498	1959	2858	2443	2926	
Pistachio (Mature)	3533	3399	3392	2354	1261	11	6	6	6	3	0	1971	2172	
Pistachio (Young)	0	95	399	796	1355	1077	1795	1444	2313	2857	3446	2046	1707	
Pomegranates (Adolescent)	0	0	0	0	0	0	0	0	0	35	0	0	0	
Pomegranates (Young)	0	0	0	45	90	43	139	91	65	49	2	30	42	
Potatoes, Sugar beets, Turnip etc...	0	0	3407	326	0	0	0	92	0	0	0	0	7	
Riparian*	0	0	0	0	0	0	0	0	0	0	0	0	0	
Small Vegetables	1154	951	498	3536	674	458	488	1335	1405	2014	4046	616	1302	
Stone Fruit (Adolescent)	0	0	191	0		182	101	112	83	35	112	0	0	
Stone Fruit (Mature)	3100	2553	1822	3750	3010	2099	1713	1511	3	1	20	0	0	
Stone Fruit (Young)	0	72	841	174	419	391	1171	527	95	119	68	2	41	
Tomatoes and Peppers	10971	10604	10367	4457	172	2860	1108	15693	17844	24101	20685	14607	13747	
Urban, Commercial*	0	0	0	0	0	0	0	0	0	0	0	0	0	
Urban, Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0	
Wine Grapes with 80% canopy	907	877	1050	4524	3216	1815	1743	1842	3387	3819	4781	3205	4462	
Winter Wheat*	0	0	0	0	0	0	0	0	0	0	0	0	0	
Westside Subbasin Irrigated ET Dem	**177626**	**178498**	**182172**	**130889**	**110499**	**101717**	**114687**	**120333**	**127387**	**101365**	**92746**	**69345**	**76682**	
Westside Subbasin Total ET Demand	**177980**	**178498**	**182172**	**130889**	**110499**	**101717**	**114687**	**120333**	**127387**	**101365**	**92746**	**69345**	**76682**	

Notes: Fields with an Asterisk (*) are not Irrigated; Annual Total is by Calendar Year



Appendix D4
Annualized Specified Pumping by Well Field

Annualized Specified Pumping

Well field	Well_ID	1990 (AF/Y)	1991 (AF/Y)	1992 (AF/Y)	1993 (AF/Y)	1994 (AF/Y)	1995 (AF/Y)	1996 (AF/Y)	1997 (AF/Y)	1998 (AF/Y)	1999 (AF/Y)	2000 (AF/Y)	2001 (AF/Y)	2002 (AF/Y)	2003 (AF/Y)	2004 (AF/Y)	2005 (AF/Y)	2006 (AF/Y)	2007 (AF/Y)	2008 (AF/Y)	2009 (AF/Y)	2010 (AF/Y)	2011 (AF/Y)	2012 (AF/Y)	2013 (AF/Y)	2014 (AF/Y)	2015 (AF/Y)	2016 (AF/Y)
Angiola	E1	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E10	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E11	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E13	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E14	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E15	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E16	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E17	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E18	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E19	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	E21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E4	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E5	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	E7	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G1	802.33	371.37	531.65	94.54	260.14	0.00	0.00	0.00	0.00	0.00	107.68	368.95	421.22	356.02	425.48	10.51	2.24	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	G11	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G13	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G14	802.33	371.37	531.65	94.54	260.14	0.00	0.00	0.00	0.00	0.00	107.68	368.95	421.22	356.02	425.48	10.51	2.24	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	G16	802.33	371.37	531.65	94.54	260.14	0.00	0.00	0.00	0.00	0.00	107.68	368.95	421.22	356.02	425.48	10.51	2.24	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	G17	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G18	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G19	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G2(NEW)	802.33	371.37	531.65	94.54	260.14	0.00	0.00	0.00	0.00	0.00	107.68	368.95	421.22	356.02	425.48	10.51	2.24	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	G20	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G21	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G22	0.00	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	G24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	G25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	G26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	G3	802.33	371.37	531.65	94.54	260.14	0.00	0.00	0.00	0.00	0.00	107.68	368.95	421.22	356.02	425.48	10.51	2.24	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	G5	802.33	371.37	531.65	94.54	260.14	0.00	0.00	0.00	0.00	0.00	107.68	368.95	421.22	356.02	425.48	10.51	2.24	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	G7	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	W11	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	W12	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	W13	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	W14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	W15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	W16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	W17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	W6	802.33	371.37	531.65	94.54	260.14	0.00	0.00	0.00	0.00	0.00	107.68	368.95	421.22	356.02	425.48	10.51	2.24	432.82	361.13	419.98	250.76	125.95	215.42	339.20	307.72	335.78	322.74
Angiola	W7	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	W8	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
Angiola	W9	1,604.65	742.73	1,063.30	189.08	520.29	0.00	0.00	0.00	0.00	0.00	215.37	737.90	842.44	712.03	850.95	21.02	4.48	865.63	722.27	839.96	501.51	251.90	430.85	678.40	615.44	671.56	645.49
El Rico	ER_C-16	1,800.27	2,870.99	1,808.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,571.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_C-33	2,310.31	1,917.00	2,319.99	0.00	723.00	81.00	0.00	0.00	0.00	0.00	0.00	0.00	635.00	567.00	1,894.00	0.00	0.00	1,774.02	451.00	177.17	0.00	0.00	676.60	692.36	721.93	0.00	0.00
El Rico	ER_G-9	0.00	557.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	611.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_Heck1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,155.63	976.07	2,999.27	2,409.04
El Rico	ER_HR-190	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,754.98	2,495.81	1,925.97	905.10	7.48	2,119.00	1,963.66	1,667.61	1,279.25	1,120.47
El Rico	ER_HR-28	0.00	835.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,611.30	972.50	449.34	1,175.75	0.00	0.00	1,045.76	1,002.92	914.27	503.12	0.00	1,240.01	868.40	865.22	653.07	211.39
El Rico	ER_HR-29	0.00	739.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,116.93	1,132.31	424.33	1,056.00	0.00	0.00	979.28	755.17	742.50	376.96	3.11	792.86	654.05	533.04	436.01	408.77
El Rico	ER_HR-30	0.00	872.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,018.00	1,042.20	431.86	1,236.00	0.00	0.00	1,031.59	1,209.69	788.33	400.12	3.22	881.46	704.78	668.79	562.82	501.81
El Rico	ER_M-137	2,847.89	2,264.10	2,855.99	247.00	1,829.00	42.98	0.00	0.00	0.00	0.00	204.00	2,001.81	1,470.62	1,297.66	2,097.00	0.00	0.00	2,047.10	2,261.11	2,271.83	896.08	6.20	2,050.50	1,369.69	1,879.81	1,526.53	1,849.82
El Rico	ER_M-140	2,150.06	1,811.41	2,157.00	261.00	1,459.00	35.01	0.00	0.00	0.00	0.00	1,102.84	2,286.25	1,710.31	1,045.01	1,756.00	0.00	0.00	1,875.32	2,064.27	1,891.50	1,143.24	52.52	1,846.08	1,408.40	570.87	411.26	0.00
El Rico	ER_M-141	1,176.07	885.72	1,180.00	146.00	573.00	21.00	0.00	0.00	0.00	0.00	860.64	1,162.00	798.00	543.00	805.00	0.00	0.00	727.97	69.14	655.19	342.10	2.60	0.00	0.00	0.00	0.00	0.00
El Rico	ER_M-143	1,017.51	883.69	1,022.00	131.00	1,690.00	24.00	0.00	0.00	0.00	0.00	580.31	1,240.48	843.00	493.00	590.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_M-144	1,837.75	1,248.17	1,844.00	241.00	1,186.00	35.01	0.00	0.00	0.00	0.00	1,117.95	1,782.20	1,041.81	502.87	1,101.00	0.00	0.00	1,086.25	928.44	833.34	242.64	5.58	865.23	791.49	658.50	185.54	683.66
El Rico	ER_M-145	1,268.00	1,065.48	1,268.00	172.00	878.00	24.00	0.00	0.00	0.00	0.00	820.56	1,334.00	999.00	606.00	783.00	0.00	0.00	898.42	967.08	820.42	476.67	3.57	1,210.60	1,085.95	1,041.87	912.18	636.02
El Rico	ER_M-146	1,125.00	980.69	1,125.00	145.00	875.00	30.00	0.00	0.00	0.00	0.00	865.15	1,713.00	1,076.00	692.00	555.00	0.00	0.00	1,074.51	1,038.96	517.93	332.79	0.00	1,041.64	781.67	494.71	404.75	351.36
El Rico	ER_M-147	2,298.75	1,695.17	2,304.99	205.00	1,411.00	40.00	0.00	0.00	0.00	0.00	944.77	2,163.00	1,509.00	995.00	1,501.00	0.00	0.00	1,368.64	1,389.19	1,215.32	429.98	13.42	1,015.01	938.89	1,700.98	1,777.19	1,779.69
El Rico	ER_M-148	3,241.85	2,353.72	3,250.99	362.00	2,009.00	55.00	0.00	0.00	0.00	0.00	1,553.20	2,601.99	2,049.00	1,251.00	2,180.99	0.00	0.00	2,229.32	2,555.65	2,400.02	1,366.79	41.82	2,535.94	2,111.49	2,253.66	2,289.41	2,275.77
El Rico	ER_M-149	2,739.24	2,182.51	2,746.99	264.00	1,663.00	47.00	0.00	0.00	0.00	0.00	1,592.32	2,389.99	1,937.00	1,032.00	2,080.00	0.00	0.00	1,755.84	1,804.78	495.83	1,394.04	49.18	2,045.42	2,154.85	1,995.12	657.24	0.00
El Rico	ER_M-150	2,509.06	2,156.20	2,515.99	283.00	1,045.00	14.00	0.00	0.00	0.00	0.00	1,097.00	2,673.99	1,866.00	1,149.00	2,161.00	0.00	0.00	2,094.07	2,558.80	2,194.59	1,186.13	50.26	2,225.49	2,046.19	1,761.41	1,642.53	1,503.20
El Rico	ER_M-151	2,081.75	792.00	2,088.00	234.00	1,300.00	0.00	0.00	0.00	0.00	0.00	103.98	431.00	0.00	0.00	419.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_M-153	2,282.17	1,905.10	2,288.99	300.00	1,270.00	27.00	0.00	0.00	0.00	0.00	0.00	1,375.00	1,417.00	419.00	1,811.00	0.00	0.00	1,536.96	1,878.58	1,621.68	629.88	6.61	1,835.05	2,307.41	2,093.23	1,684.08	1,388.40
El Rico	ER_M-154	2,199.44	1,761.58	2,205.99	275.00	1,222.00	25.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	240.05	1,615.00	0.00	0.00	1,509.29	1,523.09	1,568.91	618.14	6.45	448.82	0.00	0.00	789.05	1,514.80

Annualized Specified Pumping

Well field	Well_ID	1990 (AF/Y)	1991 (AF/Y)	1992 (AF/Y)	1993 (AF/Y)	1994 (AF/Y)	1995 (AF/Y)	1996 (AF/Y)	1997 (AF/Y)	1998 (AF/Y)	1999 (AF/Y)	2000 (AF/Y)	2001 (AF/Y)	2002 (AF/Y)	2003 (AF/Y)	2004 (AF/Y)	2005 (AF/Y)	2006 (AF/Y)	2007 (AF/Y)	2008 (AF/Y)	2009 (AF/Y)	2010 (AF/Y)	2011 (AF/Y)	2012 (AF/Y)	2013 (AF/Y)	2014 (AF/Y)	2015 (AF/Y)	2016 (AF/Y)
El Rico	ER_M-158	2,232.55	1,527.82	2,238.99	132.00	1,323.00	0.00	0.00	0.00	0.00	0.00	0.00	661.00	1,400.00	846.00	1,190.00	0.00	0.00	677.03	1,736.03	1,542.60	616.54	16.26	825.51	0.00	0.00	0.00	0.00
El Rico	ER_M-159	0.00	75.00	908.00	101.00	361.00	825.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_M-161	0.00	0.00	1,840.00	375.00	1,728.00	42.98	0.00	0.00	0.00	0.00	129.11	3,048.72	1,916.85	661.65	2,271.99	0.00	0.00	1,259.21	1,953.95	1,996.68	841.78	7.98	1,943.88	1,984.78	318.00	0.00	0.00
El Rico	ER_M-163	0.00	0.00	1,680.00	318.00	1,778.00	966.00	0.00	0.00	0.00	0.00	173.73	2,395.99	1,344.00	619.00	1,481.00	0.00	0.00	1,210.58	1,728.49	1,099.94	513.17	4.13	1,317.26	523.36	0.00	0.00	0.00
El Rico	ER_M-166	0.00	0.00	1,671.00	346.00	1,758.00	42.98	0.00	0.00	0.00	0.00	593.35	2,699.66	2,148.02	1,280.59	2,262.99	0.00	0.00	2,247.74	2,390.46	2,402.21	725.28	6.82	2,328.07	1,810.63	0.00	0.00	0.00
El Rico	ER_M-168	0.00	0.00	1,254.00	320.00	1,546.00	32.02	0.00	0.00	0.00	0.00	325.06	2,667.79	1,735.12	592.18	1,117.00	0.00	0.00	1,672.00	2,185.50	1,940.01	784.63	0.04	2,027.28	2,070.43	1,386.28	1,832.52	1,772.13
El Rico	ER_M-169	0.00	0.00	1,381.00	316.00	1,526.00	30.03	0.00	0.00	0.00	0.00	325.67	2,724.11	1,755.43	645.10	2,174.00	0.00	0.00	1,733.90	2,405.69	1,549.94	257.02	4.94	1,077.09	1,111.80	1,011.80	913.28	0.00
El Rico	ER_M-170	0.00	0.00	254.00	304.00	1,534.00	32.02	0.00	0.00	0.00	0.00	307.88	2,575.19	1,683.01	747.92	2,075.00	0.00	0.00	1,731.22	2,450.65	2,231.45	862.97	7.96	2,152.31	2,235.27	2,145.84	2,026.97	1,951.97
El Rico	ER_M-171	0.00	0.00	147.00	1,413.00	1,510.00	28.00	0.00	0.00	0.00	0.00	343.99	2,442.99	1,501.00	666.00	756.00	0.00	0.00	1,526.34	2,208.94	2,000.90	537.82	29.32	0.00	0.00	0.00	0.00	0.00
El Rico	ER_M-172	0.00	0.00	0.00	0.00	772.00	0.00	0.00	0.00	0.00	0.00	253.00	2,315.99	1,447.00	141.00	1,546.00	0.00	0.00	1,179.42	1,821.88	1,344.49	655.27	6.37	1,674.70	1,562.70	1,539.75	1,396.80	1,251.10
El Rico	ER_M-175	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	235.20	1,674.00	1,046.00	389.00	1,134.00	0.00	0.00	854.99	1,165.23	1,061.06	280.26	1.45	674.27	648.82	539.98	405.57	0.06
El Rico	ER_M-176	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	223.54	1,577.00	1,125.00	431.00	1,102.00	0.00	0.00	862.71	924.46	618.59	215.46	2.88	821.85	625.79	517.70	511.23	485.09
El Rico	ER_M-178	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,946.00	1,348.00	554.00	1,566.00	0.00	0.00	1,008.86	1,816.84	1,504.51	550.40	5.14	1,412.16	1,476.51	1,344.94	939.62	0.00
El Rico	ER_M-179	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.00	247.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_M-181	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	166.07	1,374.00	872.00	337.00	982.00	0.00	0.00	738.93	931.46	880.21	346.94	3.47	38.47	0.00	0.00	0.00	0.00
El Rico	ER_R-26	2,265.99	411.00	2,265.99	222.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.00	514.00	411.00	0.00	0.00	999.00	746.36	255.13	0.00	0.00	1,221.08	1,143.98	948.86	653.64	174.78
El Rico	ER_R-27	1,861.00	34.00	1,861.00	296.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	443.00	0.00	0.00	0.00	831.00	238.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_R-33	0.00	787.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	42.00	436.00	1,203.00	0.00	0.00	1,440.66	1,668.12	156.32	0.00	0.00	2.00	0.00	0.00	0.00	0.00
El Rico	ER_R-35	2,144.00	471.00	2,144.00	279.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	154.00	30.00	865.00	0.00	0.00	1,351.84	1,004.22	0.00	0.00	0.00	1,435.08	888.81	0.00	0.00	0.00
El Rico	ER_R-47	1,859.48	1,610.93	1,863.00	121.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,228.00	1,344.00	520.00	1,640.00	0.00	0.00	6.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_S-111	90.00	239.00	90.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_S-113	90.00	763.27	90.00	0.00	360.00	0.00	0.00	0.00	0.00	0.00	0.00	822.00	660.00	171.00	678.00	0.00	0.00	359.45	636.40	532.75	230.80	2.08	525.67	384.38	470.03	367.38	263.73
El Rico	ER_S-120	3,124.06	2,198.62	3,132.99	366.22	706.00	43.00	0.00	0.00	0.00	0.00	162.29	2,702.99	1,663.00	604.00	1,984.00	0.00	0.00	1,888.04	2,234.46	1,852.52	691.55	6.36	1,787.12	1,656.47	1,153.40	842.51	351.44
El Rico	ER_S-127	2,904.44	2,011.31	2,911.99	348.00	1,759.00	49.03	0.00	0.00	0.00	0.00	319.14	2,693.46	1,654.08	563.24	1,964.00	0.00	0.00	1,847.00	1,906.27	416.61	830.46	7.27	2,028.06	2,000.17	1,434.00	0.00	0.00
El Rico	ER_S-160	1,615.41	1,776.86	1,622.00	255.00	928.00	20.00	0.00	0.00	0.00	0.00	0.00	1,017.00	1,337.00	487.00	1,657.00	0.00	0.00	908.71	1,722.46	1,049.80	0.00	13.15	1,006.31	934.65	652.22	43.90	370.48
El Rico	ER_S-162	2,015.00	1,912.27	2,015.00	502.00	1,738.00	56.00	0.00	0.00	0.00	0.00	282.02	3,407.99	2,171.00	786.00	2,689.99	0.00	0.00	2,433.37	2,850.05	1,979.59	530.13	7.00	1,926.89	1,854.70	1,649.31	1,422.80	1,393.60
El Rico	ER_S-164	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,461.00	314.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_S-165	1,045.00	1,445.69	1,045.00	220.00	1,030.00	0.00	0.00	0.00	0.00	0.00	74.60	2,489.99	1,641.00	592.00	2,034.00	0.00	0.00	1,639.21	1,711.75	520.57	796.53	10.19	574.24	551.17	394.73	0.00	0.00
El Rico	ER_S-167	1,626.00	1,618.86	1,626.00	384.00	1,888.00	52.00	0.00	0.00	0.00	0.00	152.49	3,048.99	1,893.00	684.00	2,262.99	0.00	0.00	2,065.85	1,245.14	0.00	0.00	0.00	0.00	1,440.79	1,077.44	1,535.36	311.72
El Rico	ER_S-173	0.00	2,085.34	0.00	106.00	2,092.00	63.00	0.00	0.00	0.00	0.00	0.00	2,325.99	2,373.99	886.00	2,969.99	0.00	0.00	1,859.87	2,717.95	2,087.83	998.67	10.23	2,932.26	3,120.53	3,114.65	3,063.55	1,652.10
El Rico	ER_S-174	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,529.99	2,101.00	779.00	2,558.99	0.00	0.00	2,185.60	2,743.38	2,424.90	966.68	7.94	1,877.19	563.24	730.78	603.26	502.54
El Rico	ER_S-188	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	985.80	1,507.20	1,185.16	288.20	3.33	750.92	311.28	679.15	409.23	196.40
El Rico	ER_S-191	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	258.84	0.00	0.00	0.00	0.00	0.00	238.00	0.00	0.00
El Rico	ER_S-192	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,099.00	2,470.89	1,076.58	0.00	2,565.67	2,601.49	2,322.96	2,055.21	1,804.77
El Rico	ER_S-193	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,983.06	2,102.49	1,079.61	9.36	2,559.21	2,639.88	2,346.56	2,241.24	2,036.11
El Rico	ER_S-194	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,558.77	2,582.76	1,082.20	9.02	2,216.67	1,910.75	910.07	358.99	2.97
El Rico	ER_S-195	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,460.00	2,699.86	1,153.29	10.14	2,836.87	3,126.31	2,966.75	2,880.80	2,816.01
El Rico	ER_S-196	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,325.00	2,731.97	1,106.82	9.67	2,402.58	2,731.07	2,569.80	2,426.92	2,298.25
El Rico	ER_S-198	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,213.84	2,609.13	1,148.39	0.00	2,777.98	2,751.41	2,415.86	2,114.48	1,830.73
El Rico	ER_S-199	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	676.34	2,409.49	1,142.78	10.16	2,677.37	2,887.71	2,794.52	2,505.17	2,553.13
El Rico	ER_S-200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,168.99	1,105.84	0.00	2,759.92	2,870.49	2,742.45	2,169.81	1,614.97
El Rico	ER_S-201	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	748.95	1,142.04	10.57	1,918.94	2,450.16	2,382.50	1,667.81	2,142.77
El Rico	ER_S-202	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	544.42	15.16	3,460.57	3,338.14	2,617.87	1,693.30	1,718.73
El Rico	ER_S-203	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	230.77	15.70	3,884.90	4,107.45	4,368.74	4,445.74	4,282.34
El Rico	ER_S-205	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,781.11	5,081.66	4,185.44	3,486.88	5,161.08
El Rico	ER_S-206	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,533.13	4,681.16	4,513.79	3,703.62
El Rico	ER_S-209	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,196.76	3,963.35	3,437.13	3,401.15
El Rico	ER_S-211	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,256.46	4,387.34	4,068.25	3,619.99
El Rico	ER_S-213	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,064.55	3,900.73	3,966.16
El Rico	ER_S-214	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3,635.46	4,518.85	4,306.07
El Rico	ER_S-215	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,909.40	3,886.35	3,975.84
El Rico	ER_S-216	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,425.40	4,537.42	4,416.25
El Rico	ER_S-217	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,757.98	4,318.93	4,497.61
El Rico	ER_S-218	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,118.39	4,278.81	4,292.27
El Rico	ER_S-219	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	498.85	4,477.82	4,406.65
El Rico	ER_S-220	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,283.65	4,397.68
El Rico	ER_S-221	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,924.61	3,970.97
El Rico	ER_S-222	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,122.29	3,786.41
El Rico	ER_S-223	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	766.91	3,935.35
El Rico	ER_S-224	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3,925.50
El Rico	ER_S-225	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3,580.64
El Rico	ER_S-226	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,928.44
El Rico	ER_S-227	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,191.19
El Rico	ER_S-228	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,146.70
El Rico	ER_S-229	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	864.59
El Rico	ER_S-70	2,569.10	2,001.72	2,574.99	314.00	1,537.00	15.00	0.00	0.00	0.00	0.00	0.00	1,928.00	1,664.00	559.00	1,956.00	0.00	0.00	1,608.48	2,251.61	1,886.48	486.25	90.47	1,655.35	1,622.35	1,081.70	622.95	0.00
El Rico	ER_SR-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	314.00	186.00	484.00	0.00	0.00	424.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_SR-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	208.00	1,430.00	0.00	0.00	585.19	1,471.77	399.48	0.00	0.00	0.00	789.73	1,810.23	1,103.14	0.00
El Rico	ER_SR-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	826.00	544.00	1,209.00	0.00	0.00	1,203.67	1,687.76	295.48	0.00	0.00	0.00	381.63	1,020.65	237.17	0.00
El Rico	ER_SR-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	181.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_SR-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	429.00	453.00	270.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_T-155	3,088.17	2,219.82	3,096.99	362.00	1,759.00	45.00	0.00	0.00	0.00	0.00	0.00	1,761.00	2,039.00	774.00	2,166.00	0.00	0.00	2,213.87	2,242.79	1,778.14	947.64	7.04	1,646.97	2,306.66	1,547.05	1,031.41	0.00
El Rico	ER_T-156	2,771.68	668.00	2,775.99	42.00	498.00	53.00	0.00	0.00	0.00	0.00	0.00	2,541.99	1,238.00	53.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_T-157	3,306.20	2,238.96	3,312.99	384.00	777.00	0.00	0.00	0.00	0.00	0.00	0.00	2,203.99	1,890.00	719.00	1,344.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Annualized Specified Pumping

Well field	Well_ID	1990 (AF/Y)	1991 (AF/Y)	1992 (AF/Y)	1993 (AF/Y)	1994 (AF/Y)	1995 (AF/Y)	1996 (AF/Y)	1997 (AF/Y)	1998 (AF/Y)	1999 (AF/Y)	2000 (AF/Y)	2001 (AF/Y)	2002 (AF/Y)	2003 (AF/Y)	2004 (AF/Y)	2005 (AF/Y)	2006 (AF/Y)	2007 (AF/Y)	2008 (AF/Y)	2009 (AF/Y)	2010 (AF/Y)	2011 (AF/Y)	2012 (AF/Y)	2013 (AF/Y)	2014 (AF/Y)	2015 (AF/Y)	2016 (AF/Y)
El Rico	ER_T-177	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	928.17	975.13	389.17	707.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
El Rico	ER_T-182	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,705.00	1,842.00	664.00	1,235.00	0.00	0.00	2,364.40	523.65	0.00	118.30	2.38	518.39	756.61	221.34	0.00	0.00
El Rico	ER_T-61	3,222.89	1,635.00	3,227.99	303.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	424.18	523.48	874.00	0.00	0.00	0.00	1,318.20	305.96	0.00	0.00	1,302.55	0.00	0.00	0.00	0.00
Creighton Ranch	CR_CR-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,626.79	1,849.41	1,705.15	1,320.74
Creighton Ranch	CR_CR-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	433.41	538.08	437.91	289.92
Creighton Ranch	CR_CR-6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	170.04	523.12	512.68	511.33
Creighton Ranch	CR_CR-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,022.41	1,342.09	1,098.35	830.86
Creighton Ranch	CR_EC-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	964.80	1,521.00	436.50	2,028.60	0.00	0.00	1,361.81	1,442.77	1,011.40	468.42	3.94	825.11	735.16	834.01	767.03	681.29
Creighton Ranch	CR_EC-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,816.20	1,339.20	437.40	1,433.70	0.00	0.00	752.12	811.61	953.34	353.70	2.89	849.40	897.20	817.27	540.13	517.71
Creighton Ranch	CR_EC-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,686.60	1,033.20	262.80	1,071.90	0.00	0.00	775.64	980.13	486.81	192.35	3.54	1,528.18	999.18	897.40	790.45	691.30
Creighton Ranch	CR_EC-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,782.90	1,187.10	88.20	715.50	0.00	0.00	757.83	1,016.12	887.14	327.42	2.73	925.07	886.85	819.55	780.30	706.68
Creighton Ranch	CR_EC-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	742.50	358.20	1,557.90	0.00	0.00	1,378.09	1,865.43	1,654.84	638.59	0.00	1,507.24	1,543.45	1,420.86	1,348.86	1,157.05
Creighton Ranch	CR_EC-6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	474.30	430.20	1,954.80	0.00	0.00	1,449.81	2,367.72	2,217.50	701.82	2.38	1,973.90	2,059.83	2,022.39	1,912.80	279.52
Creighton Ranch	CR_EC-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,329.30	0.00	0.00	1,545.86	2,080.28	2,066.13	674.60	6.43	834.67	1,737.98	1,554.98	1,247.94	1,058.44
Creighton Ranch	CR_S-100	484.00	1,074.20	484.00	110.00	314.00	15.02	0.00	0.00	0.00	0.00	0.00	1,197.05	875.26	261.80	1,050.00	0.00	0.00	923.62	1,118.45	963.91	363.81	3.60	1,104.47	1,106.76	778.83	0.00	0.00
Creighton Ranch	CR_S-103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	534.00	0.00	0.00	705.72	1,531.18	1,498.63	612.45	5.52	1,625.00	1,620.42	1,502.45	1,447.79	553.63
Creighton Ranch	CR_S-105	708.30	768.38	708.30	149.40	355.50	29.72	0.00	0.00	0.00	0.00	73.37	1,603.90	1,026.61	283.76	770.40	0.00	0.00	1,231.92	1,223.44	363.33	100.91	2.13	567.39	165.91	0.00	0.00	0.00
Creighton Ranch	CR_S-106	324.00	568.80	324.00	121.50	342.00	36.00	0.00	0.00	0.00	0.00	199.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Creighton Ranch	CR_S-108	1,727.10	1,190.05	1,727.10	231.30	1,715.40	2.70	0.00	0.00	0.00	0.00	0.00	1,631.12	1,249.14	314.31	1,623.60	0.00	1.83	1,204.17	1,722.36	1,942.71	804.47	28.36	1,572.01	980.71	669.79	615.39	1,481.35
Creighton Ranch	CR_S-109	1,227.32	1,847.11	1,227.60	244.80	1,749.60	51.30	0.00	0.00	0.00	0.00	204.62	1,324.71	772.55	316.10	1,602.90	0.00	62.02	1,180.48	1,599.53	1,427.47	615.08	27.28	1,294.39	1,561.03	873.80	859.07	1,343.12
Creighton Ranch	CR_S-110	698.12	2,335.62	698.40	0.00	0.00	48.61	0.00	0.00	0.00	0.00	343.99	1,954.25	1,495.75	487.94	2,233.79	0.00	0.00	1,657.27	2,046.15	1,234.31	700.55	16.33	1,647.26	1,635.60	1,468.44	1,304.75	1,317.23
Creighton Ranch	CR_S-114	928.80	1,416.78	928.80	165.60	1,148.40	33.31	0.00	0.00	0.00	0.00	261.45	1,418.76	966.67	384.07	1,386.90	107.10	2.05	989.20	1,273.28	1,170.74	462.43	16.27	434.15	454.04	361.08	274.32	176.55
Creighton Ranch	CR_S-115	666.90	1,254.50	666.90	114.30	817.20	23.38	0.00	0.00	0.00	0.00	185.45	1,221.72	704.39	311.38	1,257.30	89.10	0.00	891.02	1,171.90	894.20	453.19	49.00	1,020.84	946.69	819.85	543.40	507.17
Creighton Ranch	CR_S-116	544.50	1,058.24	544.50	93.60	673.20	19.80	0.00	0.00	0.00	0.00	205.84	1,075.84	803.80	305.65	1,145.70	88.20	1.61	747.45	530.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Creighton Ranch	CR_S-117	449.10	1,125.46	449.10	0.00	724.50	21.58	0.00	0.00	0.00	0.00	140.88	1,006.30	706.05	252.59	1,020.60	72.00	1.21	765.57	374.45	291.06	127.03	1.15	815.08	892.15	822.96	753.26	663.00
Creighton Ranch	CR_S-119	513.90	1,080.96	513.90	105.30	762.30	22.50	0.00	0.00	0.00	0.00	339.04	1,780.48	1,407.59	272.69	1,035.00	0.00	0.00	781.30	1,021.43	830.78	349.24	3.50	721.75	919.82	919.48	770.81	915.08
Creighton Ranch	CR_S-121	847.67	1,873.11	847.80	161.10	469.80	37.80	0.00	0.00	0.00	0.00	67.28	1,963.80	1,543.50	435.60	1,830.60	0.00	0.00	1,680.41	1,933.83	1,435.48	553.40	5.57	1,595.17	1,629.63	1,328.48	1,101.72	874.44
Creighton Ranch	CR_S-122	2,289.44	1,427.02	2,295.89	272.70	516.60	38.70	0.00	0.00	0.00	0.00	0.00	1,411.20	1,286.10	379.80	853.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Creighton Ranch	CR_S-123	508.37	1,211.83	508.50	95.40	1,029.60	127.80	0.00	0.00	0.00	0.00	227.00	1,639.80	1,062.00	295.20	1,207.80	0.00	0.00	1,125.99	1,361.89	1,066.67	395.97	4.23	1,169.63	1,288.35	1,285.32	978.43	1,006.36
Creighton Ranch	CR_S-124	757.80	511.20	757.80	117.90	1,155.60	35.10	0.00	0.00	0.00	0.00	264.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	719.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Creighton Ranch	CR_S-125	1,151.10	1,813.87	1,151.10	201.33	1,332.90	31.51	0.00	0.00	0.00	0.00	335.24	2,151.89	1,446.94	524.45	1,735.20	111.60	1.20	1,420.40	1,714.76	1,417.40	687.57	33.42	1,603.42	1,483.27	1,278.20	1,084.70	1,174.88
Creighton Ranch	CR_S-129	468.90	1,062.90	468.90	119.70	351.90	26.07	0.00	0.00	0.00	0.00	0.00	1,038.39	989.14	276.02	1,067.40	0.00	0.00	997.00	1,387.29	1,195.67	447.46	0.00	1,177.31	1,141.83	1,174.67	1,119.90	1,135.92
Creighton Ranch	CR_S-130	476.00	700.52	476.00	110.00	298.00	22.99	0.00	0.00	0.00	0.00	0.00	1,009.59	830.71	229.05	780.00	0.00	0.00	191.76	924.84	203.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Creighton Ranch	CR_S-131	311.40	1,239.39	311.40	123.30	335.70	24.27	0.00	0.00	0.00	0.00	0.00	1,011.77	978.22	283.66	1,216.80	0.00	0.00	1,014.61	1,284.51	1,152.84	449.99	4.01	1,256.76	1,404.28	1,256.95	1,118.88	990.26
Creighton Ranch	CR_S-132	1,333.24	836.22	1,337.40	141.30	358.20	29.72	0.00	0.00	0.00	0.00	0.00	1,127.70	930.20	240.93	709.20	0.00	0.00	1,361.83	1,332.57	1,340.85	513.02	4.58	1,373.03	1,394.13	1,306.25	1,205.36	1,196.98
Creighton Ranch	CR_S-134	345.60	1,211.96	345.60	66.60	511.20	15.31	0.00	0.00	0.00	0.00	0.00	333.32	901.23	287.95	1,387.80	0.00	1.70	995.66	1,358.11	1,217.67	496.88	4.70	980.34	958.35	1,108.44	1,043.79	648.49
Creighton Ranch	CR_S-135	549.00	1,267.62	549.00	138.00	394.00	30.03	0.00	0.00	0.00	0.00	0.00	1,372.00	1,061.00	305.07	1,111.00	0.00	0.00	773.37	701.81	454.06	347.44	3.81	1,070.52	730.93	863.08	835.17	890.83
Creighton Ranch	CR_S-138	1,602.46	1,463.52	1,607.40	196.20	342.00	26.10	0.00	0.00	0.00	0.00	0.00	1,140.30	1,193.40	328.45	1,539.90	0.00	0.00	1,248.92	1,700.89	1,542.83	510.08	10.12	1,457.37	1,035.02	1,300.24	1,288.59	1,304.07
Creighton Ranch	CR_S-183	0.00	1,593.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	801.00	1,554.30	370.80	2,181.59	0.00	0.00	1,765.58	1,797.71	1,785.59	710.78	18.40	1,503.65	1,560.04	1,370.94	691.79	342.08
Creighton Ranch	CR_S-187	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,312.39	1,696.80	1,498.09	538.34	4.52	1,216.82	898.60	748.61	435.77	0.00
Creighton Ranch	CR_S-189	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	676.47	1,397.26	507.94	4.93	1,251.80	864.87	1,089.38	1,090.70	1,085.31
Creighton Ranch	CR_S-197	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,375.06	3,016.17	1,130.32	9.76	2,937.88	2,980.16	3,049.06	3,425.72	3,342.29
Creighton Ranch	CR_S-204	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,989.78	5,174.18	4,814.78	4,644.04	4,492.56
Creighton Ranch	CR_S-207	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	460.40	5,700.81	4,838.66	4,195.61	2,838.11
Creighton Ranch	CR_S-208	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,429.56	5,504.19	5,132.88	4,673.93	4,034.77
Creighton Ranch	CR_S-210	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,853.51	4,542.36	3,990.52	3,818.24
Creighton Ranch	CR_S-212	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	341.65	4,909.10	4,612.65	4,075.88
Creighton Ranch	CR_S-79	1,079.66	1,386.12	1,080.00	142.20	273.60	19.80	0.00	0.00	0.00	0.00	0.00	421.20	1,057.50	237.74	1,513.80	0.00	0.00	1,255.70	1,616.90	1,390.51	499.91	6.25	1,480.50	1,529.03	1,431.37	1,366.64	1,175.41
Creighton Ranch	CR_S-80	738.00	830.23	738.00	121.50	118.80	0.00	0.00	0.00	0.00	0.00	0.00	400.50	636.30	240.30	900.90	0.00	0.00	753.18	798.32	343.46	313.21	2.57	744.00	736.72	721.53	582.38	141.32
Creighton Ranch	CR_S-81	1,371.38	1,280.23	1,375.20	159.30	339.30	25.20	0.00	0.00	0.00	0.00	0.00	1,034.10	1,034.10	310.50	1,264.50	0.00	0.00	1,093.82	1,233.06	916.40	301.90	3.08	1,304.50	1,210.52	934.69	789.60	676.48
Creighton Ranch	CR_S-82	906.86	1,271.32	909.90	63.90	346.50	23.40	0.00	0.00	0.00	0.00	0.00	819.00	801.00	274.13	1,414.80	0.00	0.00	884.21	985.61	971.44	204.58	8.16	320.34	358.49	355.36	300.10	302.90
Creighton Ranch	CR_S-83	1,645.63	442.80	1,650.60	165.60	168.30	12.60	0.00	0.00	0.00	0.00	0.00	6.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Creighton Ranch	CR_S-84	1,746.68	1,157.21	1,751.40	197.10	415.80	28.80	0.00	0.00	0.00	0.00	0.00	1,094.40	573.30	172.80	903.60	0.00	0.00	1,224.11	1,380.55	855.35	416.28	4.44	1,638.18	1,755.27	1,418.07	890.68	644.51
Creighton Ranch	CR_S-88	414.00	1,271.67	414.00	0.00	342.90	25.20	0.00	0.00	0.00	0.00	0.00	1,073.70	1,019.70	279.90	1,264.50	0.00	0.00	1,137.49	2,337.77	1,382.07	768.63	6.34	2,118.27	2,076.08	1,631.52	1,872.64	1,919.45
Creighton Ranch	CR_S-92	406.80	911.70	406.80	106.20	283.50	20.70	0.00	0.00	0.00	0.00	0.00	805.50	639.00	180.00	876.60	0.00	0.00	930.40	1,204.58	78.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcoran ID	CID_001	2,016.23	1,449.20	898.28	204.16	1,072.20	77.47	157.42	0.00	0.00	247.35	511.99	96.71	137.48	1,030.94	330.71	14.42	0.00	571.89	193.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcoran ID	CID_002	1,343.58	1,129.61	773.27	276.09	1,236.20	84.51	232.23	0.00	0.00	223.41	300.51	298.76	922.95	331.81	608.88	102.08	0.00	568.81	424.68	488.77	22.38	0.04	511.54	784.41	661.26	269.84	269.84
Corcoran ID	CID_003	2,295.40	2,455.53	1,798.95	272.49	737.44	2.14	61.66	0.00	0.00	255.57	468.39	957.97	1,569.26	871.26	554.29	0.00	0.00	1,334.59	925.45	845.58	281.71	41.63	208.52	0.00	0.00	0.00	0.00
Corcoran ID	CID_004	1,103.53	87.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcoran ID	CID_005	739.82	589.79	486.41	34.03	284.93	0.00	46.86	0.00	0.00	23.03	131.08	381.60	411.78	284.75	233.00	38.68	55.15	542.51	510.74	271.16	0.00	0.00	210.74	378.57	233.77	562.40	562.40
Corcoran ID	CID_006	554.73	449.73	364.07	26.09	243.38	0.00	45.95	0.00	0.00	102.98	216.29	421.32	598.01	79.91	346.99	99.29	83.11	928.85	590.30	271.35	0.00	0.00	80.23	297.22	683.04	580.99	580.99
Corcoran ID	CID_007	1,472.15	845.16	684.22	66.14	812.91	59.64	416.42	412.17	0.00	619.70	68.04	1,241.44	1,434.43	1,397.27	1,250.77	97.77	0.00	305.84	561.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcoran ID	CID_008	613.99	509.01	379.24	46.12	287.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcoran ID	CID_009	544.71	450.01	463.61	86.54	196.62	10.93	10.05	0.00	0.00	3.12	7.90	241.43	759.95	390.53	582.83	0.41	0.00	515.74	518.44	559.73	99.80	0.00	781.35	317.26	150.07	70.00	70.00
Corcoran ID	CID_010	627.86	634.04	535.86	20.58	386.64	0.00	50.68	0.00	0.00	166.19	91.94	560.84	611.82	401.46	637.43	49.50	27.84	563.95	514.06	426.49	144.73	0.05	629.21	743.55	626.48	843.38	843.38
Corcoran ID	CID_011	1,095.87	852.03	699.44	24.83	487.89	0.00	20.24	0.00	0.00	181.05	167.53	281.89	3.23	600.15	1,188.49	88.36	107.58	939.77	800.67	1,339.42	372.23	33.88	235.38	0.05	0.00	0.00	0.00
Corcoran ID	CID_012	2,646.53	2,904.86	2,402.93	731.41	2,376.85	172.13	961.47	832.87	159.92	1,247.80	0.00	0.00	0.00	1,249.09	1,340.48	495.63	552.67	2,241.76	1,920.72	1,547.25	482.90	218.98	929.05	1,794.97	1,578.69	1,413.54	1,413.54
Corcoran ID	CID_013	688.46	424.26	301.06	24.57	278.99	0.00	2.00	0.00	0.00	47.82	129.14	32.96	240.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcoran ID	CID_014	1,064.50	823.87	638.99	0.00	514.76	0.00	100.05	0.00	0.00	88.62	133.40	247.50	383.97	604.77	439.13	85.99	0.00	1,680.93	417.98	1,111.68	333.57	27.58	1,025.94	1,168.49	765.75	12.56	12.56
Corcoran ID	CID_015	983.35	681.20	471.33	35.58	420.81	0.00	84.55	0.00	0.00	102.53	108.71	631.10	613.15	336.36	580.81	58.85	12.85	465.51	172.01	151.65	0.01	660.30	307.92	122.48	0.00	0.00	0.00
Corcoran ID	CID_016	533.37	547.86	425.90	23.03	351.59	36.12	28.90	0.00	0.00	77.11	106.72	88.60	0.12	52.11	199.39	7.69	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcoran ID	CID_017	1,278.44	1,386.96	975.15	176.79	1,293.32	206.88	499.85	261.66	0.00	818.02	1,242.18	1,747.47	1,247.56	488.25	448.95	408.94	101.82	1,389.98	1,473.27	1,463.99	133.79	38.17	1,244.58	1,309.51	1,183.41	980.85	980.85

Annualized Specified Pumping

Well field	Well_ID	1990 (AF/Y)	1991 (AF/Y)	1992 (AF/Y)	1993 (AF/Y)	1994 (AF/Y)	1995 (AF/Y)	1996 (AF/Y)	1997 (AF/Y)	1998 (AF/Y)	1999 (AF/Y)	2000 (AF/Y)	2001 (AF/Y)	2002 (AF/Y)	2003 (AF/Y)	2004 (AF/Y)	2005 (AF/Y)	2006 (AF/Y)	2007 (AF/Y)	2008 (AF/Y)	2009 (AF/Y)	2010 (AF/Y)	2011 (AF/Y)	2012 (AF/Y)	2013 (AF/Y)	2014 (AF/Y)	2015 (AF/Y)	2016 (AF/Y)
Corcorian ID	CID_018	943.66	749.64	701.03	152.18	949.61	64.22	0.00	0.00	0.00	389.81	552.60	674.14	968.82	810.87	919.52	489.30	96.06	1,480.59	1,008.63	729.60	264.65	240.75	1,249.10	1,122.97	980.39	887.85	887.85
Corcorian ID	CID_019	1,141.43	1,055.25	797.10	130.18	733.06	0.00	116.50	0.00	0.00	258.48	146.36	940.79	750.55	896.51	1,415.36	306.71	199.99	1,279.65	1,343.86	929.27	154.62	81.15	1,217.95	1,479.14	1,039.33	1,226.58	1,226.58
Corcorian ID	CID_020	1,682.59	1,222.03	743.03	73.31	1,142.60	87.36	155.47	0.00	0.00	127.25	523.92	1,049.50	1,208.63	1,367.01	1,039.10	273.64	197.83	843.20	988.20	641.34	300.74	119.40	1,241.00	1,151.67	1,028.68	772.84	772.84
Corcorian ID	CID_021	973.70	1,019.30	717.27	161.22	1,259.62	42.20	283.41	765.16	116.83	574.45	1,003.18	1,414.21	600.80	1,031.67	1,343.40	264.05	220.09	1,377.89	1,046.65	649.39	393.76	12.50	974.52	792.87	797.92	128.61	128.61
Corcorian ID	CID_022	992.52	810.03	693.96	141.75	643.68	75.24	111.76	0.00	0.00	43.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_023	858.00	744.13	547.71	0.00	558.21	26.48	116.26	0.00	0.00	400.61	518.95	462.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_024	1,836.70	2,033.55	1,689.40	368.63	2,092.55	105.69	290.01	980.44	130.41	924.59	1,393.04	1,348.60	1,555.08	523.66	1,441.63	175.26	169.60	1,959.05	1,197.09	2,036.26	709.24	21.26	1,397.81	213.99	1,318.92	195.89	195.89
Corcorian ID	CID_025	2,200.45	1,742.98	1,395.37	237.66	1,347.50	141.01	330.06	599.95	134.92	599.76	1,311.78	1,680.88	1,414.68	951.18	1,395.77	369.19	311.44	2,117.80	1,833.45	1,897.24	401.36	506.80	1,865.98	1,963.80	1,541.33	1,589.06	1,589.06
Corcorian ID	CID_026	2,054.10	1,752.35	2,044.83	332.41	1,992.01	313.63	186.98	755.01	229.09	735.74	1,095.24	1,398.85	1,363.25	309.84	1,420.85	693.28	217.92	2,049.11	1,398.39	1,446.66	108.73	235.06	1,581.51	1,821.77	1,704.64	1,538.76	1,538.76
Corcorian ID	CID_027	1,346.31	1,366.56	837.69	112.16	1,086.54	79.80	538.93	671.98	0.00	369.42	704.45	1,400.45	1,106.74	693.76	388.57	366.41	76.24	332.03	645.93	1,061.16	153.59	125.36	949.56	768.78	500.00	514.07	514.07
Corcorian ID	CID_028	1,759.43	2,454.37	1,851.81	384.68	2,660.59	150.14	845.41	514.20	94.87	1,819.92	2,777.40	3,244.34	1,540.61	2,267.13	2,119.73	347.32	671.10	2,370.25	2,101.08	1,720.37	158.47	0.00	0.00	1,149.04	1,854.99	1,267.36	1,267.36
Corcorian ID	CID_029	1,869.41	2,096.46	1,683.73	321.28	2,311.90	282.17	567.92	372.23	83.58	1,331.91	2,515.63	2,623.93	1,646.22	1,753.96	1,496.24	790.66	0.20	618.44	340.29	0.00	68.66	0.00	0.00	677.62	1,008.13	194.65	194.65
Corcorian ID	CID_030	1,033.99	234.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_031	744.47	606.00	617.43	125.94	688.72	64.45	0.00	0.00	0.00	243.97	433.74	311.91	522.61	794.13	451.74	113.97	132.28	423.17	340.78	185.08	0.00	0.63	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_032	2,478.85	1,769.45	1,965.95	543.81	1,931.68	161.50	804.49	732.98	247.42	1,111.84	0.00	0.00	0.00	301.13	633.74	271.47	0.00	0.00	1,496.72	1,712.44	847.98	65.61	1,540.00	1,633.14	1,514.64	1,385.37	1,385.37
Corcorian ID	CID_033	1,379.94	899.71	1,359.42	306.02	1,413.69	150.67	288.74	0.00	0.00	734.29	1,294.95	1,373.09	1,628.69	1,515.12	1,217.83	337.36	125.60	1,773.95	1,764.90	694.03	630.17	133.66	1,365.41	812.42	22.00	453.53	453.53
Corcorian ID	CID_034	1,618.32	1,291.57	1,024.49	120.41	1,097.03	105.03	37.67	0.00	0.00	480.87	771.69	1,259.83	507.95	654.28	999.16	129.75	62.81	1,283.75	847.22	659.79	115.26	0.00	1,091.28	1,129.49	1,225.34	1,204.38	1,204.38
Corcorian ID	CID_035	1,295.37	1,693.60	1,493.93	333.89	1,721.01	111.08	512.54	273.14	215.25	1,426.21	1,590.00	499.62	0.00	985.65	2,204.94	509.33	437.62	2,442.24	2,187.69	2,419.10	871.86	58.45	1,869.01	496.05	0.00	0.00	0.00
Corcorian ID	CID_036	993.71	1,106.31	1,222.96	292.35	1,126.13	165.28	472.55	253.53	0.00	699.75	1,053.95	1,700.40	1,307.80	1,160.17	897.62	304.18	251.08	1,215.38	1,130.81	1,395.02	1,055.11	316.34	1,239.06	1,380.37	1,078.82	1,278.24	1,278.24
Corcorian ID	CID_037	1,344.64	1,981.76	1,250.45	260.64	1,723.95	150.68	600.69	341.34	65.27	128.13	419.34	741.83	1,268.20	1,484.38	1,878.90	582.54	351.38	1,532.13	1,230.39	1,151.86	538.73	23.36	612.84	0.00	-0.02	0.00	0.00
Corcorian ID	CID_038	2,139.10	2,553.65	2,343.27	360.78	2,614.25	224.79	776.11	378.39	0.00	1,367.84	1,564.95	2,101.25	2,025.91	1,740.78	1,318.42	645.71	484.89	2,221.00	2,099.24	2,049.18	810.60	27.00	1,906.51	1,063.32	2.80	369.57	369.57
Corcorian ID	CID_039	588.86	605.10	338.75	22.95	135.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_040	926.15	1,394.96	2,165.44	856.73	2,185.85	430.57	435.13	222.54	4.40	496.27	226.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_041	1,728.95	1,941.95	1,528.32	166.00	1,191.76	19.27	183.57	60.48	0.00	365.75	330.60	283.99	276.67	239.43	708.61	112.37	26.96	454.23	371.59	370.87	92.05	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_042	1,692.50	864.41	1,239.68	250.66	1,566.67	118.48	210.11	0.00	0.00	616.36	1,002.06	1,448.33	1,428.97	1,081.34	867.66	303.24	288.09	1,578.76	1,448.04	627.67	501.39	152.11	1,365.87	1,229.59	121.05	467.66	467.66
Corcorian ID	CID_043	284.50	1,025.86	788.77	0.00	945.45	0.00	188.63	0.00	0.00	450.51	352.45	735.51	786.59	229.17	743.31	634.30	278.22	1,412.90	1,390.02	1,292.64	351.27	61.51	1,094.73	1,052.46	1,104.45	1,163.51	1,163.51
Corcorian ID	CID_044	2,029.22	2,100.06	1,637.63	709.97	1,802.08	547.81	731.24	162.90	29.33	484.21	922.29	1,556.49	455.60	1,084.36	758.02	104.03	57.82	637.83	1,063.14	1,054.04	174.91	8.30	272.36	121.12	0.02	0.00	0.00
Corcorian ID	CID_045	1,224.74	1,179.34	928.36	211.27	1,088.56	110.45	292.71	464.68	0.00	936.86	1,366.65	1,420.29	1,187.86	1,415.47	757.22	403.80	260.08	1,157.39	555.50	0.03	52.14	21.44	376.24	8.26	0.00	233.10	233.10
Corcorian ID	CID_046	989.39	998.34	534.12	129.56	997.58	218.11	218.98	14.94	0.00	533.14	1,338.92	971.73	1,018.56	505.35	471.23	357.23	286.09	522.10	319.19	1,059.49	388.39	16.28	727.21	0.00	0.00	133.84	133.84
Corcorian ID	CID_047	734.05	533.05	64.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_049	1,536.11	1,242.17	1,007.51	476.14	1,683.34	172.65	513.42	502.13	102.50	962.82	61.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_050	836.66	847.12	348.50	457.36	1,775.01	319.22	759.79	617.50	114.57	166.79	0.00	772.26	1,706.63	938.81	1,506.57	365.02	464.85	1,370.48	2,063.72	1,776.53	859.53	351.17	1,995.65	1,794.20	1,651.95	1,581.65	1,581.65
Corcorian ID	CID_051	1,263.69	903.10	610.18	13.28	758.27	1.42	166.40	0.00	0.00	168.74	286.75	750.62	883.60	695.86	1,150.74	63.77	0.00	1,168.23	643.60	730.05	776.54	0.00	328.34	498.59	883.24	1,006.86	1,006.86
Corcorian ID	CID_052	1,991.91	995.68	1,036.49	0.00	749.17	80.23	149.37	87.23	0.00	0.69	414.45	750.07	1,464.56	704.16	1,556.32	127.65	0.00	1,189.35	1,446.50	831.86	576.55	72.77	1,394.98	0.36	769.40	1,783.85	1,783.85
Corcorian ID	CID_053	1,836.83	1,344.56	1,165.61	99.22	832.81	0.00	98.02	762.31	0.00	539.91	907.06	1,523.06	1,816.36	676.03	1,526.97	409.15	309.93	1,543.69	1,958.95	1,697.35	534.79	186.30	2,064.82	1,397.63	1,401.31	812.65	812.65
Corcorian ID	CID_054	1,451.67	1,174.62	1,135.27	279.69	1,492.00	217.17	413.17	229.71	121.84	743.08	1,167.10	873.06	544.35	920.54	963.95	257.76	122.34	1,244.66	1,464.17	727.87	526.74	12.28	714.45	1,678.15	1,507.17	1,201.17	1,201.17
Corcorian ID	CID_055	2,365.41	1,436.58	1,476.88	441.19	1,386.77	121.08	275.37	679.83	0.00	564.72	1,197.01	2,607.04	1,613.90	2,007.08	1,746.33	132.10	565.44	1,492.46	1,945.02	1,958.99	1,268.44	210.35	1,910.51	2,189.52	1,816.23	1,667.14	1,667.14
Corcorian ID	CID_056	738.47	899.22	907.33	30.66	525.20	0.00	90.85	0.00	0.00	137.20	146.30	240.95	112.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_057	608.80	531.36	439.66	31.84	571.42	0.00	112.63	0.00	0.00	206.13	124.98	141.95	937.95	465.40	896.06	269.11	382.14	992.97	817.96	677.84	93.08	45.76	655.66	806.32	455.50	190.09	190.09
Corcorian ID	CID_058	782.84	1,487.40	1,445.57	72.68	1,461.54	8.37	275.47	0.00	0.00	592.73	566.75	701.85	1,246.44	1,368.91	2,152.07	435.74	390.39	657.44	1,068.66	767.14	71.18	0.00	220.51	1,016.28	541.40	0.00	0.00
Corcorian ID	CID_059	1,064.65	789.51	878.63	29.92	859.07	0.00	126.21	0.00	0.00	183.55	89.17	444.63	631.08	483.03	1,203.38	83.63	156.67	1,246.42	794.91	608.13	329.65	238.86	887.67	434.38	581.54	1,126.40	1,126.40
Corcorian ID	CID_060	1,186.15	836.46	764.81	24.75	564.07	0.00	59.39	0.00	0.00	148.74	141.85	305.96	524.69	548.08	718.07	15.28	78.66	688.72	627.04	743.75	165.17	43.44	506.06	385.22	555.47	1,243.15	1,243.15
Corcorian ID	CID_061	1,839.79	1,763.78	1,343.82	96.53	1,166.08	0.00	42.90	0.00	0.00	225.47	161.15	749.72	1,345.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_062	1,510.19	1,402.87	851.17	74.78	567.56	0.00	48.19	0.00	0.00	300.69	85.41	49.06	444.21	304.33	526.07	64.98	2.41	164.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_063	2,116.83	2,169.74	1,729.88	664.94	1,792.09	275.77	981.68	887.72	167.38	1,181.73	0.00	0.00	0.00	1,438.93	1,750.63	550.79	538.72	1,868.28	1,484.65	1,675.69	1,293.54	203.43	965.59	280.73	0.03	0.00	0.00
Corcorian ID	CID_064	2,074.68	1,327.64	1,123.30	543.00	1,087.03	2.46	512.08	662.32	126.51	746.76	0.00	0.00	0.00	883.95	1,208.47	440.98	383.93	699.74	0.00	1,510.93	548.35	329.55	1,622.10	816.65	1,052.12	822.86	822.86
Corcorian ID	CID_065	1,942.43	1,804.73	2,012.33	8.49	1,601.31	235.59	660.05	338.52	68.98	7.07	56.60	809.67	361.00	912.87	570.92	294.10	290.66	1,146.88	112.93	27.01	0.87	14.62	706.91	728.36	433.30	489.35	489.35
Corcorian ID	CID_066	898.36	2,125.69	1,738.59	341.96	2,000.57	224.44	632.38	306.49	102.26	1,174.19	1,328.18	1,311.76	1,753.59	1,384.98	1,760.36	518.70	352.57	1,539.70	1,329.17	615.29	680.97	44.63	627.21	1,497.67	1,680.60	1,581.47	1,581.47
Corcorian ID	CID_067	501.07	1,786.21	1,343.64	0.90	1,171.53	362.37	630.97	259.32	60.60	1,063.45	1,475.18	2,016.68	1,693.56	1,248.29	738.11	541.95	256.87	1,379.68	708.03	1,415.60	600.85	44.10	1,440.96	1,606.41	1,662.27	1,577.51	1,577.51
Corcorian ID	CID_068	686.17	2,321.54	2,221.60	590.11	2,542.92	257.96	448.15	331.17	75.84	732.05	1,387.50	1,606.13	2,023.64	2,071.91	2,455.38	783.78	483.49	2,285.23	2,022.20	1,924.91	891.60	122.02	2,103.11	1,980.63	1,948.43	2,031.33	2,031.33
Corcorian ID	CID_069	660.62	1,174.00	1,257.34	83.78	910.55	0.00	118.40	0.00	0.00	322.60	254.88	834.92	1,318.93	1,334.52	1,335.06	142.86	151.90	1,038.21	966.18	1,481.98	581.05	59.73	1,369.45	1,773.00	1,234.69	1,662.08	1,662.08
Corcorian ID	CID_070	184.97	275.55	165.35	27.69	107.46	4.60	21.23	134.21	15.16	14.33	0.00	22.15	257.37	230.30	197.92	17.42	7.54	189.28	10.66	14.26	63.64	6.27	0.00	124.92	124.32	137.06	137.06
Corcorian ID	CID_071	0.00	118.15	142.04	0.00	103.91	9.51	56.51	153.38	17.39	32.98	93.47	255.58	240.42	184.43	216.73	27.04	10.50	59.65	0.00	21.80	106.99	12.30	320.79	344.77	231.63	240.45	240.45
Corcorian ID	CID_072	0.00	95.97	109.90	36.91	29.04	7.31	8.98	22.36	0.00	9.99	104.91	119.09	80.83	0.00	3.58	7.98	6.65	0.00	0.00	0.00	-0.90	0.89	0.01	0.00	0.00	0.04	0.04
Corcorian ID	CID_073	0.00	142.84	310.98	67.77	234.63	11.31	11.59	0.00	0.00	122.98	180.62	243.11	343.09	202.04	163.85	22.48	16.64	226.31	202.17	0.00	60.93	100.01	0.00	196.04	85.09	0.00	0.00
Corcorian ID	CID_074	0.00	0.00	364.26	397.13	1,245.96	125.65	293.08	0.00	0.00	622.39	620.98	1,253.41	1,834.78	1,616.65	2,471.79	1,059.92	512.47	2,121.78	2,147.19	1,894.95	865.95	105.57	330.88	0.57	0.00	0.00	0.00
Corcorian ID	CID_075	0.00	0.00	251.55	225.46	989.02	0.00	105.87	0.00	0.00	305.79	314.55	1,173.34	1,238.55	1,362.63	1,757.47	111.55	91.83	978.03	819.89	843.24	0.00	0.00	2.00	959.89	1,013.14	1,098.97	1,098.97
Corcorian ID	CID_076	0.00	0.00	0.00	0.00	234.89	111.78	634.61	541.05	0.00	272.51	610.40	1,860.09	1,638.49	1,356.17	1,835.78	425.89	380.38	2,196.13	2,152.32	1,863.13	790.24	97.44	1,954.80	2,143.33	219.61	0.36	0.36
Corcorian ID	CID_077	0.00	0.00	0.00	0.00	0.00	0.00	0.00	123.51	0.00	237.17	187.97	225.90	298.14	320.75	99.52	57.46	74.24	140.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_078	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,668.87	1,369.61	1,606.41	1,482.16	308.50	144.84	982.56	962.93	729.61	0.00	81.84	1,049.74	1,049.20	1,186.57	72.24	72.24
Corcorian ID	CID_079	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,735.25	1,734.52	1,824.40	1,342.88	325.61	197.09	1,309.95	1,359.77	1,443.55	340.79	170.81	1,080.45	550.07	746.57	907.46	907.46
Corcorian ID	CID_080	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,660.37	1,583.12	1,635.26	1,523.73	347.82	282.27	1,443.19	871.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_081	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	487.72	1,518.23	1,538.22	152.23	78.55	1,271.28	1,444.23	1,641.26	313.71	99.39	444.08	722.62	1,122.74	1,585.55	1,585.55
Corcorian ID	CID_082	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	315.07	1,287.24	245.95	186.05	1,239.63	492.18	922.72	497.22	18.21	1,269.58	1,409.00	1,376.68	1,127.54	1,127.54
Corcorian ID	CID_083	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	91.59	663.41	437.53	112.73	1,368.03	1,577.93	1,328.94	465.39	222.46	1,239.53	1,601.77	1,425.61	869.57	869.57
Corcorian ID	CID_084	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	125.95	183.58	93.35	834.67	947.18	988.60	223.77	37.16	540.41	0.01	49.57	987.79	987.79
Corcorian ID	CID_085	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	534.63	296.53	1,886.07	1,778.62	1,746.80	709.95	220.89	1,615.89	1,673.35	1,168.21	0.00	0.00
Corcorian ID	CID_086	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	160.70	1,036.72	330.95	1,000.21	397.67	5.91	816.21	398.68	0.04	0.00	0.00
Corcorian ID	CID_087	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	378.71	1,827.95	1,247.36	1,274.21	211.04	224.24	1,023.00	1,371.43	1,466.07	1,521.31	1,521.31
Corcorian ID	CID_088	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,263.58	1,261.12	1,461.71	246.31	0.00	1,146.15	1,440.28	1,179.16	1,313.66	1,313.66
Corcorian ID	CID_089	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	349.93	538.06	1,434.87	454.84	0.00	1,193.74	1,389.61	0.03	0.00	0.00
Corcorian ID	CID_090	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	607.56	1,291.87	467.41	0.00	342.47	1,557.85	1,126.84	1,427.48	1,427.48
Corcorian ID	CID_091	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	859.04	1,767.72	592.13	0.01	1,413.28	2,641.50	1,826.26	1,869.65	1,869.65

Annualized Specified Pumping

Well field	Well_ID	1990 (AF/Y)	1991 (AF/Y)	1992 (AF/Y)	1993 (AF/Y)	1994 (AF/Y)	1995 (AF/Y)	1996 (AF/Y)	1997 (AF/Y)	1998 (AF/Y)	1999 (AF/Y)	2000 (AF/Y)	2001 (AF/Y)	2002 (AF/Y)	2003 (AF/Y)	2004 (AF/Y)	2005 (AF/Y)	2006 (AF/Y)	2007 (AF/Y)	2008 (AF/Y)	2009 (AF/Y)	2010 (AF/Y)	2011 (AF/Y)	2012 (AF/Y)	2013 (AF/Y)	2014 (AF/Y)	2015 (AF/Y)	2016 (AF/Y)
Corcorian ID	CID_092	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	859.35	1,550.38	437.84	244.98	1,141.08	1,105.51	1,066.16	1,298.44	1,298.44
Corcorian ID	CID_093	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	741.70	1,487.20	372.01	165.25	750.50	1,032.04	999.00	1,253.67	1,253.67
Corcorian ID	CID_094	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	896.47	1,692.61	626.91	145.20	1,171.04	1,738.69	1,475.47	1,674.79	1,674.79
Corcorian ID	CID_095	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	627.84	1,662.93	573.14	87.26	1,072.90	1,293.26	1,510.39	1,427.72	1,427.72
Corcorian ID	CID_096	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.47	54.99	317.46	3,420.23	2,889.80	3,510.53	3,510.53
Corcorian ID	CID_097	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	155.44	3,085.52	2,159.80	2,290.52	2,290.52
Corcorian ID	CID_098	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,056.92	1,361.42	1,473.69	1,473.69
Corcorian ID	CID_099	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,209.37	517.23	517.23
Corcorian ID	CID_100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,885.47	1,884.87	1,884.87
Corcorian ID	CID_101	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	74.34	975.48	975.48
Corcorian ID	CID_102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corcorian ID	CID_105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Westlands WD	WWD_18S19E-18Q01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_18S19E-19K01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_18S19E-20E01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_18S19E-20F01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_18S19E-28M02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_18S19E-29D01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_18S19E-31N01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-04M01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-05K01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-07N02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-08N04	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-10E02	550.08	725.53	680.15	461.72	573.98	338.21	360.23	325.08	253.81	400.51	512.10	606.57	629.47	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.18	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-15D02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-15D03	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-15E02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-15N01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-18C01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-19K01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-26D03	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-26E03	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-27D01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-27M01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-28K02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-29A01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-29A02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-29A03	328.85	485.30	444.10	316.62	391.76	250.01	282.69	247.40	199.56	283.18	410.21	459.73	477.57	329.33	290.74	199.55	205.46	399.29	552.81	580.16	372.56	215.27	401.83	520.17	556.07	566.97	556.07
Westlands WD	WWD_19S19E-29J01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-30L01	655.02	887.19	827.97	461.72	671.23	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-30M01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-30M02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-31A01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-31D03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_19S19E-31N03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_19S19E-32K01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-33E01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_19S19E-33Q02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S18E-24H01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S18E-25E01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S18E-26K01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S18E-35D02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S18E-35E03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S18E-36C03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S18E-36D05	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-02A01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-02D01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-02E02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-02J01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-02N01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-04D02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-04D03	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-04H01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-06N04	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-07D01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-07G01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-07G02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-08M01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-09D02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-09D03	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-09N02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11

Annualized Specified Pumping

Well field	Well_ID	1990 (AF/Y)	1991 (AF/Y)	1992 (AF/Y)	1993 (AF/Y)	1994 (AF/Y)	1995 (AF/Y)	1996 (AF/Y)	1997 (AF/Y)	1998 (AF/Y)	1999 (AF/Y)	2000 (AF/Y)	2001 (AF/Y)	2002 (AF/Y)	2003 (AF/Y)	2004 (AF/Y)	2005 (AF/Y)	2006 (AF/Y)	2007 (AF/Y)	2008 (AF/Y)	2009 (AF/Y)	2010 (AF/Y)	2011 (AF/Y)	2012 (AF/Y)	2013 (AF/Y)	2014 (AF/Y)	2015 (AF/Y)	2016 (AF/Y)
Westlands WD	WWD_20S19E-10E01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-11D03	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-11E01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-14A01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-14E01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-14F01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-14H01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-17M01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-17M02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-18D02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-19D03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-19N01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-19N02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-19R01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-20D01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-20D02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-20D03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-23K01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-26C01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-31D01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_20S19E-35D02	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_20S19E-35M01	686.94	957.05	941.26	461.72	765.21	338.21	360.23	325.08	253.81	413.11	512.10	660.00	688.37	378.27	364.24	199.55	205.46	470.25	653.10	659.00	378.80	215.27	497.87	600.17	728.11	711.26	728.11
Westlands WD	WWD_21S17E-24J01	324.49	578.77	528.71	222.32	333.06	76.85	59.76	85.38	112.32	176.41	280.46	342.34	301.91	155.73	140.09	21.62	7.59	219.12	303.24	431.66	160.11	0.00	247.66	478.21	647.24	652.89	647.24
Westlands WD	WWD_21S18E-01B02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-01N01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-02C03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-02D03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-03G01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-09L01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-10B01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-11C01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-11D03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-11N01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-11Q01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-14M07	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-15M02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-16N01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-16P01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-17N03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-18R01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-22B05	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-22E01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-23B02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-23D07	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-23E01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-26N01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-27B01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-27E01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-27K02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-28G06	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-28Q02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-29E02	324.49	578.77	528.71	222.32	333.06	76.85	59.76	85.38	112.32	176.41	280.46	342.34	301.91	155.73	140.09	21.62	7.59	219.12	303.24	431.66	160.11	0.00	247.66	478.21	647.24	652.89	647.24
Westlands WD	WWD_21S18E-29N02	324.49	578.77	528.71	222.32	333.06	76.85	59.76	85.38	112.32	176.41	280.46	342.34	301.91	155.73	140.09	21.62	7.59	219.12	303.24	431.66	160.11	0.00	247.66	478.21	647.24	652.89	647.24
Westlands WD	WWD_21S18E-31H01	324.49	578.77	528.71	222.32	333.06	76.85	59.76	85.38	112.32	176.41	280.46	342.34	301.91	155.73	140.09	21.62	7.59	219.12	303.24	431.66	160.11	0.00	247.66	478.21	647.24	652.89	647.24
Westlands WD	WWD_21S18E-32R01	324.49	578.77	528.71	222.32	333.06	76.85	59.76	85.38	112.32	176.41	280.46	342.34	301.91	155.73	140.09	21.62	7.59	219.12	303.24	431.66	160.11	0.00	247.66	478.21	647.24	652.89	647.24
Westlands WD	WWD_21S18E-33G01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-33N02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-35D01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-35Q01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S18E-35Q02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-06B01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-07D01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-07N02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-17E01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-17Q01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-18N03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-19C03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-20D01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-30D04	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_21S19E-30D05	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-01E02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-01K01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-02G05	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-03B01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00

Annualized Specified Pumping

Well field	Well_ID	1990 (AF/Y)	1991 (AF/Y)	1992 (AF/Y)	1993 (AF/Y)	1994 (AF/Y)	1995 (AF/Y)	1996 (AF/Y)	1997 (AF/Y)	1998 (AF/Y)	1999 (AF/Y)	2000 (AF/Y)	2001 (AF/Y)	2002 (AF/Y)	2003 (AF/Y)	2004 (AF/Y)	2005 (AF/Y)	2006 (AF/Y)	2007 (AF/Y)	2008 (AF/Y)	2009 (AF/Y)	2010 (AF/Y)	2011 (AF/Y)	2012 (AF/Y)	2013 (AF/Y)	2014 (AF/Y)	2015 (AF/Y)	2016 (AF/Y)
Westlands WD	WWD_22S18E-04H01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-05B01	324.49	578.77	528.71	222.32	333.06	76.85	59.76	85.38	112.32	176.41	280.46	342.34	301.91	155.73	140.09	21.62	7.59	219.12	303.24	431.66	160.11	0.00	247.66	478.21	647.24	652.89	647.24
Westlands WD	WWD_22S18E-10A01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-10C01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-11C02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-11C03	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-11G01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-12R01	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_22S18E-13K02	311.52	472.04	476.59	181.10	319.20	90.51	81.94	82.06	67.59	130.95	153.24	309.43	288.00	200.33	216.07	35.99	56.71	149.91	276.10	338.57	136.64	34.49	310.36	401.68	562.00	523.80	562.00
Westlands WD	WWD_FARM_24_141	951.61	864.42	802.36	423.25	712.63	212.87	419.18	510.96	243.94	496.07	558.07	770.78	779.45	759.89	763.70	239.73	166.23	639.83	707.60	747.47	496.10	212.44	632.85	857.61	918.01	900.73	918.01
Westlands WD	WWD_FARM_25_012	613.28	515.09	548.89	17.77	269.36	16.44	41.24	119.70	65.89	127.75	104.06	441.50	427.47	413.57	529.14	116.35	52.19	289.39	509.78	542.56	89.33	4.46	311.87	800.63	1,036.48	1,023.31	1,036.67
Westlands WD	WWD_FARM_25_044	613.28	515.09	548.89	17.77	269.36	16.44	41.24	119.70	65.89	127.75	104.06	441.50	427.47	413.57	529.14	116.35	52.19	289.39	509.78	542.56	89.33	4.46	311.87	800.63	1,036.48	1,023.31	1,036.67
Westlands WD	WWD_FARM_26_001	275.60	386.59	450.92	156.07	326.58	44.00	104.66	157.88	36.72	316.41	86.83	162.60	181.16	157.15	177.76	9.55	0.00	89.14	208.00	178.48	2.45	0.00	23.43	190.50	369.83	287.40	369.83
Westlands WD	WWD_FARM_26_003	275.60	386.59	450.92	156.07	326.58	44.00	104.66	157.88	36.72	316.41	86.83	162.60	181.16	157.15	177.76	9.55	0.00	89.14	208.00	178.48	2.45	0.00	23.43	190.50	369.83	287.40	369.83
Westlands WD	WWD_FARM_26_008	275.60	386.59	450.92	156.07	326.58	44.00	104.66	157.88	36.72	316.41	86.83	162.60	181.16	157.15	177.76	9.55	0.00	89.14	208.00	178.48	2.45	0.00	23.43	190.50	369.83	287.40	369.83
Westlands WD	WWD_FARM_26_015	275.60	386.59	450.92	156.07	326.58	44.00	104.66	157.88	36.72	316.41	86.83	162.60	181.16	157.15	177.76	9.55	0.00	89.14	208.00	178.48	2.45	0.00	23.43	190.50	369.83	287.40	369.83
Westlands WD	WWD_FARM_26_029	275.60	386.59	450.92	156.07	326.58	44.00	104.66	157.88	36.72	316.41	86.83	162.60	181.16	157.15	177.76	9.55	0.00	89.14	208.00	178.48	2.45	0.00	23.43	190.50	369.83	287.40	369.83
City of Hanford	Hanford_02	102.40	99.06	105.88	111.91	120.67	118.07	142.15	143.82	129.29	147.07	151.50	156.30	269.50	233.05	299.93	328.43	299.61	334.24	305.46	3.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
City of Hanford	Hanford_11	113.39	112.69	122.58	128.31	140.26	137.11	168.62	167.88	159.18	179.28	184.81	192.29	234.03	230.14	275.32	184.07	266.40	311.91	324.67	291.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00
City of Hanford	Hanford_18	186.85	181.48	191.61	204.13	219.22	215.95	254.91	256.53	234.21	263.63	270.19	280.47	520.85	405.58	331.20	317.92	336.53	559.96	854.08	615.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
City of Hanford	Hanford_31	261.74	251.86	263.87	280.59	299.14	294.73	340.76	344.91	307.34	348.05	356.58	368.32	822.26	681.10	697.40	548.66	670.78	707.48	349.60	91.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
City of Hanford	Hanford_32	96.22	95.54	103.07	107.80	116.74	115.68	141.62	140.22	130.28	147.78	151.05	157.56	225.24	134.37	210.78	314.05	158.14	249.19	280.72	154.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00
City of Hanford	Hanford_33	206.19	193.86	204.59	218.47	235.94	226.56	269.86	276.06	243.13	274.60	286.68	291.22	587.13	73.84					13.89	426.27	487.42	935.72	285.66	312.93	48.94	31.23	11.56
City of Hanford	Hanford_34	614.68	597.66	631.99	667.18	710.53	705.48	816.25	819.50	741.51	838.28	855.84	887.24	1,846.51	1,293.61	1,238.78	1,121.06	1,770.59	1,731.57	1,188.37	888.77	233.03	0.00	0.00	0.00	0.00	0.00	0.00
City of Hanford	Hanford_35	285.27	272.85	287.83	305.56	327.44	319.54	372.41	377.61	337.77	381.36	393.84	404.11	842.03	1,097.87	1,122.26	1,277.45	854.27	464.84	832.93	403.41	347.71	315.84	288.32	278.63	25.49	58.73	68.08
City of Hanford	Hanford_36	211.55	201.39	212.34	226.34	242.33	236.11	276.88	283.06	249.97	282.84	292.62	299.34	629.07	626.07	628.28	901.04	795.99	178.64	995.84	451.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
City of Hanford	Hanford_37																73.90	435.65	374.67	266.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
City of Hanford	Hanford_38	100.71	97.15	105.18	110.65	120.04	116.39	143.06	145.01	129.90	149.22	154.17	159.32	241.52	179.08	116.58	163.01	200.08	223.35	322.31	174.12	283.19	262.46	377.34	430.89	146.21	139.46	5.52
City of Hanford	Hanford_40	404.29	393.17	416.59	438.20	466.63	461.04	535.33	535.83	485.52	548.53	562.80	581.17	1,192.58	1,109.49	1,047.04	862.25	123.37	1,717.66	1,523.56	525.05	601.79	446.13	456.49	814.28	1,077.77	361.24	536.60
City of Hanford	Hanford_41	700.43	682.01	725.15	766.28	818.86	810.69	968.71	974.11	871.39	993.08	1,014.91	1,053.27	1,998.41	357.39	1,593.93	1,953.86	1,871.00	1,941.46	1,909.83	1,060.98	0.00	0.00	0.00	0.00	0.00	0.00	126.92
City of Hanford	Hanford_42	676.84	646.25	684.73	728.22	782.32	760.35	899.56	916.40	815.26	924.48	956.39	981.47	1,916.88	1,433.44	1,197.86	0.00	0.00	0.00	707.22	1,259.53	994.28	1,246.09	1,592.03	1,671.66	1,921.12	1,343.45	1,222.72
City of Hanford	Hanford_43																			80.08	97.72	4.07	96.72	192.33	511.79	520.62	1,265.51	964.64
City of Hanford	Hanford_44																			0.00	67.06	1,326.56	2,300.01	2,306.05	497.23	1,769.99	1,601.15	1,432.46
City of Hanford	Hanford_45(16)	592.06	571.40	602.83	637.05	679.68	669.17	775.47	779.09	701.87	792.49	813.78	839.64	1,789.82	678.50	378.47	433.81	391.24	404.94	0.00	1,182.88	2,173.71	1,624.04	1,697.82	1,836.68	1,207.41	3,184.25	1,505.65
City of Hanford	Hanford_46(8)	387.84	394.83	424.30	442.70	477.72	480.41	581.43	567.39	543.16	611.14	619.96	653.80	908.09	0.55						962.51	1,337.10	643.47	602.00	997.27	1,119.86	926.88	620.64
City of Hanford	Hanford_47(22)	254.40	252.00	271.68	284.61	305.69	303.22	373.64	371.65	338.02	387.11	394.79	412.43	634.56	2.17	1.27	0.17	0.28	0.00	0.00	0.00	127.95	1,195.99	1,034.26	1,497.96	811.55	617.40	694.24
City of Hanford	Hanford_48(25)	296.46	296.08	315.90	330.28	351.96	354.39	423.87	416.57	382.60	436.75	440.52	464.36	834.77	564.41	547.16	711.74	229.77	503.55	344.90	0.00	307.79	951.61	782.60	1,647.20	639.09	246.90	957.11
City of Hanford	Hanford_49	389.12	379.55	405.57	427.31	457.80	453.78	543.29	545.98	490.71	557.99	571.50	591.86	1,064.12	48.56		440.11	356.84	522.45	637.00	361.32	0.00	0.00	0.00	0.00	0.00	0.00	47.23
City of Lemoore	LEM_02	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	215.75	178.77	233.66	284.18	574.32	590.44	594.39	634.47	620.90	594.92	593.46	0.00	75.87	0.00	360.17	0.00
City of Lemoore	LEM_04	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	215.75	178.77	233.66	284.18	574.32	590.44	594.39	634.47	620.90	594.92	593.46	446.96	836.73	1,068.20	360.96	4.38
City of Lemoore	LEM_05	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	215.75	178.77	233.66	284.18	574.32	590.44	594.39	634.47	620.90	594.92	593.46	0.00	86.80	268.55	382.28	60.44
City of Lemoore	LEM_06	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	215.75	178.77	233.66	284.18	574.32	590.44	594.39	634.47	620.90	594.92	593.46	1,811.88	1,454.78	886.18	599.81	947.31
City of Lemoore	LEM_07	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	215.75	178.77	233.66	284.18	574.32	590.44	594.39	634.47	620.90	594.92	593.46	185.36	589.68	101.76	461.95	427.91
City of Lemoore	LEM_08	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	292.25	357.47	315.26	423.81	600.92	616.80	601.25	611.47	501.97	548.90	560.06	132.40	75.87	0.00	360.17	0.00
City of Lemoore	LEM_09	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	211.56	191.52	228.92	394.94	559.85	540.33	450.23	538.57	625.12	548.15	528.96	136.28	75.87	0.00	360.17	0.00
City of Lemoore	LEM_10	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	526.94	1,420.70	2,072.97	2,416.84	2,570.42	2,298.46	2,205.27	574.32	590.44	594.39	634.47	620.90	594.92	593.46	1,809.74	1,482.52	1,784.18	862.75	1,541.31
City of Lemoore	LEM_11	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	215.75	3,175.77	4,259.05	1,243.12	574.32	590.44	594.39	634.47	620.90	594.92	593.46	661.39	622.93	713.77	506.67	599.20
City of Lemoore	LEM_12	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	473.76	2,597.27	1,461.96	2,834.40	574.32	590.44	594.39	634.47	620.90	594.92	593.46	972.56	873.70	126.17	543.30	535.47
City of Lemoore	LEM_13	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	215.75	178.77	233.66	284.18	574.32	590.44	594.39	634.47	620.90	594.92	593.46	853.49	1,279.86	1,636.77	862.22	1,445.57
City of Lemoore	LEM_14	290.78	282.54	299.17	316.07	337.92	333.04	390.89	392.77	339.74	309.35	261.46	215.75	178.77	233.66	284.18	574.32	590.44	594.39	634.47	620.90	594.92	593.46	841.73	460.35	1,056.74	709.06	799.97
Apex Ranch	APEX_RW-1	--	--	--	--	--	--	--	--	--	--	--	--	0	105.2	182.4	0	1387.8	1263.8	1087	1535.4	1269	0	1808.8	994	59.6	0	0
Apex Ranch	APEX_RW-2	--	--	--	--	--	--	--	--	--	--	--	--	0	105.2	182.4	0	1387.8	1263.8	1087	1535.4	1269	0	1808.8	994	59.6	0	0
Apex Ranch	APEX_RW-3	--	--	--	--	--	--	--	--	--	--	--	--	0	105.2	182.4	0	1387.8	1263.8	1087	1535.4	1269	0	1808.8	994	59.6	0	0
Apex Ranch	APEX_RW-4	--	--	--	--	--	--	--	--	--	--	--	--	0	105.2	182.4	0	1387.8	1263.8	1087	1535.4	1269	0	1808.8	994	59.6	0	0
Apex Ranch	APEX_RW-5	--	--	--	--	--	--	--	--	--	--	--	--	0	105.2	182.4	0	1387.8	1263.8	1087	1535.4	1269	0	1808.8	994	59.6	0	0

Appendix D5
Observed and Simulated Target Well Hydrographs

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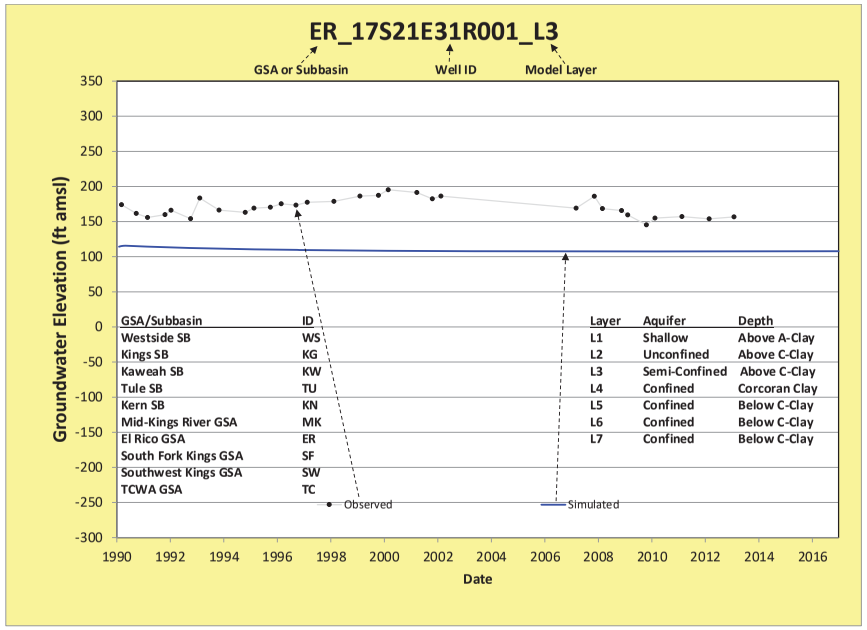
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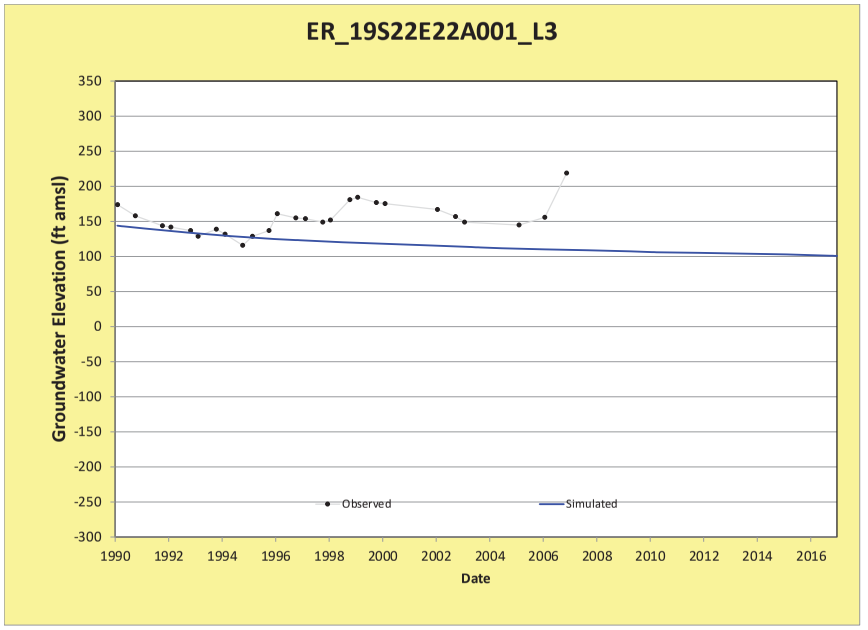
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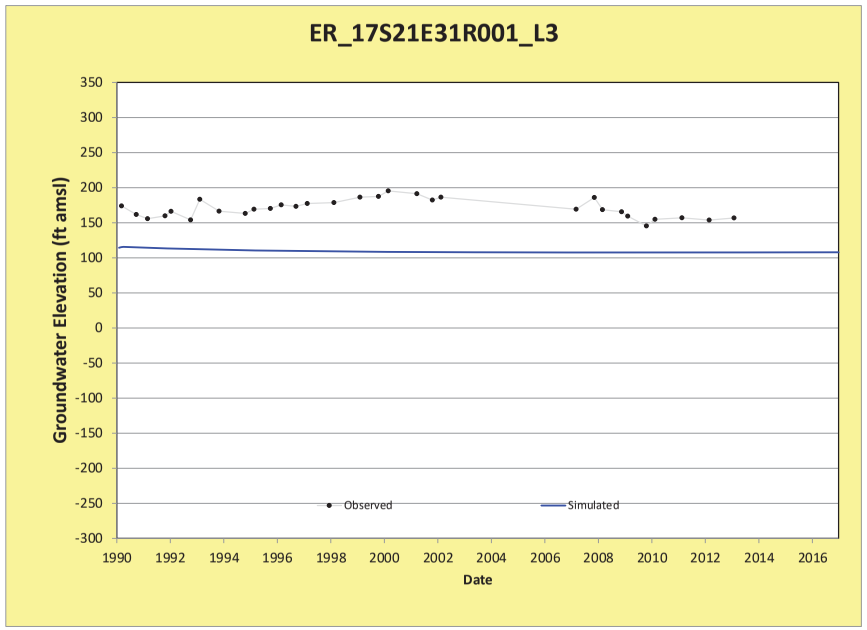
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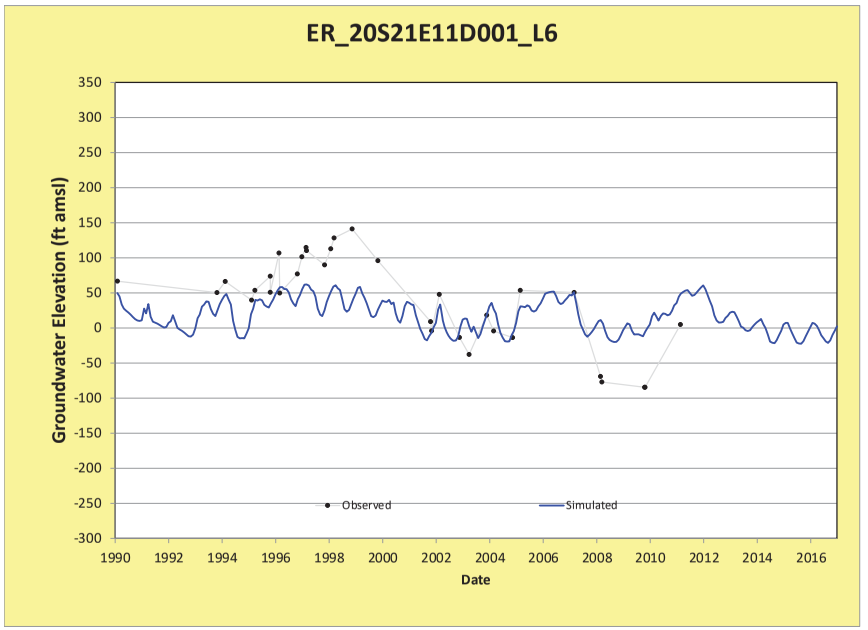
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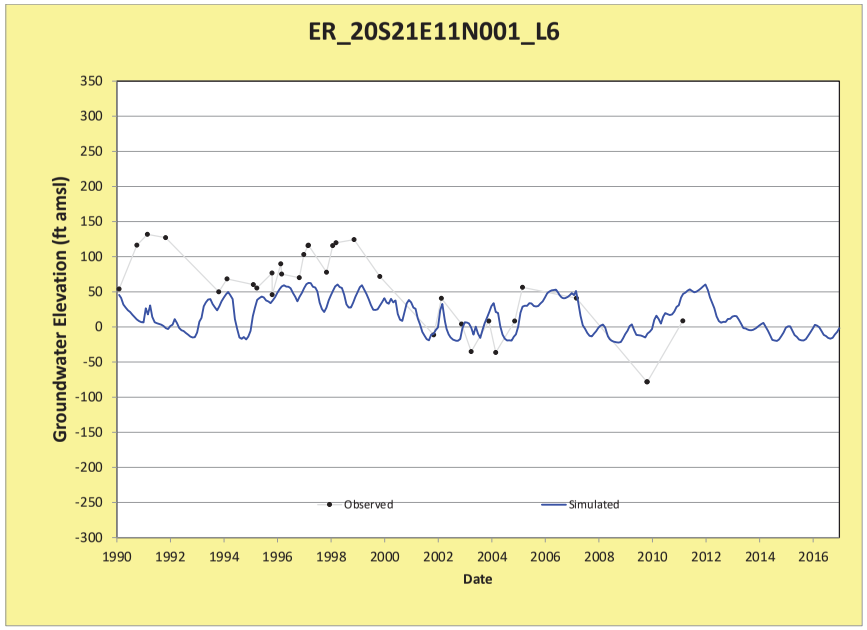
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WS_18S22E06D001_L4	116	WS_20S22E19L001_L6	130	WS_23S24E29N001_L6	143
WS_18S23E14A001_L3	117	WS_20S22E19N001_L6	130	WS_23S25E30H002_L3	144
WS_18S23E16R001_L3	117	WS_20S22E27A001_L3	130	WS_24S24E04R001_L6	144
WS_19S19E03M001_L6	117	WS_20S22E36A001_L2	131	WS_24S24E25J001_L3	144
WS_19S19E15D002_L6	117	WS_20S23E11C001_L3	131	WS_24S24E32K002_L3	144
WS_19S19E15E001_L6	118	WS_20S23E18R001_L3	131	WS_24S24E34F001_L3	145
WS_19S19E19K001_L6	118	WS_20S23E21B001_L3	131	WS_25S21E24H001_L4	145
WS_19S19E20G001_L6	118	WS_20S23E26C001_L3	132	WS_25S22E27J001_L6	145
WS_19S19E28K001_L6	118	WS_20S23E27D001_L3	132	WS_25S23E01M003_L6	145
WS_19S19E30B002_L6	119	WS_20S24E30J002_L3	132	WS_25S23E28D001_L3	146
WS_19S19E31D003_L6	119	WS_21S18E11D003_L6	132	WS_25S23E33E001_L3	146
WS_19S19E32N001_L6	119	WS_21S18E12N001_L1	133	WS_25S24E26F001_L6	146
WS_19S19E33E001_L6	119	WS_21S18E15C001_L6	133	WS_25S24E27R003_L3	146
WS_19S20E06L001_L3	120	WS_21S18E15D004_L6	133	WS_25S24E30R002_L6	147
WS_19S20E07F001_L3	120	WS_21S18E15M001_L6	133	WS_25S24E36G001_L3	147
WS_19S21E07R001_L3	120	WS_21S18E21H001_L6	134	WS_25S25E19R003_L3	147
WS_19S21E10R001_L3	120	WS_21S18E26C001_L6	134	WS_26S23E10E001_L3	147
WS_19S21E15J002_L3	121	WS_21S18E26N001_L6	134	WS_26S23E13R002_L6	148
WS_19S21E21C001_L3	121	WS_21S18E27B001_L3	134	WS_26S24E11P002_L6	148
WS_19S21E23J001_L3	121	WS_21S18E27K001_L3	135	WS_26S25E05C001_L3	148
WS_19S21E26B001_L3	121	WS_21S18E27K001_L6	135	WS_26S25E07R001_L3	148
WS_19S21E29M001_L6	122	WS_21S18E32C001_L6	135	WS_LEM_9_L6	149
WS_19S22E02K001_L3	122	WS_21S18E33K001_L3	135	WS_LEM_N-2_L5	149

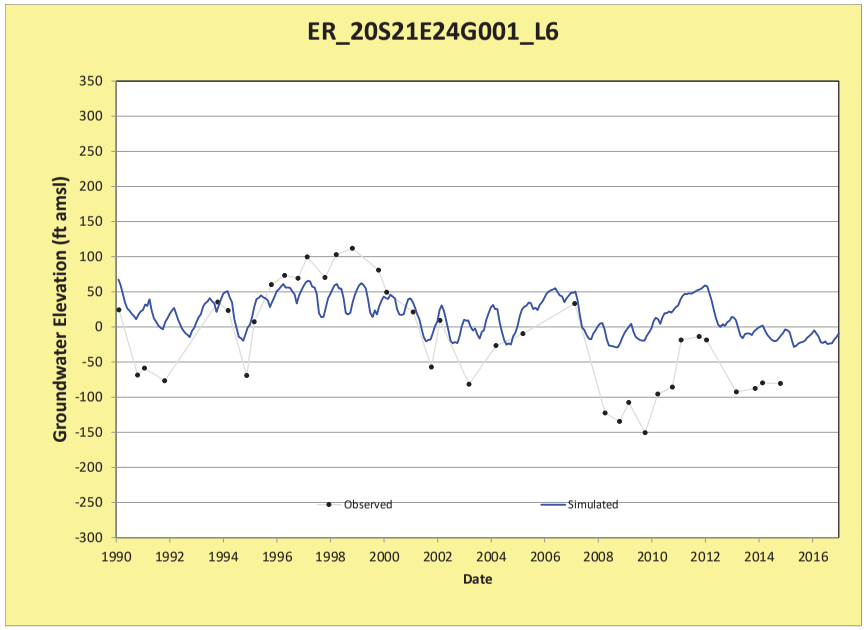

ER_17S21E31R001_L3
GSA or Subbasin
Well ID
Model Layer
Groundwater Elevation (ft amsl)
Date
Observed
Simulated
GSA/Subbasin ID
Westside SB WS
Kings SB KG
Kaweah SB KW
Tule SB TU
Kern SB KN
Mid-Kings River GSA MK
El Rico GSA ER
South Fork Kings GSA SF
Southwest Kings GSA SW
TCWA GSA TC
Layer Aquifer Depth
L1 Shallow Above A-Clay
L2 Unconfined Above C-Clay
L3 Semi-Confined Above C-Clay
L4 Confined Corcoran Clay
L5 Confined Below C-Clay
L6 Confined Below C-Clay
L7 Confined Below C-Clay

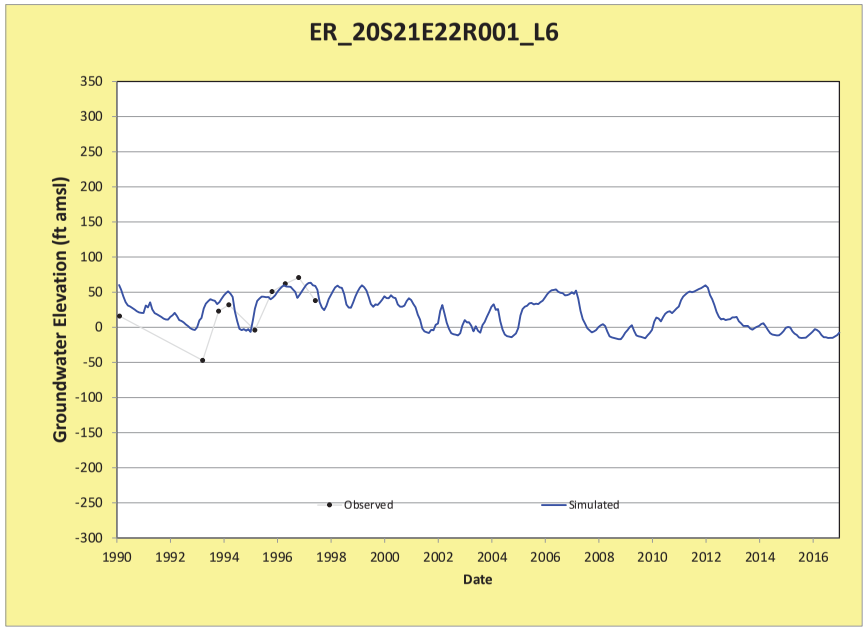

ER_19S22E22A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

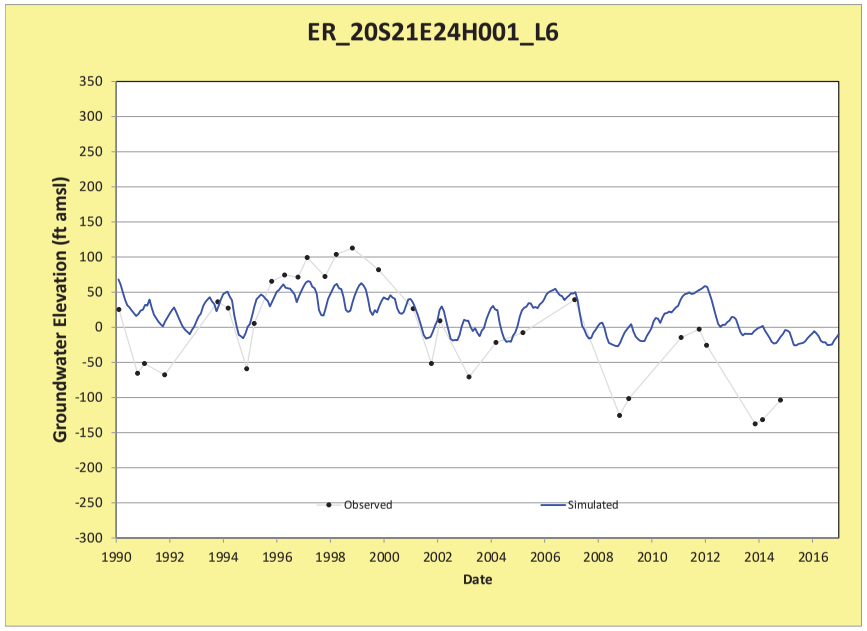

ER_17S21E31R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

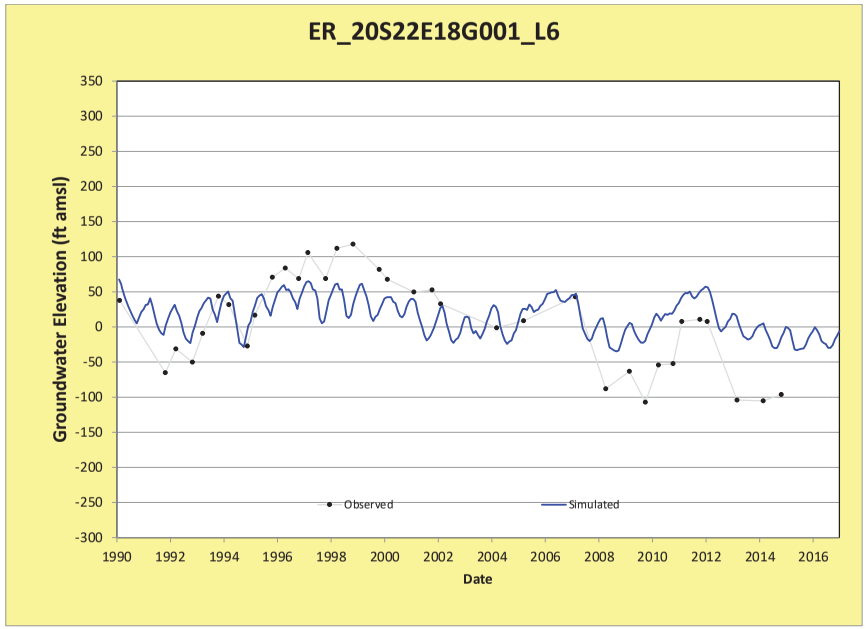

ER_20S21E11D001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

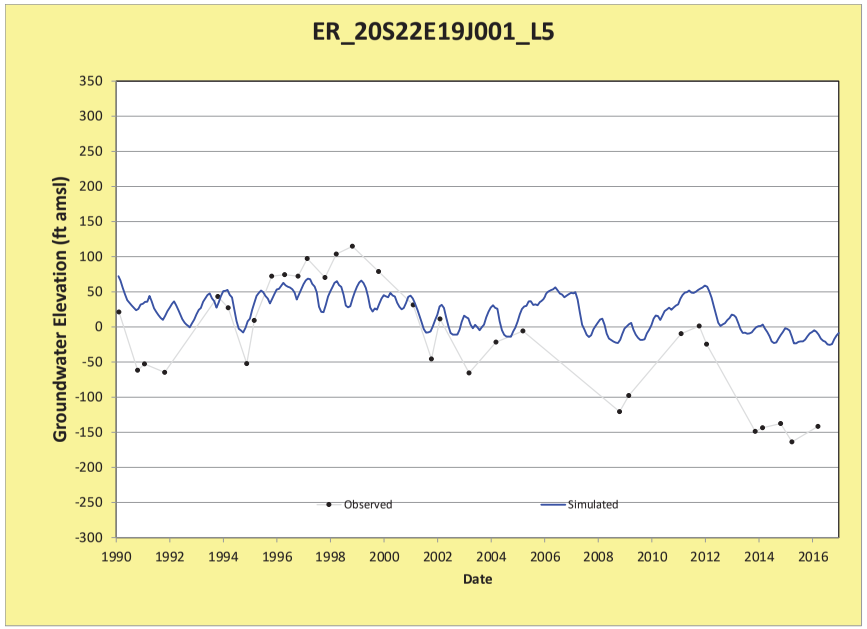

ER_20S21E11N001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

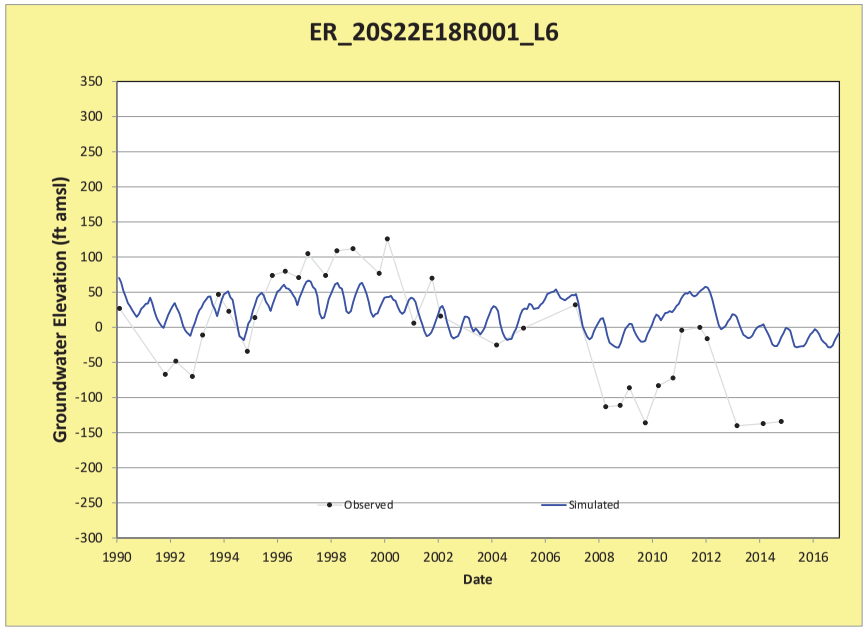

ER_20S21E24G001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

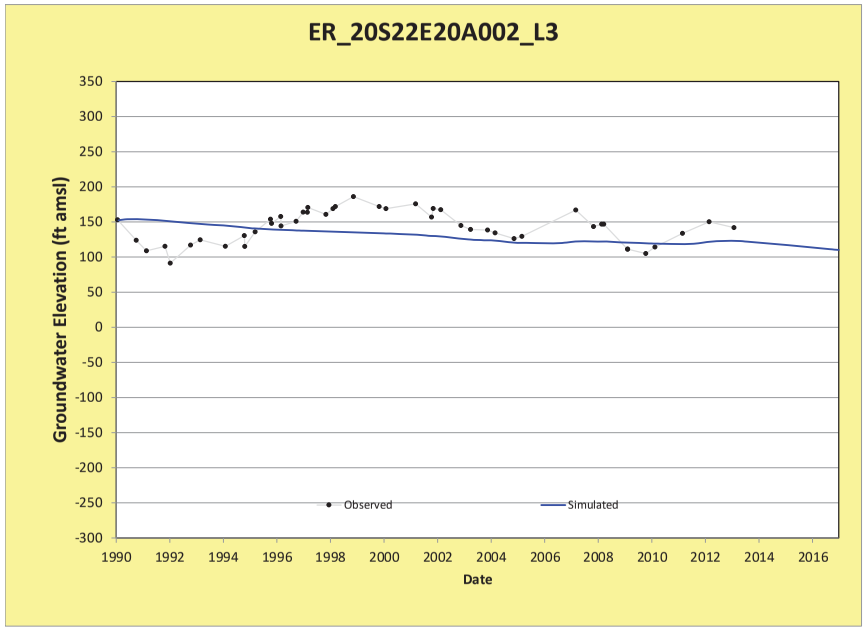

ER_20S21E22R001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

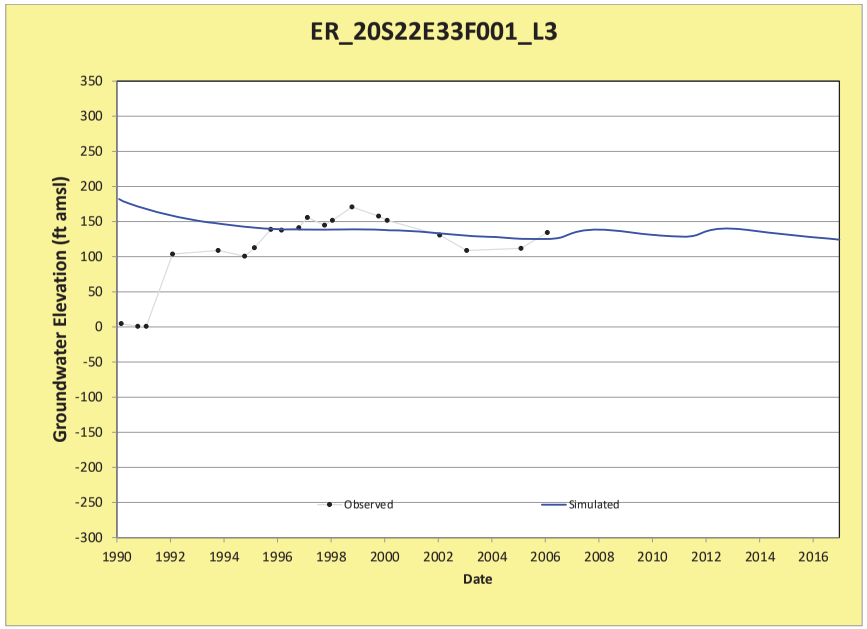

ER_20S21E24H001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

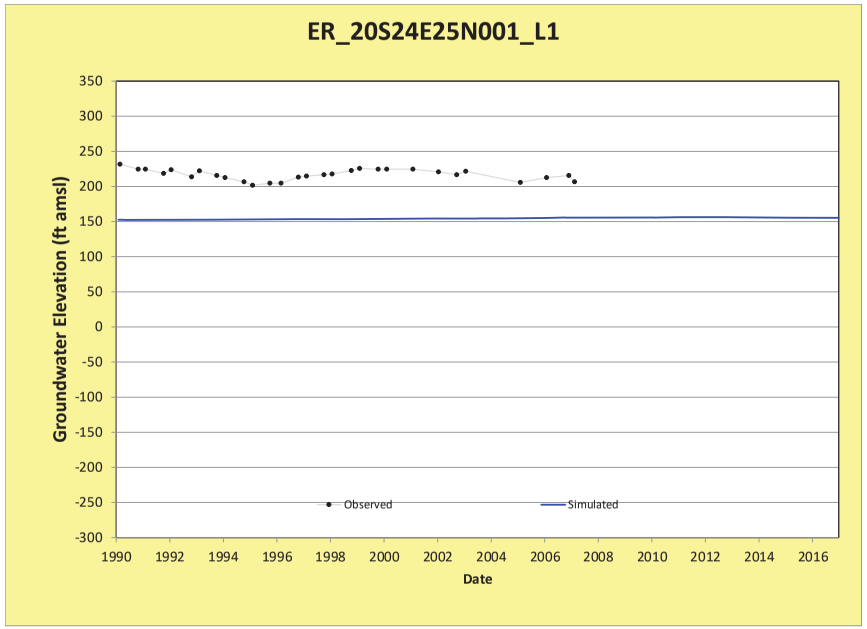

ER_20S22E18G001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

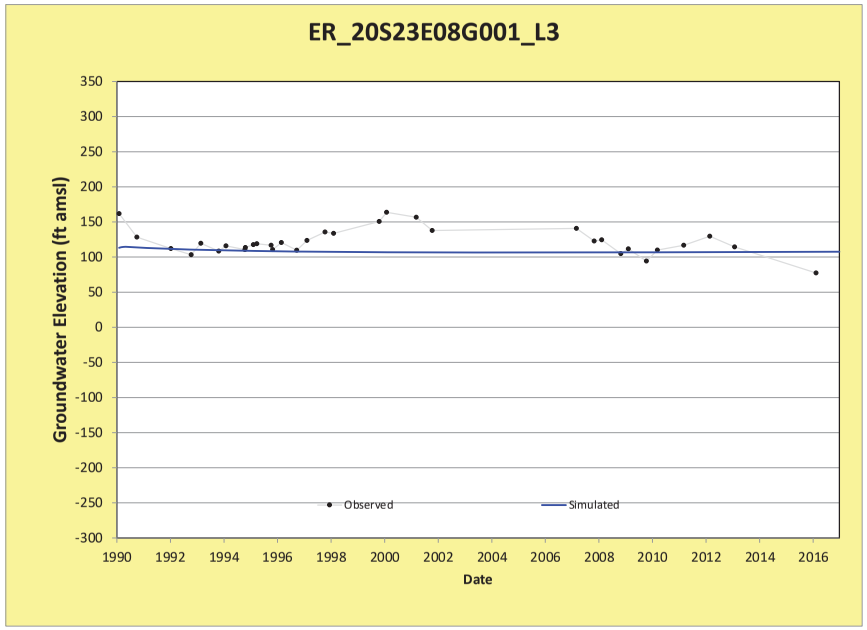

ER_20S22E19J001_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

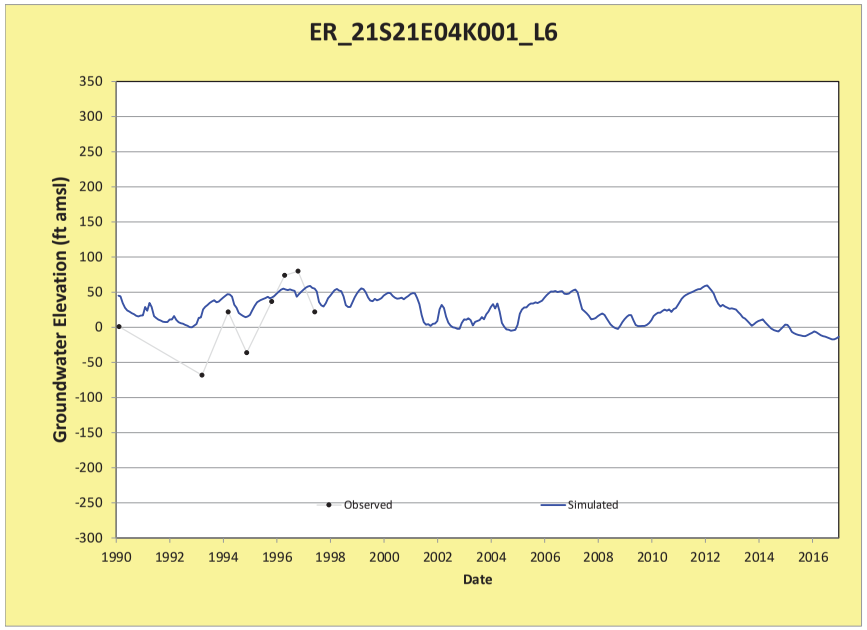

ER_20S22E18R001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

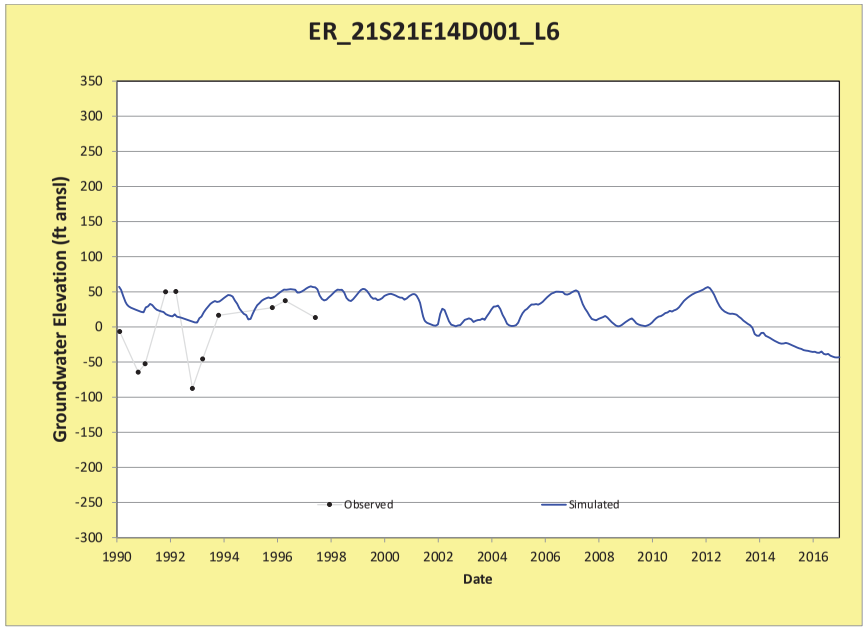

ER_20S22E20A002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

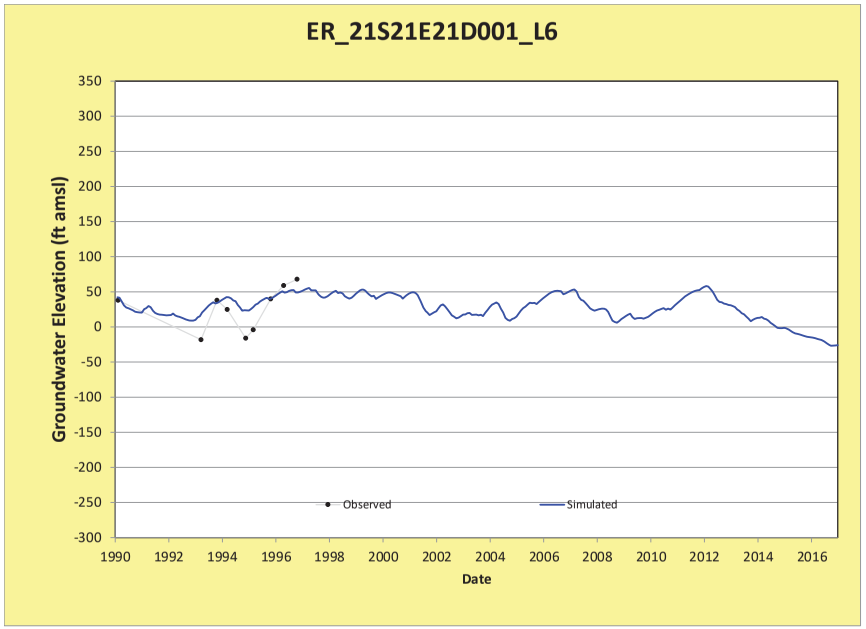

ER_20S22E33F001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

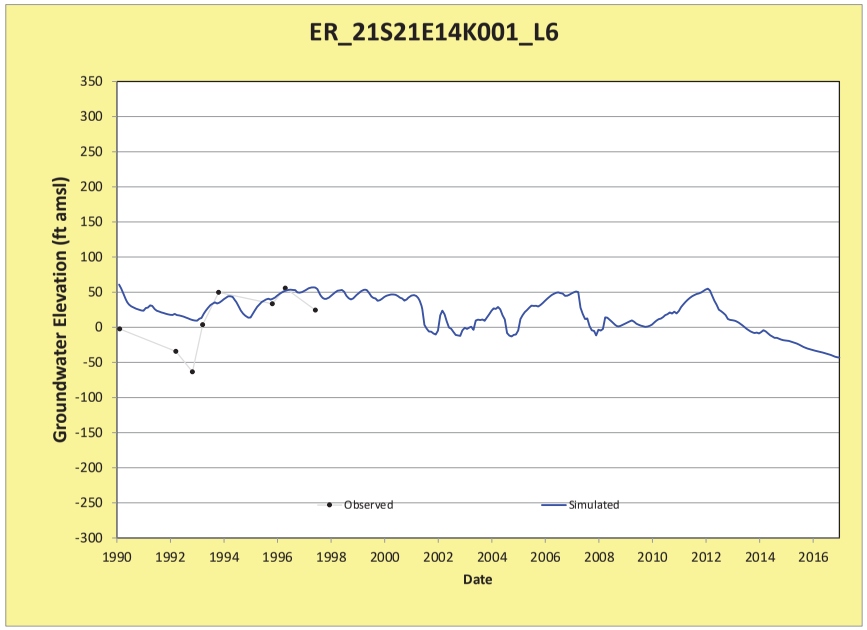

ER_20S24E25N001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

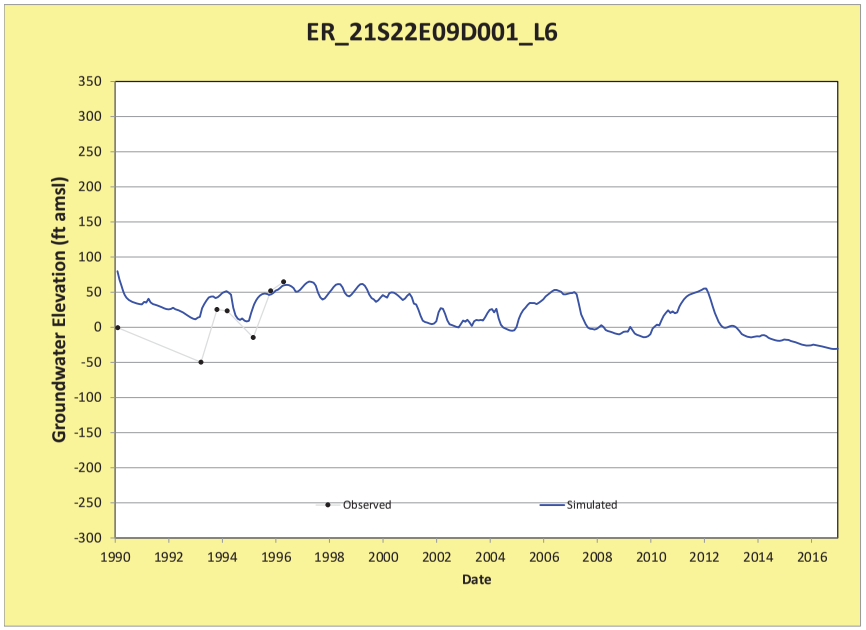

ER_20S23E08G001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

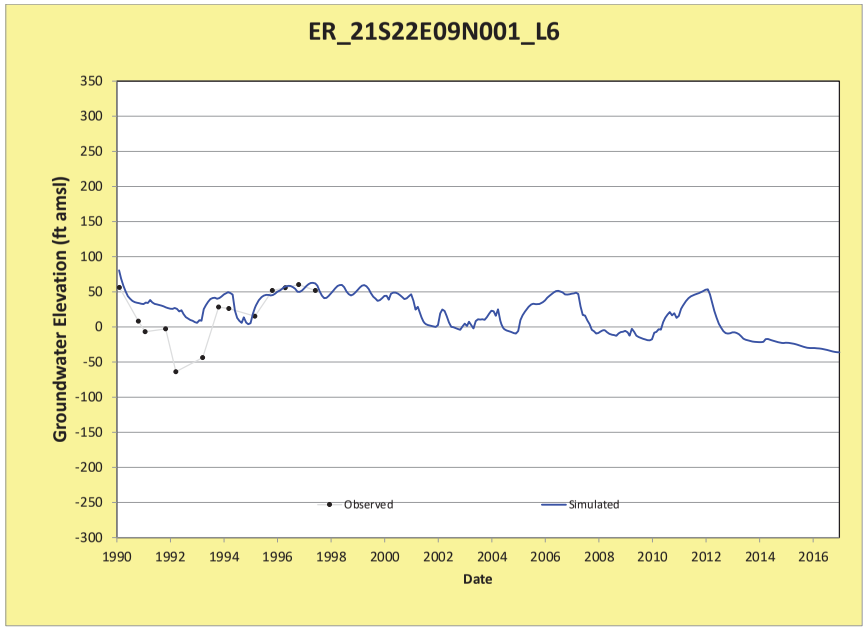

ER_21S21E04K001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

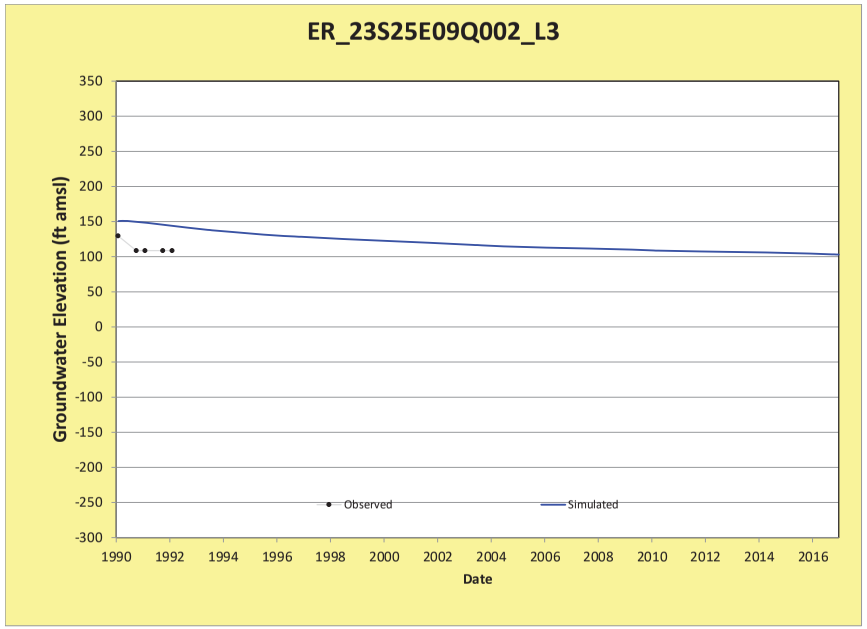

ER_21S21E14D001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

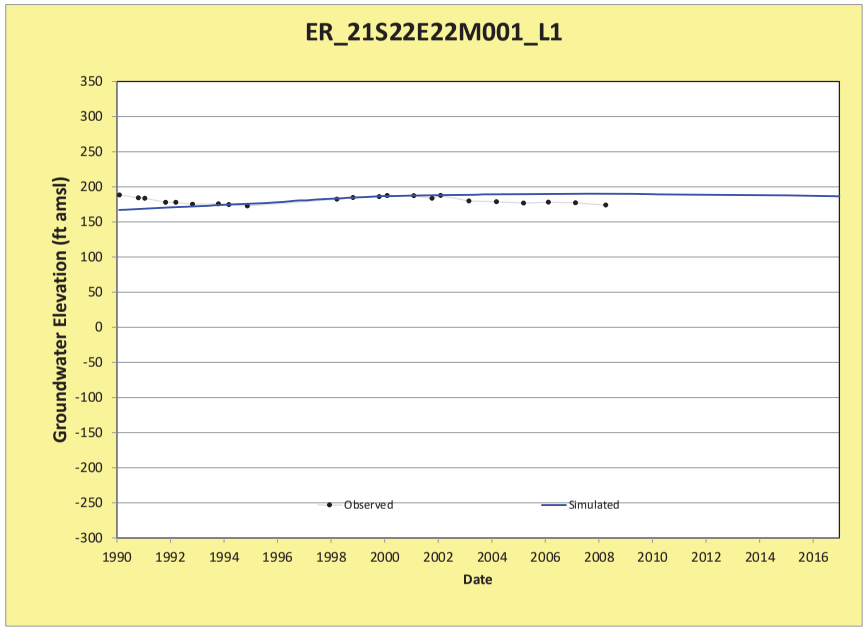

ER_21S21E21D001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

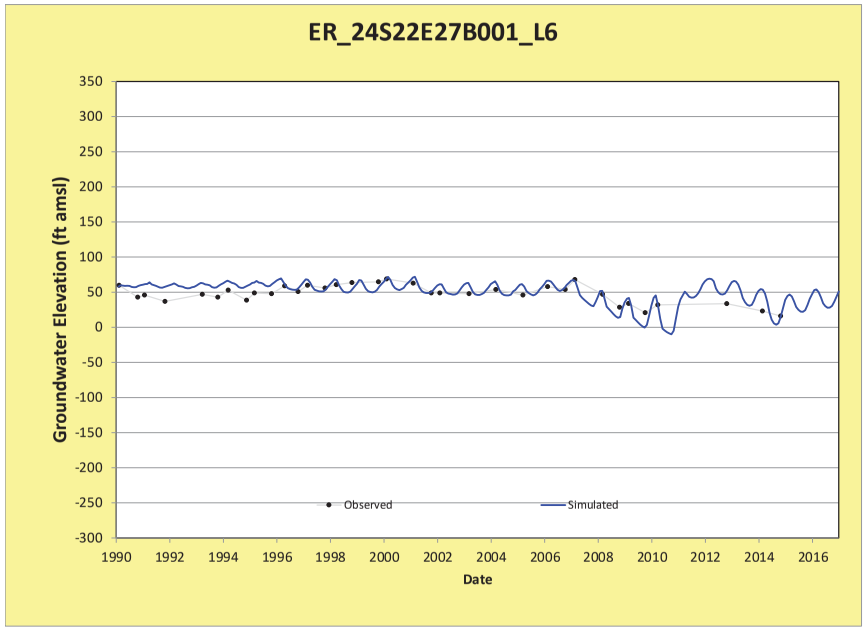

ER_21S21E14K001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

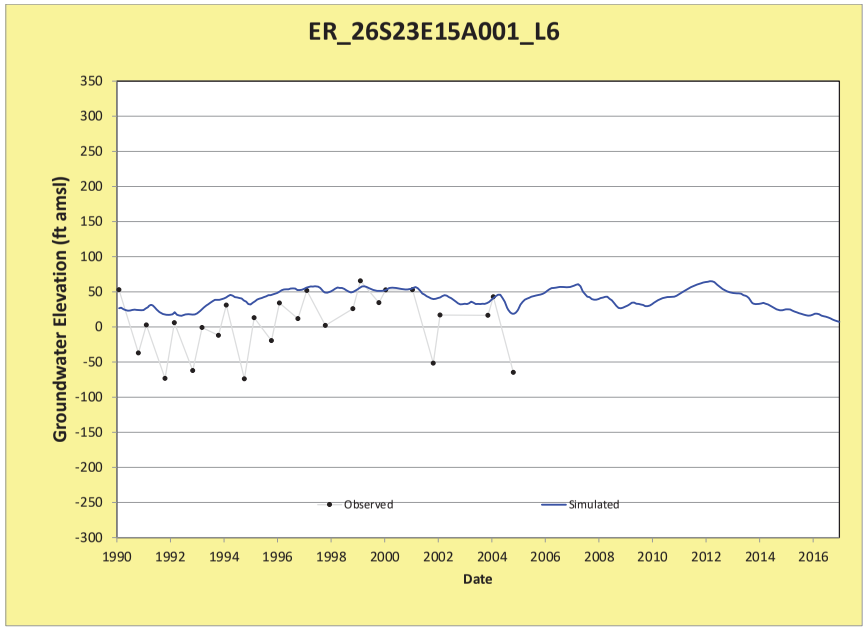

ER_21S22E09D001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

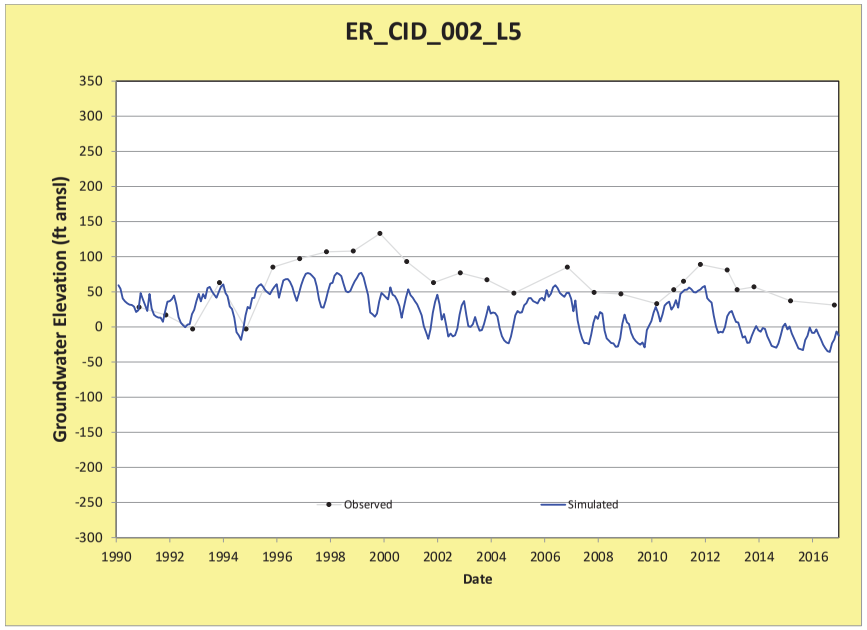

ER_21S22E09N001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

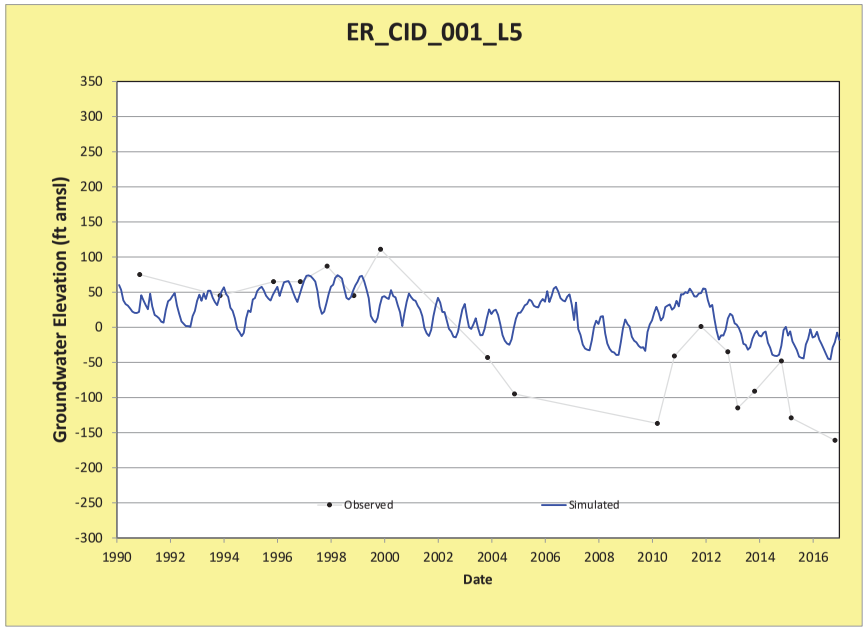

ER_23S25E09Q002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

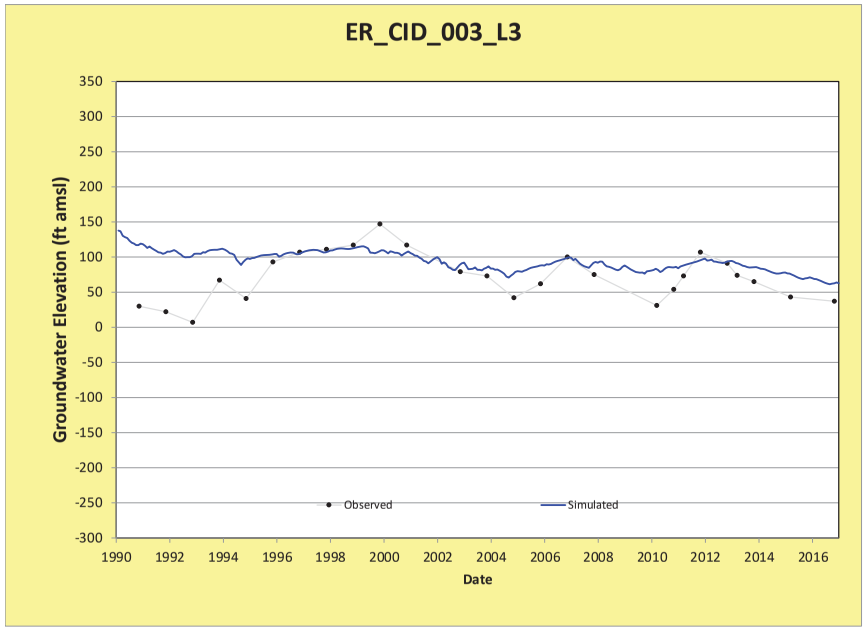

ER_21S22E22M001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

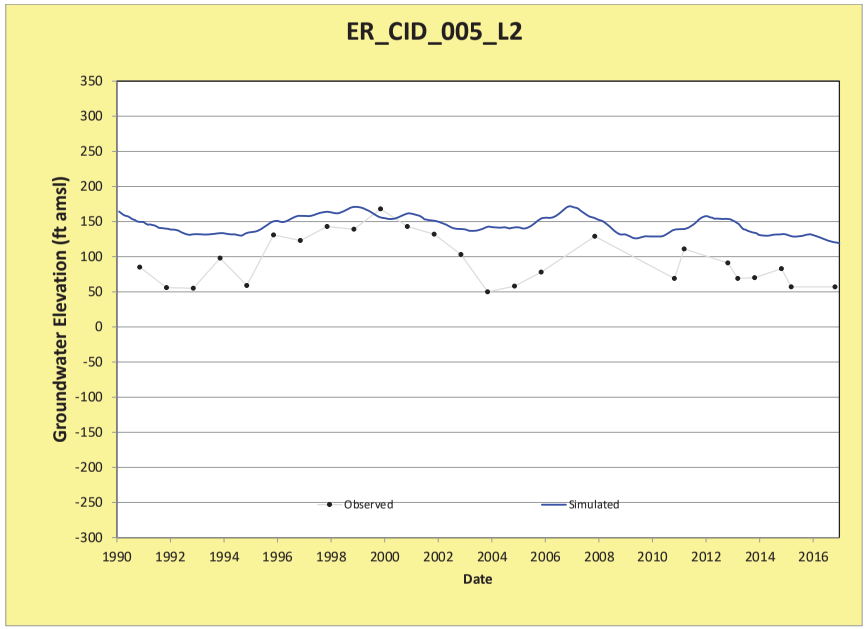

ER_24S22E27B001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

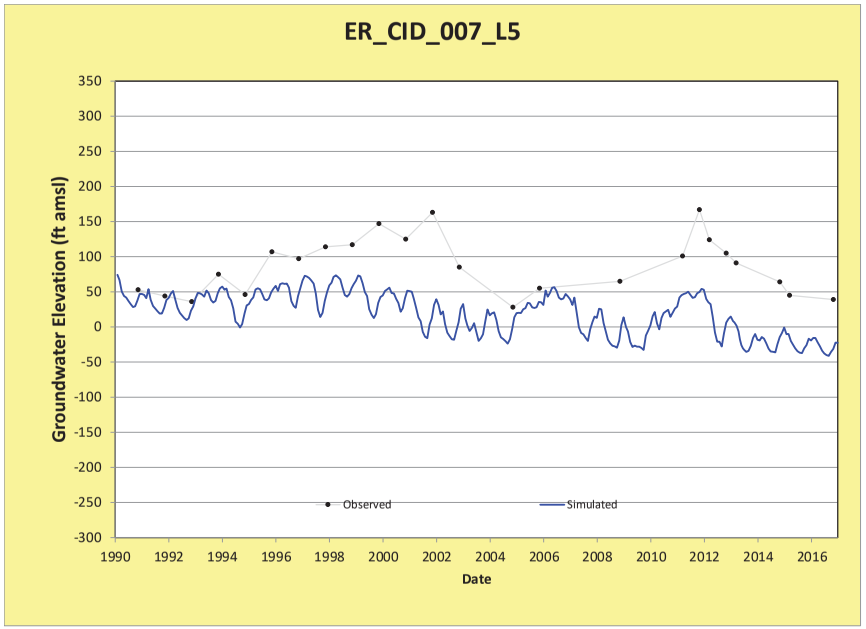

ER_26S23E15A001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

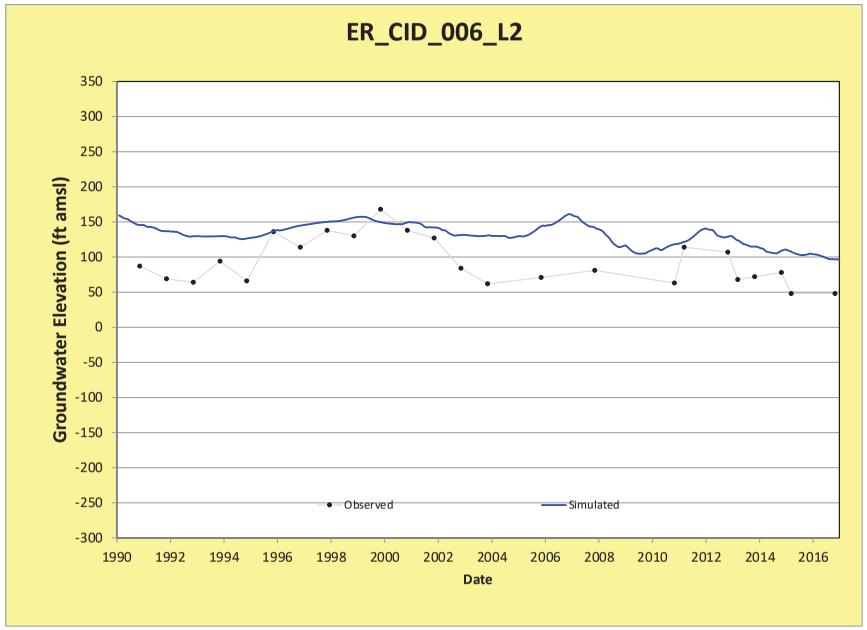

ER_CID_002_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

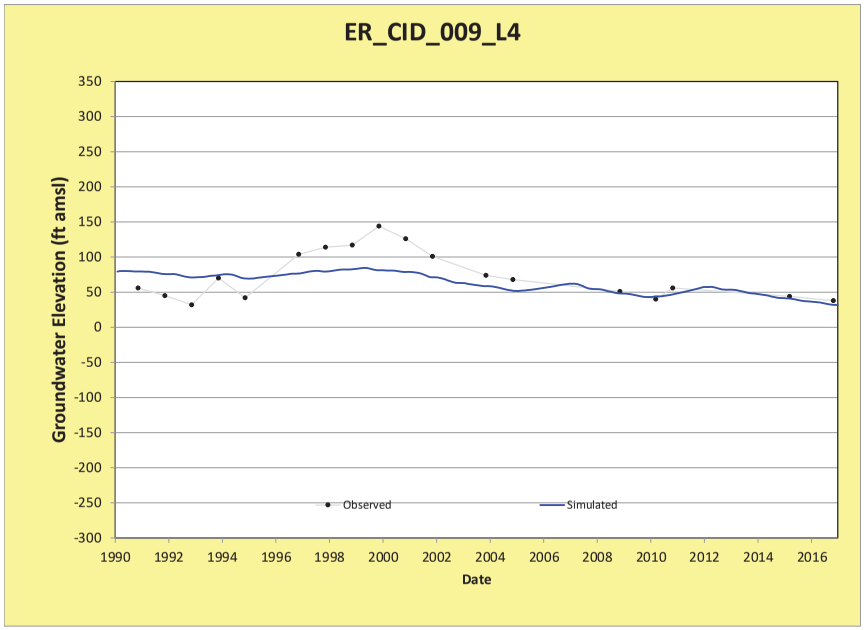

ER_CID_001_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

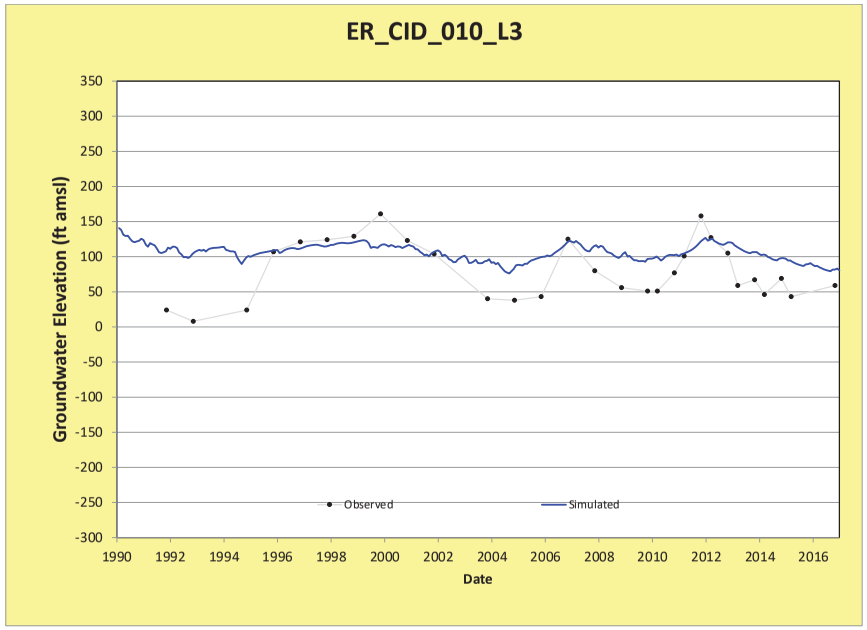

ER_CID_003_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

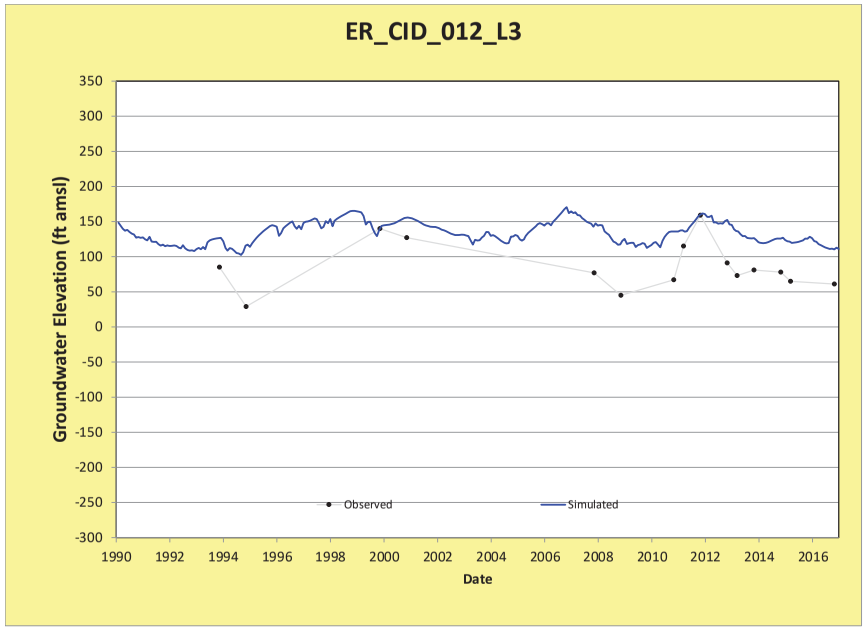

ER_CID_005_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

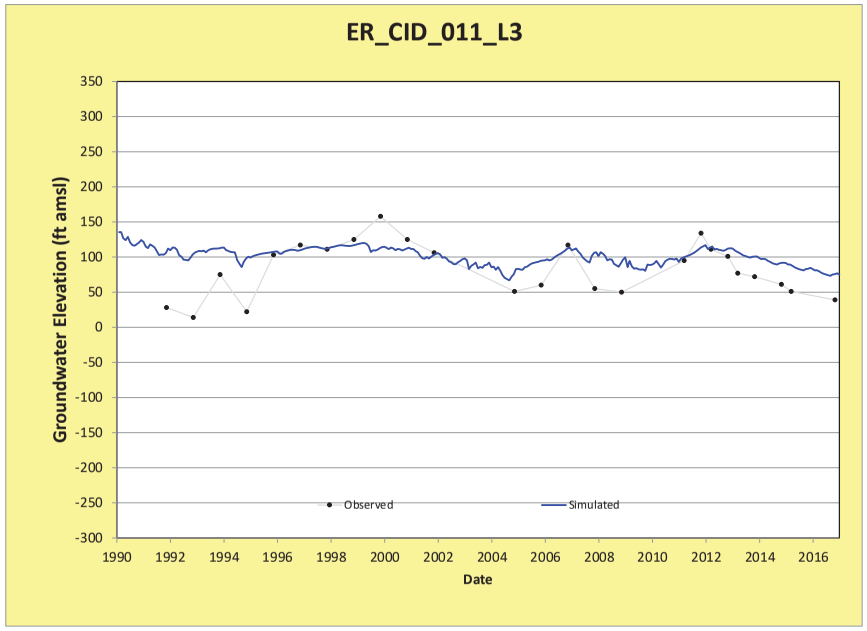

ER_CID_007_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

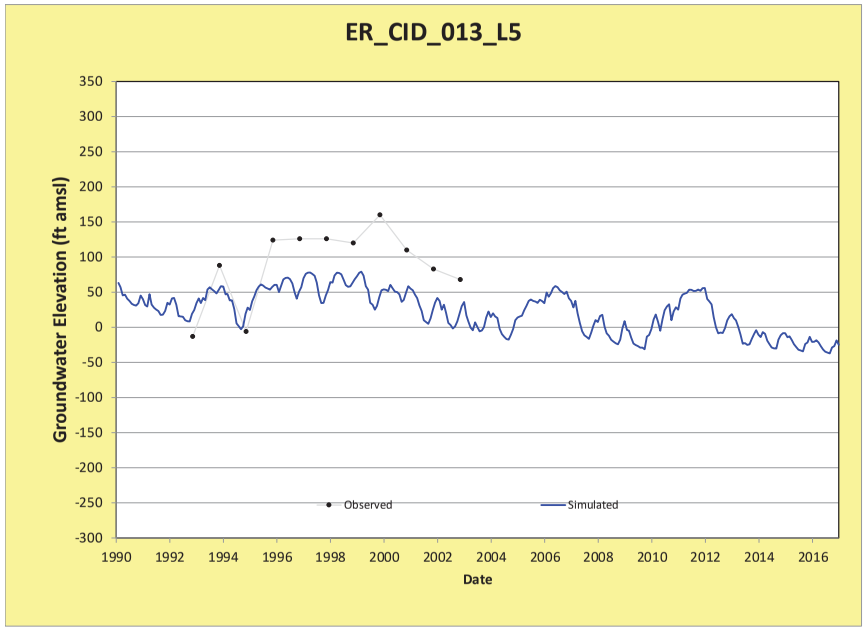

ER_CID_006_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

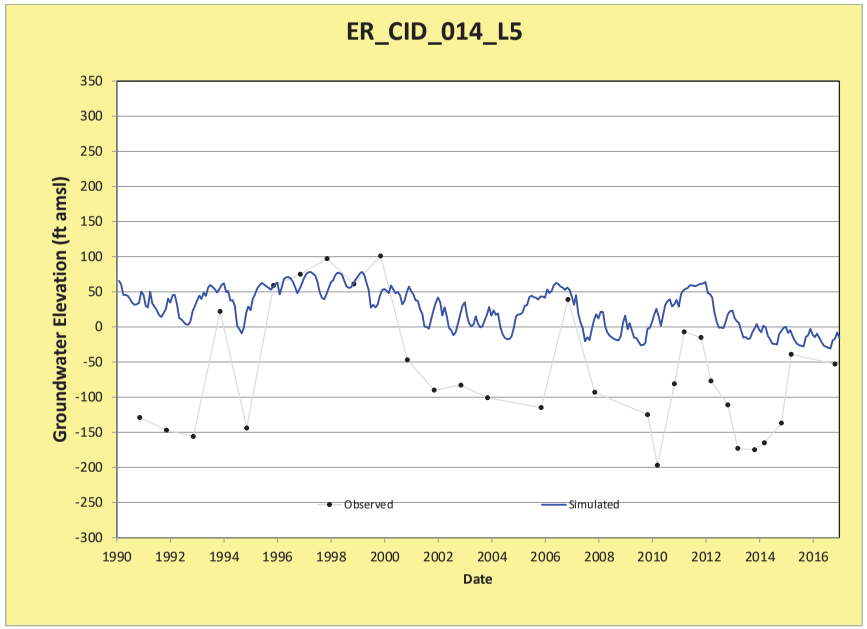

ER_CID_009_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

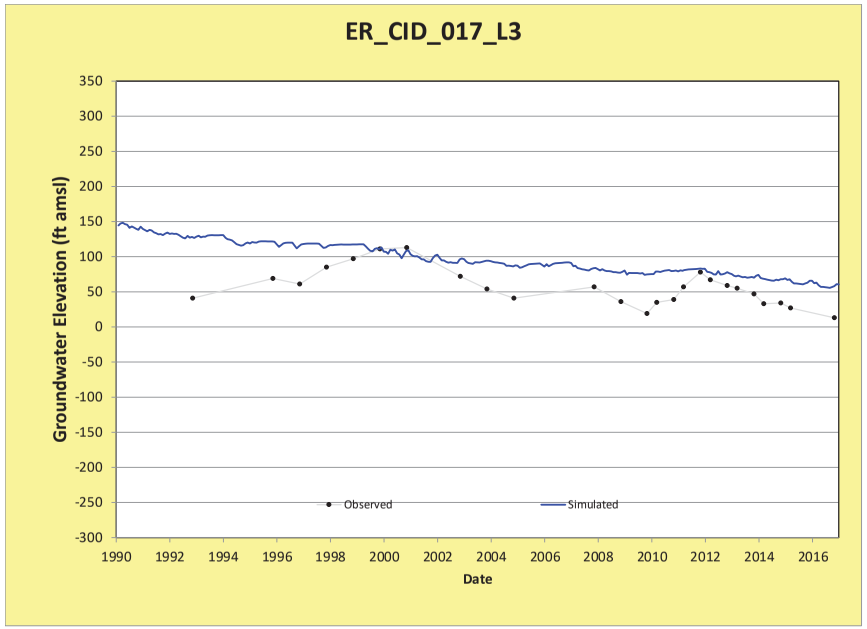

ER_CID_010_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

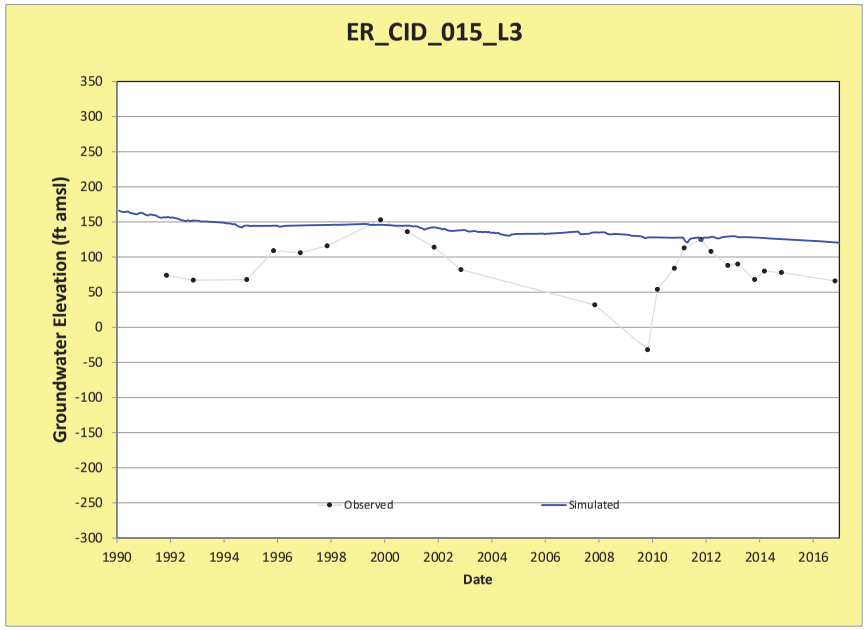

ER_CID_012_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

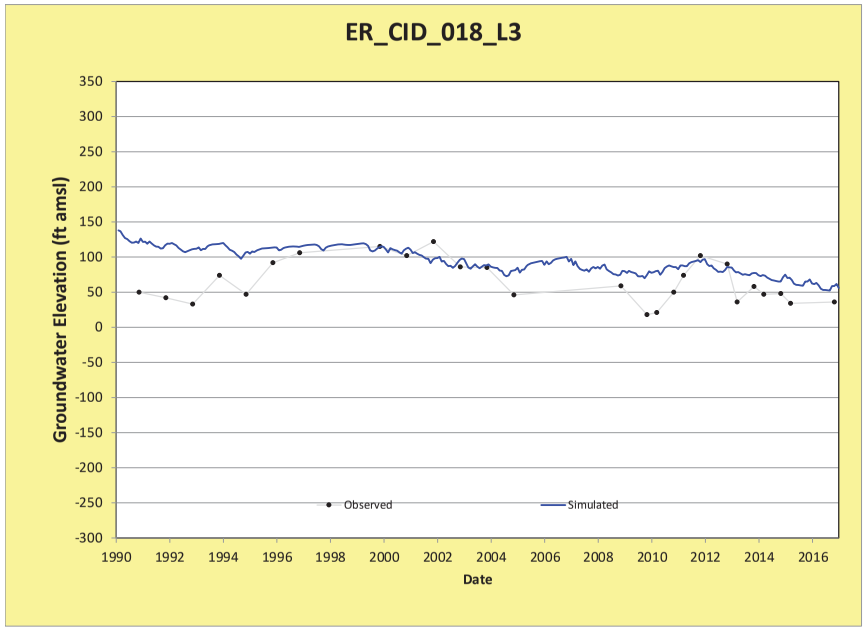

ER_CID_011_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

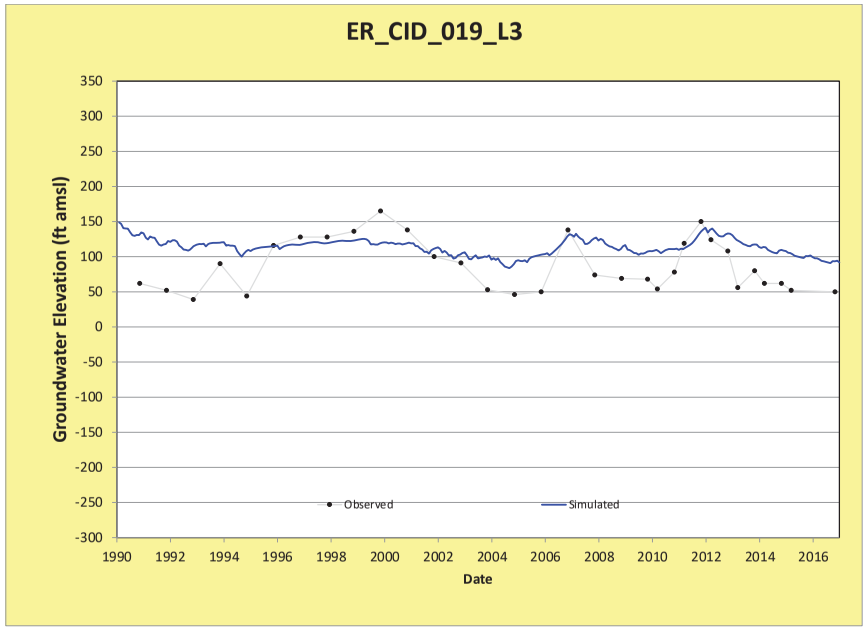

ER_CID_013_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

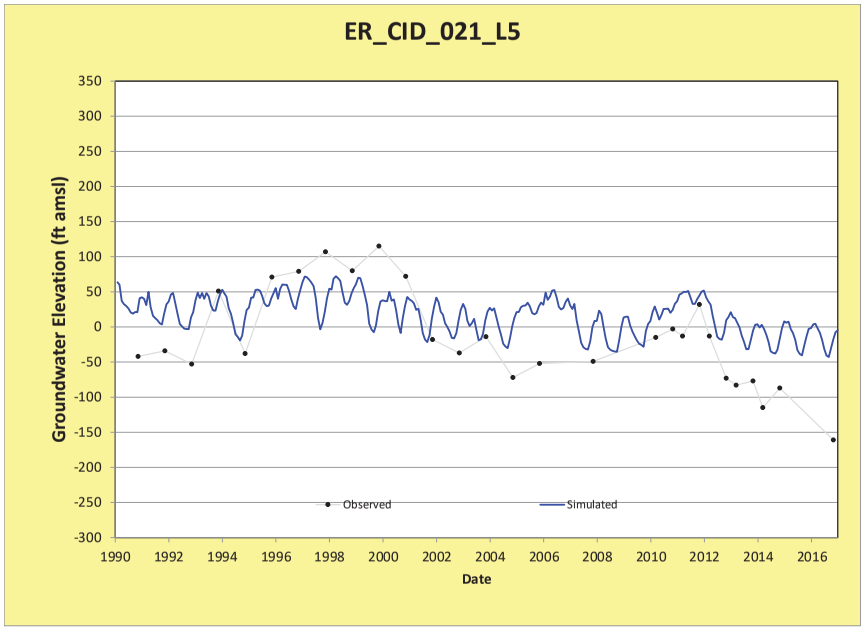

ER_CID_014_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

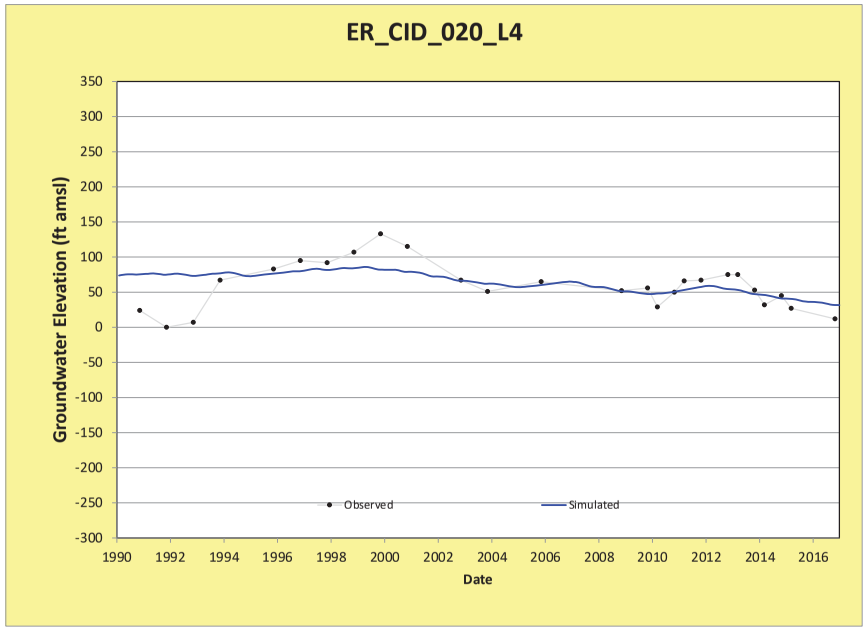

ER_CID_017_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

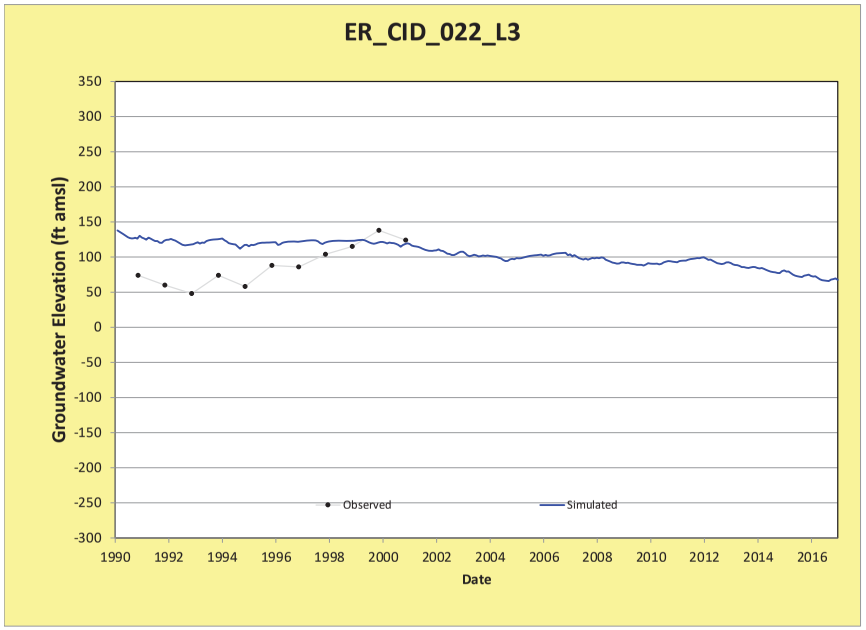

ER_CID_015_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

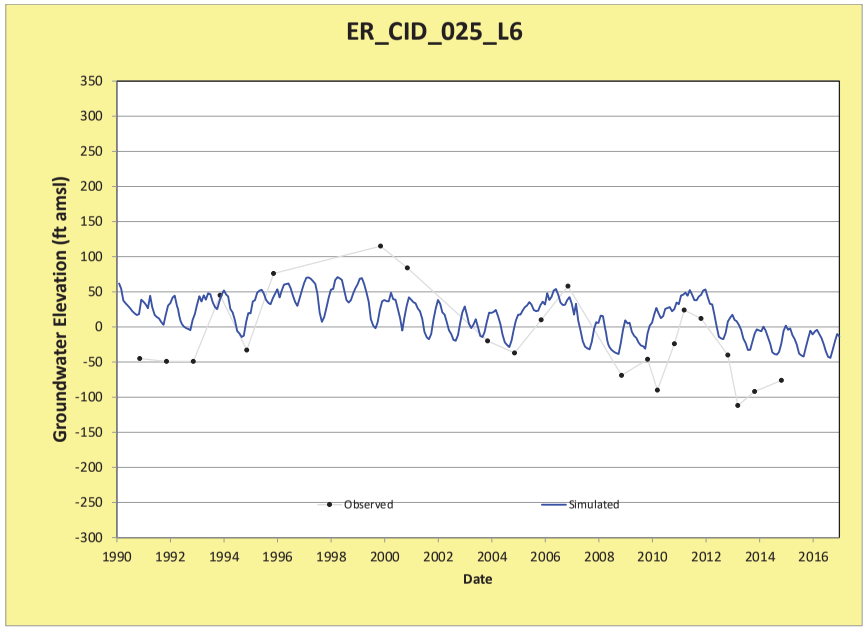

ER_CID_018_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

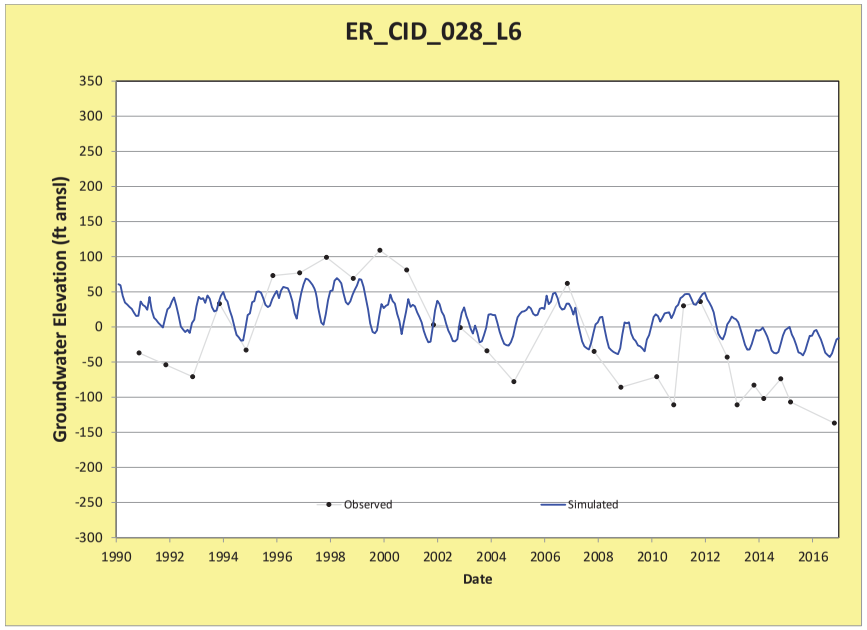

ER_CID_019_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

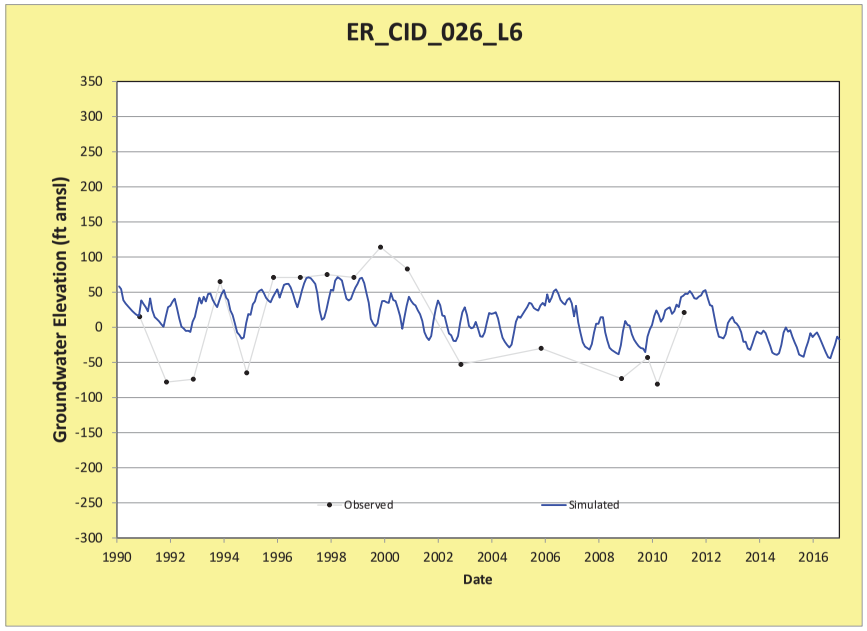

ER_CID_021_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

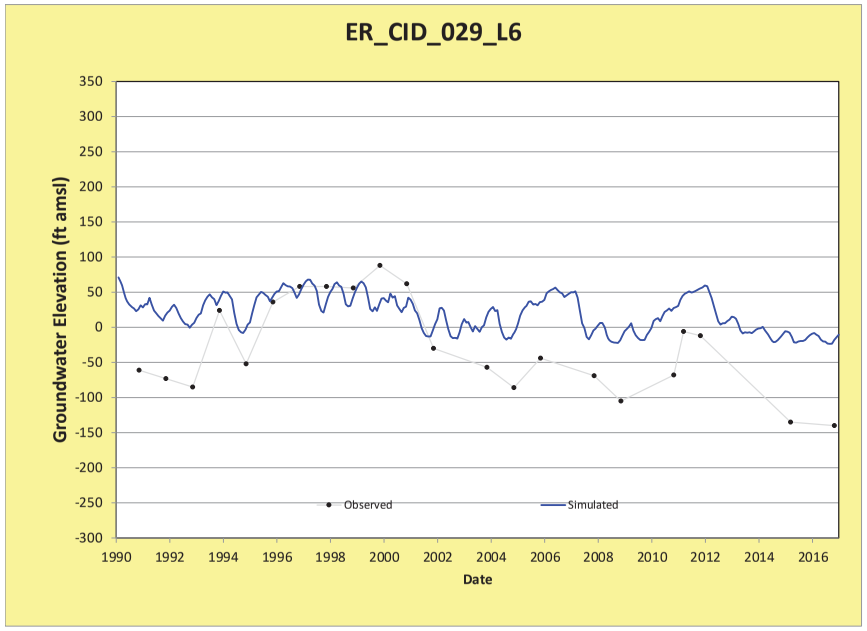

ER_CID_020_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

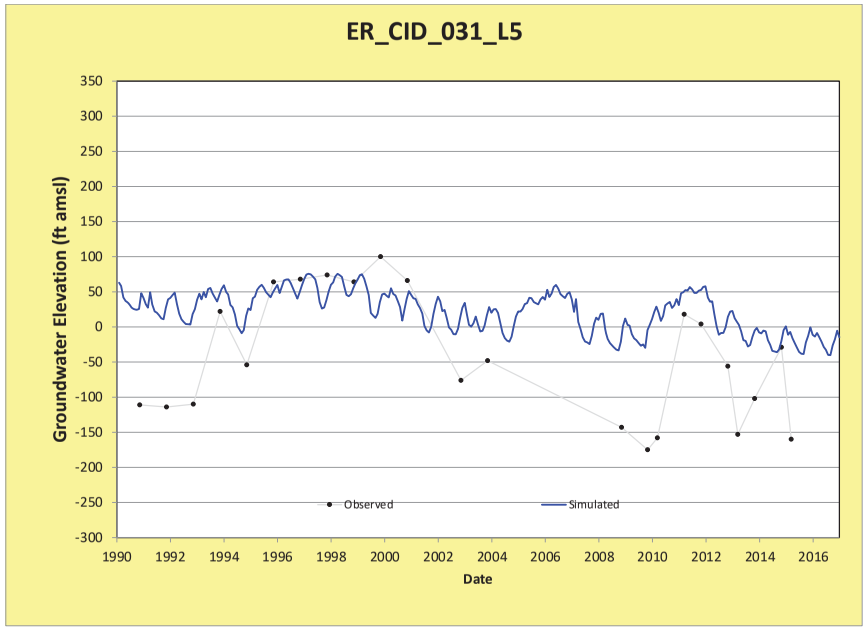

ER_CID_022_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

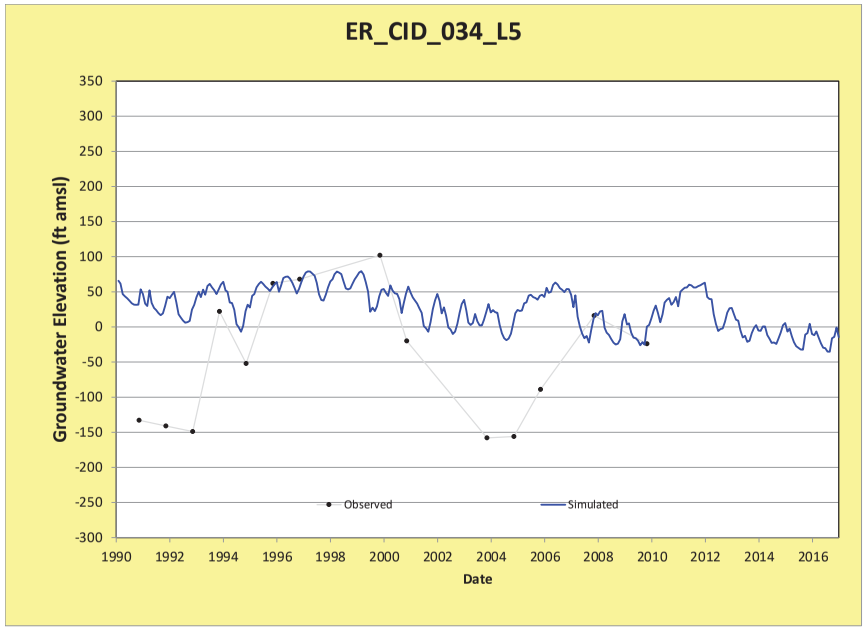

ER_CID_025_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

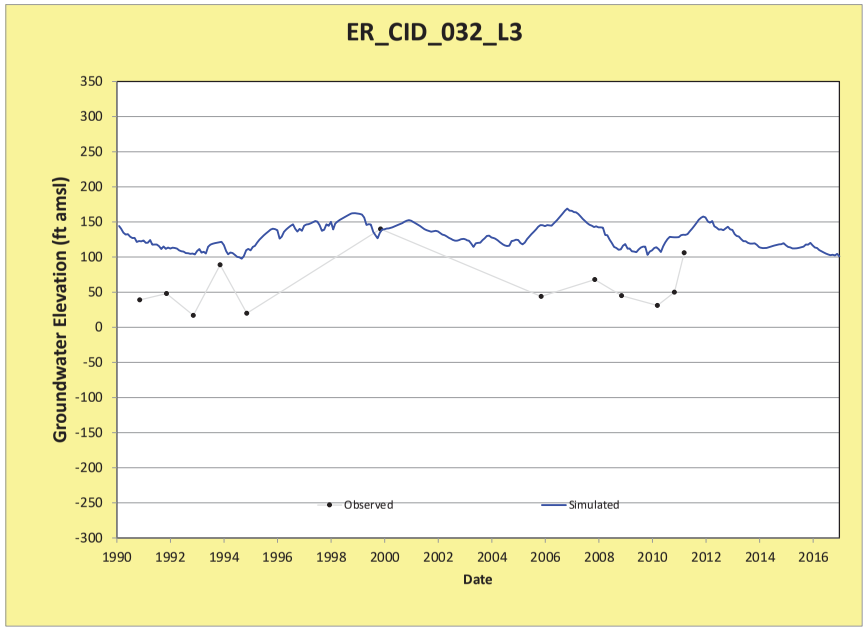

ER_CID_028_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

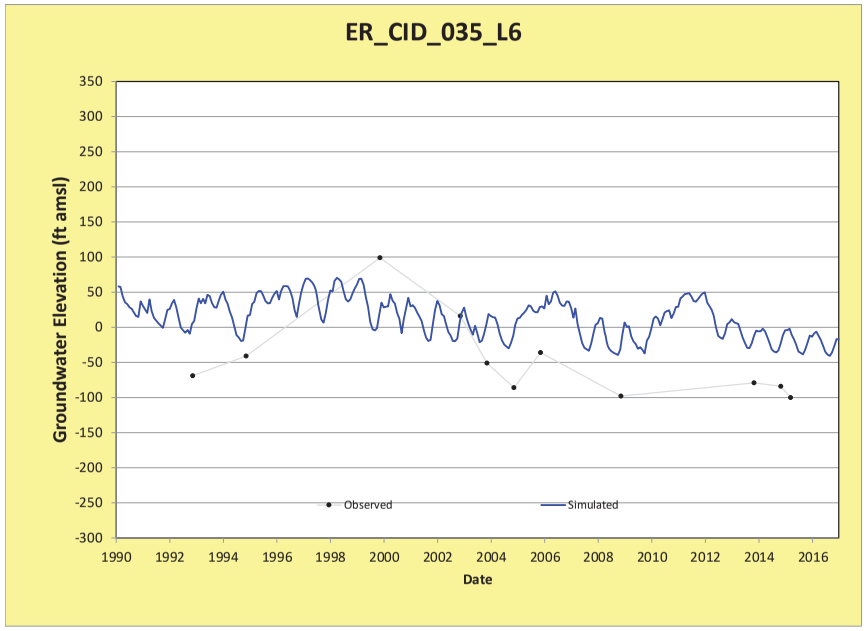

ER_CID_026_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

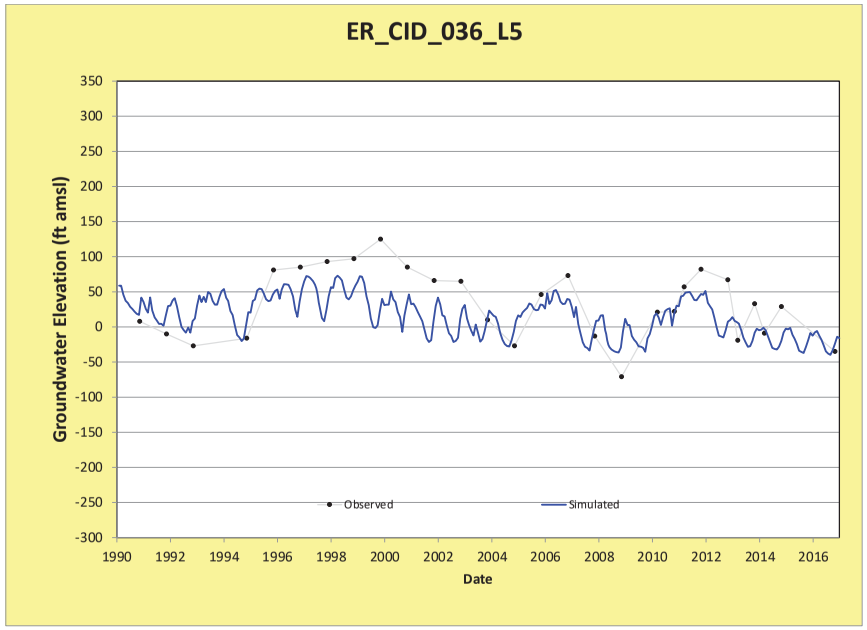

ER_CID_029_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

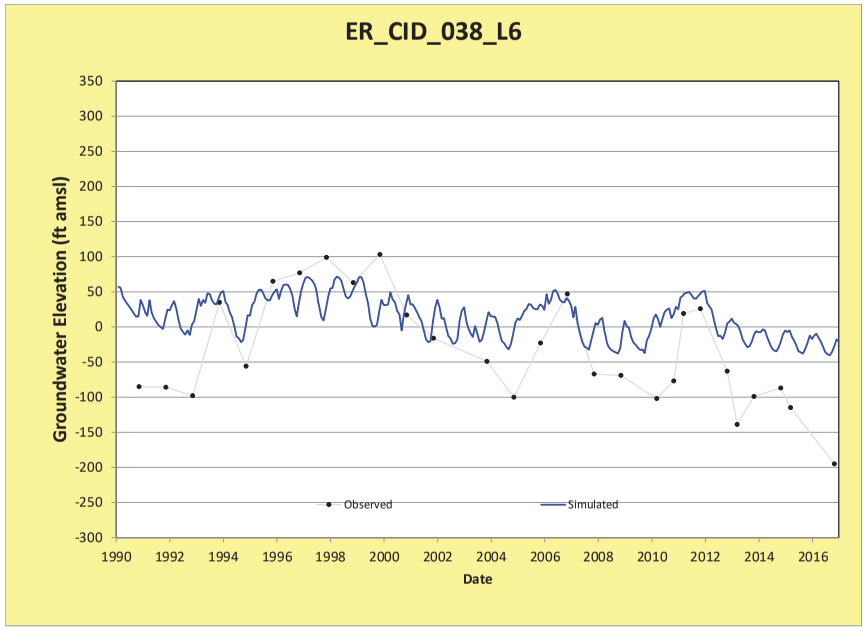

ER_CID_031_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

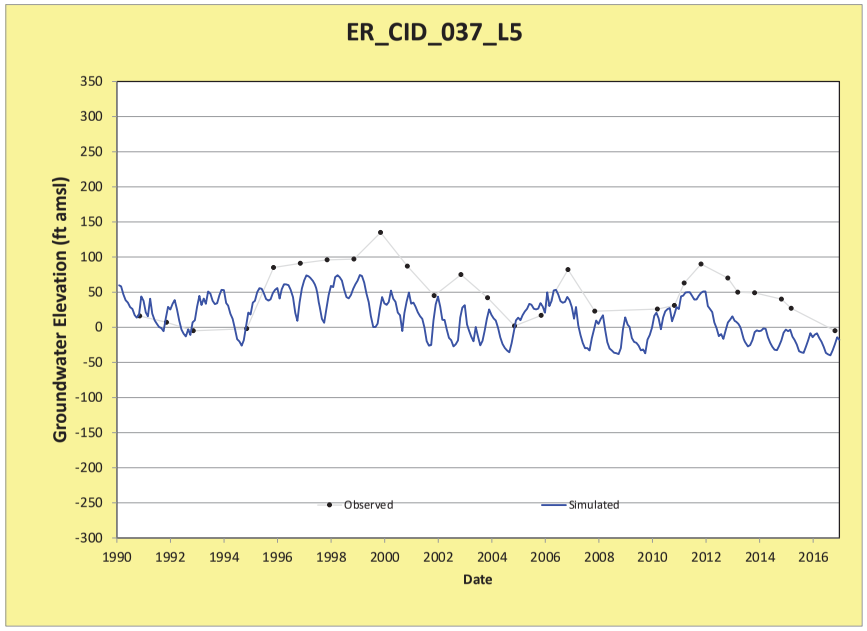

ER_CID_034_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

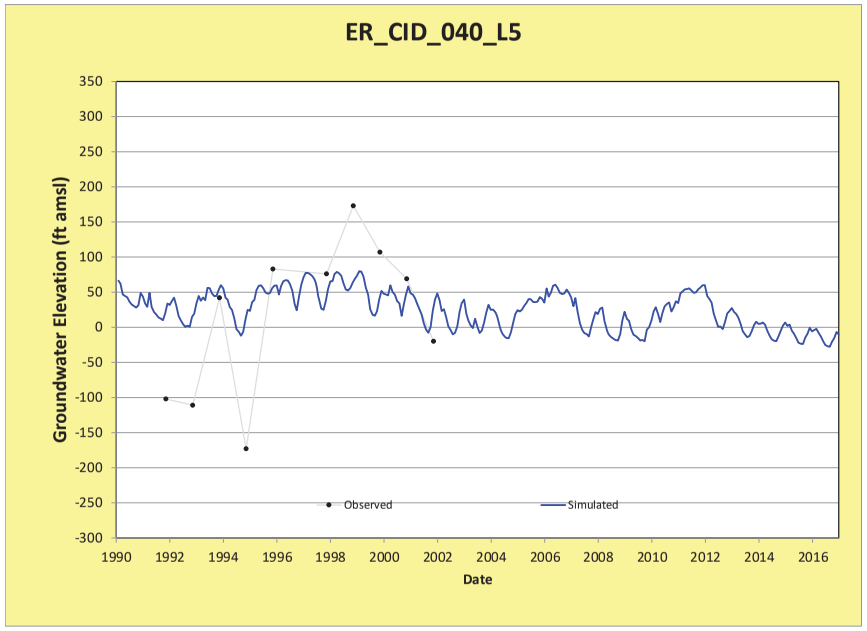

ER_CID_032_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

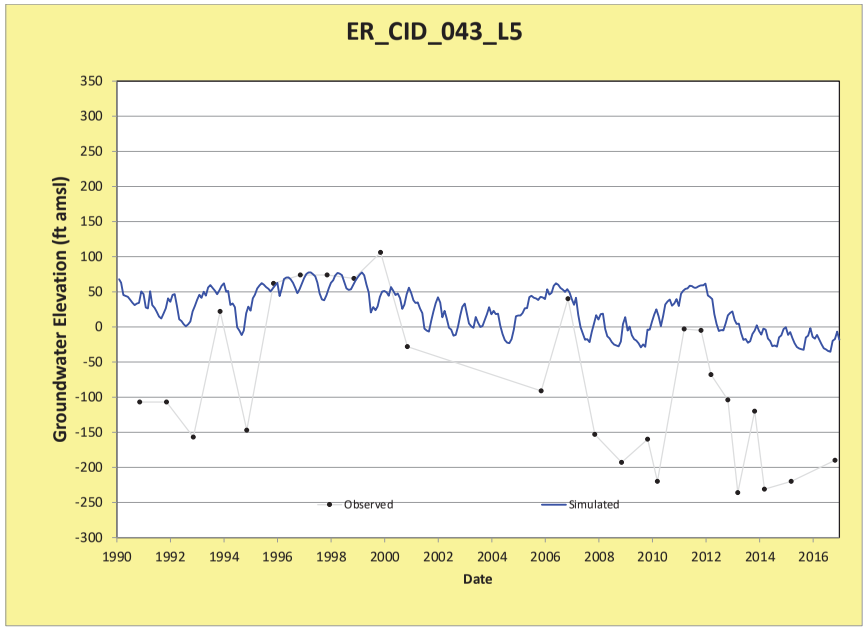

ER_CID_035_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

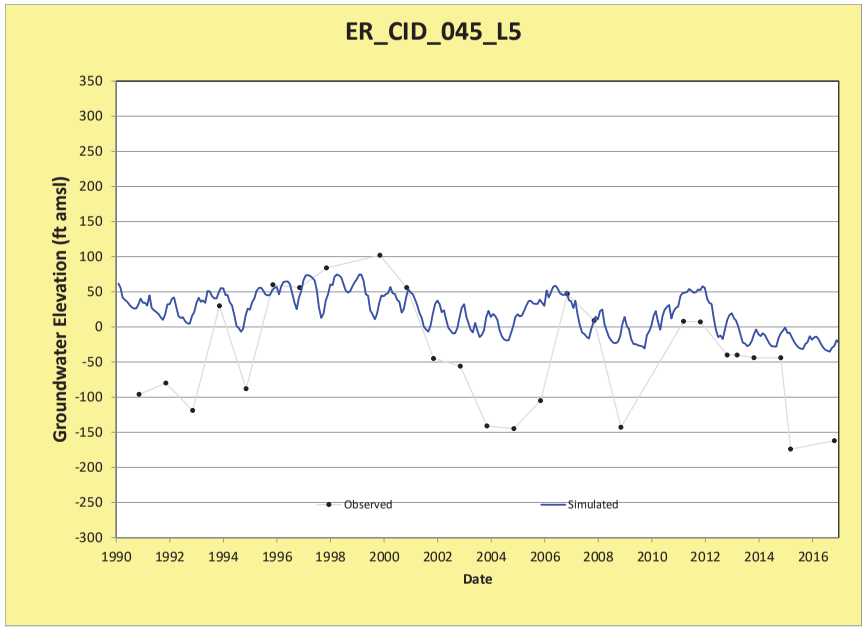

ER_CID_036_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

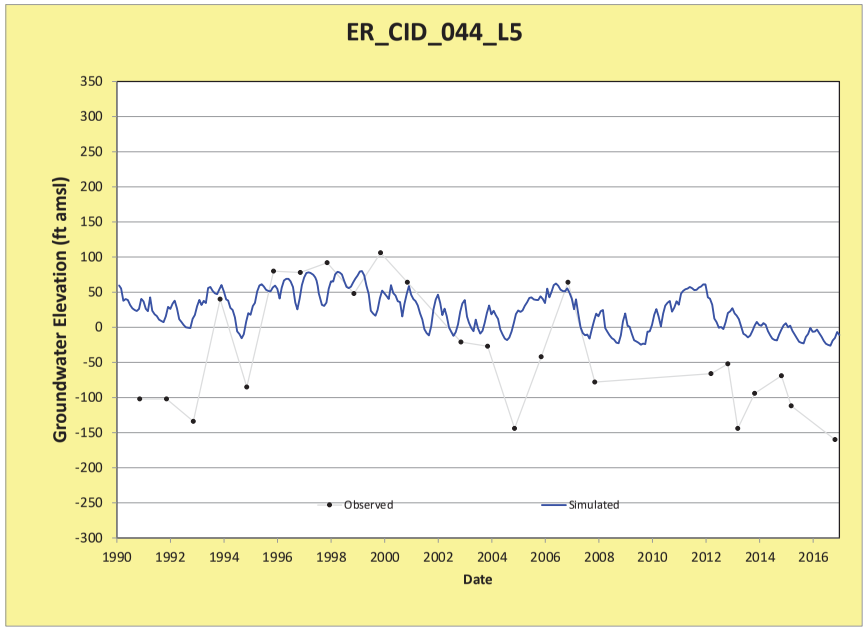

ER_CID_038_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

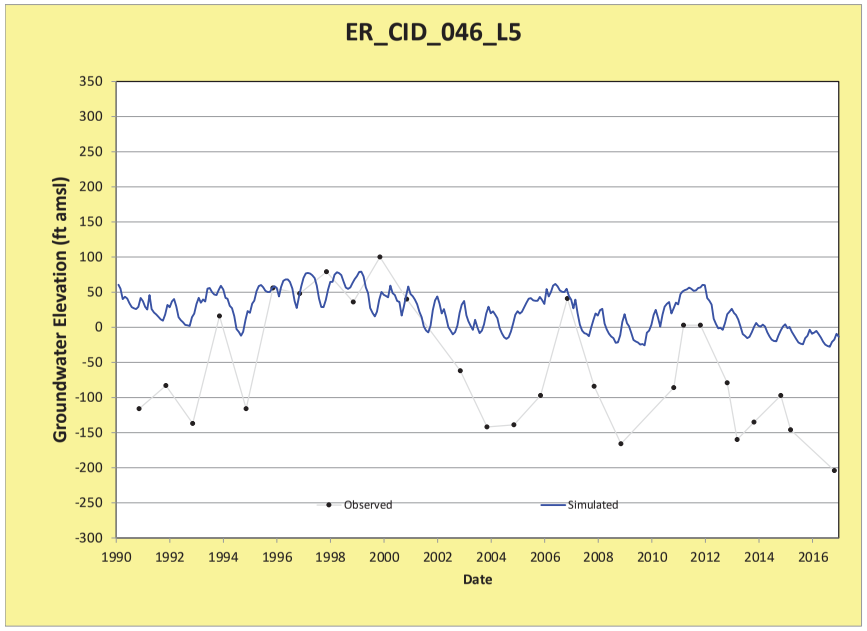

ER_CID_037_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

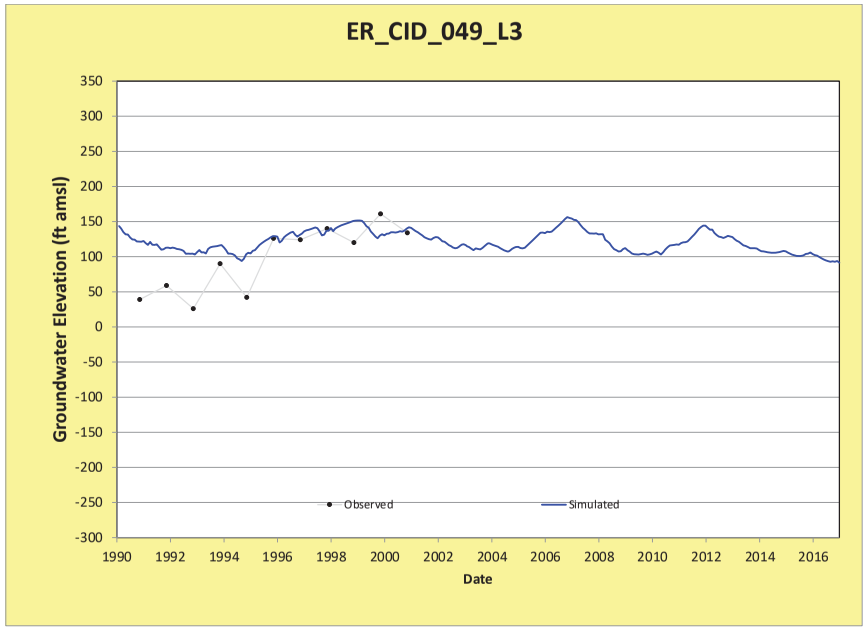

ER_CID_040_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

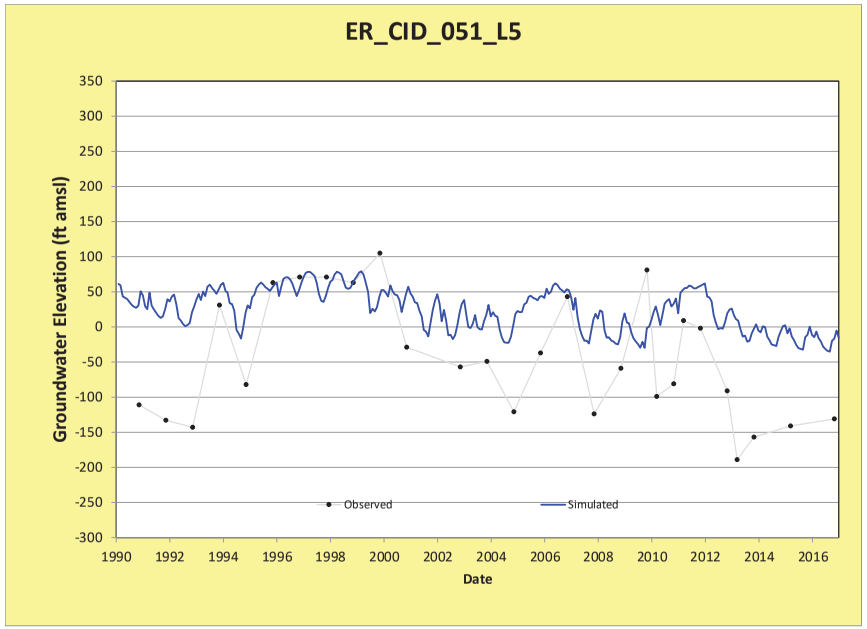

ER_CID_043_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

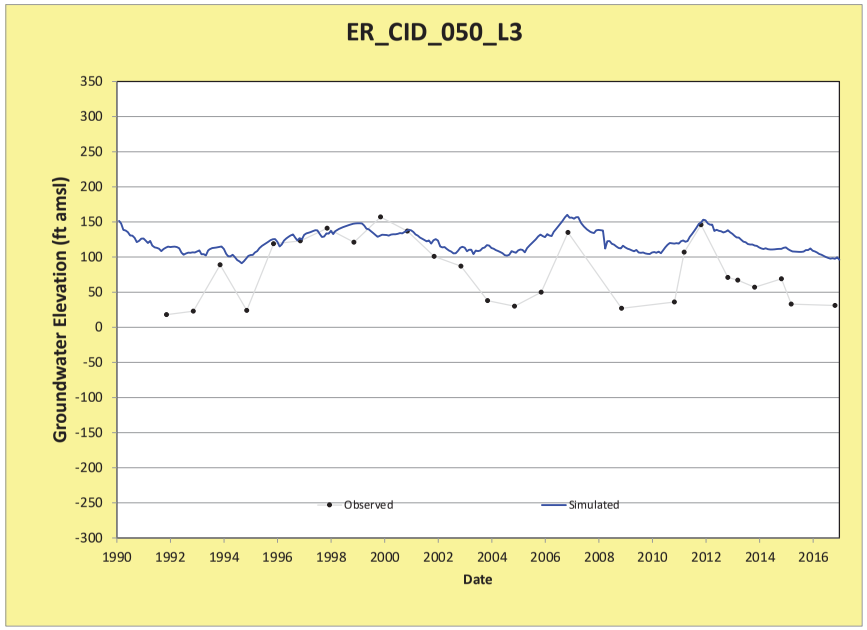

ER_CID_045_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

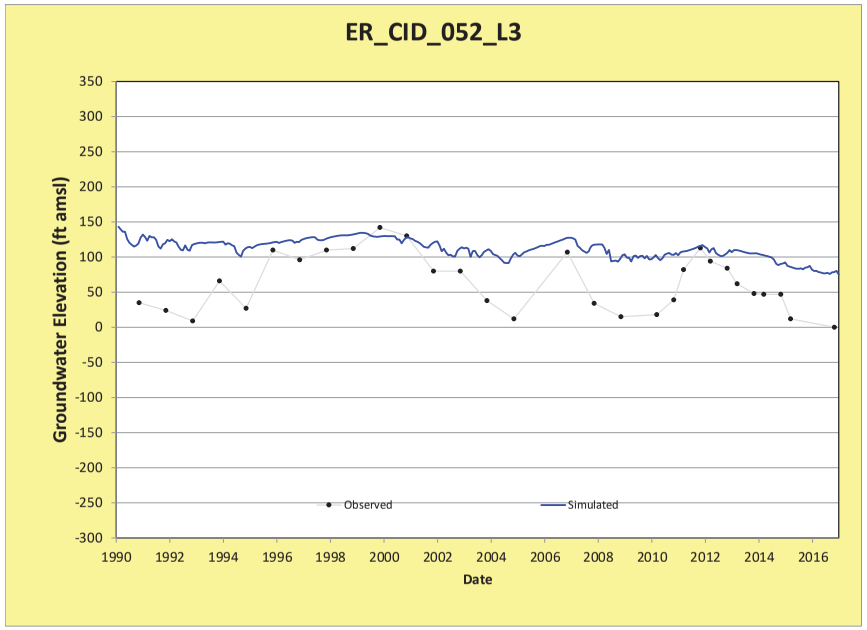

ER_CID_044_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

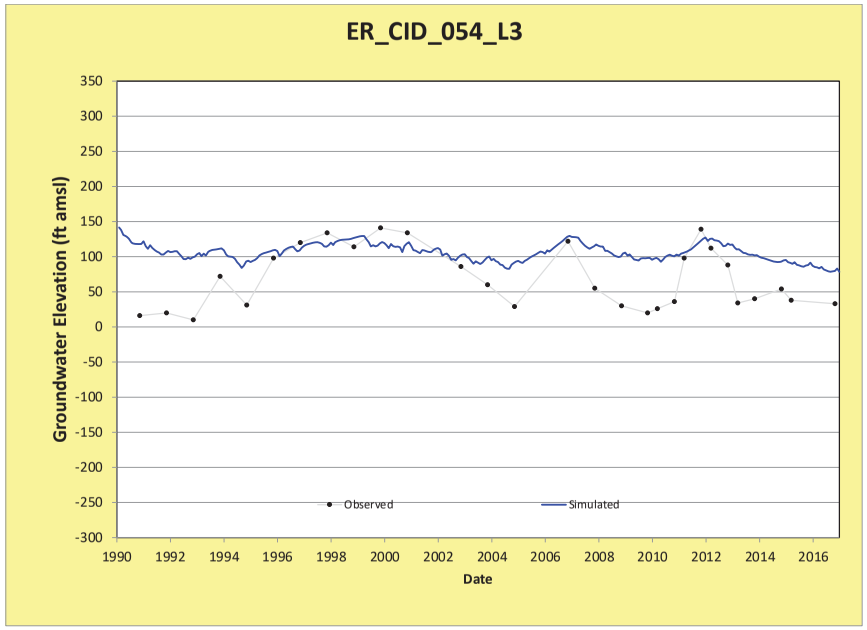

ER_CID_046_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

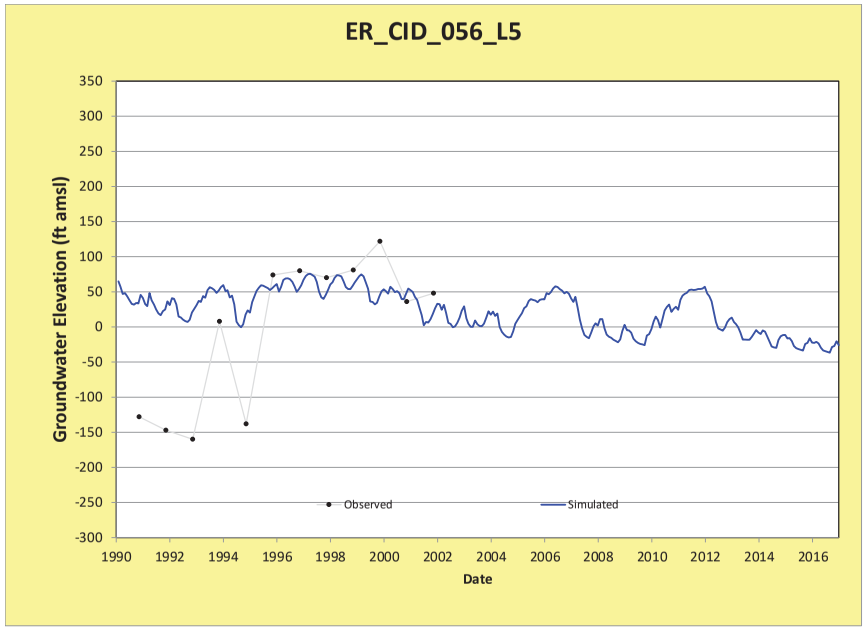

ER_CID_049_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

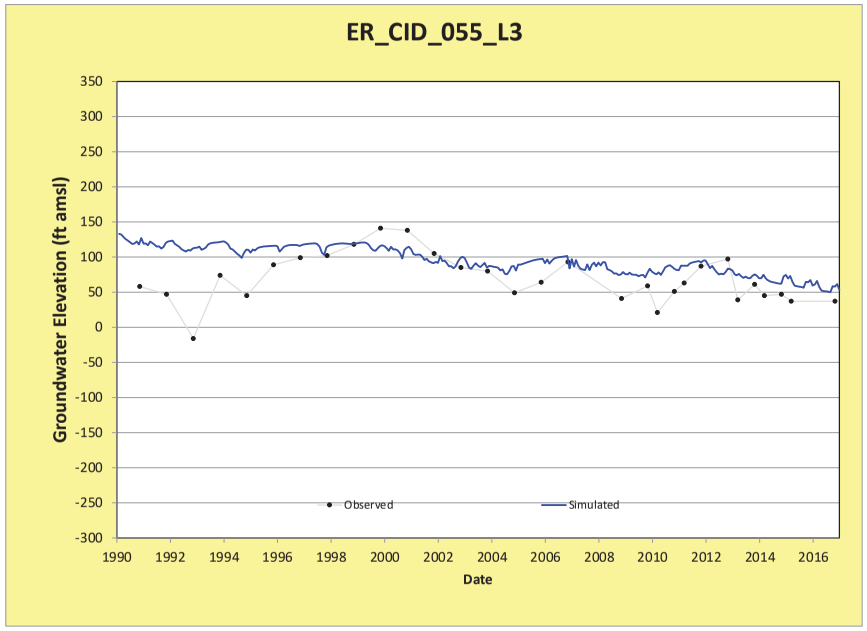

ER_CID_051_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

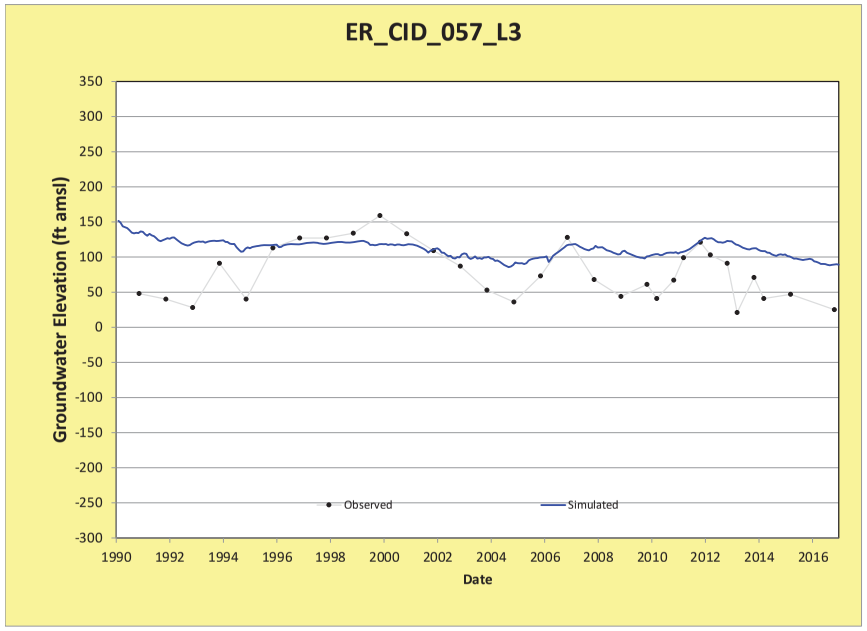

ER_CID_050_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

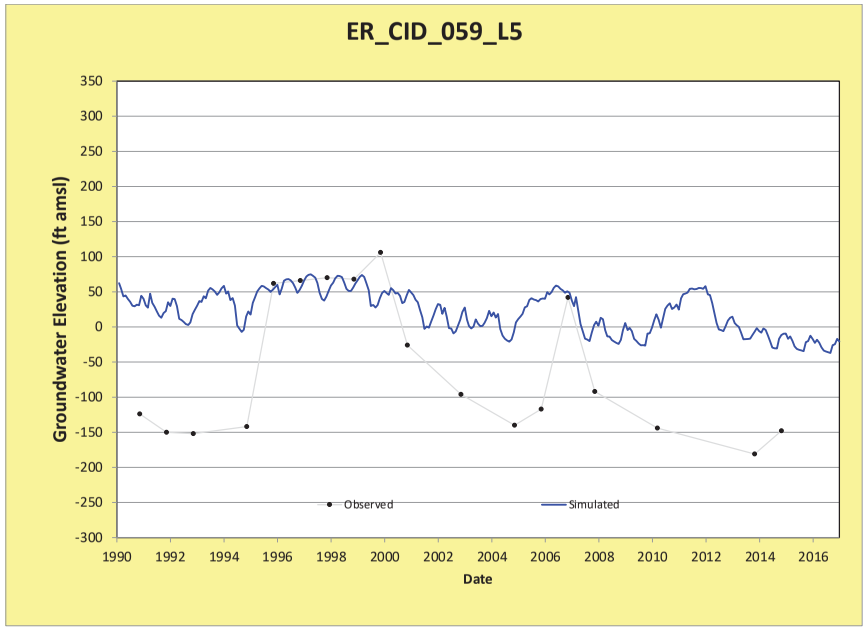

ER_CID_052_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

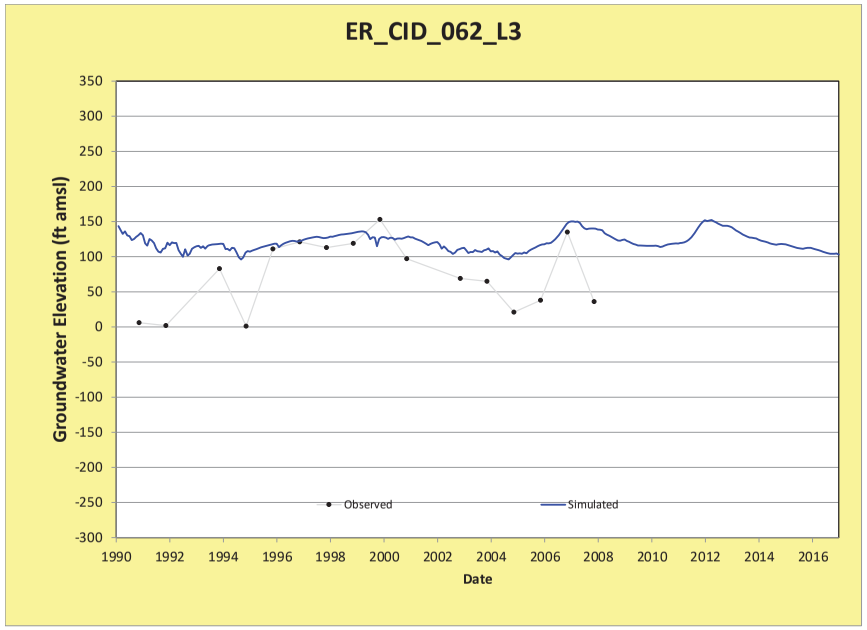

ER_CID_054_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

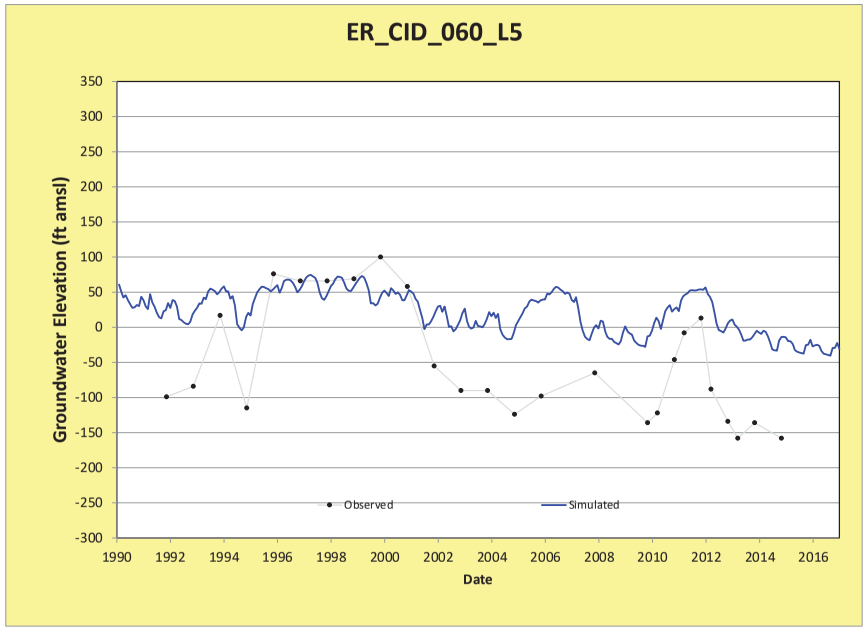

ER_CID_056_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

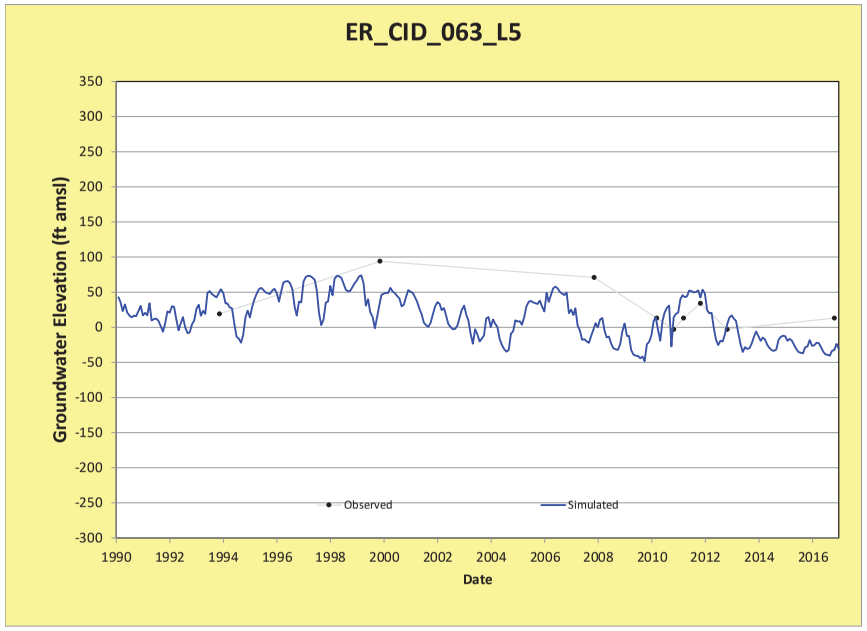

ER_CID_055_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

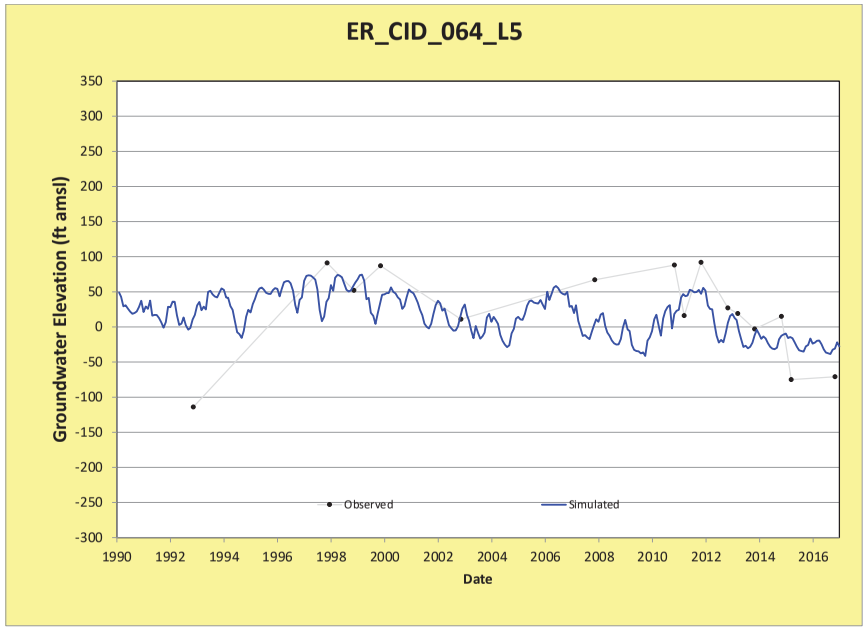

ER_CID_057_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

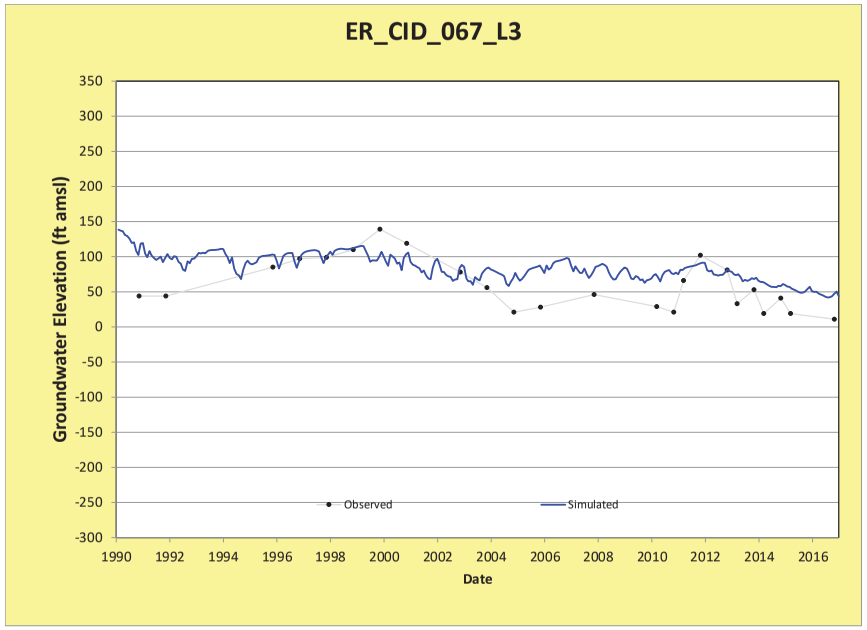

ER_CID_059_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

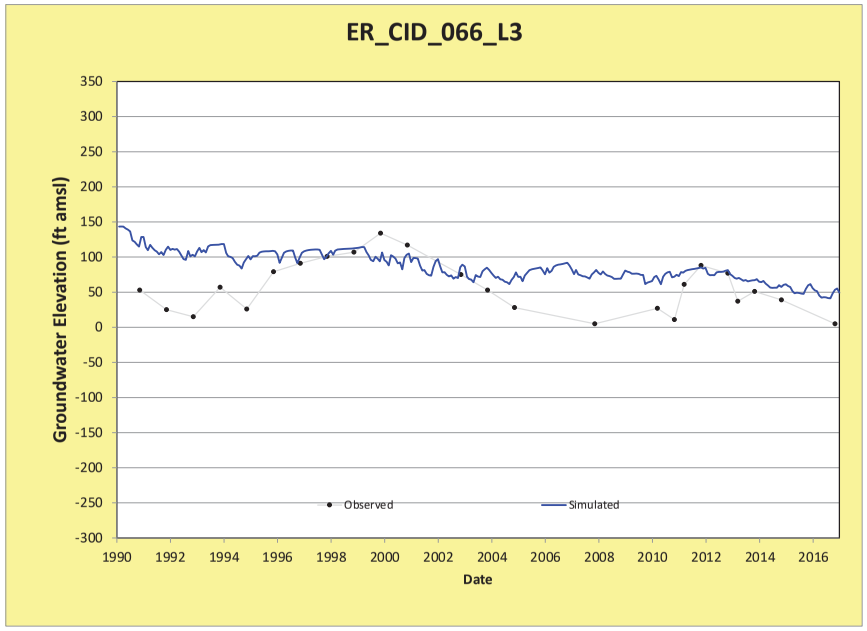

ER_CID_062_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

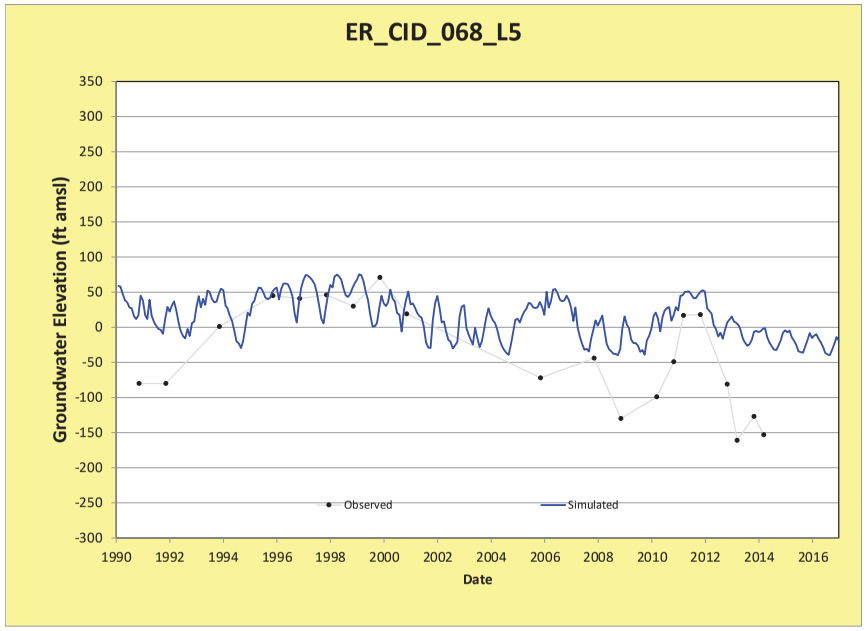

ER_CID_060_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

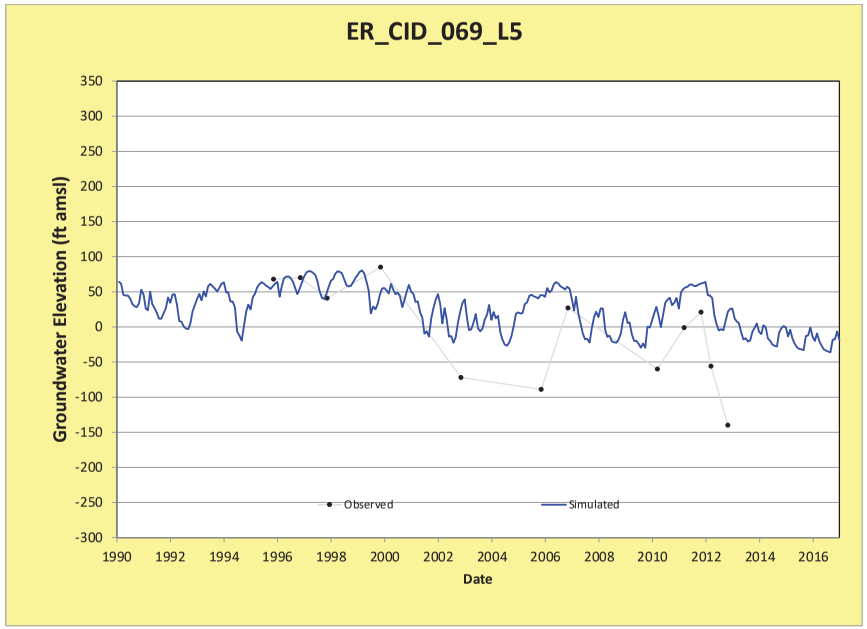

ER_CID_063_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

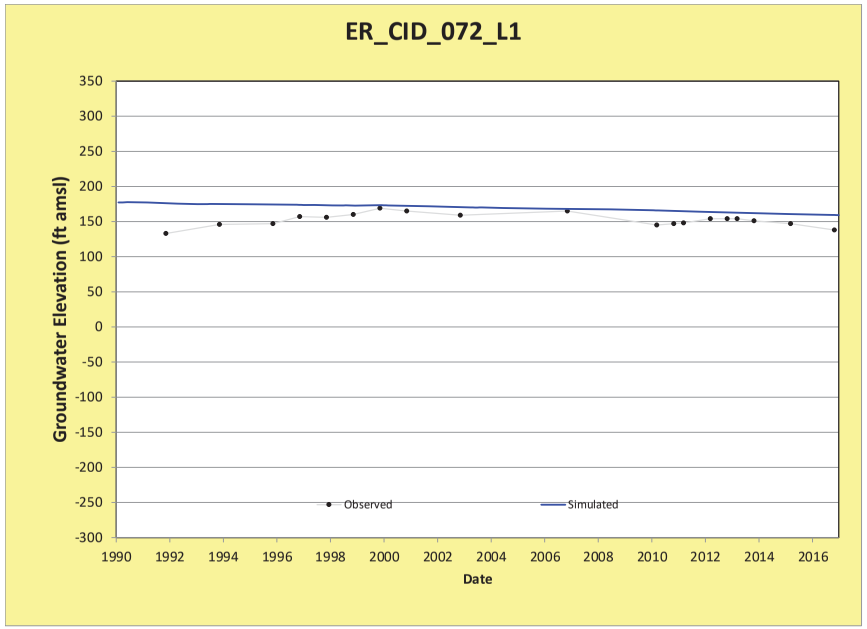

ER_CID_064_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

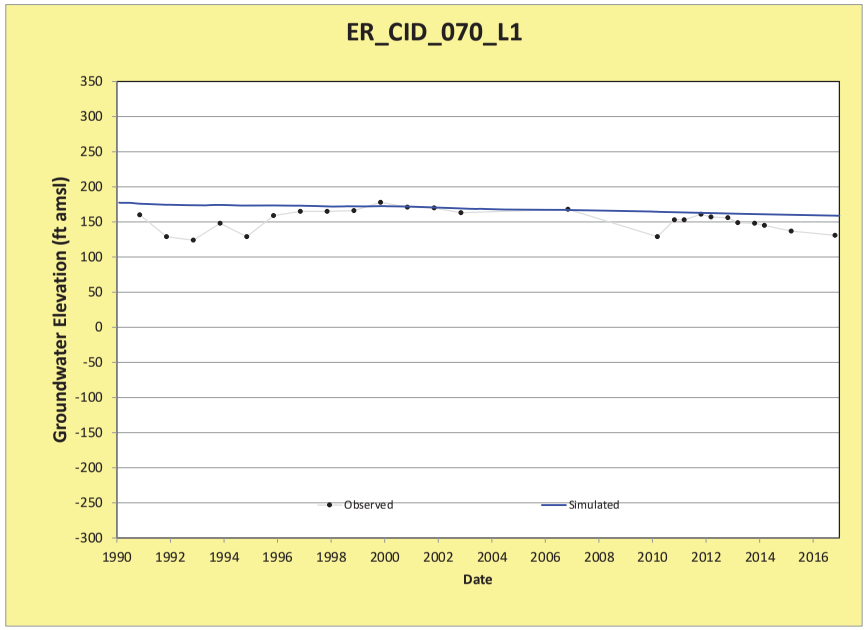

ER_CID_067_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

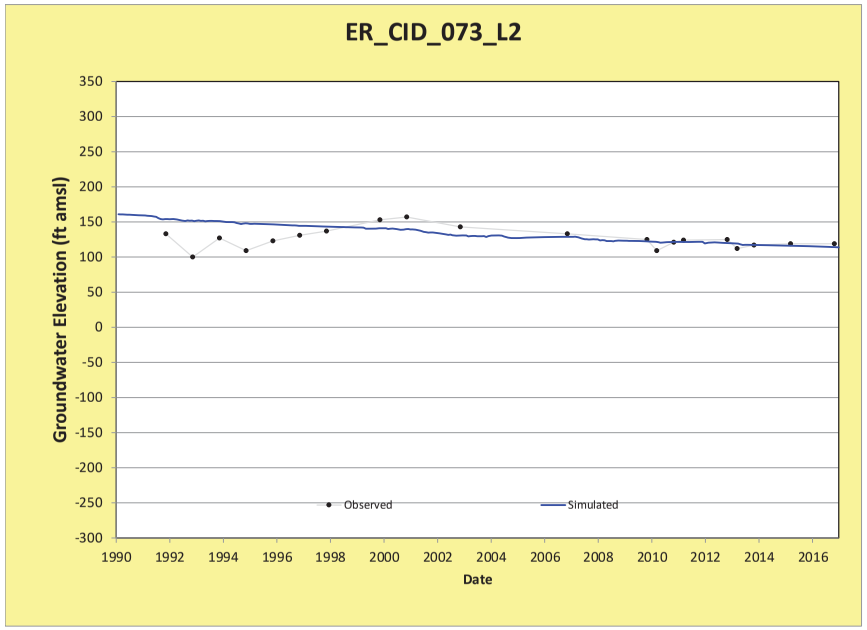

ER_CID_066_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

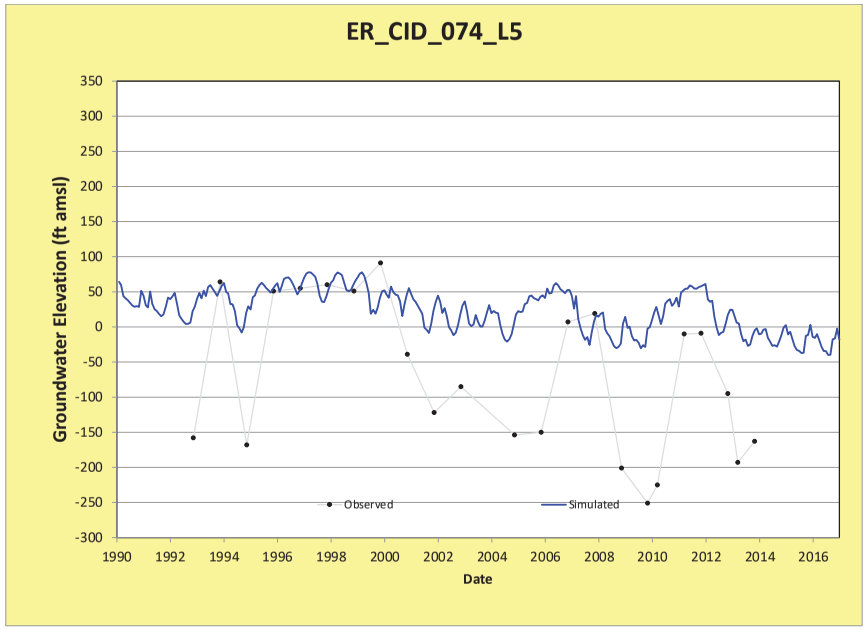

ER_CID_068_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

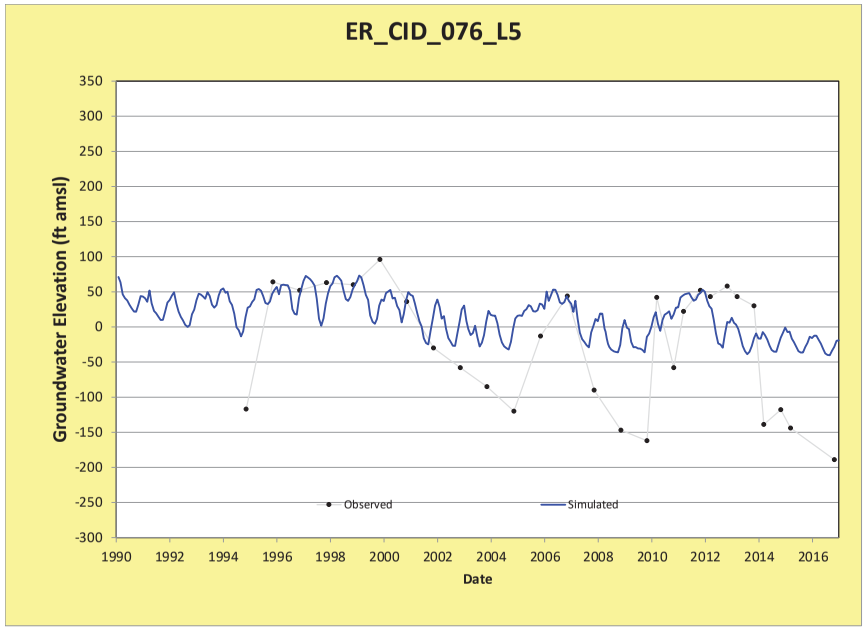

ER_CID_069_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

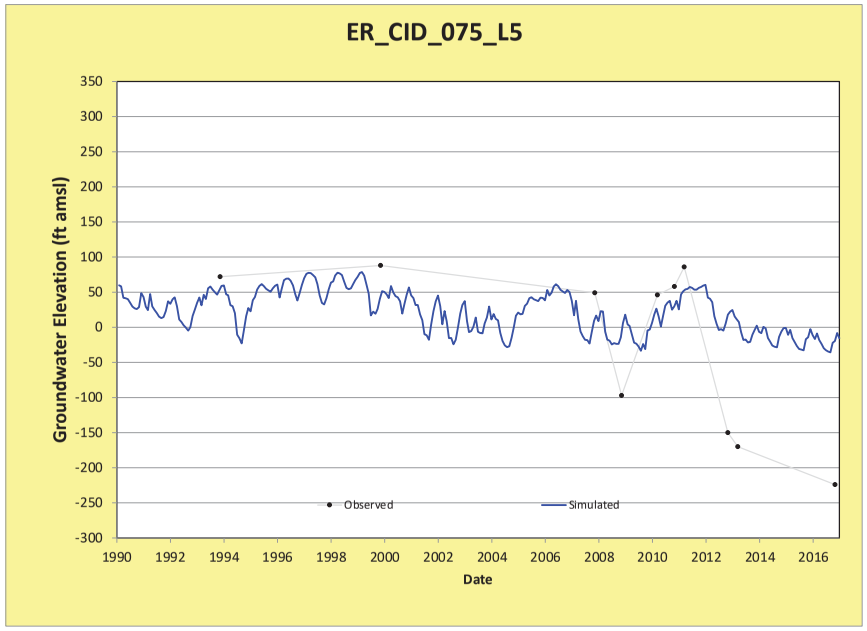

ER_CID_072_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

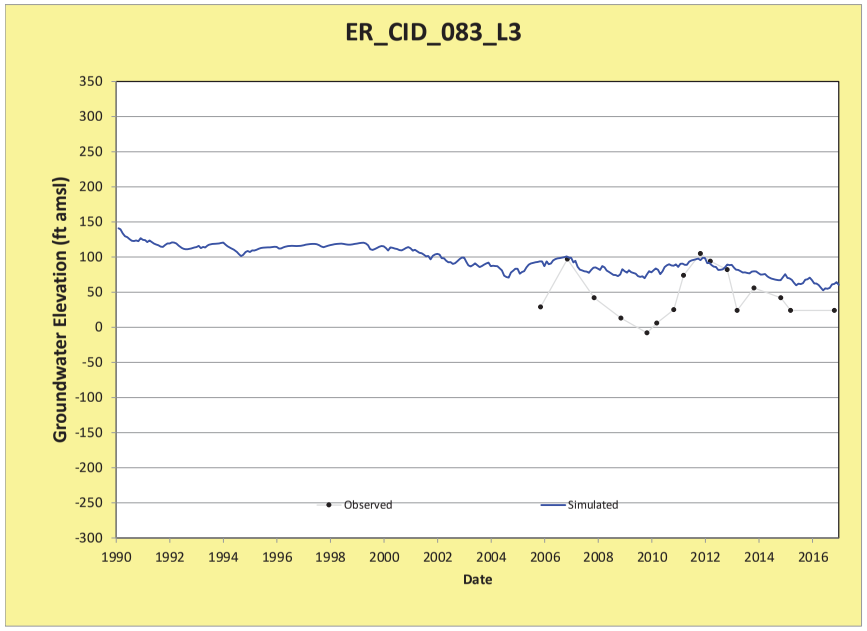

ER_CID_070_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

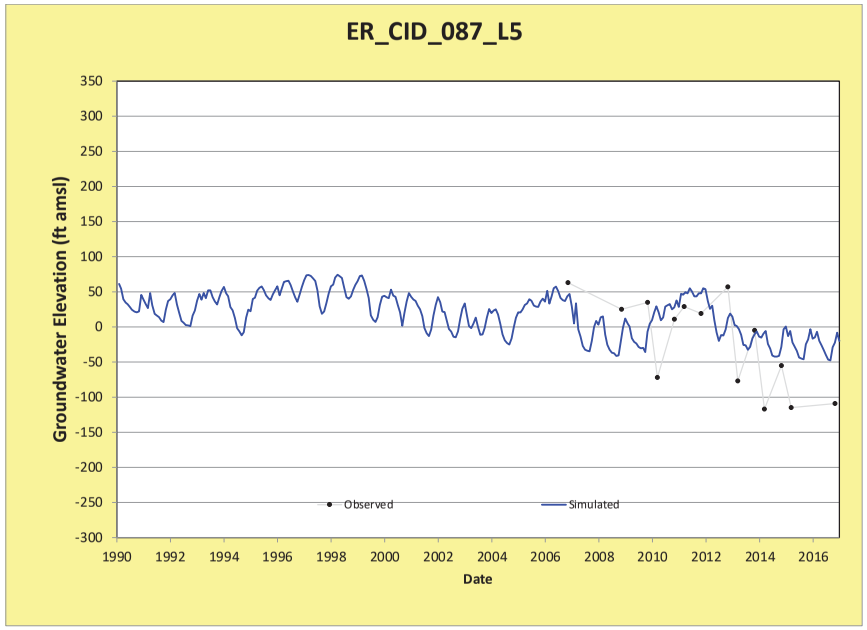

ER_CID_073_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

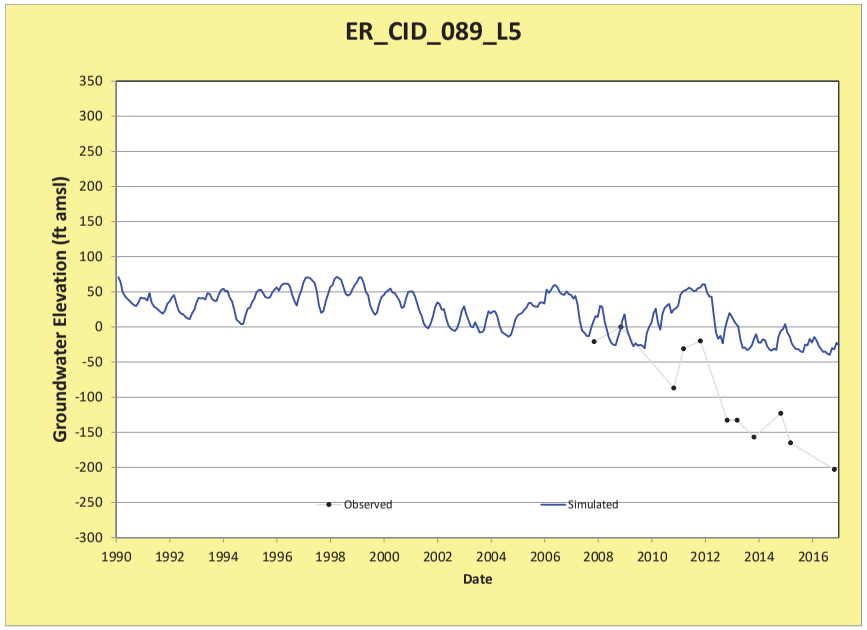

ER_CID_074_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

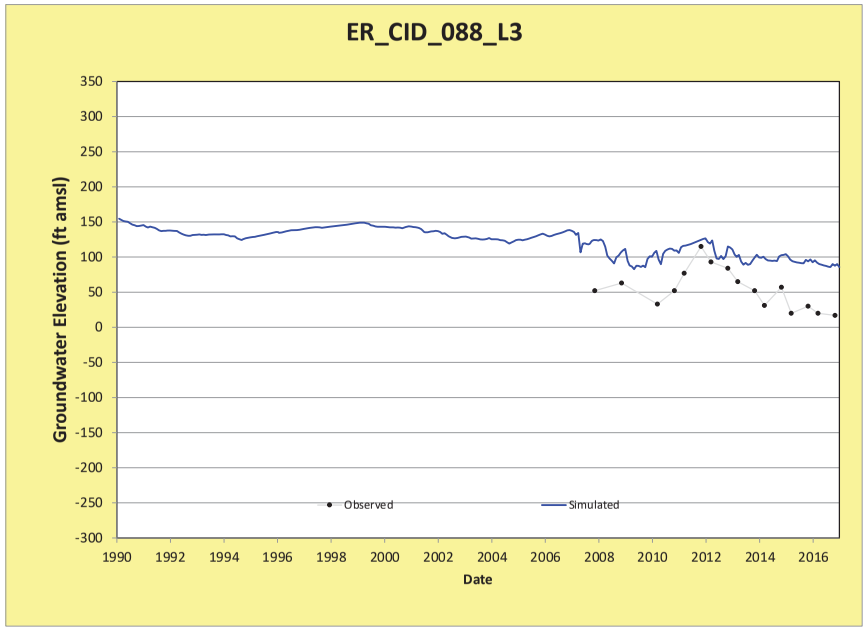

ER_CID_076_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

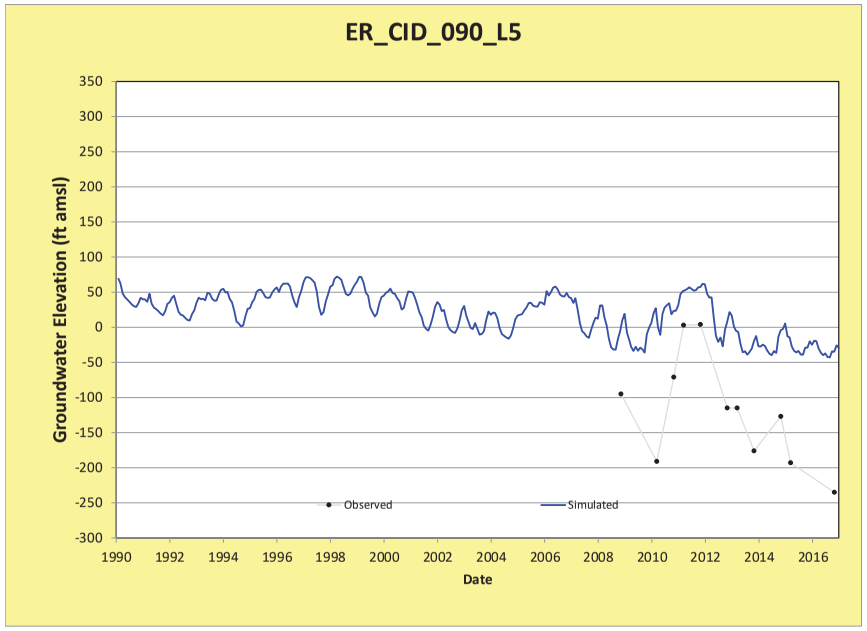

ER_CID_075_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

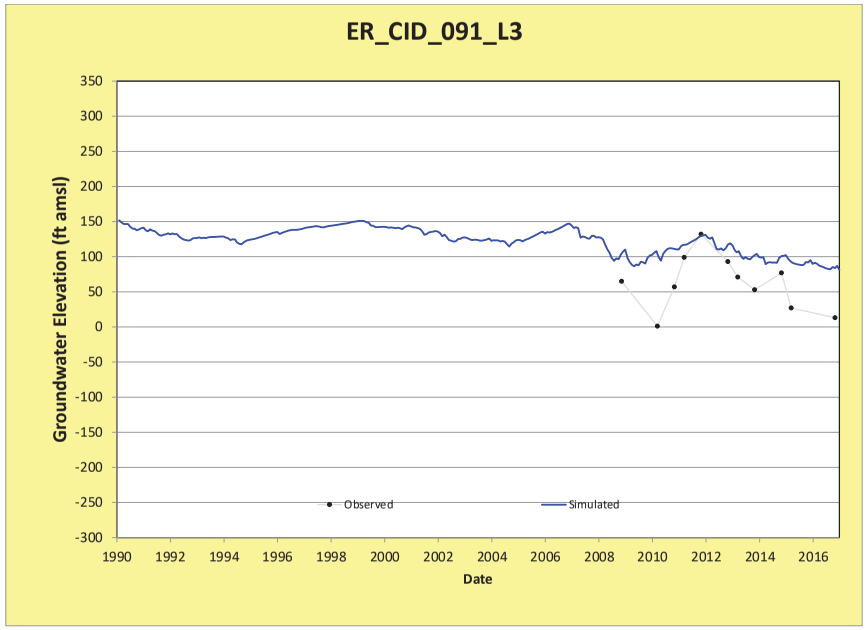

ER_CID_083_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

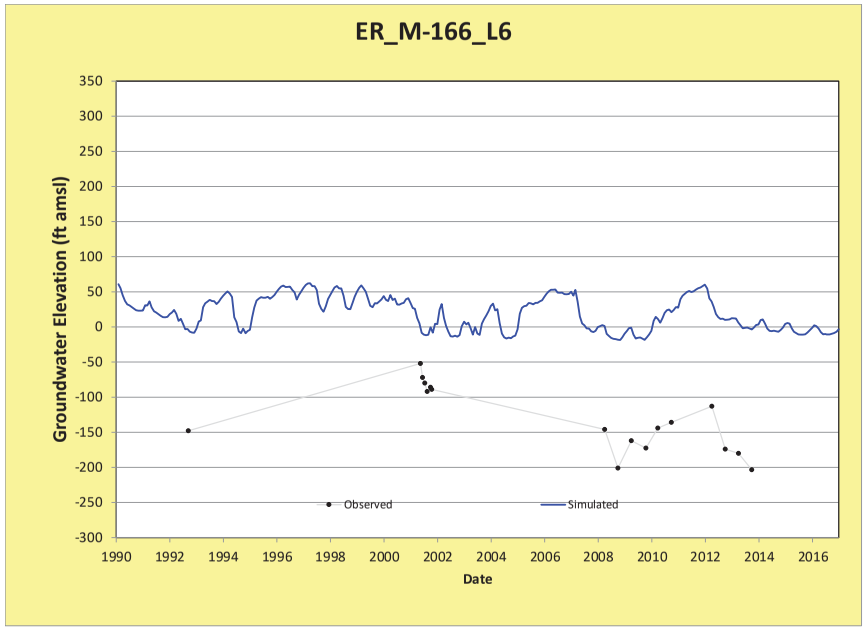

ER_CID_087_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

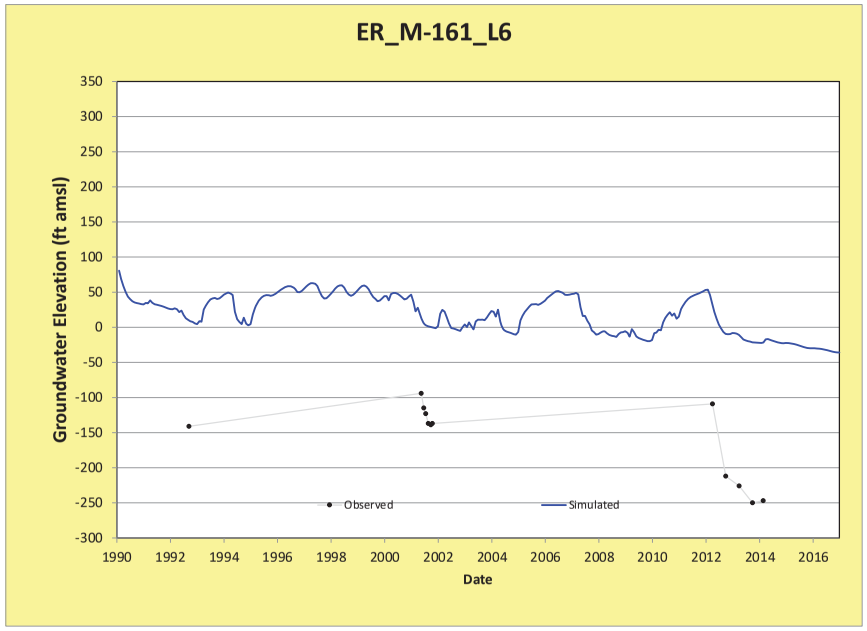

ER_CID_089_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

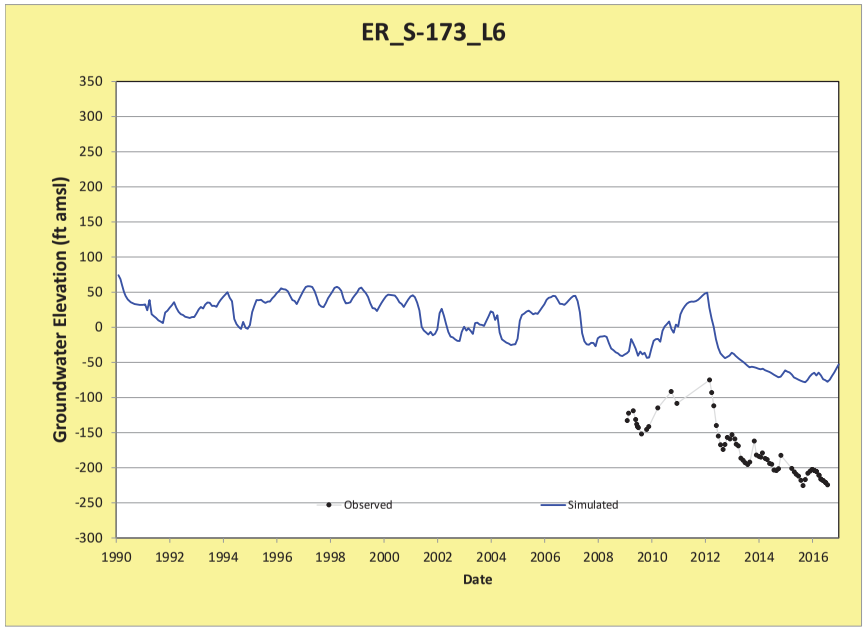

ER_CID_088_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

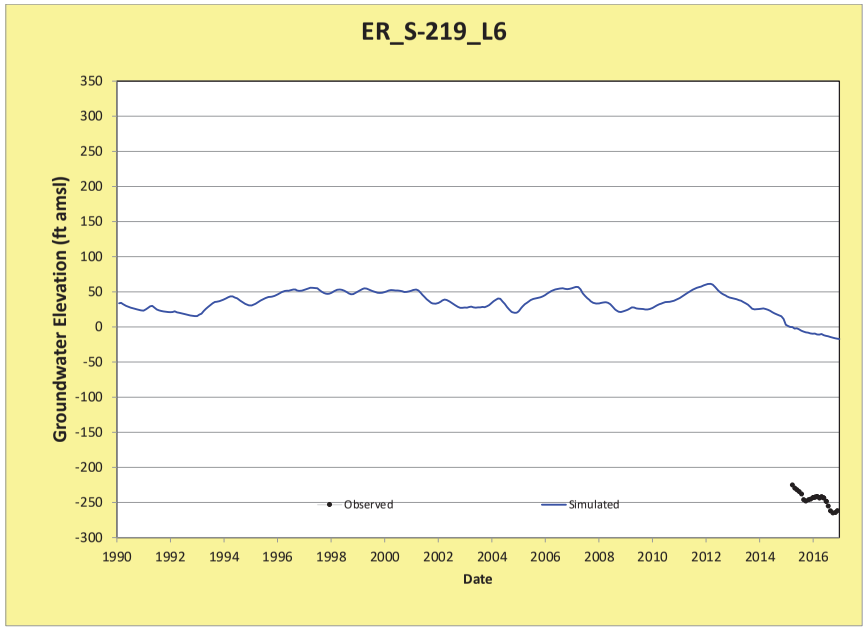

ER_CID_090_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

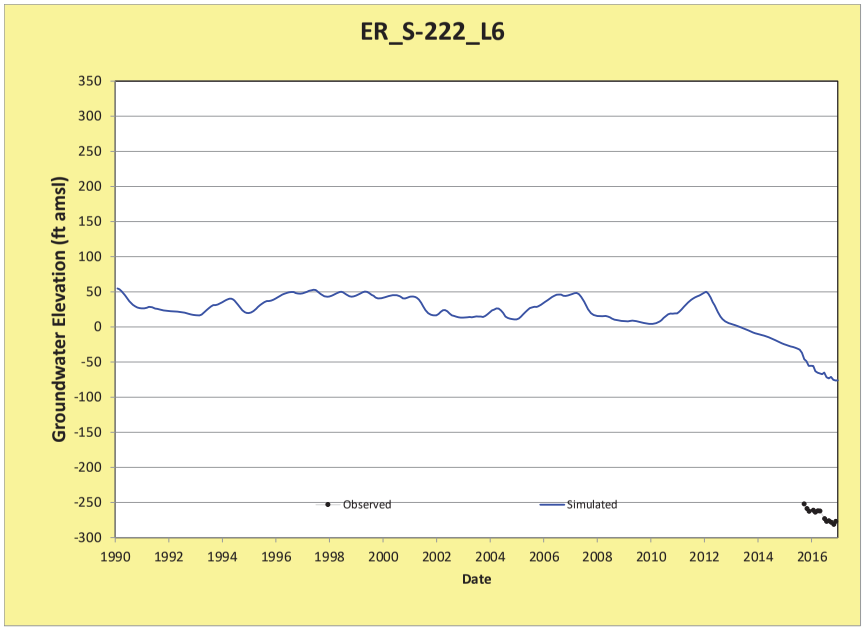

ER_CID_091_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

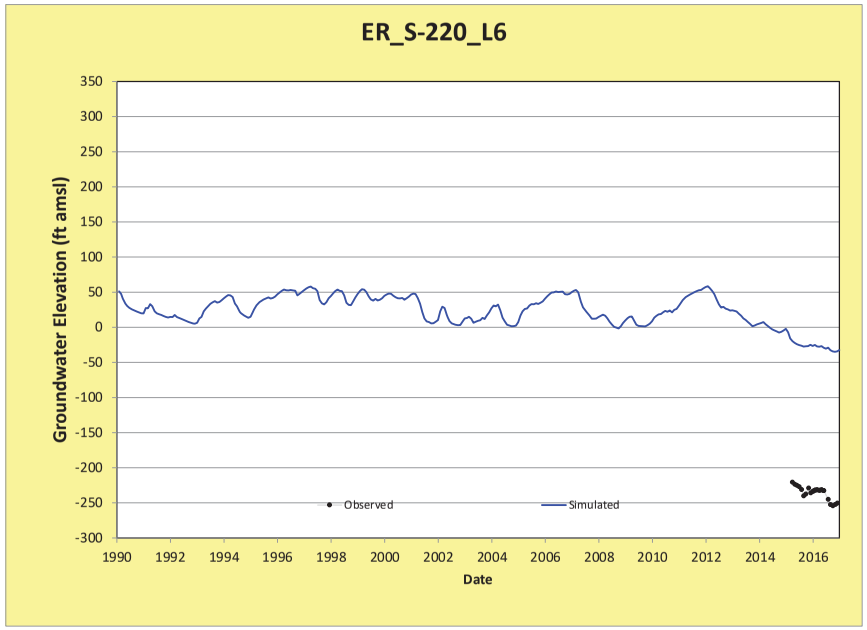

ER_M-166_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

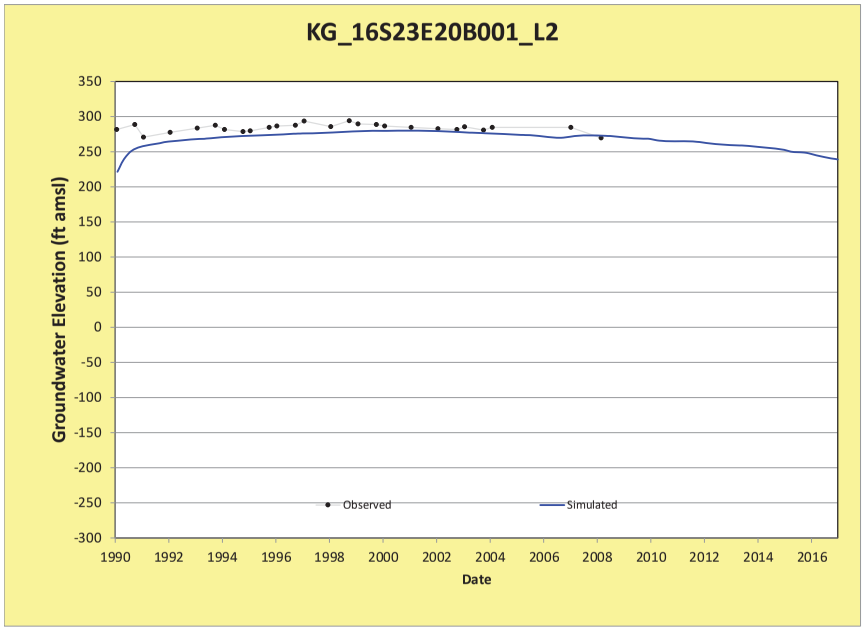

ER_M-161_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

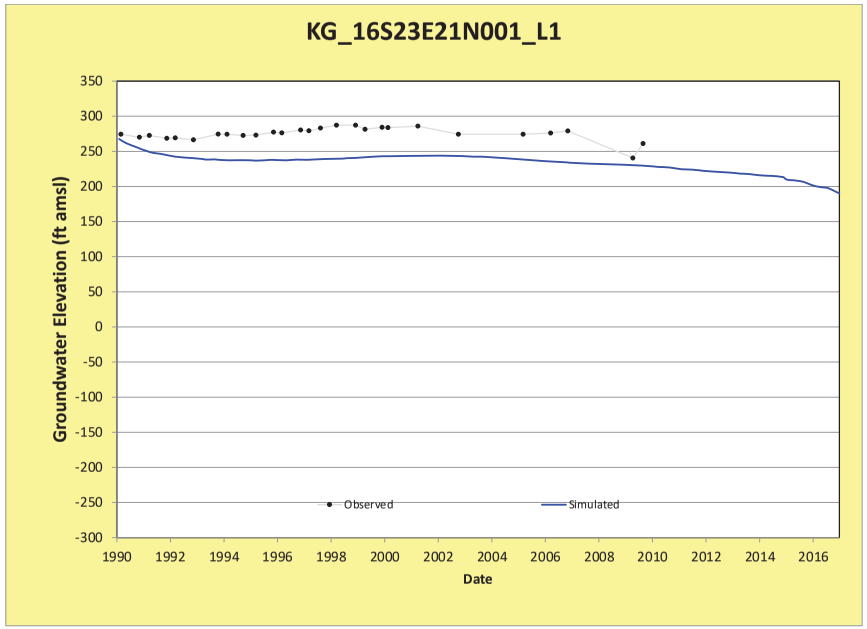

ER_S-173_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

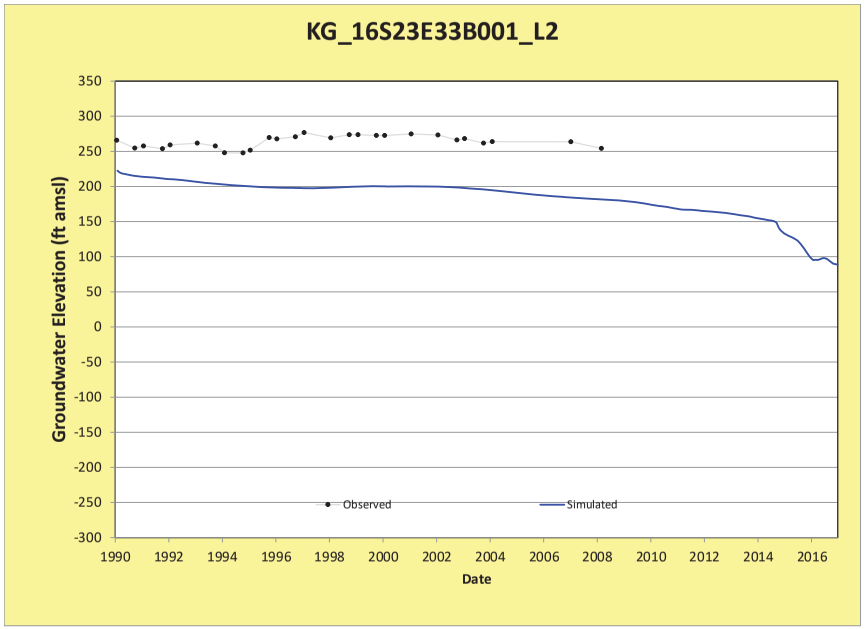

ER_S-219_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

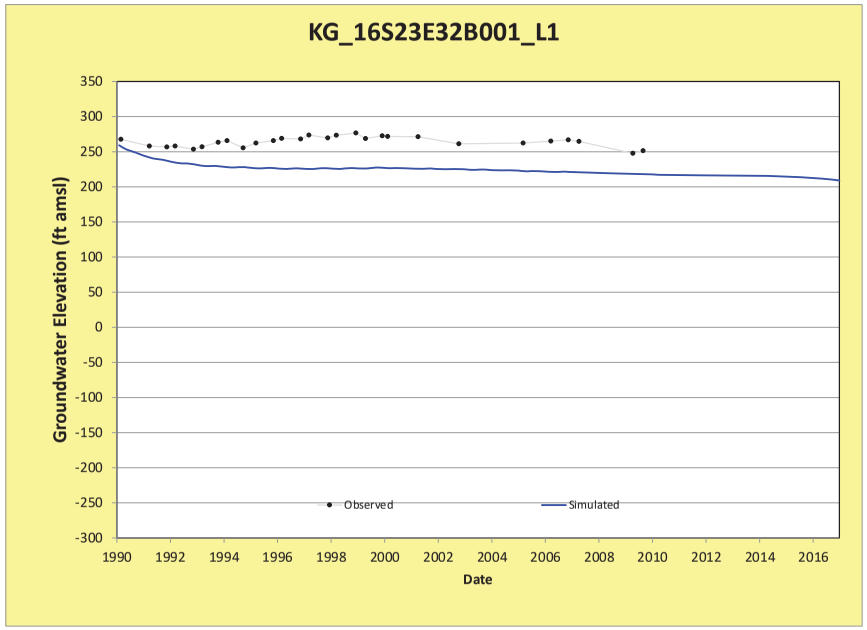

ER_S-222_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

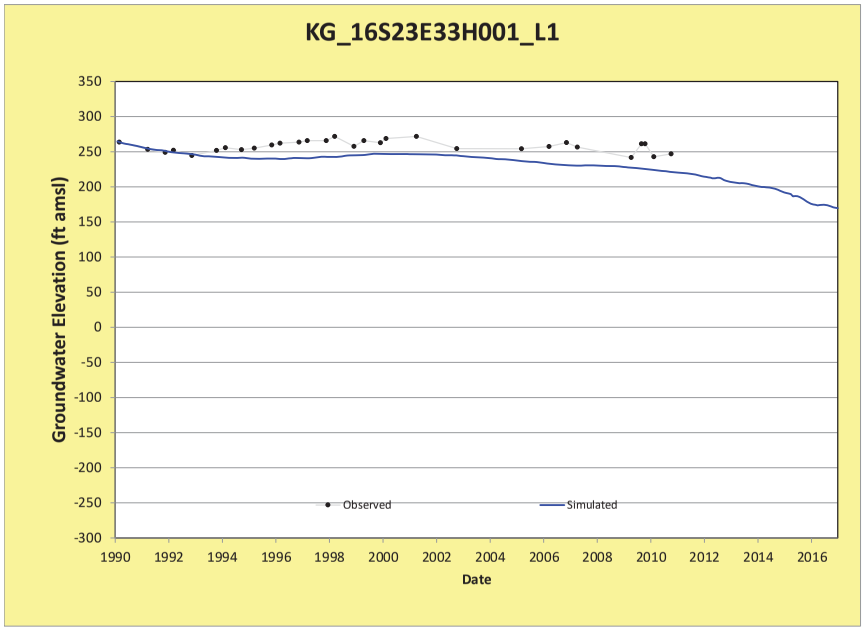

ER_S-220_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

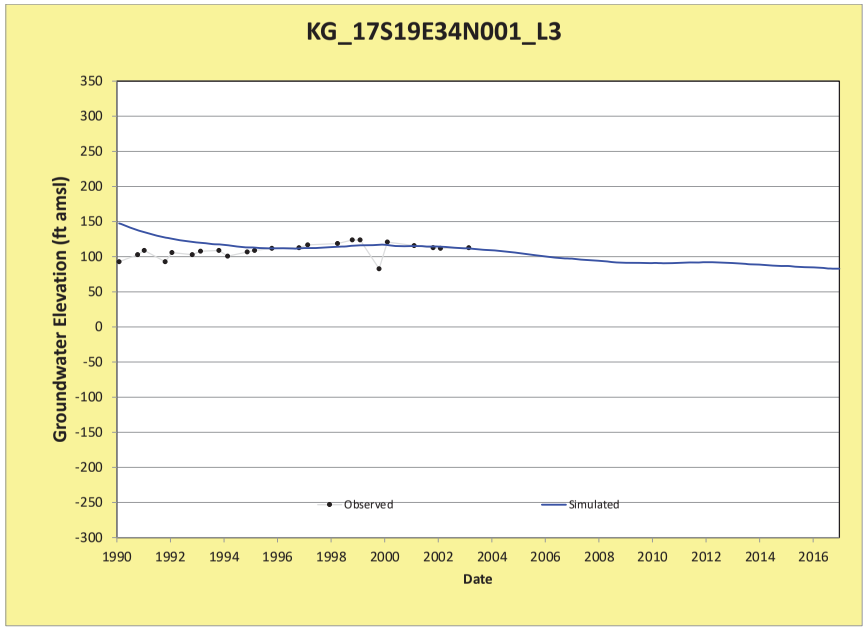

KG_16S23E20B001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

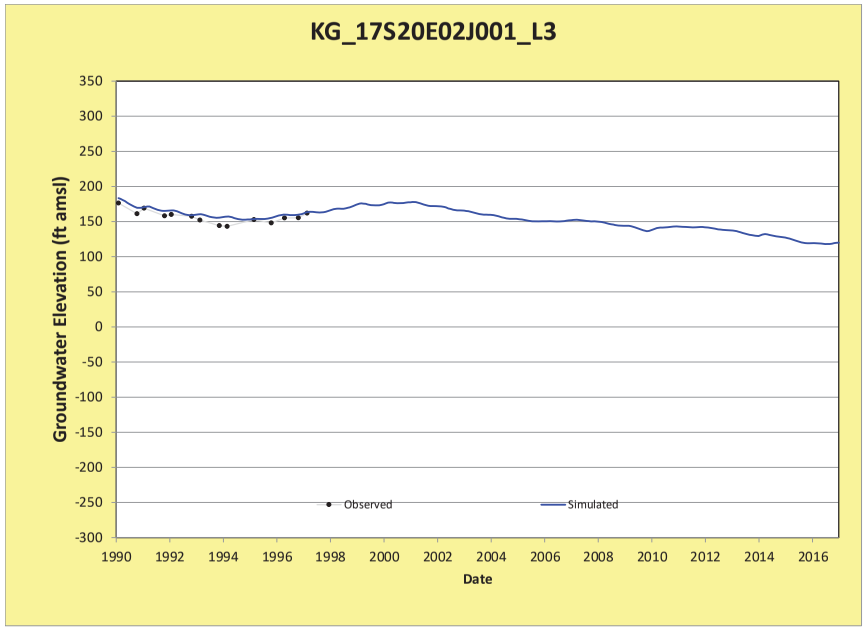

KG_16S23E21N001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

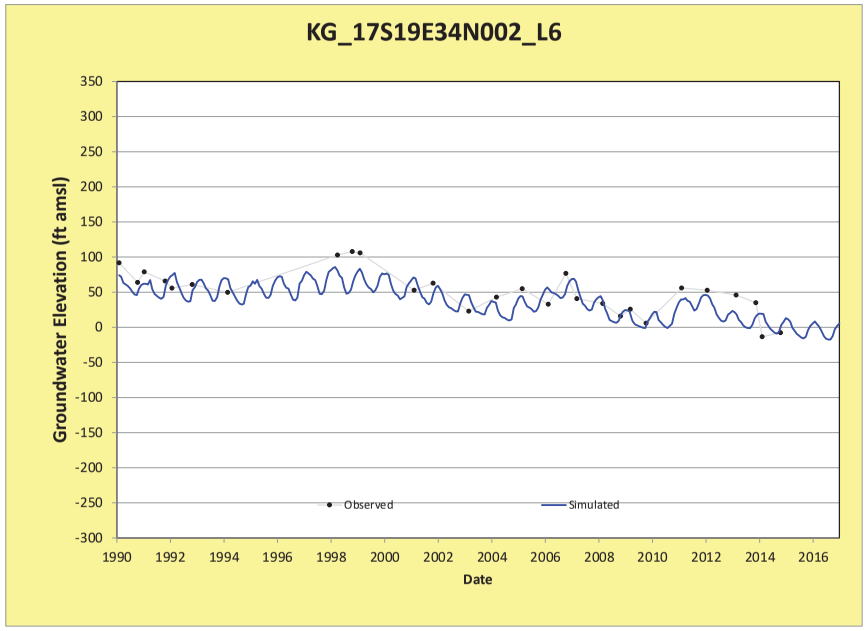

KG_16S23E33B001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

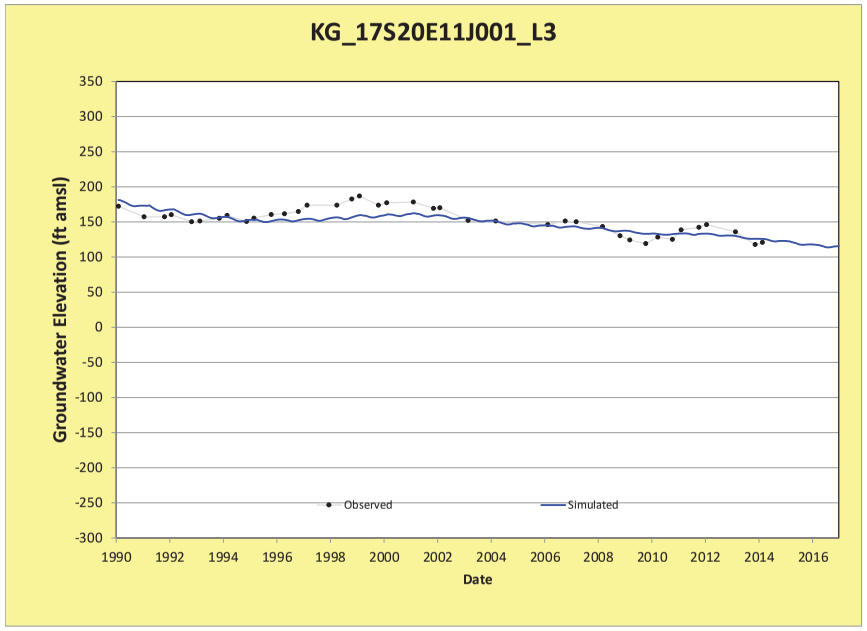

KG_16S23E32B001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

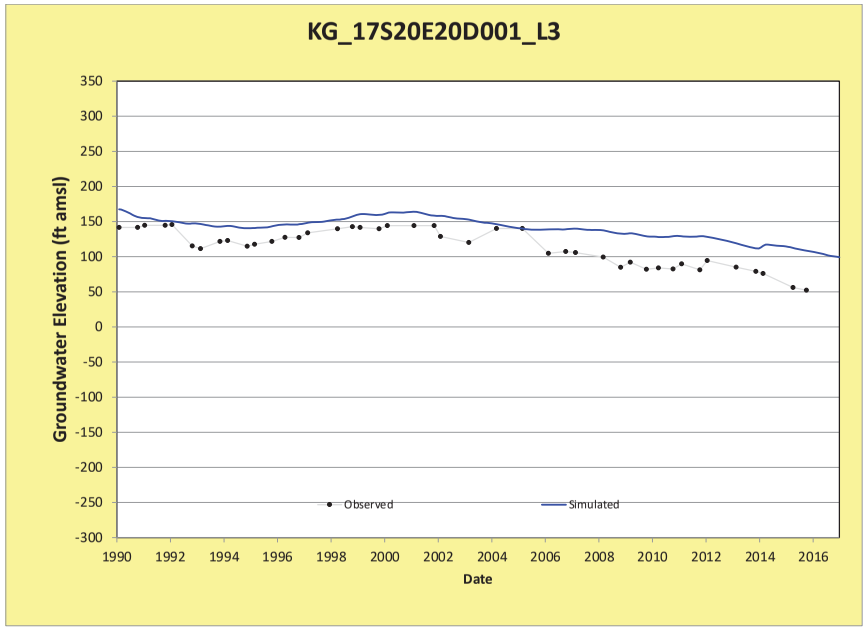

KG_16S23E33H001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

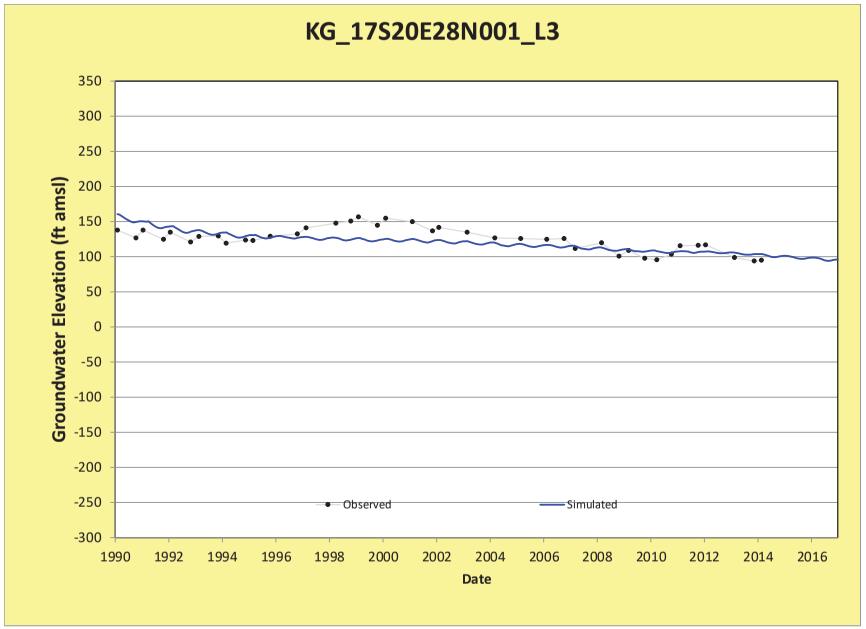

KG_17S19E34N001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

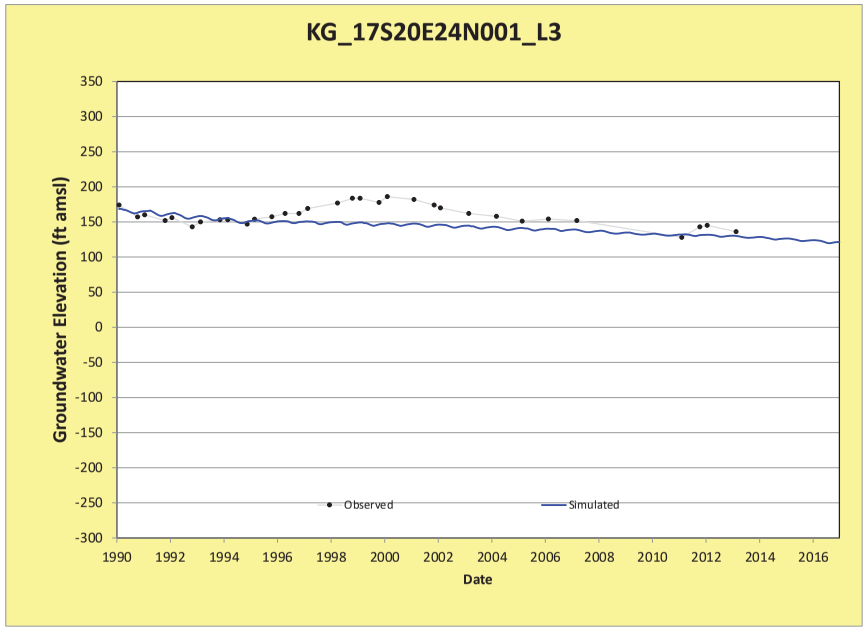

KG_17S20E02J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

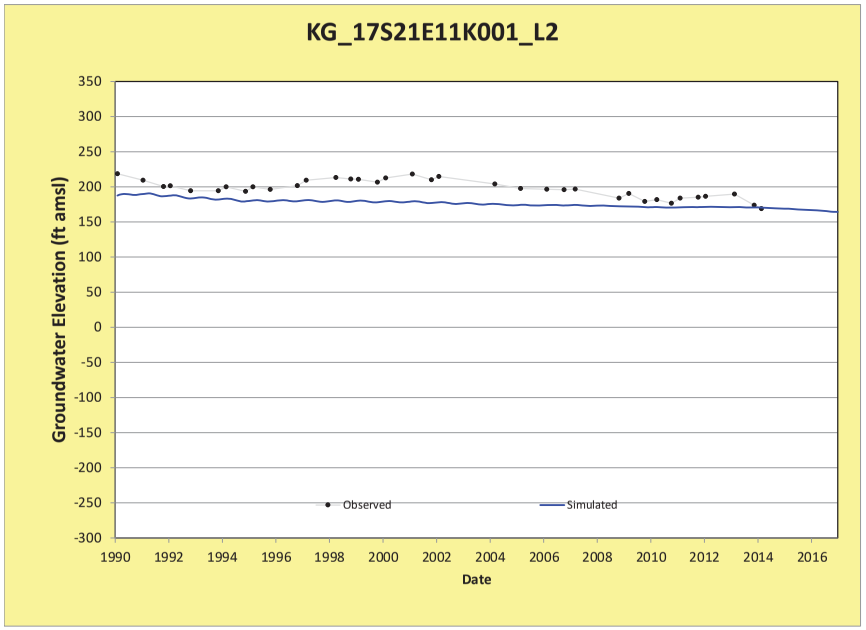

KG_17S19E34N002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

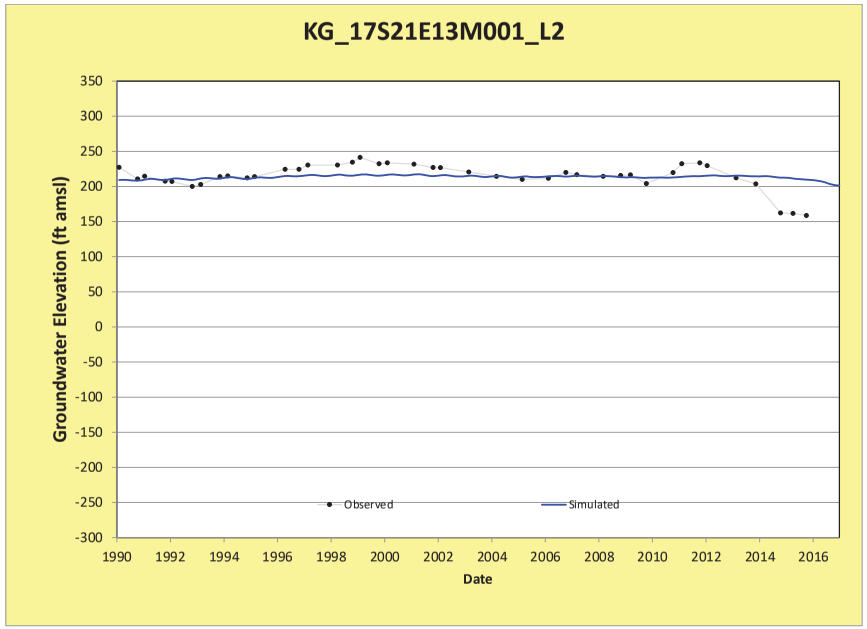

KG_17S20E11J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

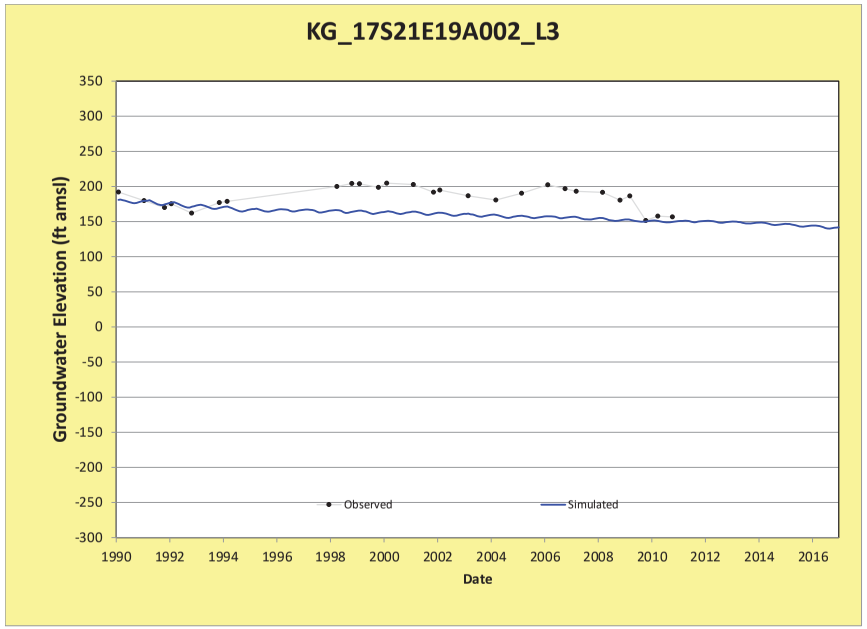

KG_17S20E20D001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

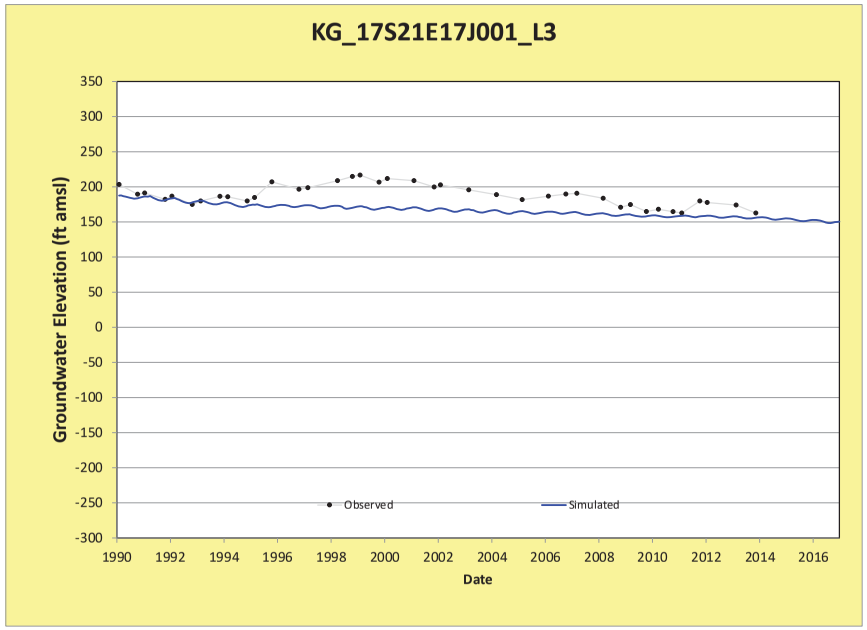

KG_17S20E28N001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

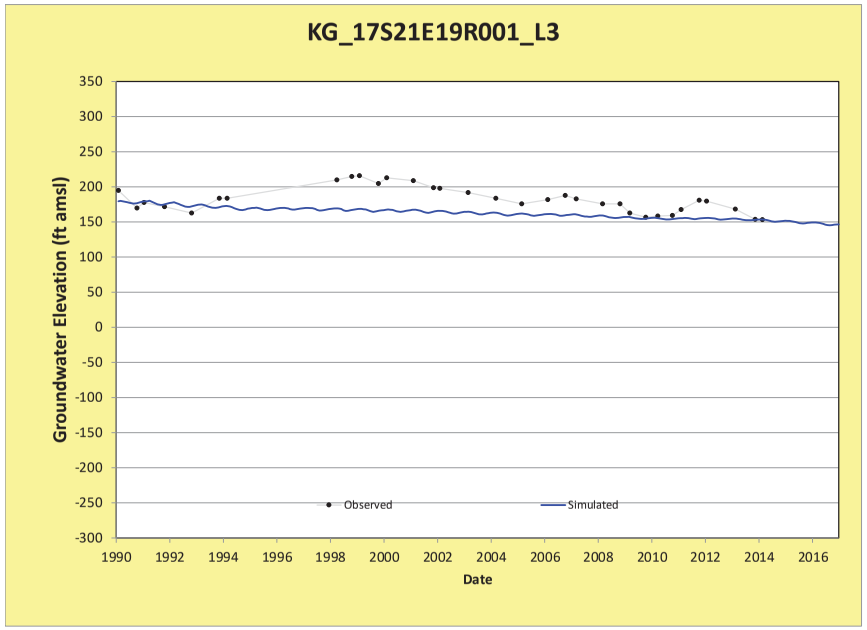

KG_17S20E24N001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

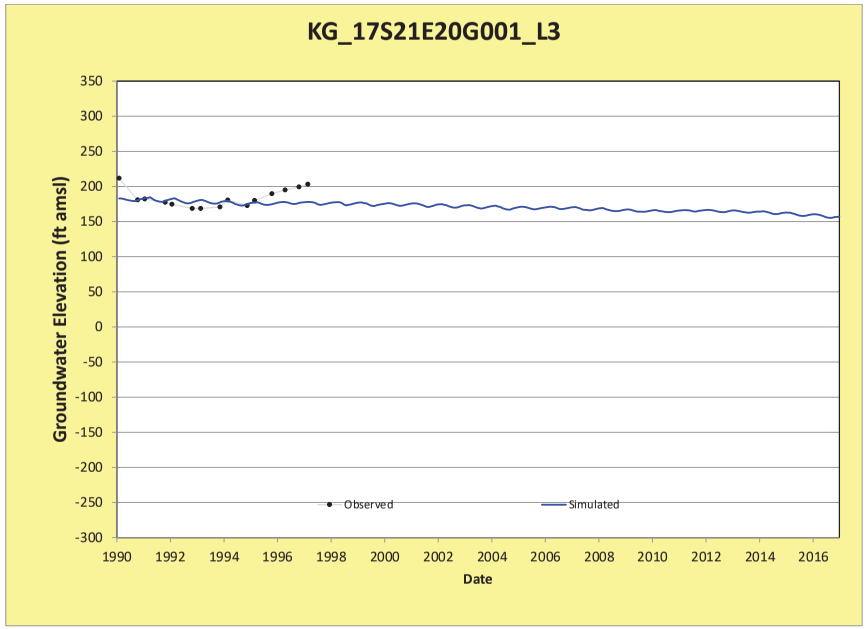

KG_17S21E11K001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

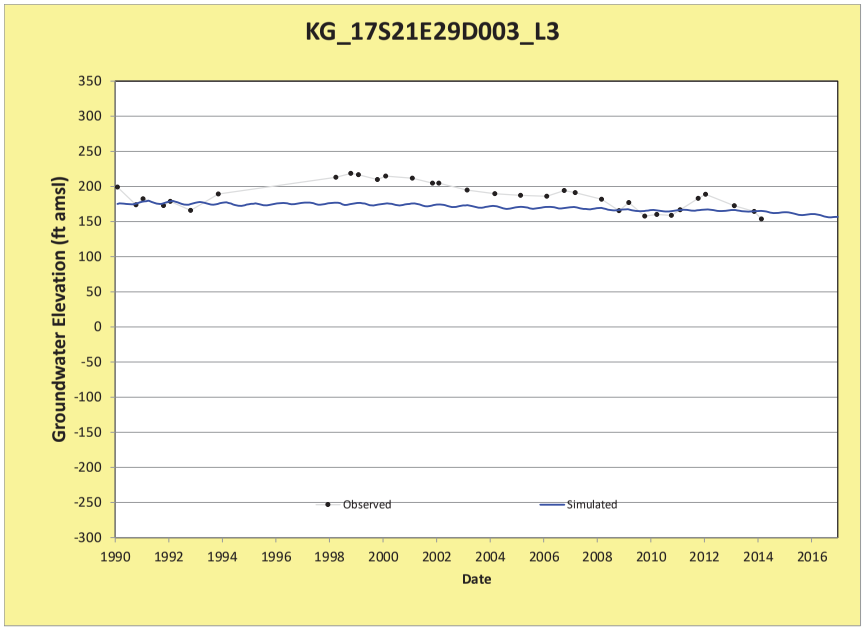

KG_17S21E13M001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

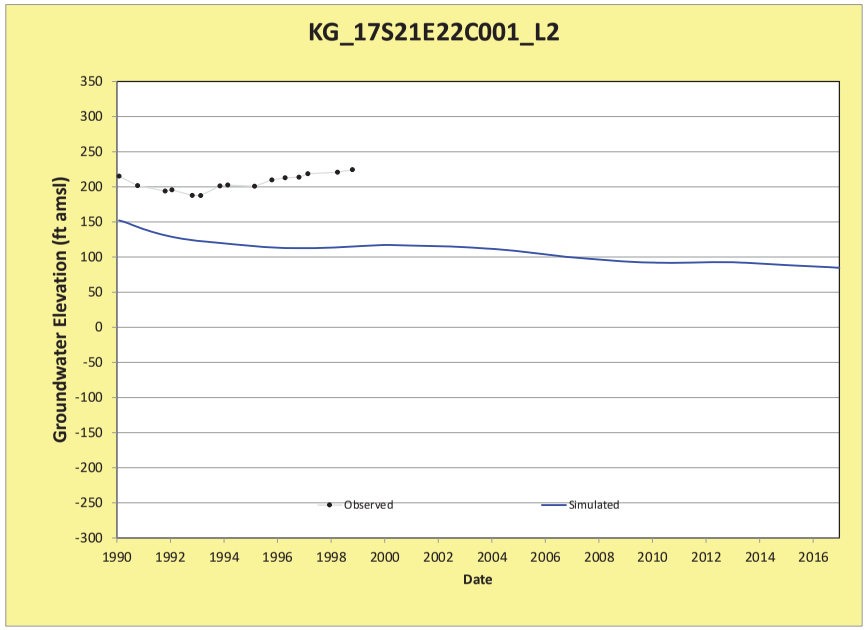

KG_17S21E19A002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

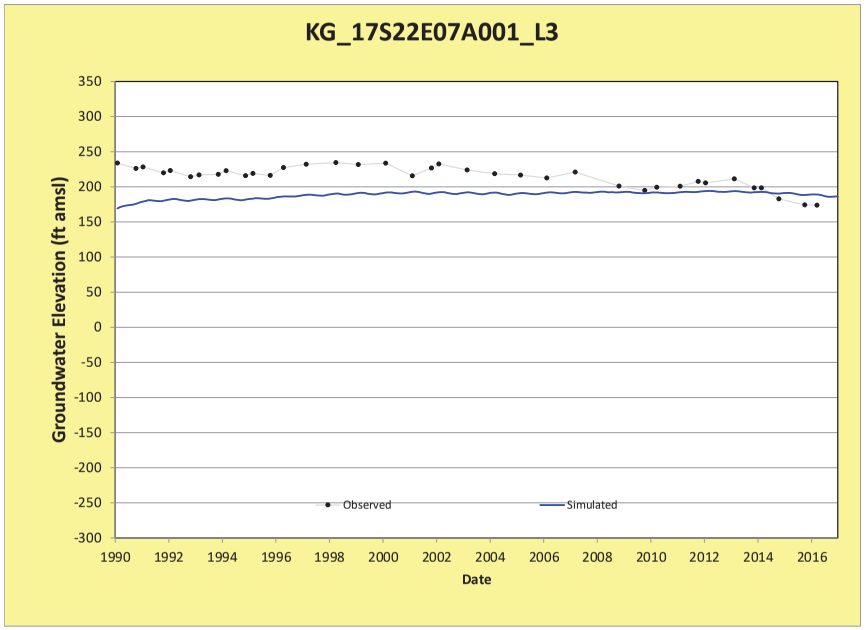

KG_17S21E17J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

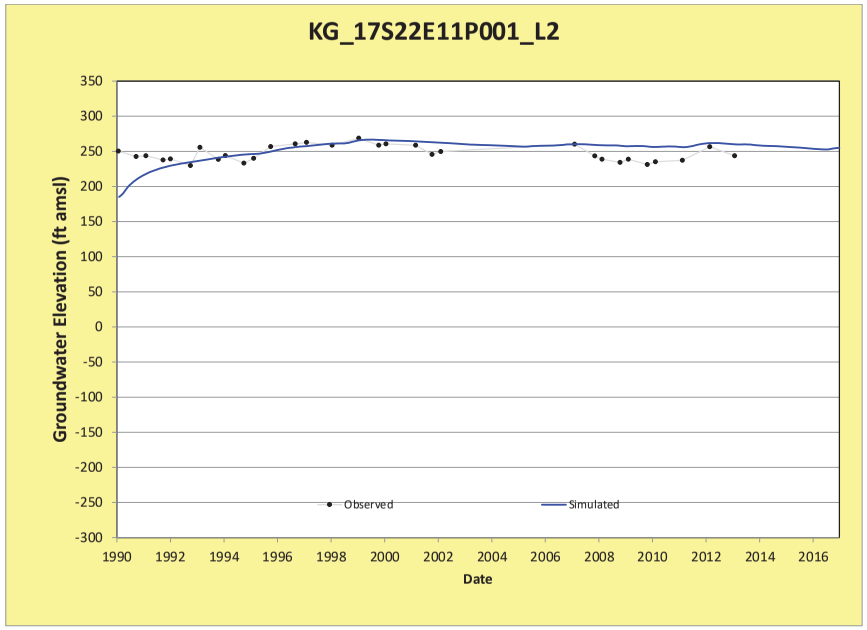

KG_17S21E19R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

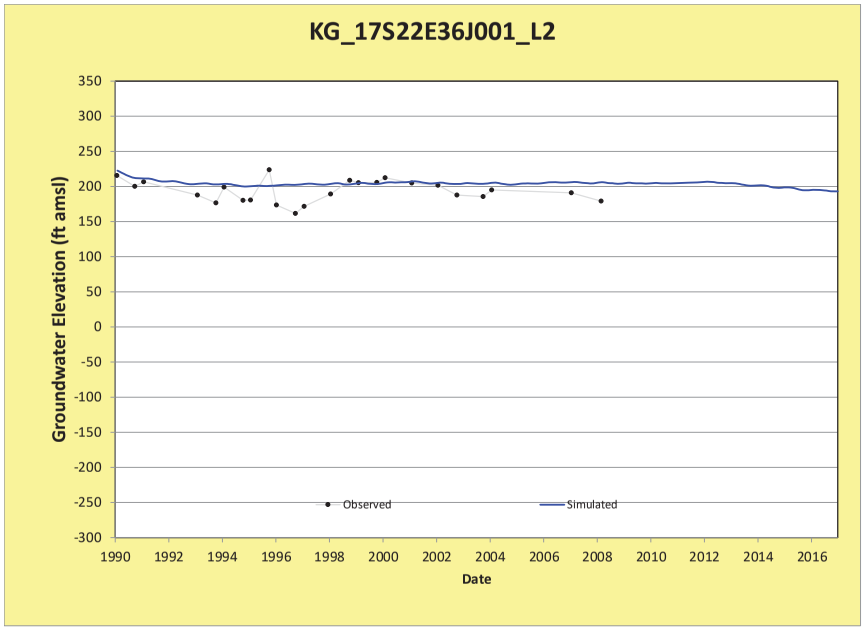

KG_17S21E20G001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

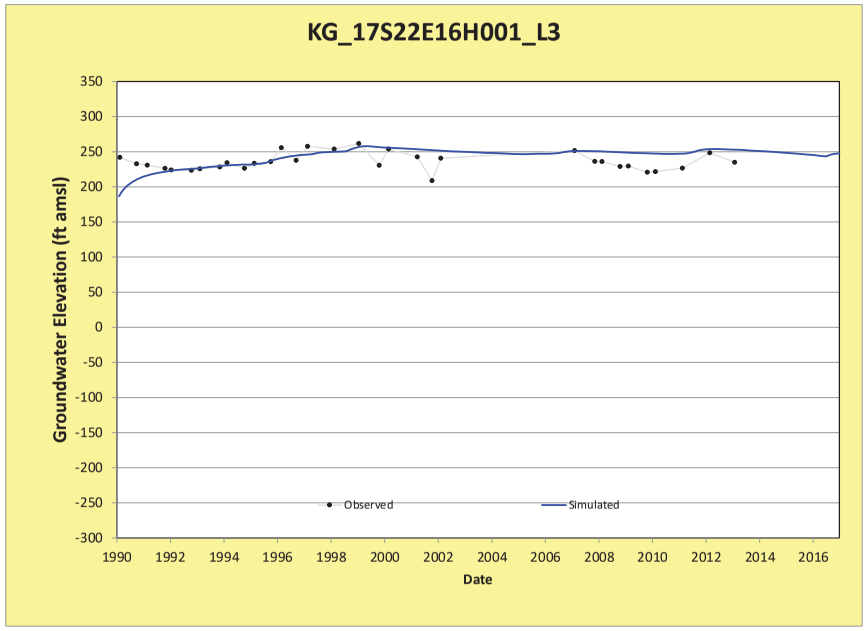

KG_17S21E29D003_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

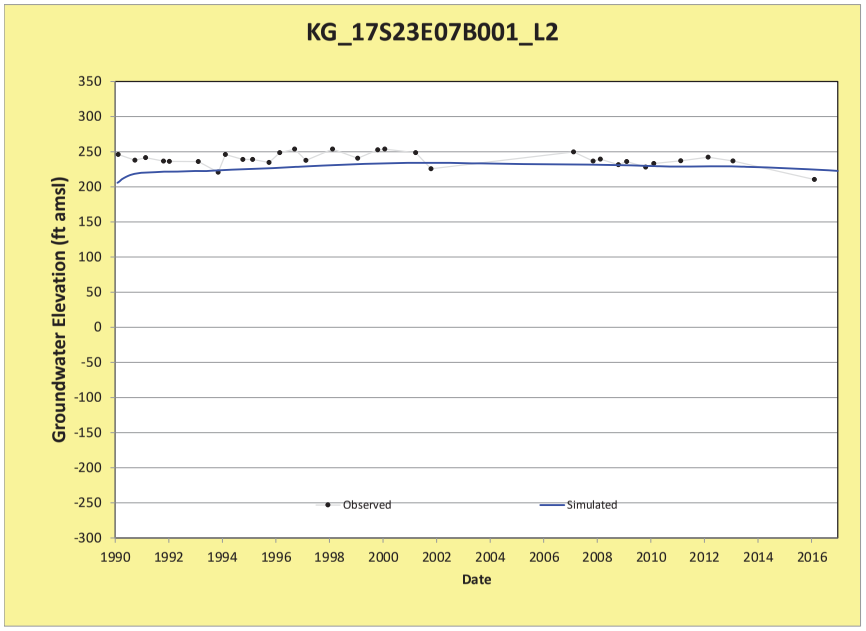

KG_17S21E22C001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

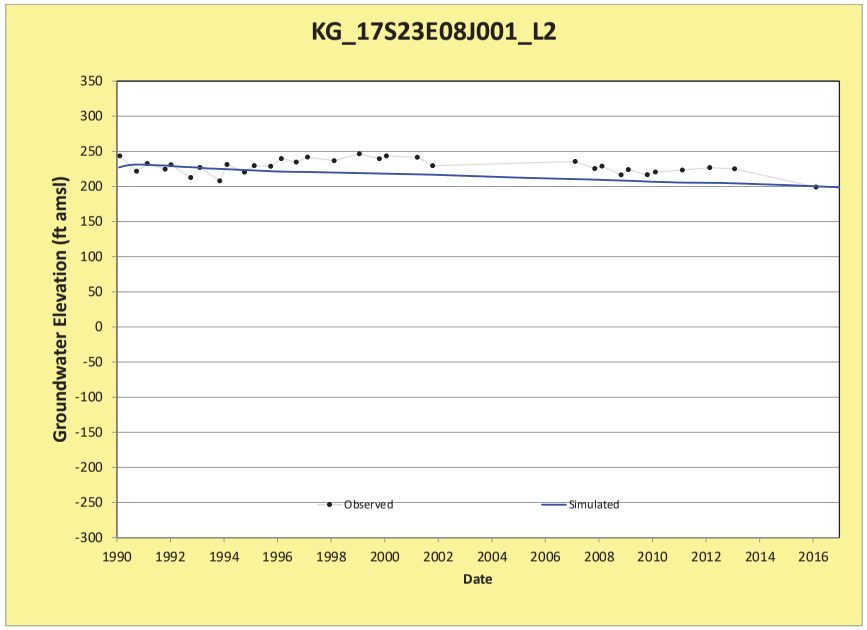

KG_17S22E07A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

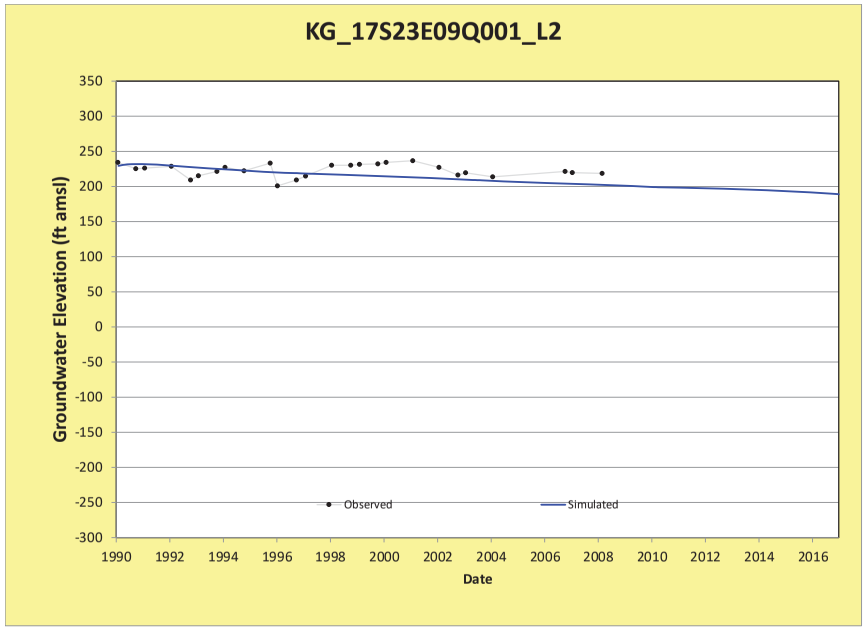

KG_17S22E11P001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

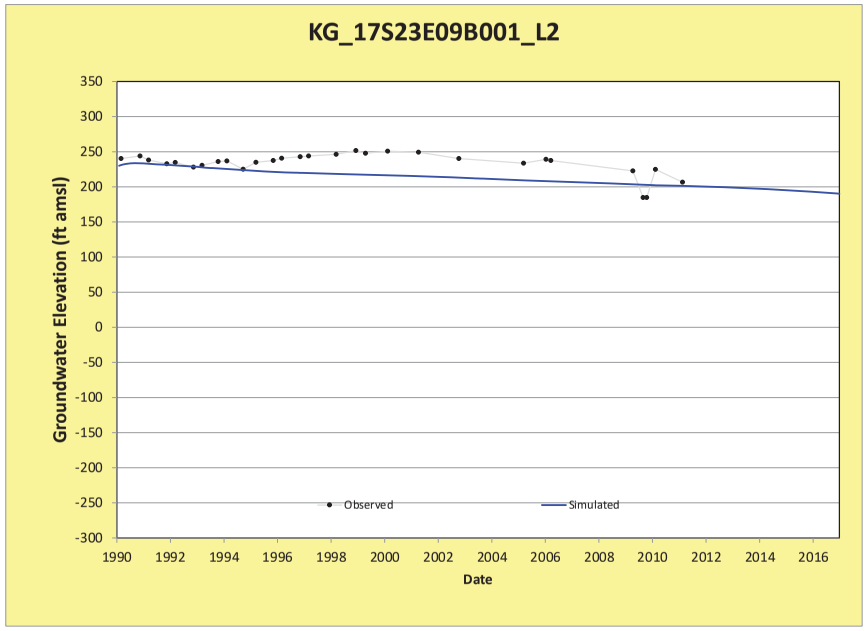

KG_17S22E36J001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

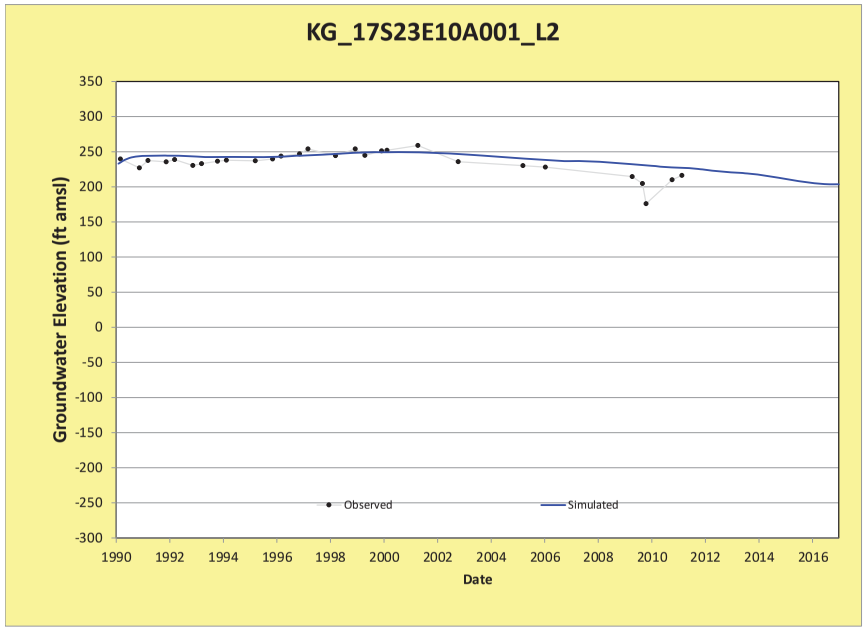

KG_17S22E16H001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

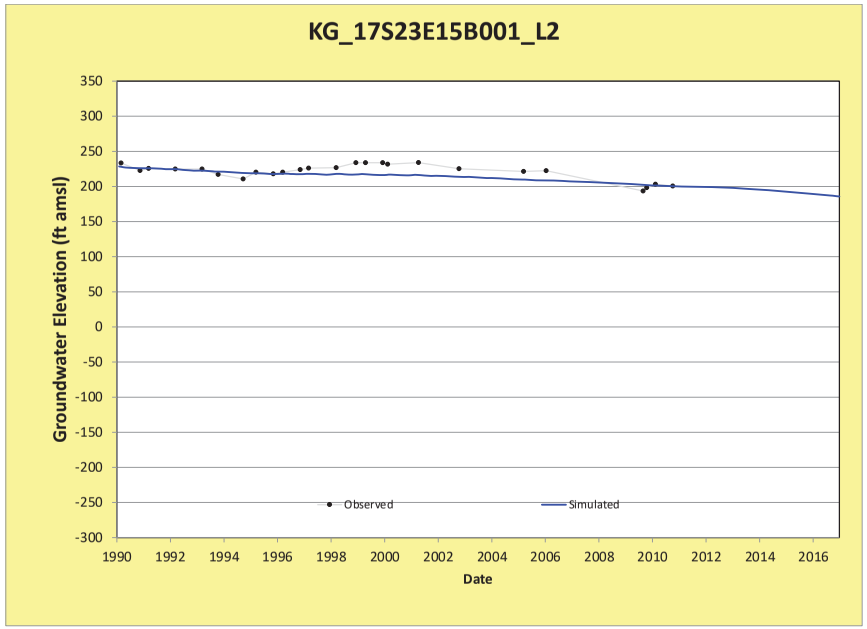

KG_17S23E07B001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

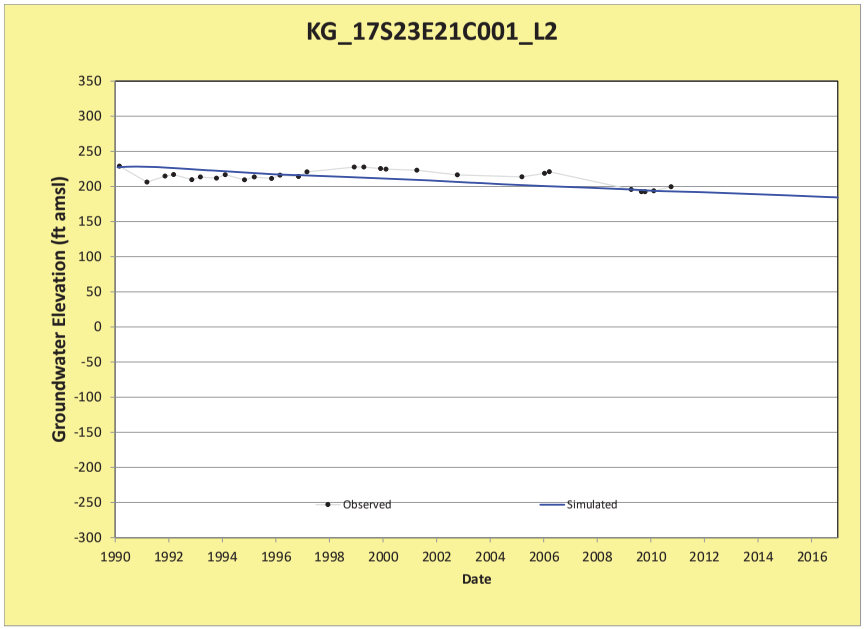

KG_17S23E08J001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

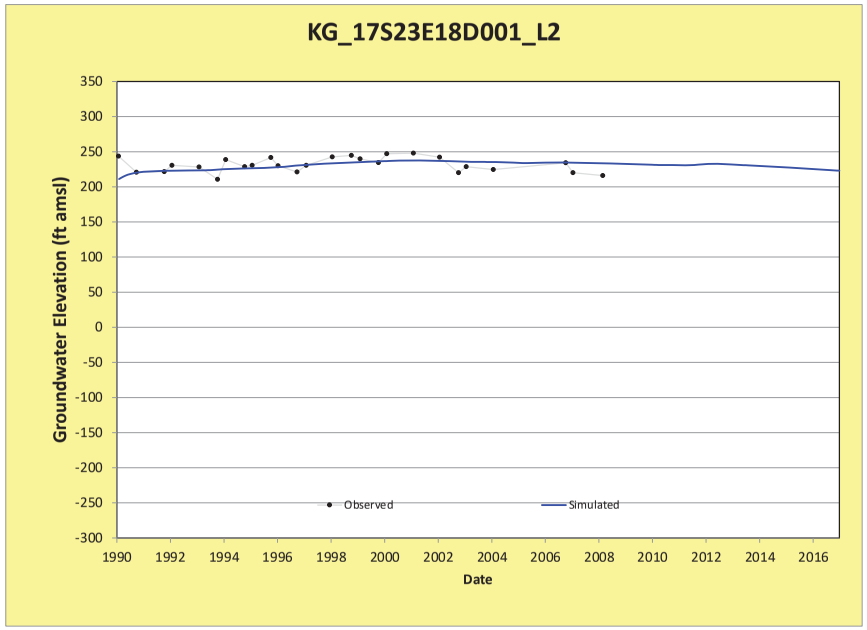

KG_17S23E09Q001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

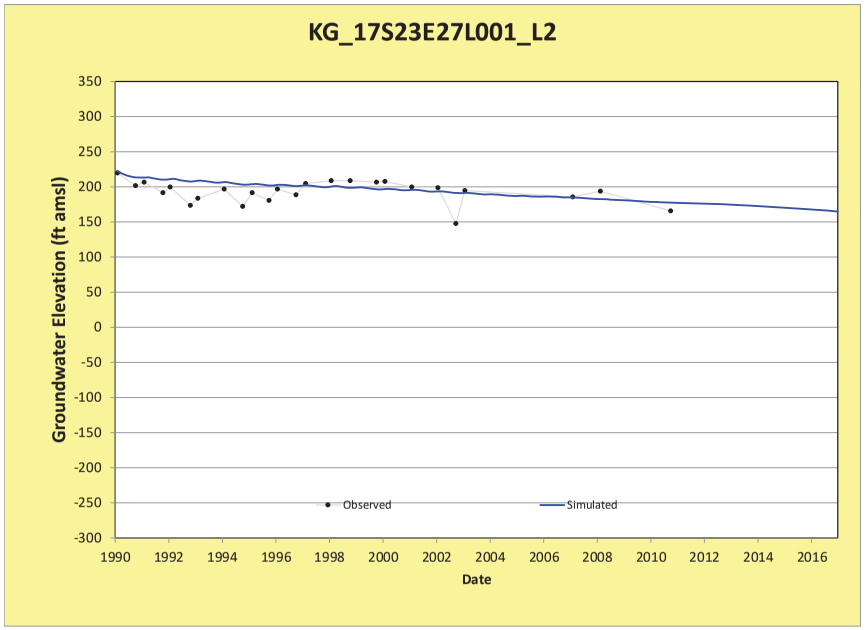

KG_17S23E09B001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

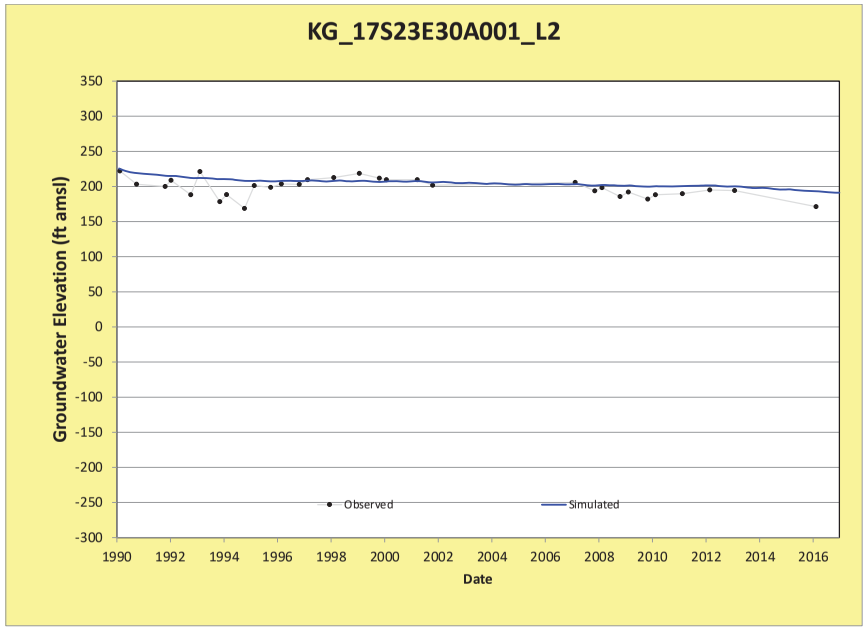

KG_17S23E10A001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

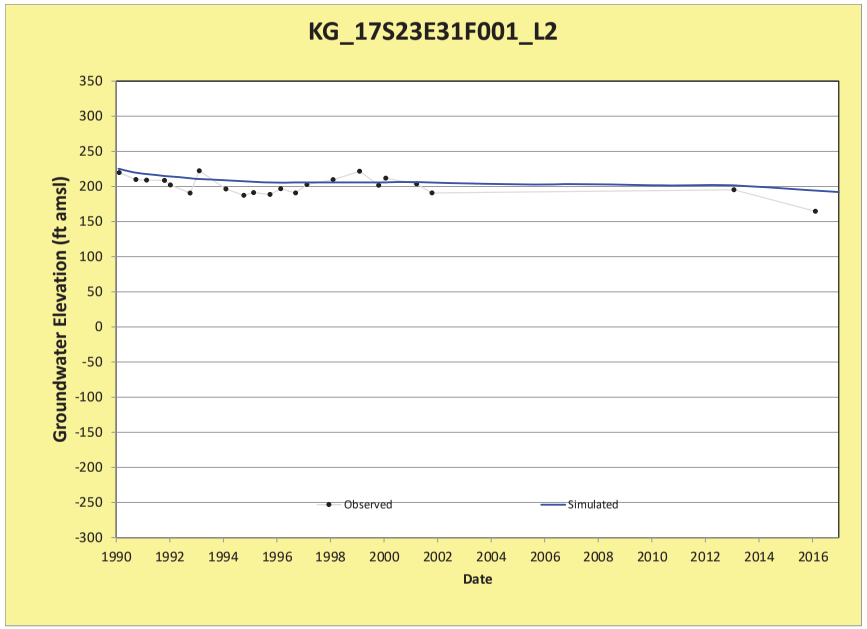

KG_17S23E15B001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

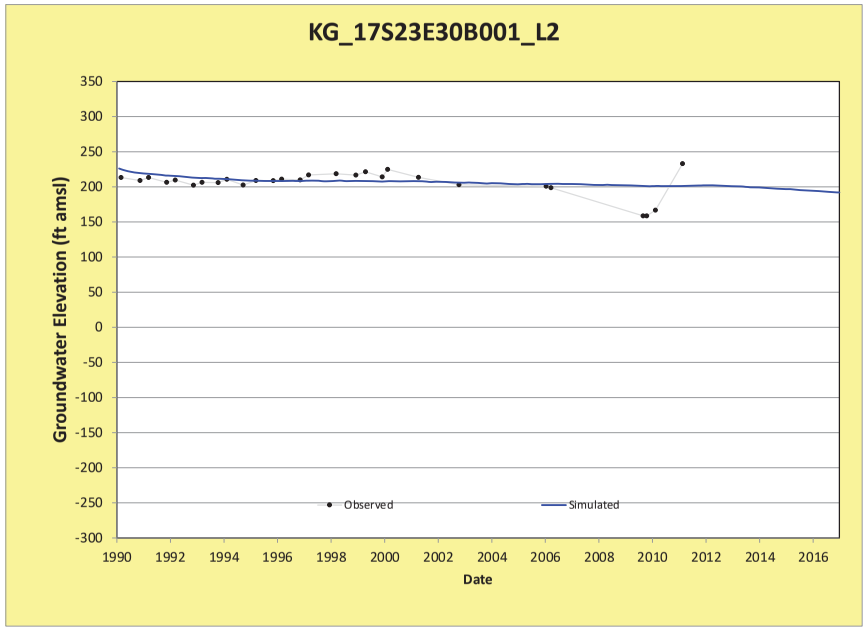

KG_17S23E21C001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

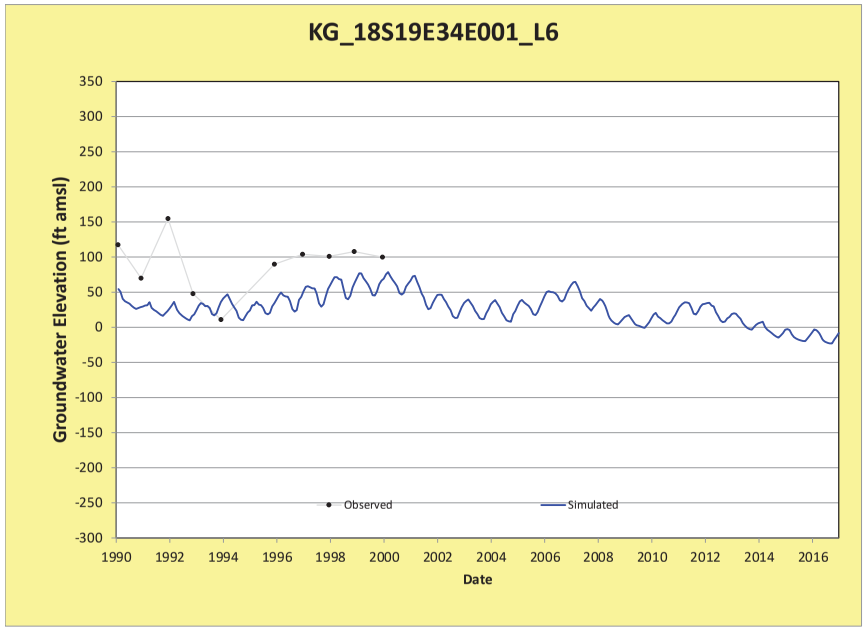

KG_17S23E18D001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

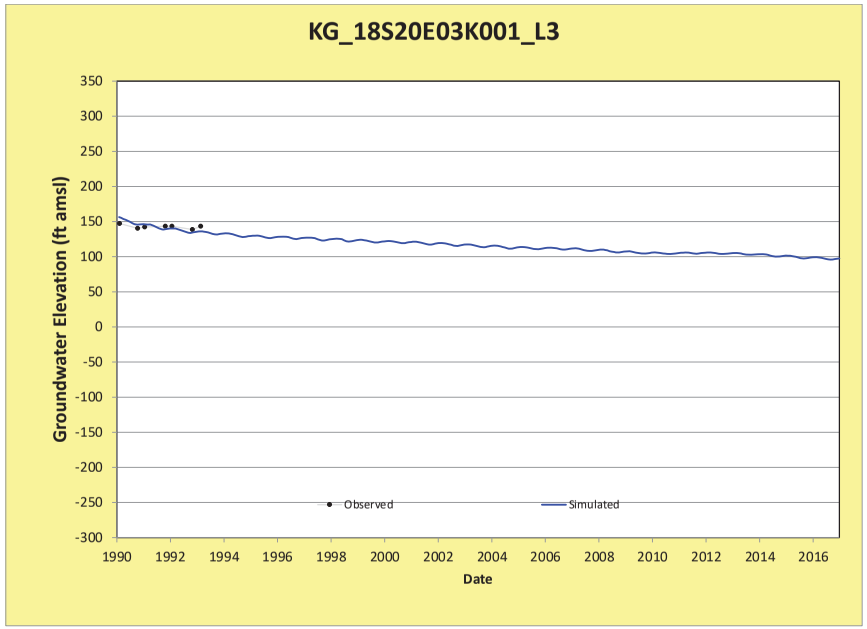

KG_17S23E27L001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

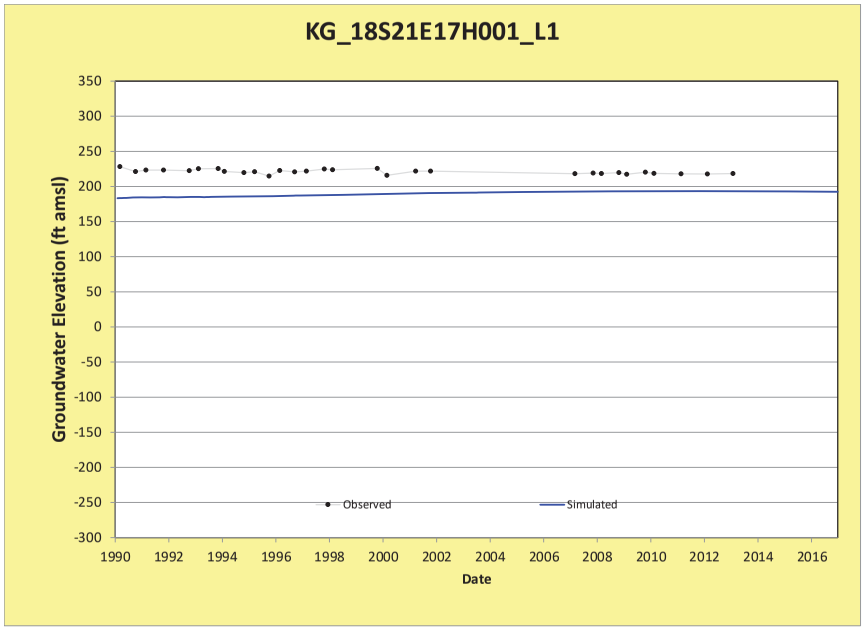

KG_17S23E30A001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

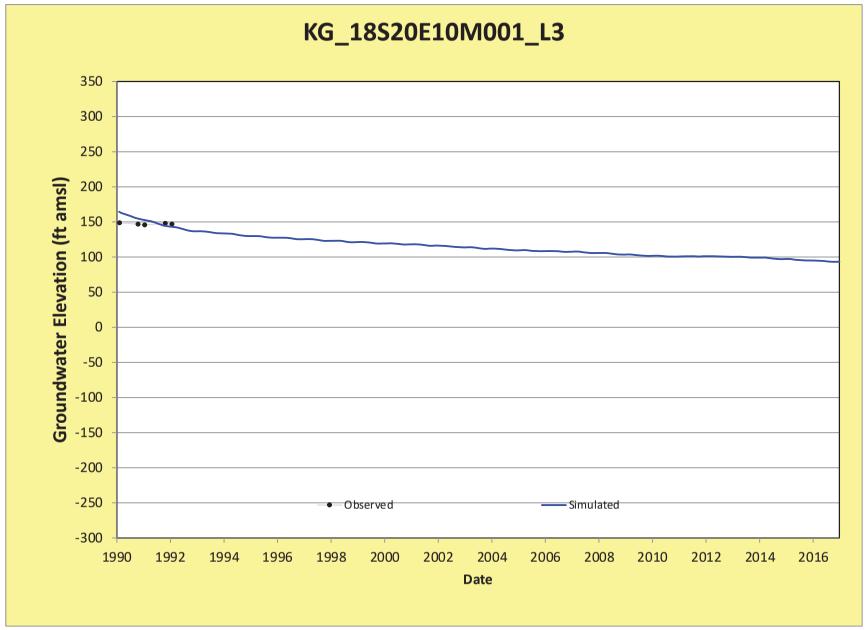

KG_17S23E31F001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

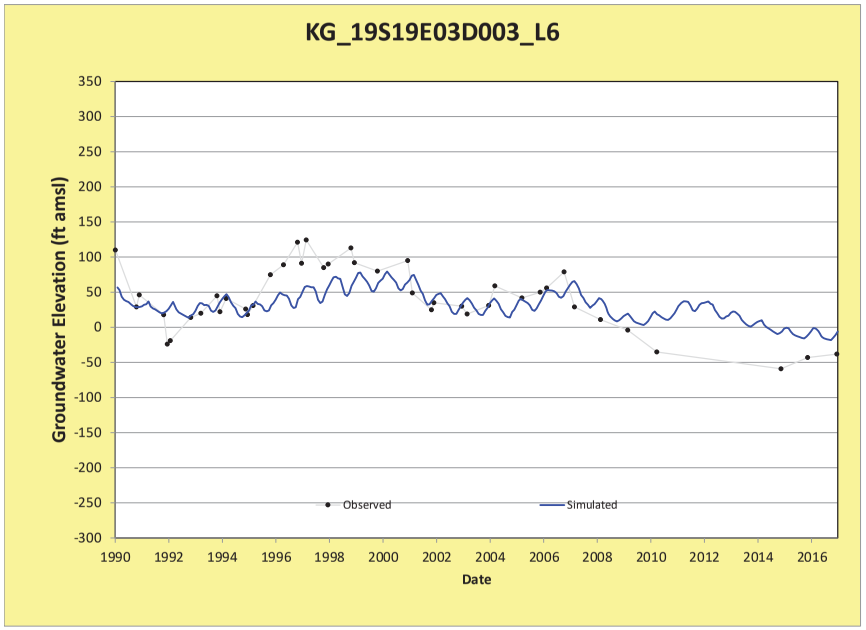

KG_17S23E30B001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

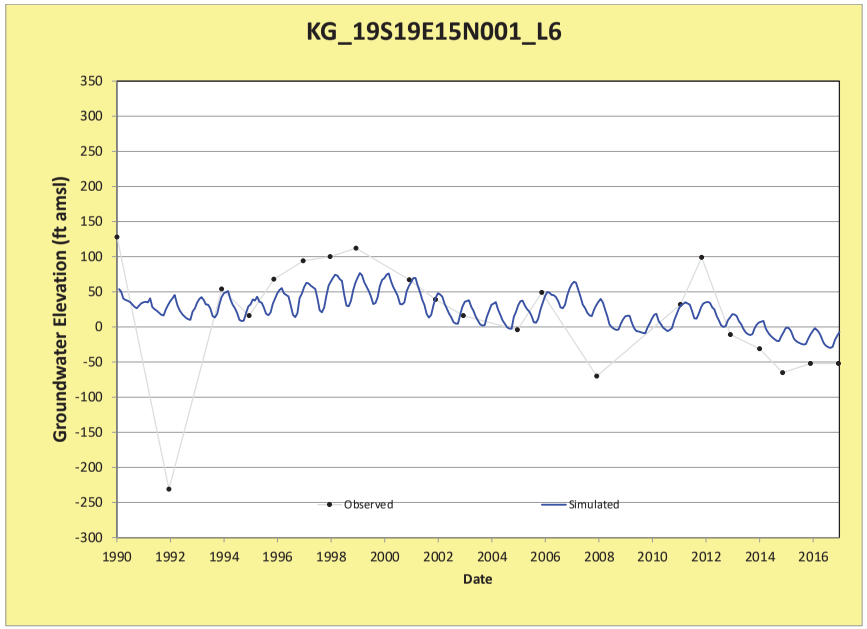

KG_18S19E34E001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

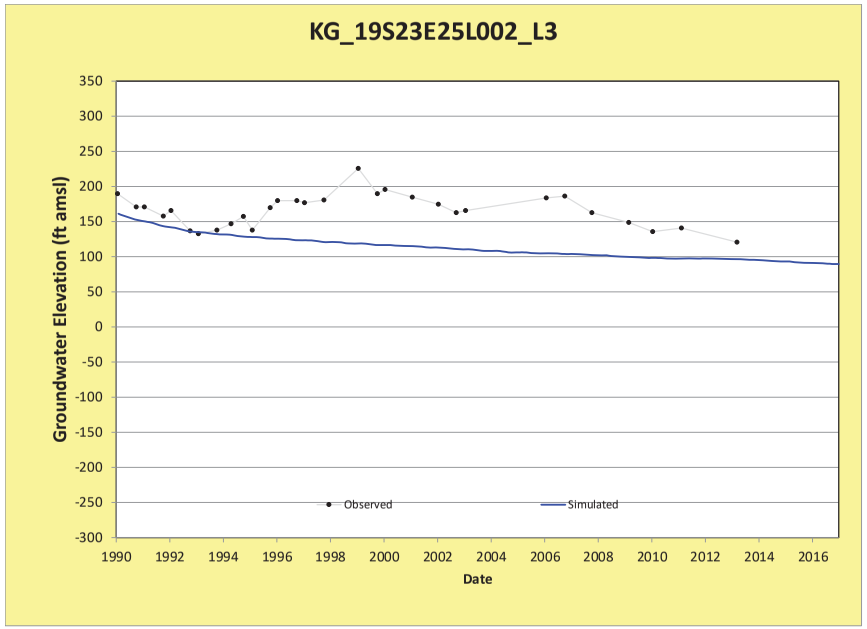

KG_18S20E03K001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

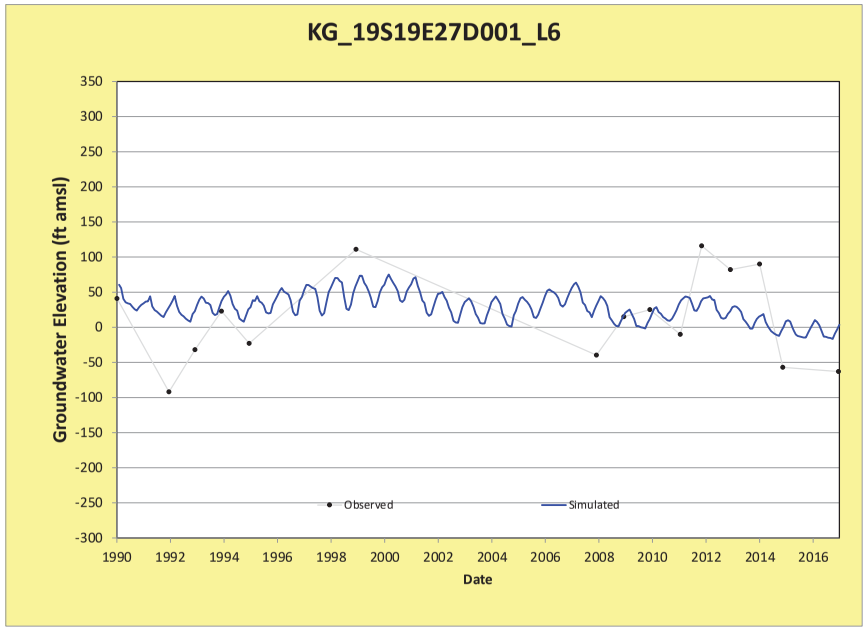

KG_18S21E17H001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

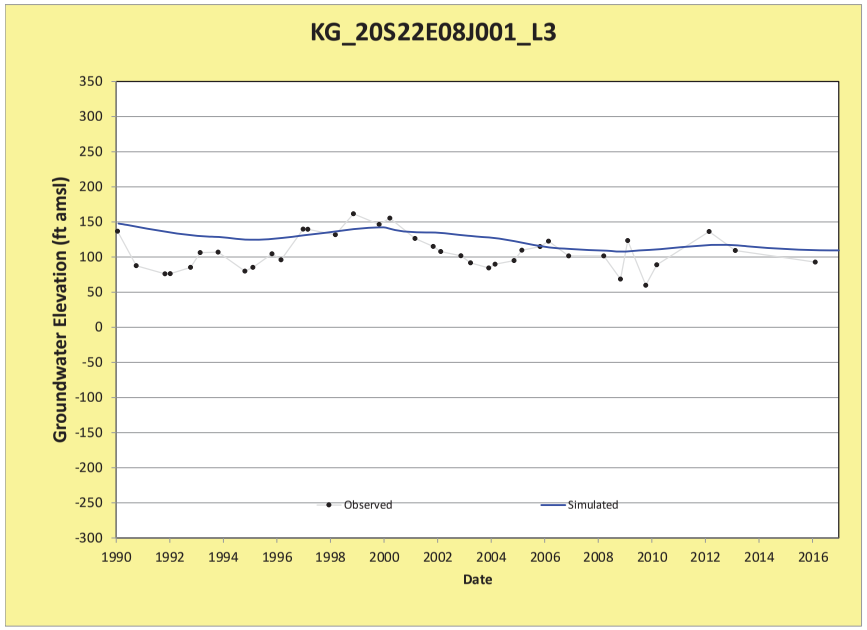

KG_18S20E10M001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

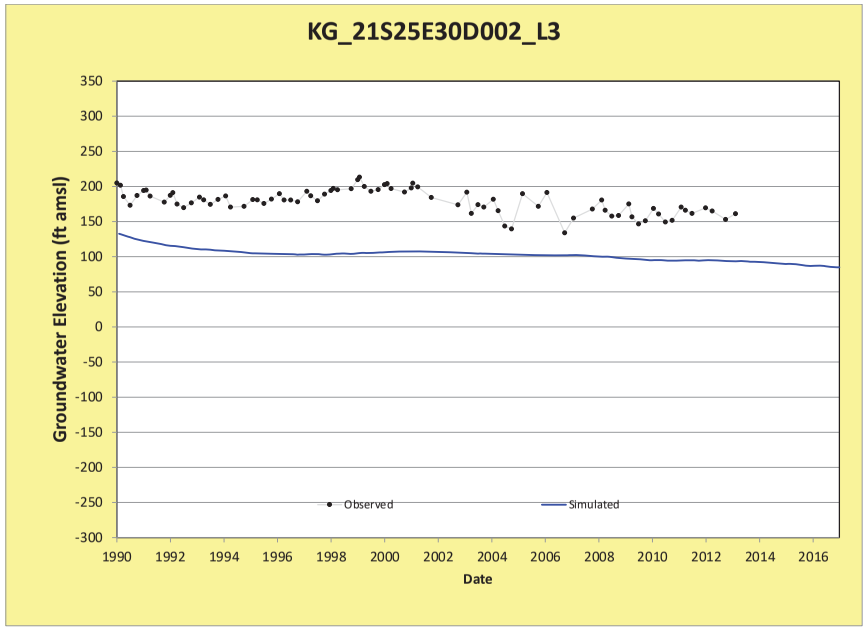

KG_19S19E03D003_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

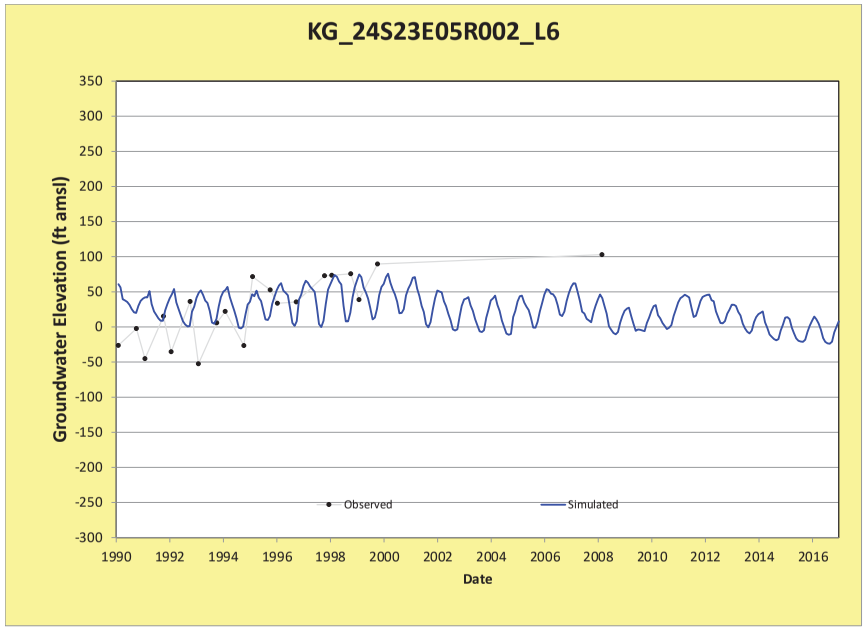

KG_19S19E15N001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

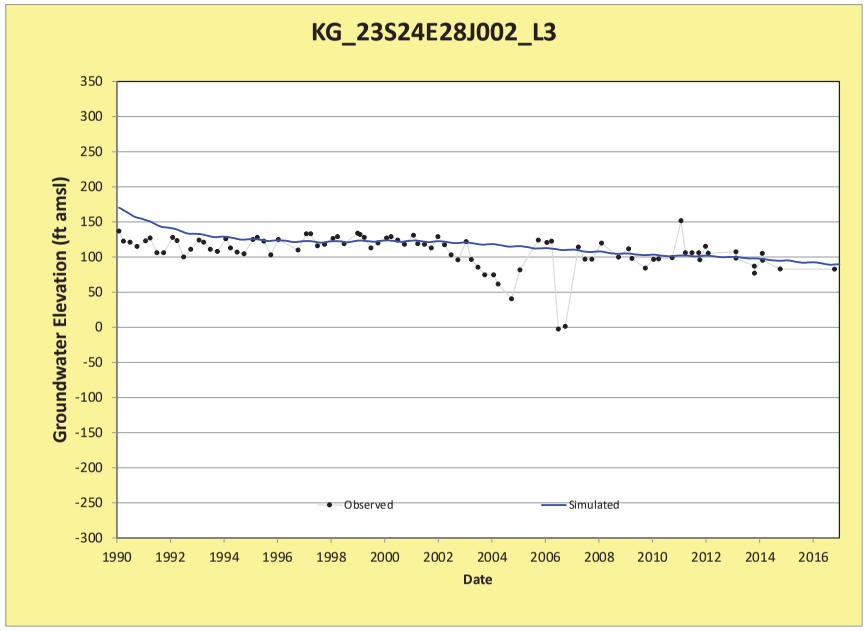

KG_19S23E25L002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

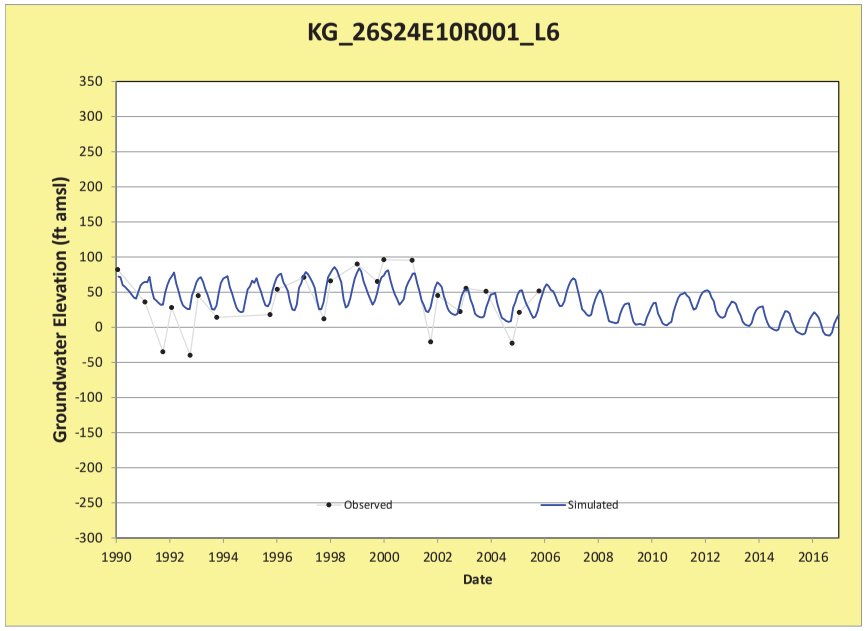

KG_19S19E27D001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

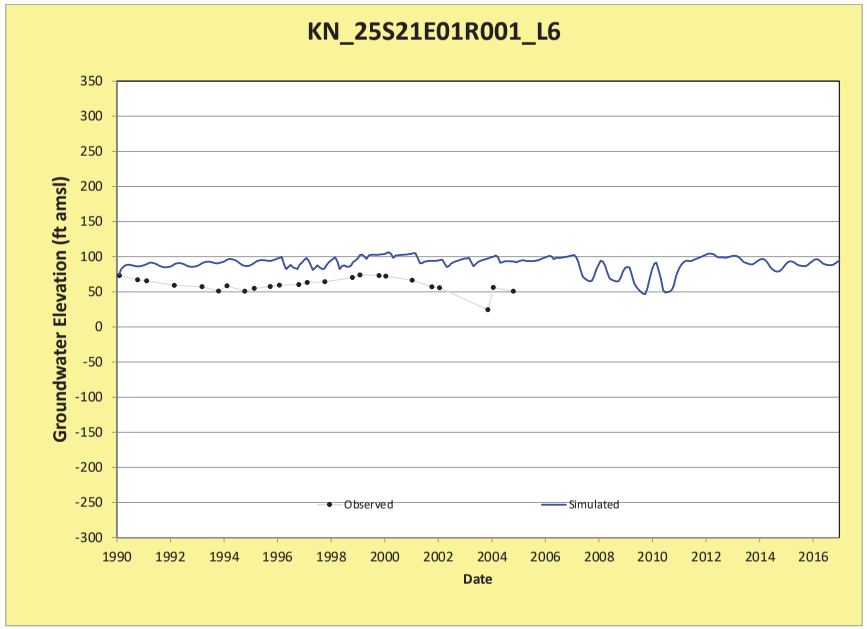

KG_20S22E08J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

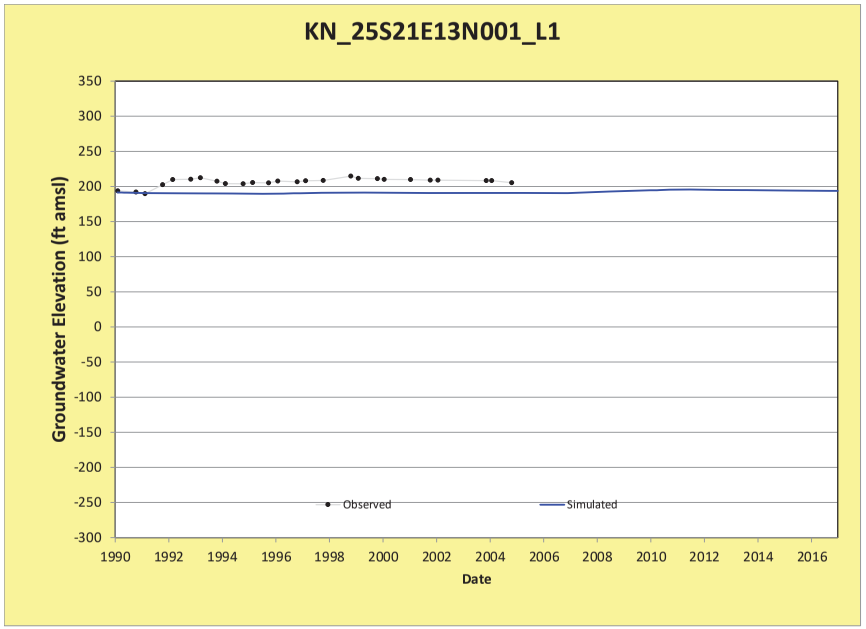

KG_21S25E30D002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

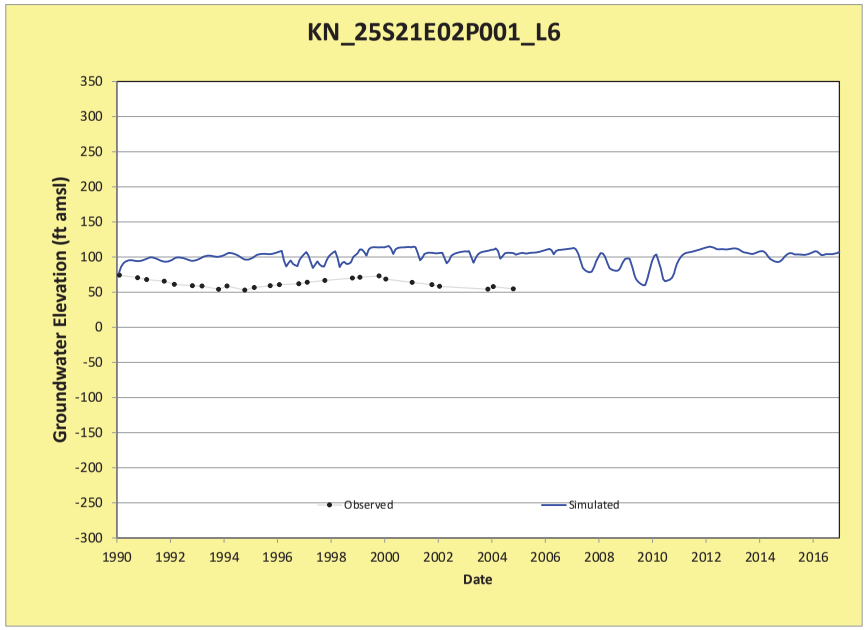

KG_24S23E05R002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

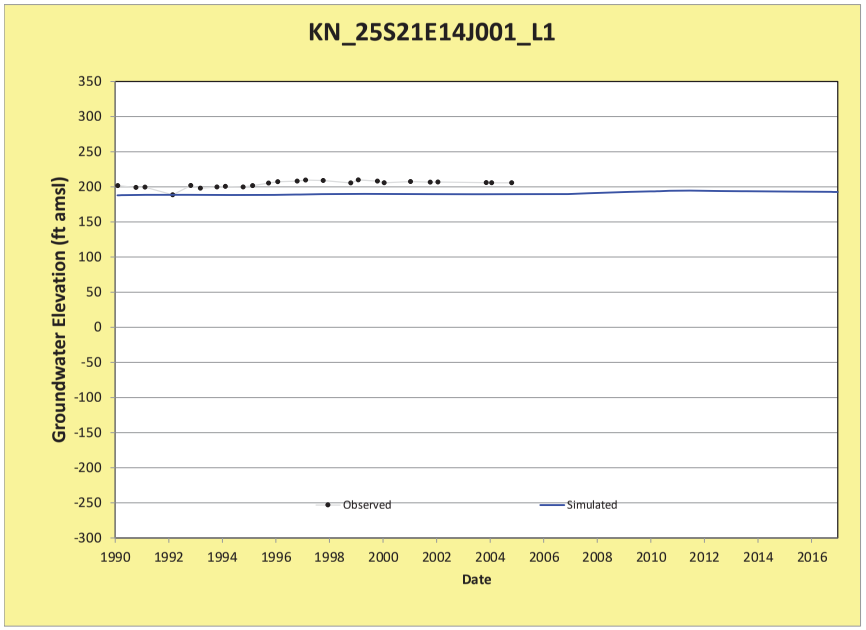

KG_23S24E28J002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

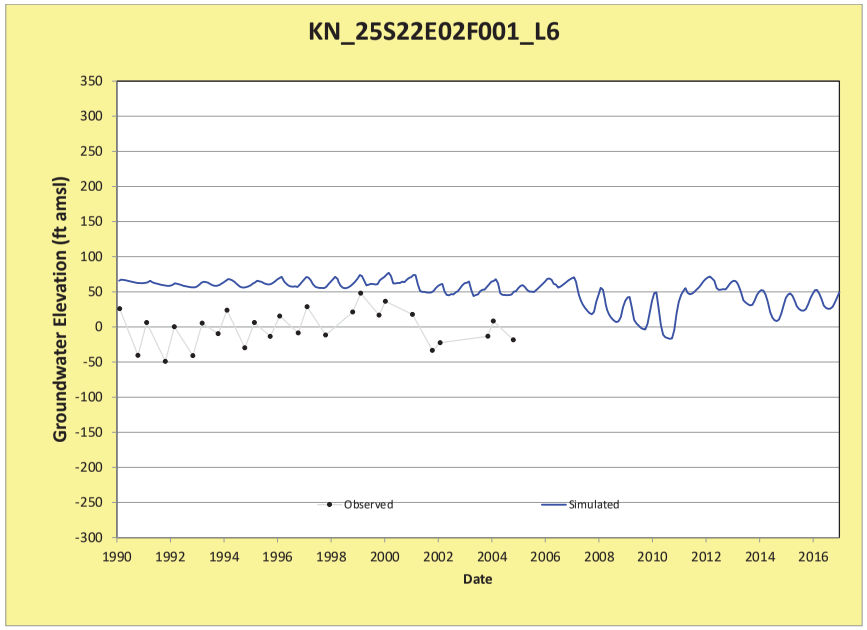

KG_26S24E10R001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

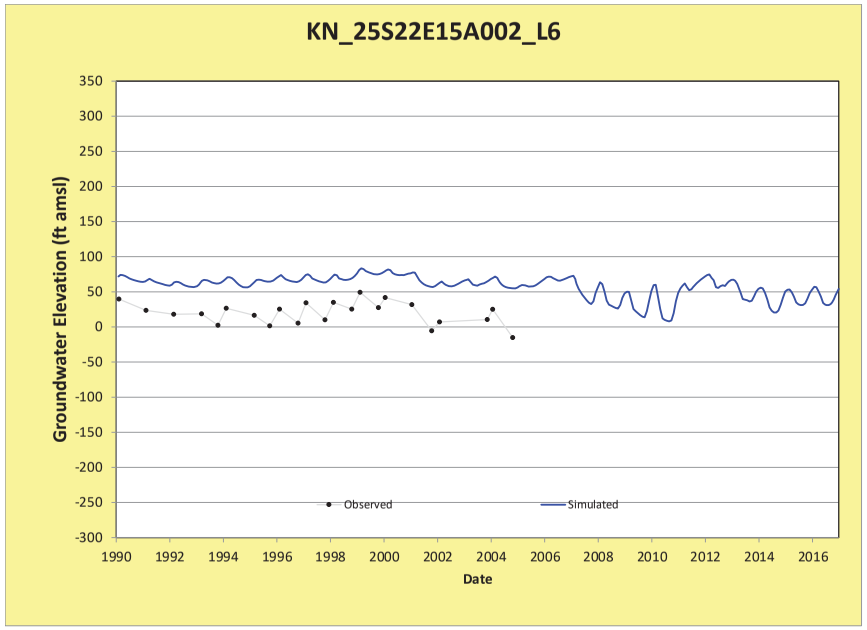

KN_25S21E01R001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

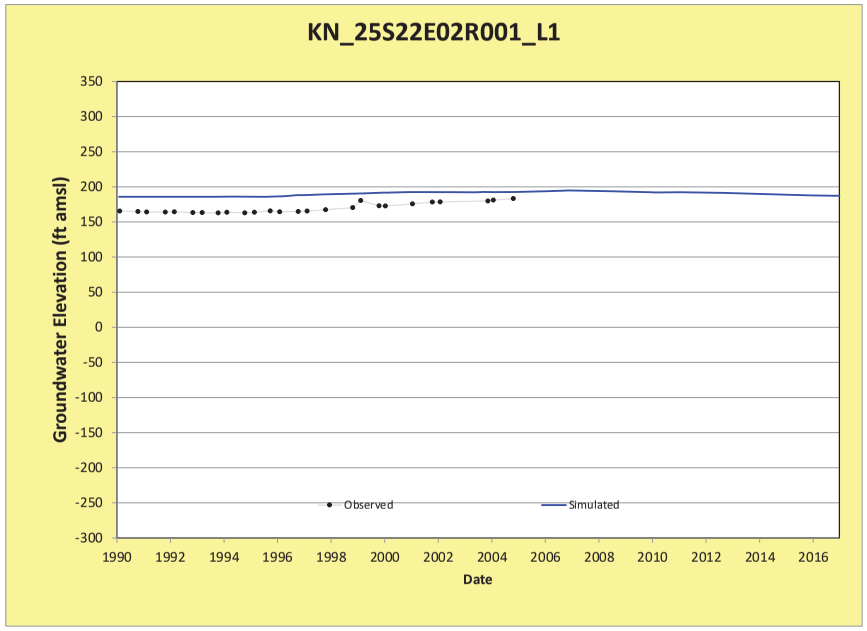

KN_25S21E13N001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

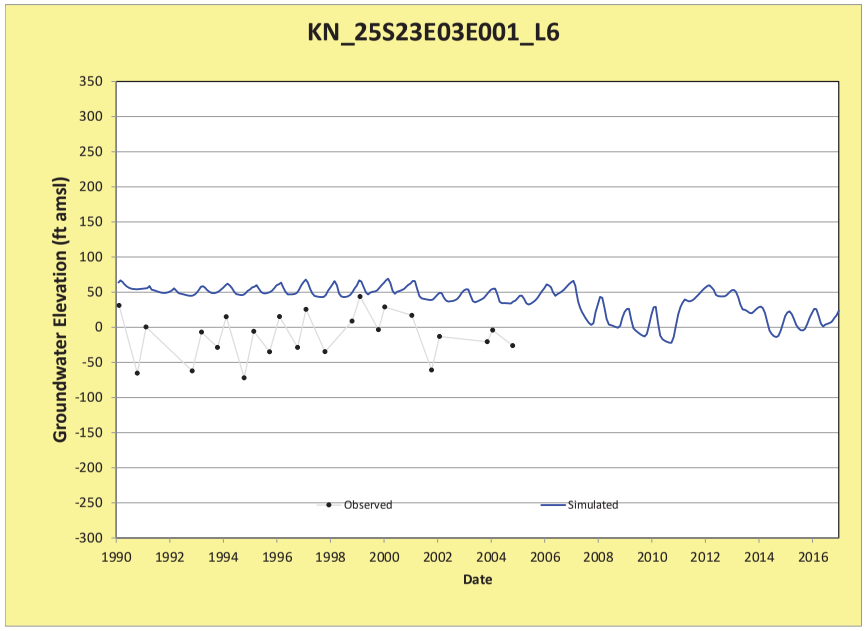

KN_25S21E02P001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

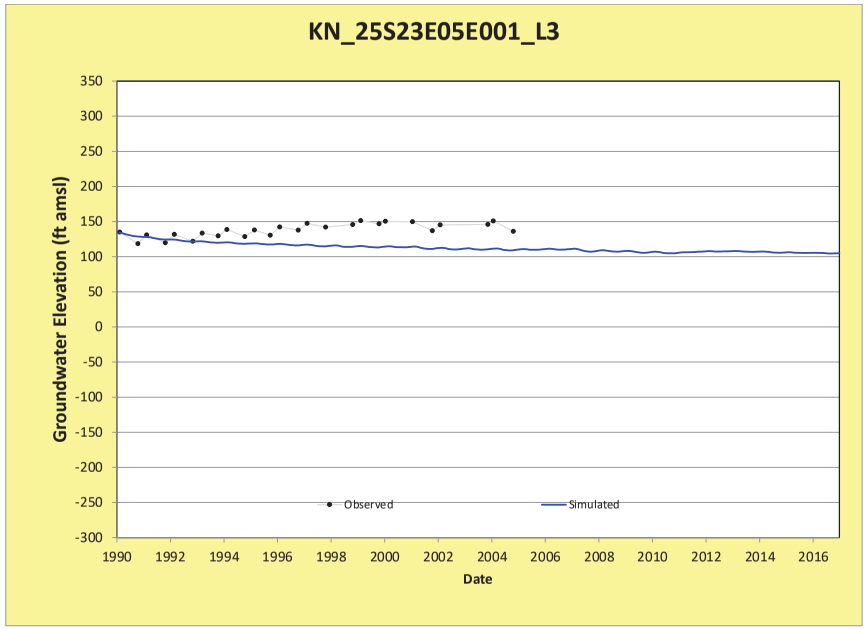

KN_25S21E14J001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

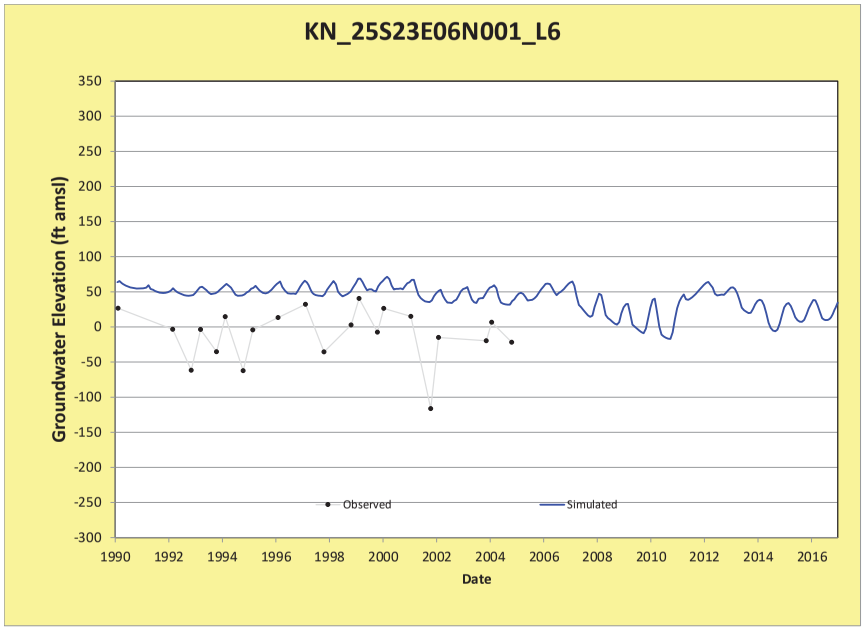

KN_25S22E02F001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

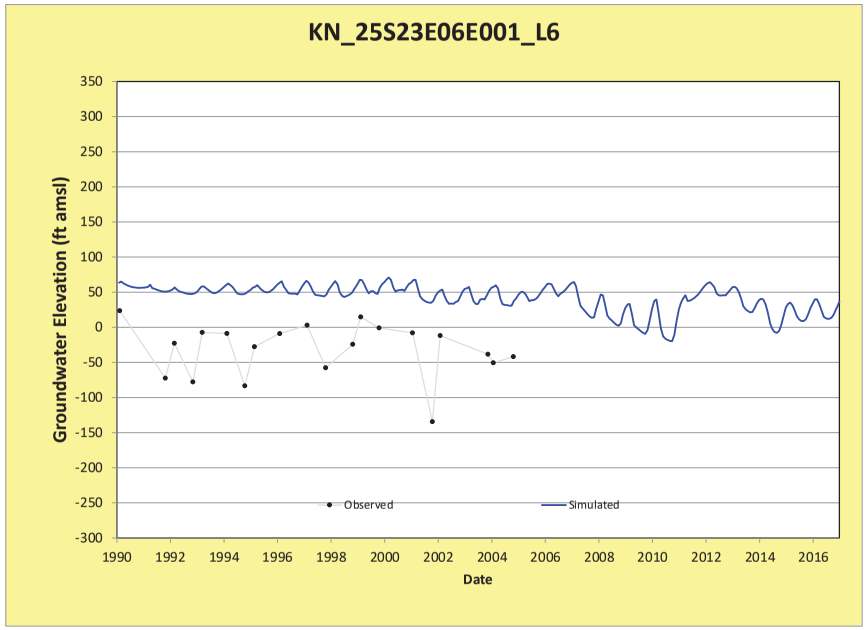

KN_25S22E15A002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

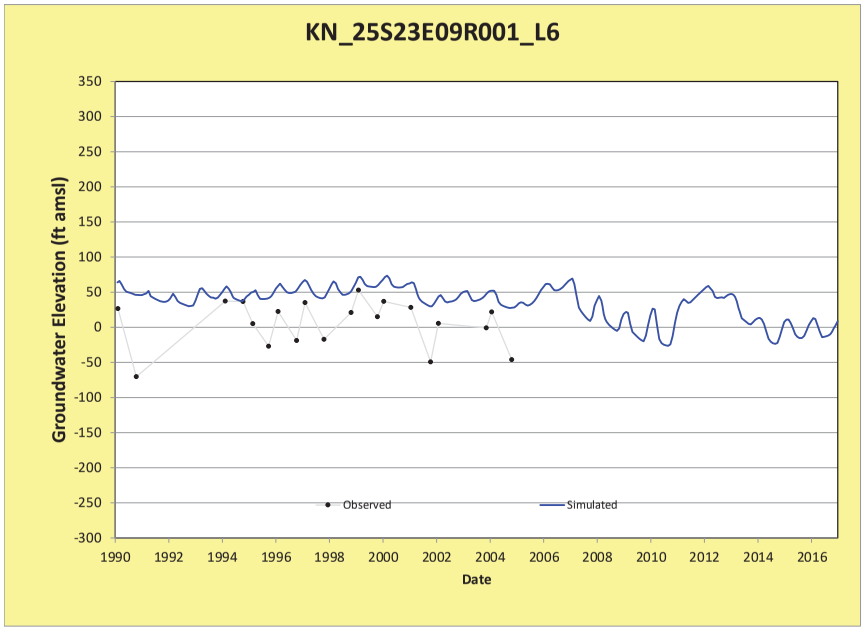

KN_25S22E02R001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

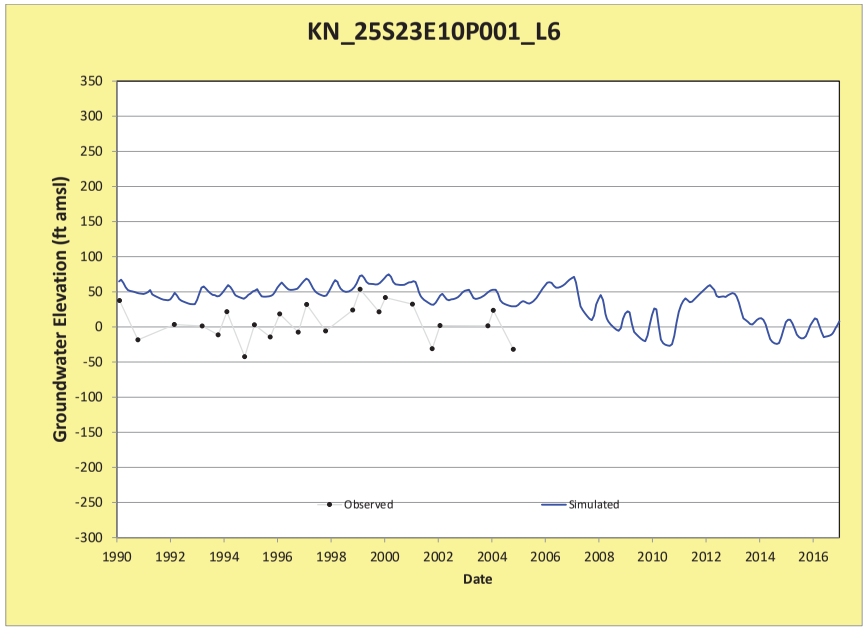

KN_25S23E03E001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

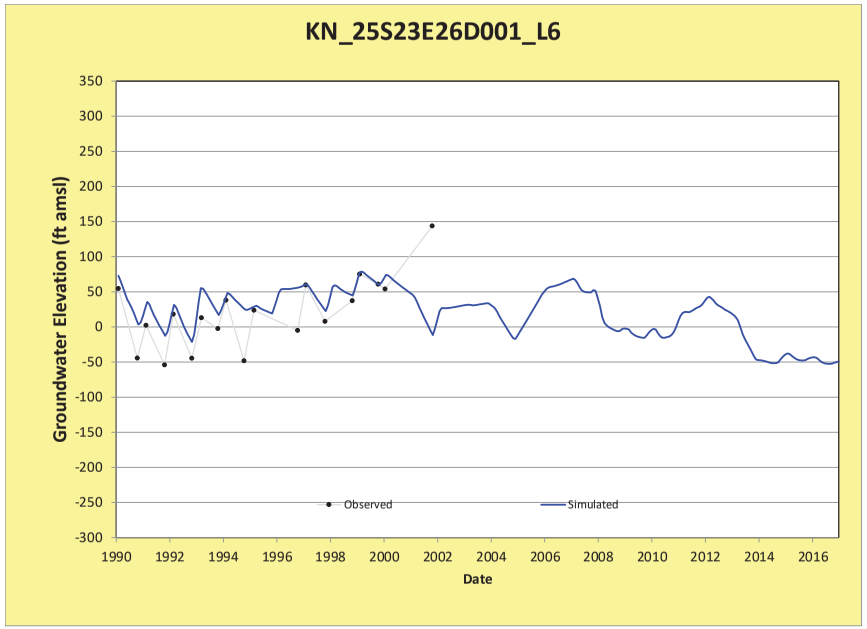

KN_25S23E05E001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

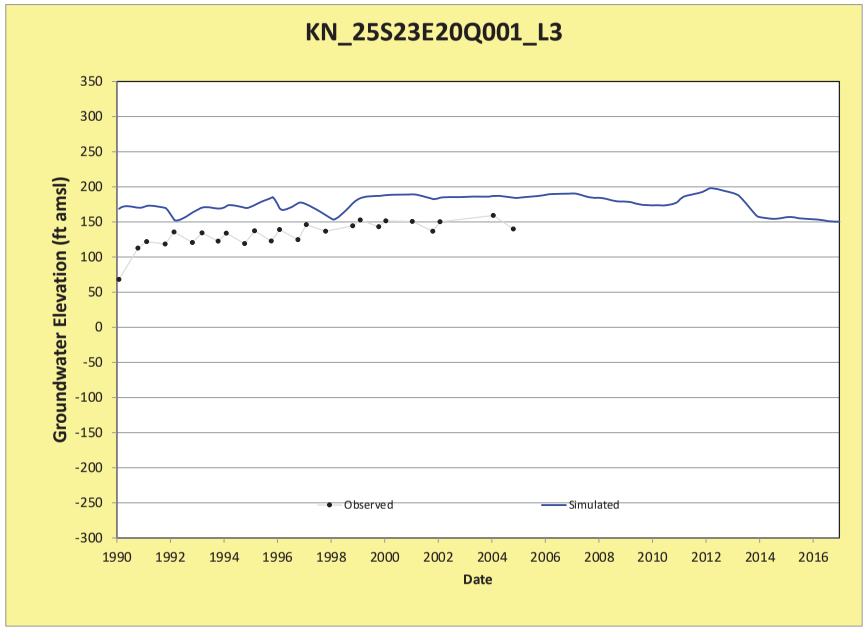

KN_25S23E06N001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

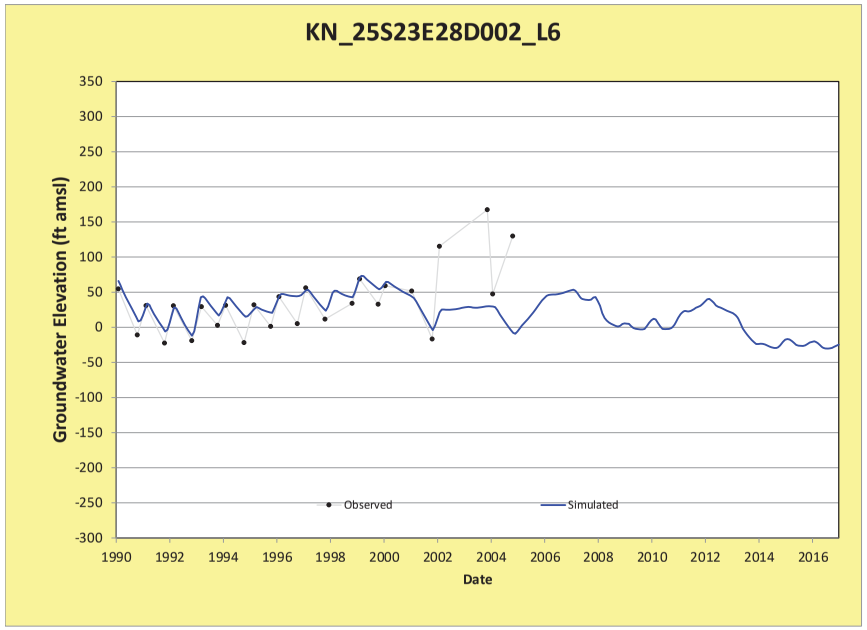

KN_25S23E06E001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

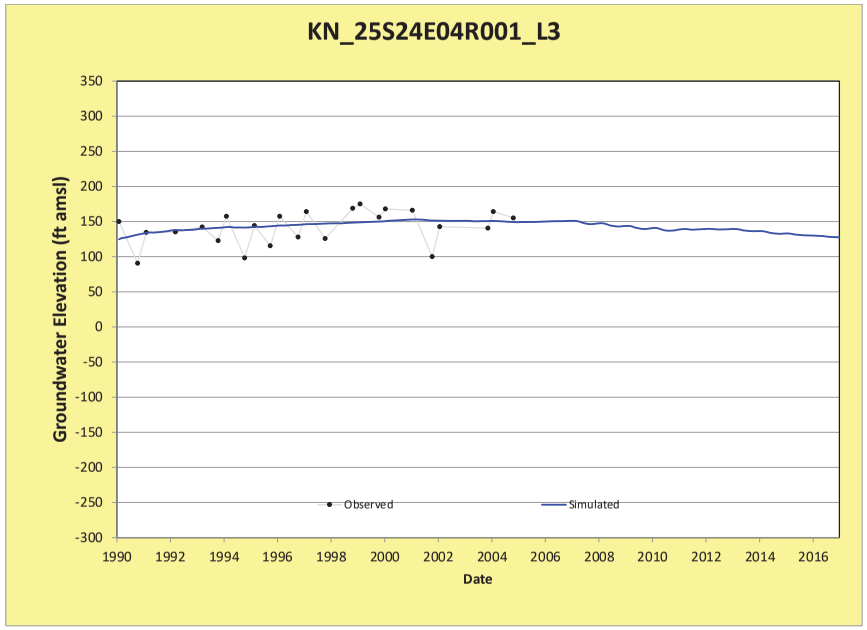

KN_25S23E09R001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

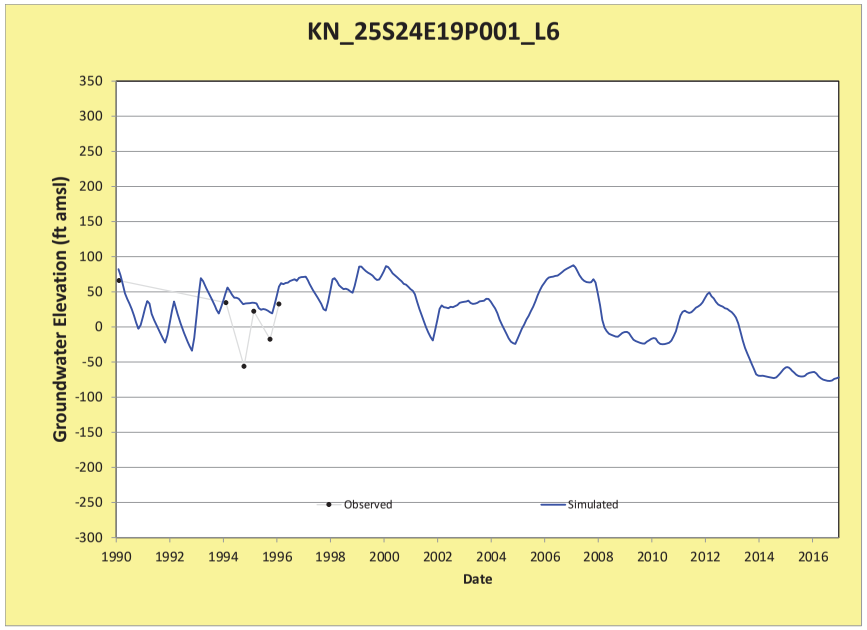

KN_25S23E10P001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

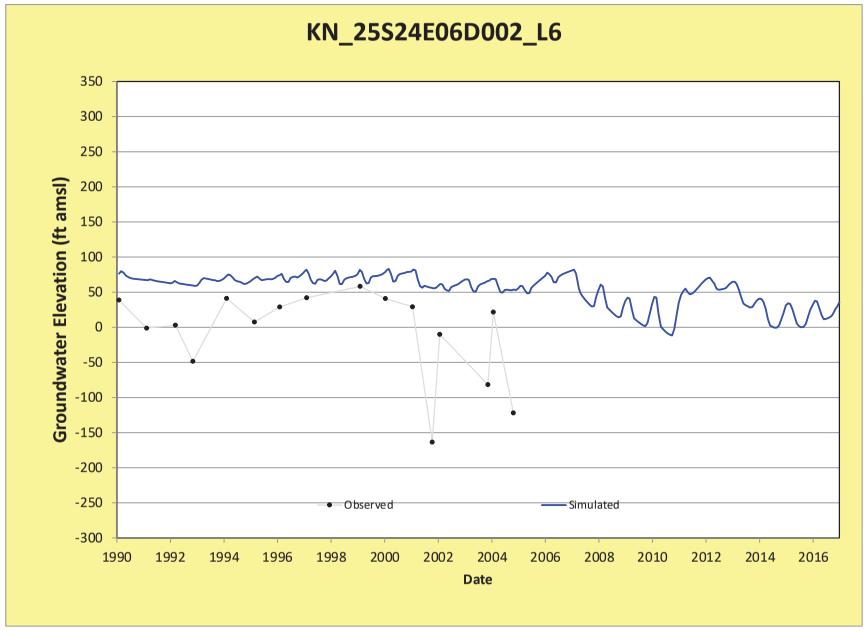

KN_25S23E26D001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

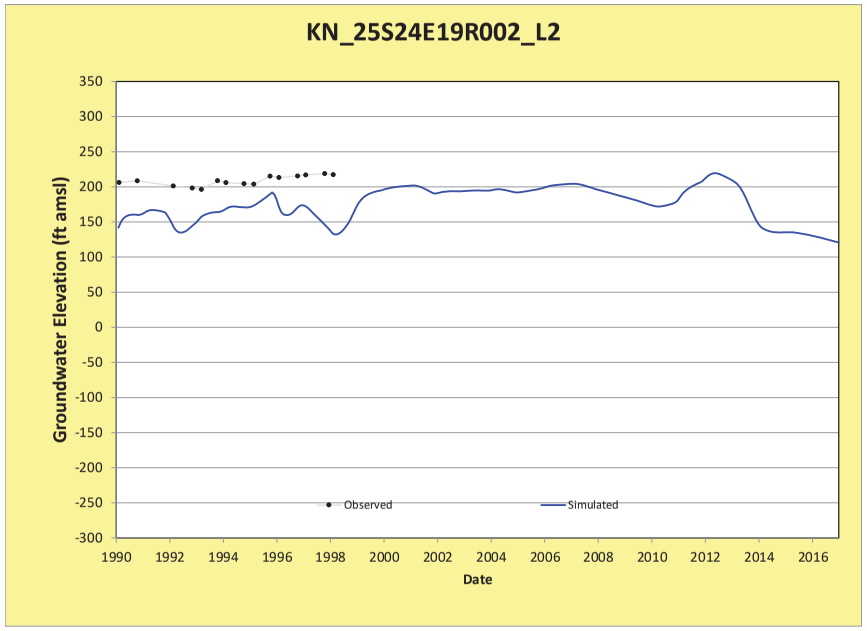

KN_25S23E20Q001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

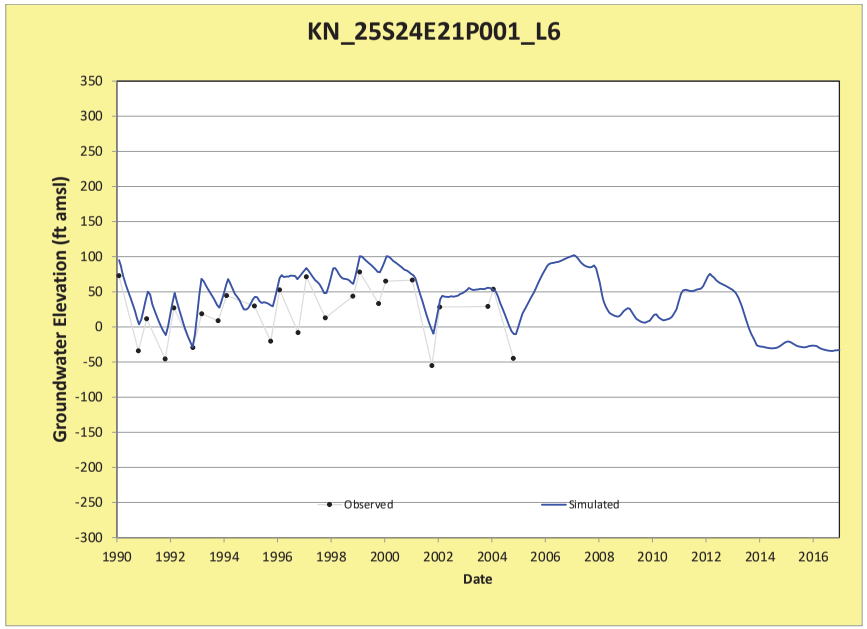

KN_25S23E28D002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

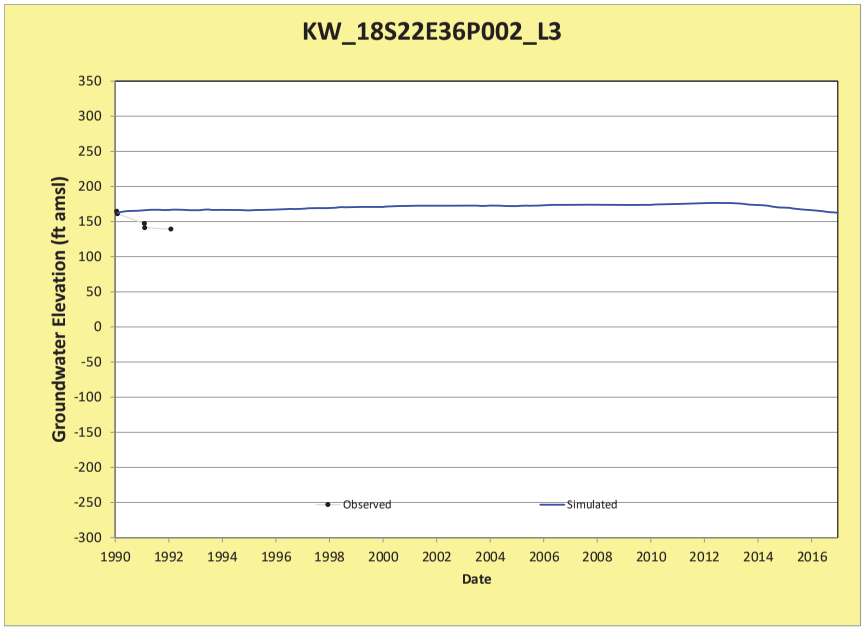

KN_25S24E04R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

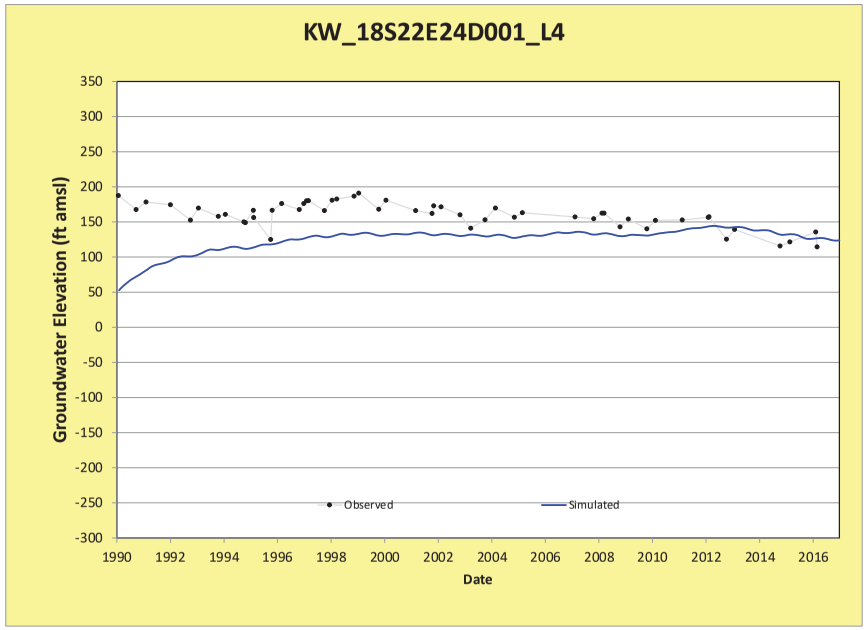

KN_25S24E19P001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

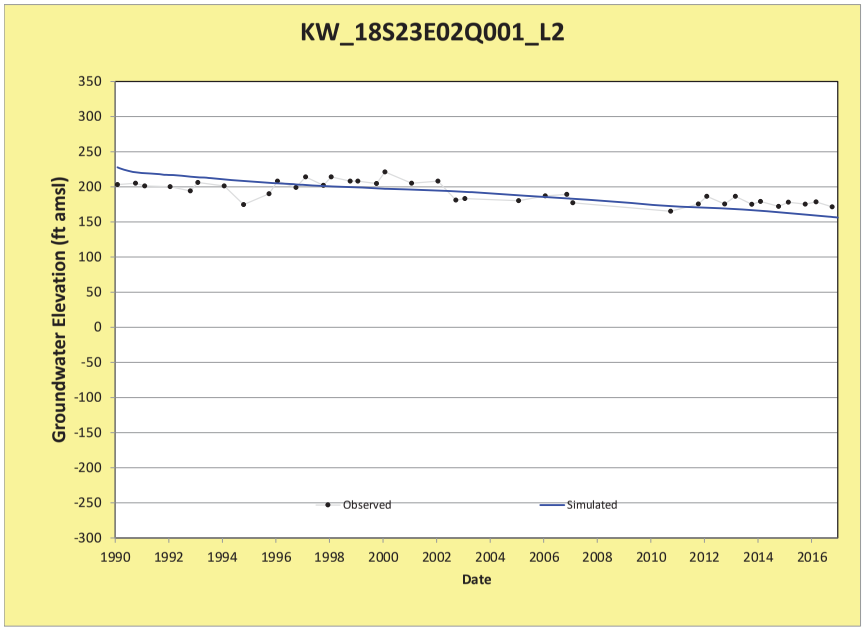

KN_25S24E06D002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

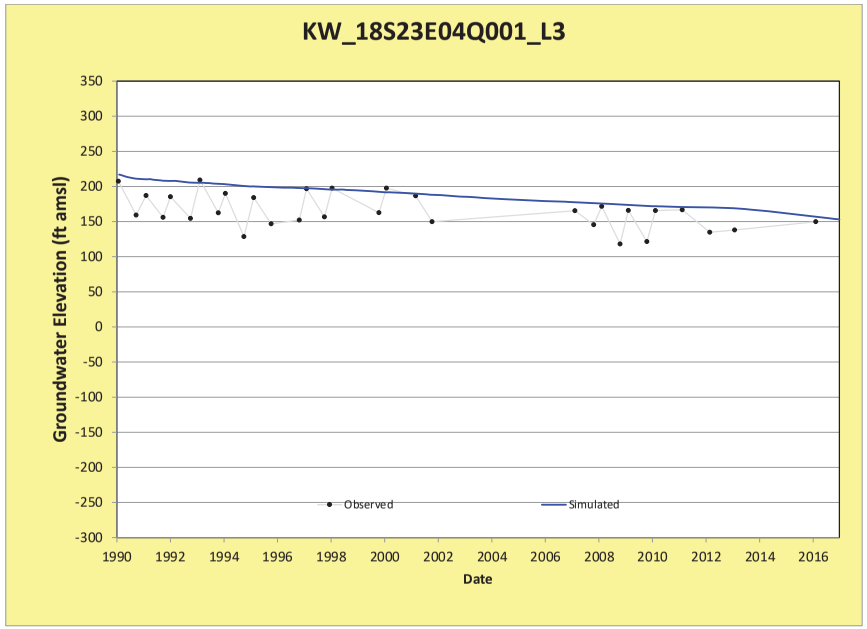

KN_25S24E19R002_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

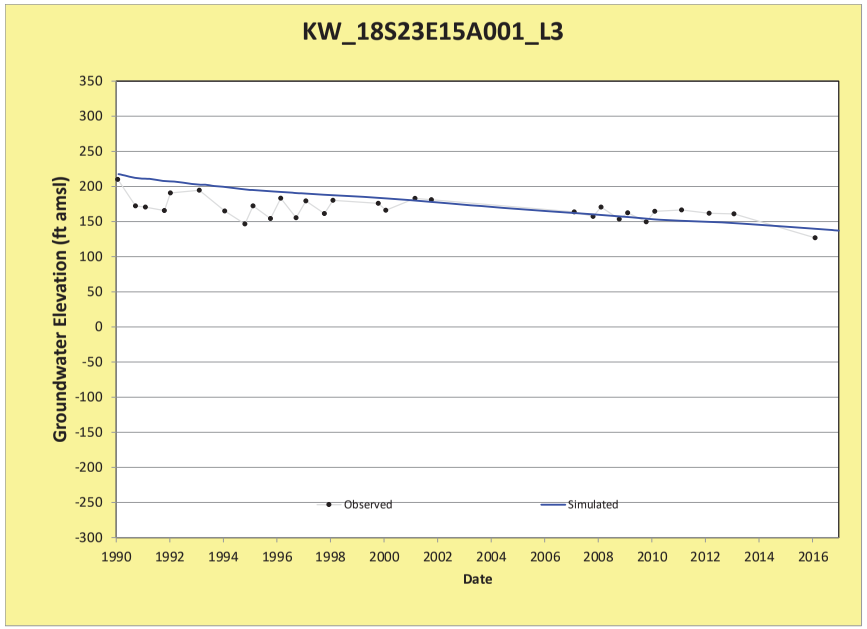

KN_25S24E21P001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

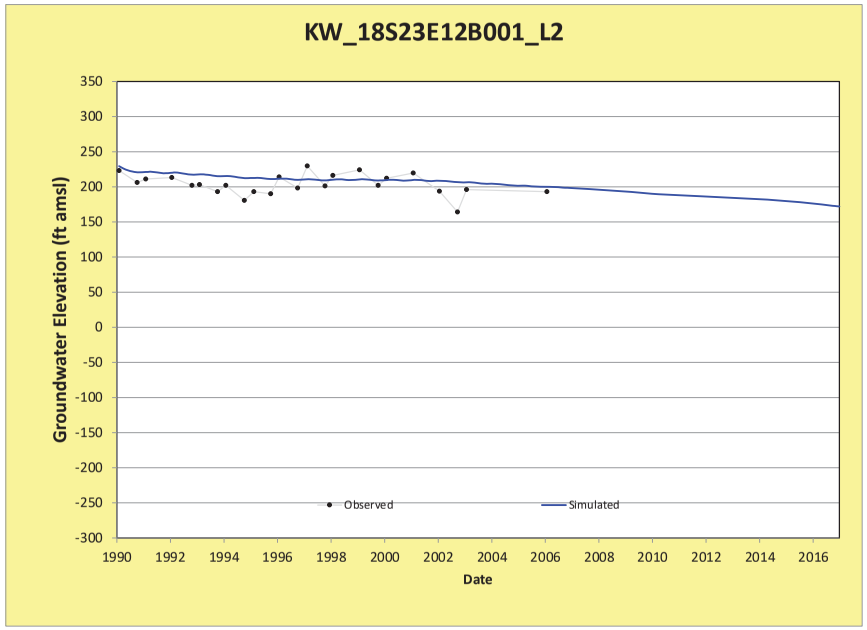

KW_18S22E36P002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

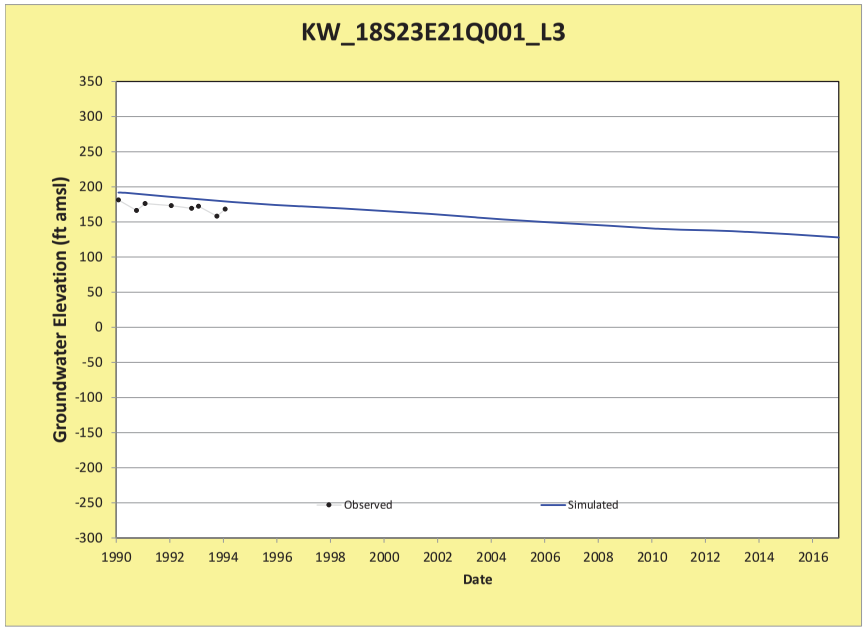

KW_18S22E24D001_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

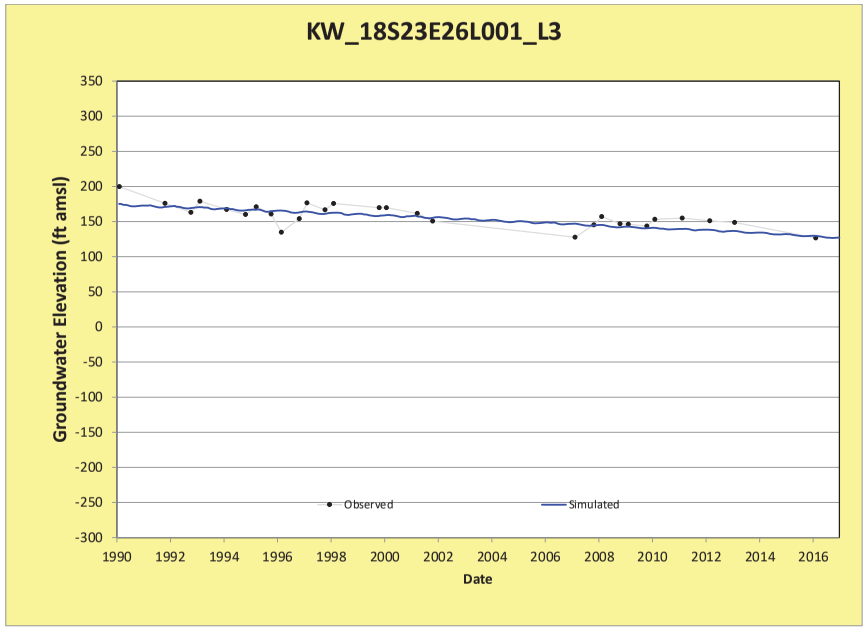

KW_18S23E02Q001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

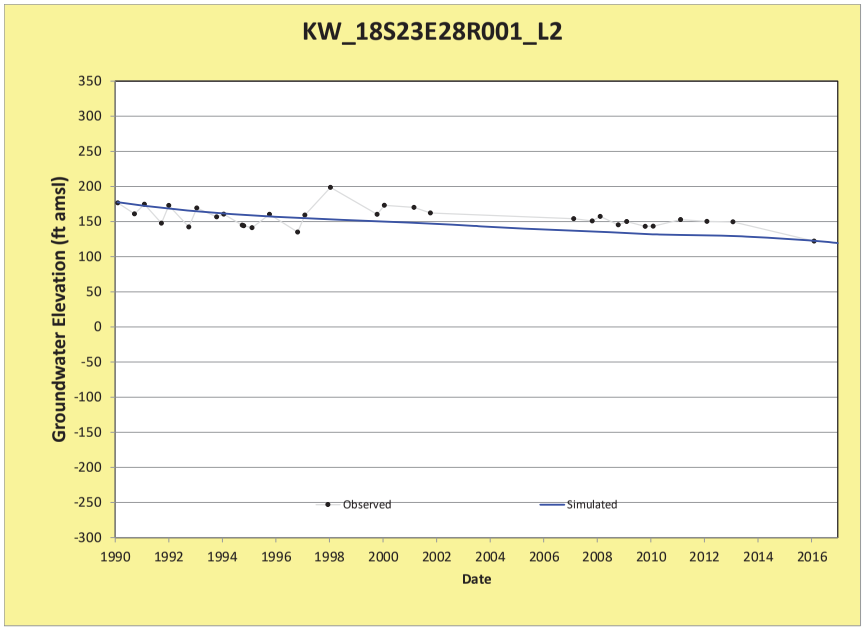

KW_18S23E04Q001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

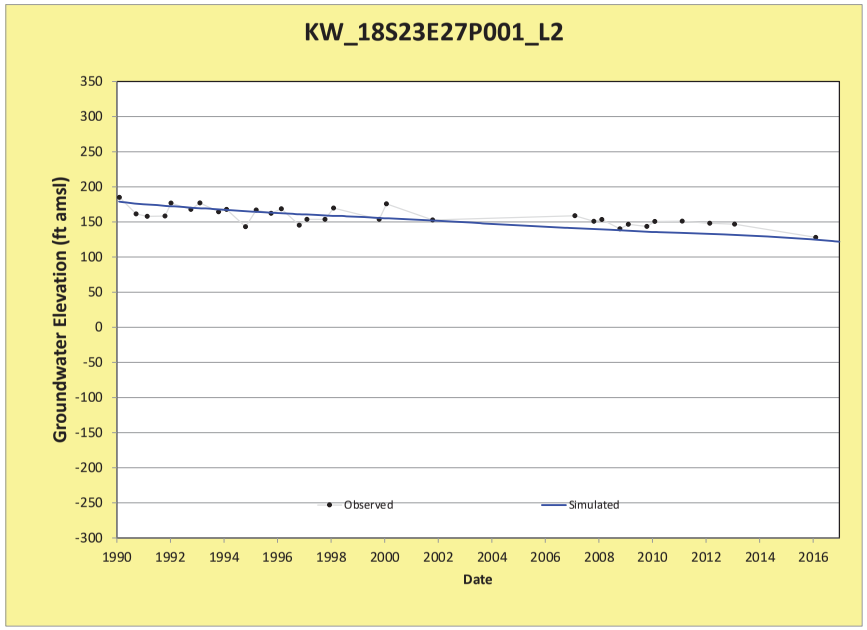

KW_18S23E15A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

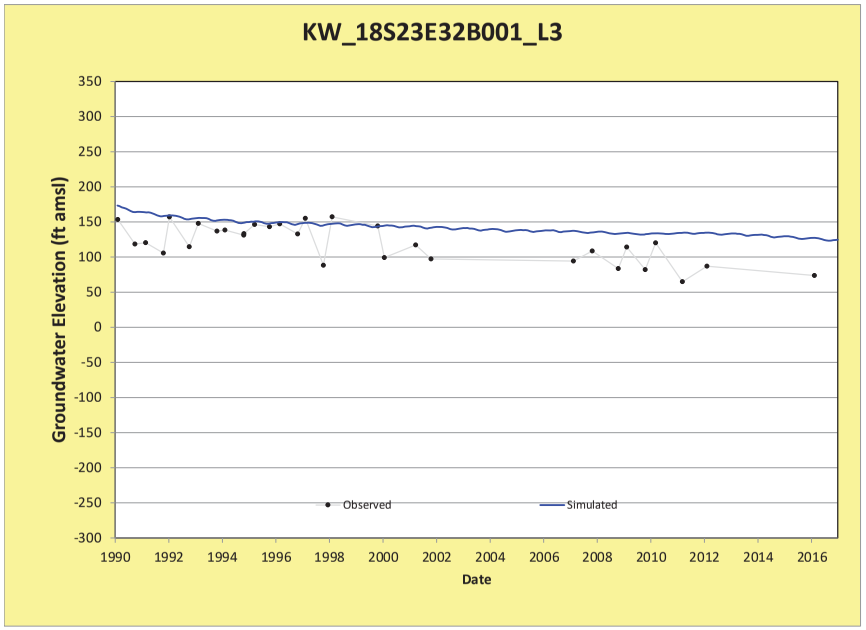

KW_18S23E12B001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

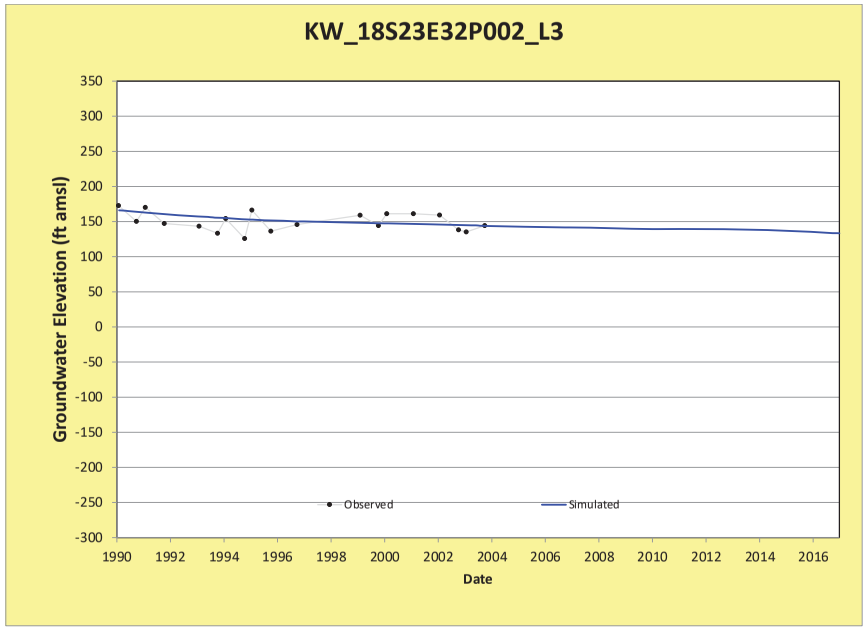

KW_18S23E21Q001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

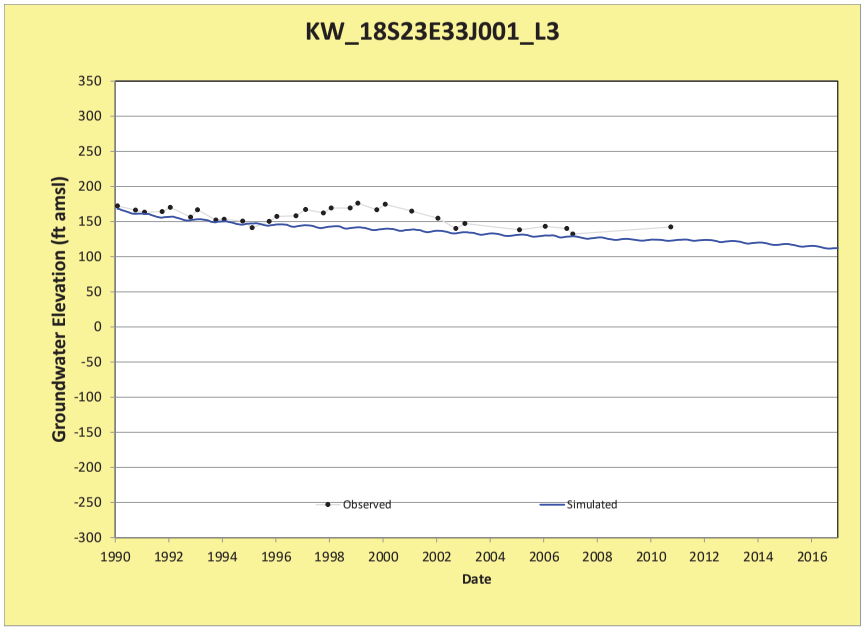

KW_18S23E26L001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

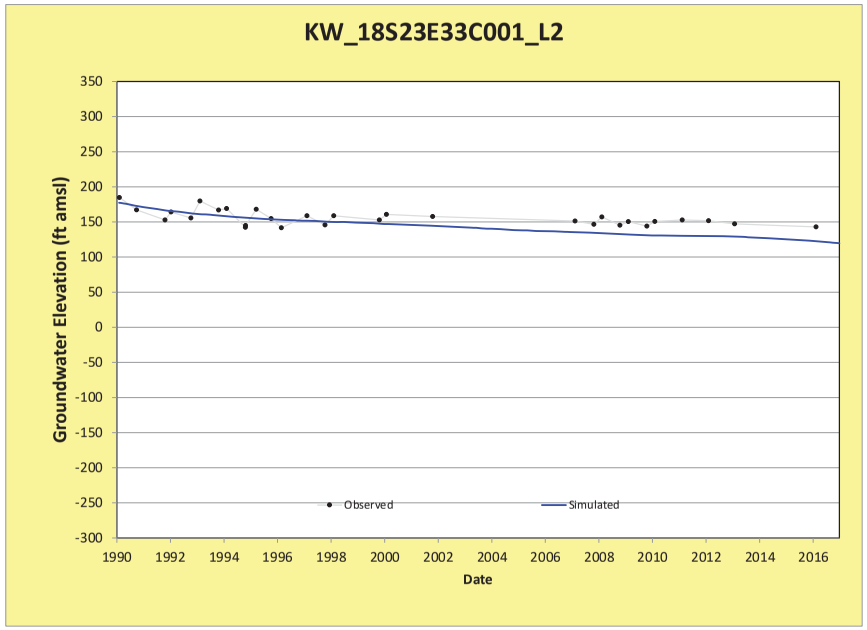

KW_18S23E28R001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

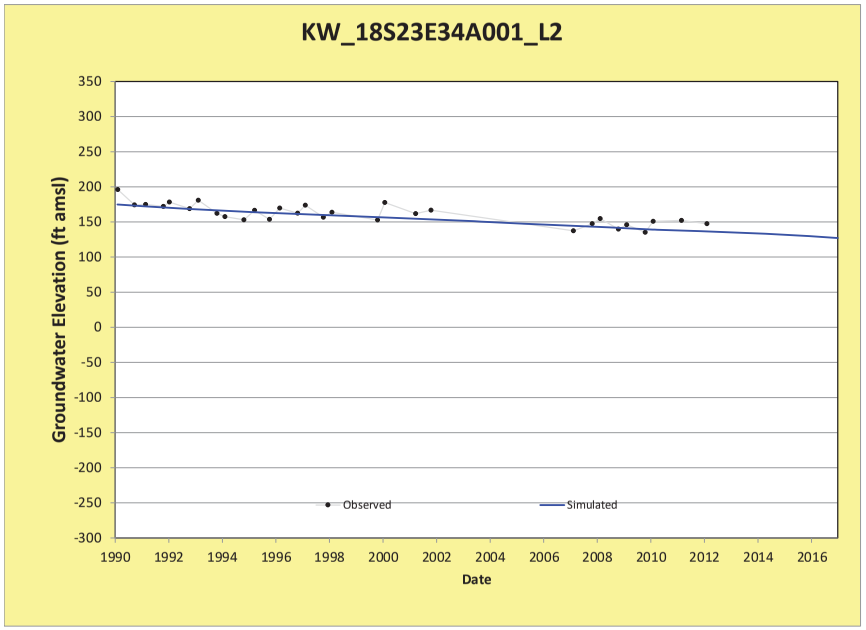

KW_18S23E27P001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

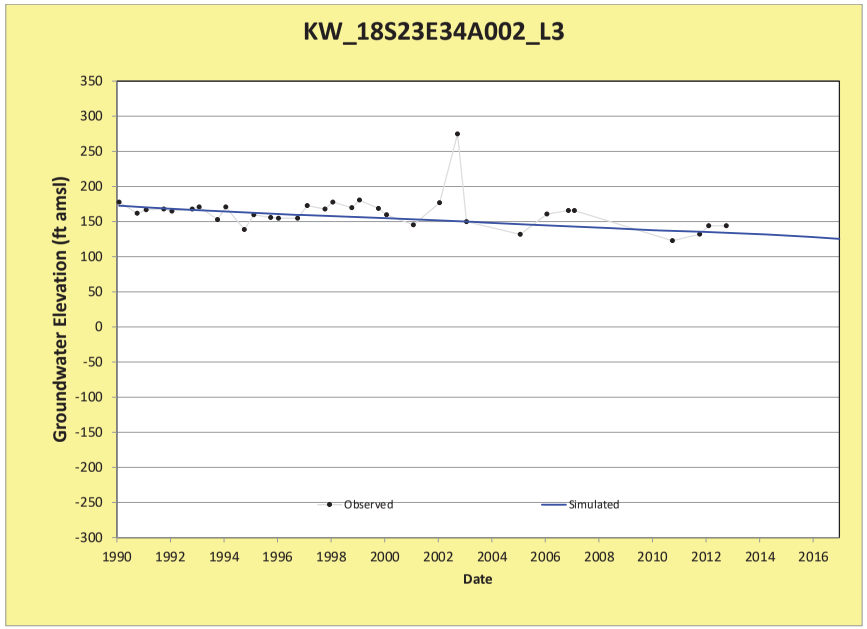

KW_18S23E32B001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

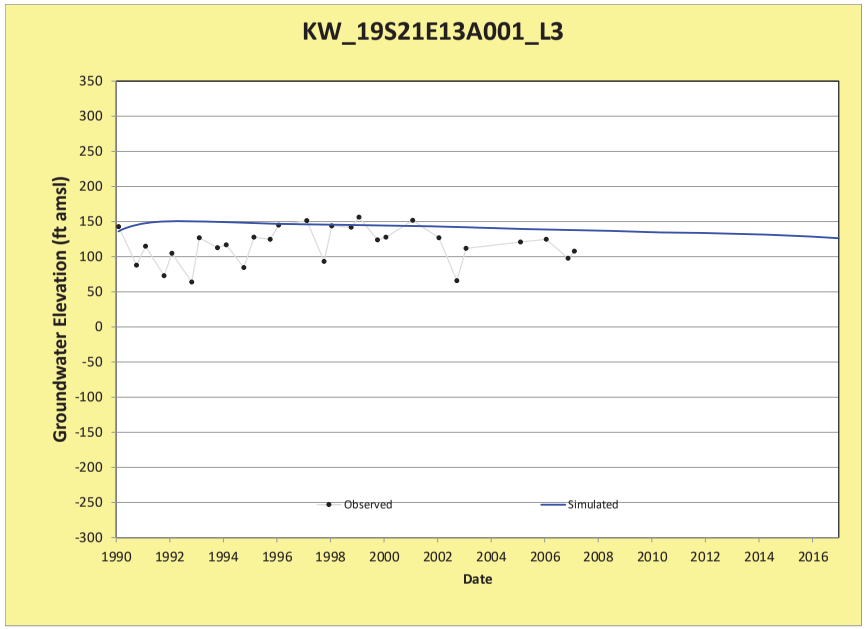

KW_18S23E32P002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

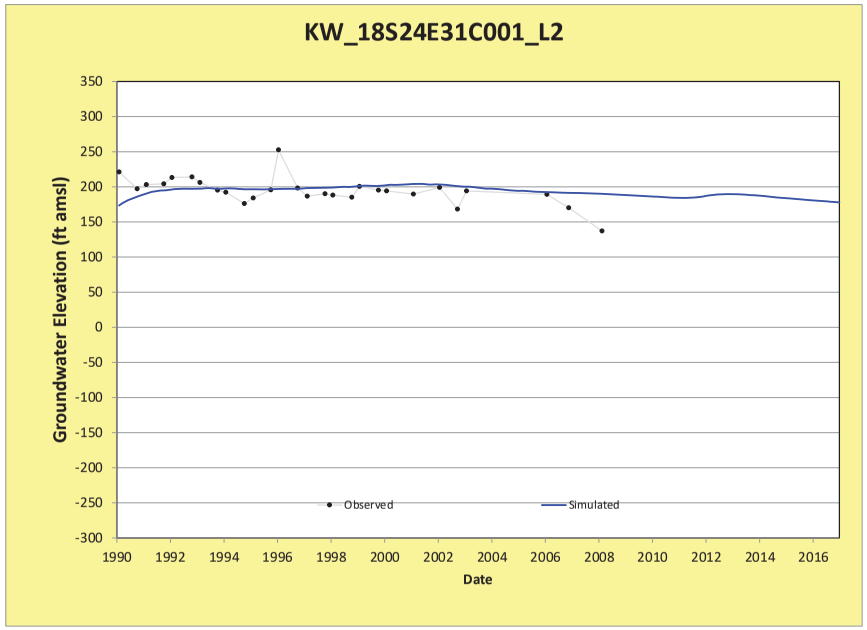

KW_18S23E33J001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

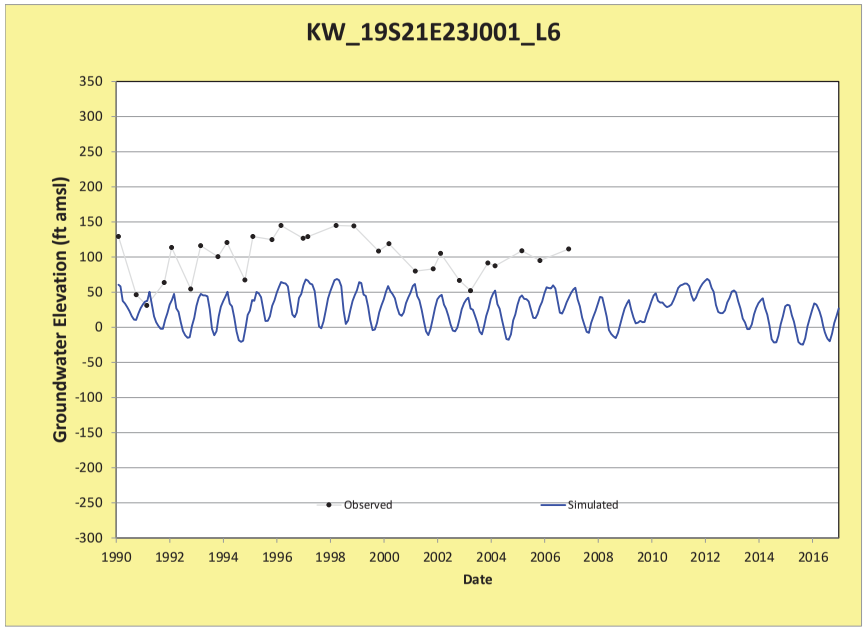

KW_18S23E33C001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

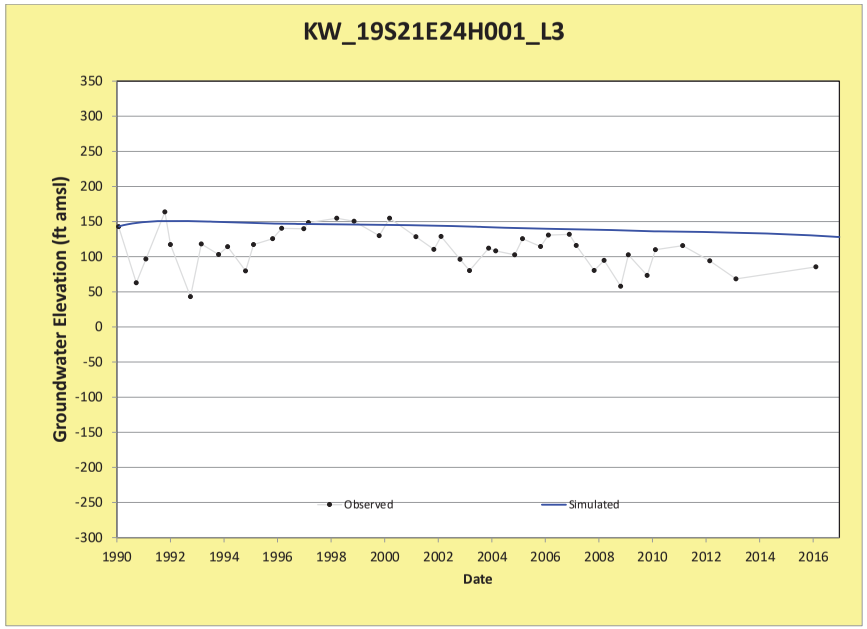

KW_18S23E34A001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

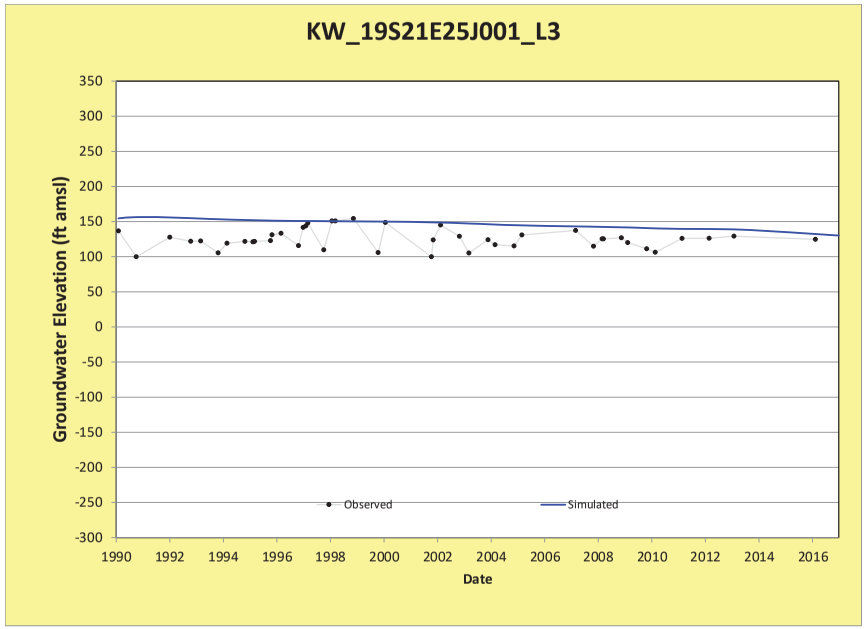

KW_18S23E34A002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

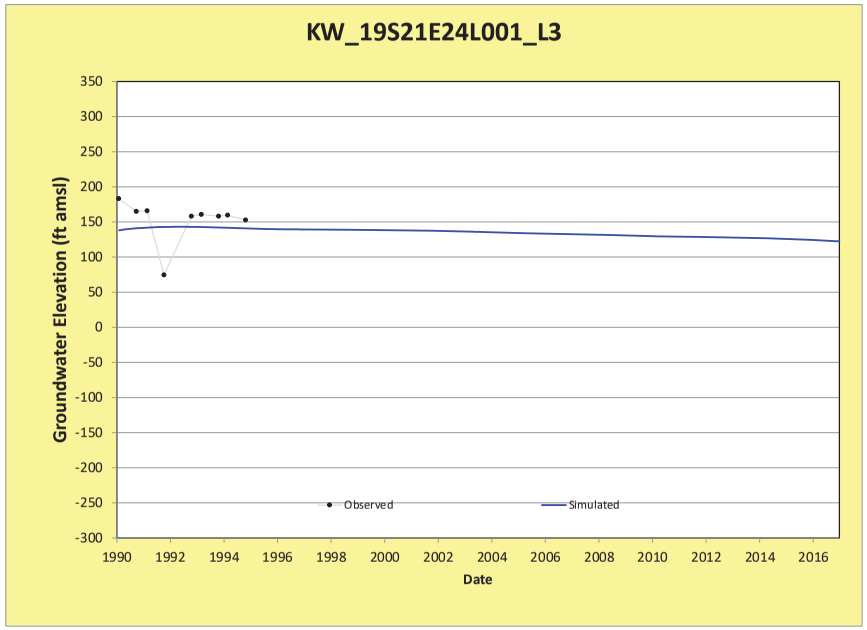

KW_19S21E13A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

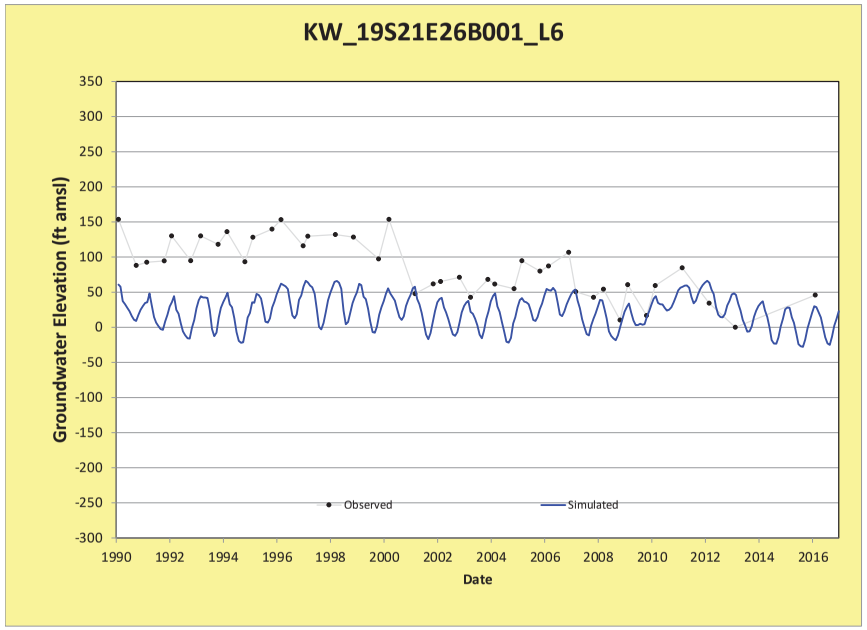

KW_18S24E31C001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

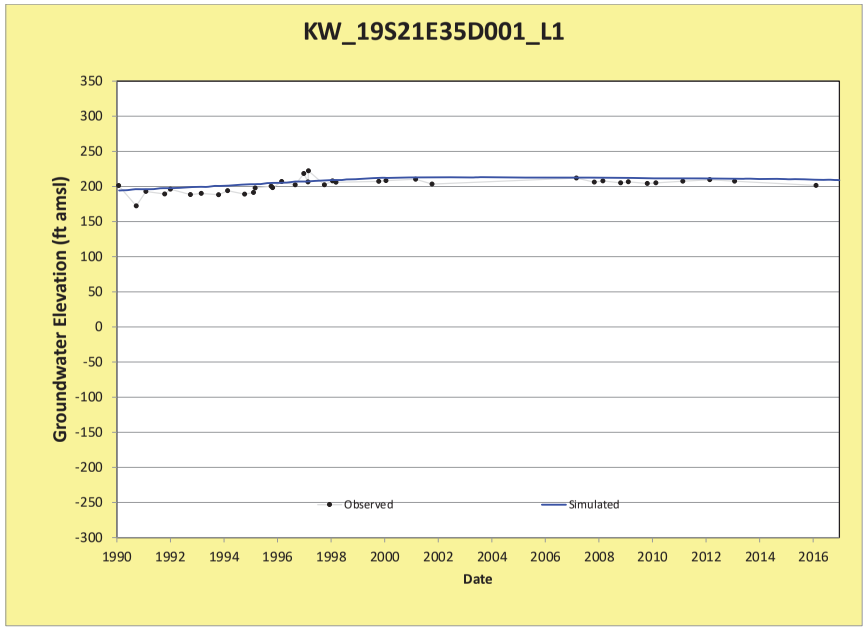

KW_19S21E23J001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

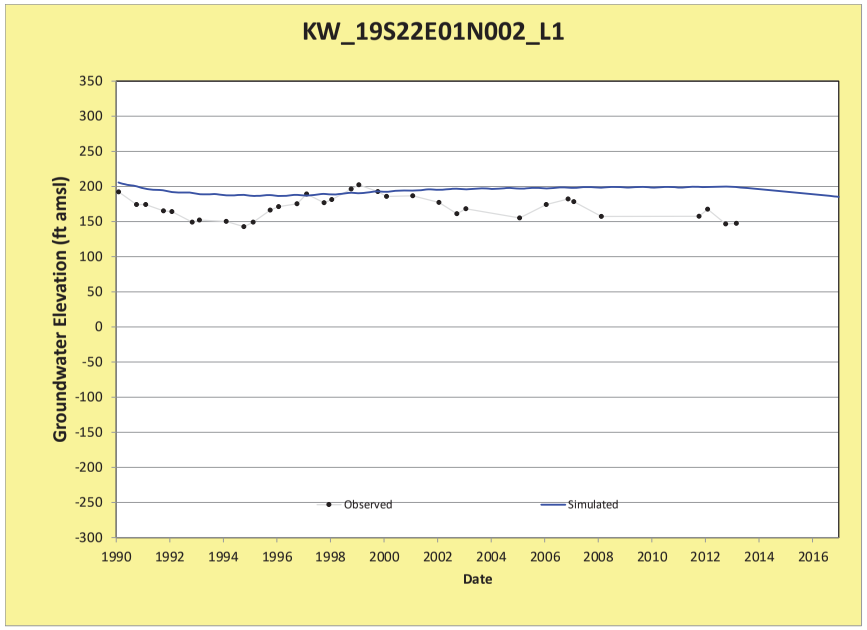

KW_19S21E24H001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

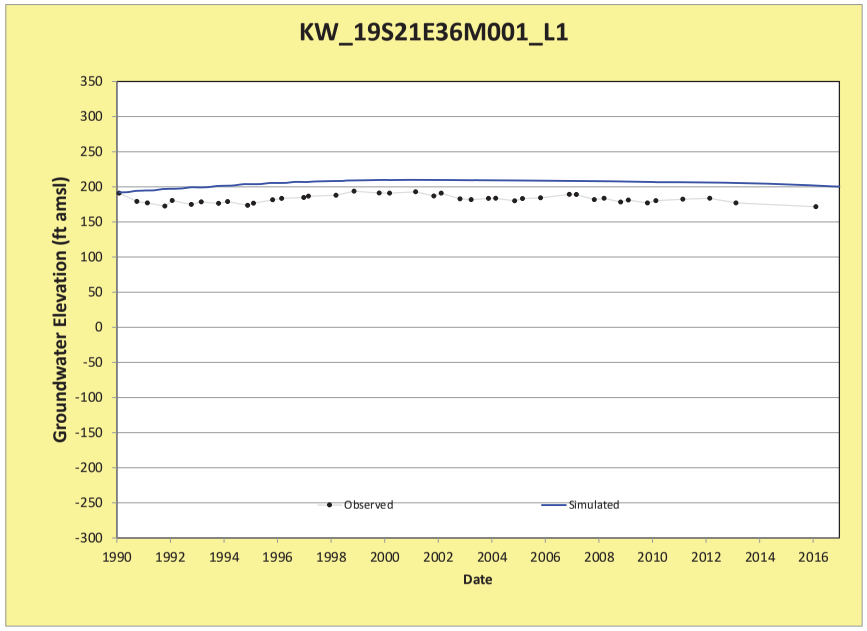

KW_19S21E25J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

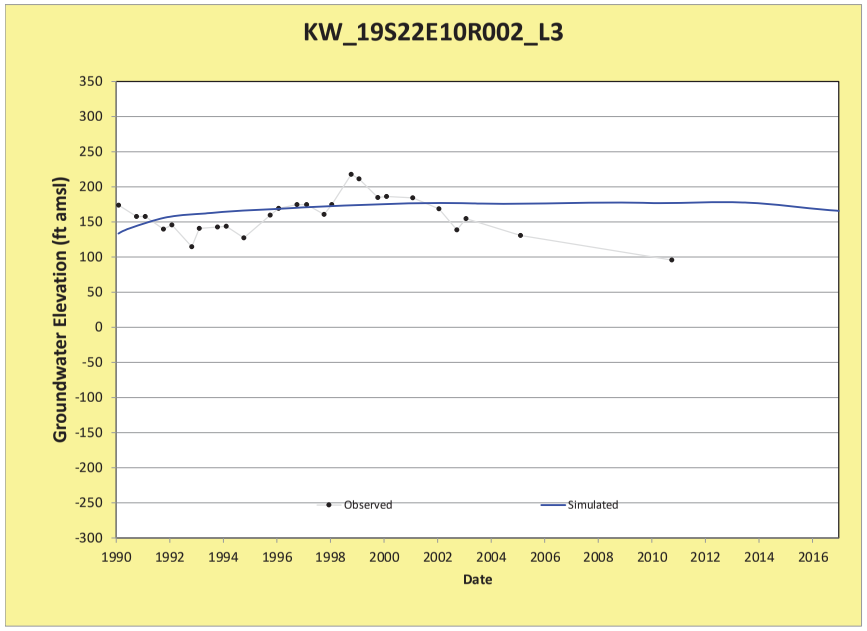

KW_19S21E24L001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

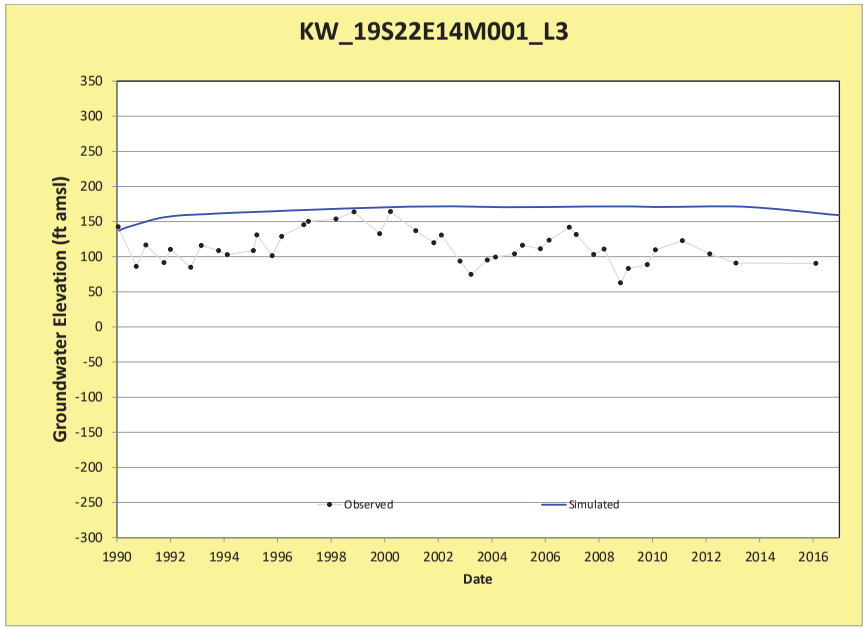

KW_19S21E26B001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

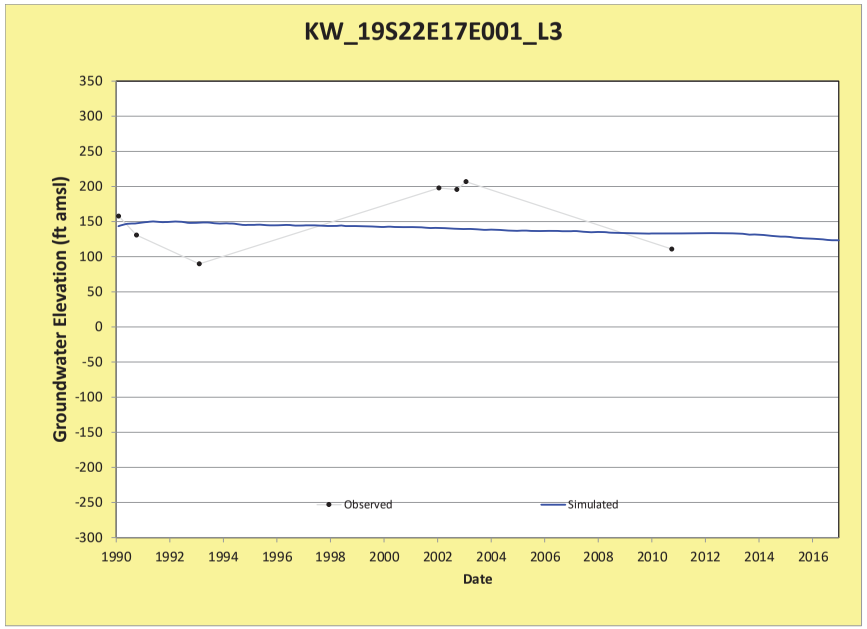

KW_19S21E35D001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

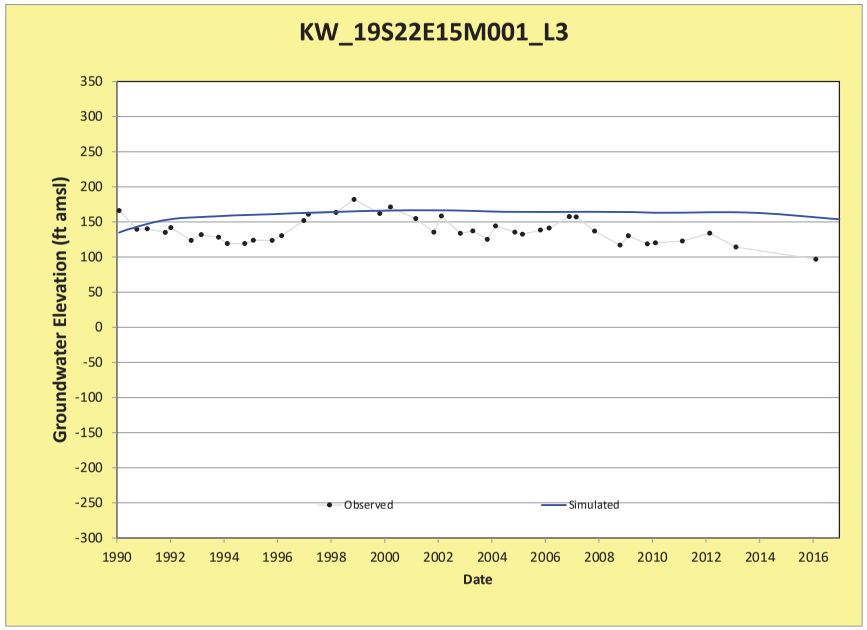

KW_19S22E01N002_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

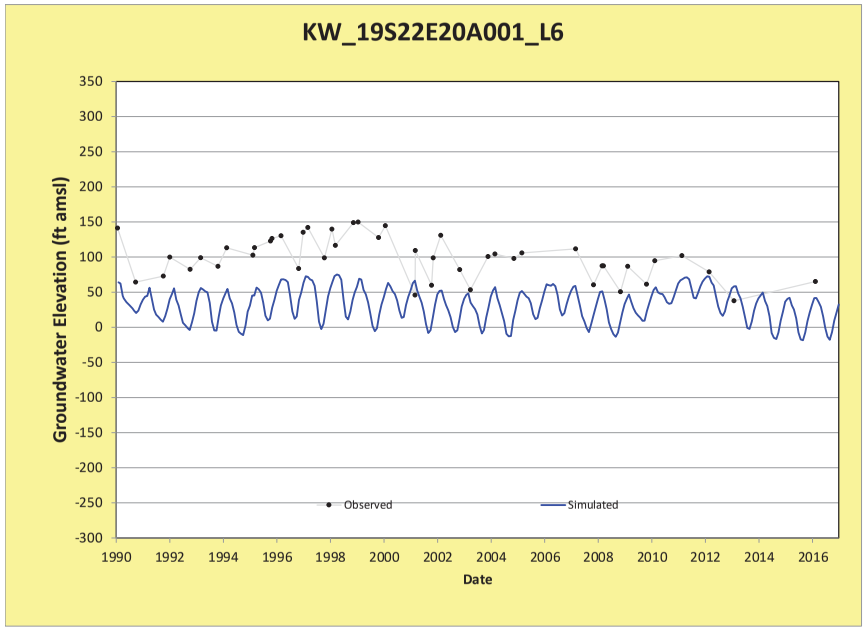

KW_19S21E36M001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

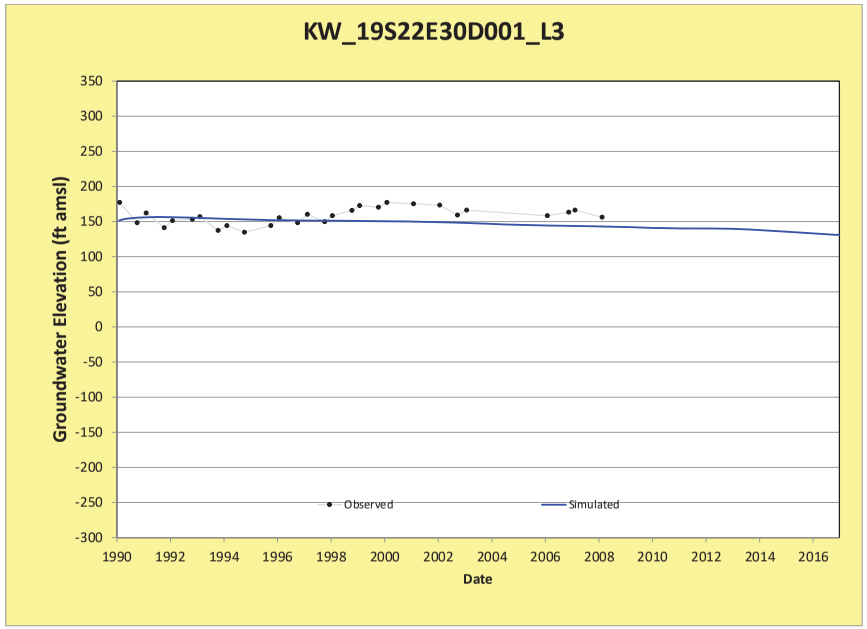

KW_19S22E10R002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

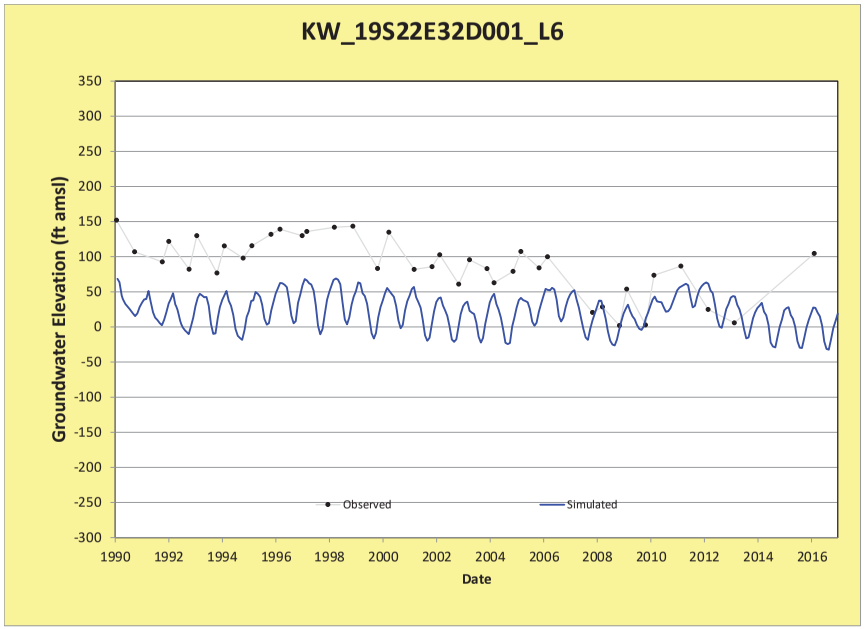

KW_19S22E14M001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

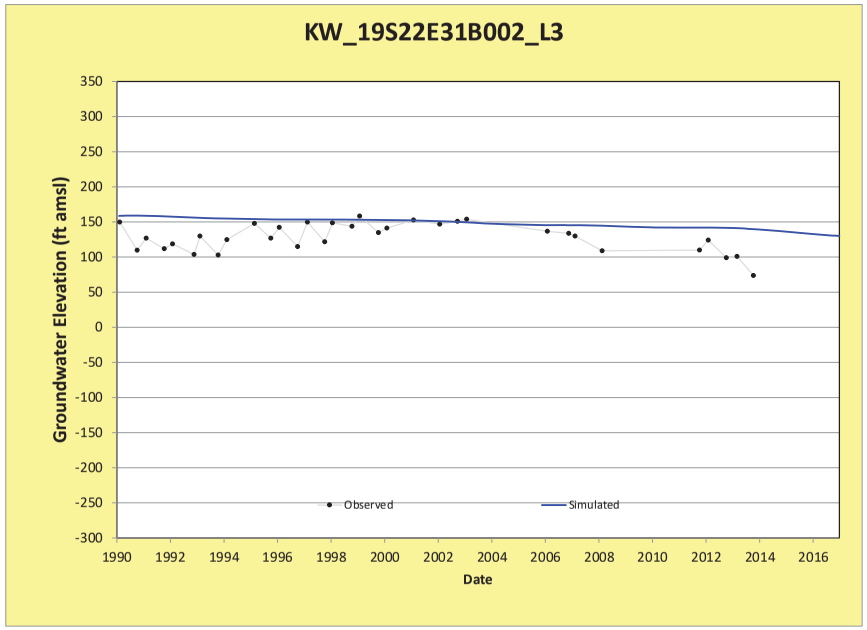

KW_19S22E17E001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

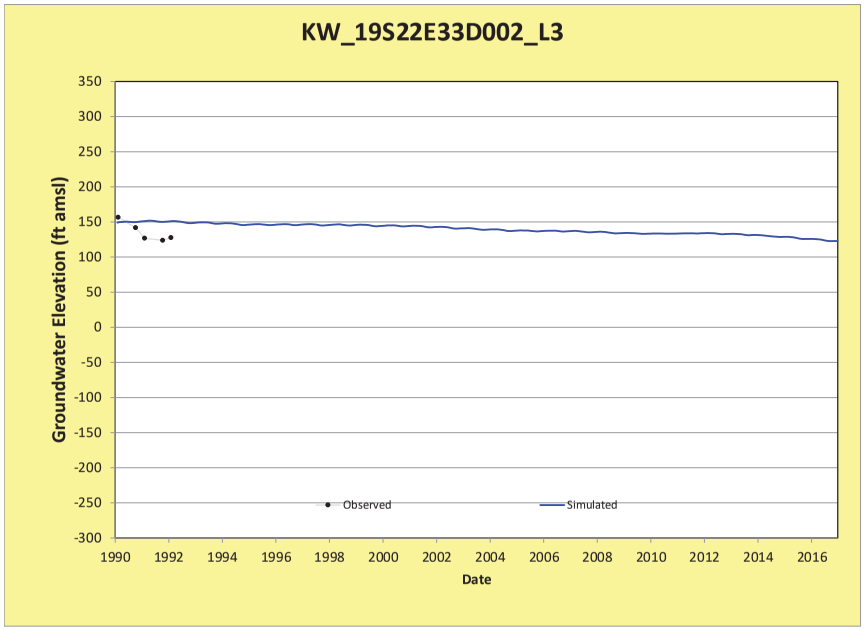

KW_19S22E15M001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

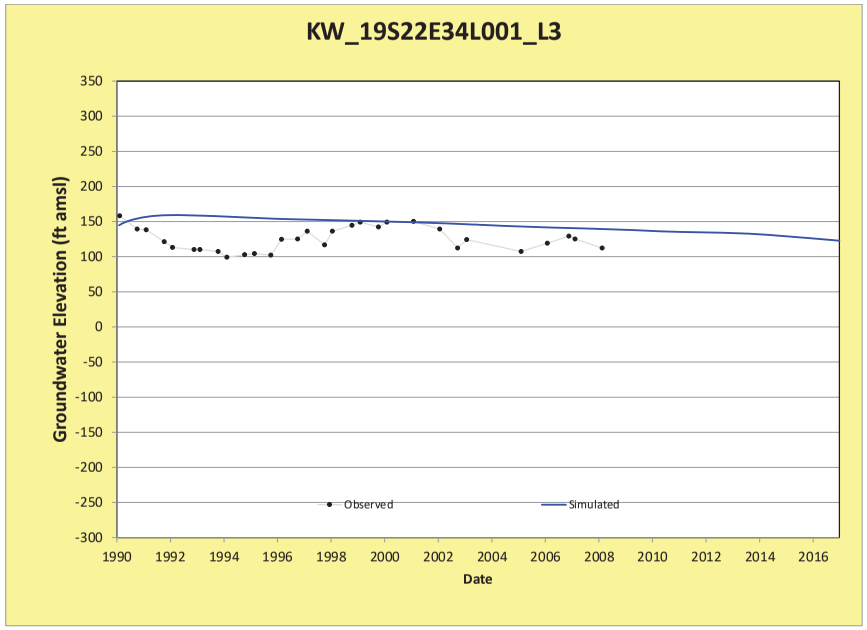

KW_19S22E20A001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

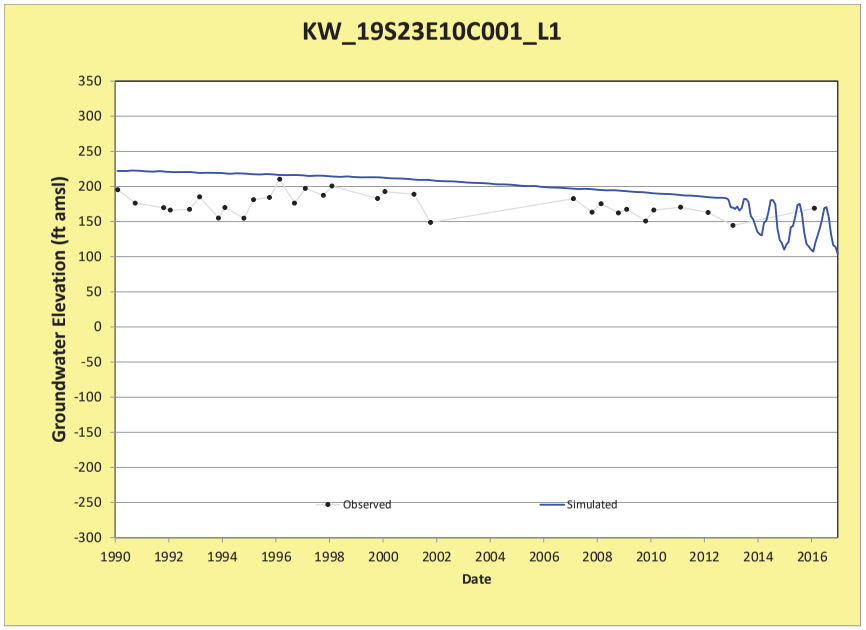

KW_19S22E30D001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

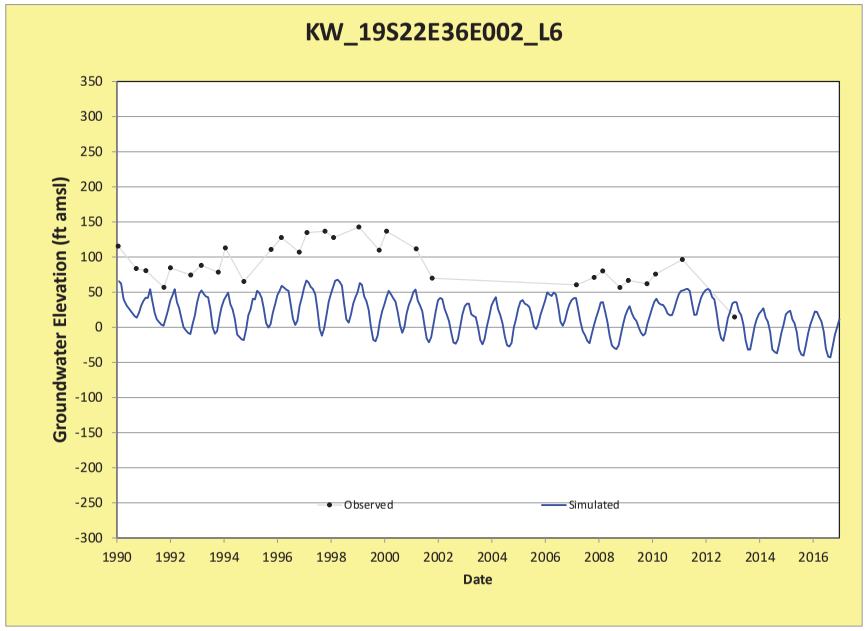

KW_19S22E32D001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

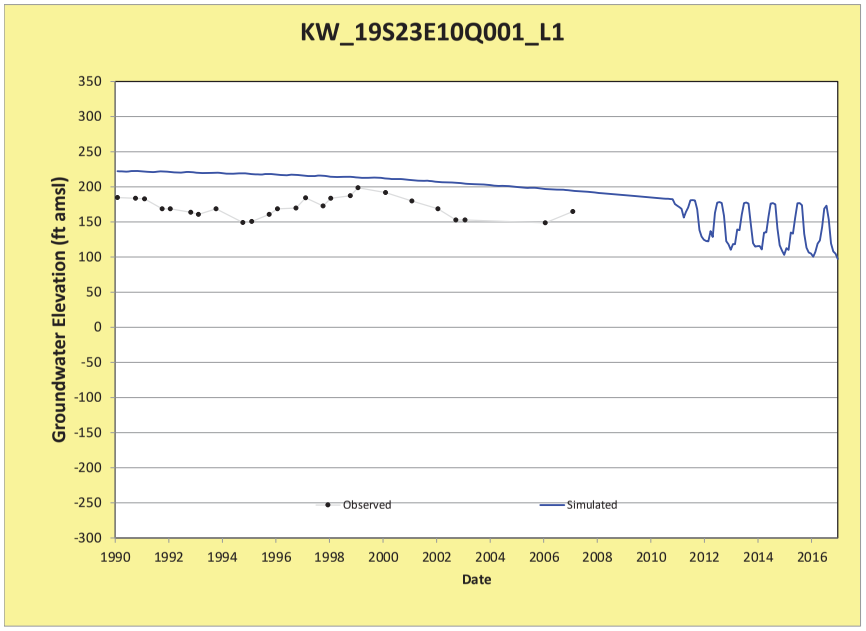

KW_19S22E31B002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

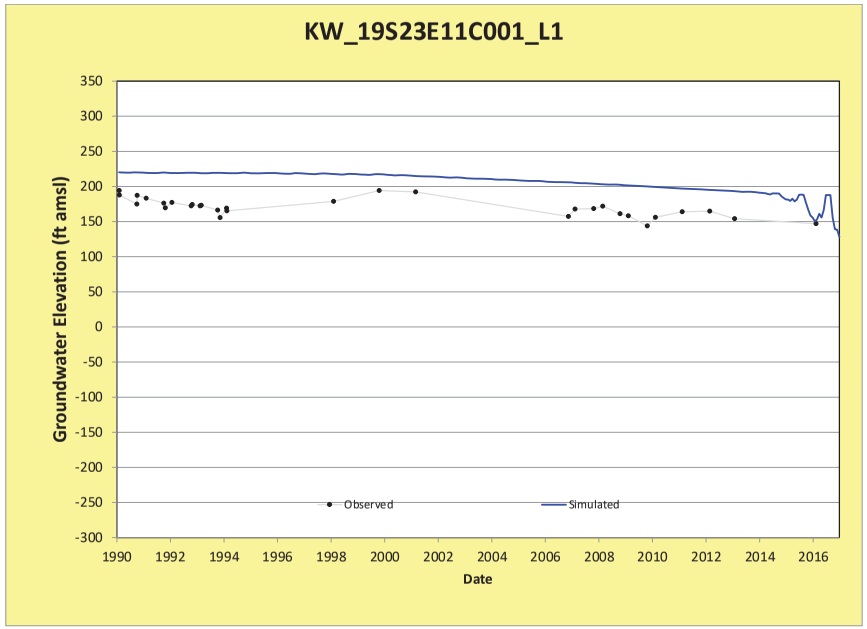

KW_19S22E33D002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

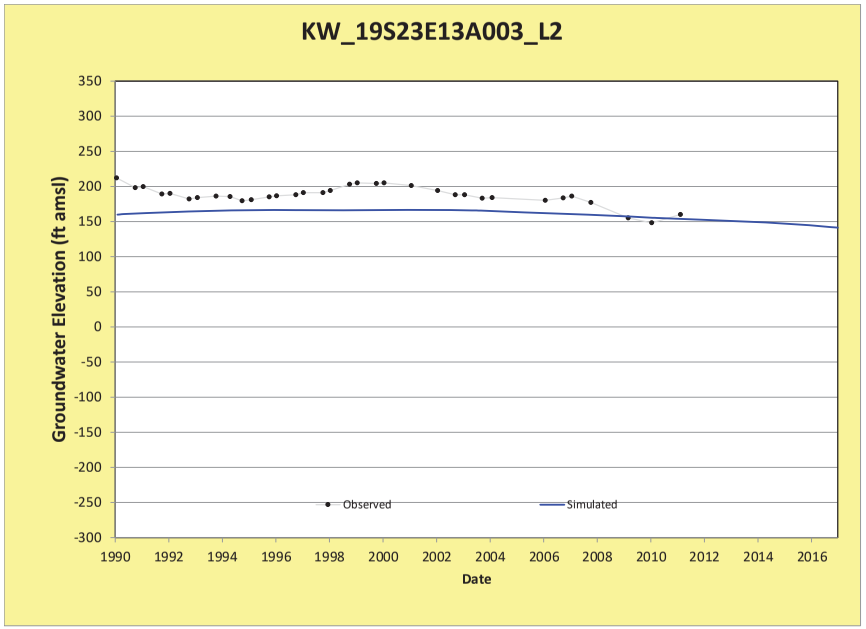

KW_19S22E34L001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

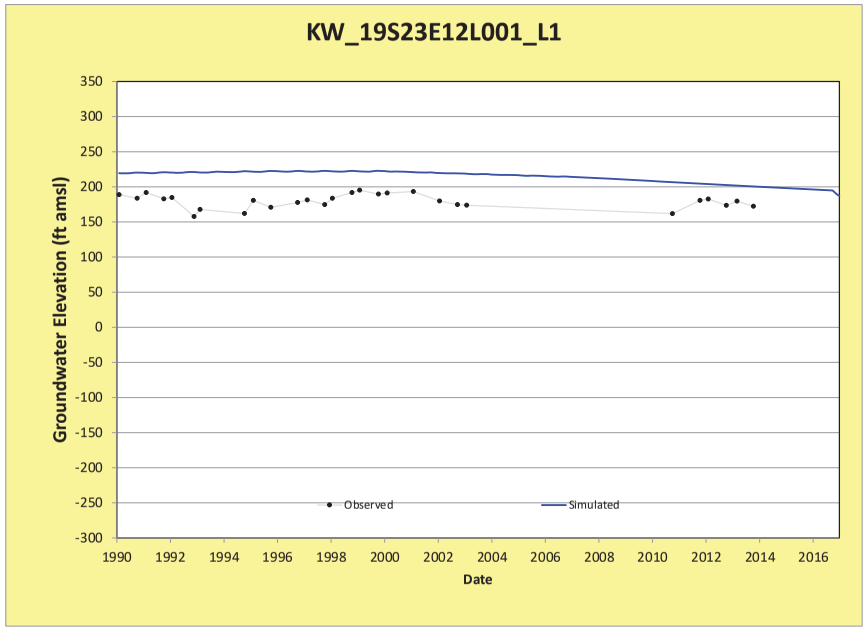

KW_19S23E10C001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

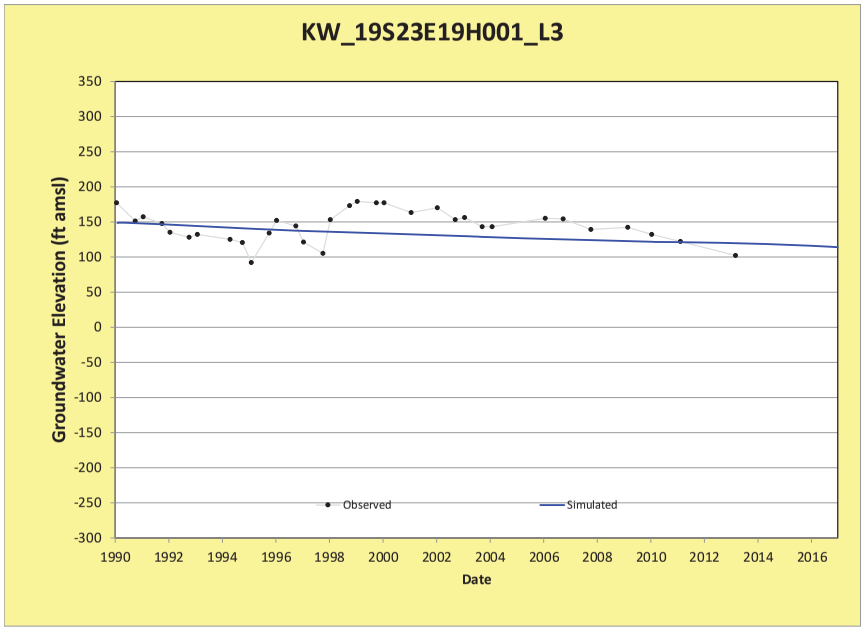

KW_19S22E36E002_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

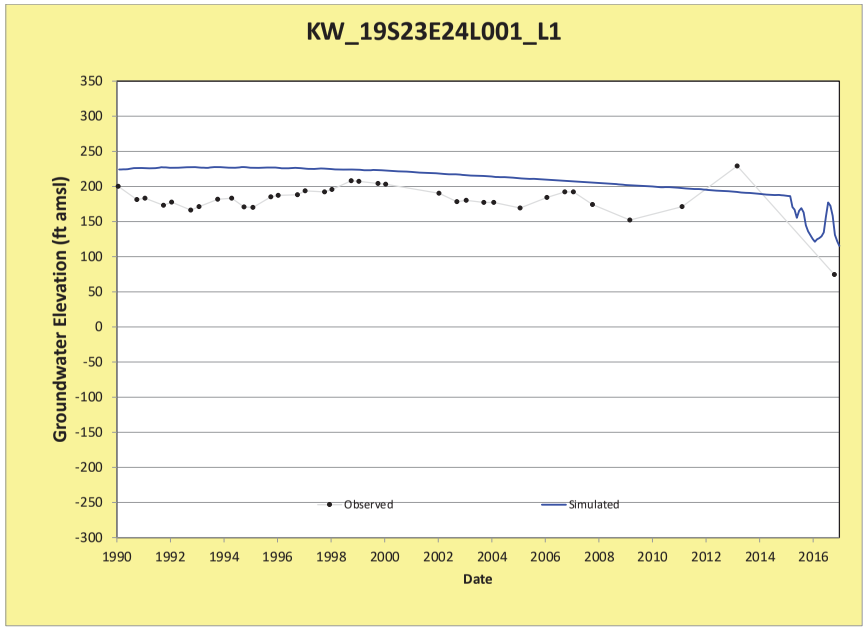

KW_19S23E10Q001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

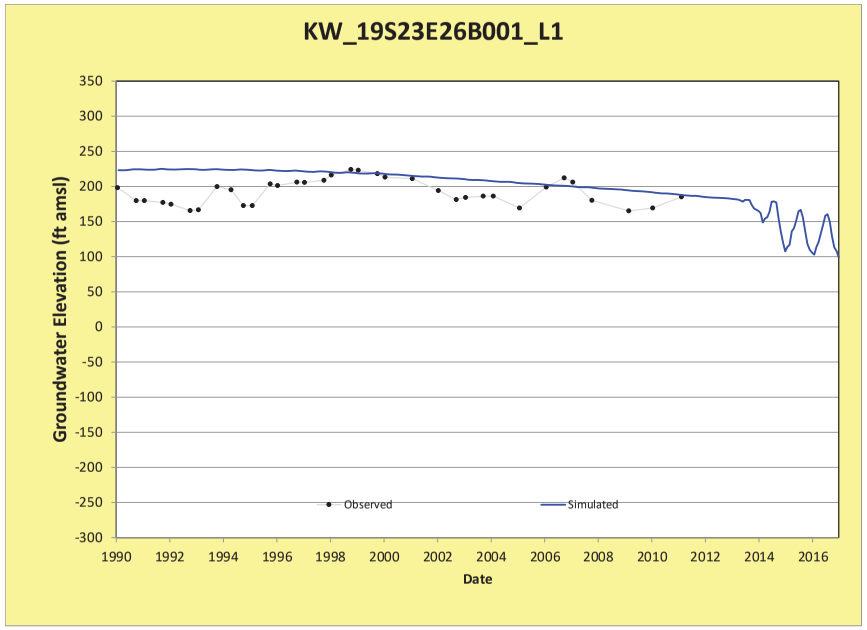

KW_19S23E11C001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

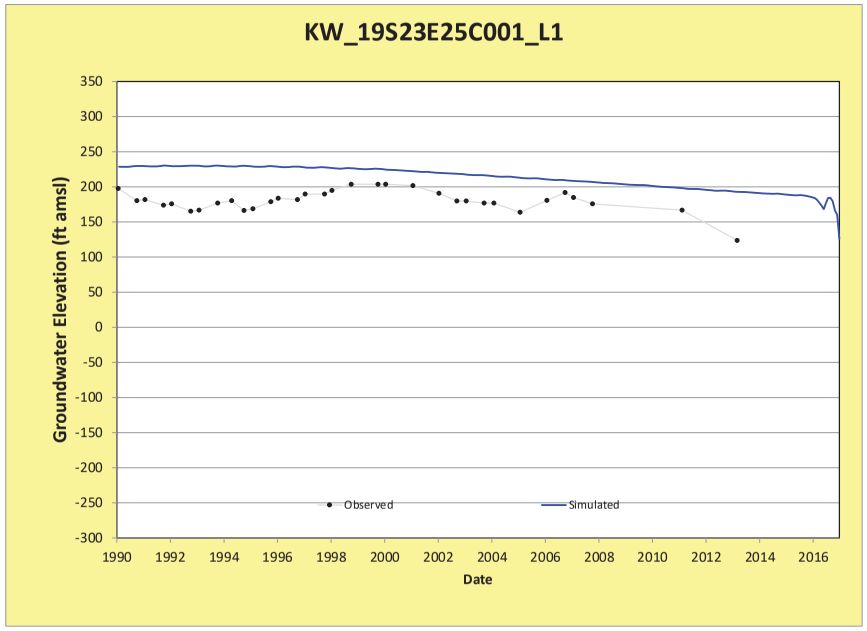

KW_19S23E13A003_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

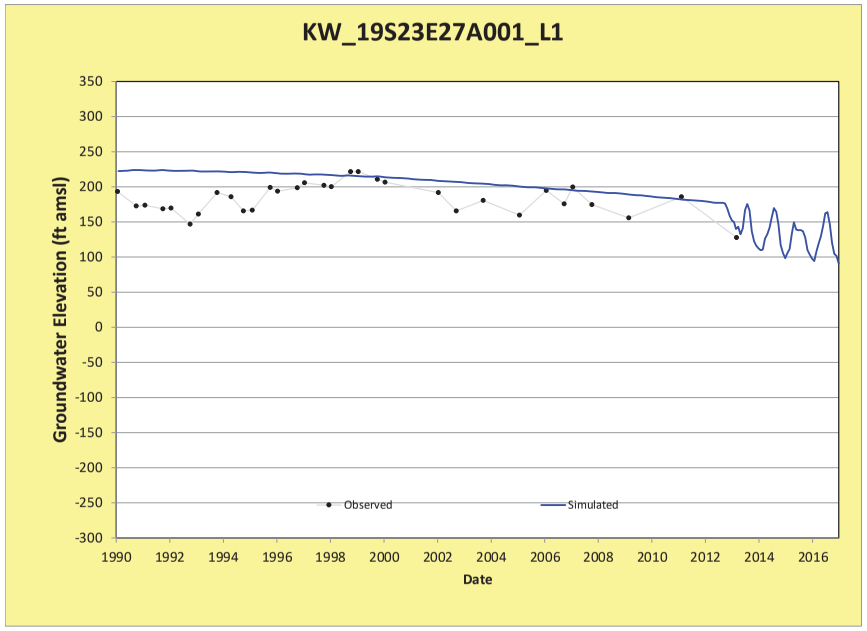

KW_19S23E12L001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

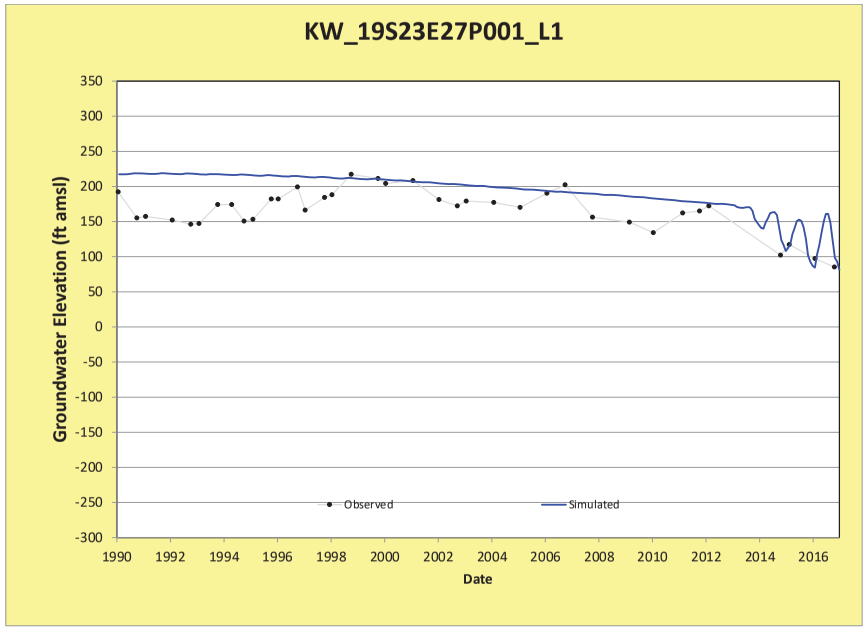

KW_19S23E19H001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

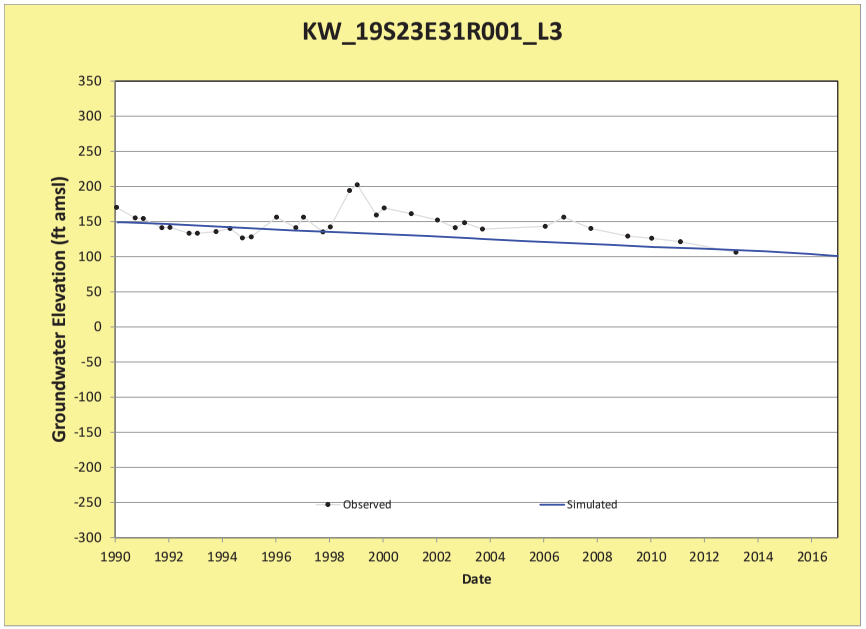

KW_19S23E24L001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

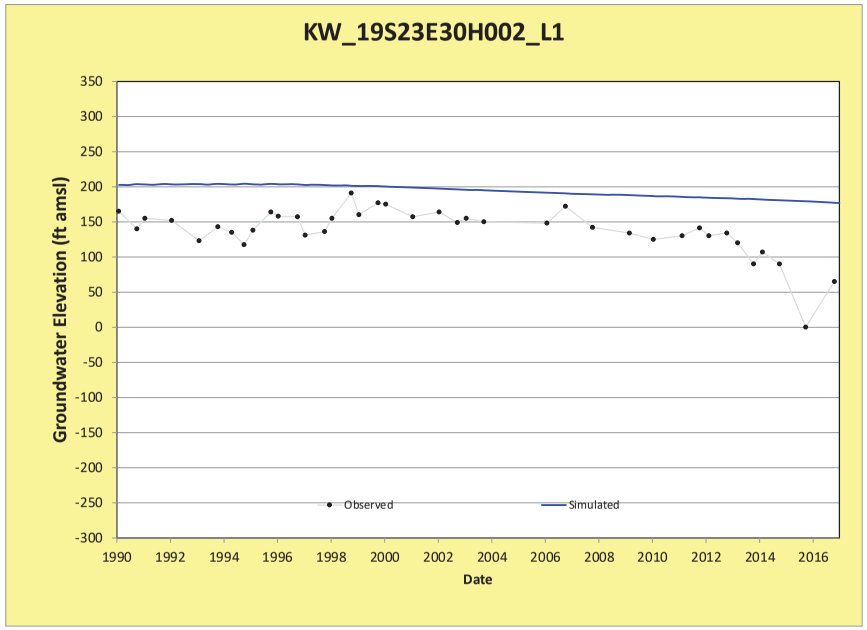

KW_19S23E26B001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

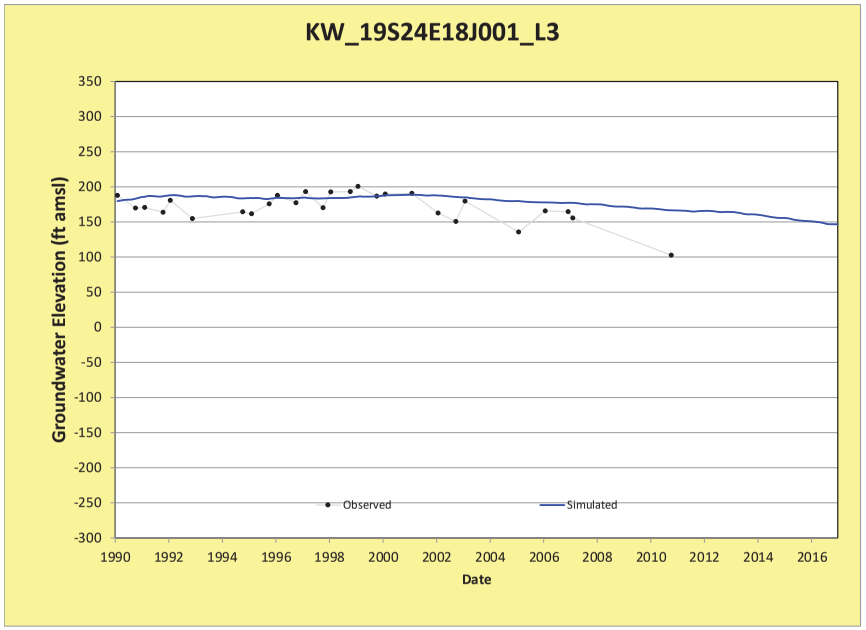

KW_19S23E25C001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

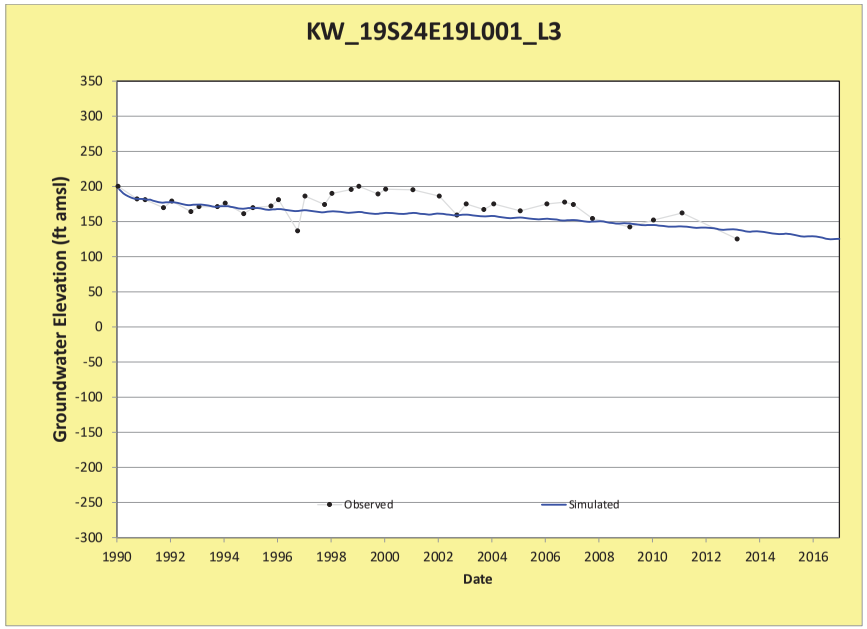

KW_19S23E27A001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

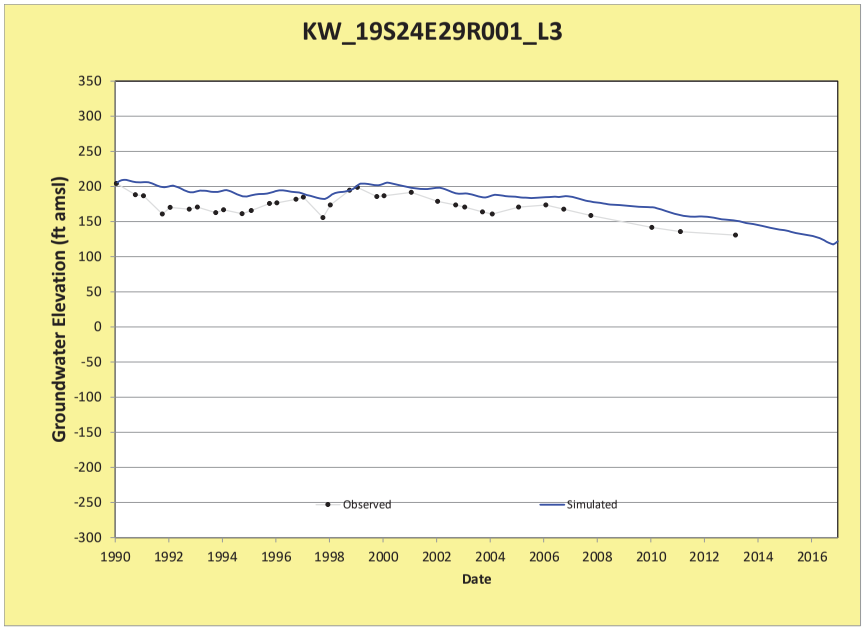

KW_19S23E27P001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

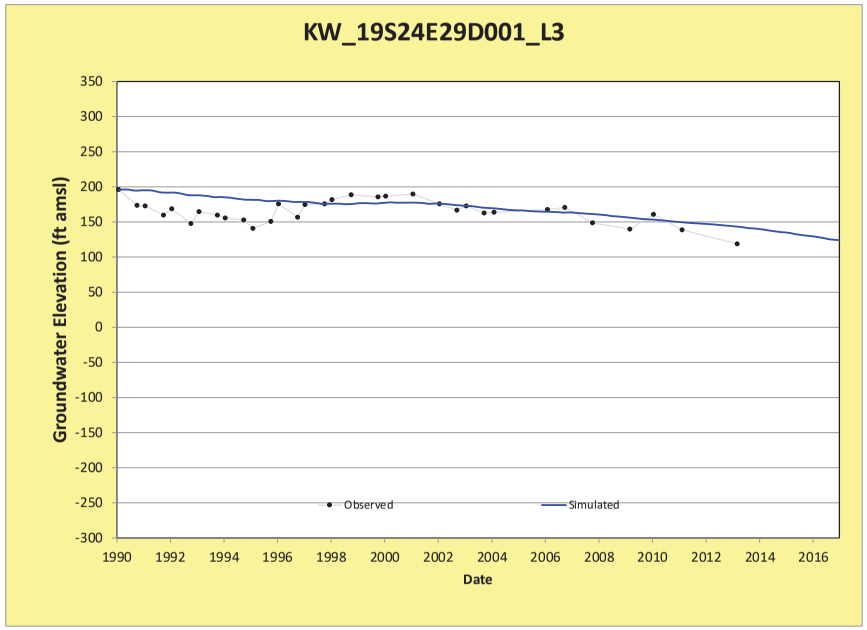

KW_19S23E31R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

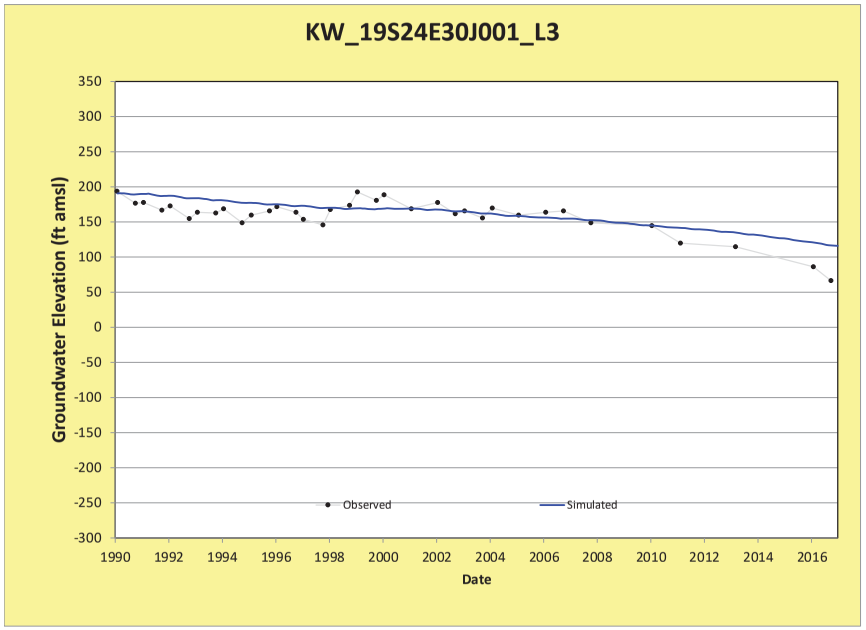

KW_19S23E30H002_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

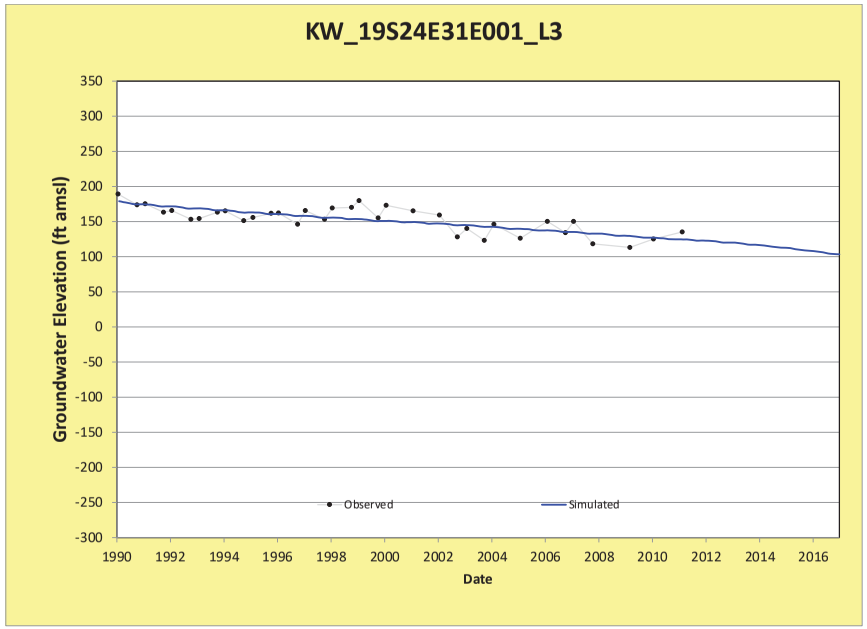

KW_19S24E18J001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

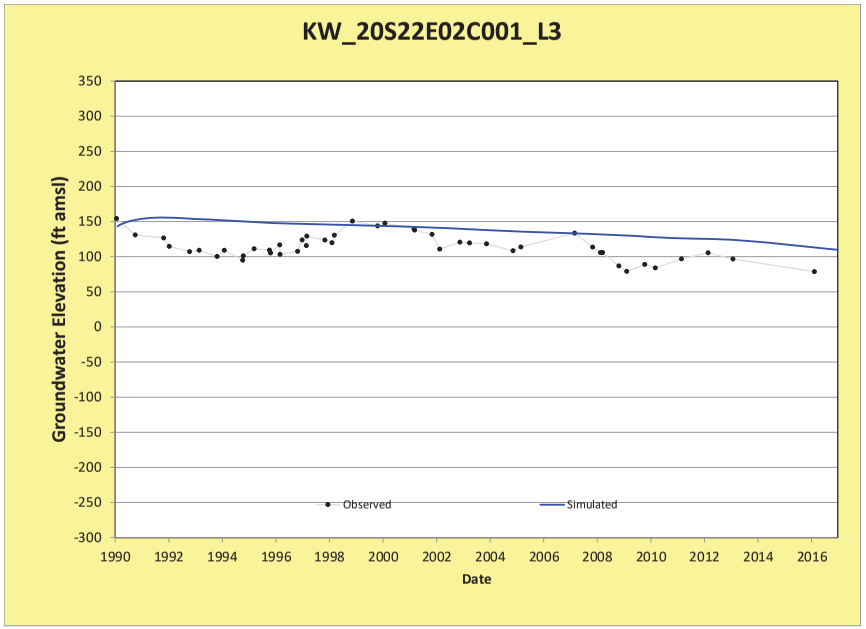

KW_19S24E19L001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

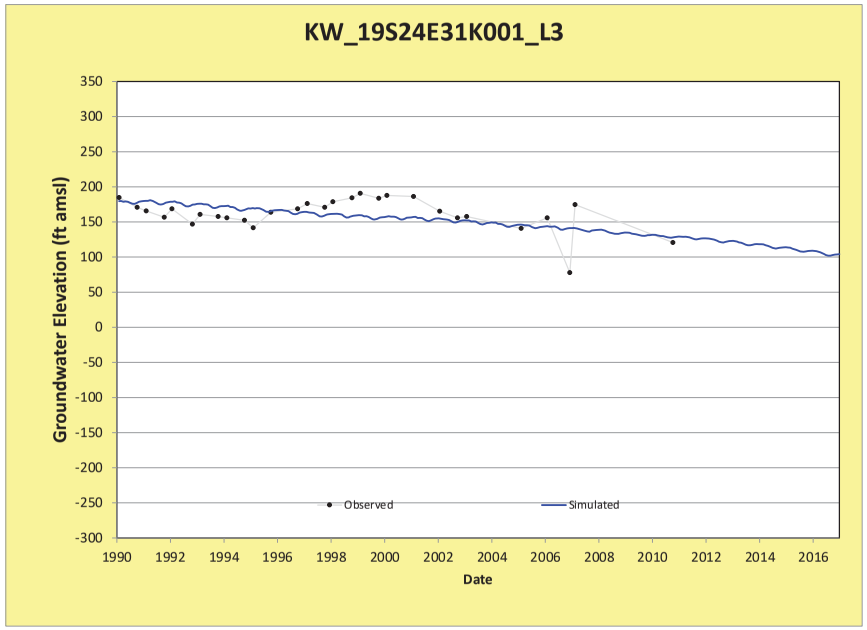

KW_19S24E29R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

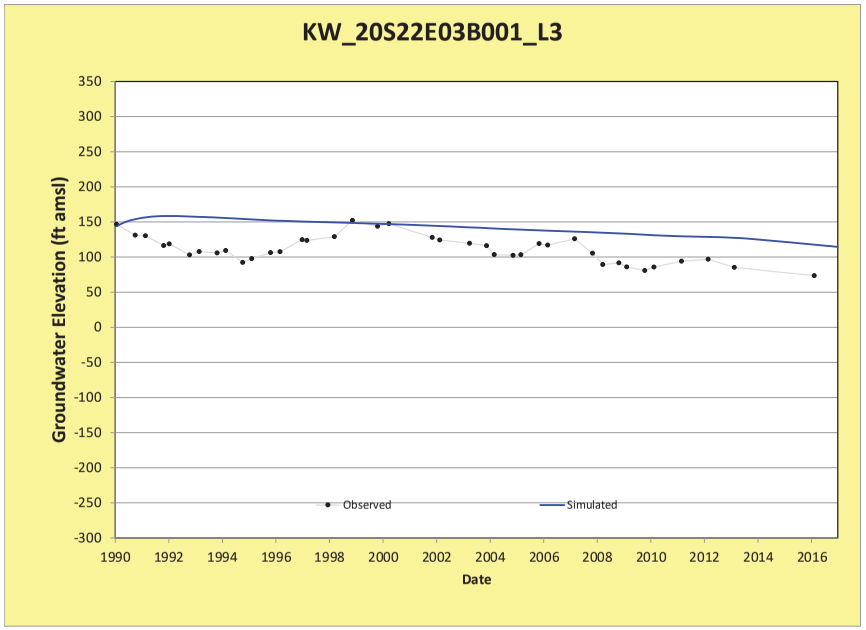

KW_19S24E29D001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

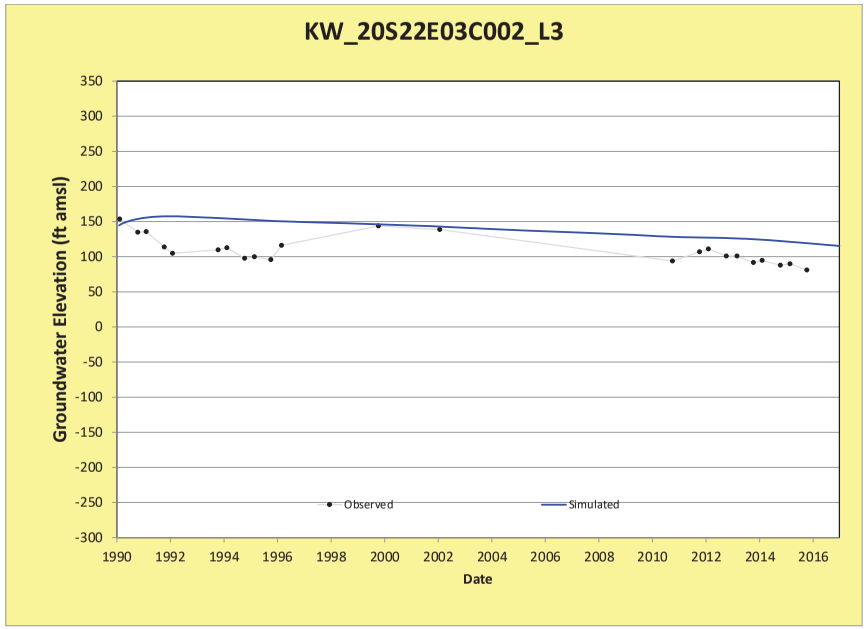

KW_19S24E30J001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

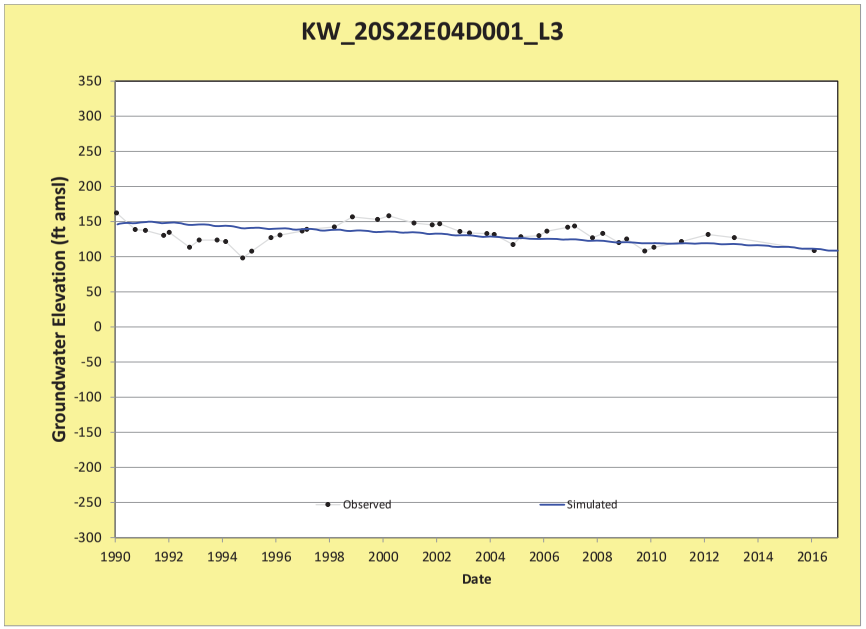

KW_19S24E31E001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

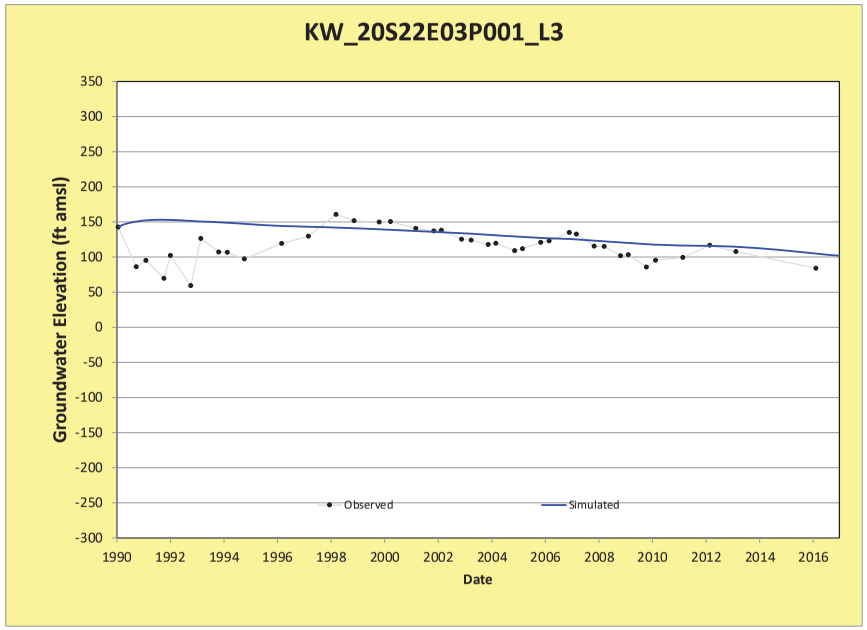

KW_20S22E02C001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

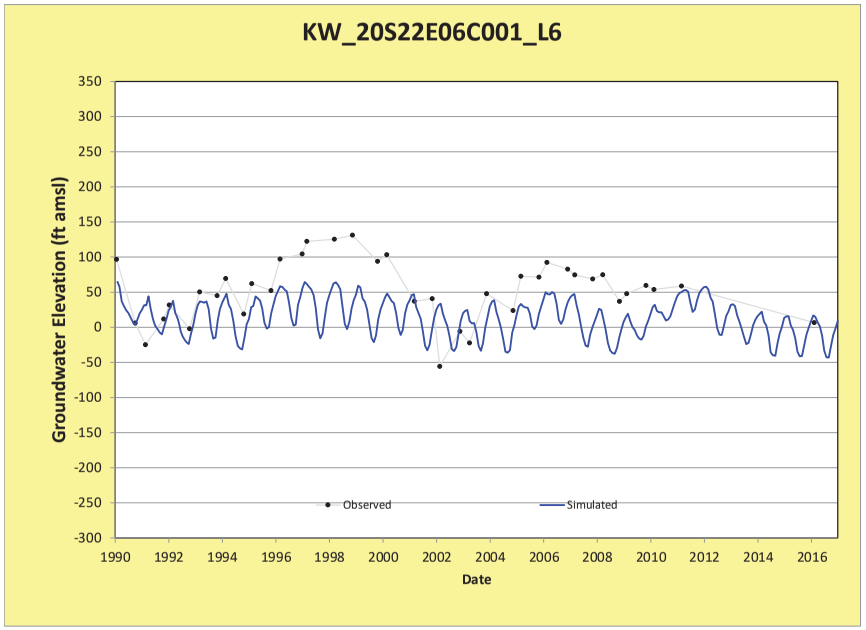

KW_19S24E31K001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

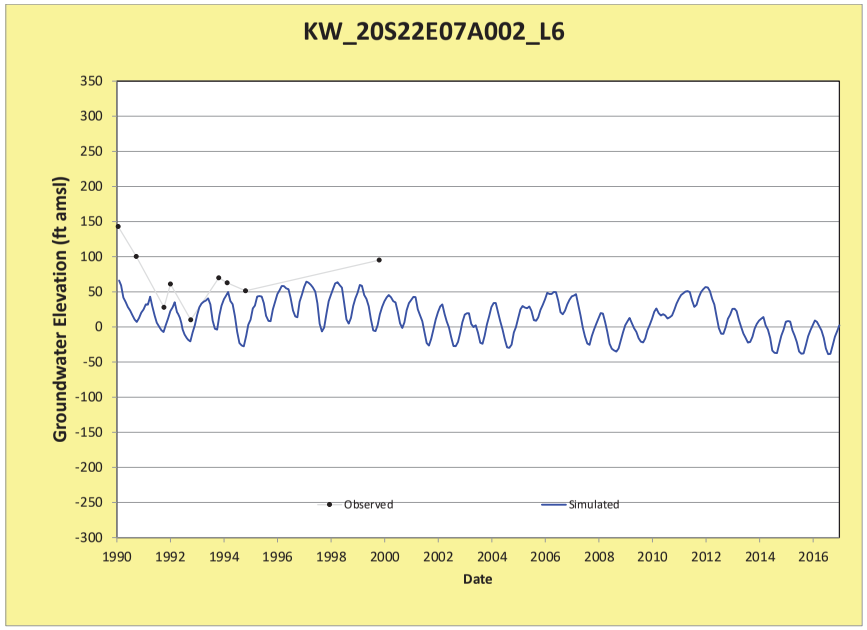

KW_20S22E03B001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

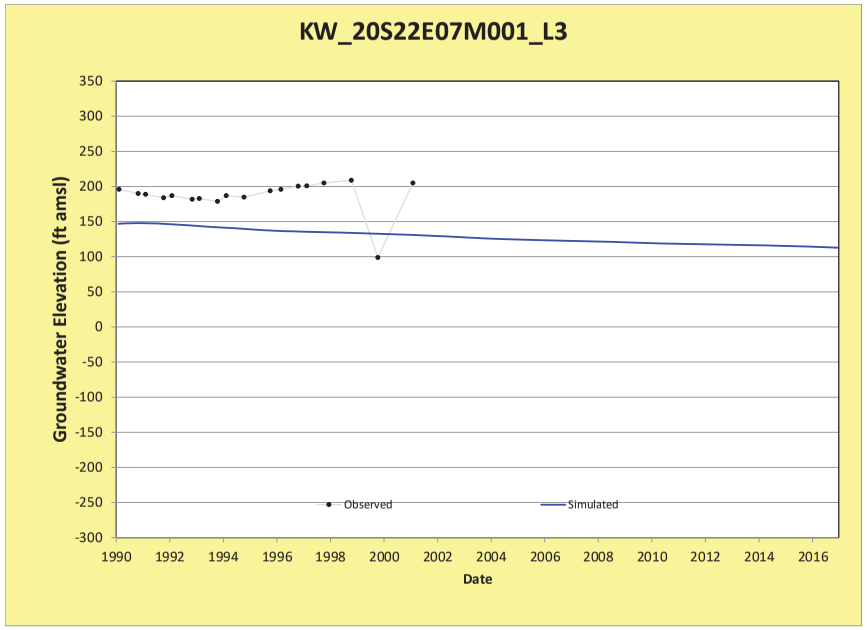

KW_20S22E03C002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

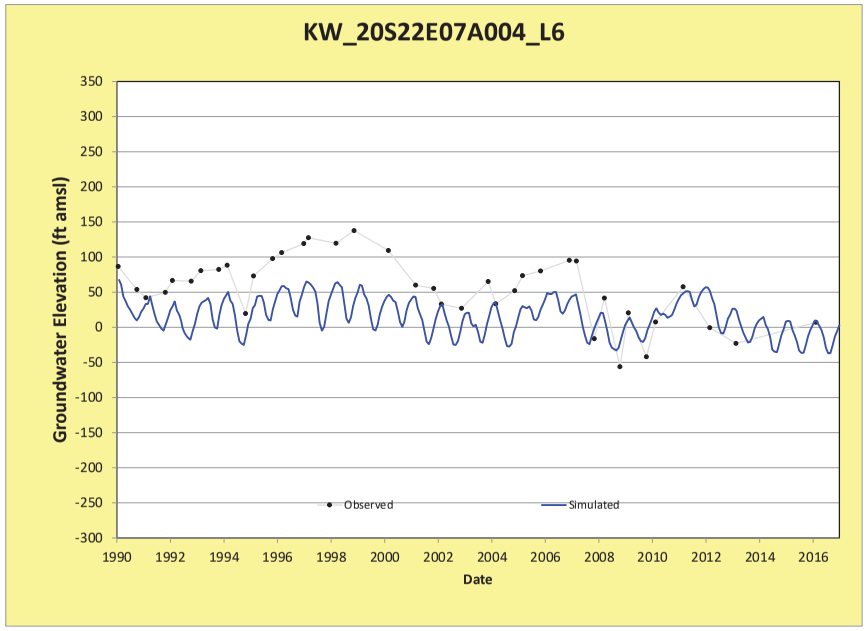

KW_20S22E04D001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

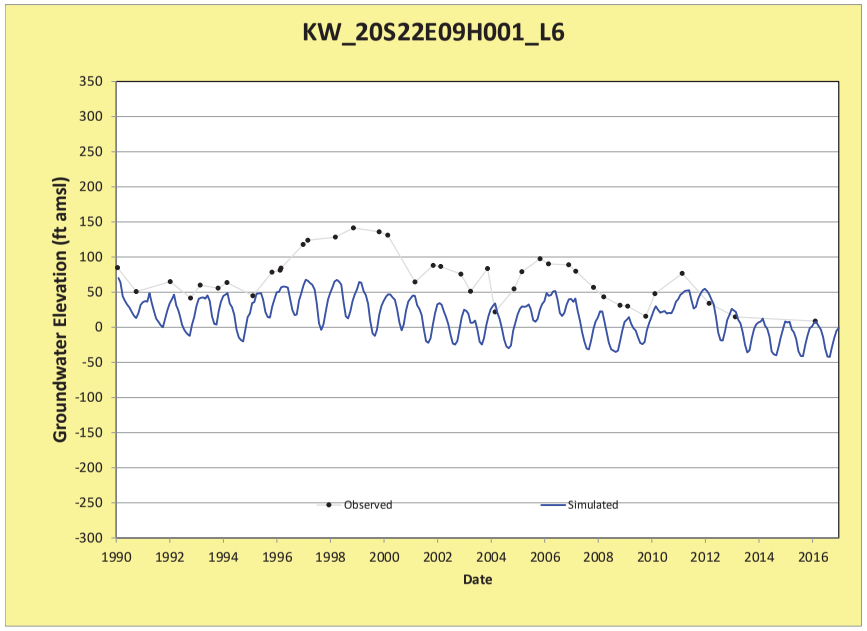

KW_20S22E03P001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

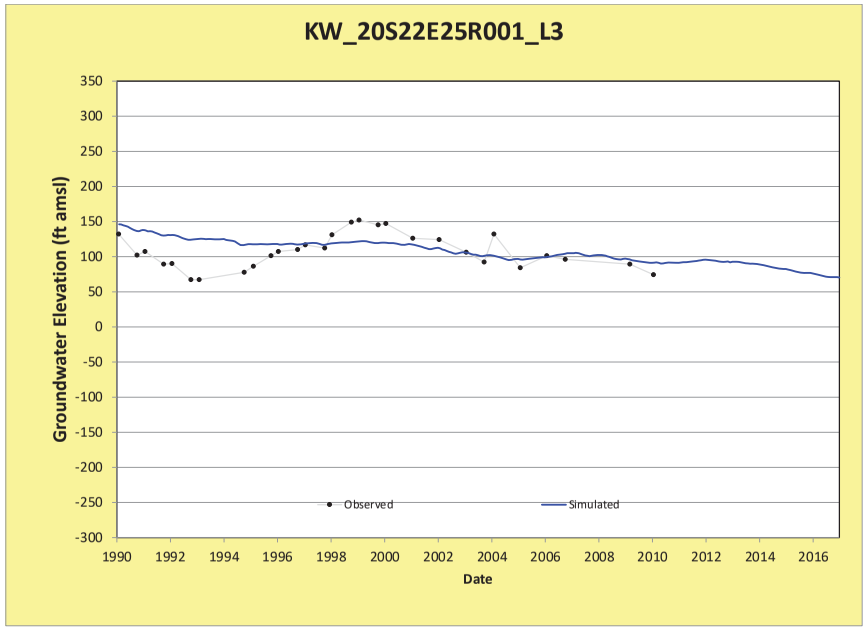

KW_20S22E06C001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

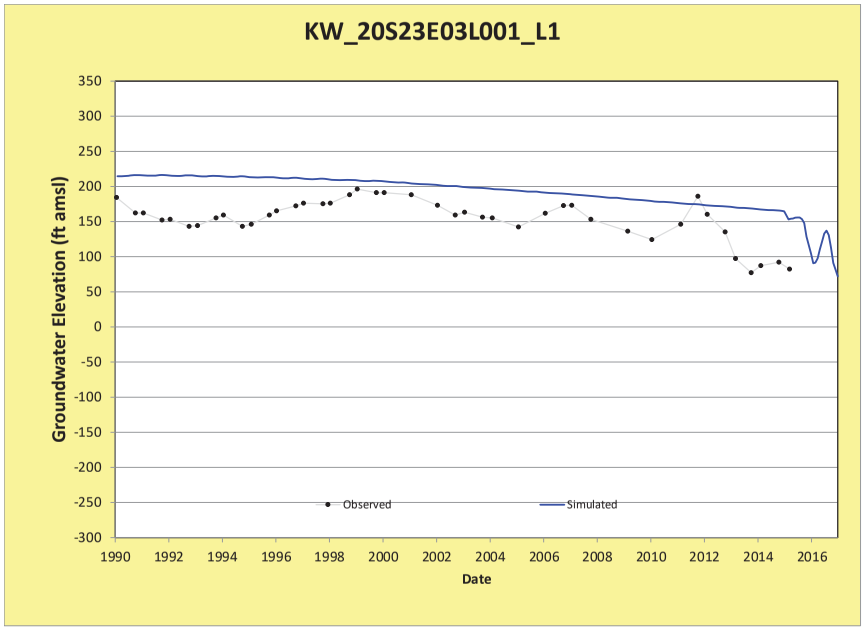

KW_20S22E07A002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

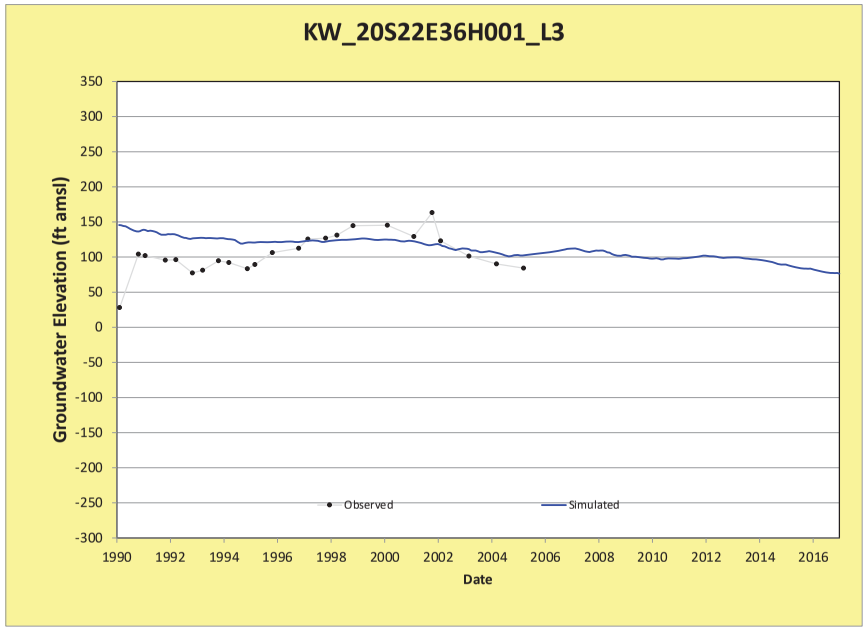

KW_20S22E07M001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

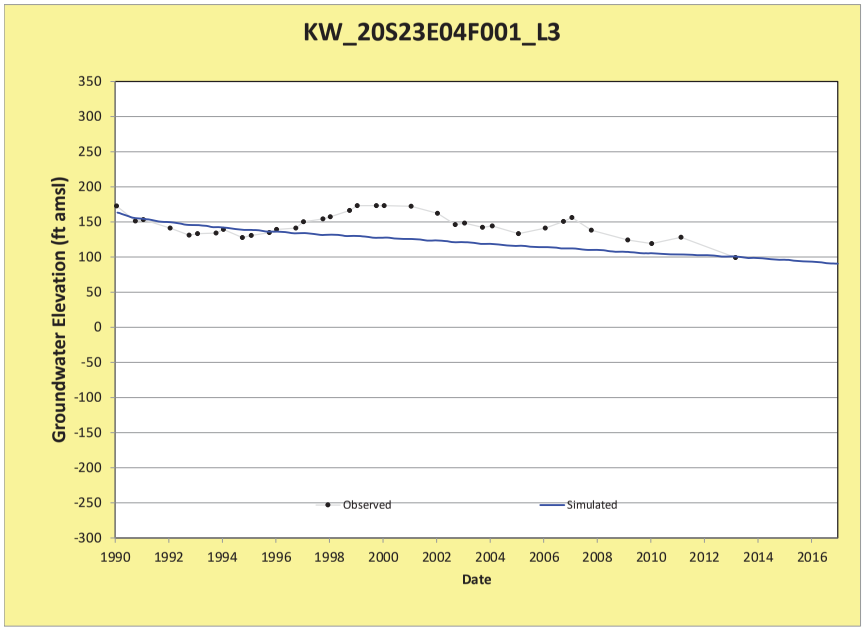

KW_20S22E07A004_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

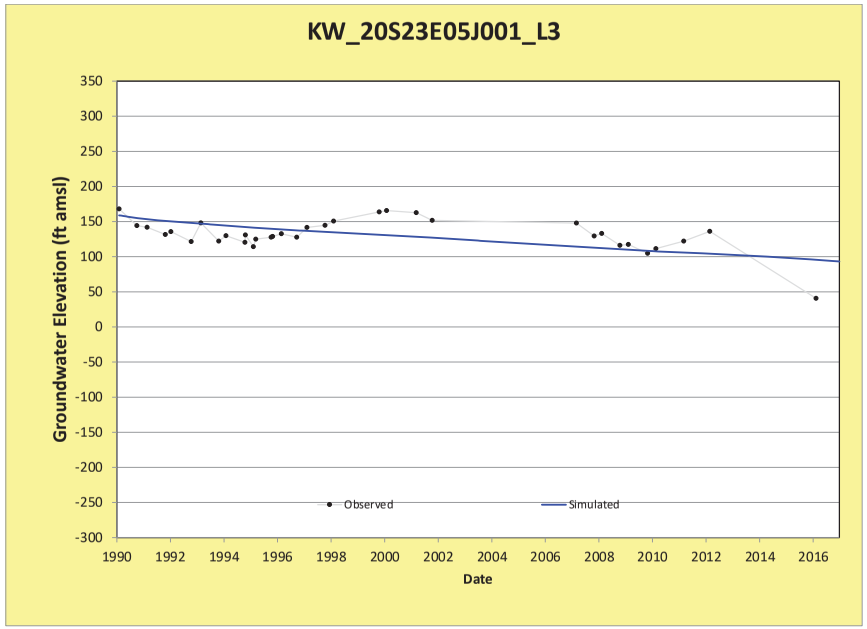

KW_20S22E09H001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

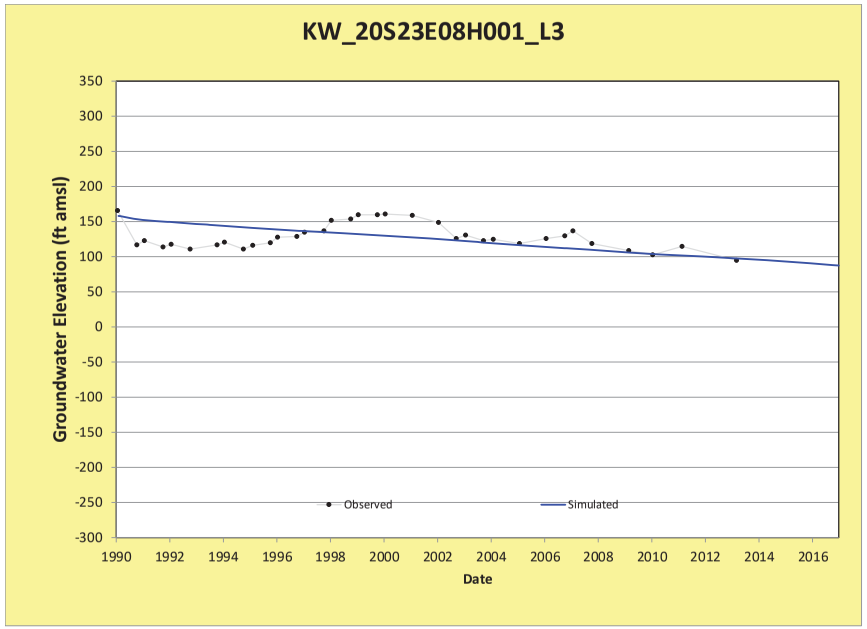

KW_20S22E25R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

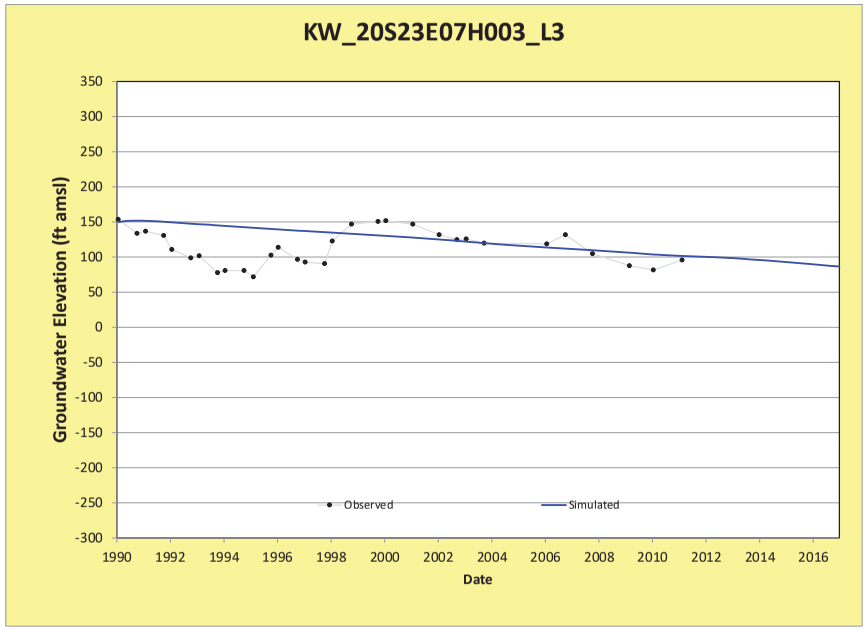

KW_20S23E03L001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

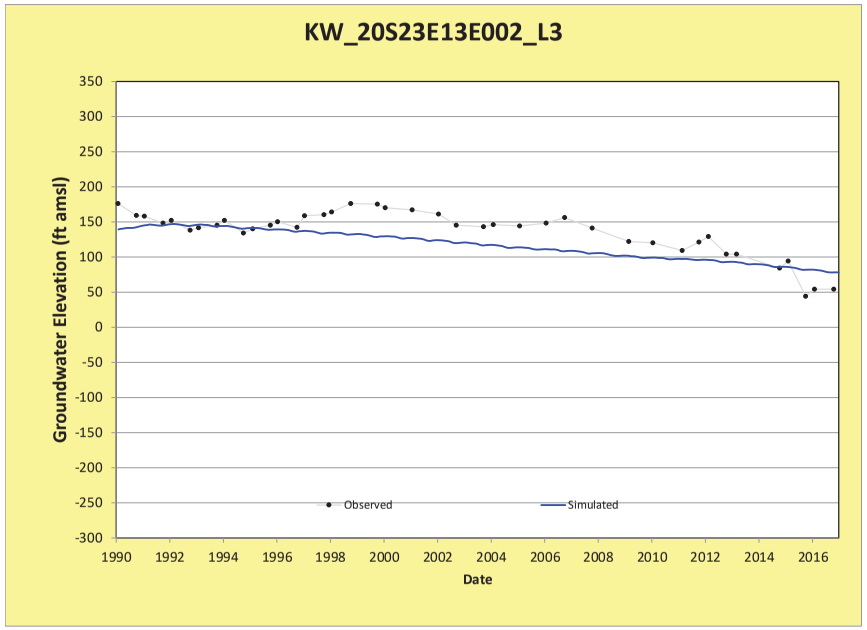

KW_20S22E36H001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

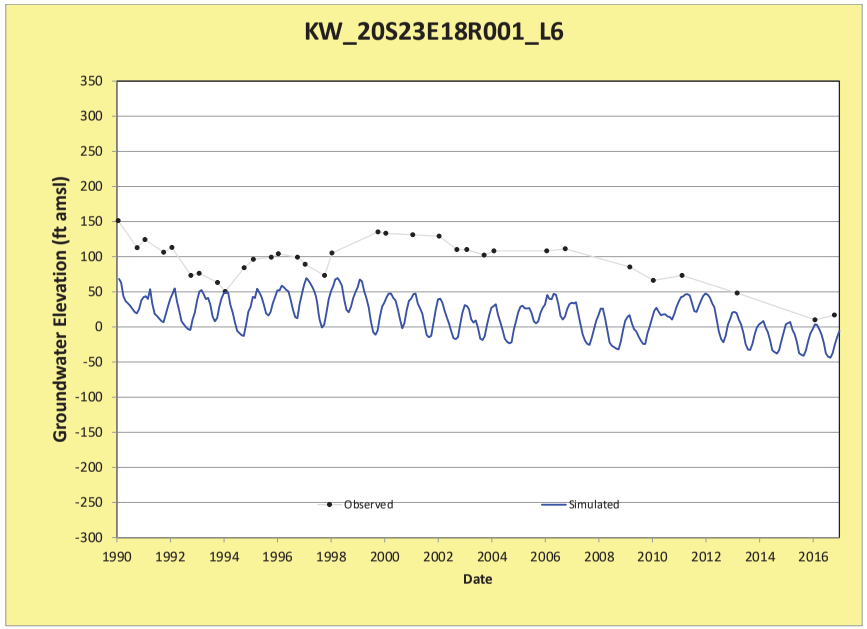

KW_20S23E04F001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

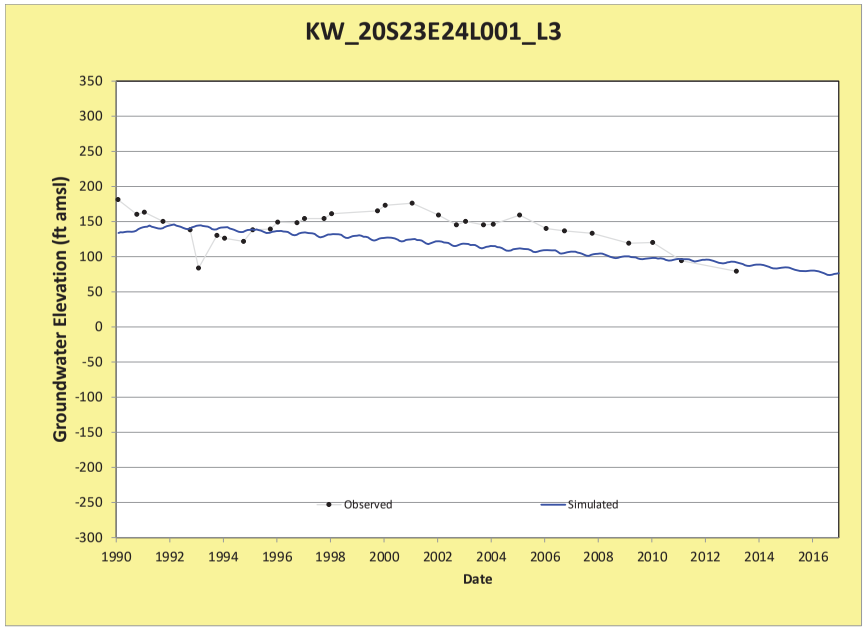

KW_20S23E05J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

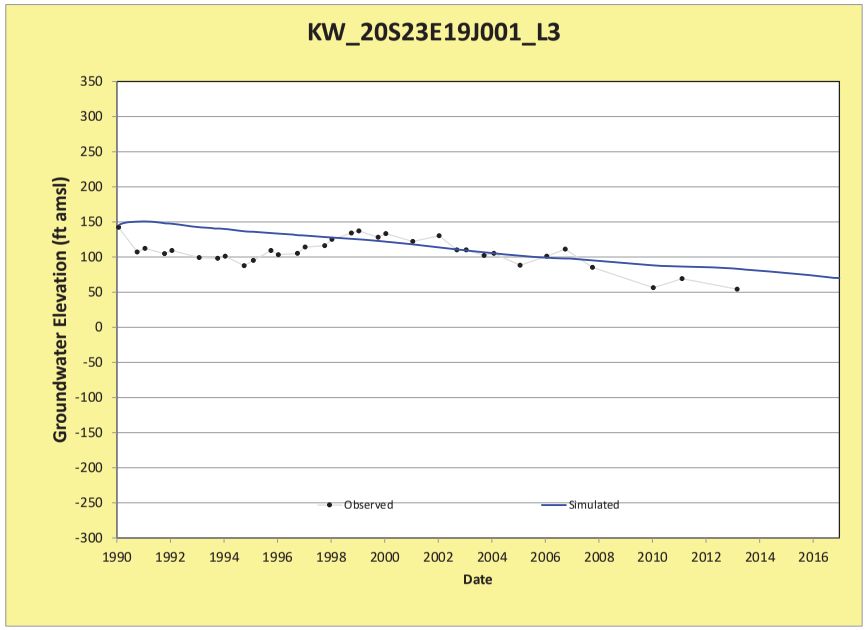

KW_20S23E08H001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

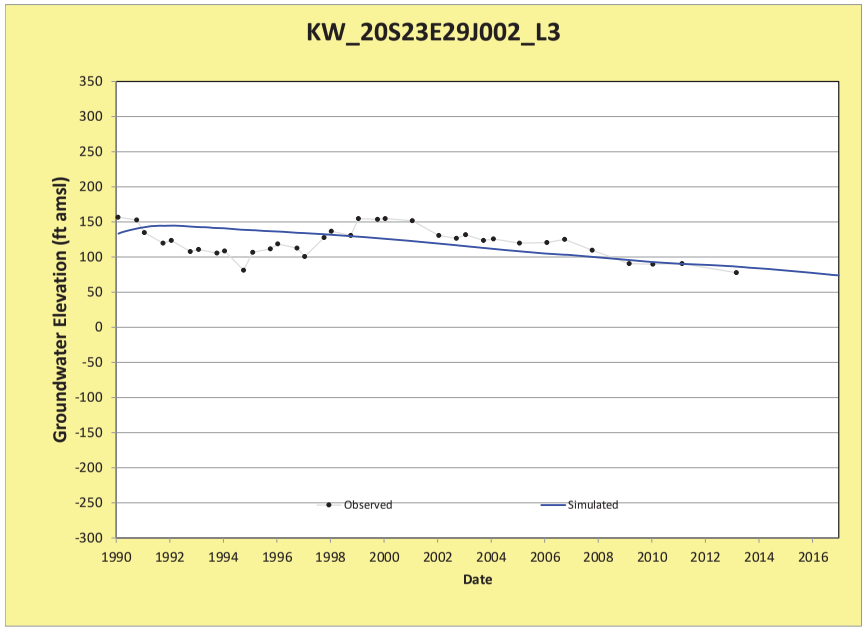

KW_20S23E07H003_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

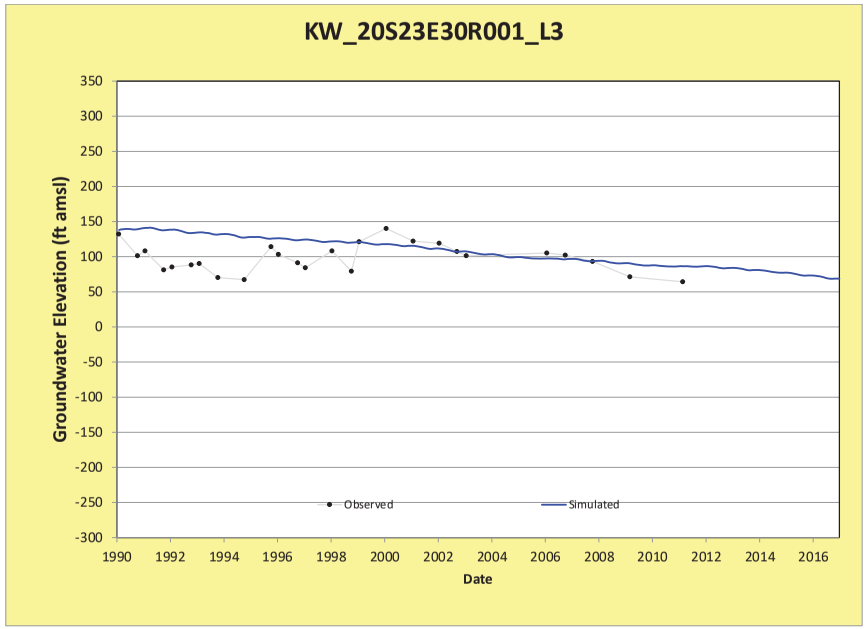

KW_20S23E13E002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

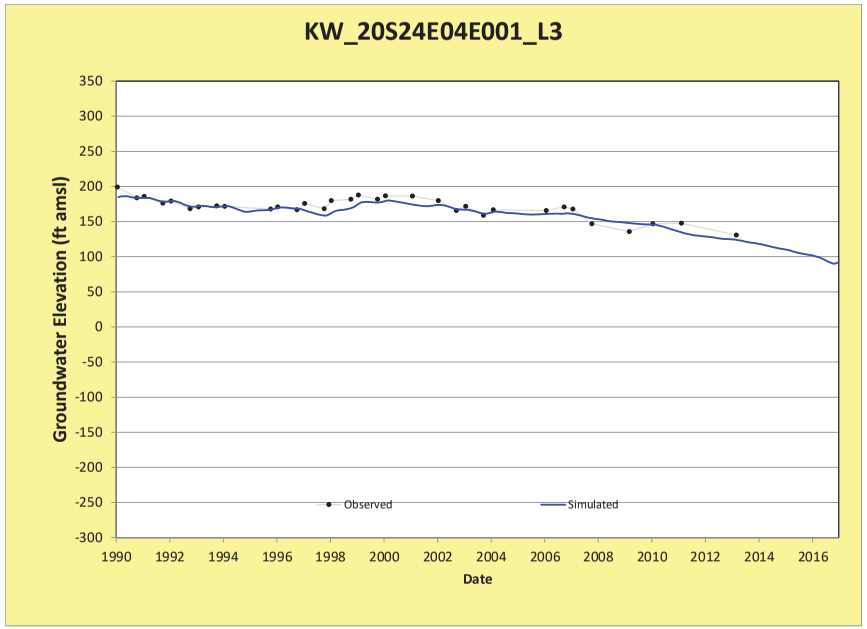

KW_20S23E18R001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

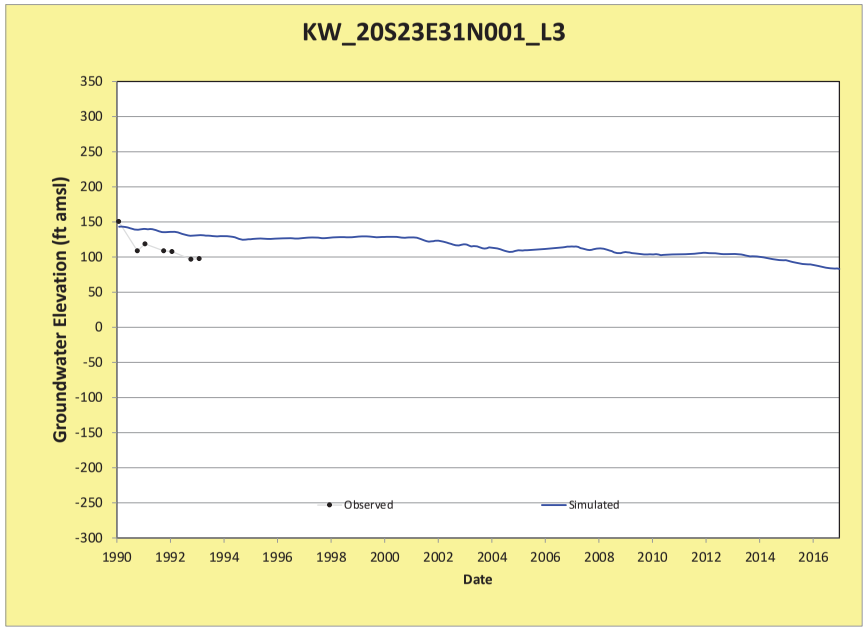

KW_20S23E24L001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

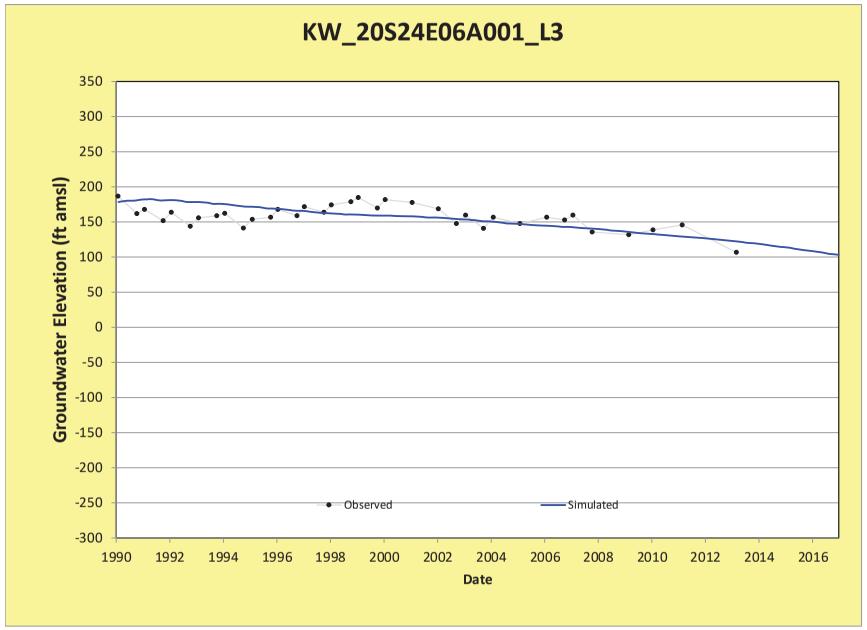

KW_20S23E19J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

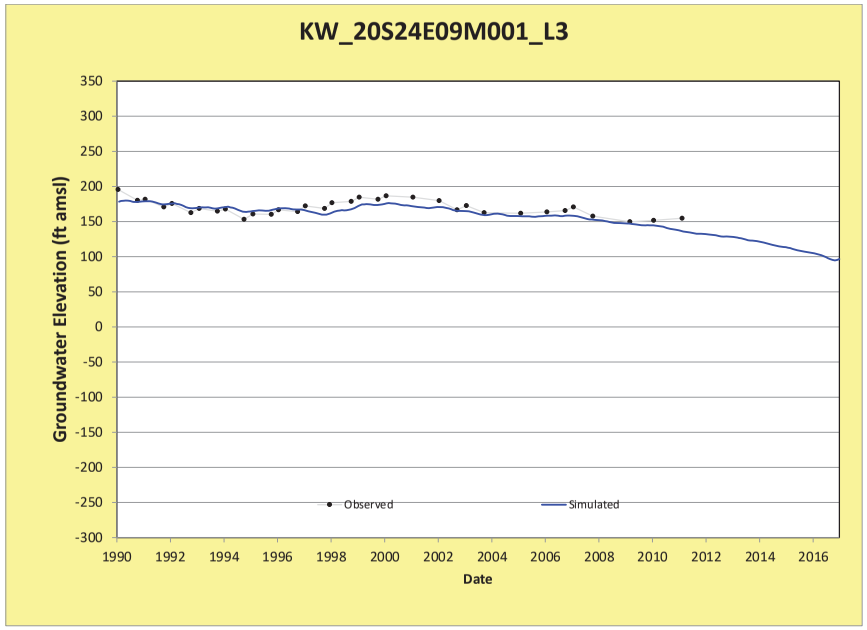

KW_20S23E29J002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

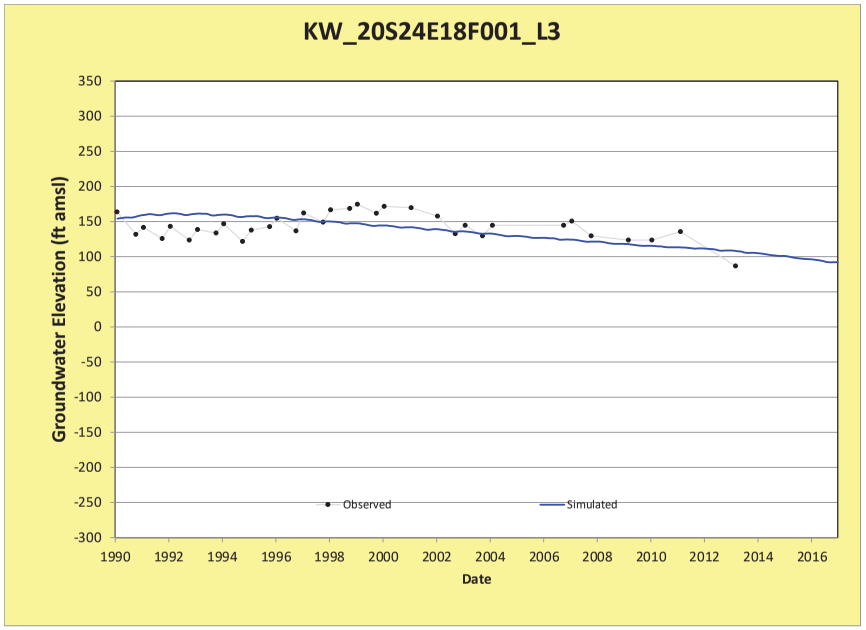

KW_20S23E30R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

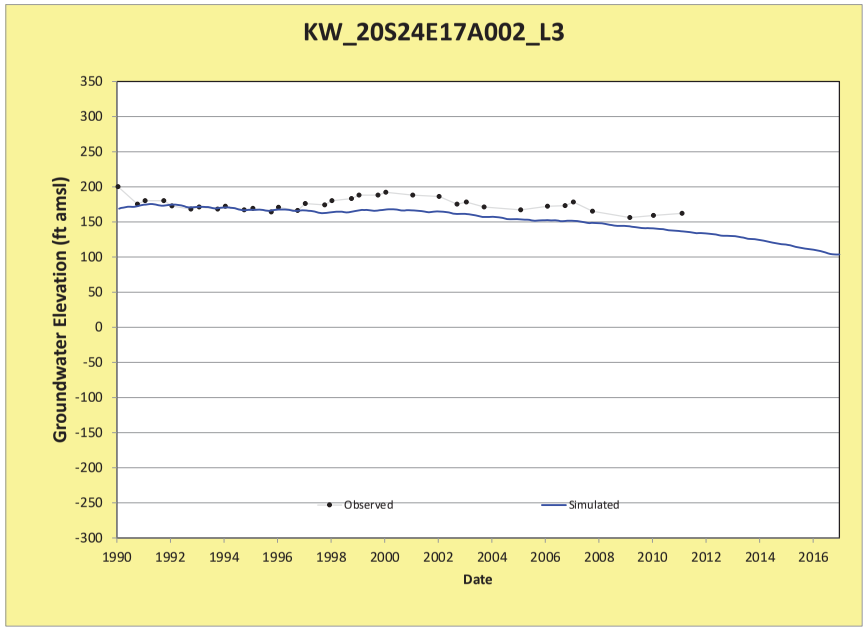

KW_20S24E04E001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

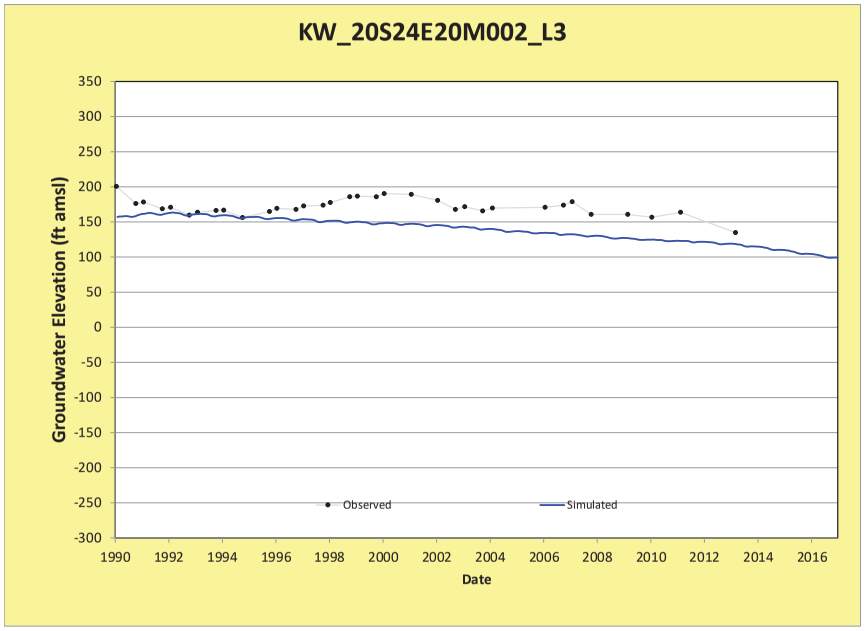

KW_20S23E31N001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

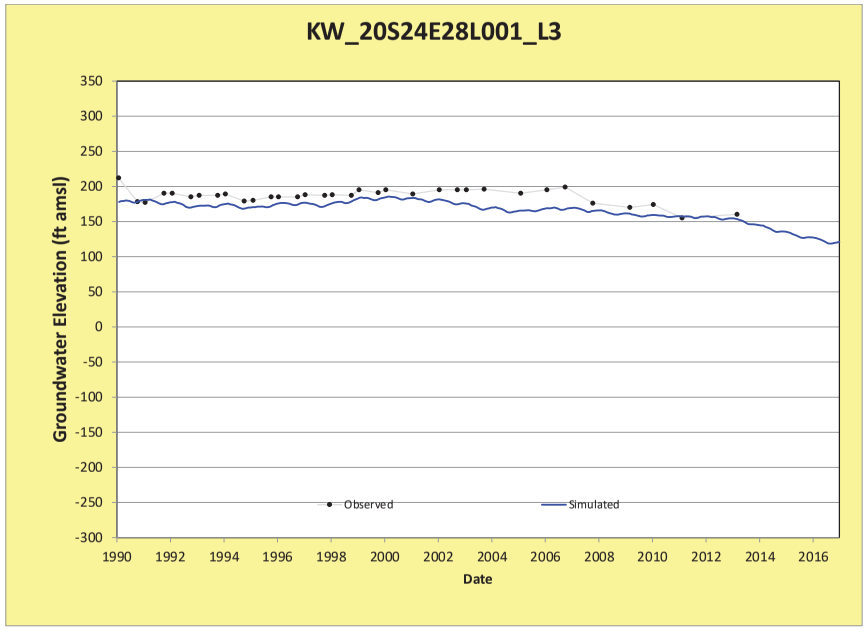

KW_20S24E06A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

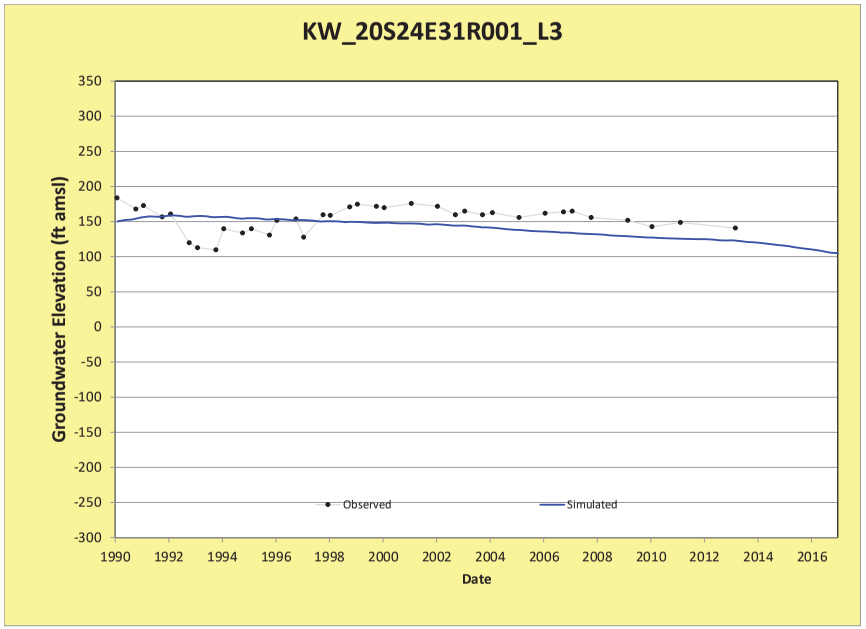

KW_20S24E09M001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

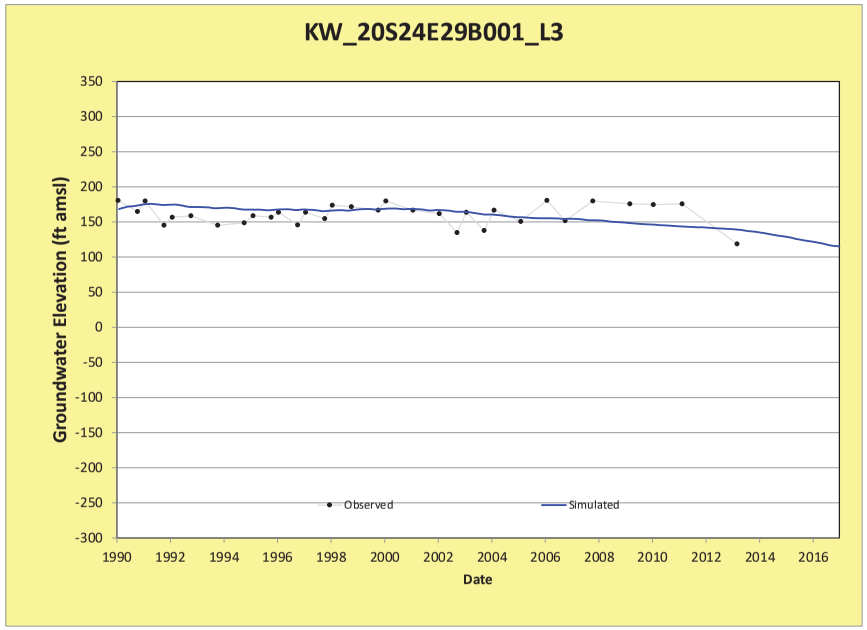

KW_20S24E18F001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

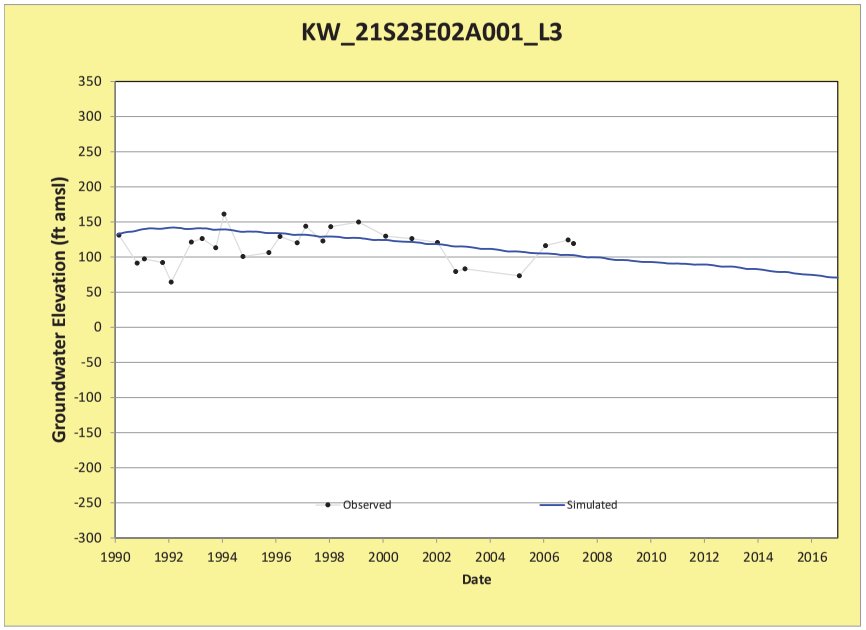

KW_20S24E17A002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

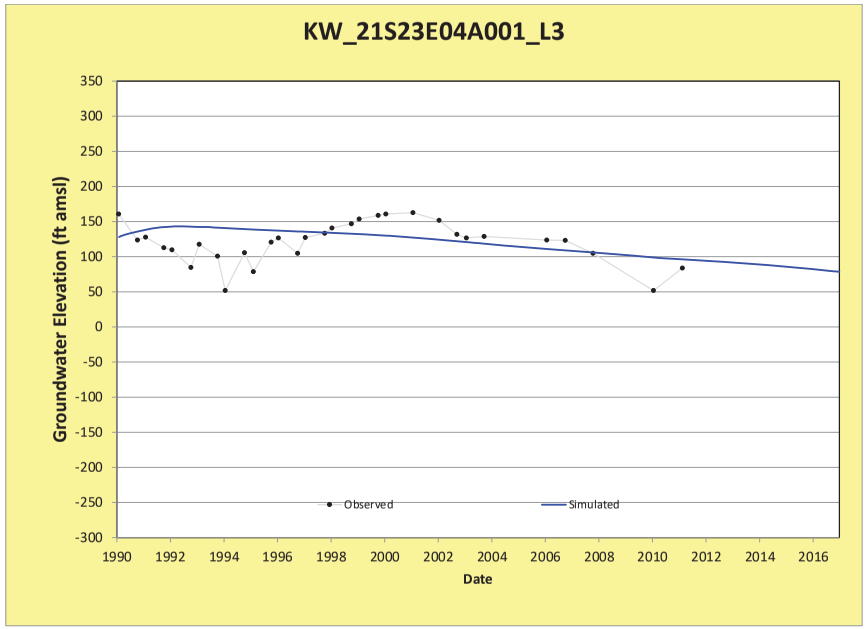

KW_20S24E20M002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

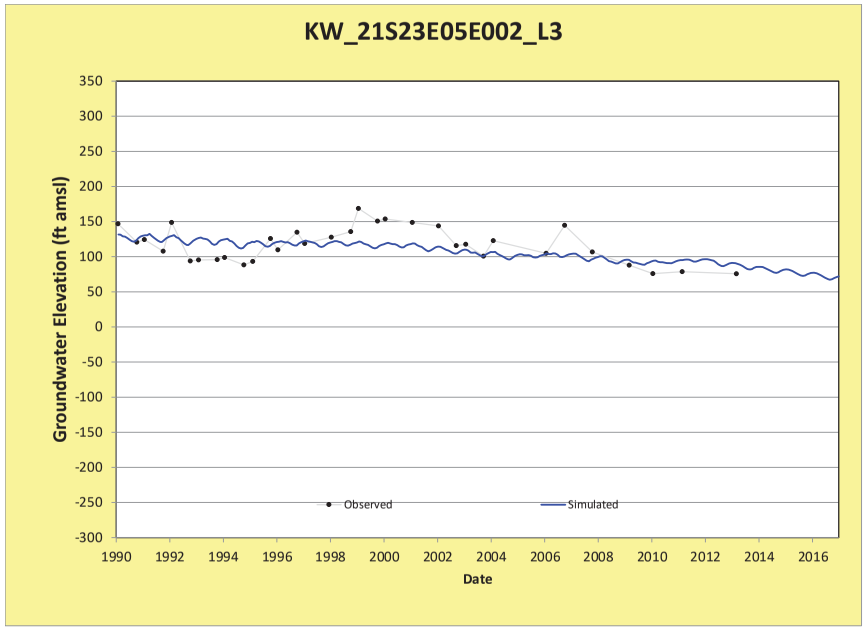

KW_20S24E28L001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

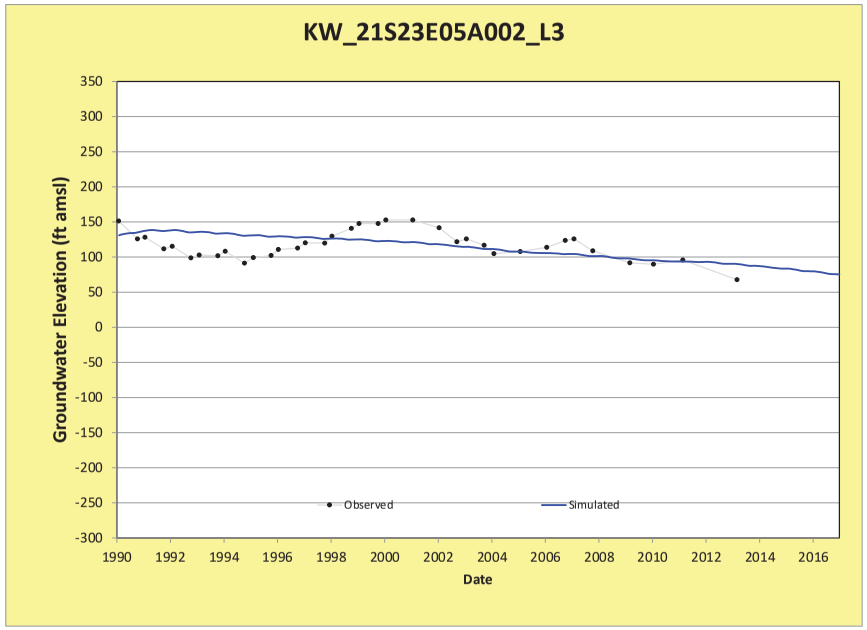

KW_20S24E31R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

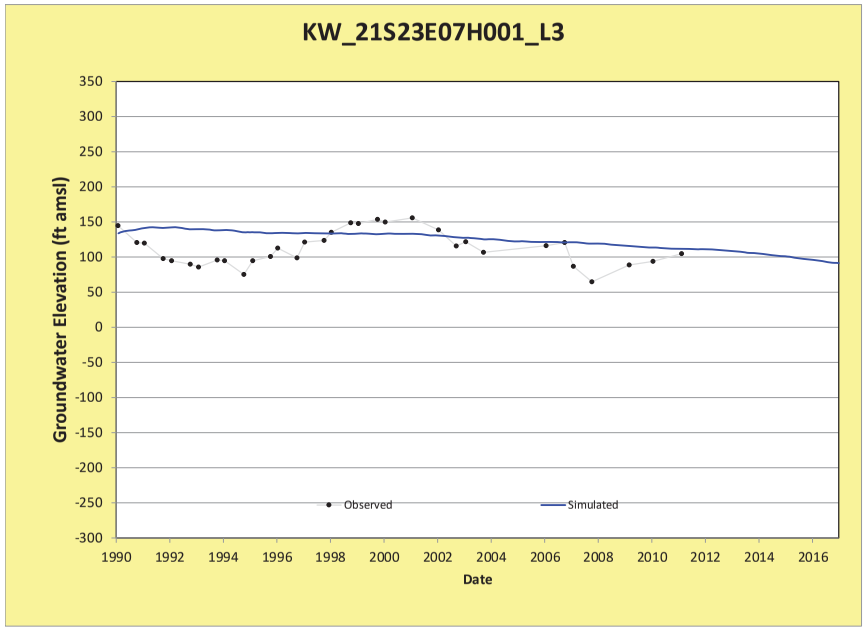

KW_20S24E29B001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

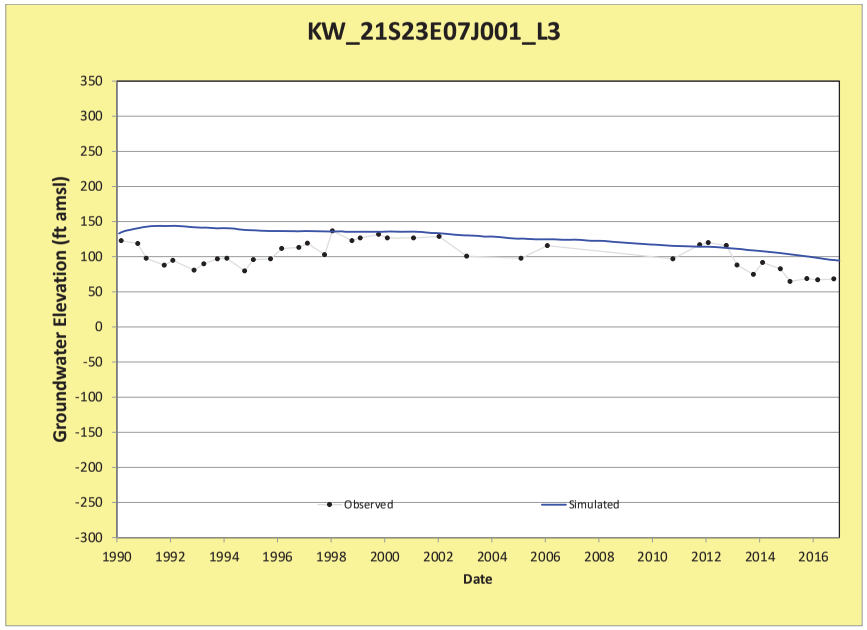

KW_21S23E02A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

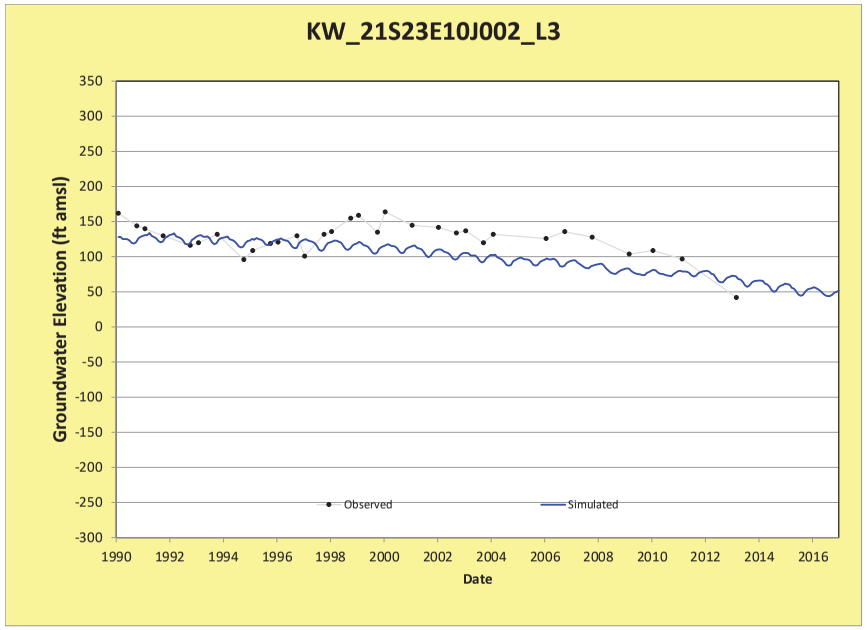

KW_21S23E04A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

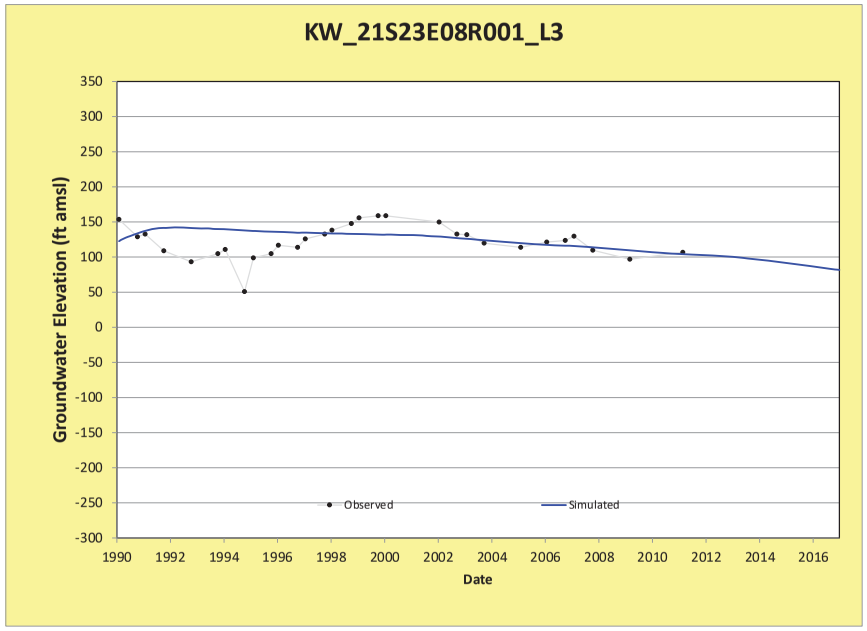

KW_21S23E05E002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

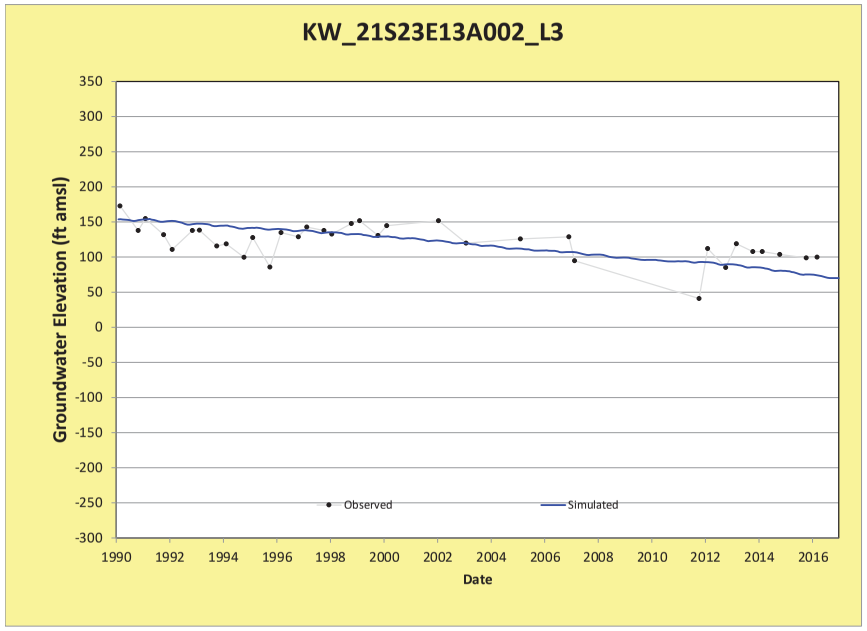

KW_21S23E05A002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

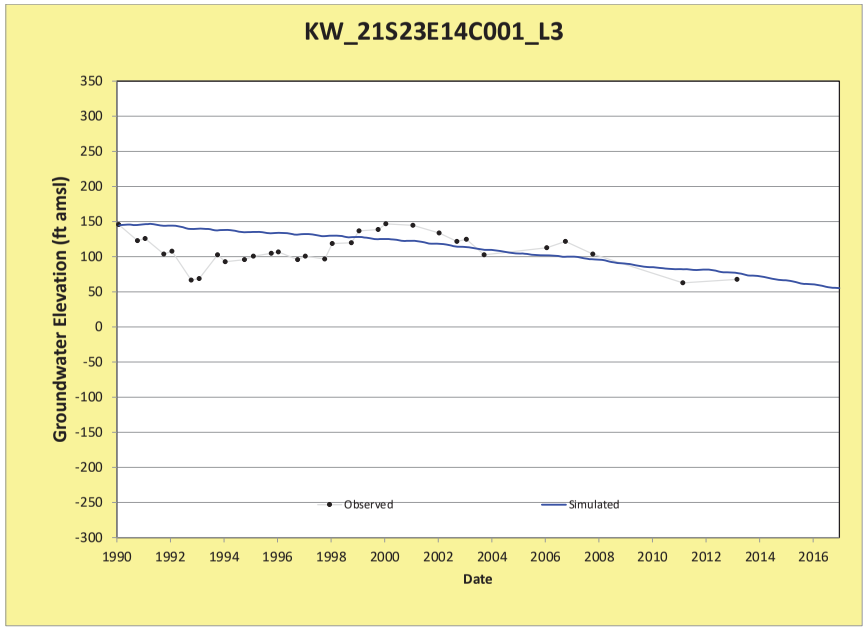

KW_21S23E07H001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

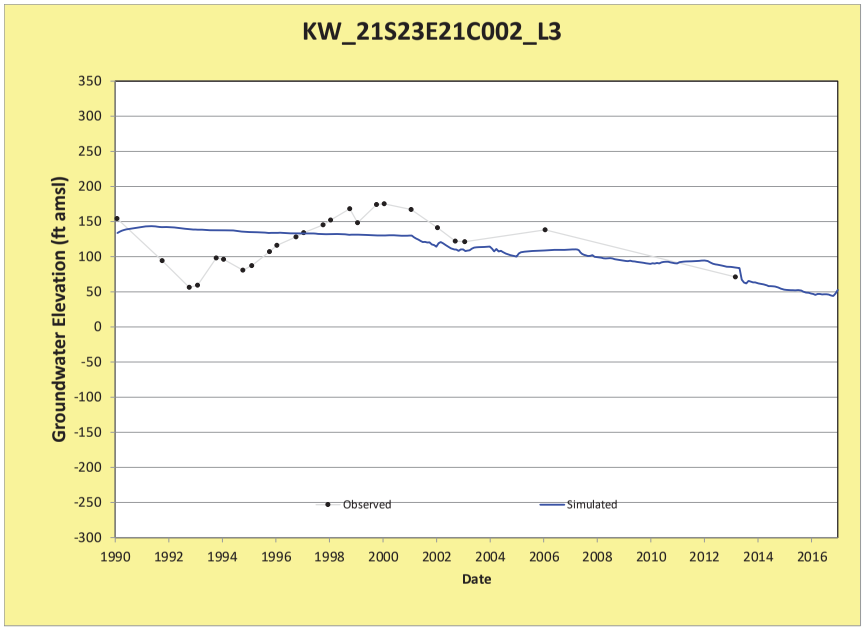

KW_21S23E07J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

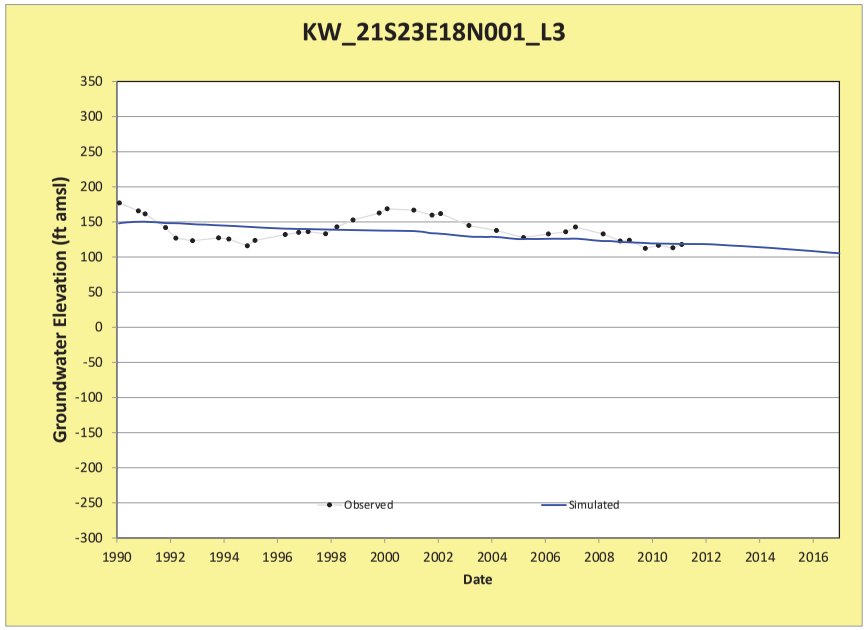

KW_21S23E10J002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

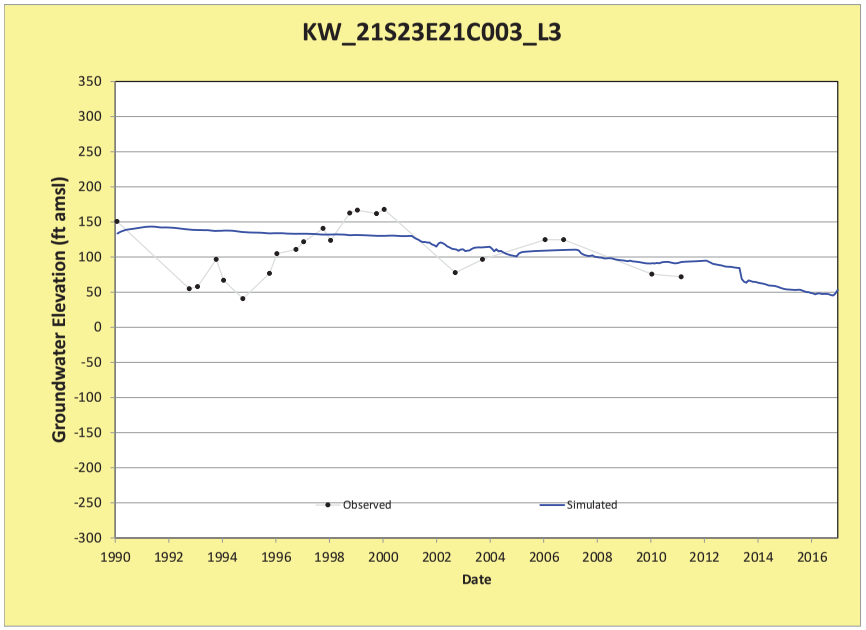

KW_21S23E08R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

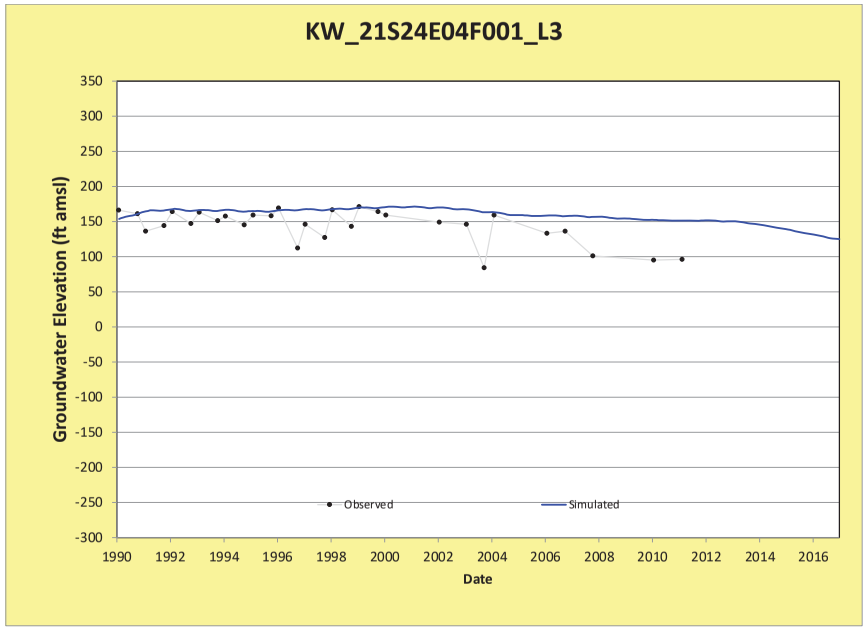

KW_21S23E13A002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

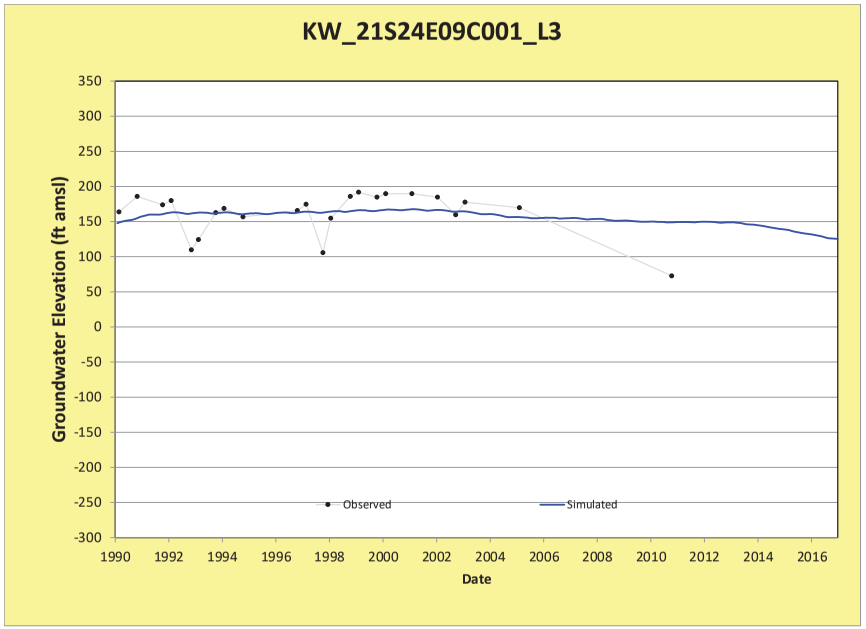

KW_21S23E14C001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

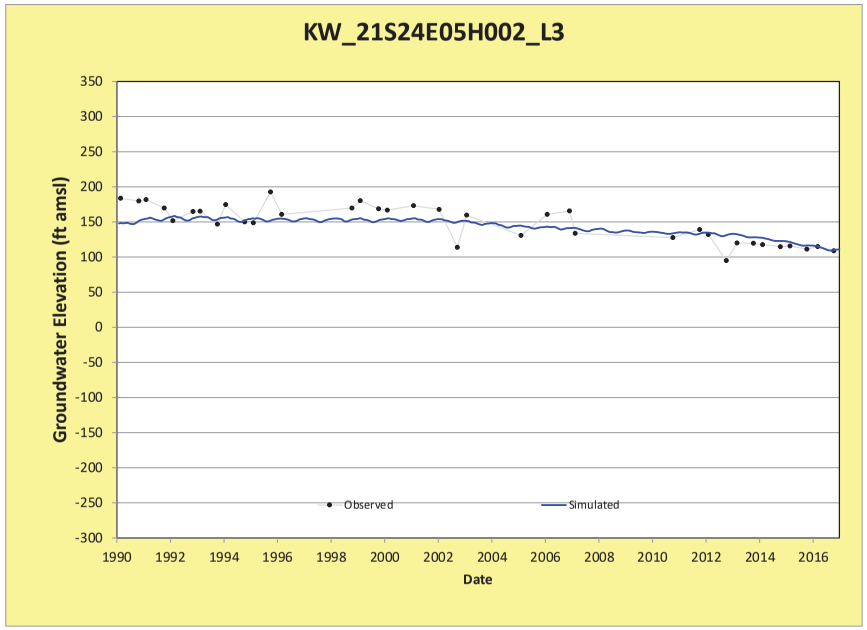

KW_21S23E21C002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

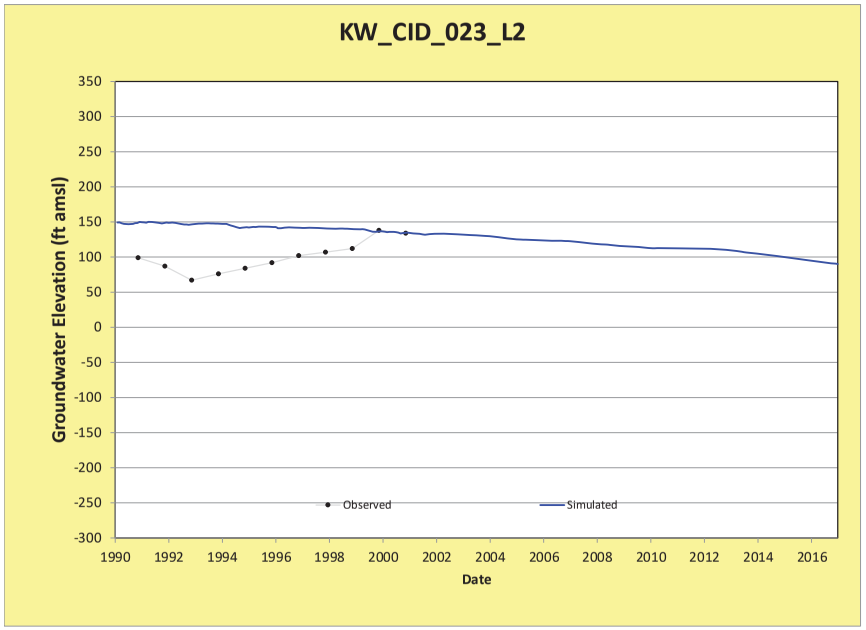

KW_21S23E18N001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

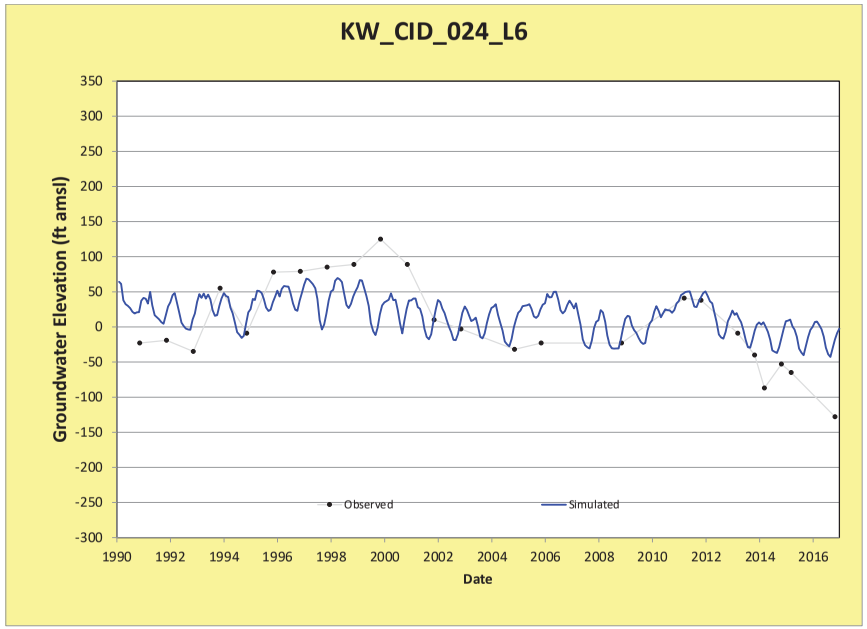

KW_21S23E21C003_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

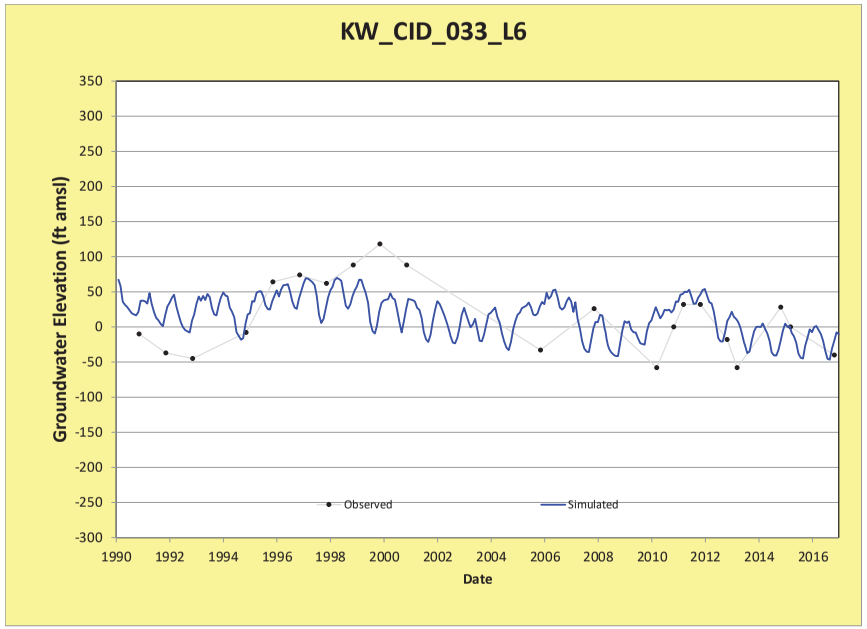

KW_21S24E04F001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

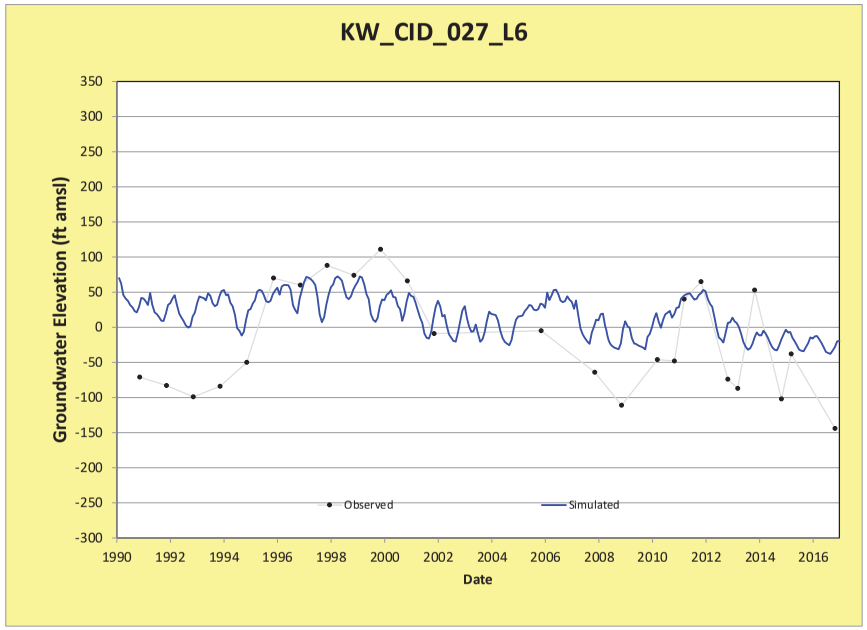

KW_21S24E09C001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

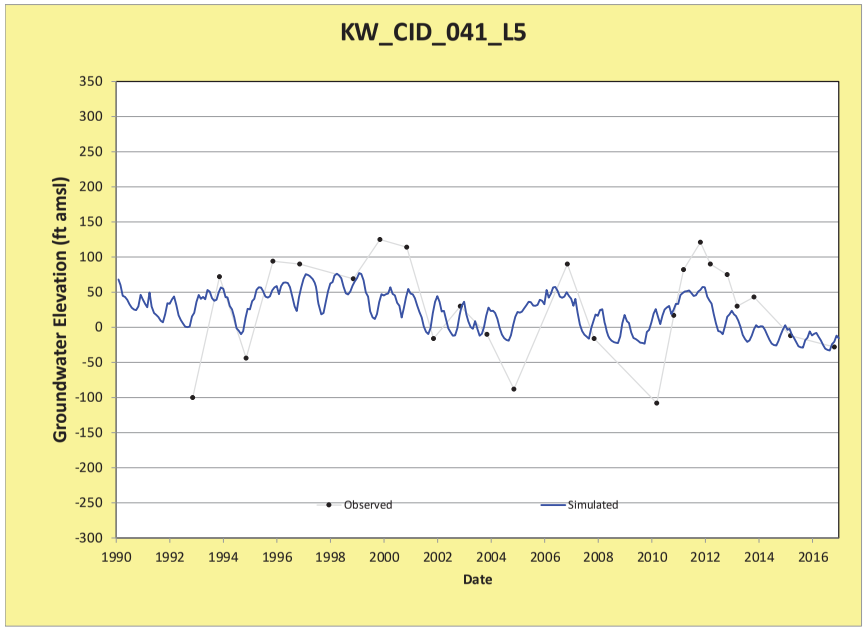

KW_21S24E05H002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

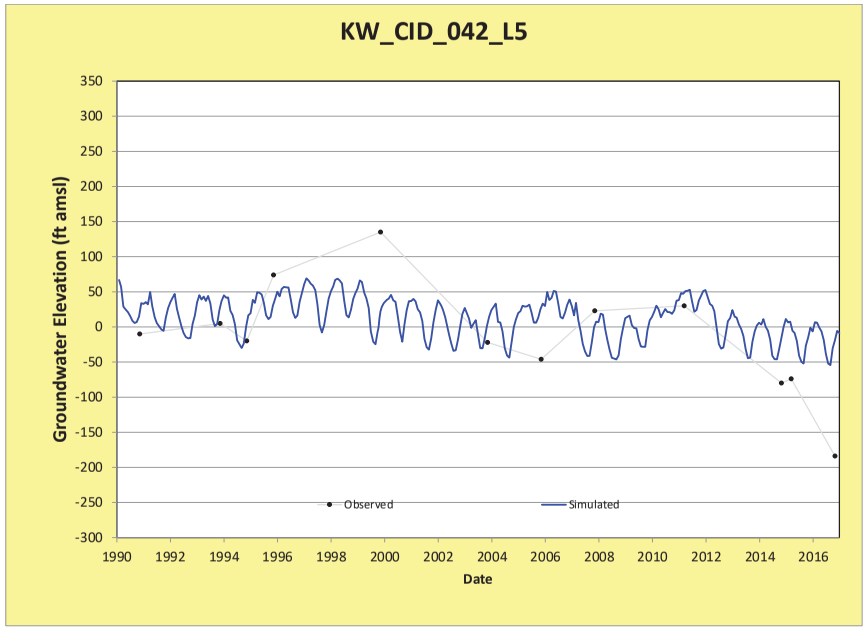

KW_CID_023_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

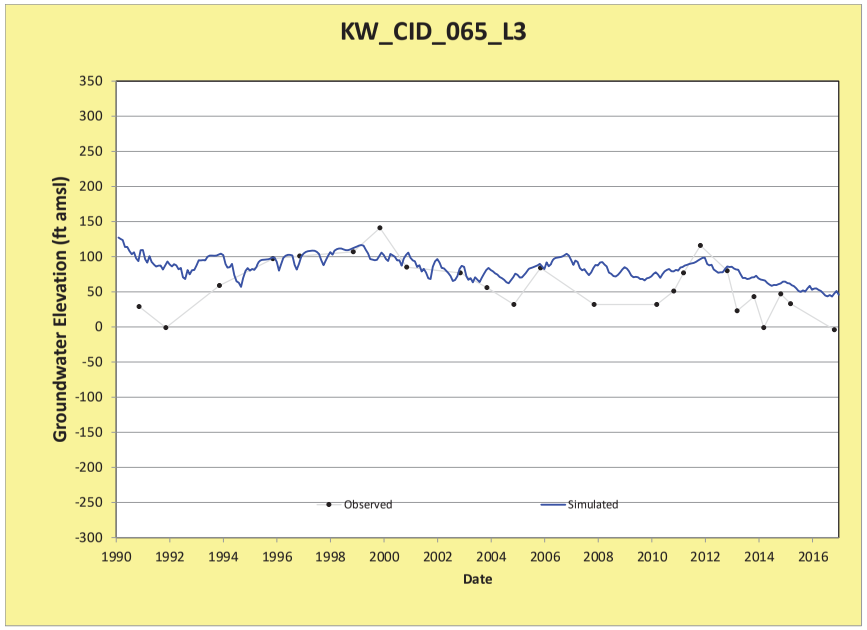

KW_CID_024_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

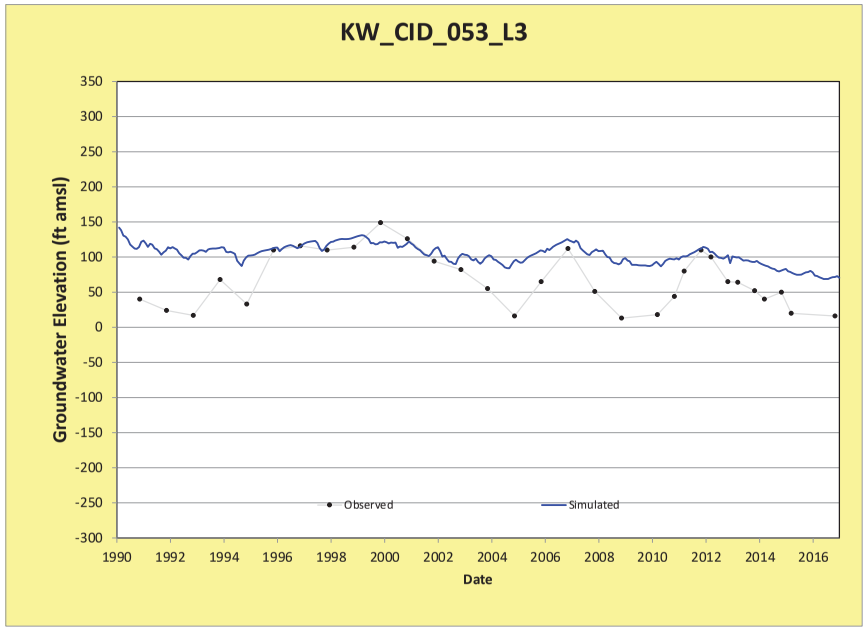

KW_CID_033_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

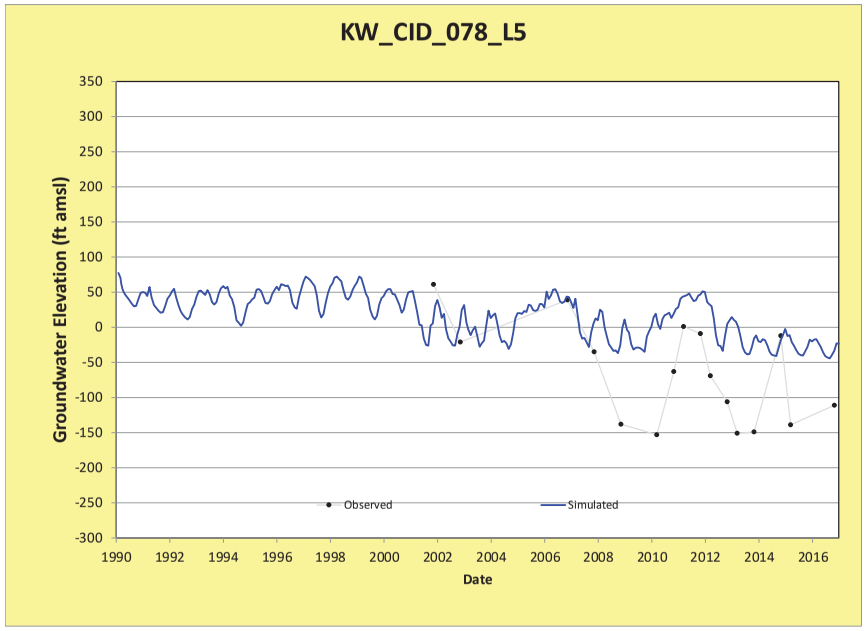

KW_CID_027_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

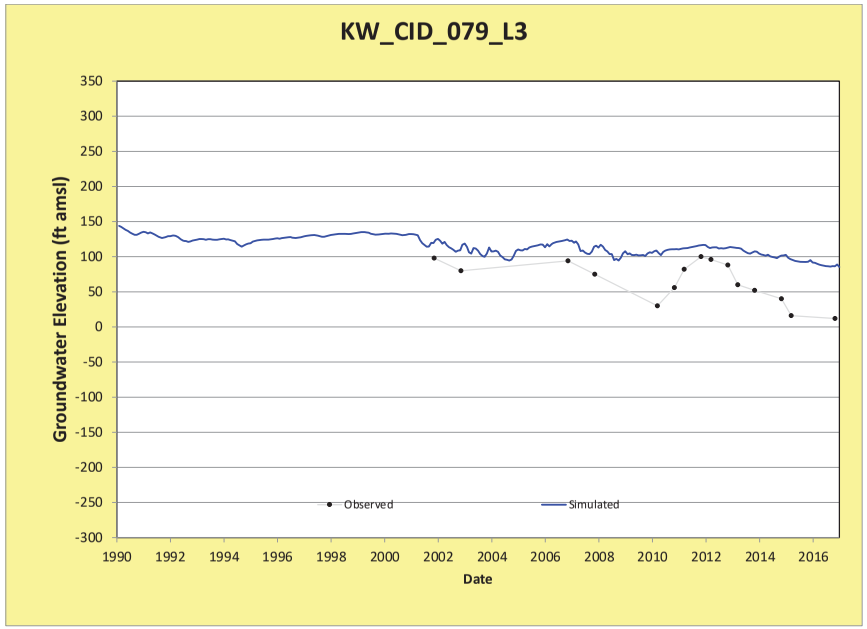

KW_CID_041_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

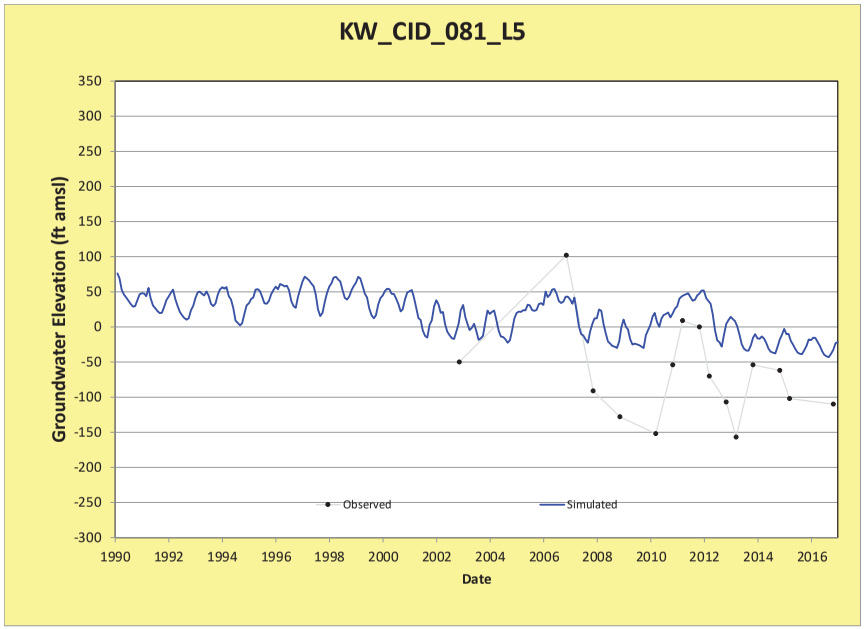

KW_CID_042_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

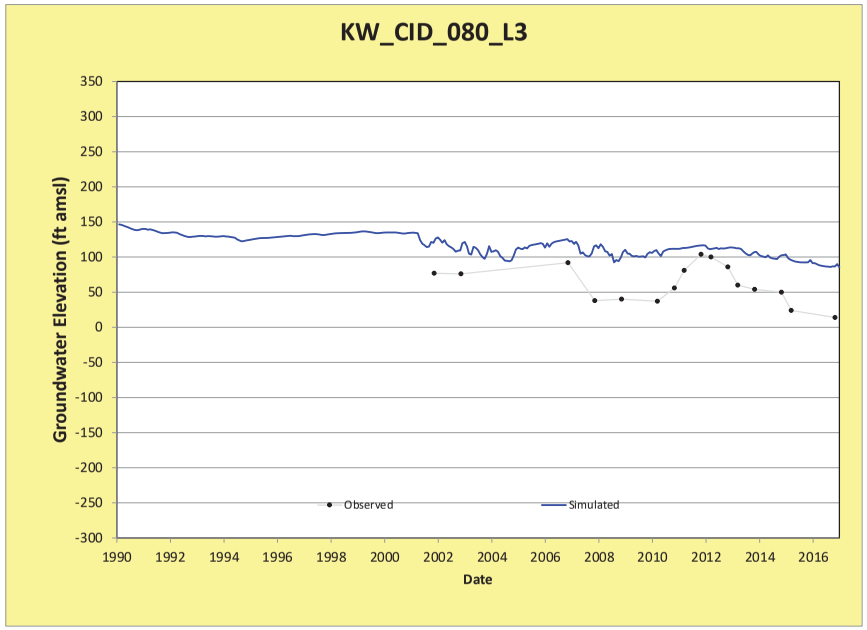

KW_CID_065_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

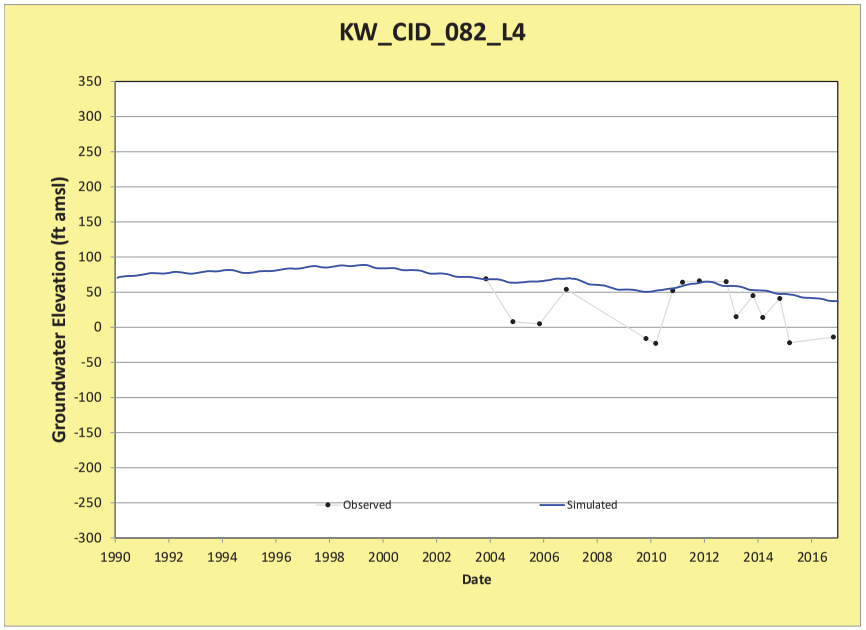

KW_CID_053_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

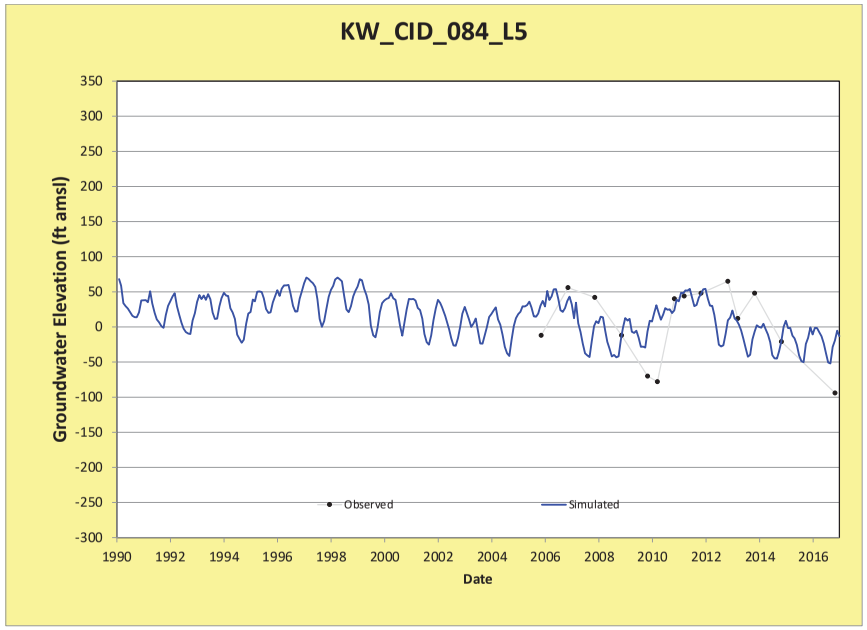

KW_CID_078_L5
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

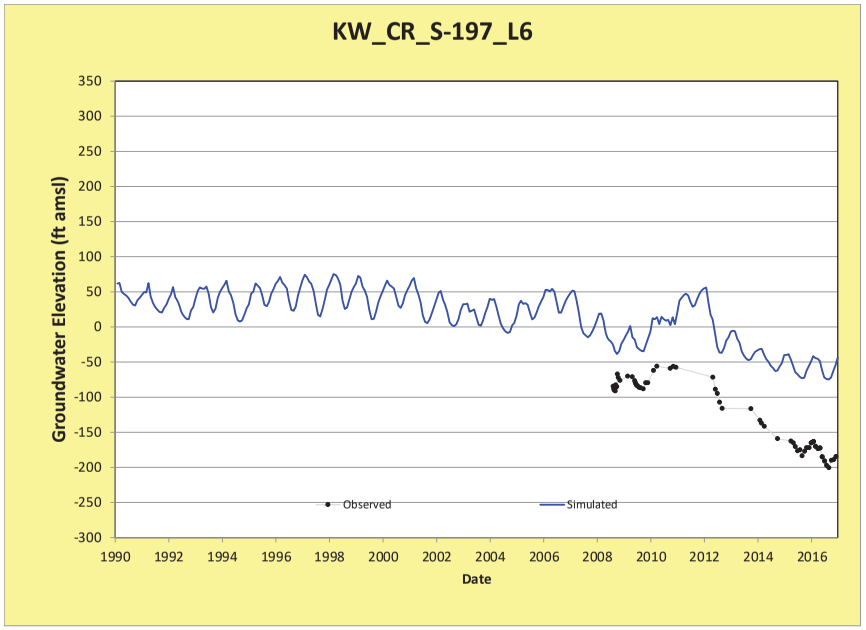

KW_CID_079_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

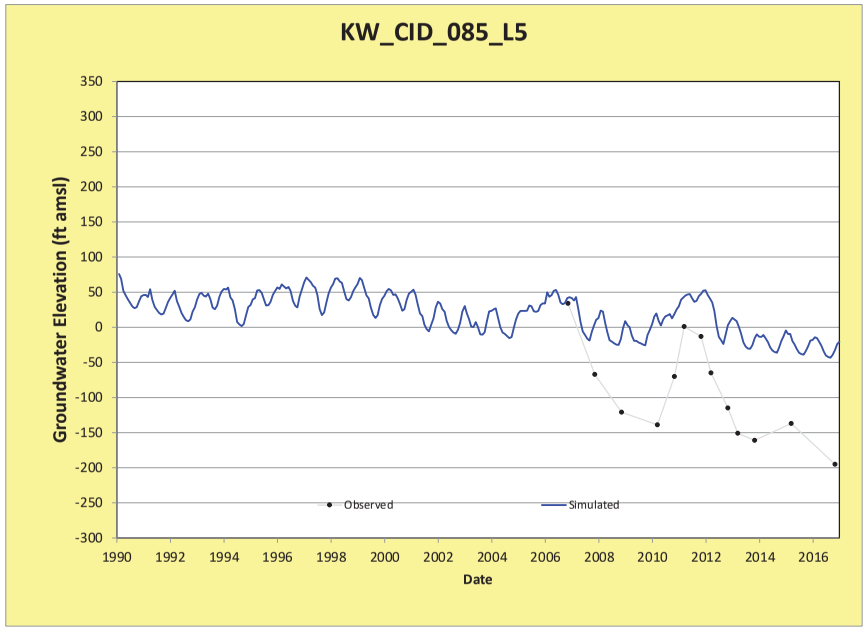

KW_CID_081_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

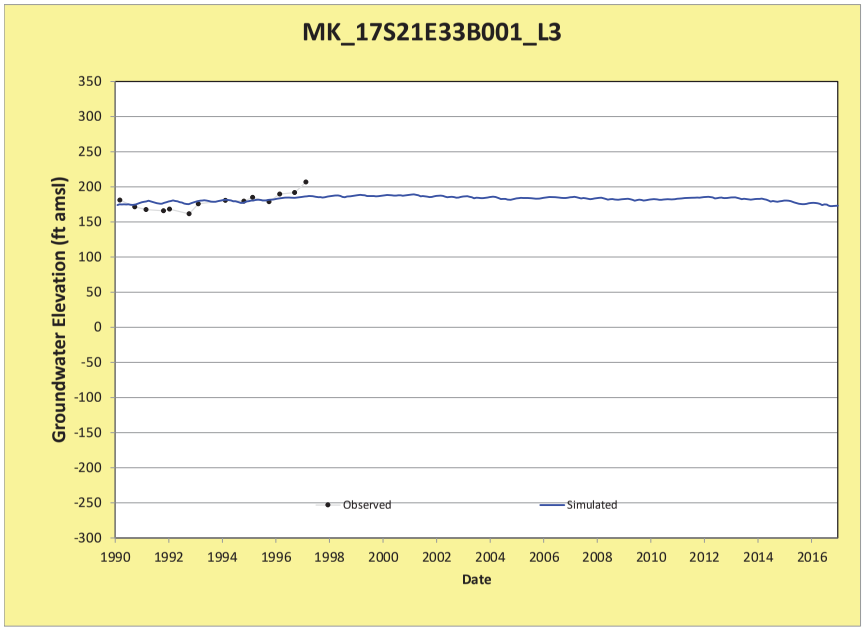

KW_CID_080_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

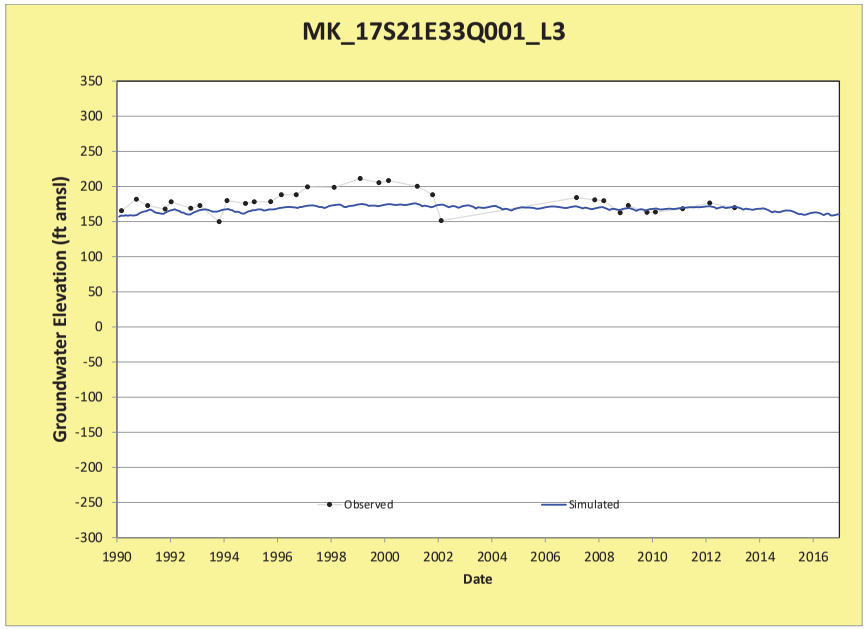

KW_CID_082_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

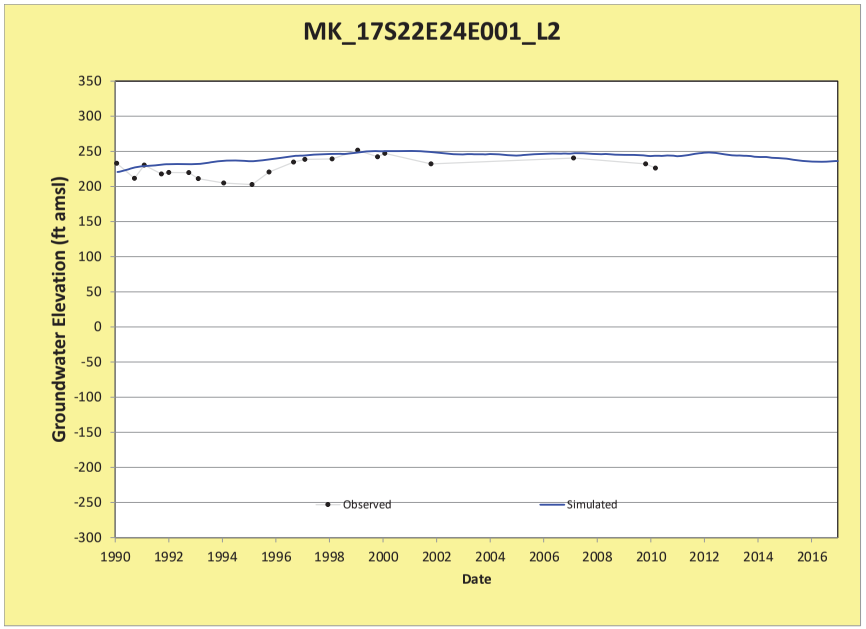

KW_CID_084_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

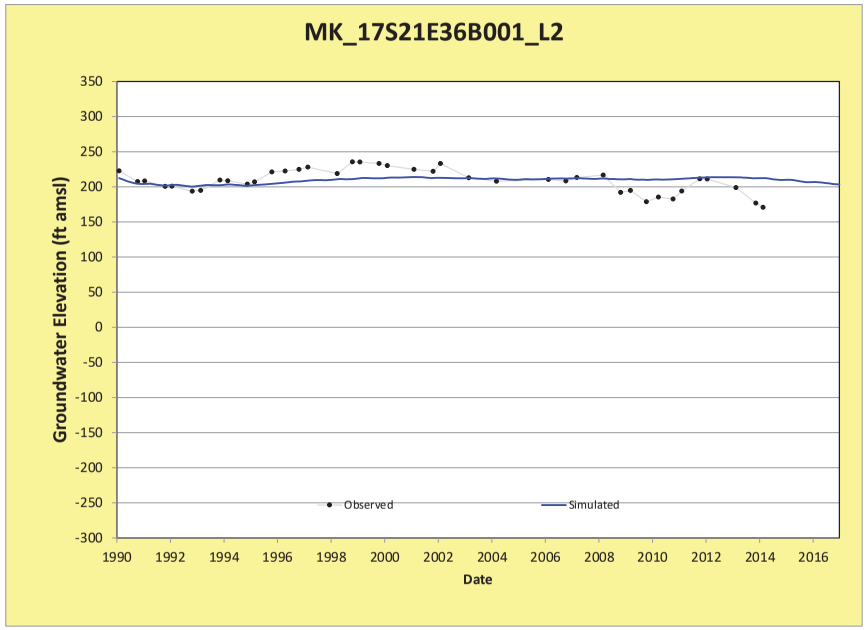

KW_CR_S-197_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

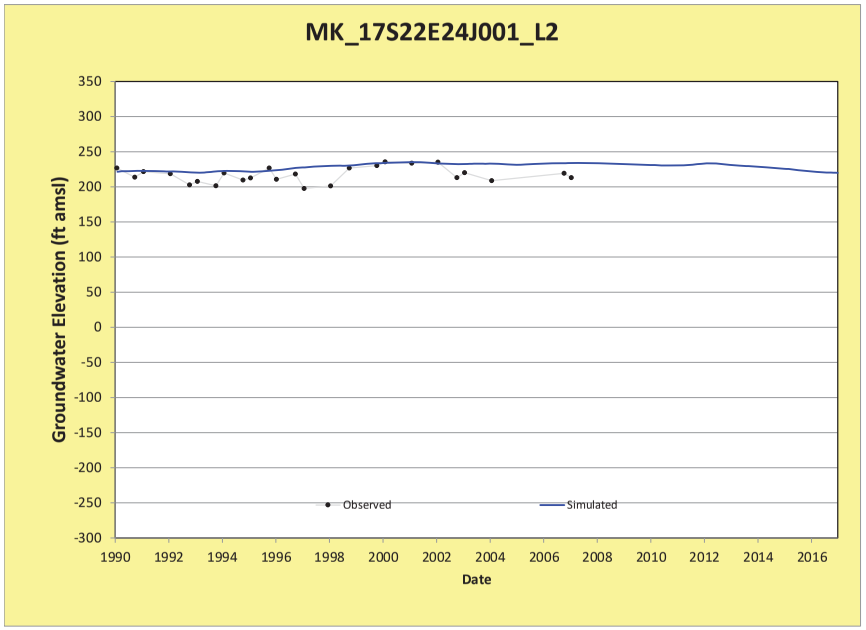

KW_CID_085_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

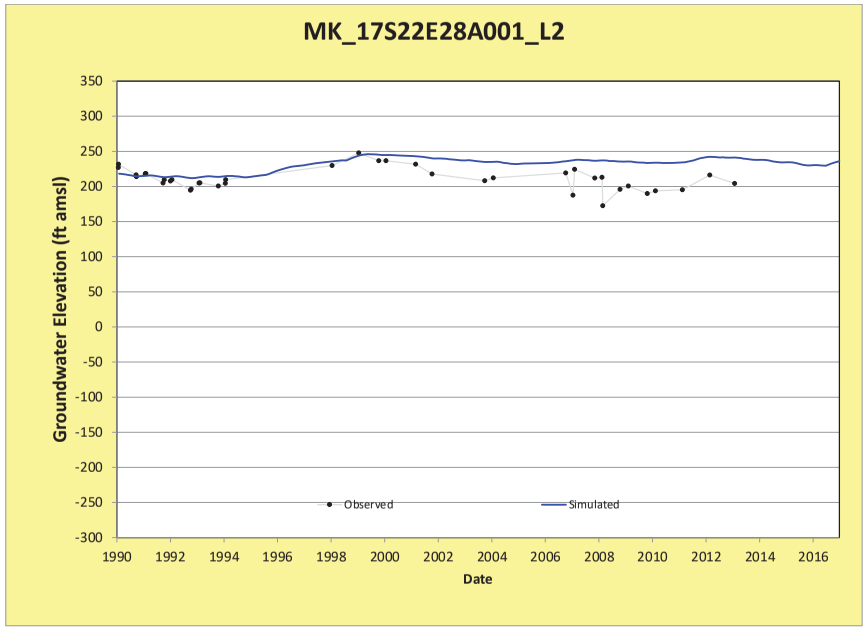

MK_17S21E33B001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

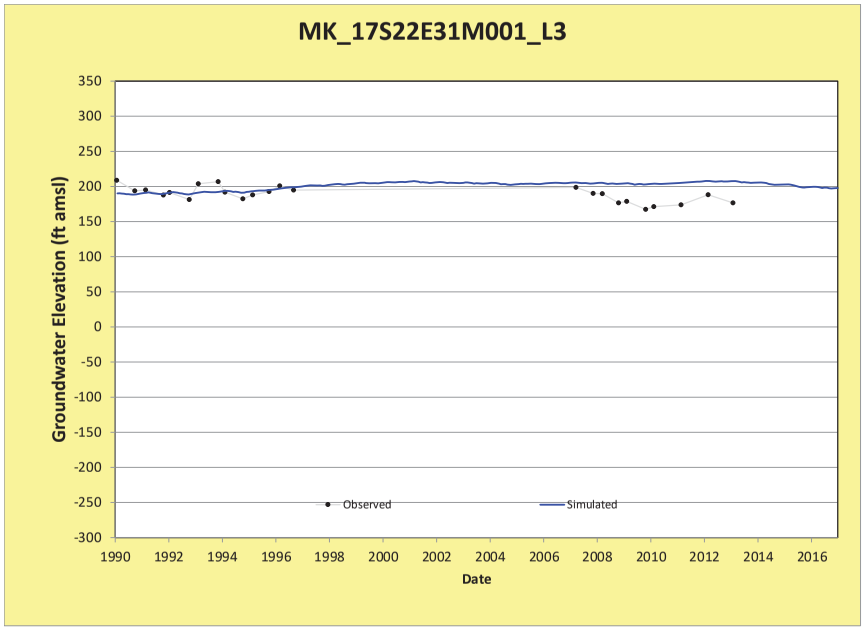

MK_17S21E33Q001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

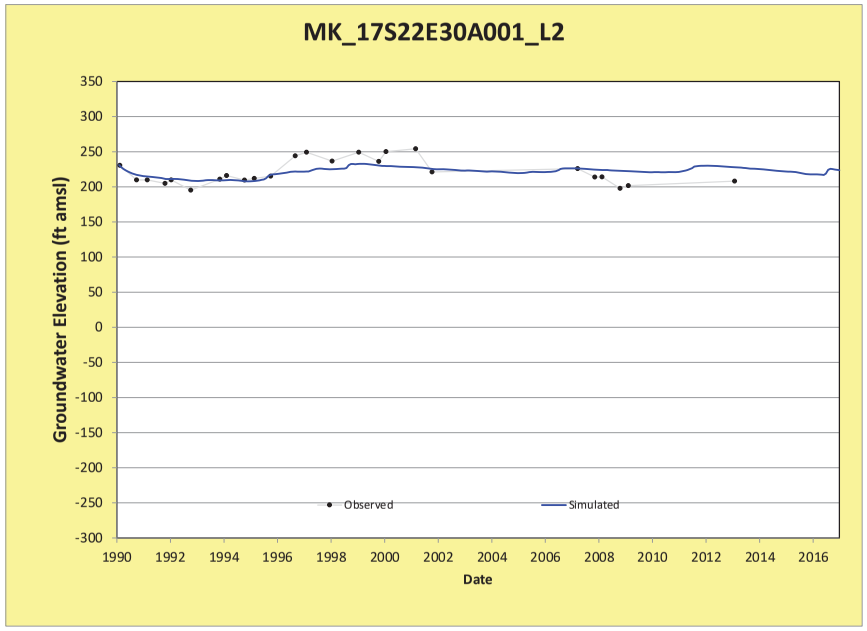

MK_17S22E24E001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

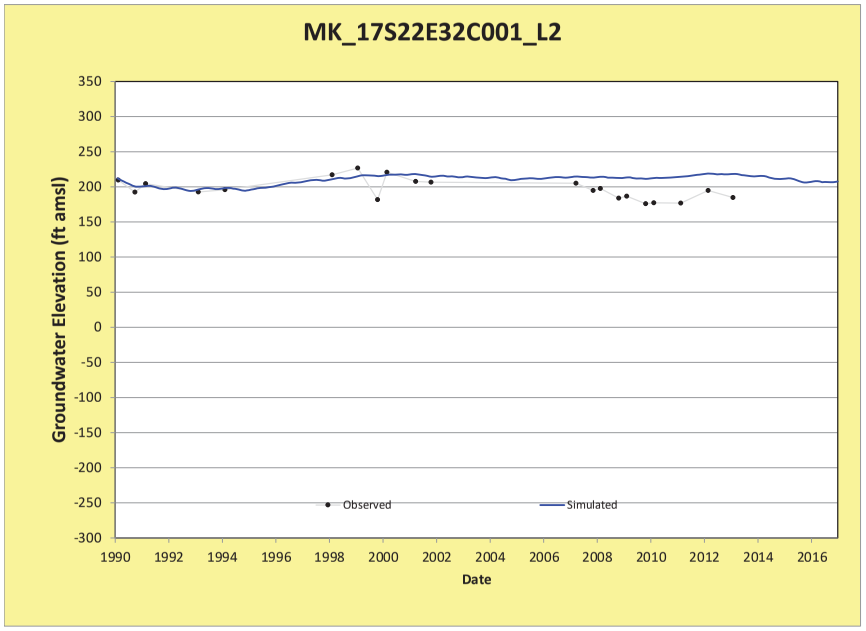

MK_17S21E36B001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

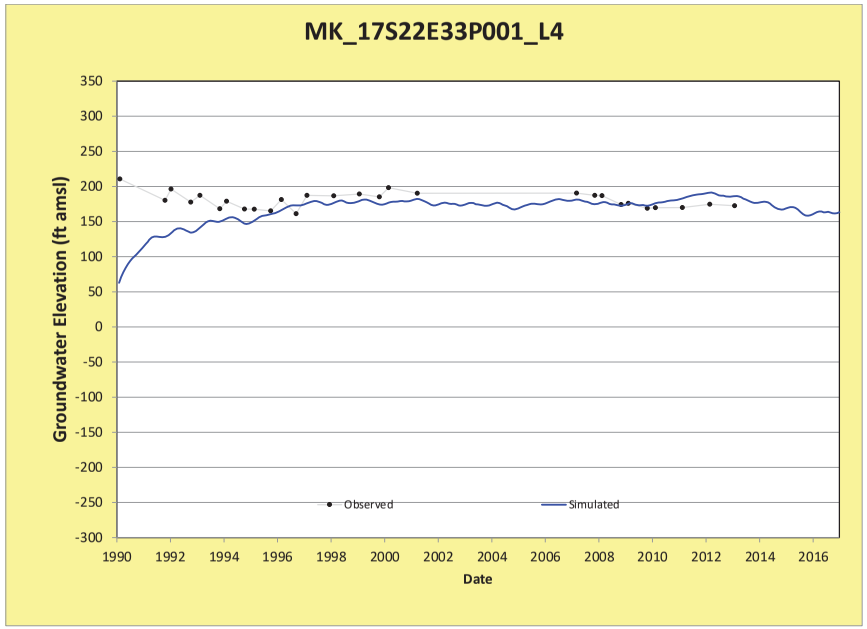

MK_17S22E24J001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

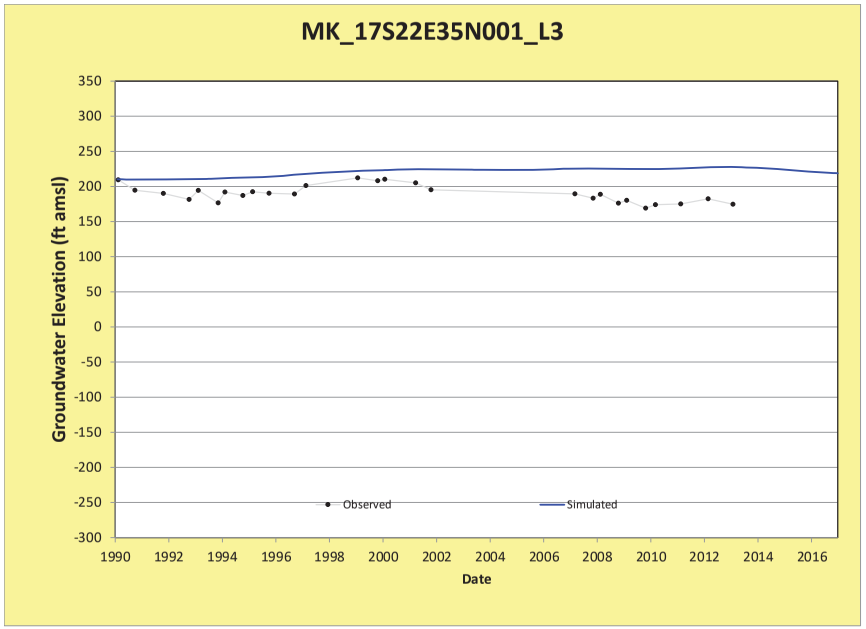

MK_17S22E28A001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

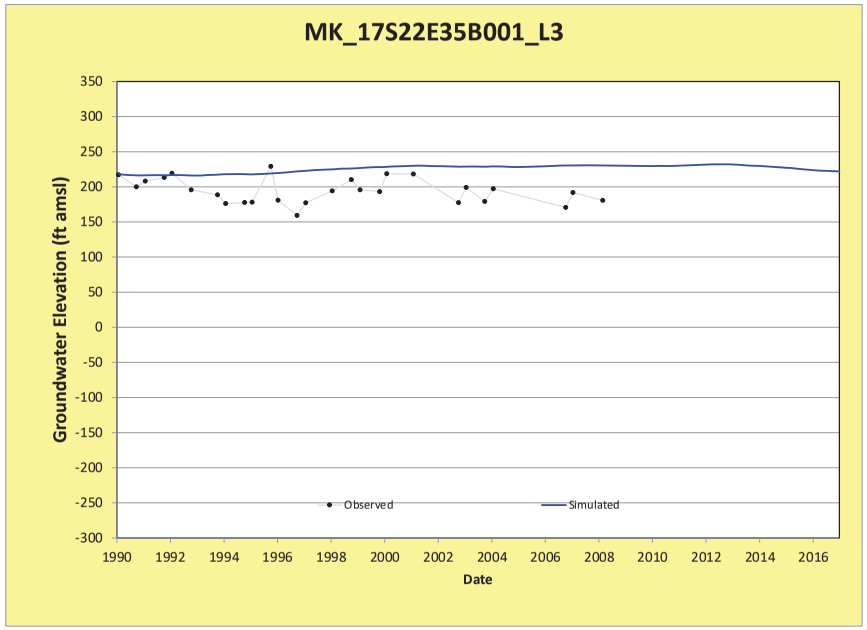

MK_17S22E31M001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

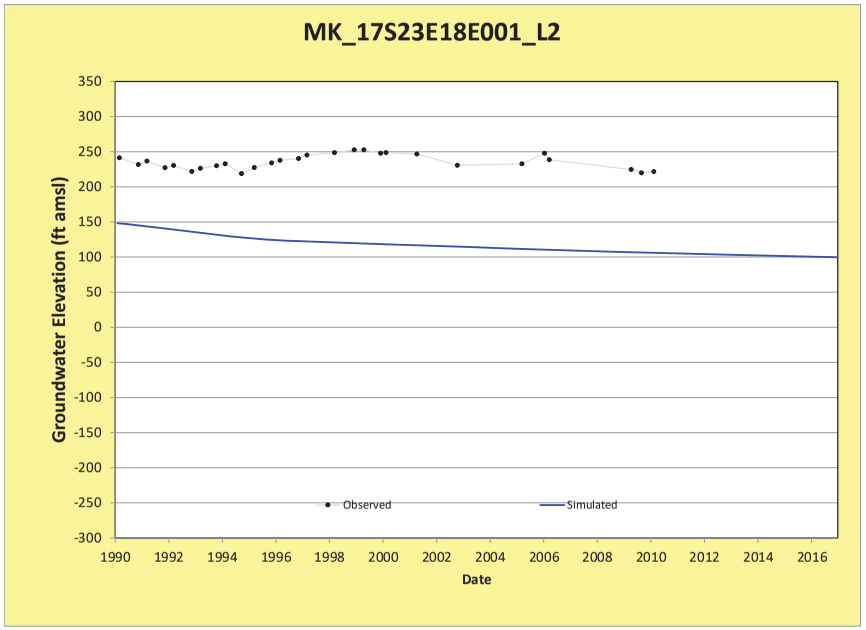

MK_17S22E30A001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

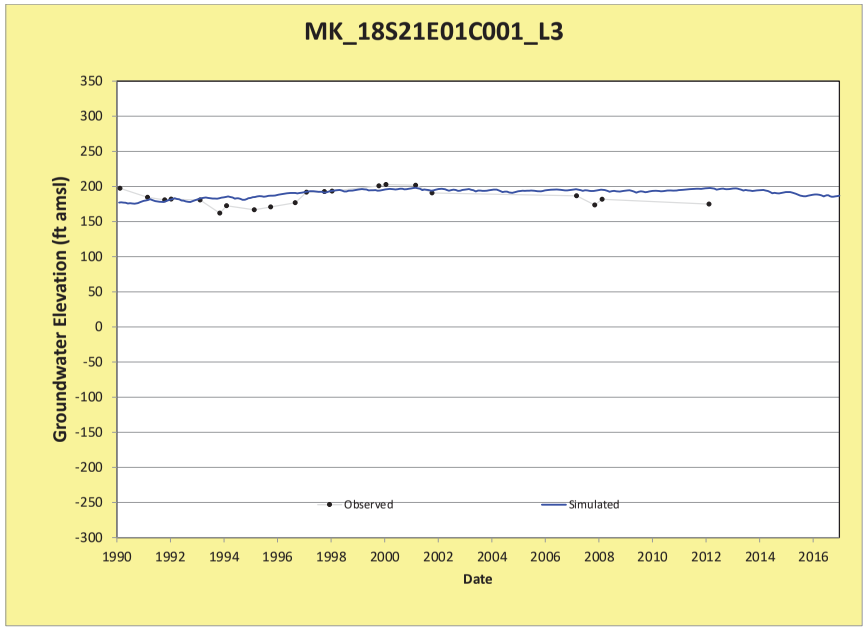

MK_17S22E32C001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

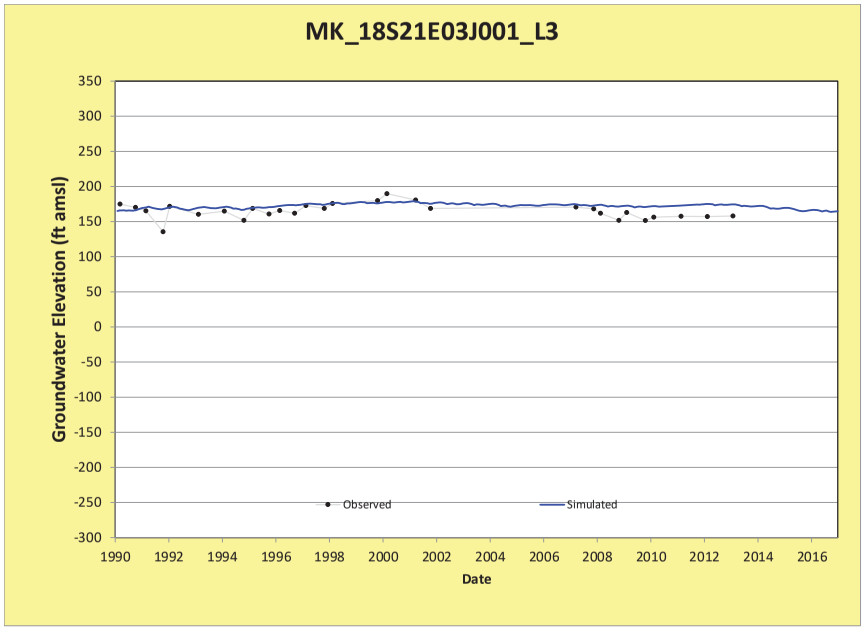

MK_17S22E33P001_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

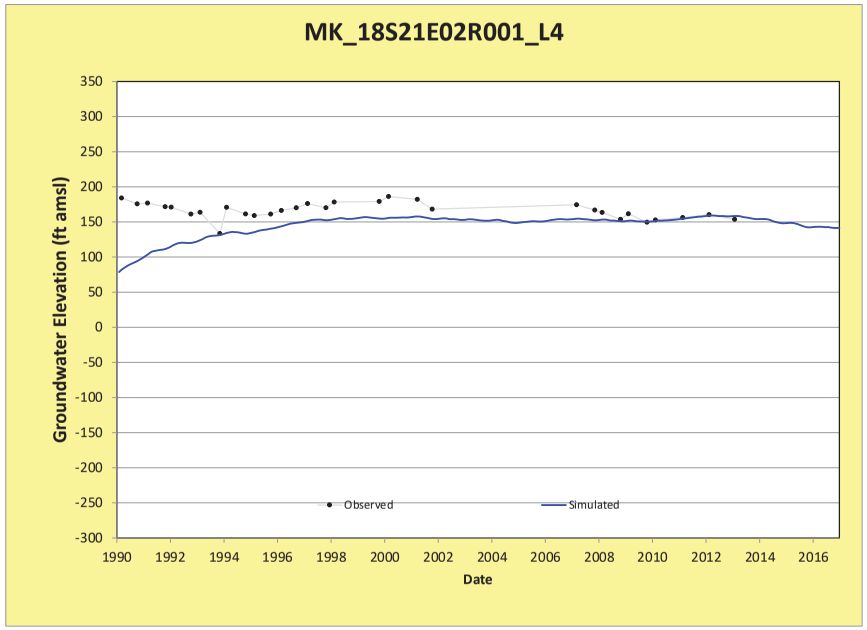

MK_17S22E35N001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

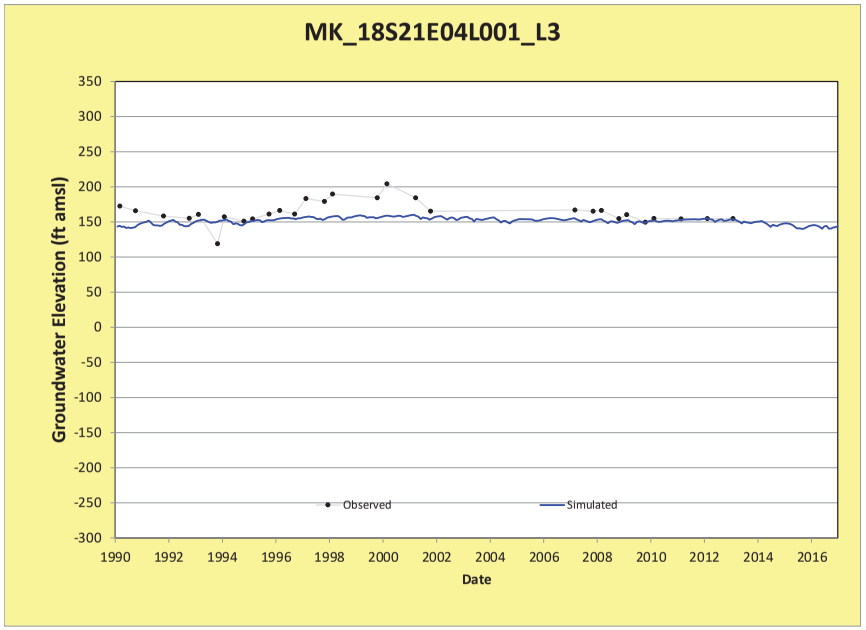

MK_17S22E35B001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

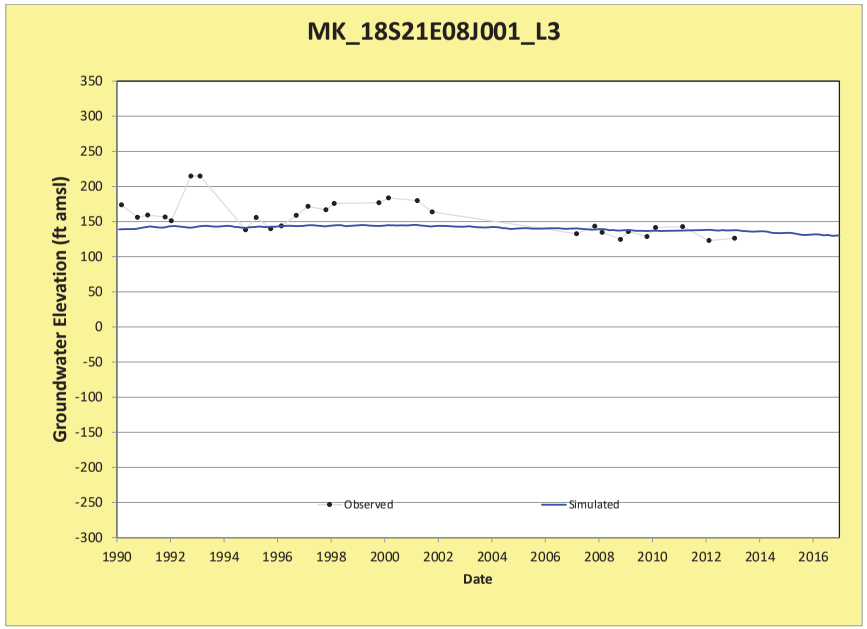

MK_17S23E18E001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

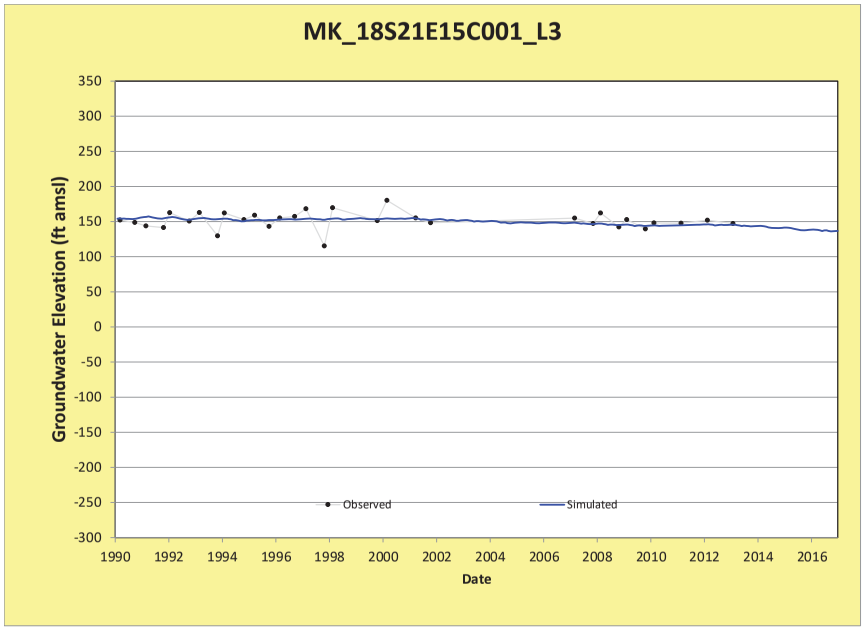

MK_18S21E01C001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

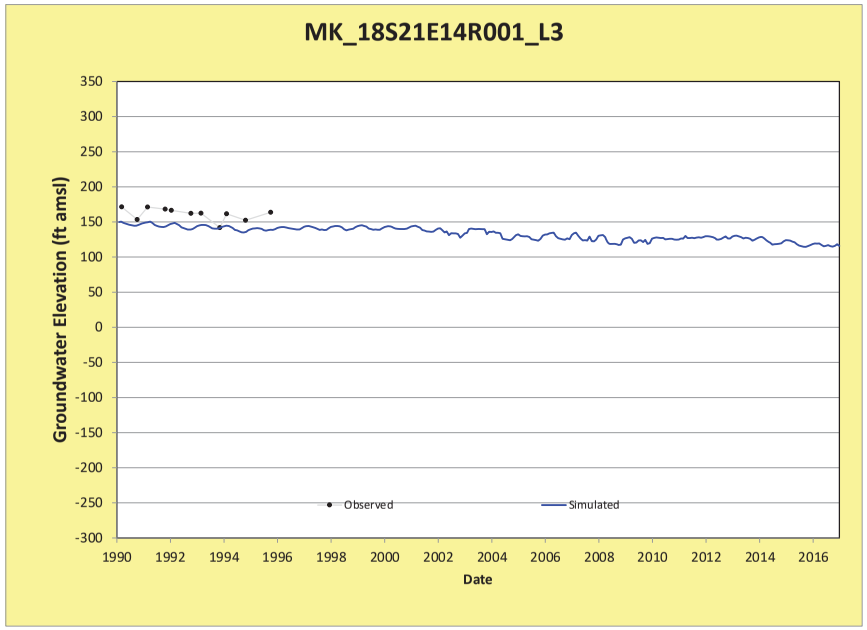

MK_18S21E03J001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

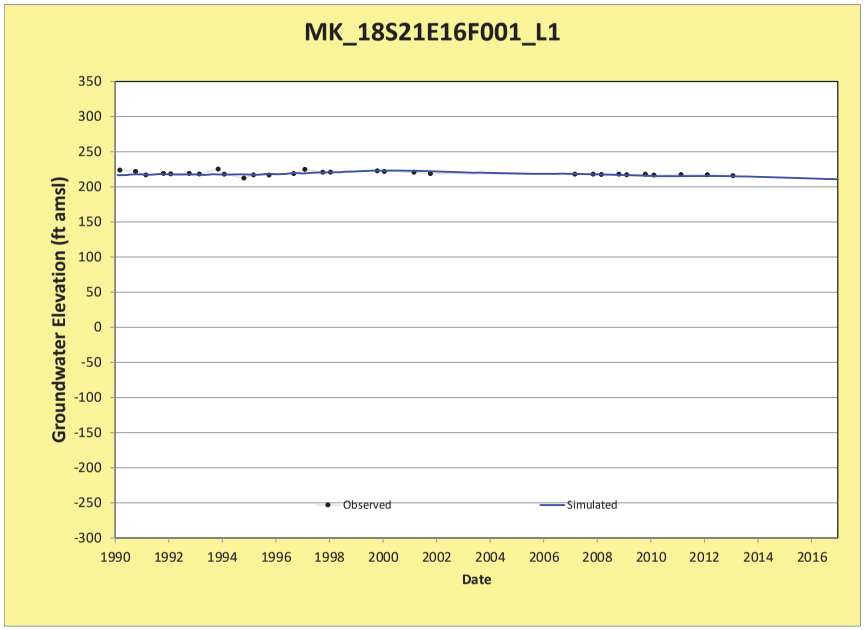

MK_18S21E02R001_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

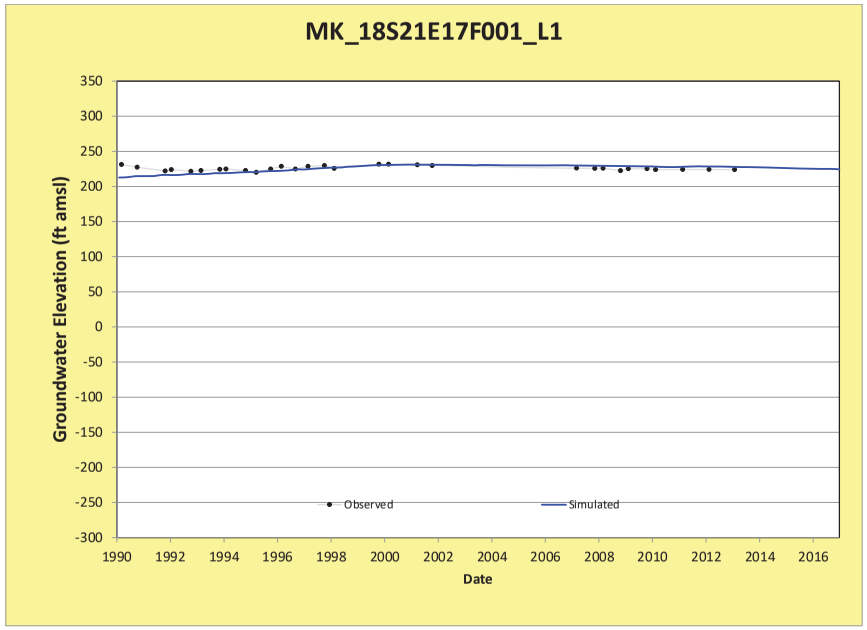

MK_18S21E04L001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

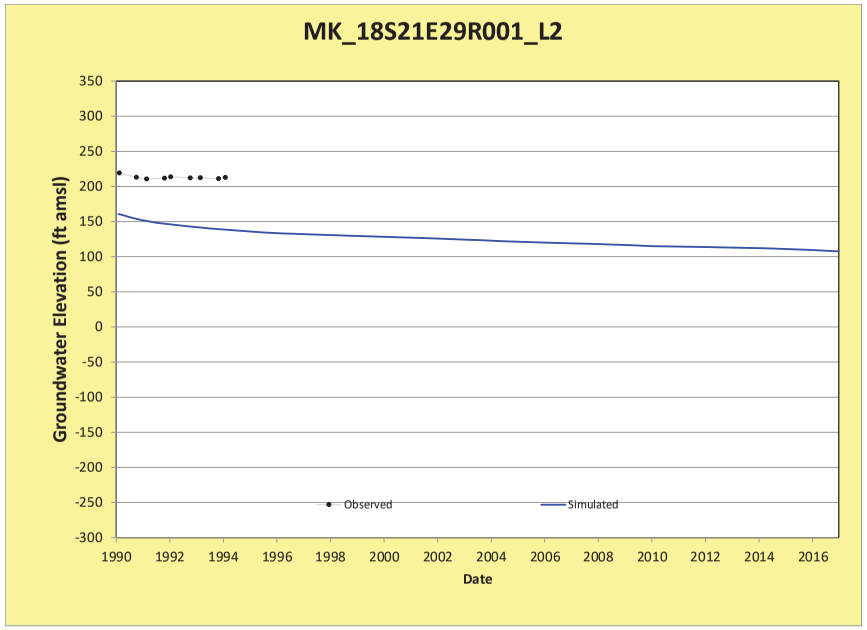

MK_18S21E08J001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

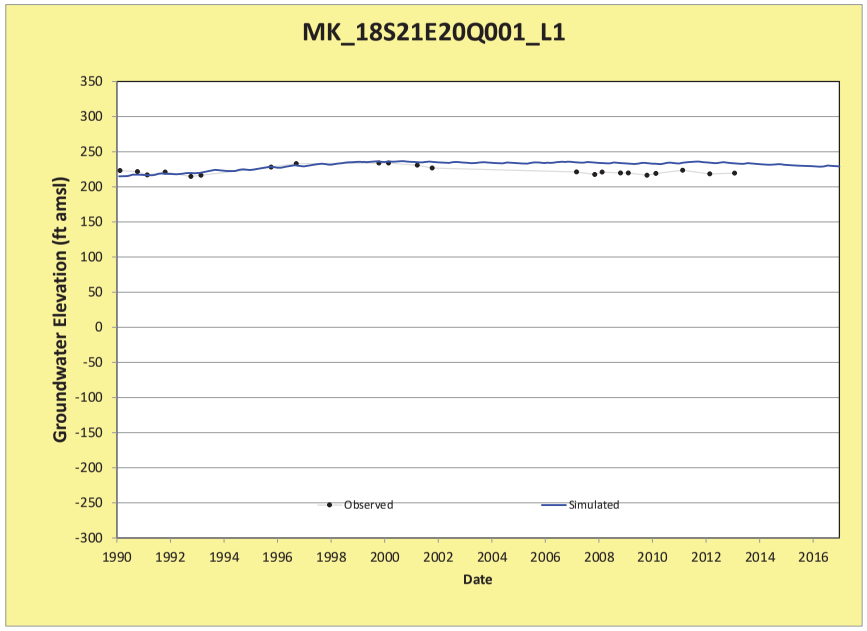

MK_18S21E15C001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

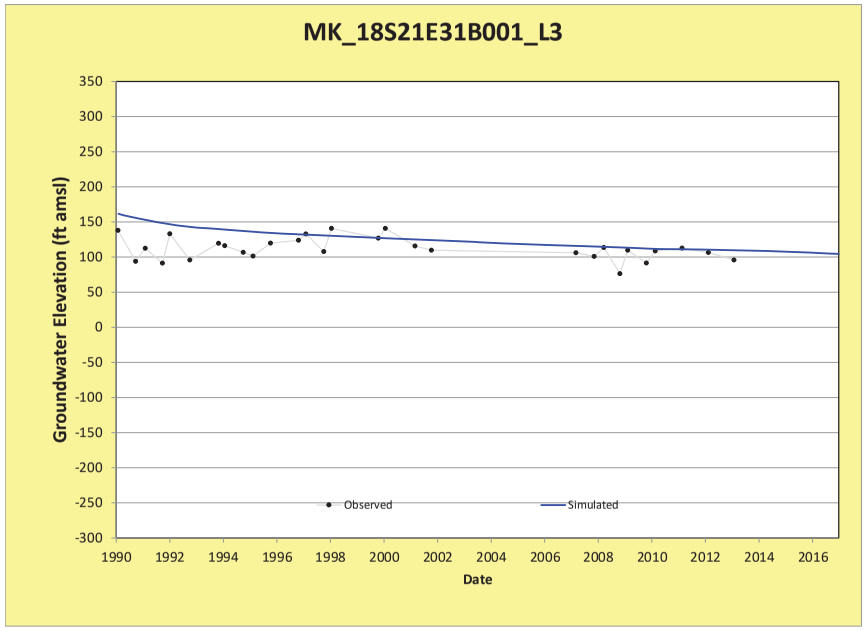

MK_18S21E14R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

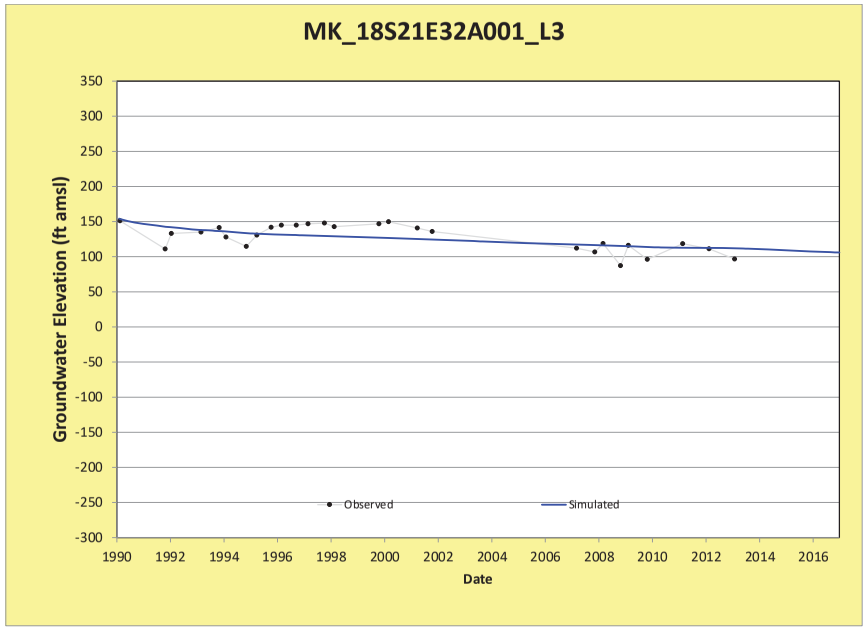

MK_18S21E16F001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

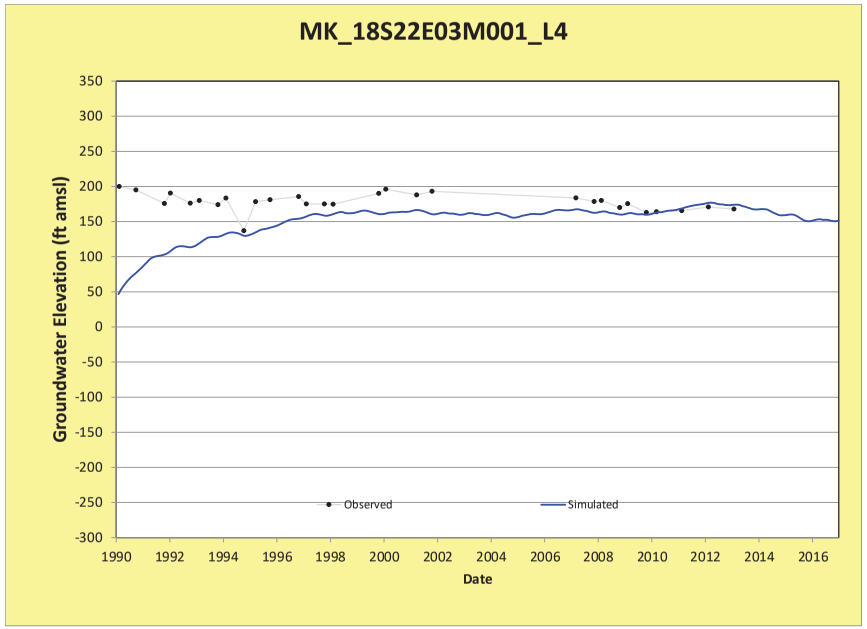

MK_18S21E17F001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

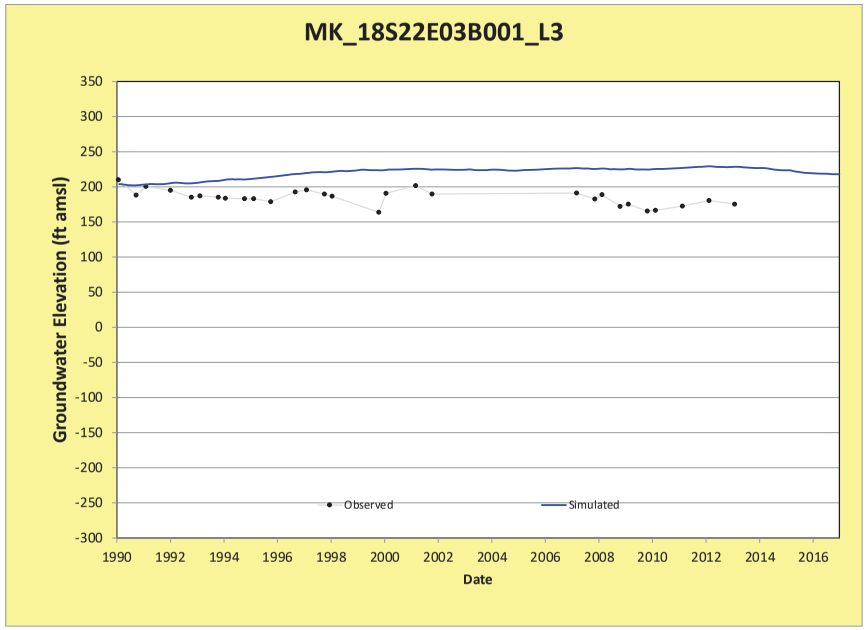

MK_18S21E29R001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

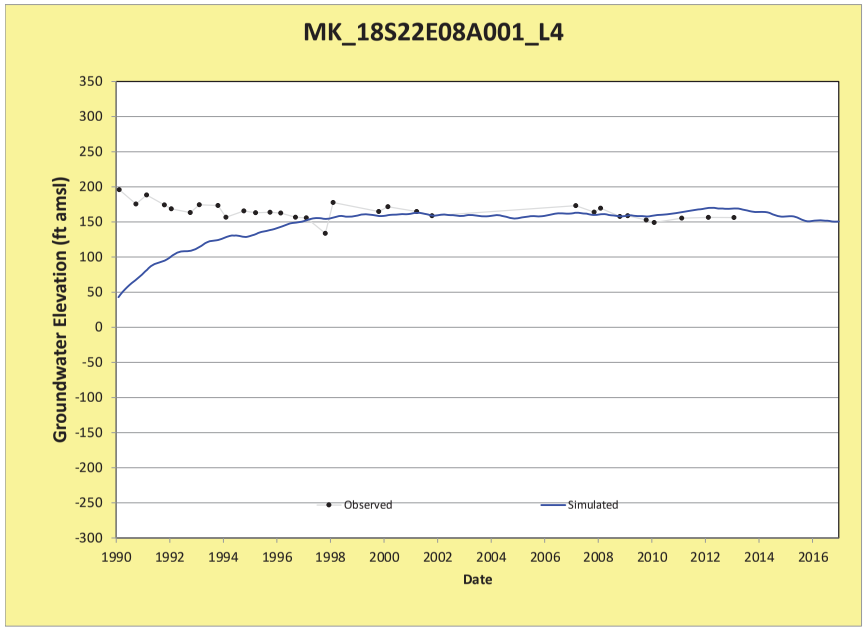

MK_18S21E20Q001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

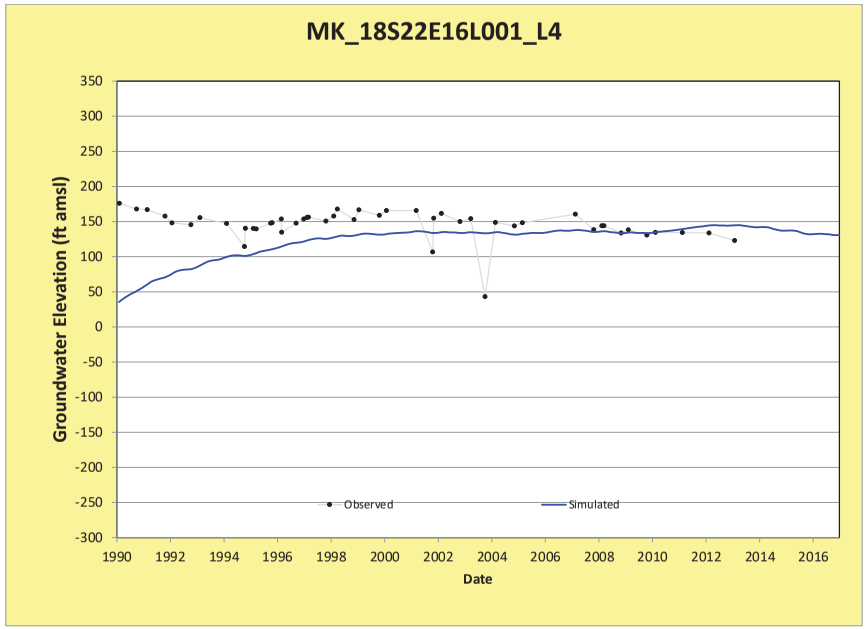

MK_18S21E31B001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

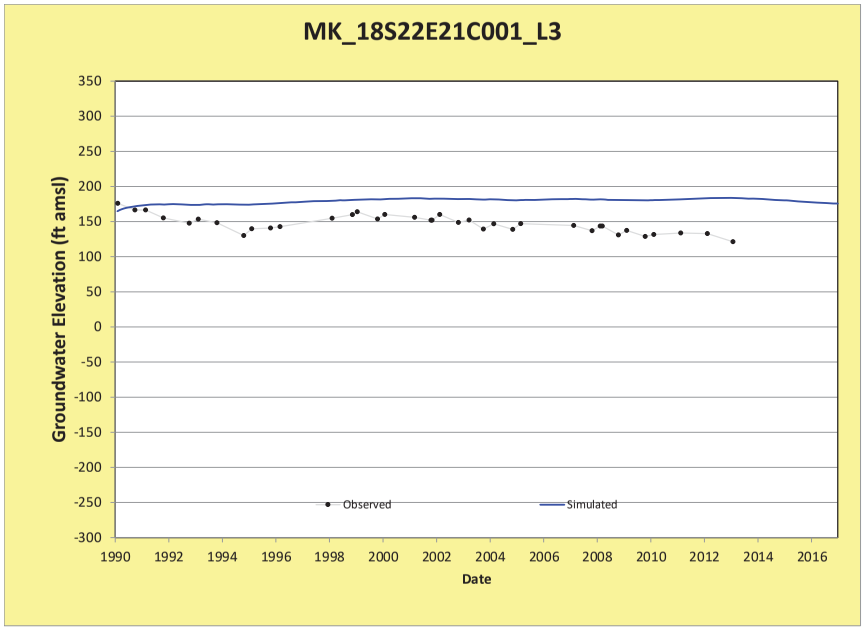

MK_18S21E32A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

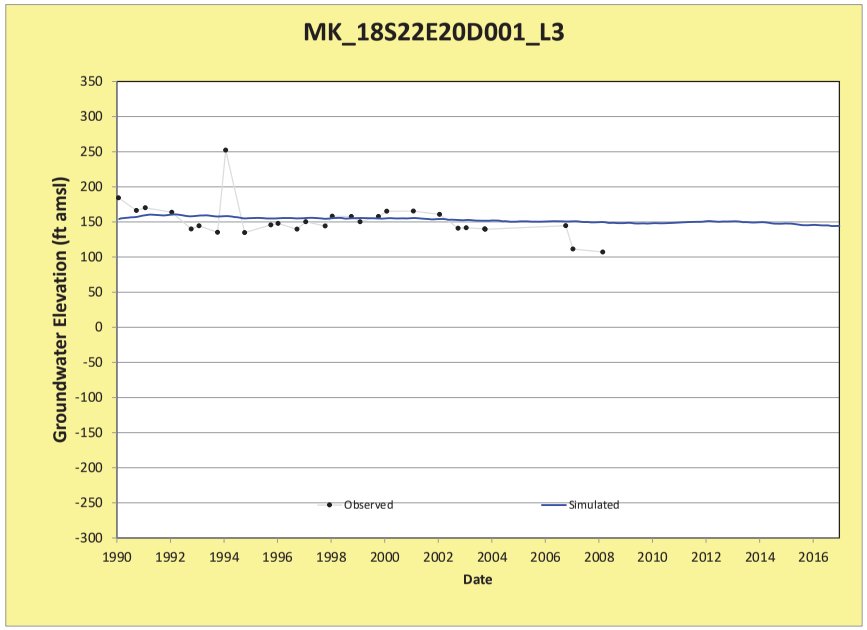

MK_18S22E03M001_L4
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

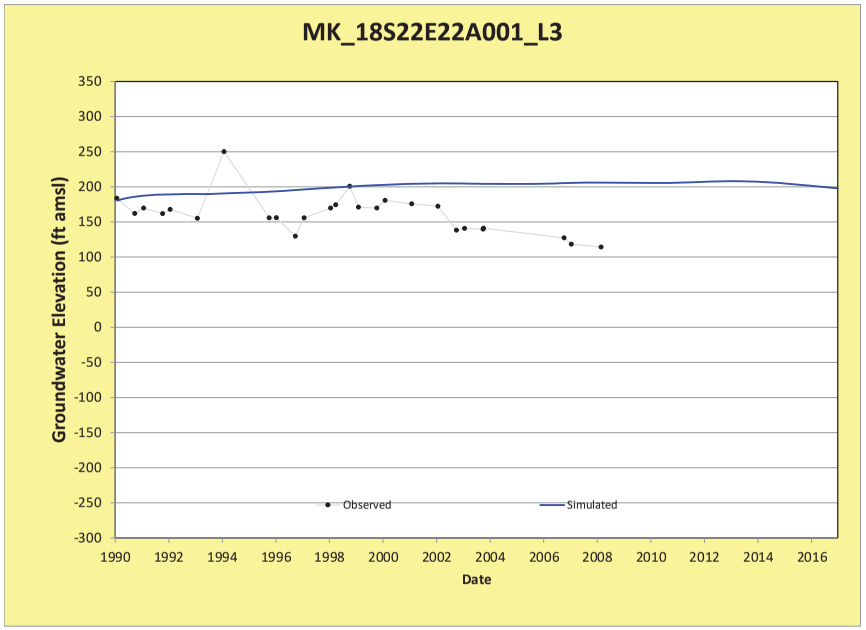

MK_18S22E03B001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

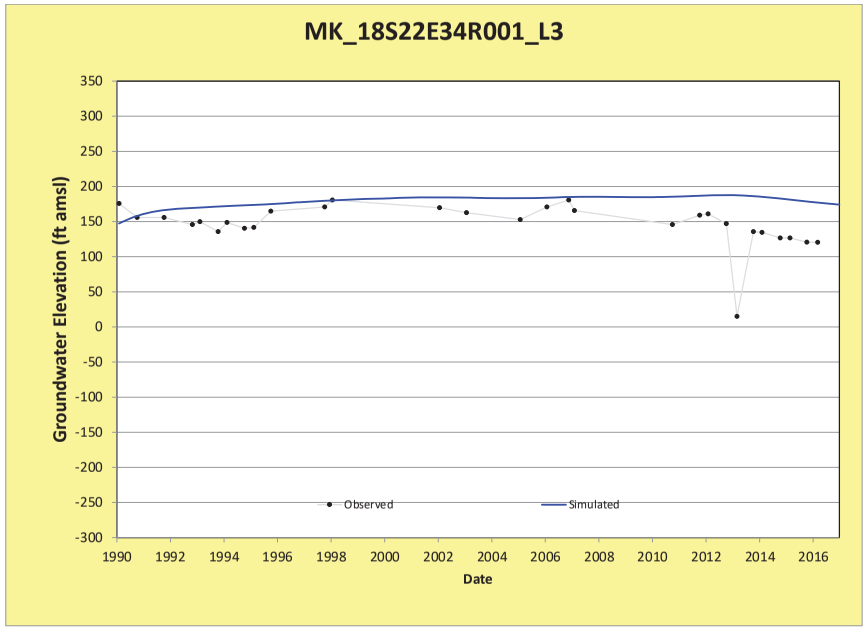

MK_18S22E08A001_L4
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

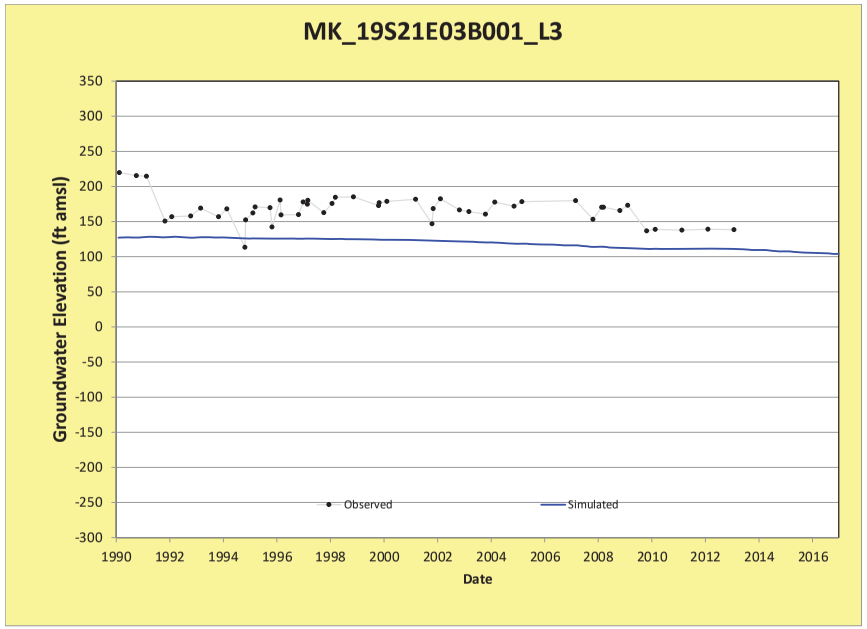

MK_18S22E16L001_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

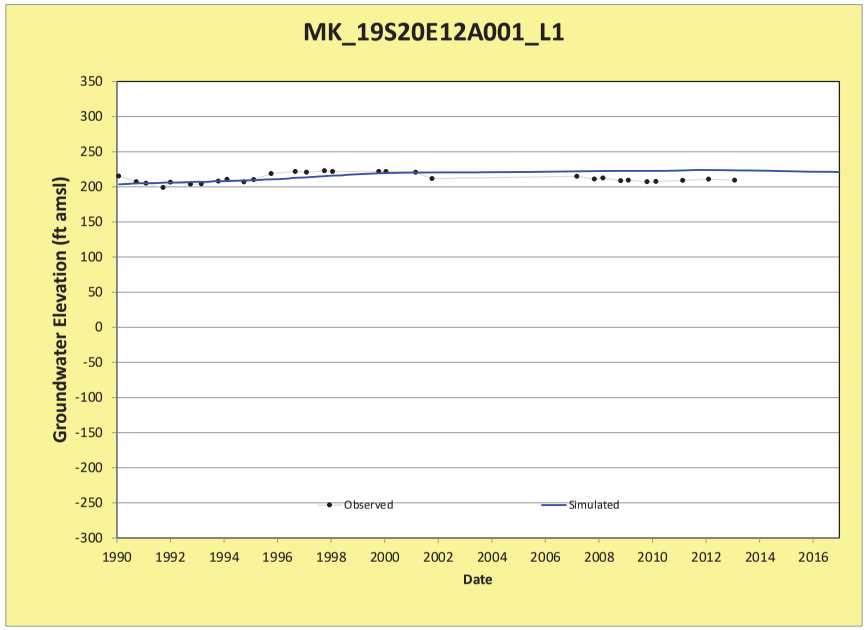

MK_18S22E21C001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

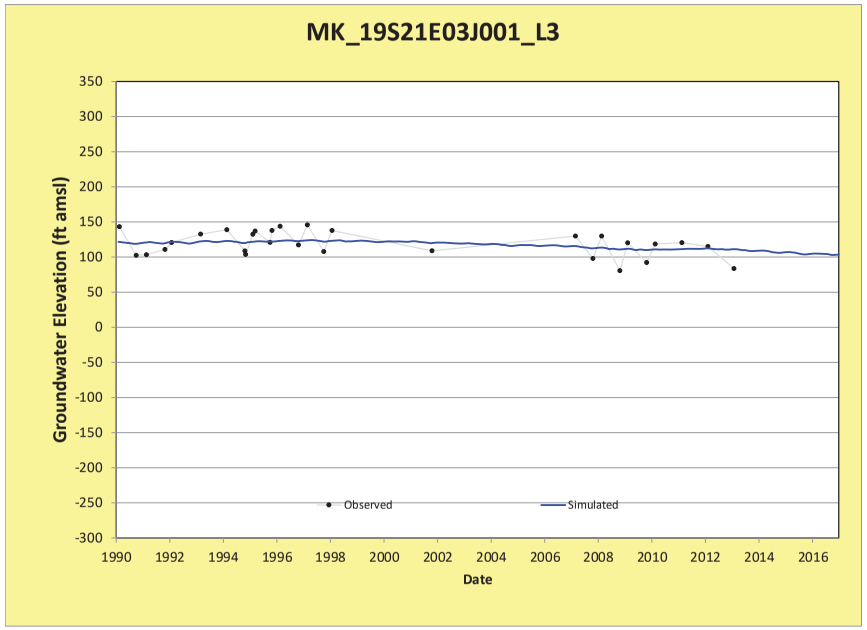

MK_18S22E20D001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

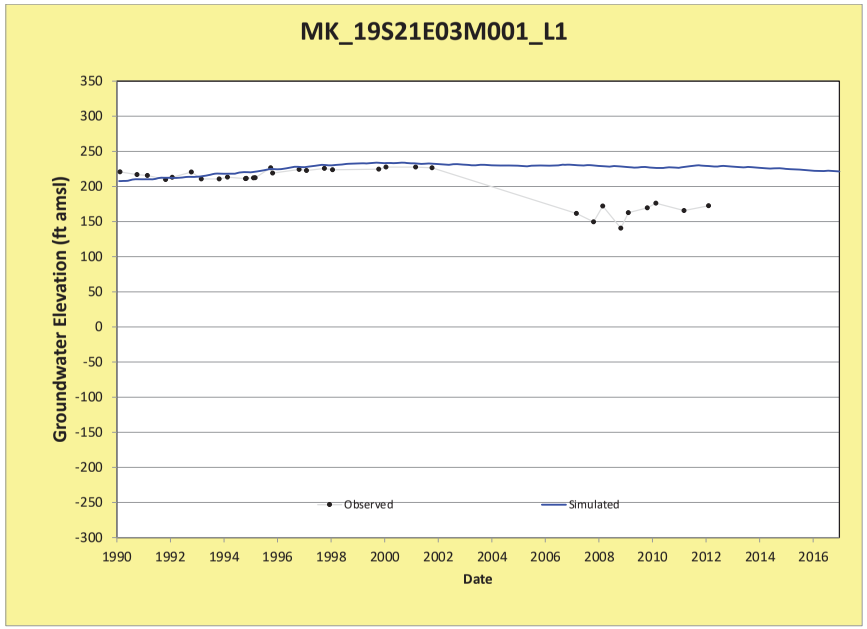

MK_18S22E22A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

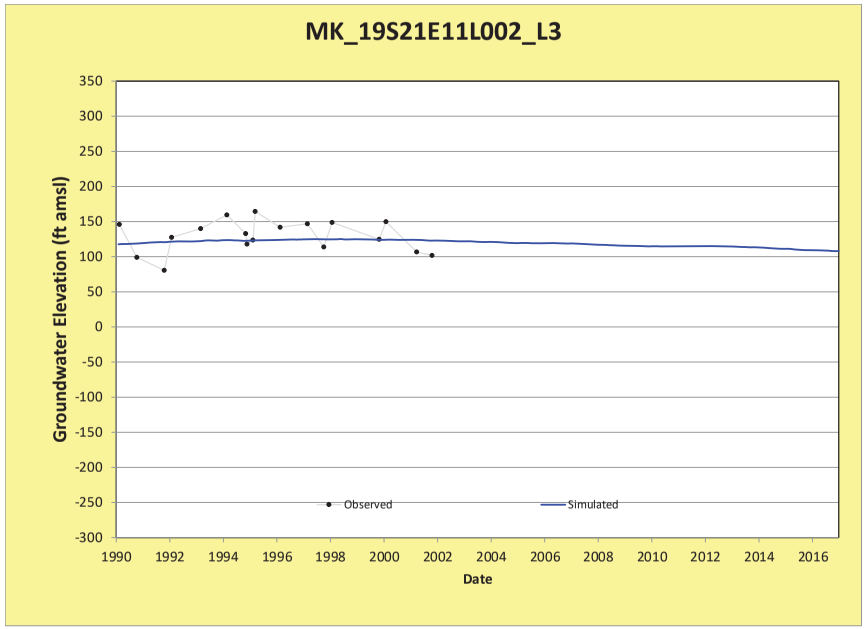

MK_18S22E34R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

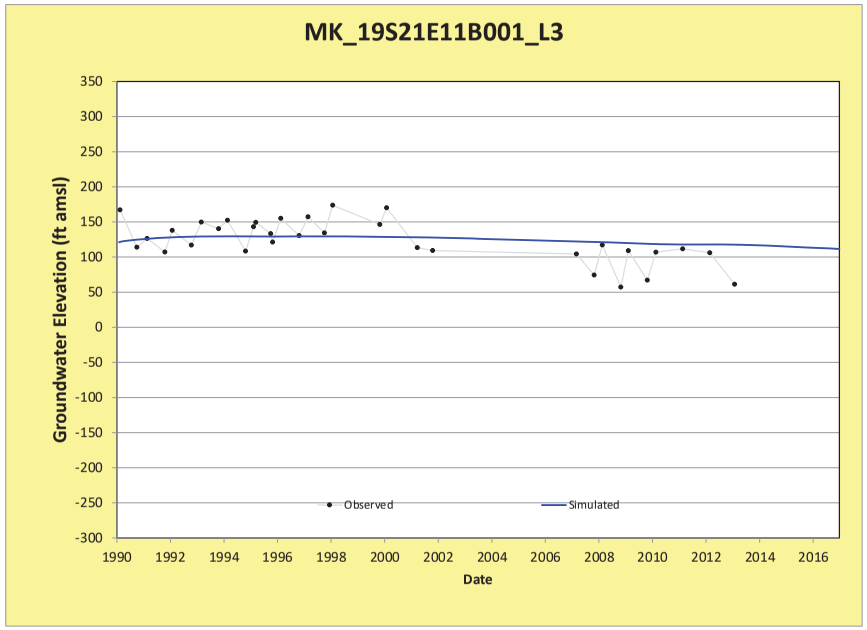

MK_19S21E03B001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

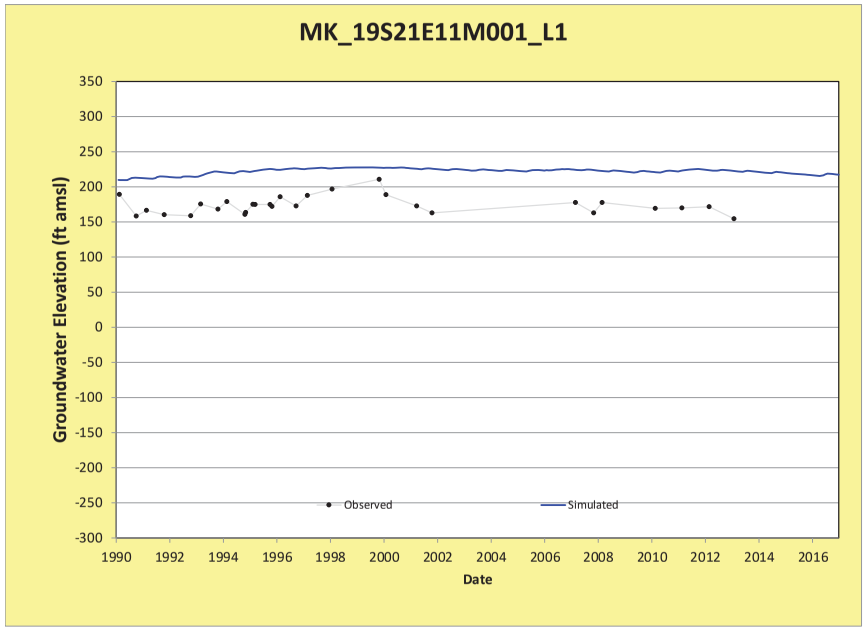

MK_19S20E12A001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

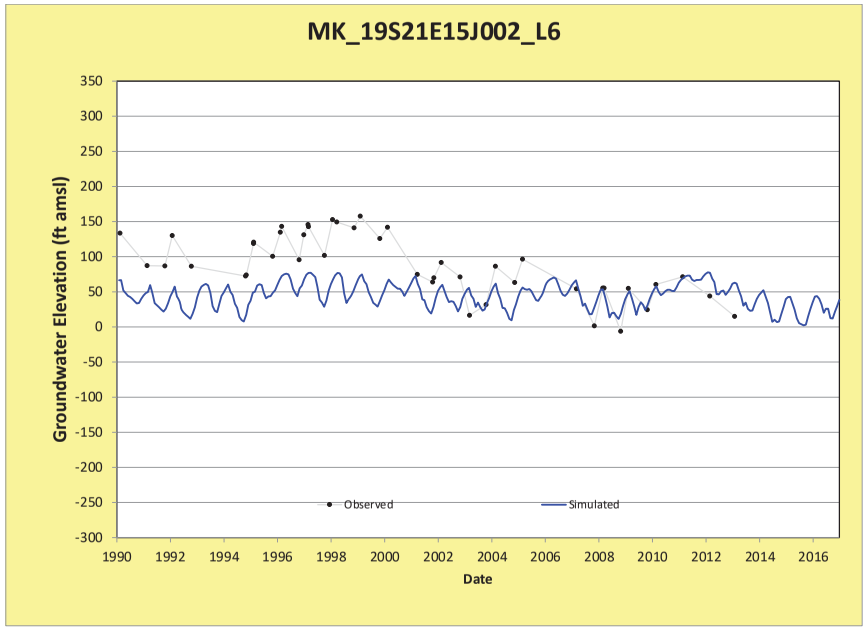

MK_19S21E03J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

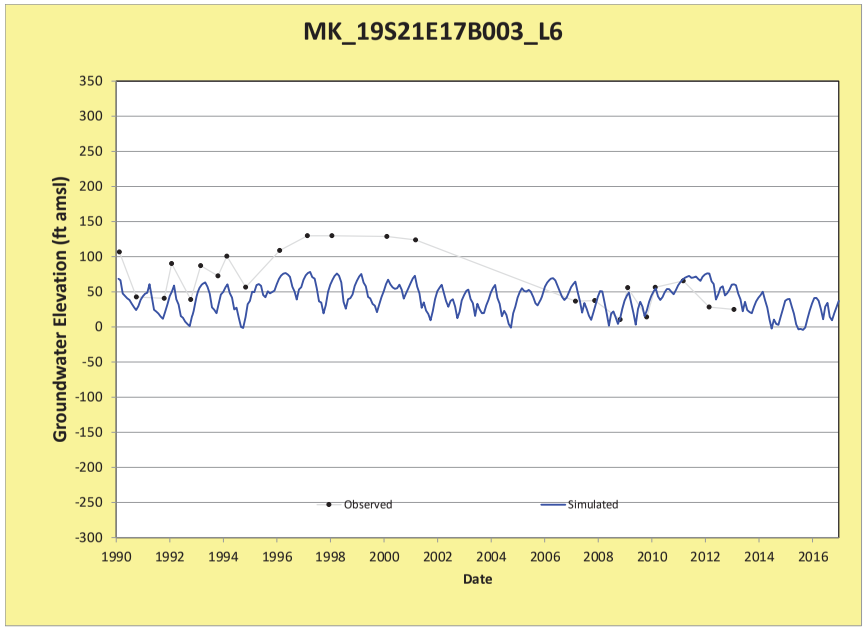

MK_19S21E03M001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

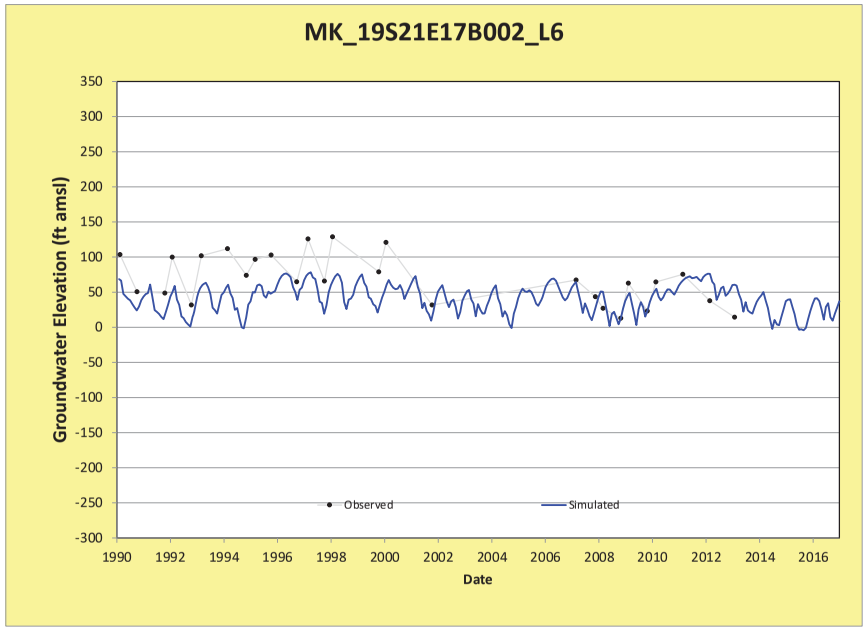

MK_19S21E11L002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

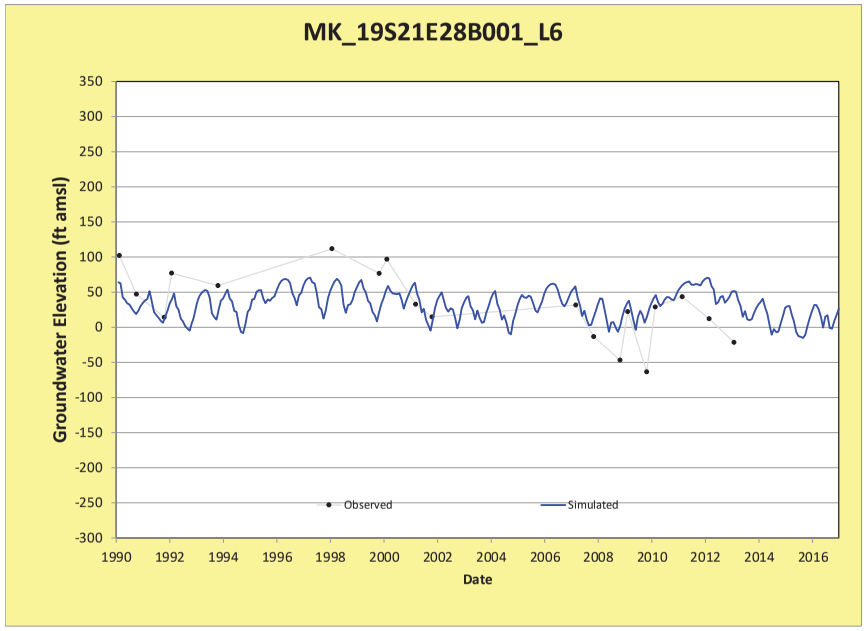

MK_19S21E11B001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

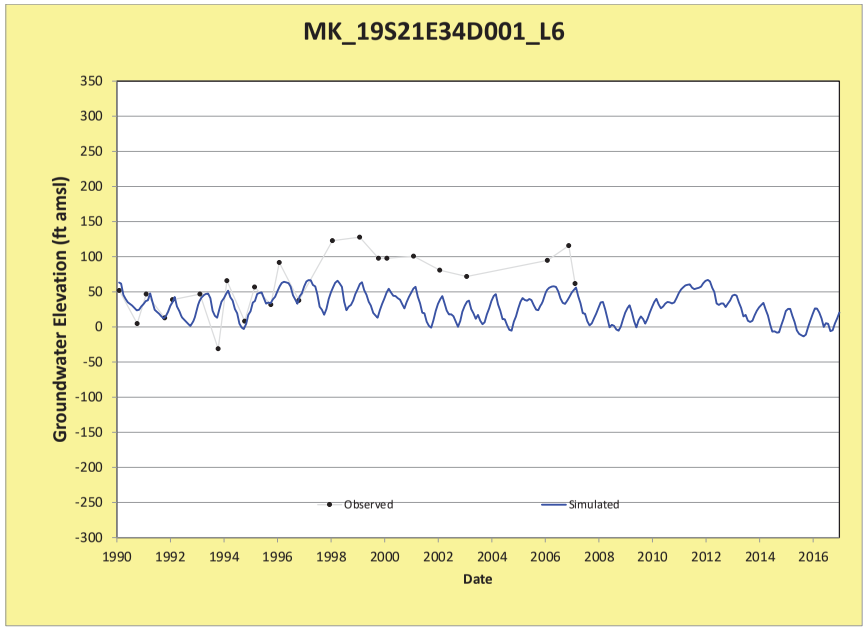

MK_19S21E11M001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

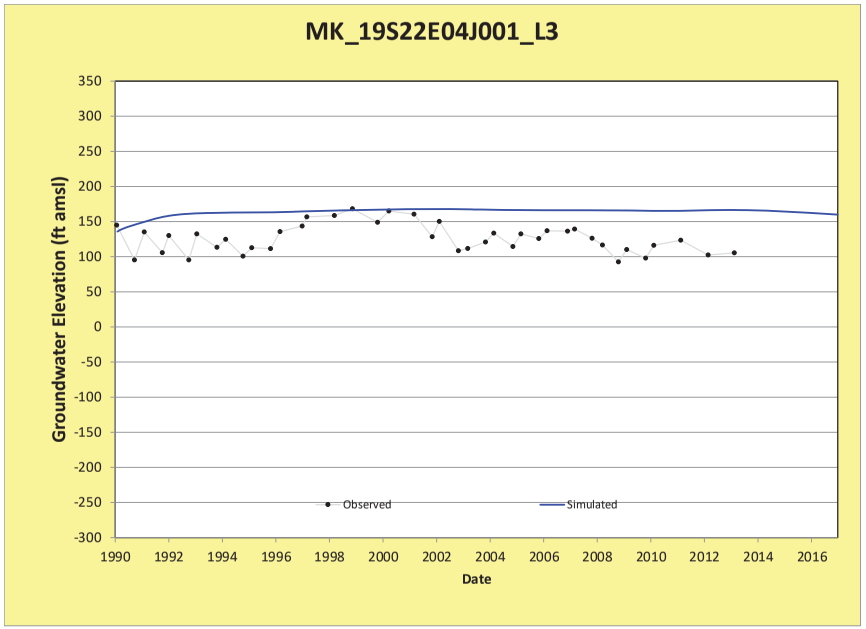

MK_19S21E15J002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

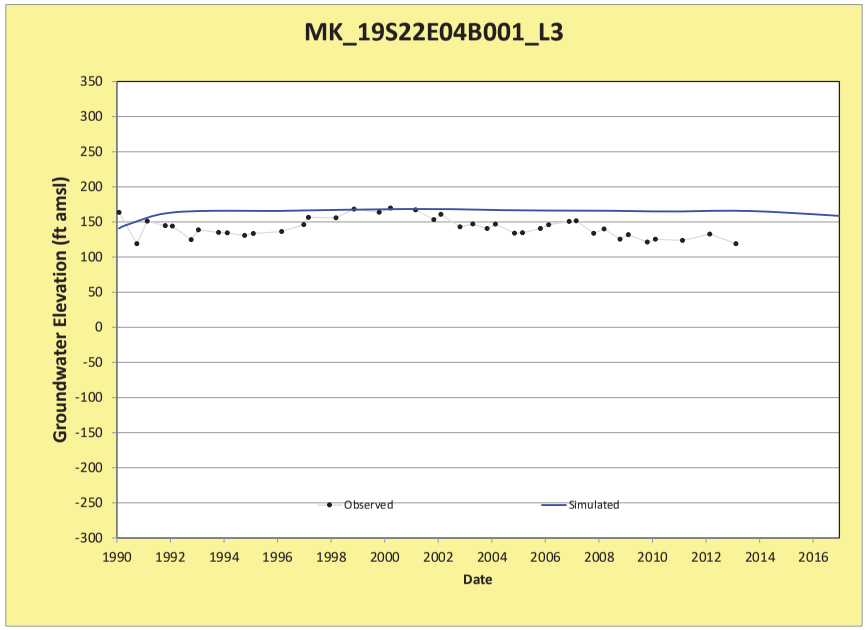

MK_19S21E17B003_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

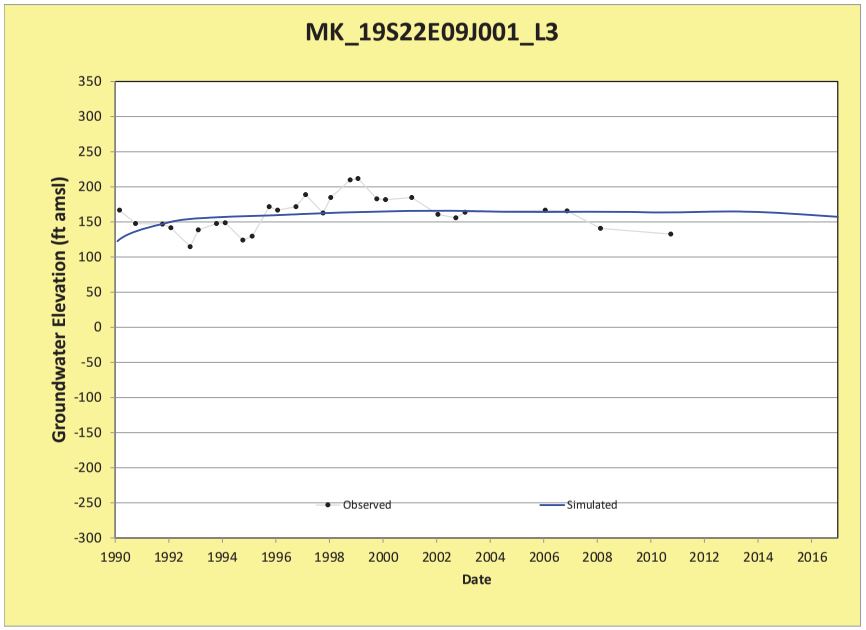

MK_19S21E17B002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

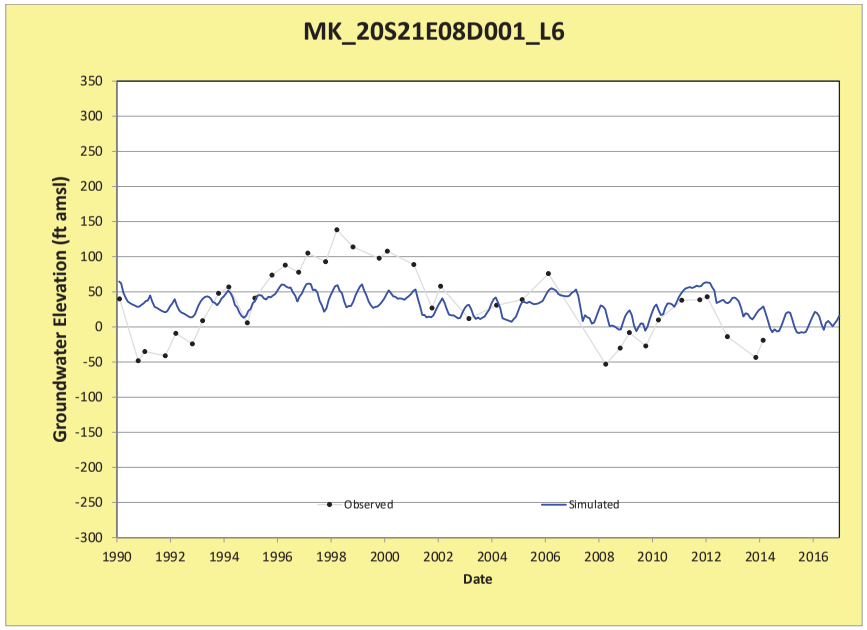

MK_19S21E28B001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

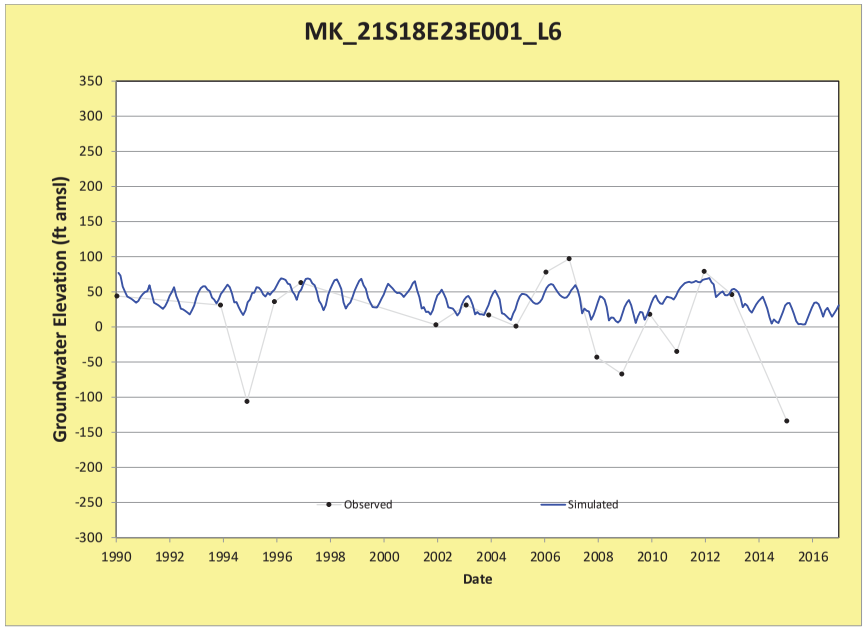

MK_19S21E34D001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

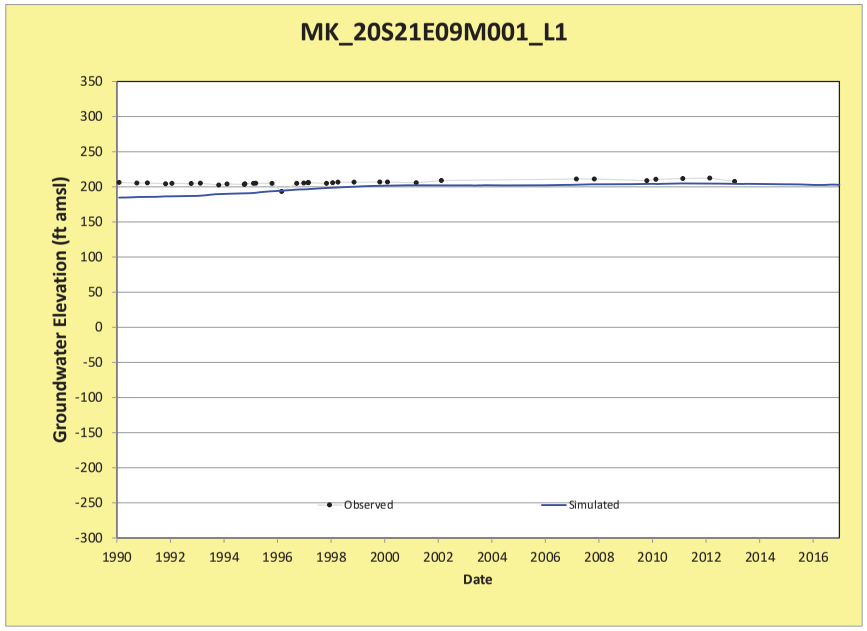

MK_19S22E04J001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

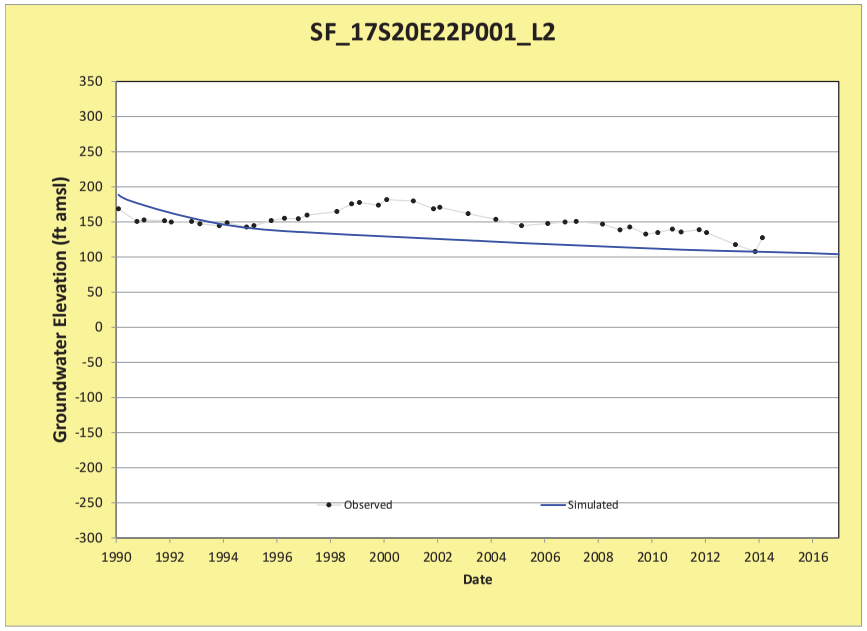

MK_19S22E04B001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

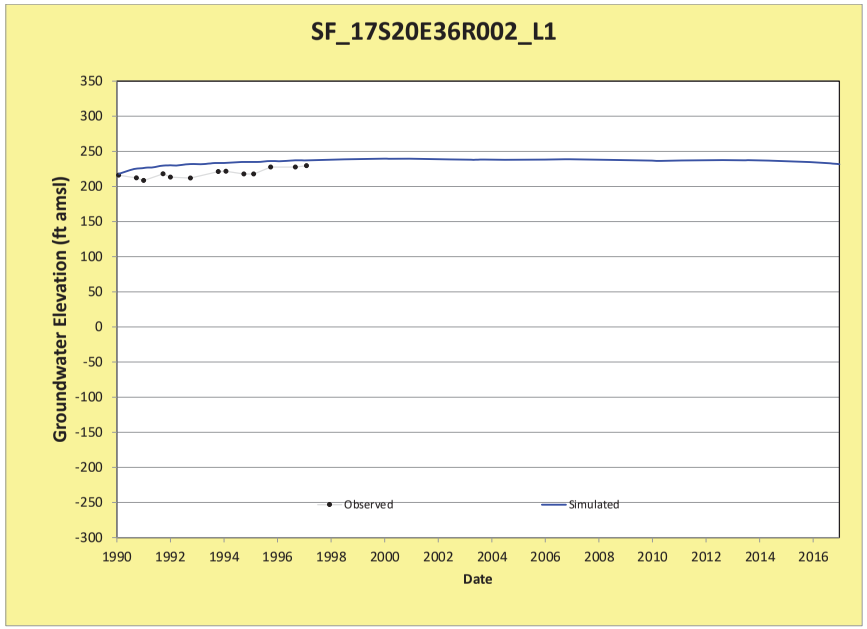

MK_19S22E09J001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

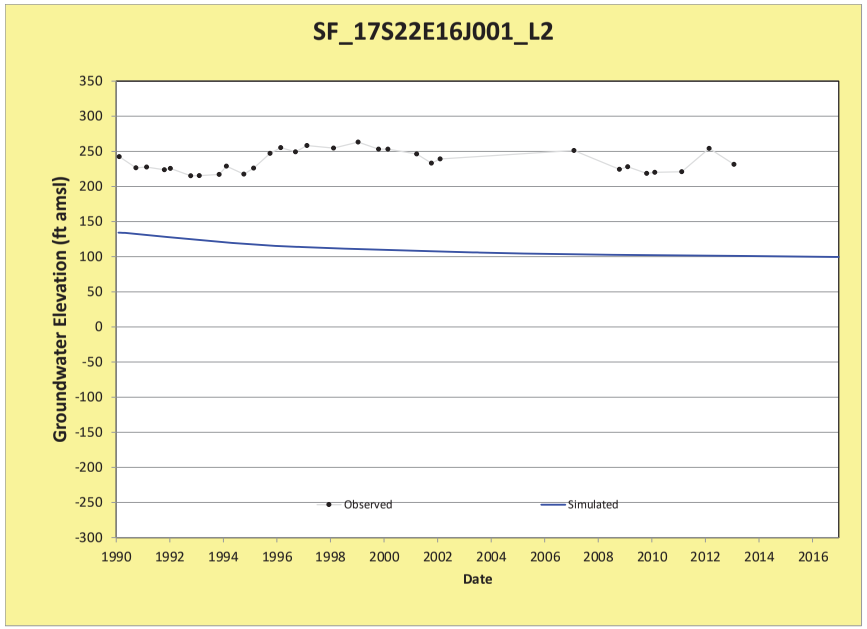

MK_20S21E08D001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

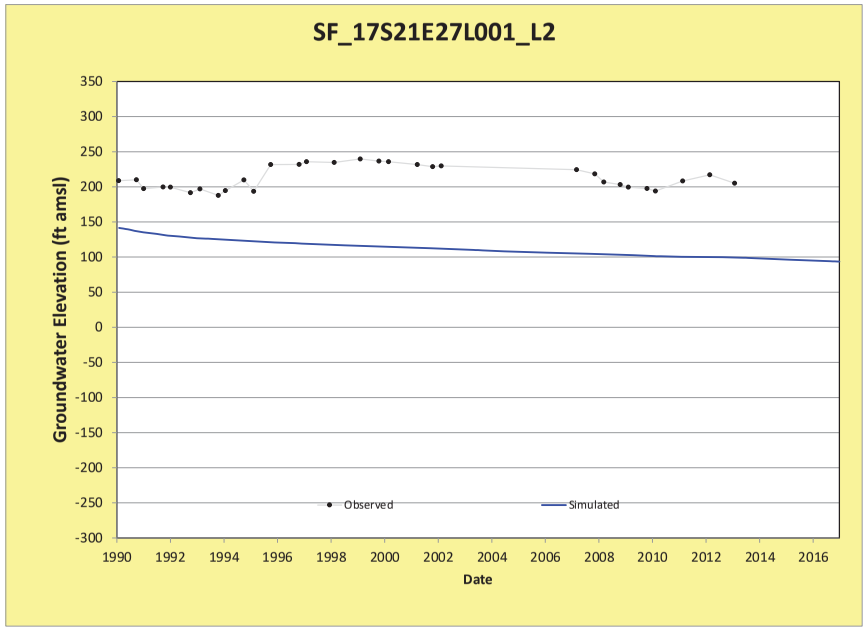

MK_21S18E23E001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

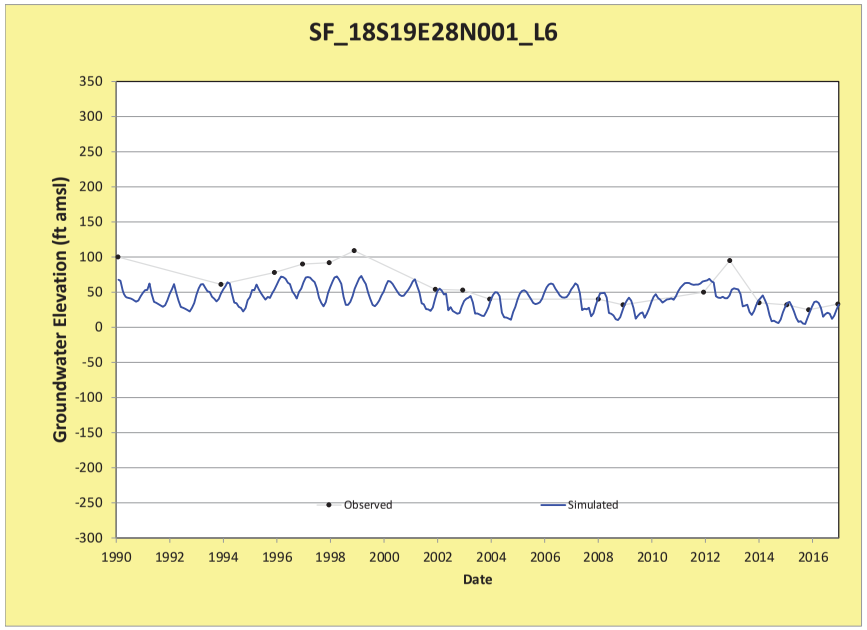

MK_20S21E09M001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

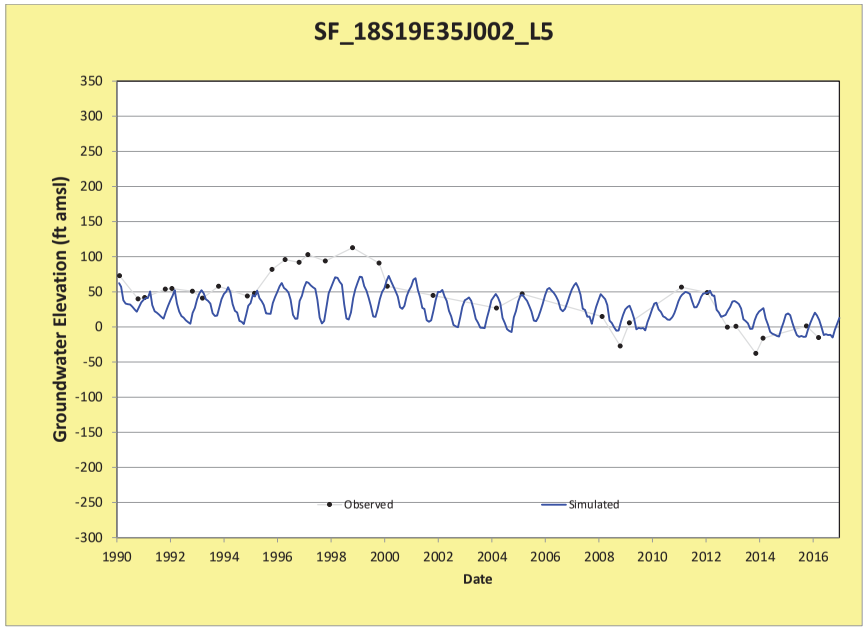

SF_17S20E22P001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

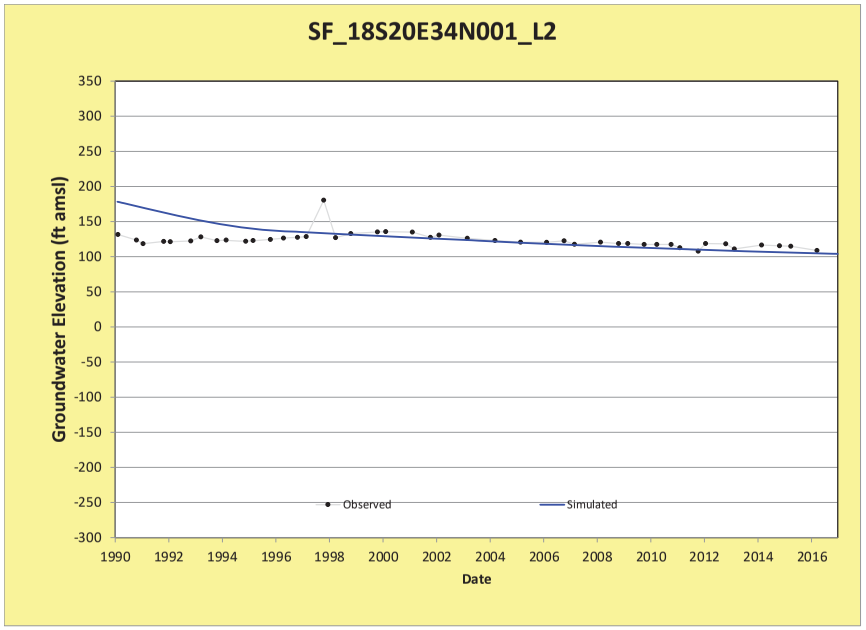

SF_17S20E36R002_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

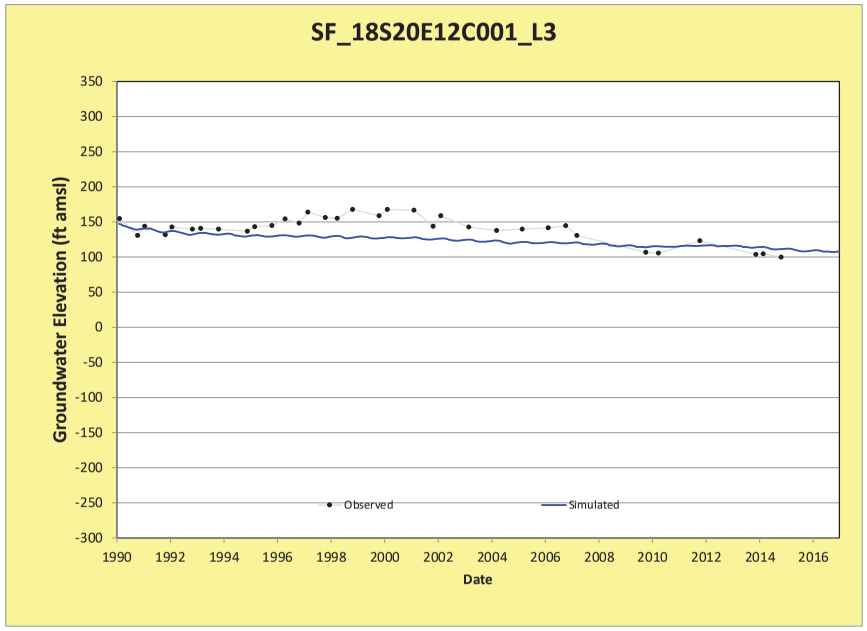

SF_17S22E16J001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

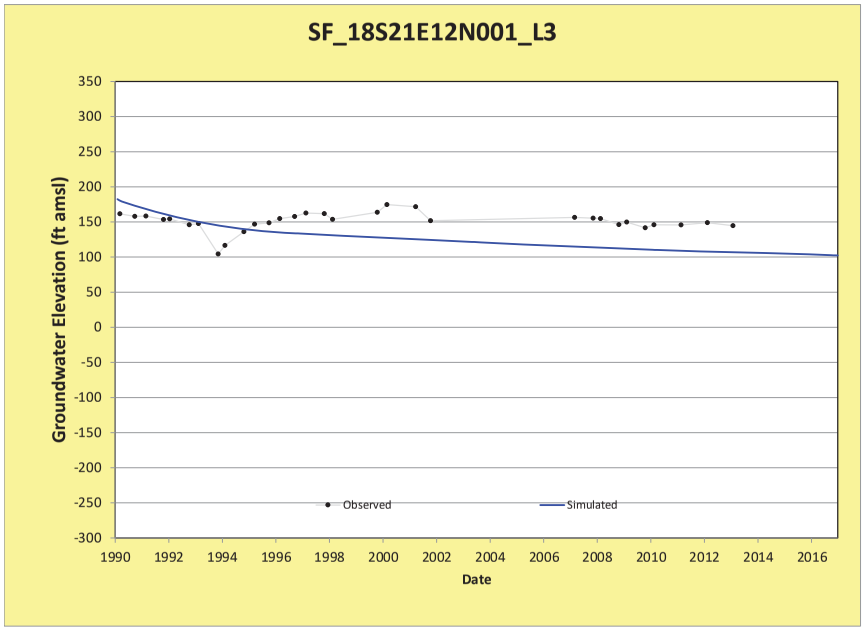

SF_17S21E27L001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

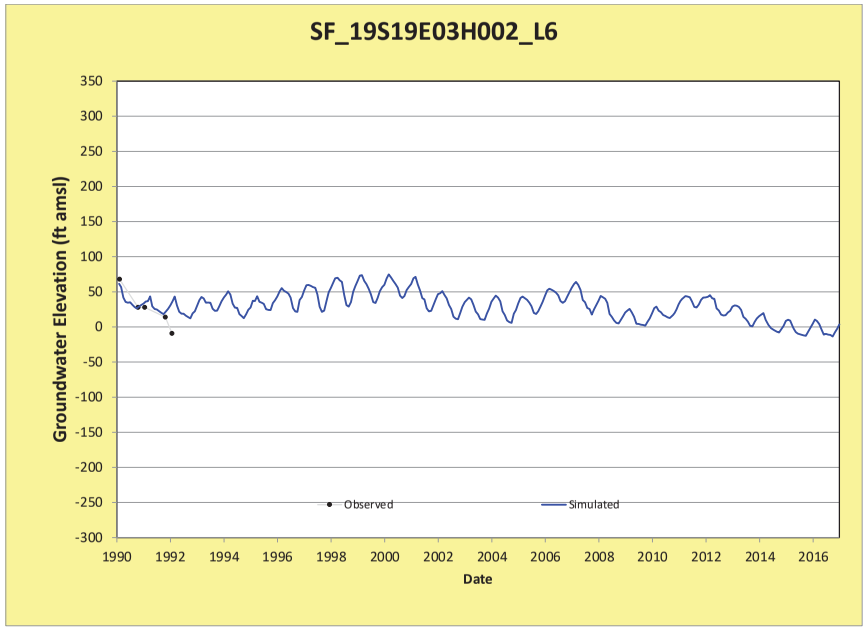

SF_18S19E28N001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

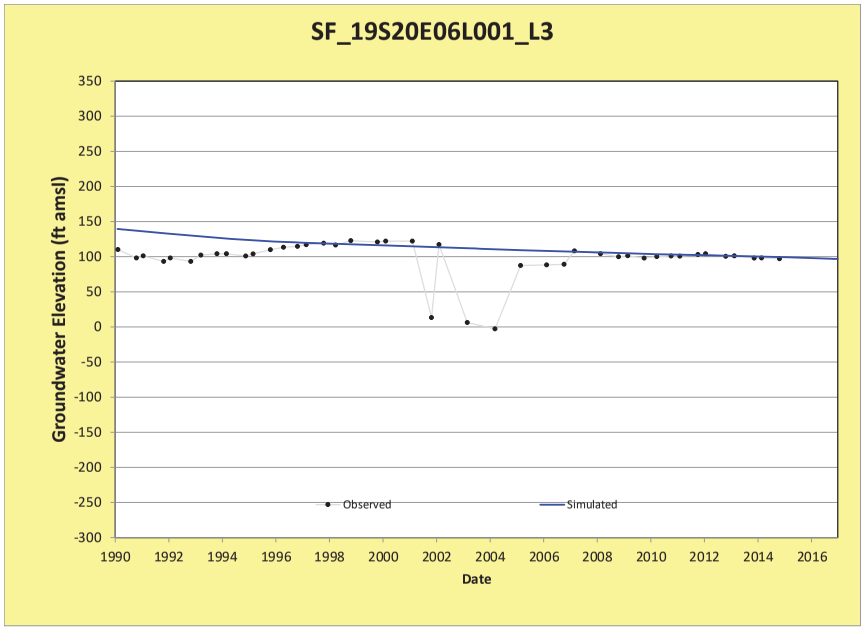

SF_18S19E35J002_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

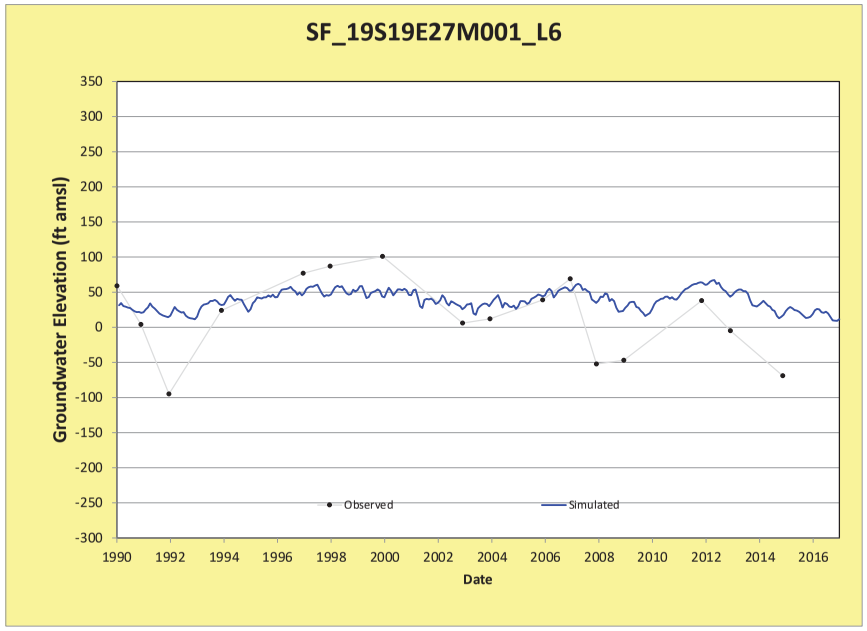

SF_18S20E34N001_L2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

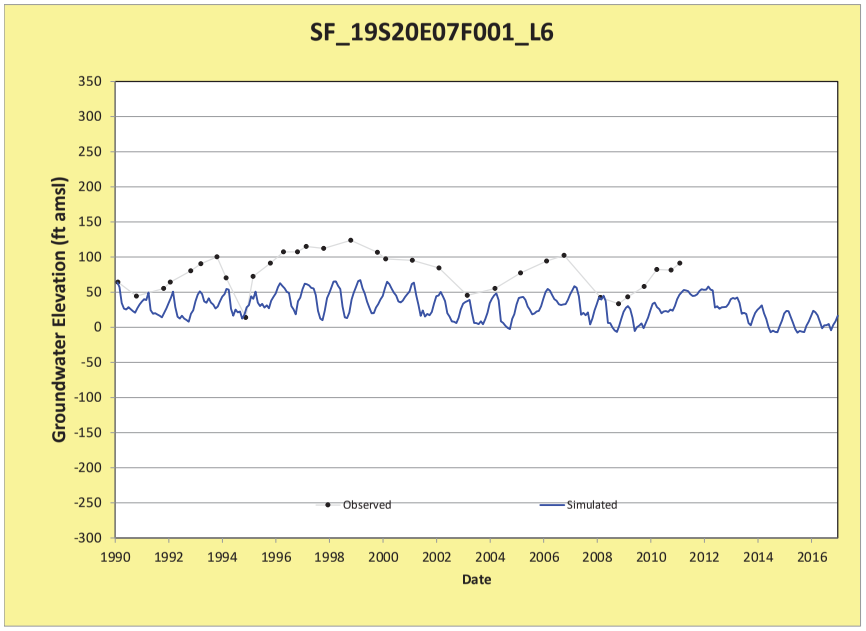

SF_18S20E12C001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

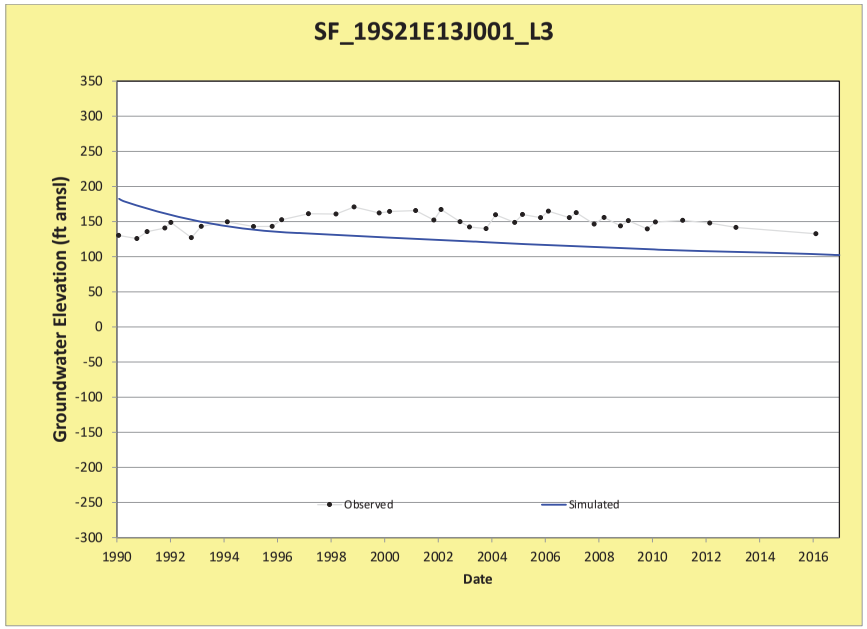

SF_18S21E12N001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

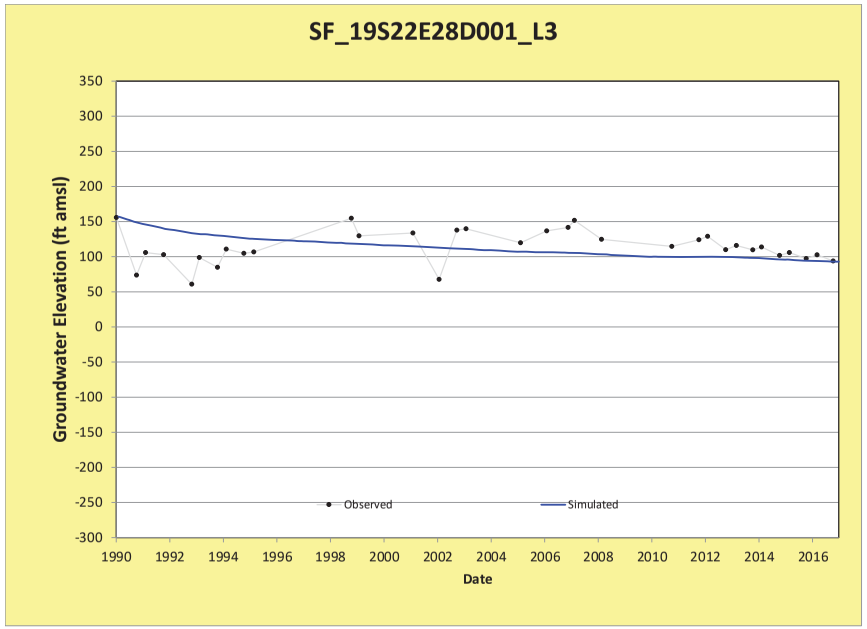

SF_19S19E03H002_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

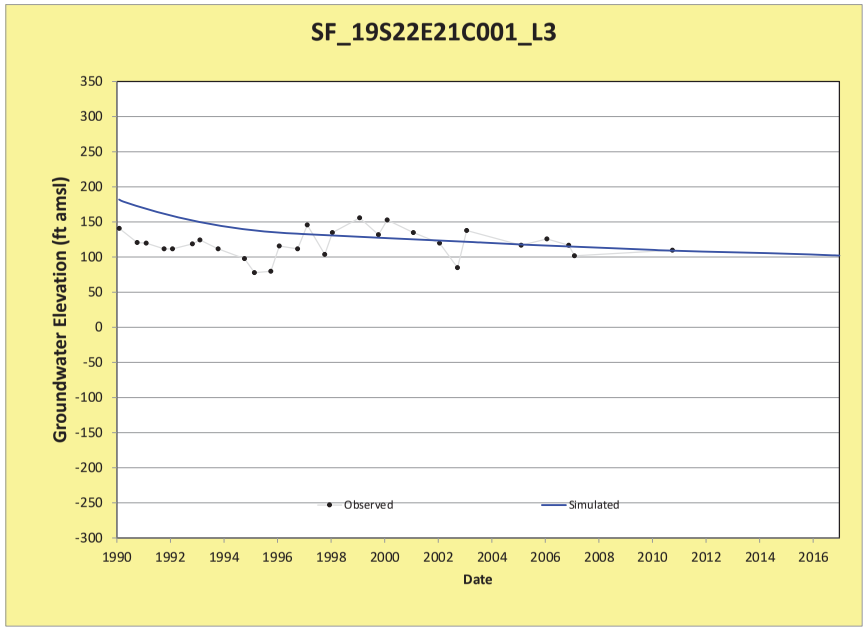

SF_19S20E06L001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

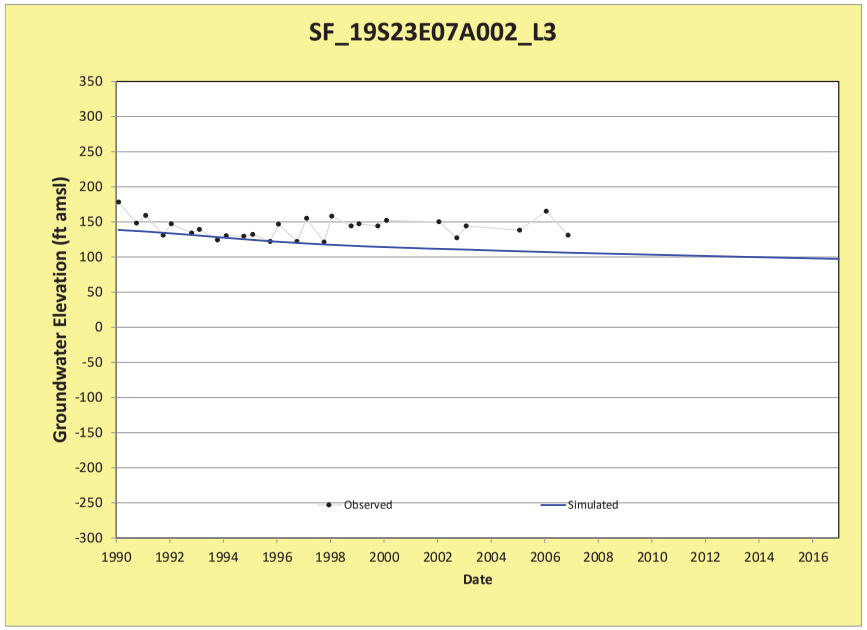

SF_19S19E27M001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

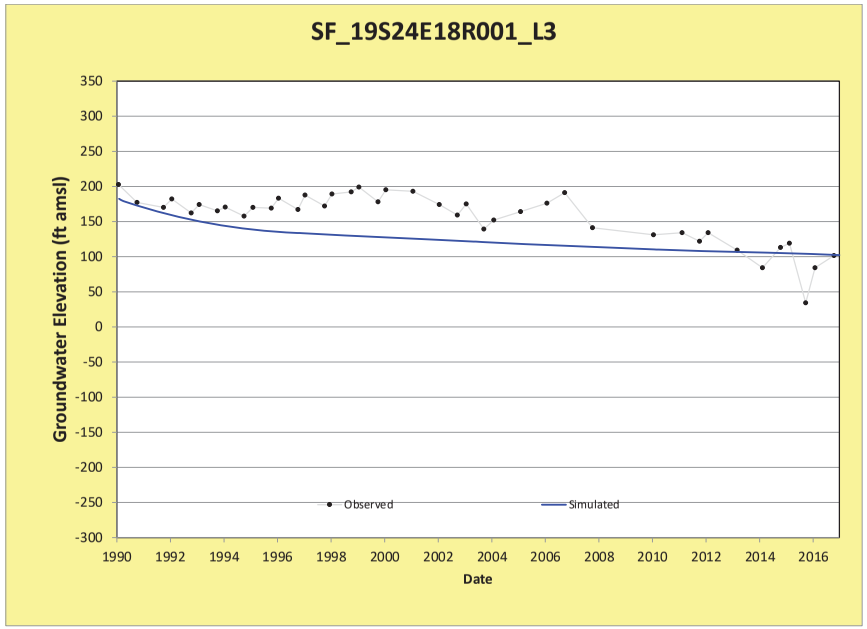

SF_19S20E07F001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

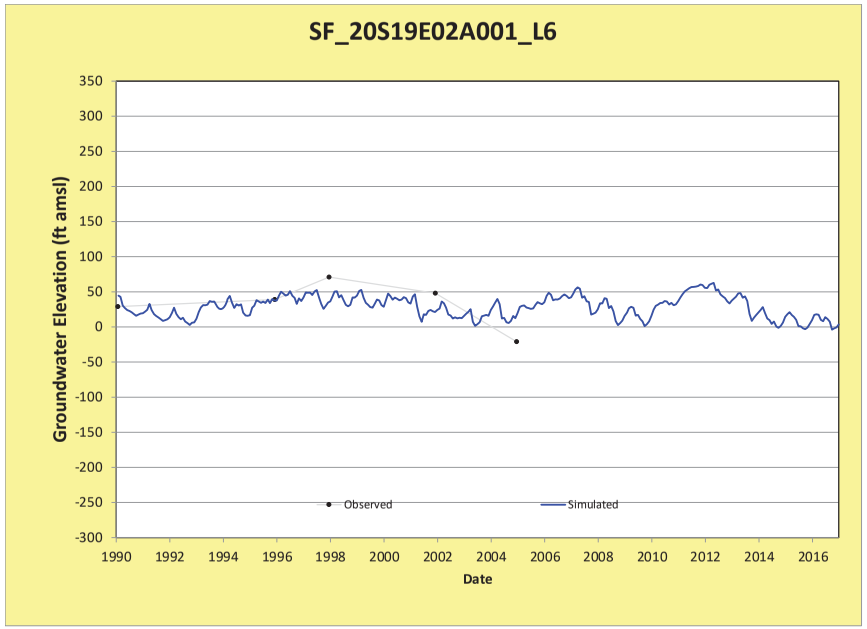

SF_19S21E13J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

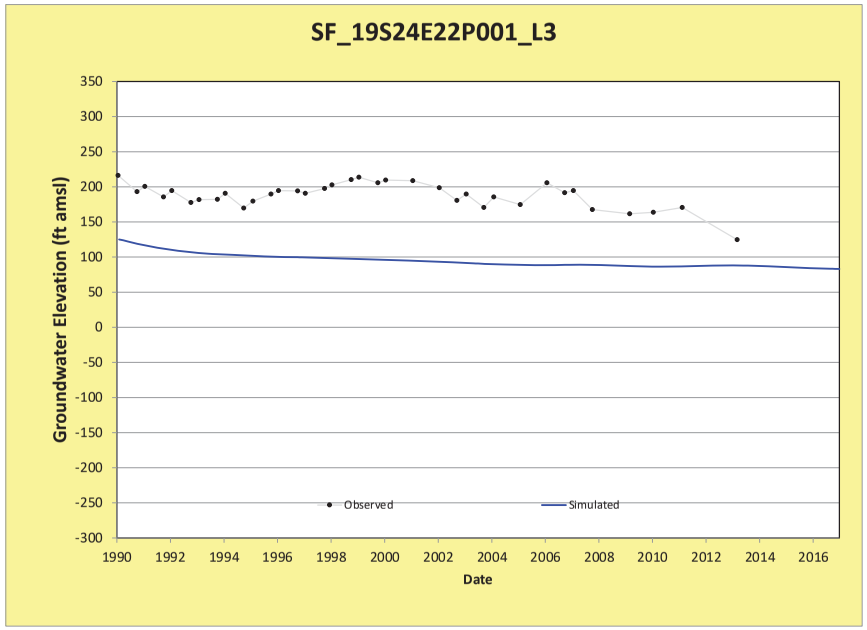

SF_19S22E28D001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

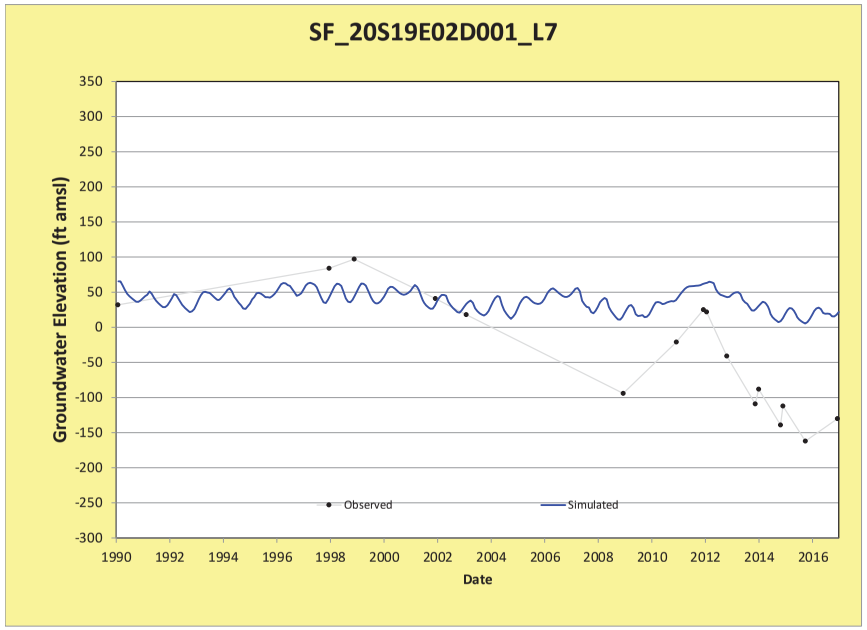

SF_19S22E21C001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

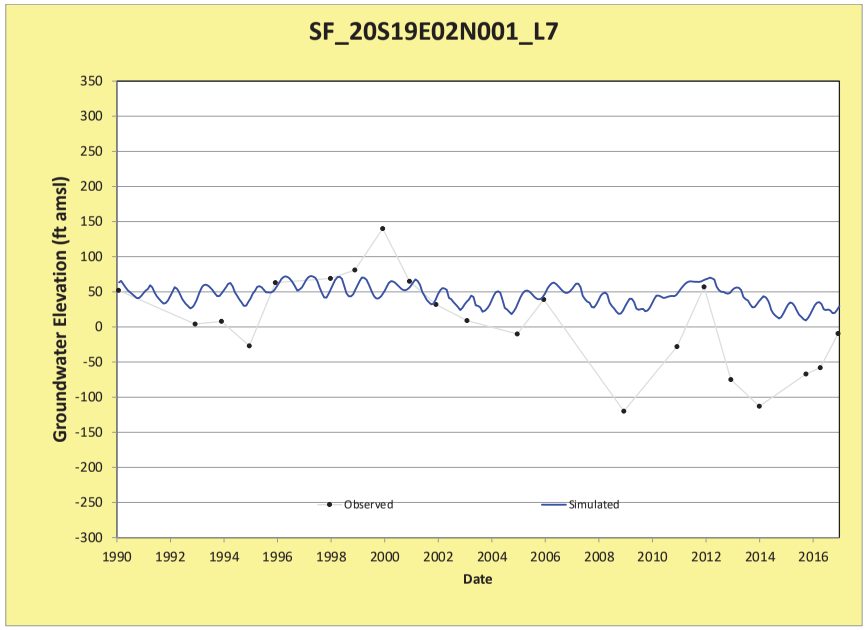

SF_19S23E07A002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

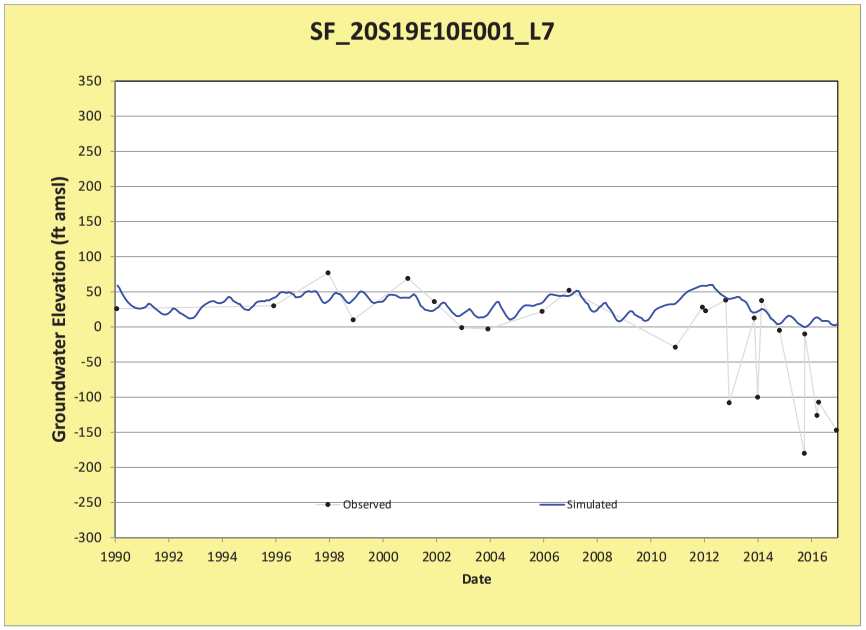

SF_19S24E18R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

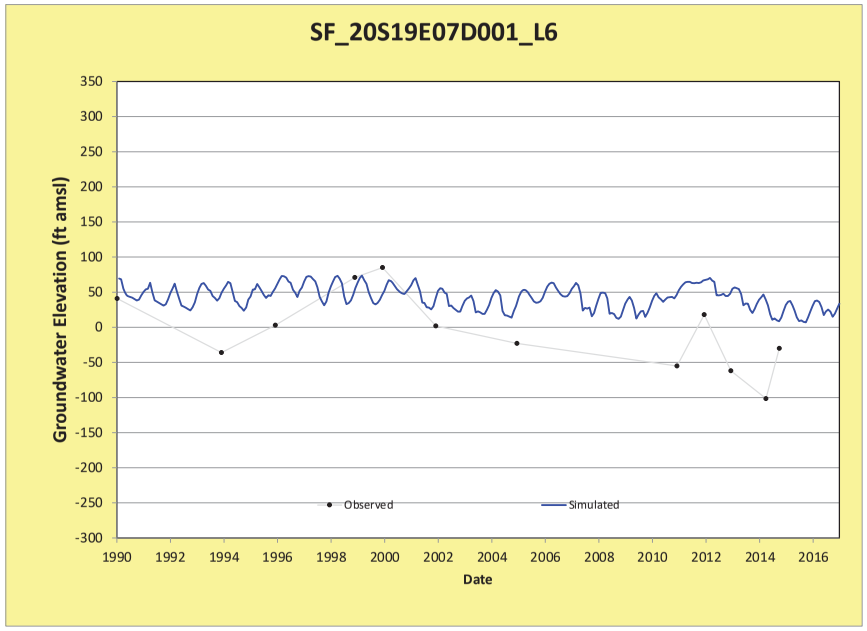

SF_20S19E02A001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

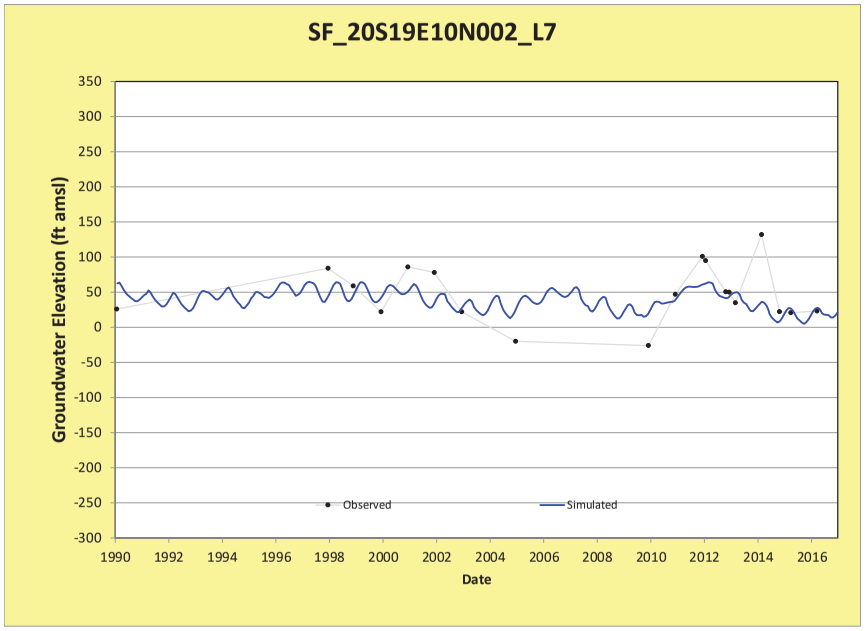

SF_19S24E22P001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

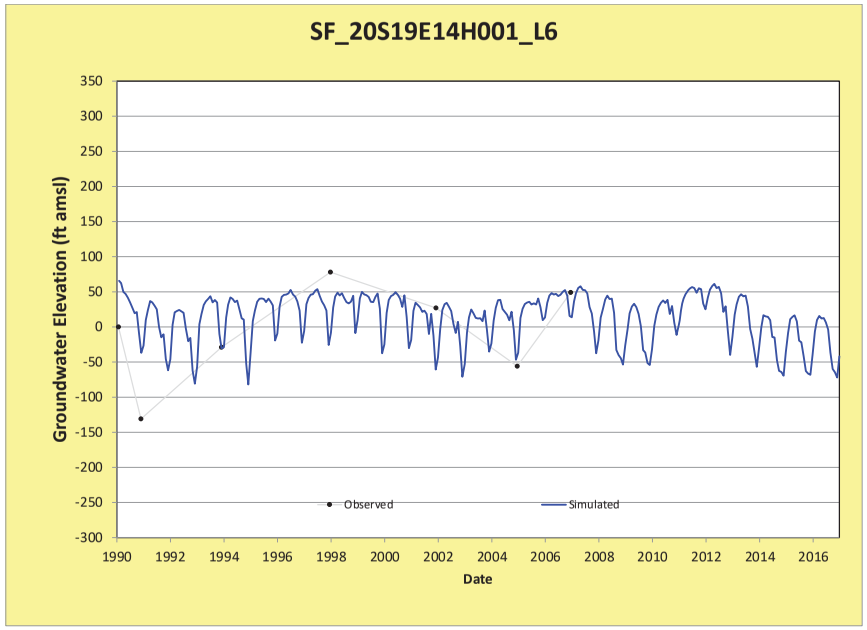

SF_20S19E02D001_L7
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

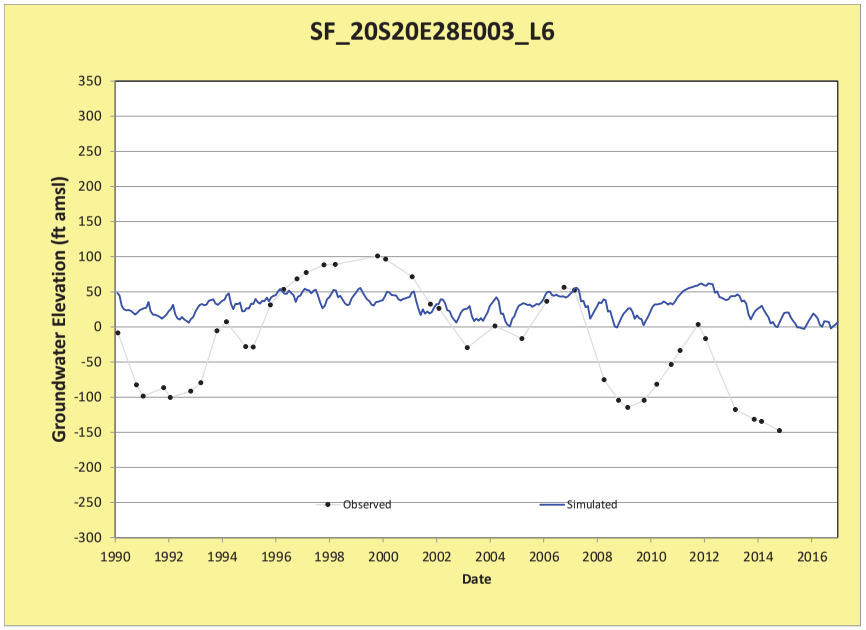

SF_20S19E02N001_L7
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

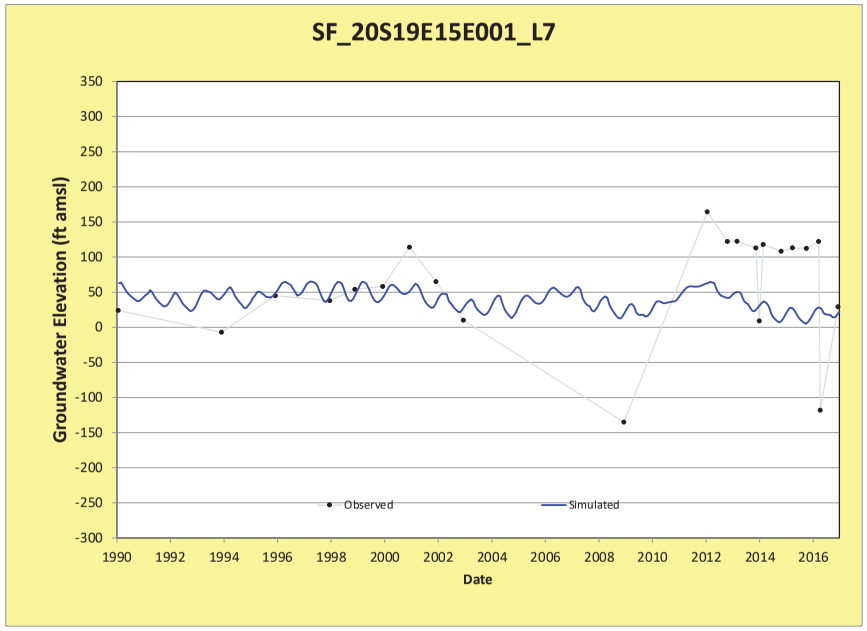

SF_20S19E10E001_L7
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

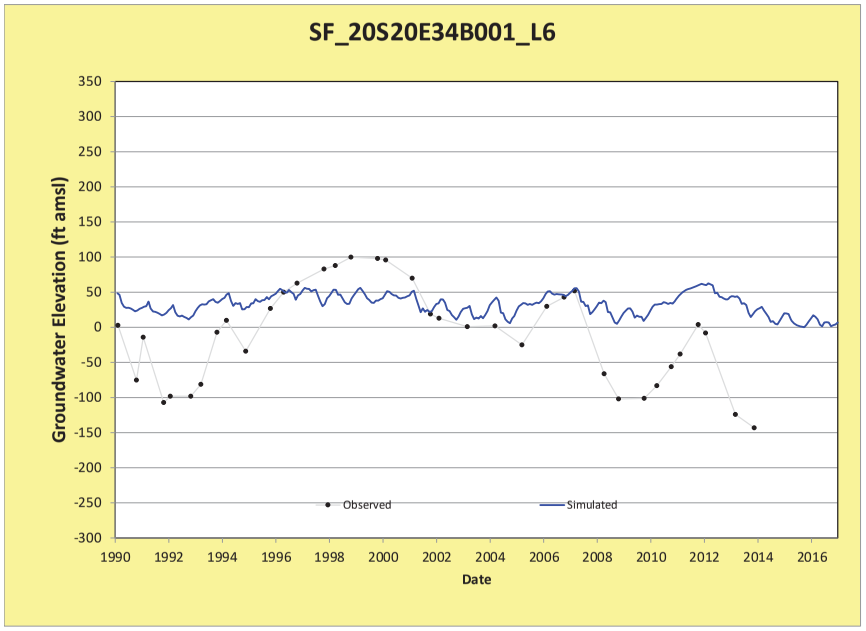

SF_20S19E07D001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

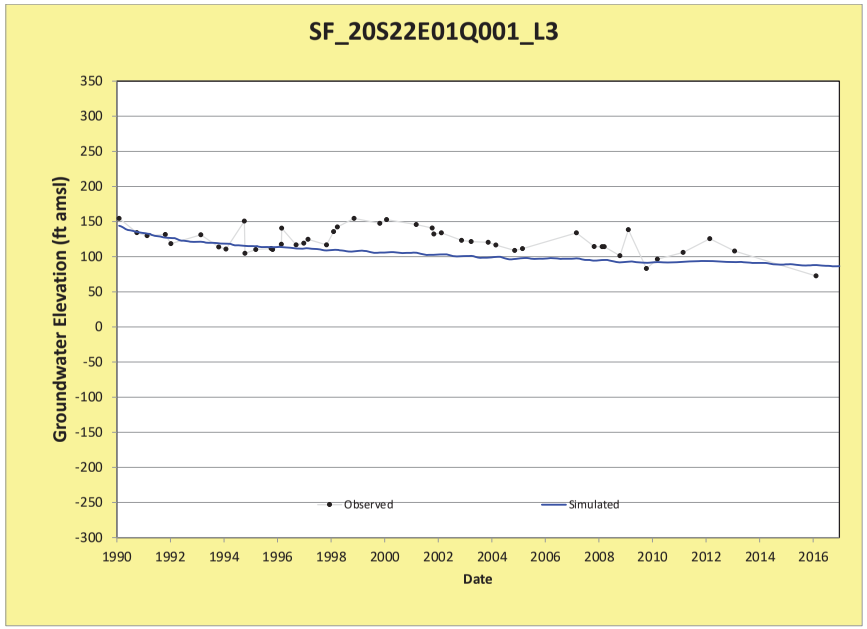

SF_20S19E10N002_L7
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

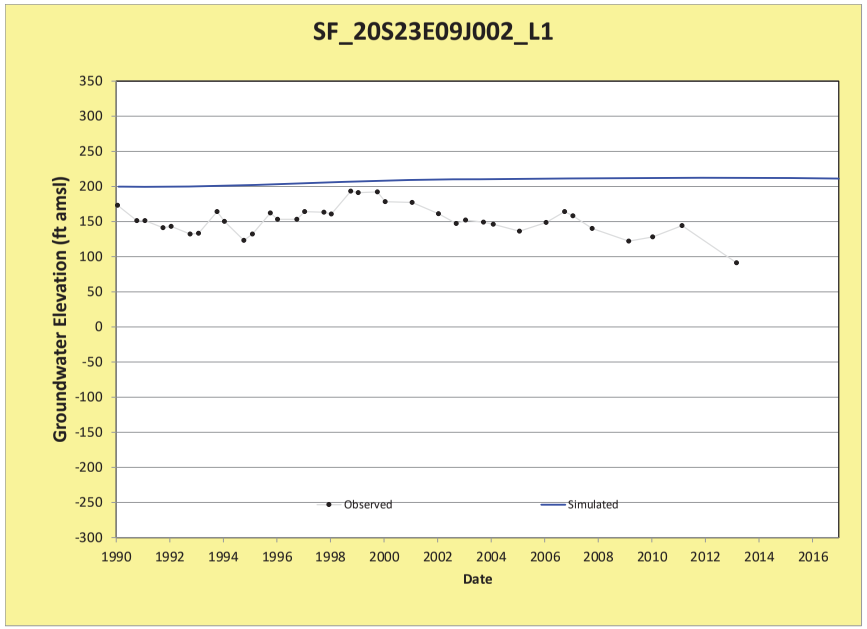

SF_20S19E14H001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

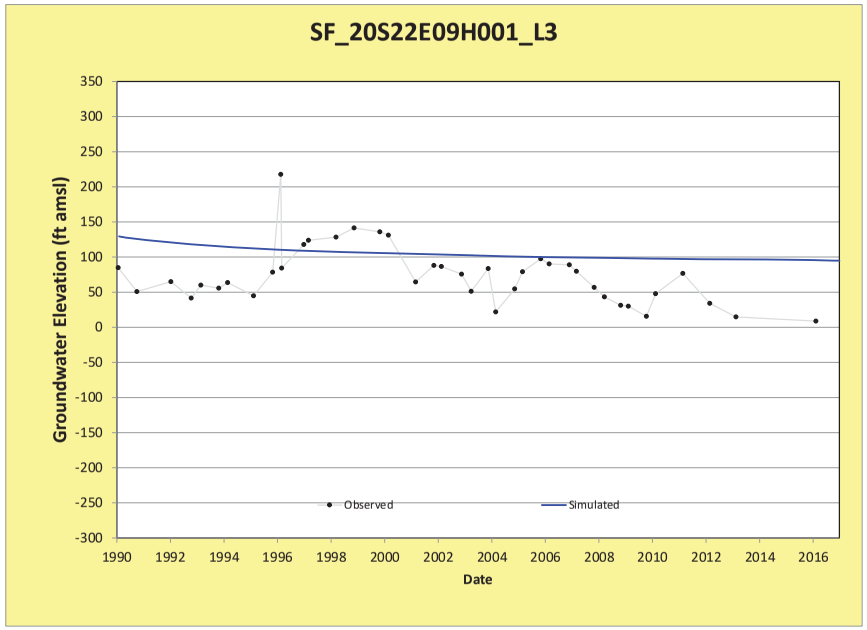

SF_20S20E28E003_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

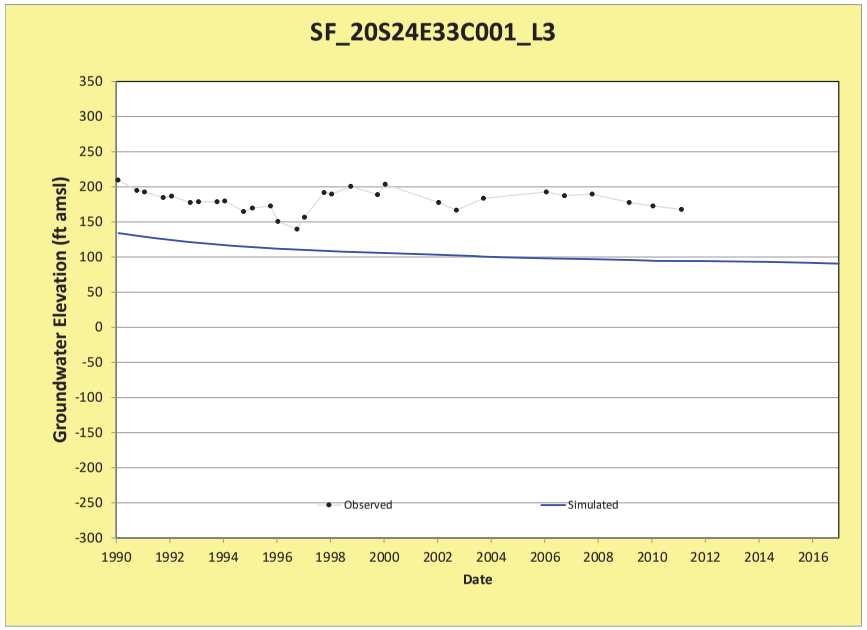

SF_20S19E15E001_L7
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

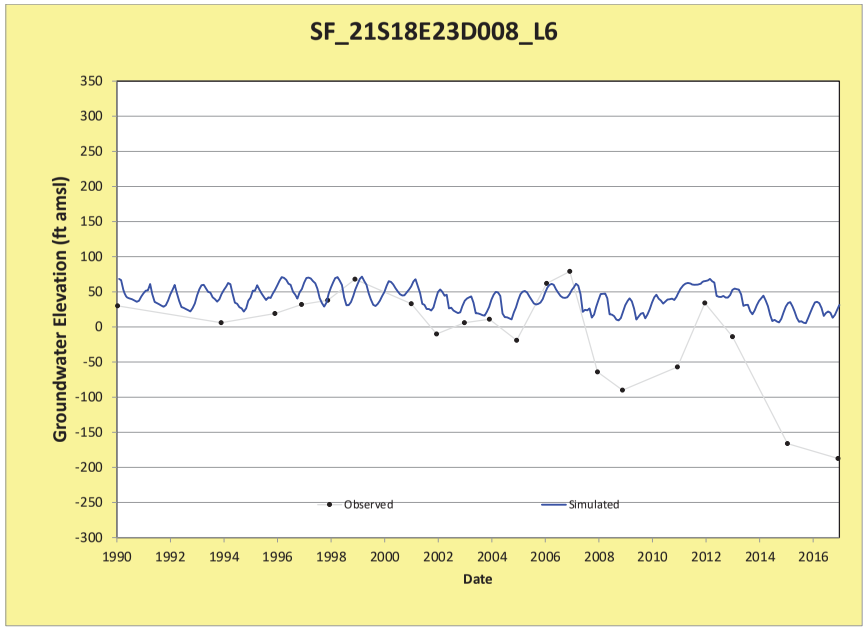

SF_20S20E34B001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

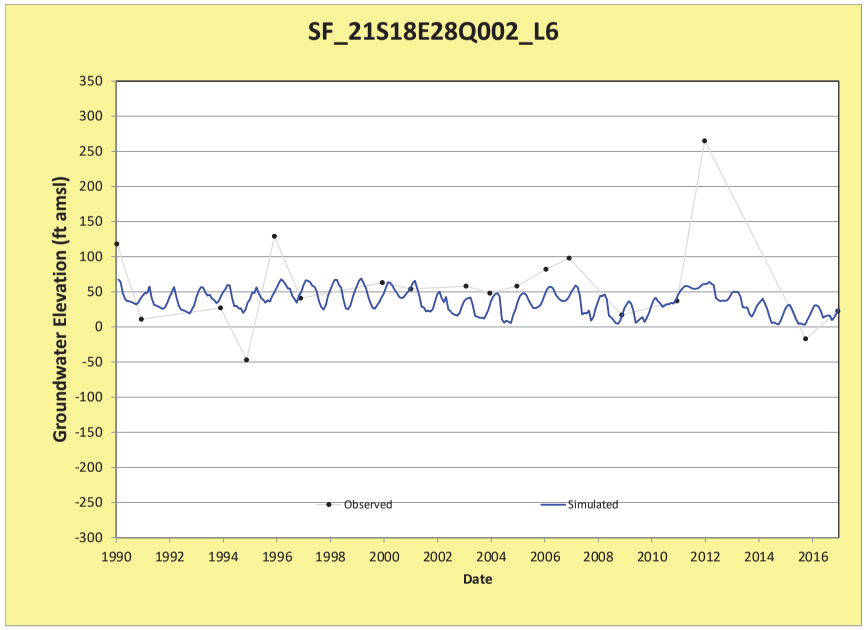

SF_20S22E01Q001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

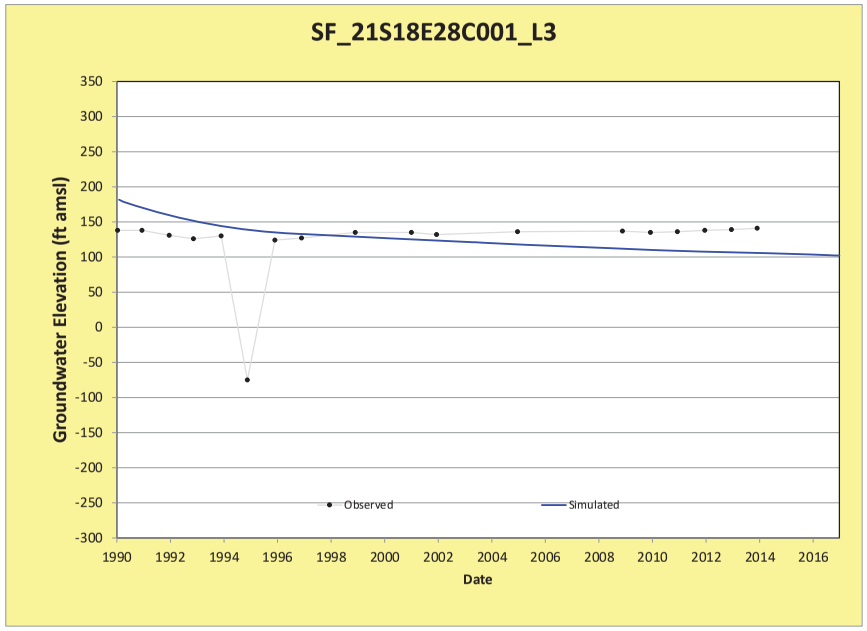

SF_20S23E09J002_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

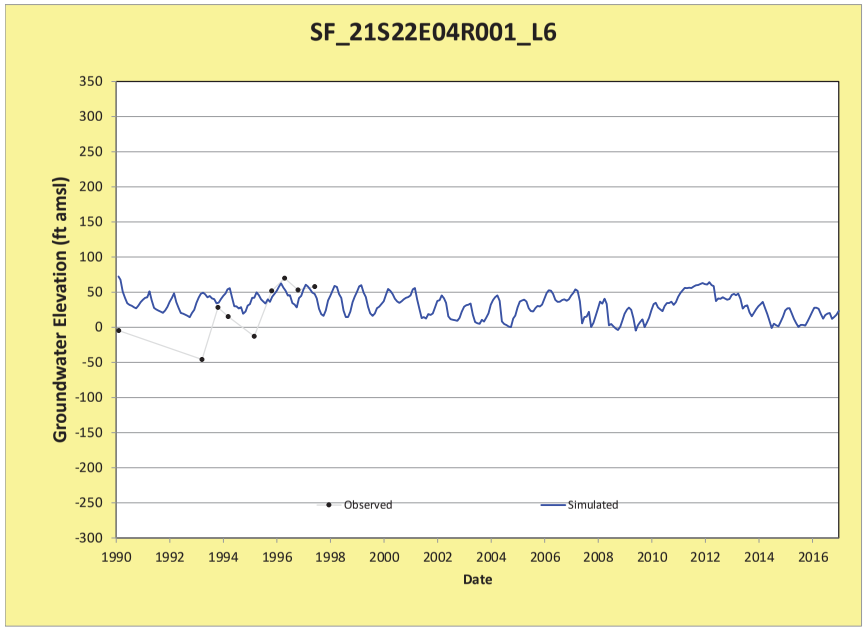

SF_20S22E09H001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

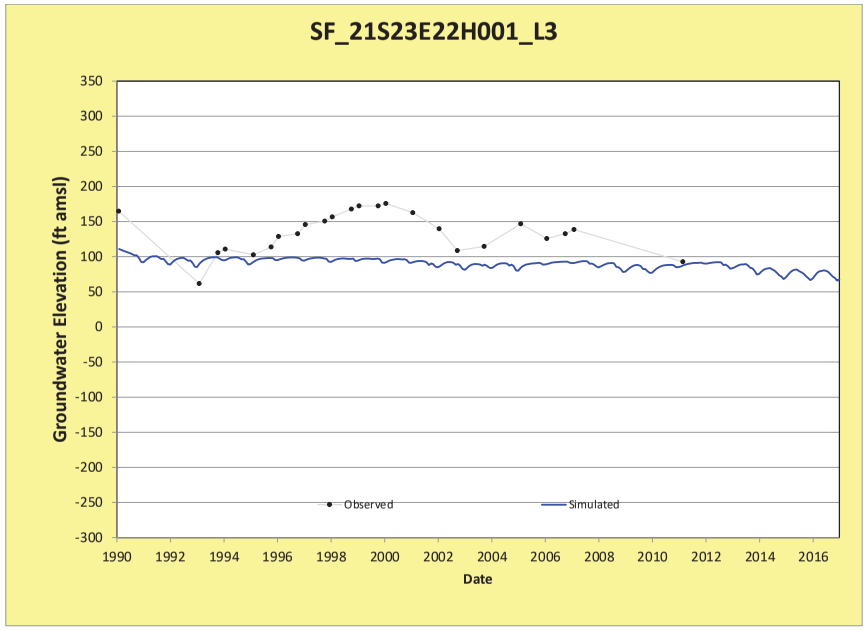

SF_20S24E33C001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

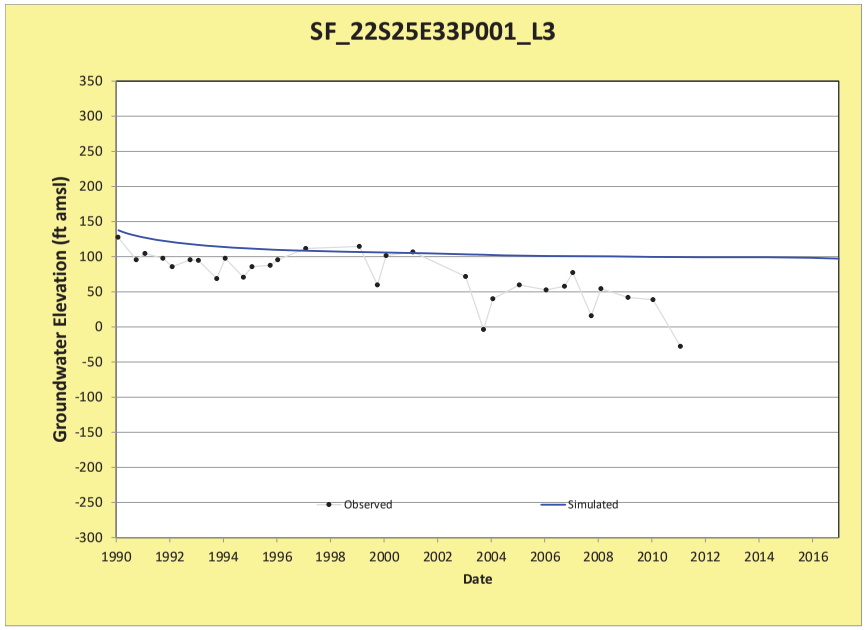

SF_21S18E23D008_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

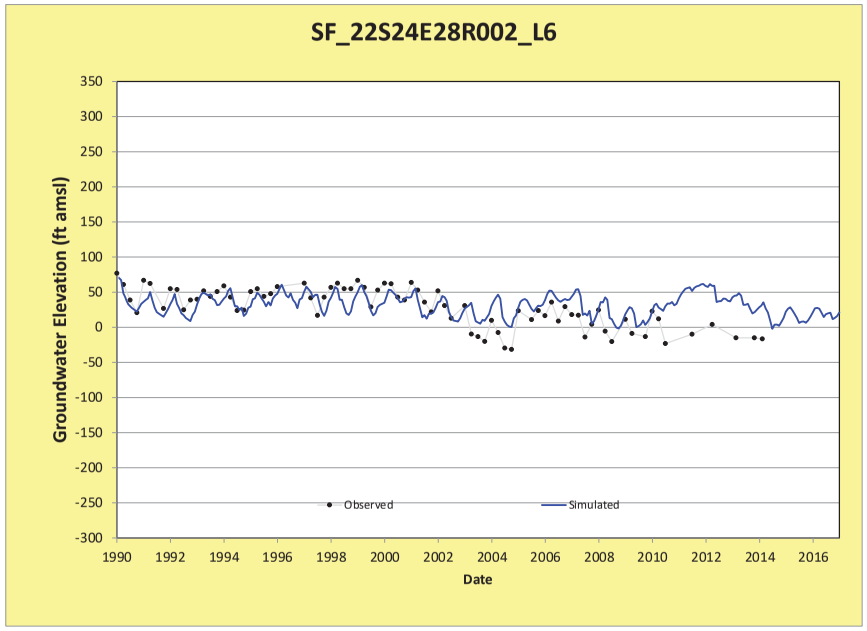

SF_21S18E28Q002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

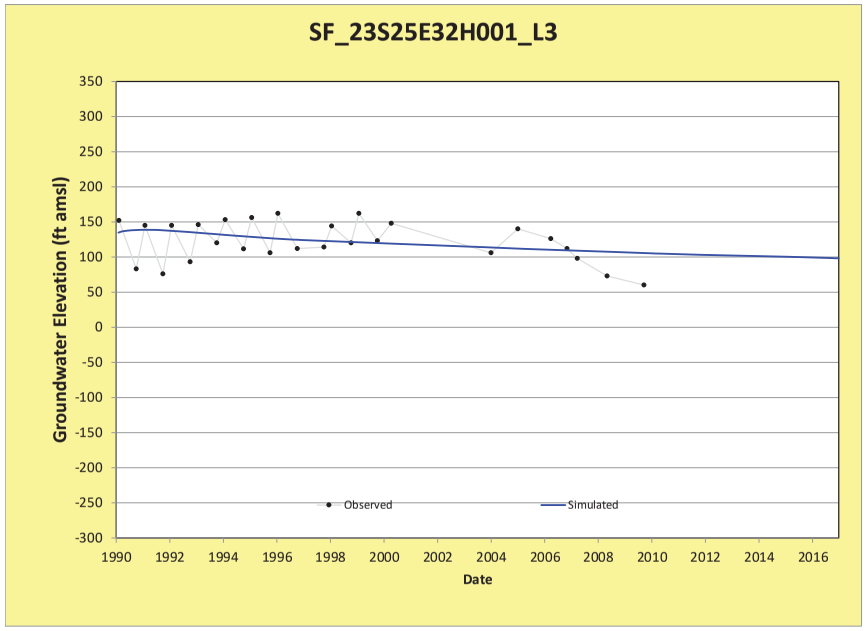

SF_21S18E28C001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

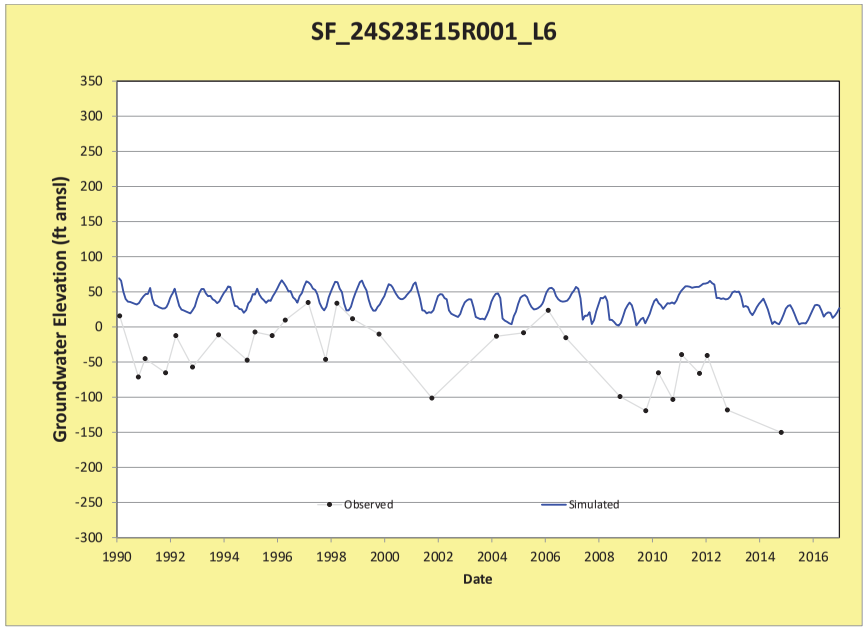

SF_21S22E04R001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

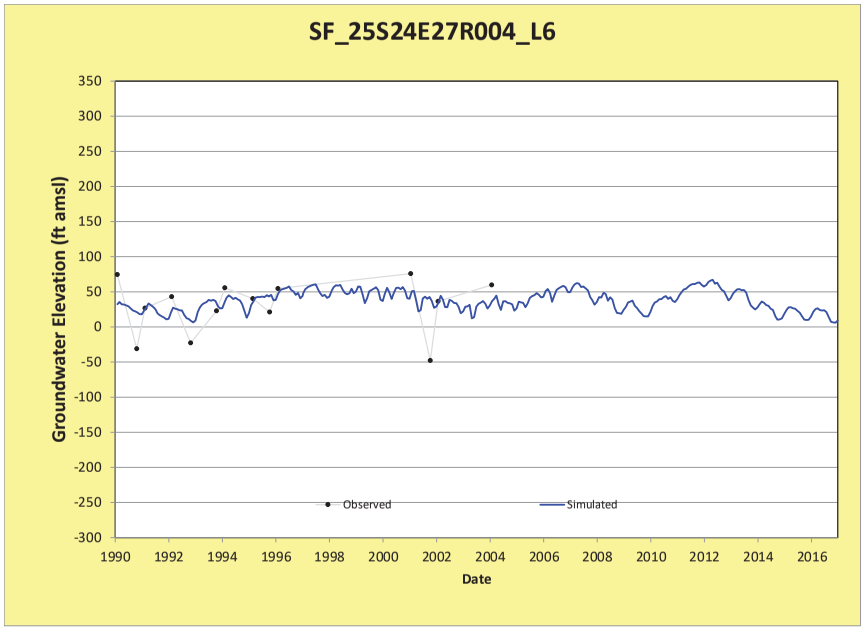

SF_21S23E22H001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

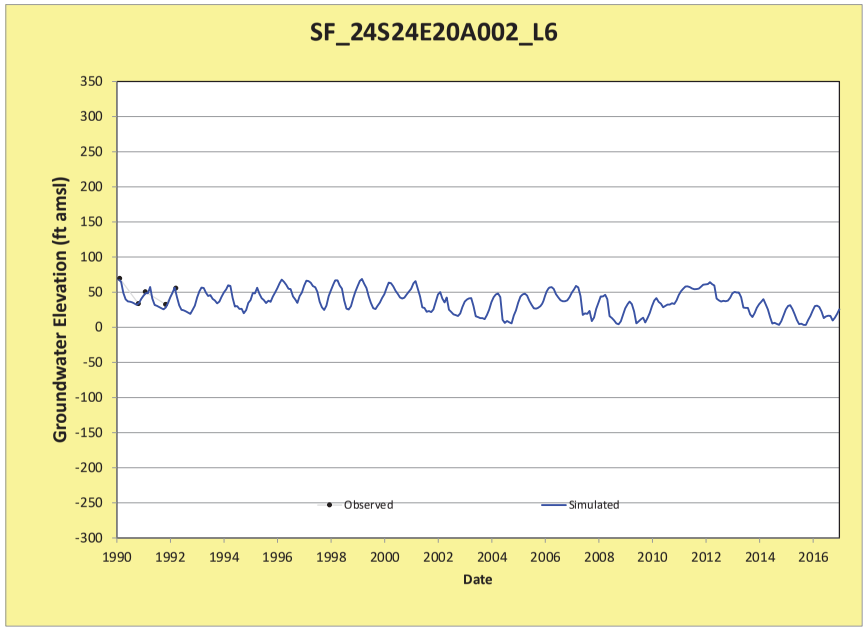

SF_22S25E33P001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

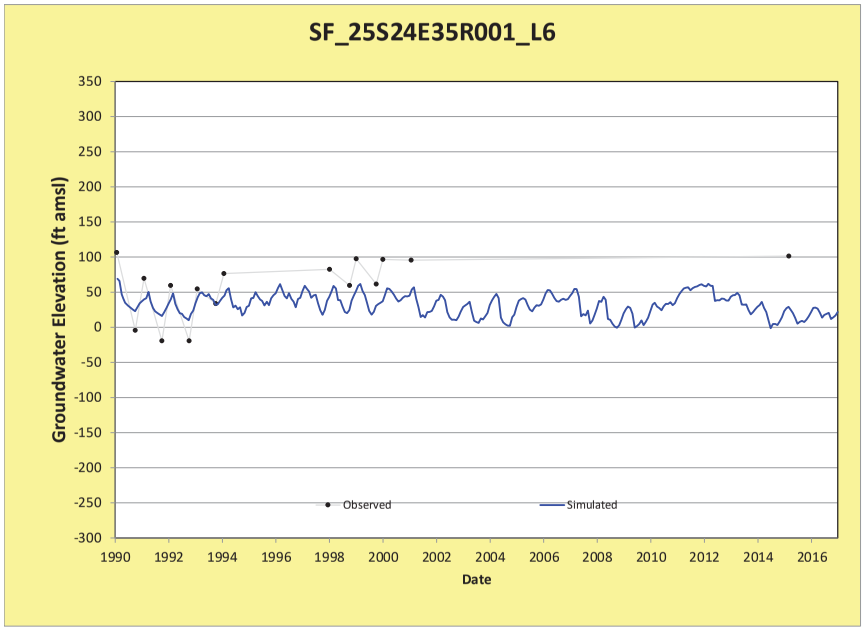

SF_22S24E28R002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

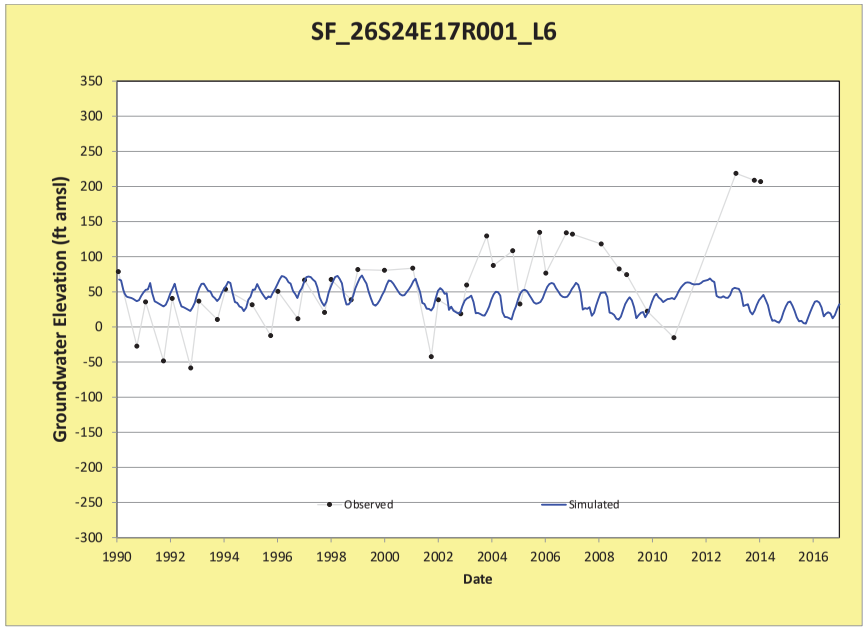

SF_23S25E32H001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

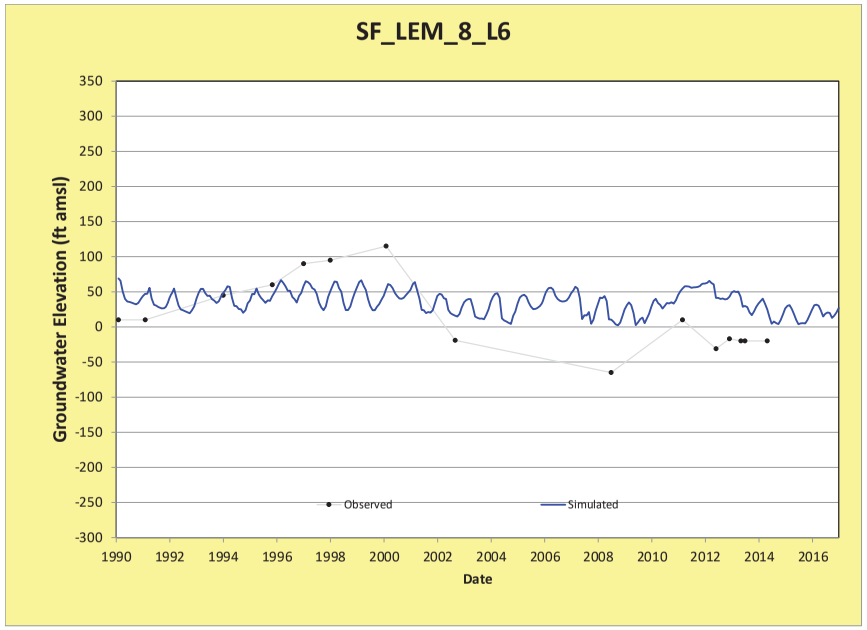

SF_24S23E15R001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

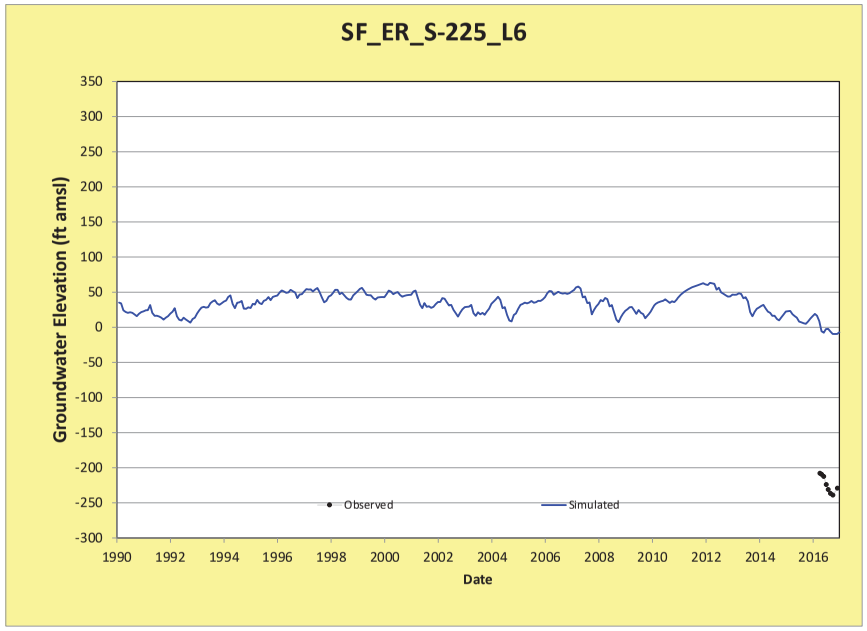

SF_25S24E27R004_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated


SF_24S24E20A002_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

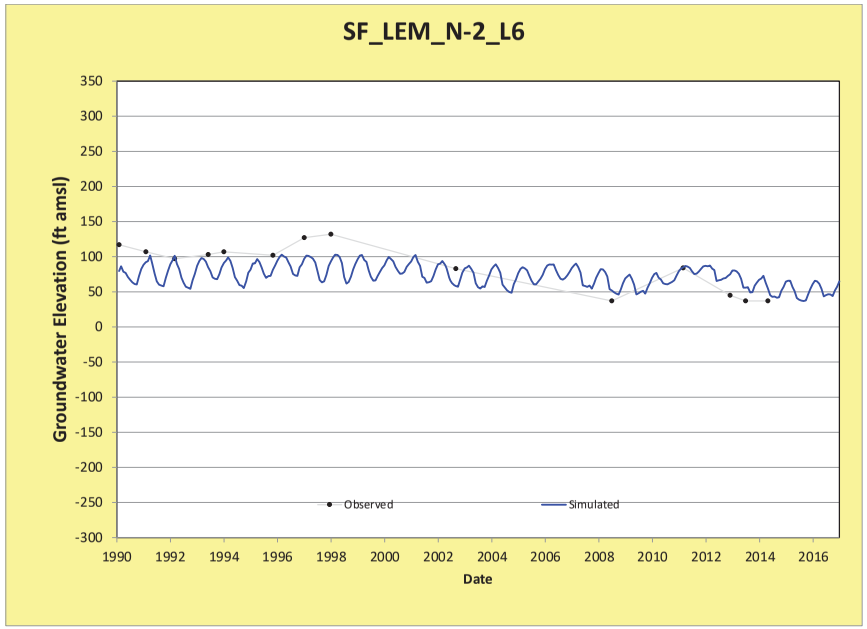

SF_25S24E35R001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

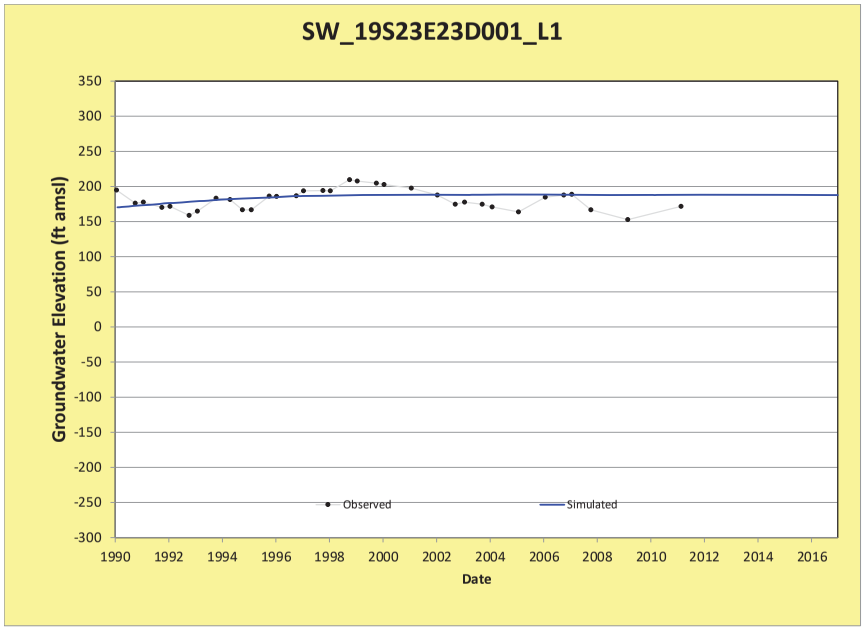

SF_26S24E17R001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

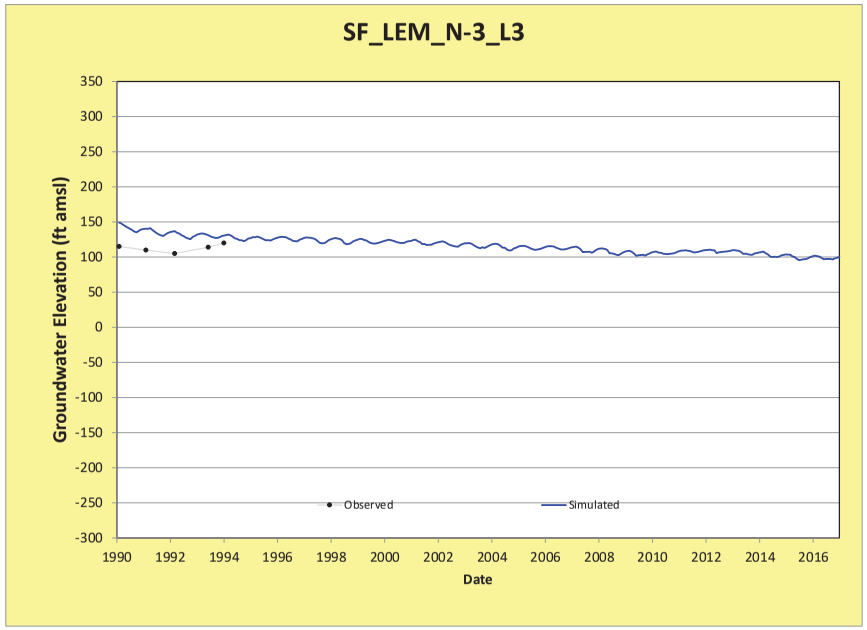

SF_LEM_8_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

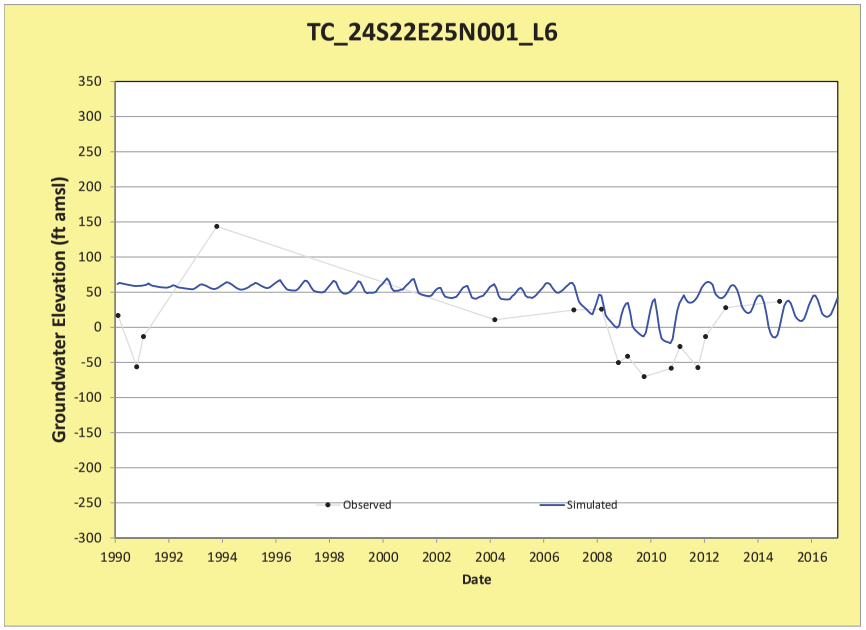

SF_ER_S-225_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

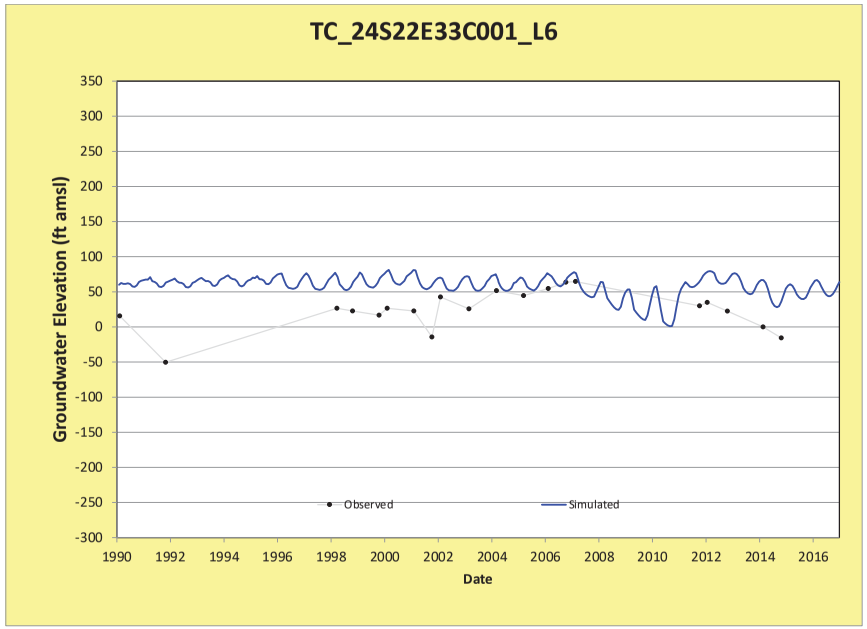

SF_LEM_N-1_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

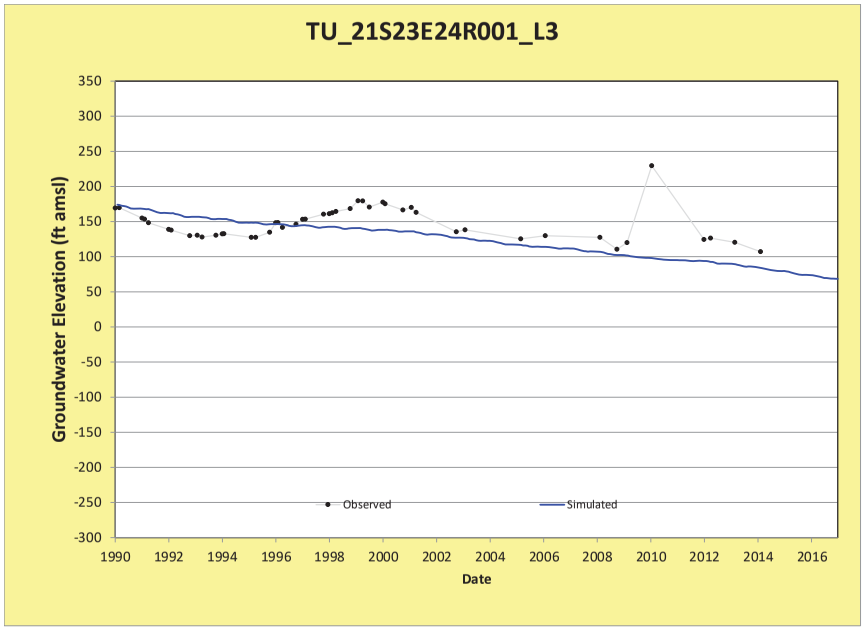

SF_LEM_N-2_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

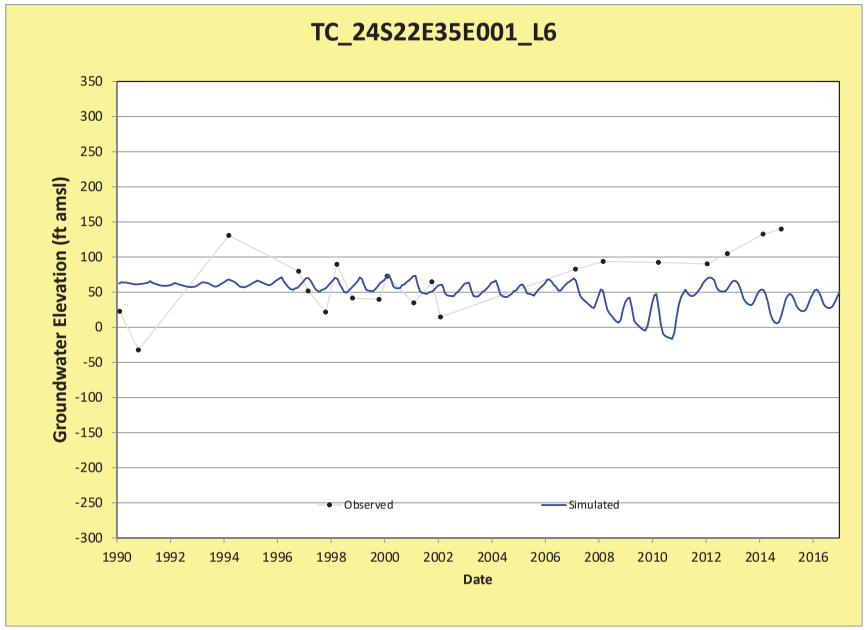

SW_19S23E23D001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

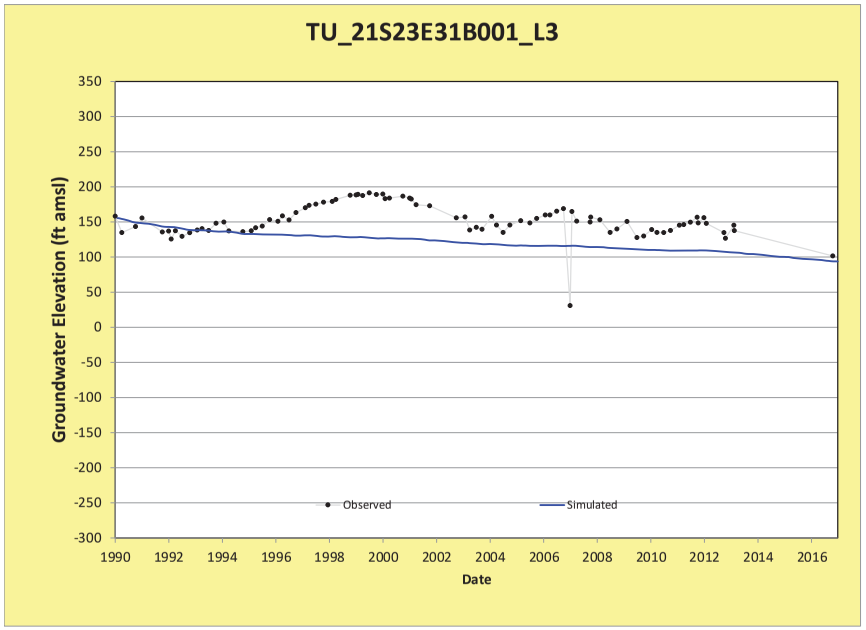

SF_LEM_N-3_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

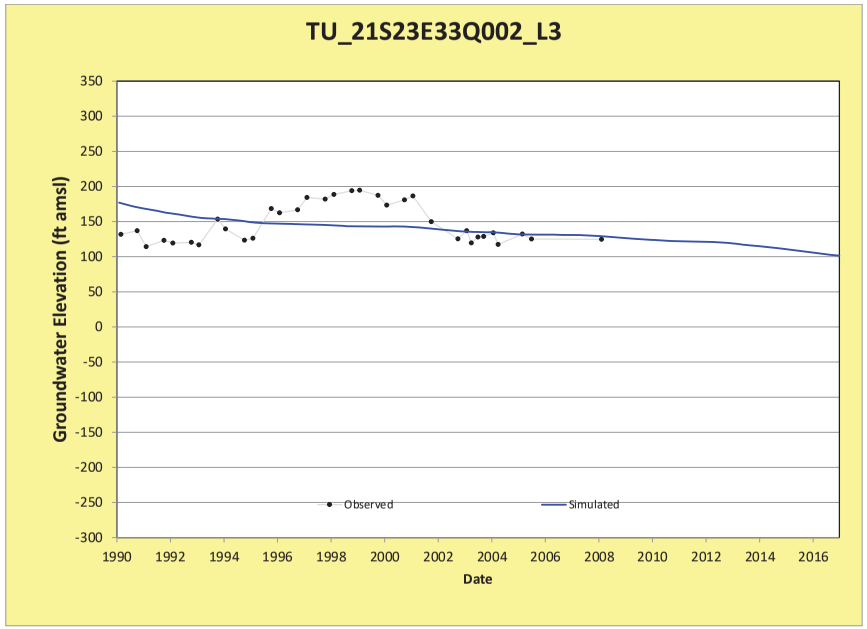

TC_24S22E25N001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

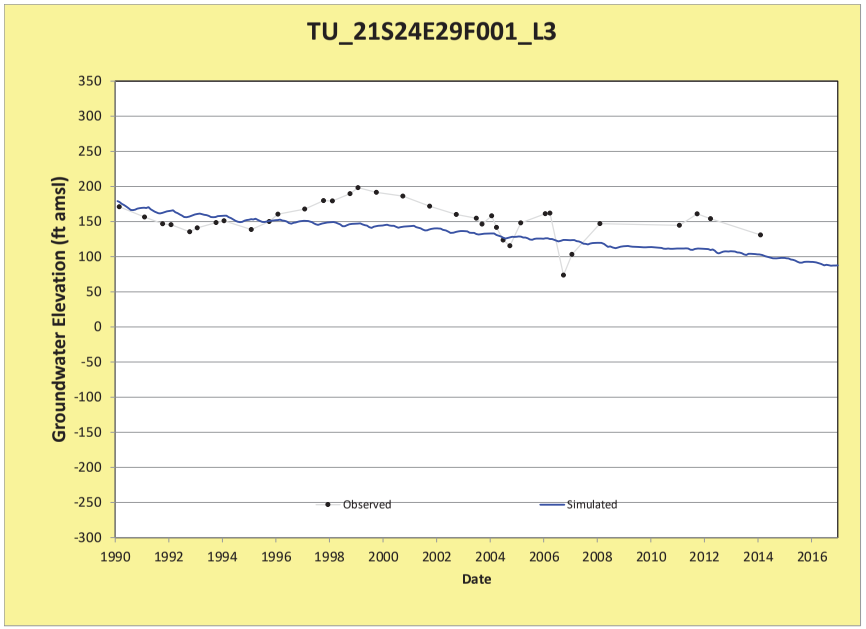

TC_24S22E33C001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

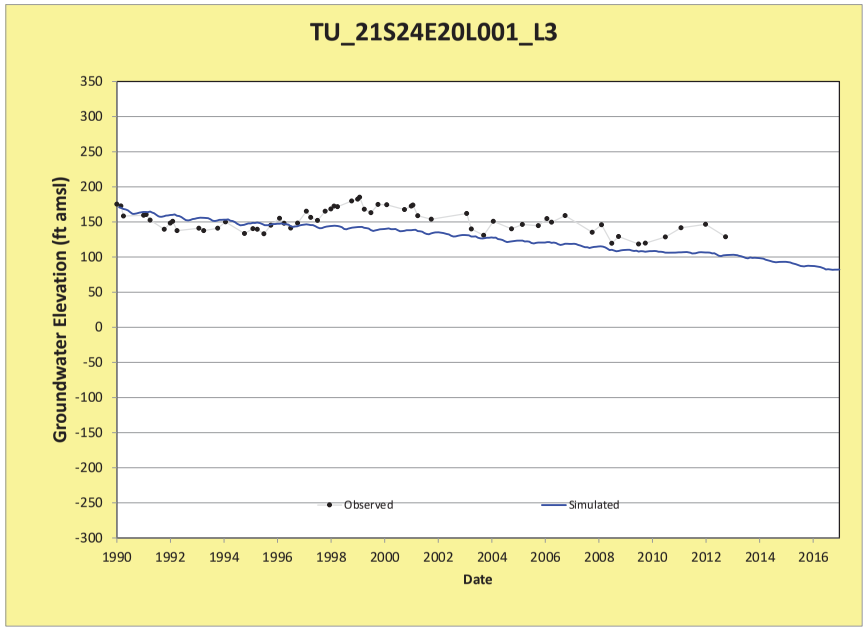

TU_21S23E24R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

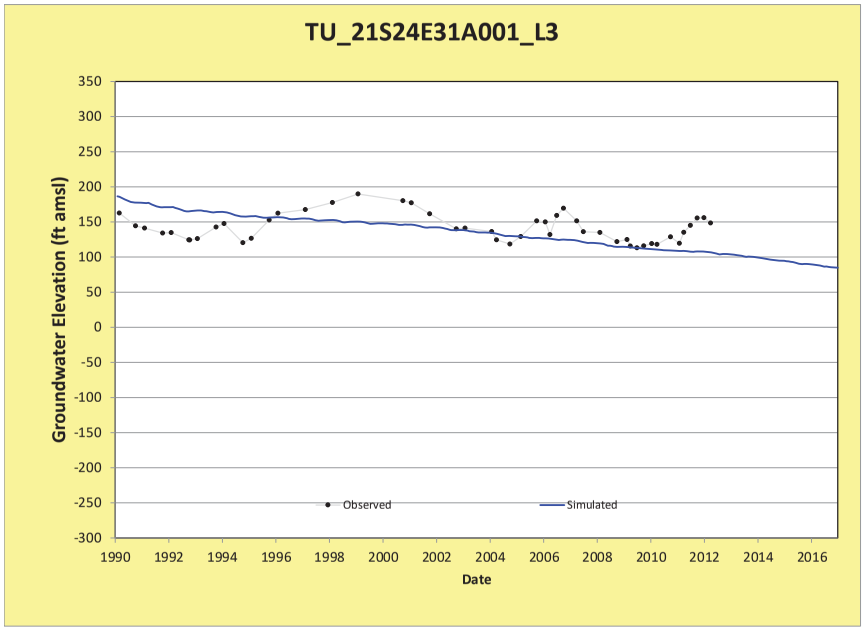

TC_24S22E35E001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

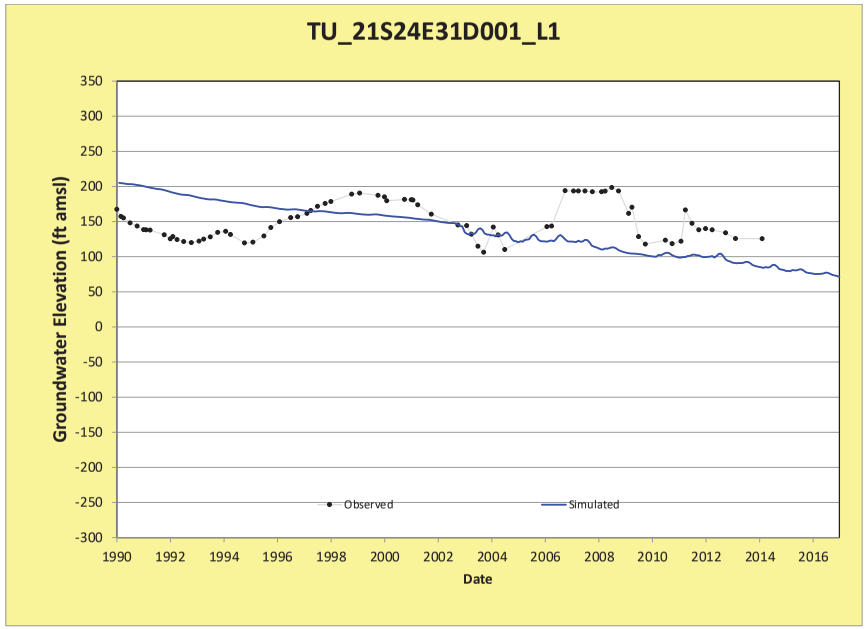

TU_21S23E31B001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

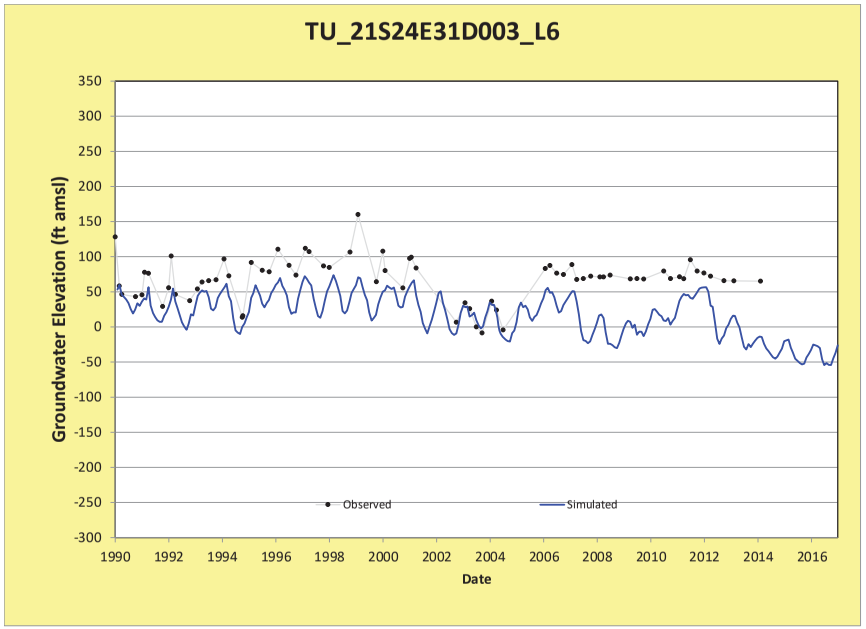

TU_21S23E33Q002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

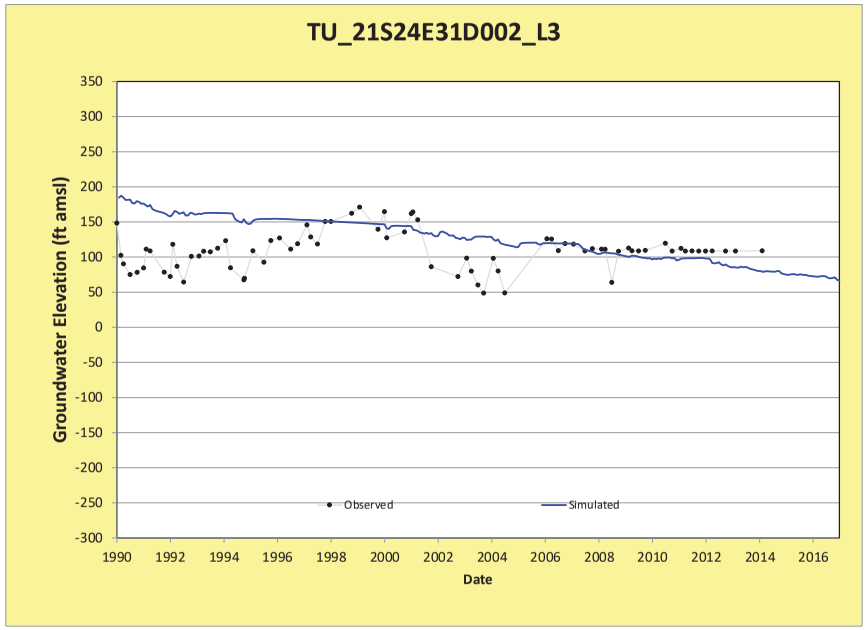

TU_21S24E29F001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

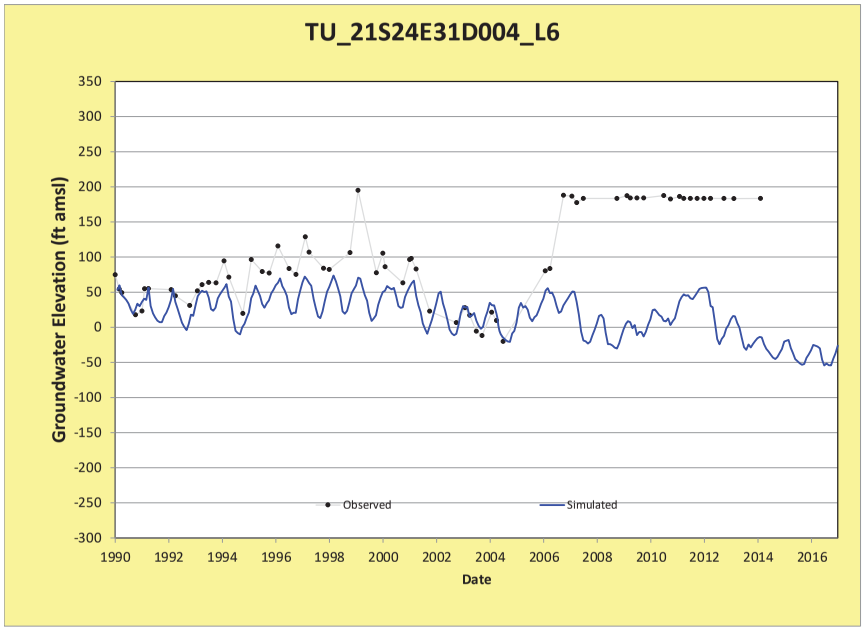

TU_21S24E20L001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

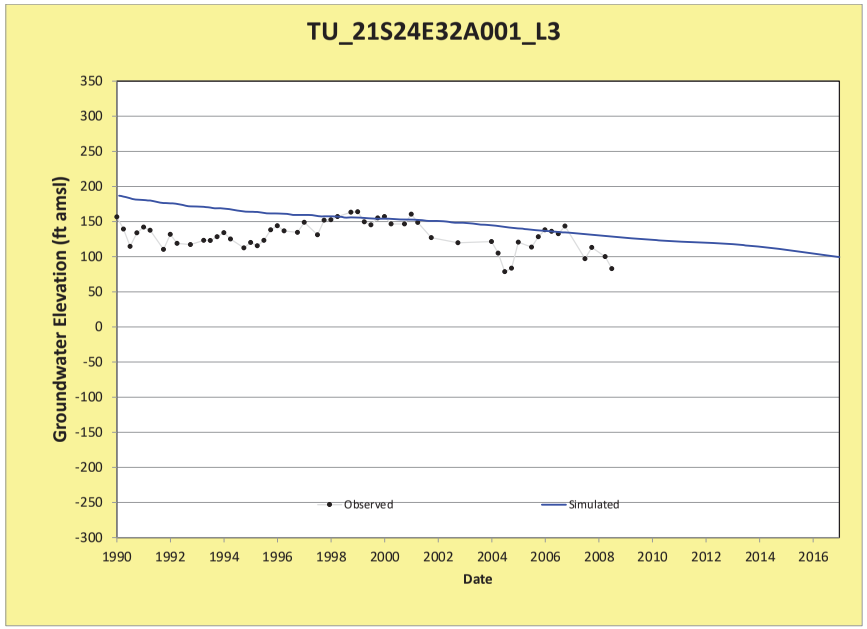

TU_21S24E31A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

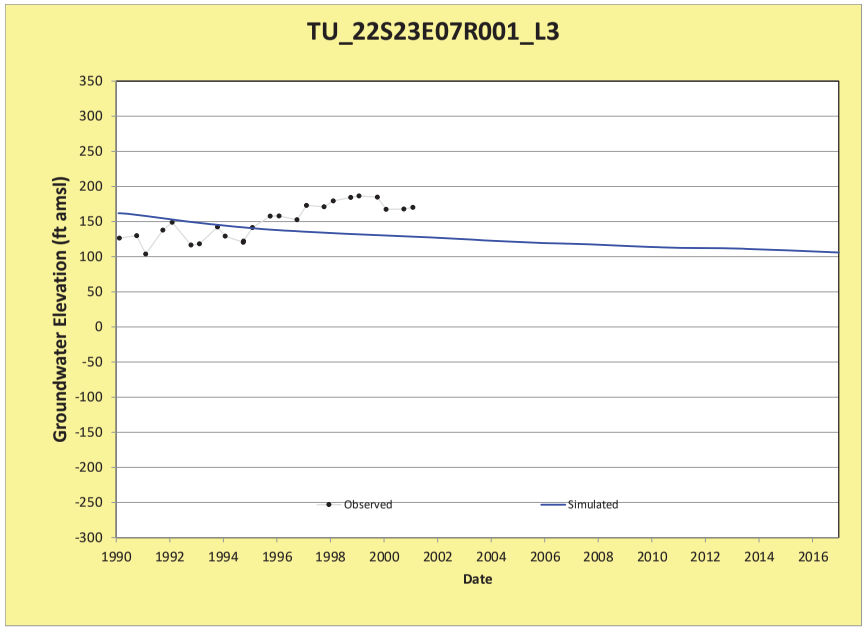

TU_21S24E31D001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

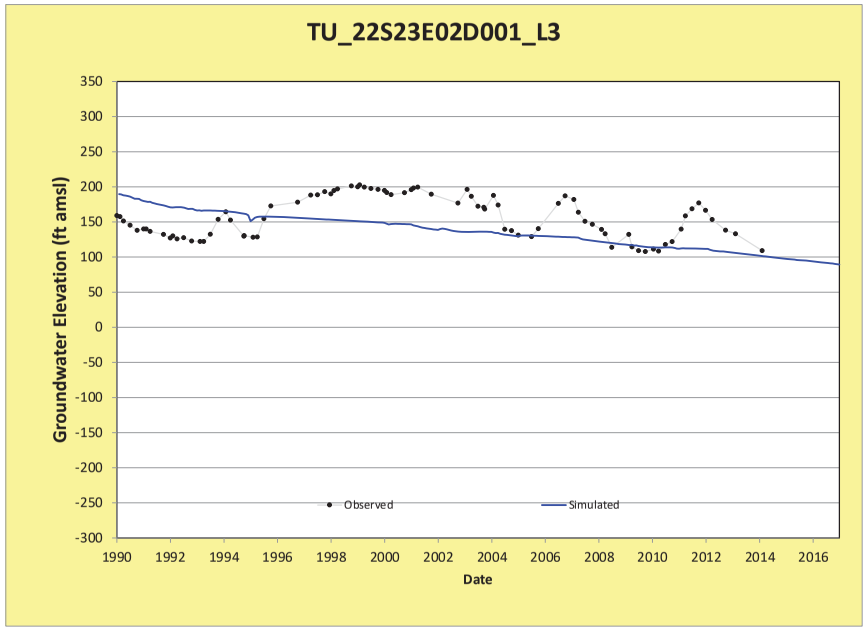

TU_21S24E31D003_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

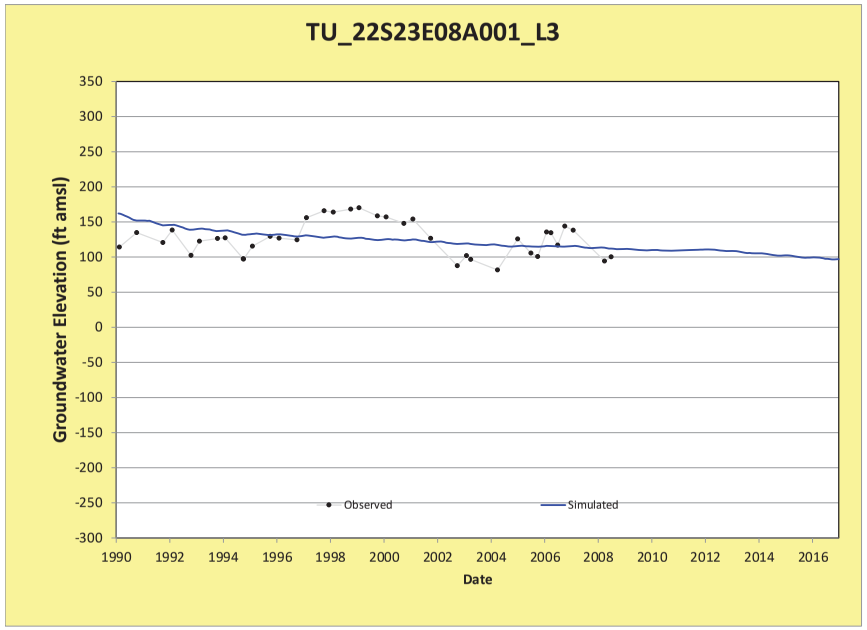

TU_21S24E31D002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

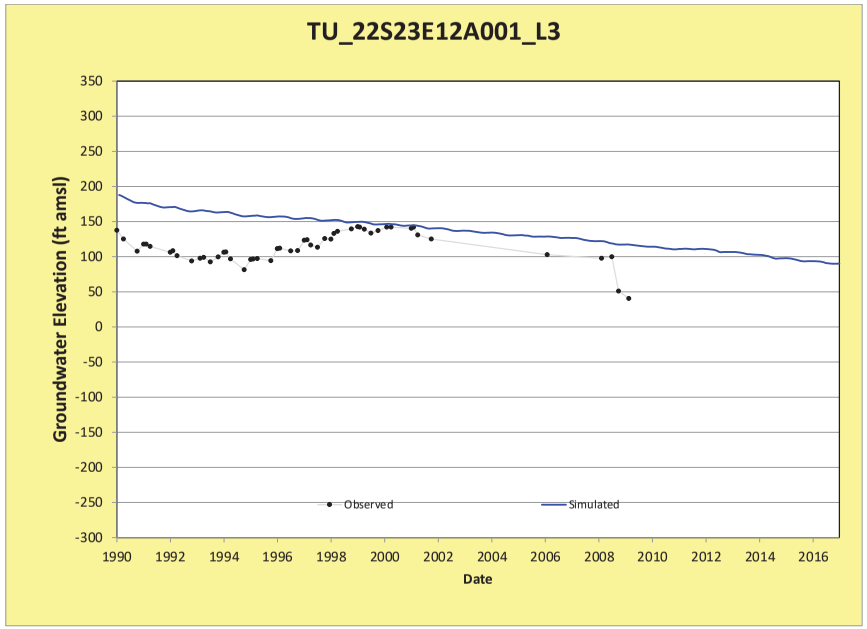

TU_21S24E31D004_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

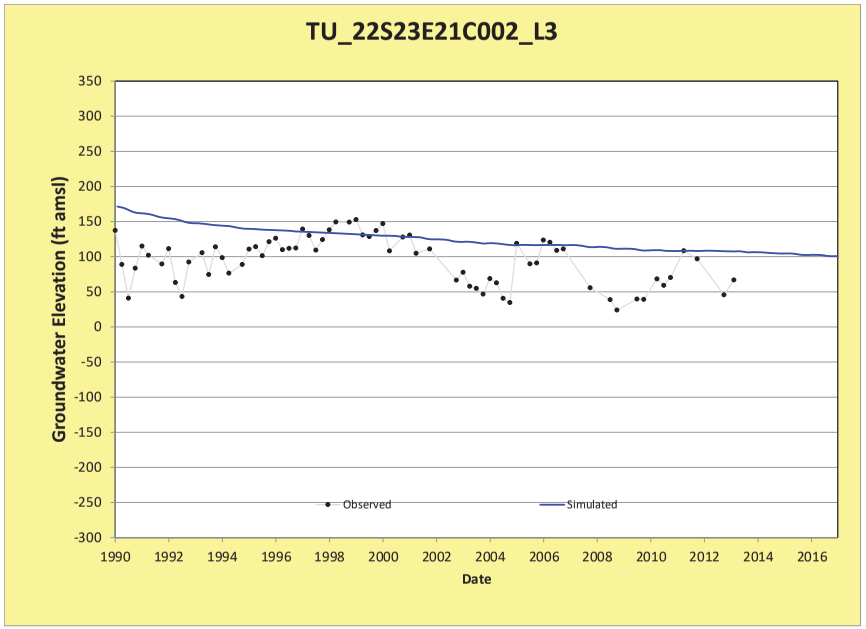

TU_21S24E32A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

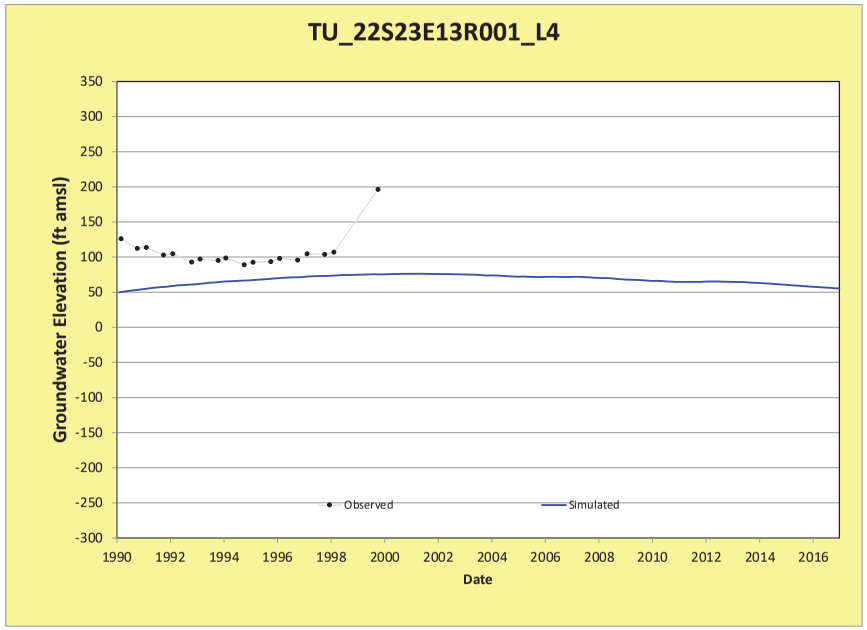

TU_22S23E07R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

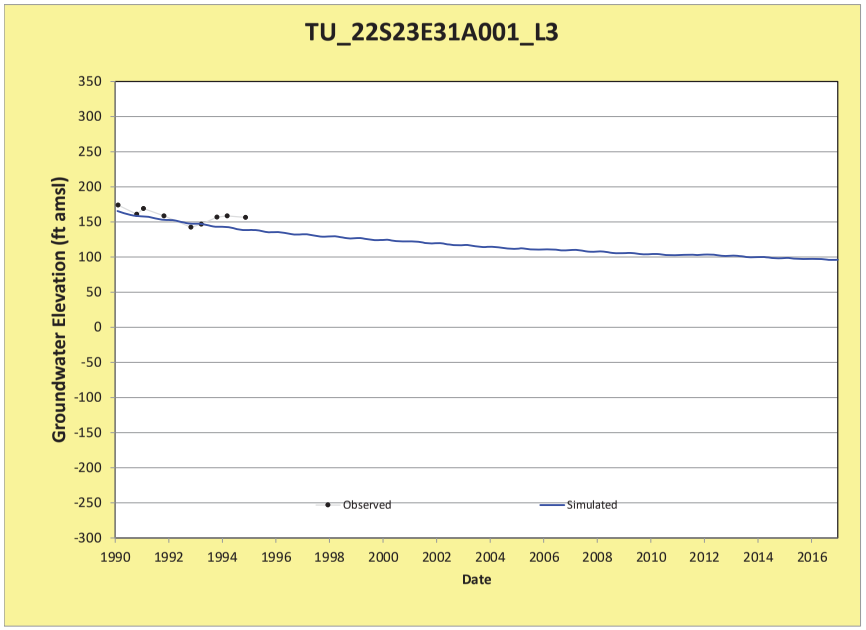

TU_22S23E02D001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

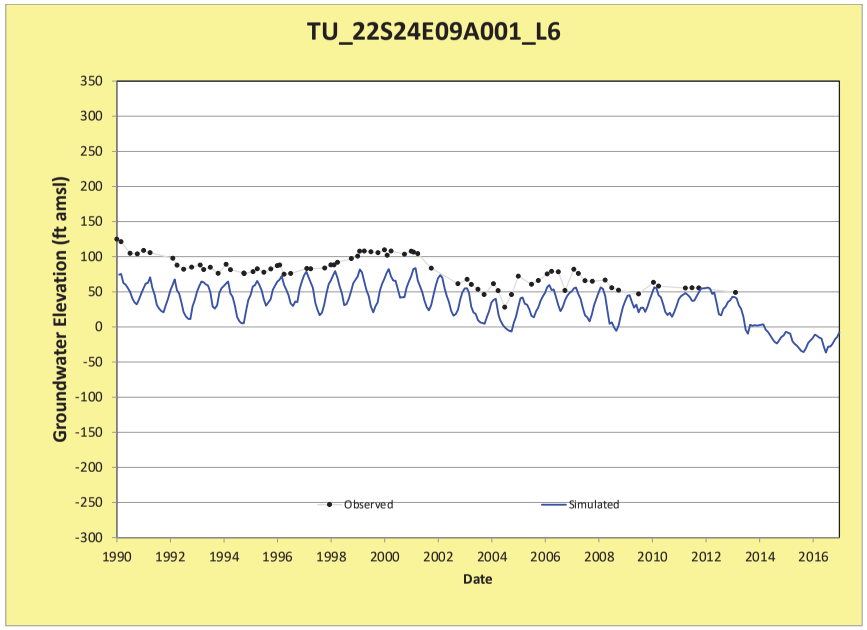

TU_22S23E08A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

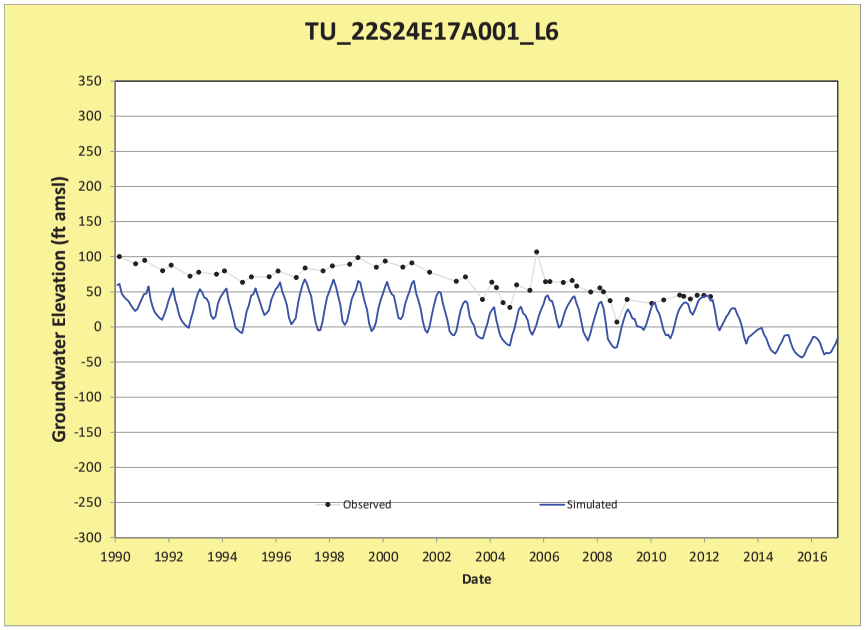

TU_22S23E12A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

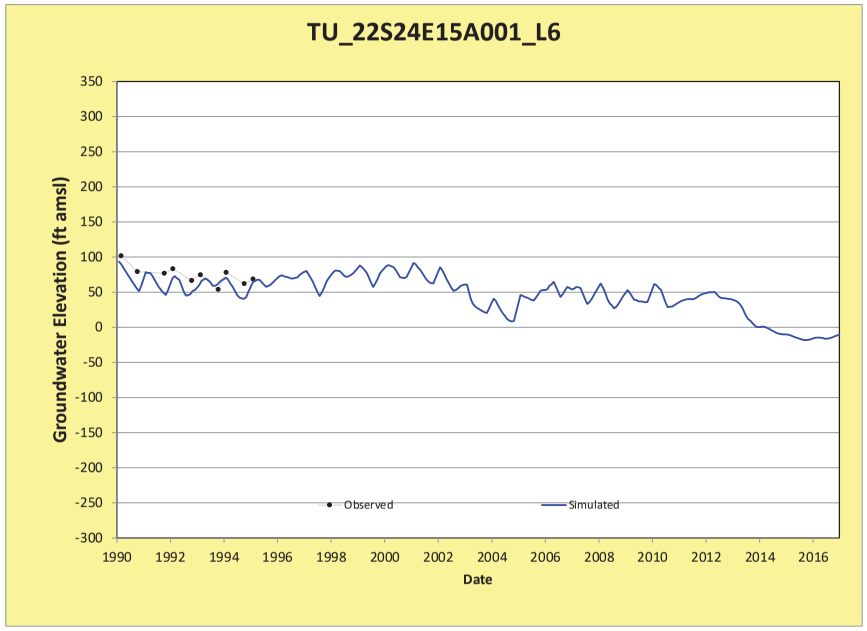

TU_22S23E21C002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

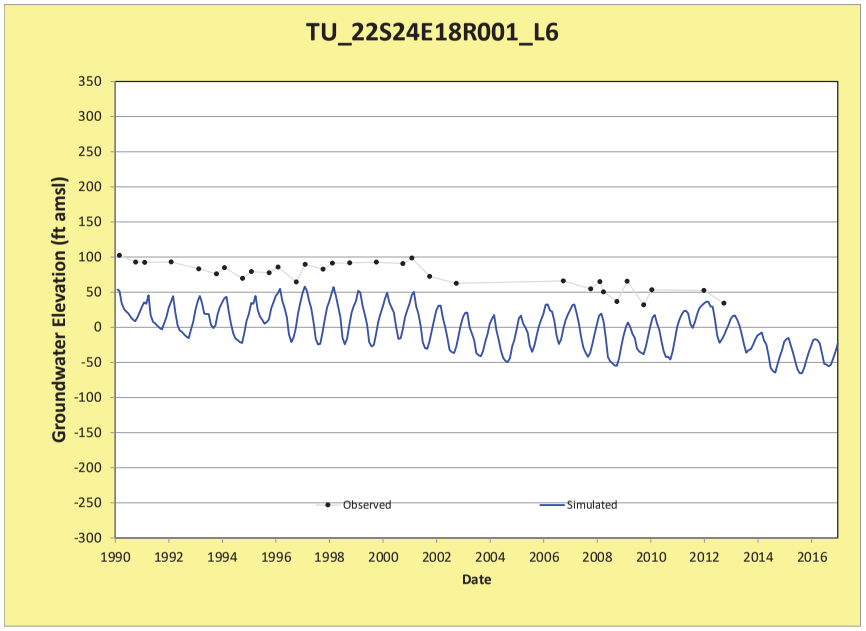

TU_22S23E13R001_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

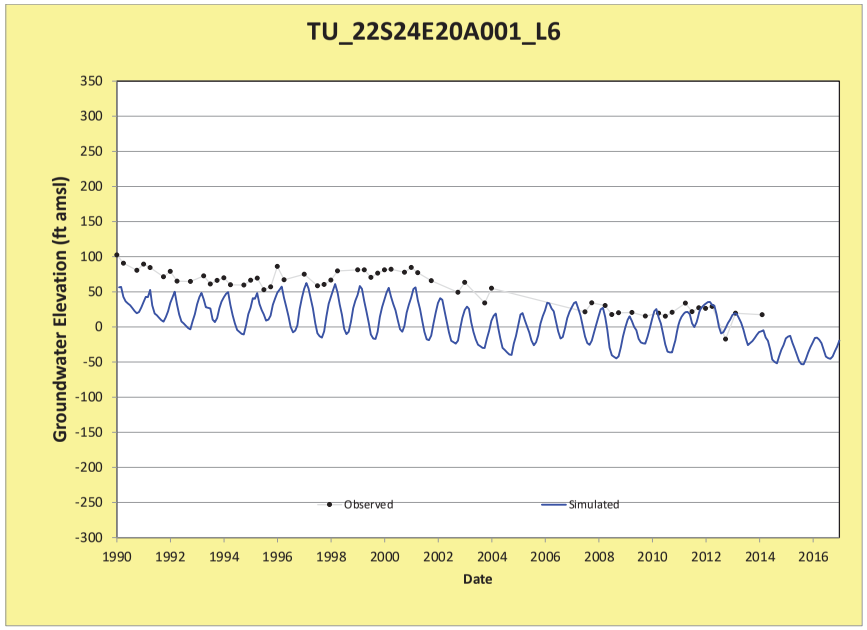

TU_22S23E31A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

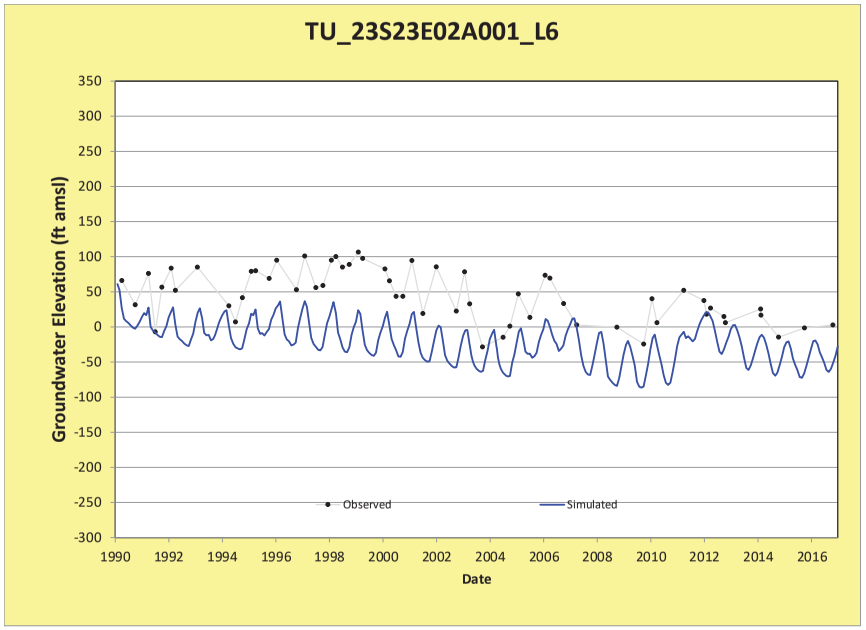

TU_22S24E09A001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

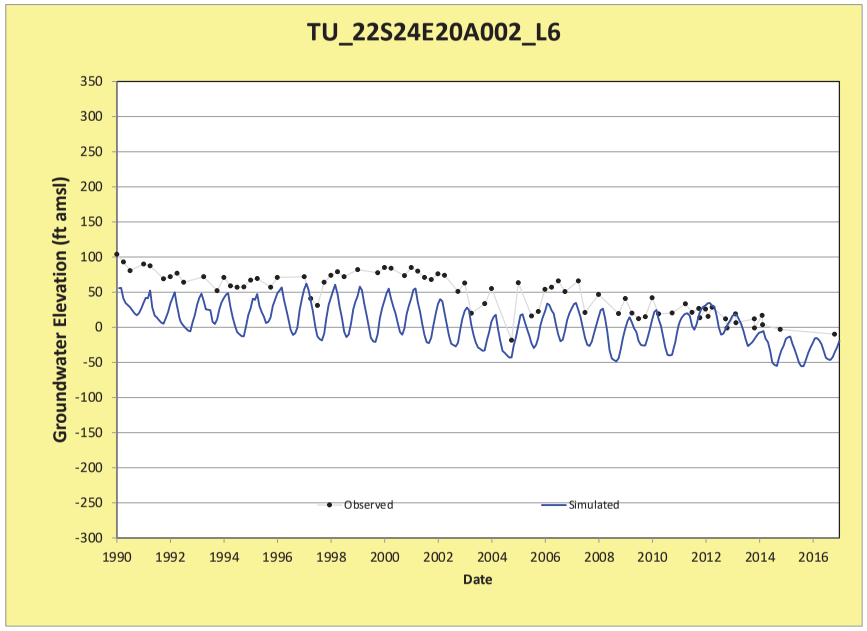

TU_22S24E17A001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

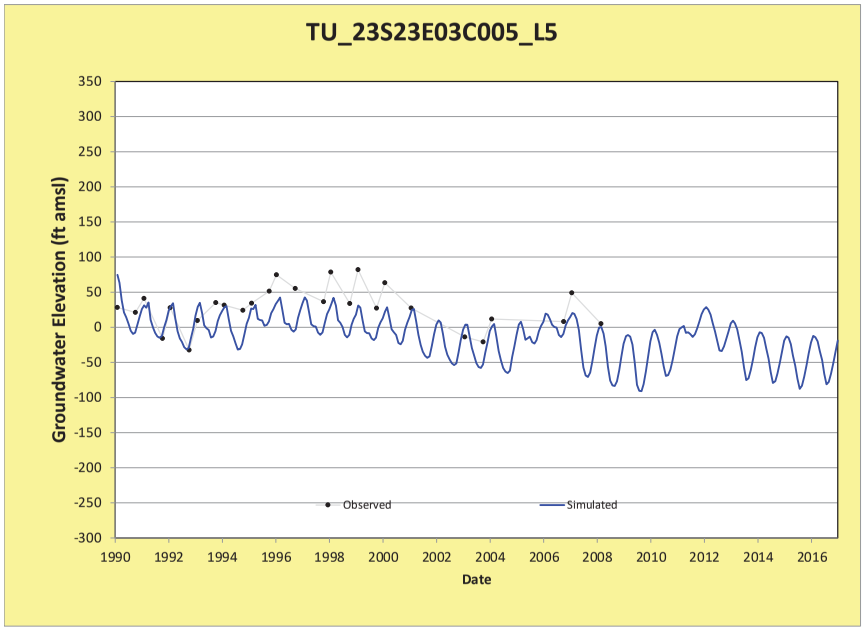

TU_22S24E15A001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

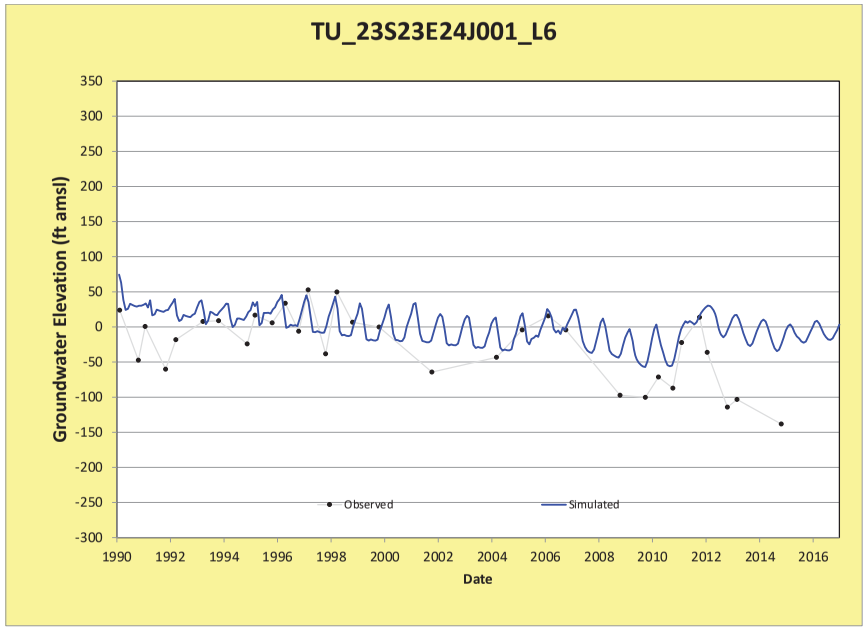

TU_22S24E18R001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

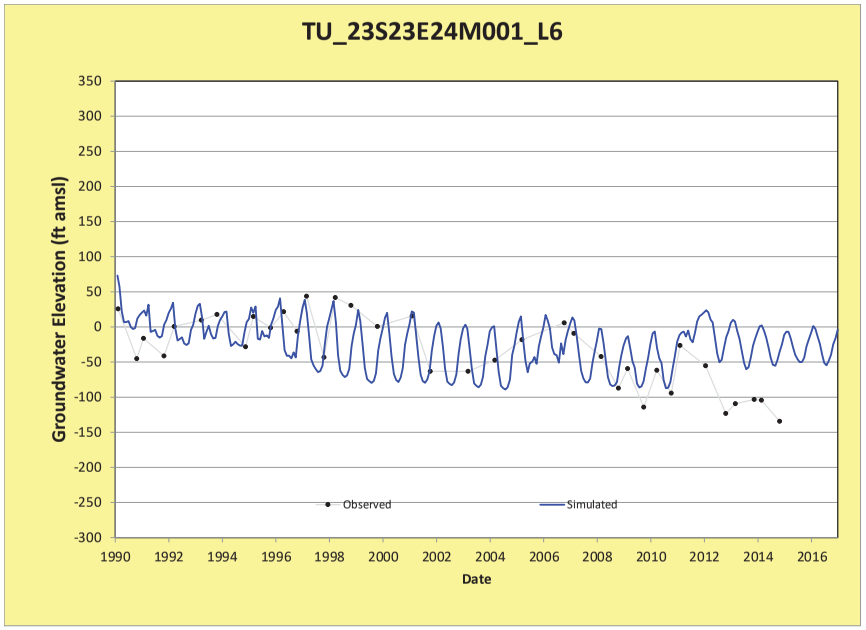

TU_22S24E20A001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

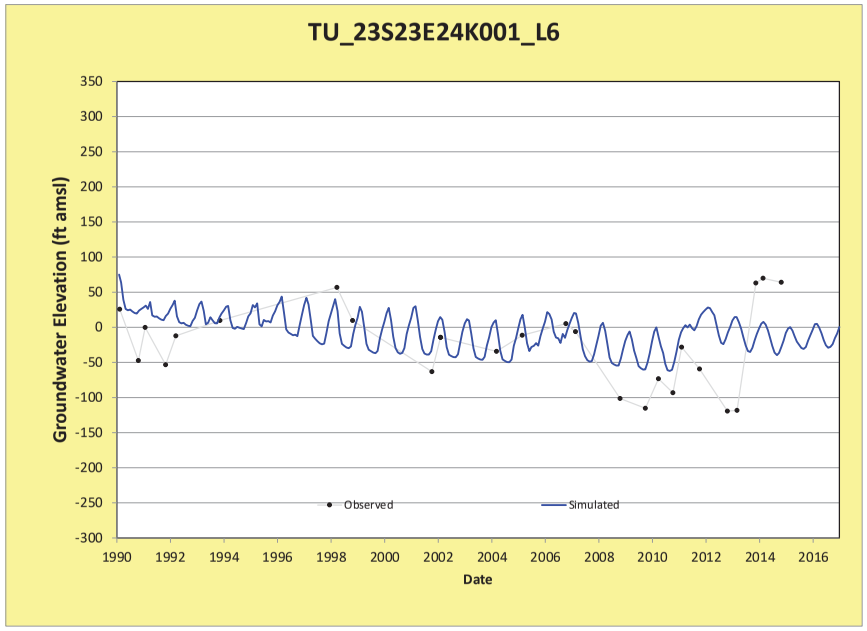

TU_23S23E02A001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

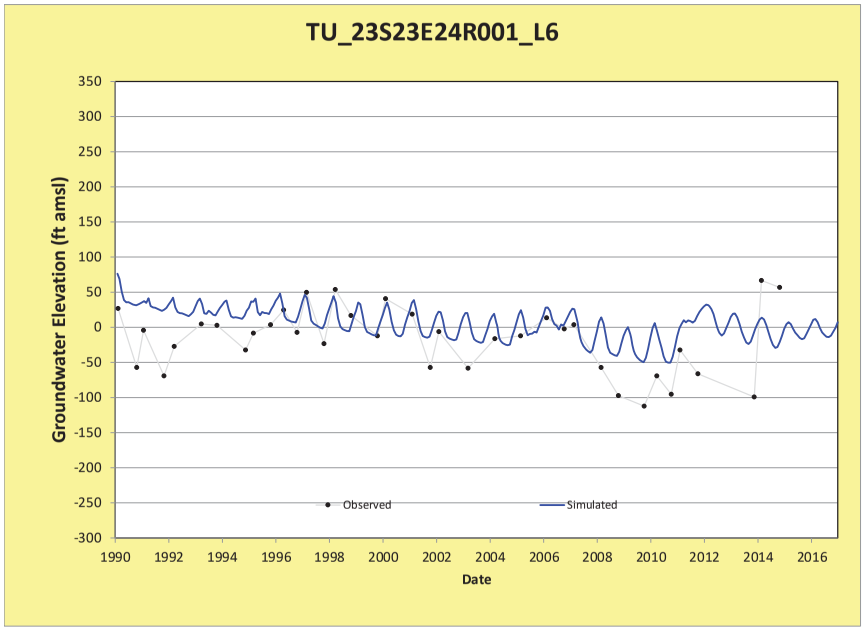

TU_22S24E20A002_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

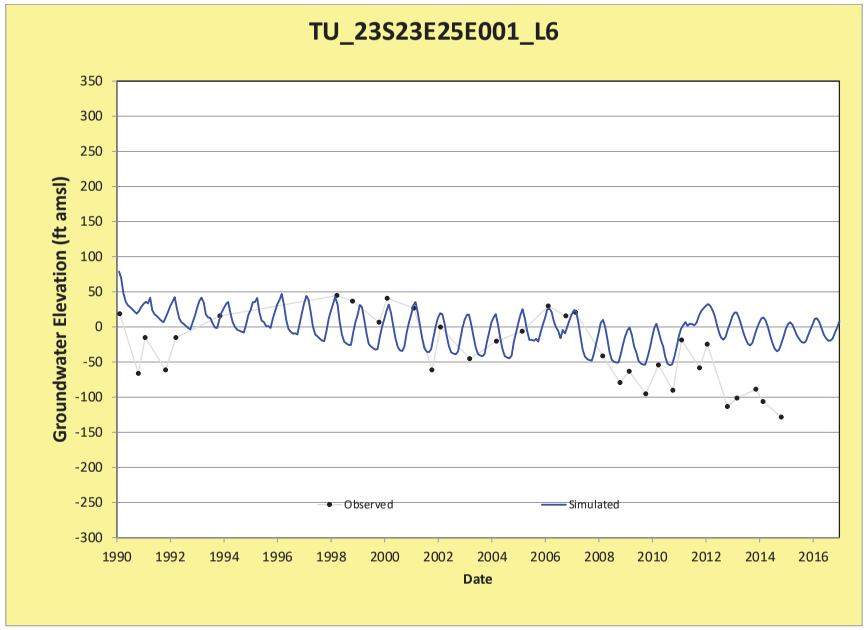

TU_23S23E03C005_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

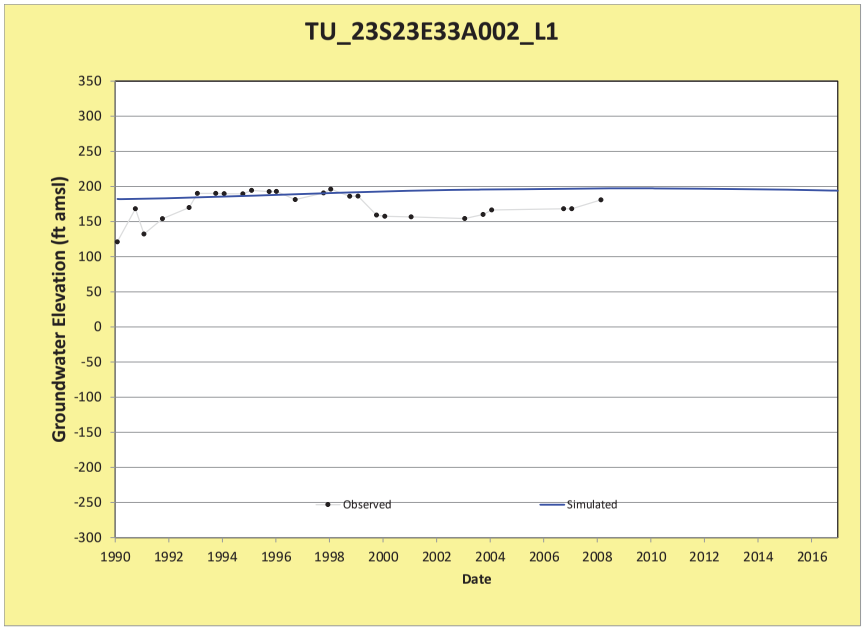

TU_23S23E24J001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

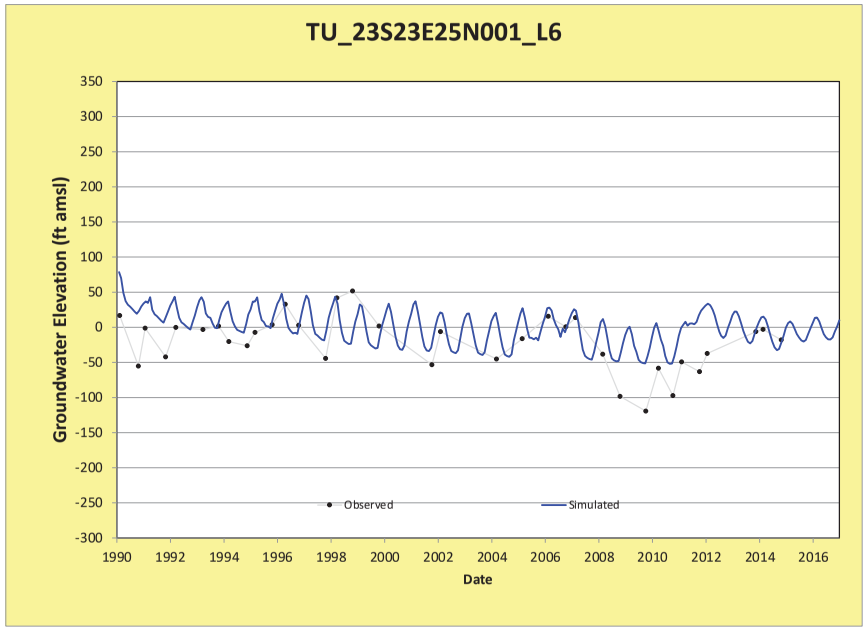

TU_23S23E24M001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

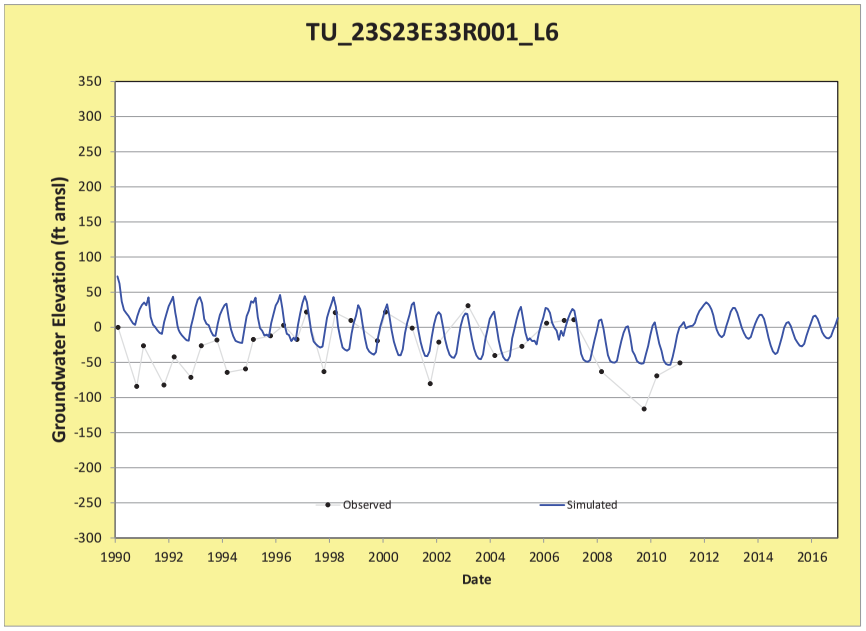

TU_23S23E24K001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

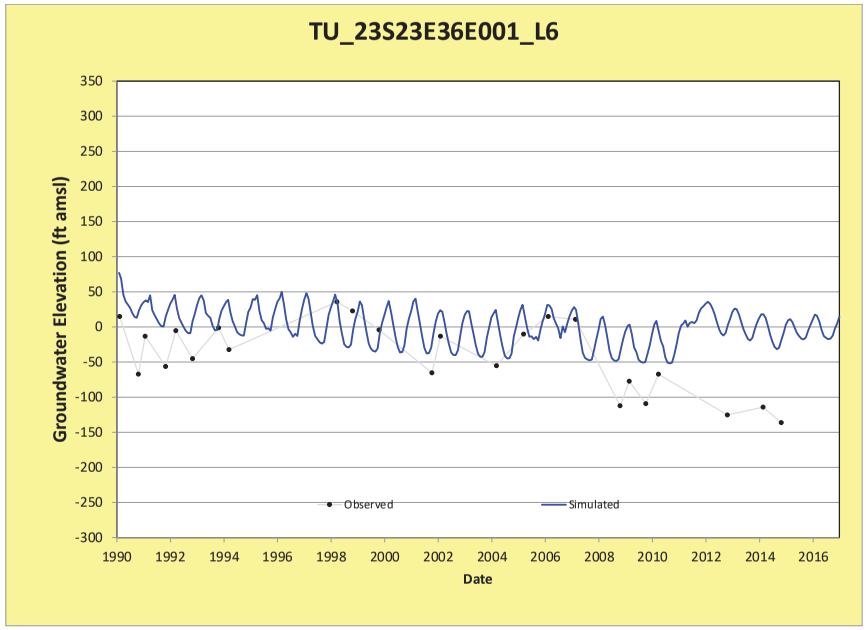

TU_23S23E24R001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

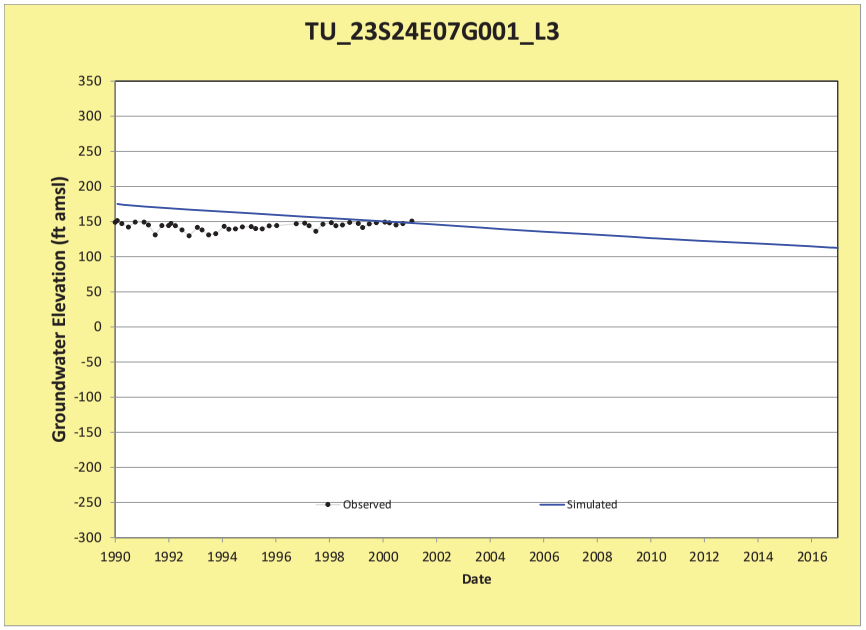

TU_23S23E25E001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

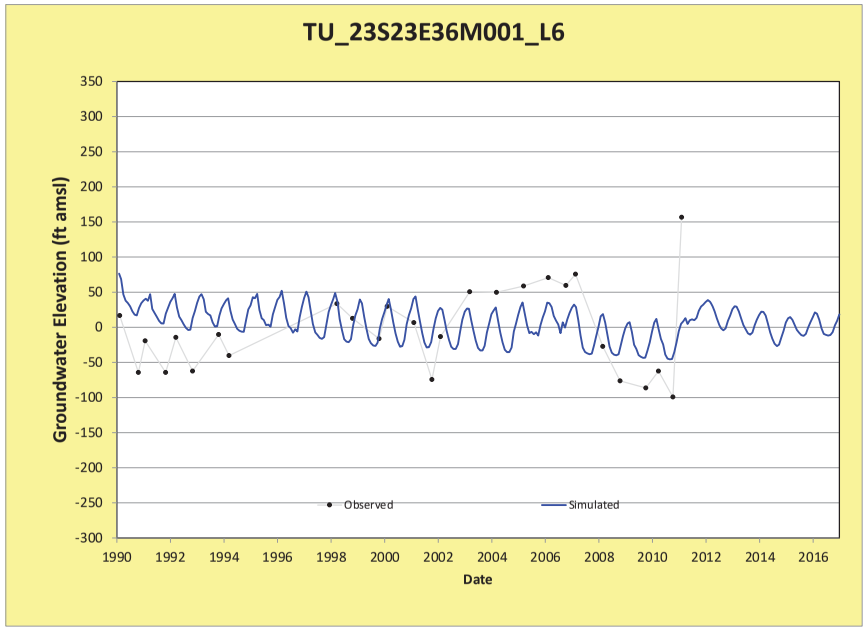

TU_23S23E33A002_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

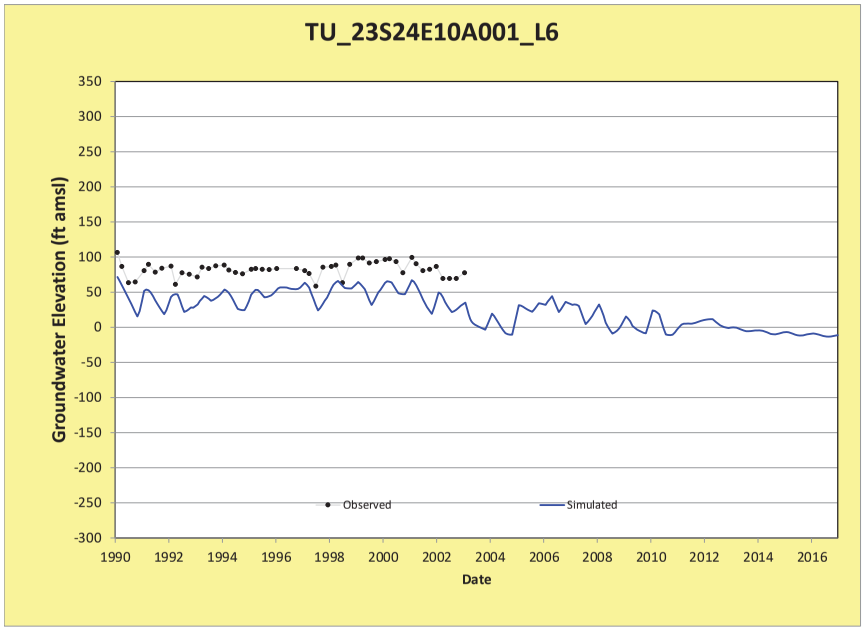

TU_23S23E25N001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

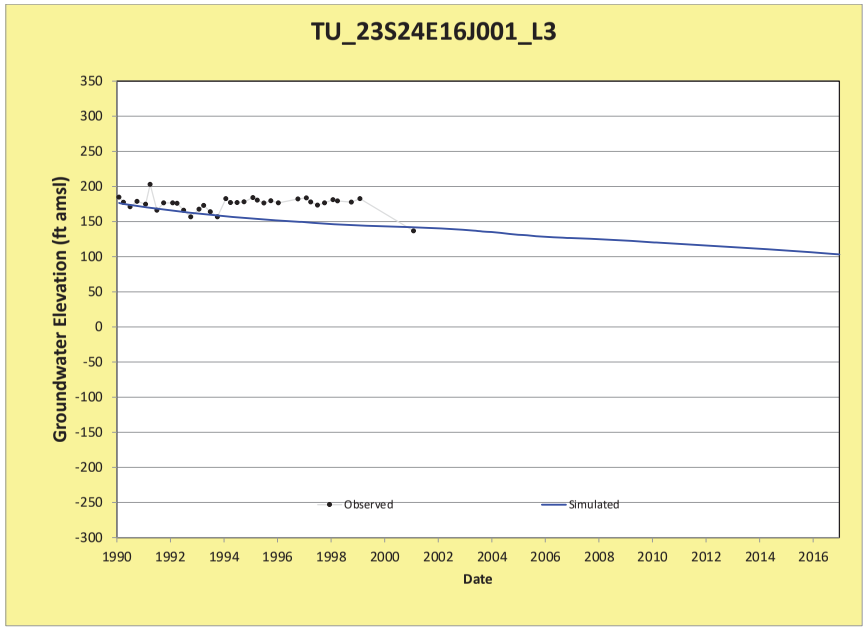

TU_23S23E33R001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

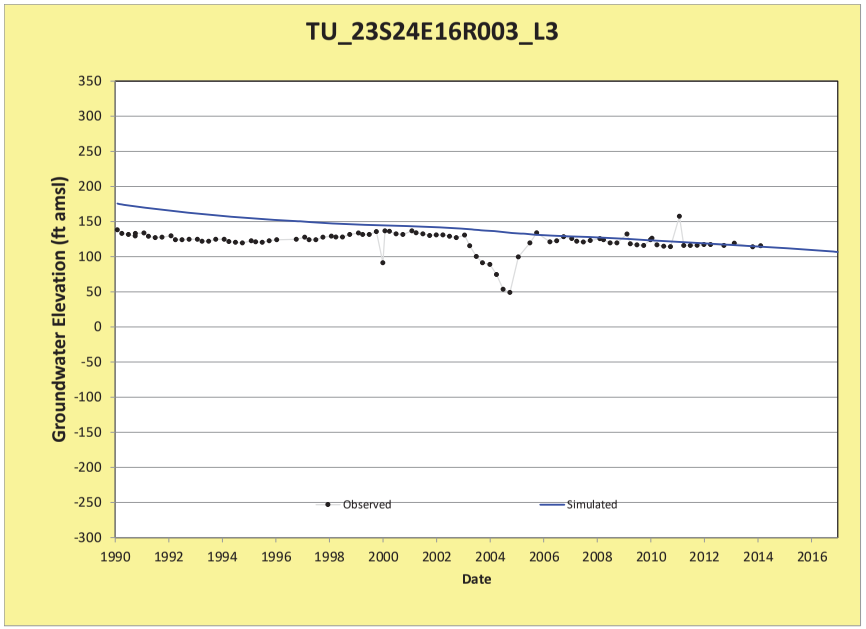

TU_23S23E36E001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

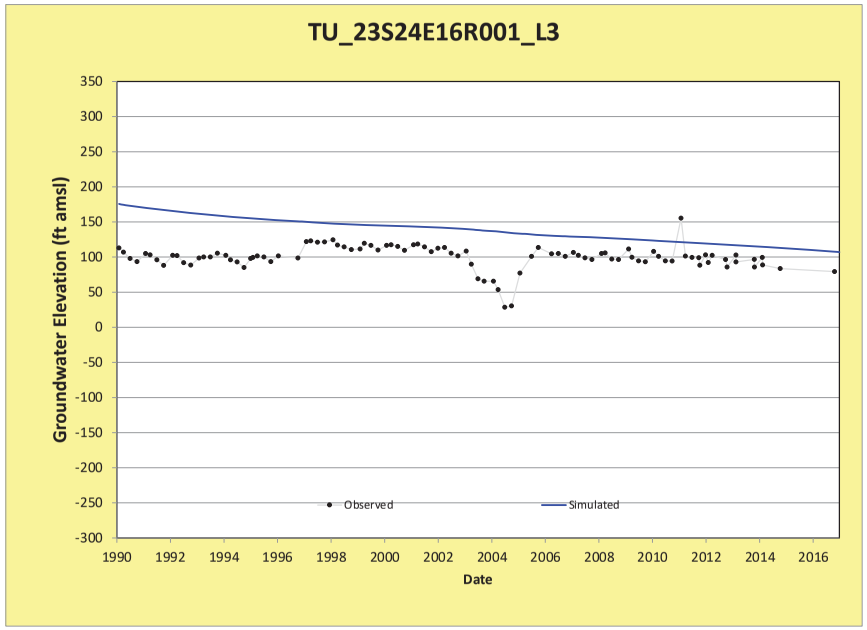

TU_23S24E07G001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

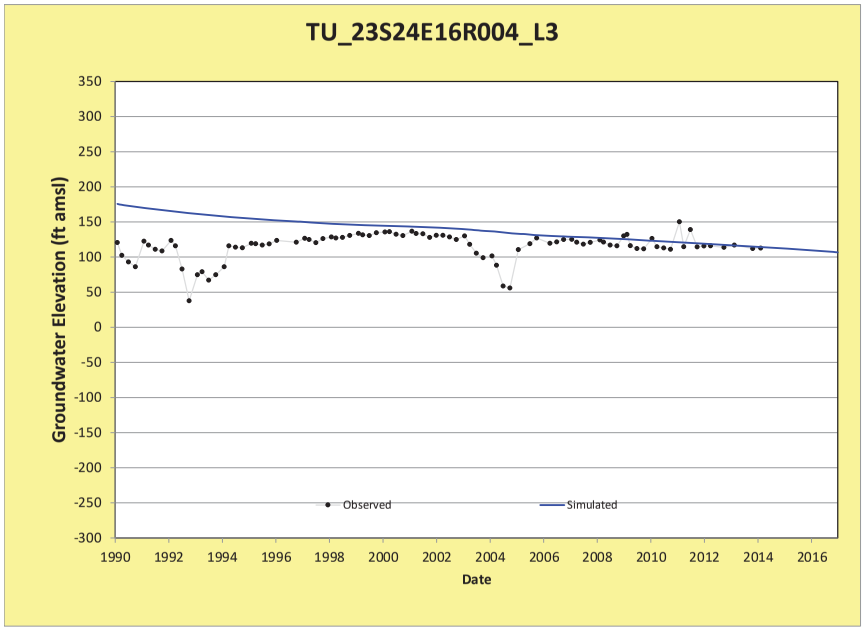

TU_23S23E36M001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

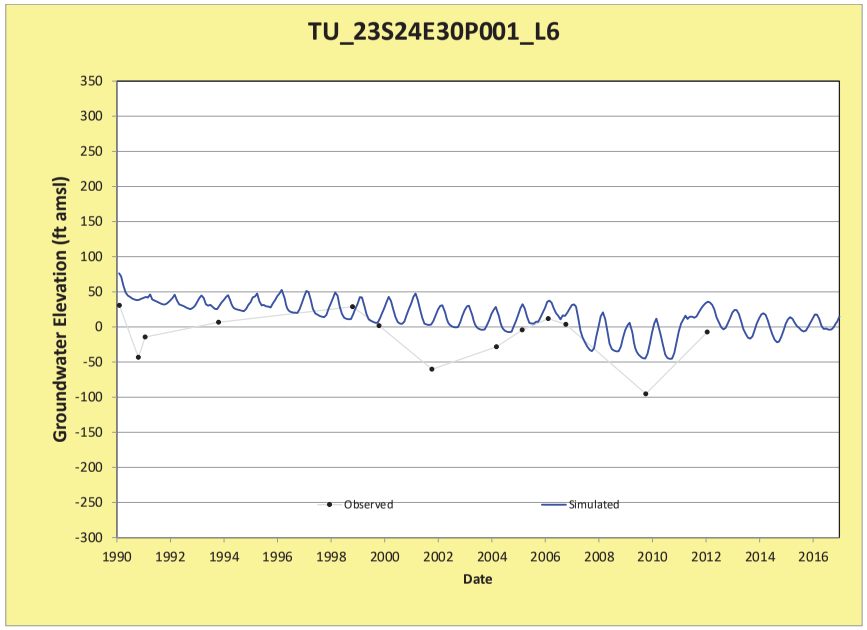

TU_23S24E10A001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

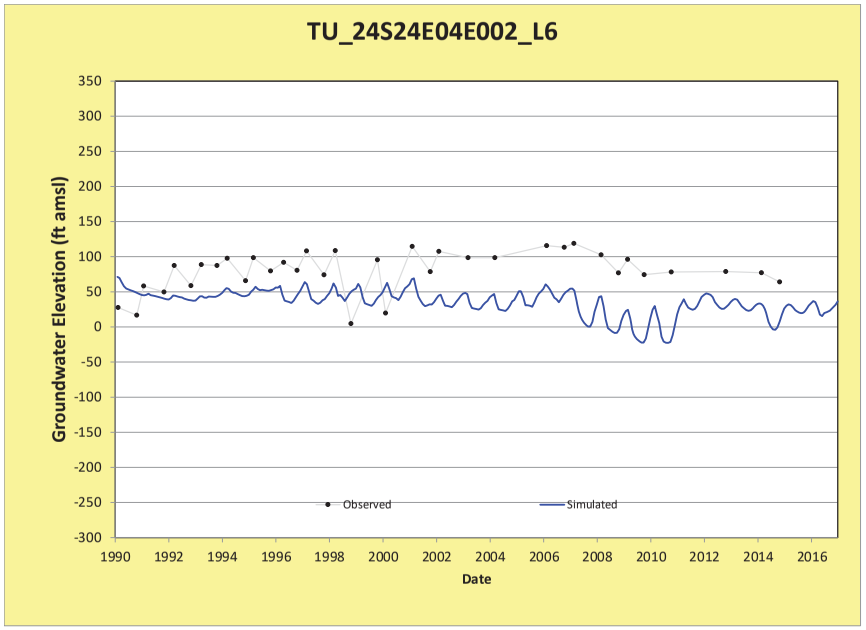

TU_23S24E16J001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

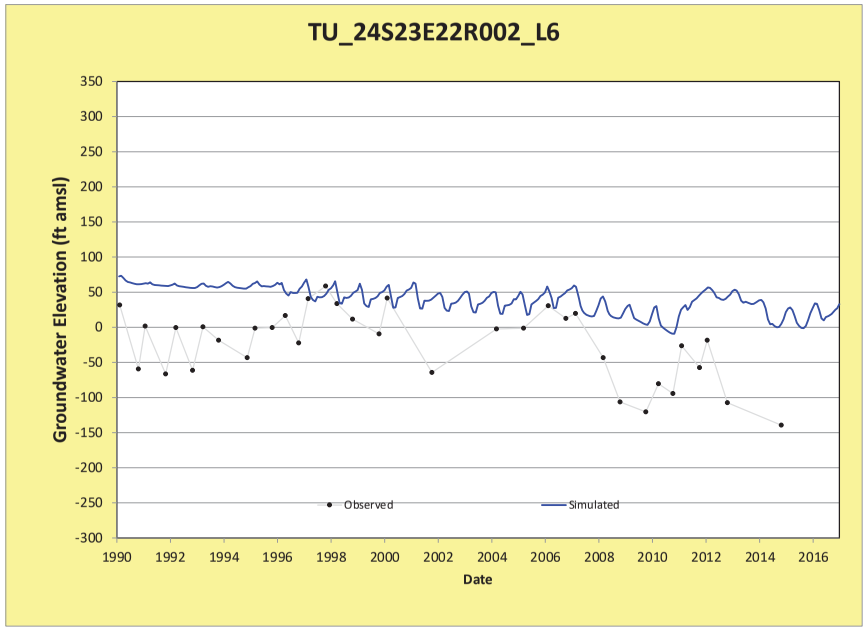

TU_23S24E16R003_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

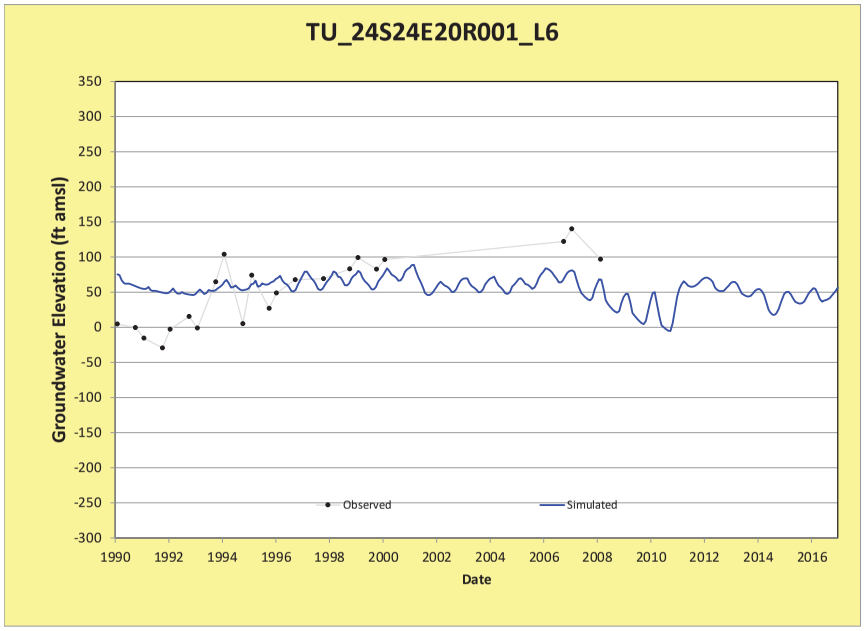

TU_23S24E16R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

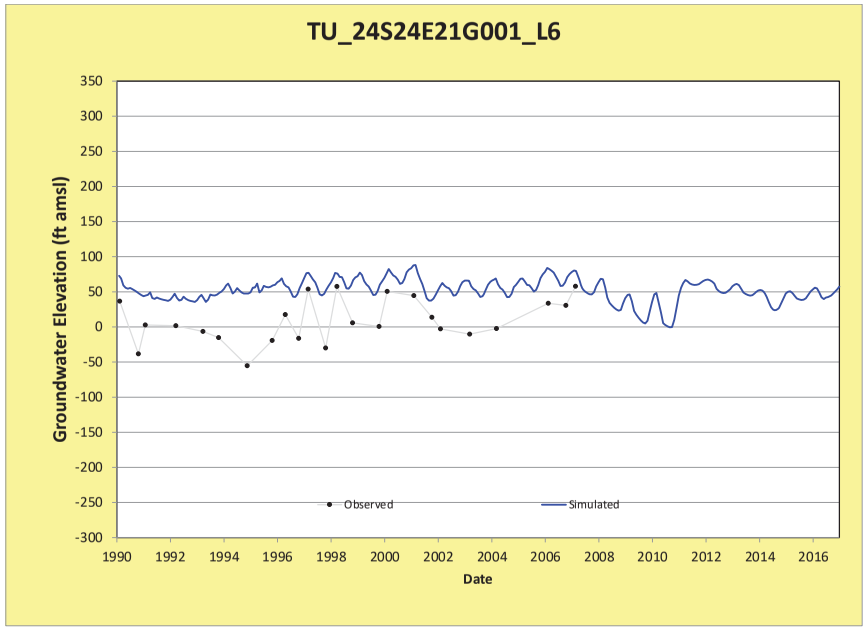

TU_23S24E16R004_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

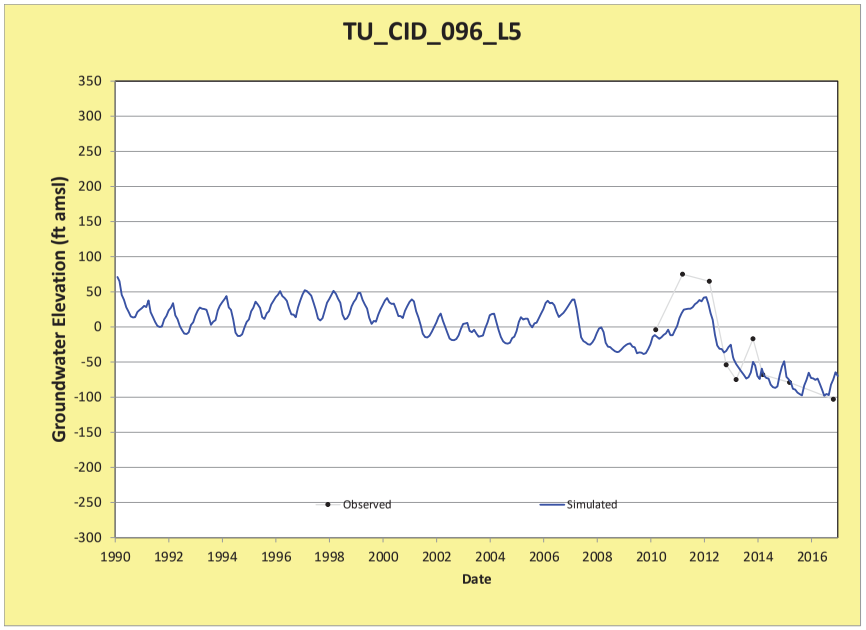

TU_23S24E30P001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

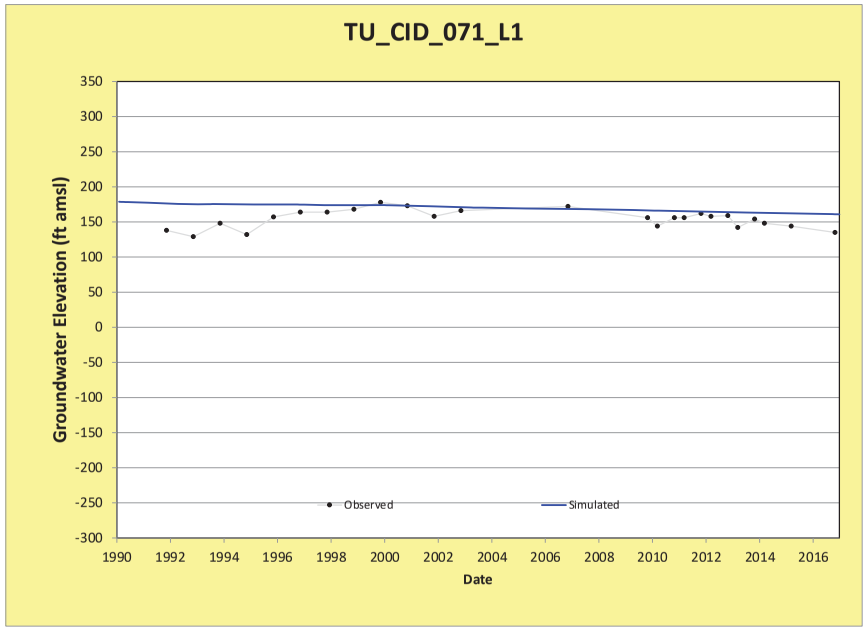

TU_24S24E04E002_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

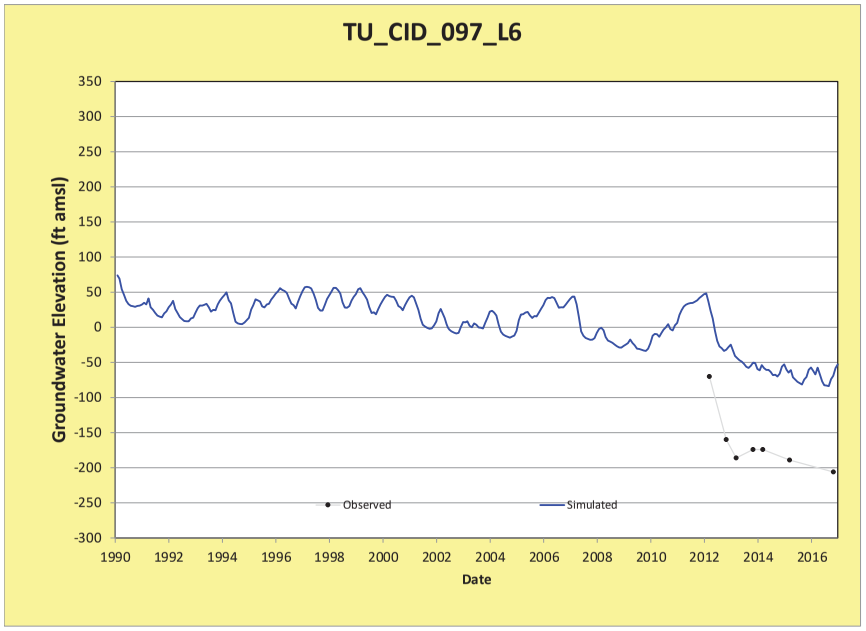

TU_24S23E22R002_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

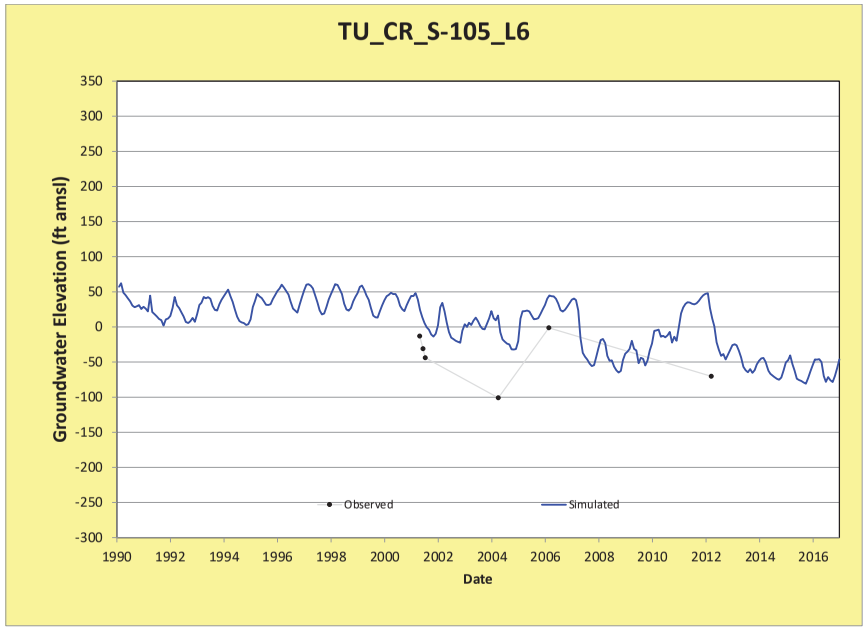

TU_24S24E20R001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

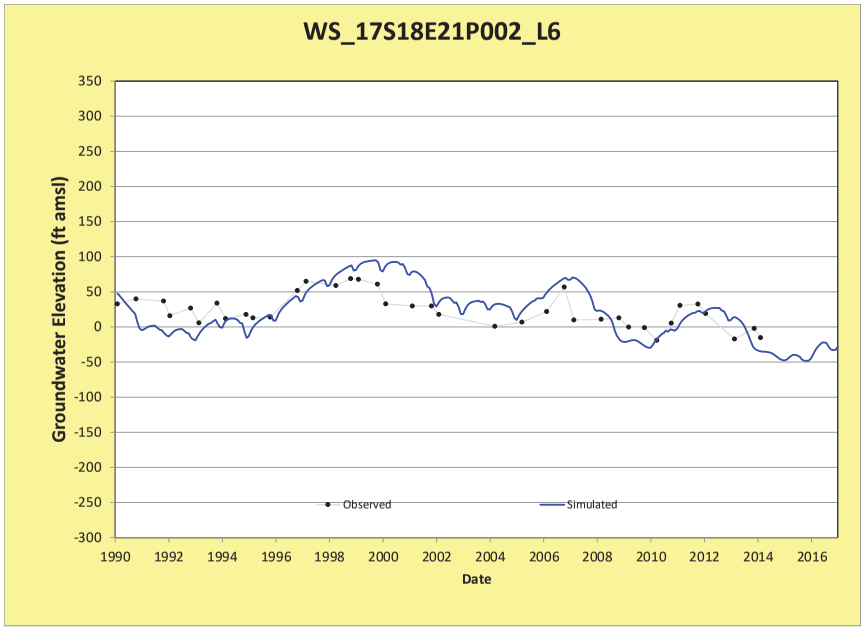

TU_24S24E21G001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

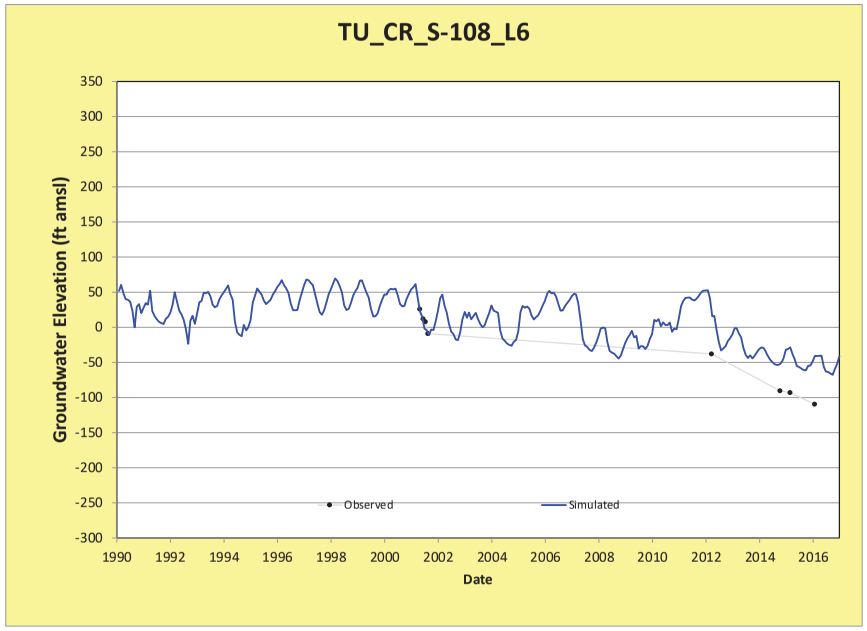

TU_CID_096_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

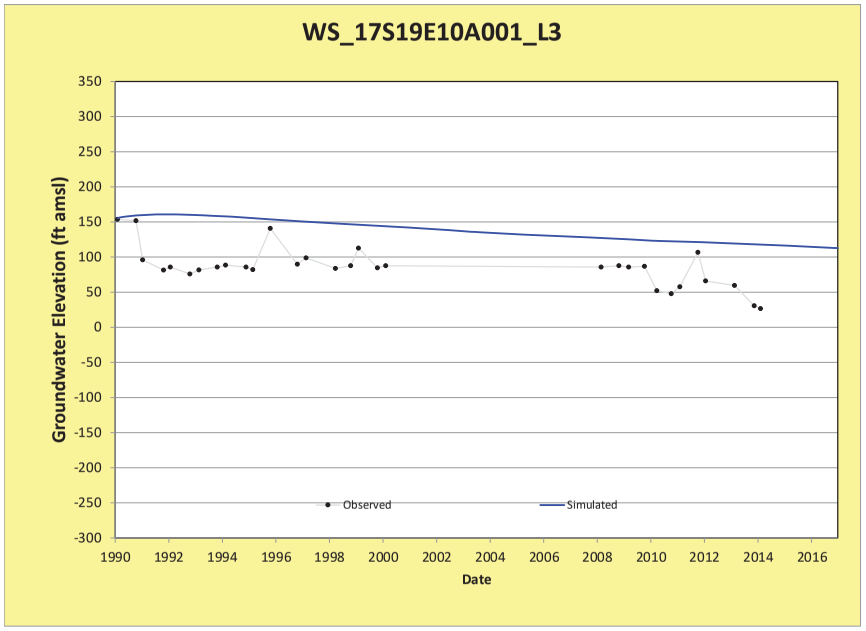

TU_CID_071_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

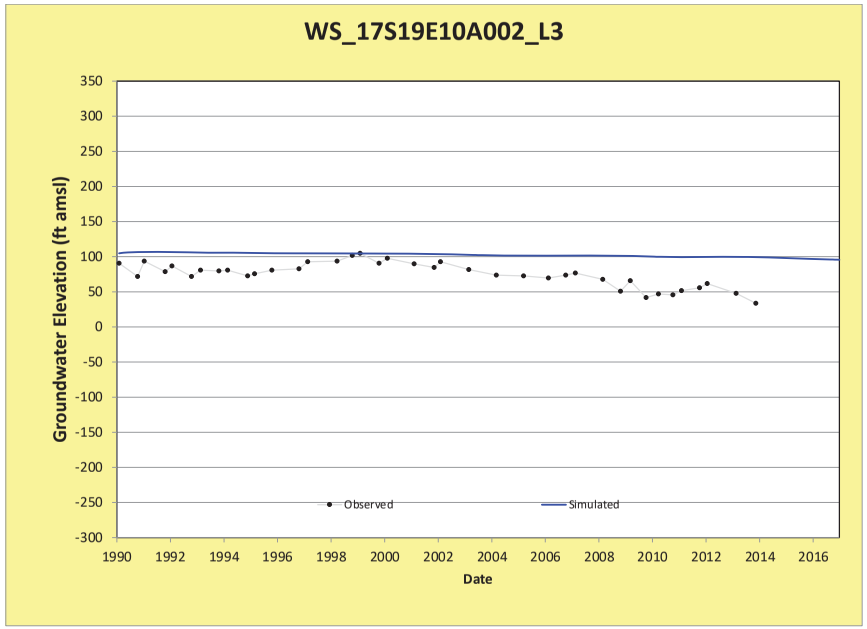

TU_CID_097_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

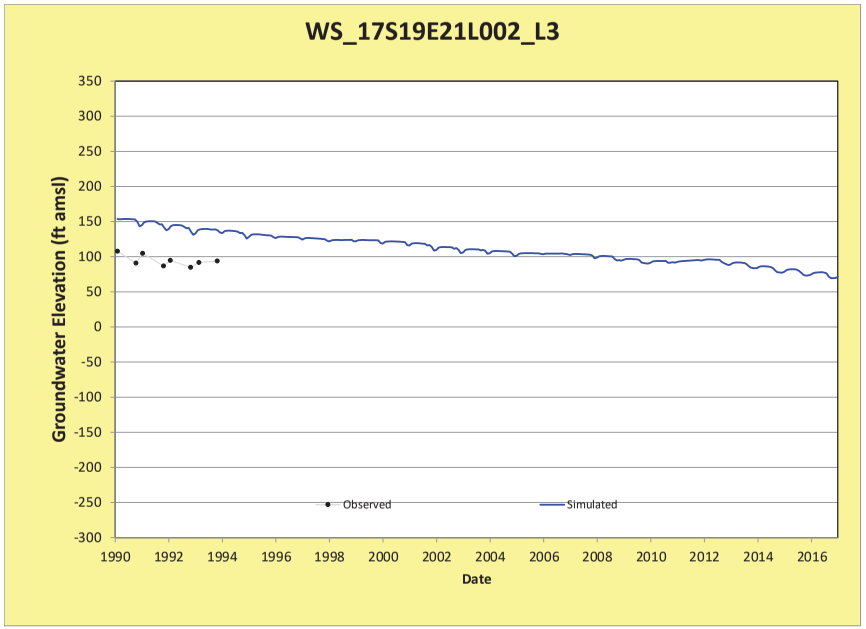

TU_CR_S-105_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

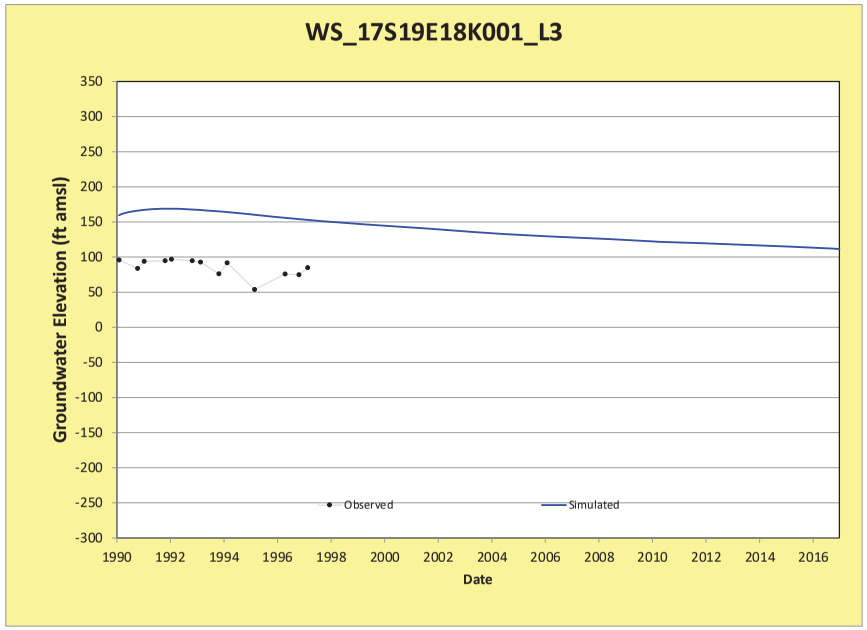

WS_17S18E21P002_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

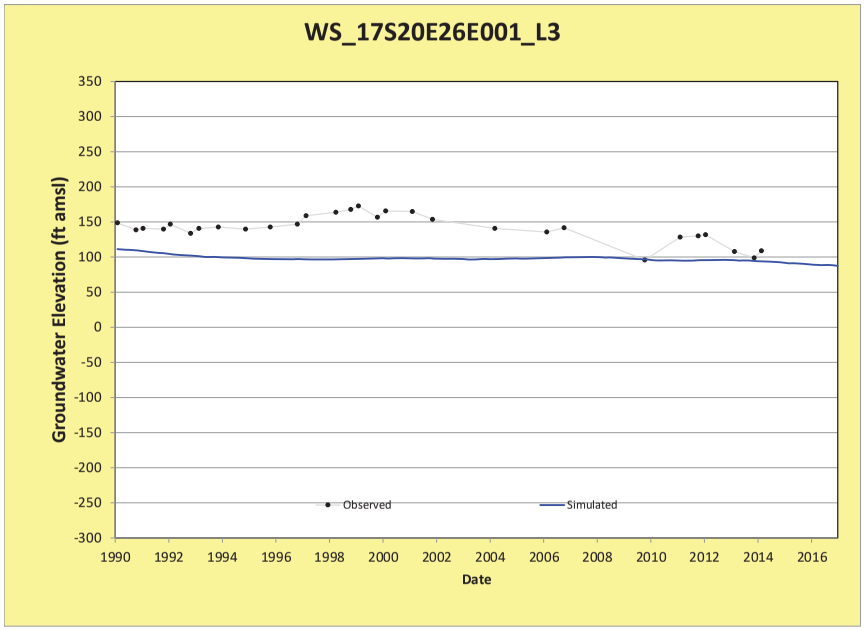

TU_CR_S-108_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

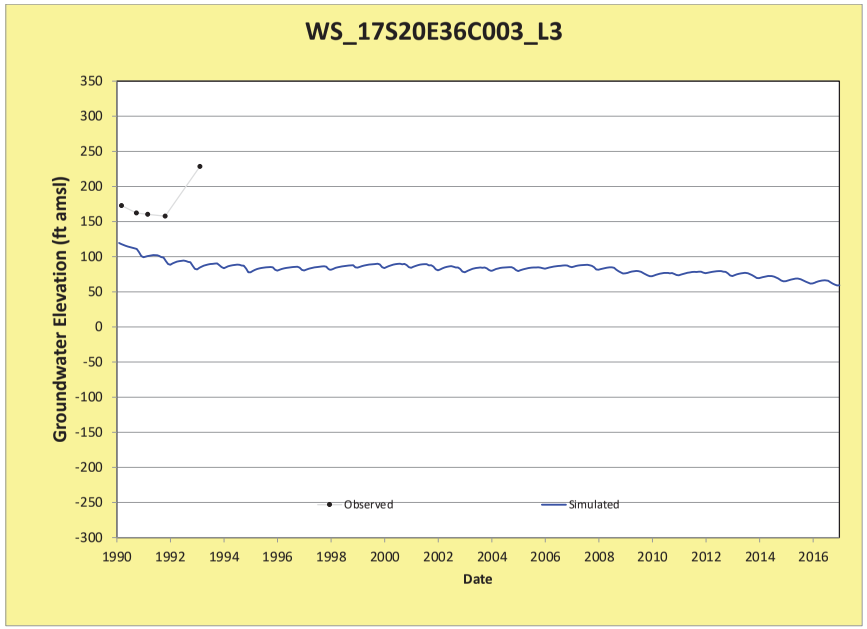

WS_17S19E10A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

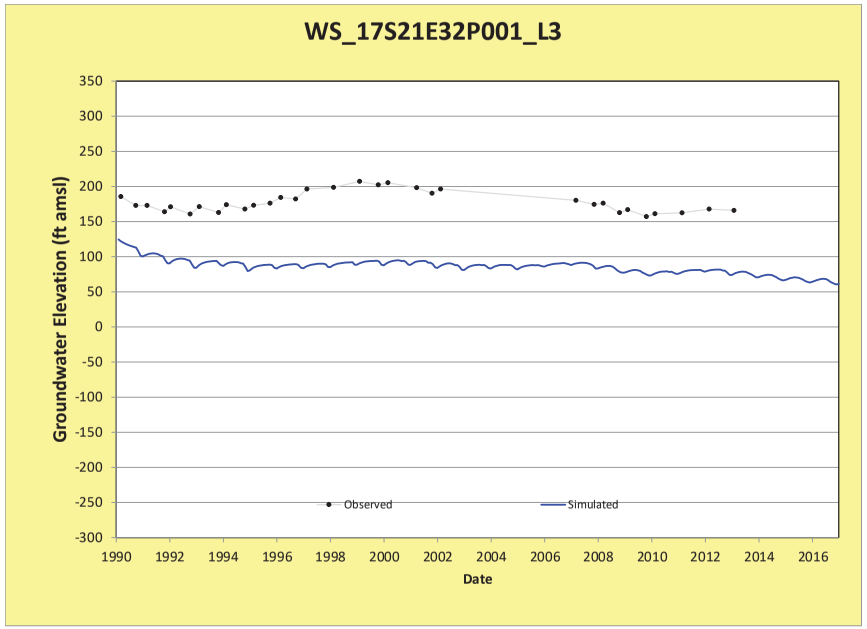

WS_17S19E10A002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

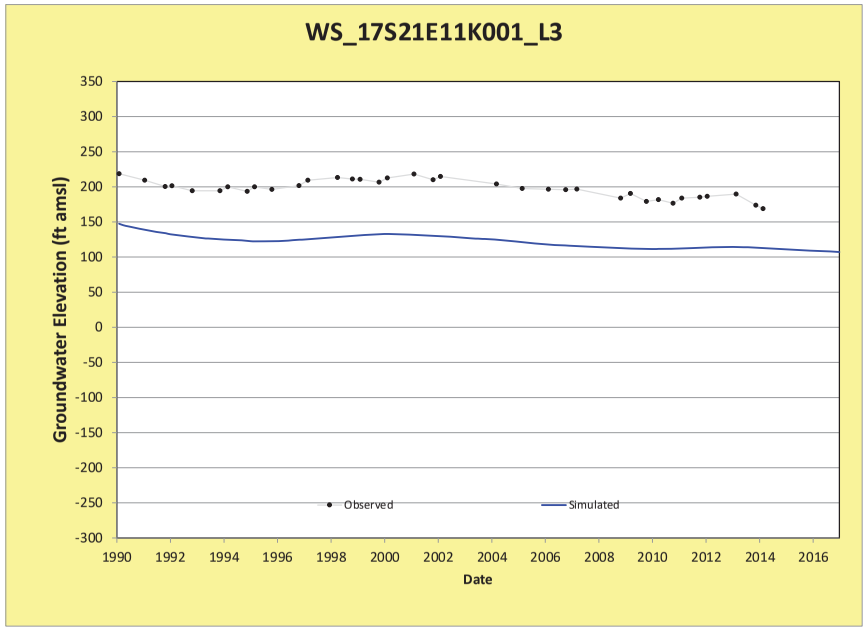

WS_17S19E21L002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

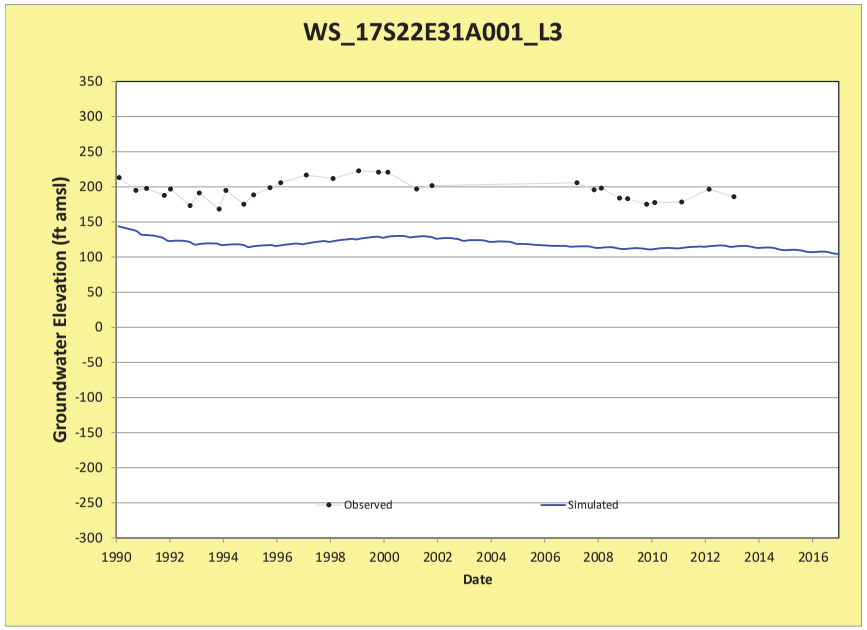

WS_17S19E18K001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

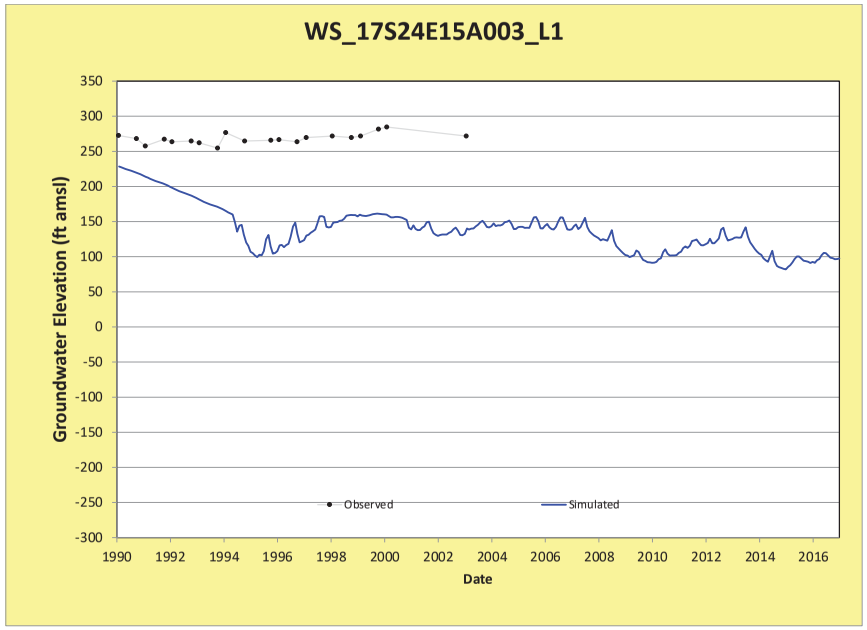

WS_17S20E26E001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

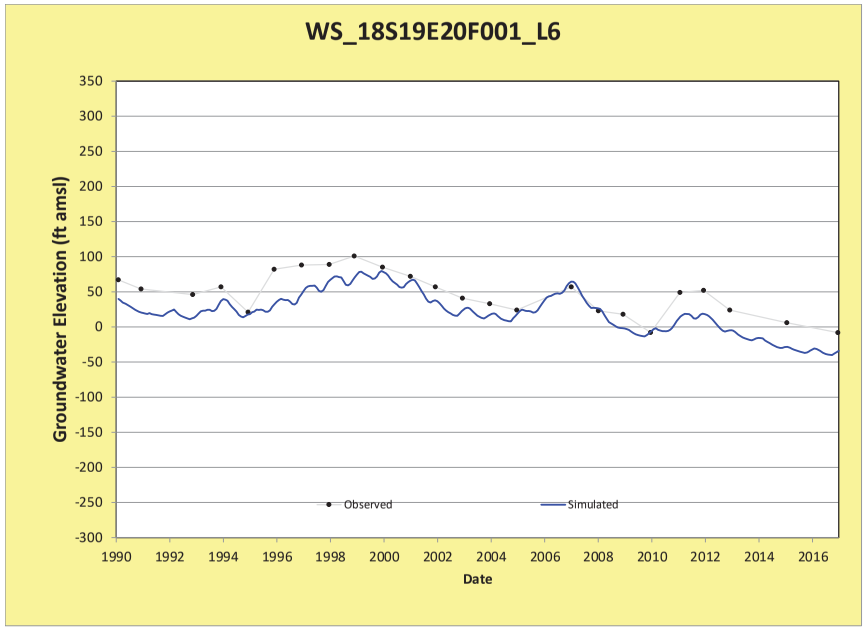

WS_17S20E36C003_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

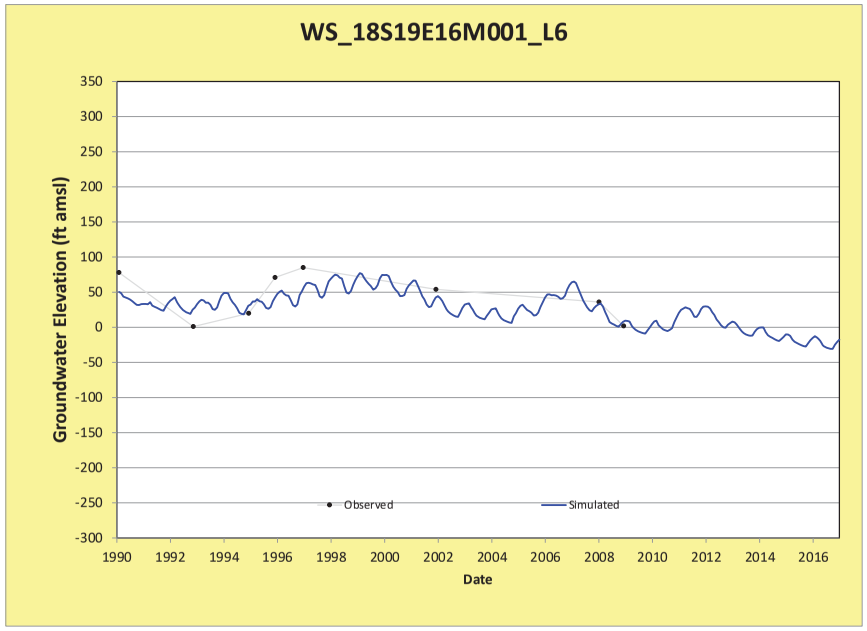

WS_17S21E32P001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

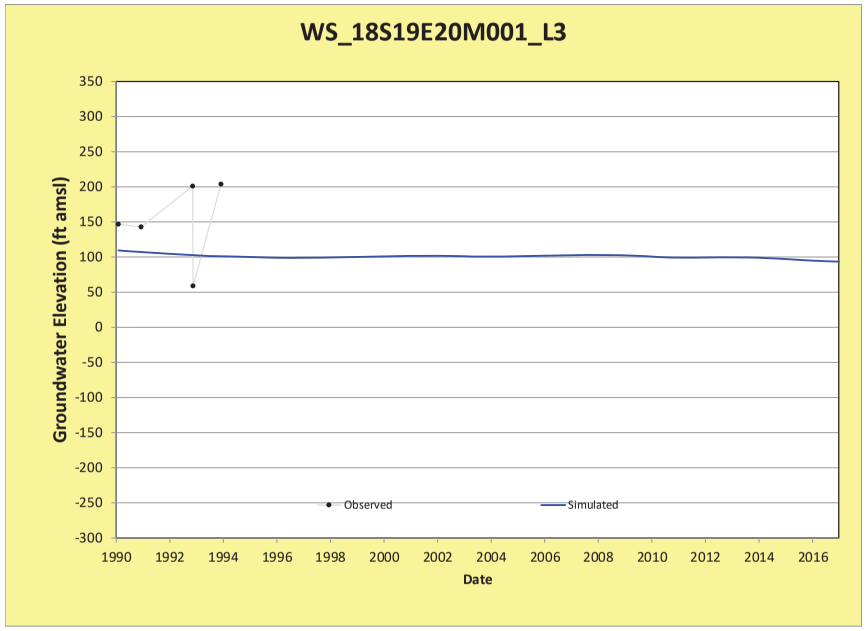

WS_17S21E11K001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

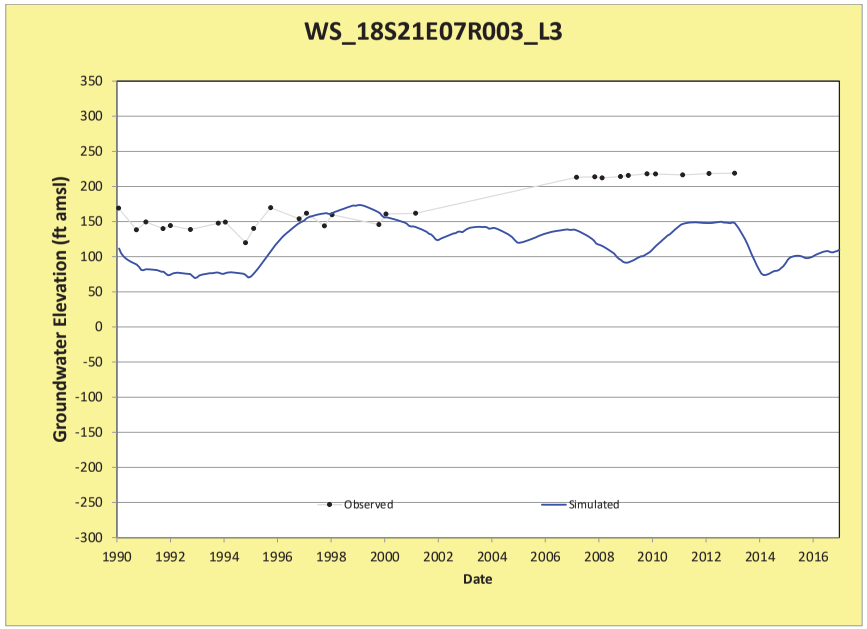

WS_17S22E31A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

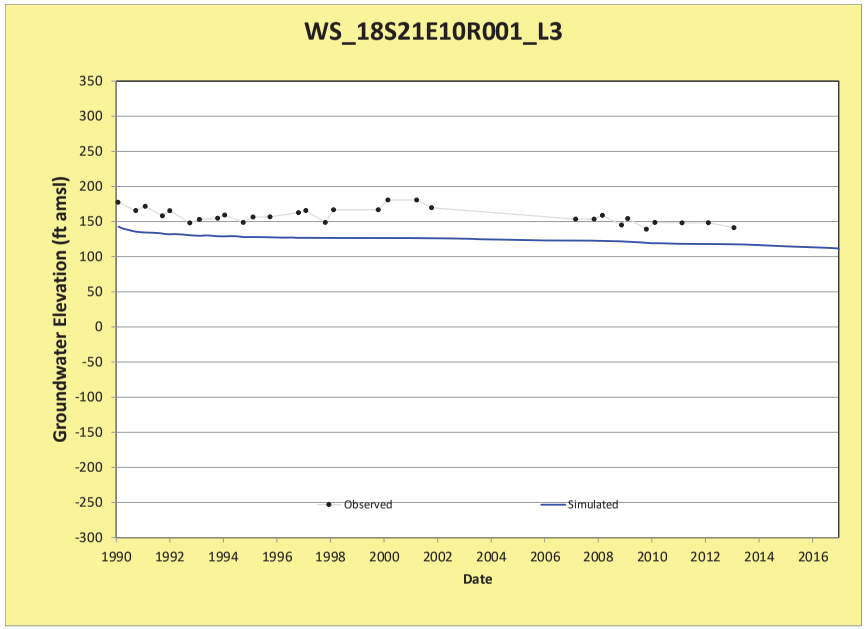

WS_17S24E15A003_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

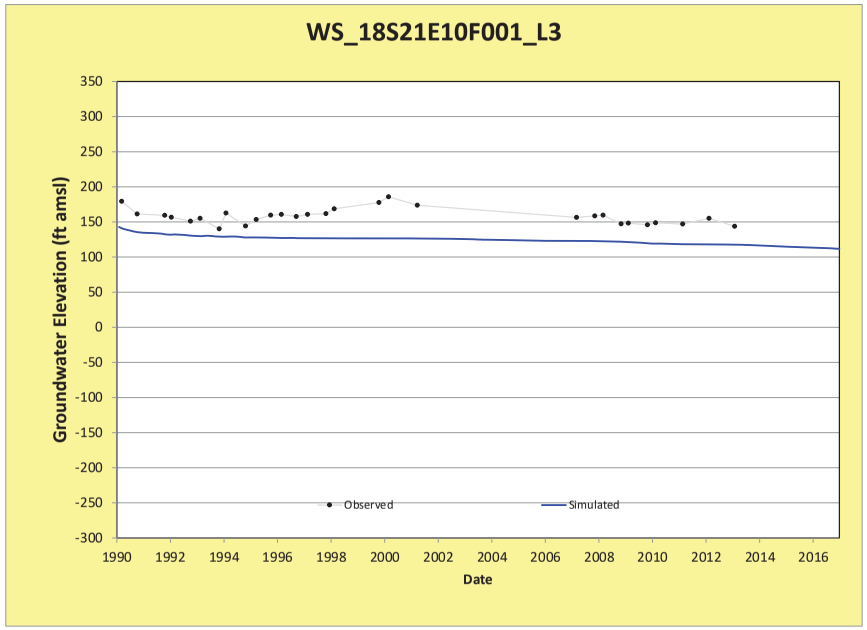

WS_18S19E20F001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

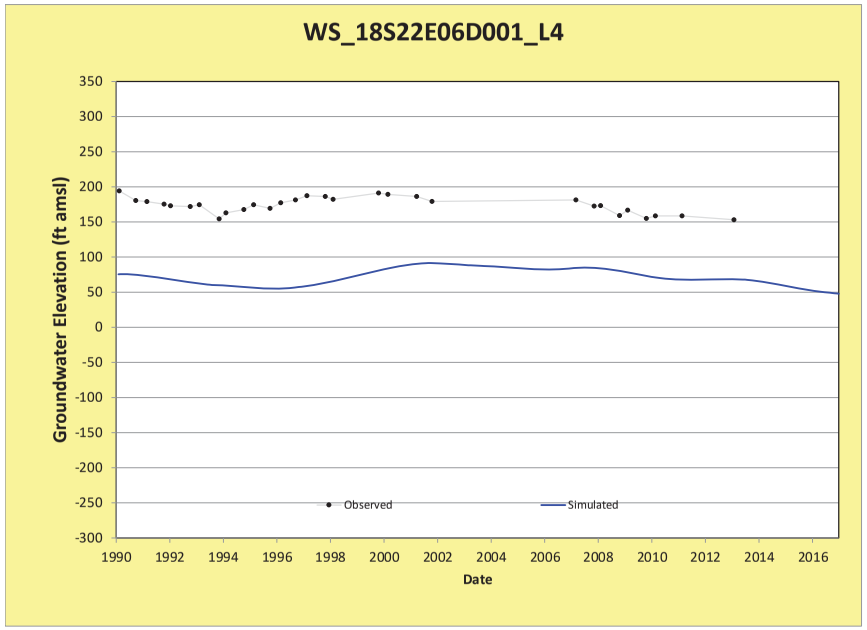

WS_18S19E16M001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

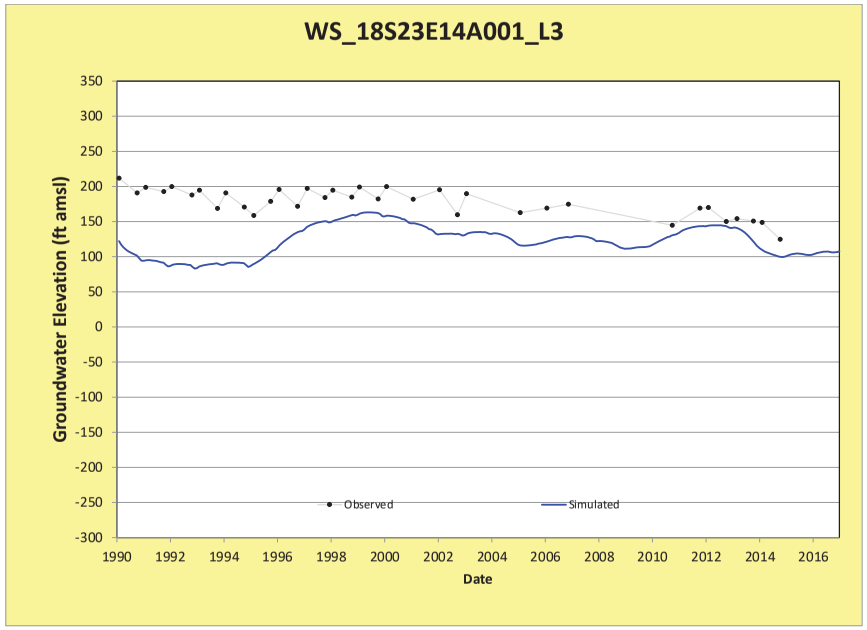

WS_18S19E20M001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

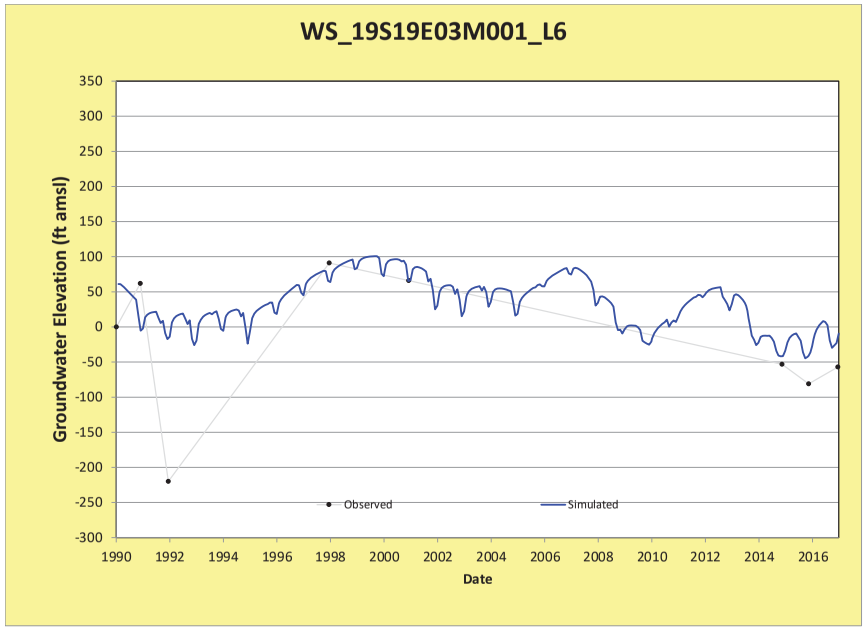

WS_18S21E07R003_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

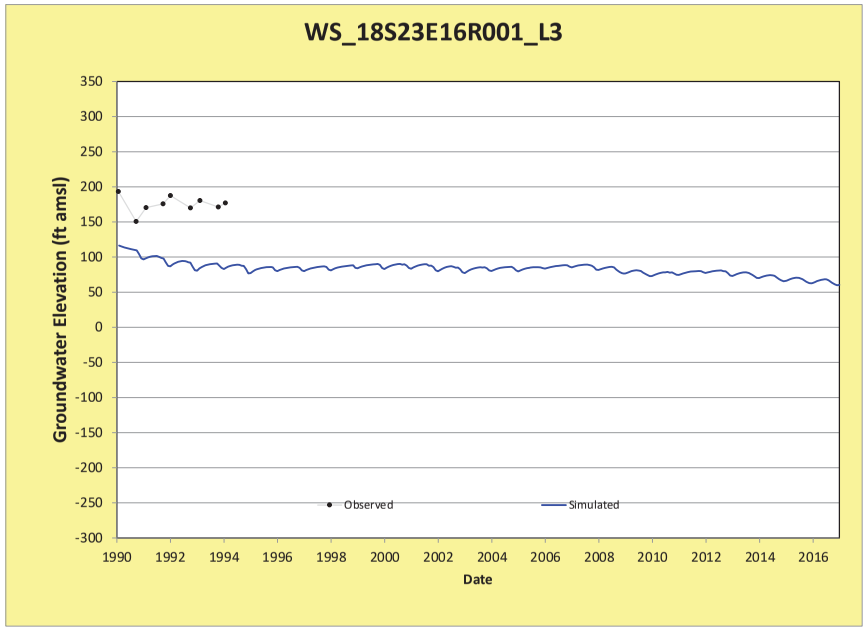

WS_18S21E10R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

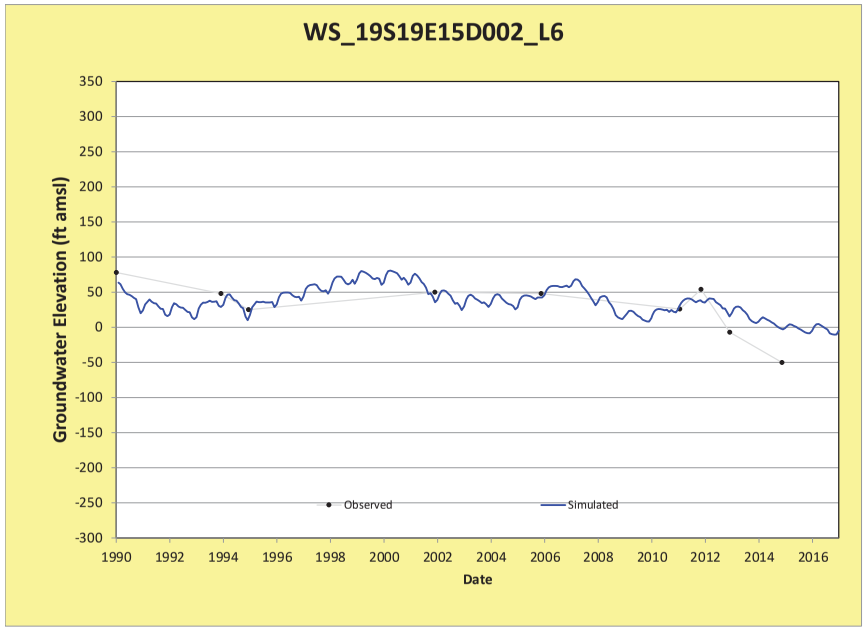

WS_18S21E10F001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

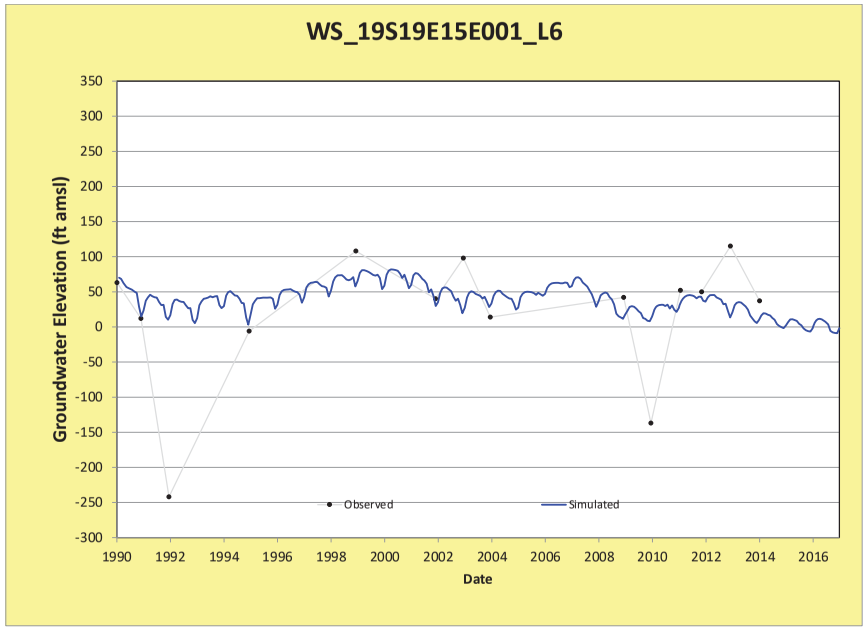

WS_18S22E06D001_L4
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

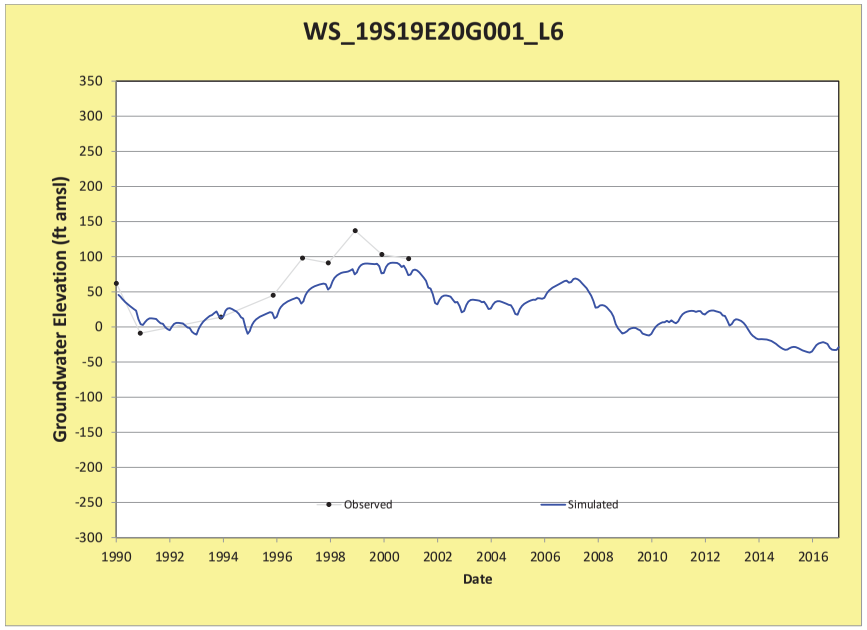

WS_18S23E14A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

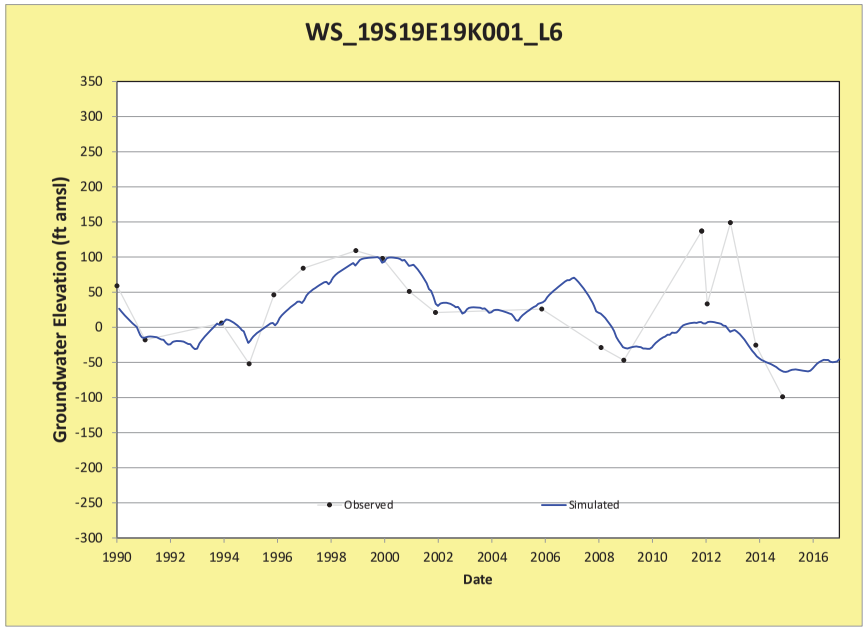

WS_19S19E03M001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

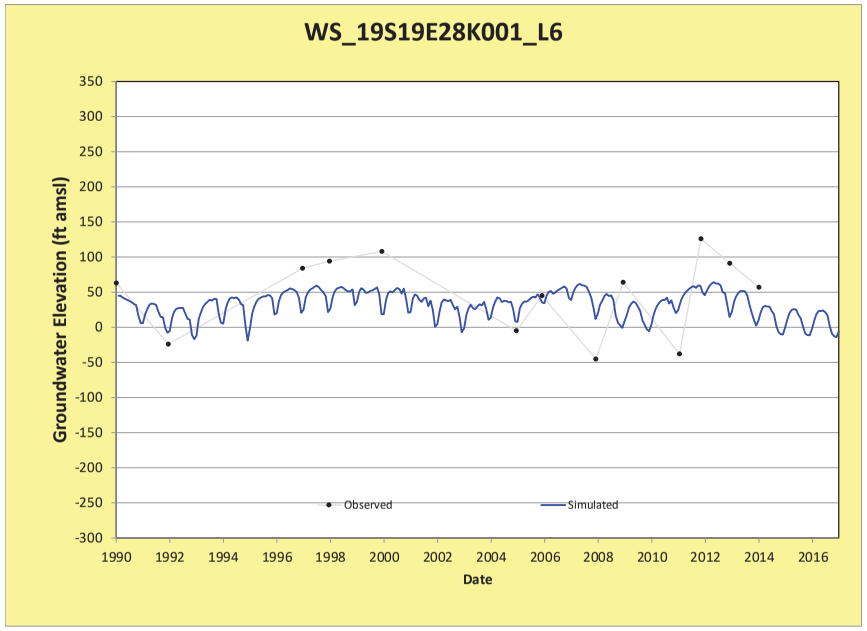

WS_18S23E16R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

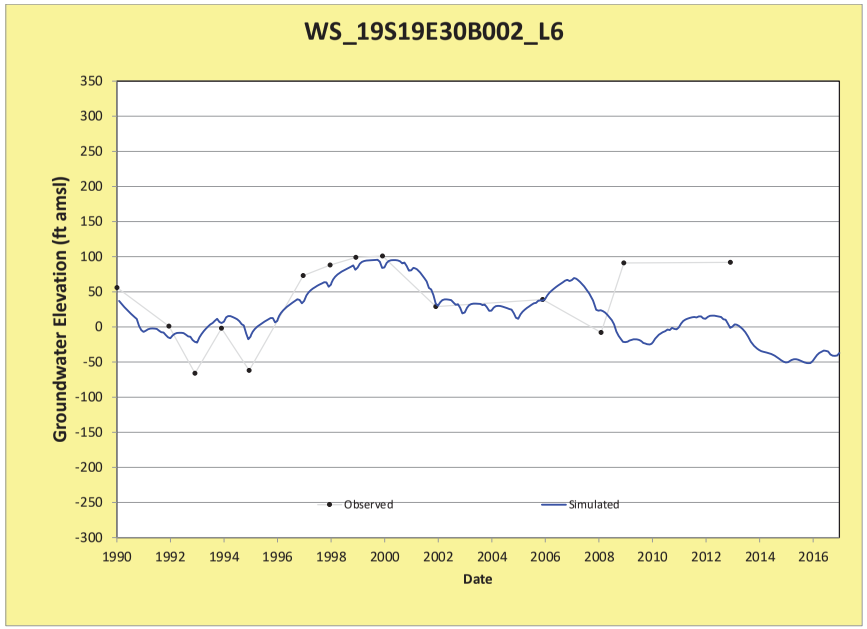

WS_19S19E15D002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

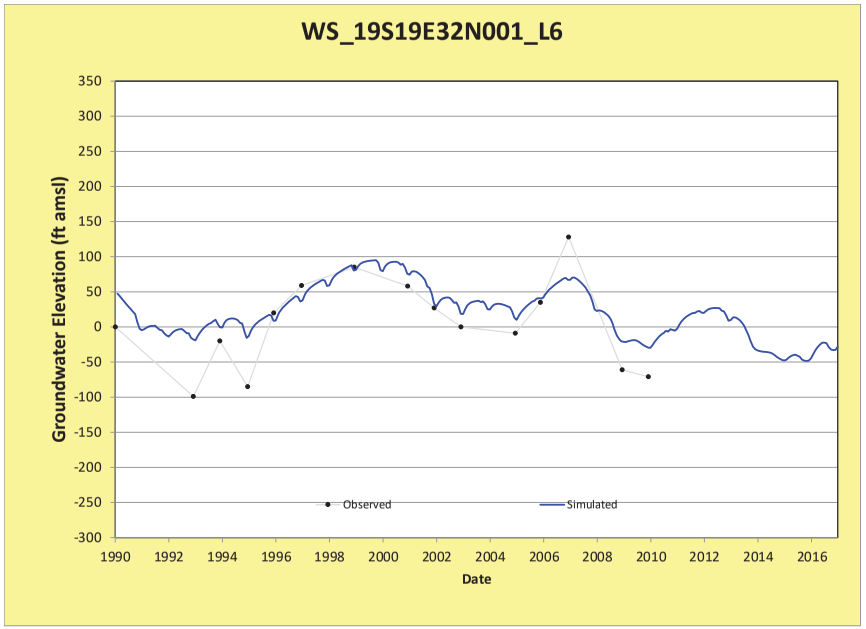

WS_19S19E15E001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

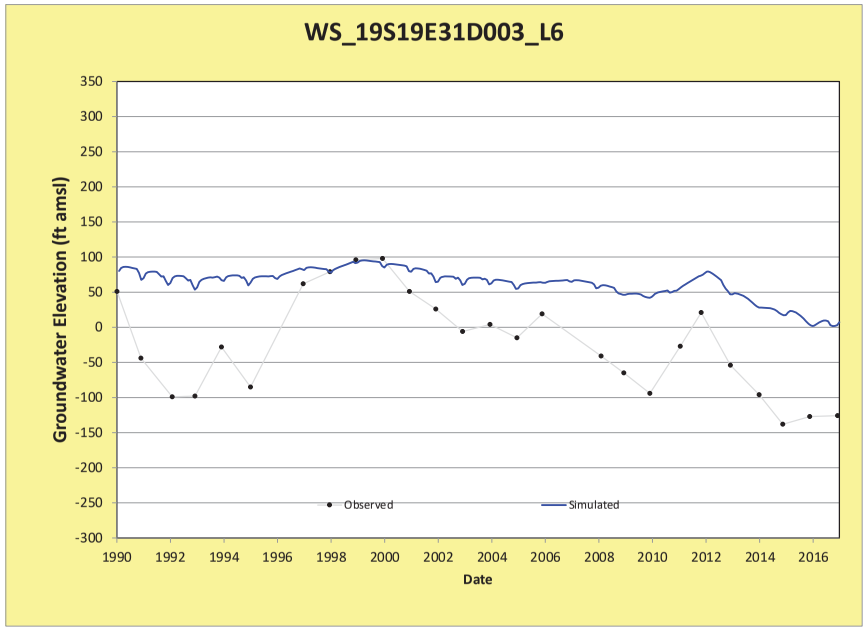

WS_19S19E20G001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

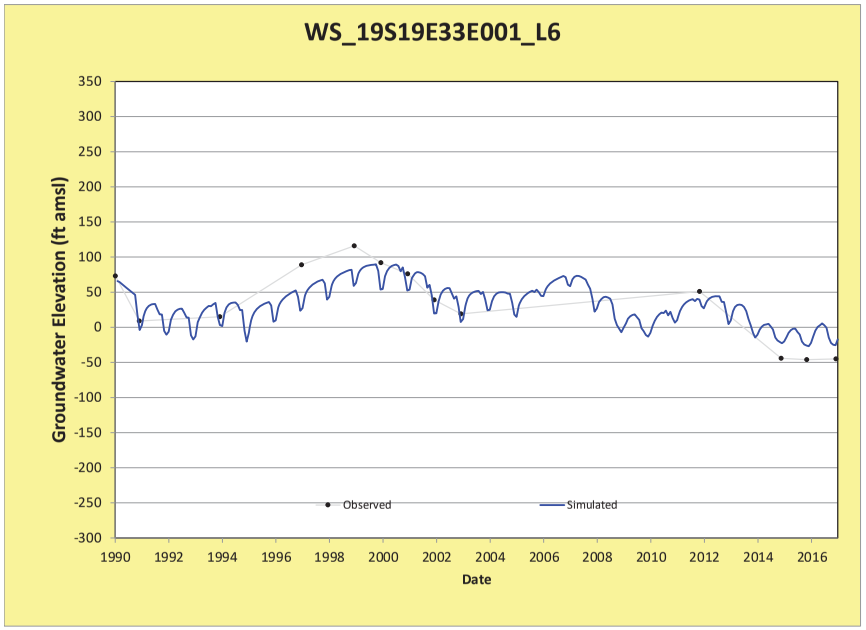

WS_19S19E19K001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

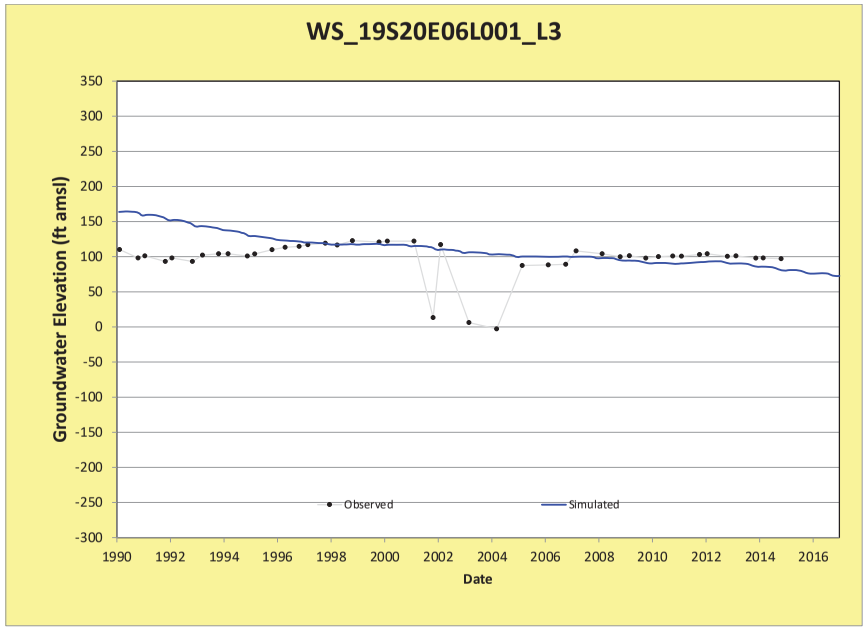

WS_19S19E28K001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

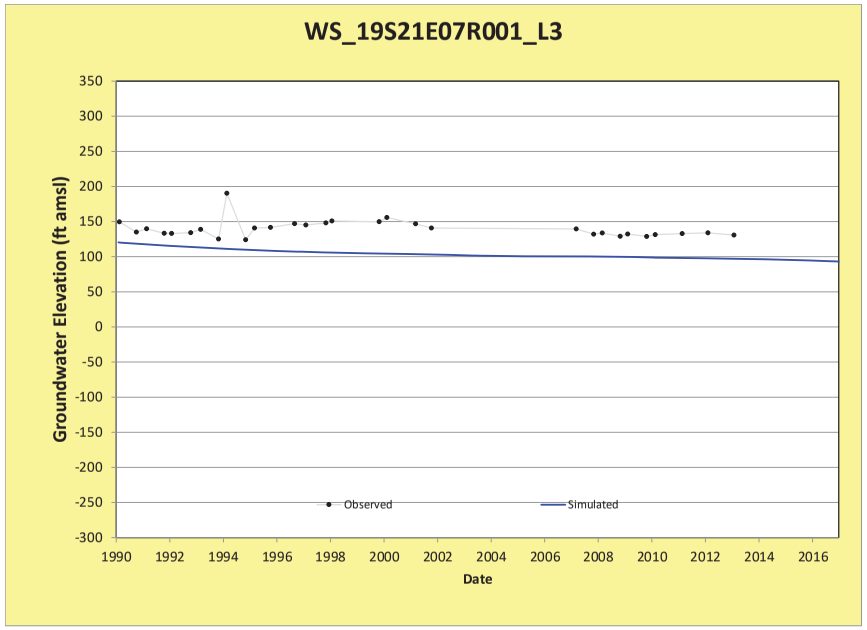

WS_19S19E30B002_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

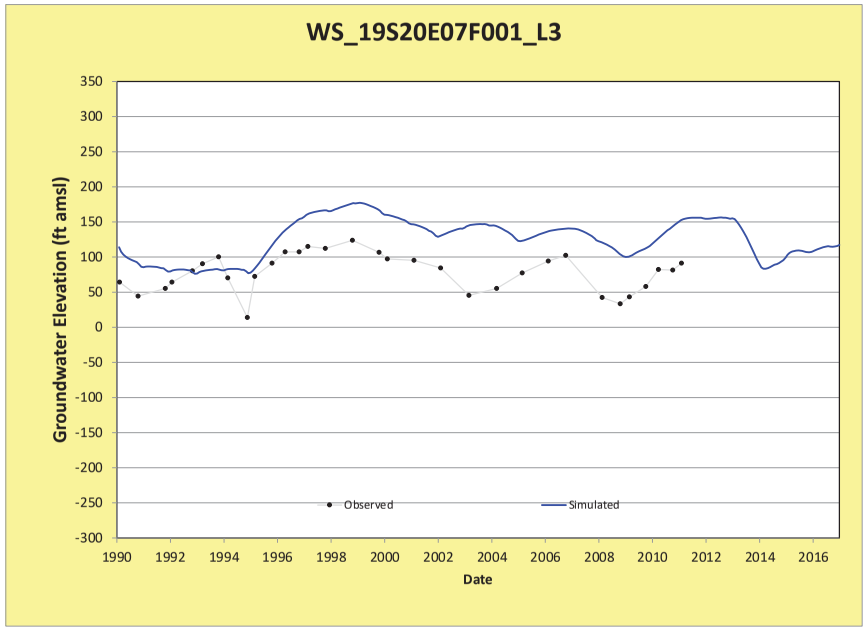

WS_19S19E32N001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

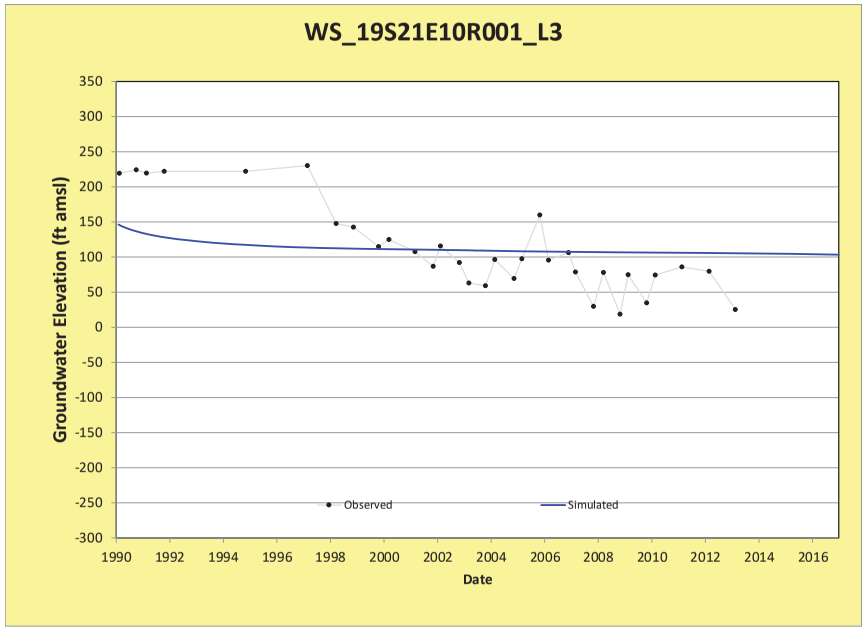

WS_19S19E31D003_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

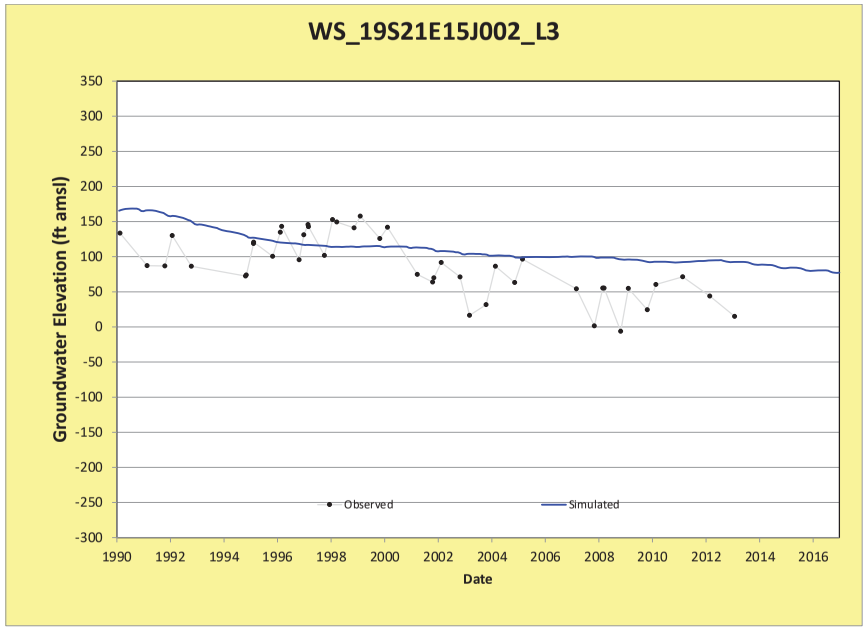

WS_19S19E33E001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

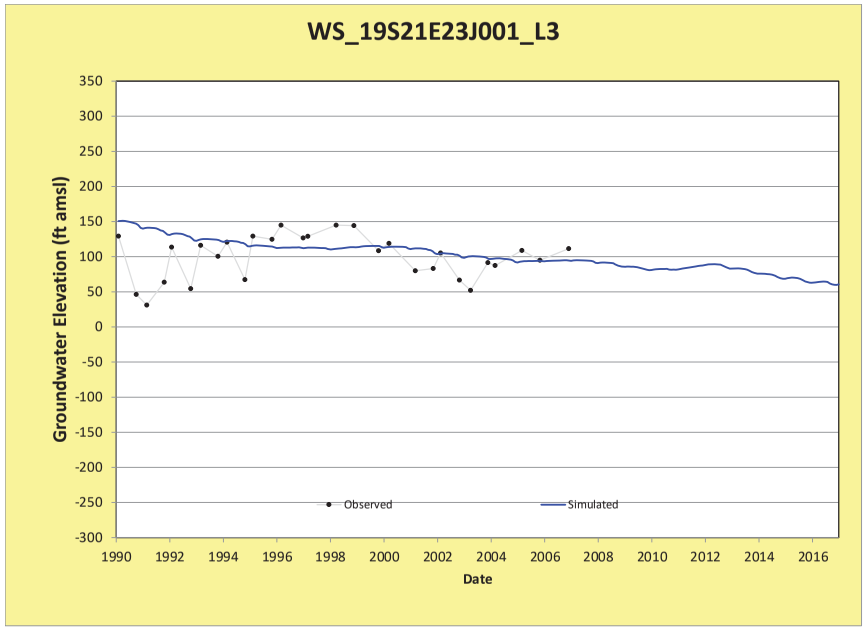

WS_19S20E06L001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

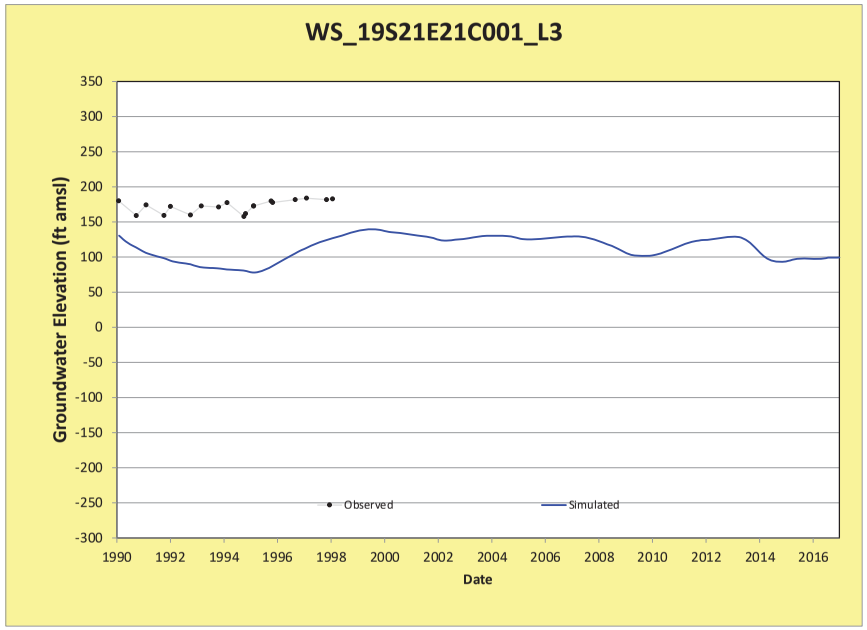

WS_19S21E07R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

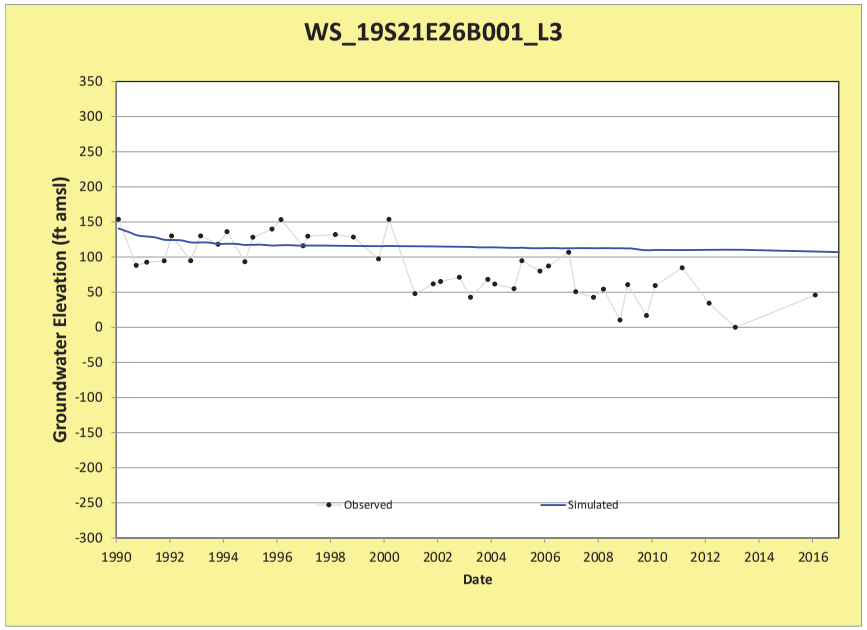

WS_19S20E07F001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

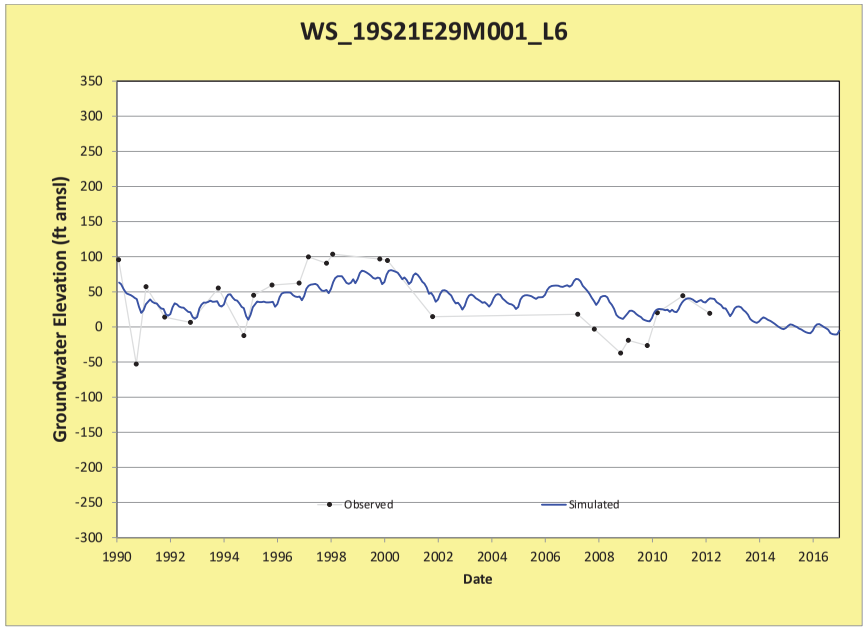

WS_19S21E10R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

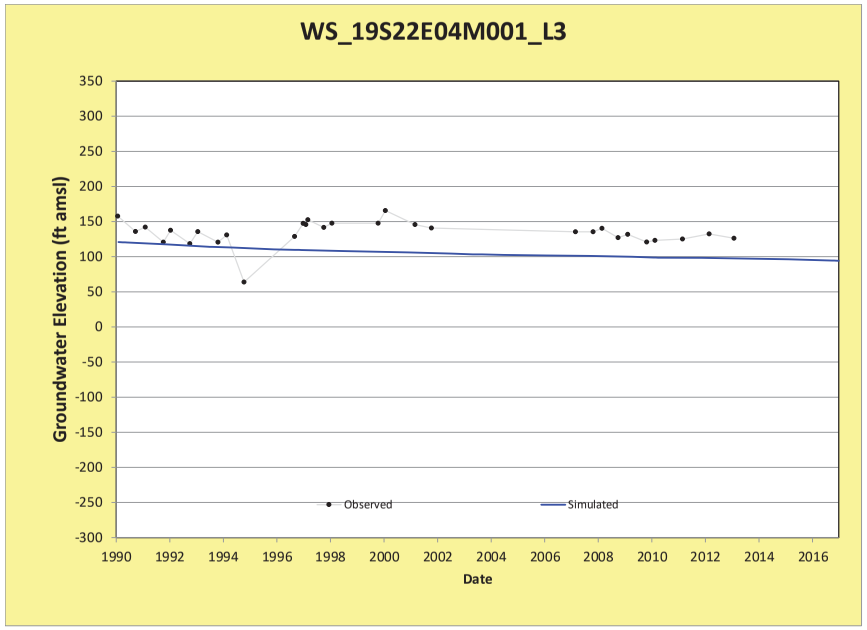

WS_19S21E15J002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

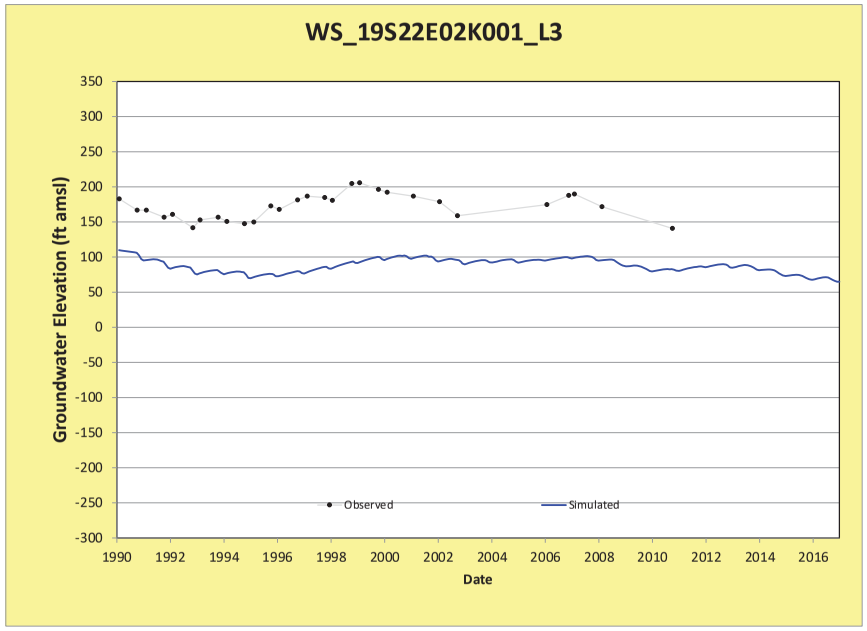

WS_19S21E23J001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

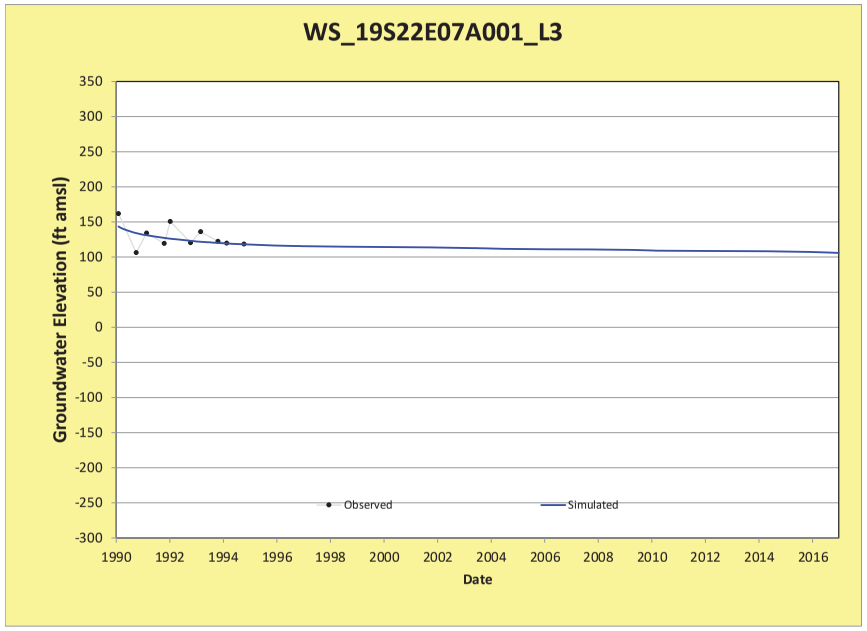

WS_19S21E21C001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

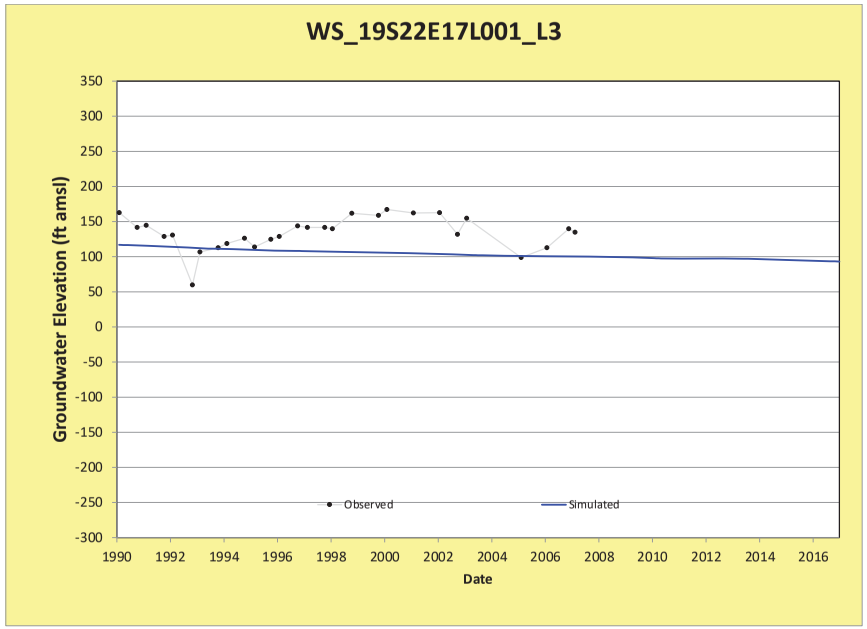

WS_19S21E26B001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

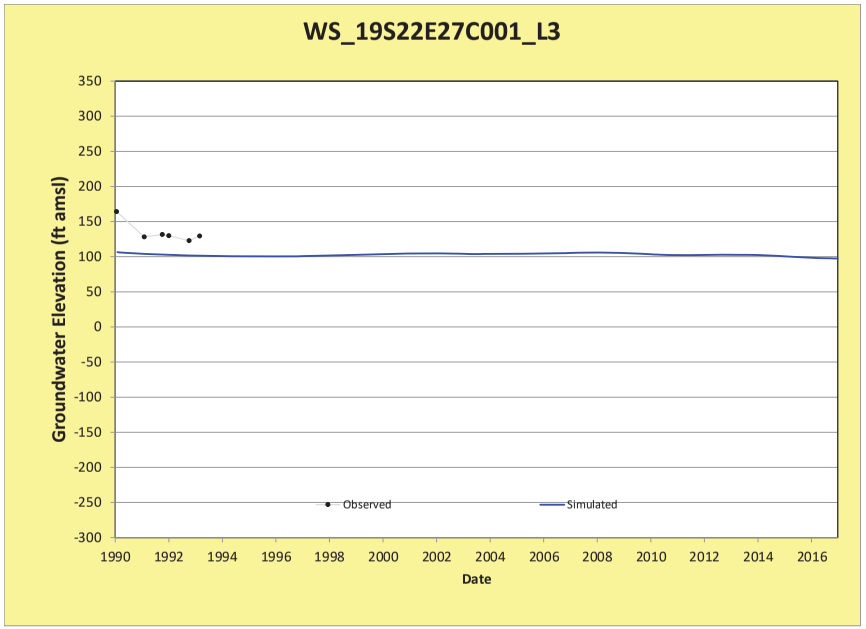

WS_19S21E29M001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

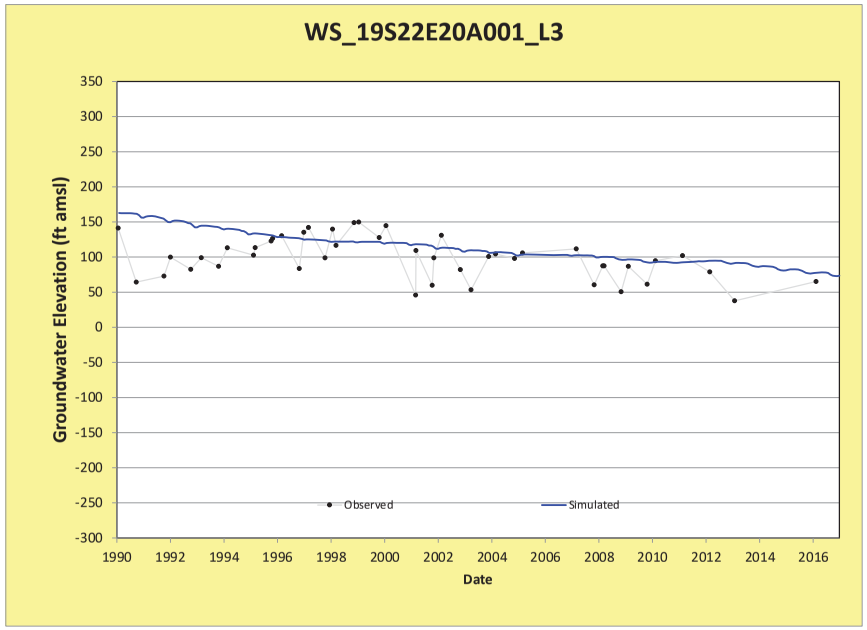

WS_19S22E04M001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

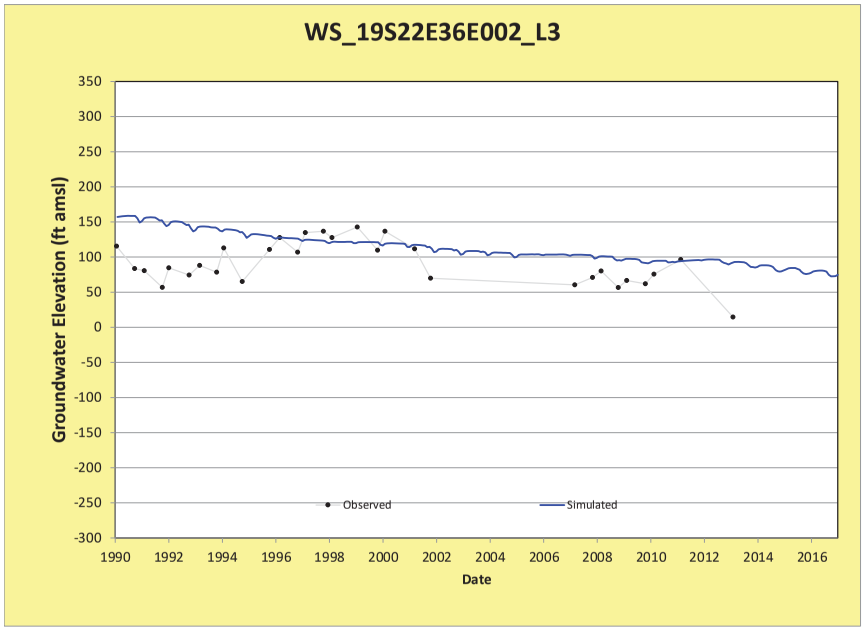

WS_19S22E02K001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

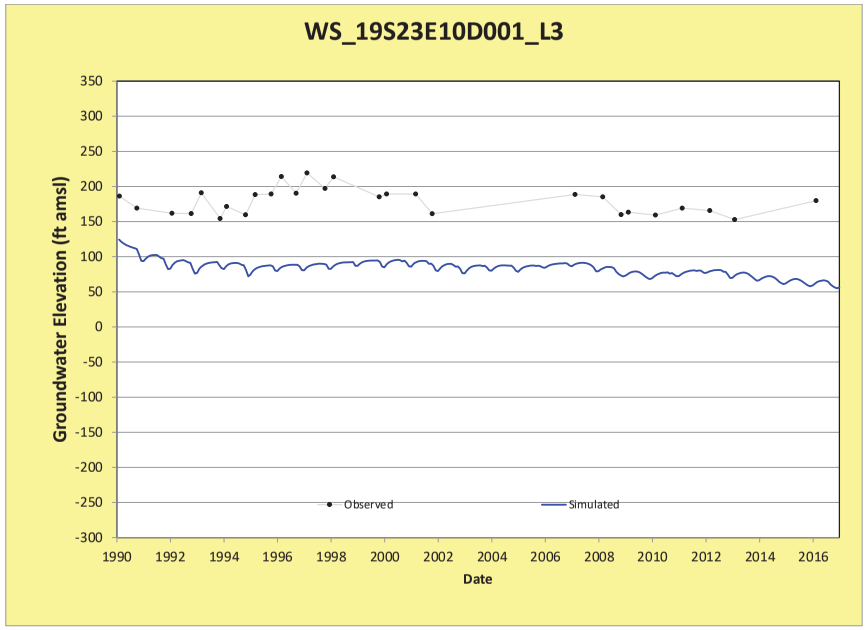

WS_19S22E07A001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

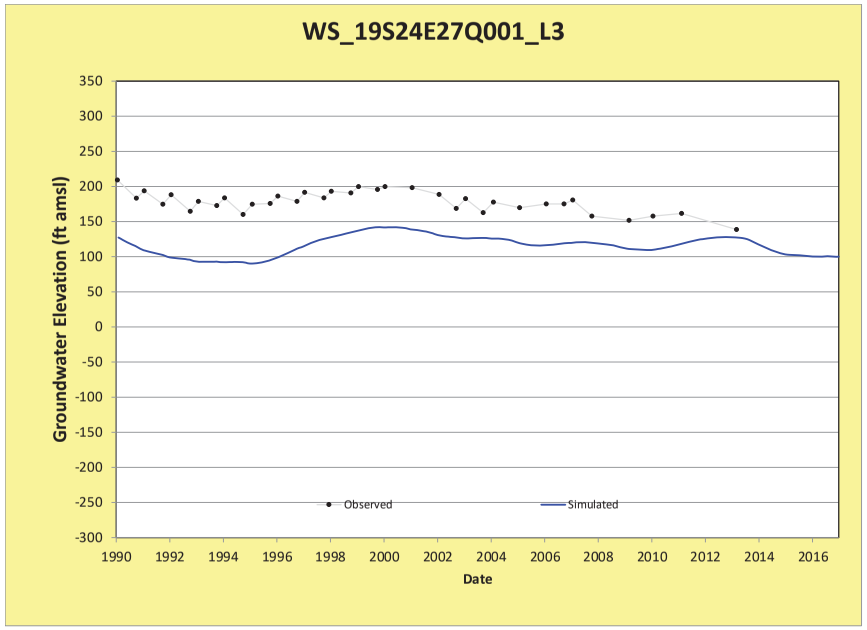

WS_19S22E17L001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

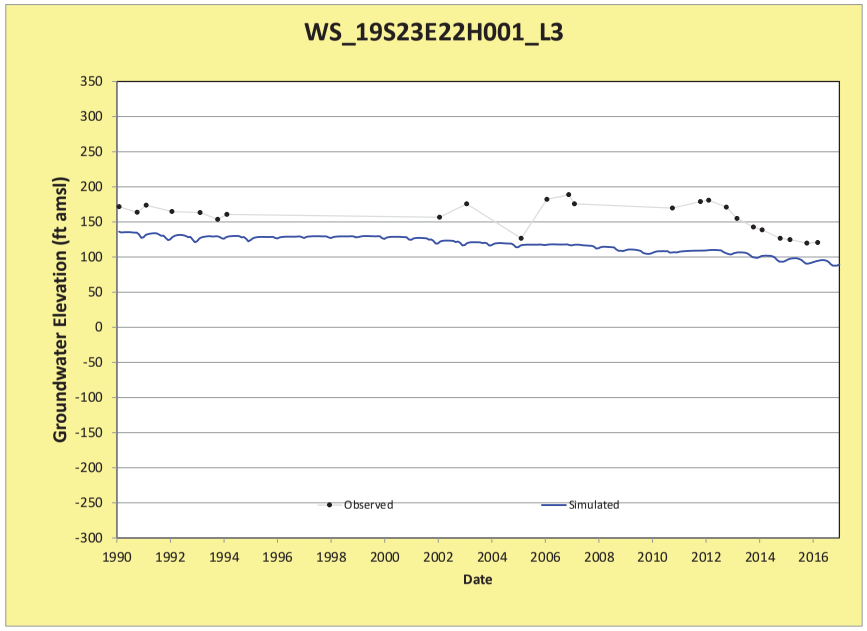

WS_19S22E27C001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

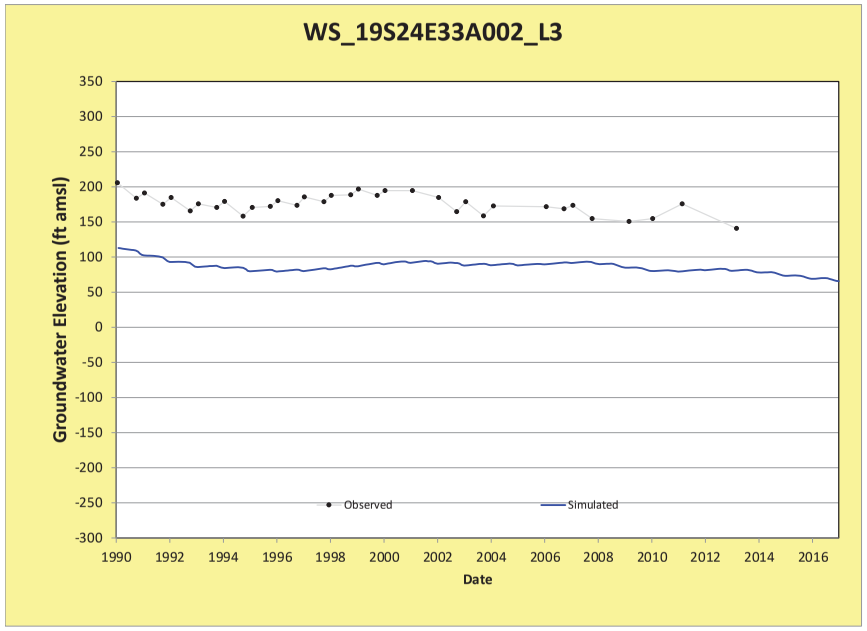

WS_19S22E20A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

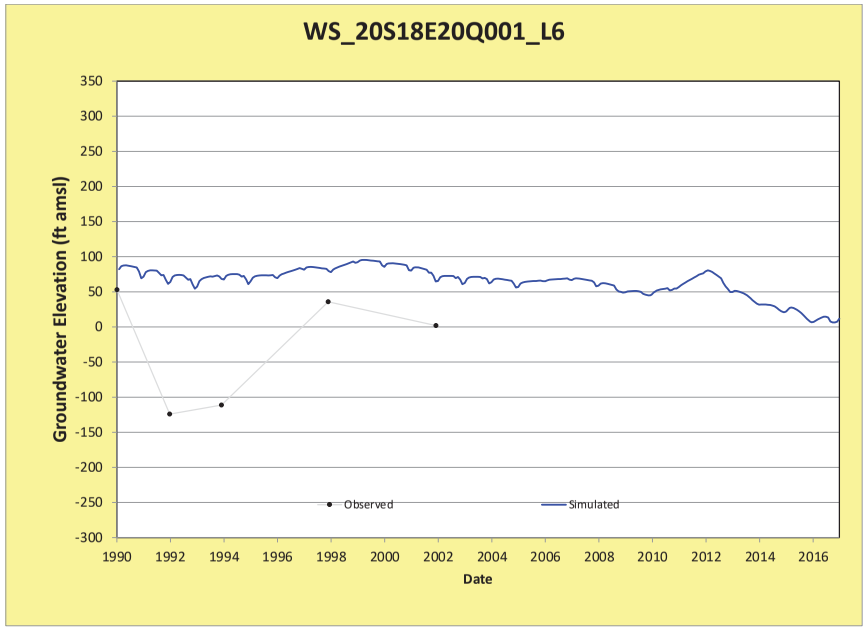

WS_19S22E36E002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

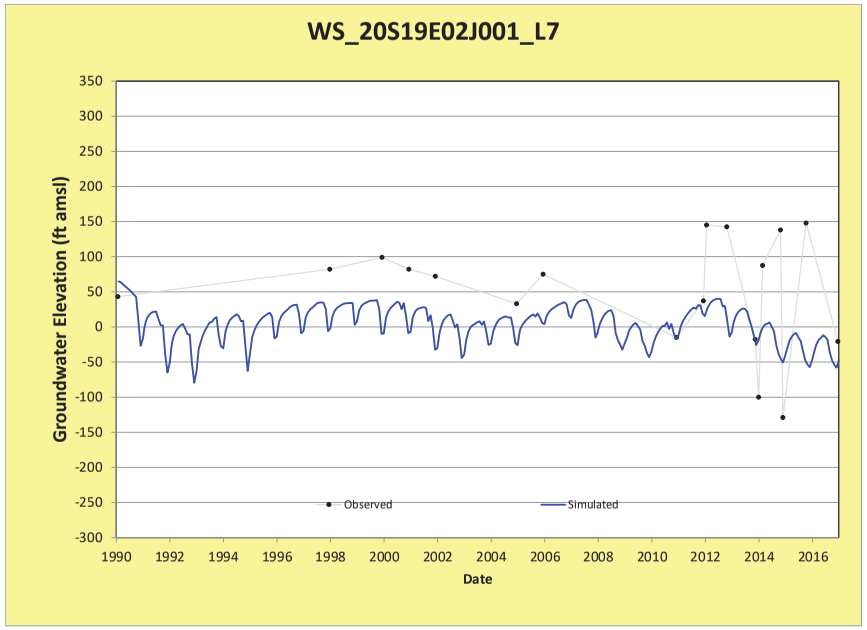

WS_19S23E10D001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

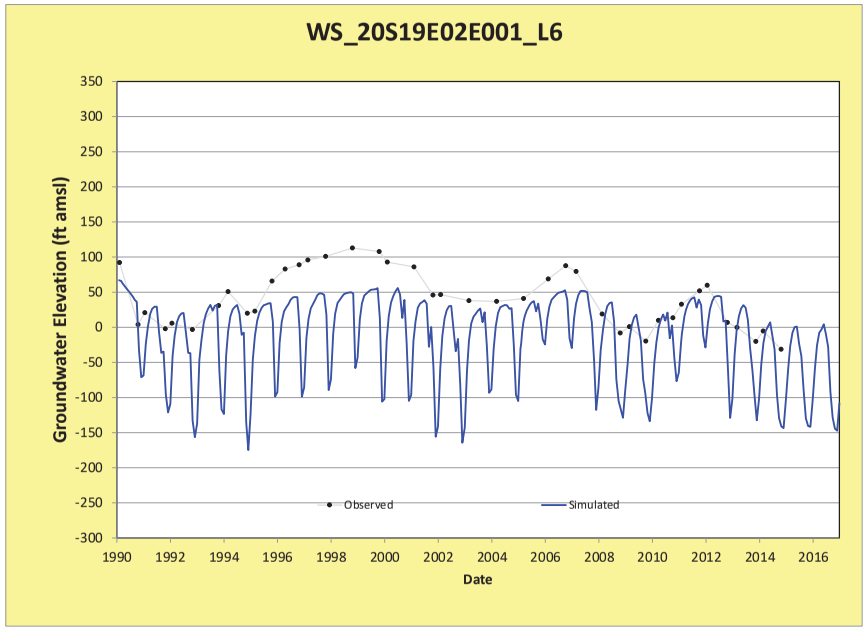

WS_19S24E27Q001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

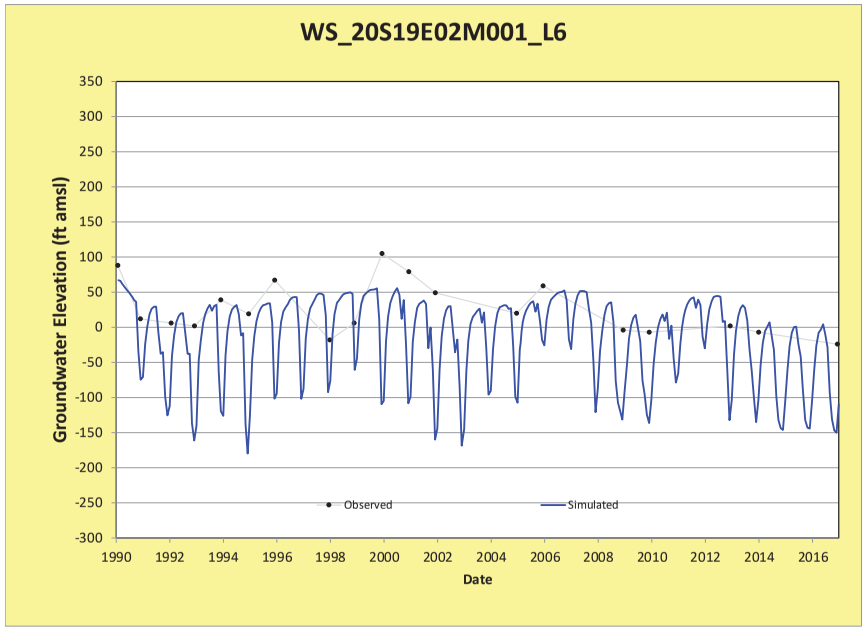

WS_19S23E22H001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

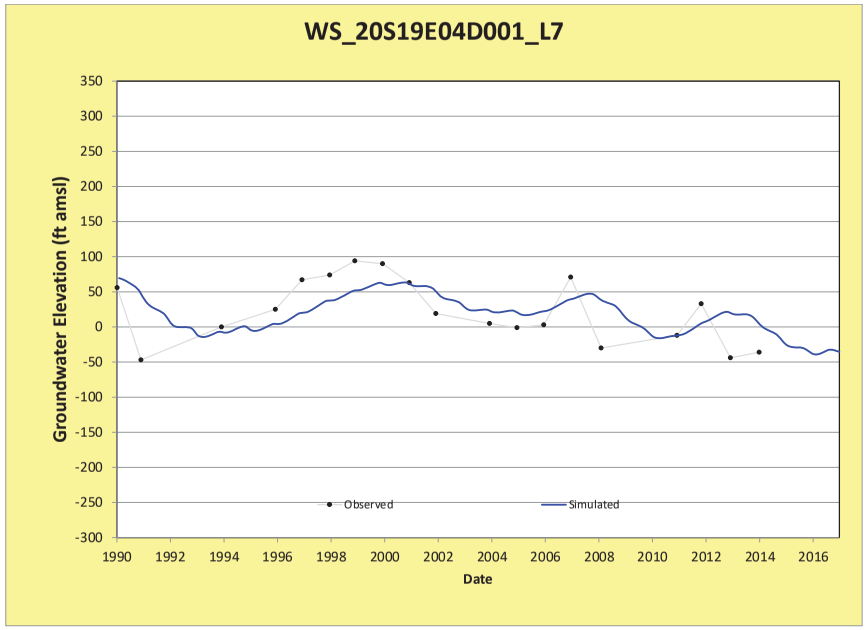

WS_19S24E33A002_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

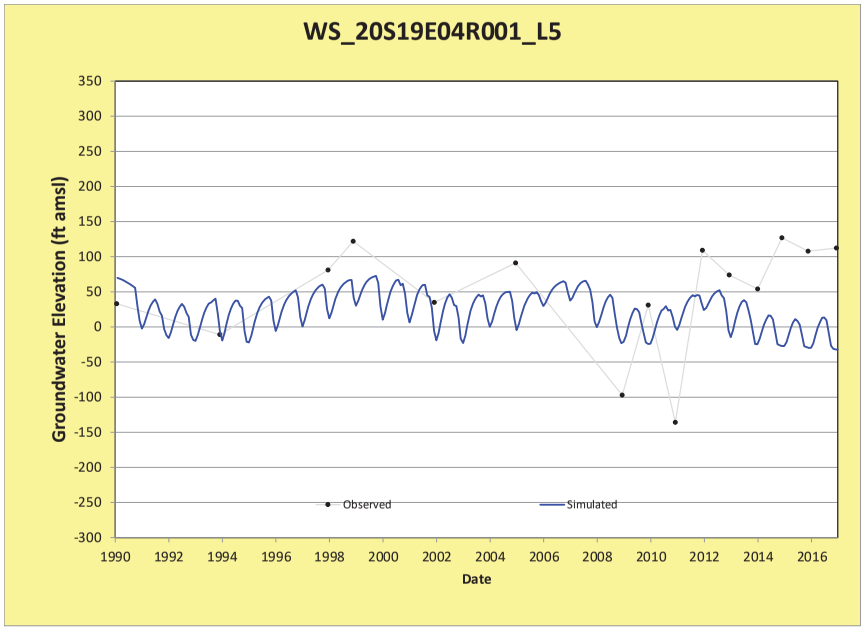

WS_20S18E20Q001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

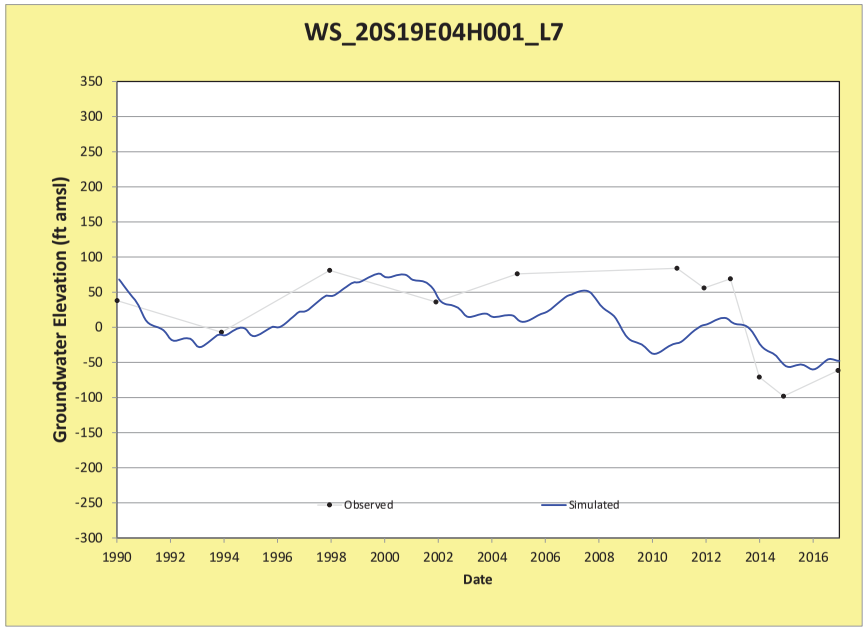

WS_20S19E02J001_L7
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

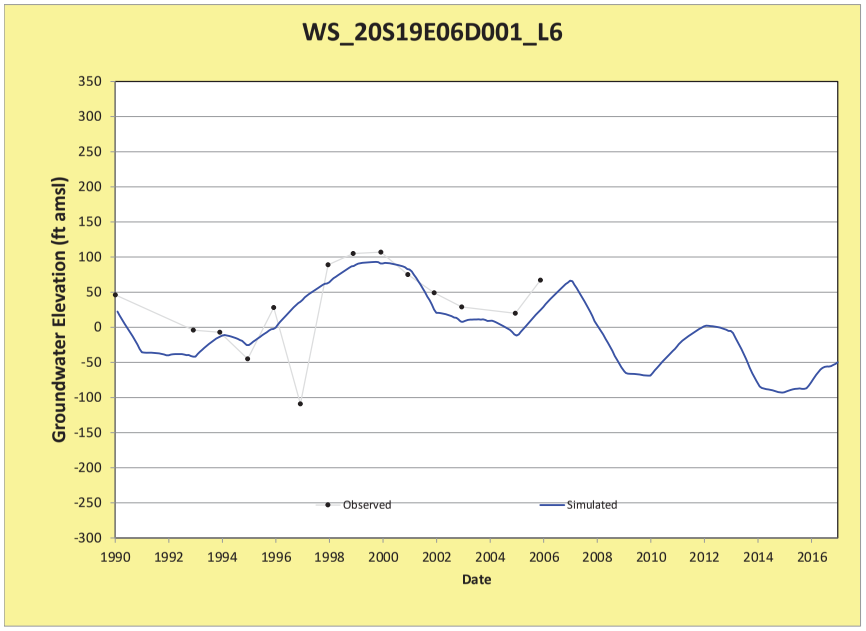

WS_20S19E02E001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

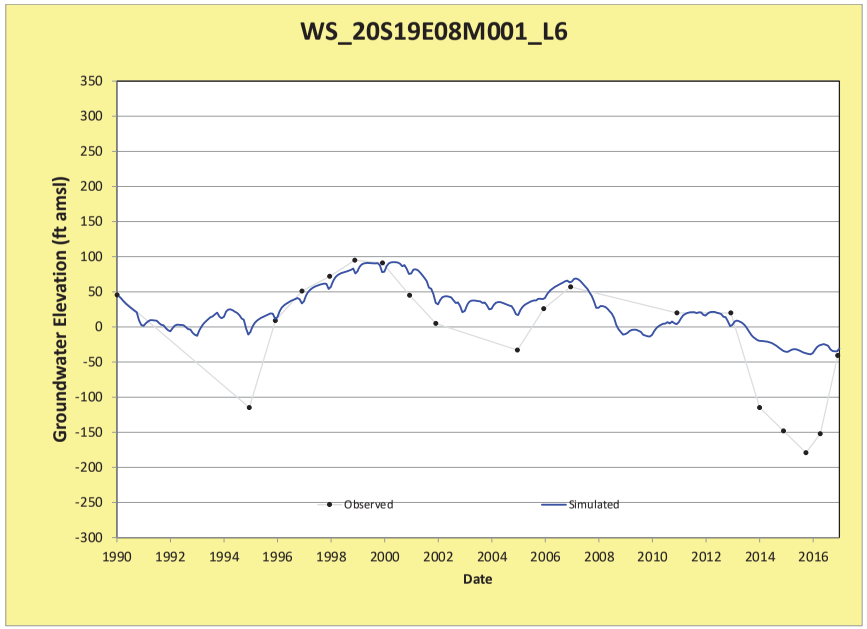

WS_20S19E02M001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

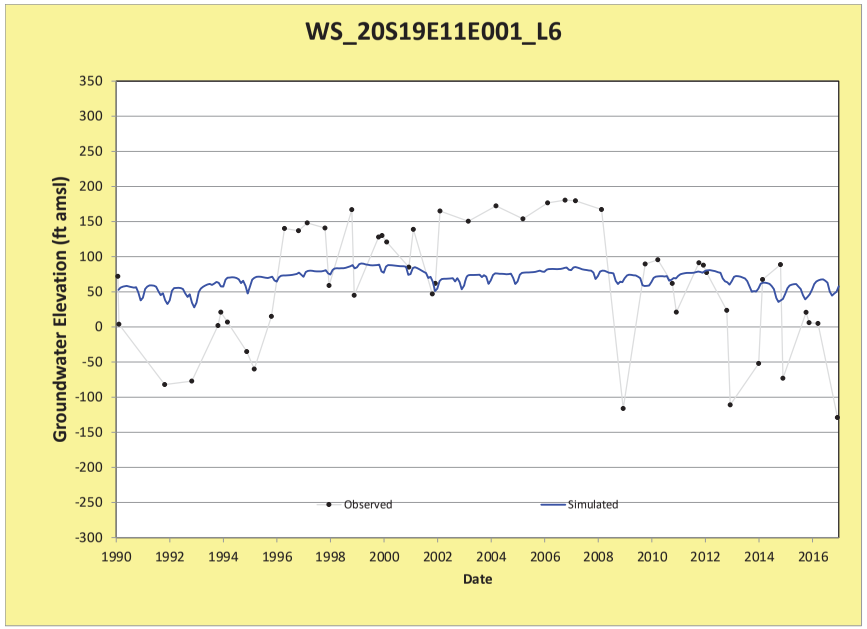

WS_20S19E04D001_L7
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

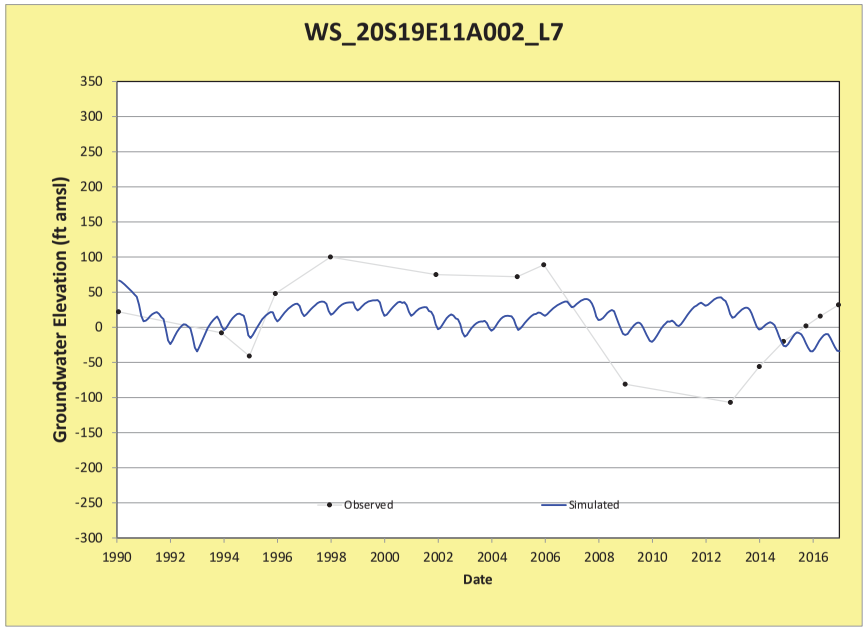

WS_20S19E04R001_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

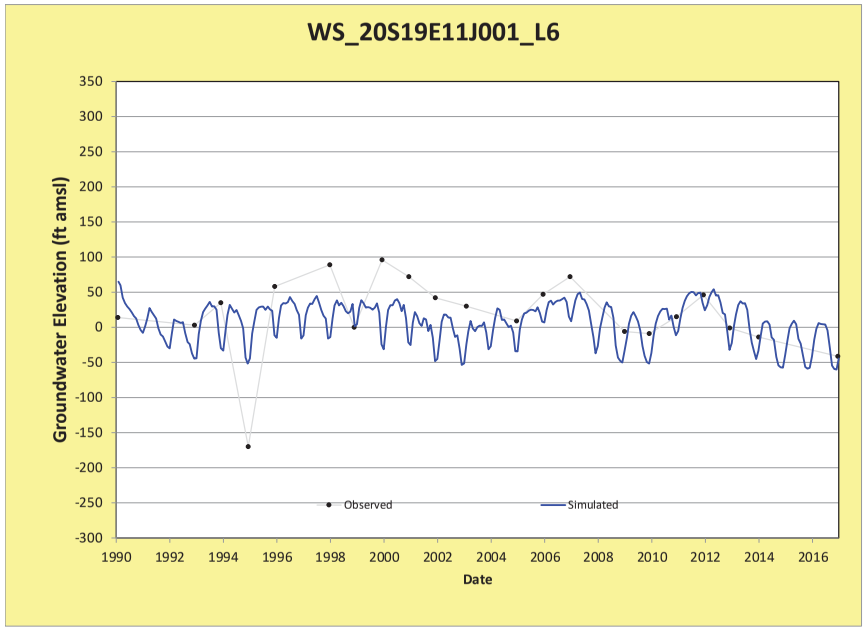

WS_20S19E04H001_L7
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

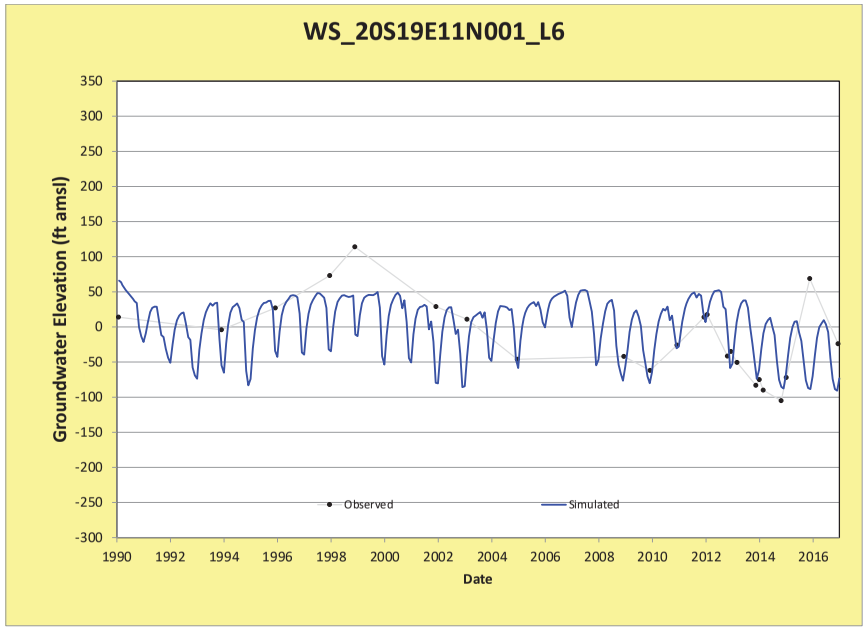

WS_20S19E06D001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

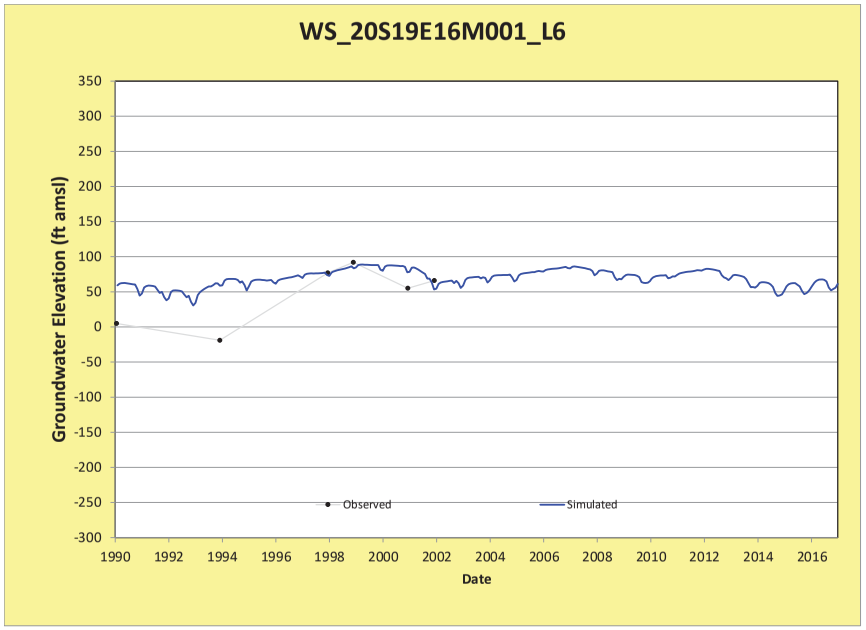

WS_20S19E08M001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

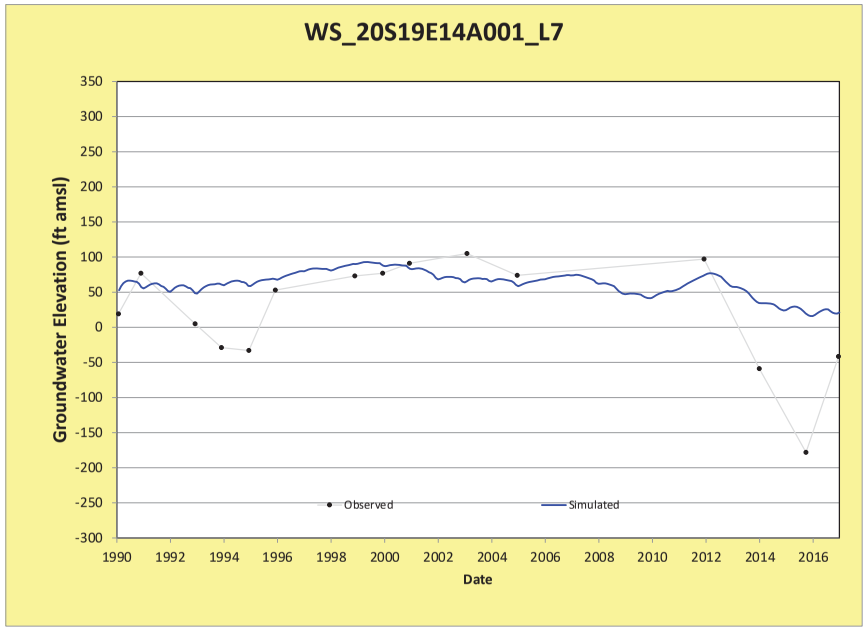

WS_20S19E11E001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

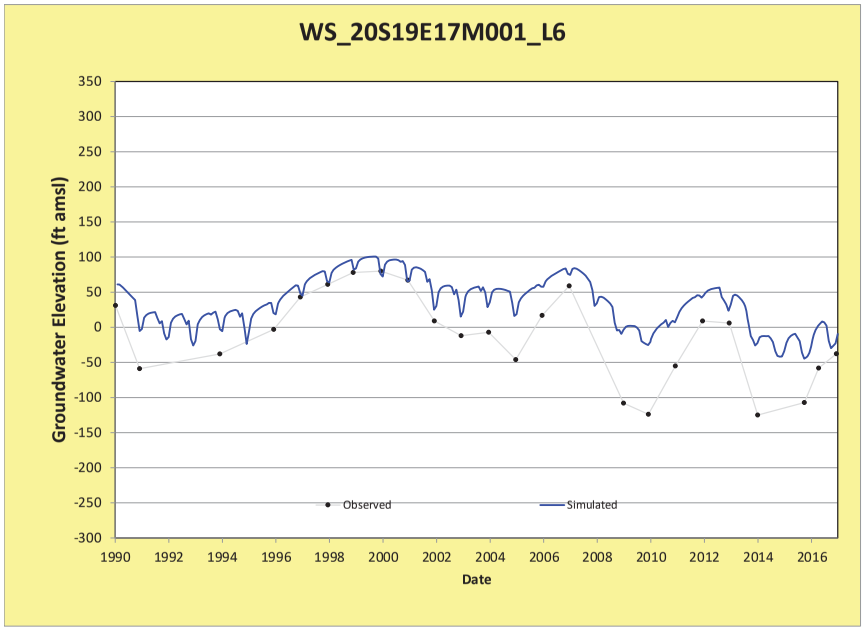

WS_20S19E11A002_L7
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

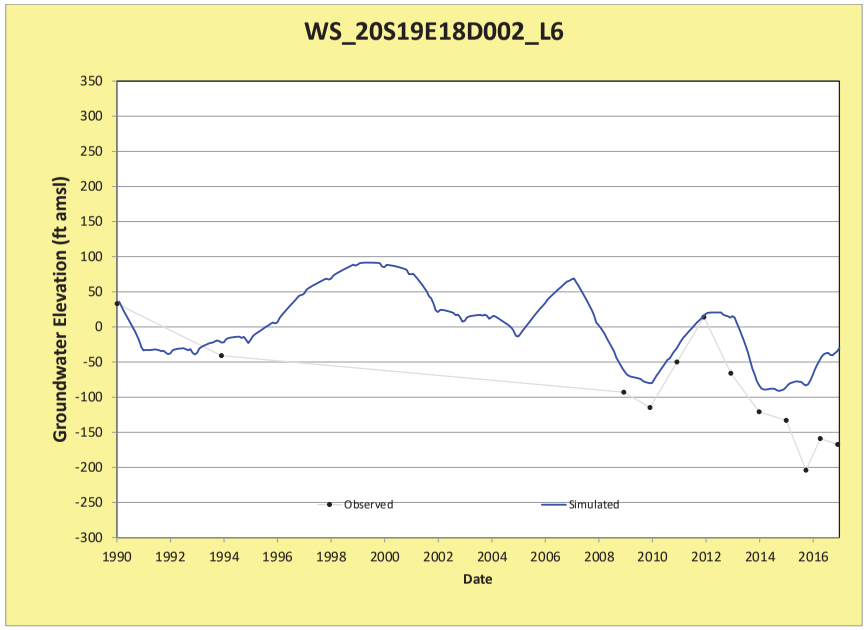

WS_20S19E11J001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

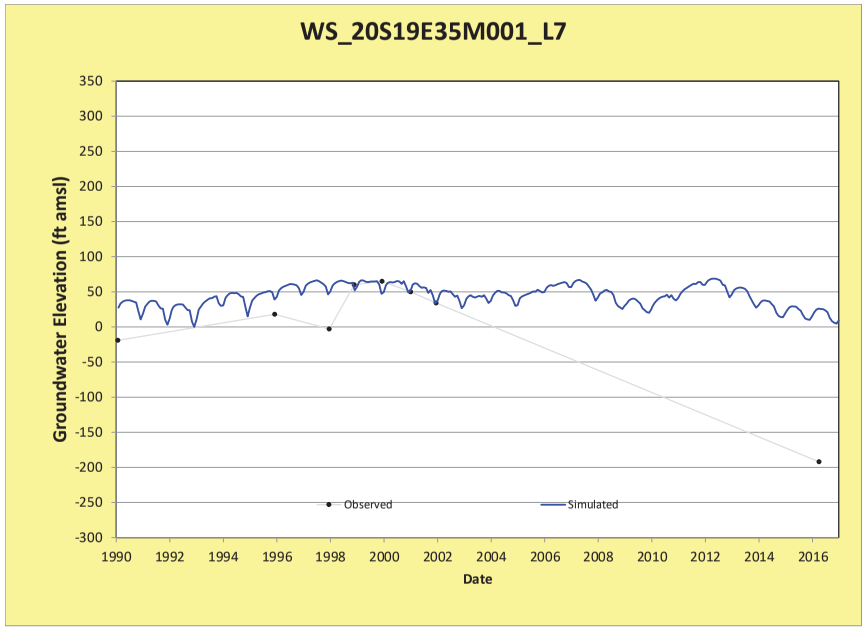

WS_20S19E11N001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

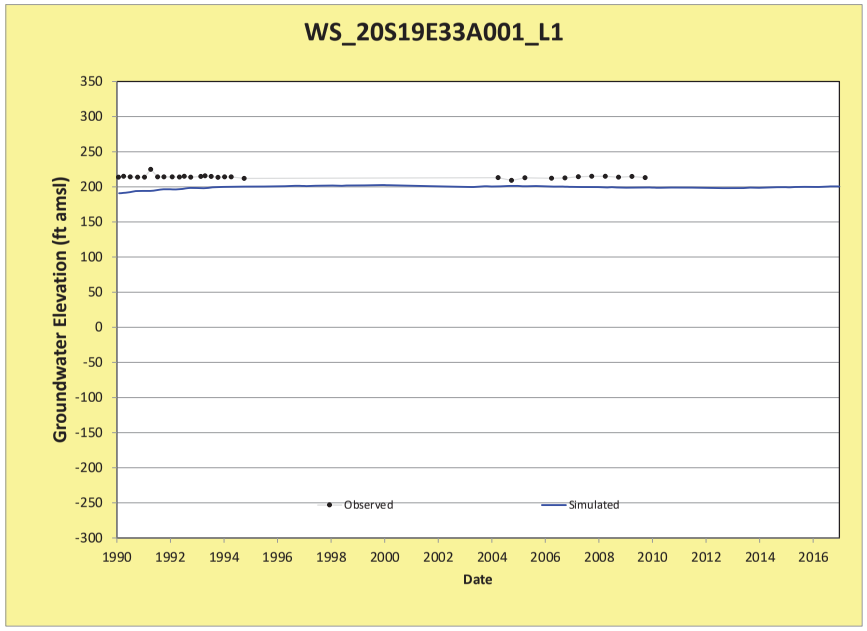

WS_20S19E16M001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

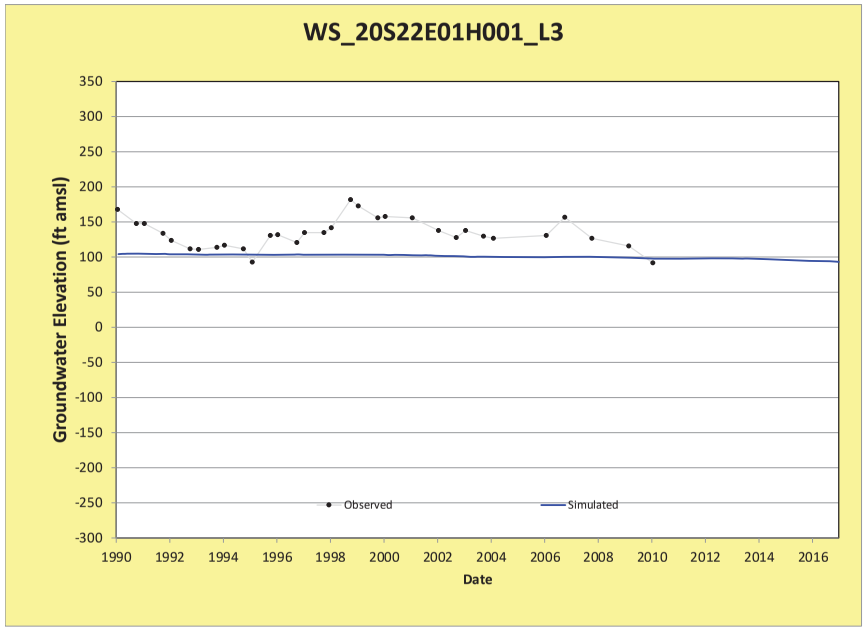

WS_20S19E14A001_L7
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

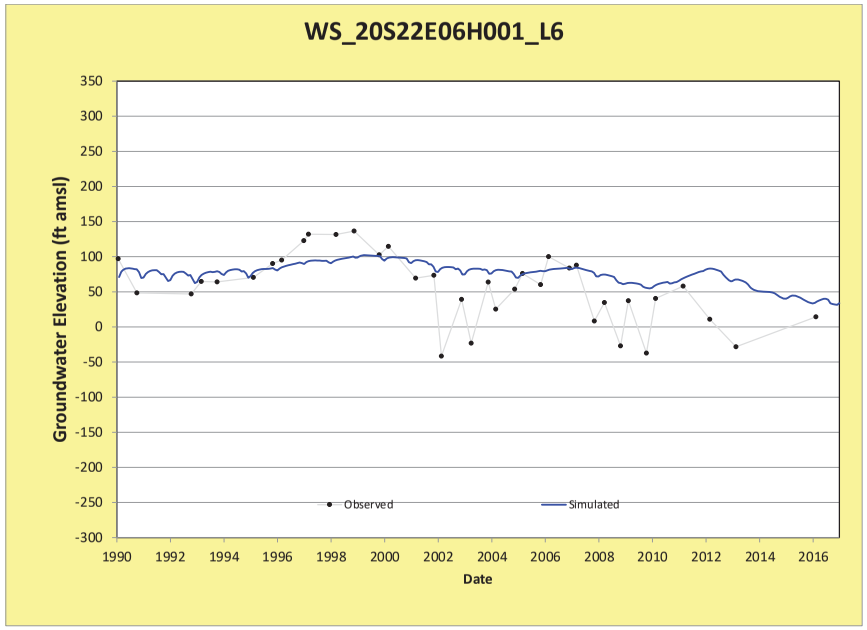

WS_20S19E17M001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

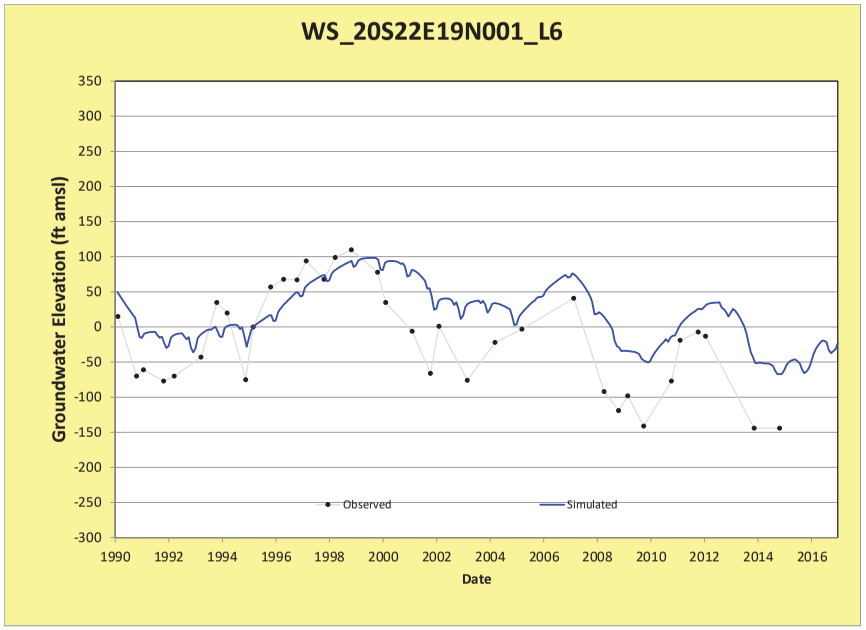

WS_20S19E18D002_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

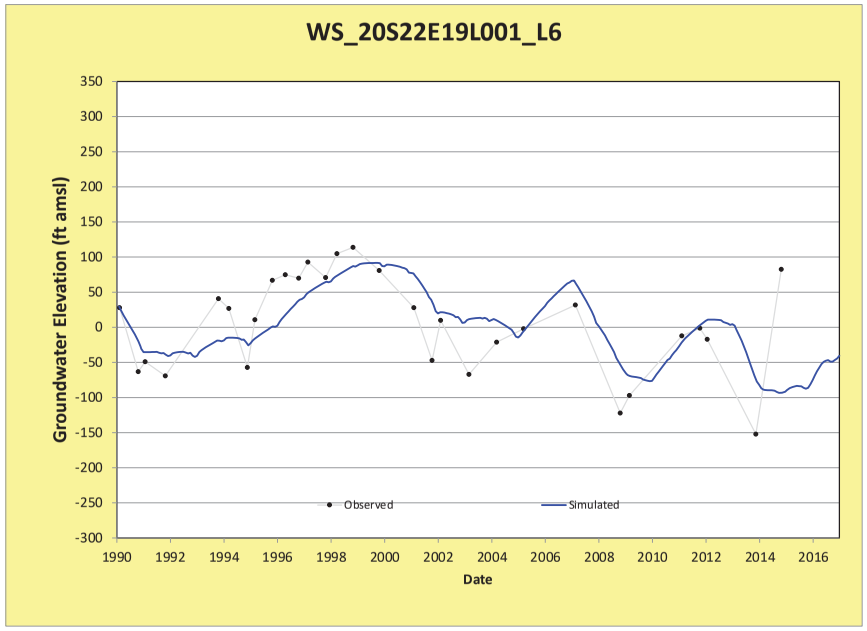

WS_20S19E35M001_L7
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

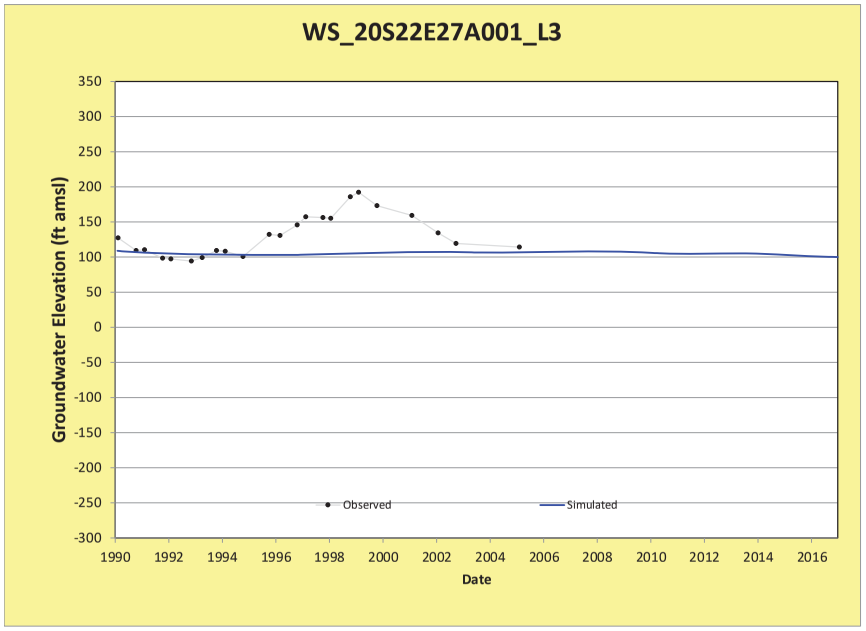

WS_20S19E33A001_L1
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

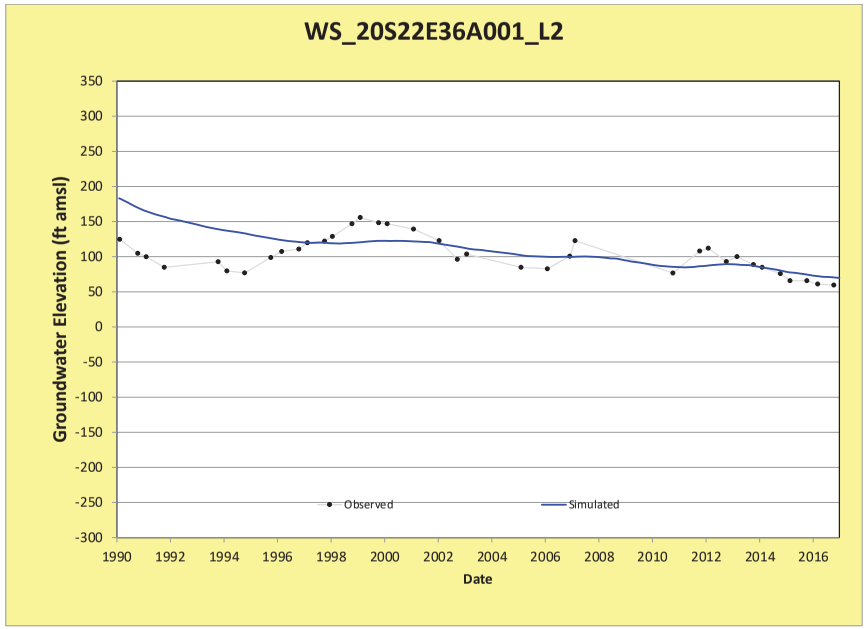

WS_20S22E01H001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

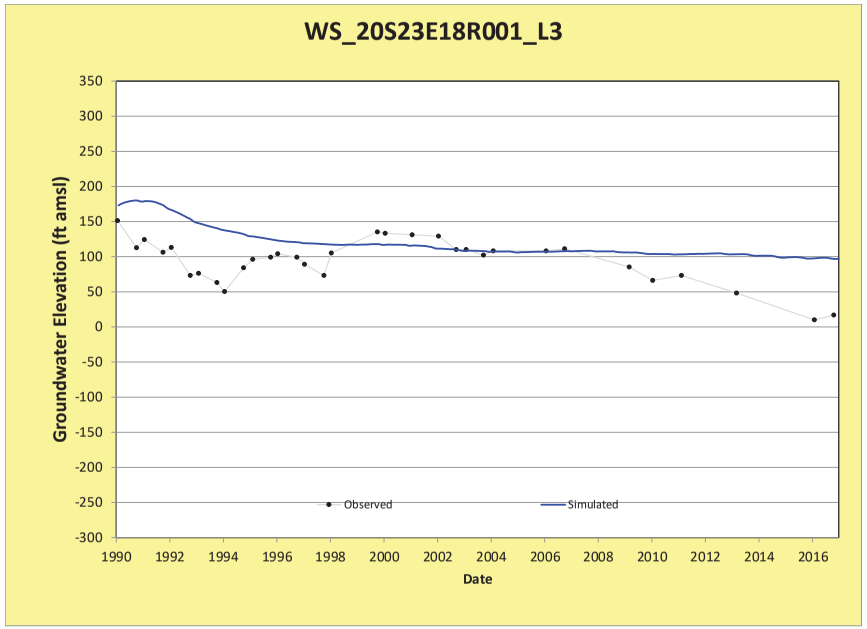

WS_20S22E06H001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

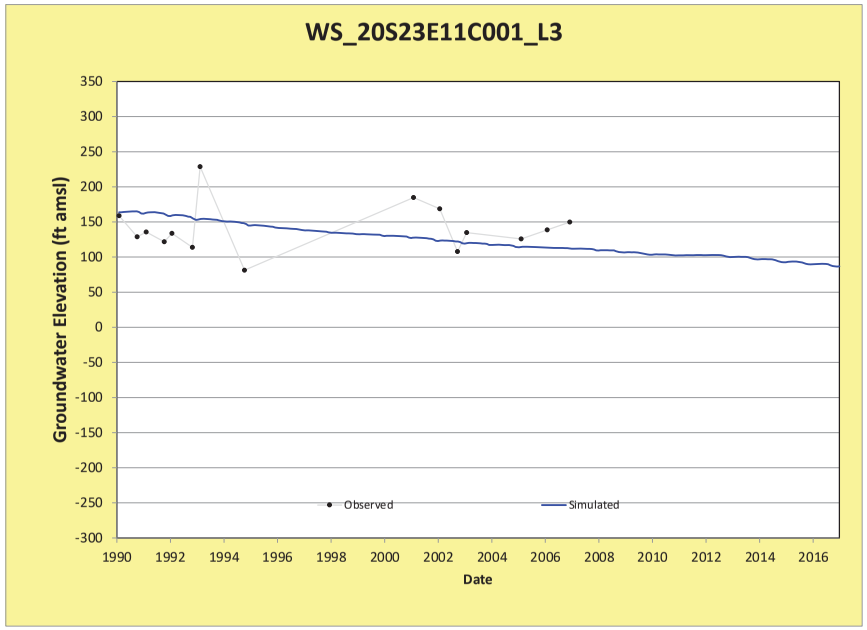

WS_20S22E19N001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

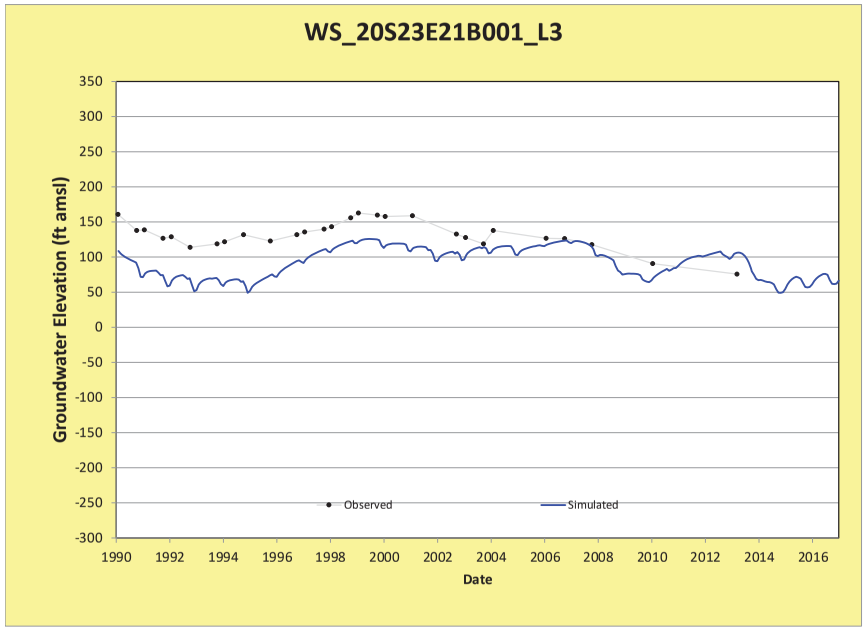

WS_20S22E19L001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

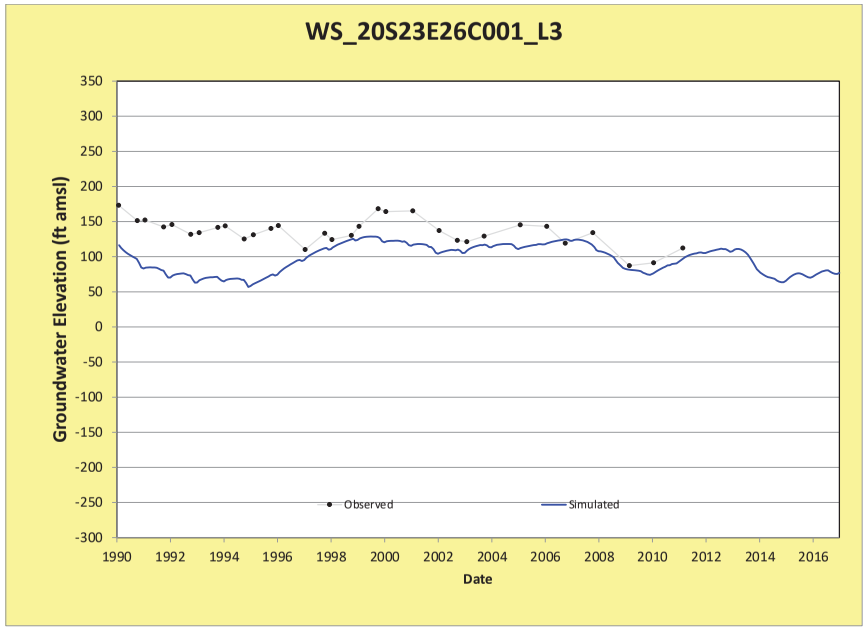

WS_20S22E27A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

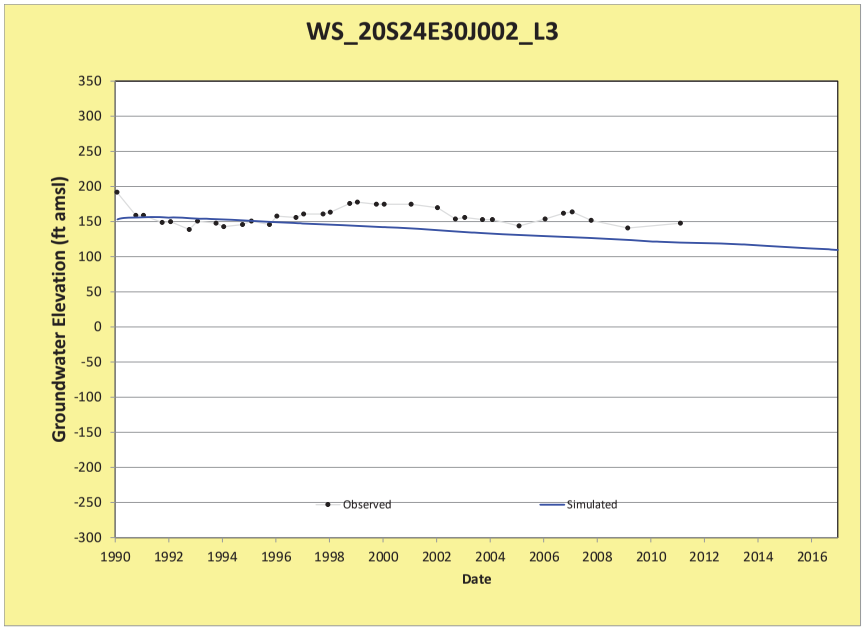

WS_20S22E36A001_L2
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

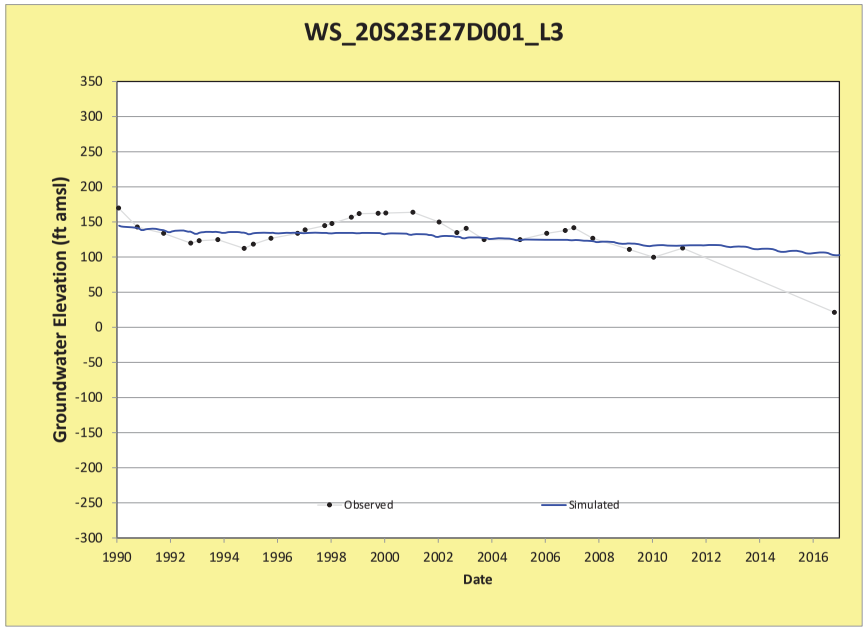

WS_20S23E18R001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

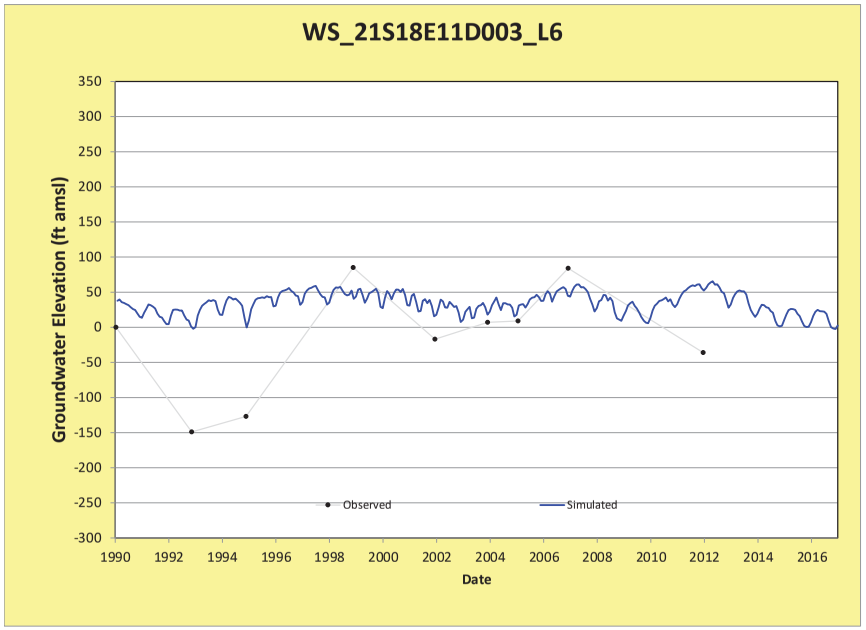

WS_20S23E11C001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

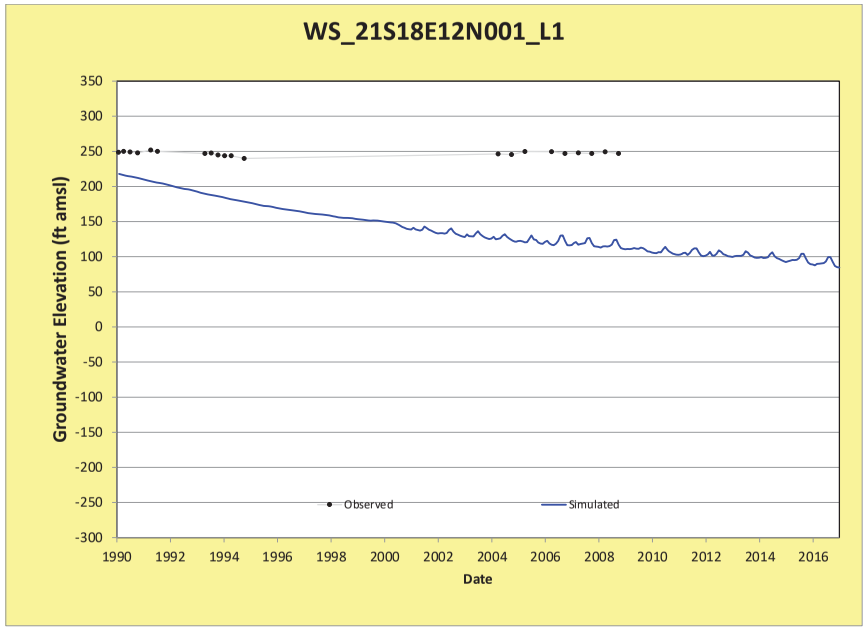

WS_20S23E21B001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

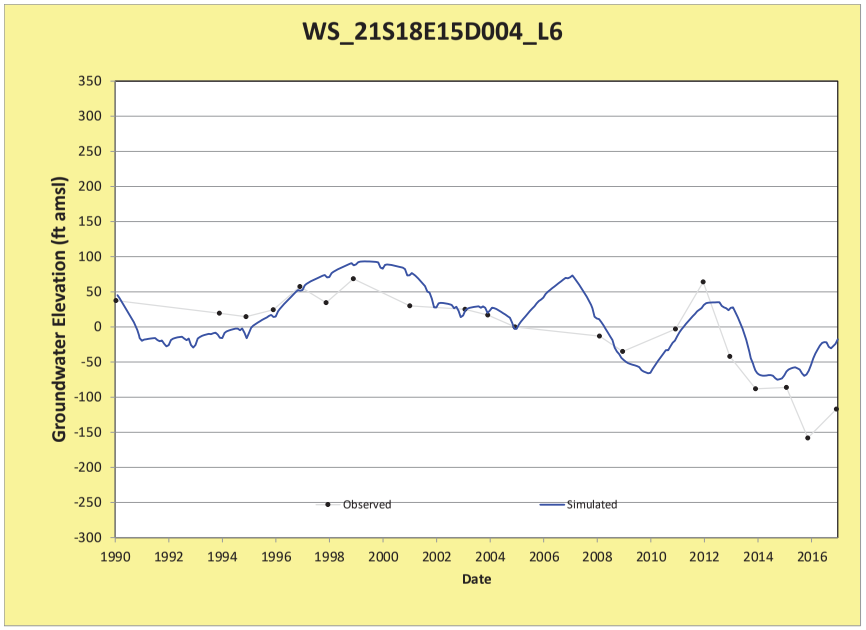

WS_20S23E26C001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

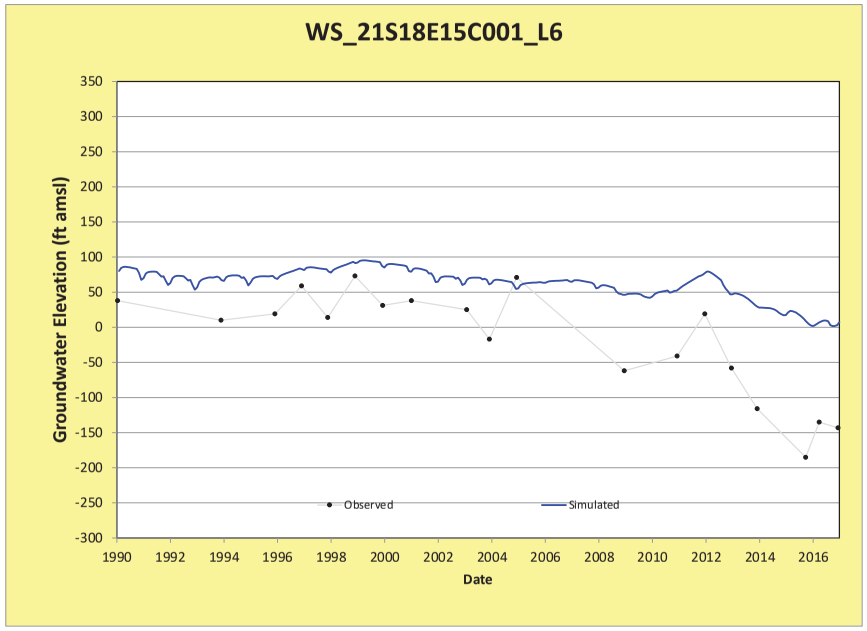

WS_20S24E30J002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

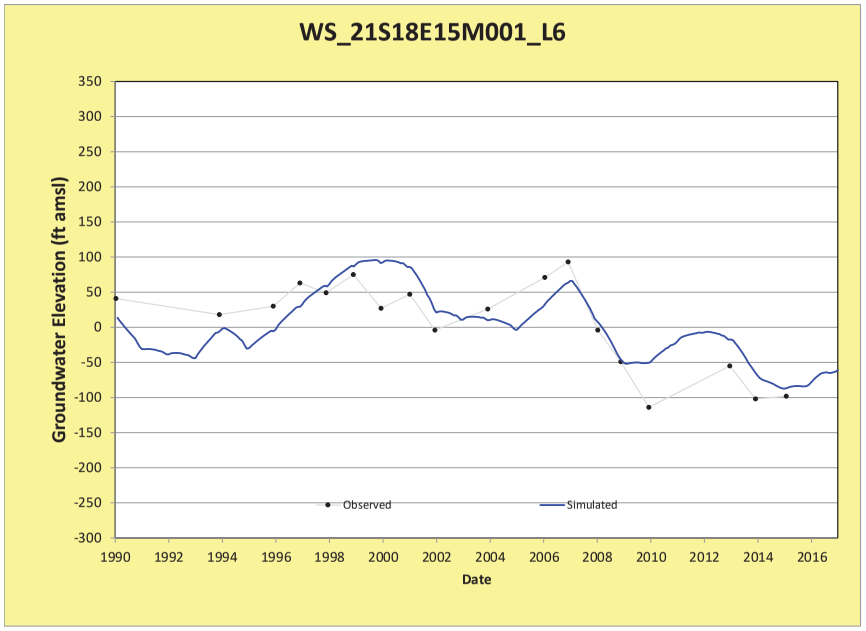

WS_20S23E27D001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

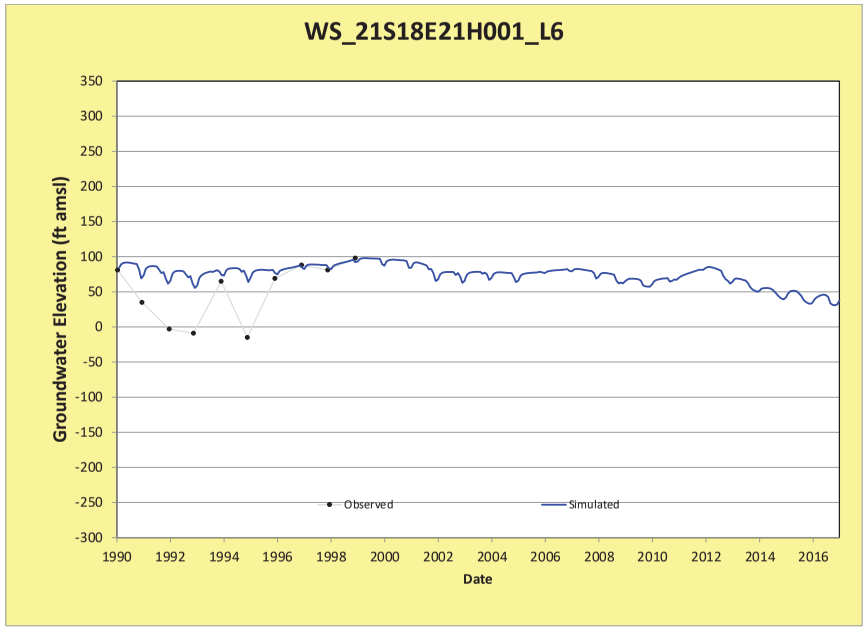

WS_21S18E11D003_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

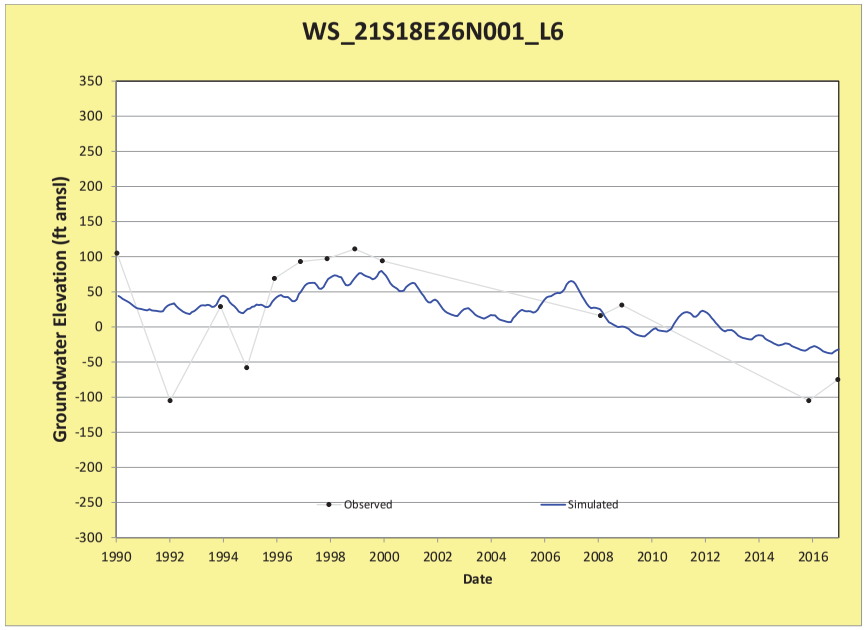

WS_21S18E12N001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

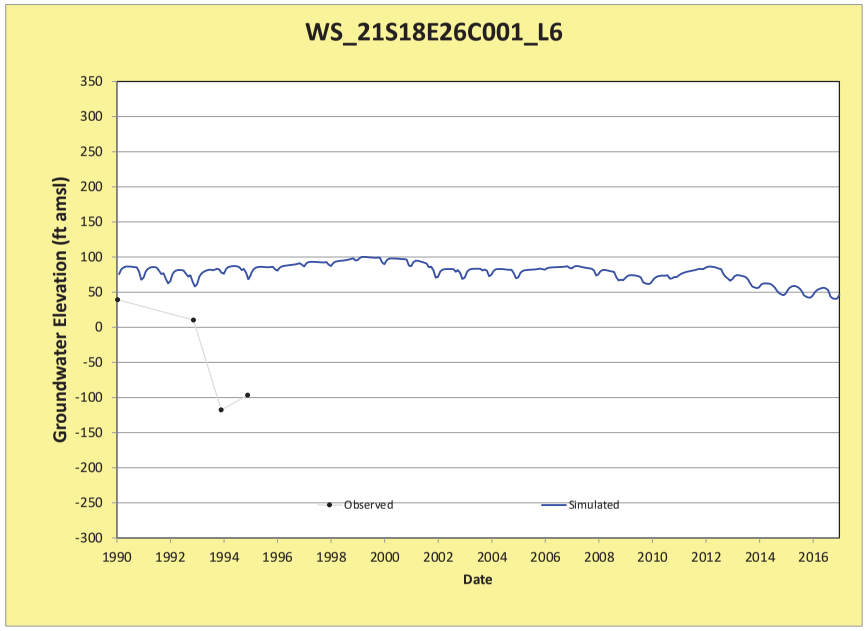

WS_21S18E15D004_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

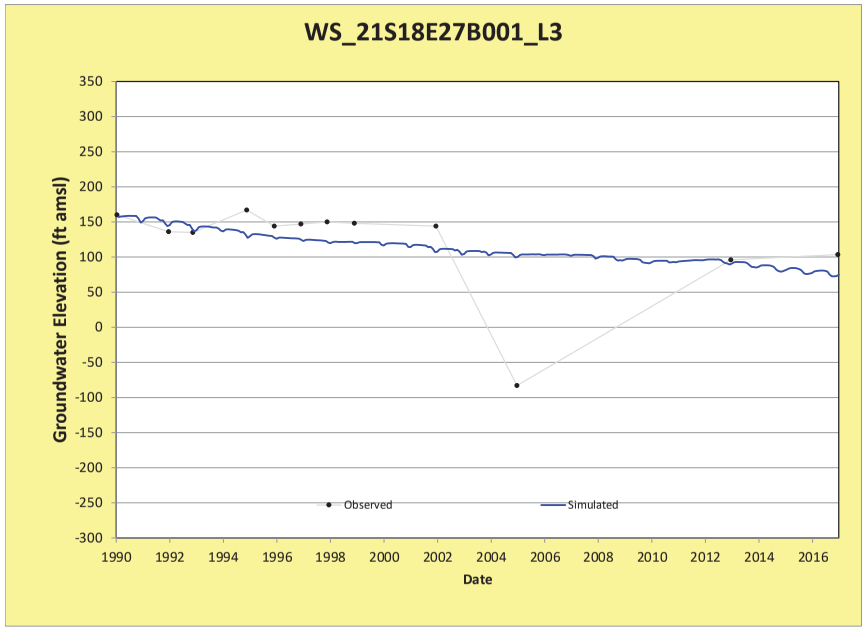

WS_21S18E15C001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

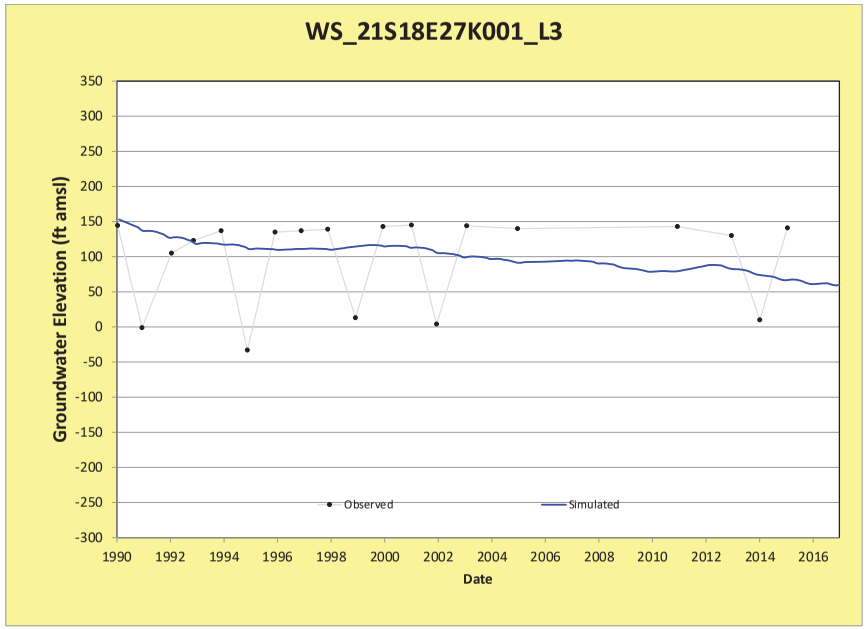

WS_21S18E15M001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

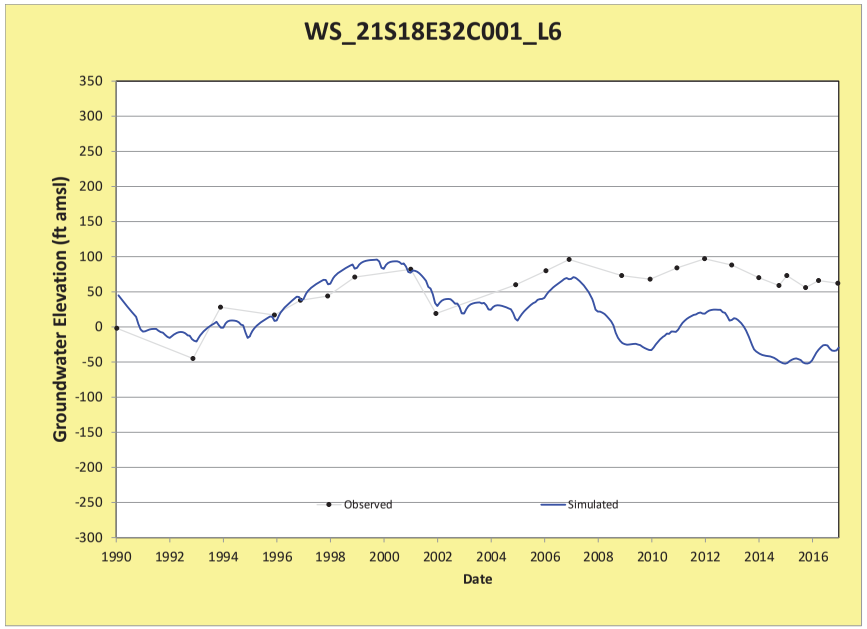

WS_21S18E21H001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

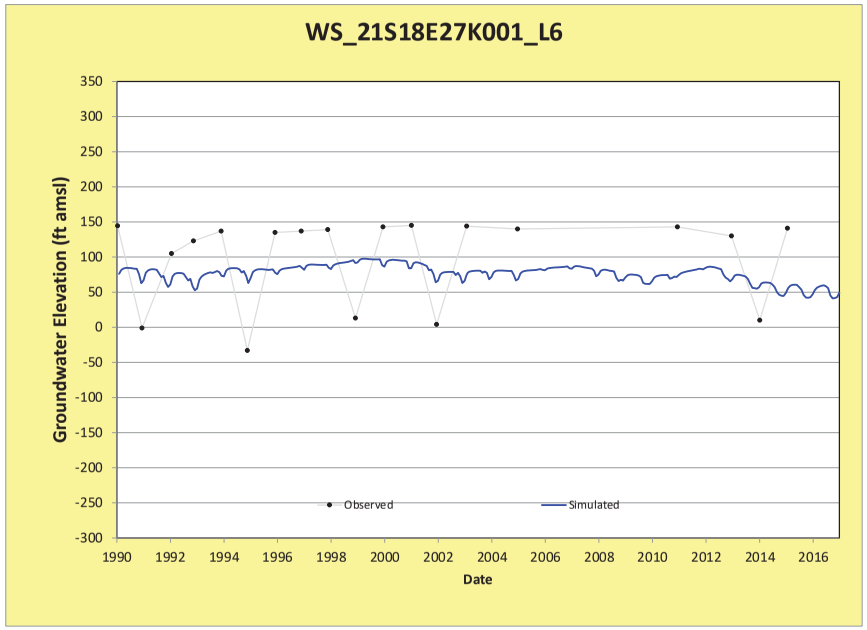

WS_21S18E26N001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

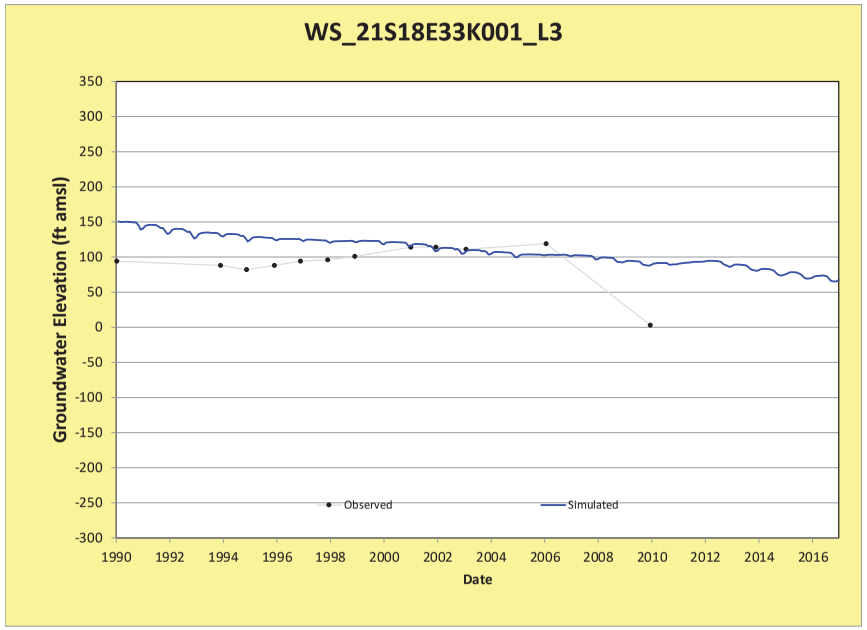

WS_21S18E26C001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

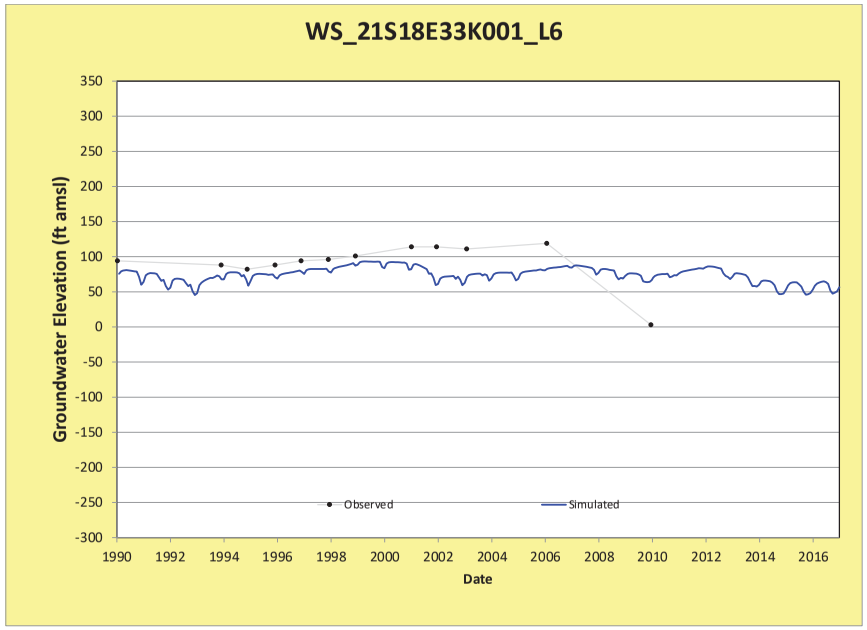

WS_21S18E27B001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

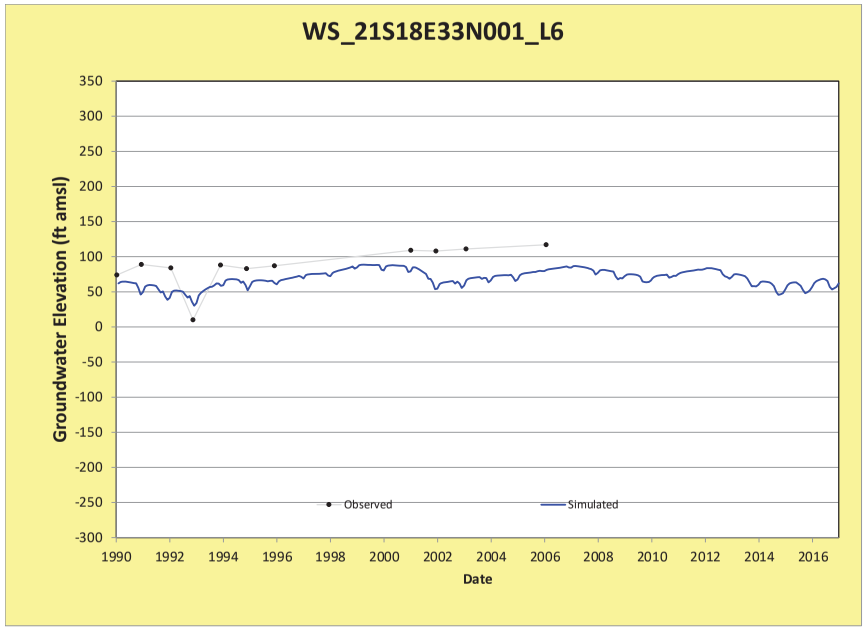

WS_21S18E27K001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

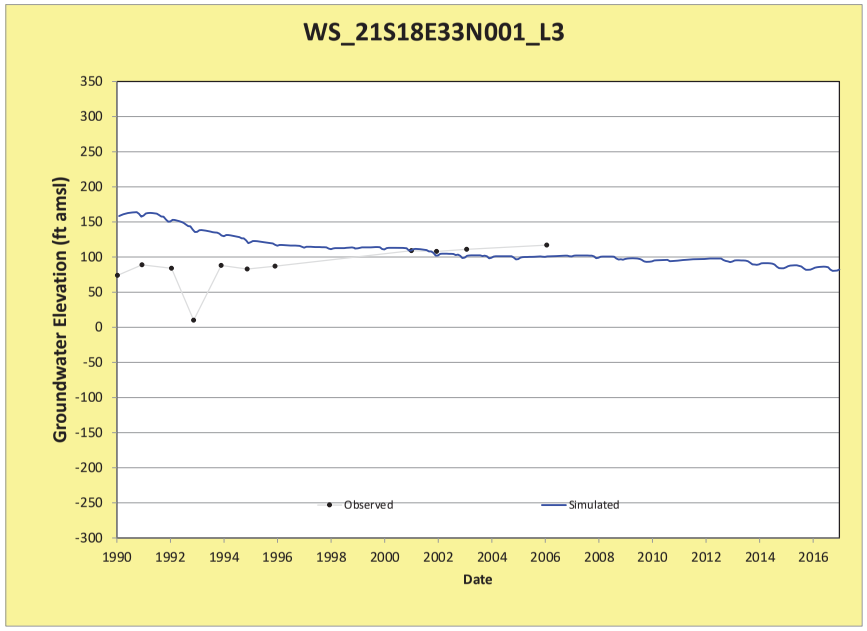

WS_21S18E32C001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

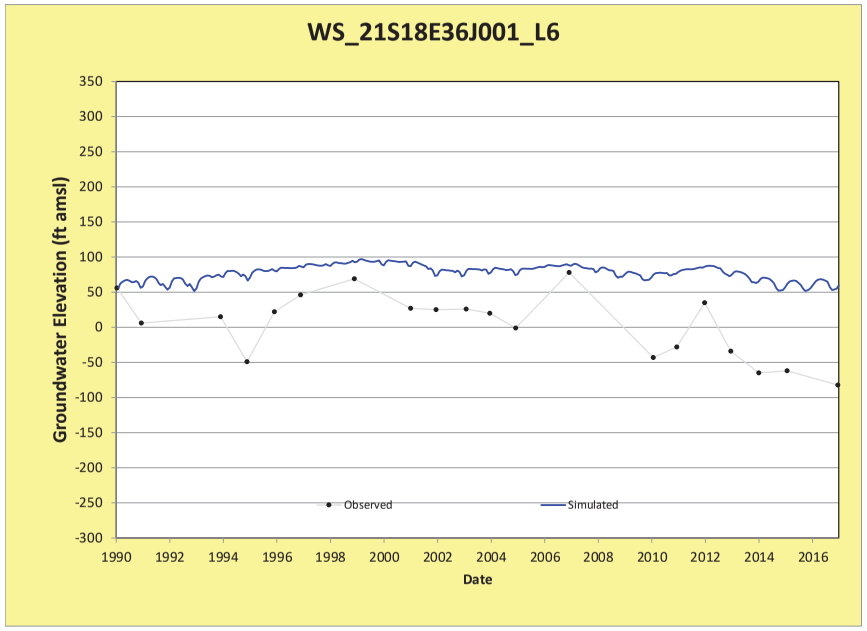

WS_21S18E27K001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

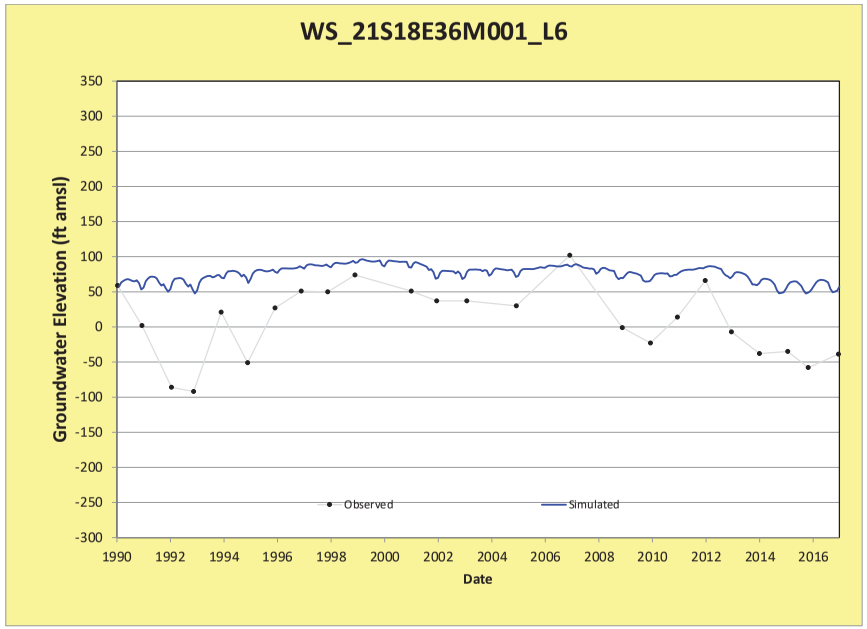

WS_21S18E33K001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

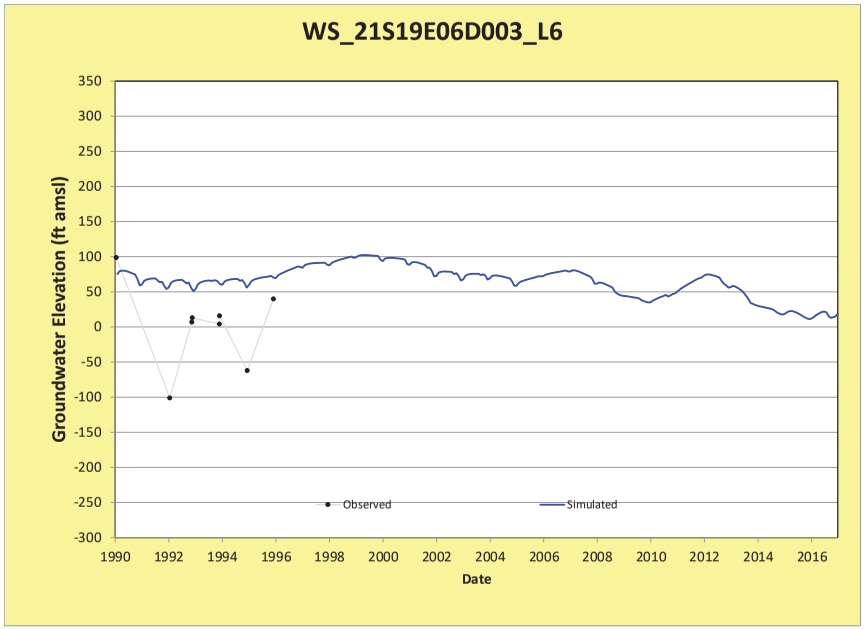

WS_21S18E33K001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

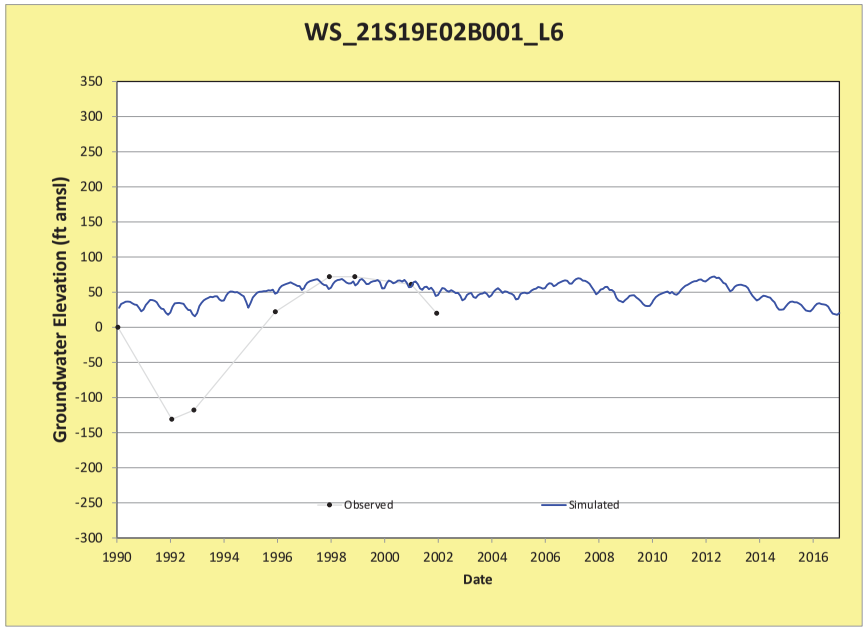

WS_21S18E33N001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

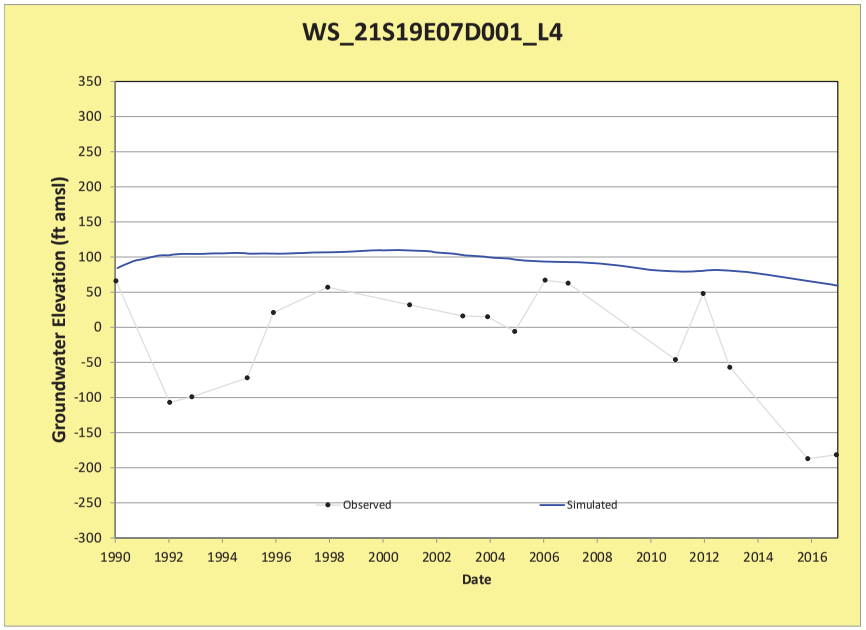

WS_21S18E33N001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

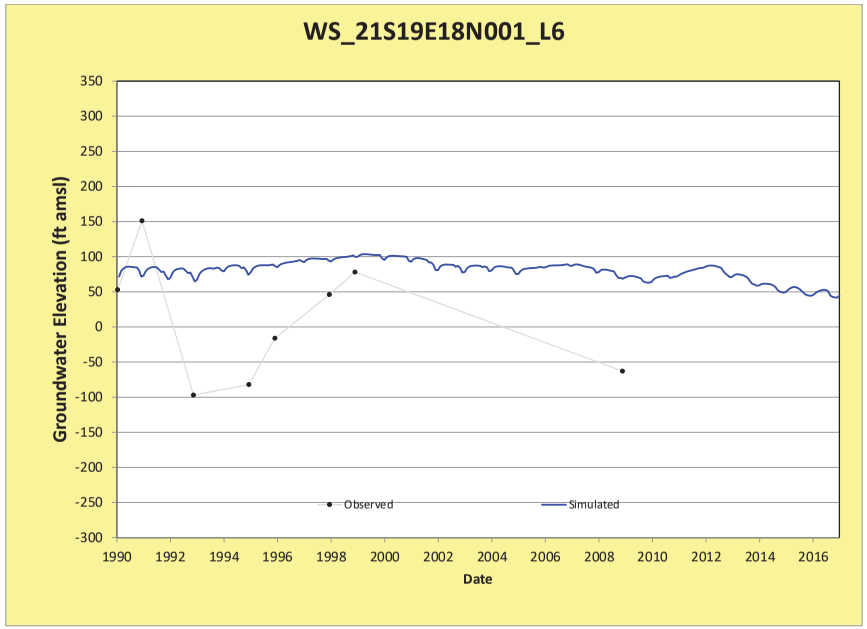

WS_21S18E36J001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

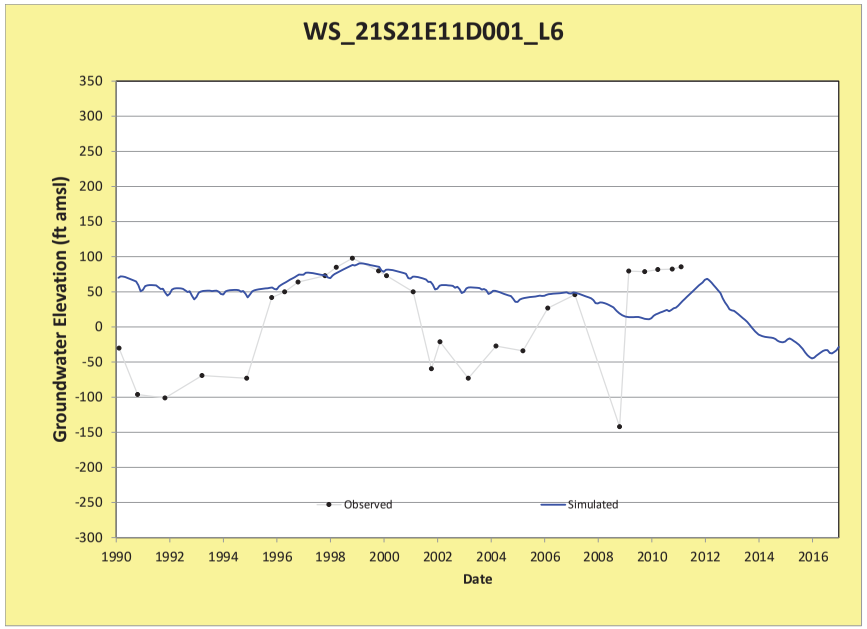

WS_21S18E36M001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

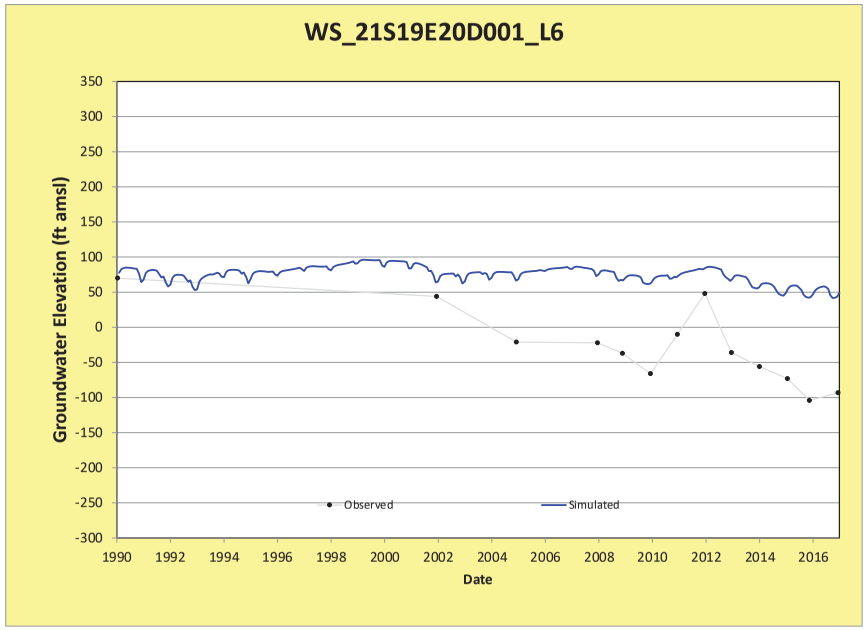

WS_21S19E06D003_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

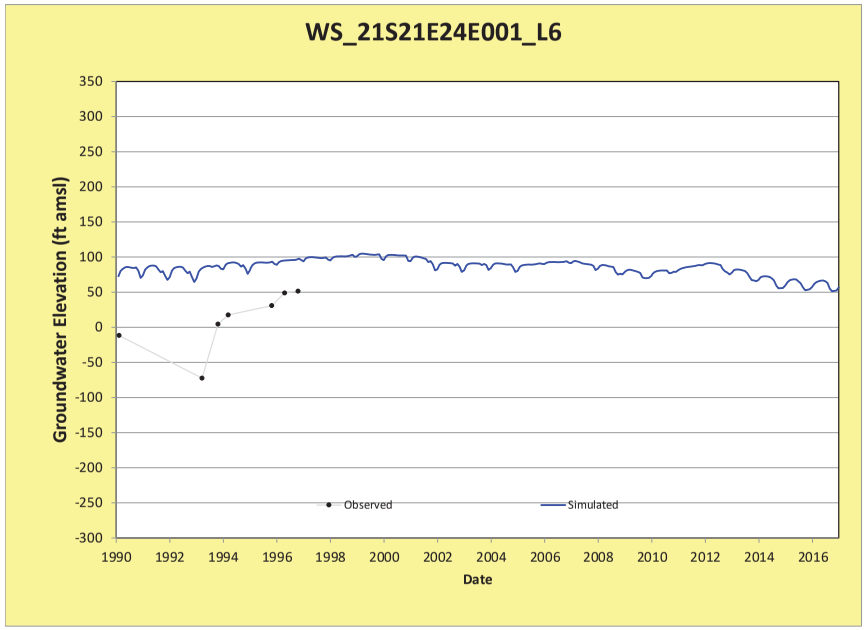

WS_21S19E02B001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

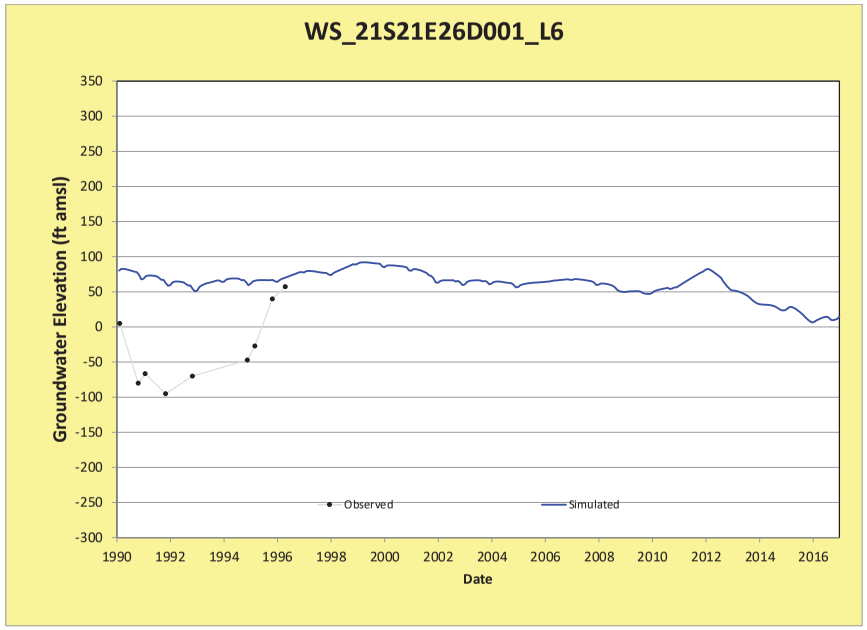

WS_21S19E07D001_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

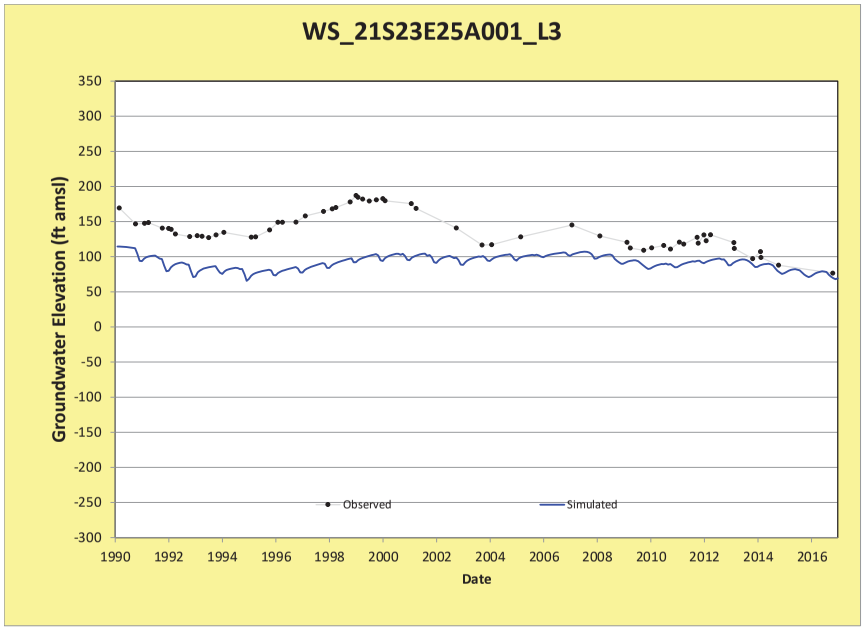

WS_21S19E18N001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

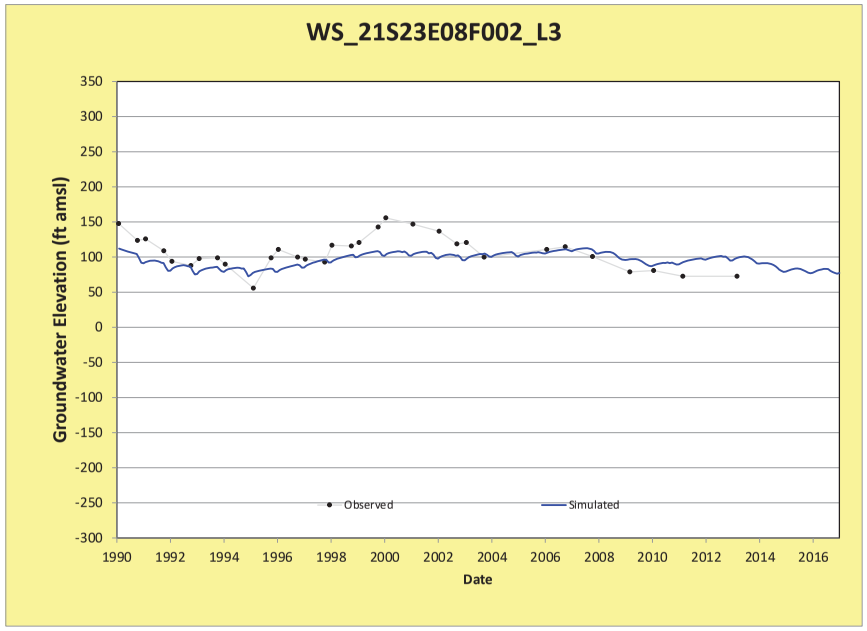

WS_21S21E11D001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

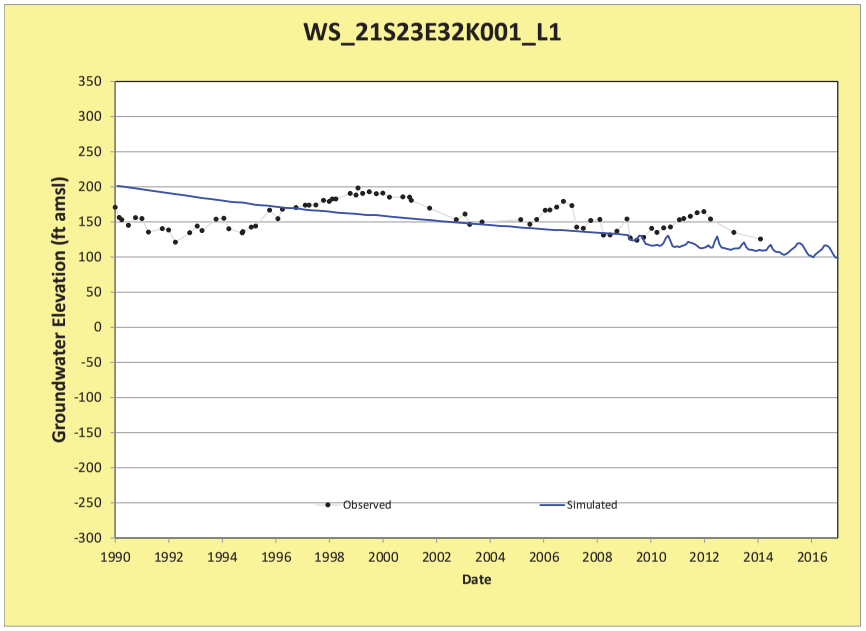

WS_21S19E20D001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

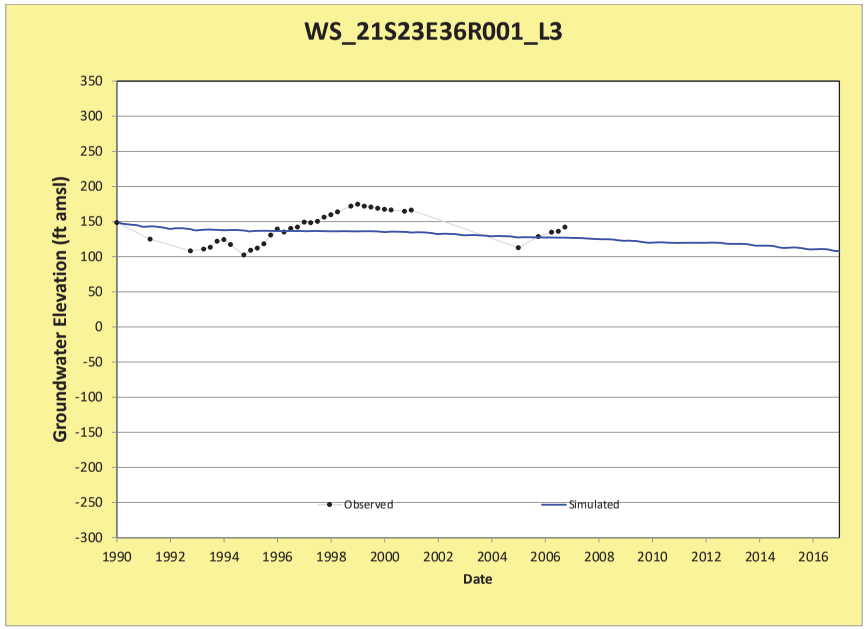

WS_21S21E24E001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

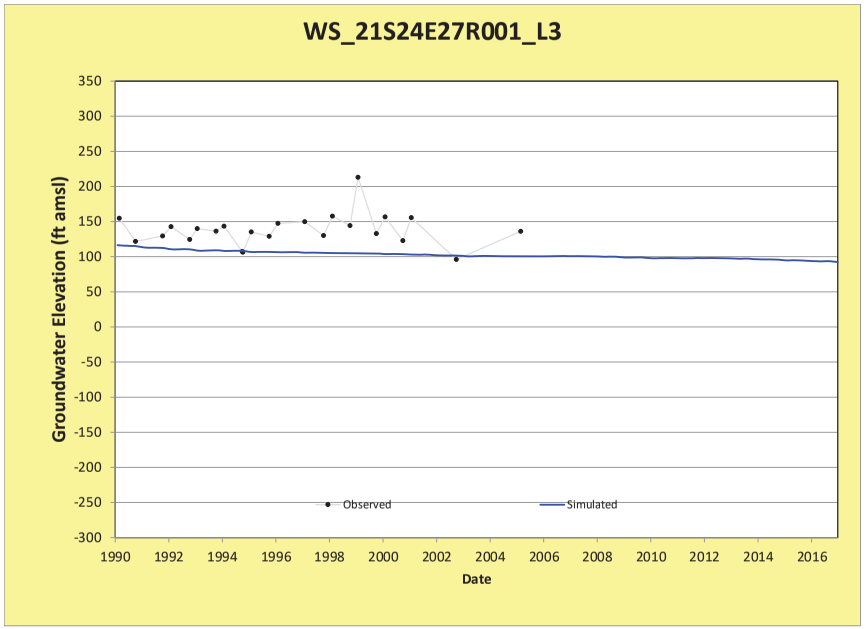

WS_21S21E26D001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

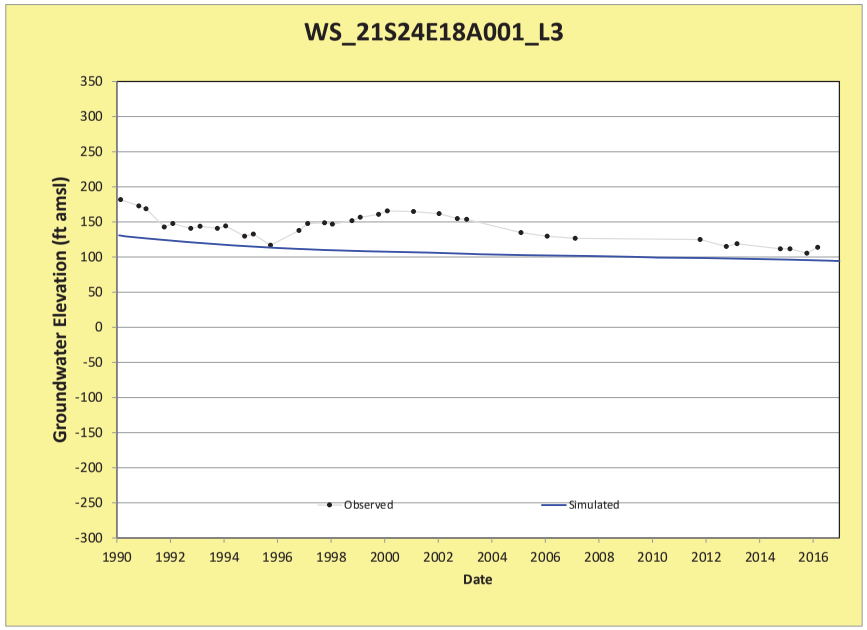

WS_21S23E25A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

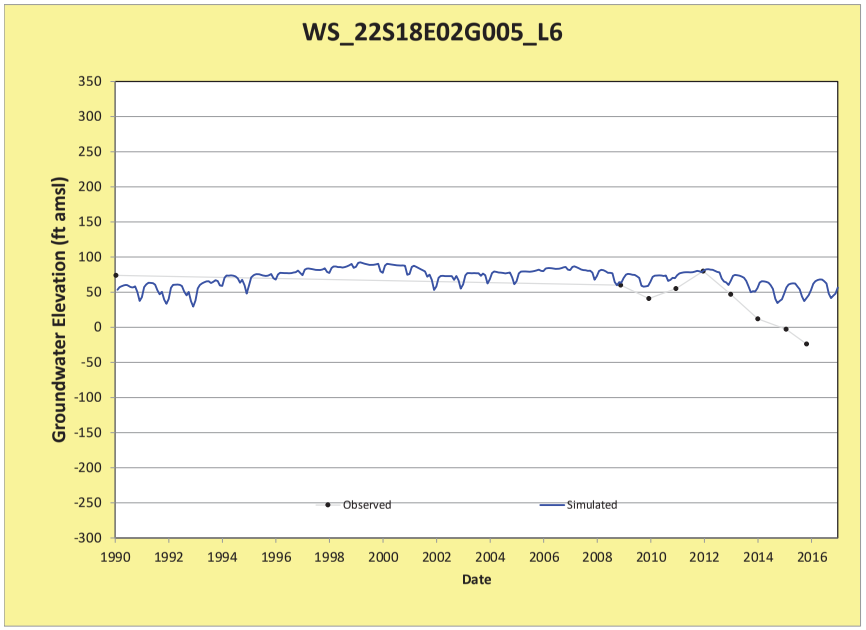

WS_21S23E08F002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

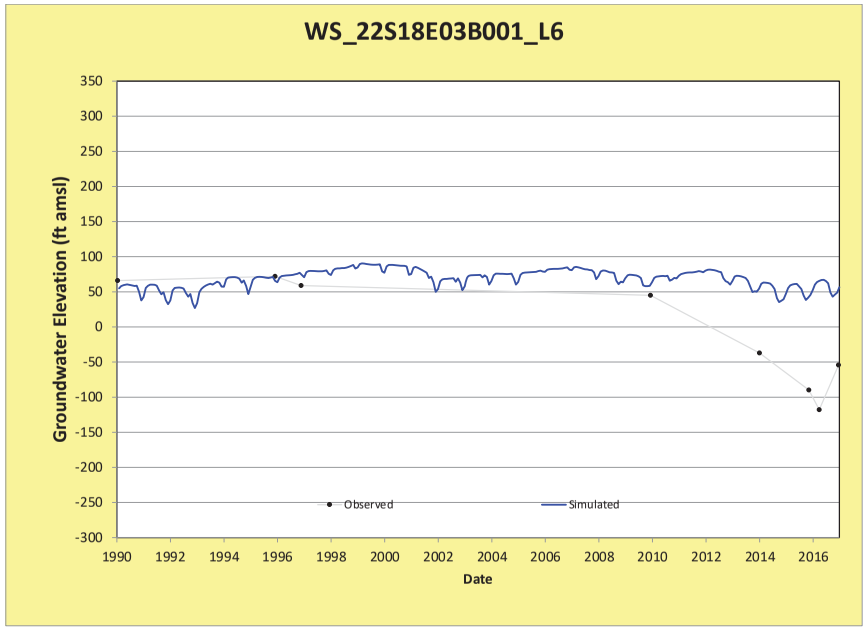

WS_21S23E32K001_L1
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

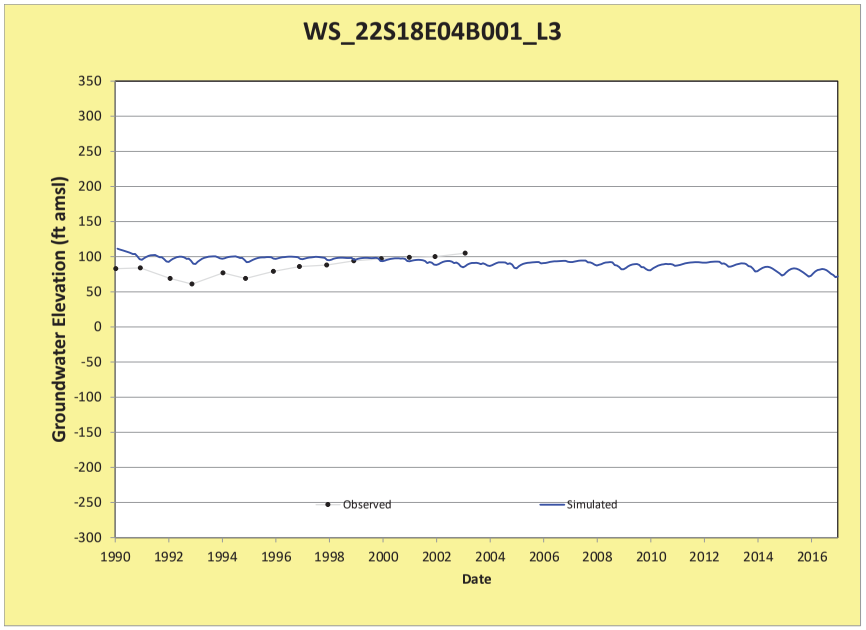

WS_21S23E36R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

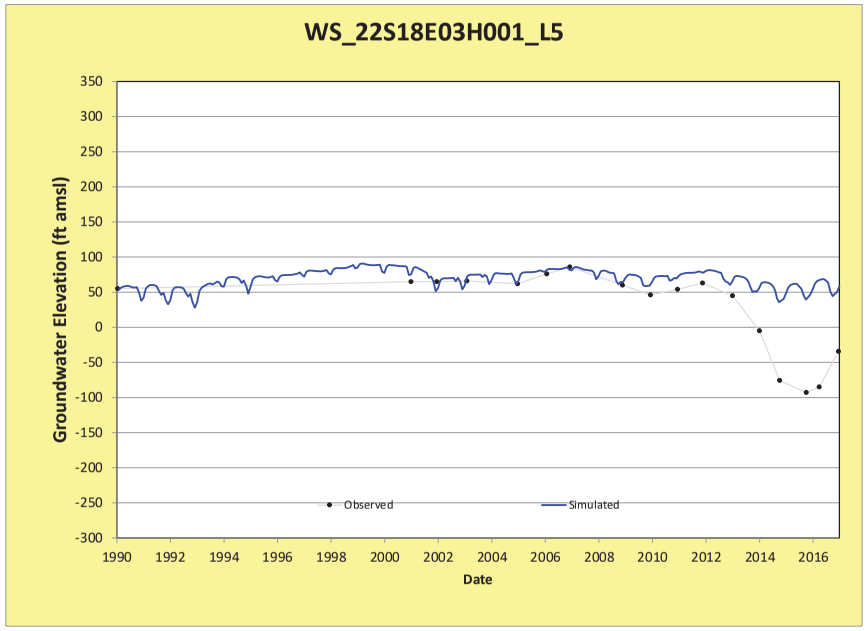

WS_21S24E27R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

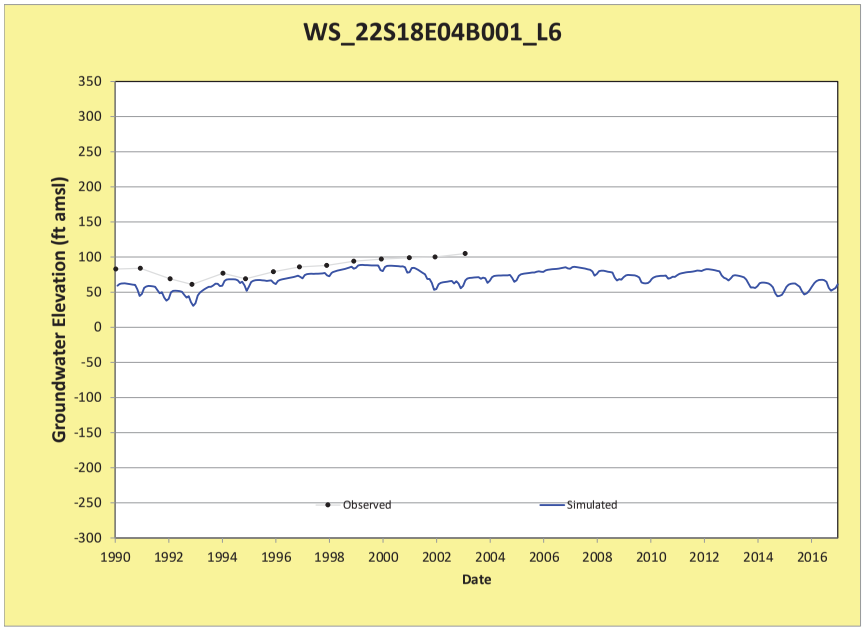

WS_21S24E18A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

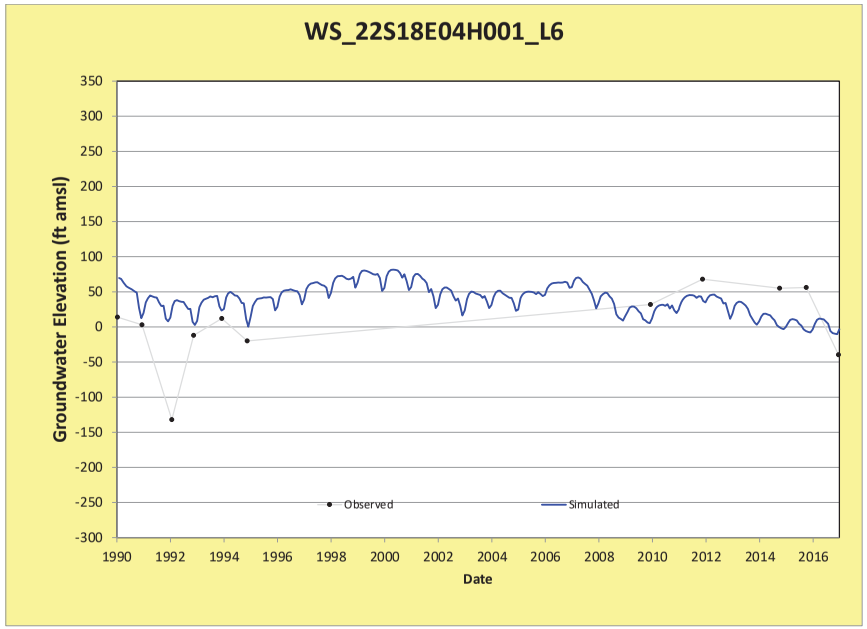

WS_22S18E02G005_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

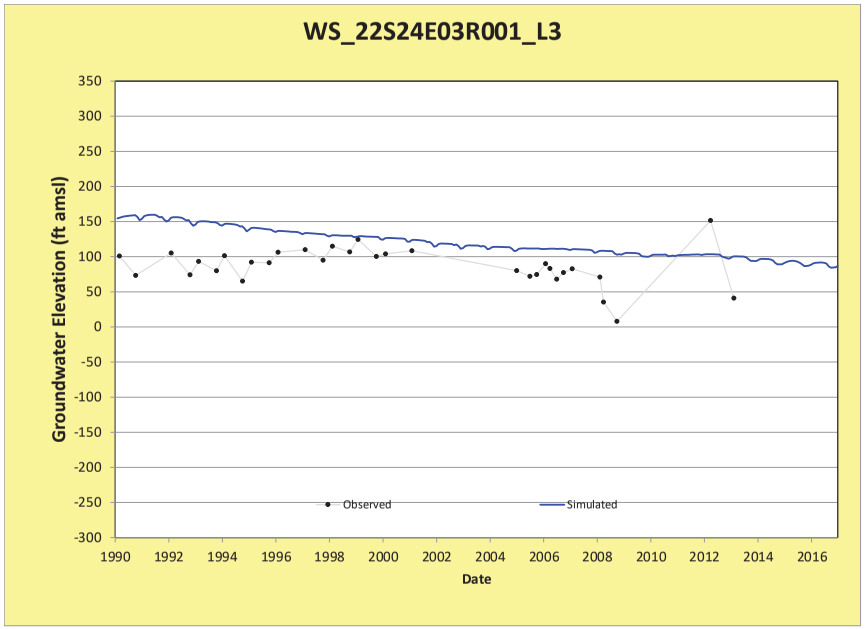

WS_22S18E03B001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

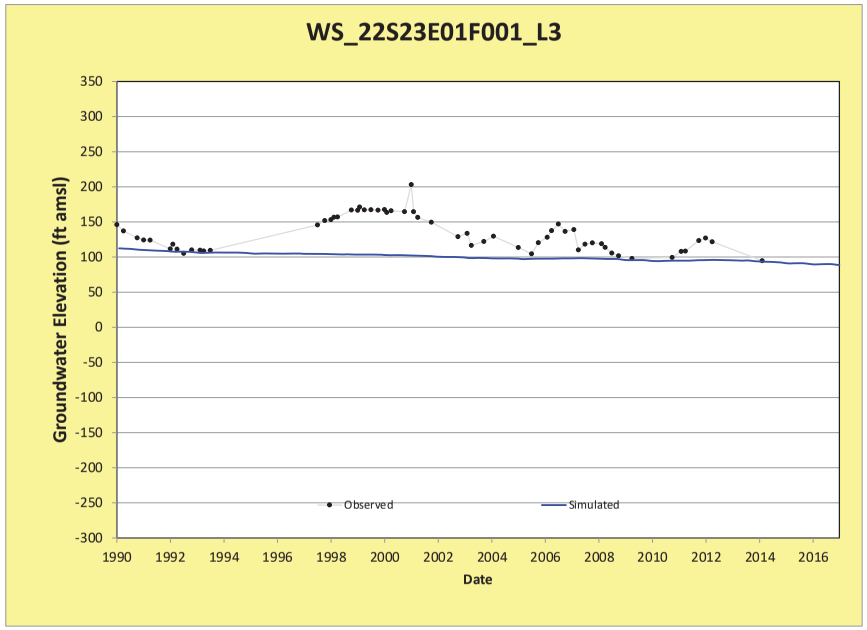

WS_22S18E04B001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

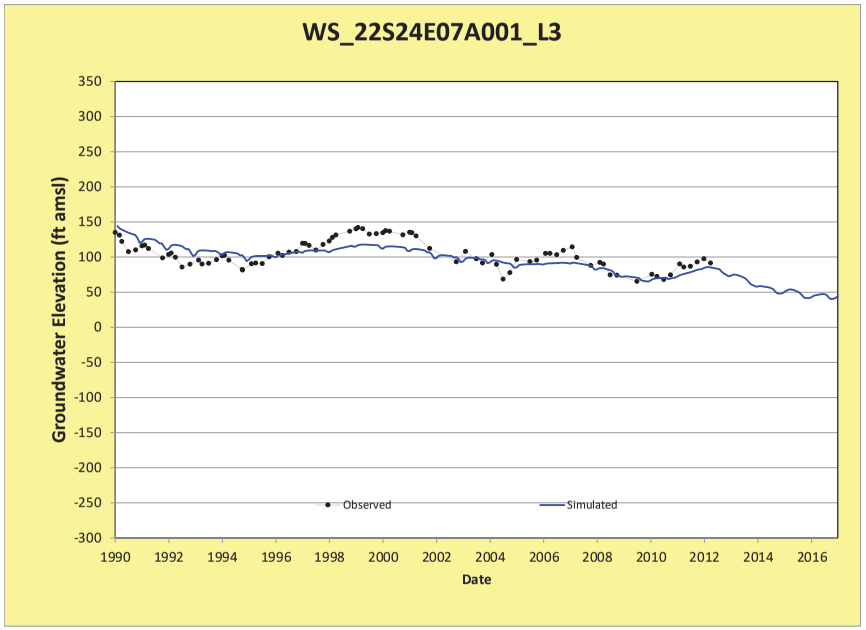

WS_22S18E03H001_L5
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

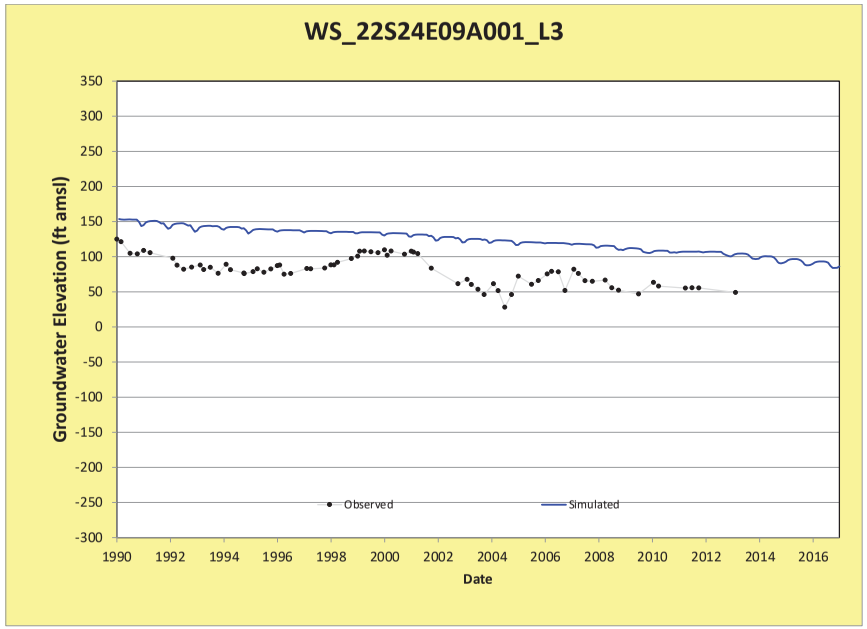

WS_22S18E04B001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

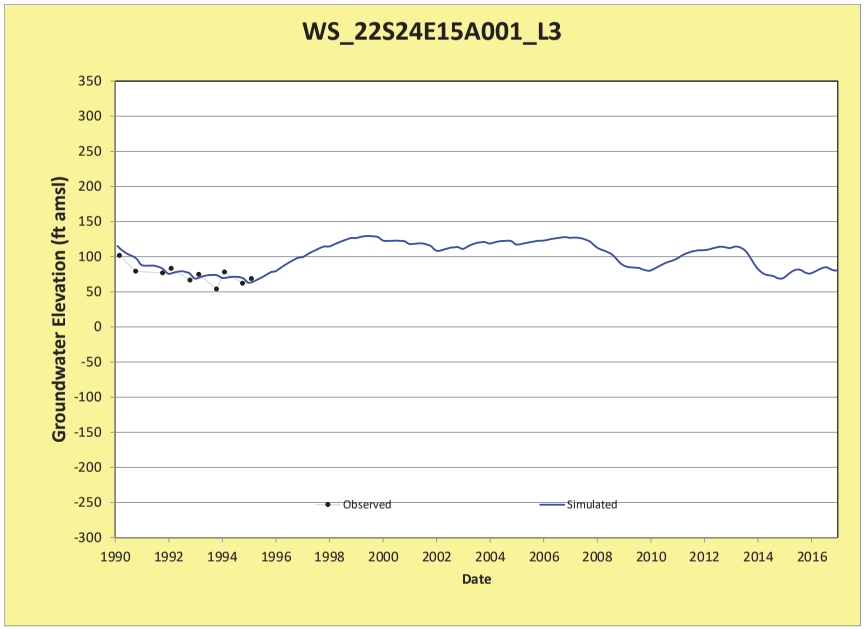

WS_22S18E04H001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

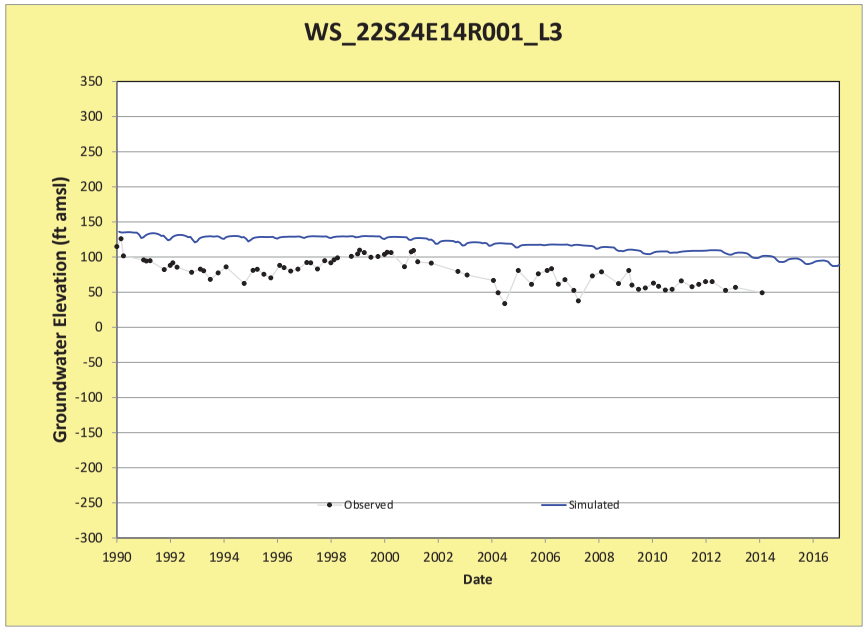

WS_22S24E03R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

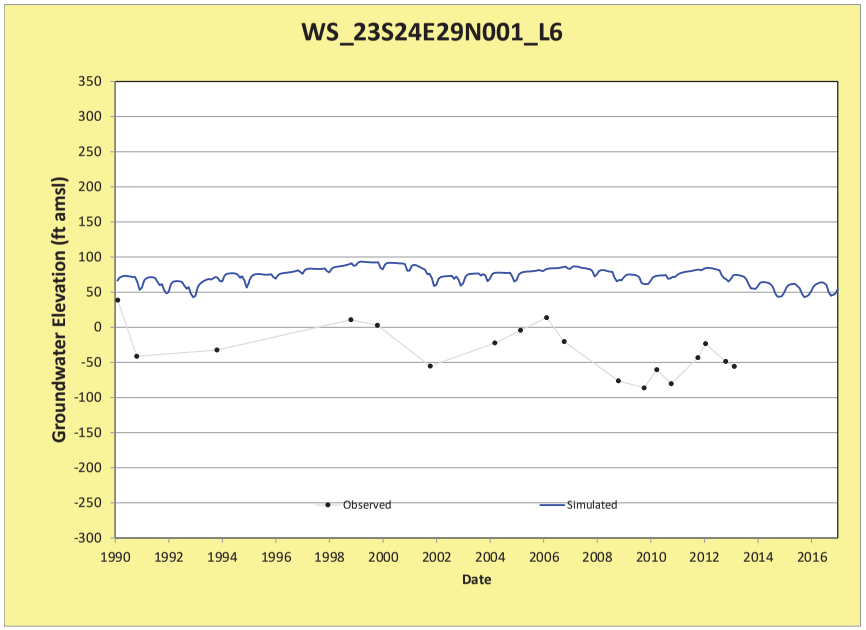

WS_22S23E01F001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

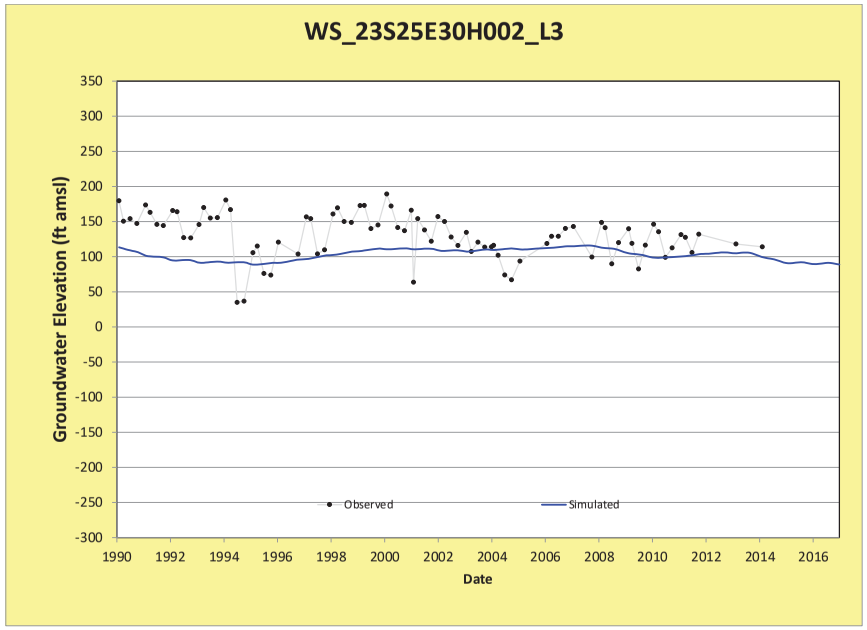

WS_22S24E07A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

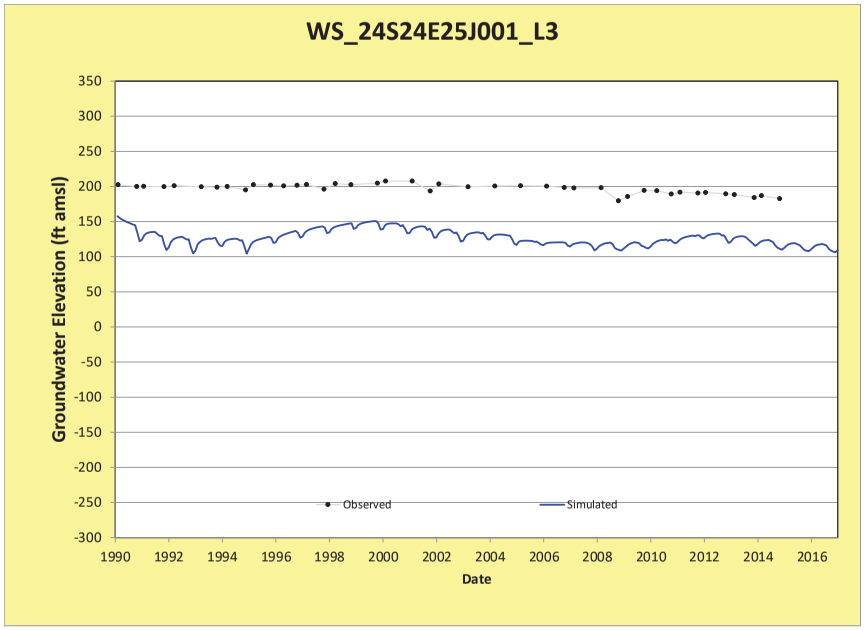

WS_22S24E09A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

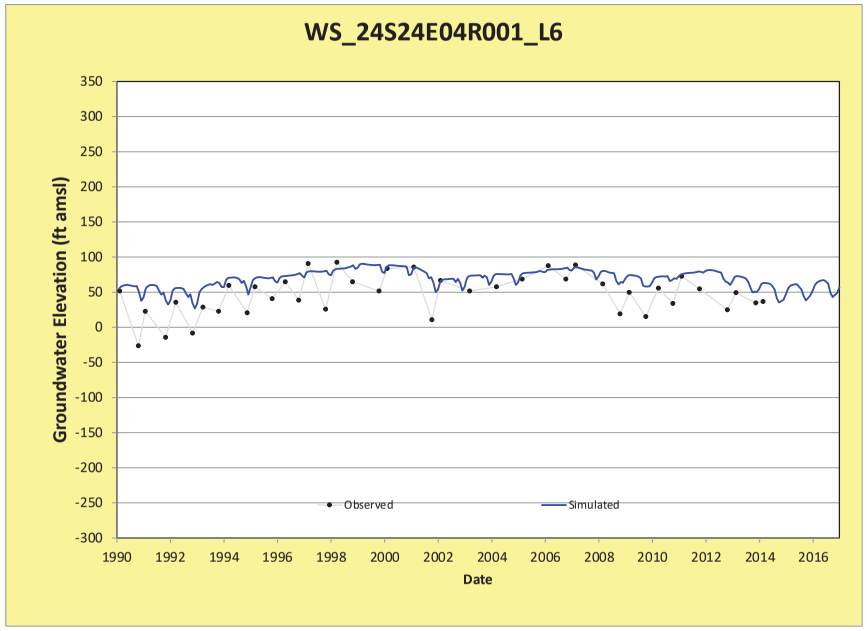

WS_22S24E15A001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

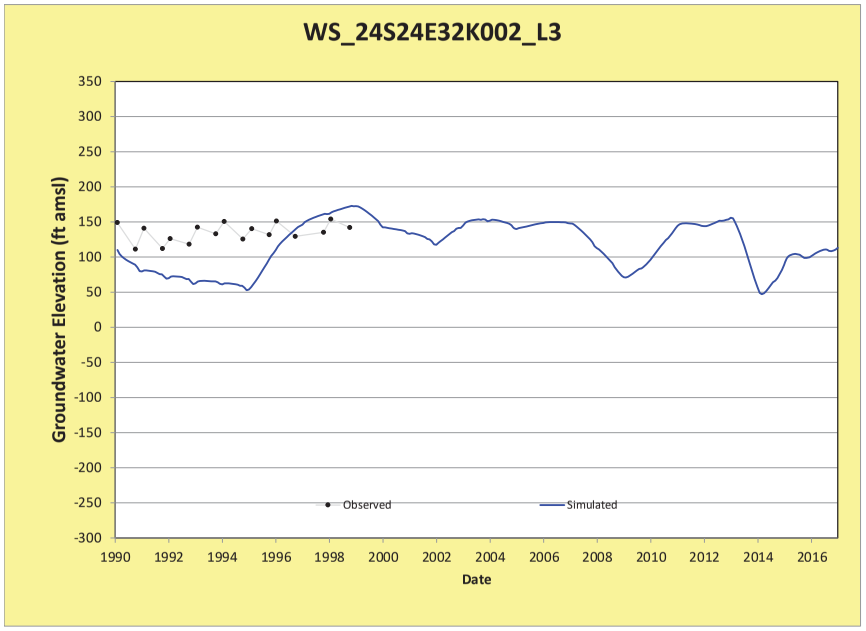

WS_22S24E14R001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

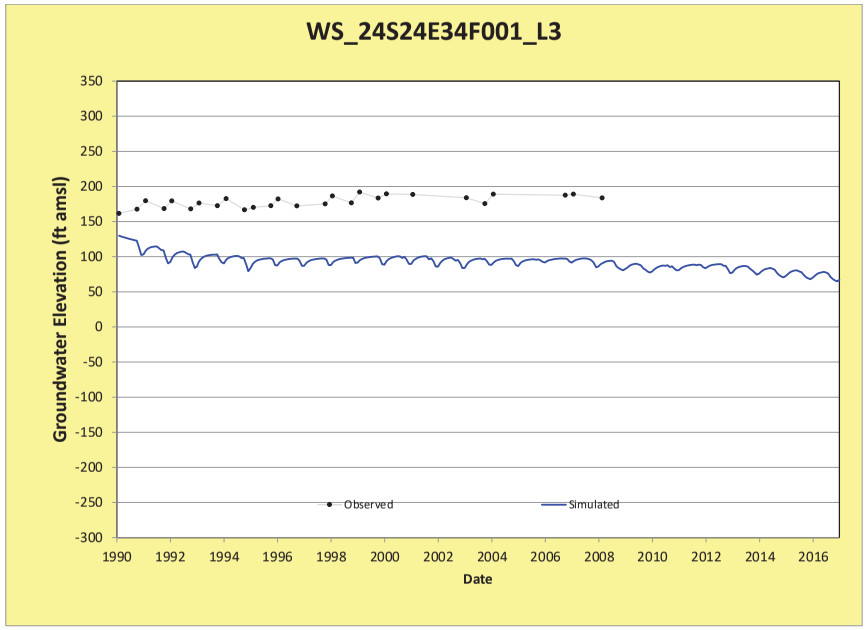

WS_23S24E29N001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

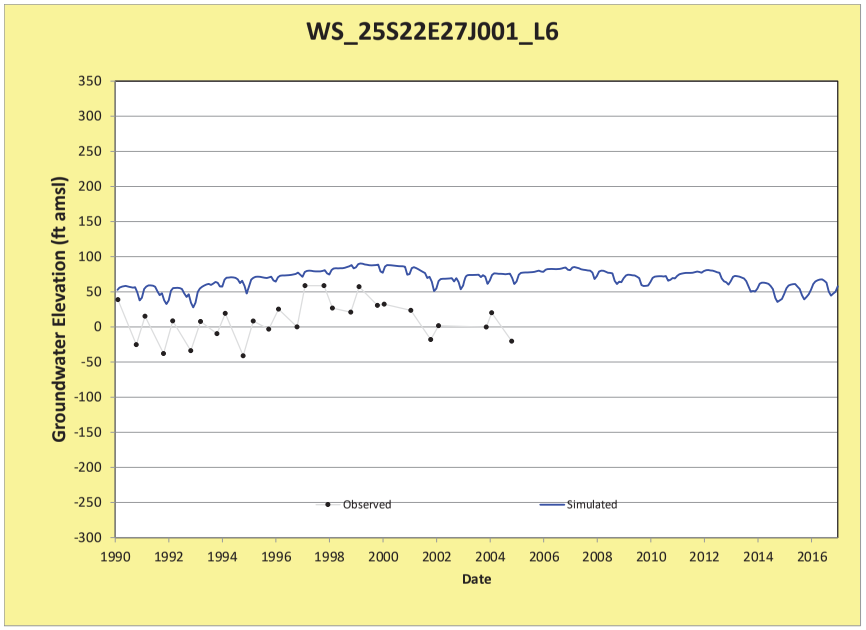

WS_23S25E30H002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

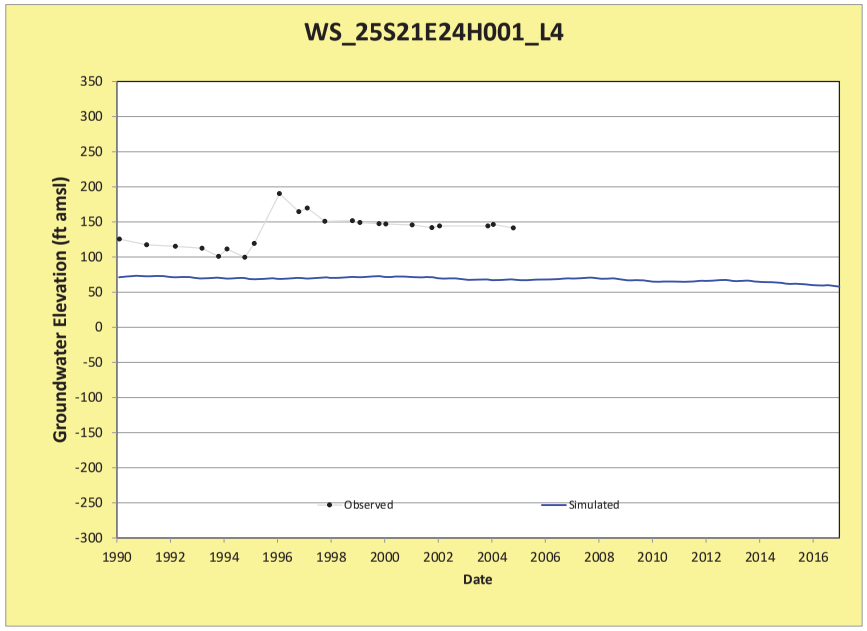

WS_24S24E25J001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

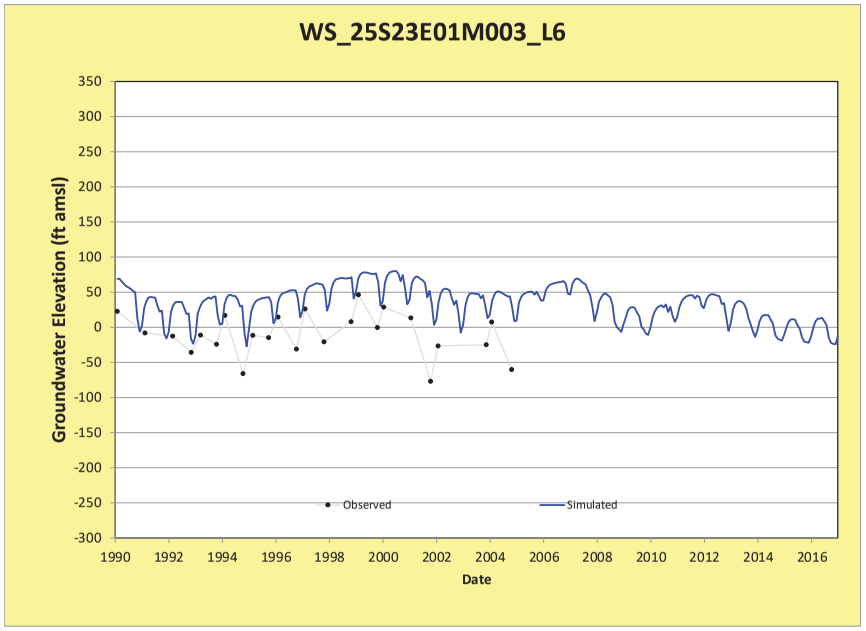

WS_24S24E04R001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

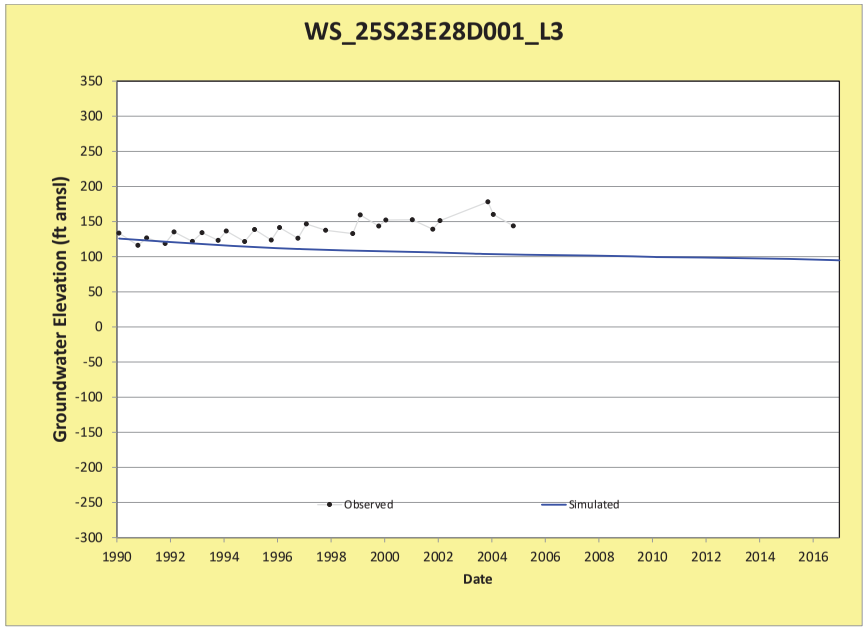

WS_24S24E32K002_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

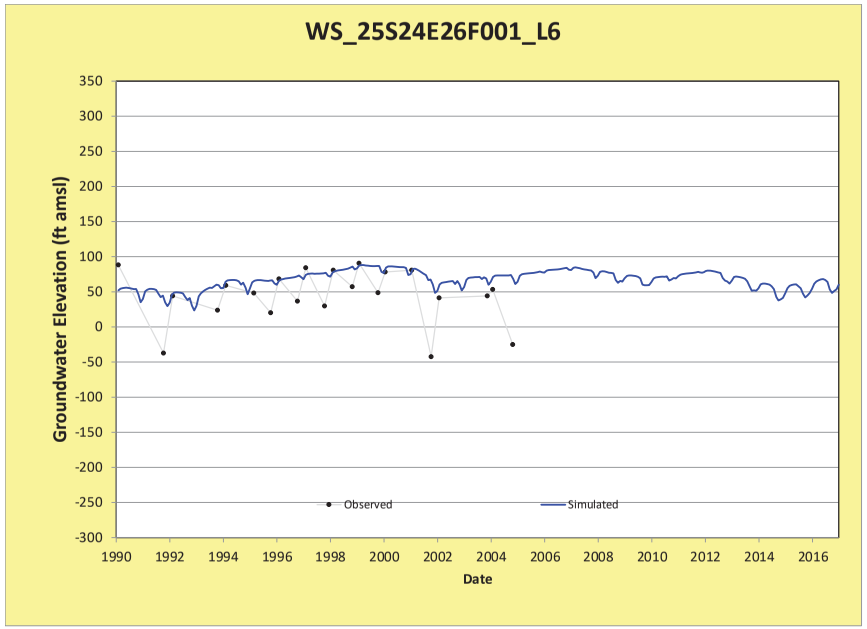

WS_24S24E34F001_L3
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

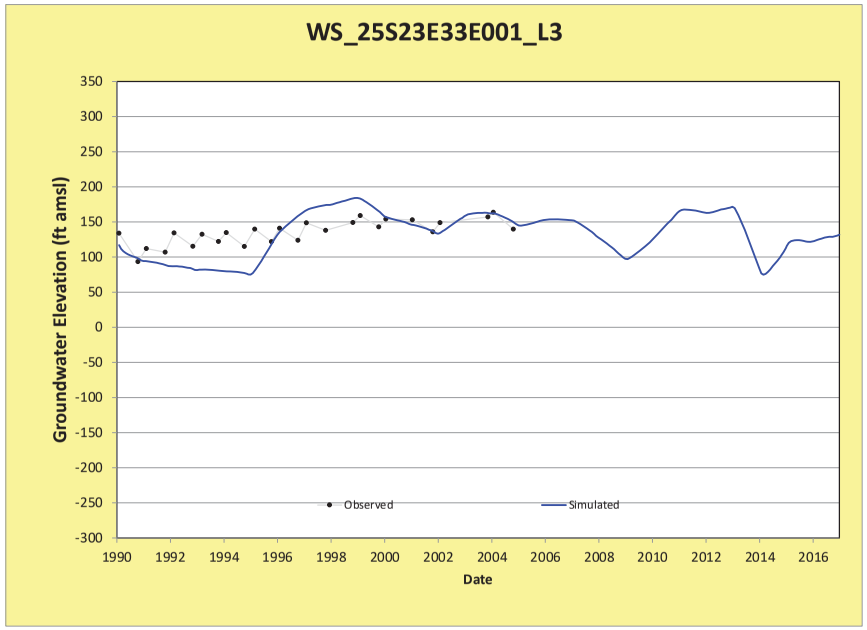

WS_25S22E27J001_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

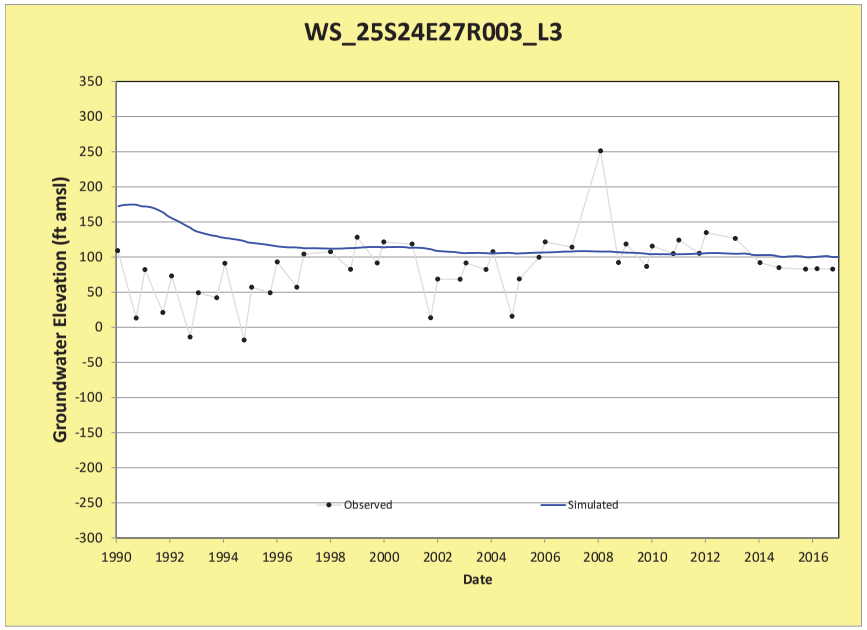

WS_25S21E24H001_L4
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

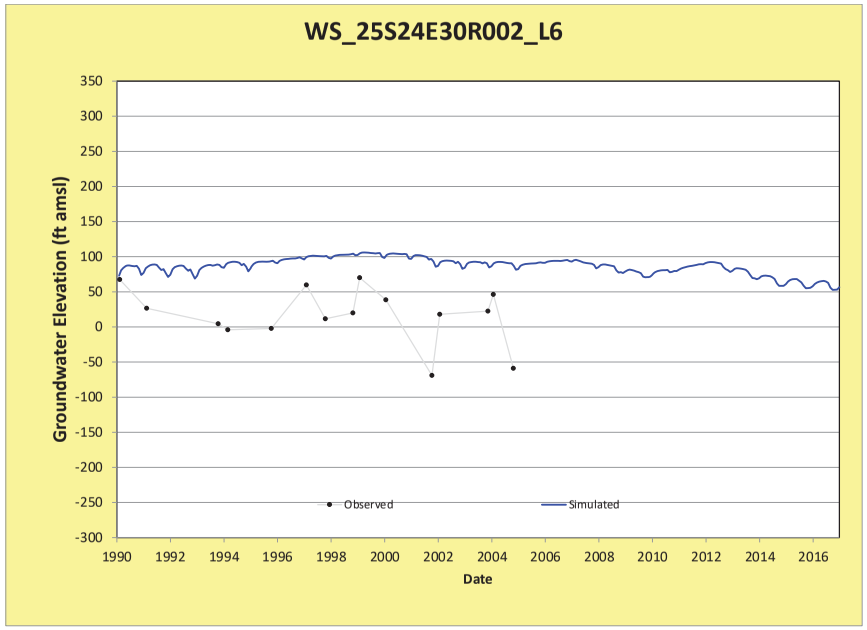

WS_25S23E01M003_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date
Observed
Simulated

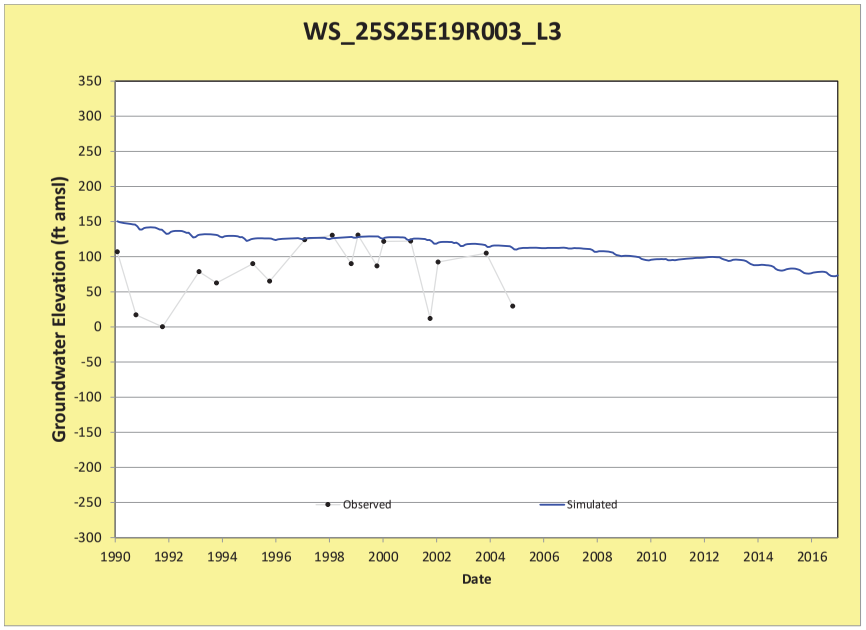

WS_25S23E28D001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

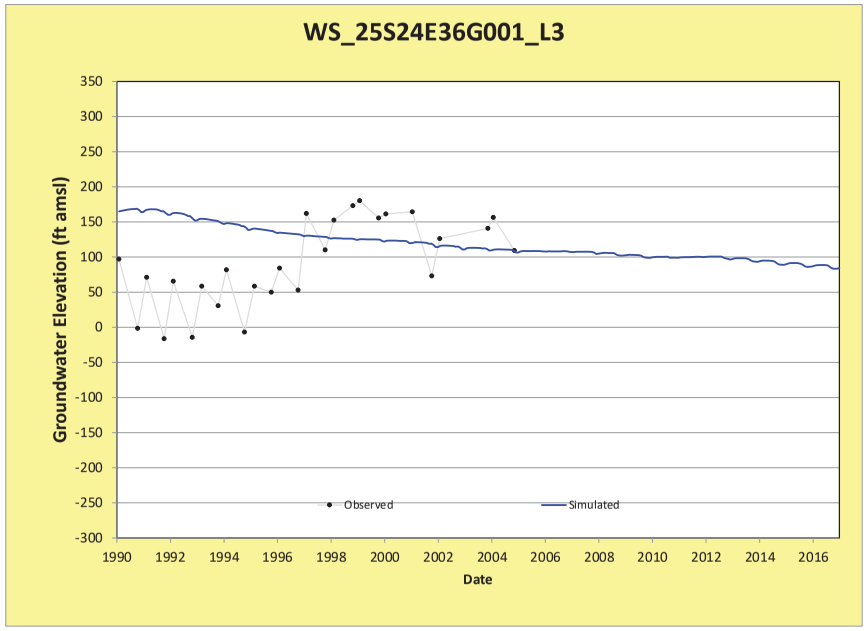

WS_25S24E26F001_L6
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

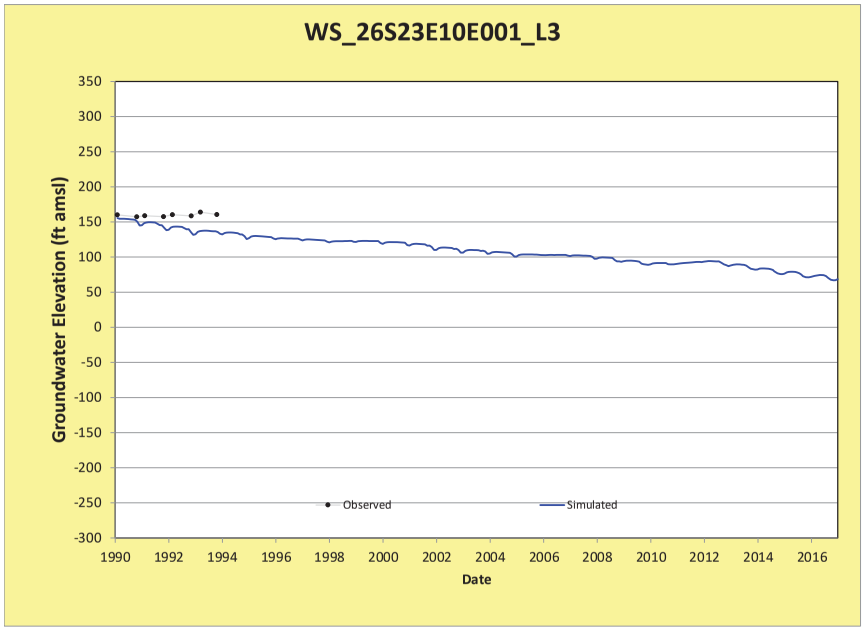

WS_25S23E33E001_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

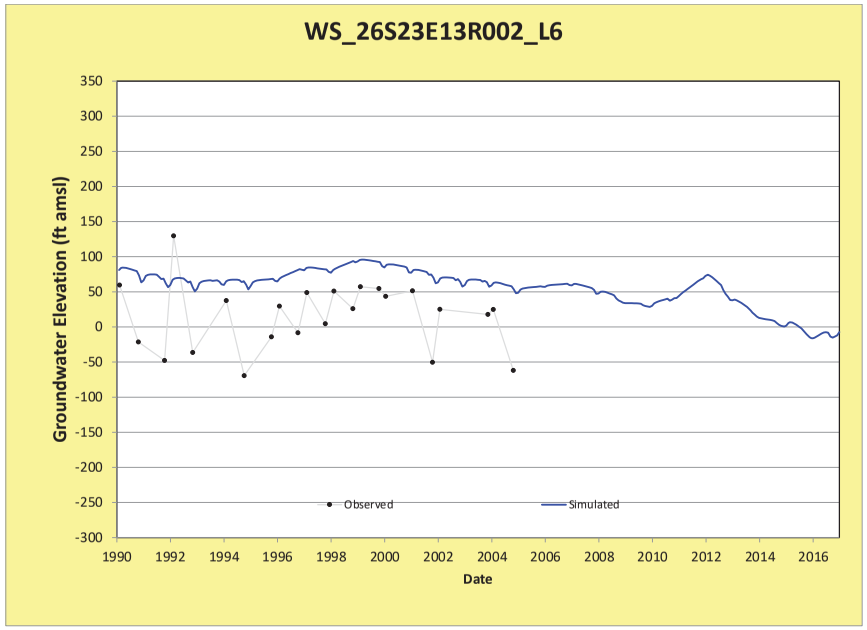

WS_25S24E27R003_L3
Groundwater Elevation (ft amsl)
Date
Observed
Simulated

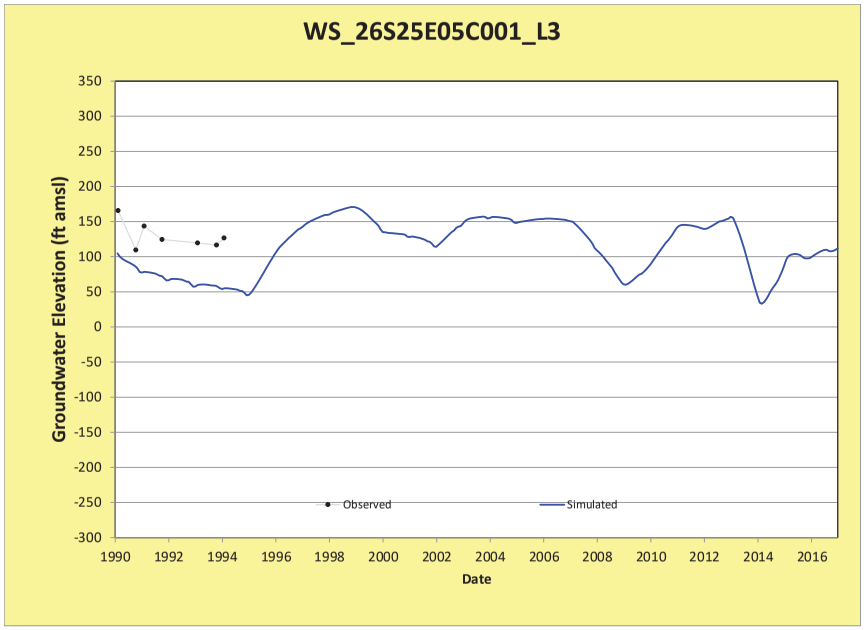

WS_25S24E30R002_L6
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
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Date
Observed
Simulated

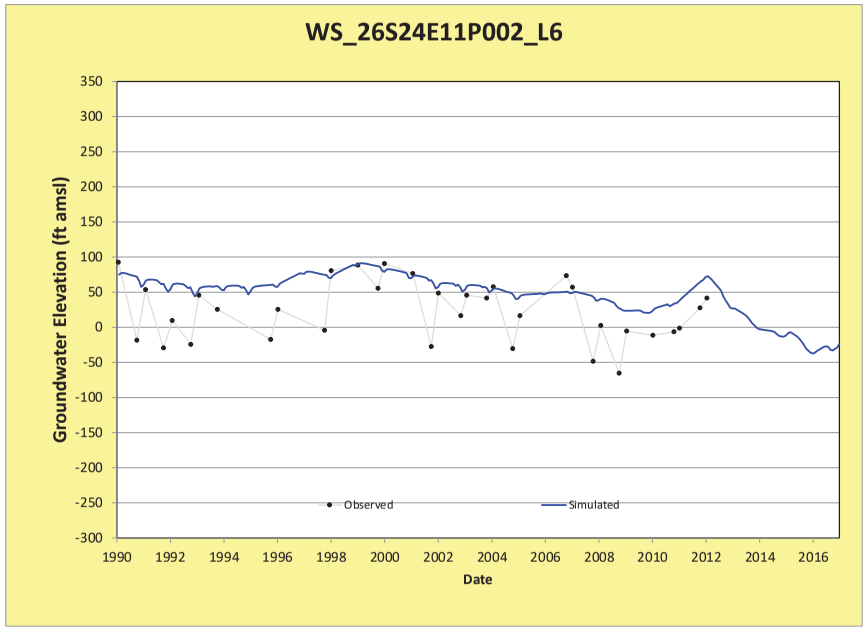

WS_25S25E19R003_L3
Groundwater Elevation (ft amsl)
350
300
250
200
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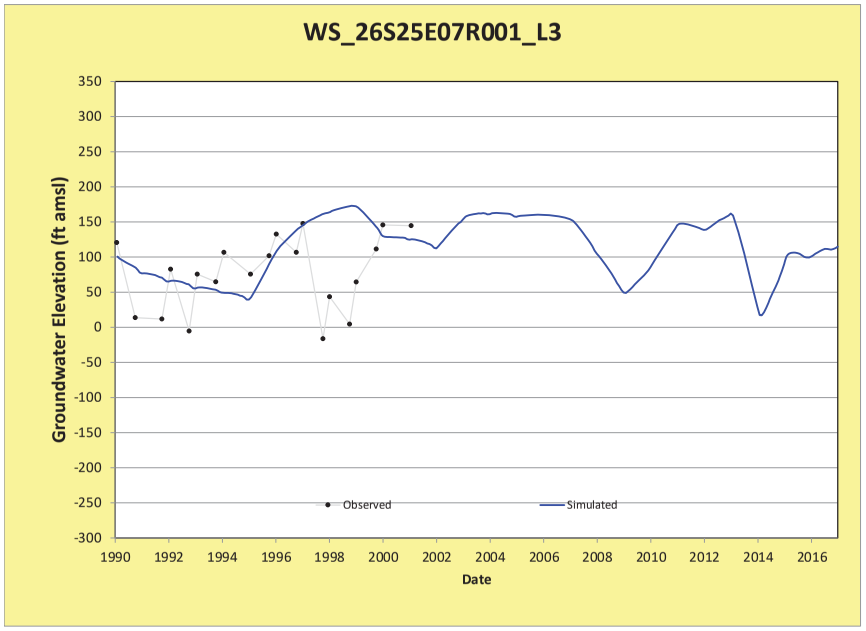

WS_25S24E36G001_L3
Groundwater Elevation (ft amsl)
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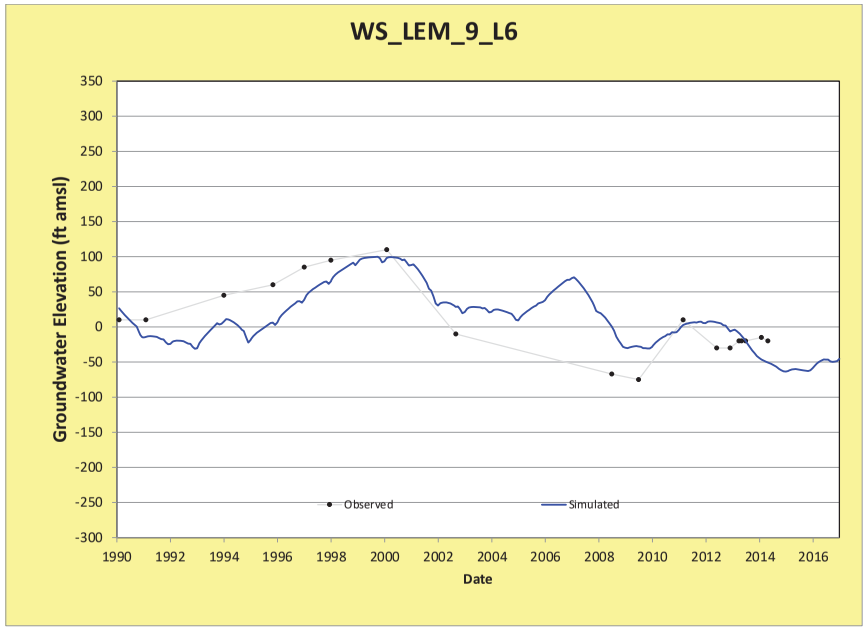

WS_26S23E10E001_L3
Groundwater Elevation (ft amsl)
350
300
250
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Observed
Simulated

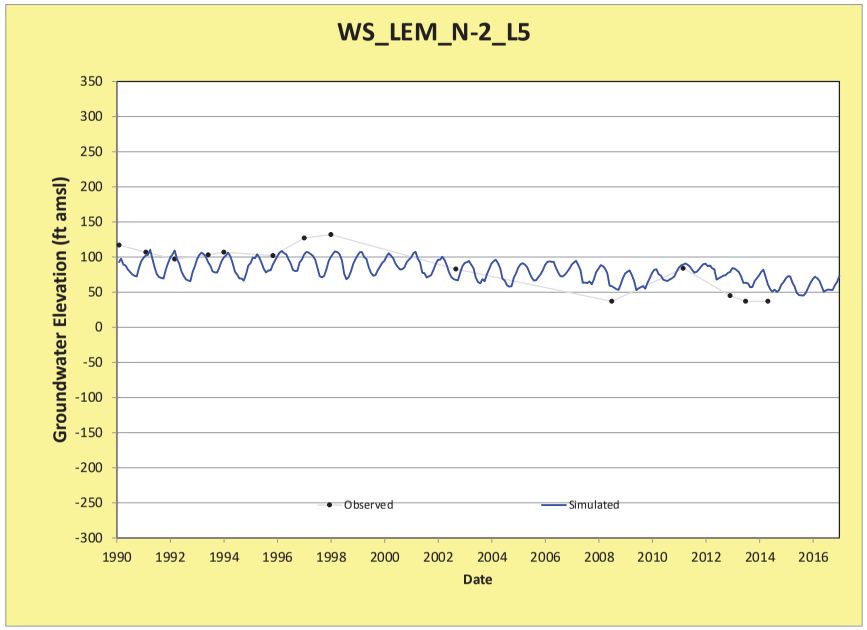

WS_26S23E13R002_L6
Groundwater Elevation (ft amsl)
350
300
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Observed
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WS_26S25E05C001_L3
Groundwater Elevation (ft amsl)
350
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Observed
Simulated


WS_26S24E11P002_L6
Groundwater Elevation (ft amsl)
350
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250
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-50
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Observed
Simulated


WS_26S25E07R001_L3
Groundwater Elevation (ft amsl)
350
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Observed
Simulated


WS_LEM_9_L6
Groundwater Elevation (ft amsl)
350
300
250
200
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-50
-100
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-250
-300
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2016
Date
Observed
Simulated


WS_LEM_N-2_L5
Groundwater Elevation (ft amsl)
350
300
250
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-50
-100
-150
-200
-250
-300
1990
1992
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Appendix D6
Peer Review of TLSBHM

GSA GeoSystems Analysis, Inc.
Innovations in Hydrology

08 November 2019

Bill Pipes
Principal Hydrogeologist
Wood Plc.
1281 East Alluvial Avenue, Suite 101
Fresno, CA 93720-2659

Re: Kings County – Tulare Lake Subbasin GSP Project: Groundwater Model Peer Review

As requested, I performed a technical peer review of the Tulare Lake Subbasin Hydrologic Model (TLSBHM) and associated report developed by Wood Environment & Infrastructure Solutions, Inc. ("Wood"). This model has been and is continuing to be utilized as a tool for evaluation of hydrologic impacts of future water management scenarios being considered as part of the Groundwater Sustainability Plan (GSP) for the Tulare Lake Subbasin (TLSB) as part of the required Sustainable Groundwater Management Act (SGMA) implementation for that planning region. My review focused of four aspects of the model, specifically:

- the model objectives,
- the Hydrogeologic Conceptual Model (HCM) of the TLSB,
- the development and documentation of numerical groundwater model as a predictive simulation tool based on the HCM, and
- documentation of model development and application in a report that is included as an appendix as part of the final GSP report.

Each of these topics is discussed in separate subsections below.

Model Objectives

Model objectives are clearly stated in Section 1.2, and importantly the stated objectives are consistent with model requirements define in the SGMA (Sustainable Groundwater Management Act of 2014) regulations. Specifically, as required by SGMA, the stated objectives include development of a model capable of forecasting groundwater management actions over a 50-year planning horizon (Cal. Water Code §10727.2(c)), establishment of measurable objectives and critical / minimum thresholds (Cal. Code of Regulations, "CCR," §354.29 and CCR §354.30), and development of a numerical model to quantify and evaluate projected water budget conditions (CCR §354.18).

3393 North Dodge Blvd
Tucson, Arizona 85716

phone:520-628-9330
fax: 520-628-1122

Hydrogeologic Conceptual Model

A hydrogeologic conceptual model (HCM) is the fundamental basis upon which a numerical model of groundwater flow is based. The HCM is basically a narrative description of the physical system, including:

- the areal extent of the model (typically referred to as the model domain)
- the hydrostratigraphic units within the model domain, including a description of the spatial distribution (area covered, depth, continuity, and thickness)
- the water sources and sink, also referred to as the inflows and outflows, within the model domain
- a description of the flow system functioning, and a preliminary water budget.

Section 2 of the Wood report covers the HCM, utilizing block diagrams to illustrate key flow components under both pre-development and developed conditions. The report section on the HCM covers all items listed above, including a narrative description of the evolution and chronology of hydrogeologic conditions in the basin / study area since development began. The conceptual model describes all recharge sources and surface water sources available and applied to meet water demands in the study area. Land subsidence due to groundwater withdrawal is explicitly described in the HCM, setting the stage for explicit simulation of subsidence in the TLSB numerical model. The HCM section also includes a separate subsection on the basin water budget, citing ranges of values for each of the inflow and outflow components. It is recommended that a table be added that summaries the preliminary water budget documented in the HCM section.

Development and Documentation of Numerical Groundwater Model

As previously noted, CCR §354.18 requires the development of a model to quantify and evaluate projected water budget conditions for the GSP. While a simple spreadsheet model can be employed for development of historical water budgets based on available data, a more quantitative approach is need for predict basin sustainability into future conditions. A numerical model is the most common tool employed for quantitative predictions of basin response to future stresses. Per SGMA requirements, the numerical model must: include publicly available supporting documentation; be based on field or laboratory measurements and calibrated against site specific field data; and developed using public domain, open-source software (CCR §352.4(f)(1-3)) As part of the model documentation, the Wood (2019) groundwater model report notes that the model was developed using the MODFLOW-2005-NWT code, and cites publicly available background documents related to this code, its mathematical development, capabilities, and user guide. The Wood (2019) report also describes the preliminary application of the MODFLOW-OWHM code, and explains why that code ultimately was not utilized for this current phase of the TLSB GSP project. The "Model Design" section of the Wood (2019) report provides a detailed description of each of the key model inputs and data sources for assigning/developing input values, including all the boundary conditions used. The methodology employed to develop agricultural pumping estimates are well-described, as well as the methodology for accounting for in-basin storage and management of excess surface inflows in wet years (for subsequent irrigation when surface inflow supplies are insufficient to meet demands).

The model calibration section describes in detail calibration criteria employed, as well as a description of the calibration data. It appears that that significant effort was invested in gathering and compiling whatever calibration data could be obtained from public sources, as well as from stakeholders / participants in the GSP process. For example, the 1990 – 2016 calibration period included 16,621 groundwater level observations collected from 593 observation wells across the model domain. The 1998 – 2010 "normal hydrology" calibration period included 7,028 groundwater level observations collected from 544 observation wells across the model domain. Wood (2019) also note that additional data was available and reviewed as part of the calibration process, but ultimately was not used due to data uncertainty / data quality concerns. The trial & error calibration procedure is well described, and plots are presented showing "goodness-of-fit for wells employed in the calibration process. The final calibration statistics are presented, showing that the final calibrated model generally meets defined criteria for an adequately calibrated model (e.g., Normalized Root Mean Squared Error < 10%).

Detailed water balance results are presented for the calibrated model, including for interactions between the TLSB and adjacent subbasins in the southern San Joaquin Valley. The calibration model simulated subsidence is also presented, although Wood (2019) notes that additional calibration of the model to observed subsidence is needed.

Consistent with good model practice, a model parameter sensitivity analysis is presented to show that the sensitivity of the model results to changes in hydraulic conductivity and storage parameters. The sensitivity analysis showed the calibrated model to be quite robust to changes in model parameters, and the importance of the Kv parameter of the Corcoran Clay layer, and Kh for the shallow and deeper aquifers (above and below the Corcoran, respectively).

Finally, the Wood (2019) report summarizes forecast models to predictive TLSB hydrologic condition 50 years into the future under two future scenarios:

- a Baseline Forecast scenario projecting current cropping patterns into the future, a slow growth rate in municipal pumping(0.3% per year) with a 50-year hydrology driver that accounts for climate change following the guidelines of the California Natural Resources Association (CNRA) for applying "change factors" to historical precipitation, ET demand, and surface water delivery data to make historical data consistent with forecasted conditions under climate change.
- multiple Project Forecast simulations; that involved by modifying the Baseline Forecast and incorporating various potential projects and management actions developed by the GSAs for the TLSB and surrounding subbasins. Potential projects and management action considered include: (i) Above ground surface water storage projects, (ii) Intentional recharge basins, (iii) On-Farm Recharge, (iv) Aquifer Storage and Recovery (ASR), and (v) Agricultural demand reductions.

The results for the Forecast model results include projected water budgets into the future, as well as piezometric levels and changes to basin storage (both elastic and inelastic) for the Baseline and Sustainability Project scenarios. The forecast model results are also presented for water level hydrographs for selected Compliance Wells (which were identified in the main body of the GSP report) in Figures 7-6 and 7-15 and predicted subsidence for Subsidence Compliance

Monitoring points (Figures 7-8 and 7-17). Identification of and calculation of responses at designated Compliance Monitoring points meets the SGMA requirement that the model be able to quantify Sustainability Indicators (23 CCR §354.28(b)), which are clearly defined in Chapter 4 of the GSP report.

Summary

The TLSB groundwater model developed to support groundwater sustainability planning for the TLSB was reviewed and evaluated against explicit needs and requirements for basin sustainability planning under SGMA. Based on this Peer Review of the model, it was found that the model was developed following good groundwater modeling practice in terms of compilation and integration of historical available data and information, groundwater calibration criteria, sustainability analyses, forecasts of future conditions under Baseline and implementation of sustainability Projects, and clear documentation of model development and application. As required under SGMA, the model develops a rigorous groundwater budget under the historical calibration period as well as under the two future Forecast scenarios (Baseline and Project). In addition, it also quantifies groundwater response at key monitoring points in the basin in the context of sustainability criteria and thresholds identified in Chapter 4 of the GSP.

If you have any questions, please do not hesitate to contact me. As always, we appreciate this opportunity to work with the Wood – Provost & Pritchard team.

Best Regards,

James T. McCord

Jim McCord, PhD, PE
Principal Hydrogeologist

APPENDIX E

GSP CHECKLIST

Appendix E - GSP Checklist

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 1. Administrative Information				
354.4	10733.2	General Information	a. Executive Summary- written in plain language b. A list of references and technical studies. Groundwater Sustainability Agencies (GSAs) must provide the California Department of Water Resources (DWR) an electronic copy of documents that are not available to the public	a. Executive Summary p. ES-1 to ES-40 b.Ch. 8, References p. 8-1 to 8-12
354.6	10733.2	Agency Information	a. GSA Mailing Address b. Organization and Management Structure including persons with management authority for Groundwater Sustainability Plan (GSP) implementation c. Contact Information of Plan Manager d. Legal Authority of GSA e. Estimate of Implementation Costs	a. Appendix A b. Section 1.4.1 (p. 1-6) c. Appendix A d. Section 1.4.2 (p. 1-6) e. Section 1.4.3 (p. 1-7)
354.8.(a)	10733.2	Map(s)	1. Area covered by GSP 2. Adjudicated areas, other agencies within the basin, and areas covered by an Alternative 3. Jurisdictional boundaries of federal or state land 4. Existing Land Use Designations & identification of water use sector/water source type 5. Density of wells per square mile	1. Chapter 2 (p. 2-1) 2. Section 2-1, (p. 2-3) 3. Section 2-1, (p. 2-3) 4. Chapter 2 (p. 2-1) 5. Chapter 2 (p. 2-2)
354.8.(b)	10733.2	Description of the Plan Area	b. Written summary of jurisdictional areas and other features	Section 2-1, (p. 2-3)

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
354.8.(c, d, e)	10733.2	Water resource monitoring and management programs	c. Description of water resources monitoring and management programs d. Description of how water resource monitoring or management programs may limit operational flexibility e. Description of Subbasin's conjunctive use programs	c. Section 2.2.1 (p. 2-10) d. Section 2.2.2 (p. 2-13) e. Section 2.2.3 (p. 2-14)
354.8.(f)	10733.2	Land Use Elements or Topic Categories of Applicable General Plans	1. Summary of general plans and other land use plans 2. Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects 3. Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans 4. Summary of the process for permitting new or replacement wells in the basin 5. Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	1. Section 2.3.1 (p. 2-15) 2. Section 2.3.2 (p. 2-15) 3. Section 2.3.3 (p. 2-16) 4. Section 2.3.4 (p. 2-18) 5. Section 2.3.5 (p. 2-20)
354.8.(g)	10727.4	Additional GSP Contents	Additional GSP elements	Section 2.4 (p. 2-21)
354.10	10733.2	Notice and Communication	a. Description of beneficial uses and users b. List of public meetings c. GSP comments and responses d. Communication section including the following:	a. Section 2.5.3 (p. 2-28) and Appendix B b. Appendix B c. Appendix C D. Appendix B

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
			1. Explanation of GSA's decision making process 2. Identification of opportunities for public engagement and how public input will be used 3. How agencies will encourage diverse active involvement from community 4. How the GSAs will inform the public about progress of the GSP	1. Section 2.5.2 (p. 2-27) 2. Section 2.5.4 (p. 2-29) 3. Section 2.5.5 (p. 2-31) 4. Section 2.5.4 (p. 2-29)
Article 5. Plan Contents, Subarticle 2. Basin Setting				
354.14.(a-b)	10727.2	Hydrogeologic Conceptual Model (HCM), descriptive text	a. Hydrogeologic Conceptual Model and maps of the physical components and interaction of the surface water and groundwater systems in the basin. b. The HCM will include: 1. Regional geologic and structural setting of the Subbasin, as well as surrounding areas 2. Lateral basin boundaries including major geologic features 3. Definable bottom of the basin 4. Principal aquifers and aquitards including: a. formation names b. physical properties of aquifers and aquitards c. structural properties of the Subbasin that restrict groundwater flow within the aquifers d. General water quality of principal aquifers e. identification of primary uses of each aquifer including domestic, irrigation, municipal water supplies f. Identification of data gaps and uncertainty in the HCM	a. Section 3.1 (p. 3-2) and Appendix D b. HCM summarized in written descriptions within: 1. Sects 3.1.1 to 3.1.3 (p. 3-2) 2. Section 3.1.6 (p. 3-14) 3. Section 3.1.7 (p. 3-17) 4a. Section 3.1.8 (p. 3-20) 4b. Section 3.1.8 (p. 3-20) 4c. Section 3.1.8 (p. 3-20) 4d. Section 3.2.5 (p. 3-33) 4e. Section 3.1.11 (p. 3-27) 4f. Section 3.1.12 (p. 3-28)

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
354.14.(c-d)	10733.2	HCM, Maps	c. Include at least 2 cross section maps of the HCM that depict major stratigraphic and structural features of the Subbasin d. Map(s)pf physical characteristics of the Subbasin 1. Topographic information 2. Surficial geology (by USGS or other applicable agency) 3. Soil characteristics (by NCRS or other applicable agency) 4. Delineation of existing recharge areas, potential recharge areas, and discharge areas 5. Surface water bodies 6. Source and point of delivery for imported water supplies	c. Figures 3-14a to 3-14c d1. Figure 3-7 d2. Figure 3-12 d3. Figures 3-9 to 3-11 d4. Figure 3-22 d5. Figure 3-5 d6. Section 3.1.1.6 (p. 3-8)
354.16	10733.2	Groundwater Conditions	a. Groundwater elevation data 1. Groundwater elevation contour maps (depict groundwater table or potentiometric surface) 2. Hydrographs for long term groundwater elevations, historic levels, and hydraulic gradients b. Estimate of groundwater storage (graph). Graph must include annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions including annual use and water year type c. Seawater intrusion conditions (including maps and cross sections for each principal aquifer) d. Groundwater quality issues including locations of known groundwater contamination sites and plumes e. Extent, cumulative total, and annual rate of land subsidence (including map of total subsidence based on data from DWR)	a1. Figures 3-24 to 3-27 a2. Figures 3-23 through 3-28d and Appendix D b. Figures 3-29a,b,c c. Section 3.2.4 (p. 3-32) d. Section 3.2.5 (p. 3-33) e. Section 3.2.6 (p. 3-35) f. Section 3.2.8 (p. 3-37) g. Section 3.2.8.1 (p. 3-38)

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
			f. Identification of interconnected surface water systems and estimate of quantity and timing of the depletions using DWR data g. Identification of groundwater-dependent ecosystems (using data from DWR)	
354.18.(a-b)	10733.2	Water Budget Information	a. Water budget that provides an assessment of total annual volume of groundwater and surface water entering and leaving the Subbasin (including historic, current, and projected) b. The water budget shall quantify the following through estimates or direct measurements: 1. Total surface water entering and leaving the Subbasin (by water source type) 2. Inflow to the groundwater system by water source type 3. Outflows from the groundwater system by water use sector 4. Change in annual volume of groundwater in storage 5. Quantification of overdraft over a period of years including water year and water supply conditions compared to average conditions 6. Water year type associated with annual supply, demand, and change in groundwater 7. Estimate of sustainable yield	a. Section 3.3 (p. 3-40) b1. Section 3.3.1 (p. 3-41) b2. Section 3.3.1 (p. 3-41) b3. Section (3.3.1 p. 3-41) b4. Section 3.3.2 (p. 3-49) b5. Section 3.3.3 (p. 3-50) b6. Section 3.3.4 (p. 3-51) b7. Section 3.3.4 (p. 3-51)
354.18.(c)	10733.2	Quantification of Water Budget	c. Each Plan shall quantify the current, historic, and projected water budget including: 1. Current water budget information including current inflows and outflows 2 Historical water budget must include the following:	1. Section 3.3.5 (p. 3-52) 2. Section 3.3.6 (p. 3-52) 3. Section 3.3.7 (p. 3-54)

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
			• Quantitative evaluation of availability/reliability of historical surface water supply (by water source type and water year type) *must be based on the most recent 10 years of data • Quantitative evaluation of historic water budget to project the future water budget information and future aquifer response to GSP implementation • Description of how historical conditions have impacted GSA ability to create sustainable yield 3. Projected water budget to estimate future baseline conditions for GSP implementation and identify uncertainties. This section should include the following: • Projected hydrology must include 50-year historical precipitation, evapotranspiration, and streamflow information as the baseline *climate change must also be incorporated • Projected water demand will utilize the most recent land use, evapotranspiration, and crop coefficient data. Projected changes in local land use planning, pop growth and climate must be included • Projected surface water supply will use most recent data and also consider historical surface water supply	
354.18 (d)	10733.2	Water Budget Data Source	d. The Agency shall utilize the following information provided by the DWR (or other comparable data) to develop the Water Budget 1 .Historical water budget information: use mean annual temperature, mean annual precipitation, water year type, and land use 2. Current water budget information for temperature, water year type, evapotranspiration, and land use	d. Section 3.3 (p. 3-40) 1. Section 3.3.6 (p. 3-52) 2. Section 3.3.5 (p. 3-52) 3. Section 3.3.7 (p. 3-54)

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
			3. Projected water budget information for population, population growth, climate change.	
354.18 (e, f)	10733.2	Water Budget	e. Must use a numerical groundwater and surface water model or the Plan must identify and describe an alternate method f. DWR will provide the Ca Central Valley Groundwater-Surface Water Simulation Model and the Integrated Water Flow Model for GSA use. (GSA can also select an alternate method but must be called out by type)	e. Appendix D f. Noted
354.20	10733.2	Management Areas	a. Define management areas and if they will have different measurable objectives (MOs) and minimum thresholds (MTs) b. Describe the following on Management areas: 1. Reason for creation of each management area 2. MO/MTs for each management area and why those values were selected if vary from Subbasin 3. Level of monitoring and analysis in each management area 4. Why MO/MTs can differ without causing undesirable results c. GSP must include descriptions and maps of management areas.	a. Section 3.4 (p. 58) b1. Section 3.4 (p. 58) b2. Section 3.4 (p. 58) b3. Section 3.4 (p. 58) b4. Section 3.4 (p. 58) c. Section 3.4 (p. 58)
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria				
354.24	10733.2	Sustainability Goal	Description of the Sustainability Goal	Section 4.1.1 (p. 4-2)
354.26	10733.2, 10721, 10723.2, 10727.2, 10733.2, 10733.8	Undesirable Results	a-b. Description of Undesirable Results, including: 1. Cause of Groundwater Conditions that would lead to Undesirable Results 2. Criteria used to define Undesirable Results for each sustainability indicator	a-b. Section 4.2 (p. 4-4) 1. Causes of undesirable results are discussed in Section 4.2.1 (p. 4-4)

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
			3. Potential effects of Undesirable Results on beneficial uses and users of groundwater c. Evaluation of multiple MTs and monitoring sites to determine undesirable results	2. Criteria to define undesirable results are discussed in Section 4.2.2 (p. 4-10) 3. Potential effects of undesirable results are discussed in Section 4.2.2 (p. 4-10) c. Section 4.3 (p. 4-11)
354.28 (a-b)	10723.2, 10727.2.(d).1, 10727.2.(d).2,	Minimum Thresholds	a-b. Description of each MT and how they were established for each sustainability indicator, including numeric values. 1. Information and criteria that establish and justify the MTs for each sustainability indicator 2. Relationship between MTs for each sustainability indicator 3. How MTs have been selected to avoid undesirable results for each sustainability indicator 4. How MTs may affect the interest of beneficial uses and users of groundwater 5. How state, federal, or local standards relate to the relevant sustainability indicator 6. How each MT will be quantitatively measured	a-b. Section 4.3 (p. 4-11) describes each MT 1. Section 4.3.1 (p. 4-12) 2. Section 4.3.1 (p. 4-12) 3. Section 4.4.1 (p. 4-12) 4. Section 4.3.1 (p. 4-12) 5. Section 4.3.1 (p. 4-12) 6. Section 4.3.2 (p. 4-16)
354.28 (c-d)	10733.2	Minimum Thresholds	c. Definition of MTs for each sustainability indicator: 1. Chronic lowering of groundwater levels a. Rate of groundwater elevation decline based on historical trends, water year type, and projected use b. Potential effects on other sustainability indicators 2. Reduction of groundwater storage	c. Section 4.3 (p. 4-11) 1. Section 4.3.1.1 (p. 4-12) a. Section 4.3.1.1 (p. 4-12) b. Section 4.3.1.1 (p. 4-12) 2. Section 4.3.1.2 (p. 4-14) 3. N/A

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
			3. Seawater intrusion 4. Degraded water quality 5. Land subsidence a. Identification of land uses and property interests affected by land subsidence and explanation of how the GSAs have determined and considered those uses and interests b. Maps and graphs showing the extent and rate of land subsidence 6. Depletions of interconnected surface water a. The location, quantity, and timing of depletions of interconnected surface water b. Description of the groundwater and surface water model used to quantify surface water depletion (or an equally effective method) d. Representative MT for groundwater elevation to serve as the value for multiple sustainability indicators e. Undesirable results related to sustainability indicators that are not present in the basin are not required to establish MTs	4. Section 4.3.1.4 (p. 4-15) 5. Section 4.2.1.3 (p. 4-7) a. Section 4.2.1.3 (p. 4-7) b. Figures 3-34, 3-34a, and 3-34b 6. N/A a. N/A b. N/A d. Section 4.3 (p. 4-11) e. N/A

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
354.30	10727.2.(b).1, 10727.2.(b).2, 10727.2.(d).1 10727.2.(d).2, 10727.4, 10733.2	Measureable Objectives	a-b. Establishment of the measureable objectives for each sustainability indicator c. Description of how a reasonable margin of operational flexibility was established for each measureable objective d-e. Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones f-g. Optional inclusion of additional MOs, interim milestones where appropriate	a-b. Section 4.4.1 (p. 4-19) c. Section 4.4.2 (p. 4-21) d-e. Section 4.4.3 (p. 4-22) f-g. N/A
Article 5. Plan Contents, Subarticle 4. Monitoring Network				
354.34.(a-b)	10727.2.(d).1, 10727.2.(d).2, 10727.2.(e), 10727.2.(f)	Monitoring Network	a-b. Description of Monitoring Network objectives and how the network will be developed and implemented with sufficient spatial and temporal frequency to: 1. Demonstrate progress towards achieving MOs 2. Monitor impacts to beneficial uses or users of groundwater 3. Monitor changes in groundwater conditions relative to MOs and MTs 4. Quantify annual changes in water budget components	a-b. Section 5.1.1. (p. 5-5) 1. Sections 5.1.5 through 5.1.8 (p. 5-8 through 5-12)

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
354.34.(c)	10727.2.(d).1, 10727.2.(d).2, 10727.2.(e), 10727.2.(f)	Monitoring Network	c. Description of how the monitoring network provides adequate coverage of sustainability indicators: 1. Chronic lowering of groundwater levels a. Sufficient density of monitoring wells b. Static groundwater elevation measurements collected two times per year 2. Reduction of groundwater storage 3. Seawater intrusion 4. Degraded water quality 5. Land subsidence 6. Depletions of interconnected surface water d. Adequate coverage of sustainability indicators to evaluate conditions in the basin e. Site information and monitoring data from existing sources	c. Section 5.1 (p. 5-2) 1. a. Section 5.1.5 (p. 5-8) b. Section 5.1.5 (p. 5-8) 2. Section 5.1.6 (p. 5-11) 3. N/A 4. Section 5.1.7 (p. 5-11) 5. Section 5.1.8 (p.5-11) 6. N/A d. Section 5.1.3 (p. 5-7) e. Section 5.1.3 (p. 5-7)
354.34.(e-i)		Monitoring Network	f. Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends determined by: 1. Amount of current and projected water use 2. Aquifer characteristics that affect groundwater flow 3. Impacts to beneficial uses and users 4. Whether the Agency has long-term existing monitoring results to demonstrate aquifer response g. Scientific rational (or reason) for site selection	f. Section 5.1 (p. 5-3) 1. Section 3.3.5 (p. 3-51); Section 3.3.7 (p. 3-54) 2. Section 3.1 (p. 3-2) 3. Section 3.1.11 (p. 3-27) 4. Section 5.1.3 (p. 5-7) g. 1. Section 5.2 (p. 5-13) 2. Section 5.2 (p. 5-13)

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
			1. Consistency with data and reporting standards 2. Corresponding sustainability indicator, MTs, MOs, and interim milestone h. Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used i. Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	h. Figures 5-1 through 5-5; Tables 5-1 through 5-6 i. Section 5.2 (p. 5-13)
354.36		Representative Monitoring	a. Description of representative sites with defined quantitative MTs, MOs, and interim milestones b. Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators c. Adequate evidence demonstrating representative monitoring sites reflects general conditions in the area	a. Section 5.3 (p. 5-15) b. N/A c. Section 5.4 (p. 5-16)
354.38		Assessment and Improvement of Monitoring Network	a. Review and evaluation of the monitoring network b-c. Identification and description of data gaps 1. Location and reason for data gaps 2. Local issues and circumstances that limit or prevent monitoring d. Description of steps to fill data gaps before the next 5-year assessment e. Adjustment of monitoring frequency and site density to provide site-specific surface water and groundwater conditions	a. Section 5.4 (p. 5-16) b-c. Section 5.4.1.2 (p. 5-18) 1. Section 5.4.1.2 (p. 5-18) 2. Section 5.4.1.2 (p. 5-18) d. Section 5.4.1.3 (p. 5-20) e. Section 5.4.1.3 (p. 5-20)

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) and Page Number(s) in the GSP
354.40	10733.2	Reporting Monitoring Data to the Department	Monitoring data stored in the data management system developed pursuant to Section 352.6 and included in the Annual Report	Noted
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions				
354.44 (a-b)		Projects and Management Actions	a-b. Description of projects and management actions, including the following: 1. List of projects and management actions with a description of the MO that it addresses a. The circumstances and criteria to trigger project implementation and the process by which the GSAs will determine the conditions requiring implementation b. How the GSAs will notice the public and other agencies that projects will be implemented	a-b. Sections 6.3 (p. 6-5) and 6.4 (p. 6-18) 1. Sections 6.3 (p. 6-5) and 6.4 (p. 6-18) a. Section 7.2 (p. 7-2) b. Appendix B
354.44 (c-d)			c. Projects and management actions shall be supported by the best available science d. Level of uncertainty associated with the basin should be taken into account when developing projects or management actions	c-d. Occurs throughout Chapter 6.

APPENDIX F

INTERIM OPERATING AGREEMENT

Interim Operating Agreement for the Tulare Lake Subbasin to Develop and Implement a Groundwater Sustainability Plan

THIS INTERIM OPERATING AGREEMENT FOR THE TULARE LAKE SUBBASIN TO DEVELOP AND IMPLEMENT A GROUNDWATER SUSTAINABILITY PLAN (this “Agreement") is effective September 1, 2017, among the MID-KINGS RIVER GROUNDWATER SUSTAINABILITY AGENCY, SOUTH FORK KINGS GROUNDWATER SUSTAINABILITY AGENCY, EL RICO GROUNDWATER SUSTAINABILITY AGENCY, SOUTHWEST KINGS GROUNDWATER SUSTAINABILITY AGENCY, TRI-COUNTY WATER AUTHORITY, and ALPAUGH IRRIGATION DISTRICT. The signatories to this Agreement are hereinafter referred to collectively as the "Parties" or individually as "Party".

RECITALS

WHEREAS, the Parties are all located within the Tulare Lake Hydrologic Region, San Joaquin Valley Groundwater Basin, Tulare Lake Subbasin, a groundwater subbasin recognized by the California Department of Water Resources ("DWR") Bulletin 118 (2016) as Groundwater Basin No. 5-22.12 (hereinafter “Subbasin”) and a depiction of the Subbasin is attached hereto as Exhibit "A" and incorporated herein by this reference; and

WHEREAS, the State of California has classified the entire Subbasin as an Economically Distressed Area and each community within the Subbasin as a Disadvantaged Community; and

WHEREAS, all lands within the Subbasin are included within one of the six groundwater sustainability agencies (“GSAs”) that are the Parties to this Agreement, and each Party has been or are in the process of being determined an “exclusive” GSA by DWR; and

WHEREAS, the Sustainable Groundwater Management Act ("SGMA") requires the development and establishment of groundwater sustainability plans ("GSPs"), which are designed to ensure the sustainability of groundwater basins and subbasins; and

WHEREAS, DWR has identified the Subbasin as a critically overdrafted subbasin; and

WHEREAS, SGMA allows local agencies or a combination of local agencies overlying a groundwater basin to serve as a GSA to develop and implement a GSP over an entire basin, subbasin, or a portion of a basin; and

WHEREAS, pursuant to Water Code §10727, SGMA allows for the preparation of a GSP by three methods: (a) a single GSP covering the entire basin/subbasin developed and implemented by one GSA, (b) a single GSP covering the entire basin/subbasin developed and implemented by multiple GSAs, or (c) multiple GSPs implemented by two or more GSAs that are subject to a single Coordination Agreement that covers the entire basin/subbasin; and

WHEREAS, Water Code §10727.6 requires that if multiple GSPs will be implemented within a subbasin, then a Coordination Agreement must be prepared to ensure that the GSPs utilize the same data and methodologies within that subbasin for the following items: (a) groundwater elevation data, (b) groundwater extraction data, (c) surface water supply, (d) total water use, (e) change in groundwater storage, (f) water budget, and (g) sustainable yield; and

WHEREAS, the Parties acknowledge that multiple GSAs have been formed within the Subbasin and those GSAs currently seek to explore the possibility of developing and implementing a single GSP. The Parties also acknowledge the desire to have a single GSP may not be achievable, but regardless of whether one or more GSPs are developed for the Subbasin, an interim agreement is beneficial to the Parties in proceeding to initially develop and coordinate the data and methodologies required by SGMA for the Subbasin; and

WHEREAS, the Parties acknowledge that the GSAs need to do further data collection prior to making decisions with regard to GSP preparation and implementation, but the Parties agree that in the future a Coordination Agreement or an amendment to or replacement of this Agreement will be necessary based on the additional information obtained and decisions made by the Parties under this Agreement; and

WHEREAS, the purpose of this Agreement is to provide a framework among the Parties for a cooperative means of gathering the initial data and information for a single GSP, applying for grant funding, selecting consultants, and coordinating on other SGMA-related issues for the Subbasin.

NOW, THEREFORE, in consideration of the mutual promises, covenants, and conditions hereinafter set forth and the above Recitals, which are hereby incorporated herein by this reference, it is agreed by and among the Parties hereto as follows.

SECTION 1. DEFINITIONS

1.1 "Tulare Lake Subbasin" or "Subbasin" refers to that subbasin identified and described in California Department of Water Resources Groundwater Bulletin 118 as part of the Tulare Lake Hydrologic Region, San Joaquin Valley Groundwater Basin, Tulare Lake Subbasin, also identified as Groundwater Basin No. 5-22.12, and is depicted in Exhibit “A” of this Agreement.

1.2 "Groundwater Sustainability Agency" or "GSA" means one or more local agencies that implement the provisions of SGMA as defined by Water Code §10721(j).

1.3. "Groundwater Sustainability Plan" or "GSP" means a plan of one or more GSAs proposed or adopted under SGMA as defined in Water Code §10721(k).

1.4 "Coordination Agreement" shall be the agreement (whether one or more GSPs are developed within the Subbasin) to ensure coordination of the data and methodologies used by each GSA in developing the GSP(s) within the Subbasin for the following assumptions: (a) groundwater elevation data, (b) groundwater extraction data, (c) surface water supply, (d) total water use, (e) change in groundwater storage, (f) water budget, and (g) sustainable yield (Water Code §10721(d); 10727.6).

SECTION 2. PURPOSES AND GOALS

2.1 The Parties are entering into this Agreement to perform the following:

(a) Set forth their mutual intent to work towards the development of a single GSP for the Subbasin.

(b) Authorize research and collection of the data required for the GSP according to a mutually agreeable timeline.

(c) The Parties agree to utilize their best efforts in selecting and fully cooperating with the consultants gathering the information, preparing grant applications, and preparing the GSP.

(d) The Parties agree that after they gather data and determine an appropriate governance structure, they will either (1) amend or replace this Agreement to reflect specifics required to finalize a GSP or (2) if a single GSP is not to occur, prepare and enter into a Coordination Agreement setting forth appropriate assumptions based on information gathered and developed as a result of this Agreement.

SECTION 3. COST SHARING AND GOVERNANCE

3.1 The Parties agree that if grant funds are available for grant applications, efforts necessary to develop a GSP(s), facilitation and/or consultant costs, and similar efforts to develop a GSP(s) for the Subbasin, then the Parties have the authority to and shall act jointly in applying for and seeking to obtain such grant funds. Any grant funds received on behalf of the Subbasin and/or all of the Parties, shall first be applied to eligible costs incurred after July 1, 2017; should any funds then remain, the Parties may develop a method for reimbursing relevant costs incurred by the Parties prior to the effective date of this Agreement.

3.2 The Parties agree to the following formula, identified in the table below, for sharing costs to develop and implement the actions taken within the confines of this Agreement. As shown below, after combining the El Rico GSA and Alpaugh Irrigation District, one-half the costs shall be allocated one-fifth to each of the participants and one-half of the costs shall be allocated in proportion to the relative acreage of each Party. The overall proportionate cost of each Party is shown as the Total Cost Allocation in the table below.

GSA	Acres	Acreage Portion	Participant Portion	Total Cost Allocation
Mid-Kings River GSA	97,384.6	0.09084	0.1	0.19084
South Fork Kings GSA	71,310.9	0.06652	0.1	0.16652
El Rico GSA/Alpaugh ID	228,653.4	0.21328	0.1	0.31328
Southwest Kings GSA	90,037.1	0.08398	0.1	0.18398
Tri-County WA	48,656.5	0.04538	0.1	0.14538
Totals	536,042.5	0.50000	0.5	1.00000

3.3 All decisions related to implementing or amending this Agreement shall require a unanimous vote of the authorized representatives of each of the five (5) entities[1] identified in the table shown in Section 3.2 of this Agreement; a quorum is represented by any four (4) authorized representatives of these five (5) entities. Decisions may include, but are not limited to hiring experts or consultants to prepare and draft documents associated with this Agreement that would exceed $100,000, developing the Coordination Agreement (if necessary), applying for grant funding, and/or developing all or portions of a GSP(s).

SECTION 4. GENERAL PROVISIONS

4.1. Term. This Agreement shall become effective on the date first above written and shall remain in effect until superseded by amendment to this Agreement or another agreement among the Parties which shall address more specifics that are not available at this time for the final development and implementation of the GSP(s).

4.2 Withdrawal. Any Party shall have the right to withdraw from this Agreement by giving each of the other Parties written notice at least 30 days prior to its date of withdrawal ("Withdrawal Date"). The withdrawing Party shall be responsible for its share of any costs incurred under this Agreement up to its Withdrawal Date. Except as set forth in the preceding sentence, and except for the withdrawing Party's obligations under Section 5 hereof relating to confidential information, effective as of the Withdrawal Date, the withdrawing Party shall be

[1] For purposes of cost sharing and voting, the El Rico GSA and Alpaugh ID are to be considered as one entity; it shall be up to those two GSAs to determine their internal cost-sharing and voting process.

relieved and released of all obligations under this Agreement.

4.3 Construction of Terms. This Agreement is for the sole benefit of the Parties and shall not be construed as granting rights to or imposing obligations on any person other than the Parties.

4.4 Good Faith. Each Party shall use its best efforts and work in good faith for the completion of the purposes and goals of this Agreement and the satisfactory performance of its terms.

4.5 Rights of the Parties and Constituencies. This Agreement does not contemplate the Parties taking any action that would (a) adversely affect the rights of any of the Parties or (b) adversely affect the constituencies of any of the Parties.

4.6 Counterparts. This Agreement may be executed in counterparts and the signed counterparts shall constitute a single instrument. The signatories to this Agreement represent that they have the authority to sign this Agreement and to bind the Party for whom they are signing.

4.7 Governing Law. This Agreement and all documents provided for herein and the rights and obligations of the Parties hereto shall be governed in all respects, including validity, interpretation and effect, by the laws of the State of California (without giving effect to any choice of law principles).

4.8 Waiver. The failure of any Party to insist on strict compliance with any provision of this Agreement shall not be considered a waiver of any right to do so, whether for that breach or any subsequent breach. The acceptance by any Party of either performance or payment shall not be considered to be a waiver of any preceding breach of the Agreement by any other Party.

4.9 Recitals and Exhibits. The Recitals and Exhibits are incorporated into the Agreement.

SECTION 5. CONFIDENTIALITY PROVISIONS

5.1 Confidential Information. The confidential information to be disclosed under this Agreement ("Confidential Information") includes data, information, modeling, projections, estimates, plans, that are not public information and in which each Party has a reasonable expectation of confidentiality, regardless of whether such information is designated as Confidential Information at the time of its disclosure.

5.2 Duty to Protect. In addition to the above, Confidential Information shall also include, and the Parties shall have a duty to protect, other confidential and/or sensitive information which is (a) disclosed in writing and marked as confidential (or with other similar designation) at the time of disclosure; and/or (b) disclosed in any other manner

and identified as confidential at the time of disclosure or is summarized and designated as confidential in a written memorandum delivered within thirty (30) days of the disclosure.

5.3 Limited Use. The Parties shall use the Confidential Information only for the purposes set forth in this Agreement.

5.4 Limited Disclosure. The Parties shall limit disclosure of Confidential Information within its own organization to its directors, officers, partners, members and/or employees having a need to know and shall not disclose Confidential Information to any third party (whether an individual, corporation, or other entity) without prior written consent of all the Parties. The Parties shall satisfy their obligations under this paragraph if they take affirmative measures to ensure compliance with these confidentiality obligations through their employees, agents, consultants and others who are permitted access to or use of the Confidential Information.

5.5 Allowable Disclosure. This Agreement imposes no obligation upon the Parties with respect to any Confidential Information (a) that was possessed before receipt; (b) is or becomes a matter of public knowledge through no fault of receiving Party; (c) is rightfully received from a third party not owing a duty of confidentiality; (d) is disclosed without a duty of confidentiality to a third party by, or with the authorization of the disclosing Party; or (e) is independently developed.

IN WITNESS WHEREOF, the Parties hereto have executed this Agreement to be effective as of the date first above written.

(the remainder of this page has been intentionally left blank)

Mid-Kings River Groundwater Sustainability Agency

By: Barry McCutcheon Title: Chairman

Name: Barry McCutcheon

South Fork Kings Groundwater Sustainability Agency

By: _____ Title: _____

Name: _____

El Rico Groundwater Sustainability Agency

By: _____ Title: _____

Name: _____

Southwest Kings Groundwater Sustainability Agency

By: _____ Title: _____

Name: _____

Tri-County Water Authority

By: _____ Title: _____

Name: _____

Alpaugh Irrigation District

By: _____ Title: _____

Name: _____

Mid-Kings River Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

South Fork Kings Groundwater Sustainability Agency

By: Joe Neves Title: CHAIRMAN

Name: Joe Neves

El Rico Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

Southwest Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

Tri-County Water Authority

By:_____ Title:_____

Name: _____

Alpaugh Irrigation District

By:_____ Title: _____

Name: _____

Mid-Kings River Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

South Fork Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

El Rico Groundwater Sustainability Agency

By: _____ Title: CHAIRMAN

Name: JEOF WYRICK

Southwest Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

Tri-County Water Authority

By:_____ Title:_____

Name: _____

Alpaugh Irrigation District

By:_____ Title: _____

Name: _____

Mid Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

South Fork Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

El Rico Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

Southwest Kings Groundwater Sustainability Agency

By:_____ Title: President

Name: William D Phillimores

Tri-County Water Authority

By:_____ Title:_____

Name: _____

Alpaugh Irrigation District

By:_____ Title:_____

Name: _____

Mid Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

South Fork Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

El Rico Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

Southwest Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name:_____

Tri-County Water Authority

By:_____ Title: Chairman

Name: MATTHEW H. HURLEY

Alpaugh Irrigation District

By:_____ Title: _____

Name: _____

Mid-Kings River Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

South Fork Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

El Rico Groundwater Sustainability Agency

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Name: _____

Southwest Kings Groundwater Sustainability Agency

By:_____ Title:_____

Name: _____

Tri-County Water Authority

By:_____ Title:_____

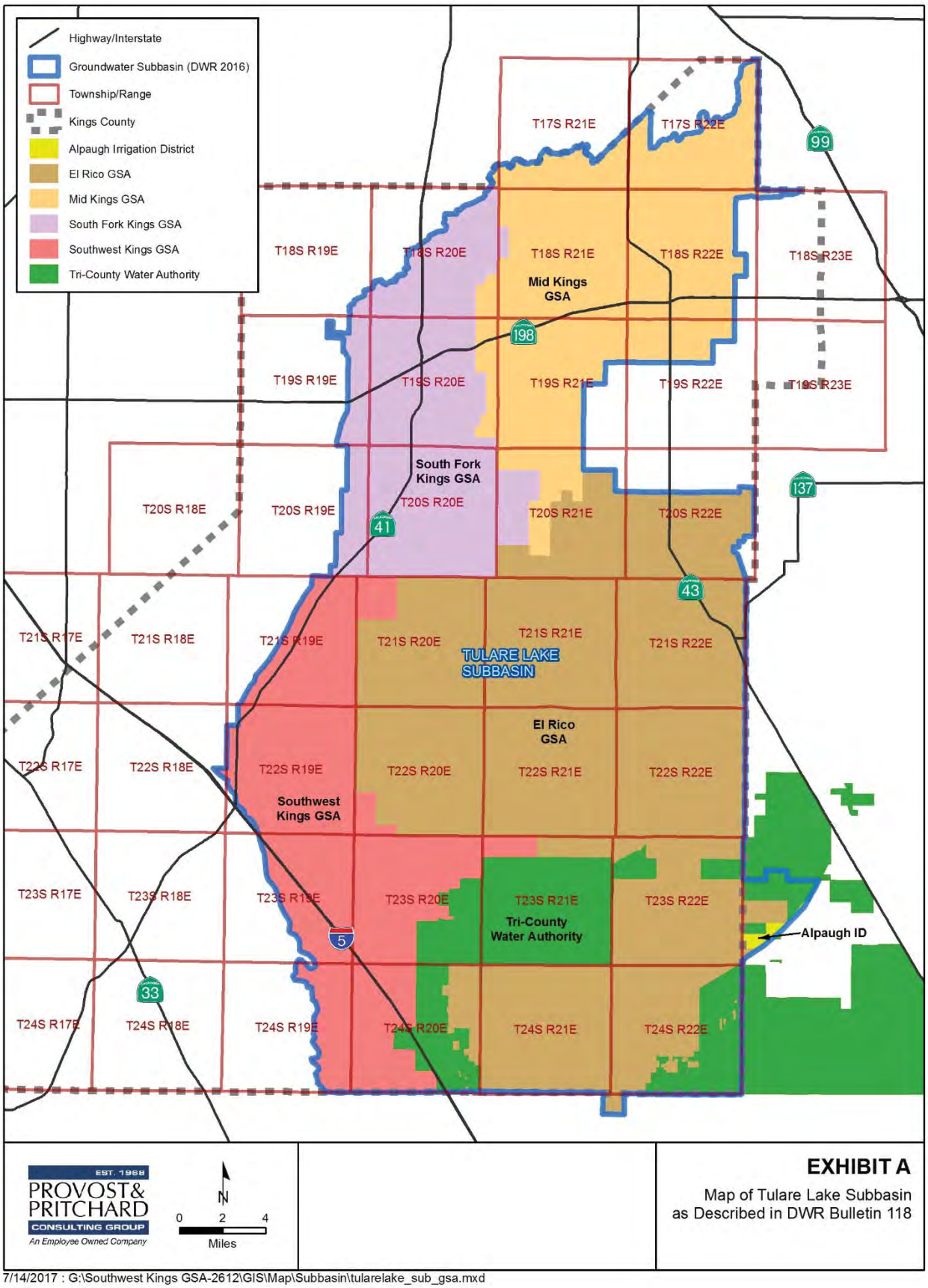
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Alpaugh Irrigation District

By: _____ Title: G.M.

Name: BRUCE HOWARTH

Exhibit "A"
Map of Tulare Lake Subbasin as Described in
DWR Bulletin 118

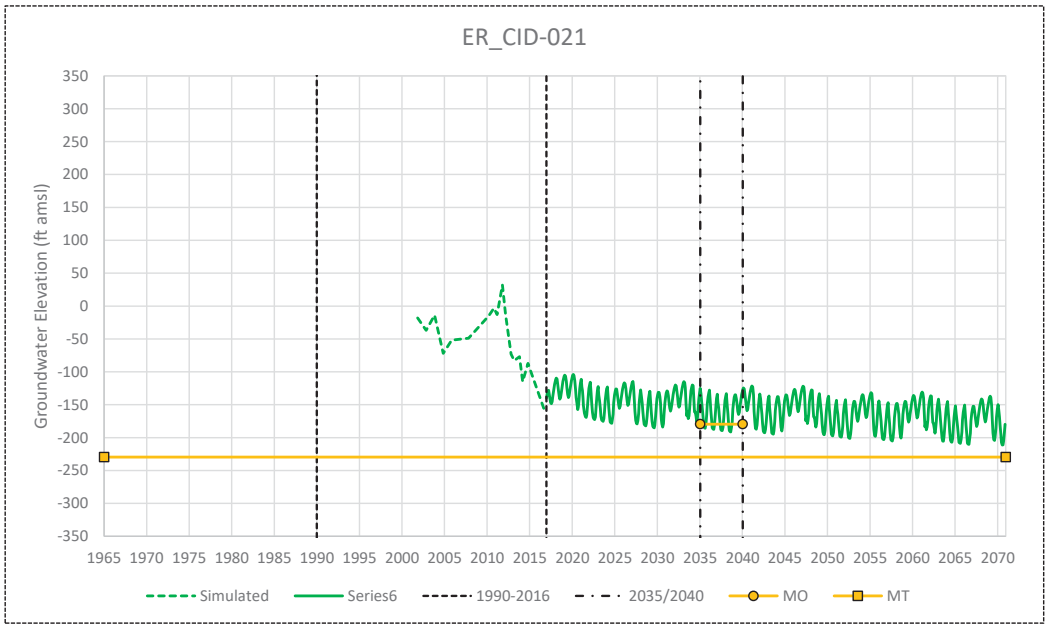


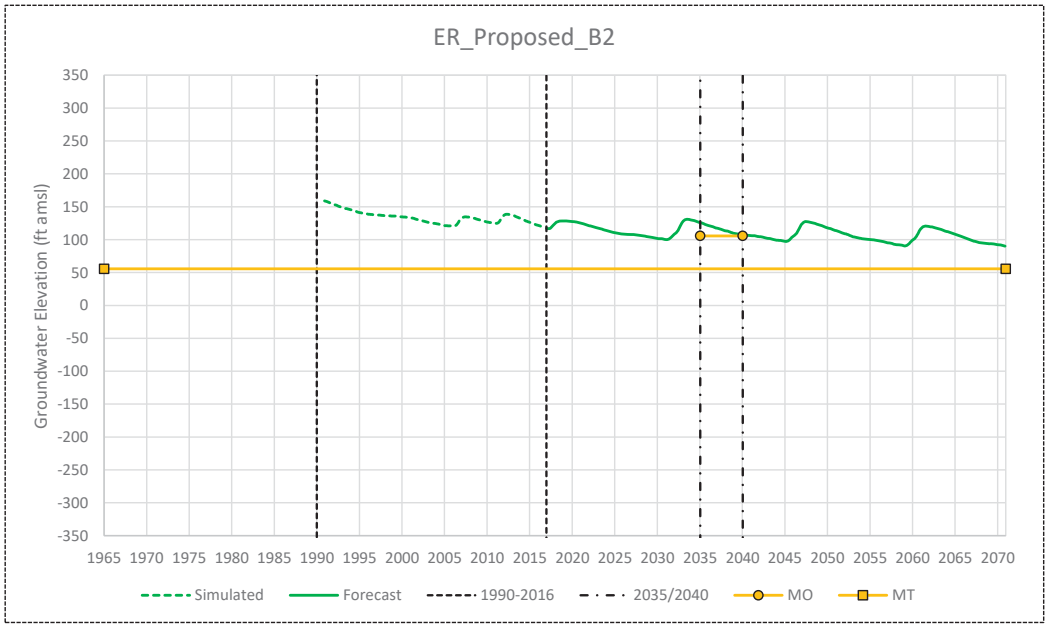
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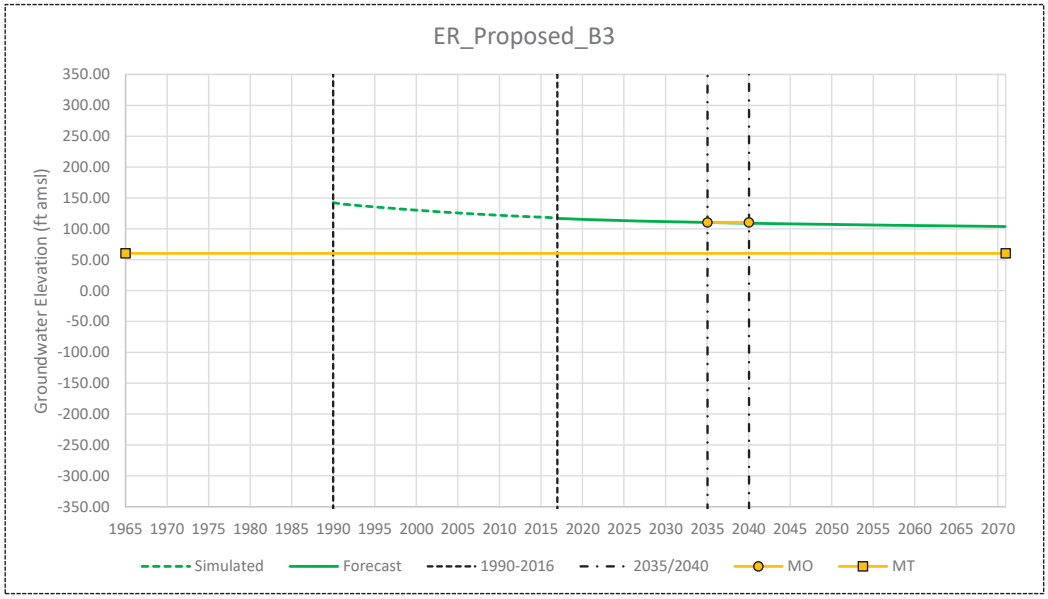
APPENDIX G

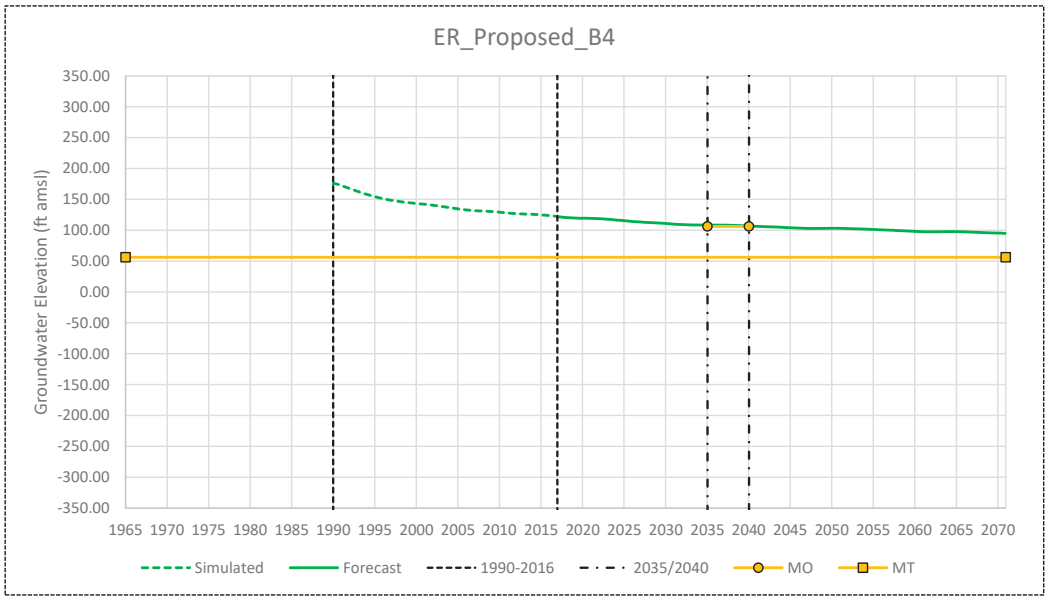
REPRESENTATIVE MONITORING SITES FORECAST HYDROGRAPHS WITH PROJECTS

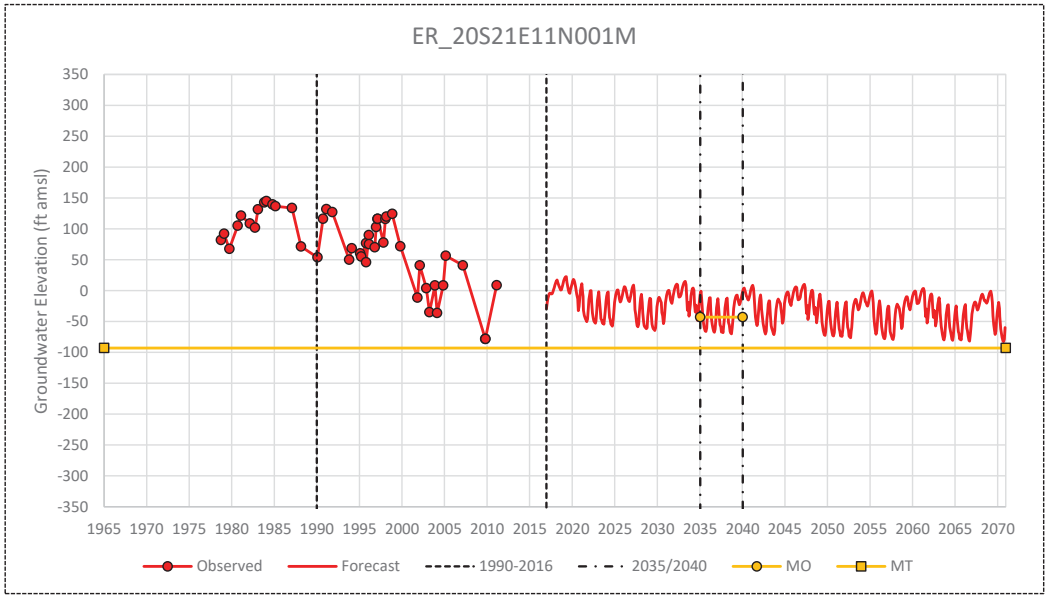
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MKR_MWH_DEEP	26
MKR_Proposed_C1	27
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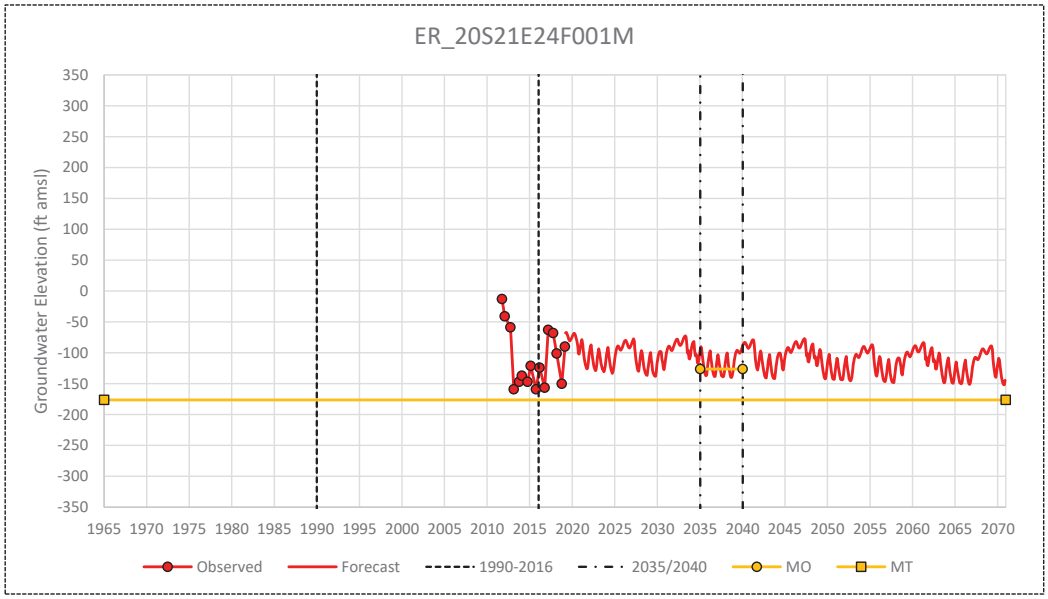

ER_CID-021
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Series6
1990-2016
2035/2040
MO
MT

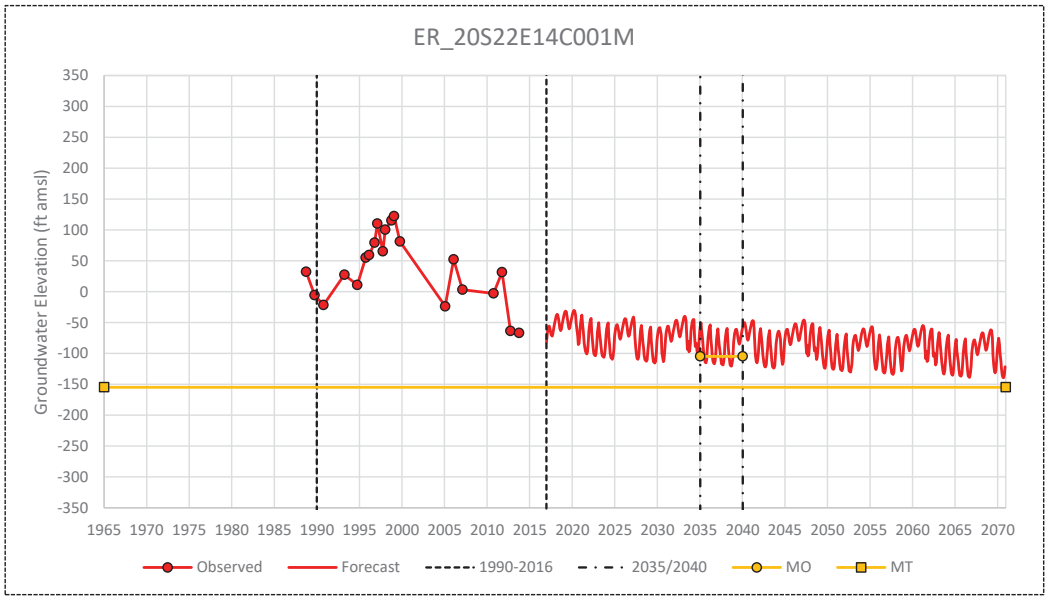

ER_Proposed_B2
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

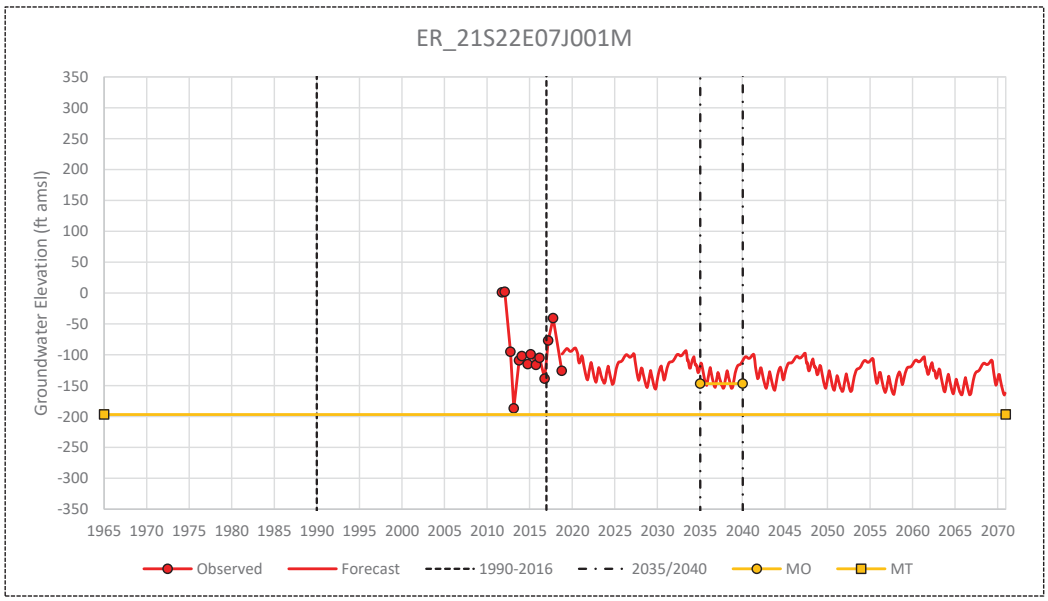

ER_Proposed_B3
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

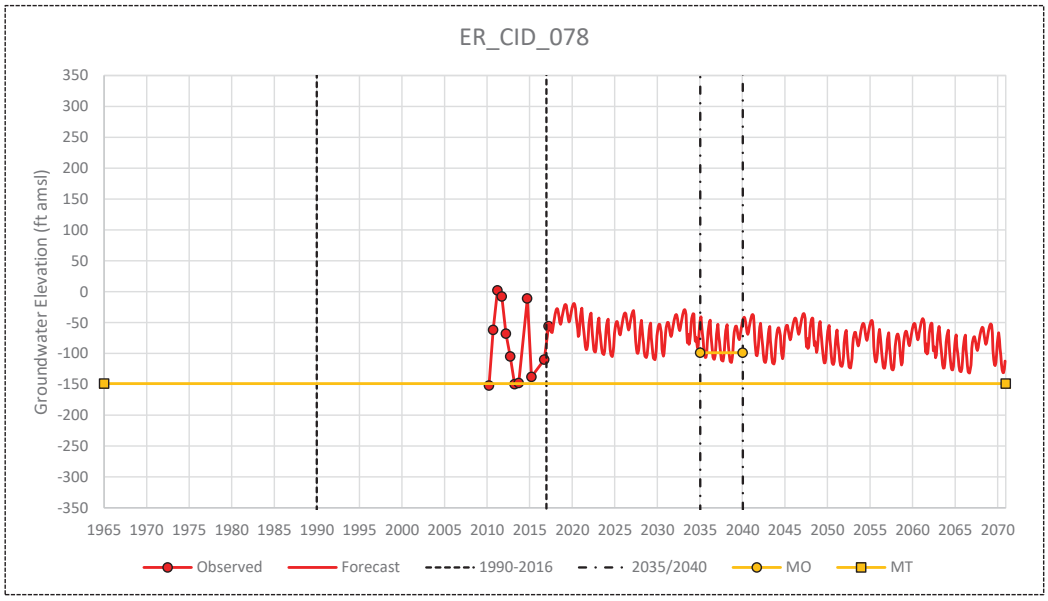

ER_Proposed_B4
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

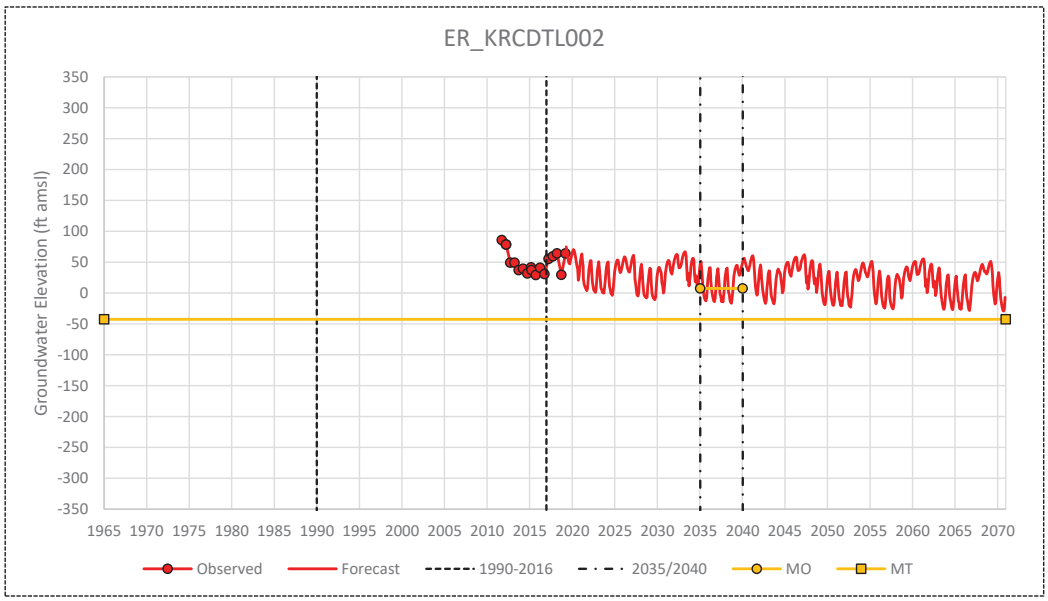

ER_20S21E11N001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

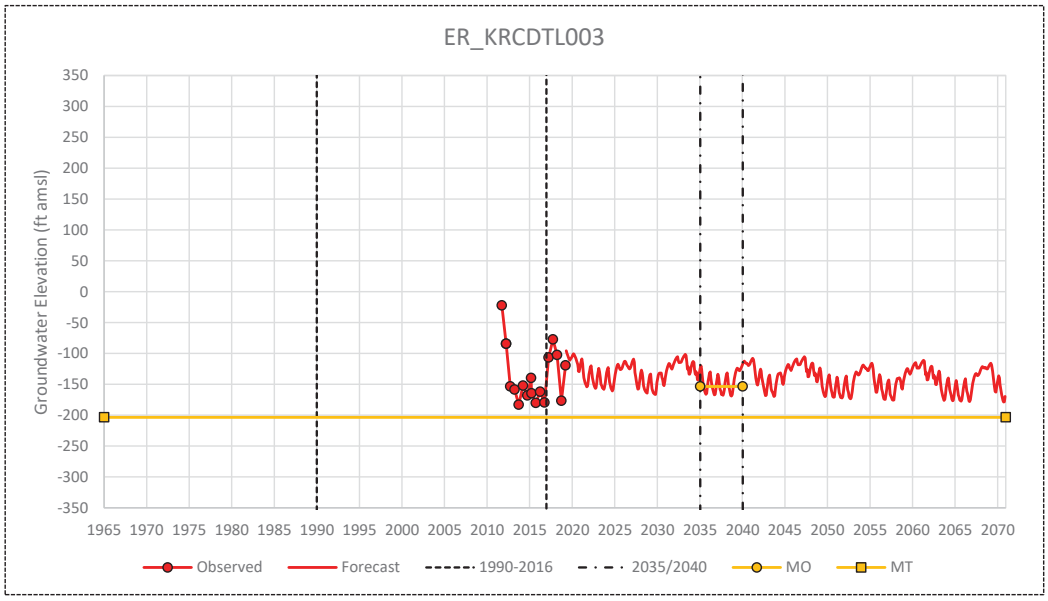

ER_20S21E24F001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

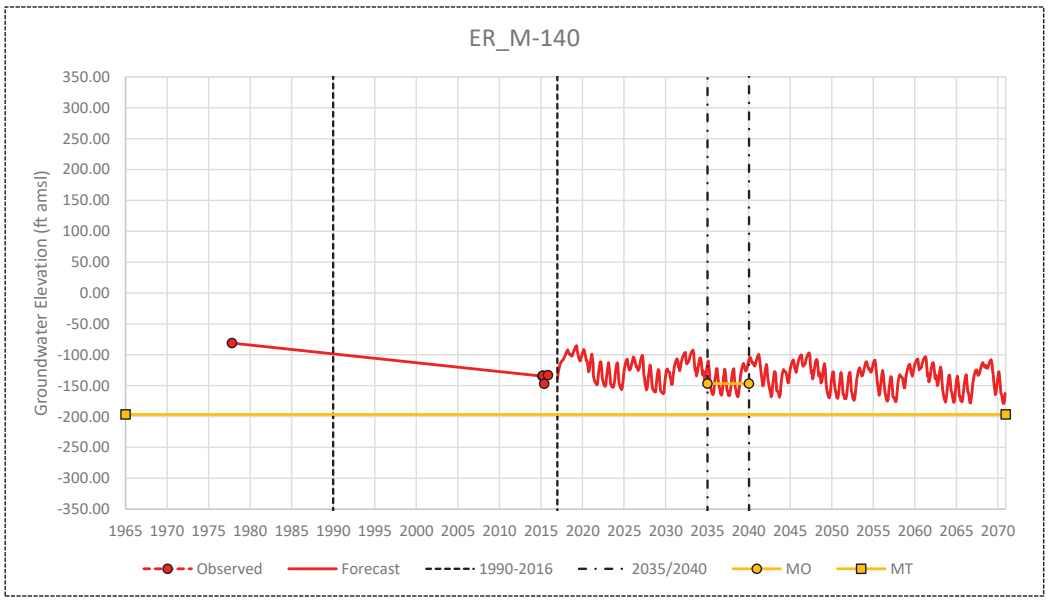

ER_20S22E14C001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

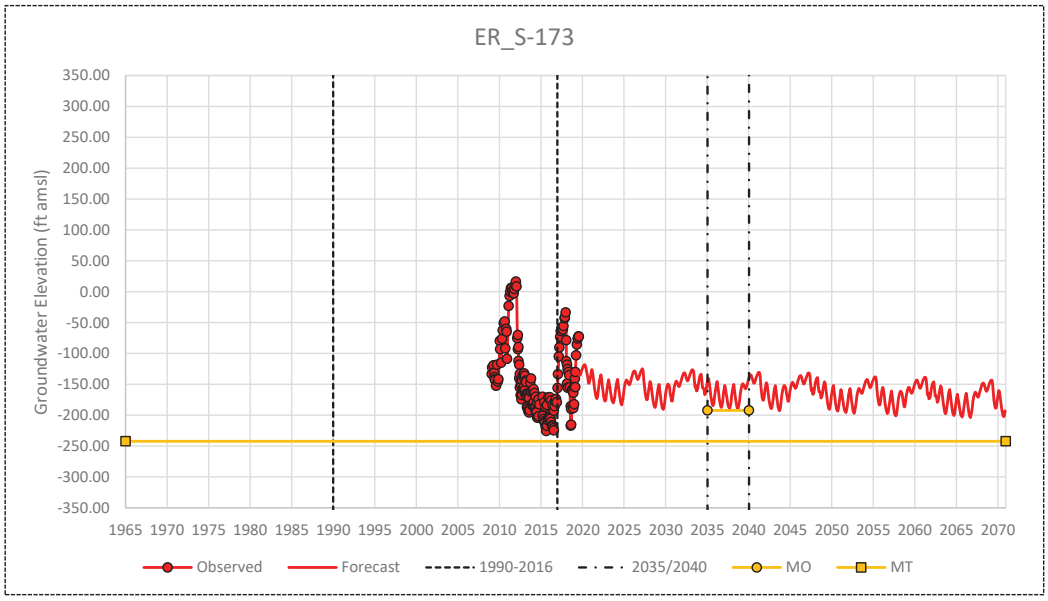

ER_21S22E07J001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

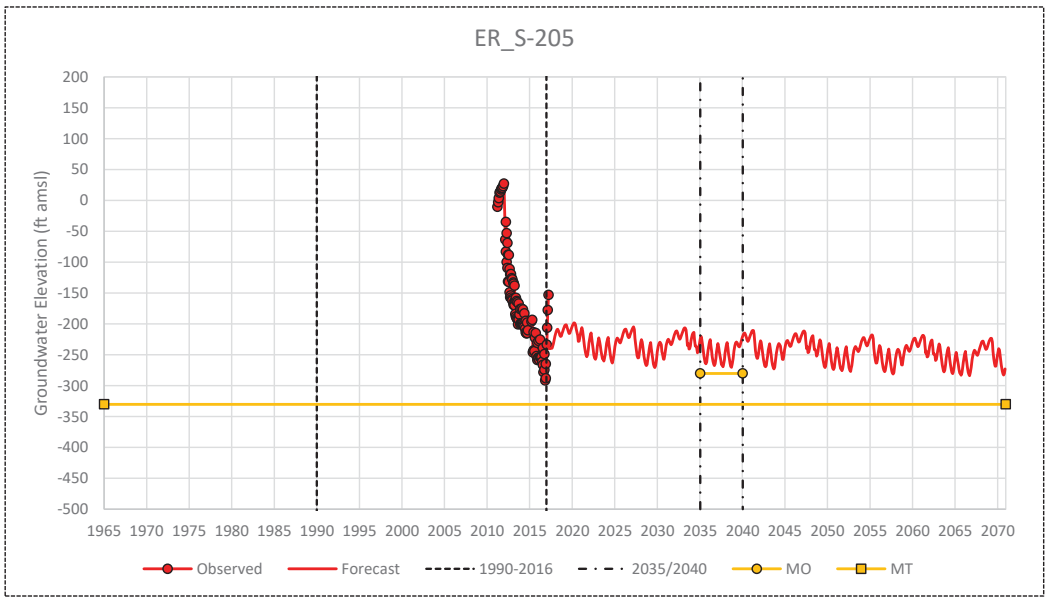

ER_CID_078
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

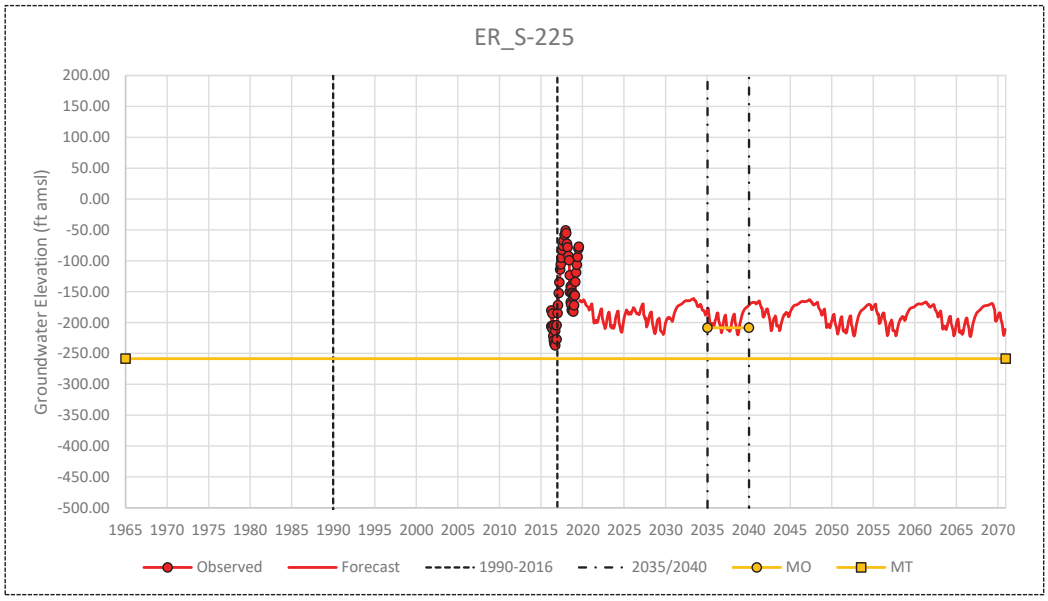

ER_KRCDTL002
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

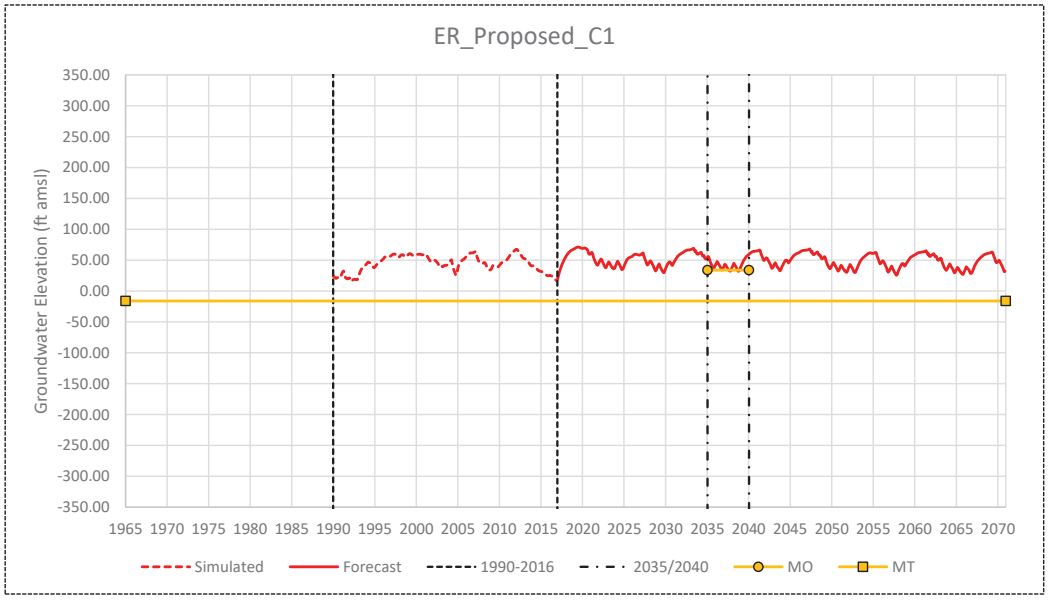

ER_KRCDTL003
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

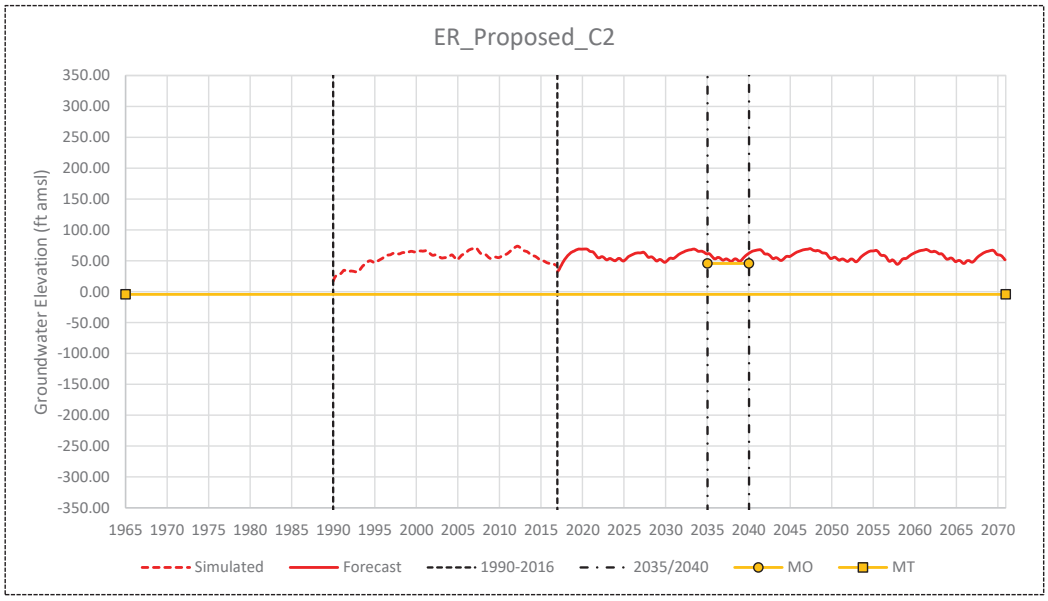

ER_M-140
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

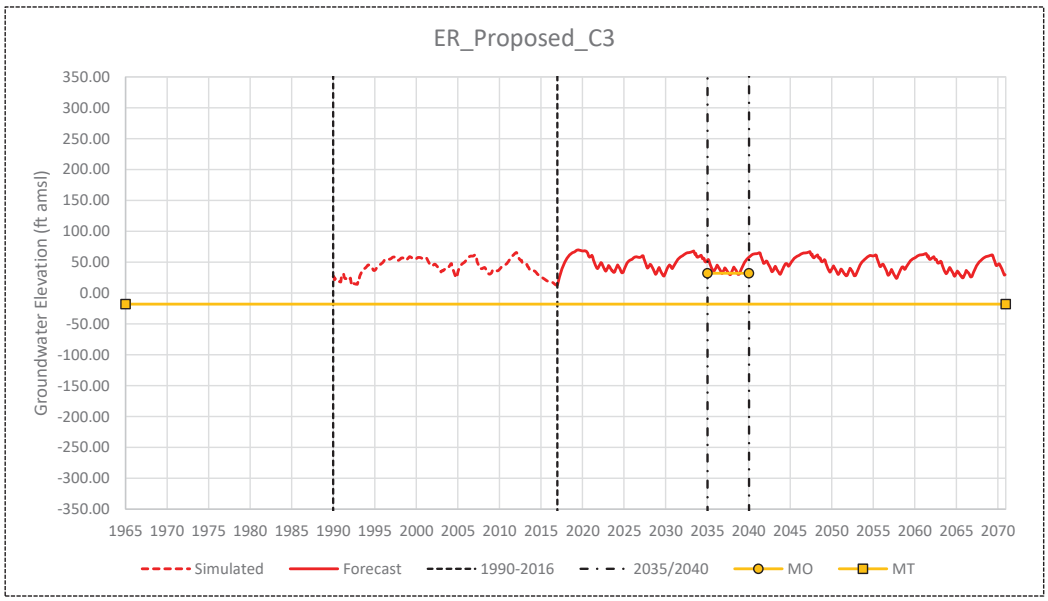

ER_S-173
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

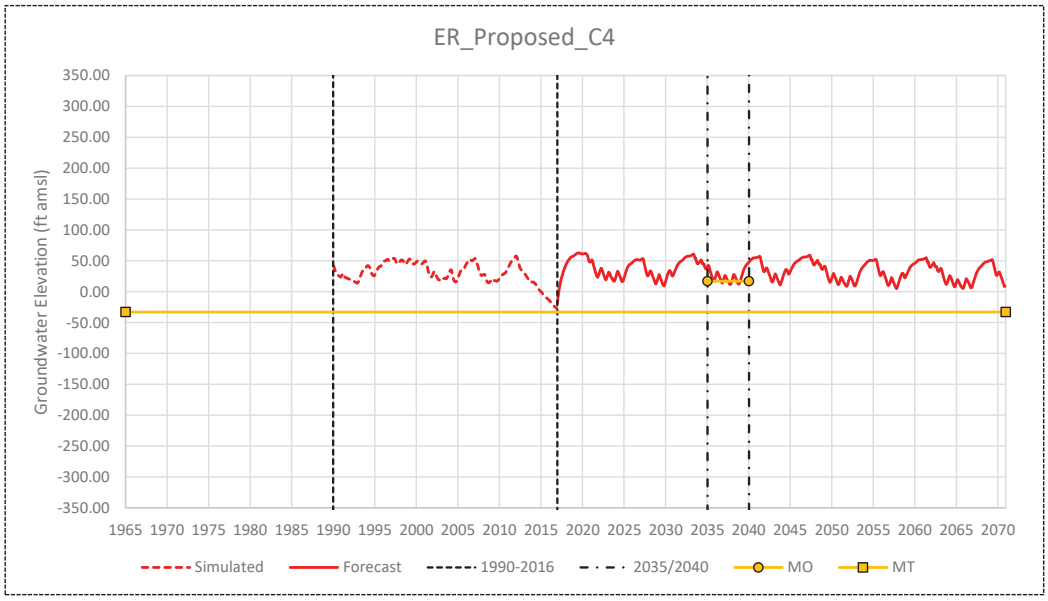

ER_S-205
Groundwater Elevation (ft amsl)
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

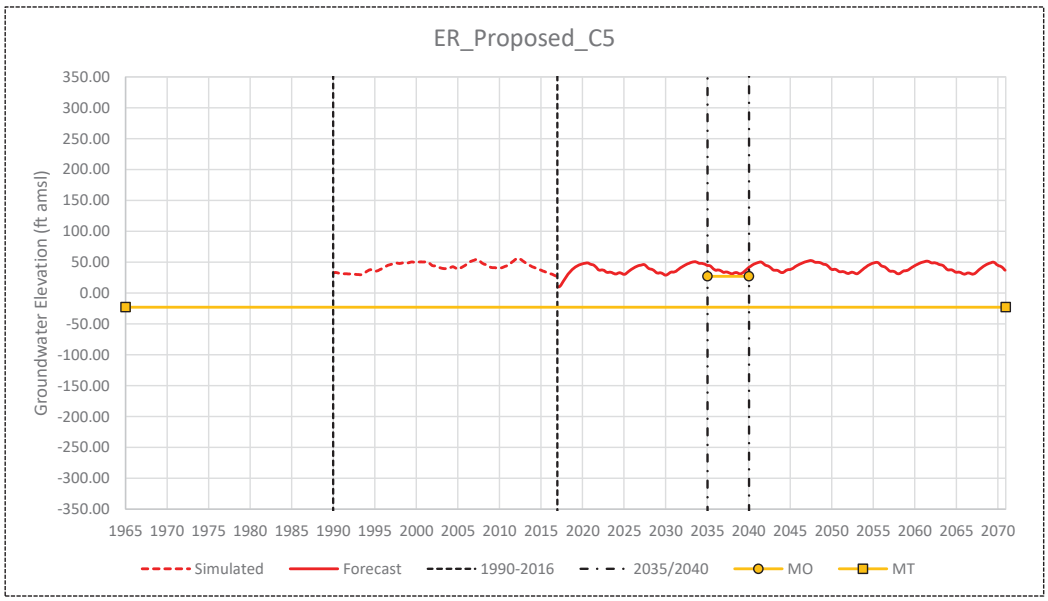

ER_S-225
Groundwater Elevation (ft amsl)
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
-400.00
-450.00
-500.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

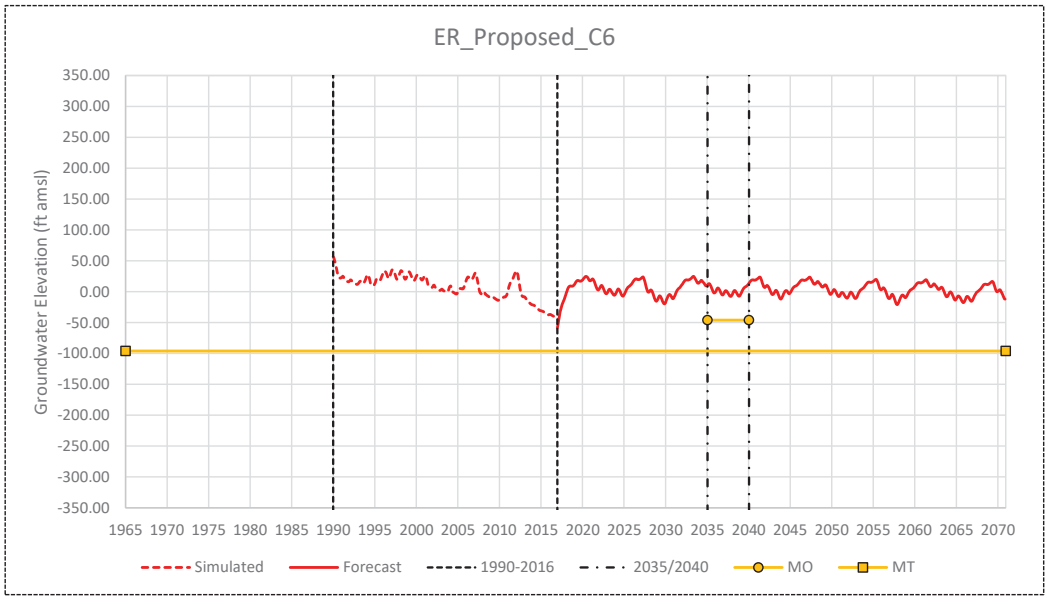

ER_Proposed_C1
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

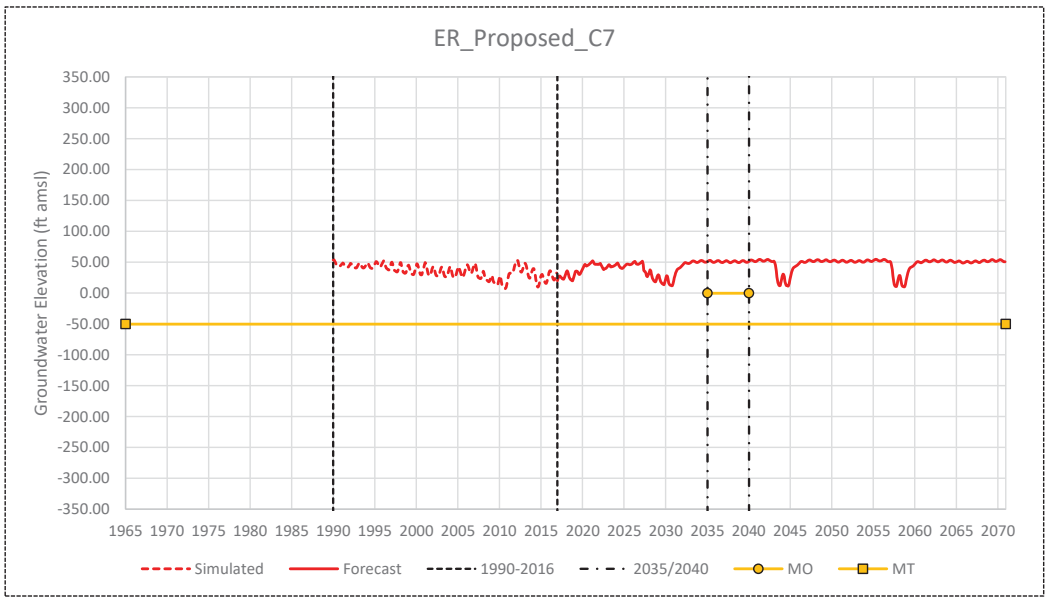

ER_Proposed_C2
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

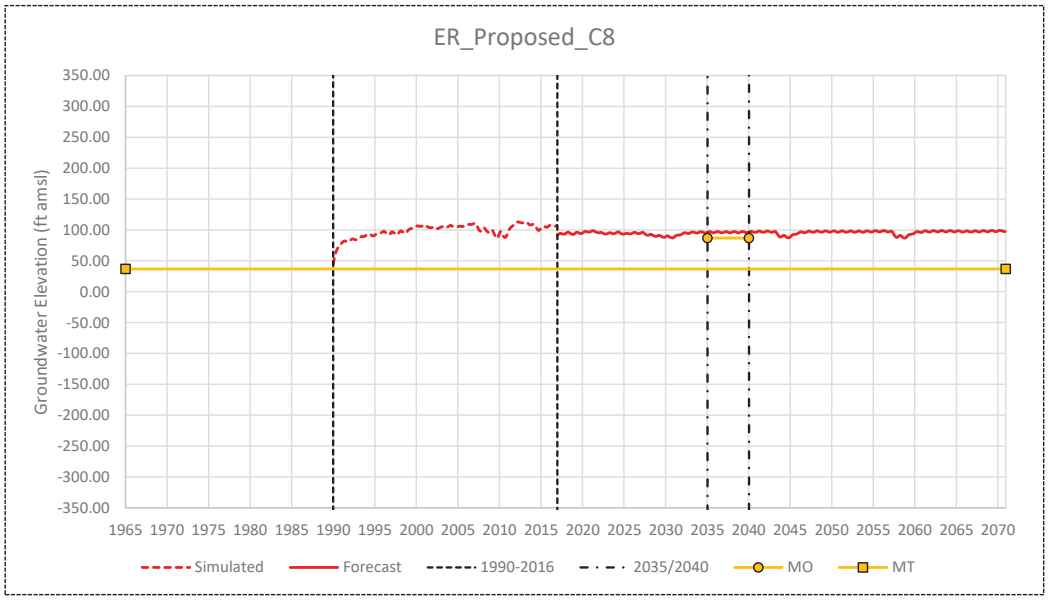

ER_Proposed_C3
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

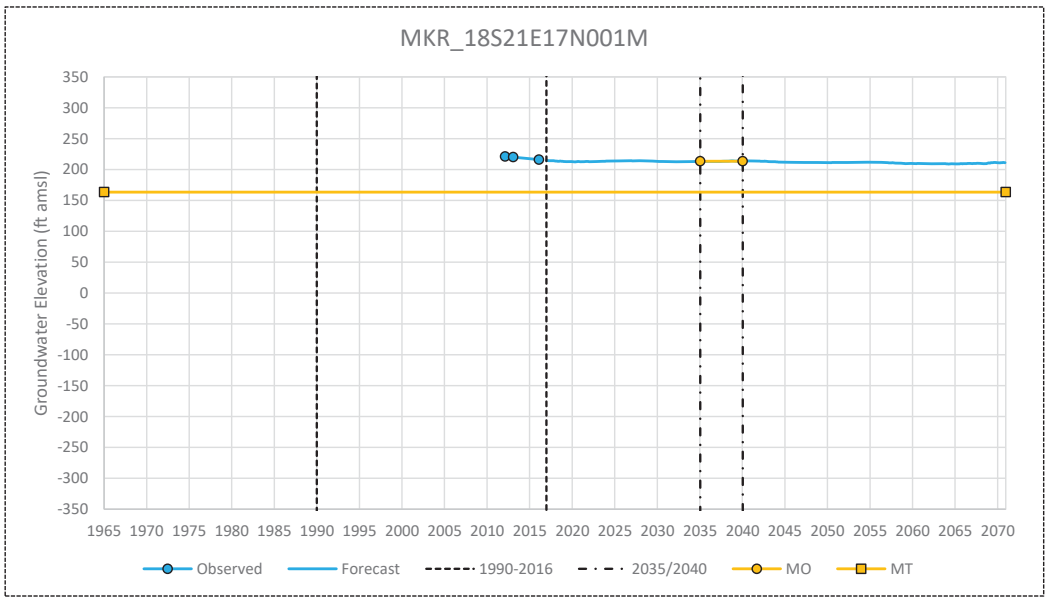

ER_Proposed_C4
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

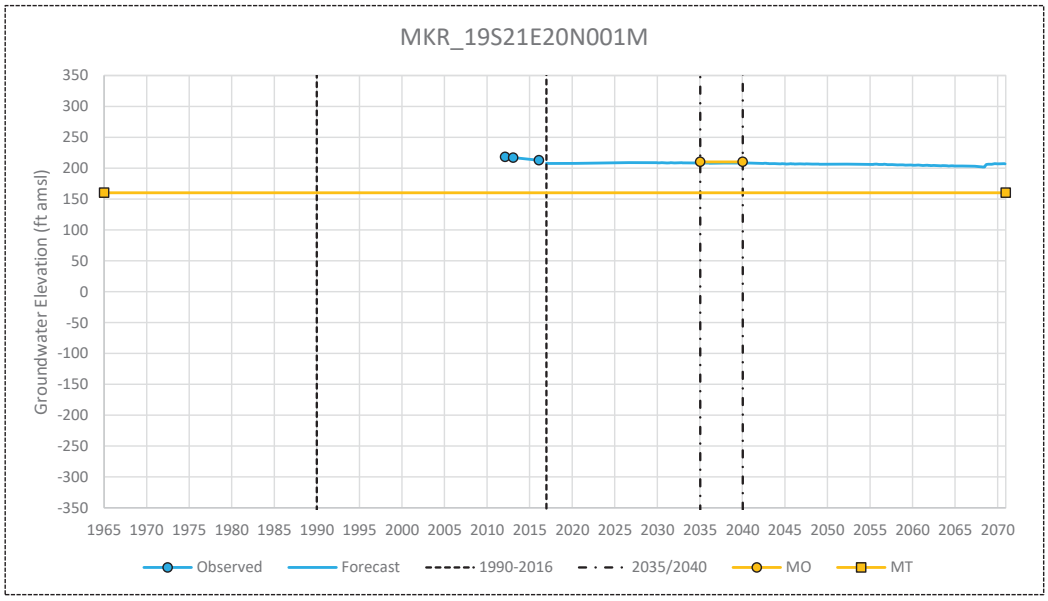

ER_Proposed_C5
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

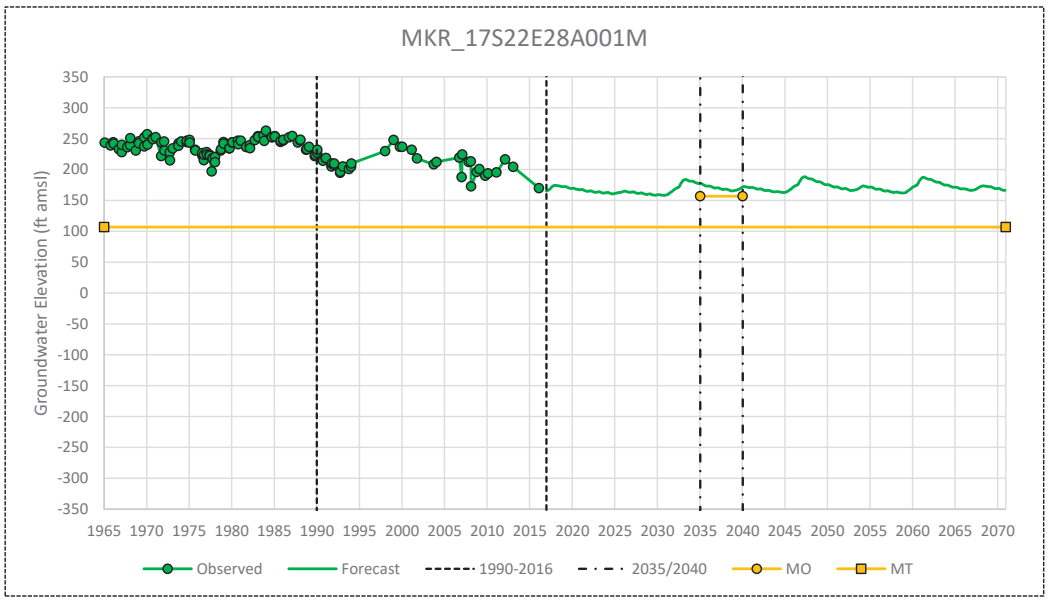

ER_Proposed_C6
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

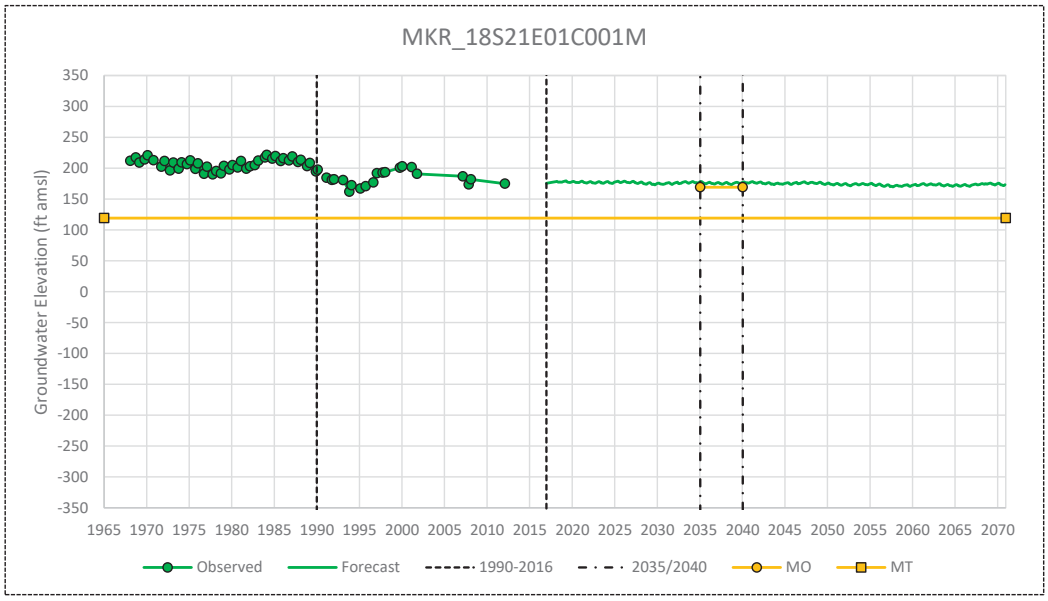

ER_Proposed_C7
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

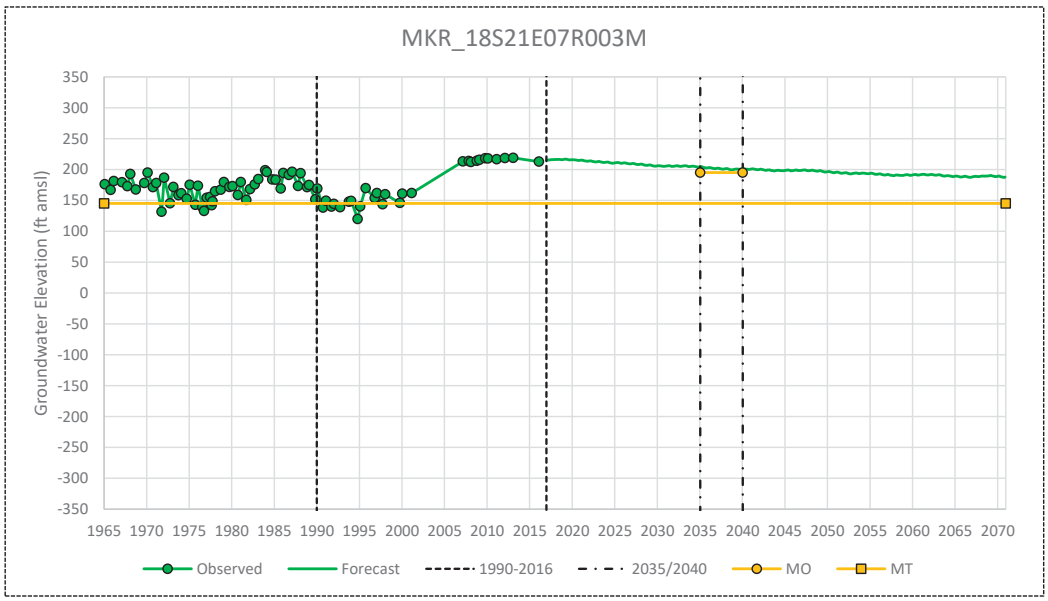

ER_Proposed_C8
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

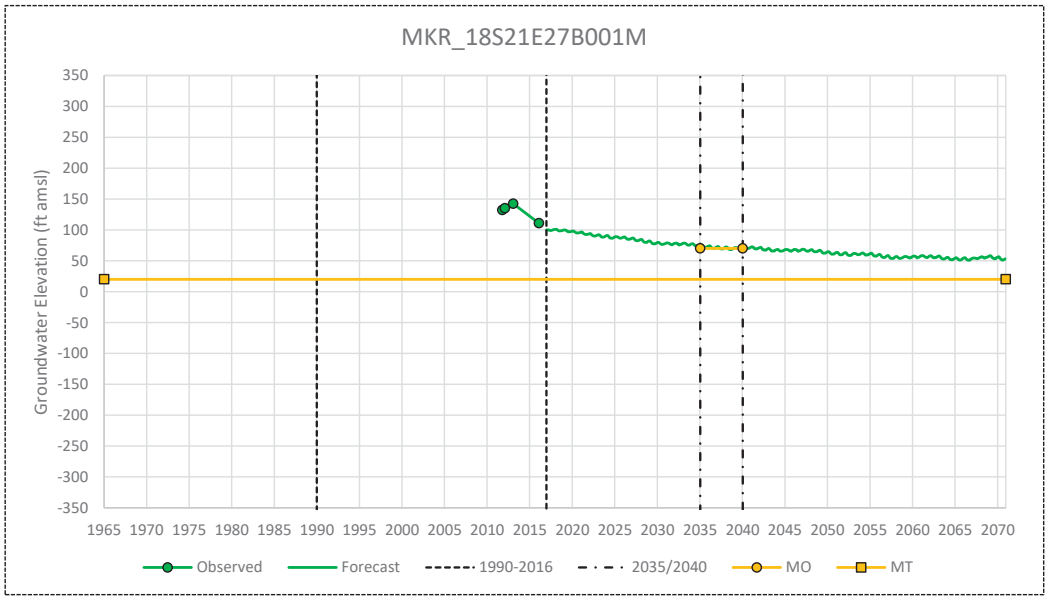

MKR_18S21E17N001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

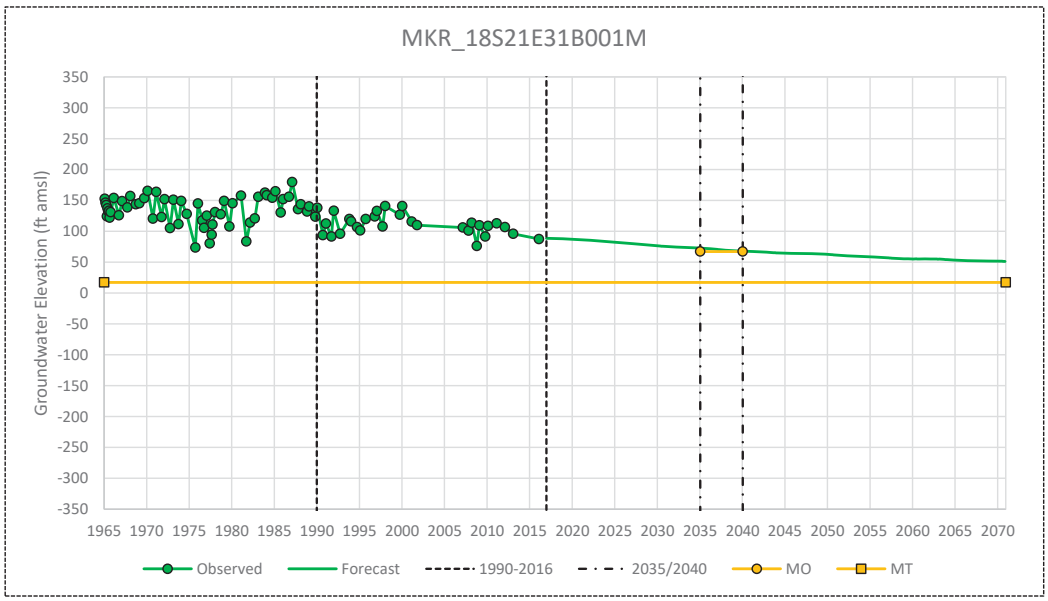

MKR_19S21E20N001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

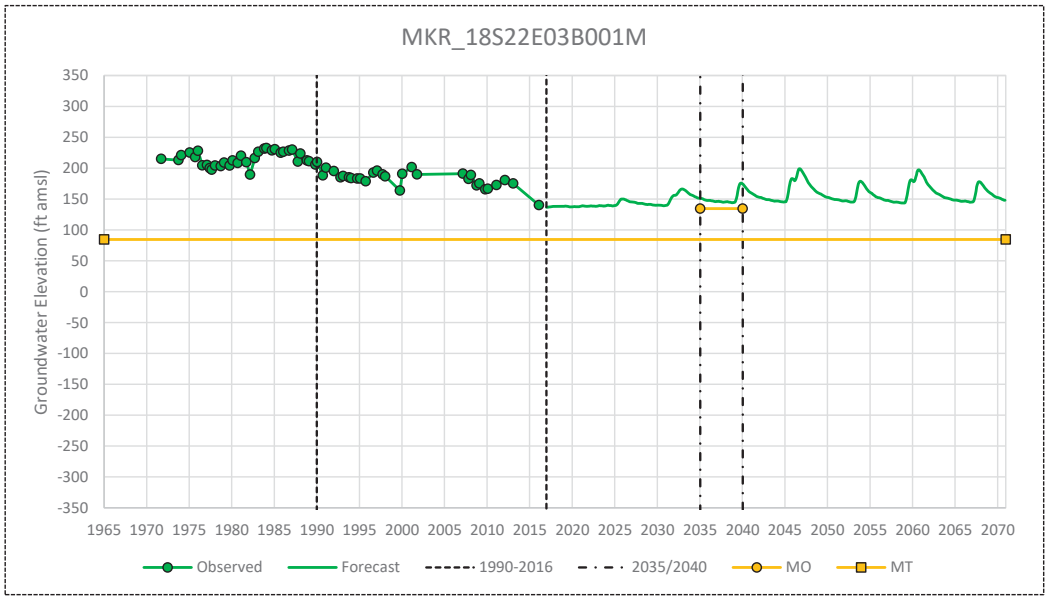

MKR_17S22E28A001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

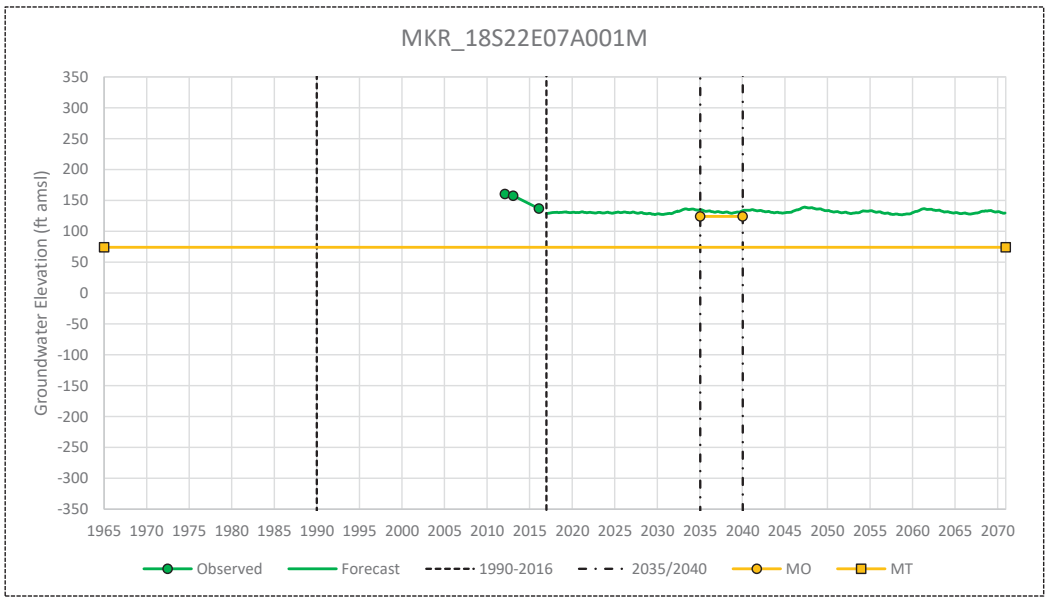

MKR_18S21E01C001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

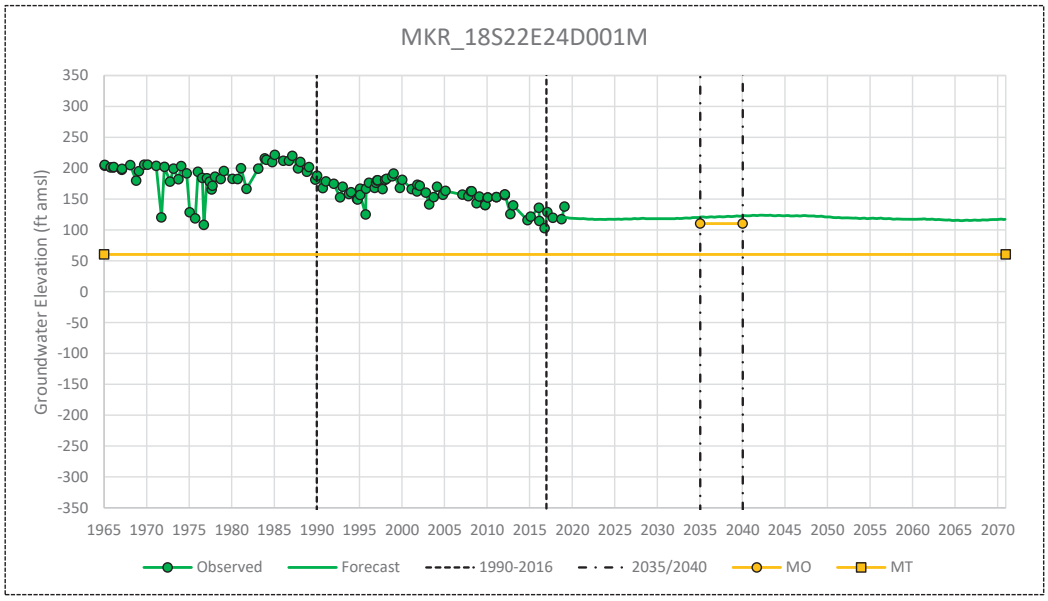

MKR_18S21E07R003M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

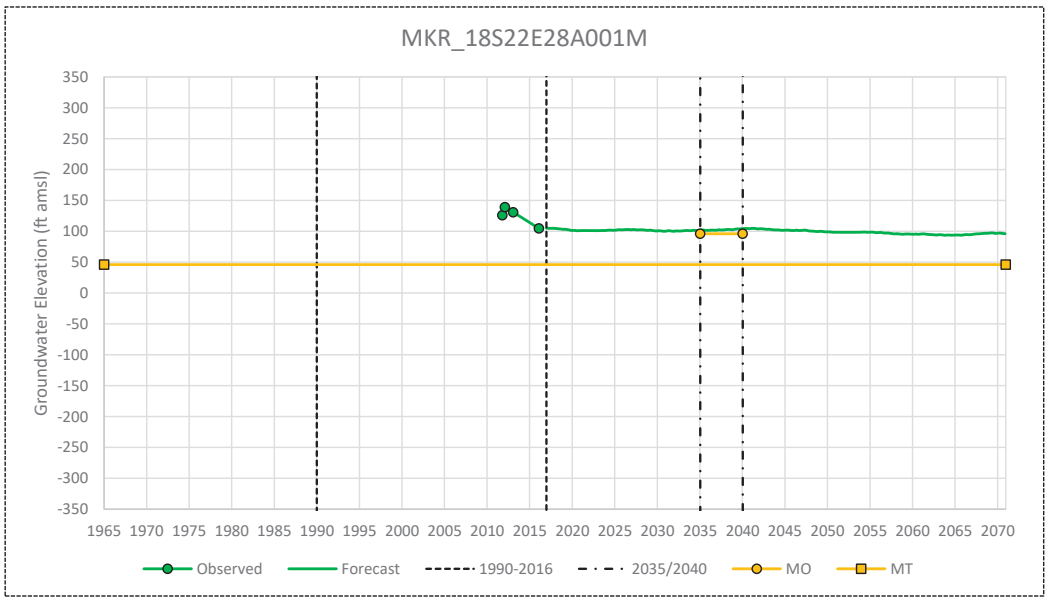

MKR_18S21E27B001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

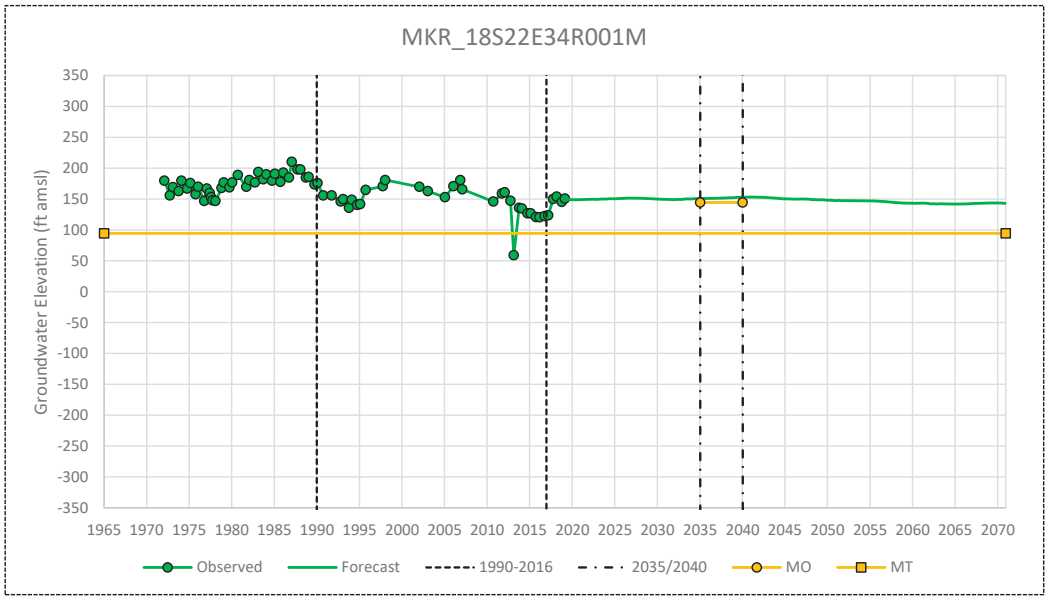

MKR_18S21E31B001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

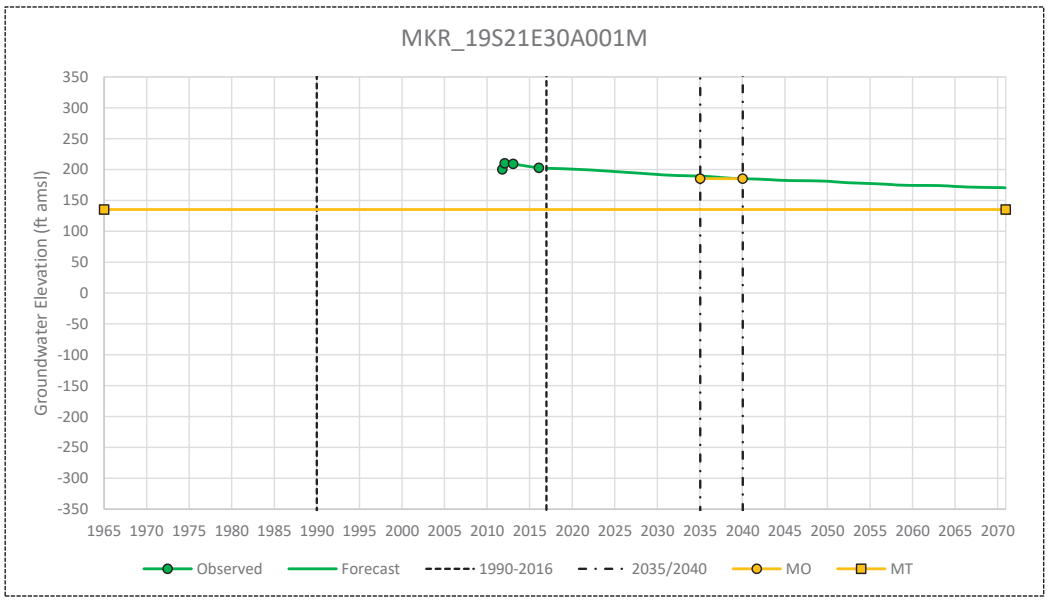

MKR_18S22E03B001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

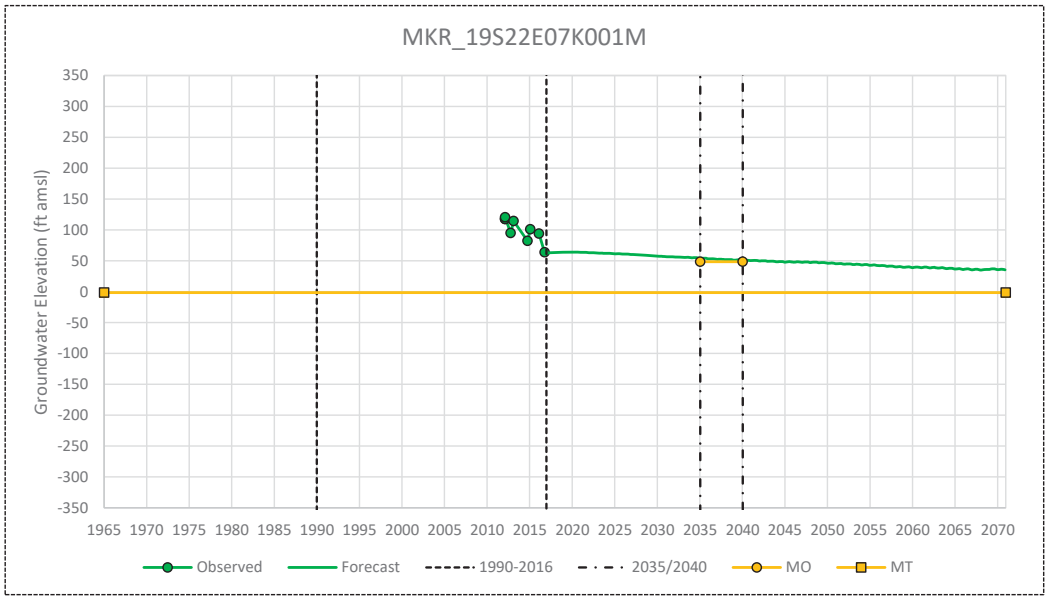

MKR_18S22E07A001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

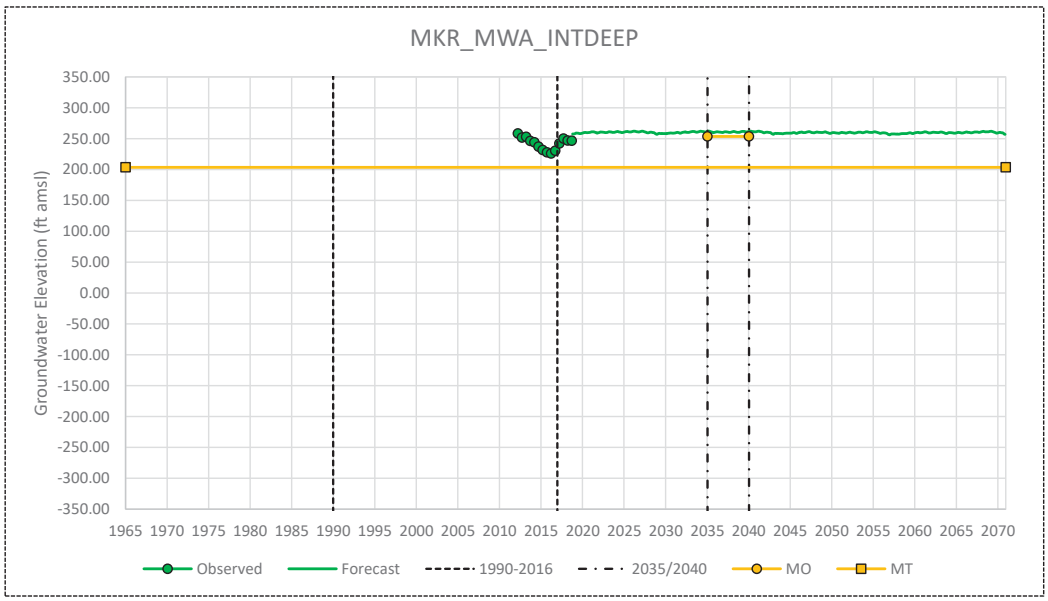

MKR_18S22E24D001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

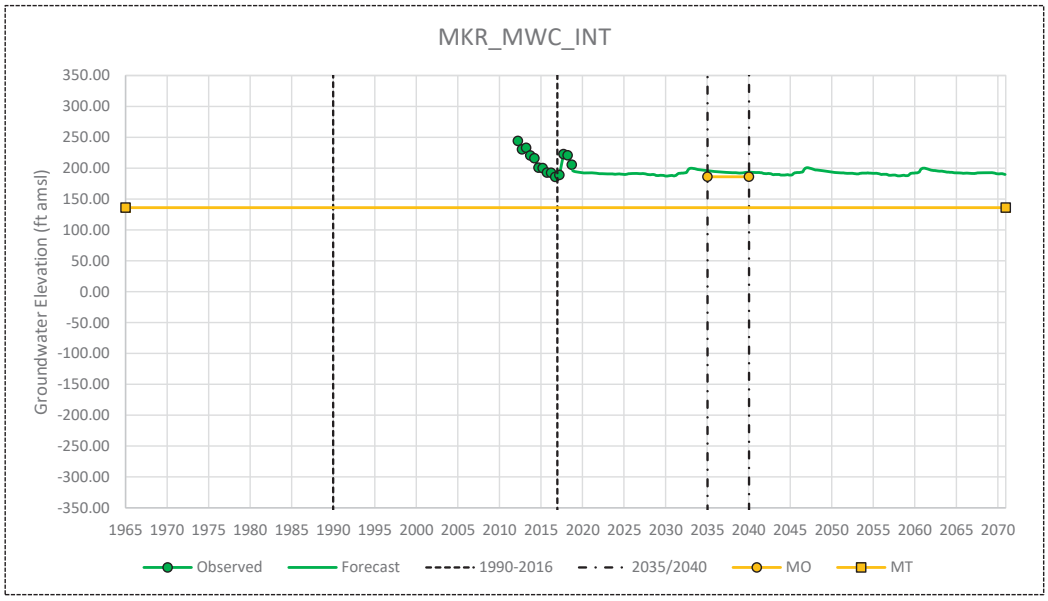

MKR_18S22E28A001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

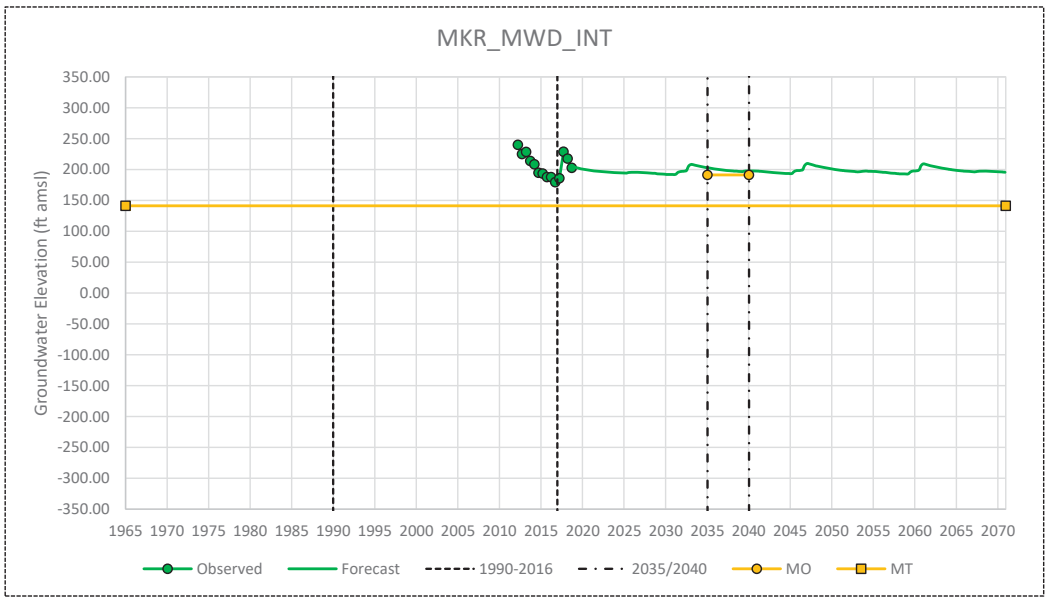

MKR_18S22E34R001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

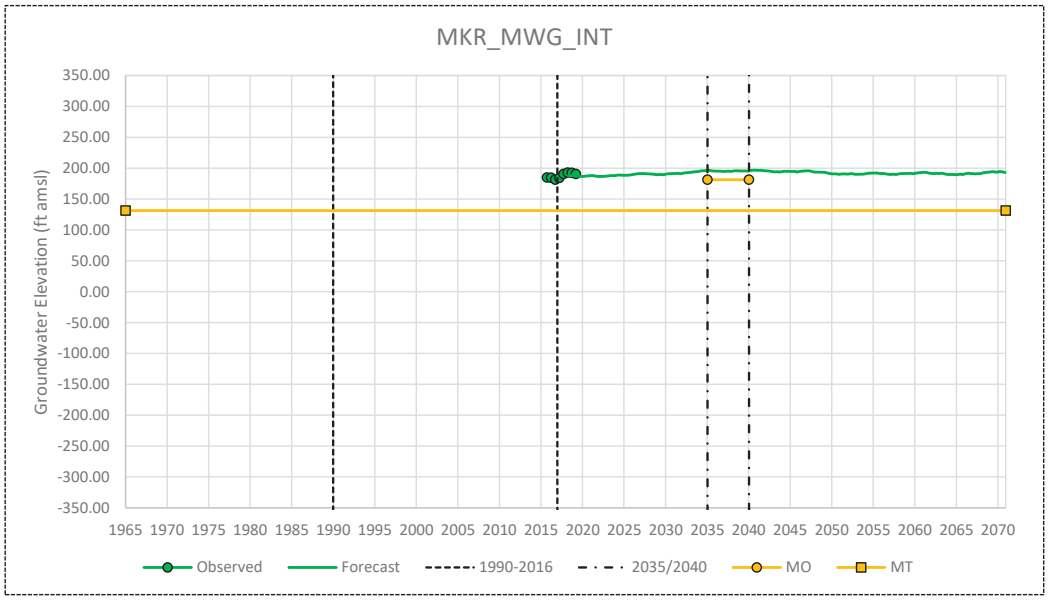

MKR_19S21E30A001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

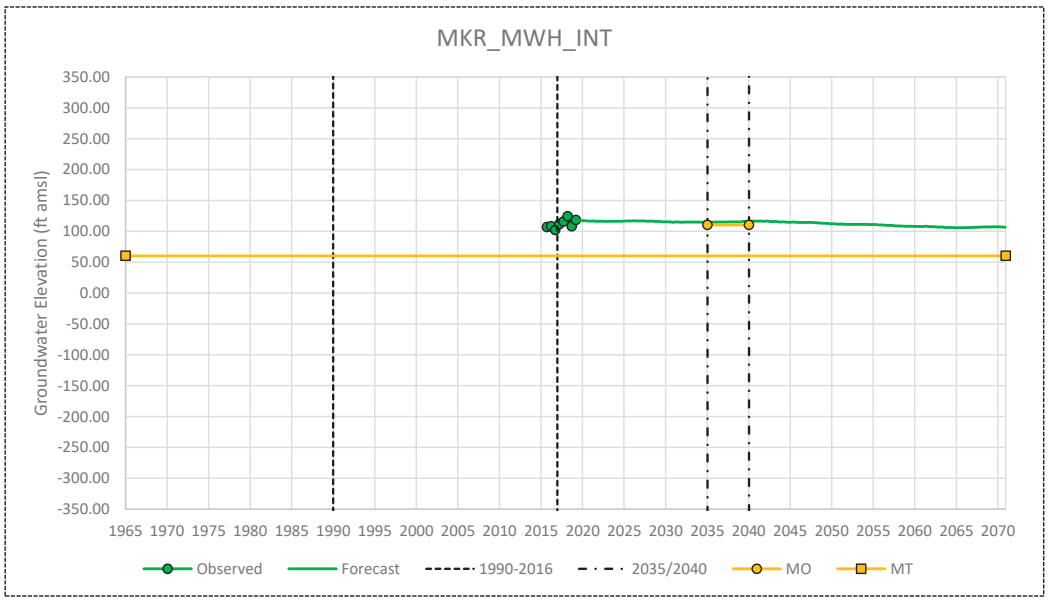

MKR_19S22E07K001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

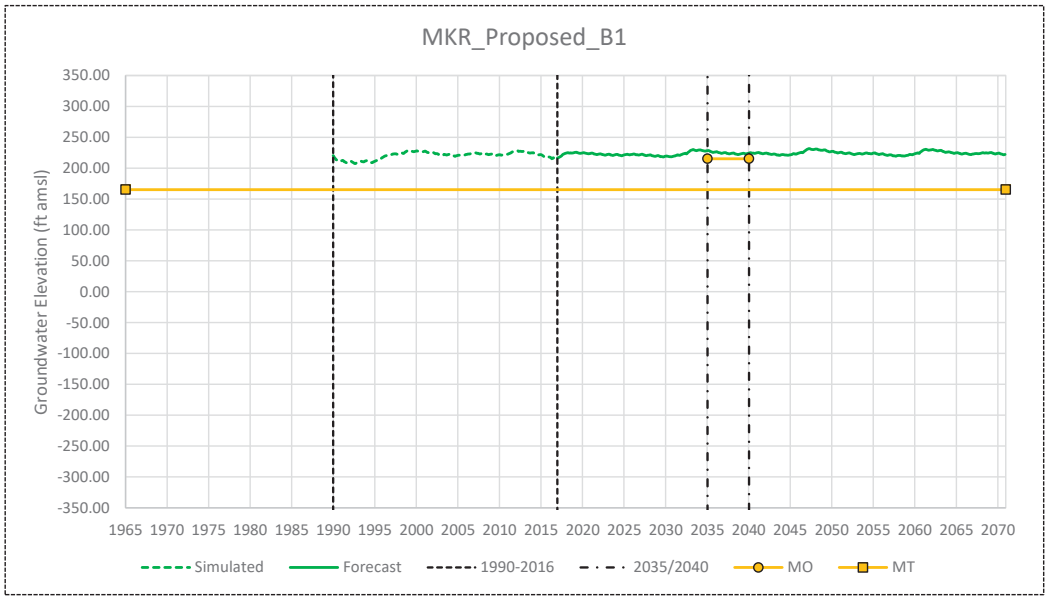

MKR_MWA_INTDEEP
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

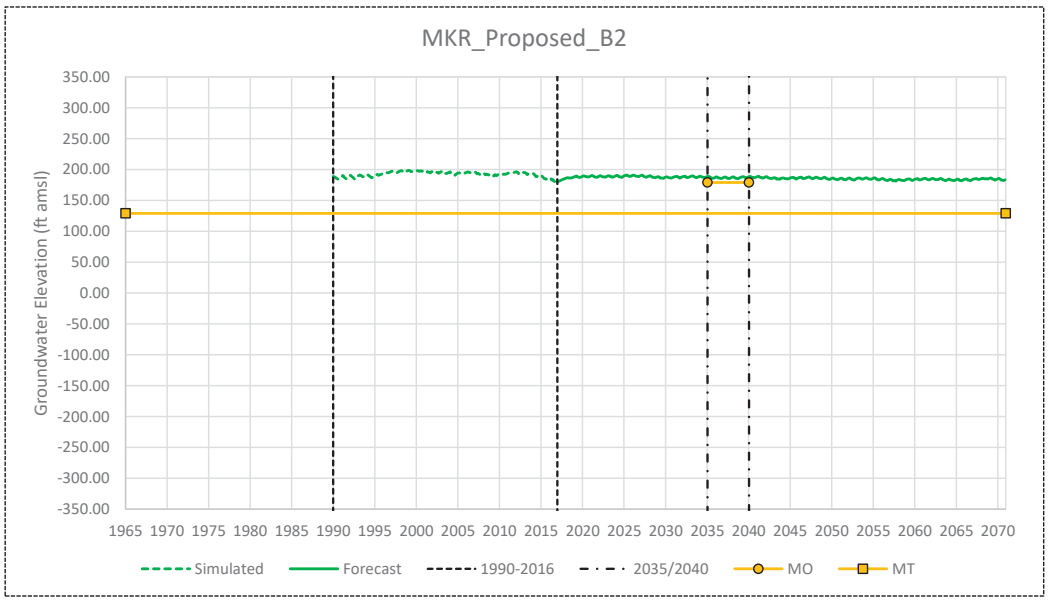

MKR_MWC_INT
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

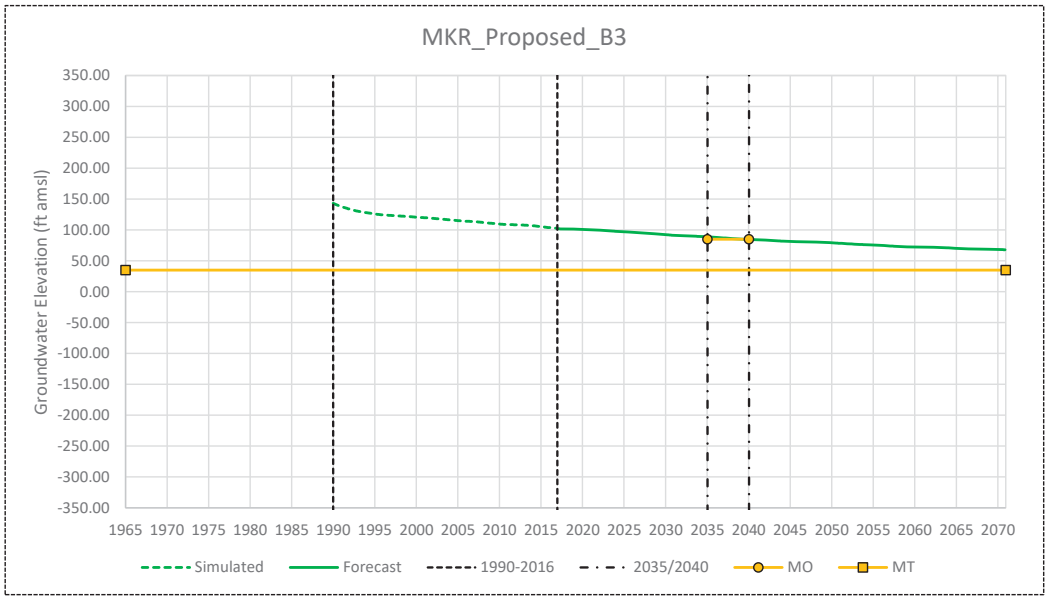

MKR_MWD_INT
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

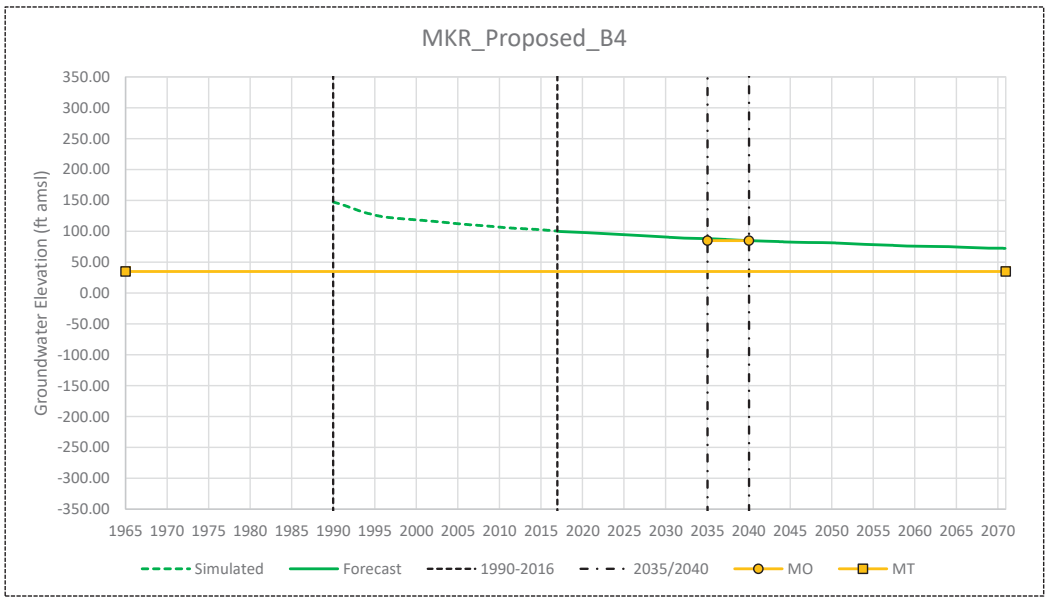

MKR_MWG_INT
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

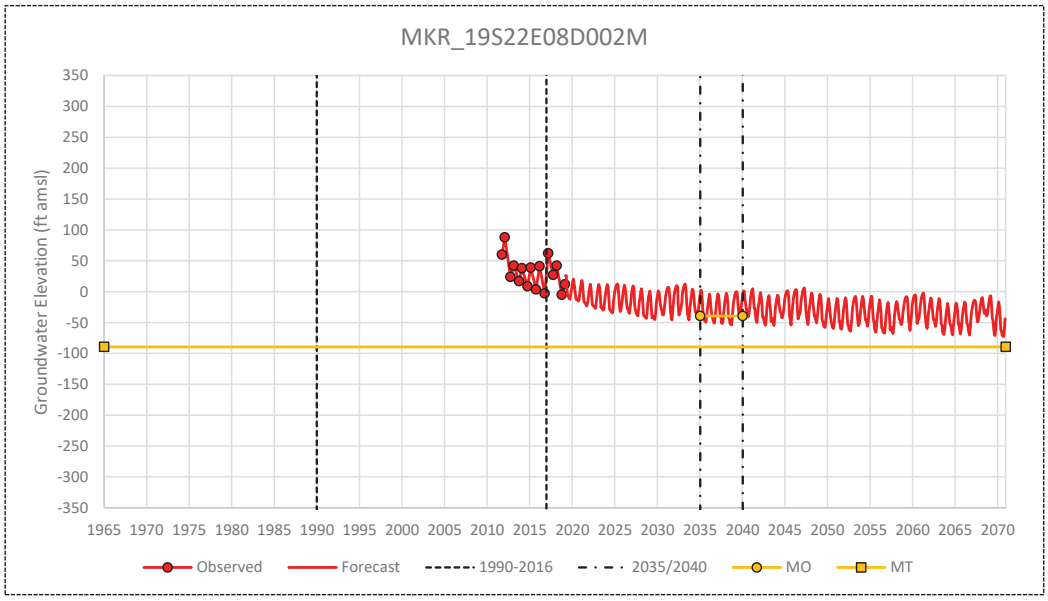

MKR_MWH_INT
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

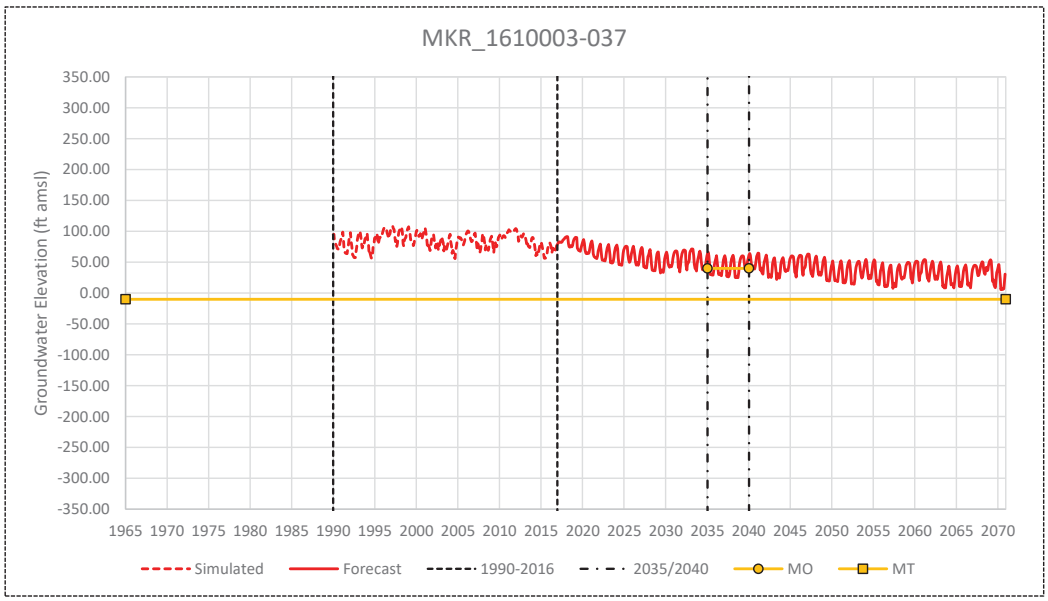

MKR_Proposed_B1
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

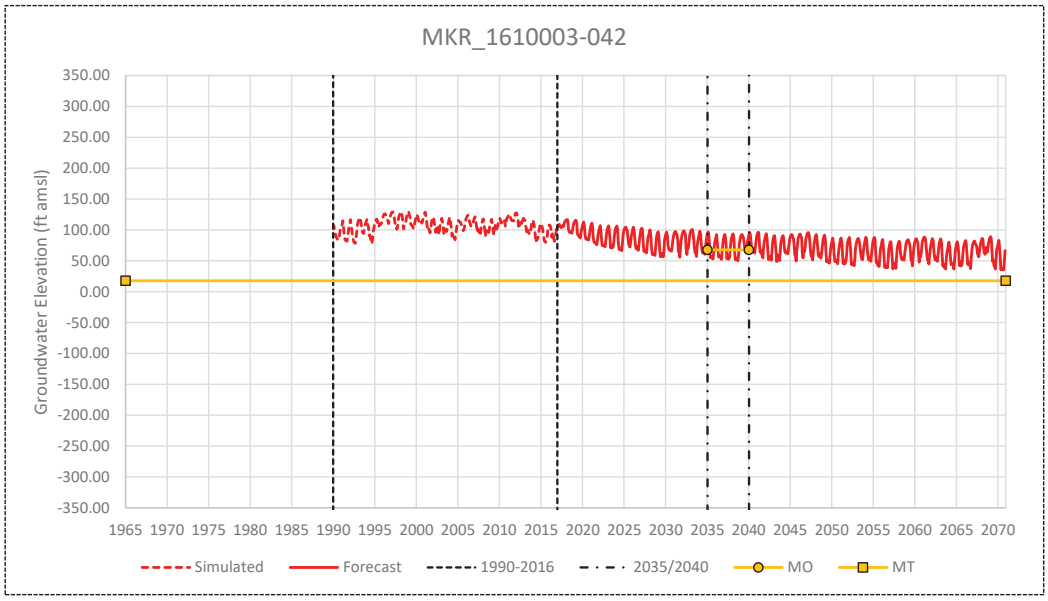

MKR_Proposed_B2
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

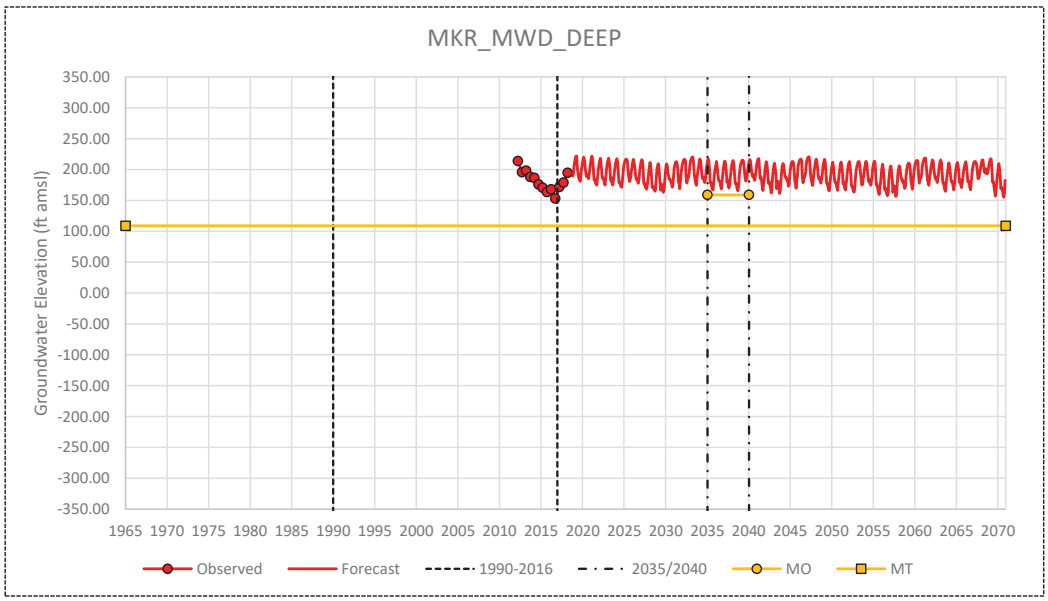

MKR_Proposed_B3
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

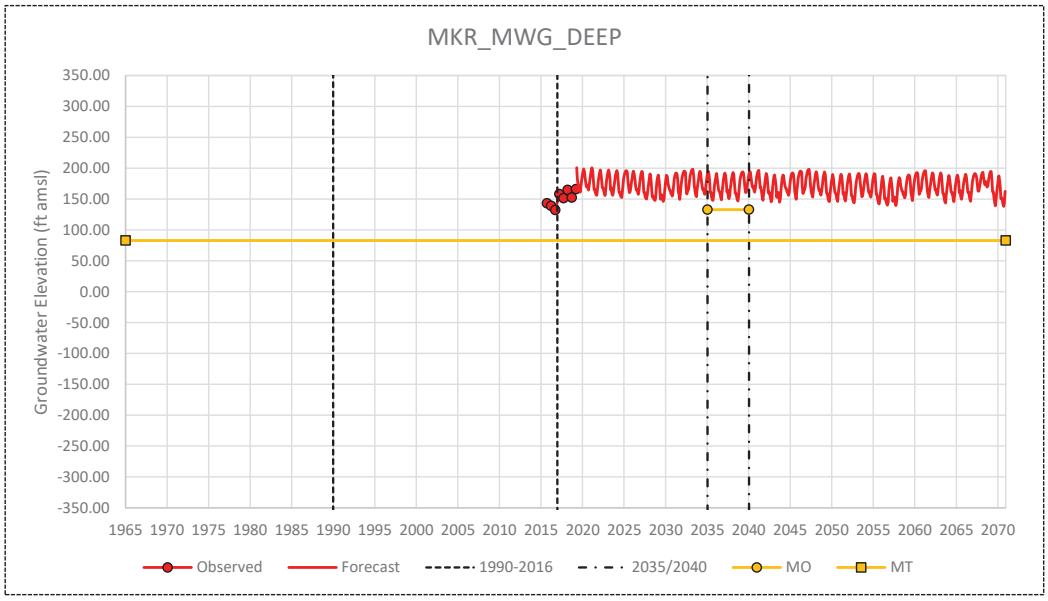

MKR_Proposed_B4
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

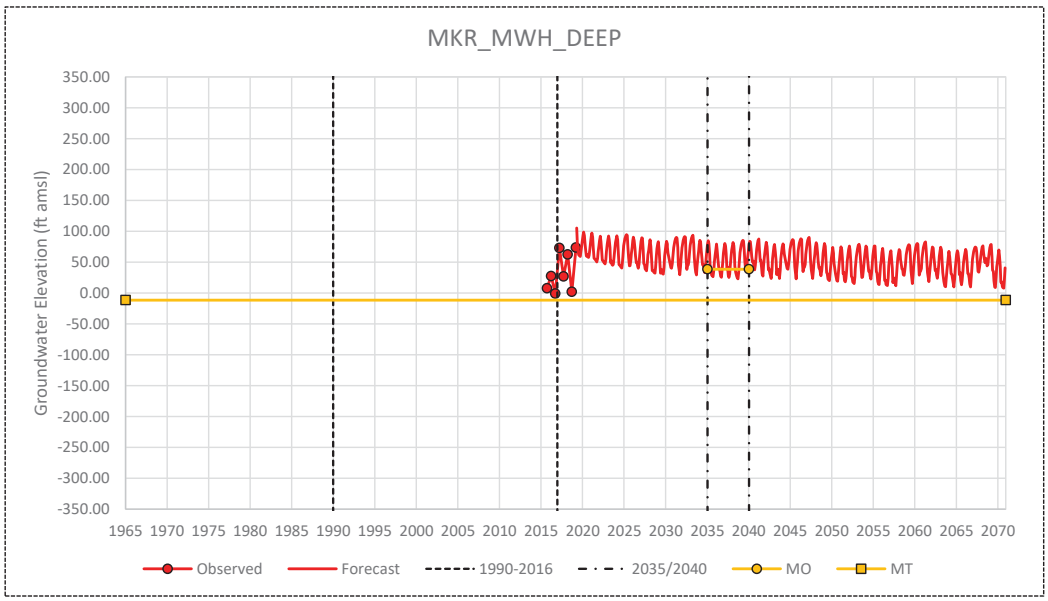

MKR_19S22E08D002M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

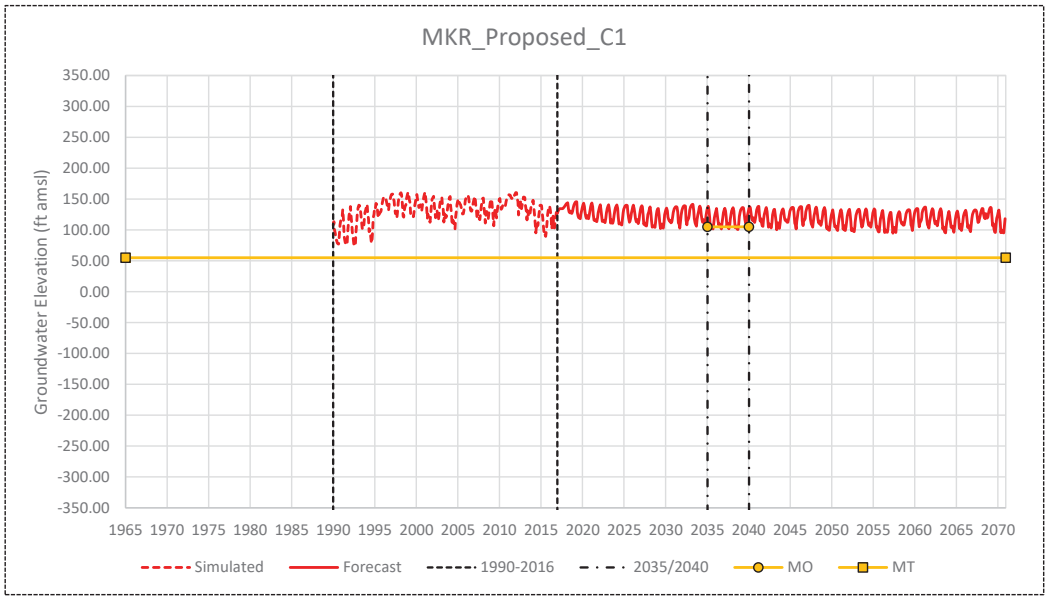

MKR_1610003-037
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

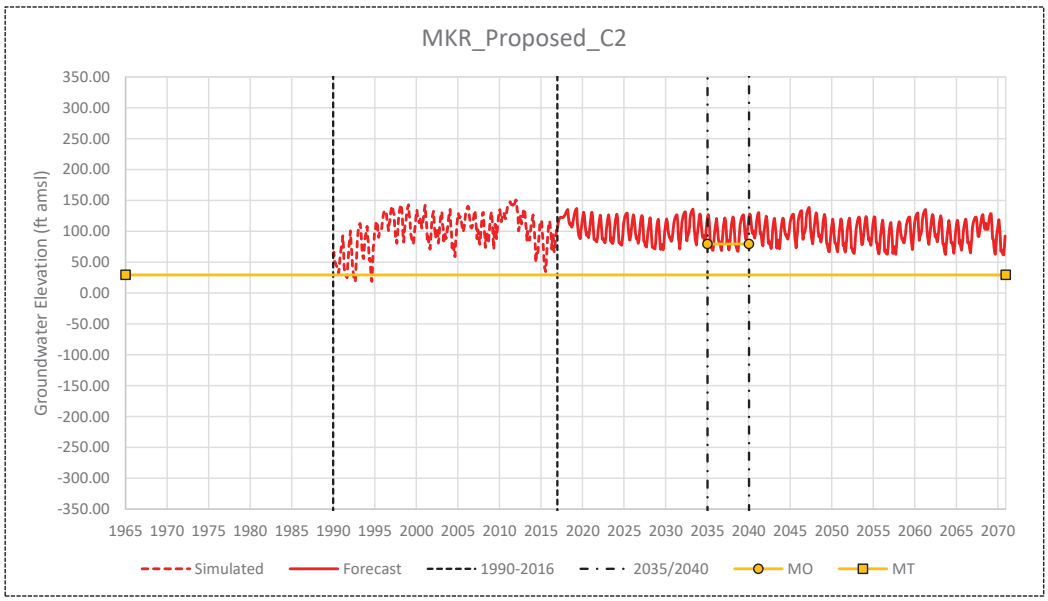

MKR_1610003-042
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

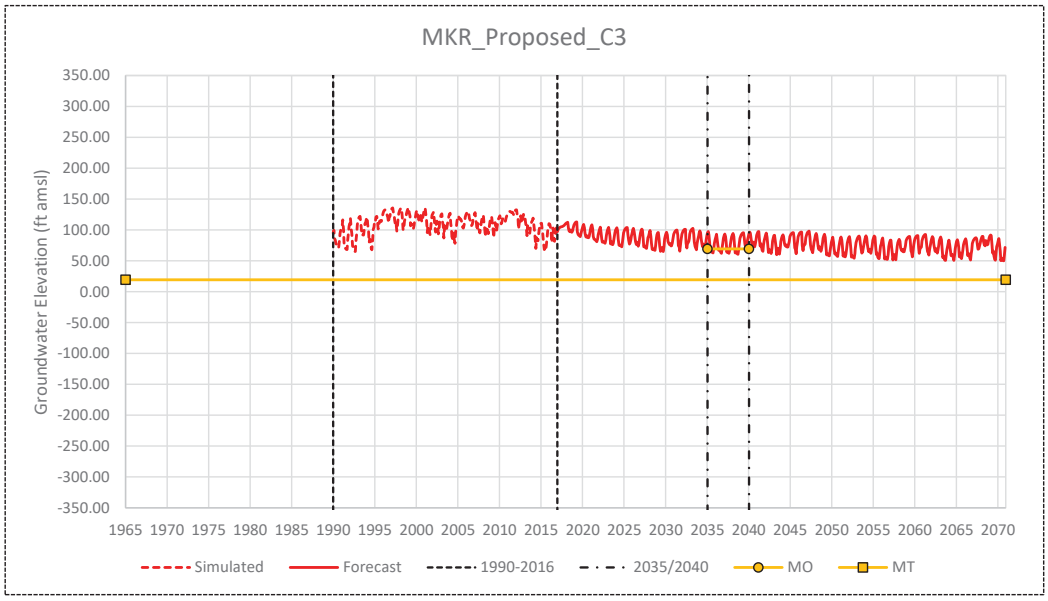

MKR_MWD_DEEP
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

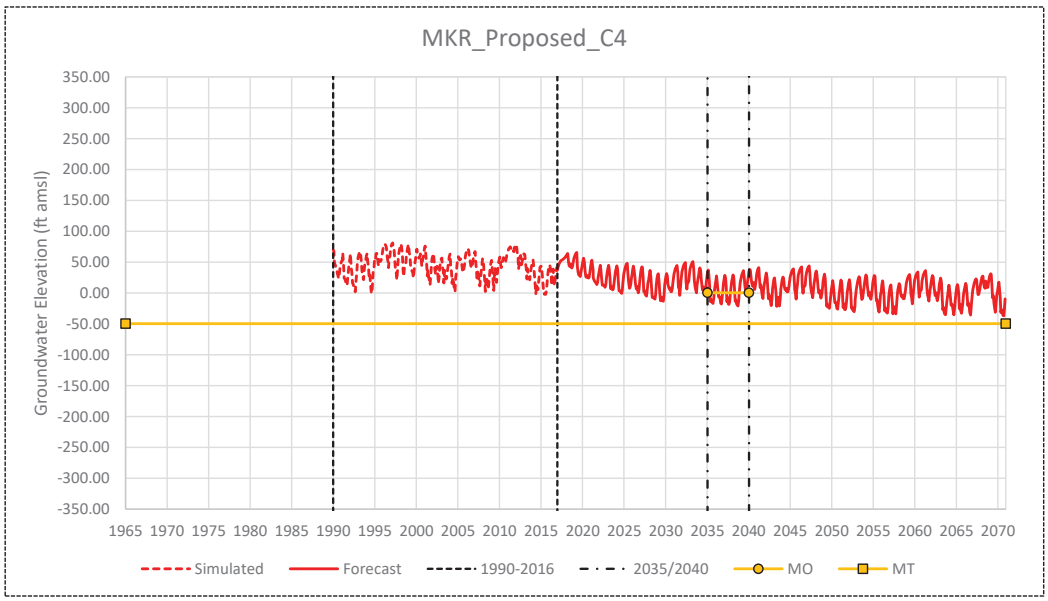

MKR_MWG_DEEP
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

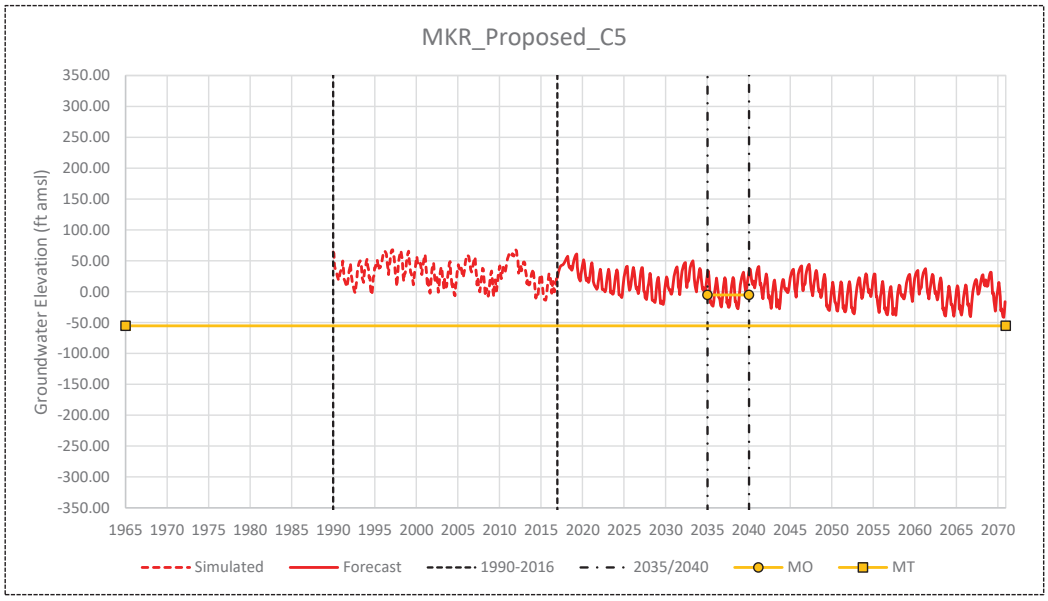

MKR_MWH_DEEP
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

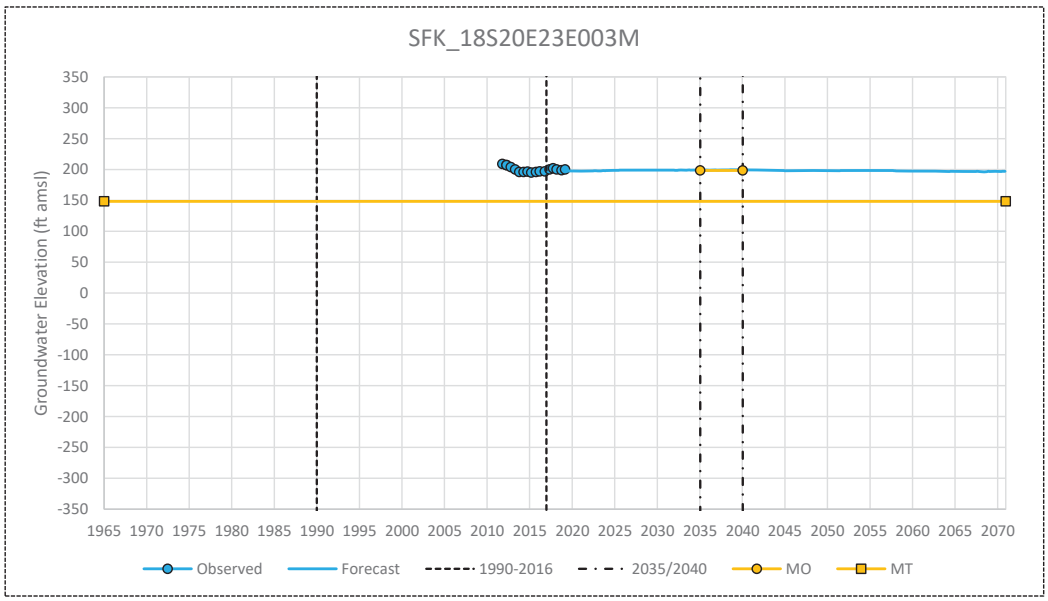

MKR_Proposed_C1
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

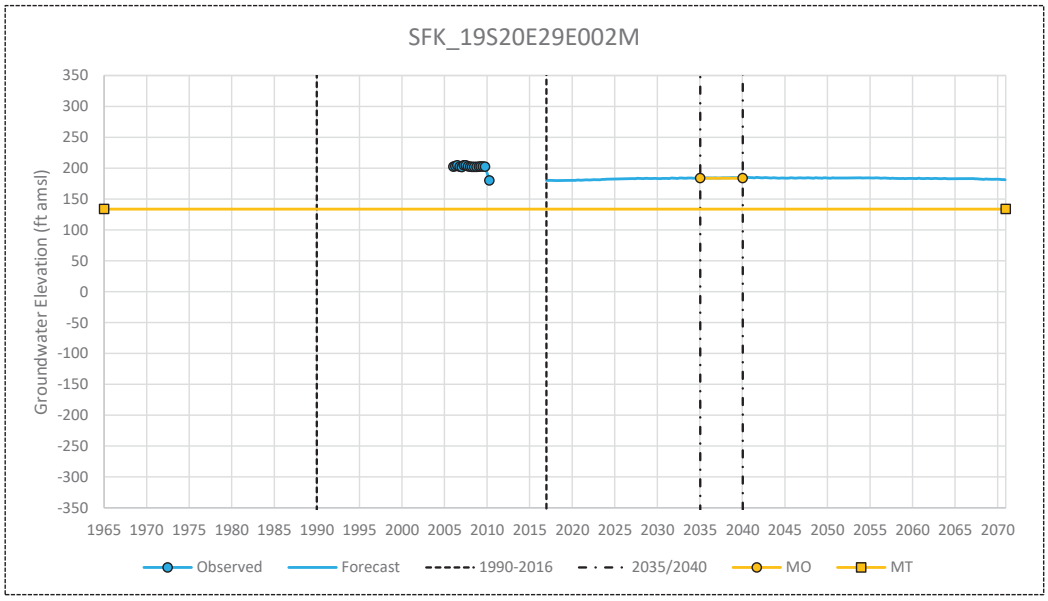

MKR_Proposed_C2
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

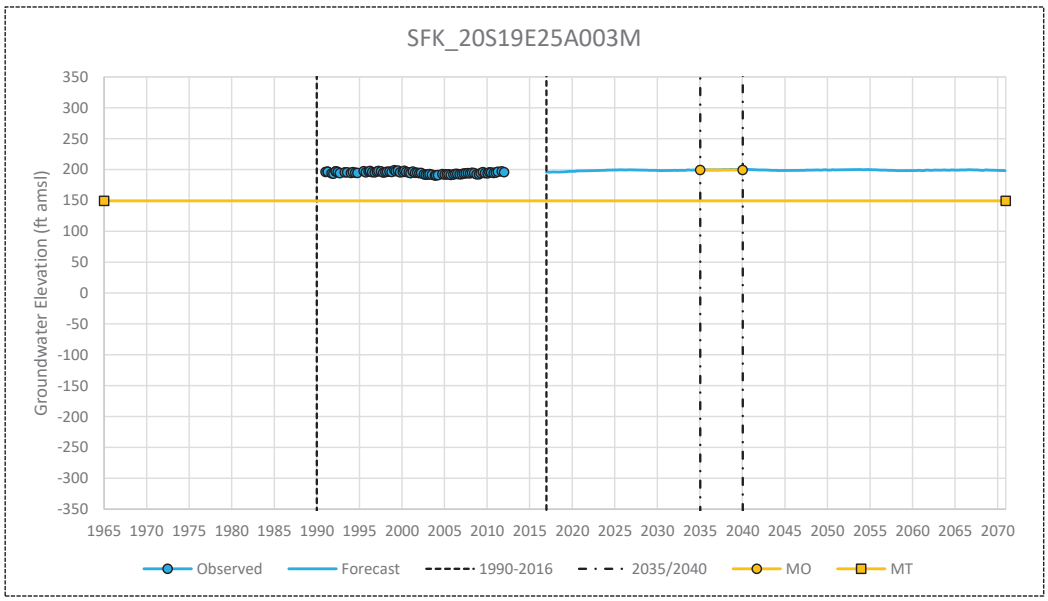

MKR_Proposed_C3
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

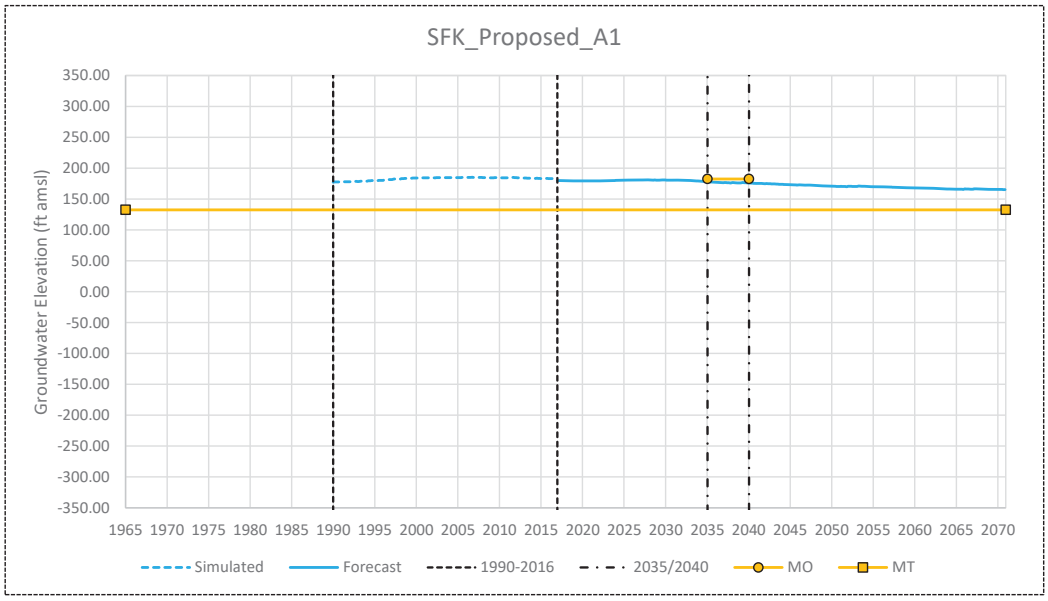

MKR_Proposed_C4
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

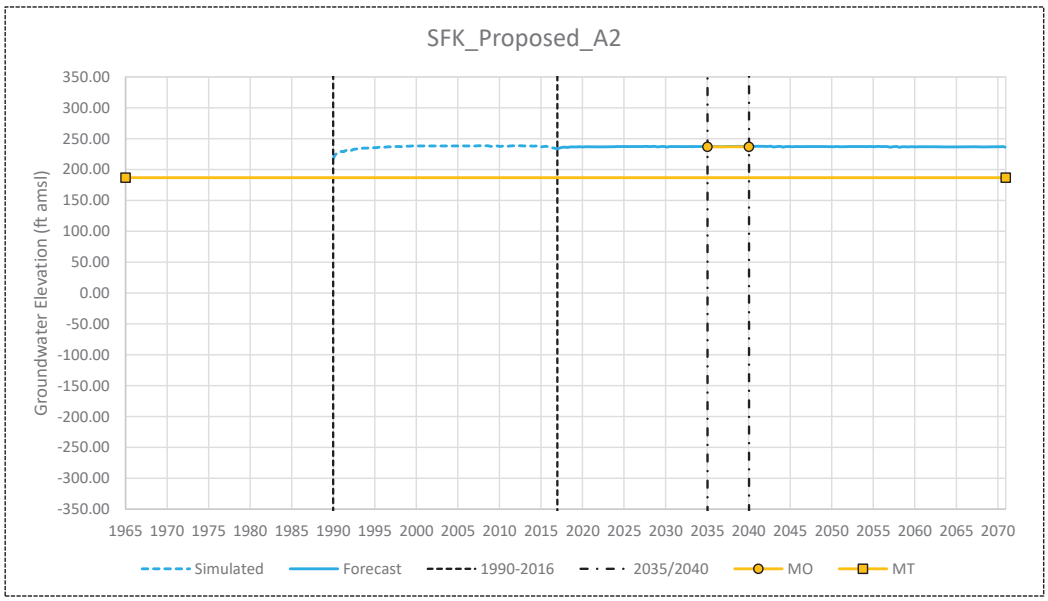

MKR_Proposed_C5
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

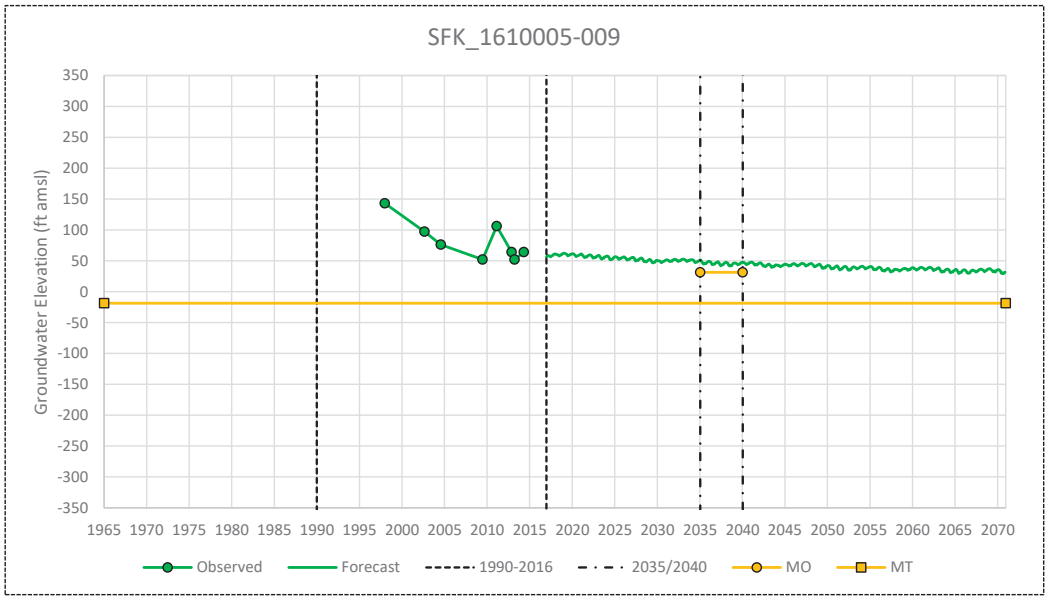

SFK_18S20E23E003M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

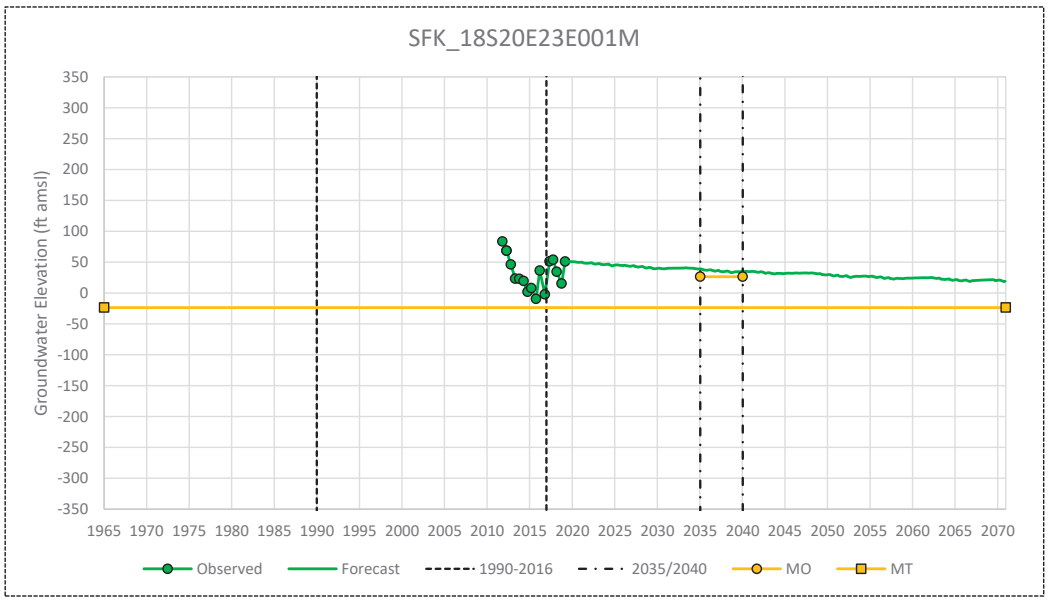

SFK_19S20E29E002M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

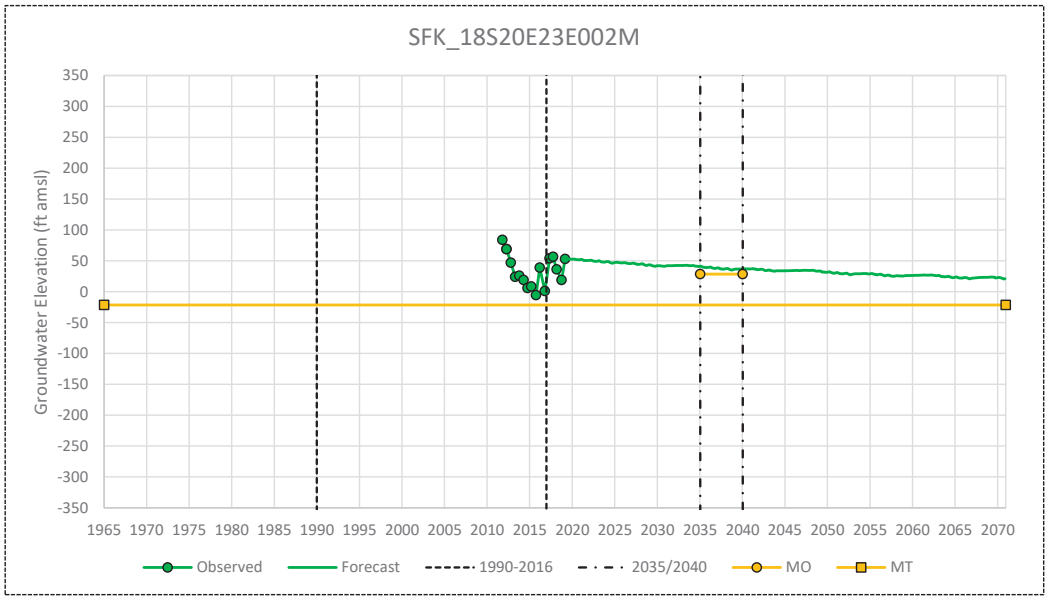

SFK_20S19E25A003M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

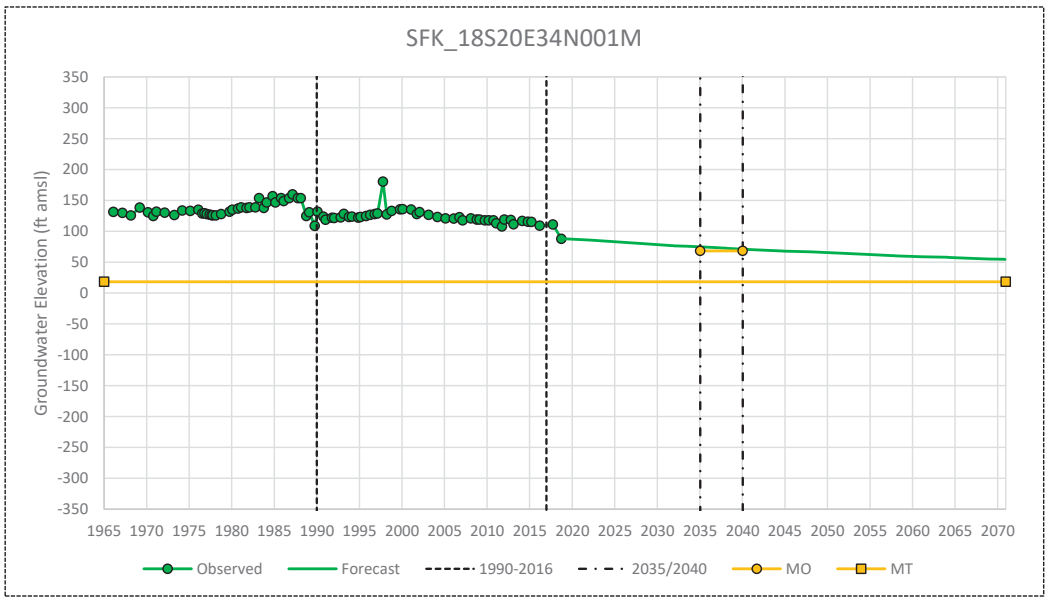

SFK_Proposed_A1
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

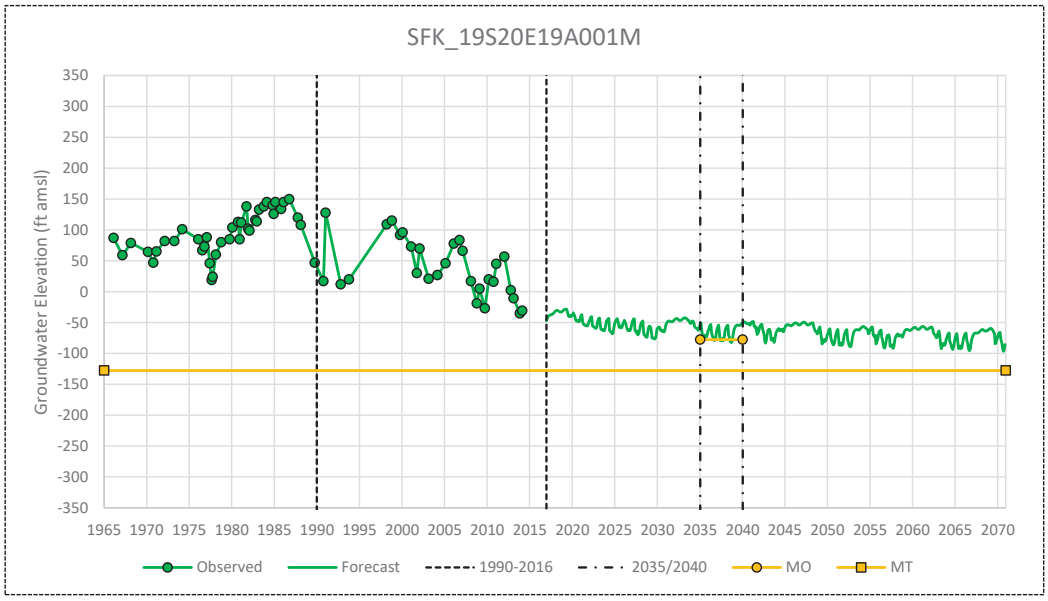

SFK_Proposed_A2
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

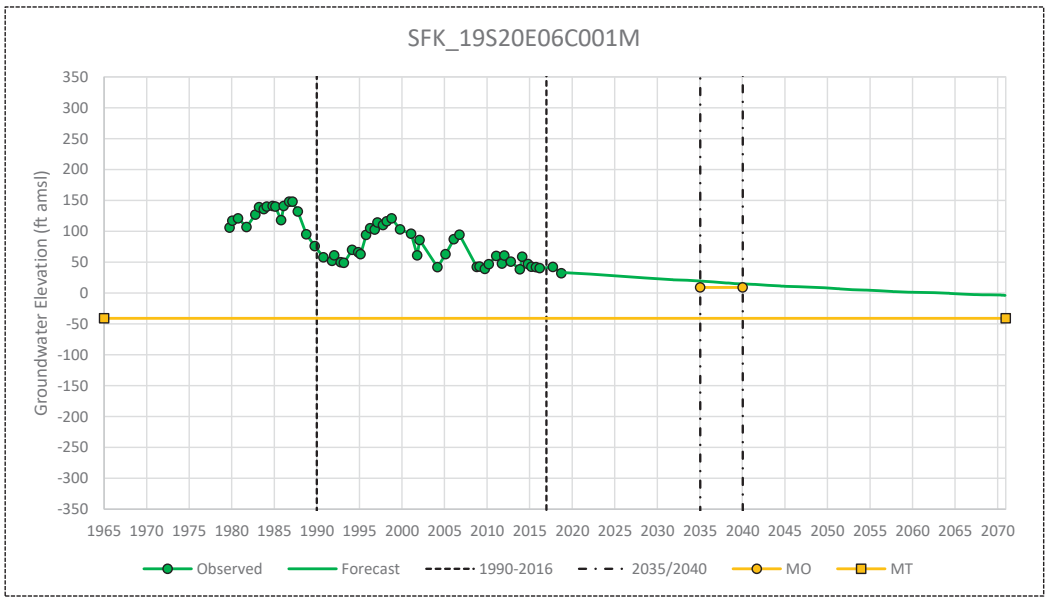

SFK_1610005-009
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

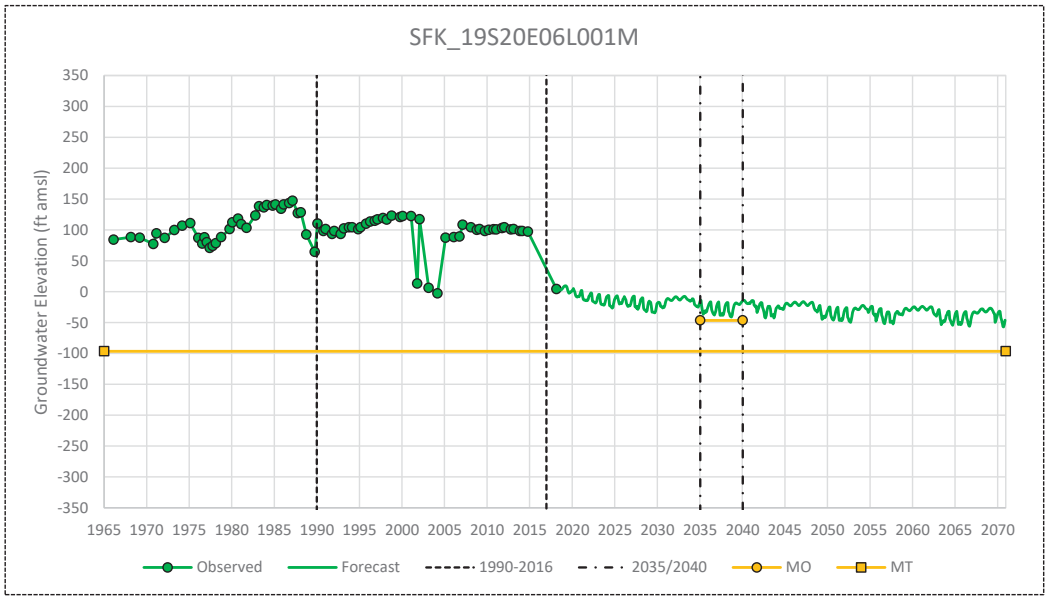

SFK_18S20E23E001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

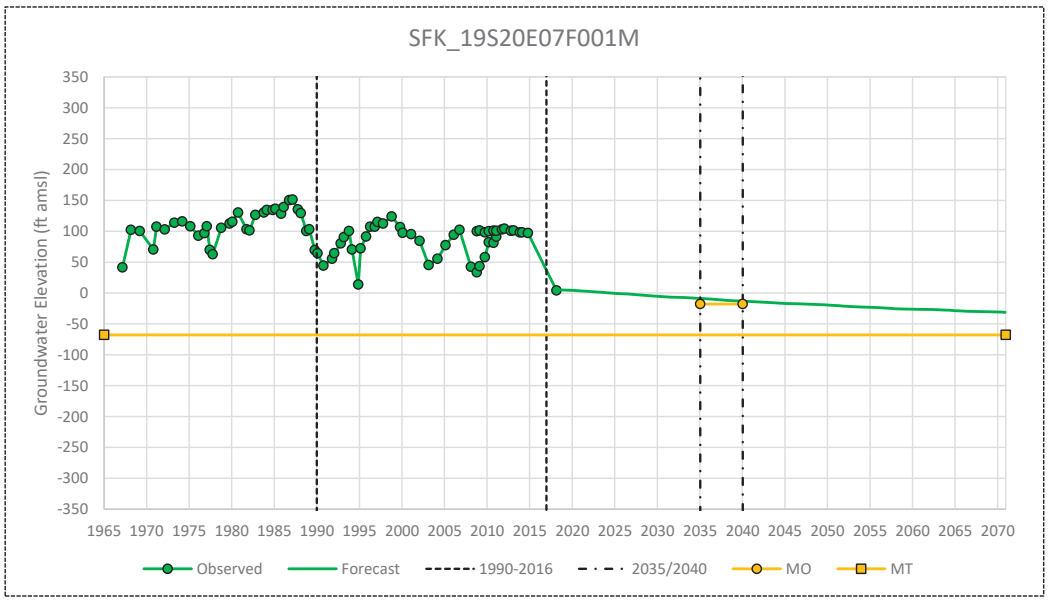

SFK_18S20E23E002M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

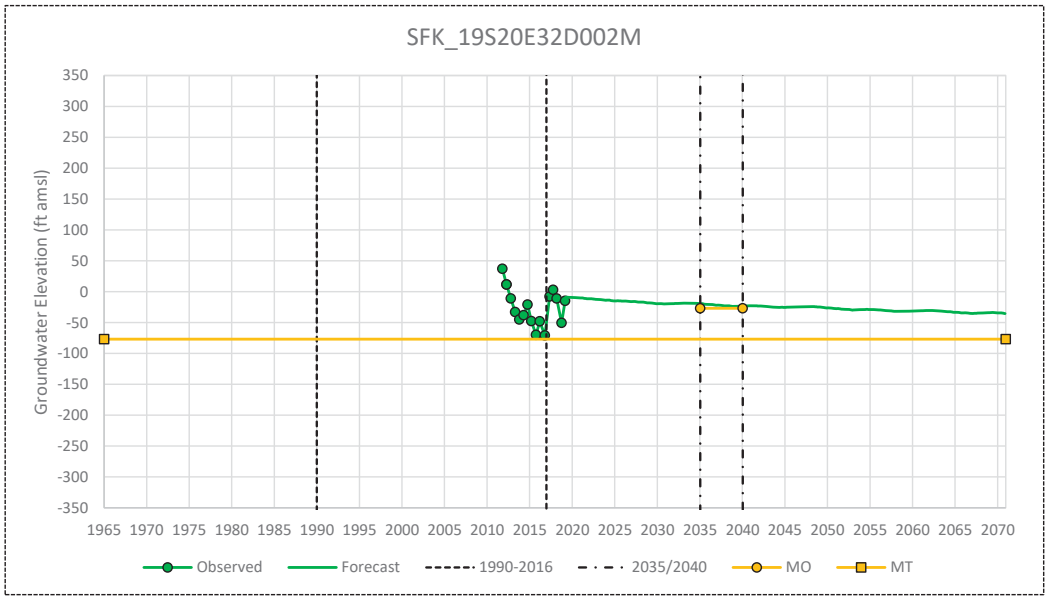

SFK_18S20E34N001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

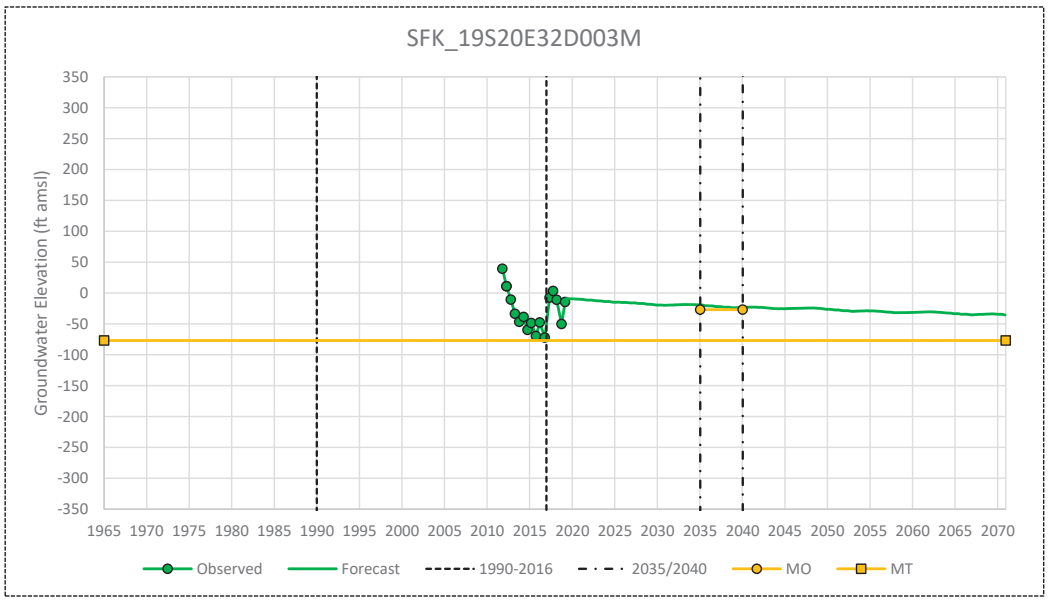

SFK_19S20E19A001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

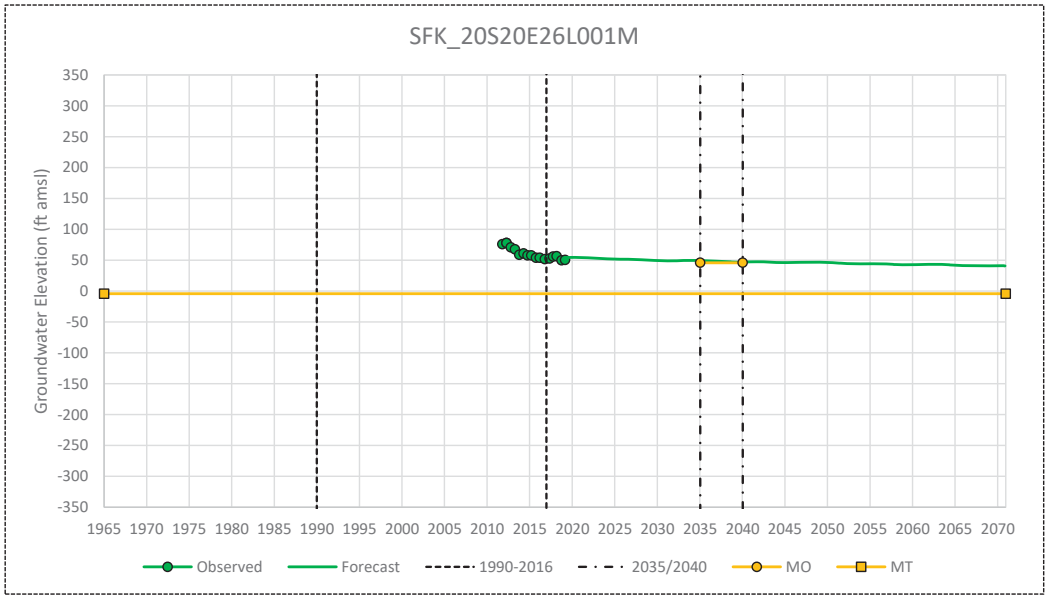

SFK_19S20E06C001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

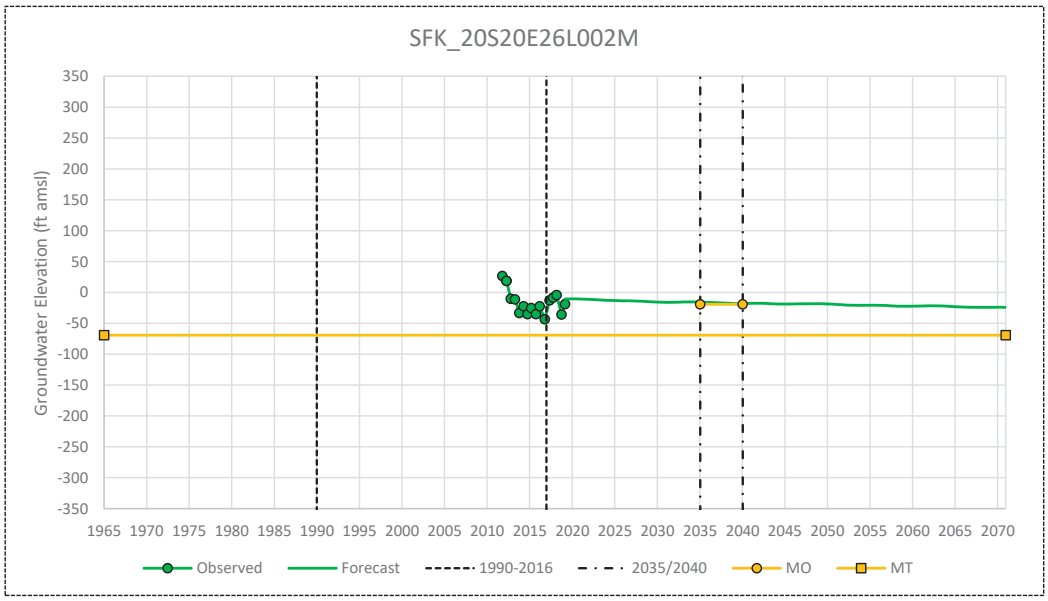

SFK_19S20E06L001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

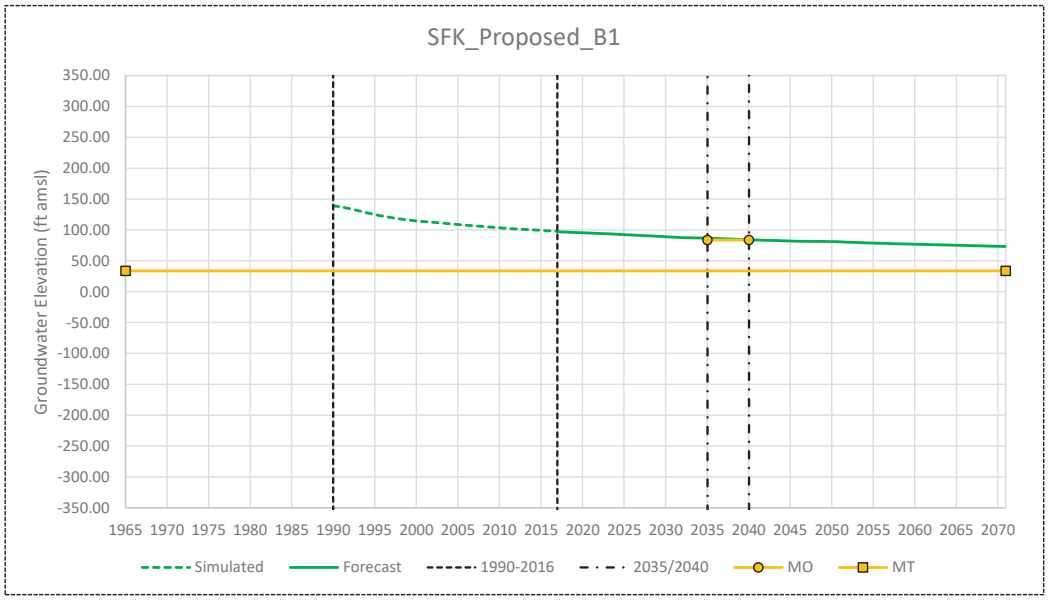

SFK_19S20E07F001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

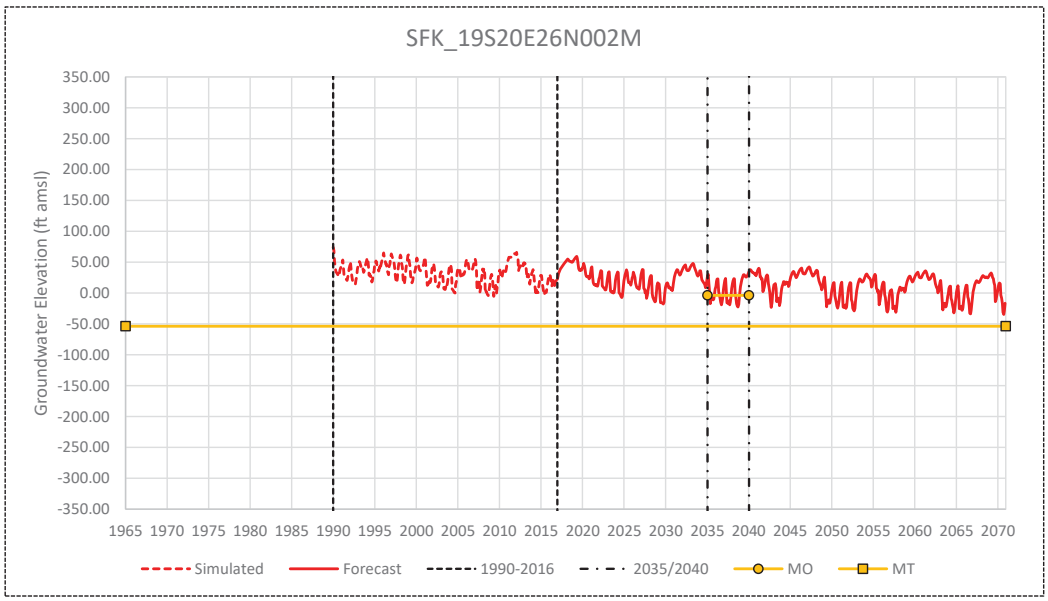

SFK_19S20E32D002M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

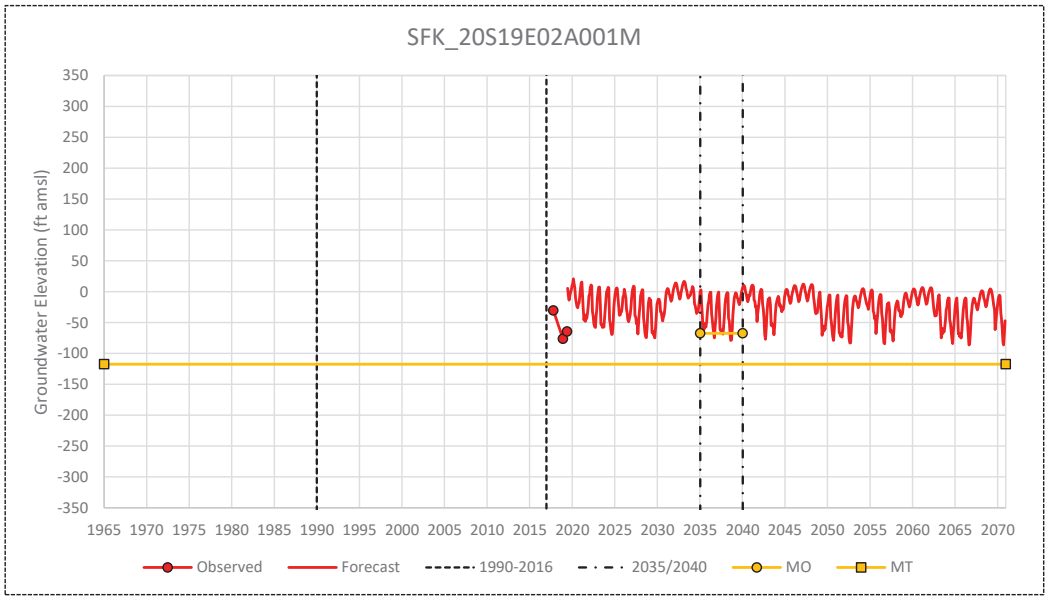

SFK_19S20E32D003M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

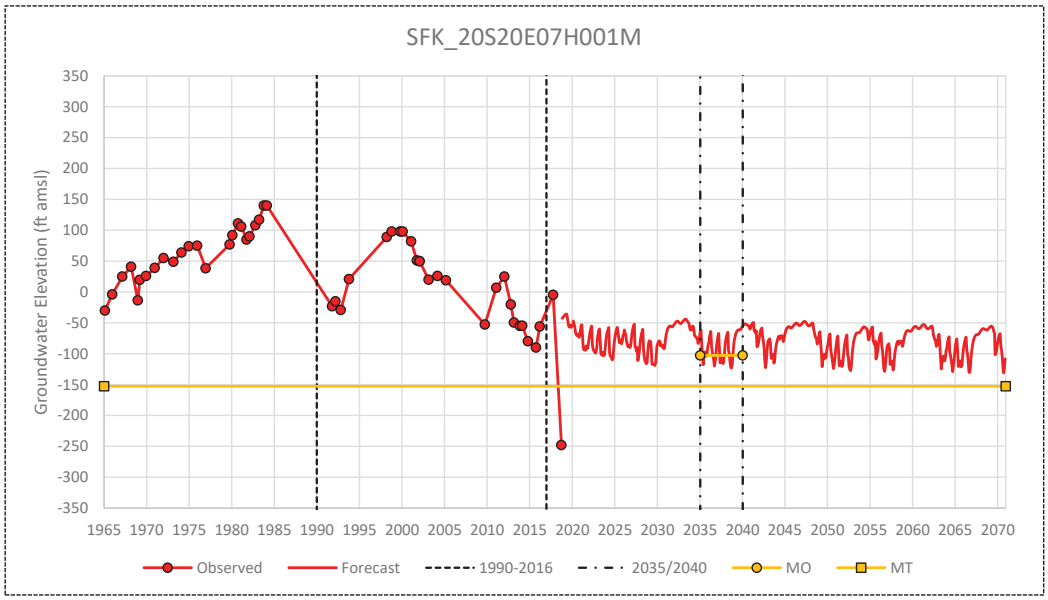

SFK_20S20E26L001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

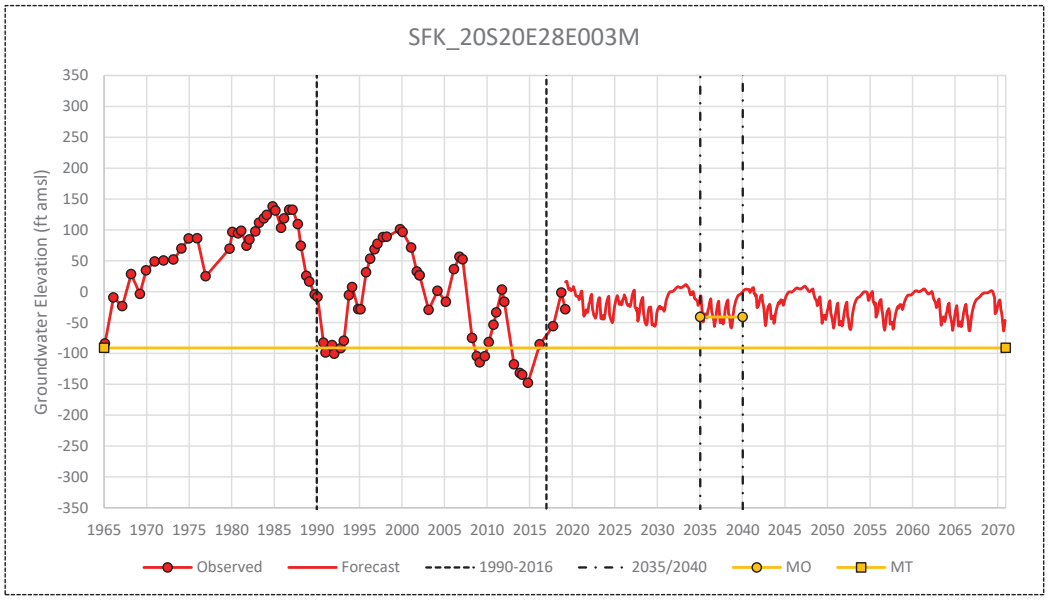

SFK_20S20E26L002M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

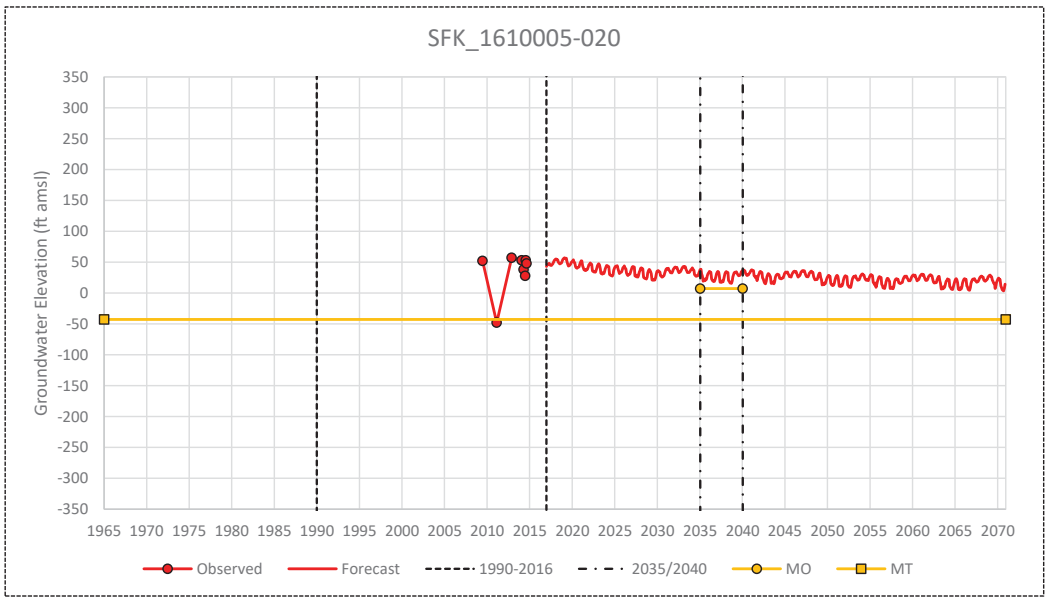

SFK_Proposed_B1
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

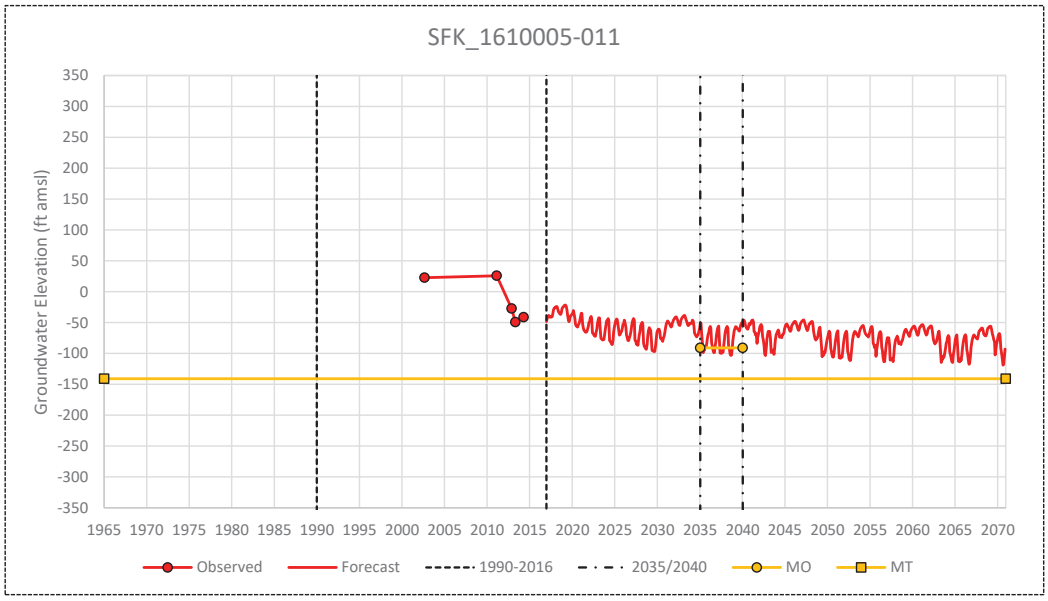

SFK_19S20E26N002M
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

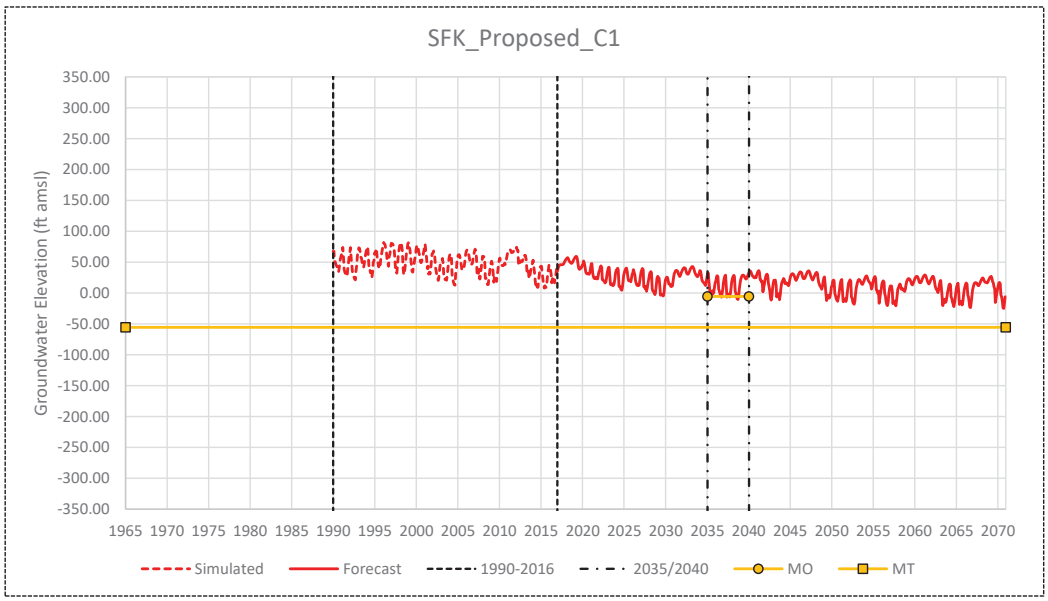

SFK_20S19E02A001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

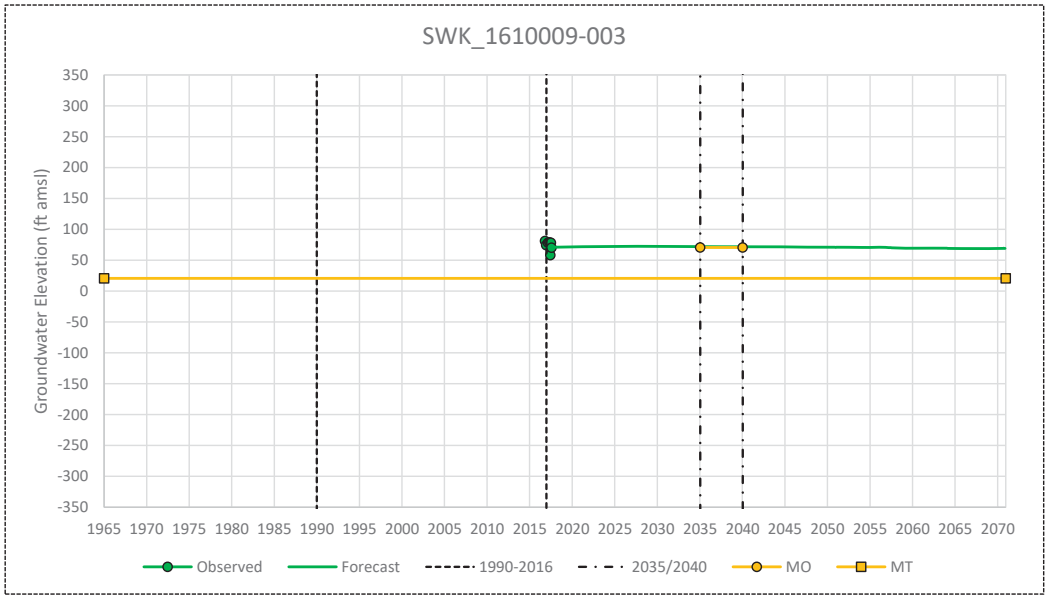

SFK_20S20E07H001M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

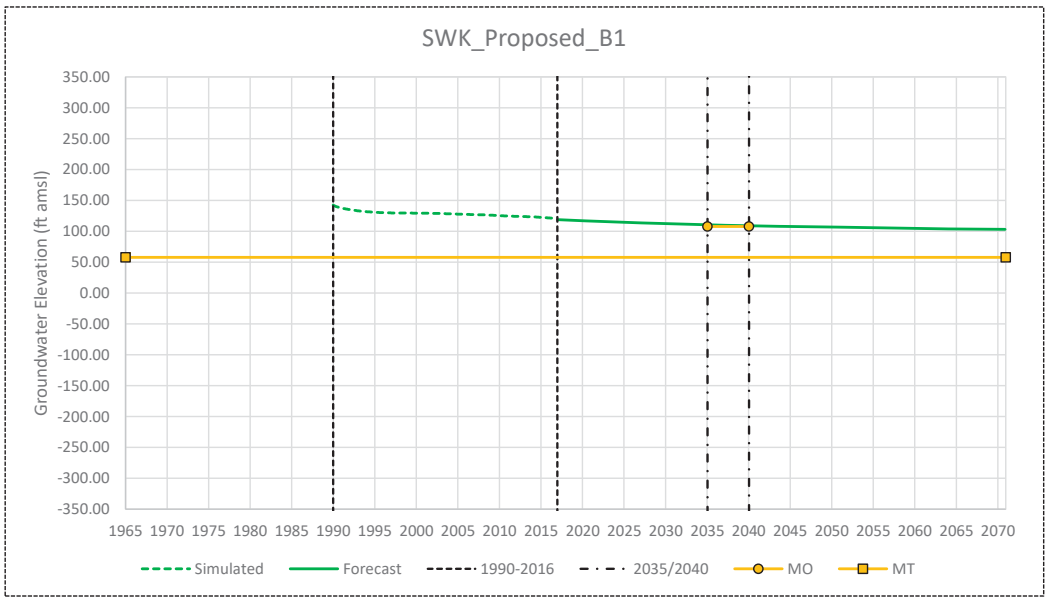

SFK_20S20E28E003M
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

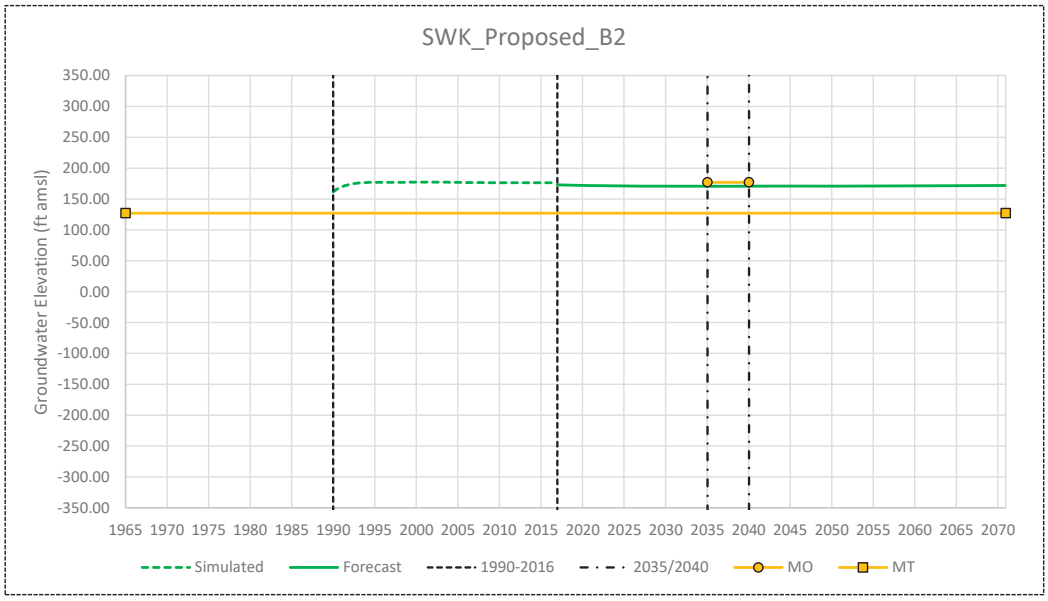

SFK_1610005-020
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

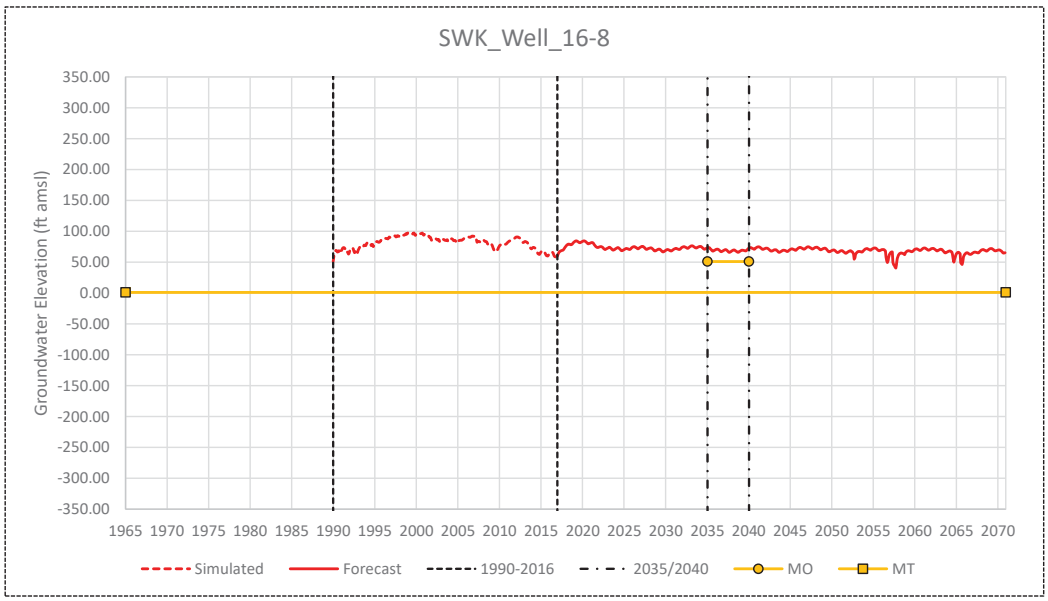

SFK_1610005-011
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

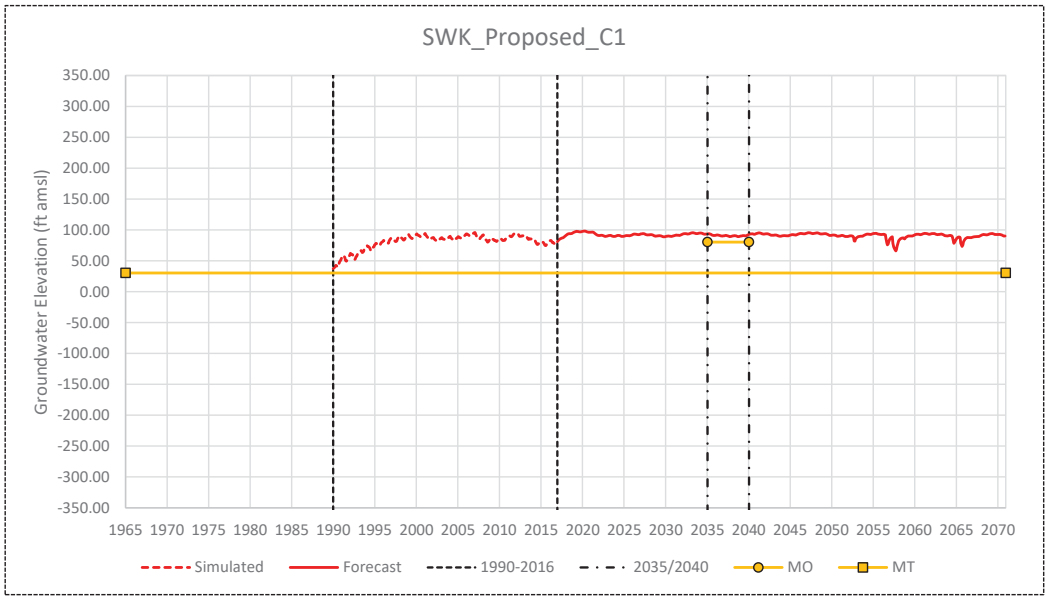

SFK_Proposed_C1
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Simulated
Forecast
1990-2016
2035/2040
MO
MT

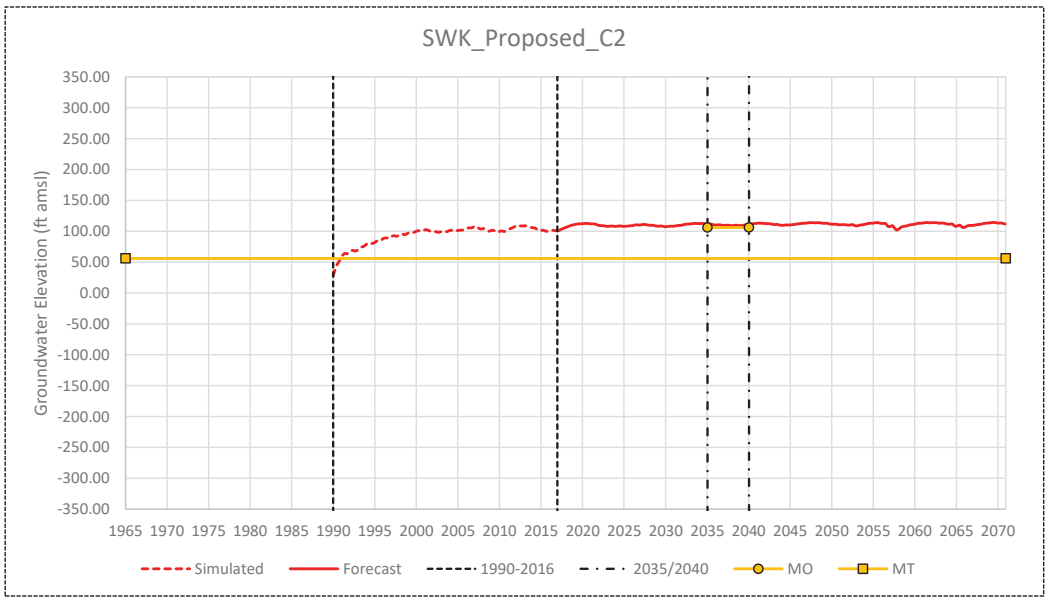

SWK_1610009-003
Groundwater Elevation (ft amsl)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Observed
Forecast
1990-2016
2035/2040
MO
MT

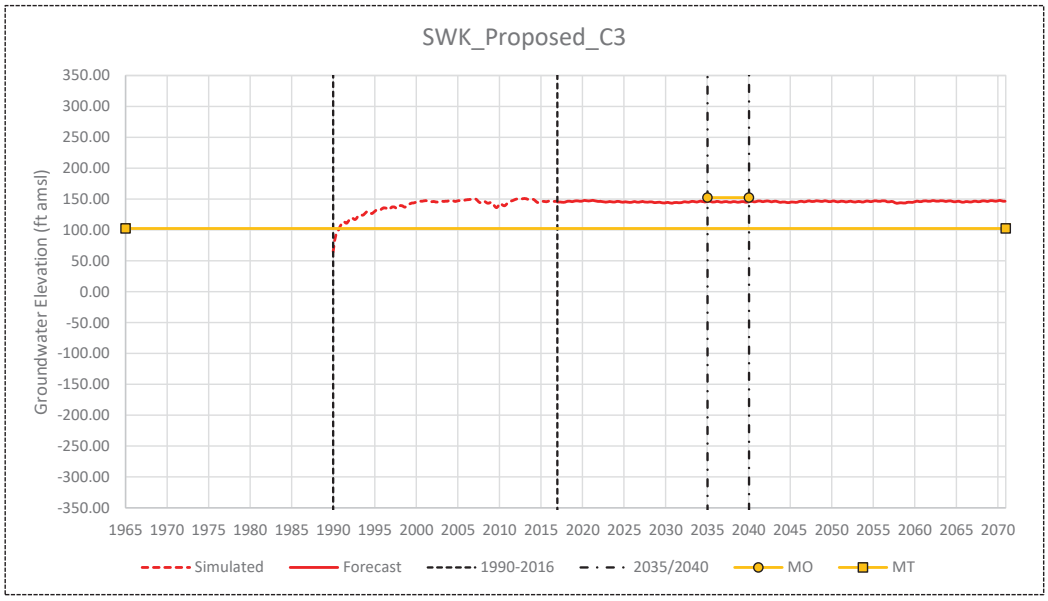

SWK_Proposed_B1
Groundwater Elevation (ft amsl)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
-350.00
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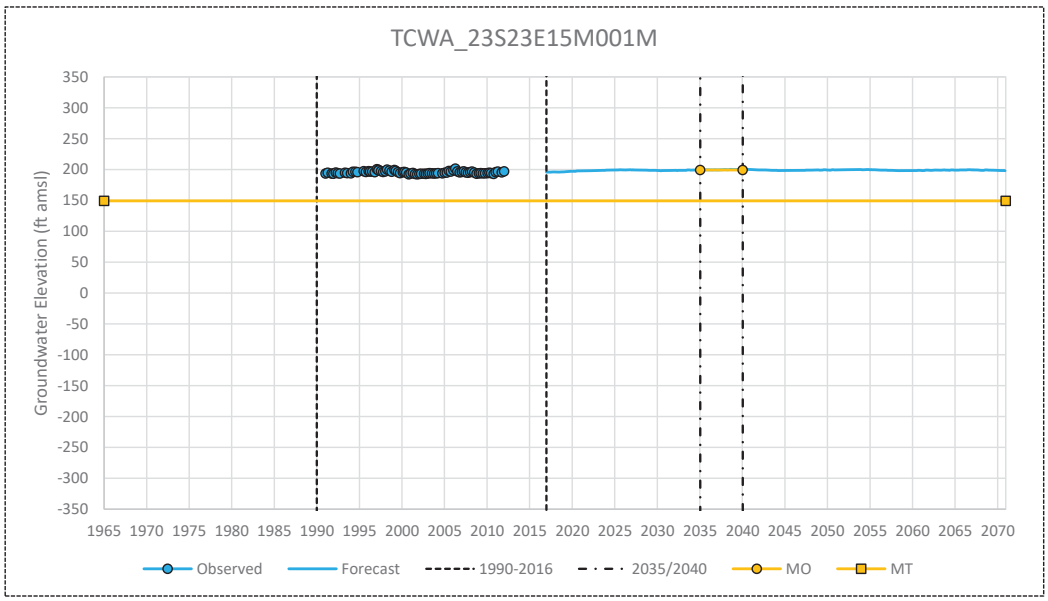

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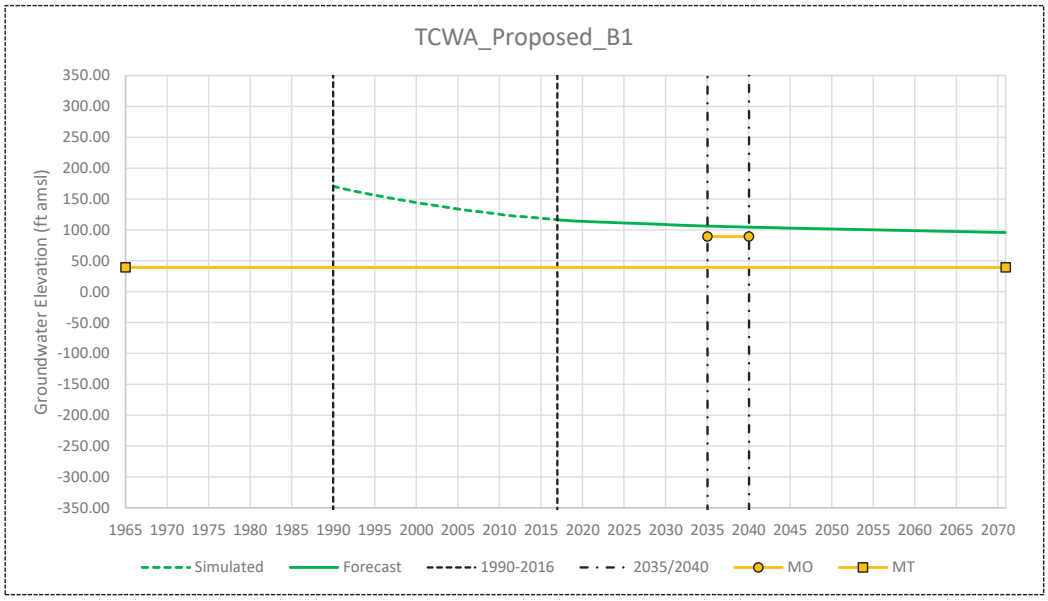

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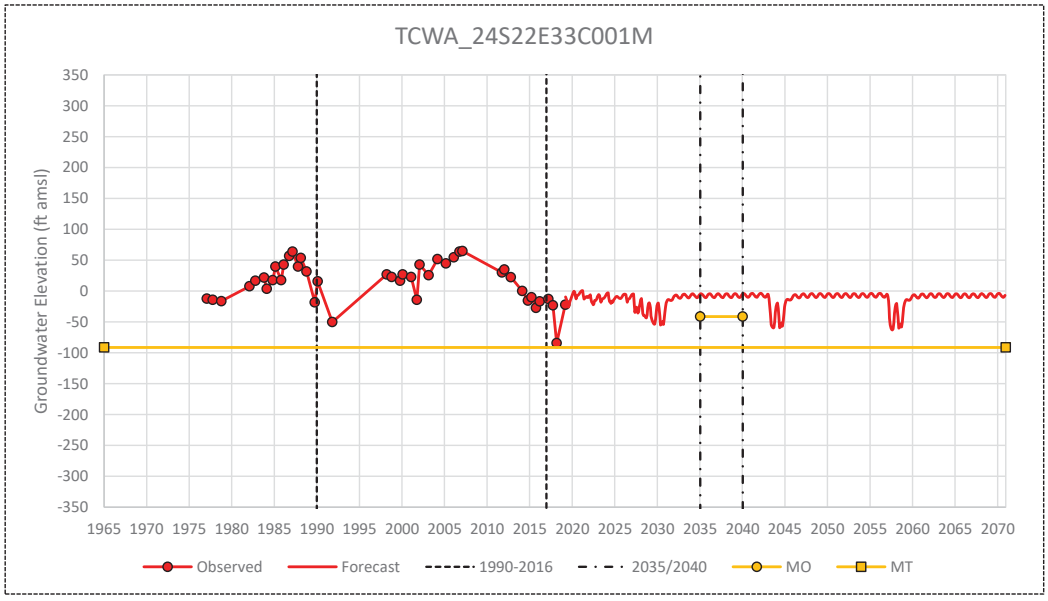

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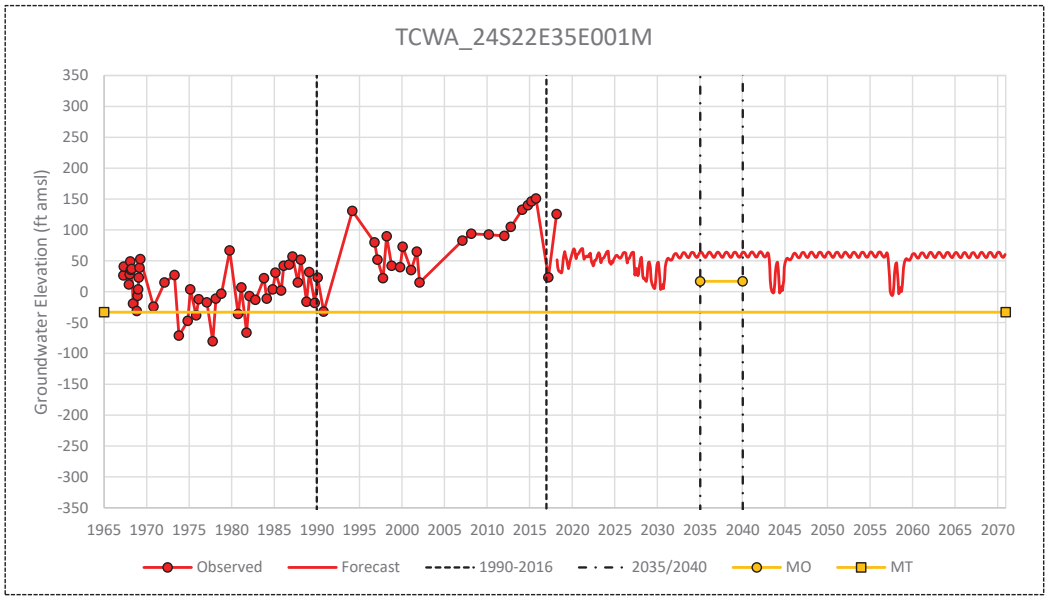

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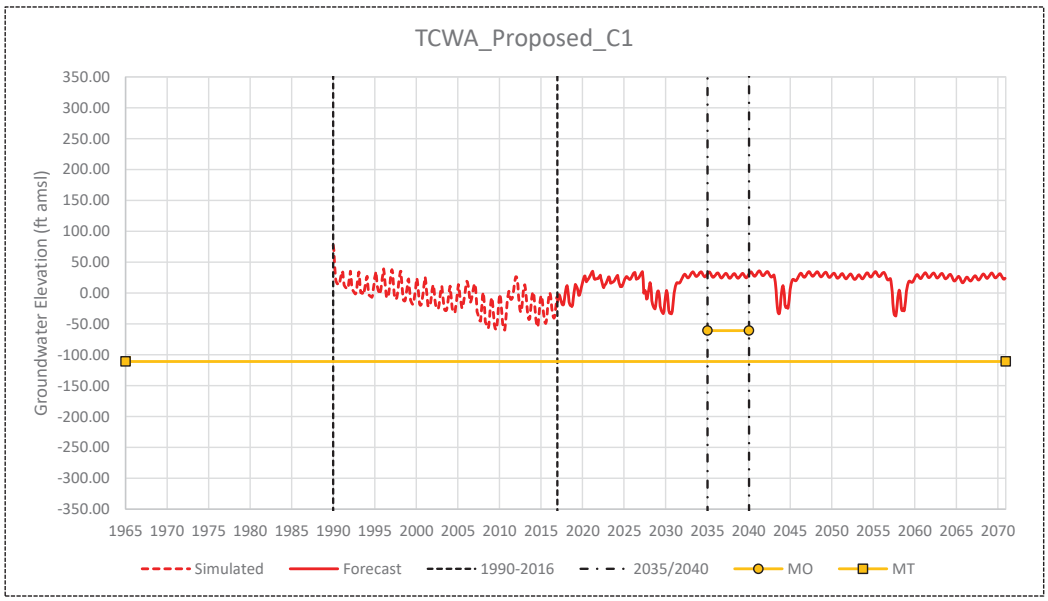

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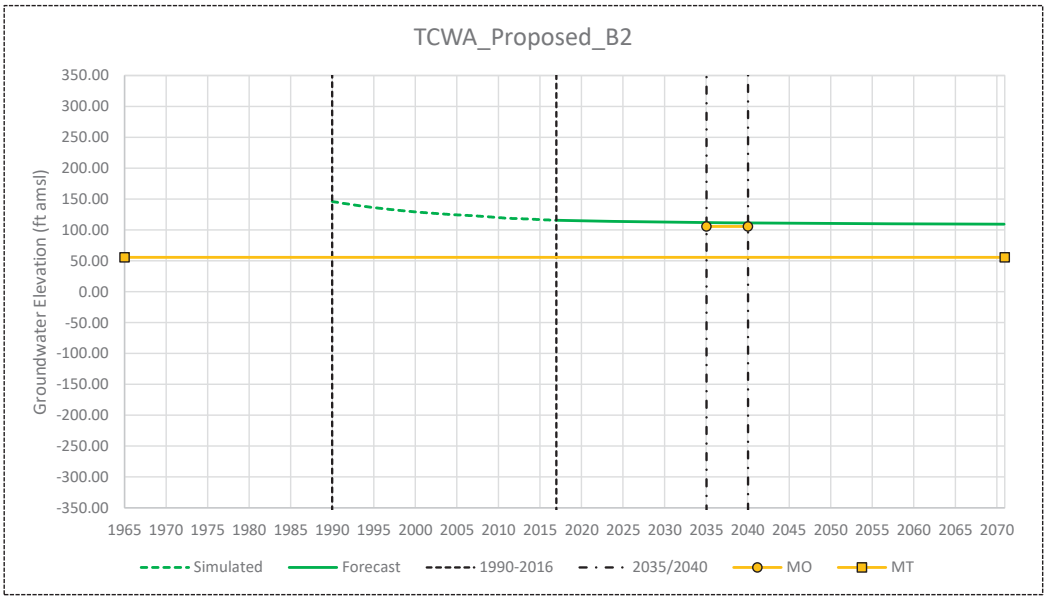

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TCWA_Proposed_B1
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TCWA_Proposed_B2
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Chapter Groundwater Sustainability Plan

Prepared for:



Prepared by:



December 2019

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Appendices

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Abbreviations and Acronyms

Term	Definition
2015 UWMP	West Kern Water District *2015 Urban Water Management Plan*
AF	acre-feet
AFY	acre-feet per year
AMR	automated meter reading
bgs	below ground surface
BMP	best management practice
BVWSD	Buena Vista Water Storage District
CAA	California Aqueduct
CASGEM	California Statewide Groundwater Elevation Monitoring
CDPH	California Department of Public Health
CDPR	California Department of Pesticide Regulation
CEQA	California Environmental Quality Act
COCs	constituents of concern
CVP	Central Valley Project

Abbreviations and Acronyms

CWC	California Water Code
Delta	Sacramento-San Joaquin River Delta
DOGGR	Division of Oil, Gas, and Geothermal Resources
DWR	California Department of Water Resources
EIR	*Environmental Impact Report*
EIR/EIS	Delta Conveyance Facility's *Environmental Impact Report/Environmental Impact Statement*
EOR	enhanced oil recovery
EPA	United States Environmental Protection Agency
FCTHSD	Ford City-Taft Heights Sanitation District
GAMA	groundwater ambient monitoring and assessment
GMP	*Groundwater Management Plan*
gpcd	gallons per capita per day
gpd/ft	gallons per day per foot
GSA	Groundwater Sustainability Agency
GSA area	West Kern Water District Groundwater Sustainability area
GSP	*Groundwater Sustainability Plan*
GWE	groundwater elevation
HCM	hydrogeologic conceptual model
IM	interim milestone
InSAR	interferometric synthetic aperture radar
IRWMP	*Integrated Regional Water Management Plan*
KCWA	Kern County Water Agency
KFMC	Kern Fan Monitoring Committee
KGA	Kern Groundwater Authority
KWBA	Kern Water Bank Authority
MCL	maximum contaminant level
mg/L	milligrams per liter
MO	measurable objective
MOU	memorandum of understanding

Abbreviations and Acronyms

MT	minimum threshold
NEPA	National Environmental Policy Act
NRCS	National Resource Conservation Service
NWIS	National Water Information System
O&M	operations and maintenance
SAGBI	Soil Agricultural Groundwater Banking Index
SGMA	Sustainable Groundwater Management Act
Subbasin	Kern County Subbasin
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
USDW	underground source of drinking water
USGS	United States Geological Survey
UWMP	*Urban Water Management Plan*
WDL	Water Data Library
WKWD	West Kern Water District
WSD	Water Storage District
WSRP	*Water Shortage Response Plan*
WWTF	wastewater treatment facility

ES-1 Executive Summary

ES-1.1 Compliance Information

The West Kern Water District (WKWD) Groundwater Sustainability Agency (GSA) has prepared this *Chapter Groundwater Sustainability Plan* (Chapter GSP) in compliance with the Sustainable Groundwater Management Act (SGMA) as specified in Part 2.74, Division 6 of the California Water Code, beginning with Section 10720. Table ES-1 summarizes the California Department of Water Resources' (DWR's) *Preparation Checklist for GSP Submittal* items that are covered in this Executive Summary. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

Table ES-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 1. Administrative Information			
Section 354.4	General Information	Executive Summary	Executive Summary

This Chapter GSP meets the requirements of DWR's emergency GSP regulations. The structure of this Chapter GSP also generally follows the order that the regulations provide, with some minor exceptions, to facilitate efficient review by DWR. Each section is written so that it can be reviewed without extensive cross-reference to other Chapter GSP sections.

ES-1.2 Introduction

In 2014, the California legislature enacted SGMA in response to continued overdraft of California's groundwater resources. The Kern County Groundwater Subbasin (Subbasin) is one of 21 basins and subbasins identified by DWR as being in a state of critical overdraft. SGMA requires preparation of a GSP to address measures necessary to attain sustainable conditions in the Subbasin. Within the framework of SGMA, sustainability is generally defined as the conditions that result in long-term reliability of groundwater supply, and the absence of undesirable results.

In 2016, in response to SGMA, the WKWD GSA was formed. The WKWD GSA was created on June 28, 2016 when WKWD's Board of Directors adopted Resolution 16.03, electing to become a GSA in the Subbasin and included the WKWD service area. During GSP development, the GSA boundary has expanded to include undistricted areas in and around the WKWD service boundary that were not previously part of another GSA. KCWA is one of several members of the Kern Groundwater Authority (KGA), a joint powers agency created to enhance coordination among agencies in the Subbasin.

The majority of KGA member agencies are in the KGA GSA's jurisdiction; four member agencies have formed their own GSAs, and are participating fully with the KGA's coordination, including the WKWD GSA, the Pioneer GSA, the Cawelo GSA and the Semitropic GSA.

Each KGA member agency has prepared a Chapter GSP that provides information, data, and descriptions of groundwater conditions on a localized scale. Each Chapter GSP supports the Umbrella GSP that is being developed by the KGA GSA. Chapter GSPs will supplement the Umbrella GSP where detailed local information is needed. In turn, the Umbrella GSP will supplement Chapter GSPs when a broader,

Subbasin-wide approach is more appropriate. The Umbrella GSP is also being coordinated with other GSPs under development by other GSAs that are not member agencies of the KGA GSA.

This Chapter GSP is now available for public review and comment. SGMA requires the WKWD GSA to develop a GSP that achieves groundwater sustainability in the Subbasin by 2040. Although SGMA references 2015 as a basis for groundwater planning, SGMA does not require a GSP to address undesirable results that occurred before 2015. This Chapter GSP outlines the current and historical sustainable management of groundwater in the WKWD GSA area through a balanced water budget and operation. Additionally, this Chapter GSP highlights the need for continued coordination within the KGA and neighboring regions, and for continued groundwater monitoring.

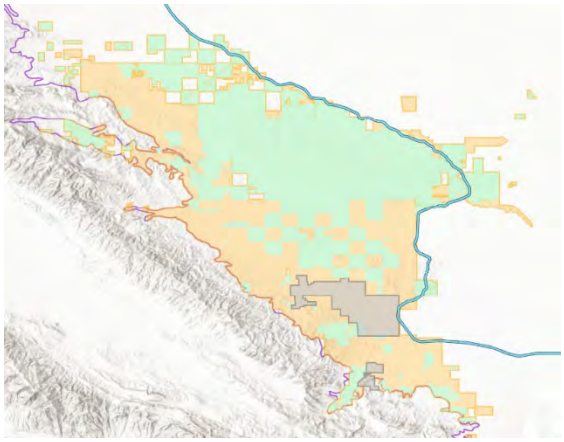


Figure ES-1. WKWD GSA Boundary

ES-1.3 Plan Area

The WKWD GSA jurisdictional area is defined by the WKWD service boundary with some addition proximal parcels owned and operated by oil production companies and other private landowners. The WKWD GSA boundary lies within the Kern County Subbasin, as shown in Figure ES-1.

ES-1.4 Subbasin Setting

The Subbasin is located toward the southern end of the San Joaquin Valley in Central California. The WKWD GSA is located along the western edge of the Subbasin, encompassing the cities of Taft and Maricopa. The GSA boundary is comprised of 299 square miles as shown in Figure ES-2. The WKWD GSA is bordered by the KGA GSA and Buena Vista Water Storage District GSA to the north, and the Henry Miller Water District GSA and the KGA GSA to the east.

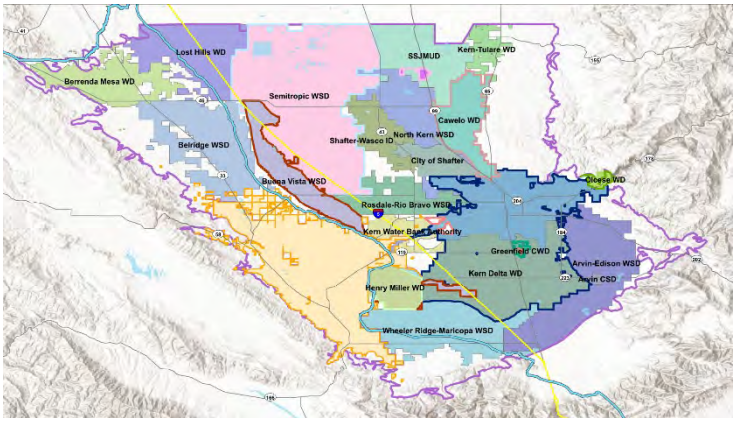


Figure ES-2. WKWD GSA Boundary

WKWD GSA formed four management areas, namely the North Project, South Project, Lake and Western management areas. Groundwater pumping in any large scale is undetectable via remote sensing, and the only pumping known in the area considered de minimis domestic use; in general, yields of water in this area are unsuitable for domestic or industrial use. As a result, no management or monitoring actions have been established in the Western Management Area. Management actions in this Chapter GSP focus on the North Project, South Project

and Lake management areas in the GSA, where groundwater pumping occurs above de minimis amounts and yields water that is acceptable for domestic and industrial use.

The hydrogeology in the WKWD GSA's area is well understood in the North, South, and Lake management areas. The North Management Area has two primary aquifers, above and below Corcoran or E clay. Corcoran or E clay is absent in both the South and Lake management areas. The unconfined aquifer extends to a depth of approximately 200 to 300 feet below the ground surface and consists of interbedded silts, sands, and some clay. Both the North and South wellfields are screened within the semi-confined to unconfined aquifer, with the South wellfield being exclusively within the unconfined to semi-confined aquifer. The confined aquifer system exists in the GSA's North Project Management Area and ranges from approximately 600 to 800 feet below the ground surface.

ES-1.5 Existing Groundwater Conditions

ES-1.5.1 Groundwater Levels

Groundwater levels in WKWD GSA's North and South Project management areas generally fluctuate with climactic cycles and reached a historical low in 2015 (ES-3). Groundwater levels in these management areas recovered significantly from 2015 to 2018. Change in storage has generally matched climactic trends as well, and subsidence has not occurred in the WKWD GSA area. Groundwater-dependent ecosystems are limited to the Western Management Area and are not present in the other management areas.

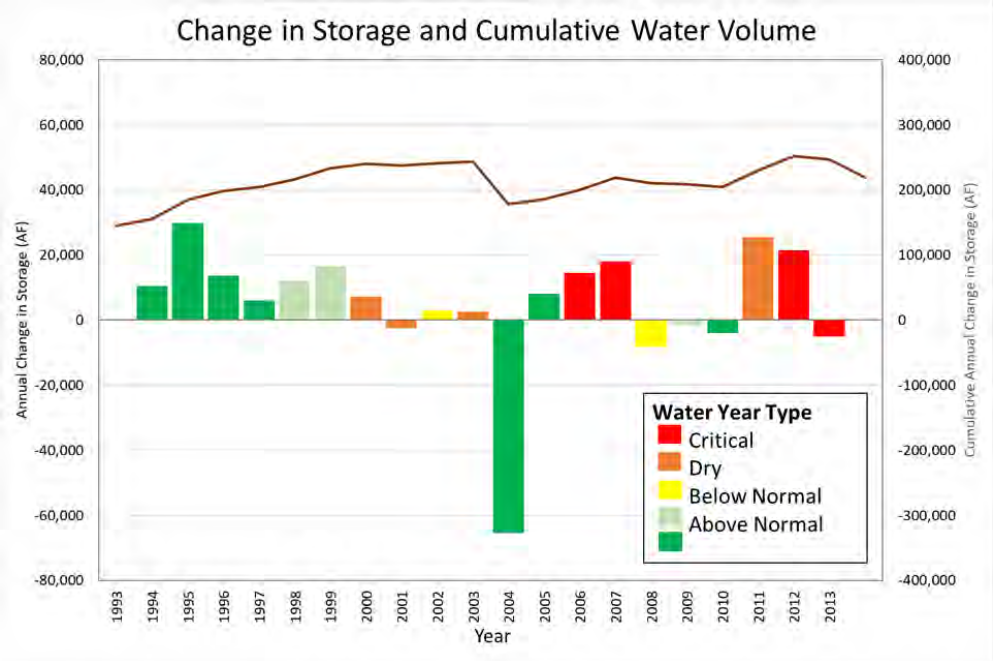


Figure ES-3. Change in storage by Year, Water Year Type, and Cumulative Water Volume

ES-1.5.2 Groundwater Quality

Overall, groundwater quality in the North and South Project management areas is excellent and meets all federal and state drinking water health standards. The only COCs detected during routine annual testing are arsenic and antimony. While both were detected at concentrations below their MCL for drinking water, WKWD took a proactive approach to manage any concerns; those actions are discussed below. Groundwater quality within the GSA area degrades toward the Western Management Area, where groundwater is generally unusable due to high salinity levels.

ES-1.6 Subsidence

Although groundwater pumping has caused land subsidence elsewhere in the southern San Joaquin Valley, data indicate that the Kern Fan aquifer behaves elastically in response to groundwater banking operations.

ES-1.7 Undesirable Results

Undesirable results are conditions that cause significant and unreasonable reduction in the long-term viability of domestic, agricultural, municipal, or environmental uses of the Subbasin's groundwater. SGMA identifies six defined areas for classification of undesirable results, as shown in the adjacent callout. The one undesirable result that does not impact the Subbasin is seawater intrusion.

Undesirable Results Categories

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon
- Significant and unreasonable reduction of groundwater storage
- Significant and unreasonable seawater intrusion (does not apply in the Subbasin)
- Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies
- Significant and unreasonable land subsidence that substantially interferes with surface land uses
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

Due to the WKWDs sustainable banking practices, overall groundwater levels and storage do not trigger undesirable results conditions. As shown in Figure ES-3 and additional recent data, cumulative water storage in the WKWD GSA Area has experienced a net increase over the last 20 years with approximately 10 years of drought reserve stored currently. Through this sustainable management, degradation of groundwater quality and land subsidence have not adversely impacted the WKWD GSA.

ES-1.8 Sustainability

SGMA introduces several terms to measure sustainability, including the following:

- **Sustainability Goals** – These goals are the culmination of conditions resulting in an absence of undesirable results within 20 years.
- **Undesirable Results** – Undesirable results are the significant and unreasonable occurrence of conditions that adversely affect groundwater use in the Subbasin.
- **Sustainability Indicators** – Sustainability indicators refer to any of the adverse effects caused by groundwater conditions occurring throughout the Subbasin that, when significant and unreasonable, cause undesirable results, including the following:
  - Lowering groundwater levels
  - Reduction of groundwater storage
  - Seawater intrusion (does not apply in the Subbasin)
  - Degraded water quality
  - Land subsidence
  - Depletion of interconnected surface water
- **Minimum Thresholds** – Minimum thresholds are a numeric value for each sustainability indicator and are used to define when undesirable results occur, including if minimum thresholds are exceeded in a percentage of sites in the Subbasin's monitoring network.
- **Measurable Objectives** – Measurable objectives are a specific set of quantifiable goals for the maintenance or improvement of groundwater conditions. They will be included in the adopted Chapter GSP and will help the WKWD GSA achieve their sustainability goal.

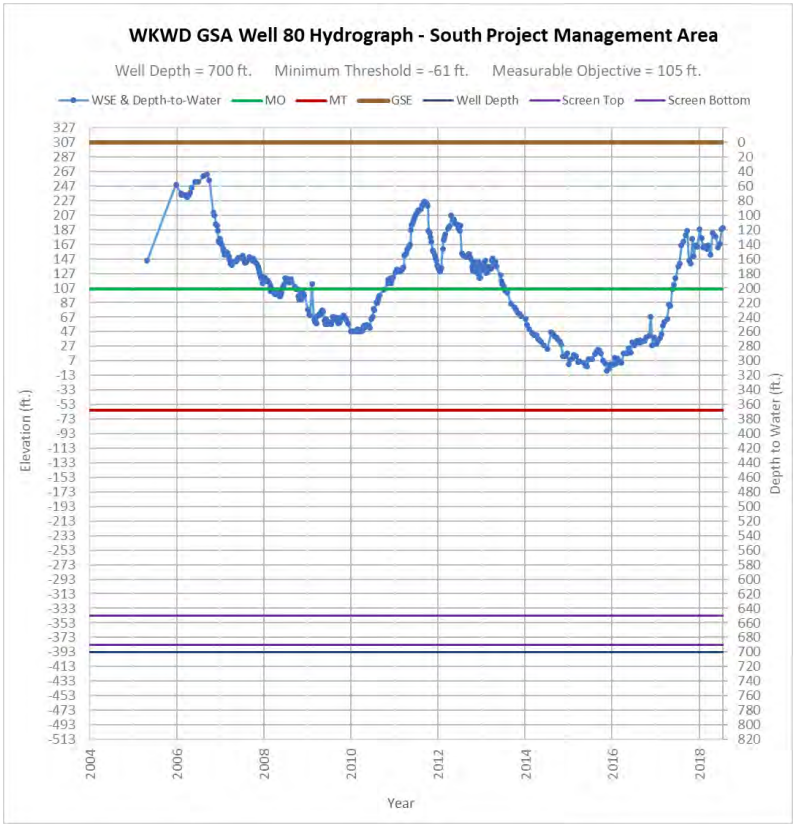


Figure ES-4. Sample Relationship Between Minimum Threshold and Measurable Objective

The method prescribed by SGMA to measure undesirable results involves setting minimum

thresholds and measurable objectives for a series of representative wells. Because of the similar groundwater conditions in both the North Project and South Project management areas, the strategies used to apply minimum thresholds and measurable objectives was consistent across both and were applied to all representative wells.

Minimum thresholds and measurable objectives were set to allow for an appropriate margin of operation flexibility to allow for normal operations and transfers of water as regularly conducted and sustainable operation by WKWD. Through coordination efforts, neighboring GSAs' minimum thresholds and measurable objectives were also taken into

consideration. Figure ES-4 shows an example of a monitoring well hydrograph with the minimum threshold and measurable objective.

ES-1.9 Water Budgets

Water budgets for the Subbasin were developed considering historical, current and projected conditions, and were developed at the Subbasin scale. This Subbasin water budget prepared for this Chapter GSP will also be provided as part of the Umbrella GSP, where each participating GSA has contributed data relevant to their respective areas.

ES-1.10 Monitoring Networks

This Chapter GSP describes the monitoring networks for the four sustainability indicators that apply in the Subbasin. The objective of these monitoring networks is to monitor conditions across the Subbasin and detect trends toward undesirable results. Specifically, the monitoring network was developed to do the following:

- Monitor impacts to the beneficial uses or users of groundwater
- Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds
- Demonstrate progress toward achieving measurable objectives described in this Chapter GSP

The monitoring networks were designed by evaluating data sources provided by DWR, including information from the California Statewide Groundwater Elevation Monitoring (CASGEM) Program, the U.S. Geological Survey, participating agencies. The monitoring network consists of wells that are already being used for monitoring in in the WKWD GSA Area. Historically, both DWR and USGS have monitored wells in the Pioneer GSA, but their monitoring efforts have been discontinued. All monitoring is currently conducted by the WKWD.

ES-1.11 Data Management System

The WKWD GSA's Data Management System incorporates current and historical data from all available sources including WKWD, DWR, the CASGEM Program, USGS, and other local sources.

ES-1.12 Projects and Management Actions

Maintaining sustainability in the WKWD GSA and contributing to sustainability efforts in the larger Subbasin requires implementation of management actions and, if demonstrated to be feasible, projects that will increase water supply. These include:

- Automatic meter reading project
- Participation in Delta Conveyance Facility
- Buena Vista Aquatic Recreation Area water supply management coordination
- Continued balanced pumping and recharge
- Implementation of the water shortage response plan
- Continued participation in Subbasin-wide coordination

Adaptive management strategies include the following:

- Taft recycled water program
- Shifting balance of pumping between the North and South wellfields
- Implementing permanent demand management measures if necessary

ES-1.13 GSP Implementation

Plan implementation is the execution of activities described in this Chapter GSP for sustainable operation of the GSA area of the Subbasin. Some of these activities include the following:

- Continued groundwater level monitoring
- Coordinating among GSAs in the Subbasin
- Installing additional monitoring equipment
- Updating the GSP

ES-1.14 Funding

WKWD GSA operations and implementation would incur costs and would be funded by the GSA. Four primary activities that would incur costs are as follows:

- Implementing the GSP
- Implementing GSP-related projects and management actions
- Developing annual reports
- Developing five-year evaluation reports

- These activities would be funded by WKWD normal operations and would be carried out by WKWD staff. Additional funding sources such as grants and water market trading may also help fund activities in the future.

Section 1.0 Agency Information, Plan Area, and Communication

Table 1-1 summarizes the California Department of Water Resources' (DWR's) *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

1.1 Compliance Information

Table 1-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 1.5
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.6	Agency Information	GSA mailing address	Section 1.2.3
		Organization and management structure	Section 1.2.4
		Contact information of Plan Manager	Section 1.2.3
		Legal authority of GSA	Section 1.2.5
		Estimate of implementation costs	Section 9.0
354.8(a)	Map(s)	Area covered by GSP	Section 1.0 and most maps
		Adjudicated areas, other agencies within the basin, and areas covered by an Alternative	Section 1.3
		Jurisdictional boundaries of federal or State land	Section 1.3
		Existing land use designations	Section 1.3
		Density of wells per square mile	Sections 6.6.4 and 6.10.4
354.8(b)	Description of the Plan Area	Summary of jurisdictional areas and other features	Section 1.3
354.8(c)	Water Resource Monitoring and Management Programs	Description of water resources monitoring and management programs	Section 1.3.3 to 1.3.5
354.8(d)		Description of how the monitoring networks of those plans will be incorporated into the GSP	Section 1.3.3 to 1.3.5
354.8(e)		Description of how those plans may limit operational flexibility in the basin	Section 1.3.3 to 1.3.5
		Description of conjunctive use programs	Section 1.3.7
354.8(f)	Land Use Elements or Topic Categories of Applicable General Plans	Summary of general plans and other land use plans	Section 1.3
		Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects	Section 1.3
		Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans	Section 1.3
		Summary of the process for permitting new or replacement wells in the basin	Section 1.3.6
		Information regarding the implementation of land	Section 1.0 and

Table 1-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
		use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	Umbrella GSP
354.8(g)	Additional GSP Contents	Description of Actions related to:	
		Control of saline water intrusion	Section 1.3.8
		Wellhead protection	Section 1.3.8
		Migration of contaminated groundwater	Section 1.3.8
		Well abandonment and well destruction program	Section 1.3.8
		Replenishment of groundwater extractions	Section 1.3.8
		Conjunctive use and underground storage	Section 1.3.8
		Well construction policies	Section 1.3.8
		Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects	Section 1.3.8
		Efficient water management practices	Section 1.3.8
		Relationships with State and federal regulatory agencies	Section 1.3.8
		Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity	Section 1.3.8
		Impacts on groundwater dependent ecosystems	Section 1.3.8
354.1	Notice and Communication	Description of beneficial uses and users	Section 1.4
		List of public meetings	Section 1.4
		GSP comments and responses	Section 1.4
		Decision-making process	Section 1.4
		Public engagement	Section 1.4
		Encouraging active involvement	Section 1.4
		Informing the public on GSP implementation progress	Section 1.4
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.16	Current and Historical Groundwater Conditions	Groundwater elevation data	Section 1.3 and Section 2.0.
	Surface Water Supply	Description of surface water supply used or available for use for groundwater recharge or in-lieu use	Section 1.0 Section 2.10 Section 4.0

1.2 Introduction and Agency Information

This section describes the West Kern Water District (WKWD) Groundwater Sustainability Agency (GSA), its authority in relation to the Sustainable Groundwater Management Act (SGMA), its relationship to other GSAs within the Kern County Subbasin (Subbasin), and the purpose of this *Groundwater Sustainability Plan* (GSP).

This Chapter GSP meets regulatory requirements established by the California Department of Water Resources (DWR) as shown by the completed *Preparation Checklist for GSP Submittal* (Appendix A). Additionally, this Chapter GSP shows that the WKWD GSA area is managed sustainably, imports more water into the Subbasin than is consumptively used by the GSA area, is adequately monitored to enable sustainable management in the future, and is coordinated with other GSAs and GSPs in the Subbasin.

On June 28, 2016, WKWD held a public hearing to consider the decision to serve as a GSA within the Subbasin. Following the hearing, WKWD's Board of Directors adopted Resolution No. 16.03, electing to become a GSA to the extent of its service boundaries. During the GSP development processes, the GSA boundary was expanded to include areas in and around the WKWD service boundary that were not previously part of any other GSA. Neighboring agencies and GSAs were consulted throughout GSP development, and these additional parcels were incorporated to provide greater coverage of the Subbasin.

In late 2019, the WKWD GSA discovered groundwater use in the Little Santa Maria Valley (LSMV), and coordinated with local landowners to add LSMV as a Management Area to the WKWD GSA area. Appendix H contains the SGMA-required information for inclusion in this Chapter GSP. During the five-year update to the GSP, the LSMV Management Area will be fully integrated into the GSA and Chapter GSP/

1.2.1 Relationship to the Umbrella GSP and Other Subbasin GSAs

The Subbasin is the southern portion of the San Joaquin Valley Groundwater Basin. Several GSAs have been formed in the Subbasin as follows:

- Buena Vista Water Storage District GSA
- Cawelo GSA
- Kern Groundwater Authority (KGA) GSA
- Greenfield County Water District GSA
- Henry Miller Water District GSA
- Kern River GSA
- Pioneer GSA
- Semitropic Water Storage District GSA
- WKWD GSA

The KGA GSA is a joint powers agency created to enhance coordination among water-related agencies in the Subbasin. Member agencies of the KGA are listed below.

- Arvin Community Services District
- Arvin Edison Water Storage District
- Cawelo Water District
- City of Shafter
- Kern County Water Agency
- Kern-Tulare Water District
- North Kern Water Storage District
- Rosedale-Rio Bravo Water Storage District
- Semitropic Water Storage District
- Shafter Wasco Irrigation District
- South San Joaquin Municipal Utilities District
- Tejon-Castaic Water District
- West Kern Water District
- Westside Water District Authority
- Wheeler Ridge-Maricopa Water Storage District

The majority of KGA's member agencies are covered under the KGA GSA's jurisdiction. However, the WKWD GSA, Pioneer GSA, Cawelo GSA, and Semitropic GSA have become their own GSAs, and are participating fully with the KGA GSA as it develops the Umbrella GSP for the Subbasin. The Umbrella GSP encompasses areas in the KGA and is being coordinated with other GSPs under development in the Subbasin. As a single document, the Umbrella GSP also complies with California Water Code (CWC) under SGMA regulations.

As the Umbrella GSP is being developed, each member agency of the KGA is preparing a Chapter GSP that provides information, data, and descriptions on a localized scale. Data from these Chapter GSP will be integrated into the Umbrella GSPs, and the Chapter GSPs will then be attached to the Umbrella GSP. Chapter GSPs supplement the Umbrella GSP where detailed information is needed, while the Umbrella GSP supplements Chapter GSPs when a broader, Subbasin-wide approach is more appropriate.

Development of the Umbrella GSP is also being coordinated with other GSAs in the Subbasin who are not members of the KGA. These non-member groups are also developing their own GSPs.

1.2.2 WKWD Background

WKWD is an industrial and municipal water provider in the southern San Joaquin Valley in western Kern County and encompasses the cities of Taft and Maricopa. WKWD's mission is "to provide its customers a reliable supply of excellent quality water in a planned, efficient, cost effective and environmentally

responsible manner, while promoting public awareness of water issues." (WKWD, 2014). WKWD was formed by election in 1959 and encompasses a roughly 300 square miles area with approximately 7,600 metered accounts. WKWD does not supply water for agricultural uses and imports water which it uses to recharge groundwater in the areas of its wellfields.

1.2.3 WKWD GSA Contact Information

WKWD GSA contact information is shown below:

- WKWD General Manager/GSA Director: Greg Hammett
- Phone Number: 661-763-3151
- Email: ghammett@wkwd.org
- Mailing Address: P.O. Box 105 800 Kern Street, Taft, CA. 93268
- Website: http://www.wkwd.org/

1.2.4 Management Structure

WKWD is governed by a five-member Board of Directors that meets monthly. The General Manager manages day-to-day operations of WKWD, with support provided by the administration, finance, and operations departments. The operations department includes four groups; engineering, field services, production, and transmission and distribution.

1.2.5 Legal Authority

Per CWC Section 10723.8(a), WKWD gave notice of its decision to form a GSA in the Subbasin (Basin 5-22.14 per DWR's Bulletin 118) (DWR, 2003). This notice is in Appendix B.

1.3 Plan Area

This section describes the WKWD GSA area, including the following:

- Major streams
- Institutional entities
- Agricultural and urban land uses
- Locations of groundwater wells and state lands
- Geographic boundaries of surface water runoff areas

This section also describes existing surface water and groundwater monitoring programs, and water management plans in the GSA area. Information in this section was gathered from publicly available sources and may not reflect all information that will be used for Chapter GSP technical analysis.

1.3.1 Plan Area Definition

The WKWD GSA was formed on June 28, 2016 by adoption of Resolution 16-03 by WKWD's Board of Directors (DWR, 2018e). The GSA area includes the WKWD boundary and adjacent oilfield properties owned by corporate and independent operators that have requested coverage under the WKWD GSA, as well as State land and privately owned parcels. The GSA area covers roughly 287 square miles of the Subbasin's southwestern region (Figure 1-1).

The GSA area includes four management areas as follows (Figure 1-2):

- Lake Management Area
- North Project Management Area
- South Project Management Area
- Western Management Area

Due to the lack of groundwater use in the Western Management Area, the Chapter GSP and monitoring networks focus primarily on the North Project, South Project, and Lake management areas.

1.3.2 Plan Area Setting

The Subbasin encompasses roughly 3,040 square miles of the southernmost San Joaquin Valley Groundwater Basin portion of the Tulare Lake Hydrologic Region. The San Joaquin Valley Groundwater Basin is a structural trough up to 200 miles long and 70 miles wide that represents the southern portion of the Great Central Valley of California (DWR, 2006).

The Subbasin is bounded by the Sierra Nevada foothills on the east, the Tehachapi and San Emigdio Mountains and White Wolf Subbasin on the south, the Temblor Range on the west, and portions of the KGA jurisdictional boundary to the north. The Kettleman Plain, Tulare Lake and Tule subbasins border the KGA jurisdictional line to the north. The GSA area overlies the southwestern portion of the Subbasin, along the western edge of Kern County, roughly 30 miles west of metropolitan Bakersfield and 100 miles north of Los Angeles. The incorporated cities of Maricopa and Taft and the communities of Fellows, Derby Acres, and McKittrick are located along the western edge of the GSA area along California State Route (Route) 33. The communities of Ford City, South Taft, Valley Acres, and Dustin Acres are in the northeast to southcentral portion of the GSA along Route 119. The community of Tupman is located on the northeast border of the GSA area adjacent to the California Aqueduct. Figure 1-3 shows key geographic features in the GSA area.

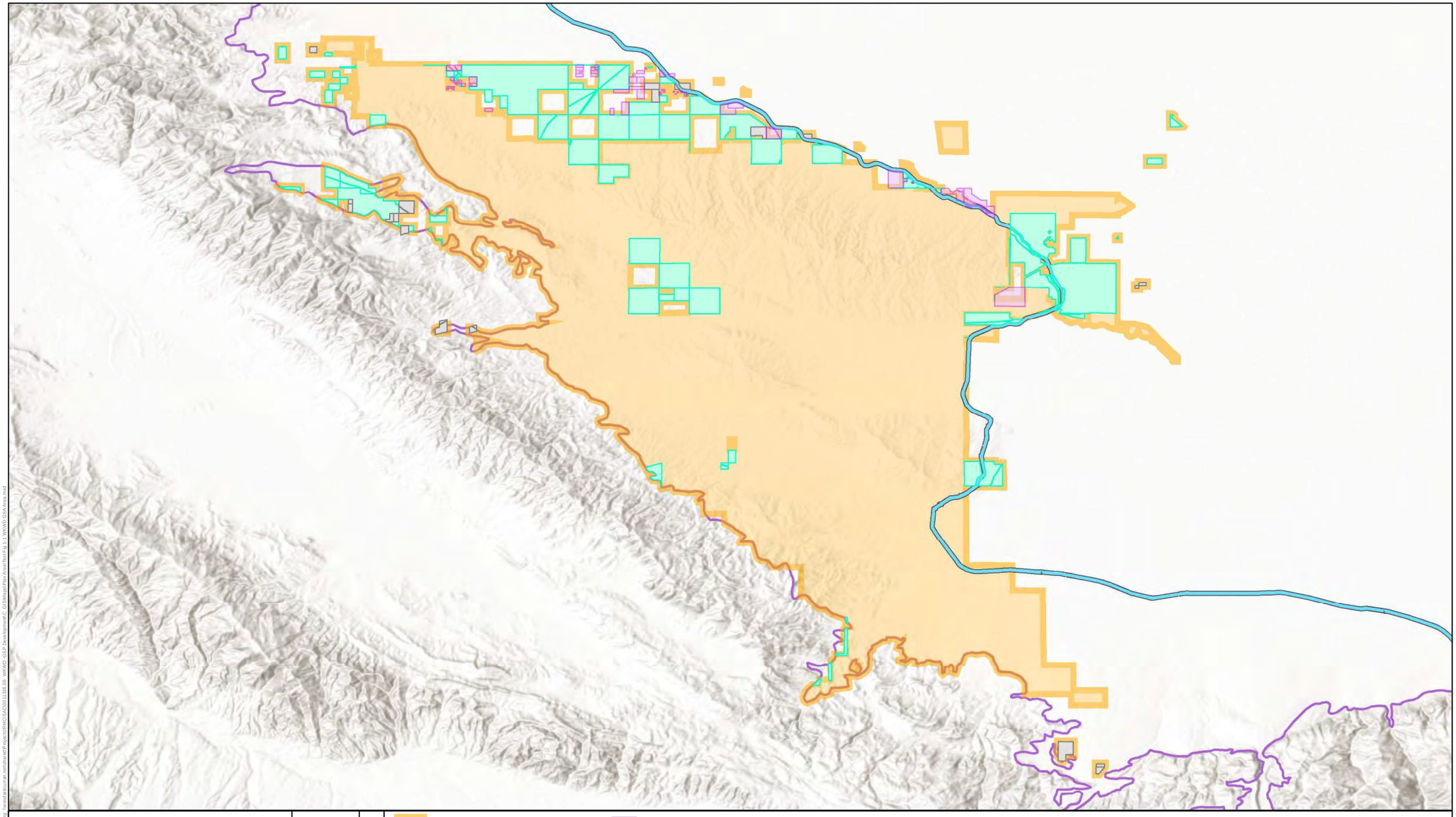


Figure 1-1: WKWD GSP
WKWD GSA Area with Participating Lands

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

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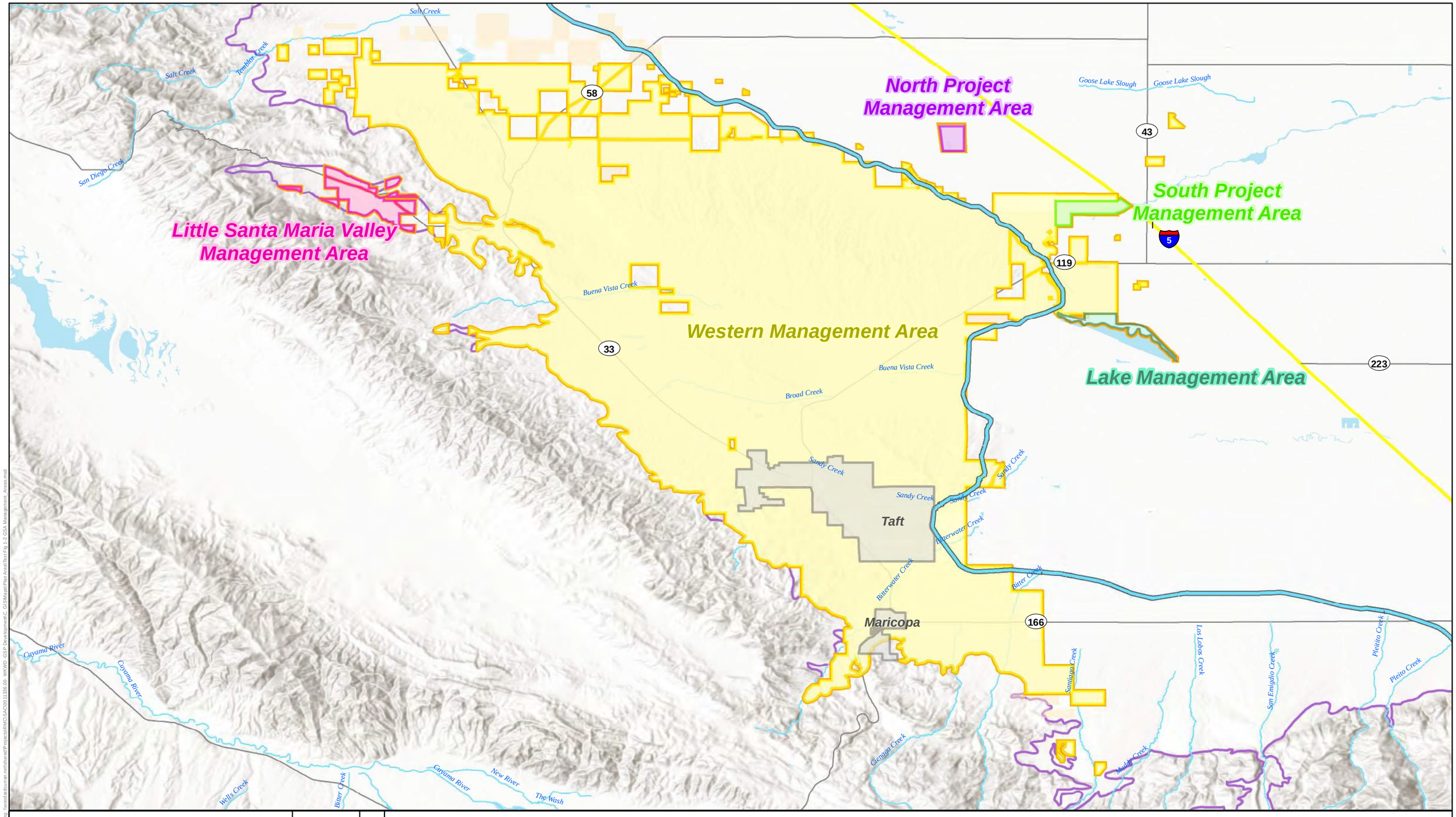


Figure 1-2: WKWD GSP Management Areas

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

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Legend

- WKWD GSA
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- North Project Management Area
- South Project Management Area
- Lake Management Area
- Western Management Area
- Little Santa Maria Valley Management Area

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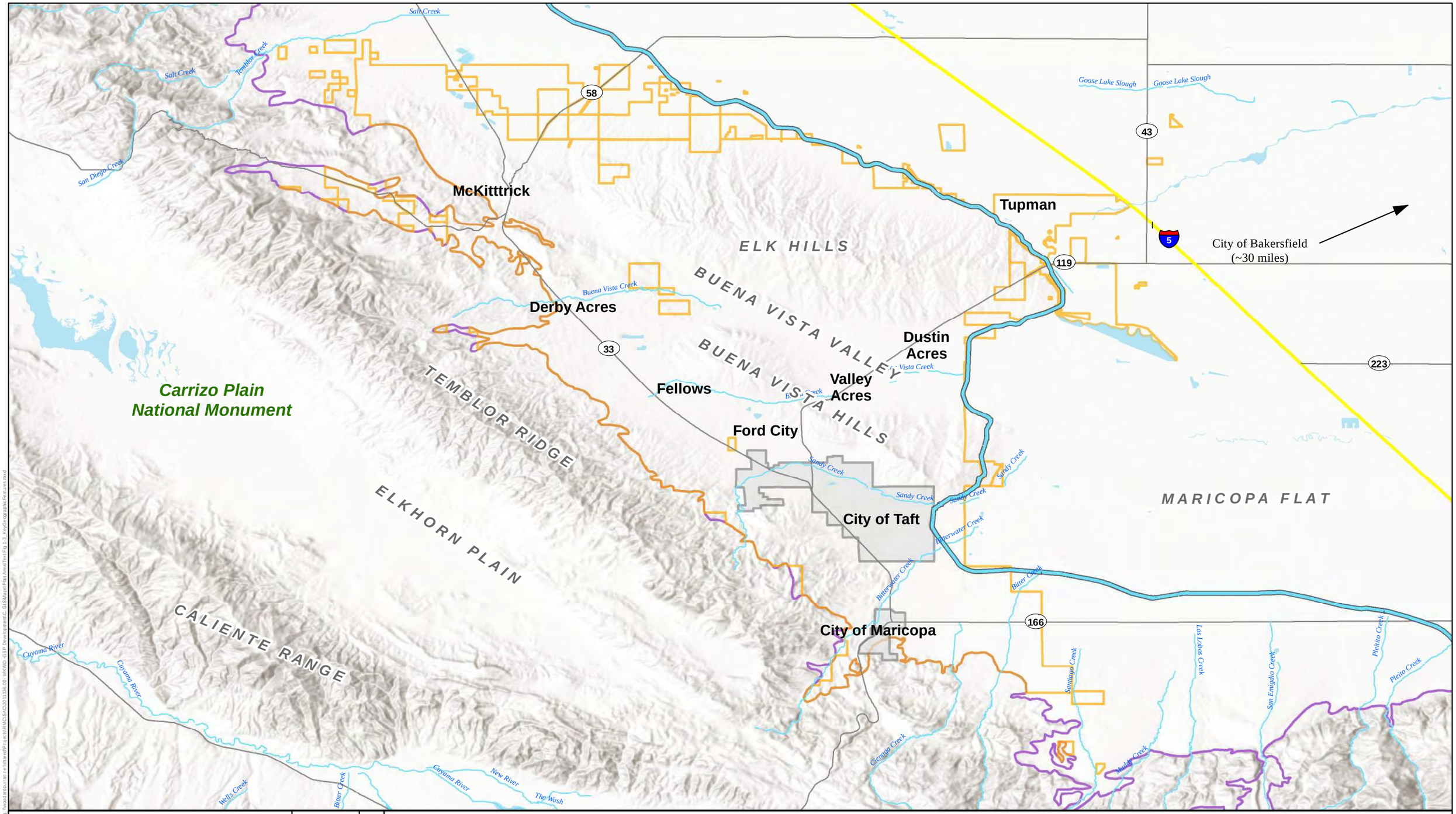


Figure 1-3: WKWD GSP
Key Geographic Features

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

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Legend

- WKWD GSA
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams

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As described in Section 1.2.1, 11 GSAs have been formed to manage groundwater sustainability in the Subbasin (Figure 1-4). In Figure 1-4, white areas indicate areas the KGA GSA was originally responsible for that were originally under Kern County jurisdiction. However, Kern County has withdrawn from the KGA GSA, leaving these areas unmanaged. Some of the white areas have been incorporated into the GSAs, but other white areas remain unmanaged.

Figure 1-4 shows the WKWD GSA and neighboring GSAs. Table 1-1 lists the Subbasin GSAs. As mentioned above, Kern County has withdrawn from the KGA; no agency with authority over white areas in the figure are identified at this time.

Table 1-2. Subbasin GSAs

GSA Name	Member Agencies
Buena Vista Water Storage District (BVWSD)	BVWSD
Cawelo Water District (WD)	Cawelo WD
City of McFarland	City of McFarland
Greenfield County WD	Greenfield County WD
Henry Miller WD	Henry Miller WD
Kern Groundwater Authority	Arvin Community Services District (CSD), Arvin-Edison Water Storage District (WSD), City of Shafter, Kern County, Kern-Tulare WD, Kern Water Bank Authority (KWBA), North Kern WSD, Rosedale-Rio Bravo WSD, Shafter Wasco Irrigation District (ID), Southern San Joaquin Municipal Utility District, Tejon-Castaic WD, Westside District Water Authority, Wheeler Ridge-Maricopa WSD
Kern River	Kern County Water Agency Improvement District 4, Kern Delta WD, City of Bakersfield, East Niles CSD, Oildale Mutual Water Company
Olcese WD	Olcese WD
Pioneer	Kern County Water Authority (KCWA)
Semitropic WSD	Semitropic WSD
West Kern WD	WKWD

The southern portion of the San Joaquin Valley in the Tulare Lake Hydrologic Region is divided into seven subbasins (Figure 1-5). Portions of the White Wolf Subbasin are separated into the South Lahontan Hydrologic Region by the White Wolf fault. The San Andreas, Poso Creek, and White Wolf faults are active faults bordering the Subbasin (DWR, 2006) (Figure 1-6).

Kern County has the largest jurisdiction in the Subbasin, covering approximately 286.5 square miles, or 99.8 percent of the GSA area (Figure 1-7). The remaining 0.5 square miles along the midwestern edge fall under San Luis Obispo County jurisdiction. Because the primary GSP focus areas (i.e., North Project, South Project, and Lake management areas) are within Kern County, and the small portion of San Luis Obispo County has no land use or water use systems, San Luis Obispo County elected to not participate in the Chapter GSP development process.

Most lands within the WKWD GSA area are covered by native grasses and vegetation. Although not shown in Figure 1-8, oil production is the majority of developed land use and thus does not utilize onsite groundwater pumping. Roughly 80 percent of WKWD's water supply is delivered to industrial companies, primarily for oil development and power plants. Domestic water sales account for the remaining 20 percent of WKWD's annual sales, and is split between residential and commercial customers (WKWD, 2016). There is a small field of alfalfa adjacent to Taft that is irrigated exclusively with treated effluent from the local wastewater treatment plant.

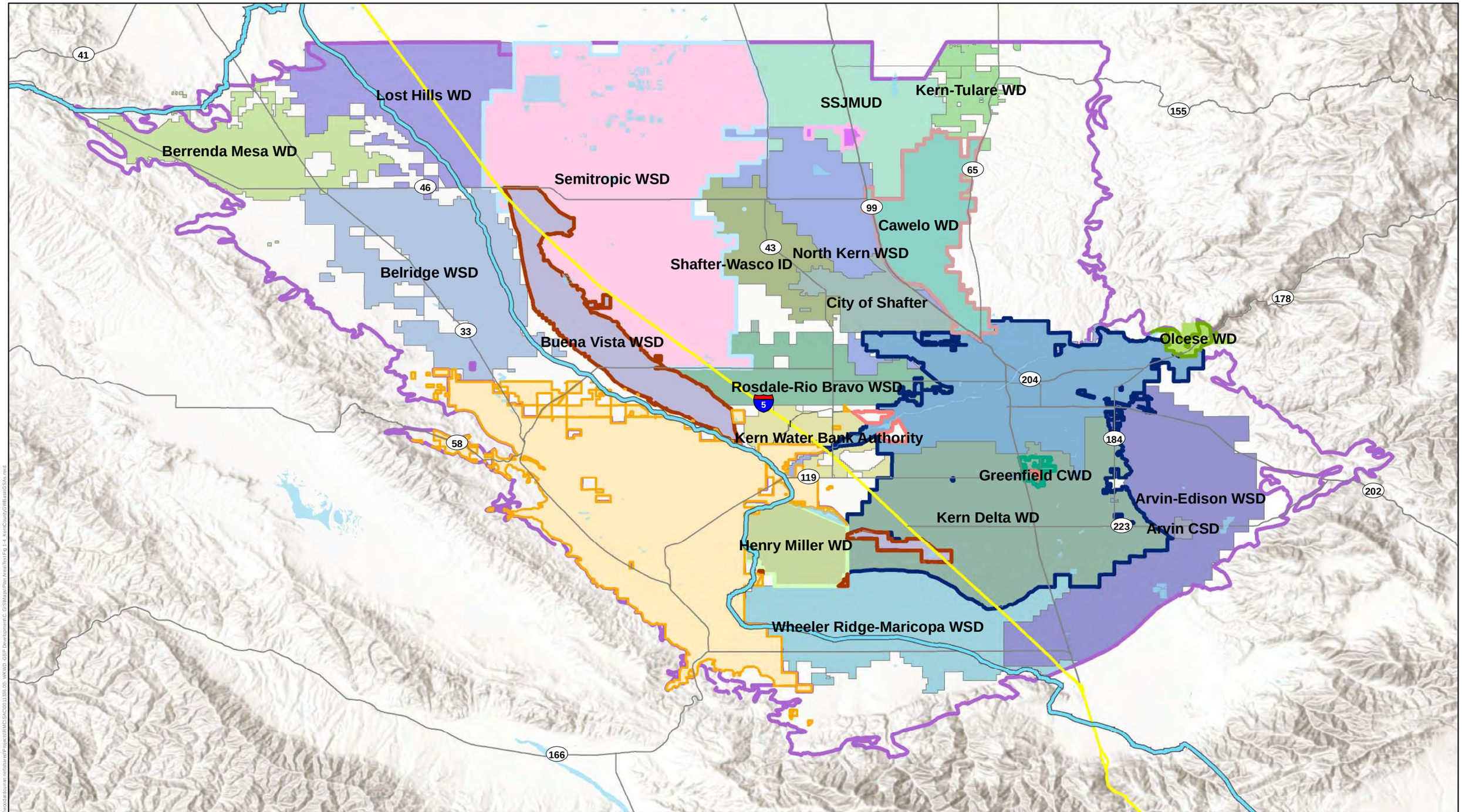


Figure 1-4: WKWD GSP
Kern County GSAs

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- California Aqueduct
- **Kern County GSAs**
- BVWSD
- Cawelo WD
- City of McFarland
- Greenfield County WD
- Henry Miller WD
- Kern Groundwater Authority
- Kern River
- Olcese WD
- Pioneer
- Semitropic WSD

N

0 5 10 20 Miles

Figure Exported: 12/4/2019 By: cegleton Using: \\woodardcurran.net\shared\Projects\BMO\SAC\001133\6.00- WKWD -GSP Development\C. GIS\Water\Plan Area\Text Fig 1-4_KernCnty\KCWBasinGSAs.mxd

SAN JOAQUIN VALLEY - WESTSIDE

SAN JOAQUIN VALLEY - KAWEAH

SAN JOAQUIN VALLEY - PLEASANT VALLEY

SAN JOAQUIN VALLEY - TULARE LAKE

SAN JOAQUIN VALLEY - TULE

CHOLAME VALLEY

SAN JOAQUIN VALLEY - KETTLEMAN PLAIN

SALINAS VALLEY - PASO ROBLES AREA

KERN RIVER VALLEY

SAN JOAQUIN VALLEY - KERN COUNTY

WALKER BASIN CREEK VALLEY

CARRIZO PLAIN

SAN JOAQUIN VALLEY - WHITE WOLF

CUYAMA VALLEY

269 190 99 155 65 33 43 46 41 229 5 178 204 184 119 202 223 101 227 58 166 1 135

Figure 1-5: WKWD GSP
Regional Groundwater Subbasins

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct

N

0 5 10 20 Miles

Figure Exported: 12/4/2019 By: cappleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001336.00- WKWD - GSP Development\C. GIS\Maps\Plan Area\Text Fig 1-5_Regional GW Basins.mxd

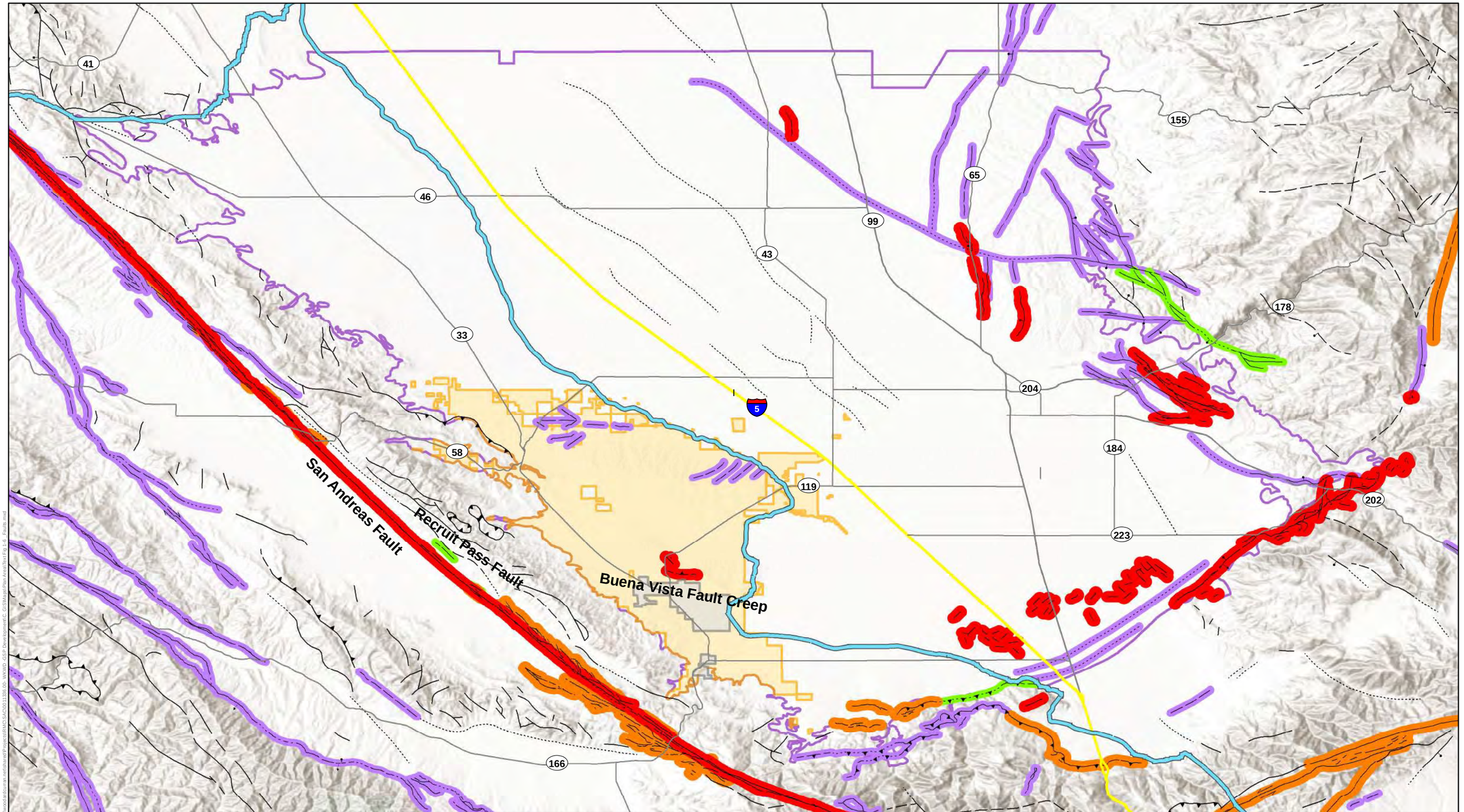


Figure 1-6: WKWD GSP
Kern County Regional Faults

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- Cities
- California Aqueduct

Fault Classification
- Fault
- Approximate fault
- Concealed fault
- Thrust fault

Recency of Movement
- Historic
- Holocene
- Late Quaternary
- Quaternary

N

0 5 10 20 Miles

Figure Exported: 12/4/2019 By: cepleiton Using: \\woodardcurran.net\shares\Projects\RMO.SAC\001\1336.05 WKWD GSP Development\C GIS\Maps\Plan Area\Text Fig 1-6 Faults.mxd

Monterey County

Kings County

Tulare County

Kern County

San Luis Obispo County

Santa Barbara County

Ventura County

Los Angeles County

41
46
33
58
43
99
65
155
178
204
184
202
223
119
5
166
135
101

Figure 1-7: WKWD GSP Counties

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- Counties
- California Aqueduct

N

0 5 10 20 Miles

Figure Exported: 12/4/2019 By: cepleiton Using: \\woodardcurran.net\shared\Projects\RMO\SAC\011336.00 WKWD GSP Development\C GIS\Water\Plan Area\Text Fig 1-7 Counties.mxd

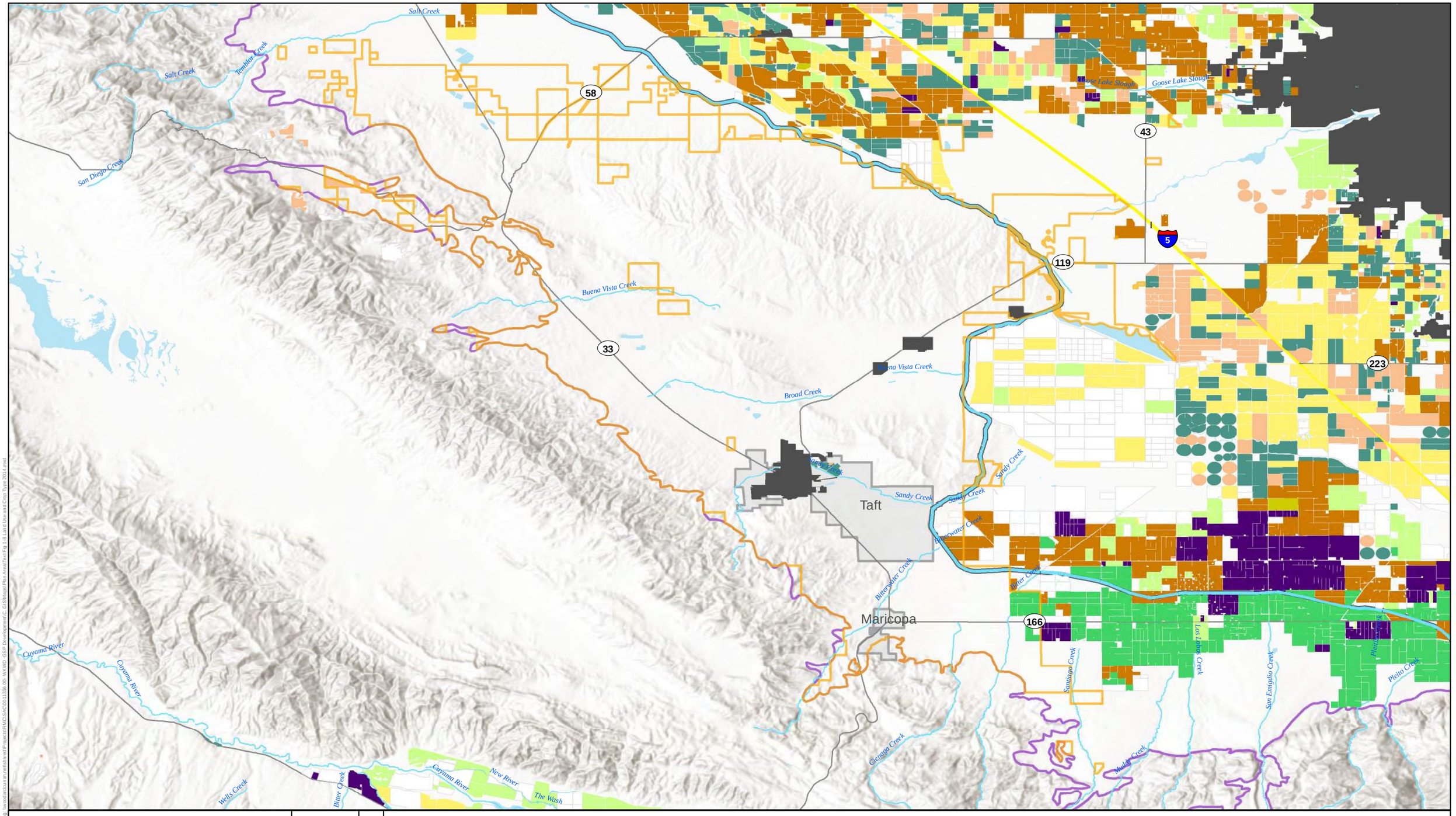


Figure 1-8: WKWD GSP
Land Use and Crop Type (2014)

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams

Statewide Crop Mapping 2014

- Citrus and Subtropical
- Deciduous Fruits and Nuts
- Field Crops
- Grain and Hay Crops
- Idle
- Pasture
- Rice
- Riparian Vegetation
- Truck Nursery and Berry Crops
- Urban
- Vineyard
- Young Perennial

N

0 3 6 12 Miles

Figure Exported: 12/6/2019 By: cwpeloton Using: \\woodardcurran.net\shared\Projects\8MO\SAC\001138.00 WKWD GSP Development\C GIS\Water\Plan Area\Text Fig 1-8 Land Use and Crop Type 2014.mxd

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Information about domestic, production, and municipal wells identified in the GSA area was downloaded from DWR's *Well Completion Report Map Application*. CWC Section 13752 allows for the release of copies of well completion reports; this application allows government agencies and the public to review these data as well density information per the Public Land Survey System (PLSS) section (DWR, 2019).

Figure 1-9 through Figure 1-11 show the total number of domestic, production, and public wells in each square mile of the WKWD GSA area contained in DWR's well completion database. DWR's well designations are based on information contained in well completion reports and have not been modified for this Chapter GSP section. In February 2018, wells in the GSA area were identified using aerial imagery to establish whether active groundwater pumping was occurring. A small number of homes and a golf course were identified in the database as using wells for irrigation; however, WKWD provides water service to these areas, and they do not rely on a local groundwater well.

Figure 1-12 shows an example assessment for PLSS Section M30S24E20. The aerial imagery shows no evidence of groundwater production from any of the wells identified in the DWR database.

WKWD's *Kern County Groundwater Subbasin Boundary Modification Request Technical Report* states there is a low density of wells west of the California Aqueduct (WKWD, 2018). Table 1-3 lists the wells identified from DWR's well completion database and the PLSS sections examined to validate groundwater production. Since large production wells were not identified during the assessment, WKWD has determined that there is not significant groundwater use in the area. WKWD will re-evaluate wells in the western area as part of its 5-year GSP update, and determine if use has increased or management is required to maintain sustainability. The analysis appears to agree with the findings in the Subbasin Modification report, that there are very few wells in the Western Management Area. Figures 1-13 through 1-15 describe the remaining wells that are above de minimis use.

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Colors in the township and range grid correspond to the number of wells within that grid.
Grids with no number have no associated wells

Source: Department of Water Resources, Well Completion Report Map Application. Downloaded on February 6, 2018. <https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37>

Figure 1-9: WKWD GSP
Domestic Wells by Township and Range

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

Township & Range with Domestic Wells

- No Wells
- 1 Well
- 2 Wells
- 3 Wells

N

0 3 6 12 Miles

Figure Exported: 12/5/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001336.00- WKWD -GSP Development\C- GIS\Maps\Plan Area\Text Fig 1-9_ DomesticWells_V2.mxd

Colors in the township and range grid correspond to the number of wells within that grid.
Grids with no number have no associated wells

Source: Department of Water Resources, Well Completion Report Map Application. Downloaded on February 6, 2018.
<https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37>

Figure 1-10: WKWD GSP
Production Wells by Township and Range

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

Township & Range with Production Wells

- No Wells
- 1 Well
- 2 Wells
- 3 Wells
- 4 Wells
- 5 Wells
- 6 Wells

N

0 3 6 12 Miles

Figure Exported: 12/5/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001336.00- WKWD -GSP Development\C- GIS\Maps\Plan Area\Text Fig 1-10_ProductionWells.mxd

Colors in the township and range grid correspond to the number of wells within that grid.
Grids with no number have no associated wells

Source: Department of Water Resources, Well Completion Report Map Application. Downloaded on February 6, 2018. <https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37>

Figure 1-11: WKWD GSP
Public Wells by Township and Range

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

Township & Range with Public Wells

- No Wells
- 1 Well
- 2 Wells
- 3 Wells

N

0 3 6 12 Miles

Figure Exported: 12/4/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001133600- WKWD -GSP Development\C- GIS\Maps\Plan Area\Text Fig 1-11. PublicWells.mxd

M30S24E18

M30S24E17

M30S24E16

M30S24E19

M30S24E20

M30S24E21

M30S24E30

M30S24E29

M30S24E28

Figure 1-12: WKWD GSP
Example Well Completion Report Aerial Analysis

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- Estimated M30S24E20 well location
- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

Township & Range with Production Wells

- No Wells
- 1 Well

N

0 0.1 0.2 0.4 Miles

Figure Exported: 12/4/2019 By: cegolston Using: \\woodardcurran.net\shared\Projects\RMC\SAC\011336.00 - WKWD - GSP Development\C. GIS\Maps\Plan Area\Text Fig 1-12 Example Well Aerial Analysis.mxd

Table 1-3. PLSS Sections Examined by Aerial Imagery

Location	Well Count			Evaluation	Management Area	Resolution
	Domestic	Public	Production			
M29S21E32	--	--	1	Barren/dry land	Western	Removed
M29S22E32	--	--	1	Barren/dry land	Western	Removed
M29S23E31	--	--	1	Barren/dry land	Western	Removed
M30S21E03	--	--	1	Barren/dry land	Western	Removed
M30S21E15	--	--	2	Barren/dry land	Western	Removed
M30S22E18	--	--	3	Oil refinery on barren land	Western	Removed
M30S23E01	--	--	2	Barren/dry land	Western	Removed
M30S23E03	--	--	1	Barren/dry land	Western	Removed
M30S23E17	--	--	1	Barren/dry land	Western	Removed
M30S23E23	--	--	1	Barren/dry land	Western	Removed
M30S24E02	3	--	3	Potential water use	North Project	Kept
M30S24E11	3	--	4	Potential water use	North Project	Kept
M30S24E16	--	--	1	Barren/dry land	Western	Removed
M30S24E20	--	--	1	Barren/dry land	Western	Removed
M30S24E22	--	--	1	Barren/dry land	Western	Removed
M30S24E23	--	--	1	Small oil production on barren land	Western	Removed
M30S24E27	--	--	1	Barren/dry land	Western	Removed
M30S24E32	1	--	--	Barren/dry land	Western	Removed
M30S25E01	3	--	--	Agriculture supplied by WKWD	Western	Removed
M30S25E20	--	--	1	Barren/dry land	Western	Removed
M30S25E21	2	3	6	Potential water use	South Project	Kept
M30S25E22	--	2	3	Potential water use	South Project	Kept
M30S25E23	--	--	2	Potential water use	South Project	Kept
M30S25E26	--	--	2	Barren/dry land	Western	Removed
M30S25E28	--	--	1	Potential water use	South Project	Kept
M30S25E32	--	--	1	Oil refinery on barren ground	Western	Removed
M30S25E34	--	--	1	Barren/dry land	Western	Removed

Table 1-3. PLSS Sections Examined by Aerial Imagery

Location	Well Count			Evaluation	Management Area	Resolution
	Domestic	Public	Production			
M30S26E06	1	--	2	Agriculture supplied by WKWD	Western	Removed
M31S22E21	1	--	--	Small oil production on barren land	Western	Removed
M31S22E23	--	--	1	Oil refinery on barren land	Western	Removed
M31S22E24	--	--	1	Small oil production on barren land	Western	Removed
M31S23E13	--	--	2	Barren/dry land	Western	Removed
M31S23E34	--	--	1	Barren/dry land	Western	Removed
M31S24E14	--	--	1	Homes supplied by WKWD	Western	Removed
M31S24E22	--	--	1	Homes supplied by WKWD	Western	Removed
M31S24E28	--	--	2	Homes supplied by WKWD	Western	Removed
M31S25E03	1	--	--	Small oil production on barren land	Western	Removed
M31S25E13	--	--	1	Potential water use	Lake	Kept
M31S25E15	3	--	3	Potential water use	Lake	Kept
M31S25E16	--	--	4	Potential water use	Lake	Kept
M31S25E17	--	--	1	Homes supplied by WKWD	Western	Removed
M31S25E18	--	--	1	Golf course supplied by WKWD	Western	Removed
M32S23E14	--	--	1	City of Taft supplied by WKWD	Western	Removed
M32S24E13	--	--	1	Barren/dry land	Western	Removed
M32S24E35	--	--	1	Barren/dry land	Western	Removed
S11N23W17	--	1	1	Homes supplied by WKWD	Western	Removed
S12N23W31	--	--	2	Small oil production on barren land	Western	Removed
S12N23W32	--	--	1	Barren/dry land	Western	Removed

Figure 1-13 shows the approximate number and average depth of verified domestic wells in the GSA area. There are approximately 11 wells in the GSA area with well completion depth ranging from 300 feet in the Lake Management Area to 1,000 feet in the North Project Management Area.

Figure 1-14 shows the approximate number and average depth of verified production wells in the GSA area. There are approximately 27 wells in the GSA area with well completion depth ranging from 310 feet in the South Project Management Area to 1,140 feet in the Lake Management Area.

Figure 1-15 shows the approximate number and average depth of verified public wells in the GSA area. There are approximately five wells in the GSA area with well completion depth ranging from 560 to 818 feet in the South Project Management Area.

The Bureau of Land Management manages most of the protected lands within the GSA area primarily along the boundary and central portion of the Western Management Area. The California Department of Fish and Wildlife (CDFW) also manages lands within the Western Management Area including the Carrizo Plain National Monument. The U.S. Fish and Wildlife Service (USFWS) Wildlands Conservancy's Wind Wolves Preserve is adjacent to the southeastern boundary of the GSA area. Figure 1-16 shows the public lands in and around the GSA area.

The GSA area is split between the Middle Kern-Upper Tehachapi-Grapevine and Tulare Lake Bed Regional Watersheds. All streams in the GSA area are ephemeral and only flow during heavy precipitation events, with most flow originating outside the GSA area. Ephemeral surface water flow into the GSA area is not actively captured or banked, but rather infiltrates or flows out of the GSA area. Figure 1-17 shows the regional watersheds overlying and around the GSA area.

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Numbers in the township and range grid correspond to the average depth of the wells within that grid.
Grids with no number have no associated well depth data.
Average well depth is given in feet below the ground surface.

Source: Department of Water Resources, Well Completion Report Map Application. Downloaded on February 6, 2018. <https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37>

Figure 1-13: WKWD GSP
Verified Domestic Wells by Township and Range

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

Township & Range with Domestic Wells

- 1 Well
- 2 Wells
- 3 Wells
- 4 Wells
- 6 Wells

N

0 3 6 12 Miles

Figure Exported: 12/4/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001338.00- WKWD -GSP Development\C. GIS\Maps\Plan Area\Text Fig 1-13 _Verified Domestic Wells.mxd

Numbers in the township and range grid correspond to the average depth of the wells within that grid.
Grids with no number have no associated well depth data.
Average well depth is given in feet below the ground surface.

Source: Department of Water Resources, Well Completion Report Map Application. Downloaded on February 6, 2018. <https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37>

Figure 1-14: WKWD GSP
Verified Production Wells by Township and Range

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

Township & Range with Production Wells

- 1 Well
- 2 Wells
- 3 Wells
- 4 Wells
- 6 Wells

N

0 3 6 12 Miles

Figure Exported: 12/4/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\SRC\SACO\011336.00- WKWD GSP Development\C. GIS\Maps\Plan Area\Text Fig 1-14_Verified Production Wells.mxd

Numbers in the township and range grid correspond to the average depth of the wells within that grid.
Grids with no number have no associated well depth data.
Average well depth is given in feet below the ground surface.

Source: Department of Water Resources, Well Completion Report Map Application. Downloaded on February 6, 2018. <https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37>

Figure 1-15: WKWD GSP
Verified Public Wells by Township and Range

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

Township & Range with Public Wells

- 1 Well
- 2 Wells
- 3 Wells

N

0 3 6 12 Miles

Figure Exported: 12/5/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001338.00- WKWD GSP Development\C. GIS\Maps\Plan Area\Text Fig 1-15, Verified Public Wells.mxd

Carrizo Plain
National Monument

Wildlands Conservancy's
Wind Wolves Preserve

Figure 1-16: WKWD GSP
Federal and State Lands

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA

California Conservation Easement Database
- California Valley Conservation Easement
- Coles Levee
- Elk Hills Conservation Easement
- Kern Water Bank

California Protected Areas Database (CPAD)
- City
- County
- Federal
- Non Profit
- Special District
- State

CDFW Owned & Operated Lands & Conservation Easements
- Ecological Reserve
- Undesignated

State Parks
- Park Boundary

N

0 3 6 12 Miles

Figure Exported: 12/6/2019 By: cepleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001139.00- WKWD -GSP Development\C. GIS\Maps\Plan Area\Text Fig 1-16_FederalandStateLands.mxd



Figure 1-17: WKWD GSP
Regional HUC-8 Watersheds

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- San Joaquin Valley Groundwater Basin
- California Aqueduct
- Rivers/Streams

N

0 15 30 60 Miles

Figure Exported: 12/4/2019 By: cstapleton Using: \\woodardcurran.net\shares\Projects\MOSAC\011336.00 WKWD -GSP Development\C. GIS\Maps\Plan Area\Text Fig 1-17 Regional Watersheds.mxd

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1.3.3 Existing Surface Water Monitoring Programs

Because of the regional arid climate, there are no surface water bodies in the GSA area. Ephemeral streams do exist; however, flows are rare and only occur during large storm events. Surface water used in the GSA area is imported via the California Aqueduct as part of the State Water Project (SWP), or from rare high flow events on the Kern River (WKWD, 2016). Except for direct industrial water deliveries from the California Aqueduct to the La Paloma Power Facility, surface water imported by WKWD is recharged and later recovered to meet in-district demands (See Section 1.3.7). Historical and current surface water monitoring in the GSA area is described below.

Natural Water Courses

United States Geological Survey (USGS) National Water Information System (NWIS). While no active monitoring of natural water courses is currently performed in the GSA area, the USGS did monitor flows in several ephemeral streams from 1959 to 1969. Metadata for those monitoring sites are summarized in Table 1-4. These gages are maintained by the USGS and data were reported to the NWIS database (USGS, 2019).

Table 1-4. Surface Flow Gages in the GSA area

Reporting Agency	Gage Number	Location	Status	Years of Record
USGS	11195150	Bitterwater Creek Near Maricopa CA	Inactive	1962-1969
USGS	11195000	Oil Creek Near Taft CA	Inactive	1959-1969
USGS	11194800	Shale Creak Near Fellows CA	Inactive	1959-1973
USGS	11194500	Sand Creek Near McKittrick CA	Inactive	1959-1968

Source: (USGS, 2019)

Surface Water Conveyance

- **Kern Water Bank Canal**. SWP and other surface water supplies can be delivered to WKWD recharge ponds through the Kern Water Bank Canal. Water delivered to WKWD from the Kern Water Bank Canal is measured by the Kern County Water Agency (KCWA) and BVWSD through a rated gate structure or a rated weir structure called “Second Measurement Point on the Kern River” (Second Measurement Point). Second Measurement Point was established by the Miller-Haggin Agreement of 1888 to measure and apportion river flows and document water deliveries to downstream rights holders.
- **Cross Valley Canal.** SWP and other surface water supplies can be delivered to the South Management Area using WKWD’s capacity rights in the Cross Valley Canal. The Cross Valley Canal is operated by the KCWA and deliveries from the Cross Valley Canal to WKWD are fully metered.
- **Eastside Canal.** SWP and other surface water supplies can be delivered to the North Project Management Area from the Eastside Canal. The Eastside Canal is owned and operated by BVWSD. Deliveries to the North Management Area from the Eastside Canal are fully metered.

- **California Aqueduct.** DWR and downstream SWP contractors maintain groundwater pump-in guidelines to protect water quality downstream of banking programs in the California Aqueduct. These guidelines are meant to reduce the need for additional treatment by downstream users (State of California, 2016). The pump-in guidelines were developed based upon existing or background water quality in the California Aqueduct and taking into consideration current state and federal drinking water standards. One pump-in monitoring site is in the GSA area near Cole's Levee at milepost 241.02, and is sampled annually between November to December.

1.3.4 Existing Groundwater Monitoring Programs

Existing groundwater monitoring in the GSA area is performed by various local, state and federal agencies. Groundwater monitoring in areas adjacent to the WKWD GSA is primarily the responsibility of the Kern Water Bank Authority (KWBA). Existing monitoring programs in the GSA area collect data related to groundwater elevation (GWE), groundwater quality, and subsidence on a routine basis. These monitoring programs are summarized below.

GWE Monitoring Programs

Through various state, regional, and local monitoring programs, groundwater levels throughout the GSA area are typically measured in spring and fall, as well as at regular intervals during periods of groundwater recovery (State of California, 2016).

- **DWR Water Data Library (WDL)**. DWR's WDL contains information about GWE measurements from 52 wells in the GSA area that have reported periodically from 1930 through 2018. KCWA, DWR, Wheeler Ridge-Maricopa WSD, Kern County Land Company, and Tenneco-West reported data to the WDL during this time period (DWR, 2018d).
- **USGS NWIS**. The USGS's NWIS contains extensive water data, including manual measurements of depth to water in wells throughout California. In the GSA area there is one active groundwater monitoring well reporting data from 2018. There are 38 inactive wells; of those inactive wells, 19 of the 38 reported data from 1953 through 1961 (USGS, 2018b).
- **DWR California Statewide Groundwater Elevation Monitoring (CASGEM) Program**. The CASGEM Program collects monitoring data about seasonal and long-term GWE trends in collaboration with local monitoring entities. WKWD participates in the Kern River Fan Group of the CASGEM Program. The Kern River Fan Group provides groundwater level data to the state for the Kern Fan region. There are 28 CASGEM Program wells and 24 additional voluntary wells in the GSA area; these wells have reported data from 1930 to 2018 (DWR, 2018a).
- **Kern Fan Monitoring Committee Groundwater Level Monitoring**. Through a Memorandum of Understanding (MOU), local adjoining entities formed the Kern Fan Monitoring Committee (KFMC) to monitor and manage groundwater operations on the Kern Fan. Seven WKWD wells are included in the KFMC monitoring network. Water level measurements are collected at least twice a year during spring and fall, with measurements taken more frequently during periods of groundwater recovery. Additionally, WKWD monitors its wells continuously using data loggers. Well data for the KFMC monitoring project are provided to both the DWR and KCWA groundwater-level databases (State of California, 2016).

Groundwater Quality Monitoring Programs

Groundwater quality in the vicinity of the WKWD wellfields is excellent (WKWD, 2016). WKWD regularly monitors groundwater conditions using dedicated monitoring wells, and water quality is tested in accordance with protocols developed by the California Department of Public Health (CDPH) for drinking water. WKWD water met all United States Environmental Protection Agency (EPA) and State drinking water health standards in 2018 (WKWD, 2018).

- **DWR WDL**. DWR's WDL contains groundwater quality data from 1909 through 1983 for 67 wells in the GSA area (DWR, 2018d). Most wells are not regularly sampled, and many have only one or two recorded sampling events with large time periods in between. Constituents most frequently reported include dissolved chloride, sodium, calcium, boron, magnesium, and sulfate. Field measurements taken include conductance, pH, total alkalinity, and hardness.
- **GeoTracker Groundwater Ambient Monitoring and Assessment (GAMA) Program**. Established in 2000, the GAMA Program collects groundwater quality monitoring data throughout California. The GAMA Program's goal is to create a comprehensive groundwater monitoring program throughout California and increase public availability and access to groundwater quality and contamination information (State Water Resources Control Board [SWRCB], 2018).
- **USGS NWIS**. The USGS' NWIS is a collection of groundwater monitoring data including chemical, physical, and biological properties in water supply wells. This system covers the GSA area, and data are uploaded on a quarterly basis to GeoTracker, a data management system operated by the California State Water Resource Control Board. In the GSA area there is one active groundwater monitoring well with historical water quality data from 1957 and there are data available for 11 of 38 inactive wells from 1954 through 2015 (USGS, 2018b).
- **KWBA**. KWBA conducts extensive monitoring to establish baseline groundwater quality and ensure constituents of concern (COCs) do not degrade water quality. This monitoring consists of two elements: regular sampling of 57 dedicated monitoring wells for potential constituents of concern, and sampling of all recovery wells. Monitoring wells are sampled according to a protocol developed by the KFMC. Recovery wells are sampled according to a monitoring schedule developed by the CDPH. Results are provided to DWR and are used to establish non-project water delivery criteria for the California Aqueduct (KWBA, 2018).
- **KCWA Groundwater Quality Monitoring Database**. Well networks in the Subbasin primarily consist of production and dedicated monitoring wells. Most production wells are sampled once or twice a year for COCs as required by Title 22 of the California Code of Regulations, and in accordance with protocols developed by CDPH for testing public drinking water supplies. Monitoring wells are typically sampled more frequently for general water quality parameters and sampled annually for Title 22 COCs. The KCWA database includes data collected from 1,953 wells (monitoring and production), many of which are sampled as part of the Kern Water Bank Groundwater Monitoring Program and for Kern Fan Water Banking Program monitoring.

- **California Department of Pesticide Regulation (CDPR) Data.** CDPR's well inventory dataset is used to monitor pesticides and compile sample data as part of its Groundwater Protection Program. The goal of this program is to improve understanding of the environmental impact and behavior of pesticides and develop pesticide-use practices that reduce threats to groundwater. There are seven wells in the GSA area with data reported by the CDPR from 1985 through 2016 (CDPR, 2018).

Subsidence Monitoring Programs

In the GSA area, subsidence monitoring is performed using continuous global positioning system (GPS) stations maintained by the University NAVSTAR Consortium's (UNAVCO) Plate Boundary Observatory (PBO) program. The National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) also provides interferometric synthetic aperture radar (InSAR) data for the Kern County region. There are no known extensometers in the GSA area.

- **UNAVCO PBO.** The UNAVCO PBO network consists of nearly 1,100 continuous GPS and meteorology stations in the western United States that monitor subsidence. There is one monitoring station in the vicinity of the GSA area east of the city of Taft that has reported ground elevation data from 2000 through 2018 (UNAVCO, 2019).
- **NASA JPL InSAR.** This dataset represents measurements of vertical ground displacement rates derived from InSAR data that are collected by the European Space Agency (ESA) Sentinel-1A satellite and that are processed by the NASA JPL, under contract with DWR. The data covers March 2015 through September 2016 (California Natural Resources Agency, 2018).

1.3.5 Existing Water Management Programs

KFMC Operations and Monitoring Program

The KFMC was established through an MOU among Kern Fan entities. Participants include KWBA participants and adjoining entities (i.e., those entities whose lands and/or banking projects are adjacent to the KWB). As part of the MOU, the KFMC operations and monitoring program was established to measure recharge, recovery, and water levels in wells, collect samples of surface water to be recharged, and collect groundwater quality samples. The KFMC monitors operations and groundwater account balances of projects on the Kern Fan and assesses project impacts. It also monitors the activities of surrounding groundwater districts (KFMC, 2012). WKWD GSA's North, South and Lake management areas are included in the KFMC's routine monitoring and reporting.

KFMC Operations and Monitoring Program's Influence on Water Demand and Chapter GSP Goals

KFMC's purpose is to monitor groundwater banking program management activities on the Kern Fan and monitor those of adjoining entities to ensure long-term sustainability of local groundwater resources. Sustainability is achieved through a collaborative effort across the Kern Fan Subregion to maintain GWEs and water quality that benefit the area. WKWD has a surplus of banked groundwater in excess of 200,000 acre-feet (AF) with an average annual demand of about 20,000 AF per year (AFY). WKWD will continue to bank water excess to maintain this operational buffer and provide sustainability well into the future. WKWD will continue to participate in the KFMC, and the wells monitored by the KFMC will be

incorporated into the broader GSP monitoring network. Data from this program will also be incorporated into the Umbrella GSP.

GSP's Influence on KFMC's Monitoring Program

Successful implementation of this Chapter GSP will help ensure that WKWD continues to manage groundwater sustainably. By continuing to participate in the KFMC monitoring program, WKWD will receive groundwater level data routinely that are related to its recharge and recovery activities. Implementation of this Chapter GSP will also establish a more robust and extensive groundwater-level monitoring network for WKWD, increasing the amount of data available.

WKWD Groundwater Management Plan

On November 29, 1995, WKWD's Board of Directors authorized preparation of a *Groundwater Management Plan* (GMP) and adopted the final plan in February 1997 (WKWD, 2016). The GMP's objectives were to protect the quality of WKWD's groundwater supply, promote and improve existing monitoring activities, and enable WKWD to identify and implement necessary means to preserve and enhance their groundwater resources.

WKWD currently monitors water levels in all wells and measures the total production at each production well on a monthly basis. Water levels from wells in the vicinity of WKWD's wellfield are monitored in a joint effort with the KCWA.

Water quality samples at these wells are collected as required by federal and state drinking water standards. General mineral, general physical, inorganic chemical, volatile organic, and synthetic organic chemical analyses are conducted once every three years. Radiological testing is conducted at each well once every four years for four consecutive quarters. Raw water well samples are also collected on a monthly basis from each operating well for bacteriological analysis.

The GMP also identified nine action items to increase the frequency and efficiency of monitoring efforts. These action items, although over 20 years old, are consistent with the goals set forth by this Chapter GSP.

These GMP action items are listed below, and a full copy of the GMP can be found in the WKWD *Urban Water Management Plans* (UWMPs) at http://www.wkwd.org/menus/urban-water-management-plan.html.

- Develop groundwater management program
- Assess hydrogeologic basin
- Develop conjunctive use program
- Evaluate wellfield
- Identify monitoring plan
- Manage groundwater contamination
- Protect wellhead and aquifer

- Develop well construction and abandonment plan
- Coordinate with land use and regulatory agencies

WKWD GMP's Influence on Chapter GSP Goals

WKWD's GMP suggests its current water management directly complements this Chapter GSP groundwater resource goals. GMP objectives include promoting monitoring activities, protecting groundwater quality, and preserving the groundwater resource. The GMP's action items (above) will be incorporated into this Chapter GSP, and its established monitoring networks and will be considered for development in future Chapter GSP updates, as appropriate.

GSP Influence on WKWD's GMP

Successful implementation of this Chapter GSP will help maintain WKWD's sustainable groundwater management practices. While some of the GMP's action items have already been implemented, development of this Chapter GSP and WKWD's monitoring networks will consider all the identified GMP action items to increase the frequency and efficiency of monitoring efforts, as needed.

WKWD Urban Water Management Plan

The WKWD UWMP describes the GSA area's water system, supplies and demands, reliability of water resources, and existing and planned water conservation measures to ensure that adequate water supplies are available to meet existing and future water needs. Per California Urban Water Management Planning Act requirements, the UWMP is prepared every five years to support WKWD's long-term resource planning (WKWD, 2016).

The UWMP also addresses Senate Bill X7-7 requirements. Enacted in November 2009, Senate Bill X7-7 requires a statewide per capita water use reduction of 20 percent by the year 2020. WKWD's 10-year baseline water use is 237 gallons per capita per day (gpcd), with a goal of 213 gpcd by 2015 and 189 gpcd by 2020. The actual per capita consumption in 2015 was 174 gpcd, which is below the 2020 target.

WKWD UWMP's Influence on GSP Goals

WKWD's UWMP stated goals are to "ensure adequate water supplies are available to meet existing and future water needs," which directly complements Chapter GSP objectives. The UWMP not only promotes efficient use of water supply but strengthens the Chapter GSPs goals of providing a long-term sustainable supply of groundwater for beneficial uses.

GSP Influence on WKWD's UWMP

Successful implementation of the GSP will help maintain WKWD's sustainable groundwater management program. Implementation of this Chapter GSP and its related monitoring networks will provide more robust and comprehensive data for WKWD with a focus on the North Project, South Project, and Lake management areas. Chapter GSP implementation will also promote the efficient use of water to promote sustainable supply, ensuring WKWD further meets or exceeds its water use reduction goal.

Tulare Lake Basin Portion of Kern County's 2011 Integrated Regional Water Management Plan

Kern County's *Integrated Regional Water Management Plan* (IRWMP) provides an overview of the water system for Kern County including water supply, water quality, interface with land use planning, and potential climate change impacts. The IRWMP describes monitoring, data reporting, identifies data gaps, and describes monitoring plan performance in Kern County. The IRWMP also provides a matrix of 26 water management strategies, divided into six categories. The IRWMP identifies which strategies are most applicable and appropriate for the nine subregions throughout the IRWMP region. According to the IRWMP, all 26 water management strategies apply to the Kern Fan subregion where WKWD is located. These strategies are listed below (KCWA 2011).

- Reduce water demand
  - Agricultural water use efficiency
  - Urban water use efficiency
- Improve operational efficiency and transfers
  - Conveyance – Sacramento-San Joaquin River Delta (Delta), and regional/local
  - System reoperation
  - Water transfers
- Increase water supply
  - Conjunctive management and groundwater storage
  - Desalination – brackish\seawater
  - Precipitation enhancement
  - Recycled municipal water
  - Surface storage – CALFED Bay-Delta Program (CALFED) and regional/local (now the Delta Stewardship Council)
- Improve water quality
  - Drinking water treatment and distribution
  - Groundwater/aquifer remediation
  - Matching quality to use
  - Pollution prevention
  - Salt and salinity management
  - Urban runoff management
- Practice resource stewardship
  - Agricultural lands stewardship
  - Economic incentives (loans, grants, water pricing)
  - Ecosystem restoration
  - Forest management
  - Land use planning and management

  - Recharge area protection
  - Urban land use management
  - Water-dependent recreation
  - Watershed management
- Improve flood management
  - Flood risk management

2011 Tulare Lake Basin Portion of Kern County IRWMP's Influence on Water Demand and Chapter GSP Goals

The 2011 Tulare Lake Basin portion of Kern County's IRWMP water management strategies and associated proposed projects for the Kern Fan subregion complement this Chapter GSP's strategies for beneficial use and conservation of groundwater resources. The primary objective of the IRWMP's strategies is to achieve sustainable yield and management of groundwater throughout the subregion, which directly aligns with the sustainability goals of this Chapter GSP.

Chapter GSP Influence on the 2011 Tulare Lake Basin Portion of Kern County IRWMP

Successful implementation of this Chapter GSP will help maintain WKWD's sustainable management of groundwater resources. Many of the strategies identified in the IRWMP were incorporated into this Chapter GSP during development, and all strategies will be considered during both project implementation and future Chapter GSP updates.

Kern County General Plan

Because of the interrelationship between water supplies, land use, conservation, and open space, the Land Use, Conservation, and Open Space Element sections of the *Kern County General Plan* are the most relevant elements for development of this Chapter GSP. These plan elements provide for a variety of land uses for future economic growth while also assuring the conservation of Kern County's agricultural and natural resources.

Relevant Kern County General Plan Goals and Policies

The following *Kern County General Plan* Land Use, Conservation, and Open Space Element goals and policies related to groundwater use would potentially influence implementation of this Chapter GSP (Kern County, 2009):

- Goal 1.4.5: Ensure that adequate supplies of quality water (appropriate for intended use) are available to residential, industrial, and agricultural users in Kern County.
- Policy 1.4.2: The efficient and cost-effective delivery of public services and facilities will be promoted by designating areas for urban development which occur in or adjacent to areas with adequate public service and facility capacity.
- Policy 1.4.2.a: Ensure that water quality standards are met for existing users and future development.
- Goal 1.6.6: Promote the conservation of water quantity and quality in Kern County.

- Goal 1.6.7: Minimize land use conflicts between residential and resource, commercial, and industrial land uses.
- Policy 1.6.11: Provide for an orderly outward expansion of new urban development so that it maintains continuity of existing development, allows for the incremental expansion of infrastructure and public service, minimizes impacts on natural environmental resources, and provides a high-quality environment for residents and businesses.
- Policy 1.9.10: To encourage effective groundwater resource management for the long-term economic benefit of the county, the following shall be considered:
- Policy 1.9.10.a: Promote groundwater recharge activities in various zone districts.
- Policy 1.9.10.c: Support the development of groundwater management plans.
- Policy 1.9.10.d: Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water and groundwater and desalination.
- Goal 1.10.1: Ensure that the county can accommodate anticipated future growth and development while maintaining a safe and healthful environment and a prosperous economy by preserving valuable natural resources, guiding development away from hazardous areas, and assuring the provision of adequate public services.
- Policy 1.10.6.39: Encourage the development of the county's groundwater supply to sustain and ensure water quality and quantity for existing users, planned growth, and maintenance of the natural environment.
- Policy 1.10.6.40: Encourage utilization of community water systems rather than the reliance on individual wells.
- Policy 1.10.6.41: Review development proposals to ensure adequate water is available to accommodate projected growth.

Kern County General Plan's Influence on Water Demand and Chapter GSP Goals

Relevant *Kern County General Plan* goals and policies about future land use development and conservation complement Chapter GSP use and conservation of groundwater resource goals. The *Kern County General Plan* explicitly encourages development of the county's groundwater supply to ensure that existing users have access to high quality water, and states that future growth should be accommodated only while ensuring that adequate high-quality water supplies are available to existing and future users.

Chapter GSP Influence on Kern County's General Plan Goals and Policies

Successful implementation of this Chapter GSP will help maintain WKWD's sustainable groundwater management program. Given the small portion of the GSA area that is the focus of Chapter GSP management, and since the Western Management Area is predominantly barren or oil fields, it is anticipated that Chapter GSP implementation will have little to no effect on the *Kern County General Plan*'s goals related to sustainable land use development in Kern County.

1.3.6 Permitting New or Replacement Wells

WKWD will default to the existing permitting processes utilized by Kern County, but requests that all wells designed to pump above de minimis levels be reviewed by WKWD GSA staff. This will provide the option to incorporate the well into the DMS system and ensure that water pumped or injected via the new or replacement well is recorded in the water budget. Details on the process to permit wells with Kern County are available at: https://kernpublichealth.com/water-wells/.

1.3.7 Conjunctive Use Programs in the Subbasin

WKWD has been banking water in the Kern Fan subregion area since 1966. All surface water deliveries to WKWD are transported through the California Aqueduct and other surface water conveyance facilities, where it is banked and later recovered from WKWD's wellfield or delivered directly to industrial customers.

By agreement, BVWSD takes direct delivery of WKWD's SWP Table A water and, in exchange, BVWSD delivers a like amount of Kern River supplies for recharge on WKWD's North Project and South Project management areas.

As of 2018, WKWD has banked approximately 200,000 AF of water. Through banking and exchange programs, other agencies owe WKWD an additional 24,000 AF. Therefore, WKWD's total banked water assets are approximately 224,000 AF. Currently, WKWD has maintained a positive balance in the banking program, and has approximately a 10-year supply currently banked (WKWD, 2016).

1.3.8 Plan Elements from California Water Code Section 10727.4

The plan elements from CWC Section 10727.4 require GSPs to address the components listed in Table 1-5. Each component is coordinated at the Subbasin level, and is addressed in the Umbrella GSP.

Table 1-5. Plan Elements from CWC Section 10727.4

Element	Location
(a) Control of saline water intrusion.	Umbrella GSP
(b) Wellhead protection areas and recharge areas.	Umbrella GSP
(c) Migration of contaminated groundwater.	Umbrella GSP
(d) A well abandonment and well destruction program.	Umbrella GSP
(e) Replenishment of groundwater extractions.	Umbrella GSP
(f) Activities implementing, opportunities for, and removing impediments to, conjunctive use or underground storage.	Umbrella GSP
(g) Well construction policies.	Umbrella GSP
(h) Measures addressing groundwater contamination cleanup, groundwater recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects.	Umbrella GSP

Table 1-5. Plan Elements from CWC Section 10727.4

Element	Location
(i) Efficient water management practices, as defined in Section 10902, for the delivery of water and water conservation methods to improve the efficiency of water use.	Umbrella GSP
(j) Efforts to develop relationships with state and federal regulatory agencies.	Umbrella GSP
(k) Processes to review land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity.	Umbrella GSP
(l) Impacts on groundwater dependent ecosystems.	Umbrella GSP

1.4 Outreach and Engagement

The KGA conducted outreach and engagement efforts at the Subbasin scale. These efforts are documented in the Umbrella GSP. These efforts include:

- A description of beneficial uses and users
- A list of public meetings
- GSP comments and responses
- Decision-making process
- Public engagement
- Encouraging active involvement
- Informing the public on GSP implementation progress

WKWD is the only user of groundwater above de minimis levels within the GSA area. Outreach performed by the KGA, as documented in the KGA's Umbrella GSP was intended to reach stakeholders within the WKWD GSA area. Because WKWD is the only user of groundwater above de minimis levels within the GSA area, Chapter GSP comments and responses were conducted through Subbasin coordination and with the Umbrella GSP.

1.4.1 Decision Making process

The WKWD GSA is governed by a board of directors who also serve as the board of directors for the WKWD. Decisions are made by majority at a meeting of the board where a quorum is present.

1.4.2 Public Engagement, Stakeholder Involvement, and GSP Implementation Progress

WKWD is the only user of groundwater above de minimis levels within the agency area. Outreach performed by the KGA, as documented in the KGA's Umbrella GSP was intended to reach stakeholders within the WKWD GSA area.

WKWD held a public workshop on July 22, 2019 to review the components of the WKWD Chapter GSP.

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Section 2.0 Basin Settings: Hydrogeologic Conceptual Model

2.1 Compliance Information

Table 2-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

Table 2-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 2.12
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.14	Hydrogeologic Conceptual Model	Description of the Hydrogeologic Conceptual Model	Section 2.0
		Two scaled cross sections	Umbrella GSP
		Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	Section 1.0 Section 2.5 Section 2.10
354.14(c)(4)	Map of Recharge Areas	Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas	Section 2.10
	Recharge Areas	Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	Section 2.10 and Umbrella GSP

2.2 Introduction

Basin settings information is composed of three Chapter GSP sections as follows:

- **Hydrogeologic Conceptual Model (HCM)**—this HCM section (Section 2.0) provides the geologic information needed to understand the framework that water moves through the Basin. It focuses on geologic formations, aquifers, structural features, and topography.
- **Groundwater Conditions**—The groundwater conditions section (Section 3.0) describes groundwater trends, levels, hydrographs and level contour maps, estimates, and changes in groundwater storage. It also identifies groundwater quality issues, and addresses subsidence and surface water interconnection.

- **Water Budget**—The water budget section (Section 4.0) provides information about the data used for water budget development and discusses how the water budget was calculated.

2.3 Hydrogeologic Conceptual Model Definition

This section describes the HCM for the GSA area. The HCM has a specific role in understanding the GSA area, and according to the DWR GSP requirements specified in the *Hydrogeologic Conceptual Model BMP*, the HCM provides the following (DWR 2016):

- Provides an understanding of the general physical characteristics related to regional hydrology, land use, geology geologic structure, water quality, principal aquifers, and principal aquitards of the basin setting
- Provides the context to develop water budgets, mathematical (analytical or numerical) models, and monitoring networks
- Provides a tool for stakeholder outreach and communication

This HCM was developed to understand and convey information about the physical conditions by which water moves through the GSA area. The HCM is also used elsewhere in this Chapter GSP to understand the distribution and movement of water within the GSA area, which will support the development of water budgets.

2.4 Useful Terms

This HCM section includes descriptions of the geologic formations and structures, aquifers, and properties of geology related to groundwater, among other related components. A glossary of pertinent technical terms is below. The glossary is intended to guide readers through this subsection, and is not a definitive definition of any term:

- **Aquifer**—An aquifer is an underground reservoir of water stored within the pores and fractures of rocks and sediments.
- **Aquitard**—An aquitard is a layer of strata that has a low conductivity that groundwater flows very slowly through. Aquitards can be regional, such as the Corcoran Clay in the Central Valley, where it prevents flow from upper strata to lower strata across the western side of the valley, or it can be localized, which is common in most alluvial settings. Localized aquitards restrict vertical flows in a small region of an aquifer, and water will generally move laterally around localized aquitards as it flows by gravity toward the bottom of the aquifer.
- **Basement complex**—The basement complex is comprised of the oldest and deepest rocks in the subsurface. Basement rocks are typically crystalline and metamorphic or igneous in origin, and groundwater generally only moves through fractures in the rock instead of pore spaces like in sedimentary rocks. No sedimentary layers are found below basement rocks.

- **Confined aquifer**—A confined aquifer is an aquifer that has an impermeable layer above it, and is pressurized by the weight of water pushing down into the aquifer. Confined aquifers are measured by measuring their potentiometric surface, which is the elevation that water rises to in a well due to pressure in the aquifer.
- **Formation**—A formation, or geologic formation, is a unit of rock of similar properties, such as grain size, mineral composition, or depositional environmental. Geologic formations are distinct from surrounding rock types and are large enough to be mapped regionally. If a formation contains a dominant rock type, such as sandstone, it may be included in the name of the formation.
- **Hydraulic conductivity**—Hydraulic conductivity is defined as the "measure of a rock or sediment's ability to transmit water," typically measured in feet or meters per unit of time (day, hour, minute) (DWR, 2003). Rocks and sediments with high conductivity values, such as gravels or coarse sands, can sustain groundwater flow better than rocks and sediments with low conductivity values. Rocks and sediments with near zero values of hydraulic conductivity, such as very fine-grained sandstones, shale, or granites, do not transmit groundwater and are considered barriers to flow. Conductivity values are used in a groundwater model to determine how quickly formations transmit groundwater and where barriers to groundwater flow (i.e., formations with very low conductivity values) exist.
- **Primary aquifer**—GSP regulations require that primary aquifers are identified, and the GSP must identify which aquifers require specific monitoring and management. Primary aquifers are regionally extensive and are sources groundwater used for beneficial uses.
- **Unconfined aquifer**—An unconfined aquifer is an aquifer that does not have an impermeable layer above it (such as a clay layer). An unconfined aquifer has an upper water surface defined as the water table and is at atmospheric pressure. Water seeps from the ground surface directly into the aquifer, as there are no impermeable layers to prevent water from entering the aquifer.
- **Water bearing formation**—A water bearing formation is a rock formation that is saturated and contains water within the pores or fractures of the unit. One or more water bearing formations compose an aquifer.

2.5 Regional Geologic and Structural Setting

The GSA area lies within the Central Valley of California, which runs approximately 400 miles north to south and approximately 50 miles inland from the Pacific Ocean. The Central Valley comprises about 20,000 square miles (Page, 1986). The Central Valley can be subdivided into the Sacramento Valley to the north and the San Joaquin Valley to the south where the GSA area is located. The San Joaquin Valley is a geosynclinal trough of low relief bounded by the Sierra Nevada Ranges to the east and the Diablo, Temblor, and San Emigdio mountains of the Coast Ranges to the west. The geosyncline is asymmetrical, with the western flank steeper than the relatively eastern flank. The eastern side of the San Joaquin Valley, which is the western portion of the Sierra Nevada fault block, is characterized by tension faults and gently folded anticlines (Hoots et al., 1954). In contrast, the western side of the San Joaquin Valley is steeply tilted, overturned, and cut by thrust faults originating from compressional forces driven by orogenic processes and lateral movement along the San Andreas fault during the Pleistocene (Hoots et al., 1954). The western side of the San Joaquin Valley is rich in oil and petroleum reservoirs, another effect of the folding and faulting activities that resulted in unconformities between geologic formations

(particularly of Cretaceous age or older), creating stratigraphic traps for oil and petroleum (Hoots et al., 1954). This environment has resulted in the San Joaquin Valley being one of the most important oil-producing areas in California (Wood and Davis, 1959).

The trough of the San Joaquin Valley is cut through the igneous and metamorphic crystalline rocks of the Sierra Nevada and Tertiary age marine rocks of the Coast Ranges, and is filled by sediments of deep marine, shallow marine, deltaic, and continental origin (Faunt et al., 2009). The fill deposits range in thickness from zero (i.e., sea level) on the eastern edge of the San Joaquin Valley to more than 50,000 feet on the western edge (Faunt et al., 2009). The continental sediments consist of basin-fill and/or lake deposits of sand and gravel interbedded with fine-grained materials, such as clay and silt and were delivered to the valley trough by major streams and tributaries (Faunt et al., 2009).

The San Joaquin Valley is characterized by four distinct geomorphic units: dissected uplands, low plains and fans, river flood plains and channels, and overflow lands and lake bottoms (Wood and Davis, 1959). The GSA area is located within regions of the dissected uplands (i.e., Elk Hills, Buena Vista Hills, and Little Signal Hills) and the river flood plains and channels. Generally, the land surface has low relief interrupted by low hills that reflect local anticlines (Hoots et al., 1954).

2.5.1 Geologic History

The southern San Joaquin Valley has been developed through periods of deformation and deposition, influenced by tectonic subsidence and cycles of marine transgression and regression. The deepest sediments in the GSA area were deposited within a marine environment associated with an inland sea that inundated the San Joaquin Valley between 200 million years ago (Jurassic Period) and 2 million years ago (end of the Tertiary Period) (Croft, 1972). Thick deposits of coarse-grained sediments at depths ranging from 300 to about 3,000 feet accumulated where the streams of the alluvial fan dropped most of their remaining load as they entered lakes and marshes around the Tulare Lake Bed (Croft, 1972). Deeper marine sediments are overlain by approximately 2,400 feet of nonmarine continental deposits associated with an alluvial environment (Planert and Williams, 1995). Throughout the depositional history of the Basin, sediment was supplied by the rising Coast Ranges, Transverse Ranges, and the Sierra Nevada.

Detailed geologic cross sections of the Kern County Subbasin are provided in the Umbrella GSP.

2.5.2 Geologic Formations/Stratigraphy

Geologic formations present within the GSA include unconsolidated to partly consolidated continental sedimentary deposits of Tertiary and Quaternary age overlying consolidated Tertiary-age marine sedimentary rocks on top of pre-Tertiary crystalline gabbro bedrock (Croft, 1972). The primary water-bearing units in the Subbasin are two-fold: fresh water is found in the coarse, unconsolidated, and oxidized continental deposits and alluvium, while brackish to saline water is found in the Tertiary age marine and continental sedimentary rocks (Croft, 1972). These units are described in further detail in Section 2.8.1. Two nearly impermeable clay layers, known as the A and E clays, impede groundwater flow in the GSA's North Project Management Area, dividing the unconfined, freshwater aquifer from the brackish, confined to semi-confined aquifer, all while dividing the alluvial sequences into separate aquifers (Croft, 1972). The E clay is not present within the GSA's South Project Management Area. Individual geologic units found in the Subbasin in the GSA area are described in detail below, in order of youngest to oldest in deposition. Geologic units mapped at the surface are shown in Figure 2-1.

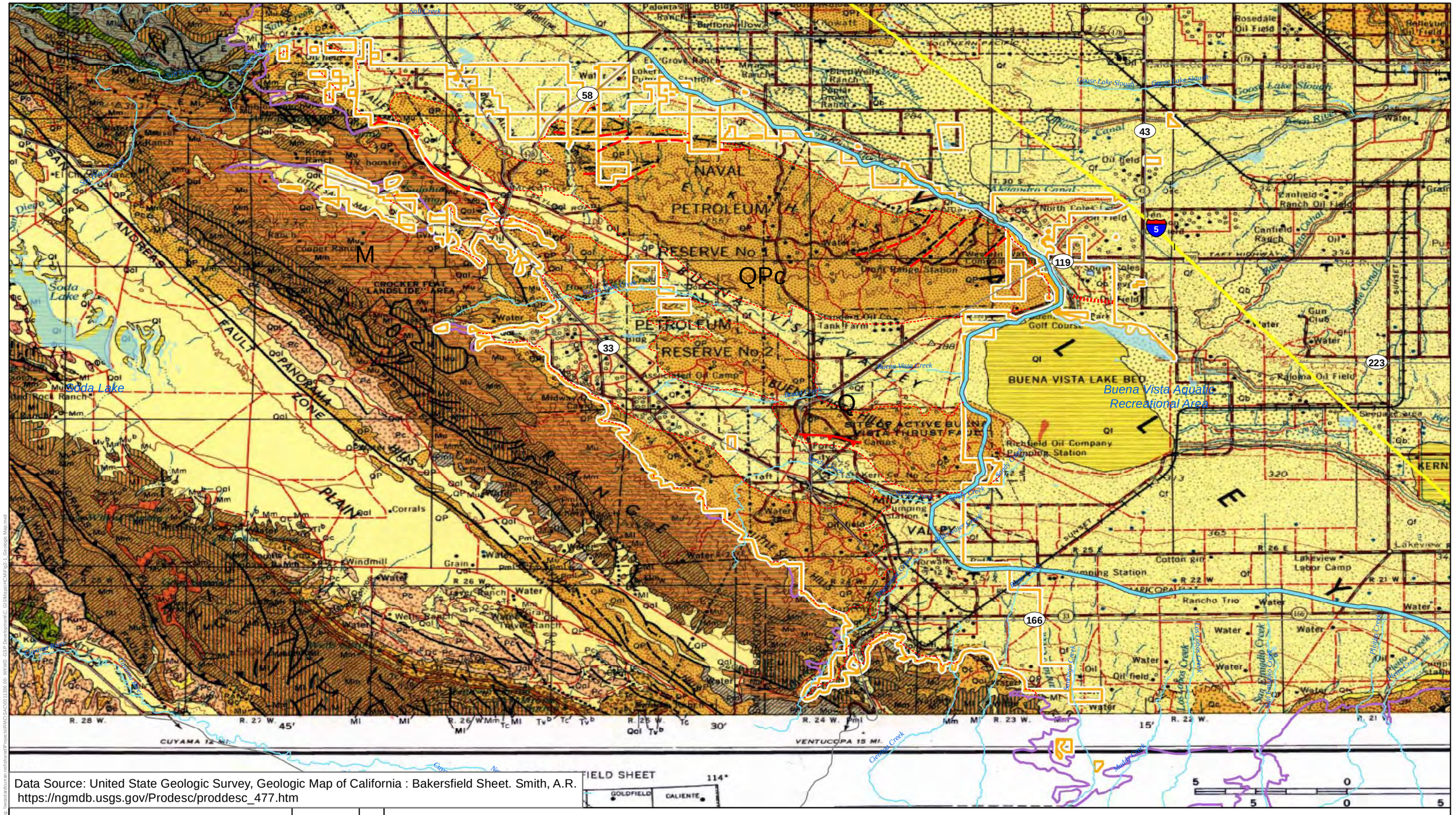
Stratigraphic Units of the Subbasin Aquifers in the GSA area

Stratigraphic units in this section are presented in order from youngest to oldest. Generally, water-bearing formations are limited to continental fill-deposits. The stratigraphic column highlights the clay lenses present throughout the subsurface and the variable thicknesses of the geologic units, roughly thickening to the east.

Recent Alluvium and Flood Basin Deposits

The youngest deposit in the Subbasin in the GSA area is the recent alluvium and flood basin deposits of the Kern River Fan complex; they are Holocene in age (DWR, 2006). These flood basin deposits are difficult to distinguish from the underlying fine-grained alluvium; as a result, they are grouped stratigraphically together (DWR, 2006). The Recent Alluvium is composed of unconsolidated valley and stream deposits with interstratified and discontinuous beds of clay, silt, sand, and gravel (Smith, 1964). The alluvium fines to the southwest where it grades into the fine-grained flood basin deposits underlying the historical lake beds. The flood basin deposits include silt, silty clay, sandy clay, and clay interbedded with poorly permeable sand layers. The deposits are sourced primarily from the western Coast Ranges and, to a lesser extent, from the eastern Sierra Nevada Ranges. Sediment sources can be differentiated by degree of reduction; oxidized deposits represent subaerial deposition while reduced deposits represent a subaqueous deposition (Croft, 1972). A contact between the oxidized and reduced deposits transgresses the alluvial deposits sourced from the Sierra Nevada (Croft, 1972). Since the Coast Ranges consist mainly of marine shale and sandstone, its derived sediments are composed of very fine-grained sediments (Dale et al., 1966).

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NAVAL PETROLEUM RESERVE No 1
NAVAL PETROLEUM RESERVE No 2
QPc
Q
M
BUENA VISTA LAKE BED
Buena Vista Aquatic Recreational Area
Soda Lake
CRACKER FLAT LANDSLIDE AREA
ANDREAS FAULT
PANOCHE FAULT ZONE
BUENA VISTA VALLEY
Richfield Oil Company Pumping Station
Lakeview Labor Camp
Rancho Trio
Cantfield Ranch Oil Field
Rosedale Oil Field
Ralphs Oil Field
Lakeview Oil Field
Cotton Gin
Windmill
Corrals
Grain
Water
Oil field
Golf Course
Tank Farm
Pumping Station
Camp
Ranch
Creek
Canal
Slough
Lake
River
Buena Vista Creek
Goose Lake Slough
Cuyama Creek
Cienega Creek
Mud Creek
Los Lobos Creek
San Emigdio Creek
Pleito Creek
Santiago Creek
Caliente Creek
Kern River
Kern Island Canal
Calloway Canal
Beardsley Canal
Buena Vista Canal
Lerdo Canal
Sunset Canal
Outside Canal
Famoso Canal
Shafter-Wasco Irrigation District
Arvin-Edison Water Storage District
Semitropic Water Storage District
Wheeler Ridge-Maricopa Water Storage District
Tejon-Castac Water District
Kern County Water Agency
Kern Water Bank
Pioneer Project
Kern Water Bank Authority
Kern Water Bank Canal
Kern Fan Element
Pioneer Canal
Pioneer Drainage Canal
Pioneer Groundwater Recharge and Recovery Project
Pioneer Project Boundary
Pioneer Project Buffer
Pioneer Project Intertie
Pioneer Project Turnout
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The Recent Alluvium and flood basin deposits are widespread throughout the GSA area, and are exposed throughout the low plains and stream channels between the hills. The thickness and character of the alluvium and flood basin deposits vary throughout the Subbasin, but at maximum, the total thickness reaches 1,000 feet (DWR, 2006). The Younger Alluvium and flood basin deposits are permeable; however, they are not the major source of groundwater in the GSA area.

Older Alluvium

Older Alluvium, which includes stream and terrace deposits, are composed of loosely consolidated to cemented lenticular deposits of clay, silt, sand, and gravel (DWR, 2006). These deposits are exposed at the subbasin margins. The unit is Pliocene to Pleistocene nonmarine sedimentary deposits, consisting mainly of slightly consolidated and dissected fan deposits (Smith, 1964). The deposits are composed of generally poorly sorted silty materials containing lenticular bodies of sand and gravel derived from the Coast Ranges that were deposited by streams. Arkosic sand and gravel are derived from the Sierra Nevada Range, while clay and mudstones are sourced from the Coast Ranges (Dale et al., 1966).

Older Alluvium is one of the principal water-bearing formations in the Subbasin and yields large quantities of water due to its moderately to highly permeability (DWR, 2006). The Older Alluvium and stream and terrace deposits, along with the Tulare Formation, compose the principal aquifer in the Subbasin (DWR, 2006). The Older Alluvium unconformably overlies the Tulare Formation.

A Clay

The A clay is a shallow aquitard locally present throughout the Subbasin. The A clay is a fine-grained lacustrine or paludal (i.e., marsh) deposit composed of plastic silty sandy gypsiferous highly organic clay (Croft, 1972). The A clay ranges in color from blue, olive brown or dark greenish gray (Croft, 1972). In some areas, the clay is interbedded with stringers of fine to medium sand and/or several thin clay layers separated by thin beds of sand. The A clay layer is typically less than 60 feet thick and occurs at shallow depths ranging from 10 to 60 feet below ground surface (bgs) (Croft, 1972). The A clay is considered Pleistocene and Holocene in age (Croft, 1972). The presence of A clay is limited to the southeasternmost edge of the GSA area, near the Buena Vista Lake bed and intersection of Route 119 and the California Aqueduct. This unit is not present in the wellfields of the GSA's North or South Project management areas.

Tulare Formation

The Pliocene to Pleistocene-aged Tulare Formation consists of alternating beds of sand and mudstone and includes the Corcoran Clay member. The Tulare Formation is highly variable in thickness and composition throughout the San Joaquin Valley and has an eastern facies equivalent known as the Kern River Formation. Generally, the Tulare Formation is a continental deposit of unconsolidated to poorly consolidated continental units that are predominantly silty sediments with lenses and stringers of poorly sorted coarse sand and gravel predominantly sourced from the Coast Range (Wood and Davis, 1959). Locally, the Tulare Formation includes thin beds of argillaceous limestone, marl, diatomaceous clay, marly silt, and shale (Smith, 1964; Wood and Davis, 1959). Near Elk Hills, the Tulare Formation is a varying combination of gypsiferous mudstone, sand, sandstone, siltstone, and shale (Provost & Pritchard Consulting Group [Provost & Pritchard], 2019). Spatially, the sandy and gravelly coarse-grained

sediments underlie the northern, eastern, and southern portions of the Tulare Formation at depths greater than 1,800 feet, while most of the silty and clayey sediments are found at depths below 1,400 feet in the western and central parts of the Tulare Formation. Below 1,400 feet, fine-grained sediments are widespread and represent the base of the formation at 2,400 to 2,800 feet bgs (Page, 1983). The base of the Tulare Formation is defined as the layer just above the upper Mya zone of the San Joaquin Formation, which represents a gradual transition from marine to lacustrine environments (Dale et al., 1966). The Tulare Formation lies conformably above the San Joaquin Formation. The Buena Vista, Elk, and Little Signal hills are composed of deformed and folded Tulare Formation (Provost & Pritchard, 2019). To the south and west of the GSA area, the Tulare Formation truncates oil bearing rocks. Coarse sediments in the Tulare Formation are moderately permeable and yield water.

Corcoran Clay Member

The lower member of the Tulare Formation includes the Corcoran Clay member, which is a regionally extensive lacustrine clay that serves as a confining layer separating the shallow semi-confined to unconfined aquifer system from a deeper confined aquifer system. Locally, an alluvial deposit of rhyolitic ash overlies the Corcoran Clay layer (Croft, 1972). Within the GSA area, the Corcoran Clay member is present in the North Project Management Area, where WKWD wells are screened above the Corcoran Clay member. The Corcoran Clay member is not present in the South Project Management Area, which allows wells to extend to greater depths.

E Clay

The E clay is the principal aquitard in the Subbasin and throughout the San Joaquin Valley (Croft, 1972). The E clay includes the Corcoran Clay member of the Tulare Formation and is the most extensive hydrologic confining layer in the San Joaquin Valley (Croft, 1972). This confining layer is composed of silty clay, clayey silt, and sand, silt, and clay and is typically found at depths of approximately 700 to 800 feet bgs in the North Project Management Area (Croft, 1972). The characteristically blue color of E clay has earned it the nickname “blue clay.” Within the GSA area, E clay is blue silty, sandy, clay and is typically less than 75 feet thick (Croft, 1972). The layer is fossiliferous and contains marine fossils of middle to late Pleistocene age.

The E clay stratum is highly warped and creates an asymmetric, northwesterly trending syncline of which the axis lies south of the present San Joaquin Valley trough. The E clay bifurcates into an upper and lower stratum that contain thin beds of moderately yellowish-brown silt and fine sand, representing the early transgression of Corcoran Lake. Based on the age of fossil diatom assemblages found in the stratum, the E clay layer is Pleistocene in age.

The E clay is not regionally present in the GSA area; from west to east, it first appears at the eastern foothills of Elk Hills at depths of 100 feet bgs and extends east toward the East Side Canal (Croft, 1972). The E clay is present within the GSA’s North Project Management Area but not within the South Project Management Area.

Santa Margarita Formation

The Santa Margarita Formation is a well shorted gray and white sandstone interbedded with gravel and shale and ranges in thickness from 100 to 400 feet thick (Croft, 1972). Locally, the formation includes very coarse fanglomerate and granitic breccia near the Temblor and Caliente ranges, along the western margin of the GSA area. The formation is upper Miocene in age and represents the final phase of marine sedimentation and sea transgression (Lagoe, 1981). The Santa Margarita Formation is not exposed at the surface within the GSA area, but is exposed directly west of the Subbasin boundary in the Temblor Range.

The Santa Margarita Formation is highly permeable and is a source of water in confined aquifers in the western and eastern margins of the Subbasin, including within the GSA area, where the groundwater is of suitable water quality (Croft, 1972).

Olcese Formation

The Olcese Formation consists of unconsolidated sandstone with interbedded pebble and siltstone beds (Smith, 1964). The formation is both continental and marine in origin, representing a sea level regression from east to west during the Miocene age (DWR, 2006). The Olcese Formation ranges in thickness from 100 to 450 feet (DWR, 2006). In the northeastern portion of the Subbasin, outside of the GSA area, the Olcese Formation is a source of drinking water in confined aquifers. The highly saline sands in the Olcese Formation result in groundwater that is more saline than aquifers in formations overlying and underlying the Olcese Formation. The saline difference separates aquifers into upper and lower sources of drinking water, based on the salinity content. Sands in the Olcese Formation are more saline along the western margin of the Subbasin and the GSA area (Gillespie et al., 2017). The Olcese Formation is not exposed within the GSA area but does outcrop directly west of the GSA's jurisdiction in the Temblor Range. The Olcese Formation underlies the Etchegoin Formation.

Stratigraphic Units Below the Subbasin Aquifer in the GSA Area

San Joaquin Formation

The San Joaquin Formation consists of blue and green fine-grained silty sands, silt, and clay (Foss and Blaisdell, 1968). The San Joaquin Formation was formed during the late Pliocene to early Pleistocene age, when the Central Valley was an inland sea. The San Joaquin Formation is predominantly marine in origin and a suite of marine fauna, including mollusks, Pecten, Mya, and gastropods, are commonly found within the coarser grained sand, sandstones, and conglomerate layers (Foss and Blaisdell, 1968). There is only one recognizable member of the San Joaquin Formation, the Cascajo Conglomerate, which is located at the base of the formation and is characterized by fossil and lithic components (Foss and Blaisdell, 1968). The San Joaquin Formation ranges in thickness from 1,500 to 4,200 feet (Foss and Blaisdell, 1968; USGS, 1996). The Midway-Sunset and Kettleman Hills oil production wells are found in the San Joaquin Formation (Foss and Blaisdell, 1968). The San Joaquin Formation is conformably overlain by the Tulare Formation and underlain by the Etchegoin Formation.

Etchegoin Formation

The Etchegoin Formation consists of marine blue and brown sandstones, poorly sorted blue or blueish gray shales, and pebble conglomerates (Foss and Blaisdell, 1986). Sands within the formation contain oil and gas. Strata of the Etchegoin Formation contain a mix of fresh and marine water molluscan assemblages and is mid to early Pliocene in age (Foss and Blaisdell, 1986). The Etchegoin Formation occurs mainly on the west side of the San Joaquin Valley and is up to 4,360 feet thick (Foss and Blaisdell, 1968). The Etchegoin Formation includes middle sand, lower shale, and basal sand members, respectively known as the Jacalitos, Bitterwater Creek, and Panorama Hills Formations. The Bitterwater Creek Formation is a semi-siliceous shale up to 3,000 feet thick that grades to the northwest into a marine sandstone (Foss and Blaisdell, 1968). The Jacalitos Formation contains diatomite shale and sand and is often referred to as the "Lower Etchegoin" (Foss and Blaisdell, 1968). The Panorama Hills Formation is a non-marine pebble gravel layer in the Lower Etchegoin and grades into the Bitterwater shale to the southeast, adjacent to the San Andreas Fault (Foss and Blaisdell, 1968). To the east, the Etchegoin Formation grades into the Kern River Formation (Foss and Blaisdell, 1968). The Etchegoin Formation lies unconformably on the Santa Margarita Formation (Croft, 1972).

The upper portion of the Etchegoin Formation was the most productive oil-bearing bed and dry-gas zone within the Elk Hills production zone in 1932 (Woodring et al., 1932).

Monterey Shale

The Monterey Shale is a brown, organic, bituminous, siliceous shale with some local thin limestone beds (Jennings and Strand, 1969). The Monterey Shale represents a period of sea level regression and a depositional environment like the Etchegoin Formation (Woodring et al., 1932). It is also known and mapped as Maricopa Shale in the Santa Margarita Formation. The Monterey Shale is divided into a lower part, principally of mud and siliceous shales and diatomite, and an upper part consisting of soft, punky diatomite and coarse detrital deposits (Woodring et al., 1932). The Monterey Shale hosts several fossil species, including diatoms, radiolarians, sponge spicules, and other foraminifera (Woodring et al., 1932). In the southwest portion of the GSA area near the city of Maricopa, the Monterey Shale is up to 4,800 feet thick and increases in thickness further south (Woodring et al., 1932). The Monterey Shale unconformably underlies the Etchegoin Formation along the western mountain front.

The Monterey Shale is regarded as the source of oil in the western portion of the San Joaquin Valley and is within the two petroleum reserves in the GSA area, in Elk Hills and Buena Vista Hill (Woodring et al., 1932).

Sierra Nevada Batholith (Basement Complex)

The basement complex in the Subbasin and in the GSA area is composed of plutonic and metamorphic rocks, commonly referred to as the Sierra Nevada batholith (Croft, 1972). The surface of the basement complex slopes approximately 3 to 5 degrees southwest from the base of the foothills toward the San Joaquin Valley floor (Croft, 1972). In the southeast portion of the GSA area near the Buena Vista Lake bed, the basement complex is buried more than 20,000 feet deep by younger marine and continental rocks of the Cretaceous, Tertiary, and Quaternary ages (Croft, 1972). Though fractures and joints in the

basement complex may produce groundwater, no wells reach this depth, and the unit is not considered an important part of the groundwater aquifer (Dale et al., 1966).

2.6 Faults and Structural Features

The GSA area contains a number of tectonic features including faults, synclines, anticlines, and a major arch (Figure 2-2), which are described below.

2.6.1 Synclines and Anticlines

There are a number of fold structures present in the older sediments in the GSA area, including the Buena Vista Syncline and several anticlines. In general, these fold structures trend and plunge from the northwest to southwest across the GSA area (Gillespie et al., 2017). Several known anticlinal folds in the GSA area and Subbasin restrict movement of groundwater.

Synclines

Synclines are structural folds where the youngest formations are located closest to the trough of the fold. Formations underlying the youngest formation presumably follow the basic law of geochronology where they increase in age of deposition.

Buena Vista Syncline

The Buena Vista Syncline runs approximately 25 miles through the GSA area, parallel to western edge of the Buena Vista Hills through Midway Valley. Development and deepening of the syncline occurred during the uplift of the Elk and Buena Vista hills (Woodring et al., 1932). The syncline is not believed to restrict the movement of groundwater.

Unnamed Syncline

An unnamed syncline is mapped within the extent of the GSA area and cuts through the North Project Management Area. The syncline trends roughly northwest to southeast throughout the GSA area (Jennings, 2010).

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Salt Creek
Tehachapi Creek
Salt Creek
San Diego Creek
58
Goose Lake Slough
Goose Lake Slough
43
5
Elk Hills
119
Buena Vista Creek
33
223
Buena Vista Creek
Broad Creek
Sandy Creek
Sandy Creek
Sandy Creek
Sandy Creek
Buena Vista Fault Creep
Bitterwater Creek
Bitterwater Creek
Bitter Creek
166
Santiago Creek
Los Lobos Creek
San Emigdio Creek
Pleitito Creek
Pleito Creek
Cienaga Creek
Middle Creek
Wells Creek
Bitter Creek
Cayama River
New River
The Wash

Anticlines

- anticline, certain
- dbl. plunging anticline, certain
- plunging anticline, certain
- anticline, concealed
- plunging anticline, concealed
- syncline, certain
- syncline, concealed
- syncline, concealed (multisym)
- fold axis, certain
- fold axis, concealed
- plunging fold axis, certain

Figure 2-2: WKWD GSP GSA Area Geology

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

Fault Classification

- Fault
- Approximate fault
- Thrust fault

Recency of Movement

- Historic
- Quaternary

N

0 3 6 12 Miles

Figure Exported: 12/5/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\RMC\SA\O0011338.00- WKWD -GSP Development\C. GIS\Maps\HCM\Fig2-2 Geology.mxd

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Anticlines

Anticlines are structural folds where the oldest formations are located at the core of the fold and younger formations drape over in sequential order.

Elk Hills-North Coles Levee Anticline

The Elk Hills, located in the eastern margin of the GSA area, are a surficial expression of a large subsurface anticline, known as the Elk Hills-North Coles Levee anticline. The anticline consists of two main anticlinal folds, a western and eastern fold, arranged en echelon (Woodring et al., 1932). The anticline, as expressed at the surface at Elk Hills, strikes to the northwest, roughly parallel to the axis of the San Joaquin Valley, and plunges to the southeast (Hoots et al., 1954). The anticline is approximately 17 miles long and 6 miles wide. The anticline is the result of folding that occurred during the early Pliocene age, consistent with regional uplift (Wood and Davis, 1959). The anticlines were first noted in 1910 after observing gypsum deposits on the upgradient side of the anticline, similar to gypsum deposits at the Lost Hills anticline (located northeast of the GSA area) (Hess, 1910; Provost & Pritchard, 2019).

In addition, there are a series of narrow anticlines that interrupt the slope of the hills and almost surround them (Woodring et al., 1932). The anticlines in the Elk Hills have been eroded primarily by streams to varying depths, and often serve as drainage features to the hills (Woodring et al., 1932). The anticline transverses the length of the Elks Hills, which are the topographic expression of anticlinal structures. Structurally, the Elk Hills are broad and flat-topped, with steeper dips along the edge that are deformed by narrow, flat-topped anticlines (Woodring et al., 1932). The crest of the eastern anticline consists of a number of terracelike steps that funnel anticlinal noses down the north slope of the hills; four faults are expressed in between the terraced anticlines (as shown in Figure 2-2) (Woodring et al., 1932). More information about the Elk Hills faults is provided in Section 2.6.2.

The Elk Hills-North Cole Levee anticline is an important petrologic structure within the GSA area and has developed a major oil field underlying the Elk Hills. The Bakersfield arch, described in Section 2.6.3, further contributes to structural deformity and uplift. The anticlines play an important role in capturing oil within the permeable rock units, and in trapping oil below impermeable layers.

The western anticline in Elk Hills is believed to divert the movement of groundwater south through the Buena Vista Valley toward the Buena Vista Lake (Page, 1986). The shallow and eastern anticlines are considered “shallow wrinkles” and not regarded as having significant impacts to groundwater or oil in the area (Woodring et al., 1932).

Buena Vista Hills Anticline

The Buena Vista Hills are in the center of the GSA area in the Subbasin and are a topographic expression of anticlinal structures. Three anticlines compose the anticline series in the Buena Vista Hills; two are located at the northern corner, and one is in the south-central portion of the hills. At the northern end of the Buena Vista Hills, a double plunging anticline is mapped plunging to the northwest and southeast. Another anticline is mapped at the northern end of the hills plunging to the southeast. The third anticline trends northwest to southeast across the Buena Vista Hills, and curves to the east near the eastern edge of

the GSA area. Past the boundary of the GSA area, this syncline becomes concealed and plunges to the east.

The Buena Vista Hills are an important oil resource in the GSA area, with a major oil field underlying the hills. The anticlines play an important role in capturing oil within the permeable rock units and trapping oil below impermeable layers.

The anticlines were first noted in 1910 after observing gypsum deposits on the upgradient side of the anticline, similar to gypsum deposits at the Lost Hills anticline (located northeast of the GSA area) (Hess, 1910; Provost & Pritchard, 2019). The axis of the anticlines strikes roughly parallel to the axis of the San Joaquin Valley and plunges to the southeast. The Buena Vista Hills anticline is believed to restrict the movement of groundwater flowing from the Buena Vista Valley (Page, 1986).

Little Signal Hill Anticlines (Unnamed)

Three unnamed anticlines are mapped by Jennings within the extent of the Little Signal Hills (Jennings, 2010). These anticlines run generally northwest to southeast along the extent of the Little Signal Hills, approximately 12 miles in total length. The unnamed anticlines are located on the western margin of the Subbasin and GSA area.

Unnamed Anticlines

There are several unnamed anticlines located in the GSA area that are not associated with a hill series. These anticlines are primarily concentrated in the west to northwest quadrant of the GSA area and roughly trend from northwest to southeast and plunge to the southeast. The anticlines are both exposed and concealed, and range in length from approximately 3 to 10 miles.

2.6.2 Major Faults

There are several faults in the GSA area as mapped in Figure 2-2. Most notable is the Buena Vista Fault, in addition to several unnamed faults in the Elk Hills that have been documented as historically active in the GSA area.

Buena Vista Fault

The Buena Vista fault is the most extensively studied fault in the area, with studies dating back to 1933 (Smith, 1984). Though little seismic activity has been recorded in the GSA area, creep activity along the Buena Vista fault has been reported as far back as the 1910s, where numerous oil-well casing failures were recorded at depths of 630 to 800 feet below sea level (Smith, 1984). The average strike of the fault is North, 75°W (Smith, 1984). Between 1933 and 1957, approximately 1.7 feet of displacement occurred, while in a two-hour period in 1970, 13.4 millimeters of creep occurred (Smith, 1984). It is suggested that slip on the Buena Vista Fault may be caused by oil withdrawal rather than tectonic forces (Smith, 1984). It was assumed by Smith (1984) that groundwater flow is not impacted by the fault.

Elk Hills Faults

As described in Section 2.6.1, a series of four faults are in the Elk Hills, lying between terraced anticlines. These faults are not expressed at the surface and are mapped within the mudstone at the base of the upper part of the Tulare Formation (Woodring et al., 1932). These four faults, named Faults 1 through 4, are thrust and normal faults that position buff-colored mudstone of the upper Tulare Formation against olive-gray mudstones of the lower Tulare Formation (Woodring et al., 1932). Faults 1 through 4 have the same trend as surface faults and subsurface faults known to displace oil-bearing beds in the Subbasin (Woodring et al., 1932). Fault 1 has the greatest maximum surface displacement of 160 feet and lies at the western edge of the Elk Hills (Woodring et al., 1932). Faults 2 through 4 are normal faults that dip toward the northwest and displace the subsurface at a range of 65 to 220 feet (Woodring et al., 1932). Additionally, there are a series of unnamed Quaternary age faults on the northern margin of Elk Hills. Little is known about these faults.

Unnamed Thrust Fault

An unnamed thrust fault is located along the western margin of the GSA area, along the boundary between alluvium and the Tulare Formation (Jennings, 2010). The fault runs approximately 5 miles parallel to the GSA boundary, from northwest to southeast.

2.6.3 Bakersfield Arch

Arches are subsurface regional and geologic features that naturally capture and accumulate oil and gas. The Bakersfield Arch, located in the southern end of the San Joaquin Valley and the GSA area, is a major west to southwest plunging structural bow (Hoots et al., 1954). The Bakersfield Arch is responsible for the northeast to southwest trending concentration of oil fields in the Subbasin and the GSA area. The Arch is aligned generally with the Elk Hills-North Coles Levee anticlinal trend (Hoots et al., 1954). The Bakersfield Arch is also a boundary separating northern folds aligned in a northwesterly direction (such as the Elk Hills-North Coles Levee) from southern folds aligned in a westerly direction (Hoots et al., 1954).

2.6.4 Outcrops of Bedrock Inside the GSA area

There are no known outcrops of bedrock in the GSA area.

2.7 Basin Boundaries

2.7.1 Lateral Boundaries

The GSA area is politically and topographically bounded in the Subbasin. To the north, east, and southeast, the GSA area is politically bounded by neighboring GSAs, directly abutting the Belridge Water Storage District GSA, the BVWSD GSA, the KWBA GSA, the Henry Miller Water District GSA, and the Wheeler Ridge-Maricopa Water Storage District GSA. To the south and west, the GSA area is defined by the western boundary of the Subbasin, which is bounded by the bedrock of the Temblor Range. The Temblor Range bedrock is a geologic groundwater divide that juxtaposes permeable sedimentary materials with impermeable bedrock. DWR defines this type of boundary as “Impermeable bedrock with

lower water yielding capacity. These include consolidated rocks of continental and marine origin and crystalline/or metamorphic rock" (DWR, 2003).

2.7.2 Boundaries with Neighboring Subbasins

The GSA area does not share a boundary with a neighboring subbasin.

2.7.3 Bottom of the Subbasin in the GSA Area

The bottom of the Kern County Subbasin has been determined during coordination with the KGA. The KGA's Umbrella GSP states the following about the bottom of the subbasin:

"An aquifer may not be suitable for beneficial use if:

a) is not currently serving as a source of drinking water,
b) it has commercially producible minerals or hydrocarbons, or
c) it is not expected to supply a public water system and
- is either economically or technologically infeasible for treatment or recovery now or in the future for domestic, agricultural, or industrial use.

The purpose of this plan is not to exempt aquifers, nor is it to define the maximum depth or water quality concentration at which groundwater is economically recoverable or treatable now or in the future. However, by applying the criteria of 40 CFR §144.3 and 40 CFR §146.4, active oil and gas aquifers and exempted aquifers are not a part of the groundwater basin for beneficial use. The following whichever is shallowest, are the lateral and vertical boundaries of the groundwater Subbasin:

a) depth to producible minerals or hydrocarbons or primacy productive limits,
b) depth to exempted aquifers,
c) depth that makes recovery of water for domestic, commercial, or industrial purposes no longer economically or technologically feasible, or
d) the depth at which groundwater cannot now or in the future serve as a source of drinking water. For example, water bearing zones below the depth to producible hydrocarbons are not within the groundwater basin; likewise, water bearing zones below an exempted aquifer are not within the groundwater basin"

2.8 Principal Aquifers and Aquitards

The primary use of water in the unconfined and confined aquifers in the WKWD GSA area is municipal. A portion of the municipal supply in the WKWD GSA is also used to generate energy, and water is also used to maintain Buena Vista Lake levels.

2.8.1 Aquifers

There are two principal aquifer systems in the GSA area, an upper semi-confined to unconfined aquifer and a deeper confined aquifer. These aquifers are defined by nearly impermeable clay layers (i.e., the Corcoran member) that impede vertical flow of groundwater. The primary, fresh water-bearing deposits in the Subbasin in the GSA area are coarse, unconsolidated, oxidized deposits of continental and alluvial deposits (i.e., the Tulare Formation and overlying alluvium), which correspond to the most permeable beds (Croft, 1972). Nearly all water wells are pumped from the unconsolidated to loosely consolidated water-bearing deposits of continental origin (Wood and Davis, 1959). The semi-confined and unconfined aquifer are primarily of the Recent and Older alluvium, in addition to the Tulare Formation. The confined aquifer is within the Tulare Formation. Water bearing intervals range in depth from 10 to 700 feet (Croft, 1972; Meiller et al., 2008).

Groundwater in the GSA area is produced from continental sedimentary deposits from the North and South wellfields, located approximately 15 to 18 miles northeast of the City of Taft, and the Buena Vista Lake area east of the City of Taft. The North and South wellfields correlate to the GSA's North and South Project management areas. Though groundwater exists within the basement complex and marine deposits, these units are typically non-water bearing in the GSA area and are not considered a part of the GSA area's aquifer system (Kennedy Jenks Consultants [Kennedy Jenks, 2010]). Rocks older than the Tulare Formation are generally considered either non-water bearing or have low yields with water quality that is too poor for municipal uses.

Semi-Confined to Unconfined Aquifer

A semi-confined to unconfined aquifer system exists within the alluvial fan complex in the GSA area, which is composed of unconsolidated to partly consolidated sand, silt, clay and gravel that yield fresh groundwater. The uppermost part of the aquifer, considered to be entirely unconfined, extends to a depth of approximately 200 to 300 feet bgs and consists of interbedded silts, sands, and some clay (Meiller et al., 2008; Kenneth D. Schmidt and Associates [Schmidt & Associates], 2001). Both the North and South wellfields are screened within the semi-confined to unconfined aquifer, with the South wellfield being exclusively within the unconfined to semi-confined aquifer.

The unconfined aquifer is separated from a middle, semi-confined aquifer by lower permeability sediments and spatially discontinuous occurrences of Corcoran Clay. The clay layers are responsible for creating semi-confined aquifer conditions within this middle aquifer (Meiller et al., 2008). The unconfined to semi-confined aquifer is separated from the deeper confined aquifer by a regionally extensive Corcoran Clay layer that is an impermeable layer acting to impede groundwater flow.

Confined Aquifer

A deeper confined aquifer system also exists in the GSA's North Project Management Area. The confined aquifer is separated from the overlying semi-confined and unconfined aquifer by an impervious layer of E clay (including Corcoran Clay) at a depth ranging from 200 to 650 feet bgs (Schmidt & Associates, 2001; Dee Jaspar & Associates, Inc. [Jaspar & Associates], 2010). The confined aquifer is primarily located

within the Tulare Formation. The lower, confined aquifer extends to a depth of approximately 600 to 800 feet bgs (Meiller et al., 2008; Provost & Pritchard, 2016).

2.8.2 Aquitards

As described in Section 2 of the Umbrella GSP, nearly impermeable flood-basin, lacustrine, and marsh deposits are widespread throughout the San Joaquin Valley. In the San Joaquin Valley, there are six differentiated clay tongues, designated A through F, that are extensively found at the base of the unconsolidated deposits. Within the extent of the GSA area, the E clay acts as the major aquitard in the Subbasin, along with the A clay to a lesser extent. These lacustrine clay tongues create a nearly impermeable layer that divides the alluvium and water-bearing strata into several aquifers that range from unconfined to semi-confined to confined.

E Clay

E clay is the principal confining bed in the Subbasin (Croft, 1972). E clay includes the Corcoran Clay member of the Tulare Formation, and is the most extensive hydrologic confining layer in the San Joaquin Valley (Croft, 1972). This confining stratum is composed of silty clay, clayey silt, and sand, silt, and clay and is typically found at depths of approximately 600 to 650 feet bgs in the GSA's North Project Management Area (Croft, 1972; Jaspar & Associates, 2010). E clay defines the base of the unconfined aquifer in the Subbasin and is responsible for the semi-confined properties of the middle aquifer due to the spatially discontinuous presence of clay. Though E clay has been mapped during earlier investigations in the GSA's South Project Management Area, it is generally absent in this portion of the GSA area.

A Clay

Water level data indicate that A clay is a confining bed throughout the Subbasin. Within the GSA area, A clay is locally discontinuous and is unlikely to act as a confining bed, though it may create semi-confined aquifer conditions. Historical studies and water-level records throughout the southern portion of the San Joaquin Valley indicate that a shallow water body occurs in the strata overlying A clay, particularly in irrigated areas (Croft, 1972). A clay is generally absent in the GSA area, except for the southeastern most part, near the South Project Management Area. Monitoring wells along the eastern edge of the WKWD near the intersection of the Kern River and Interstate 5 contain large amounts of clay (Provost & Pritchard, 2016).

2.8.3 Aquifer Properties

Hydraulic Conductivity

DWR defines hydraulic conductivity as the "measure of a rock or sediment's ability to transmit water" (DWR, 2003). Conductivity data are limited throughout the GSA area. DWR estimated hydraulic conductivity values for the GSA area during development of their San Joaquin Valley groundwater model. The average hydraulic conductivity for the unconfined aquifer, shallower than 300 feet deep, was estimated to be 880 gallons per day per square foot (gpd/ft) (Schmidt & Associates, 2001). No estimates of hydraulic conductivity were located for the confined aquifer.

Specific Yield

DWR defines specific yield as the "amount of water that would drain freely from rocks or sediments due to gravity and describes the portion of groundwater that could actually be available for extraction" (DWR, 2003). Specific yield is a measurement specific to unconfined aquifers, which includes the primary aquifer in the GSA area. Sediments that compose the shallow to intermediate depth water-bearing deposits in the Subbasin are primarily continental deposits of Tertiary and Quaternary age. From youngest to oldest, deposits in the unconfined aquifer include Recent Alluvium and flood deposits, Older Alluvium and stream deposits, and the Tulare Formation.

Specific yield values for the unconfined aquifer are estimated using data compiled from two sources, DWR's San Joaquin District office and the DWR groundwater model for the Subbasin (DWR, 2006). DWR's San Joaquin District office estimates that the specific yield values for the unconfined aquifer range from 5.3 to 19.6 percent and average 11.8 percent for the interval from surface to 300 feet bgs (DWR, 2006). DWR's 1977 groundwater model of Kern County estimates the specific yield to range from 8.0 to 19.5 percent, with an average of 12.4 percent, representing an interval thickness of 175 to 2,900 feet (DWR, 2006). The highest specific yield values for the entire Subbasin are associated with sediments of the Kern River Fan west of Bakersfield (DWR, 2006).

Specifically, in the WKWD's South Wellfield, Schmidt & Associates estimated specific yield for the upper, unconfined to semi-confined aquifer to be approximately 18 percent, which is a value near the upper range of DWR's estimate (Schmidt & Associates, 2001).

Specific Capacity

Specific capacity is defined as "the yield of the well, in gallons per minute, divided by the pumping drawdown, in feet" (Singer and Swarzenski, 1970). There is a lack of specific capacity data specific to the GSA area. However, a study performed by Wood and Davis in 1959 estimated specific capacities for irrigation wells in the Avenal-McKittrick area that includes portions of the GSA area. The study found specific capacities ranged from 2 to 120 gallons per minute per foot of drawdown in irrigation wells screened in depths from 100 to 1,700 feet (Wood and Davis, 1959). Specific capacities in the GSA area are likely to fall within the range calculated by Wood and Davis.

Pump tests and historical values for wells in the North Project Management Area and surrounding area estimate the specific capacity of the confined aquifer range from 50 to 126 gallons per minute per foot in wells screened from 250 to 600 feet bgs (Jaspar & Associates, 2010).

Transmissivity

DWR defines transmissivity as the "aquifer's ability to transmit groundwater through its entire saturated thickness" (DWR, 2003). Generally, transmissivity values are estimated to be higher in the confined aquifer than the unconfined aquifer.

In 2001, Schmidt & Associates calculated transmissivity values for the unconfined aquifer in the WKWD's South Wellfield. Transmissivity values were calculated using Darcy's law, and were estimated to be approximately 72,000 gpd/ft for strata around 160 feet deep located within the upper unconfined

aquifer (Schmidt & Associates, 2001). For overlying strata, at depths between 30 and 160 feet deep, transmissivity values were calculated using hydraulic conductivity estimates from DWR's model, and were estimated to be 114,000 gpd/ft (Schmidt & Associates, 2001). For strata deeper than 160 feet (and up to 300 feet in depth), a transmissivity value of 72,000 gpd/ft was estimated (Schmidt & Associates, 2001). Total transmissivity was estimated at 186,000 gpd/ft by Schmidt & Associates in 2001. Total transmissivity values were also calculated for areas neighboring the WKWD wellfield and generally increased to the north, up to 642,000 gpd/ft, northwest (212,000 gpd/ft), and to the west (up to 364,000 gpd/ft) (Schmidt & Associates, 2001).

Transmissivity values for the confined aquifer in the GSA's North Project Management Area were estimated to be approximately 225,000 gpd/ft based on pump tests (Jaspar & Associates, 2010). A 2009 GEI Consultants, Inc. (GEI) report states historical transmissivity values for the North Project Management Area to range from 128,000 gpd/ft up to 212,000 gpd/ft (GEI, 2009). Overall, the transmissivity of the North Project Management Area is modeled to be 202,000 gpd/ft (GEI, 2009).

2.9 Natural Water Quality Characterization

Within the GSA area's North and South Project management areas wellfields, groundwater quality is described as "excellent," according to the WKWD 2016 *Draft Urban Water Management Plan*. Groundwater quality within the wellfield is representative of water recharged by the Kern River, which is typically calcium sodium bicarbonate type and low in TDS (WKWD, 2016). The groundwater is typically a sodium bicarbonate water, although the upper portion of the aquifer contains a thin interval of calcium bicarbonate water wells (WKWD, 2016). Kern River water recharges the aquifer, and groundwater transitions from calcium sodium bicarbonate to sodium bicarbonate after undergoing an ion exchange process as it infiltrates the deeper parts of the aquifer (WKWD, 2016). TDS concentrations within the wellfield average 400 mg/L (Jaspar & Associates, 2010).

The major COC in the GSA's wellfield is arsenic, which is naturally occurring in local lacustrine deposits in the region (WKWD, 2016). WKWD has taken wells offline due to arsenic concentrations exceeding the MCL of 10 micrograms per liter (Kennedy Jenks, 2010).

Additional constituents of concern include elevated concentrations of naturally occurring TDS, sulfate, chloride, uranium, and fluoride. Schmidt & Associates reports ranges in concentration of the following constituents in wellfield groundwater as shown below (Schmidt & Associates, 2001):

- TDS: 800 to 1,300 mg/L
- Uranium: 20 – 30 mg/L
- Sulfate: > 250 mg/L
- Chloride: > 250 mg/L
- Manganese: > 0.05 mg/L

Outside of the GSA's wellfield areas, groundwater is highly saline in some areas. Groundwater in sediments derived from the marine sedimentary rocks of the Coast Range is more saline than groundwater

derived from continental sediments. Spatially, the western portion of the Subbasin and GSA area has higher TDS and salinity concentrations than the eastern portion due to the increased presence of marine sediments. In particular, groundwater within the marine Olcese sand is more saline than aquifers above or below the occurrence of the Olcese Formation (Gillespie et al., 2017). The nonmarine Tulare Formation is typically a USDW source with TDS concentrations less than 10,000 mg/L, while underlying marine formations are more saline, such as the Olcese Formation with TDS concentrations greater than 10,000 mg/L (Gillespie et al., 2017).

Wells screened within the Tulare Formation contain concentrations of TDS ranging from 3,000 to 10,000 parts per million (ppm) at depths less than 2,000 feet (Gillespie et al., 2017). The Buena Vista Oilfield has a salinity gradient that increases with depth, and the USDW occurs at approximately 1,000 feet. (Gillespie et al., 2017).

2.10 Topography, Surface Water and Recharge

This section describes the topography, surface water, soils, and groundwater recharge potential in the Subbasin.

2.10.1 Topography

The GSA area ranges from 2,531 to 269 feet above mean sea level. The GSA area generally slopes to the southeast from the Temblor Range to the valley floor, with east-west trending ridges (Figure 2-3).

2.10.2 Surface Water Bodies

Surface water bodies in the GSA area flow from west to east, and are ephemeral streams including Bitter, Cienega, Bitterwater, Sandy, Broad, and Buena Vista creeks. These creeks are present in the Western Management Area, and have no known flow requirements. The California Aqueduct flows along and inside the eastern boundary of the GSA area, and the Buena Vista Aquatic Recreational Area is present to the south of the Lake Management Area (Figure 2-4).

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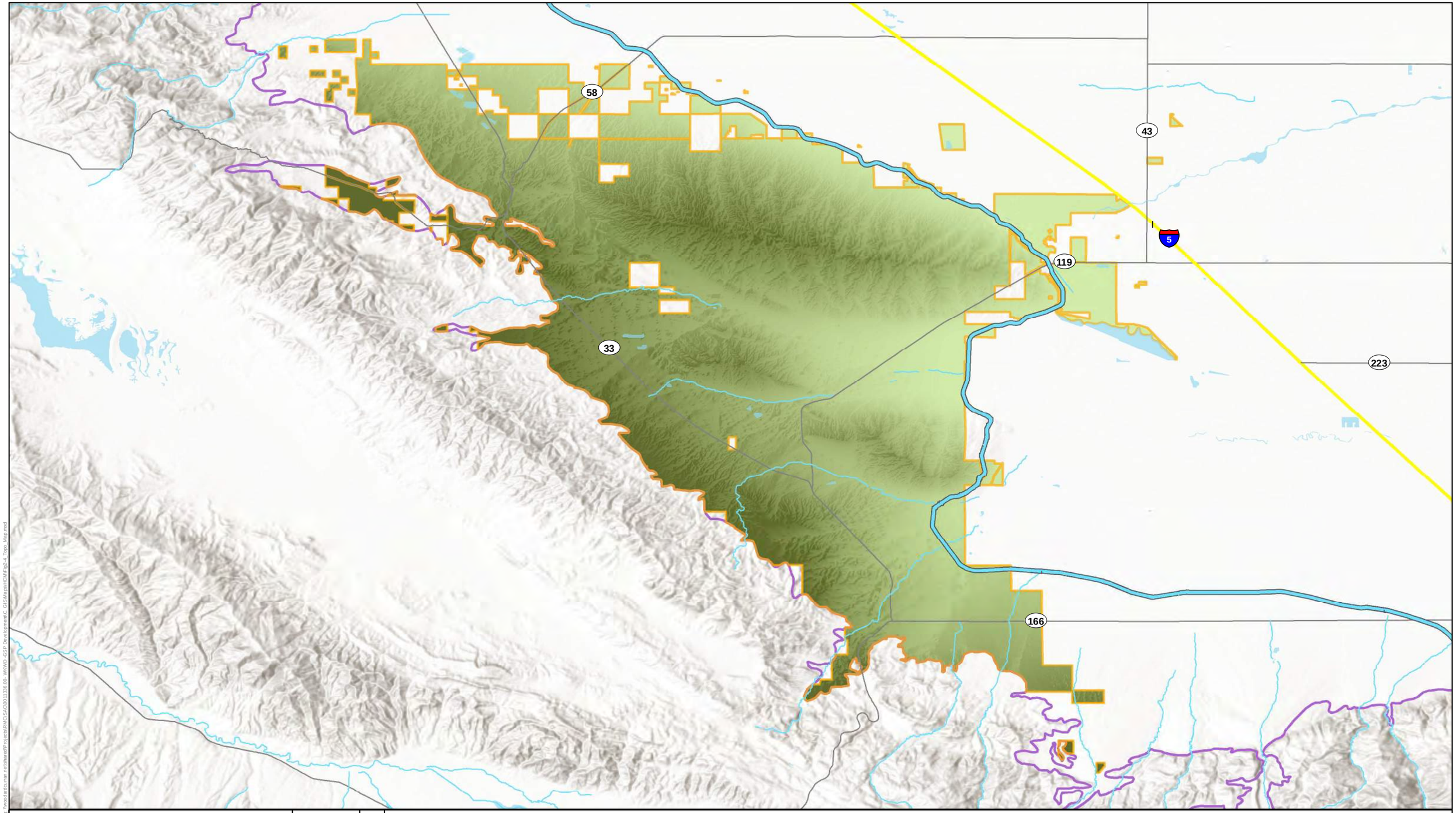


Figure 2-3: WKWD GSP Topographic Map

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

Ground surface elevation (ft.)

High : 2530

Low : 265

N

0 3 6 12 Miles

Figure Exported: 12/4/2019 By: cepleiton Using: \\woodardcurran.net\shared\Projects\RMO\SAC\001138.00 WKWD GSP Development\C GIS\Mxd\HCM\Fig2-4 Topo Map.mxd

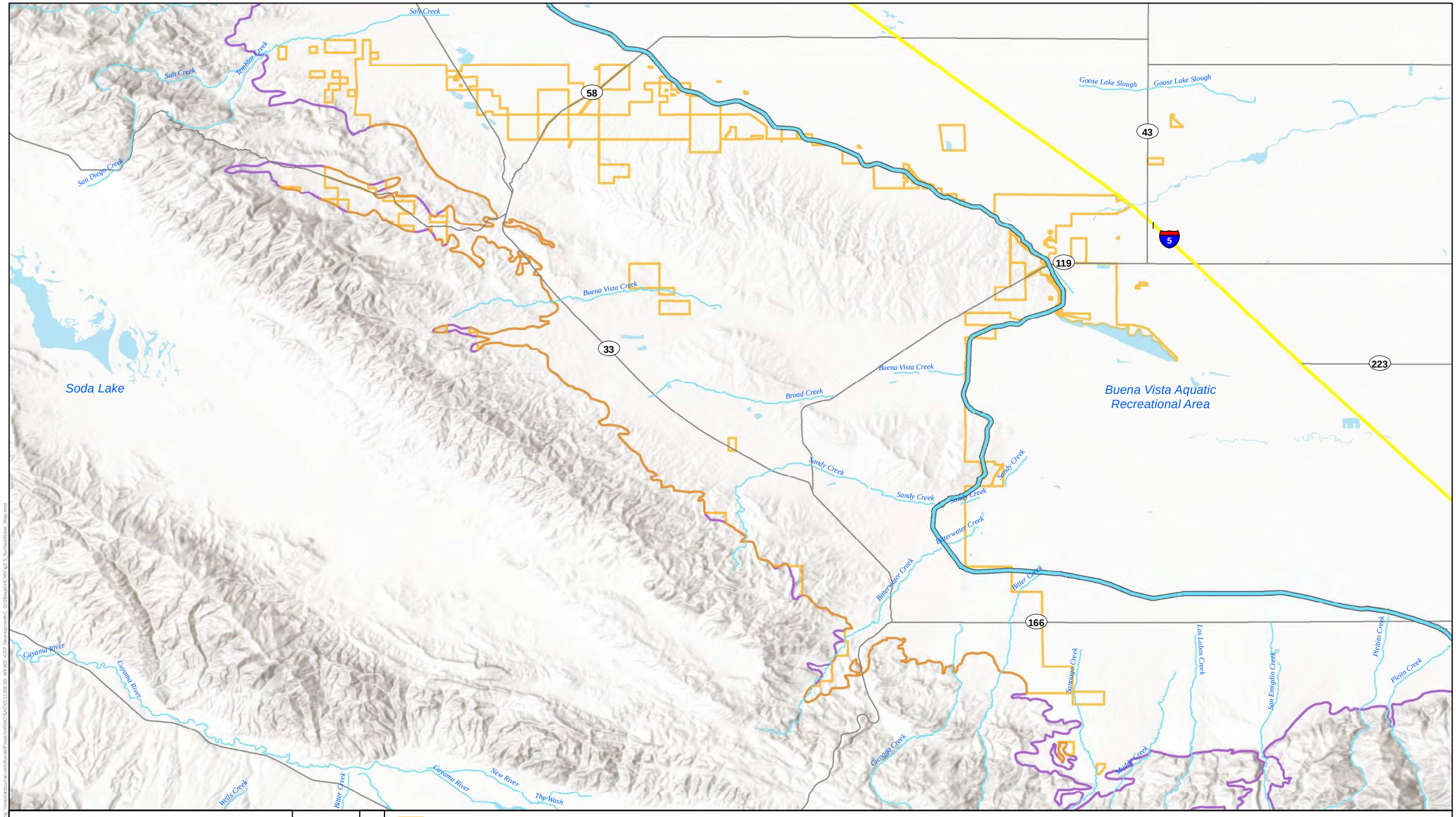


Figure 2-4: WKWD GSP Surface Waters

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

N

0 3 6 12 Miles

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2.10.3 Groundwater Discharge, and Areas of Recharge and Potential Recharge

Groundwater discharge takes place in the area of springs. Figure 2-5 shows the locations of springs near the GSA area; there are no springs in the GSA area. Figure 2-6 shows that areas of potential recharge lie generally within the flatlands of the GSA area as identified by the Soil Agricultural Groundwater Banking Index (SAGBI). SAGBI provides an index for groundwater recharge for agricultural lands by considering deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. SAGBI considers the open flatlands throughout the GSA area to be Excellent or Good. SAGBI considers the Elk Hills and Buena Vista Lake areas of the GSA area to be Poor or Very Poor.

Most recharge within the GSA area occurs from via surface flows from the California Aqueduct. Wells in both the North Project and South Project management areas conduct recharge from this surface water supply to bank water in the aquifer.

Recharge is conducted in two locations in the WKWD GSA and are delineated as management areas. The North Project Management Area is shown in Figure 1-2 and has recharge ponds that recharge into the shallow aquifer in that region. The South Project Management Area has recharge ponds that recharge into the unconfined aquifer in that region.

2.10.4 Soils

Figure 2-7 shows soils by hydrologic soil group. Hydrologic soil groups were calculated by the National Resource Conservation Service (NRCS) on a county-by-county basis. In general, hydrologic soil groups are sorted by permeability, with class A being the most permeable and class D being the least permeable. Figure 2-7 shows that, in general, most of the soils in the GSA area have lower permeabilities and are listed as class C or D, with higher permeabilities located on the north end of the GSA area and near streams and rivers. Notably, there is a change in categorization between the northwest part of Kern County and the southwest part of Kern County. Each part was likely analyzed by a different NRCS study, and as a result there are reported discrepancies.

Soils in the GSA area were categorized by the NRCS. The GSA area is comprised mostly of fine- to coarse-loamy soils (NRCS, 2018). As shown in Figure 2-8, the GSA area’s flatlands are primarily fine-loamy soils, while the GSA area’s hills are primarily eroded complexes.

2.11 Hydrogeologic Conceptual Model Data Gaps

There are no significant data gaps for the HCM in the WKWD GSA area.

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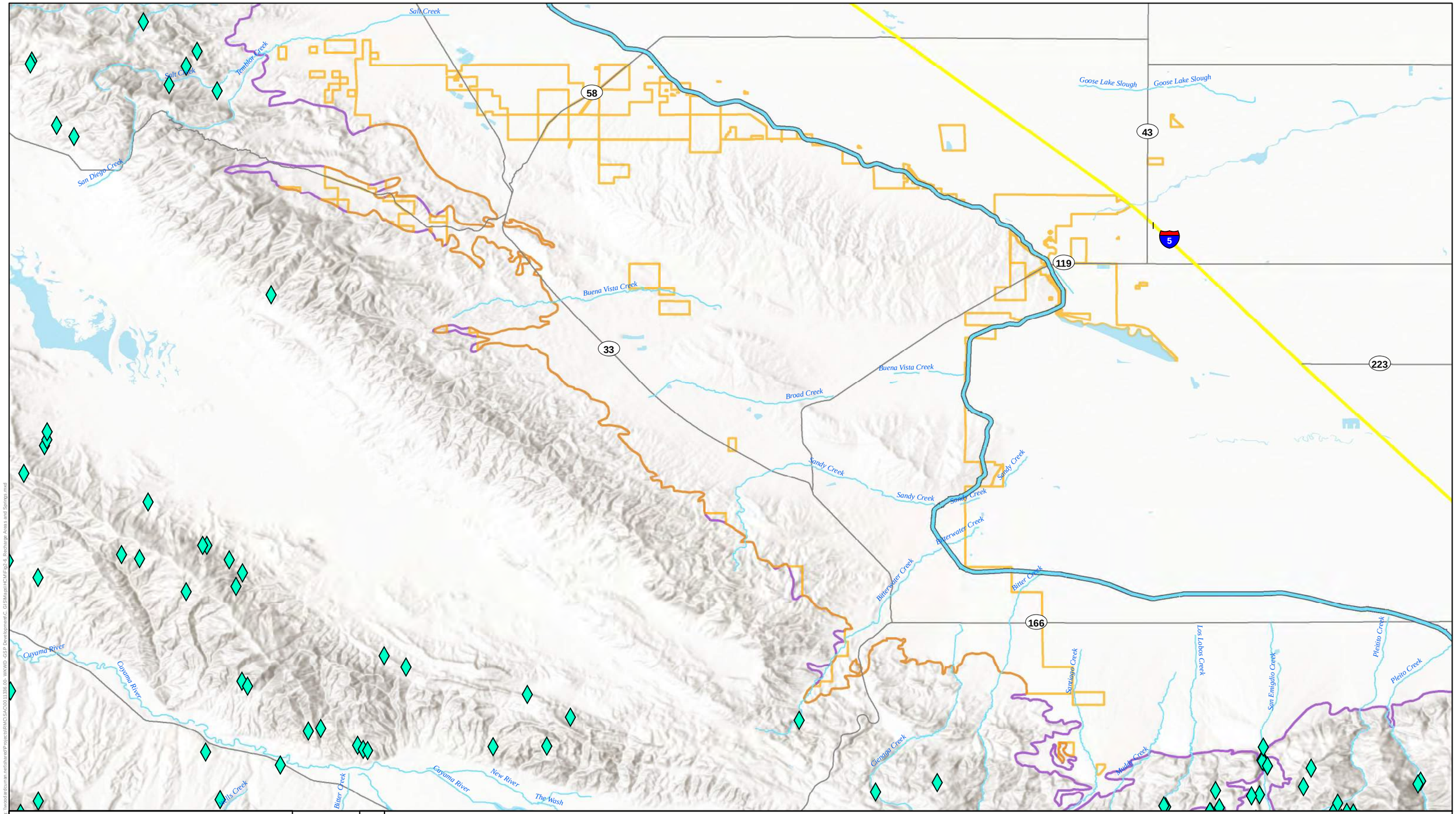


Figure 2-5: WKWD GSP Recharge Areas and Springs

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- Springs and Seeps
- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

N

0 3 6 12 Miles

Figure Exported: 12/4/2019 By: cstapleton I:\Users\Woodardcurran.net\shared\Projects\SRMC\SAC\001138.00- WKWD GSP Development\C. GIS\Maps\HCM\Fig2-5. Recharge Areas and Springs.mxd

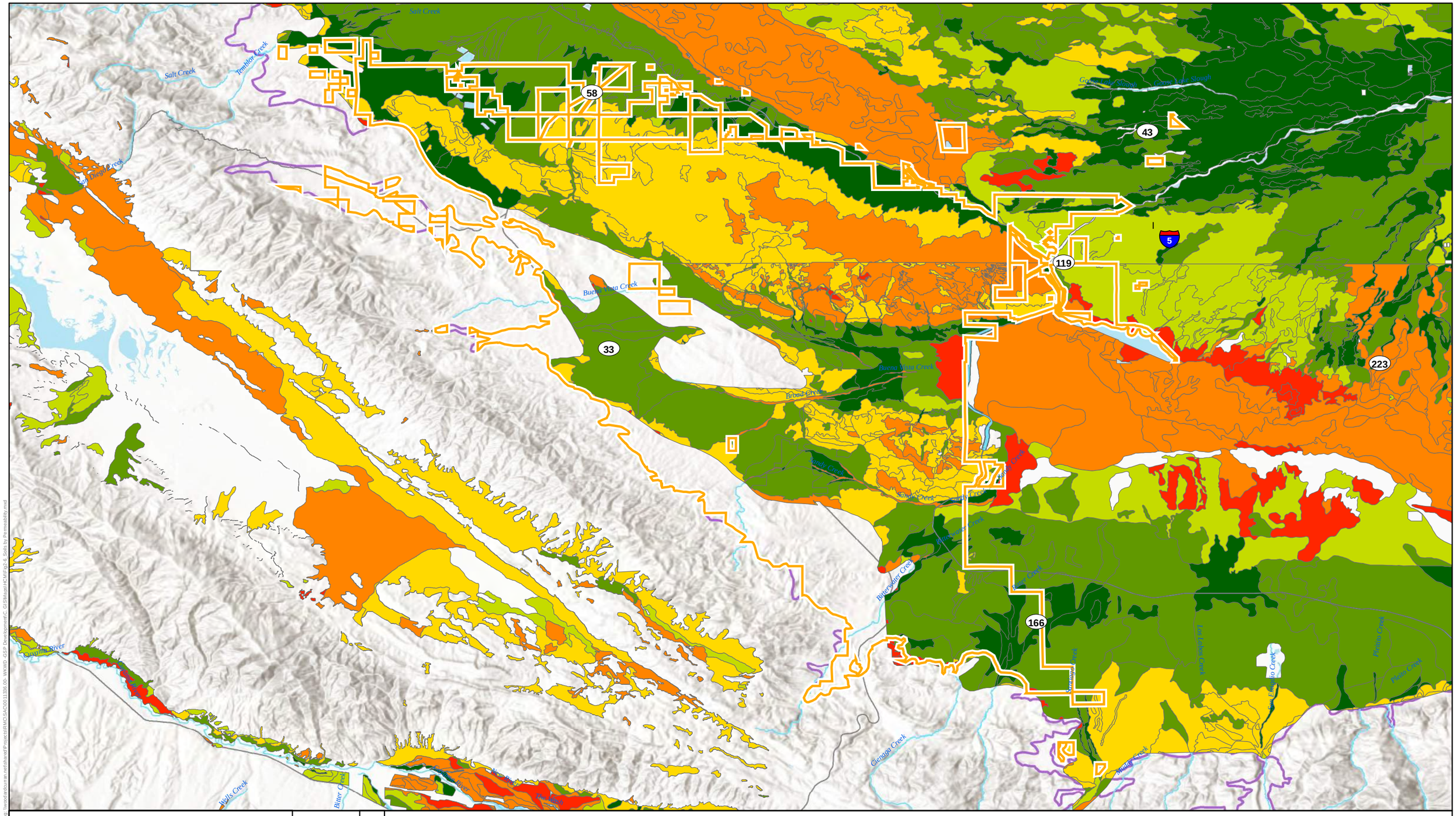


Figure 2-6: WKWD GSP
Soil Permeability Classification

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

SAGBI Soil Classification

- Excellent (85-100)
- Good (69-85)
- Moderately Good (46-69)
- Moderately Poor (29-49)
- Poor (15-29)
- Very Poor (0-15)

N

0 3 6 12 Miles

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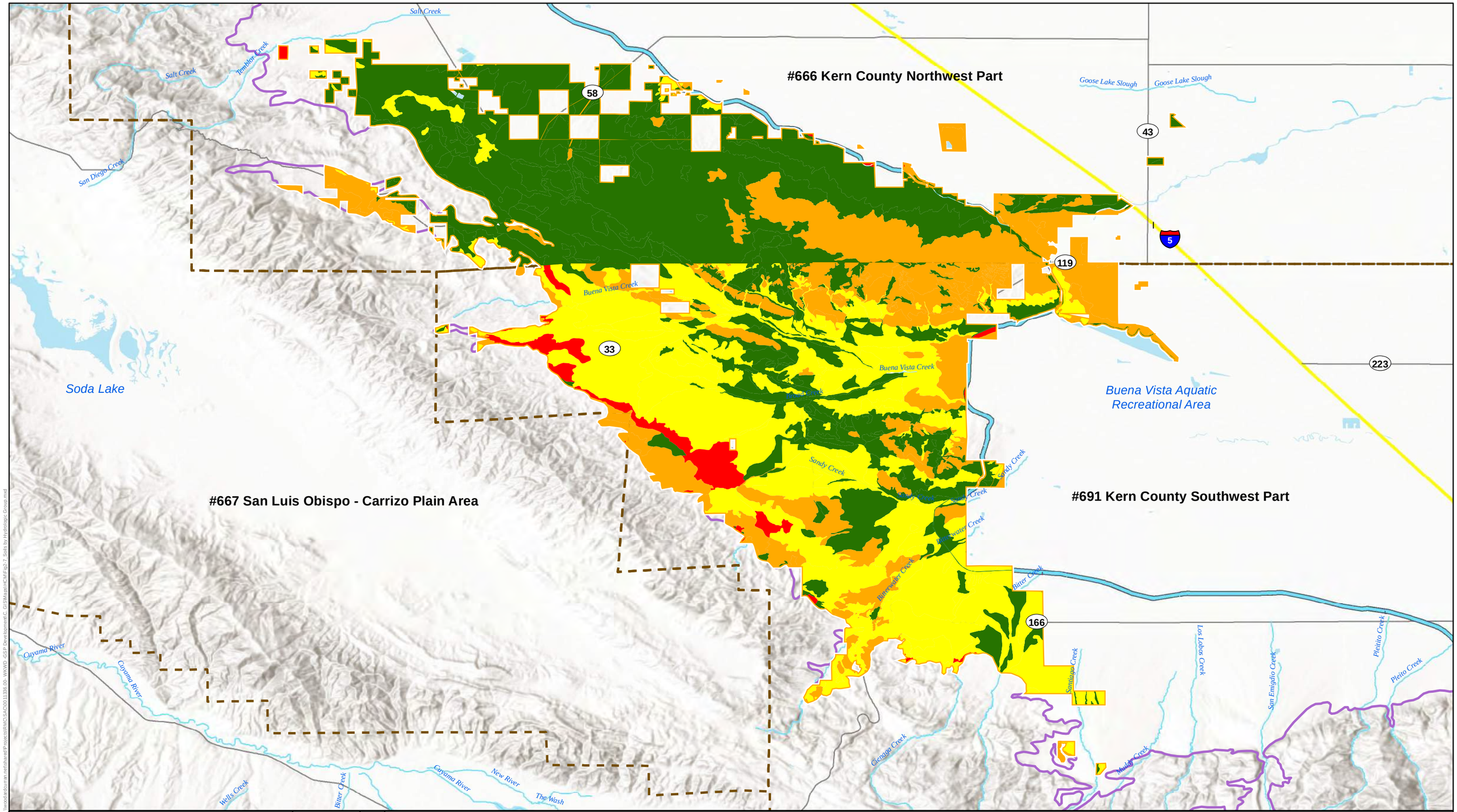


Figure 2-7: WKWD GSP Hydrologic Soil Groups

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- Soil Survey Boundaries
- California Aqueduct
- Rivers/Streams

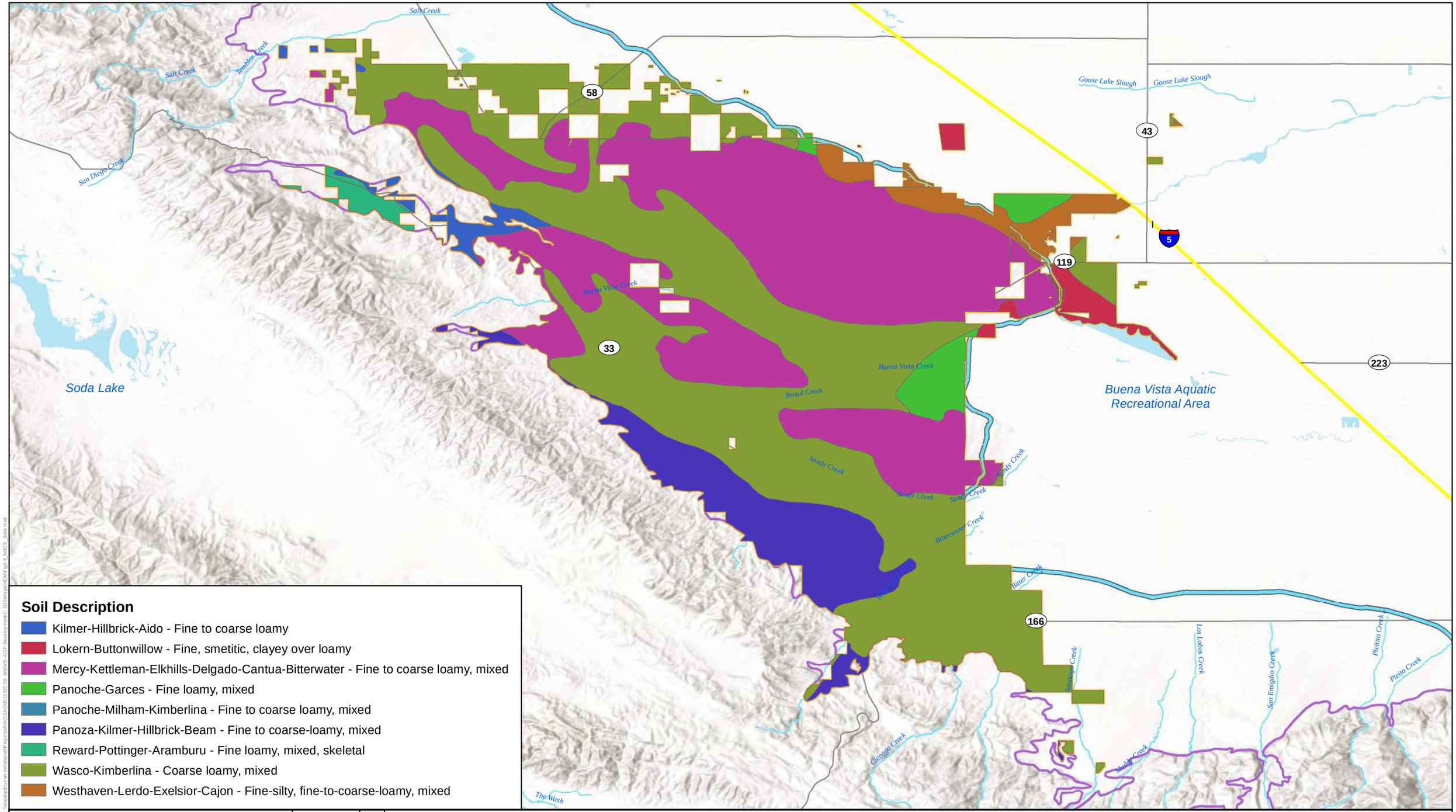
Hydrologic Soil Group

- A
- B
- C
- D
- Not classified

N

0 3 6 12 Miles

Figure Exported: 12/4/2019 By: cwppleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001136.00- WKWD -GSP Development\C. GIS\Maps\HCM\Fig2-7 Soils by Hydrologic Group.mxd



Soil Description

- Kilmer-Hillbrick-Aido - Fine to coarse loamy
- Lokern-Buttonwillow - Fine, smetitic, clayey over loamy
- Mercy-Kettleman-Elkhills-Delgado-Cantua-Bitterwater - Fine to coarse loamy, mixed
- Panoche-Garces - Fine loamy, mixed
- Panoche-Milham-Kimberlina - Fine to coarse loamy, mixed
- Panoza-Kilmer-Hillbrick-Beam - Fine to coarse-loamy, mixed
- Reward-Pottinger-Aramburu - Fine loamy, mixed, skeletal
- Wasco-Kimberlina - Coarse loamy, mixed
- Westhaven-Lerdo-Exelsior-Cajon - Fine-silty, fine-to-coarse-loamy, mixed

Figure 2-8: WKWD GSP
NRCS Soil Types

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams

N

0 2.5 5 10 Miles

Figure Exported: 12/4/2019 By: cepleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001133\6.00- WKWD -GSP Development\C. GIS\Mxd\HCM\Fig2-8_NRCS_Soils.mxd

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Section 3.0 Basin Settings: Groundwater Conditions

3.1 Compliance Information

Table 3-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

Table 3-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 3.9
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.16	Current and Historical Groundwater Conditions	Groundwater elevation data	Sections 1.3 and 3.3
		Estimate of groundwater storage	Section 3.4
		Seawater intrusion conditions	Section 5.6
		Groundwater quality issues	Sections 2.9 and 3.5
		Land subsidence conditions	Section 3.6
		Identification of interconnected surface water systems	Section 3.7
		Identification of groundwater-dependent ecosystems	Section 3.8

3.2 Introduction

This section describes historical and current groundwater availability, groundwater quality, and groundwater distribution in the GSA area to define measurable objectives, identify sustainability indicators, and establish undesirable results. As defined by the GSP regulations this groundwater conditions section is intended to:

- Describe current and historical groundwater conditions
- Describe the distribution, availability, and quality of groundwater
- Identify interactions between groundwater, surface water, groundwater dependent ecosystems, and subsidence

- Establish a baseline of quality and quantity conditions that will be used to monitor changes in the groundwater conditions relative to measurable objectives and minimum thresholds
- Support the GSPs monitoring to demonstrate that the GSP is achieving sustainability goals

3.3 Groundwater Trends

3.3.1 General Groundwater Elevation Hydrographs

Groundwater elevations in the Subbasin are dynamic by nature and have been affected over time by climatic variations, land use, and the development of surface water supplies and recharge facilities. Since 1970, regional GWEs in the Subbasin have risen and fallen in two complete cycles. Groundwater banking operations in the GSA area began in 1978 when conjunctive use began. By 2000, groundwater levels equaled those that were observed in 1970 (Bureau of Land Management, 2013). Proactive conjunctive use programs have allowed the GSA to maintain a positive balance in their groundwater banking operations. This proactive approach provided a reliable water supply and allowed the GSA to meet demands during the recent drought (WKWD, 2016). GWE levels have increased in each of the management areas since January 1, 2015.

Figure 3-1 shows the North Project Management Area well hydrographs. The hydrographs show an overall decline of GWEs during the 2012-15 drought and a steady recovery of GWEs to near pre-drought conditions from 2015 to present. GWEs in production wells are more sensitive to this cyclic effect than GWEs in monitoring wells because of the localized cone of depression created during pumping. Because of this, GWE data reported from the monitoring wells better represent local groundwater conditions within the GSA area over the same time.

Figure 3-2 shows South Project Management Area well hydrographs. Like the North Project Management Area, the hydrographs show an overall decline of GWEs during the 2012-15 drought and a steady recovery of GWEs to near pre-drought conditions from 2015 to present. GWEs in production wells are more sensitive to this cyclic effect than GWEs in monitoring wells because of the localized cone of depression created during pumping. Again, GWE data reported from the monitoring wells better represent local groundwater conditions within the GSA's South Management Area over the same time.

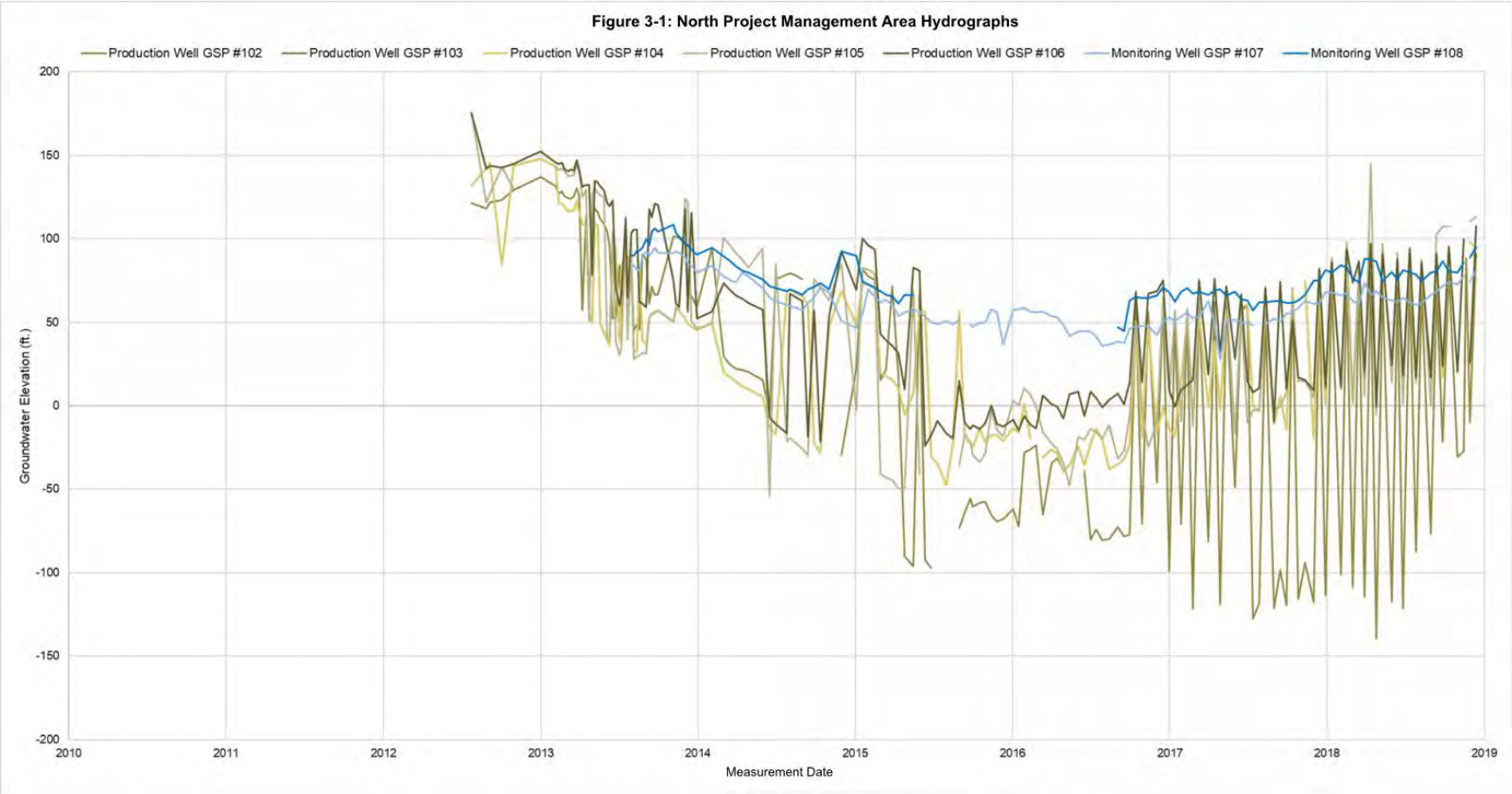


Figure 3-1. North Project Management Area Hydrographs

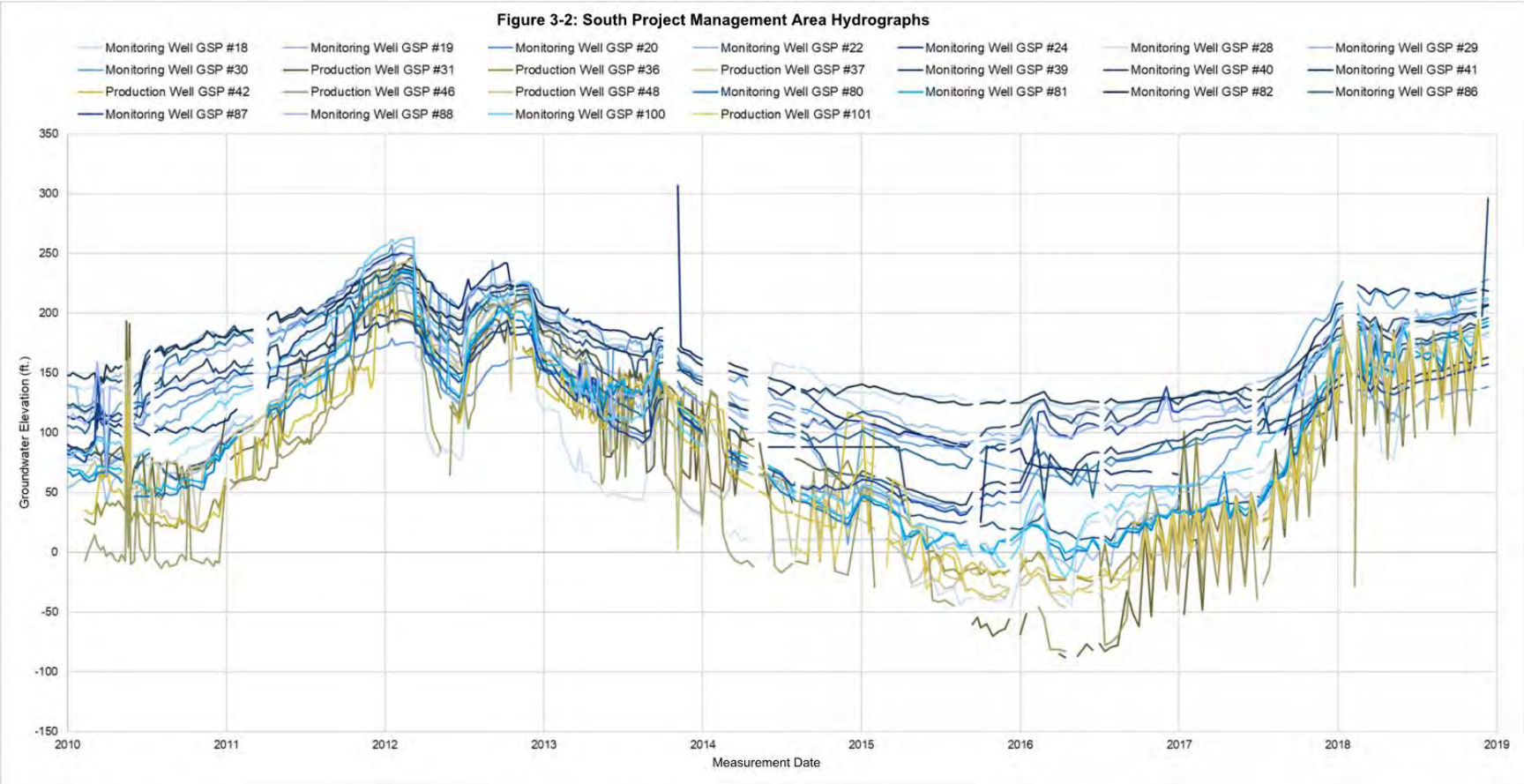


Figure 3-2. South Project Management Area Hydrographs

Little or no pumping occurs in the Western Management Area and there is no current GWE data available for the Lake Management Area.

3.3.2 Hydrographs

Figure 3-3 shows the locations of GSA monitoring network wells. Hydrographs were prepared for each well shown, and are included in Appendices C and D. Well construction information is shown in Section 6.0 of this Chapter GSP in Table 6-4. One well was selected from the North and South Project management areas to show example GWE conditions in those areas.

Figure 3-4 shows a hydrograph for Well 107, a dedicated monitoring well located in the North Project Management Area. This hydrograph shows that the GWE decreased by approximately 40 feet from 2013 to 2016 and recovered 30 feet from 2016 to 2018.

Figure 3-5 shows a combined hydrograph for a multi-completion well that was completed at three specific depths (i.e., Wells 18, 19, and 20) in the South Project Management Area. This hydrograph shows GWEs from 2000 to 2018 for each completion. In general, groundwater levels declined and recovered in all three completions in a similar manner to that in the North Project Management Area from 2013 to 2018.

The remaining hydrographs in Appendices C and D show GWE trends similar to Wells 18, 19, 20, and 107.

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#66 #68
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#39 #41
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#28 #30
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#18 #20
#19

Figure 3-3: WKWD GSP
Monitoring Network Representative Wells

West Kern Water District GSP

West Kern Water District Groundwater Sustainbility Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- Represenative Wells
- California Aqueduct
- Rivers/Streams
- North Project Management Area
- South Project Management Area
- Lake Management Area
- Western Management Area
- Little Santa Maria Valley Management Area

N

0 0.5 1 2 Miles

Figure Exported: 12/4/2019 By: cogpleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001\1336.00\ WKWD - GSP Development\C. GIS\Maps\GWCF\fig3-3_WKWD Representative Wells.mxd

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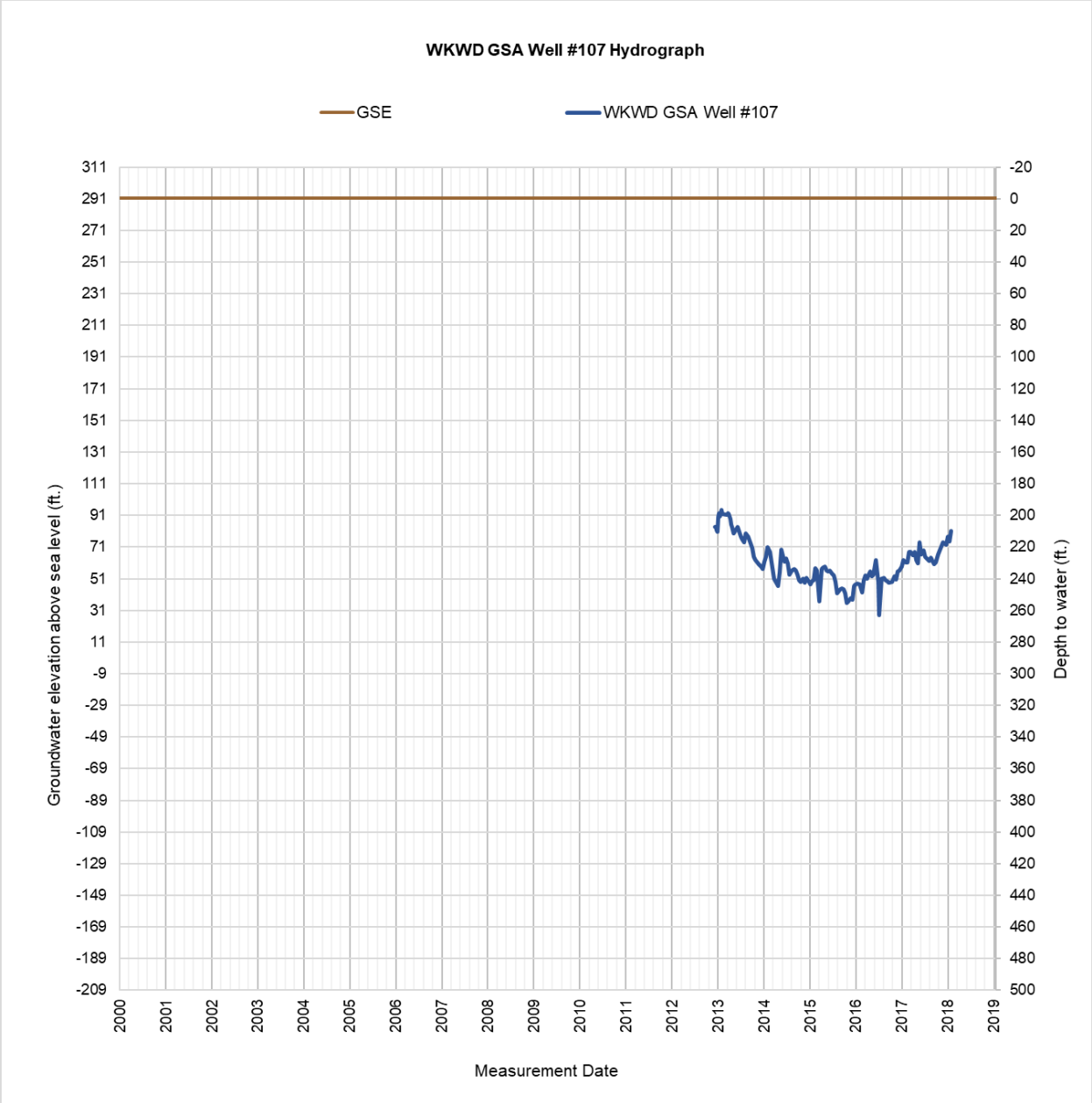


Figure 3-4. Hydrograph of WKWD GSA Well 107

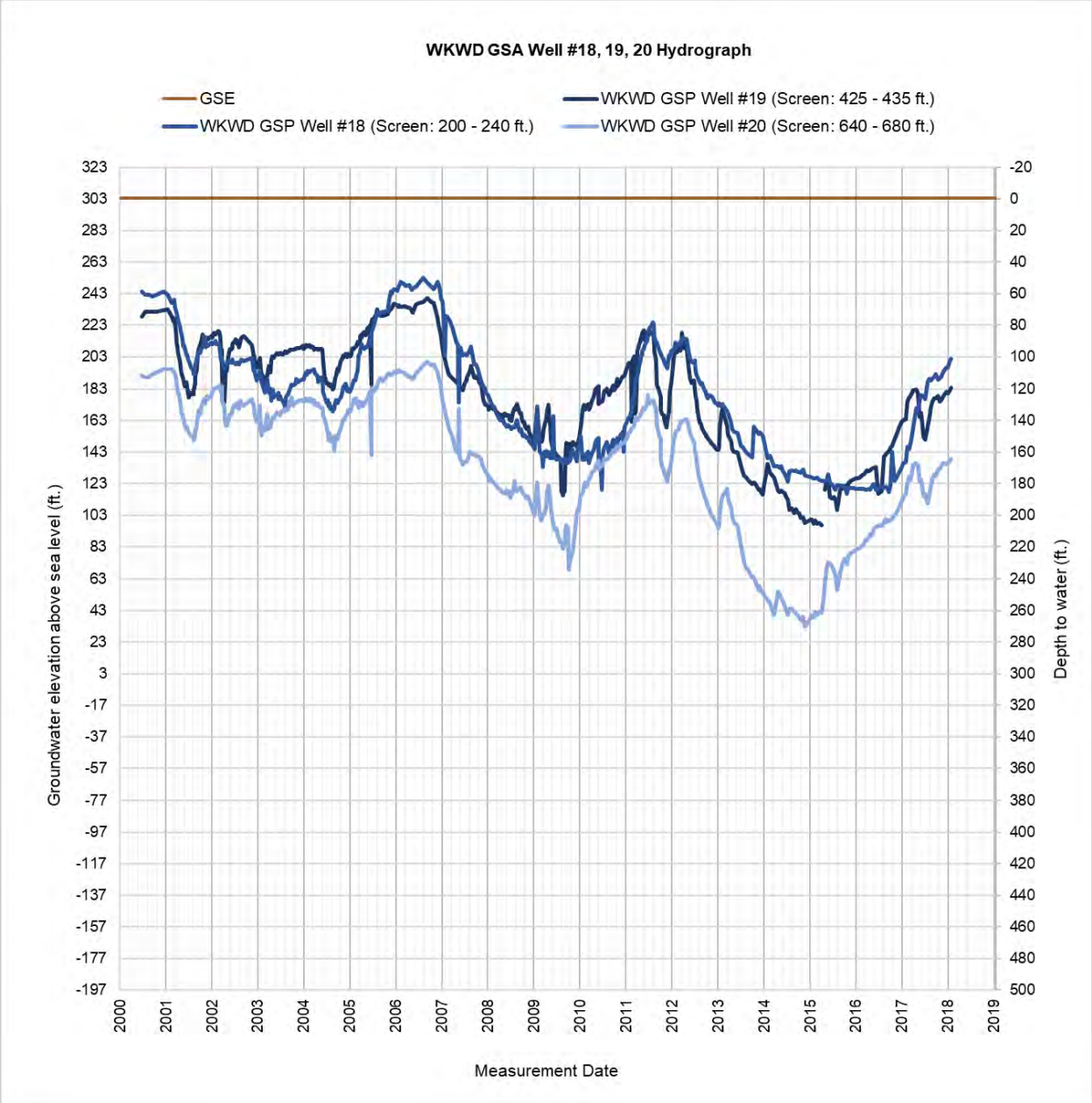


Figure 3-5. Combined Hydrograph of WKWD GSA Multiple Completion Wells 18, 19, and 20

3.3.3 Vertical Gradients

A vertical gradient describes the movement of groundwater perpendicular to the ground surface. Vertical gradient is typically measured by comparing GWE readings in a well with multiple completions located at different depths. If GWEs in the shallower completions are higher than in the deeper completions, groundwater is moving down into the ground and is referred to as a downward gradient. This would occur when there is more water percolating down through the soil toward the aquifer. If GWEs in the shallower completions are lower than in the deeper completions, groundwater is upwelling toward the surface and is referred to as an upward gradient. This would occur when a significant amount of groundwater pumping is shallower in the aquifer, causing an upwelling of water toward the well screens, or in special cases, a confined aquifer may provide an upward gradient if it were leaky. If GWEs are similar throughout the completions, there is no vertical gradient. Vertical gradients were analyzed at each of the GSA area's monitoring network wells. Each of the wells showed a downward vertical gradient. This proves the GSA area's sustainable management because it shows a trend of groundwater recharge into the Subbasin. Recharge of groundwater in GSA area percolation ponds creates a larger hydraulic head at the surface that percolates downward over time, reporting higher water levels in shallower well completions, and lower water levels in well completions deeper in the Subbasin. Figure 3-3 shows the locations of the GSA monitoring network wells.

Appendix C shows hydrographs for the North Project Management Area representative network wells. The two monitoring network wells in the North Project Management Area are single wells; therefore, only a single depth to water measurement is collected at this location. Two new multiple completion wells have been installed, but they do not have enough recorded, usable data to calculate vertical gradients. Since vertical gradient analysis requires measurements to be taken from at least two different depths (i.e., completions), there are no vertical gradients presented for the North Project Management Area.

Appendix D shows hydrographs for the South Project Management Area representative network wells. Five of the seven representative wells are multi-completion and show a downward vertical gradient through the reported GWE data. Each of the multi-completion wells show higher GWEs for the shallowest completion and the lowest GWE for the deepest completions. Water flows from high elevation to low elevation, meaning water is flowing downward in the South Project Management Area.

3.3.4 Groundwater Elevation Contour Maps

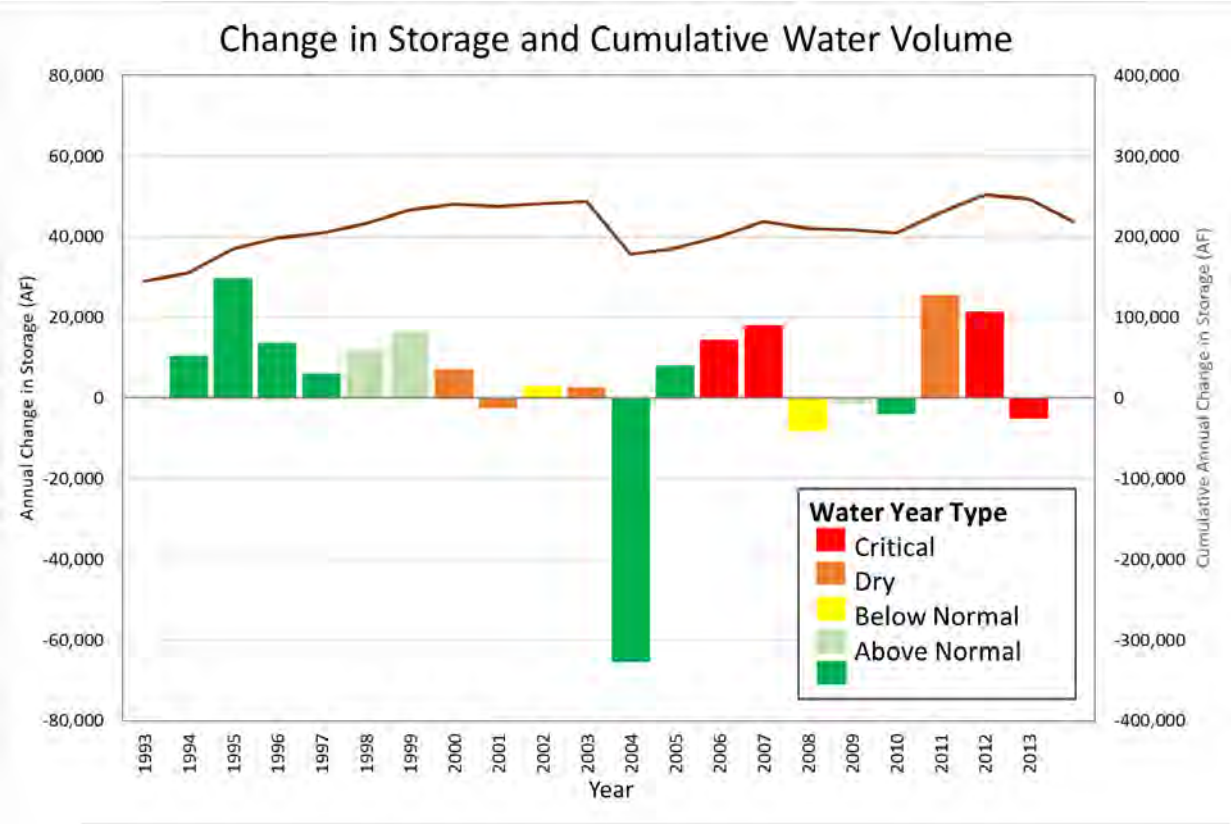
Contour maps for the South Project Management Area for January 2015 and 2018 are included in Appendix E and described in this section. January was chosen to reflect GWE under SGMA baseline condition and under current conditions. Pumping in the Western Management Area is considered de minimis; therefore, no GWE monitoring occurs and no contour maps were prepared the area.

Figures C-3 and C-4 in Appendix C show January 2015 and 2018 GWEs for the South Project Management Area. The surface elevation in the South Project Management Area fluctuates by 11 feet (i.e., 303 to 314 feet), meaning horizontal gradients are the result of groundwater management and do not occur naturally with surface elevations. Groundwater levels have risen over 100 feet in many portions of this area from 2015 to 2018.

3.4 Historical Change in Storage

Historical change in storage in the GSA area is tied to two factors: climate cycles and availability of water for import. Note: WKWD transferred 100,000 AF to Rosedale Rio Bravo WSD in 2004

Figure 3-6 shows the change in storage by year, water year type, and cumulative water volume for the last 20 years. Change in storage was calculated by comparing imported water and consumptively used water in the GSA area. Average annual use over the 20-year period was 20,154 AF. In general, groundwater rises in years that are wetter, and declines in years that are dryer.



Note: WKWD transferred 100,000 AF to Rosedale Rio Bravo WSD in 2004

Figure 3-6. Change in Storage by Year, Water Year Type, and Cumulative Water Volume

3.5 Groundwater Quality

Overall, groundwater quality in the North and South Project management areas is excellent and meets all federal and state drinking water health standards (WKWD, 2018). While arsenic and antimony were detected at concentrations below their MCL for drinking water, WKWD took a proactive approach to manage any concerns; those actions are discussed below. Groundwater quality within the Western Management Area portion of the GSA is generally unusable due to high salinity levels. There is little or no groundwater production in the Western Management Area, so water quality in that area is not discussed in this section.

WKWD monitors water quality at each of its production wells. Appendix F includes WKWD's water quality monitoring results for each well from 2012 through 2019. Monitoring results indicate there are very few instances where samples exceed the MCL for any constituents, except for antimony (discussed below), and that no constituents are consistently above the MCL in any well. Groundwater quality was consistent over the measurement period, including through the drought and the historically low groundwater levels of 2015, which indicates that groundwater quality does not degrade with decreased groundwater elevations in the WKWD GSA.

Antimony

Antimony is a trace component of many rocks and minerals common to the GSA area. Like arsenic, it occurs in groundwater through contact with rocks and sediments in the subsurface and through industrial process and other human activities.

During the January 1 to December 31 sampling period for the 2017 WKWD *Annual Water Quality Report*, one of WKWD's 13 wells reported concentrations that exceeded the 6 mg/L MCL for antimony. All other production wells did not detect antimony. To address the issue for drinking water standards, WKWD implemented a blending operation and began a trend monitoring program for four consecutive quarters beginning in June 2017. Laboratory analytical data showed WKWD's blending operations were effective at reducing the antimony concentration in water delivered to WKWD's customers to 0 mg/L.

The antimony detection is localized to a single well and is not indicative of a long-term regional trend. No further actions to address antimony are required in this Chapter GSP.

Oil and Gas Production

The GSA area overlies a petroleum producing area. Impacts to WKWD's groundwater supply by these operations, both actual and potential, are continuously monitored and evaluated. WKWD takes a proactive approach in addressing and correcting any contamination threats to its groundwater supply. To date, no significant threat to groundwater quality has occurred because of local oil and gas operations. No further actions to address oil and gas production are required in this Chapter GSP.

Water produced water in western Kern County is typically managed by either recycling it for enhanced oil recovery (EOR) operations, such as steam/cyclic steam flooding, or by permitted disposal under the regulatory oversight of the Department of Oil and Gas (DOGGR). It is important to clarify that the type of EOR described here is not hydraulic fracturing.

- **Reinjection—**Produced water used for steam or water flood EOR is reinjected under permit into the same geologic zone it was produced from in order to help maintain oil reservoir pressures and sweep residual oil towards planned extraction wells. In this way, produced water can potentially be used through several cycles of production and reinjection. During this process, a portion of the water that is reused in this way is inevitably lost to the geologic formation or to the process of steam generation etc. Because of the loss of reused water to the geologic formation, water is purchased from WKWD to be added to the water reused, called "make up water" in oil production circles is used depending on field conditions.

- **Disposa—**Disposal of brackish and saline oil field produced water in western Kern County has typically employed two methods (1) evaporation ponds or (2) reinjection into exempt aquifers identified by DOGGR. Due to water quality concerns, many of the produced water disposal ponds in Kern County have been closed. Consequently, reinjection into exempt aquifers has become the primary method of produced water disposal.

In summary, a significant percentage of the oil field produced water in the WKWD GSA's western management area is either recycled into the same geologic zones it was produced from, or is sequestered in deeper zones that are isolated from sources of drinking water. This water is supplemented by water purchased from WKWD, which indicates that very little water is disposed of, since purchasing fresh water is more expensive than recycling water.

Because the regulation of oil produced water under SGMA is not fully clear at this time, WKWD GSA will reevaluate this evaluation of oil produced water during the first five-year update of its Chapter GSP. WKWD GSA will also coordinate with oil producers to identify approaches to enhance water quality monitoring and reporting of oil produced water to ensure that groundwater quality is protected.

EnviroStor and GeoTracker Databases

The Kern County GSA reviewed the SWRCB GeoTracker website, the California Department of Toxic Substances Control's EnviroStor website, and the EPA's National Priorities List for locations of potential groundwater impacts throughout the Subbasin. Figure 2-25 of the Umbrella GSP shows no regional plumes of contaminants are associated with sites in the GSA area.

Sites of interest identified in Figure 2-26 of the Umbrella GSP indicate that they are sites related to oil production and include percolation ponds and underground injection control. These sites are in the far western portion of the Western Management Area and cannot affect water management activities in other WKWD GSA management areas.

3.6 Land Subsidence

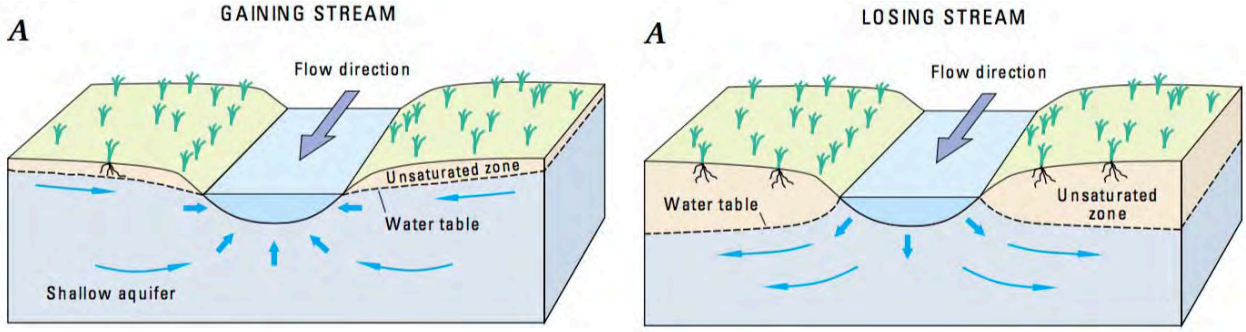
Although groundwater pumping has caused subsidence elsewhere in the southern San Joaquin Valley, data indicate that the Kern Fan aquifer behaves elastically in response to groundwater banking operations. Figures 2-27 and 2-28 in the Umbrella GSP show Subbasin subsidence rates from 2007 to 2011, and from 2015 to 2016 respectively. The data show the impact of subsidence due to groundwater pumping on ground surface elevation in the GSA area has been minimal, and over time, the average land surface elevation risen approximately 0.8 feet (KWBA, 2018).

While water entrained in oil as oil is extracted from the ground is properly excluded from the Water Budget, DWR's Water Budget BMP directs the GSA to consider whether such produced water will cause undesirable results. Subsidence can be caused by a variety of factors and will be appropriately monitored throughout the basin. Several processes contribute to land subsidence in the subbasin and include, in order of decreasing magnitude: aquifer compaction by overdraft, hydrocompaction (shallow or near-surface subsidence) of moisture deficient deposits above the water table that are wetted for the first time since deposition, petroleum reservoir compaction due to oil and gas withdrawal, and subsidence caused by tectonic forces (Ireland et al., 1984).

Subsidence Subbasinwide is fully discussed in the KGA's Umbrella GSP.

3.7 Interconnected Surface Water Systems

Interconnected surface waters are water features that are hydraulically connected by a saturated zone to the groundwater system—in other words, where water table elevations and surface water features intersect at the same elevations and locations. Interconnected surface waters are classified as either gaining or losing; the surface water feature is either gaining water from the aquifer system or losing water into the aquifer system as shown in Figure 3-7.



(Source: USGS, 2018)

Figure 3-7. Gaining and Losing Streams

There are no interconnected surface water systems in the North or South Project management areas. Intermittent streams are identified in the Western Management Area. These streams are non-jurisdictional waters of the United States, and only flow during heavy precipitation events; therefore, management of interconnected surface water is not necessary. The Buena Vista Aquatic Recreational Area (BVARA) does lie partly in the GSA area; however, Buena Vista Lake itself is not within the GSA boundary.

3.8 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are defined in the GSP regulations as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." A working group comprised of DWR, California Department of Fish and Wildlife, and The Nature Conservancy reviewed publicly available state and federal agency datasets that mapped California vegetation, wetlands, springs, and seeps, and conducted a screening process to identify types and locations commonly associated with groundwater. The results were compiled into the Natural Communities Commonly Associated with Groundwater database, and two habitat classes were defined. The first class includes wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions. The second class includes vegetation types commonly associated with the sub-surface presence of groundwater (i.e., phreatophytes). Figure 3-8 shows potential locations of GDEs in the GSA area (CNRA, 2018). All GDEs identified by the working group are in the Western Management Area where, the likelihood of groundwater emerging from the aquifer or occurring near the surface is highly unlikely.

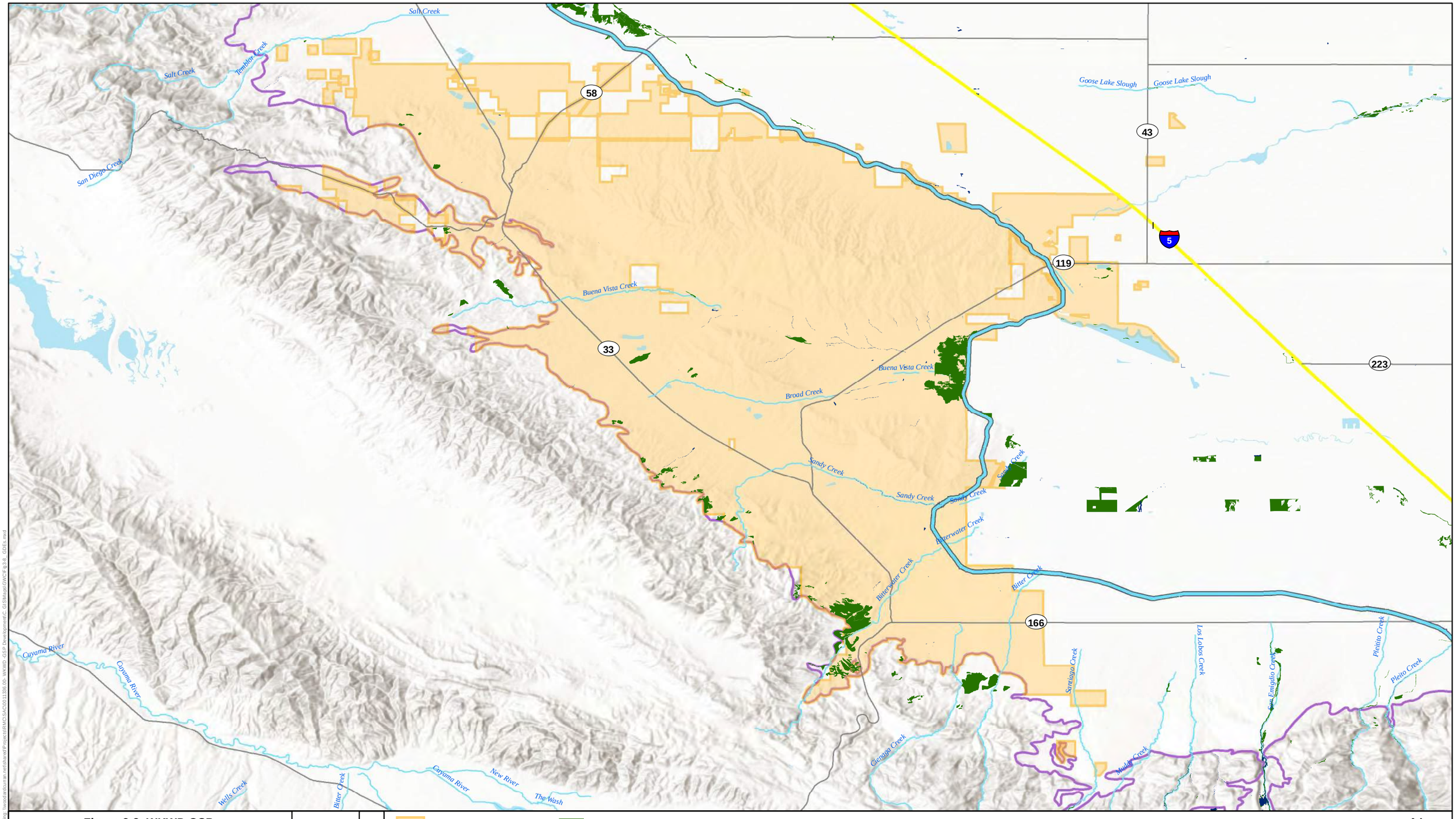


Figure 3-8: WKWD GSP
Groundwater Dependent Ecosystems

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- California Aqueduct
- Rivers/Streams
- Natural Communities Commonly Associated with Groundwater (Vegetation)
- Natural Communities Commonly Associated with Groundwater (Wetlands)

N

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3.9 References

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BVWSD. See *Buena Vista Water Services District.*

California Department of Water Resources. 2016. *Kern Water Bank Study Area Physical Data Collection Technical Report*. https://water.ca.gov/LegacyFiles/environmentalservices/docs/mntry_plus/revisedeir_volume%20II/7-1%20Data%20Report.pdf. Accessed on January 11, 2019.

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DWR. See *California Department of Water Resources.*

Reclamation. See *United States Department of the Interior Bureau of Reclamation.*

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Unites States Department of the Interior Bureau of Reclamation. 2018. *Appendix F: Conveyance Facilities and Waterways*. https://www.usbr.gov/mp/nepa/includes/documentShow.php?Doc_ID=31730. Accessed: January 16, 2019.

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WKWD. See *West Kern Water District.*

Section 4.0 Water Budget

4.1 WKWD and the Basinwide Coordinated Water Budget

All GSAs in the Subbasin coordinated and collaborated on the development of a groundwater model to evaluate historical, baseline and projected groundwater conditions. The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop the model on behalf of the Subbasin. The contract required that Todd Groundwater use the C2VSim model provided by DWR. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (see Attachment H in Umbrella GSP). Basinwide water budget results from the model are provided in Attachment H and show the Subbasin, as a whole, has a total storage deficit of approximately 324,326 AFY over the baseline period.

The Subbasin's dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a GSA level water accounting system (Checkbook) using Subbasin specific values for supply, demand and net results. The Model results reflect Subbasin-wide conditions and do not allocate water shortages/surpluses, nor do the results allocate the "ownership" of water. As a result, the GSAs, through a coordinated effort, developed the Checkbook that estimates current conditions for each GSA that are generally consistent with the Model results under baseline condition. The Checkbook and Model budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability in the interest of developing a Subbasin coordinated approach.

To ensure the individual water budgets reflected actual conditions, the KGA members developed the Checkbook budget and coordinated water accounting methodology. The result of that effort indicates a current baseline shortage/deficit for KGA members of approximately-256,281 AFY.1 This reflects the difference between a total demand for KGA members of 1,939,409 AFY, and a total supply of 1,683,128 AFY. Of the shortage/deficit of the KGA, West Kern's portion of the KGA shortage/deficit is -2,421 AF. Or a difference in demand of 36,077 AF and a water supply of 33,656 AF.

As is mentioned above, each estimate includes data gaps and has varying degrees of accuracy and/or reliability. The Checkbook is complimentary to the Model and reflects the allocation of water supply benefits and obligations independent of geographic constraints within the Subbasin. This was important to recognize and ensure the coordination of the various groundwater banking projects and water management programs amongst the various GSA's within the groundwater basin.

4.2 Compliance Information

Table 4-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

Table 4-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 4.10
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.18	Water Budget Information	Description of inflows, outflows, and change in storage	Section 4.0
		Quantification of overdraft	Umbrella GSP
		Estimate of sustainable yield	Umbrella GSP
		Quantification of current, historical, and projected water budgets	Umbrella GSP
	Surface Water Supply	Description of surface water supply used or available for use for groundwater recharge or in-lieu use	Section 1.0 Section 2.10 Section 4.6

4.3 Introduction

This Chapter GSP section includes information about the water budget. This water budget information also supports the Subbasin-scale water budget as presented in the Umbrella GSP. This water budget information meets Section 354.18 of the SGMA regulations.

In general, water budgets quantify the following:

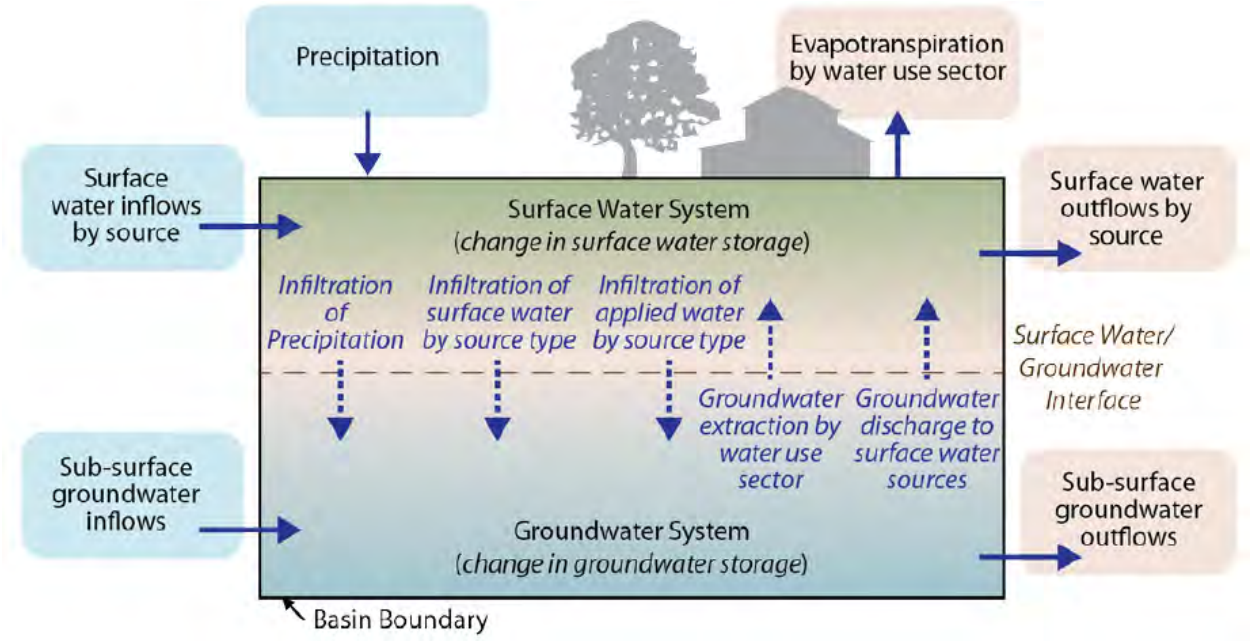
- Total surface water entering and leaving a basin by water source type
- Inflow to the groundwater system by water source type
- Outflows from the groundwater system by water source type
- Outflows from the groundwater system by water use sector
- The change in annual volume of groundwater in storage between seasonal high conditions
- If overdraft occurs, water budgets quantify overdraft over a period of years during which water year and water supply conditions approximate average conditions
- The water year type associated with annual supply, demand, and change in groundwater stored
- An estimate of sustainable yield for the Subbasin

Water budgets for the Subbasin were developed considering historical, current and projected conditions, and were developed at the Subbasin scale. This section describes WKWD data used to support and develop the historical Subbasin water budget. Current and future condition water budgets were developed based on broader, basin-wide assumptions, and are presented in the Umbrella GSP.

4.4 Water Budget Information

The Umbrella GSP's water budgets were developed to provide a quantitative accounting of water entering and leaving the Subbasin. Generally, water entering the Subbasin includes water entering on the surface and through the subsurface, and water leaves in a similar manner. Water entering and leaving does so through precipitation, streamflow, and through human activities such as recovery and recharge of surface supplies for irrigation (DWR, 2016). Figure 4-1is a diagram in cross section that shows the various water balance components used when developing a water budget.

Values presented in this Subbasin water budget describe historical, current, and projected conditions as they relate to hydrology, water demand, water supply, land use, population, climate change, sea-level rise (which does not apply in the Subbasin), groundwater and surface water interaction, and subsurface groundwater flow. This information can help the WKWD GSA manage water resources in the Subbasin by identifying, among other things, the scale of different water uses and potential opportunities to improve water supply conditions while highlighting potential risks.



(Source: DWR Water Budget Best Management Practice)

Figure 4-1. Generalized Water Budget Diagram

Water budgets can be developed on different spatial scales. For agricultural use, water budgets may be limited to the root zone in soil, with the goal of improving irrigation efficiencies by estimating crop evapotranspiration and the downward movement of applied water through the shallow subsurface. For groundwater, a water budget may be limited to assessing the behavior of water flow in the subsurface.

Global climate models simulate water budgets that incorporate elements such as atmospheric water, allowing for simulation of climate change conditions. Consistent with SGMA requirements, the water budget for the Umbrella GSP describes both surface water and groundwater systems in the Subbasin.

Water budgets can also be developed at different temporal scales. Daily water budgets may be used to demonstrate how evaporation and transpiration increase during the day and decrease at night. Monthly water budgets may be used to demonstrate how groundwater pumping increases in dry, hot summer months and decreases in the cool, wet winter months. In this section, also consistent with SGMA requirements, the water budget focuses on a full water year (i.e., 12 months spanning from October of the previous year to September of the current year), with some consideration of monthly variability.

SGMA requires that annual water budgets are based on historical, current, and projected conditions. The water budget for the Subbasin was developed to capture typical conditions during these time periods. Typical conditions were developed by averaging hydrologic conditions over time that incorporate droughts, wet periods, and normal periods. By incorporating these varied conditions, analysis of the groundwater system under certain hydrologic conditions such as drought can be performed, along with an analysis of long-term averages. The following subsections discuss the Kern County implementation of the C2VSim model, the associated data used to develop the water budget for this Chapter GSP, and how this information supports coordination with the Umbrella GSP's water budgets.

4.5 Definitions and Assumptions

According to SGMA, water budgets are "an accounting of the total groundwater and surface water entering and leaving a basin, including the changes in the amount of water stored." In the case of the Subbasin, the water budget zone is the area of interest extending from the land surface to the bottom of the Subbasin. WKWD GSA has prepared its water budget for coordination with the KGA in a 'checkbook' format, where water imported by agencies in the WKWD GSA is compiled with other factors and consumptive use. In the WKWD GSA area, the water budget zone is a compilation of information from the four management areas: the North Project, the South Project, the Western, and the Lake management areas (Figure 4-2).

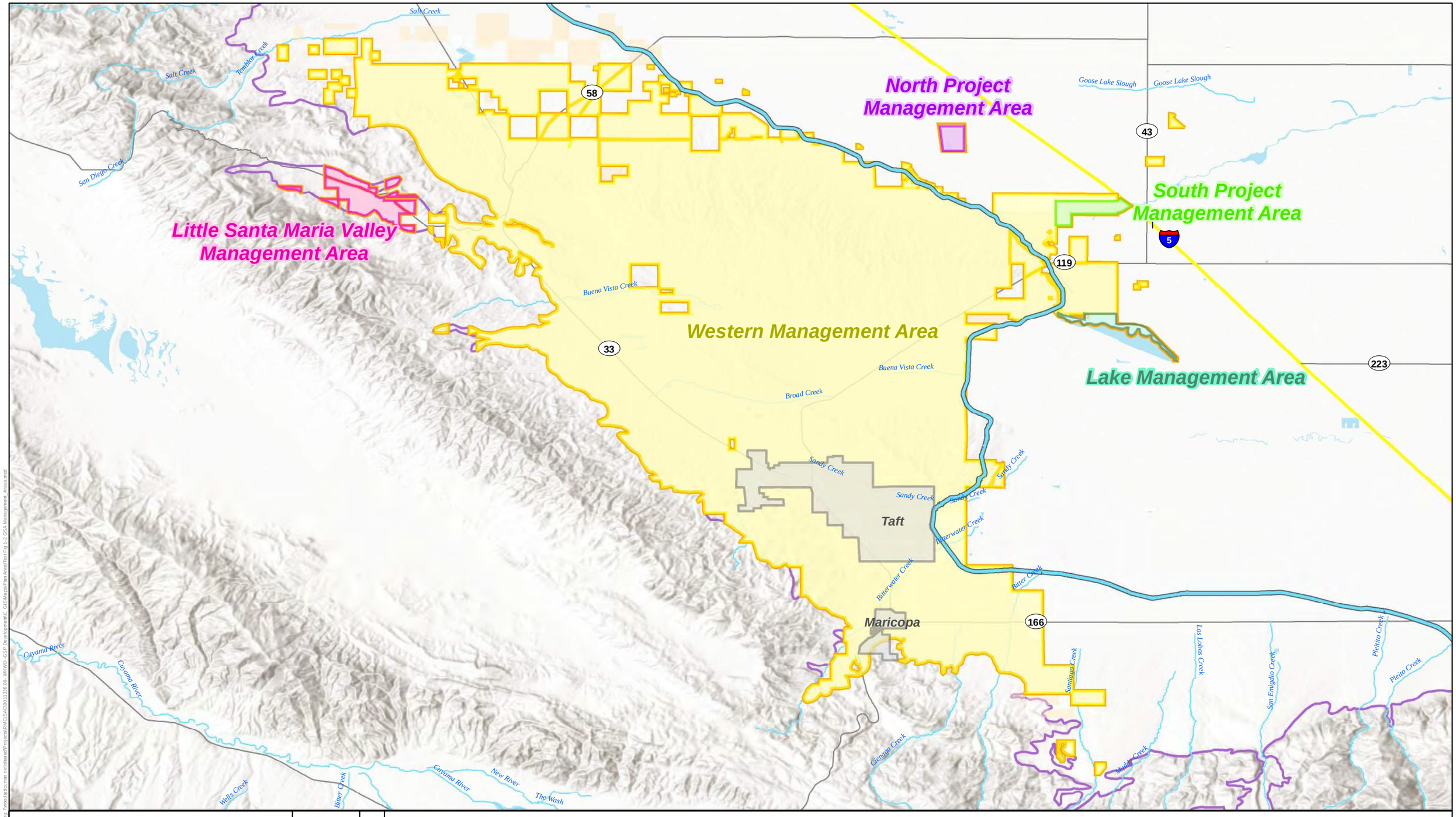


Figure 4-2: WKWD GSP Management Areas

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

Legend

- WKWD GSA
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- North Project Management Area
- South Project Management Area
- Lake Management Area
- Western Management Area
- Little Santa Maria Valley Management Area

N

0 3 6 12 Miles

Figure Exported: 12/4/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001133600- WKWD GSP Development\C- GIS\Maps\Plan Area\Text Fig 1-2 GSA Management Areas.mxd

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An accounting of water budget inflow and outflow components is based on both measured and estimated data. The accounting of water can be divided into three systems as follows:

- Land system
- Surface water system
- Groundwater system

The total water budget is a consolidation of inflows and outflows from each of these three systems, and the resulting water budget depicts inflows and outflows from the water budget zone. The primary surface water features in the Subbasin are Kern River and Poso Creek.

The land system water budget is an analysis of inflows to and outflows from the land surface in a water budget zone, including any change in storage in the land surface and unsaturated zone. It accounts for the exchange of water over a land surface, as well as the following:

- Exchange of water between surface and groundwater systems resulting from various native and managed land use activities (e.g., urban, agricultural, and managed wetlands)
- Movement of water through the unsaturated zone including infiltration into and past the root zone,
- Evaporation
- Evapotranspiration recharge from streams

A groundwater budget is an analysis of inflows to and outflows from the groundwater system in a water budget zone, including the amount of change in groundwater storage.

Inflows to a groundwater system include the following:

- Subsurface groundwater flow
- Seepage from surface water conveyance systems
- Recharge of applied water
- Migration of precipitation through the unsaturated zone
- Managed aquifer recharge from dedicated recharge facilities

Outflows from a groundwater system include the following:

- Groundwater extraction
- Losses to the surface water system
- Subsurface groundwater flow

Additional outflows from a groundwater system may also occur due to shallow groundwater discharge from seeps, wetlands, springs, and evapotranspiration.

4.6 North and South Project Management Areas: Historical Water Budget Estimates

The following components are included in each of the three system water budgets for the Subbasin.

4.6.1 Land System Water Budget

The Subbasin's land system water budget considers the following:

- Inflows
  - Precipitation
  - Applied water
- Outflows
  - Evapotranspiration
    - Agriculture
    - Native vegetation
  - Domestic water use
  - Deep percolation
    - From precipitation
    - From applied water
- Runoff
  - Stream seepage to groundwater
  - Flow out of Subbasin

4.6.2 Surface Water System Water Budget

The Subbasin's surface water system water budget considers the following:

- Inflows
  - Surface water inflow
  - Bypasses
  - Stream gain from groundwater
- Outflows
  - Evaporation
  - Surface water diversions
  - Return flow and runoff
  - Stream loss to groundwater

4.6.3 Groundwater System Water Budget

The Subbasin's groundwater system water budget considers the following:

- Inflows
  - Infiltration from precipitation
  - Infiltration from applied water
  - Recharge from local rivers and streams
  - Managed aquifer recharge (i.e., groundwater banking)
  - Boundary inflows from adjacent, non-alluvial areas
  - Subsurface inflows from adjacent basins

- Outflows
  - Evapotranspiration by water use sector
  - Groundwater production by water use sector
  - Discharge to local rivers and streams
  - Subsurface outflows to adjacent subbasins
  - Change in storage

Components of the water budgets listed above are presented at the Subbasin scale in the Umbrella GSP. The following discussion about WKWD North and South management areas' water budgets focus on the data used to support development of the Subbasin-scale water budgets.

4.6.4 North and South Management Areas: Water Budget Components

All groundwater recharge and water use in the North and South Project management areas is metered and operated by WKWD. WKWD has a contract with the KCWA to deliver water from the SWP. A portion of the SWP supply is delivered to BVWSD in exchange for BVWSD's water from the Kern River. Kern River water is physically recharged on the wellfields in the North and South Project management areas. A total of 5 percent of recharged water is considered a non-recoverable loss to benefit the Subbasin, leaving 95 percent of this water available for recovery and use in and outside WKWD.

WKWD participates in a number of water exchanges in addition to direct operations of its recharge activities, imports and pumping. BVWSD also sends additional water to WKWD in exchange for future deliveries. These exchanges are tracked as "WKWD Non-SWP recharge" in the water balance. During some water years, the WKWD groundwater banking program also conducts physical exchanges with other neighboring agencies such as the Kern Water Bank and Irrigation District (ID) 4. These are considered "Transfers In" in the water balance. WKWD also maintains a balance of "additional assets" that are tracked separately from the rest of the banked water. These additional assets consist of water exchanges with other agencies including the Rosedale-Rio Bravo Water Storage District, the North Kern Water Storage District, and the Palmdale Water District. The balance of additional assets is accounted for separately from WKWD's groundwater balance, as it includes both physical and paper exchanges.

The North and South Project management areas contain wells used to recover banked groundwater. Water recharged in these areas is extracted for both in-district use and to support exchange programs with other local water districts. Absent pumping to meet demands at BVARA, WKWD maintains a positive banked water balance in these areas and has banked water reserves in excess of 200,000 AF.

WKWD's remaining SWP supply is delivered directly through a turnout off the California Aqueduct for use by the La Paloma Power Facility. Groundwater pumping in the Western Management Area is considered de minimis. Municipal and industrial (M&I) demands are met by recovering banked water from the North and South projects. Approximately 80 to 85 percent of the water recovered is used to meet industrial demands, and the remaining 15 to 20 percent is used to meet residential demands. The Lake Management Area does not have any managed water supplies and no measured data are currently available. Evapotranspiration demands for the Lake Management Area are included in the Kern C2VSim model, and results are presented in the Umbrella GSP. The water budget information presented below pertains primarily to the sources and uses for water in WKWD.

Table 4-2 shows the balance of inflows and outflows from the WKWD for the period from 1994 to 2014. Water balance components listed in Table 4-1 are defined in more detail below.

- California Aqueduct Inflow for Direct Use—SWP water diverted and used for the La Paloma Power Facility
- California Aqueduct Inflow for Recharge—SWP exchange with BVWSD that is recharged and credited to WKWD
- WKWD Non-SWP Recharge—Other recharge credited to WKWD, typically through exchanges with BVWSD
- WKWD Transfers In—Transfers from other agencies that are credited to the total WKWD balance
- Additional Assets In—Other transfers into WKWD that are tracked separately from the WKWD groundwater balance
- WKWD Native Yield—3,000 AFY that is credited to WKWD each year.
- Total In—Sum of all inflows, not including prescriptive right or not accounting for losses
- WKWD Pumping—Net pumping from the WKWD North and South projects
- Additional Assets Out—Transfers out that are tracked separately from WKWD groundwater balance
- Direct use of California Aqueduct Water—California Aqueduct Water used for La Paloma Power Facility
- Total Out—Sum of all outflows, not accounting for losses
- WKWD Total Assets—Total Inflows with losses minus total outflows. A 5 percent loss factor is applied to California Aqueduct inflow for recharge and WKWD non-SWP recharge

Between 1965 when WKWD began banking water, and 1993 when the water balance table begins, WKWD built a surplus balance of 144,692 AF.

Tables 4-2 through 4-3 list average water supplies and demands for the wellfields and district area separately, and then show them consolidated into a total supply chain.

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Table 4-2. North and South Project Management Areas: Water Balance (AF)

Water Year	CAA Inflow for Direct Use	CAA Inflow for Recharge[2]	WKWD Non-SWP Recharge[2]	WKWD Transfers In	Additional Assets In	WKWD Native Yield	Total In	WKWD Pumping	Additional Assets Out (4)	Direct Use of CAA Water	Total Out	
1965-1993	-	-	-	-	-	-	-	-	-	-	-	
1994	--	20,474	--	--	--	3,000	20,474	12,078	8,418	--	20,496	
1995	--	40,379	--	--	--	3,000	40,379	11,638	8,418	--	20,056	
1996	--	25,597	--	--	--	3,000	25,597	13,642	8,418	--	22,060	
1997	--	17,920	--	--	--	3,000	17,920	13,962	8,418	--	22,380	
1998	--	23,602	--	--	--	3,000	23,602	13,404	8,418	--	21,822	
1999	--	29,758	--	--	--	3,000	29,758	14,692	8,418	--	23,111	
2000	14	22,480	--	--	--	3,000	22,494	17,125	8,418	14	25,557	
2001	17	10,736	--	20,377	-	3,000	31,130	15,714	8,418	17	24,149	
2002	480	17,027	--	--	--	3,000	17,507	16,247	8,418	480	25,145	
2003	2,040	16,360	2,000	--	--	3,000	20,400	17,733	8,418	2,040	28,151	
2004	4,010	3,513	10,000	6,125	33,333	3,000	56,981	20,809	108,000	4,010	132,819	
2005[3]	3,590	29,552	--	--	--	3,000	33,142	20,843	10,732	3,590	35,165	
2006	3,959	14,385	--	20,000	--	3,000	38,344	22,108	8,418	3,959	34,485	
2007	4,296	4,461	8,500	3,708	28,489	3,000	49,454	23,107	11,708	4,296	39,111	
2008	4,525	252--	2,850	10,213	11,198	3,000	29,038	22,340	18,750	4,525	45,615	
2009	4,722	5,327	3,547	6,152	11,265	3,000	31,013	21,629	14,217	4,722	40,568	
2010	4,256	10,671	14,395	--	--	3,000	29,322	21,334	17,300	4,256	42,890	
2011	1,643	25,132	20,750	--	--	3,000	47,525	20,801	8,418--	1,643	30,862	
2012	3,665	30,418	22,457	--	--	3,000	56,540	21,107	18,500	3,665	43,272	
2013	4,816	2,752	8,750	--	--	3,000	16,318	19,494	8,664	4,816	32,974	
2014	5,353	252-	1,250	--	--	3,000	6,855	33,129	8,418--	5,353	46900	
Average Annual	**2,256**	**16,717**	**4,500**	**3,170**	**4,013**	**3,000**	**30,656**	**18,711**	**15110**	**2,256**	**36,077**	

Notes:
* CAA = California Aqueduct
1: WKWD accrued balance of 144,692 AF from 1965 to 1993 by recharging more water than was extracted
2: A 5% loss factor was applied to CAA Inflow for Recharge and WKWD Non-SWP Recharge.
3: Some of the groundwater recharge in 2005 was not assigned a loss factor per agreements
4. Includes average annual recover at BVARA

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Table 4-3. North and South Project Management Areas: Wellfield Balance

Component	Historical (1994-2014) Average Annual Volume (AF)
Wellfield Recharge	
California Aqueduct	16,717
Wellfield Recovery	
WKWD Distribution System	18,711
California Aqueduct Pump In[a]	413
Cross Valley Canal Pump In[a]	401

Notes:
[a] Exports through the California Aqueduct and Central Valley Project (CVP) occurred in 2013 and 2014.

Table 4-4. North and South Project Management Areas: Non-Wellfield Balance

Component	Historical (1994-2014) Average Annual Volume (AF)
Surface Water Sources	
California Aqueduct	2,256
Groundwater Pumping	
WKWD Distribution System	18,711
Demands[a]	
In-district M&I demands	18,711
La Paloma Power Facility	2,256

Notes:
[a] Effluent from the local sanitation district is used to irrigate non-edible fodder crops in the WKWD service area and are not accounted for here.

Table 4-5. North and South Project Management Areas: Water Balance

Component	Historical (1994-2014) Average Annual Volume (AF)
Surface Water Sources	
California Aqueduct for Direct Use	2,256
California Aqueduct for Recharge	16,717
Groundwater Pumping	
WKWD Distribution System	18,711
Exports to California Aqueduct	413
Exports to Cross Valley Canal	401
Demands	
Urban residential and M&I use within the district	18,711
La Paloma Power Facility	2,256

This 1994 to 2014 historical water balance for WKWD shows that, on average, 18,973 AF of water are diverted off the California Aqueduct and recharged or delivered directly into the WKWD GSA. Historically, 2,256 AFY of SWP deliveries are sent directly to the La Paloma Power Facility, and the remaining 16,717 AFY are recharged in the wellfields in the North and South Project management areas. Except for a small amount of water delivered for agricultural purposes, all water delivered in WKWD's service area meets M&I demands. The cities of Taft and Maricopa account for most urban residential demand in the GSA area. Water exported through the California Aqueduct and Cross Valley Canal to support occasional transfer and exchange programs is considered another outflow from the system. Additional recharge from non-SWP sources account for 4,500 AFY of inflow. WKWD also receives 3,170 AFY of transfers and 4,013 AFY of additional assets. A total of 30,230 AF of water enters WKWD each year.

Average annual demand in the WKWD GSA is 20,967 AFY. This demand is met by 2,256 AFY of SWP deliveries and 18,711 AFY coming from recovery of banked groundwater supplies. Groundwater is pumped from the North and South Project management area wellfields and conveyed through WKWD's distribution system. In addition to in-district use, water from the wellfields is also pumped and exported out of WKWD for various exchange and transfer programs. These programs are part of WKWD's overall water management strategy. In addition to in-district use, WKWD also has outflows that occur as part of groundwater transfers. Excluding pumping for BVARA, an average of 6,851 AFY leaves the WKWD as part of transfers. A total of 27,819 AFY of leaves WKWD.

WKWD maintains a positive banked water balance through established banking programs dating back to 1965. From 1965 through 1993, WKWD built banked groundwater reserves of 144,692 AF. Between 1994 and 2014, WKWD had an average annual inflow of 30,230 and an average outflow of 27,819. The net difference between inflows and outflows is 2,411 AFY, WKWD tracks a balance of assets each year and manages its water supply so supplies are never depleted. When tracking the balance of the banked groundwater reserves, groundwater recharged from the SWP or other sources are assigned a 5 percent loss factor. Groundwater transfers already account for a loss factor. Between 1994 and 2014, WKWD increased its groundwater balance from 144,692 to 219,353 AF.

Historically, WKWD has managed its operations to maintain a surplus water supply. Groundwater pumped from the North and South projects draw upon previously banked supplies that are managed so that an overdraft condition will not occur. Similarly, groundwater transfers build upon previously established balances and are managed so that overdraft does not occur. Information about surface water deliveries, groundwater recharge and recovery, and exported supply information was incorporated into the Kern County C2VSim model for development of the overall basin water budgets.

4.7 Western Management Area Water Budget

As discussed in Section 4.6.4 any groundwater use in the Western Management Area is de minimis and therefore is not monitored or managed by the WKWD GSA.

4.8 Lake Management Area Water Budget

The Lake Management Area is pumped by Kern County to provide water supplies to BVARA, specifically to Lake Webb. BVARA is in and adjacent to the WKWD GSA area. The 1,585-acre BVARA is home to two manmade lakes, Lake Webb and Lake Evans, boating facilities, playgrounds and volleyball courts, camp sites, and picnic areas. The lakes lie outside of the GSA area but the park facilities such as picnic areas, restrooms, and parking areas are within the GSA area. When constructed, the lakes had a combined storage capacity of over 6,800 AF. Shoreline camping and picnic areas are landscaped with grass and are irrigated during the dry season (County of Kern Parks and Recreation Department, 2019). With no outlet, water from the lakes either evaporates or percolates into the groundwater basin. Kern County pumps groundwater from wells located within the GSA area to supplement losses at the lake. Water demand from BVARA has been estimated to be approximately 8,000 AF per year, as identified by ITRC study used in the KGA's Umbrella GSP.

Water pumped into the lake is considered overdraft at this time, and is being addressed through Project 3, described in Section 8.7.3. Table 4-6. Pumping in the Lake Management Area shows pumping into the lake per year.

Table 4-6. Pumping in the Lake Management Area

Year	Pumping (AF)
2009	8,526
2010	8,565
2011	3,461
2012	11,052
2013	7,460
2014	10,616
2015	10,706
2016	10,250
2017	3,965
2018	7,210

4.9 Treated Produced Water

Treated produced water in western Kern County is typically managed by either recycling it for enhanced oil recovery (EOR) operations, such as steam/cyclic steam flooding, or by permitted disposal under the regulatory oversight of the Department of Oil and Gas (DOGGR). It is important to clarify that the type of EOR described here is not hydraulic fracturing.

- **Reinjection—**Produced water used for steam or water flood EOR is reinjected under permit into the same geologic zone it was produced from in order to help maintain oil reservoir pressures and sweep residual oil towards planned extraction wells. In this way, produced water can potentially be used through several cycles of production and reinjection. During this process, a portion of the water that is reused in this way is inevitably lost to the geologic formation or to the process of steam generation etc. Because of the loss of reused water to the geologic formation, water is purchased from WKWD to be added to the water reused, called “make up water” in oil production circles is used depending on field conditions.
- **Disposal—**Disposal of brackish and saline oil field produced water in western Kern County has typically employed two methods (1) percolation ponds or (2) reinjection into exempt aquifers identified by DOGGR. Due to water quality concerns, many of the produced water disposal ponds in Kern County have been closed. Consequently, reinjection into exempt aquifers has become the primary method of produced water disposal.

In summary, a significant percentage of the oil field produced water in the WKWD GSA's western management area is either recycled into the same geologic zones it was produced from, or is sequestered in deeper zones that are isolated from sources of drinking water.

Oilfield produced water is produced from sediments and formations that are below the bottom of the basin as defined in Section 2.7.3.

4.10 References

California Department of Water Resources (DWR). 2016. *Best Management Practices for the Sustainable Management of Groundwater: Water Budget BMP*. Published by the Sustainable Management Program. December. https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_Water_Budget_Final_2016-12-23.pdf. Accessed December 28, 2018.

West Kern Water District (WKWD). 2019. *WKWD Water Balance Spreadsheet.*

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Section 5.0 Undesirable Results Statements

5.1 Compliance Information

Table 5-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

Table 5-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria			
354.24	Sustainability Goal	Description of the sustainability goal	Section 5.3
354.26	Undesirable Results	Description of undesirable results	Section 5.0
		Cause of groundwater conditions that would lead to undesirable results	
		Criteria used to define undesirable results for each sustainability indicator	
		Potential effects of undesirable results on beneficial uses of users of groundwater	

5.2 Introduction

This section presents information about undesirable results, and descriptions as follows:

- A set of the coordinated undesirable results statements for the Subbasin
- A description of how undesirable results are identified in the WKWD GSA
- A description of how undesirable results may be caused
- A discussion of what would happen if undesirable results were to occur

Undesirable results statements are a key component of a GSP and are used to set quantitative thresholds for specific monitoring points that indicate when an undesirable result either has occurred or may occur. Additionally, undesirable results are used to establish monitoring protocols.

Undesirable results are defined in the SGMA regulations as one or more of the following effects caused by particular groundwater conditions occurring throughout a basin:

- "Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed, as necessary, to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
- Significant and unreasonable reduction of groundwater storage.
- Significant and unreasonable seawater intrusion.
- Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
- Significant and unreasonable land subsidence that substantially interferes with surface land uses and critical infrastructure
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water."

Undesirable results related to seawater intrusion are not present in the WKWD GSA.

The information in this section was developed based on the Water Code,[1] on related regulations adopted by DWR, BMPs developed by DWR, physical conditions, and through coordination with other Subbasin GSAs.

5.3 Sustainability Goal

The goal of the WKWD GSA's Chapter GSP is coordinated with the KGA. The coordinated sustainability goal for the KGA is:

The sustainability goal of the Kern County Subbasin is to:

- Achieve sustainable groundwater management in the Kern County Subbasin through the implementation of projects and management actions at the member agency level of each GSA
- Maintain its groundwater use within the sustainable yield of the basin through as demonstrated by monitoring and reporting groundwater conditions
- Operate within the established sustainable management criteria, which are established based on the collective technical information presented in the GSPs in the Subbasin.
- Collectively bring the Subbasin into sustainability and to maintain sustainability over the implementation and planning horizon.

Further, the Subbasin sustainability goal includes a commitment to monitor and report groundwater conditions, as required by SGMA, and to continue coordination among the KGA member agencies and all other GSA's in the Subbasin to identify the potential for, or presence of, undesirable results and actions to

[1] https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=WAT&division=6.&title=&part=2.74.&chapter=6.&article=

prevent undesirable results. The coordination process established in the development of this GSP and memorialized in the Coordination Agreement will ensure that the Subbasin is managed as a shared groundwater resource and that the districts within the Subbasin work collaboratively towards achieving and maintaining sustainable groundwater use.

5.4 Chronic Lowering of Groundwater Levels

5.4.1 Description of Undesirable Results

The undesirable result for chronic lowering of water levels is the point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

5.4.2 Identification of Undesirable Results

An undesirable result would occur when the minimum threshold for groundwater levels are exceeded in at least three adjacent management areas that represent at least 15 percent of the Subbasin, or that represent greater than 30 percent of the Subbasin (as measured by each management area; see Section 7.0 for more information about Subbasin management areas). Each GSAs will set minimum thresholds by each of Chapter GSP that participates in the KGA

5.4.3 Potential Causes of Undesirable Results

WKWD has a history of successful groundwater management. Potential causes of future undesirable results from the chronic lowering of groundwater levels would likely be tied to outside forces, such as reduced deliveries of water from the SWP.

Undesirable results driven by local water use, such as increased use of water, or other local changes in the hydrologic system, such as an increase in impervious surfaces are possible, but neither are likely under projected land and water use estimates.

5.4.4 Description of Potential Effects of Undesirable Results

Should groundwater levels reach established minimum thresholds and trigger an undesirable result, one potential impact could include dewatering of a subset of the existing groundwater infrastructure, starting with the shallowest wells. This would affect pumping capacity, water quality, and may lead to costly equipment repairs. This may also potentially impact WKWD’s ability to meet water demands.

5.5 Reduction of Groundwater Storage

The undesirable result for reduction of groundwater storage is the point at which significant and unreasonable impacts, as determined by the amount of groundwater in the Subbasin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended drought period.

5.5.1 Identification of Undesirable Results

Storage in the Subbasin is monitored by proxy using groundwater levels. An undesirable result would occur when the volume of storage (i.e., above the groundwater level minimum thresholds) was depleted to an elevation lower than the groundwater level minimum threshold in at least three adjacent management areas that represent at least 15 percent of the Subbasin or represent greater than 30 percent of the Subbasin (as measured by the acreage of each management area).

5.5.2 Potential Causes of Undesirable Results

WKWD has a history of successful groundwater management. Potential causes of future undesirable results for the reduction of groundwater storage would be the same as for the chronic lowering of groundwater levels. These levels would likely be tied to outside forces, such as reduction in deliveries of water from the SWP. Undesirable results driven by local water use, such an increase in the consumptive use of water, or other local changes in the hydrologic system such an increase in impervious surfaces are possible, but neither are likely under projected land and water use estimates.

5.5.3 Description of Potential Effects of Undesirable Results

If groundwater levels were to reach levels indicating undesirable results, potential effects could include the potential dewatering of a subset of the existing groundwater infrastructure, starting with the shallowest wells. Additionally, reaching undesirable results for groundwater levels potentially could adversely affect current and projected municipal uses, which rely on groundwater in the GSA area. See Section 5.4.4 above.

5.6 Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator in the Subbasin, because seawater intrusion is not present and is not likely to occur in the Kern Subbasin due to the distance between the basin and the Pacific Ocean, bays, deltas, or inlets.

5.7 Degraded Water Quality

5.7.1 Description of Undesirable Results

The undesirable result for degraded water quality is the point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

5.7.2 Identification of Undesirable Results

In the Subbasin, degraded water quality is monitored by proxy using groundwater levels. This is determined when the minimum threshold for a groundwater quality COC is exceeded in at least three adjacent management areas, and which represent at least 15 percent of the Subbasin, or represent greater than 30 percent of the designated monitoring points in the Subbasin. Minimum thresholds are set by each of Chapter GSP that participates in the KGA.

5.7.3 Potential Causes of Undesirable Results

WKWD has a history of successful sustainable groundwater management. Potential causes of future undesirable results for degraded groundwater quality likely would be tied to potential significant increases in groundwater production, resulting in upconing of deeper saline water present in the aquifer below the fresh water aquifer accessed for water supply. The potential causes of substantial increases in groundwater production are the same as those previously described in Section 5.4 above. Additionally, degraded groundwater quality may also be caused by unforeseen point source contamination issues. These changes could occur either naturally or might result from human activity.

5.7.4 Description of Potential Effects of Undesirable Results

If groundwater quality were degraded to reach undesirable results levels, the effect could potentially cause a reduction in usable supply delivered to groundwater users, including impacting municipal suppliers. Municipal suppliers might then have to install treatment systems or seek alternate water supplies. Water quality degradation could cause adverse effects to property values and have other economic effects.

5.8 Land Subsidence

5.8.1 Description of Undesirable Results

The undesirable result for land subsidence is the point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the Subbasin, affects the surface land uses or critical infrastructure.

5.8.2 Identification of Undesirable Results

An undesirable result is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin-wide coordinated GSP subsidence monitoring plan. This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.

5.8.3 Potential Causes of Undesirable Results

WKWD has a history of successful groundwater management. Historically, successful management has prevented subsidence from occurring in the GSA area. Potential causes of future undesirable results for land subsidence likely would be tied to significant increases in groundwater pumping, resulting in dewatering of compressible clays in the subsurface. The potential causes of substantial increases in groundwater pumping are the same as those previously described in Section 5.4 above.

5.8.4 Description of Potential Effects of Undesirable Results

If land subsidence conditions were to reach undesirable results levels, the adverse effects could potentially cause damage to infrastructure, including water conveyance facilities and flood control facilities. This could impact the ability to deliver surface water, resulting in increased groundwater use, and by extension this could have adverse effects to property values.

5.9 Depletions of Interconnected Surface Water

Depletions of interconnected surface water are not an applicable sustainability indicator for the WKWD GSA area, because the three active GSA management areas (i.e., the North Project, South Project, and Lake management areas) do not have overlying surface water. Streams overly the Western Management Area, but no pumping occurs in this area over de minimis levels. If groundwater pumping were to increase above de minimis levels in the Western Management Area, the GSA would consider revising management of this sustainability indicator at the five-year GSP update interval.

5.10 Evaluation of the Occurrence of Undesirable Results

As shown in Section 6, no monitoring points are currently below the minimum threshold. This indicates that undesirable results are not occurring in the WKWD GSA area.

Section 6.0 Monitoring Networks

6.1 Compliance Information

Table 6-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

Table 6-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 3. Technical and Reporting Standards			
352.2	Monitoring Protocols	Monitoring protocols adopted by the GSA for data collection and management	Section 6.0
		Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	Section 6.0
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 6.12
354.8(a)	Map(s)	Area covered by GSP	Section 1.0 Section 6.0
		Density of wells per square mile	Sections 6.6.4 and 6.10.4
Article 5. Plan Contents, Subarticle 4. Monitoring Networks			
354.34	Monitoring Networks	Description of monitoring network	Section 6.0
		Description of monitoring network objectives	Section 6.3
		Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions	Section 6.0
		Description of how the monitoring network provides adequate coverage of Sustainability Indicators	Section 6.0
		Density of monitoring sites and frequency of measurements required to demonstrate short-term,	Section 6.6 to 6.10

Table 6-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
		seasonal, and long-term trends	
		Scientific rationale (or reason) for site selection	Section 6.6 to 6.10
		Consistency with data and reporting standards	Umbrella GSP
		Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone	Section 7.0
		Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used	Sections 6.6, 6.10, and the DMS
		Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	Umbrella GSP
354.36	Representative Monitoring	Description of representative sites	Sections 6.6 and 6.10
		Demonstration of adequacy of using GWEs as proxy for other sustainability indicators	Section 6.0 Section 7.0
		Adequate evidence demonstrating site reflects general conditions in the area	Section 6.5
354.38	Assessment and Improvement of Monitoring Network	Review and evaluation of the monitoring network	Section 9.6.4
		Identification and description of data gaps	Sections 6.6.8 and 6.10.6
		Description of steps to fill data gaps	Section 6.6.9 and Umbrella GSP
		Description of monitoring frequency and density of sites	Section 6.6.3 to 6.6.4 and Sections 6.10.3 6.10.4

6.2 Introduction

This section of the Chapter GSP discusses the planned monitoring networks needed to guide or maintain the WKWD GSA portion of the Subbasin toward groundwater sustainability. Monitoring networks need to be established for each sustainability indicator either directly or via monitoring through a proxy.

Additionally, this section also addresses the requirements set out in SGMA regulations, and discusses monitoring network objectives, the existing monitoring networks used to develop each network, and describes a monitoring network for each sustainability indicator. Data gaps, and a plan to fill data gaps if they are present, are provided for each monitoring network.

6.3 Monitoring Network Objectives

This section describes Subbasin monitoring networks for the five sustainability indicators that apply in the Subbasin. The objective of these monitoring networks is to detect undesirable results as described in Section 5 using the sustainability thresholds described in Section 7 of this Chapter GSP. The SGMA regulations also define other related monitoring network objectives; they are listed below.

- Demonstrate progress toward achieving measurable objectives described in the GSP
- Monitor impacts to the beneficial uses or users of groundwater
- Monitor changes in groundwater conditions relative to measurable objectives (MOs) and minimum thresholds (MTs)
- Quantify annual changes in water budget components

The monitoring networks described in this section were designed by evaluating data provided by the WKWD, DWR, and USGS. Wells used for monitoring are included here and were considered based on criteria described below.

WKWD and Kern County are the only users of groundwater that exceeds de minimis amounts of water in the WKWD GSA area. Therefore, the monitoring networks presented in this section are selected to be able to monitor conditions that would adversely affect WKWD and Kern County.

6.4 Existing Monitoring Used

This section discusses current groundwater level monitoring in the GSA area of the Subbasin.

6.4.1 Groundwater Level Monitoring

This section describes groundwater level monitoring conducted by agencies and other groups in the GSA area.

DWR Statewide Dataset/CASGEM

The State of California has several water-related database portals that are accessible online as follows:

- CASGEM Program
- WDL
- Groundwater Information Center Interactive Map Application

Data for these portals are organized and saved in one master database; each portal accesses and displays the intended data depending on the search criteria and portal used.

Although all groundwater production pumping in the GSA area is conducted by WKWD, analysts accessed State's database was to ensure other production wells were not missed during analysis. Analysis results indicated that monitoring wells included in the State's dataset in the GSA area were wells managed and operated by WKWD, and either had discontinued measurements, or took groundwater level measurements in an area that does not have any production pumping.

USGS

USGS data can be accessed through online portals for the National Ground-Water Monitoring Network, the Groundwater Watch, and the NWIS.

USGS online data portals provide approved data that have been quality assured and confirmed fit to be published, and provisional data that are unverified and subject to revision. To obtain all available data, researchers used the USGS URL Generation Tool to download all provisional and approved data in the GSA area.

Data processing results indicate that wells in the GSA area were either part of WKWD's existing network, were abandoned or destroyed, or monitored groundwater levels in areas with no production pumping.

WKWD

WKWD manages 72 production, monitoring, completion wells in its service boundary. Some of the data for these wells are included in DWR and USGS datasets. Figure 6-1 shows these well locations.

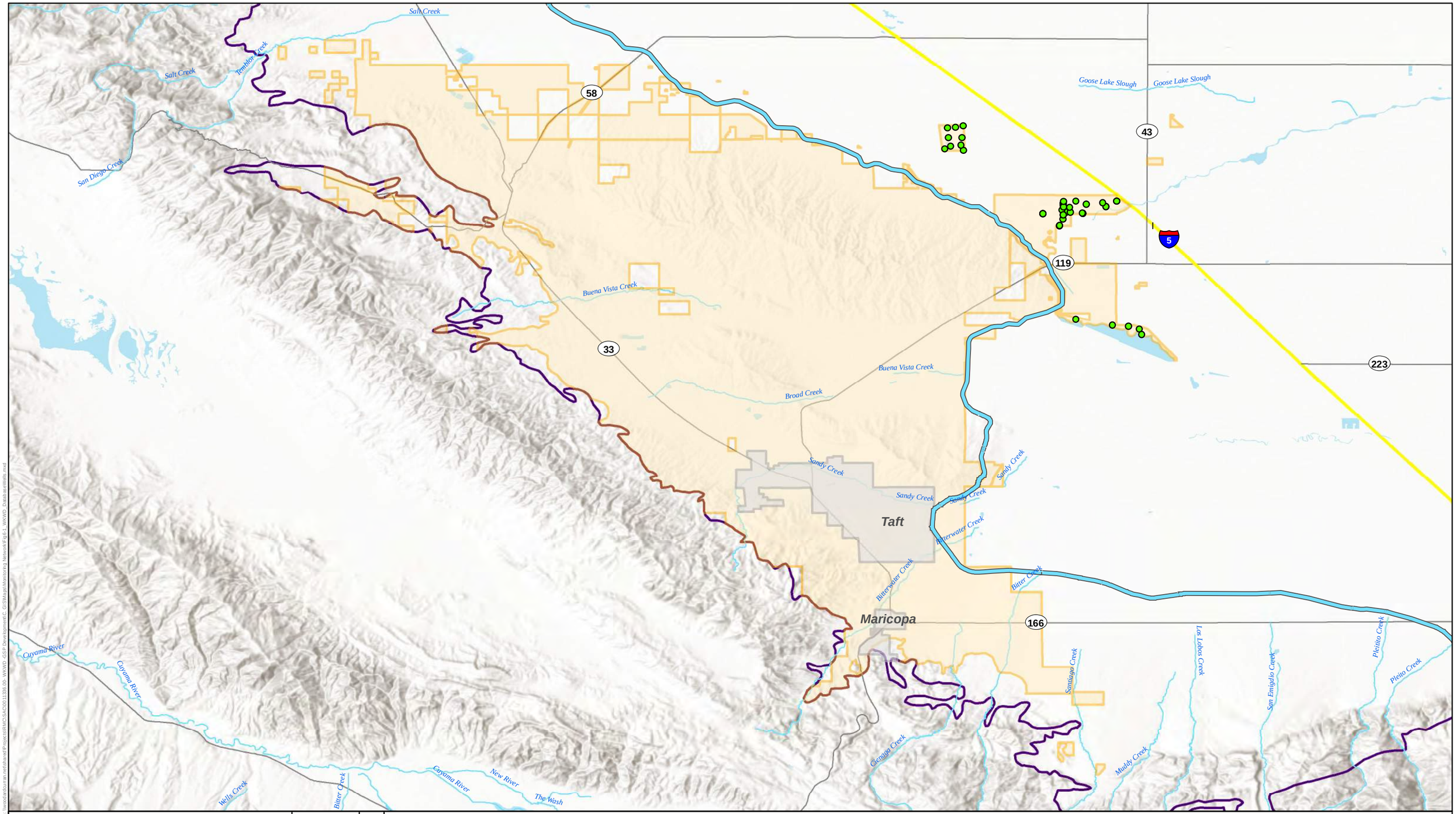


Figure 6-1: WKWD GSP
WKWD Database Wells

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

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Legend

- WKWD GSA
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- WKWD Production, Monitoring, and Multi-completion Wells

N

0 3 6 12 Miles

Figure Exported: 12/5/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001133600- WKWD GSP Development\C- GIS\Maps\Monitoring Network\Fig6-1 WKWD DatabaseWells.mxd

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6.4.2 Subsidence Monitoring

Subsidence is the sinking or downward settling of the earth's surface and is often the result of over-extraction of subsurface water. Subsidence can be measured in a few different methods such as with InSAR, continuous GPS, extensometers, and spirit leveling.

There are no continuous GPS stations in the GSA area. Other continuous GPS stations in the Subbasin are positioned too far from the GSA area to provide informative or applicable data.

Other subsidence methods used in the Kern Basin include extensometers (as shown in Figure 2-26 of the Umbrella GSP) and InSAR (as shown in Figures 2-27 and 2-28 in the Umbrella GSP). One extensometer located approximately 1 mile from the GSA area provides data representative of subsidence conditions in the GSA. Additionally, InSAR data do cover the GSA area. Further discussion about the data is provided in Section 6.10.

6.4.3 Surface Water Monitoring

The GSA area does not have any consistent natural surface water flows, and while a small portion of the Kern River channel is in the northeastern corner of the GSA area, this portion of the Kern River is dry in most years. As such, flows in that portion of the Kern River are not monitored within the GSA boundary. A gage is present on the Kern River where it flows into the South Management Area. No other surface gages exist in the GSA area.

6.5 Monitoring Rationales

This section discusses the reason why certain monitoring networks were selected. The selected monitoring networks were developed to ensure they can detect changes in Subbasin conditions. With this information, the GSA can manage the portion of the Subbasin used by WKWD to ensure sustainability goals are met, and to ensure no undesirable results are present after 20 years of sustainable management.

The monitoring networks were selected specifically to detect short-term, seasonal, and long-term trends in groundwater conditions. The monitoring networks were selected to include an adequate amount of temporal frequency, spatial density, hydraulic gradients, flow directions, and for use in estimating the annual change in groundwater storage. These factors help evaluate information about groundwater conditions, which in turn are necessary to evaluate the effectiveness of projects and management actions undertaken by the GSA.

This Chapter GSP does not include water quality, water in storage, seawater intrusion, depletions of interconnected surface water, or subsidence monitoring performed by the GSA, and therefore does not include monitoring protocols for those sustainability indicators. WKWD GSA will coordinate with the KGA to modify these as necessary in the future.

6.6 Groundwater Level Monitoring Network

Groundwater level monitoring is conducted through a groundwater well monitoring network. This section describes the following:

- How the level monitoring network was developed
- Criteria for selecting representative wells
- Monitoring frequency
- Spatial density
- Monitoring protocols
- Data gap identification and strategies to fill data gaps

6.6.1 Management Areas

There are four management areas in the GSA area: the North Project, the South Project, the Lake, and the Western management areas. Figure 6-2 shows management area locations.

6.6.2 Monitoring Wells Selected for Monitoring Network

Monitoring wells were selected based on their construction. All dedicated monitoring wells in the WKWD GSA were selected to be used for the monitoring network, and production wells were not selected for the monitoring network. In the South Project Management Area, there is one aquifer, and in the North Project Management Area there are two aquifers. Figure 6-3 shows these wells' locations.

North Project Management Area

South Project Management Area

Little Santa Maria Valley Management Area

Western Management Area

Lake Management Area

Taft

Maricopa

Salt Creek

Temblor Creek

San Diego Creek

Goose Lake Slough

Buena Vista Creek

Broad Creek

Sandy Creek

Bitterwater Creek

Bitter Creek

Cuyama River

Wells Creek

New River

The Wash

Santiago Creek

Los Lobos Creek

San Emigdio Creek

Pleito Creek

Pletito Creek

Cienaga Creek

Muddy Creek

58

33

43

5

119

223

166

Figure 6-2: WKWD GSP Management Areas

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

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Legend

- WKWD GSA
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- North Project Management Area
- South Project Management Area
- Lake Management Area
- Western Management Area
- Little Santa Maria Valley Management Area

N

0 3 6 12 Miles

Figure Exported: 12/4/2019 By: cstapleton I:\data\ \\woodardcurran.net\shared\Projects\RMC\SAC\001336.00- WKWD -GSP Development\C- GIS\Maps\Plan Area\Text Fig 1-2 GSA Management Areas.mxd

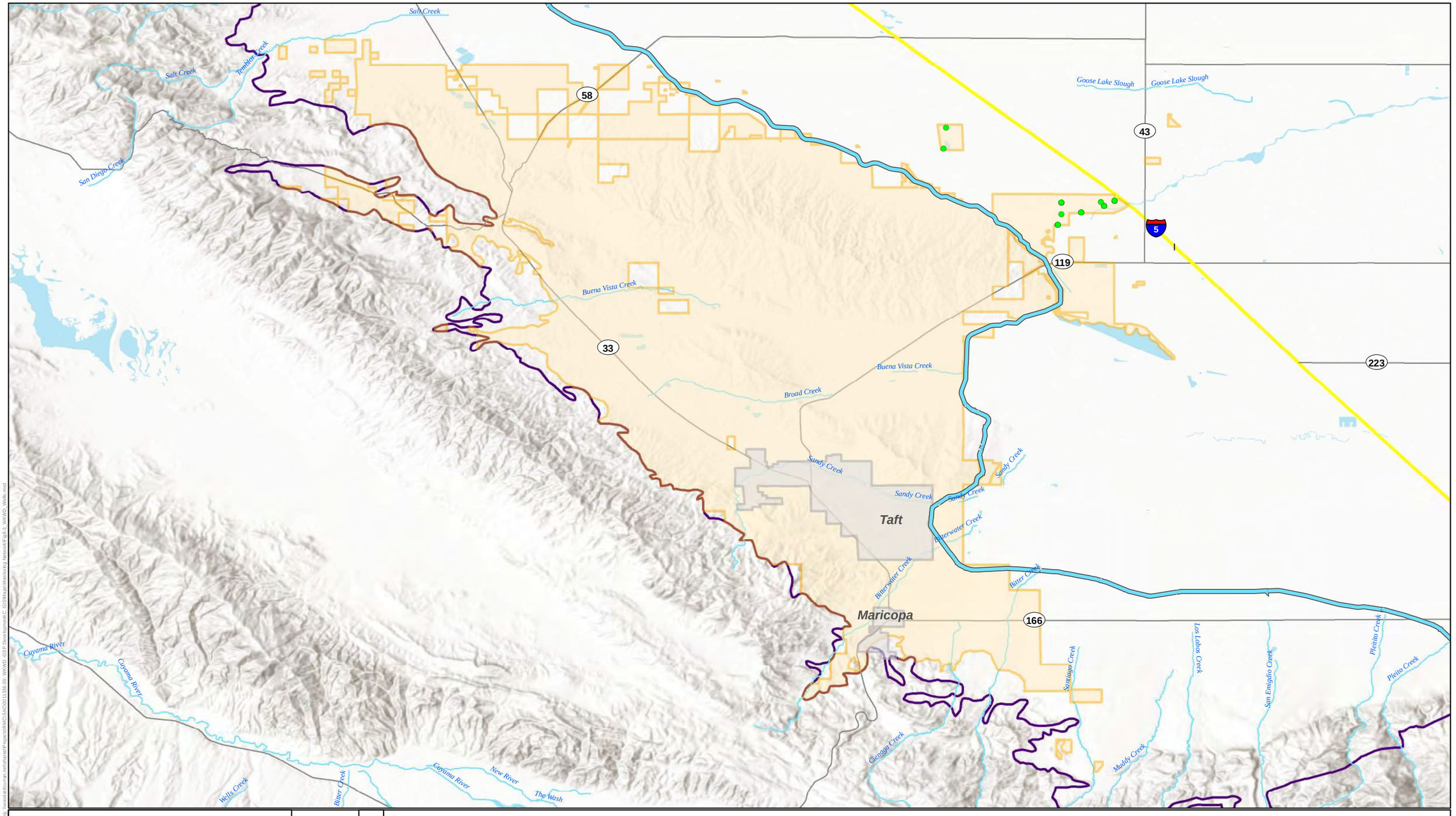


Figure 6-3: WKWD GSP Groundwater Level and Storage Monitoring Network Wells

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

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Legend

- California Aqueduct
- Cities
- WKWD GSA
- Rivers/Streams
- Kern County Subbasin
- Groundwater Level and Storage Monitoring Network Wells

N

0 2.75 5.5 11 Miles

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Most of the monitoring network wells are in the North and South Project management areas because these are the only management areas that actively pump water above de minimis levels. The Lake Management Area has pumping, but currently does not have monitoring, and the Western Management Area does not have any pumping. All wells that are currently operational and managed by WKWD are incorporated into the monitoring network.

6.6.3 Monitoring Frequency

DWR's *Monitoring Networks and Identification of Data Gaps Best Management Practices* (DWR, 2016) provide guidance about monitoring frequency based on discussion presented in the *National Framework for Ground-water Monitoring in the United States* (National Water Quality Monitoring Council, 2013). Table 6-2 lists guidance based on aquifer properties and degree of use.

The guidance described above recommends that initial characterization of monitoring locations use frequent measurements to establish the dynamic range at each monitoring site and to identify external stresses affecting groundwater levels. An understanding of these conditions based on professional judgment should be reached before normal monitoring frequencies are followed.

Table 6-2. Monitoring Frequency Based on Aquifer Properties and Degree of Use

Aquifer Type	Nearby Long-Term Aquifer Withdrawals		
	Small Withdrawals	Moderate Withdrawals	Large Withdrawals
Unconfined Aquifer			
Low recharge (<5 inches/year)	Quarterly	Quarterly	Monthly
High recharge (>5 inches/year)	Quarterly	Monthly	Daily
Confined Aquifer			
Low hydraulic conductivity (<200 feet/day)	Quarterly	Quarterly	Monthly
High hydraulic conductivity (>200 feet/day)	Quarterly	Monthly	Daily

Monitoring frequency for groundwater levels is coordinated Subbasin-wide through the Umbrella GSP. The Umbrella GSP requires Chapter GSPs to report monitoring twice per year, one taken at a time from January 15 through March 30, and one taken at a time from September 15 to November 15. More information about monitoring frequency is provided in the Umbrella GSP.

During normal operations, WKWD samples monitoring and production wells on a monthly schedule and will use data collected on this schedule to meet reporting requirements of the Umbrella GSP. WKWD will continue to monitor on this schedule to comply with the Umbrella GSP and to provide additional data for GSA planning and monitoring purposes.

6.6.4 Spatial Density

The goal of the groundwater level monitoring network is to provide adequate coverage of the aquifer in the GSA area. Adequate coverage includes the ability to monitor and identify GWE changes across the basin over time.

The *Monitoring Networks and Identification of Data Gaps Best Management Practices* published by DWR provide different sources and condition-dependent densities to guide monitoring network implementation (Table 6-3) (DWR, 2016). This information was adapted from the *CASGEM Groundwater Elevation Monitoring Guidelines* (DWR, 2010). While these estimates provide guidance about monitoring well site spatial densities, monitoring points should primarily be influenced by local geology, groundwater use, and GSP-defined undesirable results. Finally, professional judgment is essential for determine if the chosen wells are adequate.

Table 6-3. Recommended Well Densities

Reference	Monitoring Well Density (per 100 square miles)
Heath (1976)	0.2-10
Sophocleous (1983)	6.3
Hopkins (1994)	
Basins pumping more than 10,000 AFY per 100 square miles	4.0
Basins pumping between 1,000 and 10,000 AFY per 100 square miles	2.0
Basins pumping between 250 and 1,000 AFY per 100 square miles	1.0
Basins pumping between 100 and 250 AFY per 100 square miles	0.7

The GSA area covers 287 square miles. Based on Hopkins' well density estimate guidelines, the Subbasin should have four monitoring wells per 100 square miles, or 11.5 wells in the GSA area. According to Sophocleous, the Subbasin should have 6.3 monitoring wells per 100 square miles, or 18 wells in the GSA area. According to Heath, the Subbasin should have between 0.2 and 10 monitoring wells per 100 square miles, or 5.7 to 28.7 wells in the GSA area.

The GSA area is unique in that nearly all recovery is concentrated in the three relatively small management areas (i.e., the North Project, South Project and Lake management areas), and only de minimis pumping occurs in the largest management area, the Western Management Area. Because of this unique circumstance, all active monitoring wells in the North Project, South Project, and Lake management areas will be incorporated into the monitoring network, despite their relatively close proximity to one another. Table 6-4 includes information about well density per management area and indicates that the density of monitoring wells in the North and South Project management areas is significantly above recommended density.

Table 6-4. Monitoring Network Groundwater Level Well Density

Management Area	Monitoring Network Wells	Monitoring Network Well Density (per 100 square miles)
North Project Management Area	2	207 wells
South Project Management Area	17	1,223 wells
Lake Management Area	0	0 wells
Western Management Area	0	N/A
Total WKWD GSA Area	**19**	**603 wells**

6.6.5 Groundwater Level Monitoring Network

The groundwater level monitoring network is comprised of 19 monitoring wells in the GSA area. All wells are considered representative wells. Overall well density is 603 wells per 100 square miles. Figure 6-3 shows the locations of the groundwater level monitoring network monitoring wells and representative wells. Table 6-5 includes the wells in the groundwater level monitoring network and their associated metadata.

WKWD will continue to monitor groundwater levels monthly. This monitoring frequency will capture short-term, seasonal, and long-term trends in groundwater levels. These wells will also provide useful information for determining flow directions, hydraulic gradients, and change in storage calculations. This information will be used in future water budgeting efforts in portions of the Subbasin with significant land use.

6.6.6 Representative Monitoring

SGMA specifies two categories of wells as follows:

- **Representative Wells**—These wells would be used to monitor sustainability in a basin. MTs and MOs would also be calculated for these wells.
- **Monitoring Well**—Other monitoring wells would be included in the monitoring network to provide redundancy for representative wells, and to maintain a robust network for evaluation as part of five-year GSP updates.

Representative wells are wells that represent conditions in the Subbasin; representative wells are in locations that allow monitoring on the well to indicate long-term, regional changes in its vicinity.

Considering the spatial distribution of wells in the Subbasin, knowledge of local geology, and a long-documented history of operating wells in the GSA area, all monitoring network wells are considered representative for the purposes of this Chapter GSP.

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Table 6-5. Groundwater Levels Monitoring Network and Representative Well

OPTI ID	State Well Number	Managing Agency as of 2018	Well Construction Date	Well Depth (feet)	Hole Depth (feet)	Screen Interval (feet)	Ground Surface Elevation (feet above mean sea level)	First Measurement Year	Last Measurement Year	Measurement Period (years)	Measurement Count
18	30S25E28E004M	WKWD	6/5/2000	240	240	200-240	303.4054	2000	2018	18	667
19	30S25E28E003M	WKWD	5/30/2000	495	495	425-435	303.389	2000	2018	18	668
20	30S25E28E002M	WKWD	5/17/2000	680	800	640-680	303.4062	2000	2018	18	667
24	30S25E28D001M	WKWD	--	617	--	--	305.6467	1966	2018	52	942
28	30S25E21R004M	WKWD	10/8/2002	800	820	225-255	308.0642	2003	2018	15	554
29	30S25E21R003M	WKWD	10/8/2002	800	820	620-660	308.0642	2003	2018	15	555
30	30S25E21R002M	WKWD	10/8/2002	800	820	770-800	308.0642	2003	2018	15	555
39	30S25E22K003M	WKWD	10/9/2002	740	810	330-350	312.6624	2003	2018	15	556
40	30S25E22K002M	WKWD	10/9/2002	740	810	485-520	312.6624	2003	2018	15	555
41	30S25E22K001M	WKWD	10/9/2002	750	810	700-740	312.6624	2003	2018	15	555
80	--	WKWD	--	700	750	650-690	306.9312	2005	2018	13	417
81	--	WKWD	--	700	750	425-465	306.9312	2005	2018	13	417
82	--	WKWD	--	700	750	180-240	306.9312	2005	2018	13	400
86	--	WKWD	2/13/2002	710	823	250-280	313.5749	2002	2018	16	596
87	--	WKWD	2/13/2002	710	823	440-480	313.5749	2002	2018	16	596
88	--	WKWD	2/13/2002	710	823	630-690	313.5749	2002	2018	16	588
100	--	WKWD	5/1/2003	560	760	250-545	313.1553	2005	2018	13	403
107	--	WKWD	6/17/2013	740	760	220-240 380-400 715-735	291.1243	2013	2018	5	130
108	--	WKWD	5/9/2014	760	770	200-220 380-400 720-740	290.0138	2013	2018	5	101

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6.6.7 Monitoring Protocols

Monitoring protocols for the groundwater level monitoring network are included in the Umbrella GSP. WKWD will continue ongoing monitoring using the protocols currently in use until coordination of the monitoring protocols in the Umbrella GSP are completed.

6.6.8 Data Gaps

Research performed to develop this section of the Chapter GSP indicates a data gap for the Lake Management Area and, although active recovery occurs in this management area, there is no information available about pumping volumes or groundwater levels. A minimum of one well would be needed to adequately monitor this management area and fill this data gap.

6.6.9 Plan to Fill Data Gaps

WKWD uses in-house staff to monitor its well network. WKWD will coordinate with Kern County to establish monitoring protocol for the Lake Management Area.

6.7 Groundwater Storage Monitoring Network

Groundwater levels can be used as a proxy for determining changes in groundwater storage. Therefore, the WKWD GSA will use information collected from its groundwater level monitoring network described above to monitor for changes in storage.

6.8 Seawater Intrusion Monitoring Network

The GSA area is geographically and geologically isolated from the Pacific Ocean, and any other large source of saline water. As a result, the Subbasin is not at risk for seawater intrusion.

6.9 Degraded Groundwater Quality Monitoring Network

As discussed in Section 3.5, groundwater quality was consistent throughout its measurement period, including through the drought period and historically low groundwater levels of 2015, indicating that groundwater quality does not degrade with decreased groundwater elevations in the GSA. Therefore, monitoring of groundwater quality is not necessary when groundwater levels are sustainably managed.

Due to the relationship of undesirable results for water quality and the causal nexus of groundwater quality, Chapter GSP actions, and groundwater levels, no additional groundwater quality monitoring network is needed. Groundwater levels will be used as a proxy for the management of degraded groundwater quality in the GSA area.

6.10 Land Subsidence Monitoring Network

6.10.1 Management Areas

Land subsidence often occurs over large areas of land, and may be the result of dynamic groundwater levels, oil and gas extraction, or natural processes. Due to these factors, subsidence is monitored for the entire GSA, area and is not monitored in the separate management areas.

6.10.2 Monitoring Sites Selected for Monitoring Network

Currently, there are no subsidence monitoring stations in GSA area. However, there is an extensometer 1 mile north of the North Project Management Area that is operated by the KWBA. This extensometer provides adequate data about conditions in the GSA area.

6.10.3 Monitoring Frequency

Subsidence monitoring frequencies should capture long-term and seasonal fluctuations in ground level changes. DWR's *Monitoring Networks and Identification of Data Gaps Best Management Practices* does not provide specific monitoring frequency or interval guidance (DWR, 2016). Additionally, the extensometer that the WKWD GSA will use is operated by the KWBA in a neighboring GSA and has been monitored monthly since 1994.

6.10.4 Spatial Density

Figure 6-4 shows the extensometer used as a subsidence monitoring station for the WKWD GSA. DWR's *Monitoring Networks and Identification of Data Gaps Best Management Practices* does not provide specific spatial density guidelines for subsidence monitoring networks, and thus relies on professional judgment for site identification (DWR, 2016). Data from InSAR imagery and the extensometer data provided by Kern Water Bank provide adequate subsidence monitoring for the GSA area.

6.10.5 Monitoring Protocols

This Chapter GSP does not include subsidence monitoring protocols because subsidence monitoring is not conducted by the WKWD GSA. The WKWD GSA will coordinate with the KGA to modify these as necessary in the future.

6.10.6 Data Gaps

Current monitoring stations outside of the GSA area, in addition to InSAR spatial coverage provided by the Umbrella GSP, provide adequate data for monitoring subsidence in the GSA area. No data gaps for the WKWD GSA have been identified; however, subsidence monitoring is identified as a data gap in the Umbrella GSP. The KGA has prepared a Technical Memorandum regarding subsidence monitoring which is included in Appendix I.

6.11 Depletions of Interconnected Surface Water Monitoring Network

There is little surface water in the GSA area. All streams are ephemeral, and there are currently no surface stream or river gages in the GSA area. The Kern River also flows through a small part of the GSA area. However, the Kern River is a subsurface flow except during high flow events. The Kern River is also fully adjudicated. Due to these natural and legal characteristics, surface water monitoring is not conducted in the GSA area.

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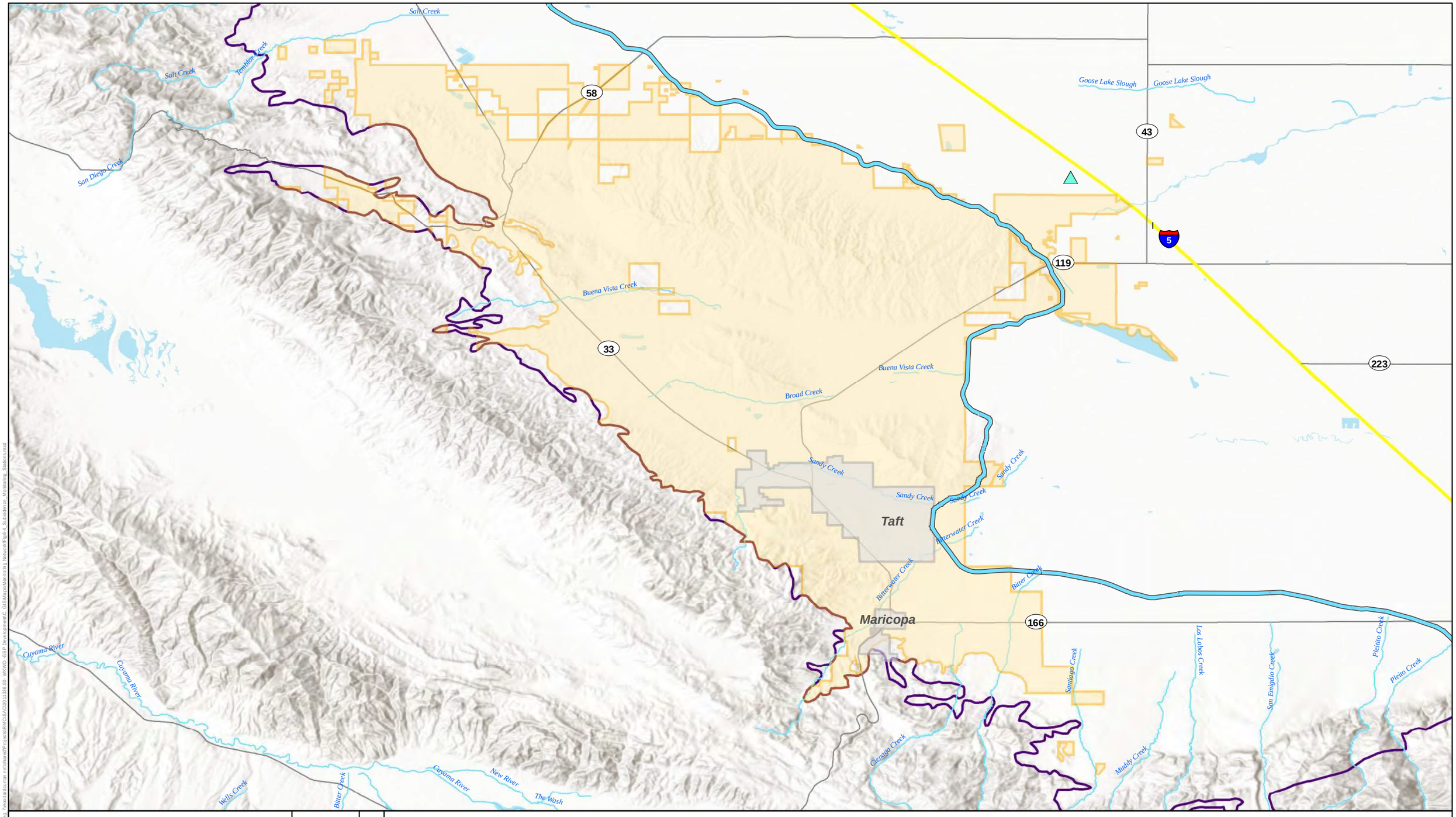


Figure 6-4: WKWD GSP
Extensometer Station - Subsidence Monitoring

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

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Legend

- WKWD GSA
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- Extensometer Location

N

0 3 6 12 Miles

Figure Extensmet 12/5/2019 By: cstapleton I:\Users\woodardcurran.net\shared\Projects\SRMC\SACO\011338.00- WKWD GSP Development\C. GIS\Maps\Monitoring Network\Fig6-4_Subsidence Monitoring Stations.mxd

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Section 7.0 Minimum Thresholds, Measurable Objectives, and Interim Milestones

7.1 Compliance Information

Table 7-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

Table 7-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 7.10
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria			
354.26	Undesirable Results	Description of undesirable results	Section 5.0 Section 7.0
		Cause of groundwater conditions that would lead to undesirable results	
		Criteria used to define undesirable results for each sustainability indicator	
		Potential effects of undesirable results on beneficial uses and users of groundwater	
354.28	Minimum Thresholds	Description of each minimum threshold and how they were established for each sustainability indicator	Sections 7.4 to 7.9
		Relationship for each sustainability indicator	
		Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater	
		Standards related to sustainability indicators	
		How each minimum threshold will be quantitatively measured	
354.3	Measurable Objectives	Description of establishment of the measurable objectives for each sustainability indicator	Sections 7.4 to 7.9
		Description of how a reasonable margin of safety was established for each measurable objective	
		Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones	
Article 5. Plan Contents, Subarticle 4. Monitoring Networks			

Table 7-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
354.2	Management Areas	Reason for creation of each management area	Section 7.3
		Minimum thresholds and measurable objectives for each management area	Sections 7.4 to 7.9
		Level of monitoring and analysis	Section 6.0
		Explanation of how management of management areas will not cause undesirable results outside the management area	Section 7.3 and Umbrella GSP
		Description of management areas	Section 7.3
354.34	Monitoring Networks	Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone	Section 7.0
354.36	Representative Monitoring	Demonstration of adequacy of using GWEs as proxy for other sustainability indicators	Section 6.0 Section 7.0

7.2 Introduction

This section of the Chapter GSP defines the sustainability criteria the WKWD GSA will use to avoid undesirable results during GSP implementation. SGMA requires the application of MTs, MOs, and interim milestones (IMs) to all representative monitoring sites identified in a GSP. These values will guide the WKWD GSA and groundwater users in the Subbasin as they identify sustainable values for sustainability indicators and progress indicators over the 20-year GDP implementation period.

7.3 Management Areas

WKWD GSA defined four management areas to allow areas with similar conditions to be grouped together so that MO, MT, and MI values could be calculated. Many of the management area boundaries were defined using established WKWD project boundaries. Management areas are shown in Figure 6-2.

The following subsections discuss the strategies used to calculate MOs, MTs, and IMs for each management area.

North Project Management Area

The North Project Management Area is a small plot of land to the northeast of the main WKWD service area. This plot of land is approximately 472 acres with 18 monitoring and production wells. GWEs in this area range from approximately -150 to 150 feet above sea level but are heavily dependent on pumping conditions.

South Project Management Area

The South Project Management Area lies to the east of the main WKWD service area along the Kern River and Interstate 5. This management area is a small plot of land of approximately 898 acres with 45 production and monitoring wells, including several multi-completion wells. Groundwater elevations in this area have ranged from approximately -50 to 250 feet above sea level but are heavily dependent on pumping conditions.

Lake Management Area

The Lake Management Area lies to the east of the main WKWD service area along the north bank of Buena Vista Lake. Wells in this management area are used to fill the lake for recreational purposes and are managed by Kern County. The lake is also used by agricultural water districts as a regulating reservoir.

Western Management Area

The Western Management Area comprises the majority of the WKWD service area and includes the cities of Taft and Maricopa. This management area does not currently have any active wells that pump above de minimis volumes. This management area also contains several parcels owned and operated by oil companies. Since this area does not have significant pumping, this management area is not monitored, nor does it have sustainability thresholds assigned to it.

7.4 Chronic Lowering of Groundwater Levels

The undesirable result for chronic lowering of water levels is the point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

Groundwater conditions, as discussed in Section 3.0, vary across the Subbasin and the GSA area. These conditions are influenced by geographic, geologic, and land uses overlying the Subbasin and GSA area. Because of the variety of conditions, threshold regions, in the form of the management areas described above, were used to establish the appropriate sustainability criteria for each region.

7.4.1 MTs, MOs, and IMs

WKWD is the only user of groundwater that exceeds de minimis amounts of water in the WKWD GSA area. Therefore, the thresholds presented in this section affect the beneficial use of groundwater by WKWD and may cause WKWD to enact projects and management actions described in Section 8 if groundwater levels approach minimum thresholds.

The following subsections describe the methods used to calculate MTs, MOs, and IMs in the four management areas.

North Project Management Area

MTs and MOs were set in the North Project Management Area to allow for an appropriate margin of operational flexibility that would allow for recovery of water as regularly conducted during normal WKWD operations. Through coordination efforts, neighboring GSAs' MTs and MOs were also taken into consideration.

The MT were calculated by finding the maximum and minimum historical values for each well; 20 percent of the difference between these elevations was calculated, and then subtracted from the minimum historical value to obtain the numerical MT value.

The MO was calculated by finding three years of drought usage/storage above the MT. Three years of drought usage/storage represents three years of normal water use and pumping done by WKWD during drought conditions. This was found by identifying the groundwater decline through a drought period and applying that decline-time ratio over three years.

Based on the available monitoring data (presented in Section 6), a drought condition existed in the North Project Management Area from approximately 2013 to 2016. Using these data, analysts found the maximum elevation between January 1, 2012 and December 31, 2014 and the minimum elevation between January 1, 2015 and December 31, 2017. Analysts then used the dates of these measurements to determine the number of days between each of those measurements. This provided a drought decline ratio of elevation decline over time.

To determine drought usage/storage over three years, the following formula was used:

$$\frac{D}{T} = \frac{X}{Y}$$

$$X = \frac{(D * Y)}{T}$$

where:

D = Decline of elevation over known drought period

T = Time between maximum value (from 2012 to 2014) and minimum value (from 2015 to 2017)

X = Three years drought storage/decline, *unknown*

Y = Three years in days = 365.25*3 = 1,095.75

Since all representative wells are currently above the MO, IMs were not set for this area.

Levels will be measured using the frequency of measurement and monitoring protocols documented in Section 6.

South Project Management Area

Because groundwater conditions and well use in the North Project Management Area are like those in the South Project Management area, the same MT, MO, and IM strategies were used in the South Project Management Area.

MTs and MOs were set in the South Project Management Area to allow for an appropriate margin of operational flexibility that would allow for recovery of water as regularly conducted during WKWD's normal operations. Through coordination efforts, neighboring GSAs' MTs and MOs were also taken into consideration.

Lake Management Area

Although WKWD and WKWD GSA know the location of production wells in the Lake Management Area, there are currently no available groundwater level monitoring data for these wells. Kern County owns and operates the production wells in this area, and, to date, been unable to provide groundwater level data sufficient for developing MTs, MOs, or IMs. As outlined in Section 6, this management area is identified as a data gap. When data become available for this area, the GSA will apply MTs, MOs, and IMs in the five-year GSP update.

Western Management Area

The Western Management Area does not use groundwater and does not have any active wells; as a result, no MOs, MTs, or IMs were calculated.

7.4.2 Selected MTs and MOs, Figures, and Tables

This section summarizes data about MTs and MOs used for each representative well. Figure 7-1 is an example hydrograph with the applied MT and MO, and Table 7-2 summarizes data for each of the wells. Hydrographs with MTs and MOs are included in Appendix G.

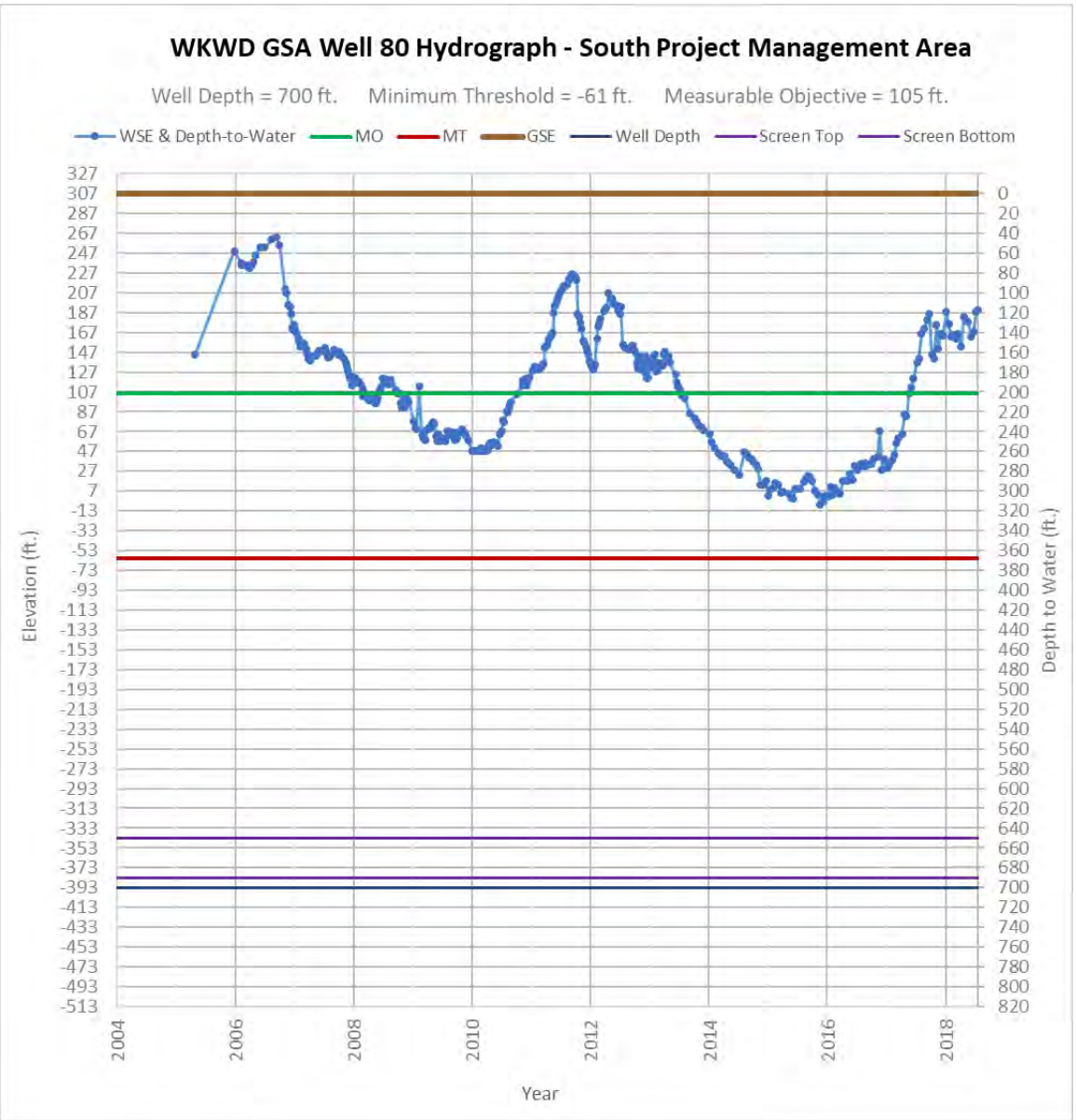


Figure 7-1. WKWD Example Hydrograph with Thresholds

Table 7-2. MTs, MOs, and IMs for WKWD GSA Representative Wells

Representative Well Number	MT (feet above mean sea level)	MO (feet above mean sea level)
18	90	163
19	68	162
20	0	122
24	-42	106
28	-107	109
29	-72	121
30	-46	90
39	2	139
40	37	163
41	95	194
80	-61	105
81	-54	115
82	-26	159
86	4	133
87	-8	132
88	23	166
100	-82	125
107	14	70
108	32	99

7.5 Reduction of Groundwater Storage

The undesirable result for reduction of groundwater storage is the point at which significant and unreasonable impacts, as determined by the amount of groundwater in the Subbasin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended drought period.

Reduction of groundwater storage is not a concern for the WKWD GSA. Based upon current demands and banked water records, WKWD GSA's banked water supply is sufficient to meet demand for nearly 10 years. Groundwater level data show that this proactive approach to banking has increased local water levels and provided a net benefit to the Subbasin.

7.5.1 Proxy Monitoring

Section 354.26(d) of the DWR Emergency Regulations permits the use of groundwater levels as a proxy sustainability indicator to monitor whether an undesirable result, due to a reduction in groundwater storage, has occurred. Additionally, there are no state, federal, or local standards that regulate groundwater storage. As described above, storage capacity is not a concern for the Subbasin, and any benefits to groundwater storage are expected to coincide with groundwater level management.

7.6 Seawater Intrusion

Due to the WKWD GSA's location, the effect of seawater intrusion is not a concern; as a result, it is not necessary to establish criteria for undesirable results, as supported by Section 354.26(d) of the DWR Emergency Regulations.

7.7 Degraded Water Quality

SGMA regulations specify that "minimum thresholds for degraded water quality shall be the degradation of water quality, including the migration of contaminant plumes that impair water supplies or other indicator of water quality as determined by the Agency that may lead to undesirable results."

The undesirable result for degraded water quality is the point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

7.7.1 Management Areas

As a domestic water purveyor, WKWD is required to monitor groundwater quality in its wells on a routine basis. As a result, no management areas were used to establish water quality sustainability thresholds.

7.7.2 Proxy Monitoring

WKWD delivers disinfected groundwater for domestic and industrial use that must meet Title 22 drinking water standards. Through the successful management of their water sources and groundwater levels, WKWD has continuously provided high quality water to its customers since 1959. Groundwater quality in the vicinity of WKWD's wellfields is of very high quality and requires minimal disinfection to meet drinking water standards. Any degradation to groundwater quality that may occur will be identified during required routine water quality monitoring, would be considered an undesirable result by nature, would and trigger a management action to determine the cause.

As discussed in Section 3.5, groundwater quality was consistent throughout its measurement period, including through the drought period and historically low groundwater levels of 2015, indicating that groundwater quality does not degrade with decreased groundwater elevations in the GSA. Therefore, groundwater levels thresholds are protective of Division of Oil, Gas, and Geothermal Resources (DOGGR).

7.7.3 MTs, MO, and IMs

As described above, groundwater levels may be used as a proxy for determining the cause of degraded water quality in a GSA area; as such, the MOs, MTs, and IMs established for degraded water quality are the same as those described in Section 7.4.

7.8 Subsidence

The undesirable result for land subsidence is the point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure.

7.8.1 Management Areas

Subsidence monitoring is conducted on a Subbasin-wide level; as a result, no management areas were used to establish subsidence criteria. Figure 6-4 shows subsidence monitoring locations in the GSA.

7.8.2 Representative Monitoring

As discussed in Section 6, the extensometer located north of the North Project Management Area is the only representative monitoring point used for this Chapter GSP. Detrimental impacts of subsidence include groundwater storage reduction, and potential damage to critical infrastructure such as large scale linear infrastructure, and canals. Portions of the California Aqueduct that lie within the GSA area have shown no negative impacts due to subsidence, and there is no groundwater pumping in these areas.

Ground surface elevations in the GSA area of the Subbasin are rising and have risen from approximately 0.5 to 0.8 feet since 1994, as shown in Section 3. Currently, there are no state, federal, or local standards that regulate subsidence rates.

7.8.3 MTs, MOs, and IMs

Although several factors can affect subsidence rates, including geologic processes, soils, oil extraction, and groundwater pumping, these factors have not induced subsidence in the GSA area. Because subsidence has not impacted local infrastructure, and the fact that surface elevations have increased since 1994, an MT rate for subsidence of 2 inches per year (as measured at Kern Water Bank Extensometer 30S/25E16L) is reasonable for warranting a management action to investigate the cause. This magnitude of subsidence, when compared to that in other areas of the San Joaquin Valley that approach 1 foot per year, is considered unlikely to cause a significant or unreasonable impact to local infrastructure over the planning and implementation horizon of this Chapter GSP.

Groundwater recovery can have a direct impact on the rate of subsidence; however, those impacts can be managed proactively by maintaining GWEs that control subsidence. As a result, the MO for subsidence in the WKWD GSA will be to maintain groundwater water elevations at levels to where no subsidence occurs.

IMs are not needed for this subsidence sustainability indicator because the current rate of subsidence is above the MO.

Subsidence rates will be measured via the frequency of measurement and monitoring protocols documented in Section 3.

7.9 Depletions of Interconnected Surface Water

SGMA regulations define the MT for interconnected surface water as "… the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on the beneficial uses of the surface water and may lead to undesirable results."

Currently, there are no beneficial uses of surface water in the GSA area, as all surface flows infiltrate into the groundwater system except during the most extreme flash flood events. It should be noted that BVARA is operated by Kern County, is adjacent to the Lake Management Area, and is a surface water source that may influence groundwater within the GSA area. Although BVARA is outside of the GSA boundary, the lake is maintained through groundwater pumping from wells in the GSA area. There are no data currently available regarding BVARA operations at this time; however, it is assumed that water loss from the lake results from evaporation and infiltration into the groundwater system.

7.9.1 Proxy Monitoring

Although the lake within BVARA (an interconnected surface water) is outside of the GSA area, the remainder of the BVARA property is within the GSA area, and beneficial uses of that water must be considered under SGMA regulations. The effect of depletions of interconnected surface waters in the GSA area will use groundwater levels as a proxy for determining sustainability, as permitted by Section 354.26(d) of the DWR Emergency Regulations.[2] Additionally, there are currently no state, federal, or local standards that regulate the depletions of interconnected surface waters.

As addressed in Section 6, the Lake Management Area has been identified as a data gap. Section 8 provides a strategy for the GSA to develop additional groundwater level monitoring in this management area in the future. This monitoring will be used to establish groundwater level sustainability thresholds that consider beneficial uses of interconnected surface water. Current groundwater level thresholds are set to be protective of conditions for the remaining areas of the GSA and are expected to provide protection of the Lake Management Area until more data are collected.

7.10 References

California Department of Water Resources (DWR). (n.d.). *Irrigated Land Regulatory Program (IRLP) website*. https://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/ Accessed January 11, 2019.

[2] https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/GSP_Emergency_Regulations.pdf

Section 8.0 Projects, Management Actions, and Adaptive Management Strategies

8.1 Compliance Information

Table 8-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

Table 8-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 8.10
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions			
354.44	Projects and Management Actions	Description of projects and management actions that will help achieve the basin's sustainability goal	Section 8.0 Section 9.0
		Measurable objective that is expected to benefit from each project and management action	
		Circumstances for implementation	
		Public noticing	
		Permitting and regulatory process	
		Timetable for initiation and completion, and the accrual of expected benefits	
		Expected benefits and how they will be evaluated	
		How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.	
		Legal authority required	
		Estimated costs and plans to meet those costs	
		Management of groundwater extractions and recharge	
354.44(b)(2)		Overdraft mitigation projects and management actions	Section 8.0 Section 9.0

8.2 Introduction

This section of the Chapter GSP includes projects, management actions, and adaptive management information, and satisfies the requirements found in Sections 354.42 and 354.44 of the SGMA regulations.[3] The projects resulting from this Chapter GSP and their benefits will help achieve WKWD GSA's sustainable management goals in the GSA area. This section of the Chapter GSP also identifies the following:

- Projects and management actions that will help move the GSA area toward sustainability
- Adaptive management strategies that may be implemented if resulting projects and management actions do not move the Subbasin toward sustainability at a sufficient pace
- Adaptive management strategies that may be implemented if monitoring demonstrates undesirable results

8.3 Addressing Sustainability Indicators

Sustainability indicators are described in Section 7. Groundwater levels are being used either directly or as a proxy for determining status of the relevant sustainability indicators, which are as follows:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

As described in Sections 8.7, 8.8, and 8.9, each of the projects, management actions, and adaptive management strategies are designed to reduce or balance sustainable groundwater pumping. This will help to reduce or avoid declines in groundwater levels, thereby contributing to sustainability in the GSA area as measured by the relevant sustainability indicators. Management actions respond to non-groundwater related conditions (e.g., drought), and the adaptive management strategies respond to changes in groundwater conditions (e.g., local declines in GWEs).

The management actions and adaptive management strategies described here will allow the WKWD GSA flexibility to respond to changing conditions.

[3] https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/GSP_Emergency_Regulations.pdf

8.4 Overdraft Mitigation

The GSA area is not known to be in overdraft because WKWD balances its recharge and pumping. However, the Subbasin, which partially underlies the WKWD GSA, is in overdraft conditions as a whole, according to WKWD's *2015 Urban Water Management Plan* (2015 UWMP) (WKWD, 2016). Further, annual groundwater pumping for BVARA is unknown, and represents potential localized overdraft near the BVARA. Projects, management actions, and adaptive management strategies described in this section contribute to protecting GWEs, and emphasize balancing recharge and pumping, offsetting potable demands, or creating new supplies.

Projects, management actions, and adaptive management strategies therefore all serve to mitigate overdraft.

8.5 Water Balance Management for Drought Preparedness

Under existing management operations, WKWD banks surplus water supplies for use during drought or other shortages. As described in its 2015 UWMP, WKWD's supplies during normal water years exceed demand by 4,900 to 11,250 AFY. This surplus has consistently been banked by WKWD, with approximately 200,000 AF currently stored in the Subbasin. Since WKWD began groundwater banking in the 1960s, it has experienced multiple droughts. The current surplus is sufficient to meet approximately 10 years of WKWD demand as the sole supply. The success of current practices, as seen by the large volume of water currently stored in the groundwater bank, demonstrate that WKWD is an experienced manager of its water balance for drought preparedness. The projects and management actions described here each contribute to WKWD's ability to continue to bank groundwater in years with surplus supply, and reduce demands on banked supplies during drought, allowing the Subbasin to recover more quickly from drought.

8.6 Projects, Management Actions, and Adaptive Management Strategies

The GSA has identified a series of projects and management actions that will support the GSA's sustainability goals. Additionally, WKWD GSA has identified adaptive management strategies that may be implemented if monitoring indicates groundwater levels are approaching the MT (and as a result may be at risk for undesirable outcomes). Table 9-2 summarizes projects and actions described in this section along with their status and timing.

Table 8-2. Project and Action Status and Timing

Project/Management Action/ Adaptive Strategy	Status	Implementation Timing	Accrual of Benefits[a]
Project 1: Automatic Meter Reading Project	Planning	Near-term	Within a few months
Project 2: Participation in Delta Conveyance	Planning	Long-term	Immediately following water deliveries

Table 8-2. Project and Action Status and Timing

Project/Management Action/ Adaptive Strategy	Status	Implementation Timing	Accrual of Benefits[a]
Facility			
Project 3: Buena Vista Recreation Area Water Supply Management Coordination	Ongoing	Now	After supplemental water management project/action is implemented
Management Action 1: Continued Balanced Pumping and Recharge	Ongoing	Now	Now
Management Action 2: Implement Water Shortage Response Plan	Ongoing, As Needed	Now; as needed	Within a few months
Management Action 3: Continued Participation in Basin-Wide Coordination	Ongoing	Now	Now
Adaptive Management Strategy 1: Taft Recycled Water Program	Pre-planning	Long-term	Immediately following water deliveries
Adaptive Management Strategy 2: Shift Balance of Pumping between North and South Wellfields	Untriggered	As needed	Within a few months
Adaptive Management Strategy 3: Implement Permanent Demand Management Measures	Untriggered	As needed	Within a few months

Notes:
[a] GWEs are expected to react to project and action benefits in a timeframe of a few weeks to a few months after direct project and action benefits are realized.

8.7 Projects

This section describes projects selected by WKWD GSA that will help achieve sustainability goals for the portion of the Subbasin that lies within WKWD GSA's boundaries.

8.7.1 Project 1: Automatic Meter Reading (AMR) Project

In 2015, WKWD began installing AMR systems for all industrial and outlying customers. To further achieve sustainability goals, WKWD would install AMR systems on the remainder of its primarily residential customer meters. The AMR system selected by WKWD for its industrial and outlying customers uploads data every 24 hours to a website where customers can access their accounts and view water use data, compare their current water use to their historical water use, and receive leak alerts.

AMR can be used by WKWD and its customers to identify potential leaks and encourage water use reductions by providing near-real-time data, using a webtool that provides water use in 15-minute intervals. Volume reductions will vary depending on initial water use, frequency of leak detection pre-

AMR system, and whether the AMR is coupled with a user-friendly interface that motivates voluntary water use reduction. AMR can also improve water conservation by providing detailed data that can be used to improve overall system management.

Public Notice and Outreach

WKWD would conduct public outreach to inform customers of their upgraded meters and provide instruction on using the website interface to track water use and identifying potential leaks. Outreach would likely include bill inserts and website updates and may include other forms of outreach such as flyers in public libraries, informational meetings, or radio ads, depending on the methods deemed most appropriate by WKWD staff at the time the project is implemented.

Permitting and Regulatory Processes

Implementation of this project is not subject to permits or additional regulation because it is part of WKWD's normal system operation, maintenance and upgrades. It would require approval by WKWD's Board of Directors.

Project Benefits

AMR provides potential water savings through early leak detection and increased awareness of water use among customers. Upgrading meters also reduces unaccounted-for losses related to accuracy degradation in older meters. WKWD estimates that AMR will save an average 8 percent of water for each metered connection, based on savings experienced by nearby agencies. The City of Sacramento had an average 4 percent water savings based on a pilot AMR project, while the Golden Hills Community Services District realized 12 percent in average savings (WKWD, 2014). WKWD's 2015 UWMP shows residential water use ranges between 2,169 AF in 2015 to a projected high of 2,597 AF in 2040, and applying the projected 8 percent conservation, anticipated water savings from this project is estimated to be 173 to 208 AFY (WKWD, 2016). Conservation achieved by the AMR project would be measured by the reduction in water deliveries to customers with AMR meters.

Increasing water conservation would reduce demands for potable water, thereby reducing the volume of water pumped from the Subbasin.

This project would benefit the MO of protecting GWEs, and supporting the four sustainability indicators relevant to the WKWD GSA as follows:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

Project Implementation

Implementation of this project would require approval by WKWD's Board of Directors and provision in the budget to fund this effort. No design or substantial engineering would be required. WKWD would purchase the meters and necessary appurtenances and perform the installation.

Project Status and Timing

The circumstance of implementation for this project would be current conditions, once funding is secured or committed and the project approved by WKWD's Board of Directors, it could be implemented. Once completed, this project would be limited to maintenance of the system and ongoing outreach as necessary. The circumstance of implementation would end at the end of the system's life or if another system is selected in the future.

This project could be implemented in the near future because it is an expansion of work WKWD has already completed for some of its customers. WKWD has already selected a meter and has the software system operating in its system. Customers are anticipated to be supportive of the project because it has been partially implemented already and would likely require less outreach to solicit public support than a project that was new to the area. WKWD installed the initial 484 meters in the original AMR project in about 2.5 months. This project would involve installing 5,900 meters; assuming a similar rate of installation, it would take approximately two and a half years to complete installation of all meters. It is likely that meter installation for residential customers could be done faster because staff would be gaining installation experience over the life of the project, and meters are located closer together, reducing travel time between work sites. This Chapter GSP assumes all meters could be installed within three years. Although it would likely take some time for customers to adjust to using the data provided by new meters to motivate behavioral changes and to calibrate meters and understand baseline water use, benefits are expected to accrue quickly once the learning curve is overcome. Benefits, particularly conservation from early leak detection, are expected to be maintained over the life of the project.

Supply Reliability

The AMR project is a conservation project and would not rely on out-of-basin supplies for successful implementation. The project would reduce potable water demands, thereby reducing groundwater pumping and allow for increased groundwater recharge in years with a surplus of supply.

Legal Authority

This project is within the normal operational authority of WKWD, who owns and operates all customer meters within its system. The project would only be implemented within WKWD's potable water system and requires no additional legal authority.

Project Costs

WKWD's cost to install AMR on 484 industrial meters and implement the necessary system upgrades was approximately $599,088, or an average per-meter cost of $1,237 (WKWD, 2014). However, the 2015 AMR project primarily served industrial customers, which generally have larger, and therefore more expensive meters than most residential customers. Adjusting costs to reflect the use of smaller meters

results in a projected cost of $690 per residential meter. WKWD has 5,900 residential connections; at a project cost of $690 per meter, the total cost would be approximately $4.1 million. Revised project costs would be determined during the planning stages of this project and are expected to vary from this estimate based on the exact number of meters for each size, potential economy of scale, cost changes since 2015, and evolution of AMR technology. Operational costs for WKWD may reduce after installation because staff will no longer need to manually read each meter, saving time and transportation costs. WKWD successfully secured grant funding to cover a portion of AMR implementation for its industrial and outlying customers. Based on grant funding obtained for this project, costs to WKWD and customers would decrease.

Technical Justification

WKWD has already experienced the benefit of AMR through installation with its industrial customers. It is difficult to quantify the water savings associated with AMR in the WKWD because demands from both industrial and residential customers have declined since the installation of AMR. However, as described in the Project Benefits section, WKWD reviewed multiple case studies that demonstrate the water saving potential of AMR (WKWD, 2014). Any reduction in potable demands allows WKWD to bank an equivalent amount of water in years with surplus supply and reduce groundwater recovery by an equivalent volume in dry years.

Subbasin Uncertainty

Water conservation achieved through AMR is largely independent of overall supply reliability and uncertainty because the primary water savings realized comes from the ability to detect leaks in real-time. Savings attributable to AMR vary depending on baseline water use and customer behaviors. Overall, AMR will help to reduce the effects of uncertainty in the Subbasin by reducing demands for water that could be used for other purposes.

California Environmental Quality Act (CEQA)/National Environmental Policy Act (NEPA) Considerations

Installation of water meters and AMR systems do not require review under CEQA. The project would only trigger NEPA if WKWD pursued federal funding for the project. Based on the WKWD's experience securing federal grant funds to install AMR for industrial customers, impacts under NEPA would be minimal.

8.7.2 Project 2: Participation in Delta Conveyance Facility

Delta Conveyance Facility is intended to address the challenges of pumping water from the Delta by diverting water upstream of the current diversion points and conveying it to existing pump stations for the SWP and the Central Valley Project (CVP). Under current operation, the SWP and CVP are unable to consistently deliver state and federal water contractors their full contract supplies. Delta Conveyance Facility is intended to address some of the conditions that impact the ability to export water from the Delta.

SWP delivers water to 23 SWP contractors, which retail or wholesale water to customers and other agencies. KCWA is the SWP contractor for the region, and directly contracts with WKWD for a SWP supply. Each year, DWR determines the amount of water available to contractors based on the hydrology for a given water year. Regulatory actions to protect fish and manage water quality in the Delta have reduced the overall reliability of supplies from the SWP. Delta Conveyance Facility is intended to increase the reliability of supplies, thereby increasing the amount of SWP water delivered to SWP contractors annually.

WKWD will participate in Delta Conveyance Facility to increase water supply reliability for its customers. While the exact increase in water supply from the Delta Conveyance Facility remains uncertain until final design, approvals, and agreements are in place, WKWD anticipates that any water supply benefits from the project would be allocated in proportion to its level of participation.

Public Notice and Outreach

Participation in Delta Conveyance Facility is anticipated to require the approval of WKWD's Board of Directors at a publicly noticed meeting. Delta Conveyance Facility itself has a substantial public outreach effort designed to inform stakeholders about the need for and benefit of the project, as well as provide information about the project components, how it works, and its benefits to the people of California. Because WKWD is not an SWP contractor itself, it is likely that participation in Delta Conveyance Facility would also require approval from KCWA's Board of Directors at a publicly noticed meeting.

Permitting and Regulatory Processes

Participation in Delta Conveyance Facility would not require WKWD to secure any permits or implement additional regulatory compliance actions. All required permits and regulatory processes would be undertaken by DWR and the Delta Conveyance Design and Construction Joint Powers Authority (i.e., DWR's designated administering agency), which together are implementing Delta Conveyance Facility (DWR, 2018a). If WKWD's cost to participate in Delta Conveyance Facility results in a need to adjust customer rates, WKWD would prepare a rate study and approve water rate adjustments in accordance with applicable laws and policies.

Project Benefits

The primary benefit of this project would be the increased reliability of imported water supplies and to expand groundwater banking opportunities to meet customer demands. Additional supplies could be 1) banked in WKWD's recharge facilities, 2) used for GWE protection if monitoring shows unexpected declines in elevation, or 3) transferred to neighboring agencies to help offset groundwater pumping in the Subbasin.

Delta Conveyance Facility is still in the planning and design stages, and project details are subject to change; therefore, quantification of project physical benefits remain uncertain. To provide context, an estimate of potential water supply benefit provided by Delta Conveyance Facility is below. These benefits are based on the current project description, recent analyses provided by DWR, and assume each participating SWP contractor will receive its pro rata share of the water supply benefits through Delta Conveyance Facility.

Potential Delta Conveyance Facility Water Supply Benefits

Benefits from the Delta Conveyance Facility are generalized because details of the Delta Conveyance Facility are still under development.

Overall, SWP contractors have contracted with the SWP for 4,172,786 AF annually. KCWA's SWP contract supply for 2019 is 982,730 AF. This represents the amount of SWP water available to KCWA if DWR allocates 100 percent of its contracted supplies (DWR, 2019). Of this amount, WKWD is entitled to 31,500 AF; therefore, WKWD anticipates receiving a minimum of 0.75 percent of any water supply benefit available to SWP contractors from Delta Conveyance Facility. This assumes all SWP contractors and KCWA member units participate in the project based on their full contracted supplies.

A 2018 economic analysis of Delta Conveyance Facility estimated that the project, assuming full SWP and CVP participation, would result in an additional 685,000 AFY of water on average, with 60 percent and 40 percent of the supply allocated to SWP and CVP contractors, respectively. Additional water would be available to SWP contractors if the CVP does not fully participate (DWR, 2018b). Based on WKWD's contracted SWP supply, which is 0.75 percent of the total contract supply of the SWP, participation in Delta Conveyance Facility could increase WKWD supplies by approximately 3,100 AFY. The exact water supply benefit will vary from year to year and will be affected by elements such as changes to the final project, project participation, and annual variations in hydrology. Benefits for the GSA and WKWD via participation in Delta Conveyance Facility would be evaluated based on metered deliveries and overall increase in groundwater storage once the project is completed.

The benefit of participation would be measured via the volume of water delivered from the SWP (including SWP supplies available through Delta Conveyance Facility).

Increasing availability of imported water through participation in Delta Conveyance Facility would allow WKWD to recharge additional water, directly contributing to groundwater level sustainability. This project would also improve reliability of SWP supplies, reducing the need to withdraw water from the banked groundwater supplies, which supports sustainable groundwater levels.

This project would benefit the MO of protecting or increasing GWEs, supporting the four sustainability indicators relevant to the WKWD GSA as follows:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

Project Implementation

Project implementation would require WKWD to participate in Delta Conveyance Facility and obligate itself to pay for its share of the project. Because all Delta Conveyance Facility facilities would be constructed by DWR and the Delta Conveyance Design and Construction Joint Powers Authority, and existing SWP facilities are sized for full SWP delivery, no additional local or regional infrastructure would be required to receive additional water made available by Delta Conveyance Facility.

Project Status and Timing

The circumstance of implementation for this project would be approval of Delta Conveyance Facility by the State of California. Once implemented, this project would remain until the end of the useful life of the Delta Conveyance Facility portion of the SWP.

The timing of this project is beyond the control of the GSA, because Delta Conveyance Facility would be implemented by the State. As of March 2019, Delta Conveyance Facility had completed the CEQA process and secured some permits but is still in the planning phase. Project changes are anticipated that may require additional CEQA documents. Once planning is complete, permitting, design, and construction are anticipated to take 17 years, with deliveries beginning around year 18 (Delta Conveyance Facility, 2019). Benefits would begin accruing following the start of water deliveries from the project. Participation in Delta Conveyance Facility participation could be approved relatively quickly at a WKWD Board meeting, depending on public support for this project.

Supply Reliability

Water made available using Delta Conveyance Facility facilities would come from sources north of the Delta including, among others, the Sacramento River and its tributaries. Water delivered using these facilities is considered more reliable than the water currently available to the SWP from the Delta, because it is less impacted by water quality standards and regulatory actions to protect fish, both of which impact existing SWP facilities ability to divert water. Actual annual water supply benefits are difficult to quantify and will vary depending on hydrology.

Legal Authority

Participation in Delta Conveyance Facility is within the authority of KCWA as an SWP contractor, and its decision to participate would require coordination with its member units. Some negotiations may be required if certain KCWA member units do not elect to participate in Delta Conveyance Facility. Regardless of overall member unit participation, WKWD's participation in Delta Conveyance Facility would require agreements with KCWA to coordinate wheeling of WaterFix supplies to WKWD.

Project Costs

Because of certain project uncertainties such as design changes and ultimate participation by SWP and CVP contractors, it is difficult to quantify WKWD's Delta Conveyance Facility fixed obligation. WKWD anticipates that the cost to participate would be proportional to the water supply benefit and incremental yield received. Per DWR's 2018 economic analysis, estimated costs to SWP contractors would be approximately $12.17 billion (in present value costs, combined urban and agricultural), assuming no

federal grants were received (DWR, 2018b). This analysis estimated that the incremental water supply made available by Delta Conveyance Facility to urban SWP contractors would cost $686 per AF. Assuming an additional $550 per AF for conveyance and treatment, total cost of water from Delta Conveyance Facility for urban suppliers would be $1,236 per AF.

Costs associated with participation in Delta Conveyance Facility would be funded through WKWD's water rates and sales of excess water to other agencies.

Technical Justification

The statewide benefits of Delta Conveyance Facility are identified and described by DWR in numerous reports and publications. Direct benefits to WKWD will be primarily increased water supplies and reliability. The purpose of Delta Conveyance Facility is to increase water supply reliability and provide ecosystem benefits and enhancements in the Delta (DWR, 2016a). If the project cannot achieve this objective, it will not be implemented. DWR completed a water supply analysis using the CALSIM II model, which was developed by DWR and the United States Department of the Interior's Bureau of Reclamation (Reclamation) to evaluate SWP and CVP deliveries under a variety of hydrologic conditions, and is considered the best available planning model for system-wide evaluations of these imported water systems (DWR, 2016b). Modeling outcomes and methods are described in detail in Delta Conveyance Facility's *Environmental Impact Report/Environmental Impact Statement* (EIR/EIS) (DWR, 2016c).

Subbasin Uncertainty

This project would help to address uncertainty in the Subbasin by providing new, additional supplies and improved reliability of SWP deliveries. Delta Conveyance Facility will provide additional water supply benefits and allow WKWD to recharge more water for use in dry years when surface supplies are limited due to drought, disaster, or other factors.

CEQA/NEPA Considerations

Delta Conveyance Facility is a project subject to both CEQA and NEPA. The EIR/EIS has been certified by DWR (Delta Conveyance Facility, 2017). Due to project changes, it is anticipated that Subsequent EIRs, Addendums to the EIR, or other additional CEQA documentation may be necessary. Such documentation would be prepared and certified by DWR. Securing NEPA compliance will be the responsibility of DWR in coordination with the appropriate lead federal agency. WKWD's participation in Delta Conveyance Facility would not require construction of any additional facilities or projects and would not entail additional CEQA or NEPA compliance beyond that already being undertaken by DWR.

8.7.3 Project 3: Buena Vista Aquatic Recreation Area Water Supply Management Coordination

BVARA is in and adjacent to the WKWD GSA area. The 1,585-acre BVARA is home to two manmade lakes, Lake Webb and Lake Evans, boating facilities, playgrounds and volleyball courts, camp sites, and picnic areas. The lakes lie outside of the GSA area but the park facilities such as picnic areas, restrooms, and parking areas are within the GSA area. When constructed, the lakes had a combined storage capacity of over 6,800 AF. Shoreline camping and picnic areas are landscaped with grass and are irrigated during

the dry season (County of Kern Parks and Recreation Department, 2019). With no outlet, water from the lakes either evaporates or percolates into the groundwater basin. Kern County pumps groundwater from wells located within the GSA area to supplement losses at the lake. Supplemental water delivered to the lakes is not metered and is not included in WKWD GSA's water balance.

There is need for Kern County to replenish the lake losses from evaporation and percolation because of a contractual responsibility between the County and BVWSD. Since the "minimum pool" level is a measure of Kern County's responsibility, any proposed variation from that water surface elevation should be considered by BVWSD.

Due to uncertainty regarding BVARA water demands, and the condition of the Subbasin near the extraction wells, this project requires ongoing coordination between the GSA and Kern County to understand BVARA's water management needs and related impacts to the GSA area. Together, the WKWD GSA and Kern County would develop an appropriate project to address the BVARA's water needs in a manner that could be accommodated without triggering an undesirable result as described in this Chapter GSP. Some projects that may be considered by WKWD GSA and Kern County include the following:

- Metering groundwater pumped for supplemental water, and charge Kern County a pump tax on the amount recovered
- Reducing pumping for supplemental water and manage the lakes at a lower level
- Acquiring supplemental water from other sources, such as the North Project Management Area, South Project Management Area, the County's Willow Springs Groundwater Bank, other water districts, or from direct diversions from the California Aqueduct

WKWD GSA and Kern County may identify other projects as appropriate.

Public Notice and Outreach

Public notice and outreach would be necessary for any project ultimately implemented that affects the public's use of the BVARA and lakes. For example, if the project results in the need to increase use fees at the BVARA to cover the cost of purchasing supplemental water, or the lakes are managed at a lower volume of water, some outreach would be necessary to inform the public of the changes and why they are necessary. Outreach would likely include informational signs or flyers available at the recreation area's information and entrance booths as well as information posted on the Kern County's Parks and Recreation website. Any decisions made as a result of this project that require approval from either WKWD's Board of Directors or the County Board of Supervisors would be made in a public meeting.

Permitting and Regulatory Processes

Specific permitting and regulatory processes would depend on which project or management action is decided upon as a result of this project. All final project decisions would likely require approval from WKWD's Board of Directors and the Kern County Board of Supervisors. WKWD or Kern County would acquire any applicable permits and consult with the appropriate regulatory bodies necessary to implement the selected project.

Project Benefits

Managing water supply for the BVARA would include a focused effort on monitoring pumping in that portion of the GSA area, and identifying which projects or management actions are needed to eliminate undesirable results in the Subbasin. Securing additional supplemental supplies would reduce the potential impacts to groundwater levels, storage, and water quality for this portion of the GSA area. Improved management of the BVARA water supply would also support ongoing use of the BVARA, a popular recreation area. The project does not have a directly measurable benefit unless implementation actions arise from these meetings.

This project would benefit the MO of protecting GWEs near the BVARA, supporting the four sustainability indicators relevant to the WKWD GSA as follows:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

Project Implementation

Implementation of this project would include ongoing coordination meetings between WKWD GSA and Kern County to discuss 1) the quantity of water needed by BVARA, 2) current condition of the groundwater Subbasin in the vicinity of BVARA, and 3) potential projects to improve how supplemental water for BVARA is acquired and used. These coordination meetings would be held in person and via teleconference as necessary, with in-person meetings held at critical decision-making junctions. Once a project or management strategy is agreed upon for the BVARA's supplemental water, an implementation plan would likely be developed, depending on the type of project or management strategy identified.

Project Status and Timing

Implementation of this project is already underway and is likely to remain an ongoing project until such time as the BVARA no longer requires water from the GSA area.

BVARA water supply management efforts are in the initial stages. WKWD GSA has met with Kern County to discuss groundwater use as supplemental supply for the lakes. Coordination between the two agencies will continue until a project or management action is identified and implemented. This Chapter GSP assumes it will take a full year to understand BVARA's supplemental water needs and identify a preliminary list of potential projects or management actions that could be implemented. Selection of the preferred project or management action may take an additional six to twelve months, depending on the alternatives being considered. Implementation of the selected project or management action may take months or years depending on the activity. Once implemented, benefits are expected to be realized immediately.

Supply Reliability

This project would address supply uncertainties for BVARA by preventing continued potential overdraft in the vicinity of BVARA. Whichever project is ultimately decided upon by WKWD GSA and Kern County, a reliable and sustainable supply will be paramount. For example, if WKWD GSA and Kern County decide to purchase banked water from WKWD, the supply would be considered highly reliable due to WKWD's relatively large banked groundwater reserves.

Legal Authority

Kern County's Parks and Recreation Department owns and operates BVARA. Substantial changes to how BVARA is managed may require approval from the Kern County Board of Supervisors. The groundwater wells currently used to pump supplemental water to BVARA are owned and operated by Kern County; changing how much water is pumped using these wells is within the authority of the County. If an alternative supply source is identified as the preferred project for management of BVARA's supplemental water, the managing entity for that supply would need to agree to provision of service, such as WKWD or other water districts.

Project Costs

Coordination costs between WKWD GSA and Kern County would primarily involve staff time and would not represent an additional capital expenditure. These costs would be covered by the general operating budgets for both agencies. Implementation costs will vary depending on the project or management action selected. WKWD has estimated a cost of as much as $500 per AF to provide a supplemental supply through groundwater pumping. Estimating costs at this early planning stage has proven difficult. Costs may be higher depending on the water source and if additional infrastructure is required.

Technical Justification

The water management needs of BVARA are unknown and currently unquantified. This project would improve WKWD GSA's understanding of these needs and identify data gaps before an appropriate project or management action could be identified to manage BVARA's supplemental water supply. Technical justification would be a consideration when evaluating potential projects and management actions to address BVARA's water supply needs. Projects and actions that are not technically sound or not likely to achieve desired results would not be implemented.

Subbasin Uncertainty

This project would address the existing uncertainty over how supplemental water for BVARA is managed, as well as provide clarification and understanding about groundwater use and conditions in the vicinity of BVARA. Coordination between WKWD GSA and Kern County would allow both agencies to share information about potential changes or concerns regarding the targeted area and reduce potential impacts from water supply uncertainties in the Subbasin. Subbasin uncertainties would be a consideration when determining the preferred project or management action to implement for BVARA's supplemental water.

CEQA/NEPA Considerations

Coordination meetings between WKWD GSA and Kern County do not constitute a project that would trigger CEQA or NEPA. Should this project's coordination meetings result in a project or management action found to be a project under CEQA or NEPA, the appropriate environmental analysis and corresponding CEQA and NEPA documentation would be prepared prior to implementation.

8.8 Management Actions

Management actions are those decisions that could be made to affect groundwater conditions without the need for additional capital projects or approval beyond the appropriate governing board.

8.8.1 Management Action 1: Continued Balanced Pumping and Recharge

Continued balanced pumping of groundwater and recharge of imported supplies has and will continue to be the operational norm for WKWD. Under this management action, recharge and recovery activity will continue to be monitored closely by WKWD to maintain balanced conditions.

The only water management agency within the WKWD GSA is WKWD, whose supplies include groundwater and imported water. The Subbasin is naturally recharged by the Kern River, primarily through seepage from the stream channel and occasional flood flows. Imported water comes from the SWP, which is ultimately sourced from the Sacramento River and the Delta. According to the 2015 UWMP, WKWD has rights to 31,500 AFY imported water from the SWP in total, with the potential to receive an additional 10,000 AFY during wet years. A portion of WKWD's SWP allocation is delivered directly to WKWD's customer, La Paloma Power Facility, as raw water, with the remainder of imported water recharged into the Subbasin and later extracted. When additional supplies are available, WKWD practices groundwater banking, storing excess water in the Subbasin.

WKWD's 2015 UWMP reports that WKWD had 200,000 AF of banked water supplies, and an additional 24,000 AF owed to WKWD by other agencies.

Public Notice and Outreach

This management action does not require public notice and outreach because it does not represent a change in how WKWD manages its water supplies. WKWD provides annual water quality reports to its customers and engages in a variety of public outreach efforts, such as classroom educational programs, to encourage responsible water use. Responsible water use is an important component of the continued sustainability of current water management practices. Important announcements are provided in both English and Spanish to increase dissemination of information.

Permitting and Regulatory Processes

Continuing sustainable operation of groundwater recharge and pumping requires maintaining existing permits and continued compliance with applicable regulations. WKWD's operations are subject to the terms of its drinking water permit (Permit No. 1510022) and wellfield operations permit (Permit No. 03-

12-09P-001), which are issued by the SWRCB. No additional permits would be required to implement this management action.

Management Action Benefits

This management action would allow WKWD to continue operating groundwater recharge and recovery in balance, resulting in a long-term net-zero balance in the Subbasin for the areas under WKWD's control. As demonstrated in WKWD's 2015 UWMP, historically WKWD has operated its groundwater banking efforts with a net positive volume of stored water for recovery during times of supply shortages, such as drought. WKWD expects that demand for groundwater will decrease as the oilfields in its jurisdiction reduce pumping (and therefore, related associated water demands); it also expects changes in SWP supply reliability. As a result, WKWD does not anticipate a long-term negative balance in its groundwater banking. The full benefits of this management action would be evaluated through water accounting of recharge volumes compared to pumping. All the wells in WKWD's jurisdiction are metered, so a full accounting of water recovered is available, and all water recharged is accounted for by WKWD's metered turnouts from the California Aqueduct and known purchases of SWP water used for recharge.

Continuing the practice of balanced pumping and recharge would benefit the MO of protecting GWEs, supporting the four sustainability indicators relevant to the WKWD GSA as follows:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

Management Action Implementation

This management action would be accomplished by continuing existing groundwater recharge and recovery operations. Surplus water would continue to be banked, while groundwater would be recovered to supplement supplies in years where imported water shortages are projected.

Management Action Status and Timing

The circumstance of project implementation would be current conditions and would remain unless conditions indicated a different management approach was needed to achieve sustainability indicators.

This management action continues WKWD's current operation of its system to bank surplus water and balance pumping with recharge and is already being implemented. The benefits of Management Action 1 are currently being realized and are reflected in WKWD's existing 200,000 AF of banked groundwater.

Supply Reliability

This management action depends on continued access to SWP supplies. The long-term reliability of SWP supplies is estimated at 61 percent in WKWD's 2015 UWMP. With an allocation of 31,500 AFY from the SWP, WKWD expects a long-term average delivery of SWP supplies to be 19,215 AFY. Additional

water is secured through transfers or exchanges with neighboring agencies, including BVWSD, Rosedale-Rio Bravo Water Storage District, and the Kern Tulare Water District, with long-term transfer of water from BVWSD expected at 6,500 AFY. Water available through individual years' transfers and exchanges are expected to vary from a low of 6,500 AF to as high as 12,450 AF from a combination of these sources.

Per the 2015 UWMP, these volumes will result in a surplus of supplies in average water years; in accordance with current management practices, this surplus is expected to be banked for use during dry years. During multiple dry years, SWP supplies are expected to drop to as low as 8 percent of normal, and imported supply shortfalls would be met using banked groundwater, projected to range between 6,300 and 12,700 AF in multiple dry years with low SWP availability. Given that WKWD has 200,000 AF of banked groundwater, this banked supply should be sufficient to serve approximately 10 years of demand without entering deficit, even when no other supplies, including imported or surface water, are available.

Legal Authority

The sole water supplier in the WKWD GSA is WKWD. WKWD owns and operates the only groundwater recovery wells in the North and South management areas. A small number of wells are operated by Kern County to maintain the BVARA, and no other private wells can be used in the GSA area. WKWD operates its groundwater recovery wellfields under a permit issued by the SWRCB's Division of Drinking Water (Permit No. 03-12-09P-001) and is an authorized public water supplier. Groundwater banking operations are undertaken in partnership with BVWSD. Continued operation of both the groundwater bank and the groundwater recovery wells falls within WKWD's authority, and as a result, within the boundary of the WKWD GSA.

Management Action Costs

The cost of continued balanced operation of groundwater recharge and recovery would remain within normal WKWD operating costs. These costs are expected to increase over time due to inflation, but do not represent an additional capital investment. WKWD's operating costs include natural gas, electricity, customary fees associated with conveying water in canals, and facility maintenance. Costs to implement this management action would be met through WKWD's standard rate structure, with rate changes implemented as necessary to address inflation and rising costs described above.

Technical Justification

Existing groundwater banking operations have been monitored since WKWD inception in the early 1960s. The volume of water recharged and available for recovery is calculated to be 90 percent of the water volume entering the North and South Project management areas. The 10 percent decrease assumes a 6 percent water loss due to evaporation and a 4 percent water loss due to groundwater migration. These losses were calculated based on groundwater scenario modeling, the siting and design of recharge ponds below the near-surface fine grained sands (which have lower infiltration potential), and the experience of other groundwater banking operations in the region (WKWD, 2010).

Subbasin Uncertainty

WKWD currently manages water supplies to address uncertainty by banking groundwater during wet years for use during years with SWP and surface water shortages. WKWD's current management practices have resulted in approximately 200,000 AF banked groundwater. This is despite high variability in available supplies for recharge since initiation of WKWD's groundwater banking activities, including times of severe drought, such as the 2012-16 drought. WKWD's 2015 UWMP indicates that the existing banked supplies are adequate as the sole source of supply for 10 years, if SWP deliveries are decreased to 0 AFY. While dry years may result in drawdown of banked groundwater, normal and wet years will result in increases to banked groundwater. Because dry years are the only years where surplus water could not be banked, the long-term net forecast for dry, normal, and wet years would result in maintenance of groundwater levels or an increase in banked groundwater. Existing banked supplies demonstrate that current groundwater management can provide sufficient reserves to act as a buffer for uncertainty in the GSA area.

Subbasin uncertainty identified in the Basin Setting sections of this Chapter GSP is not anticipated to substantially affect WKWD's ability to implement this management action or the overall effectiveness of this management action given the substantial water supply reserves already banked.

CEQA/NEPA Considerations

No additional CEQA or NEPA documentation or compliance measures would be required to implement this management action because it does not require implementation of a project as defined by CEQA or NEPA.

8.8.2 Management Action 2: Implement Water Shortage Response Plan

WKWD's *Water Shortage Response Plan* (WSRP) is incorporated into the 2015 UWMP and includes triggers for when the WSRP would be implemented. The WSRP describes management actions and use restrictions that would be implemented if water shortages were declared. Because current operation of groundwater recharge and recovery in the GSA area has shown a long-term increase in banked groundwater, and normal water years are projected to have a surplus of supply that can be banked, it is not expected that the WSRP would go into effect during normal or wet years. During extended dry periods, groundwater pumping would increase, and WKWD would use banked supplies to meet demands in excess of available imported and surface water supplies. The WSRP might be implemented to address statewide conservation requirements, such as during the 2012-16 drought, or when supplies are restricted, or for other reasons that may require a reduction in demand.

In the WSRP, demand on imported and surface water is reduced as a result of customer conservation and increased pumping from the groundwater bank. The WSRP has four stages, which are implemented following a Response Level declaration by WKWD's Board of Directors. Table 8-3 lists those Response Levels, the conservation required, and the groundwater bank pumping needed.

Table 8-3. WSRP Response Levels

Response Level	Conservation Target (Percent)	Customer Conservation (AF)	Groundwater Bank Pumping (AF)
Level 1 – Water Awareness	0 to 10	0	2,800
Level 2 – Water Restrictions	20	2,750	2,750
Level 3 – Critical/Water Reduction	30	4,150	4,150
Level 4 – Emergency/Water	50	6,900	6,900

Notes:
[a] Groundwater bank reserves will make up for any part of the Response Level 1 conservation not met
[b] Adapted from Table 8-1 in WKWD's 2015 UWMP

For Response Levels 2 through 4, a variety of water use restrictions would be implemented using a mix of voluntary and mandatory restrictions, depending on the Response Level and at the discretion of WKWD's Board of Directors. Restrictions may include limits on when landscape irrigation may occur, time limits for repairing leaks, and measures to avoid excess runoff and water waste, among other measures. Enforcement of WSRP violations would include warnings, fees, and potential discontinuation of service per WKWD's 2015 UWMP.

The WSRP includes triggers for when WKWD's Board of Directors may declare a Response Level, though only Response Level 1 has hard triggers. Response Level 1 may be declared if the following three conditions are met:

- Consecutive three-year state-wide drought
- Significant reduction in groundwater levels, as deemed by the Board of Directors
- Significant reduction in groundwater storage, as deemed by the Board of Directors

Response Level 1 may also be declared if facility or infrastructure issues result in a significant reduction of water supplies.

According to WKWD's 2015 UWMP, Response Levels 2 through 4 do not have hard triggers, but are declared by the Board of Directors after declaration of a water shortage emergency and upon consideration of the following factors:

- Local drought conditions
- General statewide drought conditions
- Groundwater depths, including recent changes
- Total banked groundwater storage, including recent changes
- Changes in well capacity due to groundwater level declines
- Recent allocation of surface water
- Short-term ability to purchase water from other sources

- Water quality issues impacting water supply
- Infrastructure issues (such as well failure, pipeline failure, or aqueduct breach) that could significantly reduce water supplies

Although Response Levels 2 through 4 are more subjective than Response Level 1, the circumstances that trigger them can generally be described as needing to reduce water use due to drought or other restriction in supply (Response Level 2), needing to increase cutbacks due to continued drought or disaster (Response Level 3), and requiring reduced demand so that WKWD has sufficient water supply to meet basic needs (Response Level 4).

Public Notice and Outreach

At all four Response Levels, WKWD implements public outreach to encourage water conservation and notify customers of voluntary and mandatory water use restrictions per the 2015 UWMP. Declaration of a Response Level by WKWD's Board of Directors takes place at public Board meetings, which are publicly noticed.

For each violation of a Response Level requirement, a customer would receive written notice of the violation and information about the consequences of continued violation. WKWD's 2015 UWMP, including the WSRP, underwent public review and was noticed in accordance with the *Final 2015 Urban Water Management Plan Guidebook for Urban Water Suppliers* and California Water Code Sections 0642 and 10608.26 (DWR, 2016c).

Permitting and Regulatory Processes

As previously mentioned, implementation of the WSRP requires WKWD's Board of Director approval through a Response Level declaration. Implementation of the water use restrictions following declaration would not require any additional permitting or regulatory action.

Management Action Benefits

The WSRP is designed to reduce customers' overall water use by implementing restrictions on when and how water may be used. As a result, implementation of this management action would reduce overall demand, which offsets demand for imported water and groundwater. Each Response Level is designed to help achieve a specific conservation target, and would reduce overall demands between 0 and 6,900 AF (i.e., 0- to 50 percent conservation) (Table 8-3). Conservation achieved by this management action would be measured by the reduction in metered water deliveries after this management action is implemented.

Increasing water conservation would reduce demands for potable water, thereby reducing the volume of water pumped from the Subbasin.

This management action would benefit the MO of protecting GWEs from excess pumping during years with supply shortages, supporting the four sustainability indicators relevant to the WKWD GSA as follows:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

Management Action Implementation

Implementation of the WSRP requires declaration of a Response Level from WKWD's Board of Directors, at which time WKWD staff would begin outreach efforts with customers and explain restrictions that would be implemented for a given Response Level. WKWD staff would be responsible for enforcement of the restrictions described in the WSRP, and for changes to pumping volumes from the groundwater bank. Individual customers would be responsible for complying with water use restrictions, and WKWD would penalize violations in accordance with the WSRP.

Management Action Status and Timing

The circumstance of implementation for this project would be times of water shortage, supply interruption, or drought, as declared by WKWD's Board of Directors. Implementation would cease when shortages are no longer being experienced, and as approved by the WKWD's Board of Directors.

The WSRP is not actively being implemented, but it is available for implementation should the WKWD Board of Directors initiate a Response Level declaration. The WSRP was activated during the 2012-16 drought, and while water supply conditions have since improved and restrictions have been lifted, the WRSP is ready to be activated at any moment. Once activated, water use restrictions in the WSRP would apply immediately or in the near future, pending the terms of the Board of Director's declaration activating the Response Level. Water conservation benefits would begin accruing immediately after these water use restrictions were implemented, though it may take a short period of time for customers to learn about and adjust to the restrictions before full benefits are realized. The enforcement actions available to WKWD through the WSRP would help achieve full benefits relatively quickly.

Supply Reliability

This management action includes conservation, which does not depend on supplies for successful implementation, and groundwater pumping from banked resources. The groundwater pumped during implementation of the WSRP would come from the surplus banked groundwater and is considered 100 percent reliable for the short-term because WKWD has 200,000 AF currently stored, which is enough to meet the normal-year demand as the sole source of water for a period of 10 years.

Legal Authority

As the sole water supplier in the WKWD GSA area, WKWD has the authority to implement the WSRP at the discretion of its Board of Directors and in accordance with the process described in the WSRP.

Project Costs

Some additional costs associated with public outreach and enforcement of the WSRP Response Levels may be incurred when the WSRP is implemented. Further, as a result of conservation encouraged or required by the WSRP, WKWD's revenue stream is anticipated to decrease when this management action is implemented. However, groundwater is WKWD's lowest cost water supply, so supply-related costs would decrease compared to years when the WSRP is not implemented, which will help offset potential costs for enforcement of the WSRP and reduction of revenue. According to the 2015 UWMP, potential revenue deficiencies created by implementation of this management action could be covered by WKWD's operating funds.

Technical Justification

The WSRP includes water use reduction measures that are commonly implemented in similar plans across the state, including reduction in irrigation volumes, limits on when irrigation may occur and for how long, and prohibitions on excess water use, among other measures. These restrictions provide direct water savings.

Subbasin Uncertainty

Implementation of the WSRP is triggered by changes in the basin setting, specifically drought status and availability of supplies. Successful implementation of the WSRP relies on customer behavior and availability of reliable water supply from banked groundwater. Should customers not achieve conservation targets described in the WSRP, or should they not comply with mandatory restrictions in place for a given Response Level, the WSRP includes measures to penalize customers who are in violation, including the ability to shut off water service to repeat offenders.

CEQA/NEPA Considerations

Implementation of the WSRP is not a project as defined by CEQA and NEPA, and therefore does not require CEQA or NEPA compliance to implement.

8.8.3 Management Action 3: Continued Participation in Basin-Wide Coordination

The WKWD GSA is one of 11 GSAs in the Subbasin. Coordination among these GSAs is necessary for sustainable management of the Subbasin as a whole and has been ongoing during development of their respective GSPs. Coordination during GSP development has included regular in-person meetings and calls to discuss sustainability thresholds, potential projects and management actions, and to discuss specific issues and concerns. As described in this Chapter GSP, the KGA is developing an Umbrella GSP for the Subbasin, while the other GSAs in Kern County are developing Chapter GSPs.

The KGA was established in 2014 as a joint powers agency to develop and implement a groundwater management plan in the Subbasin and in the neighboring Tulare Lake Groundwater Basin (KGA, 2017). The KGA currently serves as a forum for coordinating groundwater management activities.

Other nearby entities that WKWD GSA would coordinate with under this management action include the following:

- Kern Water Bank
- Kern River GSA
- Henry Miller GSA
- Pioneer GSA
- Buena Vista GSA

WKWD GSA is adjacent to Kern Water Bank, the Henry Miller GSA, and the Buena Vista GSA. As such, WKWD GSA would engage more frequently with these GSAs because their activities are likely to have a greater potential effect on WKWD GSA, and vice versa.

This management action would involve attending KGA manager meetings and coordination meetings, which are already held monthly, and KGA stakeholder meetings, which are held as needed. Quarterly coordination meetings would be held with Buena Vista GSA, the Henry Miller GSA, and the Kern River GSA, while annual coordination meetings would be held with the Pioneer GSA. These meetings would be an opportunity to discuss progress toward meeting sustainability goals, potential changes in overall groundwater levels and quality, and potential management actions and projects to address common concerns. Coordination of five-year updates to GSPs in the Subbasin would also occur as part of this management action (see Section 9.0).

Public Notice and Outreach

This management action involves internal coordination between GSA managers, and does not require public participation in the meetings themselves. KGA stakeholder and Board of Director meetings are publicly noticed, with agendas and meeting materials posted online. This management action assumes that decisions made in these meetings would be presented at an appropriate Board of Directors meeting or stakeholder meeting.

Permitting and Regulatory Processes

No permits or regulatory approvals would be required to implement this management action because it involves coordination meetings rather than physical projects. Actions or projects resulting from decisions based on coordination meeting outcomes would be subject to the appropriate permitting and regulatory processes if implemented.

Management Action Benefits

This management action would continue existing coordination activities among GSA managers, helping to build and maintain relationships with neighboring GSAs. Potential conflicts between GSAs regarding groundwater management would be reduced because GSAs would better understand the challenges experienced in each GSA area, and how these challenges are being addressed. Coordination meetings will also provide an opportunity for GSAs to inform each other of potential issues that may require intra-Subbasin coordination to address, and to notify neighboring GSAs of management actions or projects that might affect a decision made by another GSA.

Coordination among GSAs would help identify potential threats to groundwater levels and develop projects or actions to address them, which would benefit the MO of protecting GWEs, supporting the four sustainability indicators relevant to the WKWD GSA as follows:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

Management Action Implementation

This management action would be accomplished through continued attendance at existing KGA coordination meetings and arranging periodic coordination meetings with the Kern Water Bank, the Kern River GSA, the Henry Miller GSA, the Buena Vista GSA, and the Pioneer GSA. WKWD GSA would designate one or more representatives to participate in these coordination meetings; representatives may include the GSA manager or their staff. Decisions made in coordination meetings would not be binding until approved by the appropriate authority, such as the WKWD GSA manager or WKWD's Board of Directors.

Management Action Status and Timing

The circumstance of implementation for this project is ongoing.

This management action is currently being implemented and may decrease in frequency following completion of GSPs, as GSAs move toward implementation of their GSPs. Timing of coordination meetings are expected to generally align with the frequency described above, as appropriate. Benefits from continued coordination are being realized; WKWD GSA has identified a previously unknown use of groundwater to supplement BVARA lake levels because of coordination activities in the Subbasin. As coordination continues, benefits are expected to continue.

Supply Reliability

This management action does not involve physical water supplies; as a result, supply reliability is does not apply to this management action.

Legal Authority

WKWD GSA is the agency responsible for sustainable management of the GSA area. It has the authority to designate staff to meet with staff from other GSAs and share information as appropriate.

Management Action Costs

Costs associated with this management action would include staff time (salary), transportation costs for in-person meetings, and potential costs associated with reserving facilities, if meetings are not hosted at a GSA member agency's facility. WKWD is a member of the KGA and pays an annual fee to participate. This cost is included in WKWD's annual budget.

Technical Justification

This management action does not involve capital project funding or changes to operations. Direct benefits of this action are not physical. As such, no technical justification is required.

Subbasin Uncertainty

This management action would help address uncertainty in the Subbasin by maintaining communication among groundwater management entities and use existing forums for information sharing. This will help WKWD GSA and its neighbors better understand, anticipate, and plan for uncertain conditions in the Subbasin.

CEQA/NEPA Considerations

This management action does not include implementation of a project as defined by CEQA or NEPA.

8.9 Adaptive Management Strategies

Adaptive management strategies would only be considered for implementation if designated trigger events for that strategy occur. Triggers for each adaptive management strategy are described below. Triggering events would be based on monitoring results and data and are set in relation to undesirable results as described in this Chapter GSP's Section 7.0.

8.9.1 Adaptive Management Strategy 1: Taft Recycled Water Program

The Taft Recycled Water Program would create up to 423 AFY of tertiary recycled water suitable for Title 22-approved applications for recycled water. This project would be implemented in partnership between WKWD, the City of Taft, and the Ford City-Taft Heights Sanitation District (FCTHSD). WKWD provides water within the WKWD GSA area, but sanitation services are provided by the City of Taft and FCTHSD, which jointly own the Taft Wastewater Treatment Facility (WWTF). The Taft WWTF currently produces undisinfected secondary effluent that is suitable for and applied to feed crops, specifically alfalfa. This effluent is not suitable for wider recycled water use, but through upgrade to tertiary treatment, it could be used more widely for non-potable applications, such as landscape irrigation, which currently use potable water to meet demands (WKWD, 2018).

While the *2018 Administrative Draft Recycled Water Project Report* (2018 Feasibility Study) included four subalternatives for tertiary recycled water, this Chapter GSP assumes the Taft Recycled Water Program would install the most comprehensive of these subalternatives, Subalternative 4 (WKWD, 2018).

The project would accomplish the following:

- Install a 1.5-million gallon per day capacity tertiary treatment train that uses direct microfiltration and chlorine disinfection
- Construct a recycled water conveyance and distribution system to serve the identified use sites
- Construct pump stations, booster stations, and pressure reducing stations
- Construct a 1.5-million gallon covered storage facility for tertiary treated recycled water

Secondary effluent not needed for tertiary recycled water production would bypass the tertiary treatment train and would either be used for alfalfa irrigation (or similar approved use) or would be disposed of via spray fields. If Harrington Farms, the current (and only) user of secondary effluent, finds it is infeasible to use excess secondary effluent not needed for tertiary recycled water production, the City of Taft and FCTHSD would resume effluent spray disposal operations. These operations would require some equipment updates and ongoing maintenance of both the spray field and equipment.

Adaptive Management Trigger

This strategy would be triggered if regulatory requirements increase the feasibility of recycled water above the costs, if public demands for recycled water are sufficiently high to offset the cost of implementation, if implementation costs decrease sufficiently that recycled water becomes the preferred alternative, or if a future evaluation of recycled water otherwise determines it to be the preferred alternative.

Public Notice and Outreach

Public outreach would be necessary to bolster public support for the project, as well as to encourage potential customer participation. As identified in the 2018 Feasibility Study, most potential use sites are public parcels, such as schools, sports fields, and parks, though some privately owned sites with large irrigation needs were included in the study as potential customers. Public outreach could help identify additional potential customers or could lead to recommended changes in the project to accommodate anticipated future demands or address potential concerns raised by the public.

Public outreach is also necessary under the CEQA process. The degree of outreach required would depend on the appropriate CEQA document needed for the project. Outreach required by CEQA ranges from public noticing and posting of documents to public meetings at different stages of CEQA document development. Common types of CEQA-related outreach include sending mailers, posting website announcements, and publishing newspaper notices.

Permitting and Regulatory Processes

In addition to construction-related permits, the project partners (WKWD, City of Taft, and FCTHSD) would need to develop a *Title 22 Engineering Report* for approval under the SWRCB's General Waste Discharge Requirement permit (Order WQ 2014-0090-DWQ) that authorizes certain non-potable recycled water uses consistent with Title 22. The existing Taft WWTF is operated under an individual Waste Discharge Requirement permit (Order 5-00-080 and National Pollutant Discharge Elimination System Permit CA0080161), which specifies the quality of effluent from the Taft WWTF, and where and how this effluent may be discharged or used. Modification to the Waste Discharge Requirement permit is also expected to be required before tertiary recycled water could be used.

Moving forward with project implementation would also require an agreement between the three project partners regarding the preferred project alternative and a cost and revenue sharing structure, as well as agreements with potential customers to provide recycled water service. While not required, this project would also benefit from coordination with Harrington Farms, the current user of secondary effluent from the Taft WWTF.

Adaptive Management Strategy Benefits

The project would create up to 423 AFY of tertiary recycled water, offsetting an equal volume of potable water (WKWD, 2018). Available and unused potable water is currently banked for future use during imported and surface water supply shortages. This project would both reduce demand for groundwater pumping during dry years and allow for additional water to be banked during wet years. Tertiary recycled water would be a local supply with high supply reliability, even during drought years. The volume of water offset by this project would be measured by quantifying the amount of tertiary recycled water both produced and delivered.

Offsetting demand for potable water, thereby reducing the volume of water pumped from the Subbasin, would benefit the MO of protecting GWEs, supporting the four sustainability indicators relevant to the WKWD GSA as follows:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

Adaptive Management Strategy Implementation

This project would be implemented through an agreement between WKWD, the City of Taft, and FCTHSD. Construction of the project components would involve soliciting bids for design and construction, while delivery of water would involve outreach to and coordination with potential customers and use sites. Once construction is complete and sites are converted for delivery of tertiary recycled water, the treatment component of the Taft Recycled Water Project would be operated by City of Taft and FCTHSD as part of normal Taft WWTF operations, while recycled water conveyance and delivery

systems would be maintained and operated by WKWD. WKWD would also be responsible for billing recycled water customers for deliveries.

Adaptive Management Strategy Status and Timing

The circumstance of implementation for this strategy is reaching one of the triggers described above.

The Taft Recycled Water Program would take longer to implement than the other adaptive management strategies listed here. It is not currently the preferred use of treated wastewater from the Taft WWTF due to the cost of the project and current use of secondary effluent from the Taft WWTF for irrigation, so no further planning for this strategy will take place until a triggering event is reached. This strategy is included here because the WKWD GSA anticipates it will become a more viable project as the State continues to move toward increased water reuse, and as regulations change. Planning, design, permitting, CEQA compliance, and construction of a tertiary recycled water system would take multiple years. Once implemented, benefits will begin to accrue immediately after delivery of tertiary water begins, because it will directly offset demands for potable water.

Supply Reliability

Tertiary recycled water is sourced from wastewater flows, which can vary depending on water conservation efforts, but a minimum baseflow always exists due to basic health and safety-related uses of water. For this reason, tertiary recycled water is reliable and minimally affected by drought.

Legal Authority

Implementation of this project would require coordination between the water supplier (WKWD) and the owners of the Taft WWTF (City of Taft and FCTHSD). Such coordination would most likely be laid out in an MOU similar to the MOU implemented for the 2018 Feasibility Study between the City of Taft, WKWD, West Side Recreation and Park District, and West Side Cemetery District.

For a successful project, a mechanism to guarantee the use of the tertiary recycled water would also be necessary. This may take the form of formal requests for service, MOUs with customers, or mandatory use ordinances. Formal requests for service and MOUs with customers would only require agreements between the project partners (WKWD, City of Taft, and FCTHSD) and the customer, while mandatory use permits would require WKWD or the City of Taft to pass an ordinance.

WKWD is a member of the WKWD GSA and would be able to implement this project in coordination with project partners if it becomes feasible to do so.

Project Costs

The 2018 Feasibility Study estimated capital costs to construct a tertiary treatment and distribution system would be $14,455,000, with annual O&M costs of $415,000. Annualized total cost for the full tertiary recycled water project is $1.51 million, with a recycled water cost of $5,000 per AF. As of 2018, the cost of the proposed project was too high to make it a preferred alternative over the no-project alternative (WKWD, 2018). However, it is anticipated that tertiary recycled water use will increase in value in the future due to increased costs of imported water, changes in regulations, and culture regarding water use.

The cost of the project is expected to be borne by recycled water customers. Costs to individual customers would be determined by which components of the project are required to provide customers service, and how much recycled water is expected to be used. Project costs and costs to individual customers are anticipated to vary from those provided in the 2018 Feasibility Study depending on how many customers participate, potential changes to the project, and when the project might be implemented.

Technical Justification

Design and engineering of the project would comply with applicable standards and regulations, and the project would be designed to meet Title 22 regulations and other applicable recycled water use regulations and permits. Tertiary recycled water is commonly used throughout California and is a known technology with proven safety standards. Any tertiary water used by customers would directly offset potable water demands by physically replacing it with recycled water for irrigation purposes.

Subbasin Uncertainty

Recycled water itself is a reliable supply and is not substantially subject to Subbasin uncertainty. The project would help address uncertainty in the Subbasin by reducing demands for other supplies, allowing for potable water to be used for other purposes such as groundwater banking, sales to other agencies, and to meet other potable demands. Offsetting demands for potable water acts as a buffer against fluctuations in supply and overall Subbasin uncertainty.

CEQA/NEPA Considerations

This project would require CEQA compliance due to the type and size of the project. One of the project partners would be the lead agency under CEQA and would prepare an *Initial Study* to determine the appropriate CEQA document for the project. The other project partners would be responsible agencies under CEQA. Unless the project partners pursue federal funding for the project, NEPA is unlikely to be required as the project in unlikely to require federal actions that would trigger NEPA.

8.9.2 Adaptive Management Strategy 2: Shift Balance of Pumping between North and South Project Management Areas Wellfields

In 2010, WKWD's North Wellfield (wells within the North Project Management Area) was constructed in response to falling groundwater levels at the South Wellfield (wells within the South Project Management Area). Despite a surplus of banked groundwater, local levels at the South Wellfield showed a trending decline associated with groundwater recovery activities. A single wellfield for recovery activities also limited WKWD's operational flexibility. To combat these two management challenges, the North Wellfield was constructed along with additional recharge basins. Under current operation of the two wellfields, 11,300 AFY are pumped from the South Wellfield and 12,700 AFY are pumped from the North Wellfield. The North Wellfield has an annual pumping capacity of 24,000 AFY (WKWD, 2010).

This adaptive management strategy entails WKWD increasing the proportion of groundwater pumped at the wellfield that is experiencing the least decline in groundwater levels. This strategy would allow local recovery of groundwater levels in the other wellfield.

Adaptive Management Triggers

This adaptive management strategy would be considered if groundwater levels in either wellfield fell below baseline groundwater levels. As banked water is extracted, groundwater levels are expected to temporarily decline. Assuming equivalent aquifer hydraulic properties, the greatest decline would be localized around the wellfield pumping the most water. These temporary declines in groundwater levels are generally planned, such as during years when large water transfers occur. This trigger would only apply when declines in groundwater levels are not associated with planned events.

This trigger would be activated at the discretion of the WKWD's General Manager or their designee. The decision to activate this trigger would be based on a trend of declining GWEs (i.e., more than 20 percent of the historical GWE range below the historical minimum for each well, exclusive of declines attributable to a planned management decision).

Alternatively, WKWD may choose to implement an adaptive management zone which would serve as the trigger for considering adaptive management strategies. An adaptive management zone would establish a range of GWEs; if monitoring finds groundwater levels are within the adaptive management zone, the trigger would be activated.

Public Notice and Outreach

The decision to adapt groundwater pumping between the two wellfields is an internal management decision and does not require public notice or outreach. Changes to wellfield production would be reported using standard reporting methods, consistent with current management processes.

Permitting and Regulatory Processes

Pumping volumes are limited in the North Project Management Area wellfield to 12,700 AFY and are not limited on the South Project field. Operation of both wellfields are regulated by their respective permits. If pumping at each wellfield remains within its permitted capacities, and are in accordance with applicable agreements, no additional permits would be required to implement this adaptive management strategy.

Adaptive Management Strategy Benefits

This adaptive management strategy would reduce groundwater pumping in a localized area, allowing water levels in that area to recover or to decline less sharply during times of drought. Minimizing groundwater level declines reduces the potential for localized subsidence and long-term decrease in groundwater storage capacity. It also helps to maintain well efficiency, allowing for improved wellfield longevity. Local recovery of GWEs would be determined by standard monitoring activities that are part of regular wellfield management. Local groundwater level recovery from this strategy would be measured by monitoring of groundwater levels in the vicinity of the two wellfields.

This adaptive management strategy would help local recovery of groundwater levels, which would benefit the measurable objective of protecting GWEs, supporting the four sustainability indicators relevant to the WKWD GSA:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

Adaptive Management Strategy Implementation

This adaptive management strategy would be implemented by WKWD staff by changing how much water is pumped from each wellfield as an operational change. It would not require infrastructure improvements or additional investment, nor would it require any additional permits or budgetary changes.

Adaptive Management Strategy Status and Timing

The circumstance of implementation for this adaptive management strategy would be if the trigger as described above is reached.

Implementation would require easy-to-implement operational changes and could be implemented quickly once triggered. Benefits of this strategy are expected to begin accruing immediately after it is implemented, though some time may be required before monitoring shows related changes in groundwater levels.

Supply Reliability

WKWD has a surplus of banked groundwater available to recover. This adaptive management strategy would address potential long-term reliability issues with recovery of this banked groundwater that may arise if localized groundwater levels decline too far. The North Wellfield was constructed specifically to address supply reliability concerns that arose at the South Wellfield, where local GWEs had fallen to the point where there were concerns about impacts to overall well capacity. By balancing pumping between the two wellfield operations, and if unplanned localized declines are identified, WKWD would proactively protect wellfield reliability and long-term access to its banked groundwater supplies.

Legal Authority

WKWD is a member of the GSA and has full control over the North and South wellfields. WKWD makes operational decisions associated with both wellfields, and all management decisions within the legal limits of applicable permits. Additionally, all agreements are within the authority of WKWD.

Project Costs

This adaptive management strategy does not change the total volume of water recovered by WKWD; it adjusts how much water is pumped in each wellfield. Costs associated with this adaptive management strategy include energy demands for pumping and conveyance. Because energy demands for both wellfields are met with the same supply, and total pumping would remain consistent with regular demand,

and cost differences associated with shifting pumping volumes are expected to be negligible. Some cost savings may be realized by adjusting the balance of pumping between the wellfields because energy demands for pumping increase as groundwater levels decline.

Technical Justification

In the absence of water use restrictions, water demands within the GSA area are independent of available supply. Demands originally served by only the South Wellfield are now served using a combination of the two wellfields, decreasing the intensity of overall pumping at the South Wellfield. Long-term GWE data from both two wellfields are anticipated to support the use of the North Wellfield to allow groundwater levels in the South Wellfield to recover or maintain GWEs. The North Wellfield was constructed at the beginning of the 2012-16 drought. As a result of imported water supply shortages during the drought, groundwater levels in both wellfields declined. Benefits to the South Wellfield from construction of the North Wellfield are expected to be realized as the region recovers from drought. For more information, see WKWD's 2015 UWMP.

Subbasin Uncertainty

This adaptive management strategy would be implemented in response to unplanned changes in the GSA area, specifically changes in groundwater levels that would impact long-term ability to pump banked groundwater at either of the two wellfields. Pumping volumes for each wellfield would be determined by WKWD staff and may be adjusted during implementation of this adaptive management strategy as appropriate, depending on demand and recovery of GWEs in response to the changes.

CEQA/NEPA Considerations

The South Wellfield was constructed in the late 1960s and predates both CEQA and NEPA. As such, it was not subject to CEQA and NEPA review when constructed. The North Wellfield achieved CEQA compliance in 2010, under the WKWD Groundwater Banking Project's *2010 Final Environmental Impact Report* (WKWD, 2010). It was not subject to NEPA review because it did not require discretionary approval from a federal agency. Operation of the North Wellfield is covered by its CEQA and NEPA compliance documentation. Implementation of this adaptive management strategy would not trigger CEQA or NEPA because it falls within the operational boundaries established for the two wellfields and is not a project under CEQA or NEPA.

8.9.3 Adaptive Management Action 3: Implement Permanent Demand Management Measures

According to the 2016 WSRP, Response Level 1 is ongoing, and all water use restrictions are strictly voluntary. These actions only become mandatory if a Response Level 2 is declared, which requires a declaration by the WKWD's Board of Directors. This adaptive management strategy would convert the Response Level 1 actions in the WSRP from voluntary to mandatory. These water restrictions would require a 25 percent reduction in large landscape watering from 2007 levels, prohibit water waste, and reduce non-contracted industrial water use by 15 percent from 2007 levels. WKWD may choose to implement these or a different set of permanent demand management measures as appropriate at the time this adaptive management strategy is approved.

Adaptive Management Strategy Triggers

This adaptive management strategy would be considered for implementation if GWEs meet the following two thresholds:

- Groundwater elevations are within 10 percent of the minimum threshold
- Groundwater elevations are not trending toward the interim milestone or measurable objective

This adaptive management strategy may also be triggered if GWEs that were in the margin of operational flexibility dip below the MT for unplanned reasons, or when groundwater levels fall within the adaptive management zone. If these triggers are met, the GSA would notify WKWD and request that WKWD's Board of Directors approve and implement this adaptive management strategy.

Public Notice and Outreach

Implementation of permanent demand management measures would involve a public outreach campaign similar to that which would be implemented during a Response Level 2 water shortage scenario. Implementation of the action would require WKWD Board of Director approval and would occur at a publicly noticed meeting.

Permitting and Regulatory Processes

The process for implementing this action is WKWD Board of Directors approval, to be held at a public meeting as part of the Board's agenda for that meeting. Upon approval of the Board of Directors, WKWD would be authorized to implement enforcement consistent with the measures in the WSRP. No additional regulatory or permitting processes would be required for implementation.

Adaptive Management Strategy Benefits

Project benefits are expected to be like those achieved under Management Action 2 (Implement WSRP), though they will have long-term benefits because they are permanent measures rather than temporary ones under the WSRP. Conservation achieved by this management action would be measured by the reduction in metered water deliveries after this management action is implemented.

Like Management Action 2, increasing water conservation would reduce demands for potable water, thereby reducing the volume of water pumped from the Subbasin. This project would benefit the MO of protecting GWEs, supporting the four sustainability indicators relevant to the WKWD GSA as follows:

- Chronic lowering of groundwater levels (direct)
- Reduction in groundwater storage (proxy)
- Degraded water quality (proxy)
- Subsidence (proxy)

Adaptive Management Strategy Implementation

Implementation of this adaptive management strategy would involve approval from WKWD's Board of Directors, public outreach to inform customers about the new permanent conservation measures, and enforcement of those measures by WKWD staff. Approval from WKWD's Board of Directors would include clarification on the specific activities that would be prohibited, as well as the penalties for violations. This Chapter GSP assumes that enforcement of this adaptive management strategy would be consistent with enforcement of Response Level 2 of the WSRP.

Adaptive Management Strategy and Timing

The circumstance of implementation for this adaptive management strategy would be if the trigger as described above is reached.

Permanent demand management measures are not currently implemented by WKWD and may require additional time to determine the specific demand management measures to make permanent. It is anticipated that it would require some time to finalize the demand management measures and an enforcement structure before implementation and enforcement. Benefits of this adaptive management strategy are expected to begin accruing immediately after the strategy is implemented, though it may require some additional time before monitoring shows related changes in groundwater levels.

Supply Reliability

This adaptive management strategy is a conservation action and does not depend on a given water supply to implement. Supply reliability therefore does not apply to this adaptive management strategy.

Legal Authority

As the water supplier within the GSA, WKWD has the legal authority to limit non-essential water use. A resolution from WKWD's Board of Directors would be necessary to implement this strategy, but additional approvals would not be necessary.

Project Costs

Like Management Action 2 (Implement WSRP), costs for this adaptive management strategy would be funded by WKWD's normal operating budget. According to the 2015 UWMP, the WSRP shows that implementation of Response Level 2 would reduce WKWD's revenues by $2,746,000, which would be offset by reduced costs associated with not supplying the conserved water and would not require monetary adjustments by WKWD. Implementation of this adaptive management strategy is expected to cost a similar amount and is expected to be funded in the same way.

Technical Justification

Reduction in irrigation water volumes, limits on when irrigation may occur and for how long, and prohibitions on excess water use, among other measures, are commonly used mechanisms for reducing water demand. As when restrictions are implemented under the WSRP, these restrictions provide direct water savings, and were found to be effective during the 2012-16 drought.

Subbasin Uncertainty

This adaptive management strategy would be implemented in response to uncertainty about water supply in the GSA area, and is intended to help reduce that uncertainty by offsetting overall water demands.

CEQA/NEPA Considerations

This adaptive management strategy is not a project under CEQA or NEPA and therefore does not require any CEQA or NEPA compliance.

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Section 9.0 GSP Implementation

9.1 Compliance Information

Table 9-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix A.

Table 9-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 4. Monitoring Networks			
354.38	Assessment and Improvement of Monitoring Network	Review and evaluation of the monitoring network	Section 9.6.4
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions			
354.44	Projects and Management Actions	Description of projects and management actions that will help achieve the basin's sustainability goal	Section 8.0 Section 9.0
		Measurable objective that is expected to benefit from each project and management action	
		Circumstances for implementation	
		Public noticing	
		Permitting and regulatory process	
		Timetable for initiation and completion, and the accrual of expected benefits	
		Expected benefits and how they will be evaluated	
		How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.	
		Legal authority required	
		Estimated costs and plans to meet those costs	
		Management of groundwater extractions and recharge	
354.44(b)(2)		Overdraft mitigation projects and management actions	Section 8.0 Section 9.0

Table 9-1. Applicable Preparation Checklist Items

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 8. Interagency Agreements			
357.4	Coordination Agreements - Shall be submitted to the Department together with the GSPs for the basin and, if approved, shall become part of the GSP for each participating Agency.	Coordination Agreements shall describe the following:	Umbrella GSP
		A point of contact	
		Responsibilities of each Agency	
		Procedures for the timely exchange of information between Agencies	
		Procedures for resolving conflicts between Agencies	
		How the Agencies have used the same data and methodologies to coordinate GSPs	
		How the GSPs implemented together satisfy the requirements of SGMA	
		Process for submitting all Plans, Plan amendments, supporting information, all monitoring data and other pertinent information, along with annual reports and periodic evaluations	
		A coordinated data management system for the basin	
		Coordination agreements shall identify adjudicated areas within the basin, and any local agencies that have adopted an Alternative that has been accepted by the Department	

9.2 Introduction

As discussed in Section 8.0, several projects, management actions, and adaptive management strategies will or may be implemented by the WKWD GSA. These include the following:

- GSP implementation
- Management actions
- Project implementation
- Adaptative management strategies

Plan implementation is the execution of activities described in this Chapter GSP for sustainable operation of the GSA area of the Subbasin. Some of these activities include the following:

- Continued groundwater level monitoring
- Coordinating among GSAs in the Subbasin
- Installing additional monitoring equipment
- Updating the GSP

Management action implementation activities consist of continued balancing of water recharge and pumping within the GSA area and implementation of the WSRP, as needed.

Project implementation activities are additional projects identified in this Chapter GSP that reduce water demands or increase water supplies within the GSA area. These projects are as follows:

- AMR Project
- Participation in Delta Conveyance Facility
- Buena Vista Lake Project

Adaptive management actions are strategies that would be implemented to support WKWD GSA in achieving sustainability as needed. These include the following:

- Taft Recycled Water Program
- Pump balancing and shifting
- Implementing permanent demand management measures

9.3 Implementation Schedule

Figure 9-1 illustrates this Chapter GSP's implementation schedule. Included in the chart are activities necessary for ongoing GSP monitoring and updates, as well as tentative schedules for projects and management actions. More detailed descriptions of the timing and duration of each activity is provided in the respective sections of this Chapter GSP.

Certain GSP implementation activities occur continuously through the planning horizon, and others occur periodically, such as the evaluation of interim targets, which occur every five years (i.e., five-year GSP updates). In Figure 9-1, management actions occur throughout the planning horizon because they are either already being implemented or may be implemented at any time during the Chapter GSP's duration. The implementation schedule for projects is tentative, but the timelines for implementation are intended to provide context for how long it would likely take to implement a project and when benefits could potentially be realized. For the AMR Project, benefits would begin to accrue as meters were installed and customers were added to the online system. For other projects, benefits would begin to be realized after completion of construction. Adaptive management strategies do not have a schedule or duration because they would be implemented only if triggered.

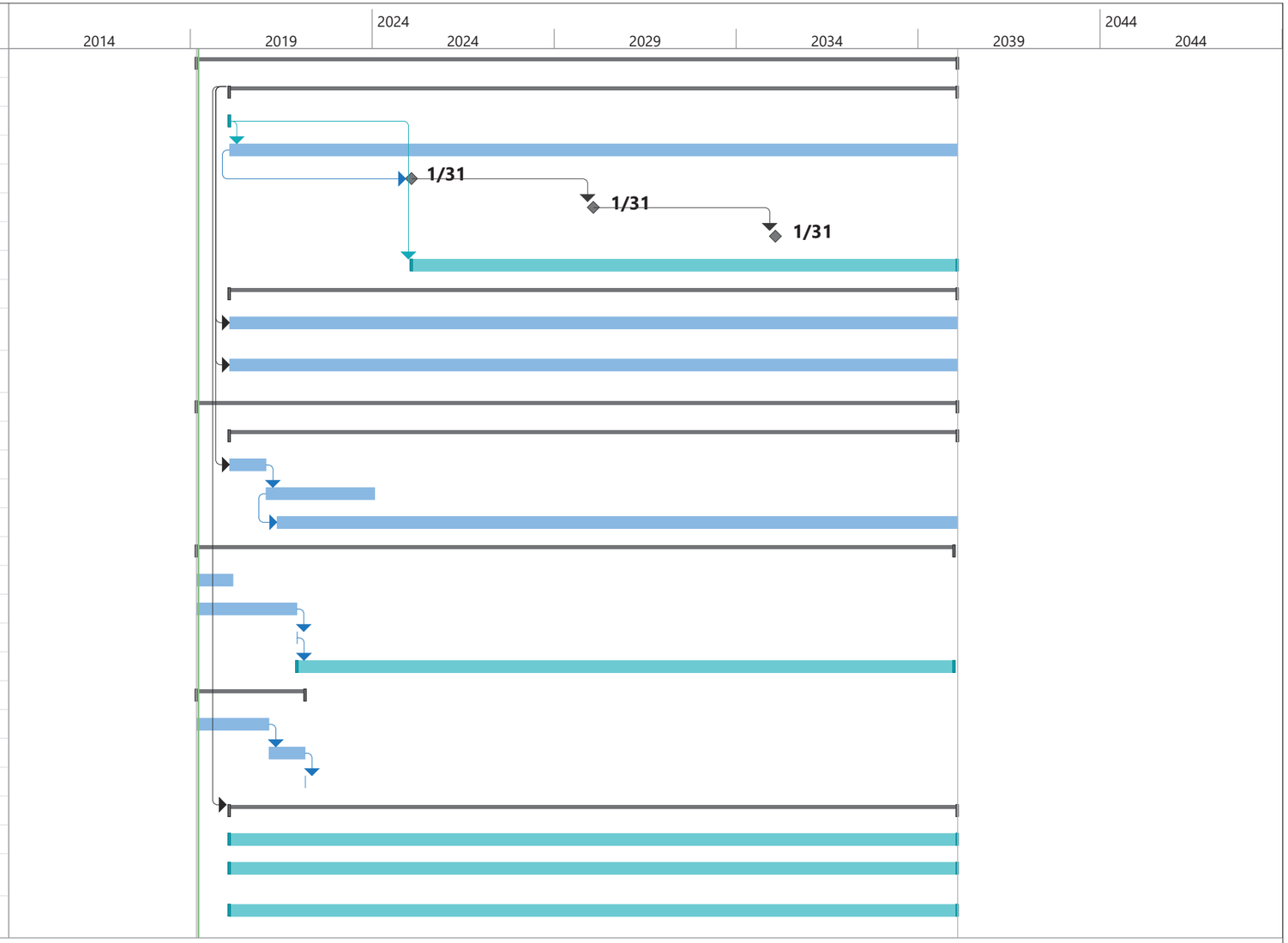
9.4 GSA and GSP Implementation Costs and Funding Source

GSA operations and GSP implementation will incur costs, which will require funding by the GSA. The five primary activities that will incur costs are listed below.

- Implementing the GSP
- Implementing GSP-related projects and management actions
- GSA operations
- Developing annual reports
- Developing five-year GSP updates

The following sections describe these primary activities and discuss potential funding sources.

ID	Task Name	Duration	Start	Finish
1	**WKGSP Implementation**	**5458 days?**	**Mon 3/4/19**	**Wed 2/1/40**
2	**Plan Implementation**	**5218 days**	**Fri 1/31/20**	**Tue 1/31/40**
3	Plan submittal to the State	1 day	Fri 1/31/20	Fri 1/31/20
4	Monitoring	5218 days	Fri 1/31/20	Tue 1/31/40
5	Interim Target Evaluation 1	0 days	Fri 1/31/25	Fri 1/31/25
6	Interim Target Evaluation 2	0 days	Thu 1/31/30	Thu 1/31/30
7	Interim Target Evaluation 3	0 days	Wed 1/31/35	Wed 1/31/35
8	Plan Updates	3913 days	Fri 1/31/25	Tue 1/31/40
9	**Management Action Implementation**	**5218 days**	**Fri 1/31/20**	**Tue 1/31/40**
10	1. Continued Balanced Recharge and Pumping	5218 days	Fri 1/31/20	Tue 1/31/40
11	2. Implement Water Shortage Response Plan	5218 days	Fri 1/31/20	Tue 1/31/40
12	**Project Implementation**	**5458 days?**	**Mon 3/4/19**	**Wed 2/1/40**
13	**1. Automatic Meter Reading Program**	**5219 days**	**Fri 1/31/20**	**Wed 2/1/40**
14	Planning	52 wks	Fri 1/31/20	Thu 1/28/21
15	Construction	156 wks	Fri 1/29/21	Thu 1/25/24
16	Benefits	4879 days	Fri 5/21/21	Wed 2/1/40
17	**2. Participate in California WaterFix**	**5435 days?**	**Mon 3/4/19**	**Sat 12/31/39**
18	Decision to Participate	262 days	Mon 3/4/19	Tue 3/3/20
19	California WaterFix Planning	36 mons	Mon 3/4/19	Fri 12/3/21
20	California WaterFix Construction	1 day?	Mon 12/6/21	Mon 12/6/21
21	Benefits	4715 days	Tue 12/7/21	Sat 12/31/39
22	**3. Buena Vista Lake Placeholder Project**	**781 days?**	**Mon 3/4/19**	**Mon 2/28/22**
23	Planning	104 wks	Mon 3/4/19	Fri 2/26/21
24	Construction	52 wks	Mon 3/1/21	Fri 2/25/22
25	Benefits	1 day?	Mon 2/28/22	Mon 2/28/22
26	**Adaptive Management Action Implementation**	**5218 days?**	**Fri 1/31/20**	**Tue 1/31/40**
27	Taft Recyeld Water Program	5218 days	Fri 1/31/20	Tue 1/31/40
28	Pump Balancing and Shifting between North and South Well Fields	5218 days?	Fri 1/31/20	Tue 1/31/40
29	Implementation of Permanent Demand Management Measures	5218 days?	Fri 1/31/20	Tue 1/31/40



Project: Implementation Schedu
Date: Mon 3/25/19

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone

Figure 9-1: Implementation Schedule

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9.4.1 GSP Implementation Costs

Costs associated with GSP implementation include the following:

- Performing well monitoring
- Performing management tasks
- Developing annual reports
- Developing five-year GSP updates
- Implementing projects
- Implementing management actions
- Implementing adaptive management strategies

Monitoring of WKWD GSA's current well network is conducted as part of normal WKWD operations. The cost to monitor the current well monitoring network is approximately $25,000 annually and is funded through WKWD's service fee.

WKWD has also undertaken initial management of the WKWD GSA and covered those costs through normal service fees. GSA management is anticipated to cost approximately $100,000 annually, which includes support staff services, GSA General Manager services, and costs for GSA coordination within the Subbasin.

The anticipated cost for developing an annual and a five-year GSP update are $50,000 and $200,000, respectively.

Management actions are generally covered by WKWD's normal operating costs because they represent activities already being undertaken by WKWD. Management Action 3 (continued participation in GSA coordination) would be covered by WKWD GSA's operating costs and is part of GSA management.

Project implementation would incur costs only when implemented and would vary by project activity. Implementation of the actual costs may change depending on when the project is implemented and final design of projects. Installation of AMR systems is projected to cost $4.1 million, though O&M would be included in WKWD's normal operating costs. Participation in Delta Conveyance Facility is expected to cost $1,236 per acre-foot of water received, though costs are expected to change as the State continues to refine the project. Coordination activities to manage water supply at BVARA would be included in WKWD GSA's management activities, though any projects or management decisions that come out of this project could have additional costs that would be determined during evaluation of those projects.

Adaptive management strategies would only be implemented if triggered, and their costs would be incurred only when triggered. The Taft Recycled Water Program is projected to cost $14.5 million, with annual O&M costs of approximately $415,000. The relatively high cost is why this program is an adaptive management strategy rather than a project, though costs are expected to change as technology advances and as planning and design is finalized if triggered. The other two adaptive management strategies would be incorporated into WKWD or WKWD GSA's normal operating costs, because if

implemented, they would be management actions that would not incur additional capital costs, and they would not incur substantial staff costs.

Cost information for GSP implementation is provided in Table 9-2. Individual project, management action, and adaptive management strategy costs are detailed in Section 8.0 of this Chapter GSP.

Table 9-2. Implementation Costs

Implementation Activity	Estimated Cost
Monitoring	$25,000 per year
Management Tasks	$100,000 per year
Annual Reporting	$50,000 per year
Five-Year GSP Updates	$200,000 every five years
Project 1: Automatic Meter Reading Project	$4.1 million ($690/meter)
Project 2: Participation in Delta Conveyance Facility	$1,236 per AF water received
Project 3: BVARA Water Supply Management Coordination	Included in Management Tasks; implementation of projects identified by this Project would have variable costs
Management Action 1: Continued Balanced Pumping and Recharge	Included in WKWD operating costs
Management Action 2: Implement Water Shortage Response Plan	Included in WKWD operating costs
Management Action 3: Continued Participation in Subbasin-Wide Coordination with other GSAs	Included in Management Tasks
Adaptive Management Strategy 1: Taft Recycled Water Program	$14.5 million construction; $415K O&M. Annualized cost $1.51M
Adaptive Management Strategy 2: Shift Balance of Pumping between North and South Wellfields	Included in Management Tasks
Adaptive Management Strategy 3: Implement Permanent Demand Management Measures	Included in WKWD operating costs

9.4.2 GSP Implementation Funding

Initial GSP development and GSA management costs are covered by WKWD through service fees, paid by its customers. WKWD will continue to provide management and funding of GSA and GSP activities, but may seek other funding sources in the future, such as grants, pumping fees, or acreage-based fees. Some GSP-identified projects and management actions, such as monitoring of groundwater wells are already incorporated into WKWD's routine operations and funded through services fees to customers. This method of funding may continue in the future. Costs associated with GSP-identified projects and management actions not previously undertaken by WKWD may be funded through the service fees or through other potential funding sources noted above.

9.5 Annual Reports

Per DWR's Emergency Regulations, GSAs must submit annual reports by April 1 of each year, following GSP adoption.[4] Annual reports must include three key sections described below.

9.5.1 General Information

Annual reports will contain an executive summary that summarize the content of the report and provide information about Subbasin condition. This section will also describe sustainability goals, describe GSP projects and their progress, and describe a general implementation schedule paired with a map of the GSA. Key components of this section required by regulation include the following:

- Executive Summary
- Map of the GSA

9.5.2 Basin Conditions

Annual reports will contain a basin conditions section will describe how conditions have changed in the Subbasin over the past year. Additionally, this section will evaluate GWEs and compare newly collected groundwater data against historical data. The GSA's water extraction volumes and practices will also be described in this section. Information about extraction data, surface water flows, total water use, and groundwater storage will also be included. Key components of this section required by regulation include the following:

- Groundwater elevation data from the monitoring network
- Hydrographs of elevation data
- Groundwater extraction data
- Surface water supply data
- Total water use data
- Change in groundwater storage, including maps

9.5.3 Plan Implementation Progress

In the annual report's plan implementation section, the GSA's progress toward implementing Chapter GSP projects and management actions will be evaluated. This includes evaluating and comparing data about sustainability indicators, including IMs and Subbasin progress toward or maintaining sustainability. Descriptions of the project schedules and funding options will also be provided.

[4] https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/GSP_Emergency_Regulations.pdf

The plan implementation section of the annual report will also describe GSA management actions and may include the following:

- Schedule of management actions
- Management action description
- Management action review of success or progress
- Management action effectiveness helping the GSA reach sustainability per the California Code of Regulations.

If applicable, this section will also evaluate the GSA's adaptive management strategies to help it achieve the sustainability goals. Key components of this section required by regulation include the following:

- Plan implementation progress
- Sustainability progress

9.6 Five-Year Chapter GSP Update

WKWD GSA is required by SGMA to evaluate the progress of their GSP in reaching approved sustainability goals at least every five years, or whenever the GSP is amended. These five-year updates will result in an update of the original GSP, and must include additional information as follows:

- Descriptions of management actions taken
- Reviews of additional data or information about the Subbasin
- Reviews and assessments of monitoring networks
- Descriptions of progress toward addressing data gaps

The components of a five-year GSP update are described below.

9.6.1 Sustainability Evaluation

This section of a five-year GSP update will describe current groundwater conditions for each applicable sustainability indicator and will discuss progress toward sustainability by evaluating current conditions along with IMs, MTs and MOs.

A re-evaluation of wells located in the Western Management Area will be conducted to ensure that groundwater is not produced in the area beyond de-minimis users. Should non-de-minimis use be determined to be occurring, WKWD GSA will consider development of sustainable management criteria for portions of the Western Management Area where non-de-minimis use is occurring.

9.6.2 Plan Implementation Progress

This section of a five-year GSP update will provide information about the progress GSP implementation components, discuss projects that have been implemented, projects that are in the process of being implemented, and projects still on the planning horizon, with an approximate implementation timeline. GSP implementation components include projects, management actions, and adaptive management strategies.

9.6.3 Reconsideration of GSP Elements

Upon submission of a five-year GSP update, DWR may reconsider GSP elements, including basin settings, management areas, undesirable results, MOs, MTs, and IMs. Information that may impact these GSP elements include the following:

- Data collected through the monitoring network
- Changes in water use or water supply
- Changes to water resources through projects and plan implementation

9.6.4 Monitoring Network Description

Per the requirements of DWR Emergency Regulations Section 356.4. (e),[5] the monitoring network will be described, and its function will be assessed. The five-year GSP update will also analyze data collected to date. This section of a five-year GSP update will also re-identify data gaps, and identify actions required to improve the monitoring network. If data gaps are identified, this section will also describe a program for addressing those data gaps, provide a time line for closing data gaps, and describe how data will be incorporated into a five-year GSP update.

9.6.5 New Information

A five-year GSP update will provide new information that has become available since publishing the last GSP annual report, and more specifically, will discuss how this information may impact the Chapter GSP or Subbasin. This section could include information about impacts to the Subbasin setting, MOs, MTs, IMs, or criteria that help define undesirable results.

9.6.6 Regulations or Ordinances

A five-year GSP update will describe any regulations or ordinances implemented by the GSA.

9.6.7 Legal or Enforcement Actions

A five-year GSP update will describe any legal or enforcement actions taken by the GSA during implementation of the GSP to attain the sustainability goals.

[5] https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/GSP_Emergency_Regulations.pdf

9.6.8 Plan Amendments

Any amendments to a GSP will be described in the five-year GSP update.

9.6.9 Coordination

A five-year GSP update will summarize coordination efforts that have occurred among the GSA, other GSAs, and other agencies. This section may include a summary of meetings and discussions held with these groups or may include information about joint projects or data collection efforts.

Appendix A

Preparation Checklist for Groundwater Sustainability Plan Submittal

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Table A-1. DWR Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	Executive Summary	Executive Summary
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 1.5
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.6	Agency Information	GSA mailing address	Section 1.2.3
		Organization and management structure	Section 1.2.4
		Contact information of Plan Manager	Section 1.2.3
		Legal authority of GSA	Section 1.2.5
		Estimate of implementation costs	Section 9.0
354.8(a)	Map(s)	Area covered by GSP	Section 1.0 Most maps
		Adjudicated areas, other agencies within the basin, and areas covered by an Alternative	Section 1.3
		Jurisdictional boundaries of federal or State land	Section 1.3
		Existing land use designations	Section 1.3
		Density of wells per square mile	Section 6.6.4 Section 6.10.4
354.8(b)	Description of the Plan Area	Summary of jurisdictional areas and other features	Section 1.3
354.8(c)	Water Resource Monitoring and Management Programs	Description of water resources monitoring and management programs	Section 1.3.3 to 1.3.5
354.8(d)		Description of how the monitoring networks of those plans will be incorporated into the GSP	Section 1.3.3 to 1.3.5
354.8(e)		Description of how those plans may limit operational flexibility in the basin	Section 1.3.3 to 1.3.5
		Description of conjunctive use programs	Section 1.3.7
354.8(f)	Land Use Elements or Topic Categories of Applicable General Plans	Summary of general plans and other land use plans	Section 1.3
		Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects	Section 1.3
		Description of how implementation of the GSP may affect the water supply assumptions of	Section 1.3

Table A-1. DWR Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulation Section	Water Code Section	Description	GSP Section
		relevant land use plans	
		Summary of the process for permitting new or replacement wells in the basin	Section 1.3.6
		Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	Section 1.0 Umbrella GSP
354.8(g)	Additional GSP Contents	Description of Actions related to:	
		Control of saline water intrusion	Section 1.3.8
		Wellhead protection	Section 1.3.8
		Migration of contaminated groundwater	Section 1.3.8
		Well abandonment and well destruction program	Section 1.3.8
		Replenishment of groundwater extractions	Section 1.3.8
		Conjunctive use and underground storage	Section 1.3.8
		Well construction policies	Section 1.3.8
		Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects	Section 1.3.8
		Efficient water management practices	Section 1.3.8
		Relationships with State and federal regulatory agencies	Section 1.3.8
		Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity	Section 1.3.8
		Impacts on groundwater dependent ecosystems	Section 1.3.8
354.1	Notice and Communication	Description of beneficial uses and users	Section 1.4
		List of public meetings	Section 1.4
		GSP comments and responses	Section 1.4
		Decision-making process	Section 1.4
		Public engagement	Section 1.4
		Encouraging active involvement	Section 1.4
		Informing the public on GSP implementation progress	Section 1.4

Table A-1. DWR Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.16	Current and Historical Groundwater Conditions	Groundwater elevation data	Section 1.3 Section 2.0.
	Surface Water Supply	Description of surface water supply used or available for use for groundwater recharge or in-lieu use	Section 1.0 Section 2.10 Section 4.0
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 2.12
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.14	Hydrogeologic Conceptual Model	Description of the Hydrogeologic Conceptual Model	Section 2.0
		Two scaled cross sections	Umbrella GSP
		Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	Section 1.0 Section 2.5 Section 2.10
354.14(c)(4)	Map of Recharge Areas	Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas	Section 2.10
	Recharge Areas	Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	Section 2.10 Umbrella GSP
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 3.9
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.16	Current and Historical Groundwater Conditions	Groundwater elevation data	Section 1.3 Section 3.3
		Estimate of groundwater storage	Section 3.4
		Seawater intrusion conditions	Section 5.6
		Groundwater quality issues	Section 2.9 Section 3.5
		Land subsidence conditions	Section 3.6
		Identification of interconnected surface water systems	Section 3.7
		Identification of groundwater-dependent ecosystems	Section 3.8

Table A-1. DWR Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 4.10
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.18	Water Budget Information	Description of inflows, outflows, and change in storage	Section 4.0
		Quantification of overdraft	Umbrella GSP
		Estimate of sustainable yield	Umbrella GSP
		Quantification of current, historical, and projected water budgets	Umbrella GSP
	Surface Water Supply	Description of surface water supply used or available for use for groundwater recharge or in-lieu use	Section 1.0 Section 2.10 Section 4.6
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria			
354.24	Sustainability Goal	Description of the sustainability goal	Section 5.3
354.26	Undesirable Results	Description of undesirable results	Section 5.0
		Cause of groundwater conditions that would lead to undesirable results	
		Criteria used to define undesirable results for each sustainability indicator	
		Potential effects of undesirable results on beneficial uses of users of groundwater	
Article 3. Technical and Reporting Standards			
352.2	Monitoring Protocols	Monitoring protocols adopted by the GSA for data collection and management	Section 6.0
		Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	Section 6.0
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 6.12
354.8(a)	Map(s)	Area covered by GSP	Section 1.0 Section 6.0
		Density of wells per square mile	Section 6.6.4

Table A-1. DWR Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulation Section	Water Code Section	Description	GSP Section
			Section 6.10.4
Article 5. Plan Contents, Subarticle 4. Monitoring Networks			
354.34	Monitoring Networks	Description of monitoring network	Section 6.0
		Description of monitoring network objectives	Section 6.3
		Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions	Section 6.0
		Description of how the monitoring network provides adequate coverage of Sustainability Indicators	Section 6.0
		Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends	Sections 6.6 to 6.10
		Scientific rationale (or reason) for site selection	Sections 6.6 to 6.10
		Consistency with data and reporting standards	Umbrella GSP
		Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone	Section 7.0
		Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used	Sections 6.6 Section 6.10 DMS
		Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	Umbrella GSP
354.36	Representative Monitoring	Description of representative sites	Section 6.6 Section 6.10
		Demonstration of adequacy of using GWEs as proxy for other sustainability indicators	Section 6.0 Section 7.0
		Adequate evidence demonstrating site reflects	Section 6.5

Table A-1. DWR Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulation Section	Water Code Section	Description	GSP Section
		general conditions in the area	
354.38	Assessment and Improvement of Monitoring Network	Review and evaluation of the monitoring network	Section 9.6.4
		Identification and description of data gaps	Section 6.6.8 Section 6.10.6
		Description of steps to fill data gaps	Section 6.6.9 Umbrella GSP
		Description of monitoring frequency and density of sites	Section 6.6.3 to 6.6.4 Section 6.10.3 to 6.10.4
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 7.10
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria			
354.26	Undesirable Results	Description of undesirable results	Section 5.0 Section 7.0
		Cause of groundwater conditions that would lead to undesirable results	
		Criteria used to define undesirable results for each sustainability indicator	
		Potential effects of undesirable results on beneficial uses and users of groundwater	
354.28	Minimum Thresholds	Description of each minimum threshold and how they were established for each sustainability indicator	Sections 7.4 to 7.9
		Relationship for each sustainability indicator	
		Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater	
		Standards related to sustainability indicators	
		How each minimum threshold will be quantitatively measured	
354.3	Measurable Objectives	Description of establishment of the measurable objectives for each sustainability indicator	Sections 7.4 to 7.9
		Description of how a reasonable margin of safety was established for each measurable objective	
		Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones	

Table A-1. DWR Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulation Section	Water Code Section	Description	GSP Section
Article 5. Plan Contents, Subarticle 4. Monitoring Networks			
354.2	Management Areas	Reason for creation of each management area	Section 7.3
		Minimum thresholds and measurable objectives for each management area	Sections 7.4 to 7.9
		Level of monitoring and analysis	Section 6.0
		Explanation of how management of management areas will not cause undesirable results outside the management area	Section 7.3 Umbrella GSP
		Description of management areas	Section 7.3
354.34	Monitoring Networks	Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone	Section 7.0
354.36	Representative Monitoring	Demonstration of adequacy of using GWEs as proxy for other sustainability indicators	Section 6.0 Section 7.0
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 8.10
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions			
354.44	Projects and Management Actions	Description of projects and management actions that will help achieve the basin's sustainability goal	Section 8.0 Section 9.0
		Measurable objective that is expected to benefit from each project and management action	
		Circumstances for implementation	
		Public noticing	
		Permitting and regulatory process	
		Timetable for initiation and completion, and the accrual of expected benefits	
		Expected benefits and how they will be evaluated	
		How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.	
		Legal authority required	
		Estimated costs and plans to meet those costs	
		Management of groundwater extractions and	

Table A-1. DWR Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulation Section	Water Code Section	Description	GSP Section
		recharge	
354.44(b)(2)		Overdraft mitigation projects and management actions	Section 8.0 Section 9.0
Article 5. Plan Contents, Subarticle 4. Monitoring Networks			
354.38	Assessment and Improvement of Monitoring Network	Review and evaluation of the monitoring network	Section 9.6.4
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions			
354.44	Projects and Management Actions	Description of projects and management actions that will help achieve the basin's sustainability goal	Section 8.0 Section 9.0
		Measurable objective that is expected to benefit from each project and management action	
		Circumstances for implementation	
		Public noticing	
		Permitting and regulatory process	
		Timetable for initiation and completion, and the accrual of expected benefits	
		Expected benefits and how they will be evaluated	
		How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.	
		Legal authority required	
		Estimated costs and plans to meet those costs	
		Management of groundwater extractions and recharge	
354.44(b)(2)		Overdraft mitigation projects and management actions	Section 8.0 Section 9.0
Article 8. Interagency Agreements			
357.4	Coordination Agreements - Shall be submitted to the Department together with the GSPs for the basin and, if approved, shall become part of the GSP for each	Coordination Agreements shall describe the following:	Umbrella GSP
		A point of contact	
		Responsibilities of each Agency	
		Procedures for the timely exchange of	

Table A-1. DWR Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulation Section	Water Code Section	Description	GSP Section
	participating Agency.	information between Agencies	
		Procedures for resolving conflicts between Agencies	
		How the Agencies have used the same data and methodologies to coordinate GSPs	
		How the GSPs implemented together satisfy the requirements of SGMA	
		Process for submitting all Plans, Plan amendments, supporting information, all monitoring data and other pertinent information, along with annual reports and periodic evaluations	
		A coordinated data management system for the basin	
		Coordination agreements shall identify adjudicated areas within the basin, and any local agencies that have adopted an Alternative that has been accepted by the Department	

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Appendix B

West Kern Water District Notice of Decision to Form Groundwater Sustainability Agency

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Board of Directors
David A. Wells
President

Gary J. Morris
Vice President

Barry M. Jameson
Roger Miller
Scott Niblett

Harry O. Starkey
General Manager

J.D. Bramlet
Director of Operations

Sanjay "Sunny" Kapoor
Director of Finance

July 14, 2016

VIA E-MAIL AND FIRST CLASS MAIL
Mr. Mark Nordberg, GSA Project Manager
Sustainable Groundwater Management Program
California Department of Water Resources
901 P Street, Room 213-B
P.O. Box 942836
Sacramento, CA 94236
mark.nordberg@water.ca.gov

Re: **NOTICE OF THE WEST KERN WATER DISTRICT'S INTENT TO BECOME A GROUNDWATER SUSTAINABILITY AGENCY**

Dear Mr. Nordberg:

Per Section 10723.8(a) of the California Water Code, the West Kern Water District ("West Kern") gives notice of its decision to form a Groundwater Sustainability Agency ("GSA") for the portion of its jurisdictional boundaries that overly the Kern County Subbasin (Basin Number 5-22.14, DWR Bulletin 118) within the San Joaquin Valley Groundwater Basin.

West Kern's jurisdictional boundaries are depicted in **Exhibit A**.

On June 28, 2016, the West Kern Board of Directors held a public hearing to consider the decision to serve as a GSA. In accordance with Section 10723(b) of the California Water Code, and Section 6066 of the California Government Code, a notice of public hearing was published in a newspaper of general circulation. Proof of publication is shown as **Exhibit B**.

Following the public hearing, West Kern's Board of Directors adopted Resolution No. 16-03, enclosed as **Exhibit C**, electing to become a GSA to the extent of the boundaries depicted in Exhibit A. West Kern is not proposing any new bylaws, ordinances, or other new authorities associated with this GSA formation.

Other agencies that are managing or proposing to manage groundwater within the Kern County Subbasin include: the Kern Groundwater Authority, Buena Vista Water Storage District, Kern River Groundwater

West Kern Water District · 800 Kern St., P. O. Box 1105 · Taft, California 93268-1105 · 661 763-3151 · FAX 661 765-4271

Sustainability Agency, the County of Kern, and the Greenfield County Water District.

As required by Water Code section 10723.8(a)(4), West Kern established and is maintaining a list of interested parties that West Kern will amend as necessary during the GSA formation process and Groundwater Sustainability Plan (GSP) development process. As required by SGMA, West Kern will consider all classes of beneficial users and users of groundwater within the Basin, as well as those responsible for developing GSPs. An initial list of stakeholders and interested party classes includes:

(a) Holders of overlying groundwater rights

(1) Agricultural users
- None known at this time.

(2) Domestic well operators
- Aera Energy, LLC
- California Resources Corporation

(b) Municipal well operators
- City of Taft
- City of Maricopa

(c) Public Water Systems
- West Kern Water District
- Wheeler Ridge-Maricopa Water Storage District

(d) Local land use planning agencies
- County of Kern

(e) Environmental users of groundwater
- None known at this time.

(f) Surface water users
- None known at this time

(g) Federal Government agencies
- Federal Bureau of Prisons (Taft Federal Correctional Institution)

(h) California Native American Tribes
- None known at this time

(i) Disadvantaged communities
- None known at this time

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(j) Entities monitoring and reporting groundwater elevations in all or a part of the groundwater basin
- Kern Groundwater Authority
- Kern Water Bank Authority
- Arvin-Edison Water Storage District
- Deer Creek & Tule River Authority
- Kern County Water Agency Improvement District 4
- Kern-Tulare Water District
- North Kern Water Storage District
- Semitropic Water Storage District
- Shafter-Wasco Irrigation District
- Kern Fan Authority

West Kern is committed to working with all interested parties, across the basin, to develop a GSP that achieves sustainable groundwater management.

By this notice, West Kern has provided DWR with all applicable information required by Water Code section 10723.8(a). If any further information is required, please contact West Kern's general manager, Harry Starkey, at Harry@wkwd.org.

Sincerely,

Harry Starkey
General Manager

cc: Mike McKenzie, South Central Region Contact

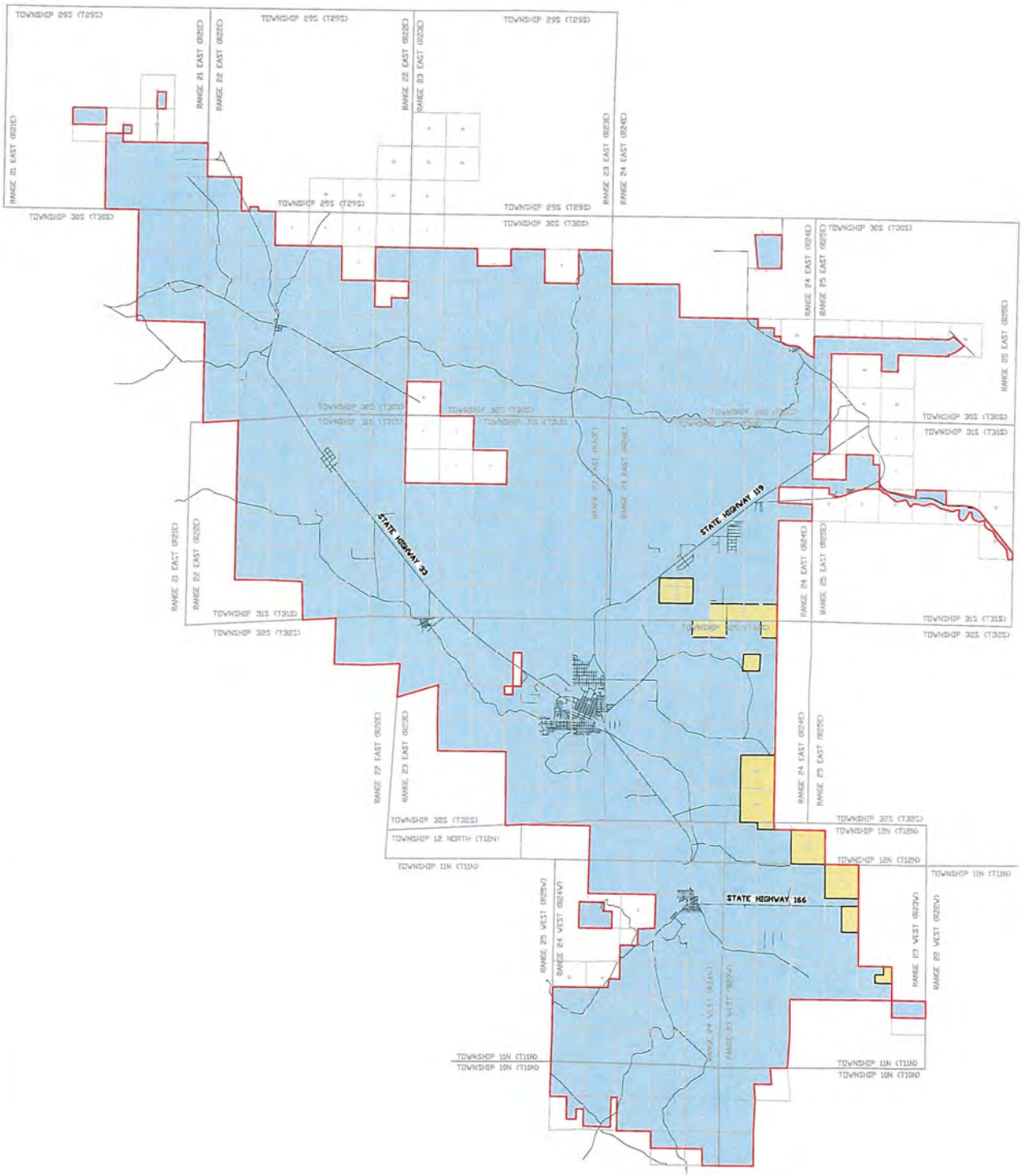
West Kern Water District • P. O. Box 1105 • Taft, California 93268-1105 • 661 763-3151 • FAX 661 765-4271

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EXHIBIT A

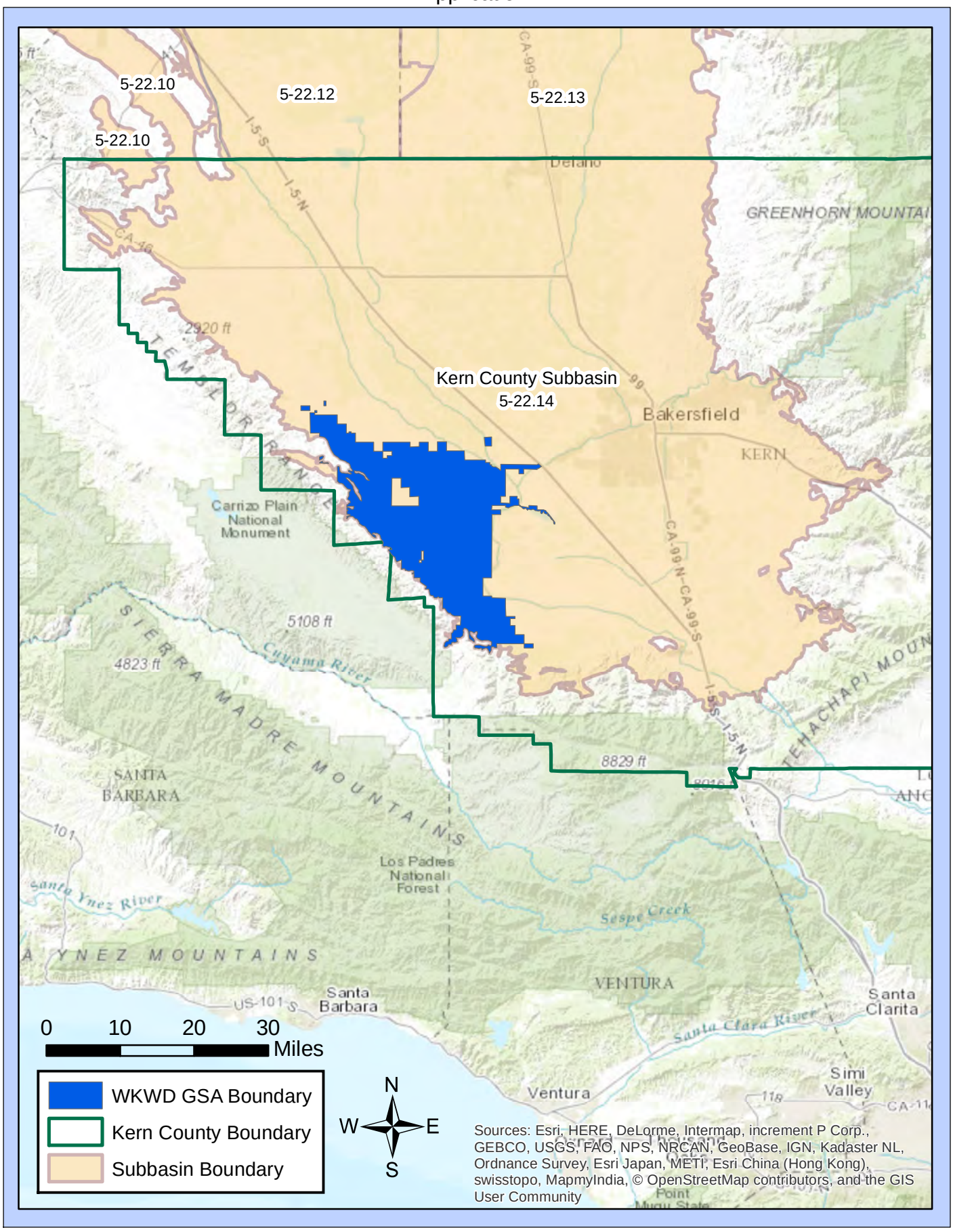
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WEST KERN WATER DISTRICT BOUNDARIES



WEST KERN WATER DISTRICT

Groundwater Sustainability Agency (GSA)
Application



Author: Doug Jameson - West Kern Water Engineering

EXHIBIT B

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PROOF OF PUBLICATION
(2015.5 C.C.P.)
STATE OF CALIFORNIA)
)ss
County of Kern)

I am a citizen of the United States and a resident of the County aforesaid. I am over the age of eighteen years, and not a party to or interested in the above entitled matter. I am the principal clerk of the DAILY MIDWAY DRILLER, a newspaper of general circulation, printed and published bi-weekly in the City of Taft, County of Kern, and which newspaper has been adjudged a newspaper of general circulation by the Superior Court of the County of Kern, State of California under the date of February 11, 1952, Book 90, Page 280, Case Number 57637; that the notice of which the annexed is printed copy (set in type not smaller than nonpareil), has been published in each regular and entire issue of said newspaper and not in any supplement thereof on the following dates, to wit:

June 14, 21

all in the year 2016

I certify (or declare) under penalty of perjury that the foregoing is true and correct.

Date at Taft, California, this 21

day of June 2016

SIGNATURE

NOTICE OF PUBLIC HEARING

NOTICE IS HEREBY GIVEN THAT, pursuant to California Water Code section 10723(b), the West Kern Water District (the "District") will hold a public hearing on June 28, 2016 at 6:00pm at the District offices, located at 800 Kern St., Taft, CA 93268.

The purpose of the hearing will be to consider and determine whether the District should become a "Groundwater Sustainability Agency" for a portion of the Kern County Groundwater Sub basin.

The hearing will be open to the public and any person present will have an opportunity to be heard.

Publish Dates: 06/14/16, 6/21/16

PUB: JUNE 14, 21, 2016
PUB: MIDWAY DRILLER

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EXHIBIT C

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RESOLUTION NO. 16-03

RESOLUTION ELECTING TO ESTABLISH THE WEST KERN WATER DISTRICT AS A GROUNDWATER SUSTAINABILITY AGENCY FOR THOSE PORTIONS OF THE KERN COUNTY SUBBASIN OF THE SAN JOAQUIN VALLEY GROUNDWATER BASIN

WHEREAS, the California Legislature passed a statewide framework for sustainable groundwater management, known as the Sustainable Groundwater Management Act (California Water Code § 10720 et seq.) pursuant to Senate Bill 1168, Senate Bill 1319, and Assembly Bill 1739, which was approved by the Governor and Chaptered by the Secretary of State on September 16, 2014; and

WHEREAS, the SGMA went into effect on January 1, 2015; and,

WHEREAS, the SGMA requires all high- and medium-priority groundwater basins, as designated by the California Department of Water Resources (DWR) Bulletin 118, to be managed by a Groundwater Sustainability Agency (GSA) or multiple GSAs; and,

WHEREAS, the Kern County Groundwater Sub-basin has been designated by DWR as a high-priority basin and in critical groundwater overdraft; and,

WHEREAS, the SGMA authorizes a local public agency overlying groundwater sub-basin to elect to become a GSA; and,

WHEREAS, the West Kern Water District (the "District") is a local public agency as defined under the SGMA and is therefore eligible to serve as a GSA; and,

WHEREAS, Section 10723.2 of the SGMA requires that a GSA consider the interests of all beneficial uses and users of groundwater, as well as those responsible for implementing groundwater sustainability plans; and,

WHEREAS, Section 10723.8 of the SGMA requires that a local public agency electing to be a GSA to notify the DWR of its election and intention to undertake sustainable groundwater management within a sub-basin; and,

WHEREAS, the District is committed to sustainable management of its groundwater resources; and,

WHEREAS, pursuant to Government Code Section 6066, notices of a public hearing regarding whether to adopt a Resolution to elect to become a GSA were published on June 14, 2016 and June 21, 2016 in the Taft Daily Midway Driller; and,

WHEREAS, the District held a public hearing on June 28, 2016, after publication of notice pursuant to Government Code section 6066 to consider adoption of this Resolution; and,

WHEREAS, the District wishes to exercise the powers and authorities of a GSA granted by the SGMA;

NOW, THEREFORE, BE IT RESOLVED that this Board of Directors of the West Kern Water District hereby elects to become a GSA for those portions of Kern County subbasin shown in the map attached hereto as Exhibit A; and,

BE IT FURTHER RESOLVED that the District authorizes the General Manager to, within 30 days from the date of this Resolution, provide notification of this election to the DWR, including a copy of this Resolution and additional information required by Water Code Section 10723.8, in the manner required by law; and,

BE IT FURTHER RESOLVED that the District directs the General Manager to begin preliminary negotiations concerning the resolution of potential overlapping GSA boundaries, and to report back about the potential options to resolve any overlapping boundaries.

All the foregoing being upon the motion of Director Morris, seconded by Director Niblett and carried by the following vote:

AYES:	President Barry M. Jameson Vice President David A. Wells Director Gary J. Morris Director Scott Niblett Director Roger Miller
NOES:	None
ABSENT:	None
ABSTAIN:	None

ADOPTED, SIGNED, AND APPROVED this 28th day of June 2016.

Barry M. Jameson,
President of the Board of Directors of
WEST KERN WATER DISTRICT

SECRETARY'S CERTIFICATE

I, Harry O. Starkey, being the appointed secretary of the **West Kern Water District**, do hereby certify that the above and foregoing **Resolution No. 16-03** was duly adopted by the Board of Directors of said District at a legally convened meeting of said Board held on the **28th day of June 2016,** that the above and foregoing is a full, true, and correct copy of **Resolution No. 16-03**, and that the same has not been amended or repealed.

ATTEST:

Harry O. Starkey,
Secretary of the Board of Directors of
WEST KERN WATER DISTRICT

(SEAL)

dg

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From:	Doug Jameson
To:	Nordberg, Mark@DWR
Cc:	Harry Starkey; JD Bramlet; Taylor Miller; Ravi Patel; Wendy Adams-Rosenberger; Gooding, Benjamin@DWR; McKenzie, Charles@DWR
Subject:	West Kern Water District GSA Application - map modification/revision
Date:	Wednesday, November 09, 2016 4:00:18 PM
Attachments:	WKWD-GSA rev.11092016.pdf WKWD-GSA rev.11092016.zip

---

Wednesday, November 9, 2016 4:00pm

Mr. Mark Nordberg,

West Kern Water District wishes to modify our desired GSA area in order to allow another local agency to potentially be formed and to adjust for the subbasin revisions recently made available to us.
Attached, please find a .pdf map outlining the requested revision. I have also included an ESRI shape file of the revised WKWD-GSA desired area for your use.

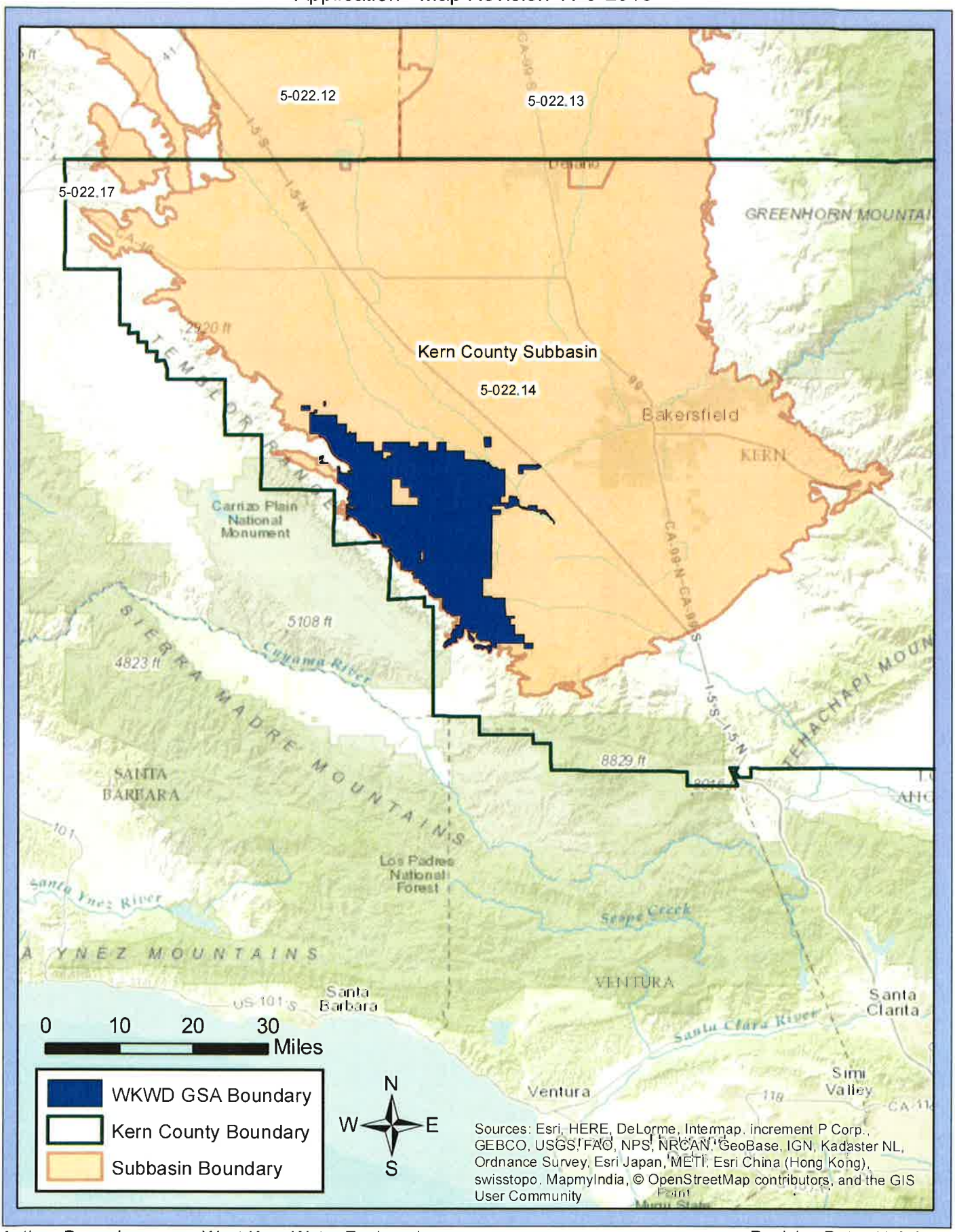
Thank You.

Doug Jameson
Engineering Technician/Project Manager
West Kern Water District
800 Kern St.
Taft Ca. 93268
661.763.3151 EXT128
661.577.6868 Cellular
661.765.5435 FAX
doug@wkwd.org
http://www.wkwd.org

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WEST KERN WATER DISTRICT

Groundwater Sustainability Agency (GSA)
Application - Map Revision 11-9-2016



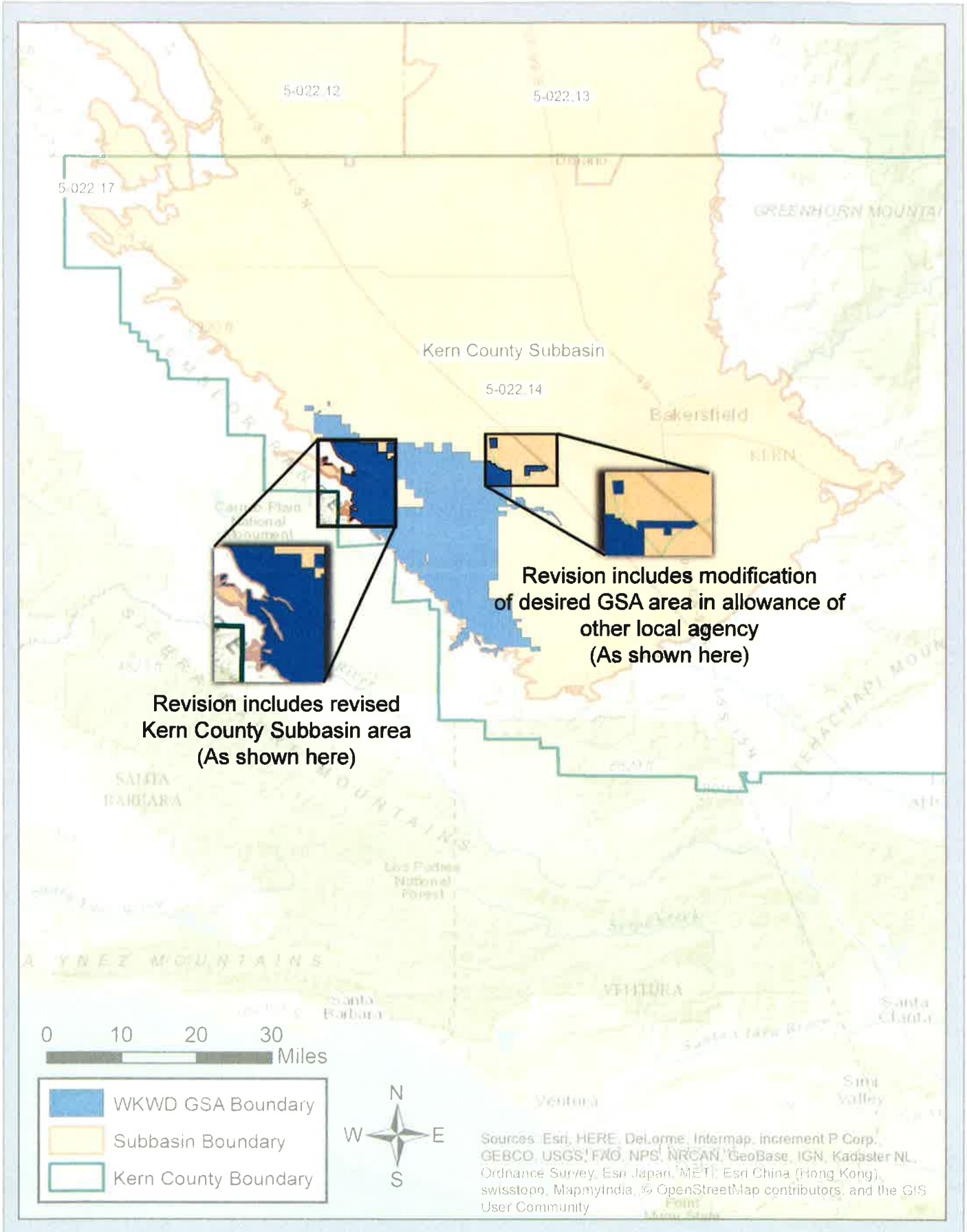
Author: Doug Jameson - West Kern Water Engineering

Revision Date: 11-9-2016

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WEST KERN WATER DISTRICT

Groundwater Sustainability Agency (GSA)
Application - Map Revision 11-9-2016



Author: Doug Jameson - West Kern Water Engineering

Revision Date: 11-9-2016

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From:	Doug Jameson
To:	Nordberg, Mark@DWR
Cc:	Harry Starkey; JD Bramlet; Taylor Miller; Ravi Patel; Wendy Adams-Rosenberger; Gooding, Benjamin@DWR; McKenzie, Charles@DWR; Maurice Etchechury
Subject:	West Kern Water District GSA Application - map modification/revision #2
Date:	Thursday, December 15, 2016 1:02:03 PM
Attachments:	WKWD-GSA rev.12152016.pdf WKWD-GSA rev.12152016.zip

---

Thursday, December 15, 2016 1:00pm

Mr. Mark Nordberg,

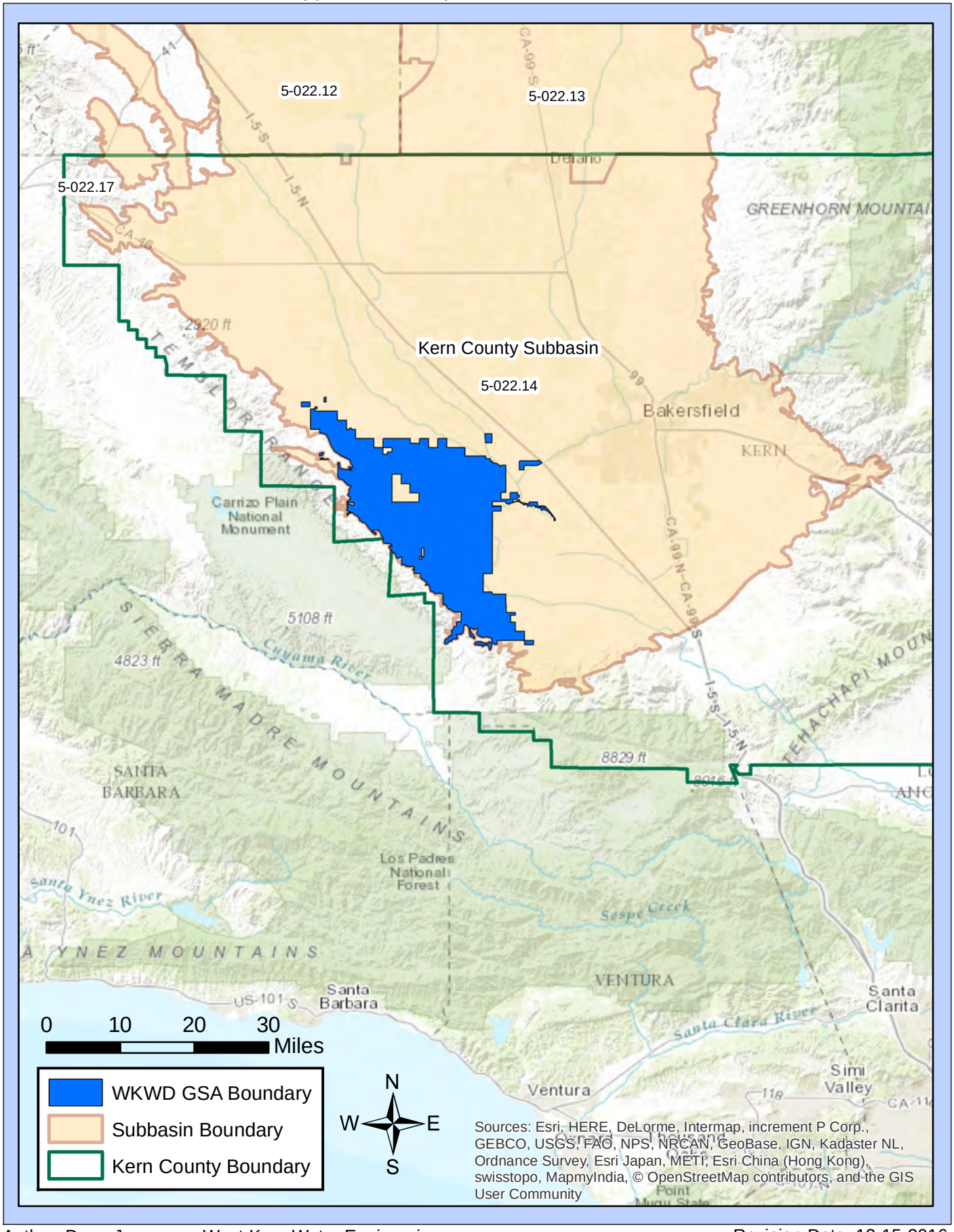
West Kern Water District wishes to submit a second modification of our desired GSA area in order to allow another local agency to potentially be formed.
Attached, please find a .pdf map outlining the requested revision #2. I have also included an ESRI shape file of the revised WKWD-GSA desired area for your use.

Thank You.

Doug Jameson
Engineering Technician/Project Manager
West Kern Water District
800 Kern St.
Taft Ca. 93268
661.763.3151 EXT128
661.577.6868 Cellular
661.765.5435 FAX
doug@wkwd.org
http://www.wkwd.org

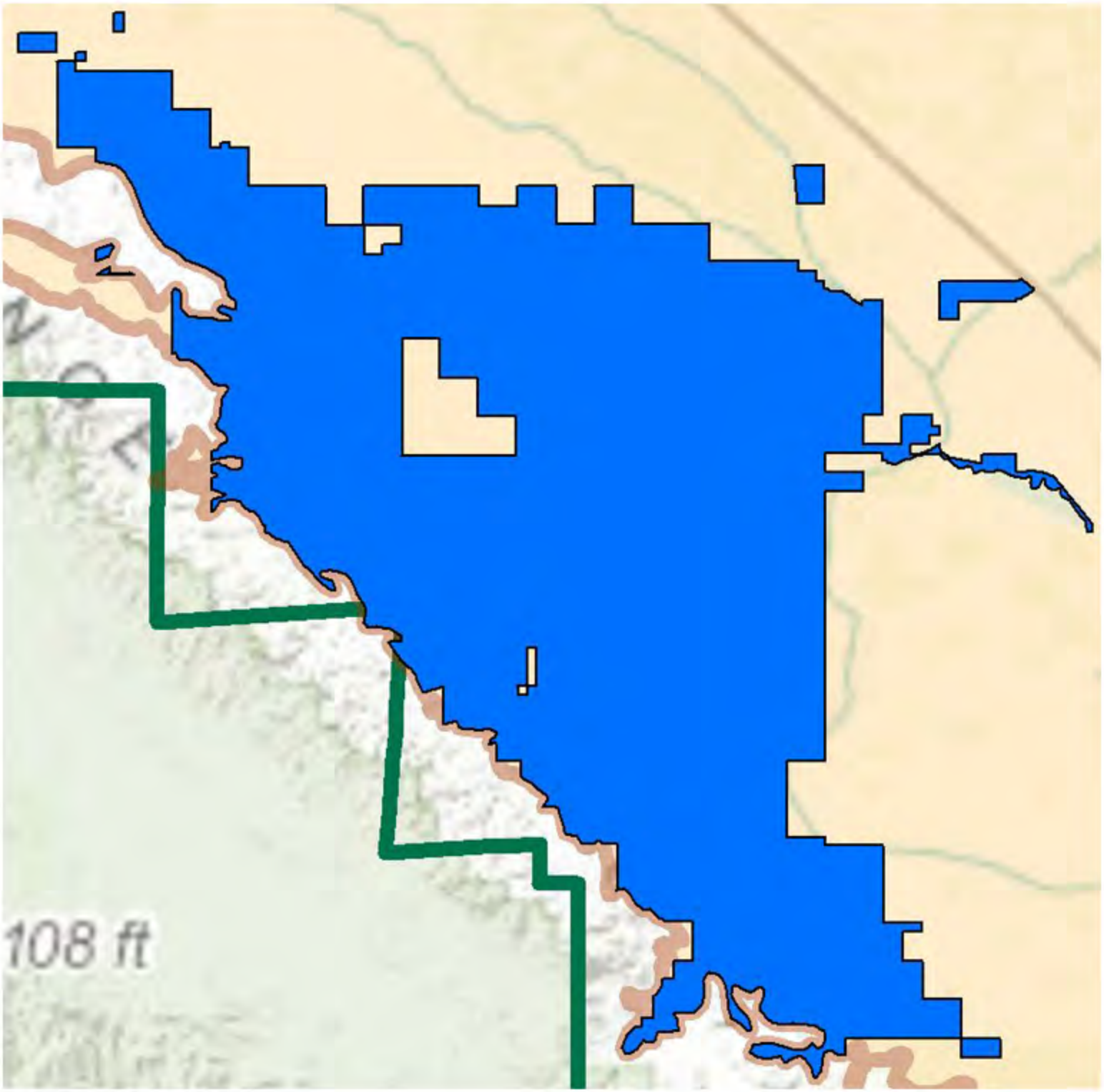
WEST KERN WATER DISTRICT

Groundwater Sustainability Agency (GSA)
Application - Map Revision 12-15-2016

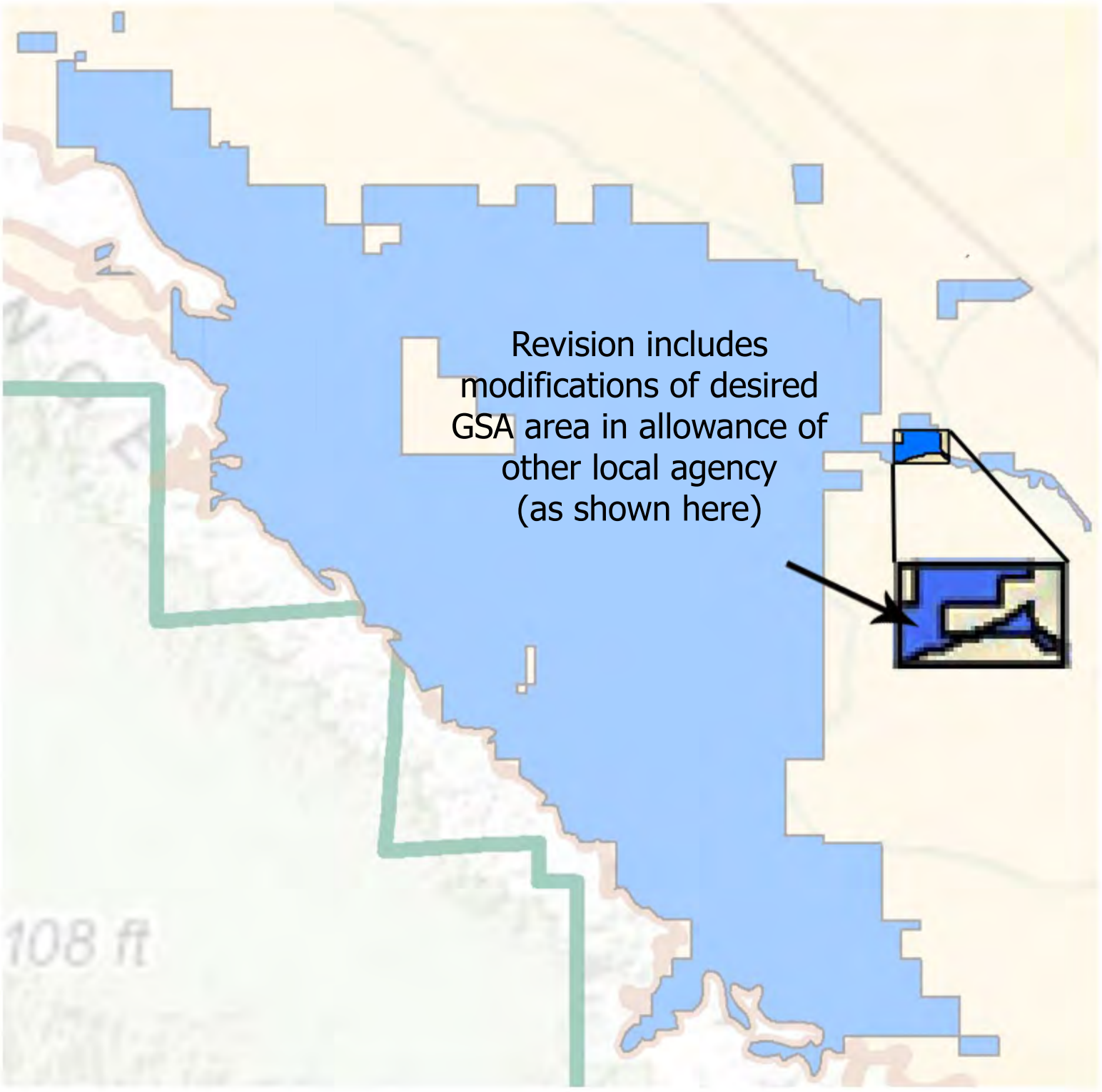


Author: Doug Jameson - West Kern Water Engineering

Revision Date: 12-15-2016



DETAIL 1


Revision includes
modifications of desired
GSA area in allowance of
other local agency
(as shown here)
108 ft

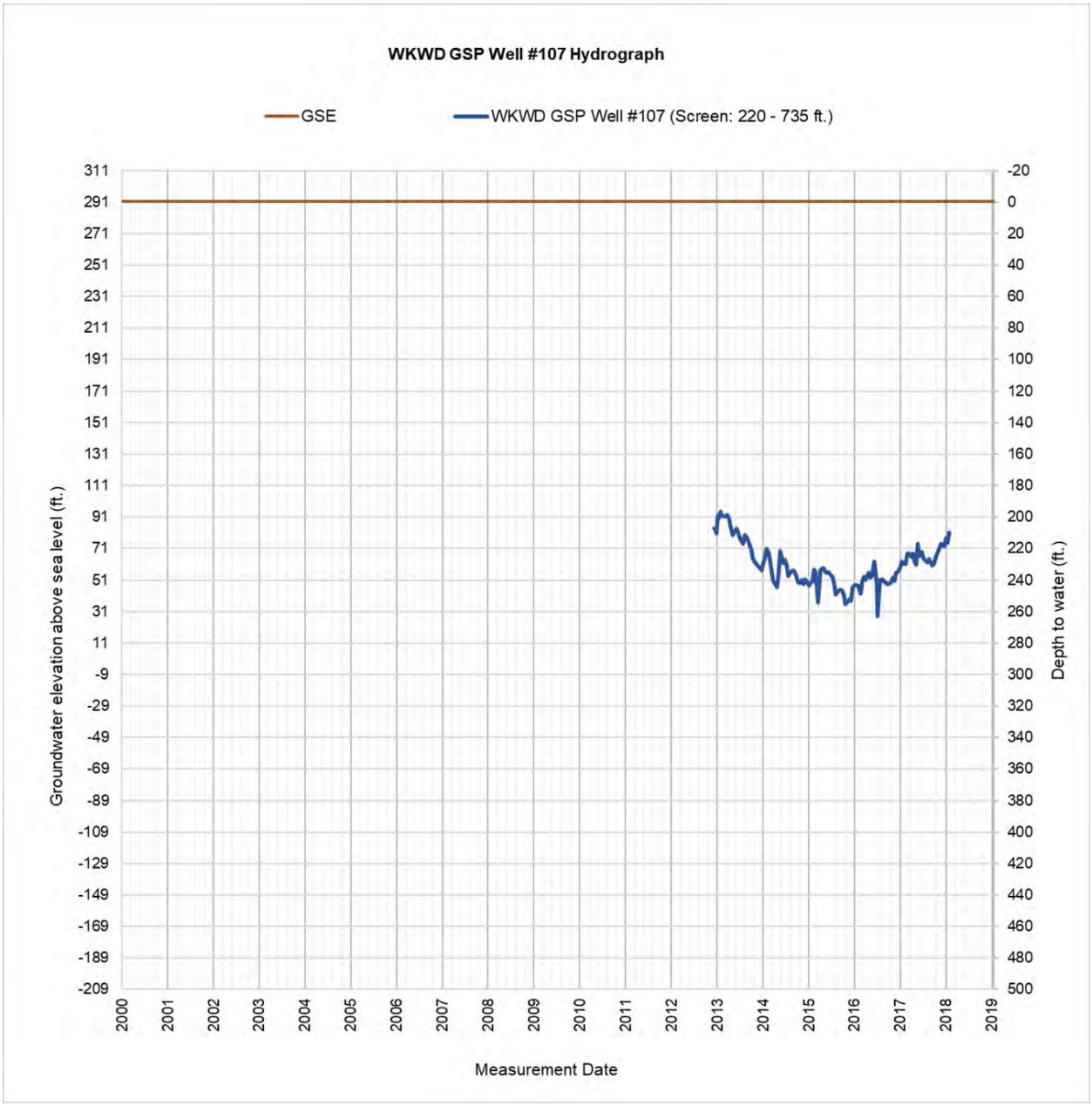
DETAIL 2

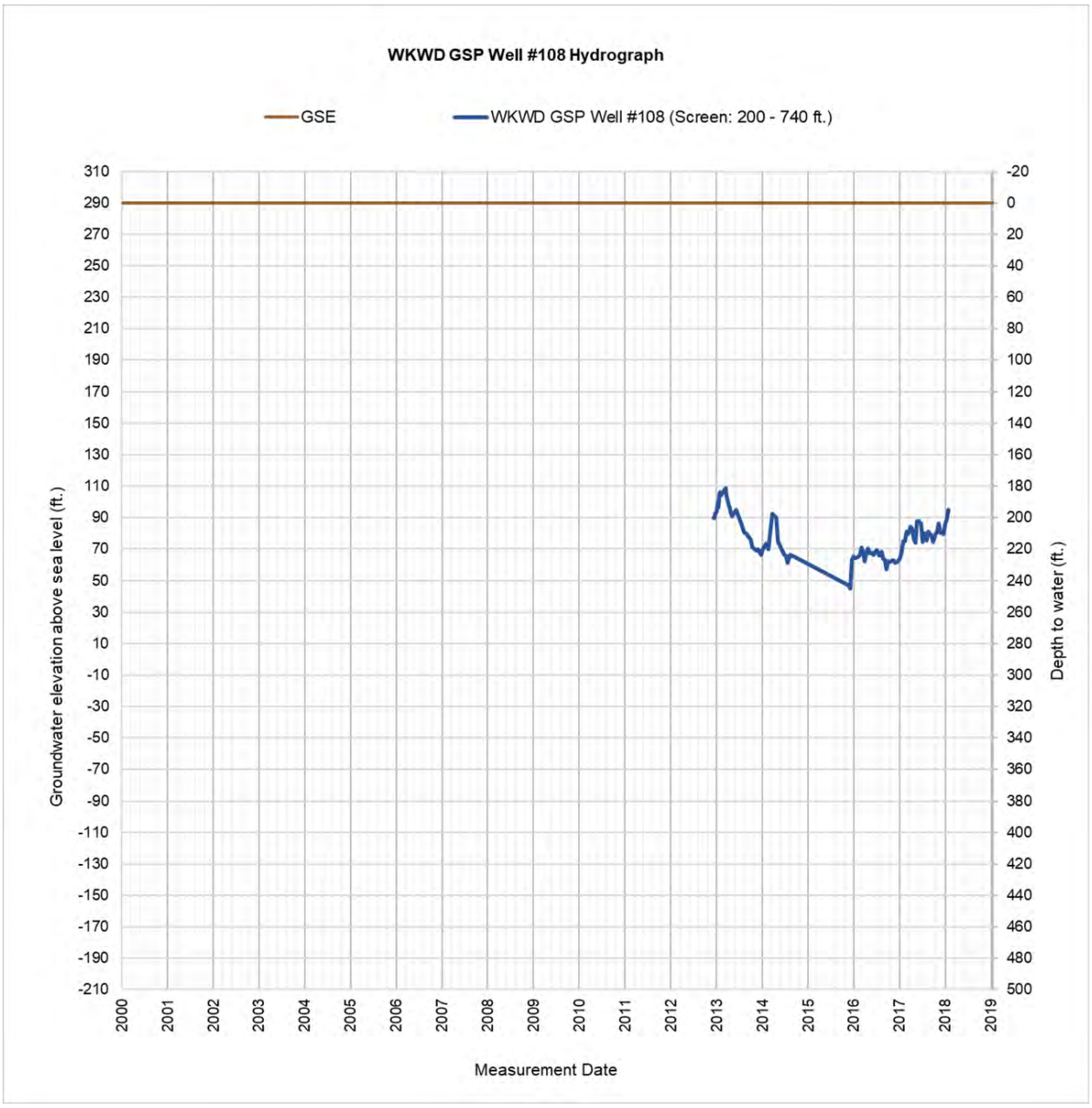
Appendix C

North Project Management Area Hydrographs

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3


WKWD GSP Well #107 Hydrograph
GSE
WKWD GSP Well #107 (Screen: 220 - 735 ft.)
Groundwater elevation above sea level (ft.)
Depth to water (ft.)
311
291
271
251
231
211
191
171
151
131
111
91
71
51
31
11
-9
-29
-49
-69
-89
-109
-129
-149
-169
-189
-209
-20
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Measurement Date

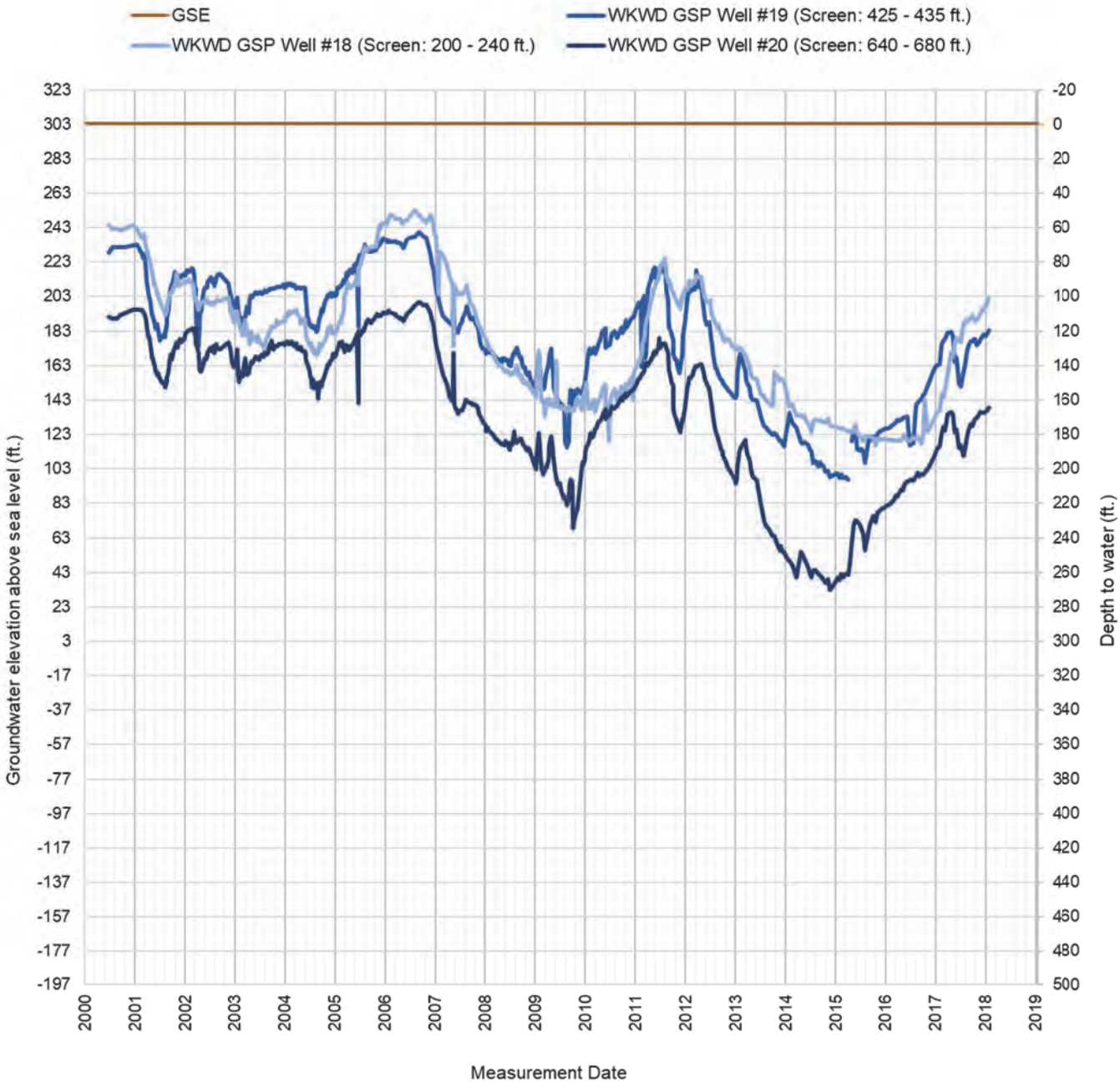

WKWD GSP Well #108 Hydrograph
GSE
WKWD GSP Well #108 (Screen: 200 - 740 ft.)
Groundwater elevation above sea level (ft.)
Depth to water (ft.)
Measurement Date
310
290
270
250
230
210
190
170
150
130
110
90
70
50
30
10
-10
-30
-50
-70
-90
-110
-130
-150
-170
-190
-210
-20
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20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
2000
2001
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Appendix D

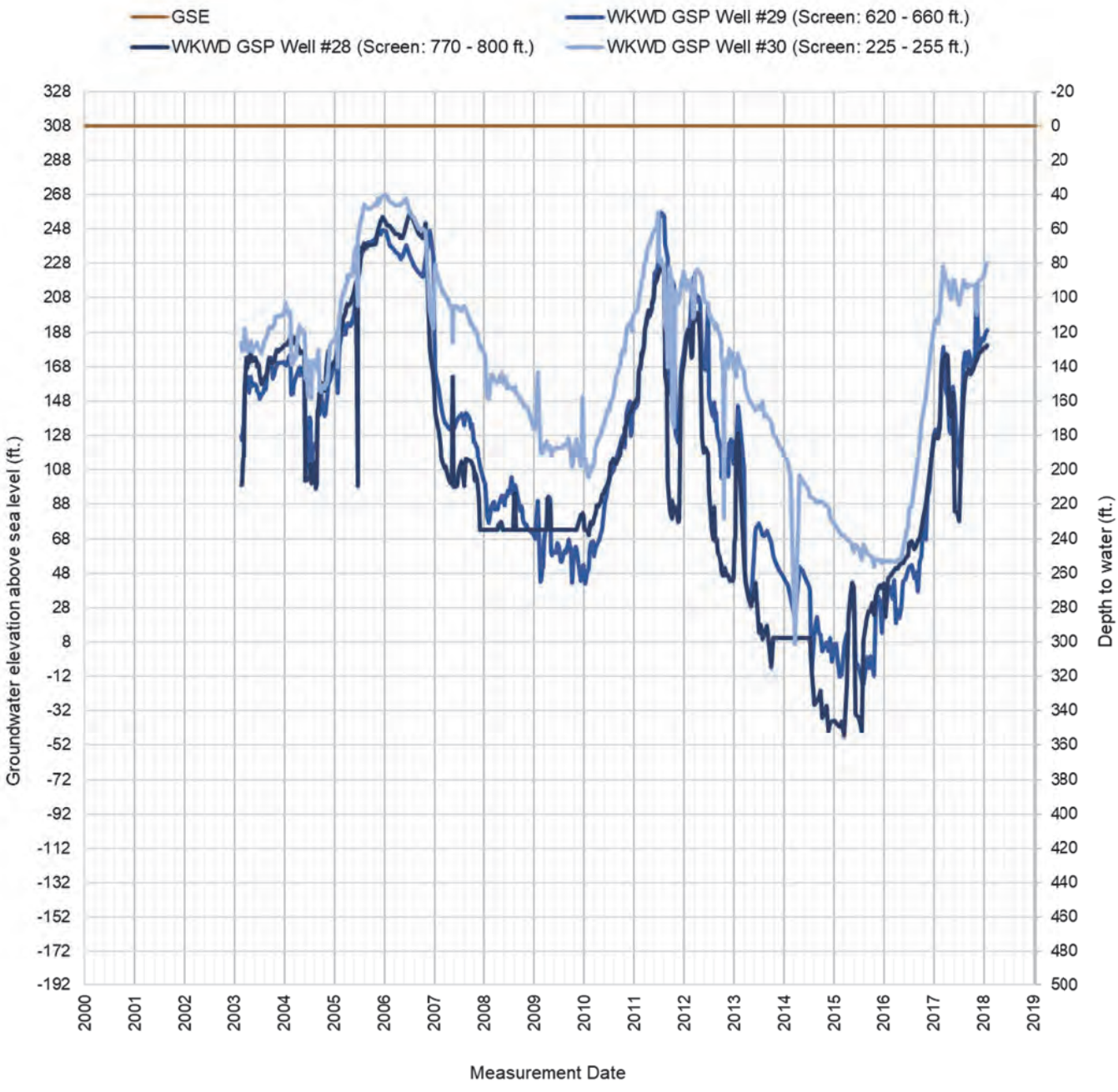
South Project Management Area Hydrographs

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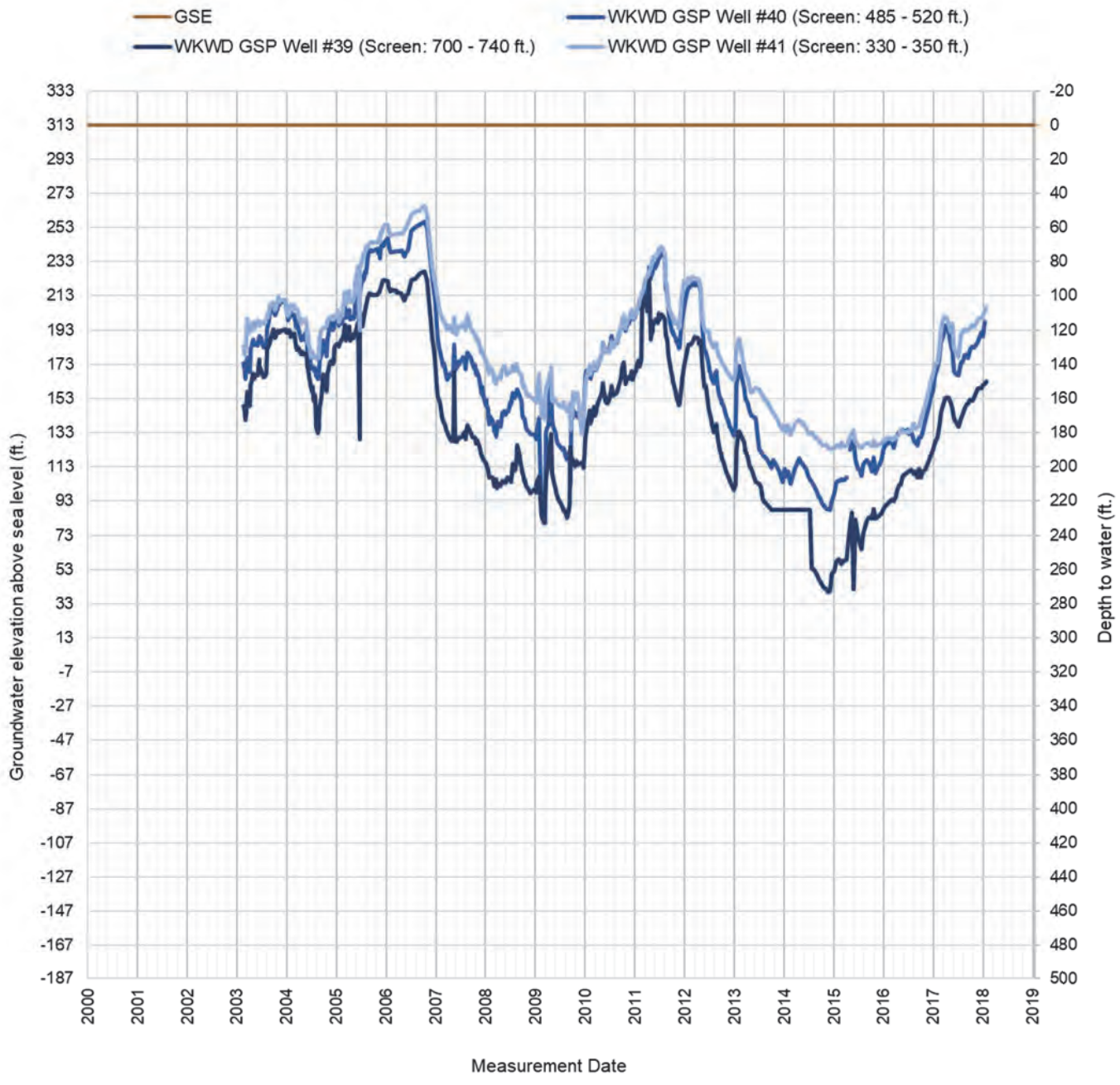
Appendix C-1: WKWD GSP Well #18, 19, 20



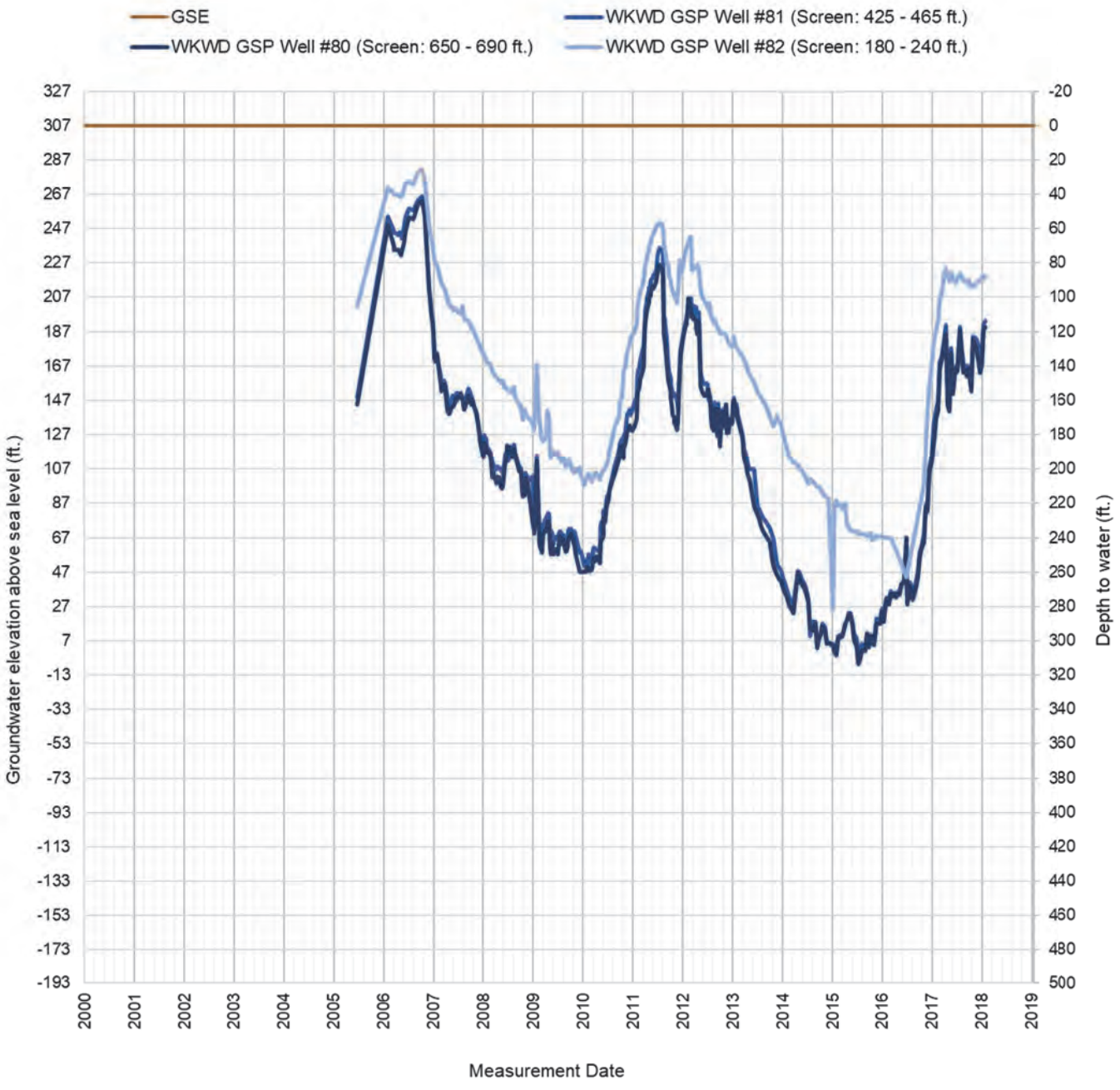
Appendix C-2: WKWD GSP Well #28, 29, 30



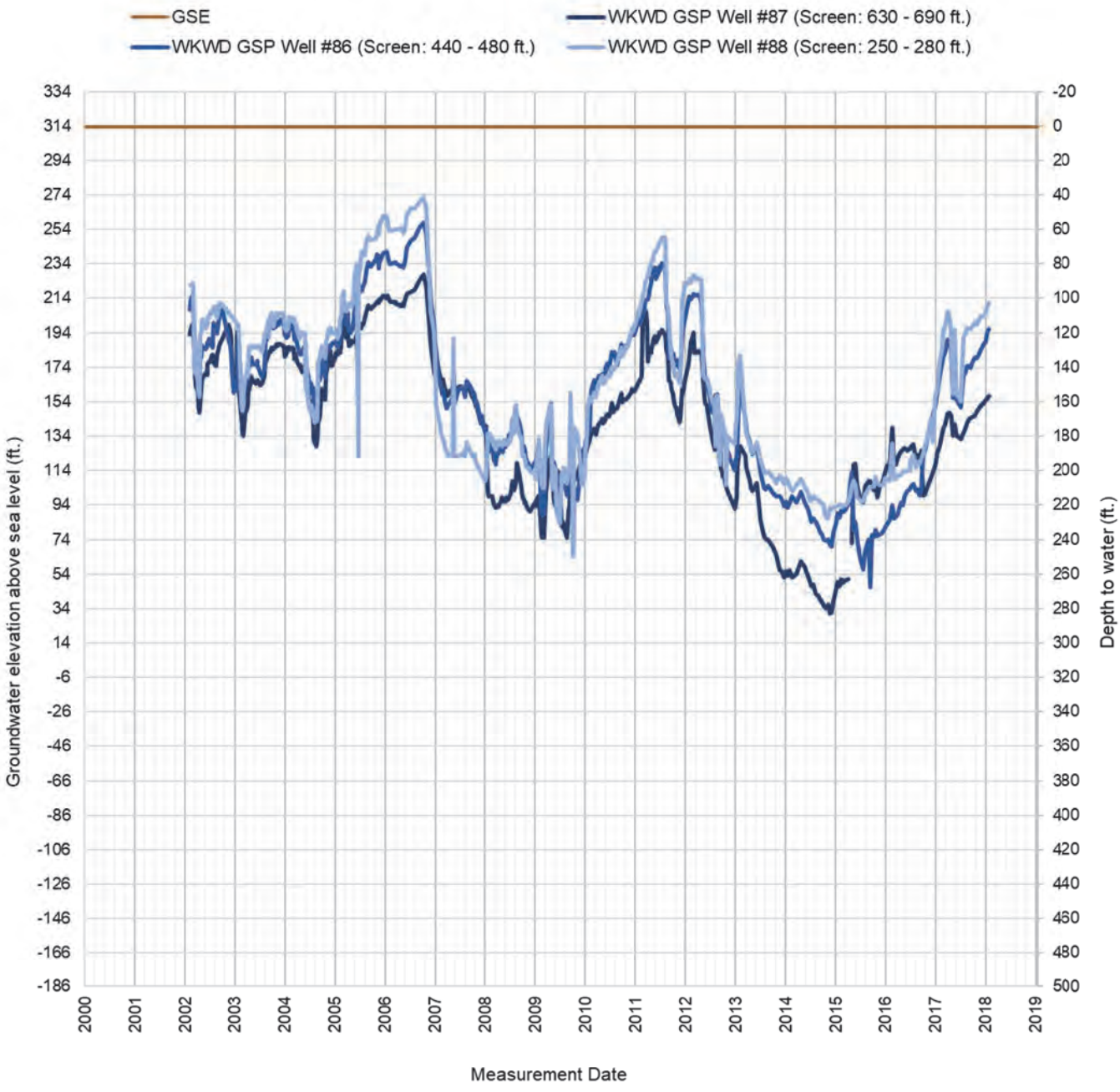
Appendix C-3: WKWD GSP Well #39, 40, 41



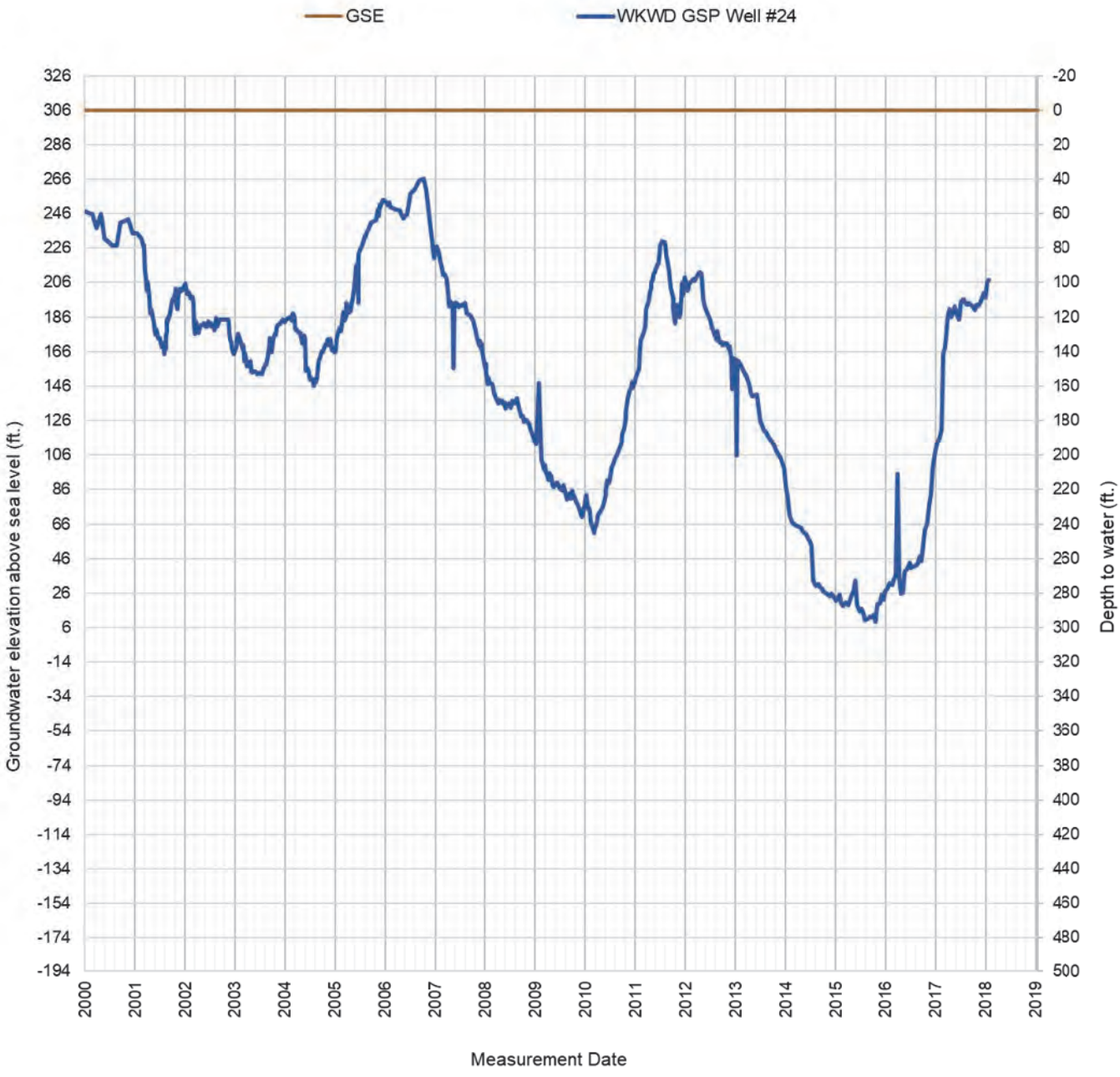
Appendix C-4: WKWD GSP Well #80, 81, 82



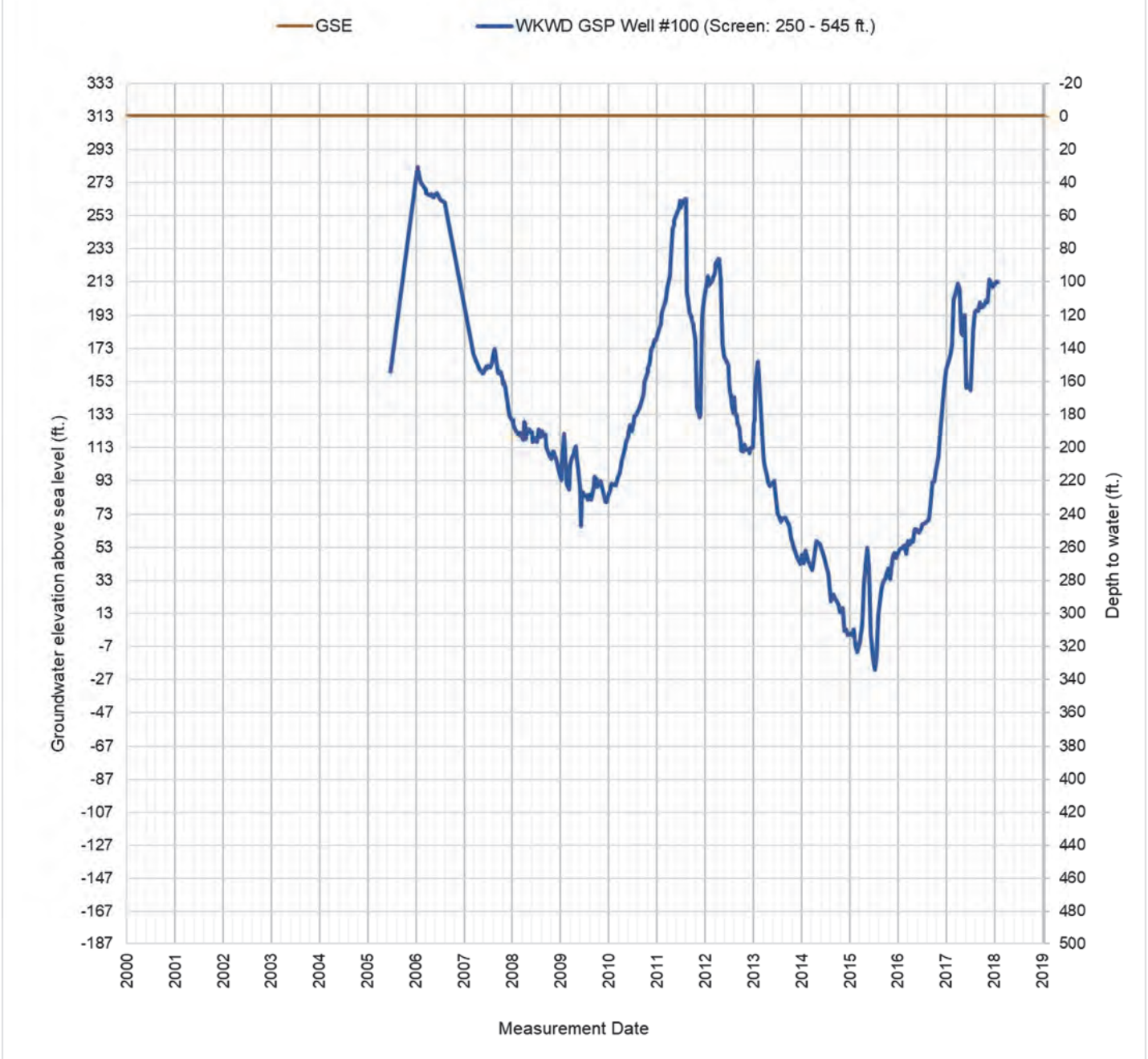
Appendix C-5: WKWD GSP Well #86, 87, 88



Appendix C-6: WKWD GSP Well #24



Appendix C-7: WKWD GSP Well #100

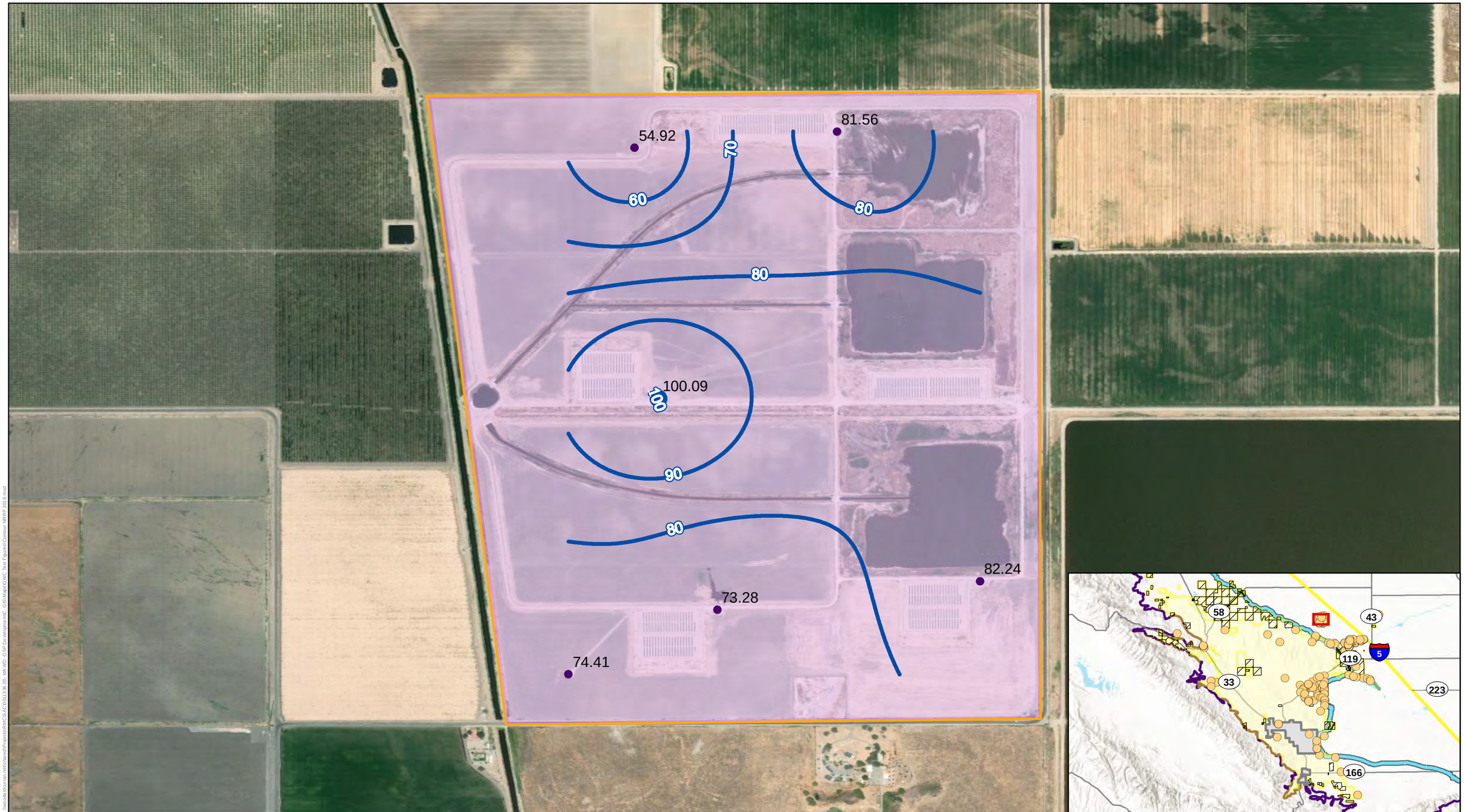


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Appendix E

South Project Management Area Contour Maps

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Appendix D-1: WKWD GSP
North Project Management Area Contours (2015)

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

February 2019

WOODARD &CURRAN

Legend

- Well with January 2015 water surface elevation (WSE) data
- WKWD GSA
- AERA, EBNR, Chevron or Holmes properties
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- WSE contour (10 ft.)
- Lake Management Area
- North Project Management Area
- South Project Management Area
- Western Management Area

N

0 0.1 0.2 0.4 Miles

Figure Exported: 3/11/2019 By: dvalle.rcruela Using: \\woodardcurran.net\shared\Projects\RMC\SAC\00113636.00- WKWD -GSP Development\C- GIS\Maps\GWC Text Figures\Contour NRPP 2018.mxd

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Appendix D-2: WKWD GSP
North Project Management Area Contours (2018)

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

February 2019

WOODARD &CURRAN

Legend

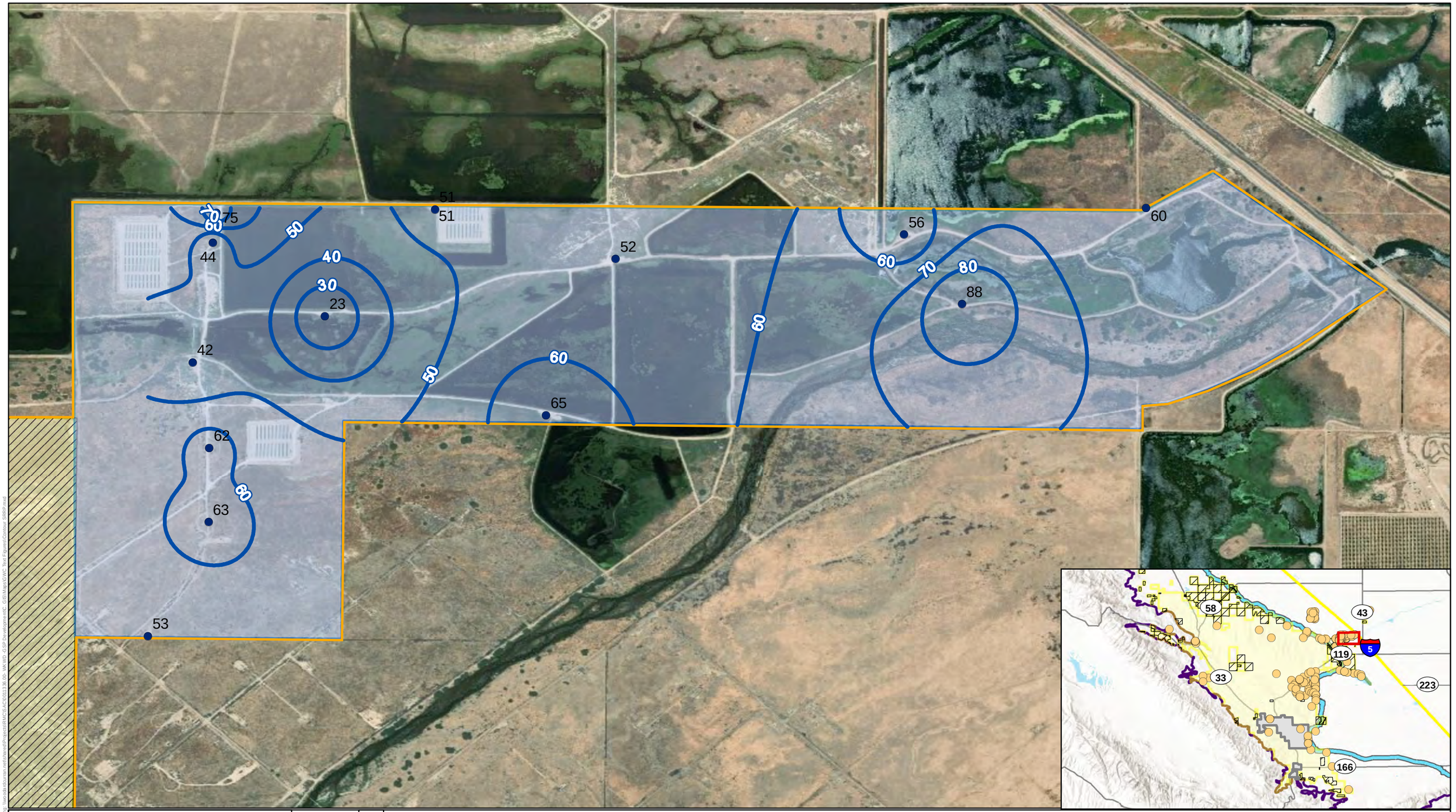
- Well with January 2018 water surface elevation (WSE) data
- WKWD GSA
- AERA, EBNR, Chevron or Holmes properties
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- WSE contour (10 ft.)
- Lake Management Area
- North Project Management Area
- South Project Management Area
- Western Management Area

N

0 0.1 0.2 0.4 Miles

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Appendix D-3: WKWD GSP
South Project Management Area Contours (2015)

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

February 2019

WOODARD &CURRAN

Legend

- Well with January 2015 water surface elevation (WSE) data
- WKWD GSA
- AERA, EBNR, Chevron or Holmes properties
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- WSE contour (10 ft.)
- Lake Management Area
- North Project Management Area
- South Project Management Area
- Western Management Area

N

0 0.15 0.3 0.6 Miles

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Appendix D-4: WKWD GSP
South Project Management Area Contours (2018)

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

February 2019

WOODARD &CURRAN

Legend

- Well with January 2018 water surface elevation (WSE) data
- WKWD GSA
- AERA, EBNR, Chevron or Holmes properties
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- WSE contour (10 ft.)
- Lake Management Area
- North Project Management Area
- South Project Management Area
- Western Management Area

N

0 0.15 0.3 0.6 Miles

Figure Exported: 3/11/2019 By: cjwilkerson4a Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001138.00 - WKWD -GSP Development\C- GIS\Maps\GWC Text Figures\Contour SRP.mxd

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Appendix F

Production Well Water Quality Monitoring Information, 2012 to 2019

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WKWD Well 2-01
GSP Well 4

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA								
Yearly AVG of StaticWL	NA								
Alkalinity(as CaCO3) mg/L	None				89.2			121	
Aluminum ug/L	1				0			0	
Antimony ug/L	6								
Arsenic ug/L	10				0.013				
Barium ug/L	1				0.008	0.009	0.045	0.02	0.009
Bicarbonate mg/L	None				107			148	
Boron	None				0.21			0.21	
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5				0			0	
Calcium mg/L	None				16.2			33.4	
Calcium (as CACO3) mg/L	None				48	21.5	115	52	36
Carbonate mg/L	None				0.68			0	
Chloride mg/L	500				30.5			24.6	
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50				1.3			0	
Chromium VI ug/L	None				1.1				
Color Units	15				0			0	
Conductivity umhos/cm	None				354			439	
Copper ug/L	1.3				0			0	
DBCP ug/L	2				0				
Dichlorodifluoromethane	None				0				
EDB ug/L	None				0			0	
Flouride mg/L	None				0.27			0.44	
Gross Alpha (pCi/L)	15		0			0			0
Gross Alpha (counting error)	None		10.7		5.29	12.8			10.6
Gross Beta (millirems/yr)	4								0
Gross Beta (counting error)	None								0
Hardness (as CACO3) mg/L	None				40.8			92	
Hydroxide mg/L	None				0			0	
Iron ug/L	300				0.04			0	
Lead ug/L	15				0				
LSI	None				-0.17				
Manganese ug/L	50				0.31			0	
MBAS ug/L	None				0			0	
Magnesium mg/L	None				0.07	0	0.15	2.07	0.49
Mercury ug/L	2				0.001			0	
MTBE ug/L	None				0			0	
Nitrate mg/L	10							4.19	
Nitrate (as N) mg/L	10		0.852		0.96	0.96	0.78		1.22
Nitrogen (as N)	10				0.96	0.23	1.53	1.12	0.64
ODOR Units	3				0			0	
Percholrate	None		0		0	0	0	0	0
PH units	6.5-8.5				8.37			7.85	
Potassium mg/L	None				0.4			0.646	
Radium 228	None				0	0			
Radium 226	None		0.558		0	0.69			
Radium 226	None		0		0	0			
Radium 228	None				0.932	0.315			
Selenium ug/L	50				0				
Silver ug/L	100				0			0	
Sodium mg/L	None				60.7			58.1	
Sulfate mg/L	250				34.5			27.6	
TDS mg/L	1000		260		253			299	

Groundwater Quality Monitoirng

WKWD Well 2-01

GSP Well 4

Temp	None				20				
Tert-ButylEthyl Ether	None				0				
Thallium ug/L	2								
Turbity NT Units	None				0.5			0.09	
Uranium pCi/L	None		5.2		6.5	8.7			17.4
Uranium	None								0
1,2,3 Trochloropropane	None				0				
Tert - Butyl Alcohol	None				0				
Tert - Amyl Methyl Ether	None				0				
Vanadium	None								
Zinc ug/L	5				0.005			0	

WKWD Well 2-02
GSP Well 36

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	144.3	168.0						
Yearly AVG of StaticWL	NA	105.9	130.8						
Alkalinity(as CaCO3) mg/L	None				58.5			121	
Aluminum ug/L	1				0			0	
Antimony ug/L	6				0.007				
Arsenic ug/L	10				0.012			3.7	
Barium ug/L	1				0.009			28.1	
Bicarbonate mg/L	None				70.6			147	
Boron	None				0.249			0.238	
Bromide (as Ethylene dibromide) (ug/L)	0.005				0.47				
Cadmium ug/L	5				0			0	
Calcium mg/L	None				21.5			35.2	
Calcium (as CACO3) mg/L	None				21.5	115	52	36	
Carbonate mg/L	None				0.25			0	
Chloride mg/L	500				99.3			46.7	
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50				1.3			2.2	
Chromium VI ug/L	None				0.25				
Color Units	15				0			0	
Conductivity umhos/cm	None				560			555	
Copper ug/L	1.3				0			39	
DBCP ug/L	2				0				
Dichlorodifluoromethane	None				0			0	
EDB ug/L	None				0				
Flouride mg/L	None				0.2			0.382	
Gross Alpha (pCi/L)	15		0		0				
Gross Alpha (counting error)	None		2.01		0				
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None				53.8			96.1	
Hydroxide mg/L	None				0			0	
Iron ug/L	300				0.043			0	
Lead ug/L	15				0			0	
LSI	None				-0.2				
Manganese ug/L	50				0.88			0	
MBAS ug/L	None				0			0	
Magnesium mg/L	None				0			1.96	
Mercury ug/L	2				0.001				
MTBE ug/L	None				0			0	
Nitrate mg/L	10				0		4.55	5.94	
Nitrate (as N) mg/L	10		0.971		0.23	1.03	1.03		
Nitrogen (as N)	10				0.23	1.53	1.12	0.64	
ODOR Units	3				0			0	
Percholrate	None		0		0	0	0		
PH units	6.5-8.5				8.4			7.83	
Potassium mg/L	None				0.463			0.887	
Radium 228	None						0		
Radium 226	None				0		0.124		
Radium 226	None				0		0		
Radium 228	None						0.0893		
Selenium ug/L	50				0.006			0	
Silver ug/L	100				0				
Sodium mg/L	None				86.6			71.7	
Sulfate mg/L	250				64.1			42	
TDS mg/L	1000		290		345			352	

Temp	None				20				
Tert-ButylEthyl Ether	None				0			0	
Thallium ug/L	2				0.001				
Turbity NT Units	None				0.23			0.09	
Uranium pCi/L	None				3.7				
Uranium	None								
1,2,3 Trochloropropane	None				0				
Tert - Butyl Alcohol	None				0			0	
Tert - Amyl Methyl Ether	None				0			0	
Vanadium	None								
Zinc ug/L	5				0				

WKWD Well 6-01

GSP Well 42

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	144.49	164.48						
Yearly AVG of StaticWL	NA	97.03	123.14						
Alkalinity(as CaCO3) mg/L	None				107			110	
Aluminum ug/L	1				0			0	
Antimony ug/L	6								
Arsenic ug/L	10				0			0	
Barium ug/L	1				0.045			34.8	
Bicarbonate mg/L	None				130			134	
Boron	None				0.21			0.169	
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5				0			0	
Calcium mg/L	None				46.1			40.3	
Calcium (as CACO3) mg/L	None				115				
Carbonate mg/L	None				0			0	
Chloride mg/L	500				47.1			41.1	
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50				0			0	
Chromium VI ug/L	None				1.2				
Color Units	15				0			0	
Conductivity umhos/cm	None				486			500	
Copper ug/L	1.3				0			0	
DBCP ug/L	2				0				
Dichlorodifluoromethane	None				0			0	
EDB ug/L	None				0				
Flouride mg/L	None				0			0.177	
Gross Alpha (pCi/L)	15				0			0	
Gross Alpha (counting error)	None				14.3			28.4	
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None				116			108	

Groundwater Quality Monitoirng

WKWD Well 6-01
GSP Well 42

Hydroxide mg/L	None				0			0	
Iron ug/L	300				0.13			0	
Lead ug/L	15				0			0	
LSI	None				-0.12				
Manganese ug/L	50				1.25			0	
MBAS ug/L	None				0			0	
Magnesium mg/L	None				0.15			1.8	
Mercury ug/L	2				0			0	
MTBE ug/L	None							0	
Nitrate mg/L	10						1.3	6.2	
Nitrate (as N) mg/L	10		0.94		1.53	1.06	5.76		
Nitrogen (as N)	10				1.53				
ODOR Units	3				0			0	
Percholrate	None				0		0		
PH units	6.5-8.5				7.89			7.79	
Potassium mg/L	None				0.68			0.832	
Radium 228	None				0				
Radium 226	None				0.0621				
Radium 226	None				0				
Radium 228	None				0.357				
Selenium ug/L	50				0			0	
Silver ug/L	100				0			0	
Sodium mg/L	None				61.2			63.4	
Sulfate mg/L	250				58.5			38.9	
TDS mg/L	1000		292		349			327	
Temp	None				20				
Tert-ButylEthyl Ether	None				0			0	
Thallium ug/L	2								
Turbity NT Units	None				0.21			0.08	
Uranium pCi/L	None				13			21.4	
Uranium	None							0	
1,2,3 Trochloropropane	None				0				
Tert - Butyl Alcohol	None				0			0	
Tert - Amyl Methyl Ether	None				0			0	

Vanadium	None								
Zinc ug/L	5				0.007			0	

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WKWD Well 6-02
GSP Well 37

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	152.32	173.67						
Yearly AVG of StaticWL	NA	107.43	131.05						
Alkalinity(as CaCO3) mg/L	None				93.5			112	
Aluminum ug/L	1				0			0	
Antimony ug/L	6								
Arsenic ug/L	10				0.003			2.7	
Barium ug/L	1				0.02			30.9	
Bicarbonate mg/L	None				114			272	
Boron	None				0.16				
Bromide (as Ethylene dibromide) (ug/L)	0.005							0	
Cadmium ug/L	5				0			0	
Calcium mg/L	None				21			33.3	
Calcium (as CACO3) mg/L	None				52				
Carbonate mg/L	None				0			0	
Chloride mg/L	500				30.8			32.9	
Chlorobenzene (mg/L)	0.1							0	
Chromium (Chrome Cr) mg/L	50				0			0	
Chromium VI ug/L	None				1.2				
Color Units	15				0			0	
Conductivity umhos/cm	None				340			436	
Copper ug/L	1.3				0			0	
DBCP ug/L	2				0				
Dichlorodifluoromethane	None				0			0	
EDB ug/L	None				0				
Flouride mg/L	None				0.15			0.18	
Gross Alpha (pCi/L)	15			0	0		0		
Gross Alpha (counting error)	None			9.06	5.79		11.6		
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None				52.8			92.3	
Hydroxide mg/L	None				0			0	
Iron ug/L	300				0.05			0	
Lead ug/L	15				0			0	
LSI	None				-0.26				
Manganese ug/L	50				1.14			0	
MBAS ug/L	None				0			0	
Magnesium mg/L	None				0.08			2.2	
Mercury ug/L	2				0			0	
MTBE ug/L	None				0			0	
Nitrate mg/L	10						0.66	3.85	
Nitrate (as N) mg/L	10		0.931		1.12	1.06	2.91	3.48	
Nitrogen (as N)	10				1.12				
ODOR Units	3				0			0	
Percholrate	None		0		0	0	0	0	
PH units	6.5-8.5				8.15			7.81	
Potassium mg/L	None				0.48			0.752	
Radium 228	None				0		0		
Radium 226	None				0.186		0.232		
Radium 226	None				0		0		
Radium 228	None				0.659		0.133		
Selenium ug/L	50				0			0	
Silver ug/L	100				0			0	
Sodium mg/L	None				54.5			53.1	
Sulfate mg/L	250				26.3			27.8	
TDS mg/L	1000		236		251			290	

Groundwater Quality Monitoirng

WKWD Well 6-02
GSP Well 37

Temp	None				20			20	
Tert-ButylEthyl Ether	None				0			0	
Thallium ug/L	2								
Turbity NT Units	None				0.1			0.18	
Uranium pCi/L	None			8.4	7.8		17		
Uranium	None								
1,2,3 Trochloropropane	None				0				
Tert - Butyl Alcohol	None				0			0	
Tert - Amyl Methyl Ether	None				0			0	
Vanadium	None								
Zinc ug/L	5				0.005			0.016	

WKWD Well 6-03
GSP Well 46

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	186.20	208.54						
Yearly AVG of StaticWL	NA	107.78	126.08						
Alkalinity(as CaCO3) mg/L	None				62.9			80	
Aluminum ug/L	1				0				
Antimony ug/L	6								
Arsenic ug/L	10				0.003				
Barium ug/L	1				0.009				
Bicarbonate mg/L	None				73.4			97.6	
Boron	None				0.11				
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5				0				
Calcium mg/L	None				14.6			25.7	
Calcium (as CACO3) mg/L	None				36				
Carbonate mg/L	None				1.12				
Chloride mg/L	500				46.4			43	
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50				0				
Chromium VI ug/L	None				0.82				
Color Units	15				0				
Conductivity umhos/cm	None				350			378	
Copper ug/L	1.3				0				
DBCP ug/L	2								
Dichlorodifluoromethane	None								
EDB ug/L	None								
Flouride mg/L	None				0.07			0.1	
Gross Alpha (pCi/L)	15								
Gross Alpha (counting error)	None				3.78				
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None				38.5			66.6	
Hydroxide mg/L	None				0				
Iron ug/L	300				0.05				
Lead ug/L	15				0				
LSI	None				-0.3				
Manganese ug/L	50				0.19				
MBAS ug/L	None								
Magnesium mg/L	None				0.49			0.562	
Mercury ug/L	2				0				
MTBE ug/L	None								
Nitrate mg/L	10						0.66	3.35	
Nitrate (as N) mg/L	10				0.64		2.93		
Nitrogen (as N)	10				0.64				
ODOR Units	3				0				
Percholrate	None				0				
PH units	6.5-8.5				8.44			7.73	
Potassium mg/L	None				0.44			0.847	
Radium 228	None								
Radium 226	None								
Radium 226	None								
Radium 228	None								
Selenium ug/L	50				0				
Silver ug/L	100				0				
Sodium mg/L	None				62.2			54.6	
Sulfate mg/L	250				39.8			31.9	
TDS mg/L	1000		232		240			258	

Temp	None				20			68	
Tert-ButylEthyl Ether	None								
Thallium ug/L	2								
Turbity NT Units	None				0.24			0.11	
Uranium pCi/L	None				2.7				
Uranium	None								
1,2,3 Trochloropropane	None								
Tert - Butyl Alcohol	None								
Tert - Amyl Methyl Ether	None								
Vanadium	None								
Zinc ug/L	5				0.008				

WKWD Well 6-06

GSP Well 47-49

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	141.87	149.67						
Yearly AVG of StaticWL	NA	103.96	125.51						
Alkalinity(as CaCO3) mg/L	None				85.1			79.4	
Aluminum ug/L	1				0				
Antimony ug/L	6								
Arsenic ug/L	10				0.002				
Barium ug/L	1				0.026			30.8	
Bicarbonate mg/L	None				104			96.9	
Boron	None				0.14			0.141	
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5				0				
Calcium mg/L	None				24.2				
Calcium (as CACO3) mg/L	None				60			27.4	
Carbonate mg/L	None				0				
Chloride mg/L	500				37.8			40.7	
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50				0				
Chromium VI ug/L	None				1.2				
Color Units	15				0				
Conductivity umhos/cm	None				362			400	
Copper ug/L	1.3				0.003				
DBCP ug/L	2								
Dichlorodifluoromethane	None								
EDB ug/L	None								
Flouride mg/L	None				0.06			0.065	
Gross Alpha (pCi/L)	15								
Gross Alpha (counting error)	None				8.31				
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None				61			70.4	
Hydroxide mg/L	None				0				
Iron ug/L	300				0.07				
Lead ug/L	15				0				
LSI	None				-0.26				
Manganese ug/L	50				0.36				
MBAS ug/L	None								
Magnesium mg/L	None				0.13			0.452	
Mercury ug/L	2				0				
MTBE ug/L	None								
Nitrate mg/L	10						0.91	1.1	
Nitrate (as N) mg/L	10				0.93		4.04		
Nitrogen (as N)	10				0.93				
ODOR Units	3				0				

Groundwater Quality Monitoirng

WKWD Well 6-06
GSP Well 47-49

Percholrate	None				0				
PH units	6.5-8.5				8.13			7.75	
Potassium mg/L	None				0.49			0.597	
Radium 228	None								
Radium 226	None								
Radium 226	None								
Radium 228	None								
Selenium ug/L	50				0				
Silver ug/L	100				0				
Sodium mg/L	None				54.1			57.4	
Sulfate mg/L	250				31.7			32.1	
TDS mg/L	1000		220		255			257	
Temp	None				20			68	
Tert-ButylEthyl Ether	None								
Thallium ug/L	2								
Turbity NT Units	None				0.13			0.08	
Uranium pCi/L	None				7.4				
Uranium	None								
1,2,3 Trochloropropane	None								
Tert - Butyl Alcohol	None								
Tert - Amyl Methyl Ether	None								
Vanadium	None								
Zinc ug/L	5				0.008				

WKWD Well 7-01R

GSP Well 101

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	154.09	181.73						
Yearly AVG of StaticWL	NA	102.95	126.76						
Alkalinity(as CaCO3) mg/L	None		76.6		75.3	75.3		88	
Aluminum ug/L	1		0		0				
Antimony ug/L	6		0.005					0.32	
Arsenic ug/L	10		0.002		0.01	0.01		1.9	
Barium ug/L	1		0.019		0.023	0.023		33	
Bicarbonate mg/L	None		93.5		91.9	92		110	
Boron	None		0		0.129	0.13			
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5				0				
Calcium mg/L	None				28.9			39	
Calcium (as CACO3) mg/L	None		25.8			72			
Carbonate mg/L	None				0				
Chloride mg/L	500		36.1		51.6	51.6		47	
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50				0			1.7	
Chromium VI ug/L	None				1.1				
Color Units	15		0		1	0		1	
Conductivity umhos/cm	None		356		394	394		384	
Copper ug/L	1.3				0				
DBCP ug/L	2								
Dichlorodifluoromethane	None								
EDB ug/L	None								
Flouride mg/L	None		0.09		0.013	0.013		0.13	
Gross Alpha (pCi/L)	15								
Gross Alpha (counting error)	None				6.55				
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None		66		74.1	74.1		100	
Hydroxide mg/L	None				0				
Iron ug/L	300		0		0			57	
Lead ug/L	15				0				
LSI	None		-0.2			-0.21			
Manganese ug/L	50		0		0				
MBAS ug/L	None								
Magnesium mg/L	None		0.37		0.46	0.46		0.95	
Mercury ug/L	2				0			0.074	
MTBE ug/L	None								
Nitrate mg/L	10						1.06	4.6	
Nitrate (as N) mg/L	10		1.22		1.3	1.3	4.7		
Nitrogen (as N)	10		1.22			1.3			
ODOR Units	3				0				

Groundwater Quality Monitoirng

WKWD Well 7-01R
GSP Well 101

Percholrate	None				0				
PH units	6.5-8.5		8.21		8.08	8.08		7.98	
Potassium mg/L	None		0.514		0.56	0.56		0.64	
Radium 228	None								
Radium 226	None								
Radium 226	None								
Radium 228	None								
Selenium ug/L	50		0		0			1.6	
Silver ug/L	100		0		0				
Sodium mg/L	None		46		49.6	49.6		46	
Sulfate mg/L	250		42.2		45.6	45.6		30	
TDS mg/L	1000		247		271	271		260	
Temp	None		68			20			
Tert-ButylEthyl Ether	None								
Thallium ug/L	2		0						
Turbity NT Units	None		0.57		0.39	0.39		0.76	
Uranium pCi/L	None				7.9			9.5	
Uranium	None								
1,2,3 Trochloropropane	None				0				
Tert - Butyl Alcohol	None								
Tert - Amyl Methyl Ether	None								
Vanadium	None								
Zinc ug/L	5		0		0				

WKWD Well 7-02
GSP Well 31

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	206.07	206.81						
Yearly AVG of StaticWL	NA	102.03	117.77						
Alkalinity(as CaCO3) mg/L	None				83.5			115	
Aluminum ug/L	1				0				
Antimony ug/L	6								
Arsenic ug/L	10				0.003				
Barium ug/L	1				0.023			31.1	
Bicarbonate mg/L	None				102			140	
Boron	None				0.16				
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5				0				
Calcium mg/L	None				26.5			33.4	
Calcium (as CACO3) mg/L	None				66				
Carbonate mg/L	None				0				
Chloride mg/L	500				29.6			29.4	
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50				0				
Chromium VI ug/L	None				1.1				
Color Units	15				0				
Conductivity umhos/cm	None				326			389	
Copper ug/L	1.3				0.001				
DBCP ug/L	2								
Dichlorodifluoromethane	None								
EDB ug/L	None								
Flouride mg/L	None				0.1			0.1	
Gross Alpha (pCi/L)	15								
Gross Alpha (counting error)	None				6.8				
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None				67.7			93.6	
Hydroxide mg/L	None				0				
Iron ug/L	300				0.08				
Lead ug/L	15				0				
LSI	None				-0.32				
Manganese ug/L	50				1.35				
MBAS ug/L	None								
Magnesium mg/L	None				0.35			2.46	
Mercury ug/L	2				0				
MTBE ug/L	None								
Nitrate mg/L	10				1.09		0.4	2.1	
Nitrate (as N) mg/L	10				1.09		1.77		
Nitrogen (as N)	10				1.09				
ODOR Units	3				0				
Percholrate	None				0				
PH units	6.5-8.5				8.04			7.76	
Potassium mg/L	None				0.4			0.505	
Radium 228	None								
Radium 226	None								
Radium 226	None								
Radium 228	None								
Selenium ug/L	50				0				
Silver ug/L	100				0			2	
Sodium mg/L	None				44.7			38.4	
Sulfate mg/L	250				30.5			19.7	
TDS mg/L	1000		240		238			266	

Groundwater Quality Monitoirng

WKWD Well 7-02
GSP Well 31

Temp	None				20			68	
Tert-ButylEthyl Ether	None								
Thallium ug/L	2								
Turbity NT Units	None				0.35			0.06	
Uranium pCi/L	None				7.2				
Uranium	None								
1,2,3 Trochloropropane	None								
Tert - Butyl Alcohol	None								
Tert - Amyl Methyl Ether	None								
Vanadium	None								
Zinc ug/L	5				0.006				

WKWD Well NW-1

GSP Well 102

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	306.47	376.01						
Yearly AVG of StaticWL	NA	195.48	215.12						
Alkalinity(as CaCO3) mg/L	None		31.9			27			30
Aluminum ug/L	1		0						0
Antimony ug/L	6		0.004						0
Arsenic ug/L	10		0						2.1
Barium ug/L	1		0.045						44
Bicarbonate mg/L	None		38.9			27			33
Boron	None		0						
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5								0
Calcium mg/L	None					48			56
Calcium (as CACO3) mg/L	None		64			120			
Carbonate mg/L	None								0
Chloride mg/L	500		56.9			48			69
Chlorobenzene (mg/L)	0.1								2.6
Chromium (Chrome Cr) mg/L	50								0
Chromium VI ug/L	None							0.68	
Color Units	15		0			0			1
Conductivity umhos/cm	None		785			610			714
Copper ug/L	1.3								0
DBCP ug/L	2								0
Dichlorodifluoromethane	None								
EDB ug/L	None								0
Flouride mg/L	None		0.053			0			0.072
Gross Alpha (pCi/L)	15								
Gross Alpha (counting error)	None							1.52	
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None		161			120			140
Hydroxide mg/L	None								0
Iron ug/L	300		0						180
Lead ug/L	15								0
LSI	None		-0.11			-0.34			
Manganese ug/L	50		0						0
MBAS ug/L	None								0
Magnesium mg/L	None		0.209			0.17			0.24
Mercury ug/L	2								0
MTBE ug/L	None								
Nitrate mg/L	10						2.15		47
Nitrate (as N) mg/L	10		4.37			6.45	9.52	4.87	4.53
Nitrogen (as N)	10		4.37						
ODOR Units	3								

Groundwater Quality Monitoirng

WKWD Well NW-1
GSP Well 102

Percholrate	None								
PH units	6.5-8.5		8.28			8.1			8.43
Potassium mg/L	None		0.816						0
Radium 228	None								
Radium 226	None								
Radium 226	None								
Radium 228	None								
Selenium ug/L	50		0.002						2.9
Silver ug/L	100		0						0
Sodium mg/L	None		96.1			88			90
Sulfate mg/L	250		245			200			180
TDS mg/L	1000		511			390			470
Temp	None		68			23.6			
Tert-ButylEthyl Ether	None								
Thallium ug/L	2		0.001						0
Turbity NT Units	None		0.31			0.21			1.1
Uranium pCi/L	None							0.439	0.76
Uranium	None								
1,2,3 Trochloropropane	None								
Tert - Butyl Alcohol	None								
Tert - Amyl Methyl Ether	None								
Vanadium	None								
Zinc ug/L	5		0						0

WKWD Well NW-2

GSP Well 103

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	270.68	280.95						
Yearly AVG of StaticWL	NA	194.43	206.29						
Alkalinity(as CaCO3) mg/L	None		79.7			17			26
Aluminum ug/L	1		0.01						
Antimony ug/L	6		0.022						0.15
Arsenic ug/L	10		0.002						3.7
Barium ug/L	1		0.103						8.1
Bicarbonate mg/L	None		97.2			0			21
Boron	None		0						
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5								
Calcium mg/L	None					34			33
Calcium (as CACO3) mg/L	None		55.7			85			
Carbonate mg/L	None					16			5.5
Chloride mg/L	500		53.1			78			95
Chlorobenzene (mg/L)	0.1								1.1
Chromium (Chrome Cr) mg/L	50								
Chromium VI ug/L	None							0	
Color Units	15		0			0			1
Conductivity umhos/cm	None		782			590			657
Copper ug/L	1.3		0.005						
DBCP ug/L	2								
Dichlorodifluoromethane	None								
EDB ug/L	None								
Flouride mg/L	None					0.11			0.16
Gross Alpha (pCi/L)	15								
Gross Alpha (counting error)	None					0.767		2.25	
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None		140			85			84
Hydroxide mg/L	None								
Iron ug/L	300		0						30
Lead ug/L	15								0.2
LSI	None		-0.14			0.12			
Manganese ug/L	50		0						2.5
MBAS ug/L	None								
Magnesium mg/L	None		0.19			0.18			0.29
Mercury ug/L	2								
MTBE ug/L	None								
Nitrate mg/L	10						0.06		
Nitrate (as N) mg/L	10		1.61			0	0.24		0
Nitrogen (as N)	10		1.61						
ODOR Units	3								

Groundwater Quality Monitoirng

WKWD Well NW-2
GSP Well 103

Percholrate	None								
PH units	6.5-8.5		7.91			8.9			8.84
Potassium mg/L	None		0.78						0.66
Radium 228	None								
Radium 226	None								
Radium 226	None								
Radium 228	None								
Selenium ug/L	50		0.007						0.75
Silver ug/L	100		0						
Sodium mg/L	None		83.2			90			89
Sulfate mg/L	250		194			160			140
TDS mg/L	1000		487			360			400
Temp	None		68			23.3			
Tert-ButylEthyl Ether	None								
Thallium ug/L	2		0						
Turbity NT Units	None		0.11			0.1			0.42
Uranium pCi/L	None							0.363	
Uranium	None								
1,2,3 Trochloropropane	None								
Tert - Butyl Alcohol	None								
Tert - Amyl Methyl Ether	None								
Vanadium	None								
Zinc ug/L	5		0.035						10

WKWD Well NW-3

GSP Well 104

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	328.76	323.36						
Yearly AVG of StaticWL	NA	184.90	196.73						
Alkalinity(as CaCO3) mg/L	None		48			35		41	
Aluminum ug/L	1		0.081						
Antimony ug/L	6		0						
Arsenic ug/L	10		0					2.5	
Barium ug/L	1		0.046					33	
Bicarbonate mg/L	None		58.6			35		50	
Boron	None		0						
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5								
Calcium mg/L	None					44		47	
Calcium (as CACO3) mg/L	None		54.2			110			
Carbonate mg/L	None							0	
Chloride mg/L	500		51.1			45		50	
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50		0.004						
Chromium VI ug/L	None						0.55		
Color Units	15		0			0		1	
Conductivity umhos/cm	None		635			570		649	
Copper ug/L	1.3		0.013						
DBCP ug/L	2								
Dichlorodifluoromethane	None								
EDB ug/L	None								
Flouride mg/L	None					0		0.054	
Gross Alpha (pCi/L)	15								
Gross Alpha (counting error)	None								
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None		137			110		120	
Hydroxide mg/L	None							0	
Iron ug/L	300		0.706					140	
Lead ug/L	15								
LSI	None		-0.03			-0.26			
Manganese ug/L	50		0.014						
MBAS ug/L	None								
Magnesium mg/L	None		0.279			0.17		0.22	
Mercury ug/L	2								
MTBE ug/L	None								
Nitrate mg/L	10						16.8	18	
Nitrate (as N) mg/L	10		5.47			2.52	3.8		
Nitrogen (as N)	10		5.47						
ODOR Units	3								

Groundwater Quality Monitoirng

WKWD Well NW-3
GSP Well 104

Percholrate	None								
PH units	6.5-8.5		8.26			8.1		8.19	
Potassium mg/L	None		0.658					0	
Radium 228	None								
Radium 226	None								
Radium 226	None								
Radium 228	None								
Selenium ug/L	50		0						
Silver ug/L	100		0.003						
Sodium mg/L	None		75.8			83		87	
Sulfate mg/L	250		160			180		170	
TDS mg/L	1000		412			380		430	
Temp	None		68			23.4			
Tert-ButylEthyl Ether	None								
Thallium ug/L	2		0.008						
Turbity NT Units	None		3.22			0.13		0.93	
Uranium pCi/L	None							1.3	
Uranium	None								
1,2,3 Trochloropropane	None								
Tert - Butyl Alcohol	None								
Tert - Amyl Methyl Ether	None								
Vanadium	None								
Zinc ug/L	5		0.049						

WKWD Well NW-4

GSP Well 105

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	262.42	287.65						
Yearly AVG of StaticWL	NA	174.61	190.38						
Alkalinity(as CaCO3) mg/L	None		72			80			38
Aluminum ug/L	1		0						
Antimony ug/L	6		0.004						
Arsenic ug/L	10		0						2.4
Barium ug/L	1		0.029						35
Bicarbonate mg/L	None		87.8			80			47
Boron	None		0.024						
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5								
Calcium mg/L	None					61			52
Calcium (as CACO3) mg/L	None		52.3			152			
Carbonate mg/L	None								
Chloride mg/L	500		50.1			51			53
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50								
Chromium VI ug/L	None							0.42	
Color Units	15		0			0			1
Conductivity umhos/cm	None		665			600			667
Copper ug/L	1.3								
DBCP ug/L	2								
Dichlorodifluoromethane	None								
EDB ug/L	None								
Flouride mg/L	None					0			0.073
Gross Alpha (pCi/L)	15								
Gross Alpha (counting error)	None					9.96		1.3	
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None		132			150			130
Hydroxide mg/L	None								
Iron ug/L	300		0						240
Lead ug/L	15								
LSI	None		-0.09			-0.032			
Manganese ug/L	50		0						
MBAS ug/L	None								
Magnesium mg/L	None		0.234			0.25			0.24
Mercury ug/L	2								
MTBE ug/L	None								
Nitrate mg/L	10						1.9	18.4	18
Nitrate (as N) mg/L	10		4.45			1.8	8.38	4.15	
Nitrogen (as N)	10		4.45						
ODOR Units	3								

Groundwater Quality Monitoirng

WKWD Well NW-4
GSP Well 105

Percholrate	None								
PH units	6.5-8.5		8.04			7.9			8.07
Potassium mg/L	None		0.804						
Radium 228	None								
Radium 226	None								
Radium 226	None								
Radium 228	None								
Selenium ug/L	50		0						
Silver ug/L	100		0						
Sodium mg/L	None		80.2			89			95
Sulfate mg/L	250		165			200			190
TDS mg/L	1000		445			460			450
Temp	None		68			21.2			
Tert-ButylEthyl Ether	None								
Thallium ug/L	2		0						
Turbity NT Units	None		0.25			1.1			1
Uranium pCi/L	None					5.6			2.4
Uranium	None								
1,2,3 Trochloropropane	None								
Tert - Butyl Alcohol	None								
Tert - Amyl Methyl Ether	None								
Vanadium	None								
Zinc ug/L	5		0						

WKWD Well NW-5

GSP Well 106

		Year							
	MCL	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Yearly AVG of PumpingWL	NA	250.20	268.39						
Yearly AVG of StaticWL	NA	177.00	198.02						
Alkalinity(as CaCO3) mg/L	None		94.6			67			55
Aluminum ug/L	1		0						
Antimony ug/L	6		0.005						
Arsenic ug/L	10		0.002						
Barium ug/L	1		0.055			0.0058			67
Bicarbonate mg/L	None		115			67			68
Boron	None		0.111						
Bromide (as Ethylene dibromide) (ug/L)	0.005								
Cadmium ug/L	5								
Calcium mg/L	None					80			81
Calcium (as CACO3) mg/L	None		96.9			200			
Carbonate mg/L	None								
Chloride mg/L	500		67			67			72
Chlorobenzene (mg/L)	0.1								
Chromium (Chrome Cr) mg/L	50				0.001				
Chromium VI ug/L	None							1.1	
Color Units	15		0			0			1
Conductivity umhos/cm	None		947			860			867
Copper ug/L	1.3								
DBCP ug/L	2								
Dichlorodifluoromethane	None								
EDB ug/L	None								
Flouride mg/L	None					0			0.067
Gross Alpha (pCi/L)	15								
Gross Alpha (counting error)	None					12.5			
Gross Beta (millirems/yr)	4								
Gross Beta (counting error)	None								
Hardness (as CACO3) mg/L	None		245			200			200
Hydroxide mg/L	None								
Iron ug/L	300		0						210
Lead ug/L	15								
LSI	None		0.04			-0.064			
Manganese ug/L	50		0						
MBAS ug/L	None								
Magnesium mg/L	None		0.66			0.52			0.58
Mercury ug/L	2								
MTBE ug/L	None								
Nitrate mg/L	10						4.82	28.9	58.3
Nitrate (as N) mg/L	10		6.09			6.15	21.4	6.54	6.39
Nitrogen (as N)	10		6.09						
ODOR Units	3								

Groundwater Quality Monitoirng

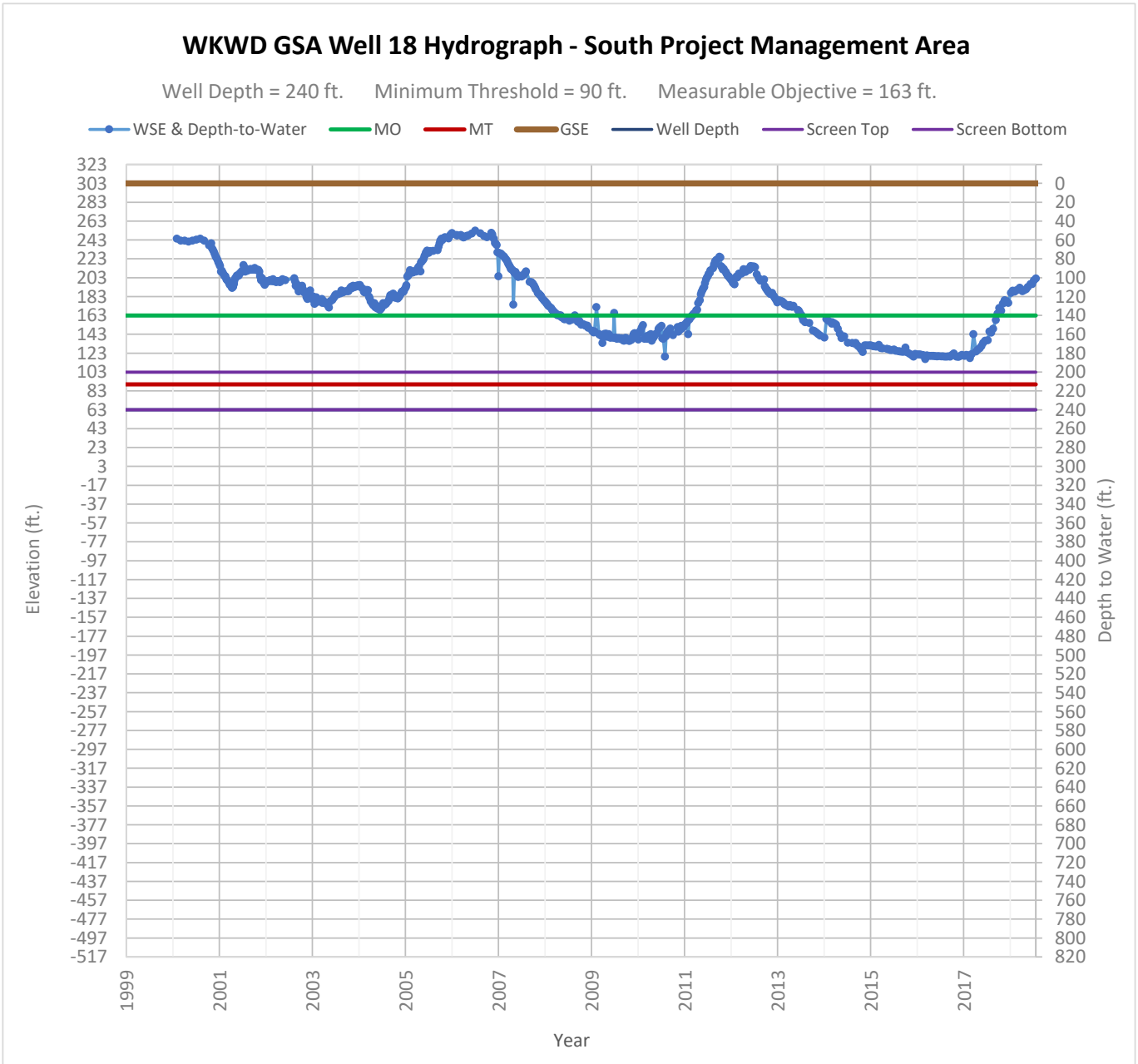
WKWD Well NW-5
GSP Well 106

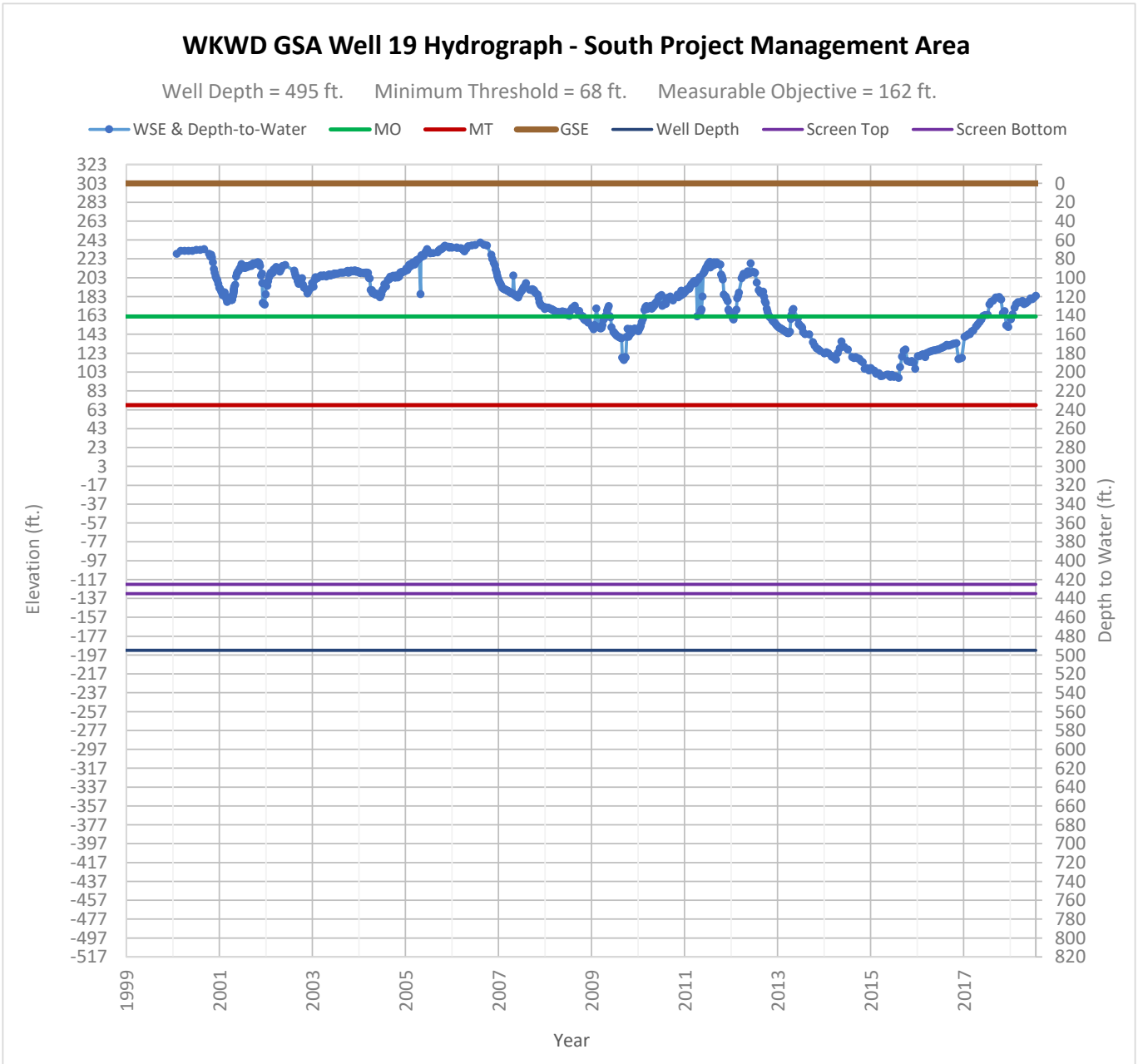
Percholrate	None								
PH units	6.5-8.5		7.78			7.9			7.95
Potassium mg/L	None		0.802						
Radium 228	None								
Radium 226	None								
Radium 226	None								
Radium 228	None								
Selenium ug/L	50		0.003						2.2
Silver ug/L	100		0						
Sodium mg/L	None		129			110			110
Sulfate mg/L	250		271			260			240
TDS mg/L	1000		693			560			560
Temp	None		68			23.9			
Tert-ButylEthyl Ether	None								
Thallium ug/L	2		0						
Turbity NT Units	None		0.15			0.15			1.2
Uranium pCi/L	None					9.3			6.5
Uranium	None								
1,2,3 Trochloropropane	None								
Tert - Butyl Alcohol	None								
Tert - Amyl Methyl Ether	None								
Vanadium	None								
Zinc ug/L	5		0						

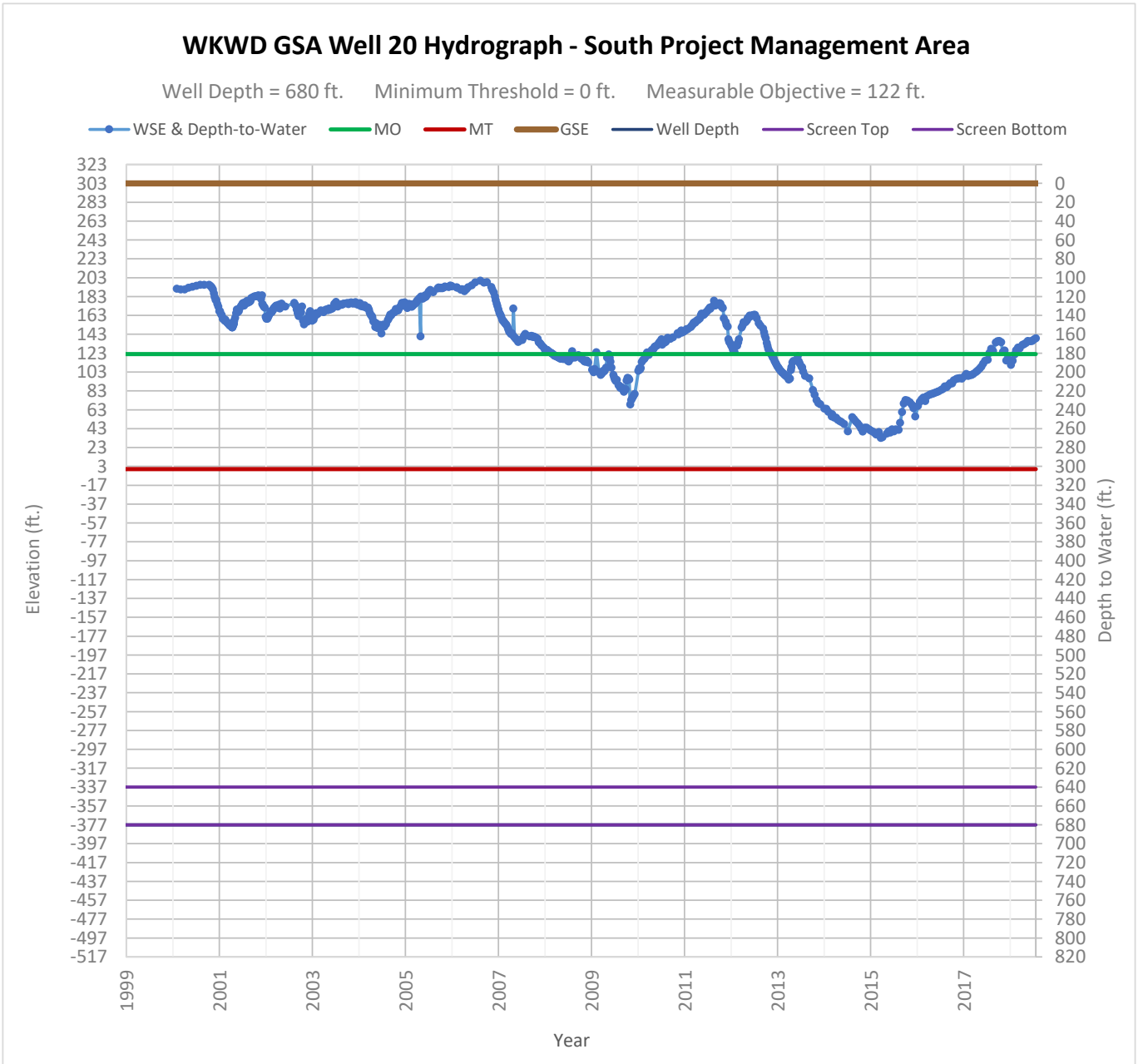
Appendix G

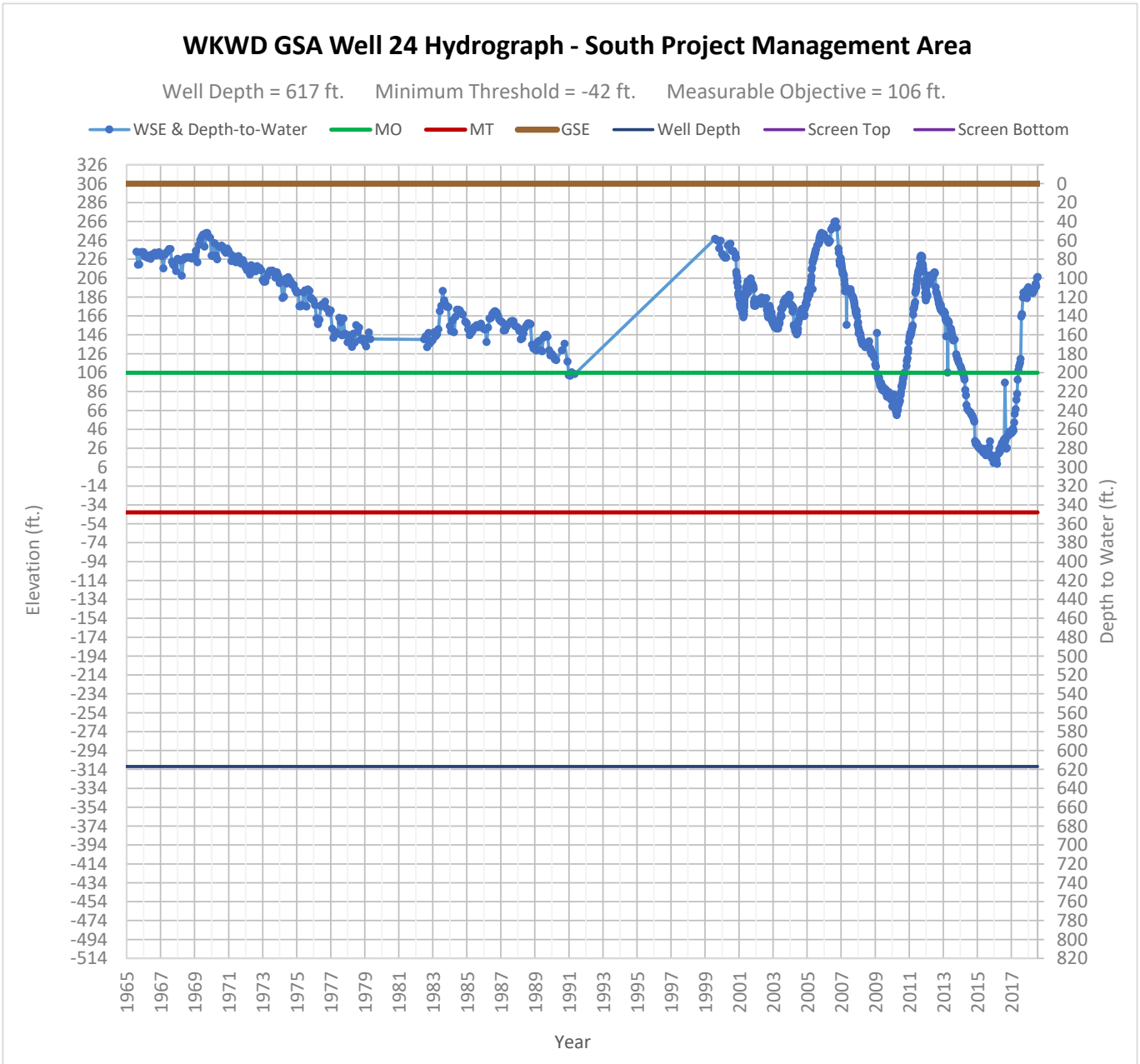
Well Hydrographs with Minimum Thresholds and Measurable Objectives

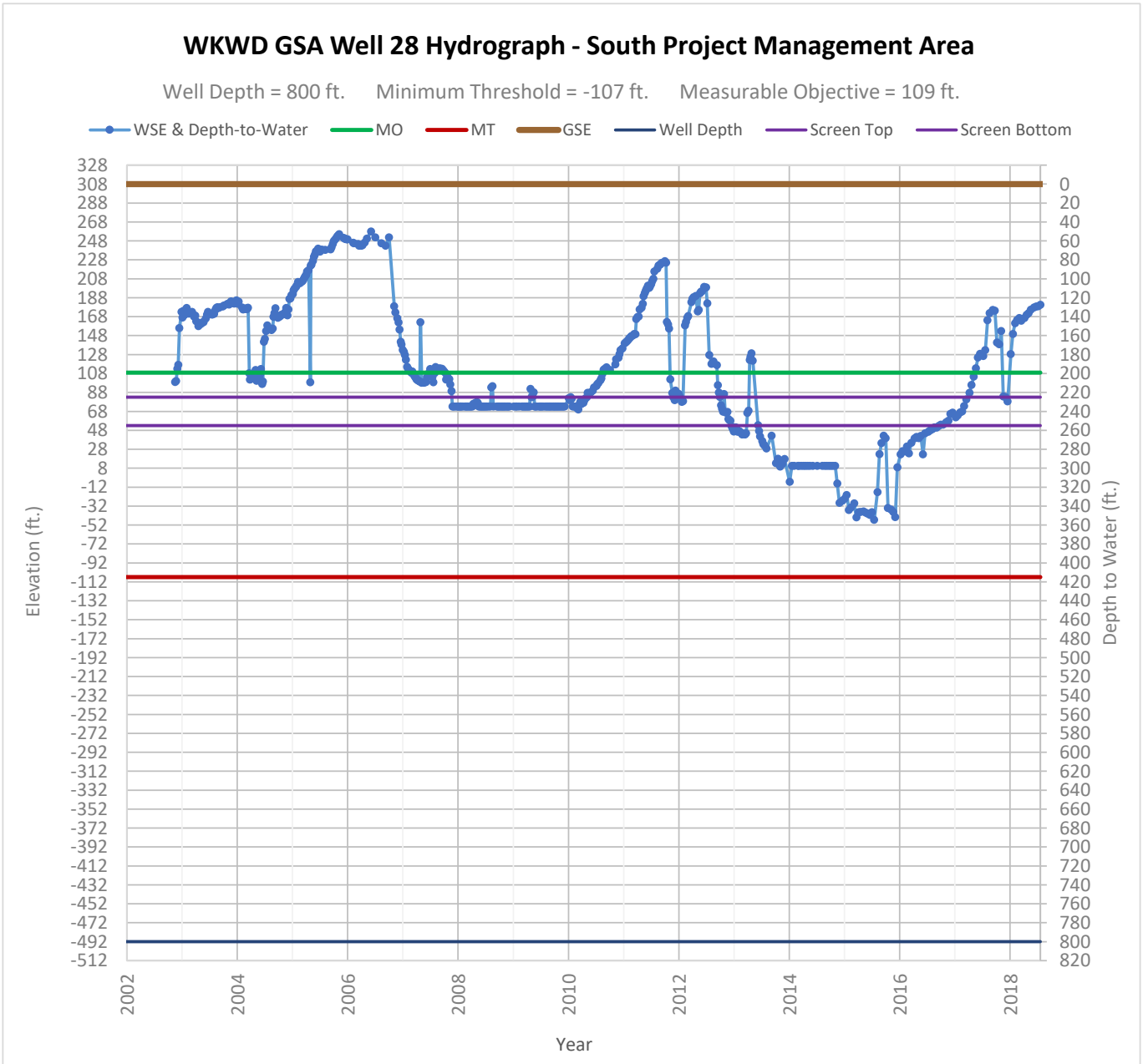
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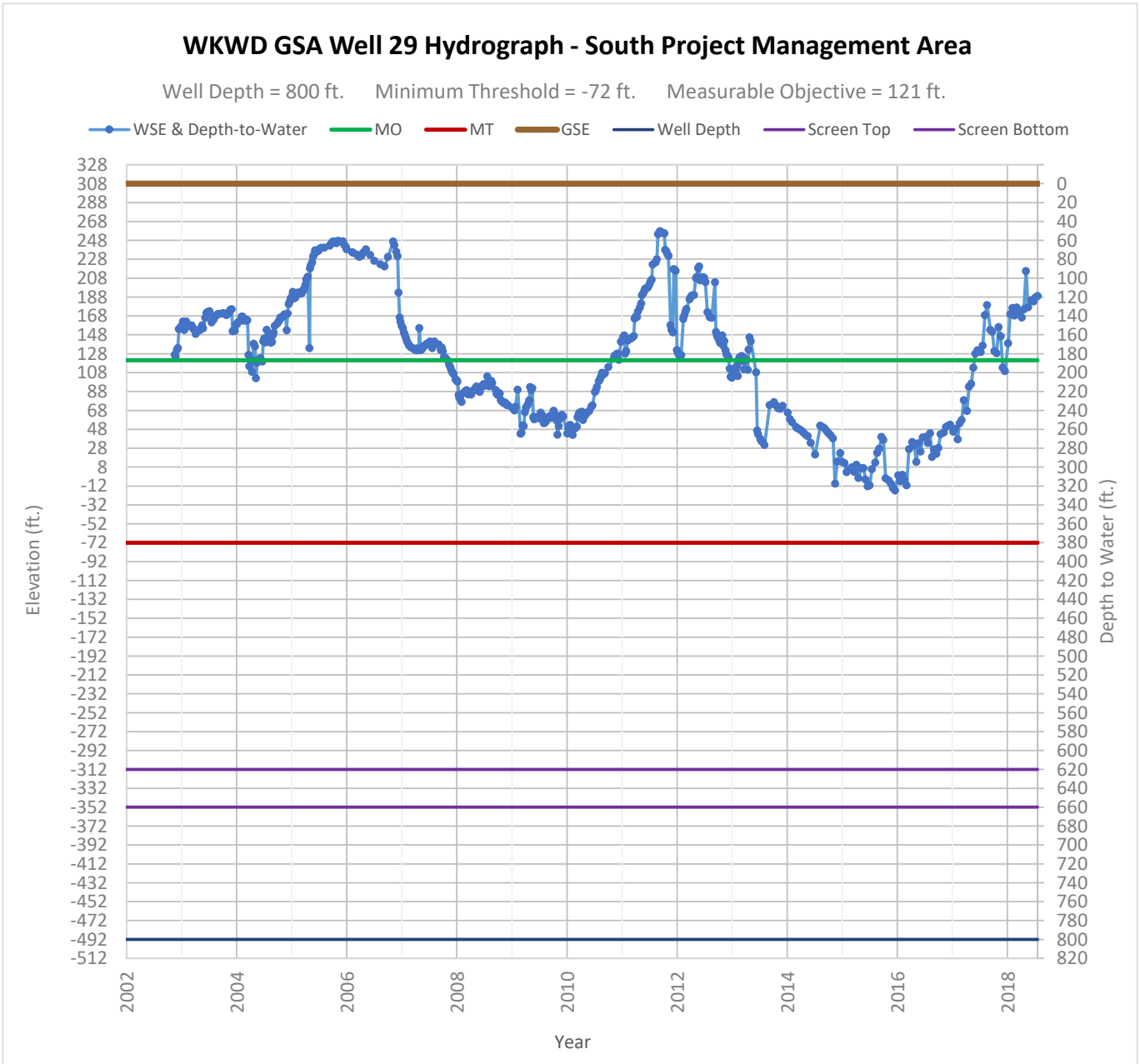

WKWD GSA Well 18 Hydrograph - South Project Management Area
Well Depth = 240 ft. Minimum Threshold = 90 ft. Measurable Objective = 163 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
323 303 283 263 243 223 203 183 163 143 123 103 83 63 43 23 3 -17 -37 -57 -77 -97 -117 -137 -157 -177 -197 -217 -237 -257 -277 -297 -317 -337 -357 -377 -397 -417 -437 -457 -477 -497 -517
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
1999 2001 2003 2005 2007 2009 2011 2013 2015 2017

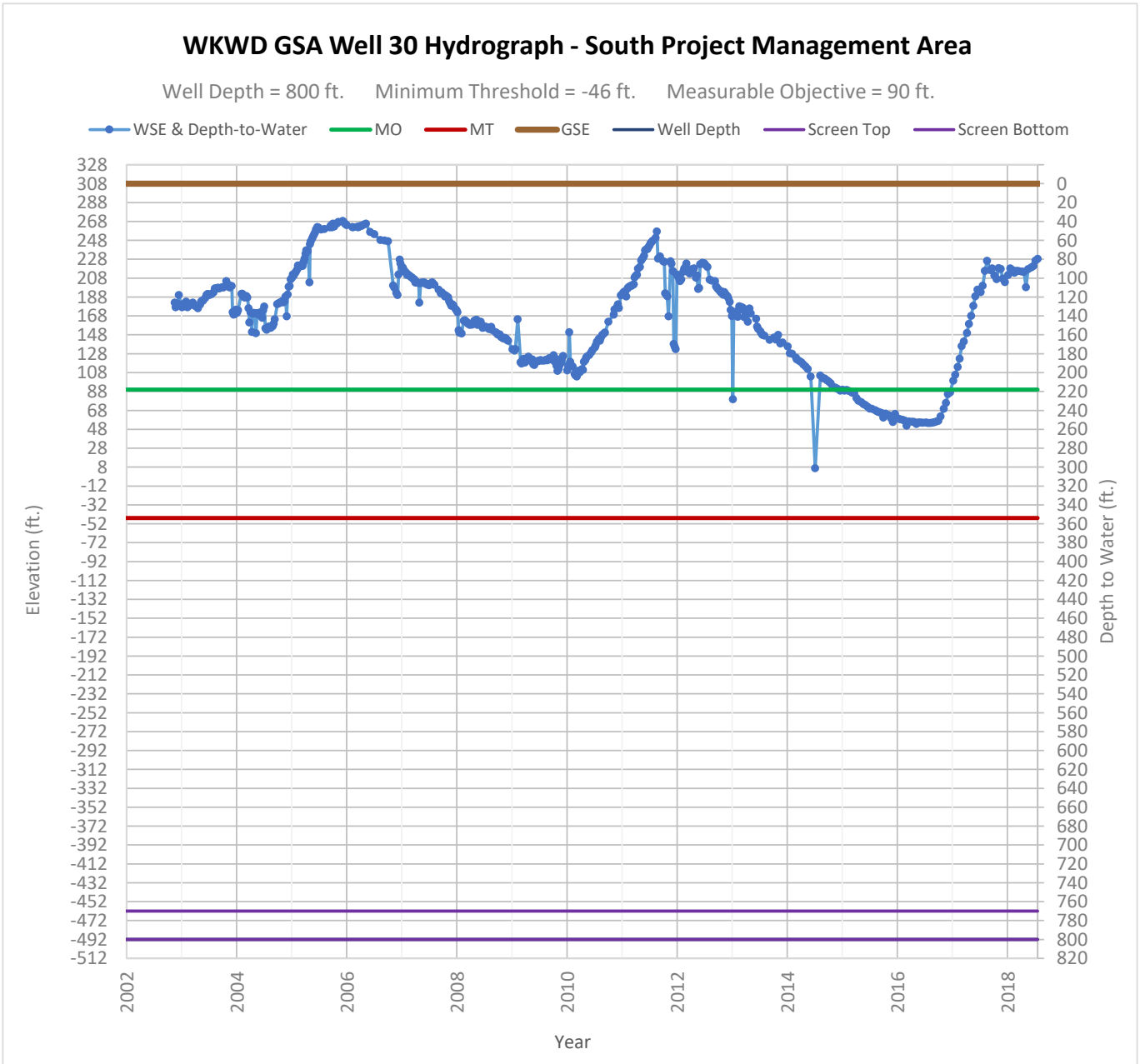

WKWD GSA Well 19 Hydrograph - South Project Management Area
Well Depth = 495 ft. Minimum Threshold = 68 ft. Measurable Objective = 162 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
323 303 283 263 243 223 203 183 163 143 123 103 83 63 43 23 3 -17 -37 -57 -77 -97 -117 -137 -157 -177 -197 -217 -237 -257 -277 -297 -317 -337 -357 -377 -397 -417 -437 -457 -477 -497 -517
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
1999 2001 2003 2005 2007 2009 2011 2013 2015 2017

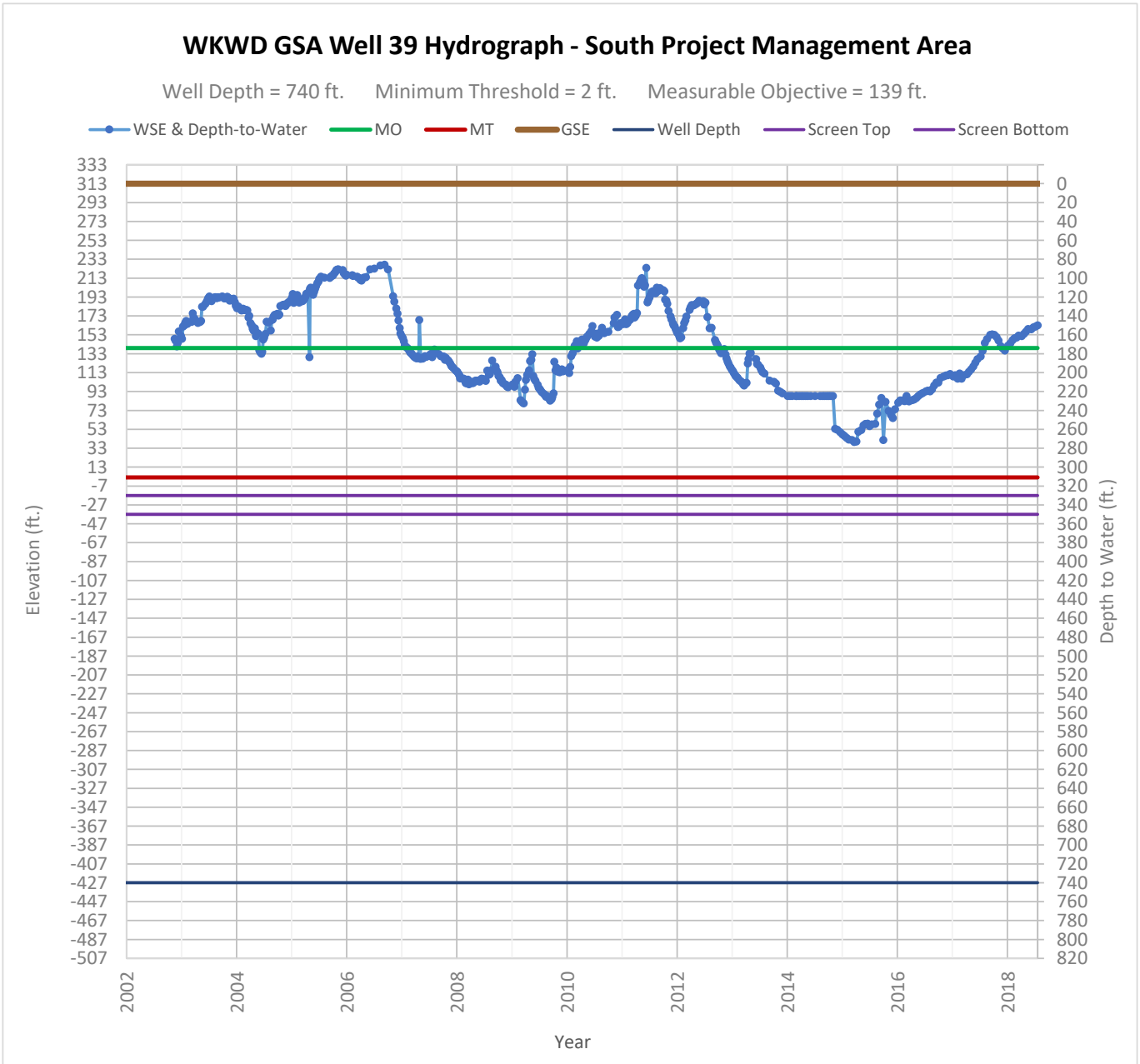

WKWD GSA Well 20 Hydrograph - South Project Management Area
Well Depth = 680 ft.
Minimum Threshold = 0 ft.
Measurable Objective = 122 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
323 303 283 263 243 223 203 183 163 143 123 103 83 63 43 23 3 -17 -37 -57 -77 -97 -117 -137 -157 -177 -197 -217 -237 -257 -277 -297 -317 -337 -357 -377 -397 -417 -437 -457 -477 -497 -517
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
1999 2001 2003 2005 2007 2009 2011 2013 2015 2017

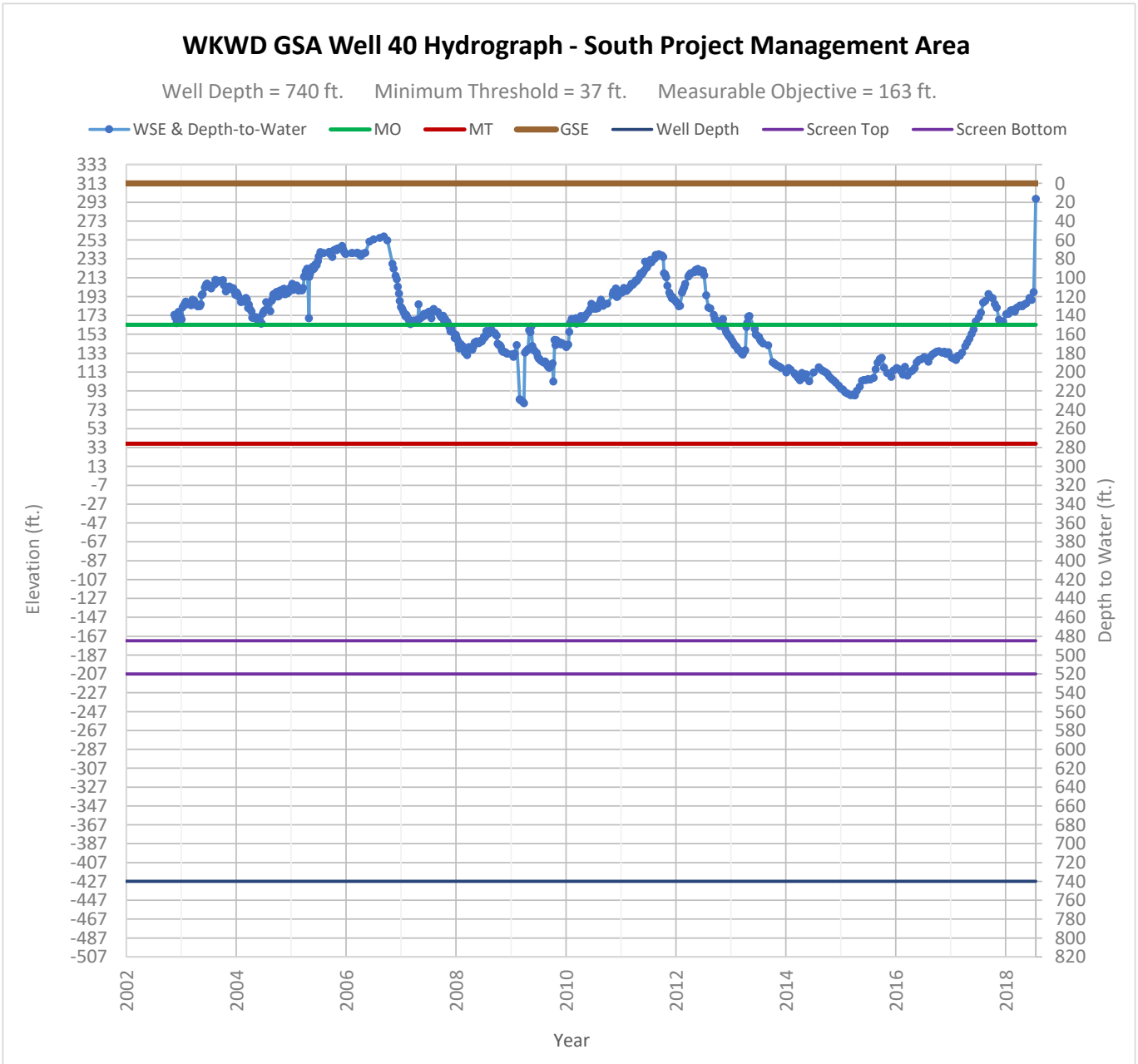

WKWD GSA Well 24 Hydrograph - South Project Management Area
Well Depth = 617 ft.
Minimum Threshold = -42 ft.
Measurable Objective = 106 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year

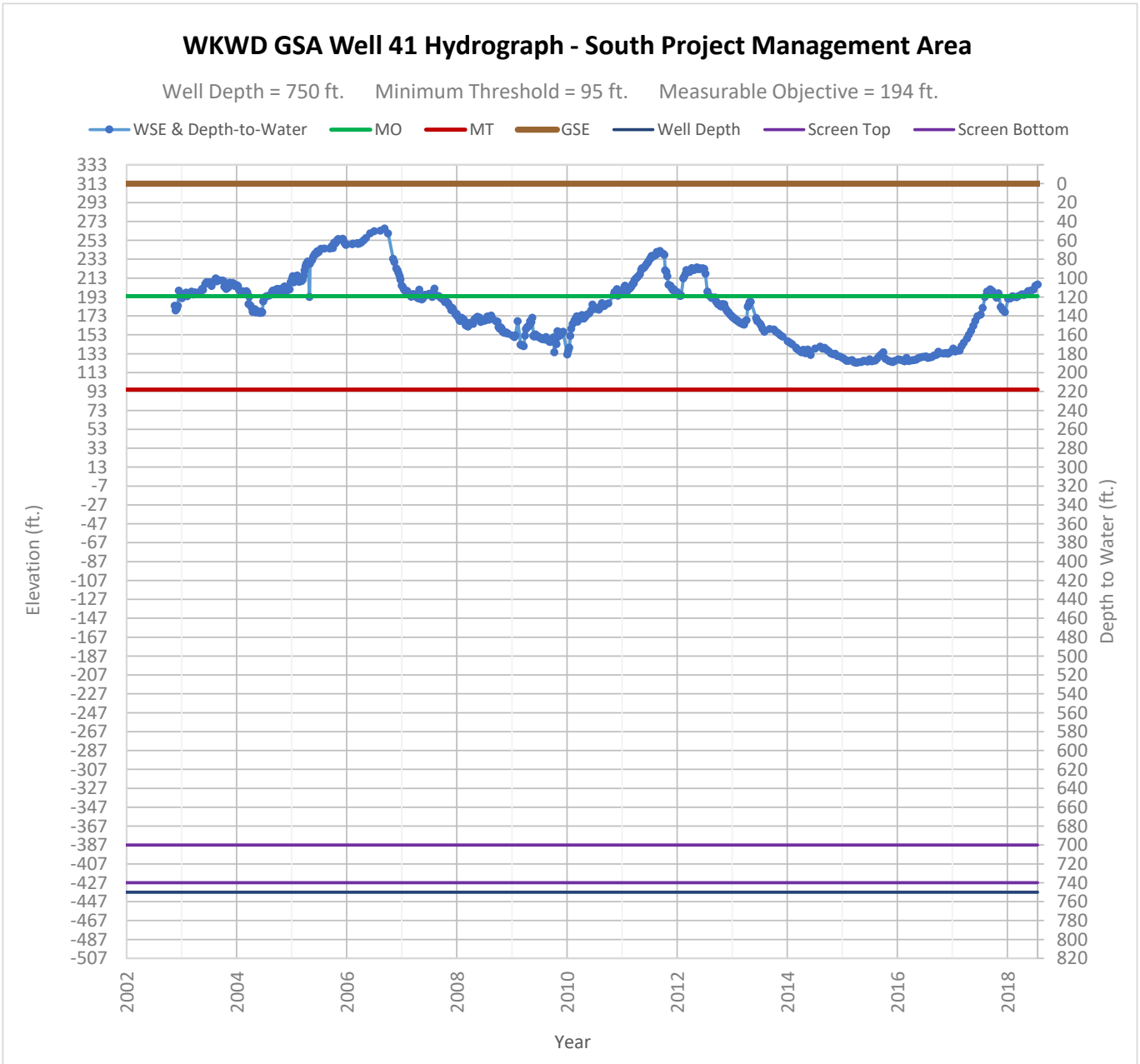

WKWD GSA Well 28 Hydrograph - South Project Management Area
Well Depth = 800 ft.
Minimum Threshold = -107 ft.
Measurable Objective = 109 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
328 308 288 268 248 228 208 188 168 148 128 108 88 68 48 28 8 -12 -32 -52 -72 -92 -112 -132 -152 -172 -192 -212 -232 -252 -272 -292 -312 -332 -352 -372 -392 -412 -432 -452 -472 -492 -512
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
2002 2004 2006 2008 2010 2012 2014 2016 2018

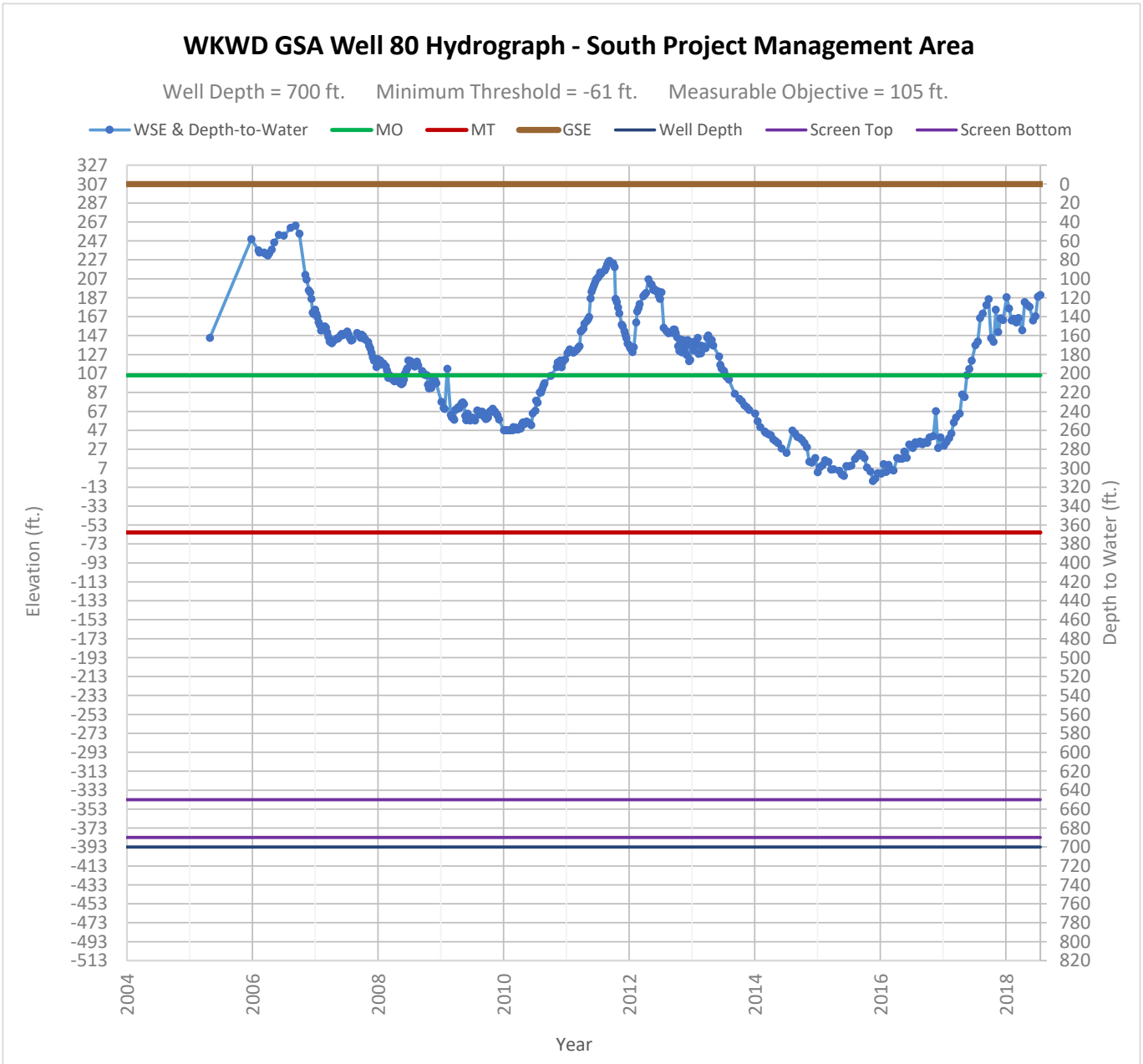

WKWD GSA Well 29 Hydrograph - South Project Management Area
Well Depth = 800 ft.
Minimum Threshold = -72 ft.
Measurable Objective = 121 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
328 308 288 268 248 228 208 188 168 148 128 108 88 68 48 28 8 -12 -32 -52 -72 -92 -112 -132 -152 -172 -192 -212 -232 -252 -272 -292 -312 -332 -352 -372 -392 -412 -432 -452 -472 -492 -512
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
2002 2004 2006 2008 2010 2012 2014 2016 2018

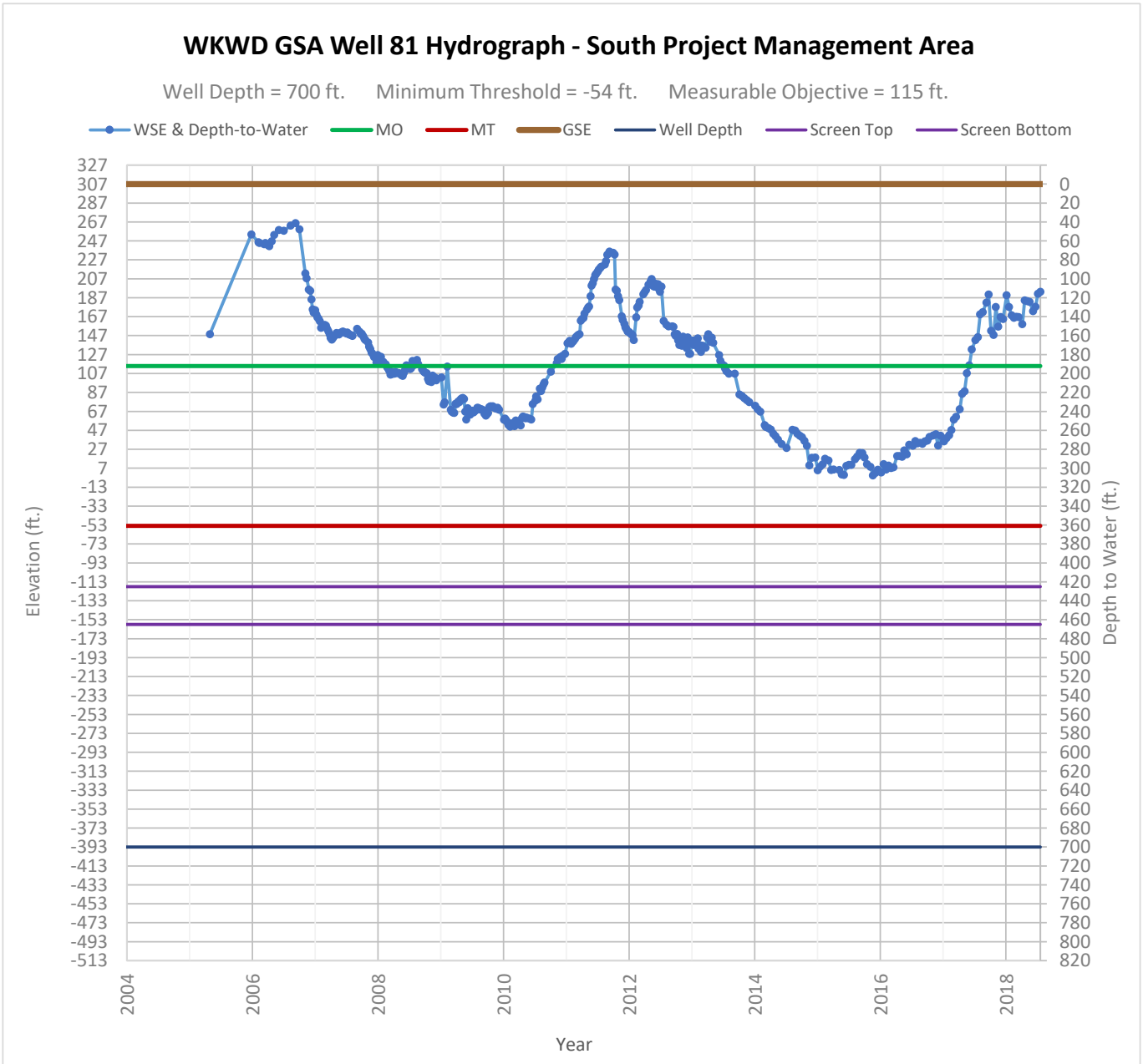

WKWD GSA Well 30 Hydrograph - South Project Management Area
Well Depth = 800 ft.
Minimum Threshold = -46 ft.
Measurable Objective = 90 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
328 308 288 268 248 228 208 188 168 148 128 108 88 68 48 28 8 -12 -32 -52 -72 -92 -112 -132 -152 -172 -192 -212 -232 -252 -272 -292 -312 -332 -352 -372 -392 -412 -432 -452 -472 -492 -512
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
2002 2004 2006 2008 2010 2012 2014 2016 2018

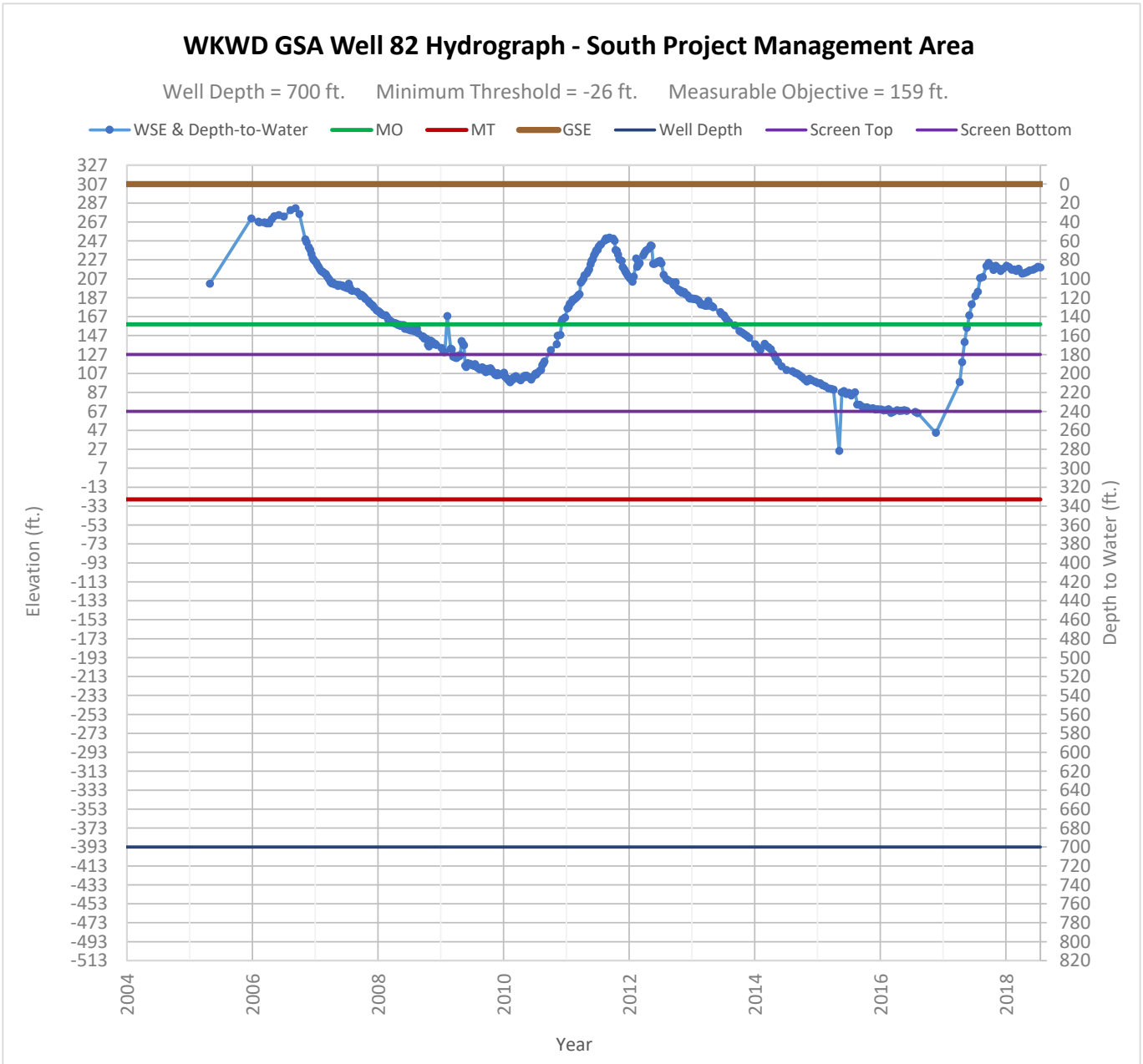

WKWD GSA Well 39 Hydrograph - South Project Management Area
Well Depth = 740 ft.
Minimum Threshold = 2 ft.
Measurable Objective = 139 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
333 313 293 273 253 233 213 193 173 153 133 113 93 73 53 33 13 -7 -27 -47 -67 -87 -107 -127 -147 -167 -187 -207 -227 -247 -267 -287 -307 -327 -347 -367 -387 -407 -427 -447 -467 -487 -507
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
2002 2004 2006 2008 2010 2012 2014 2016 2018

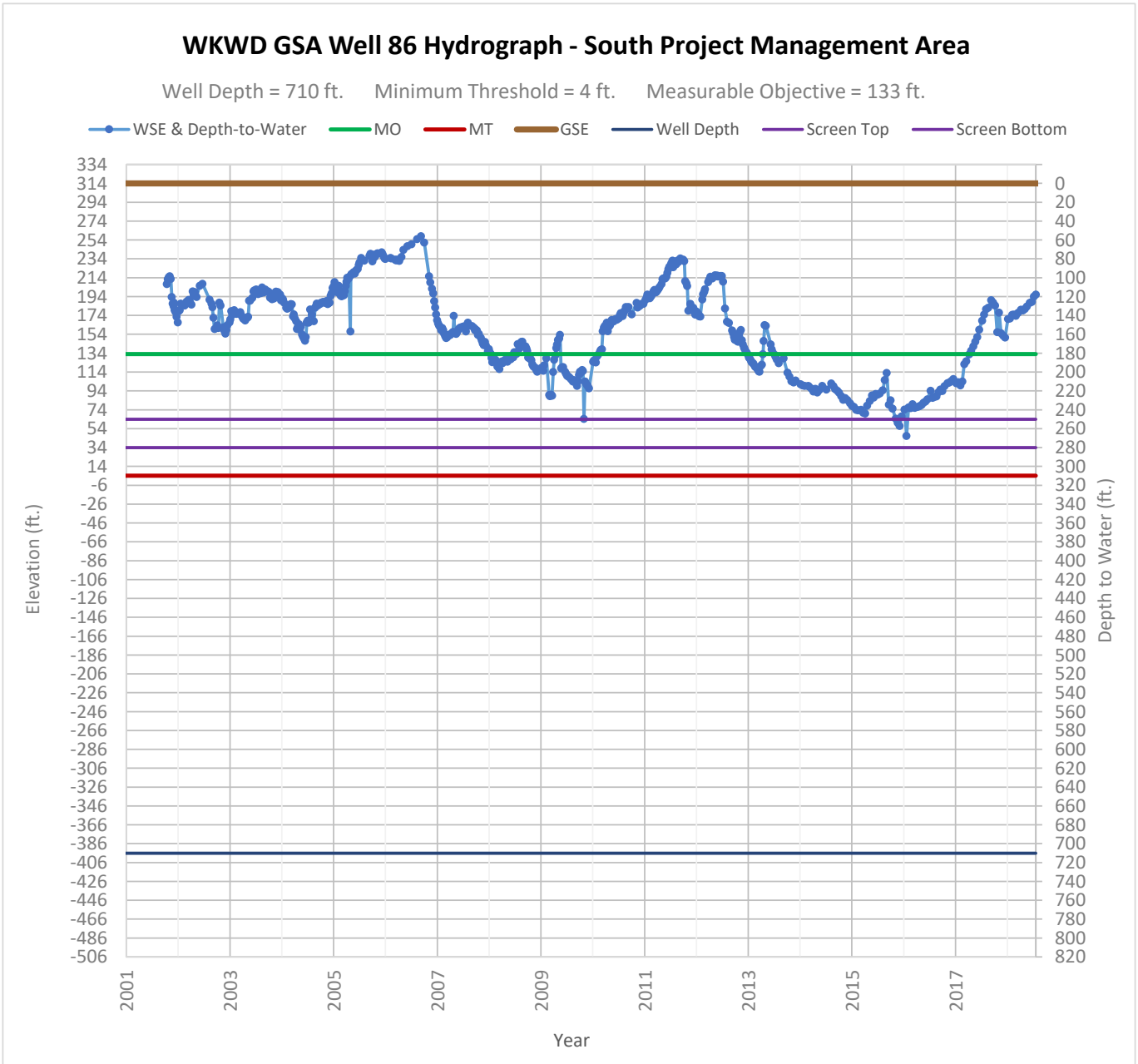

WKWD GSA Well 40 Hydrograph - South Project Management Area
Well Depth = 740 ft.
Minimum Threshold = 37 ft.
Measurable Objective = 163 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
333
313
293
273
253
233
213
193
173
153
133
113
93
73
53
33
13
-7
-27
-47
-67
-87
-107
-127
-147
-167
-187
-207
-227
-247
-267
-287
-307
-327
-347
-367
-387
-407
-427
-447
-467
-487
-507
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60
80
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120
140
160
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400
420
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460
480
500
520
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820
2002
2004
2006
2008
2010
2012
2014
2016
2018

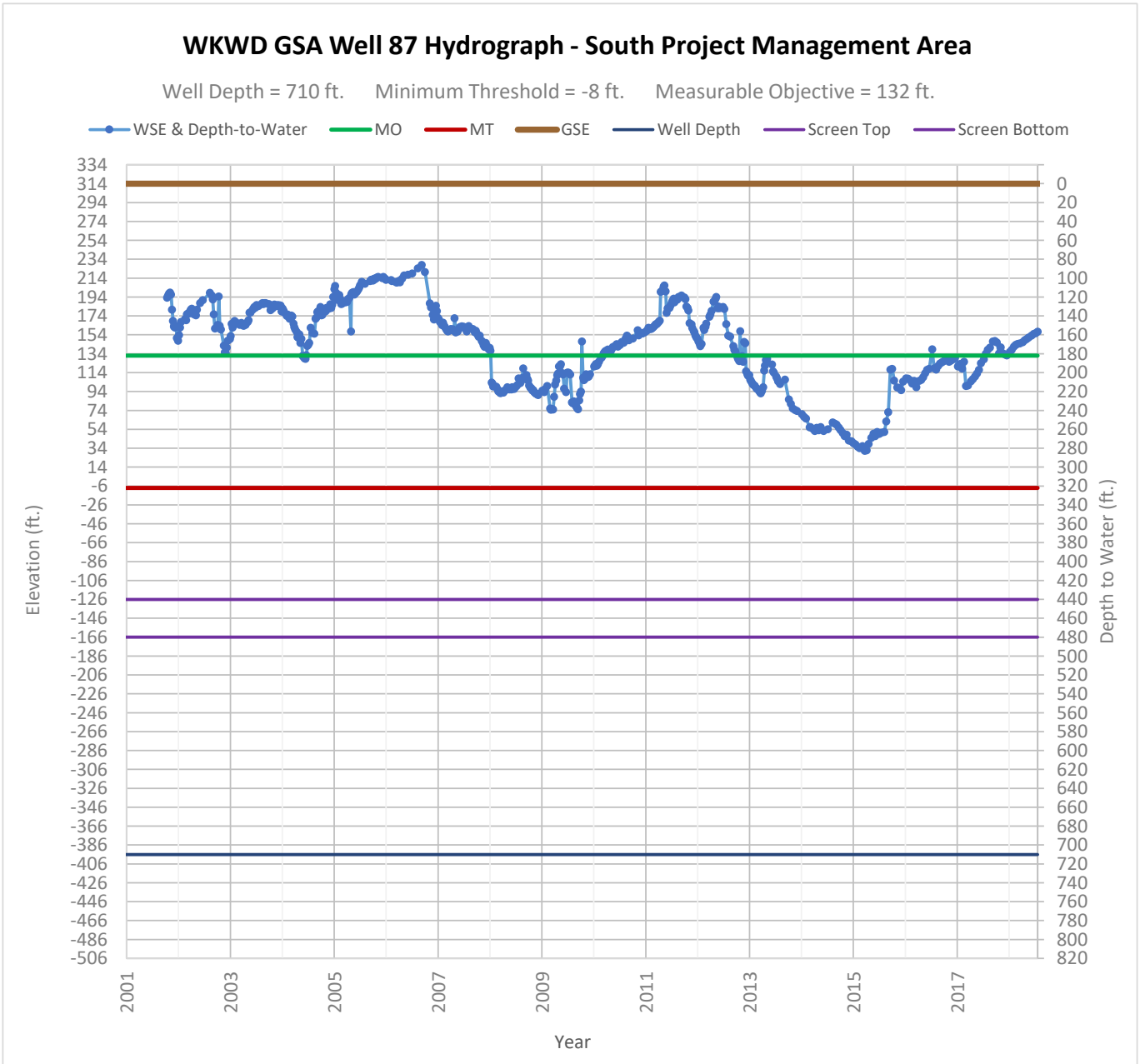

WKWD GSA Well 41 Hydrograph - South Project Management Area
Well Depth = 750 ft.
Minimum Threshold = 95 ft.
Measurable Objective = 194 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
333
313
293
273
253
233
213
193
173
153
133
113
93
73
53
33
13
-7
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460
480
500
520
540
560
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820
2002
2004
2006
2008
2010
2012
2014
2016
2018

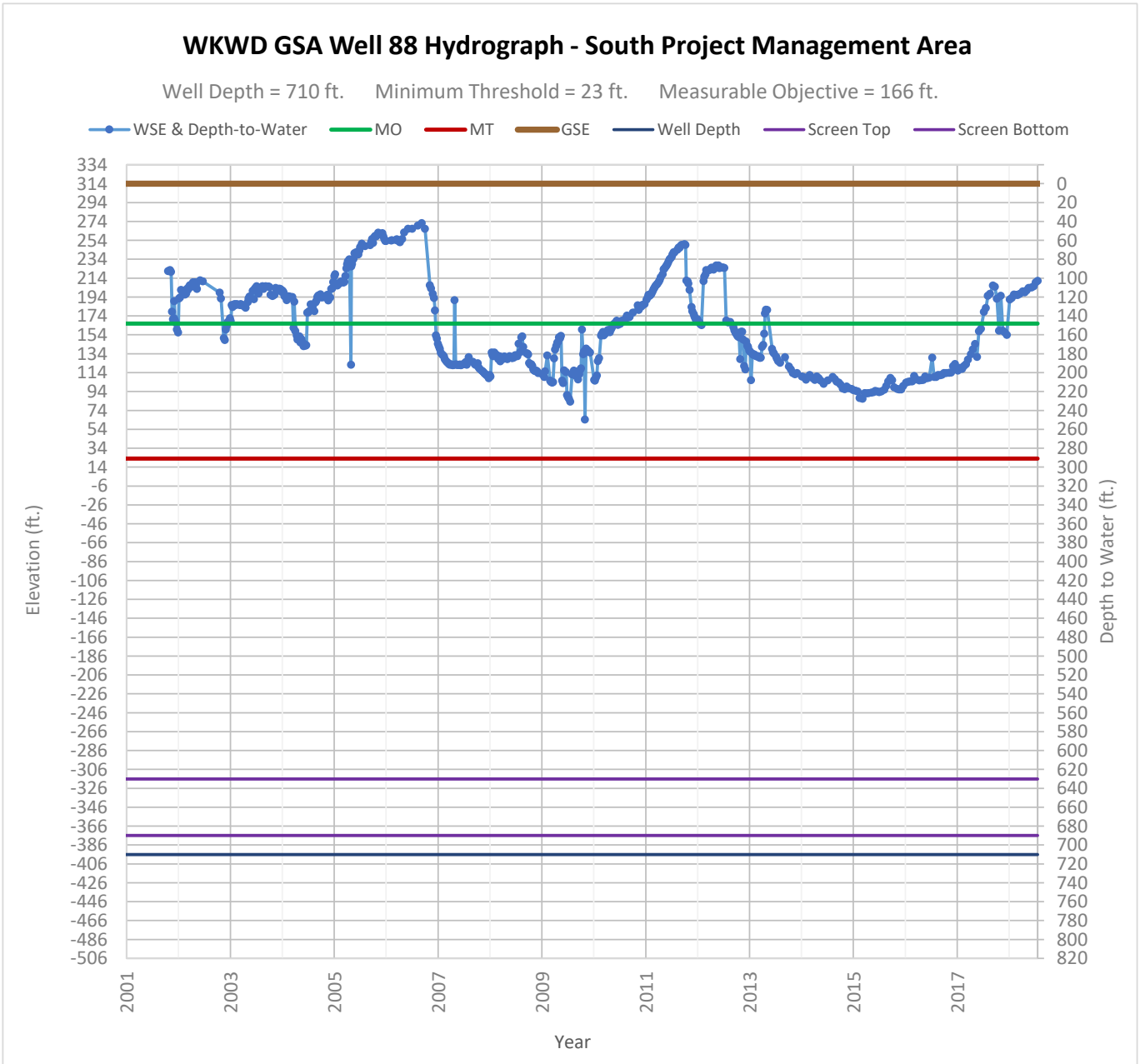

WKWD GSA Well 80 Hydrograph - South Project Management Area
Well Depth = 700 ft.
Minimum Threshold = -61 ft.
Measurable Objective = 105 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
327
307
287
267
247
227
207
187
167
147
127
107
87
67
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27
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2012
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2018

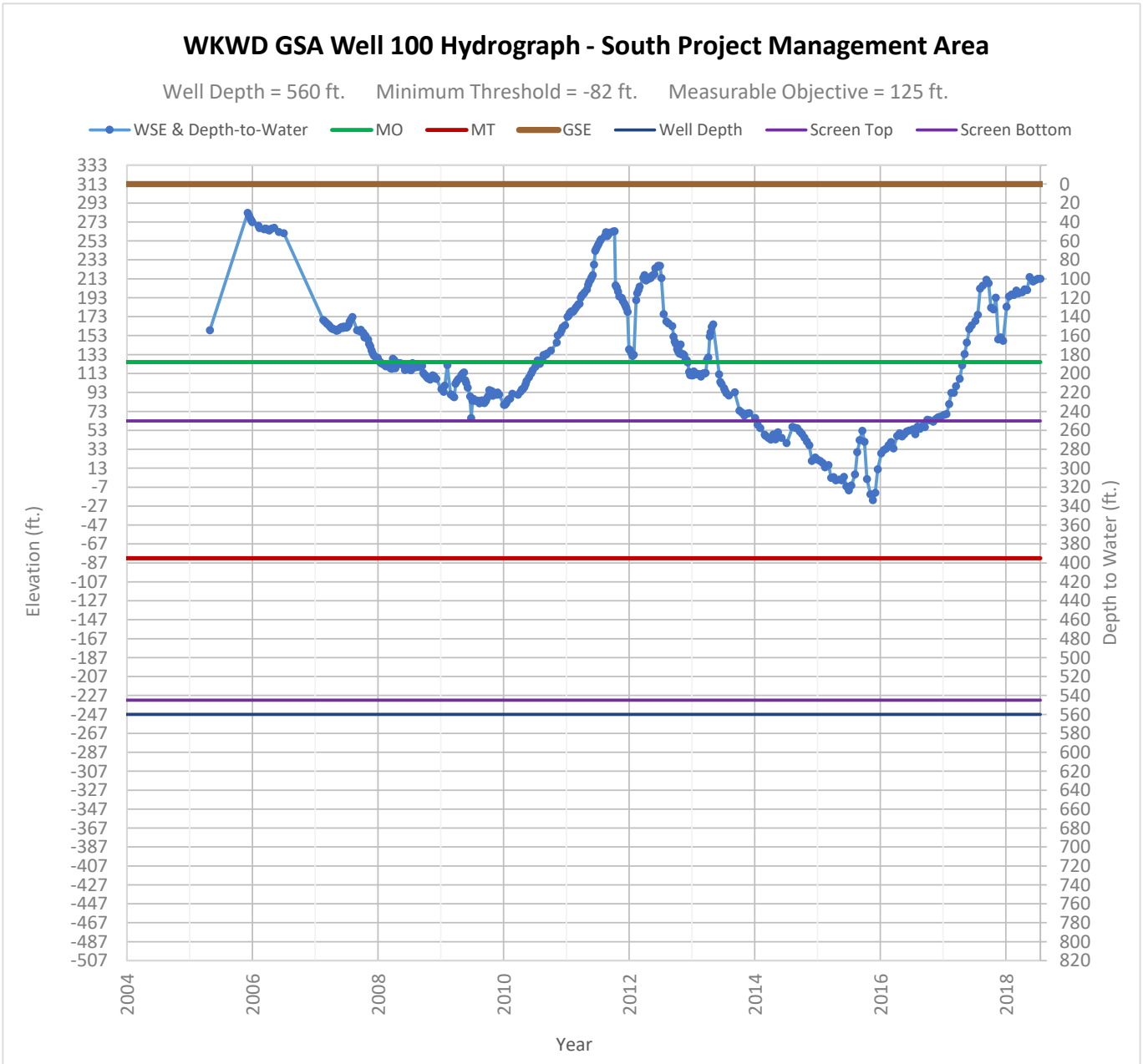

WKWD GSA Well 81 Hydrograph - South Project Management Area
Well Depth = 700 ft.
Minimum Threshold = -54 ft.
Measurable Objective = 115 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
327
307
287
267
247
227
207
187
167
147
127
107
87
67
47
27
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2016
2018

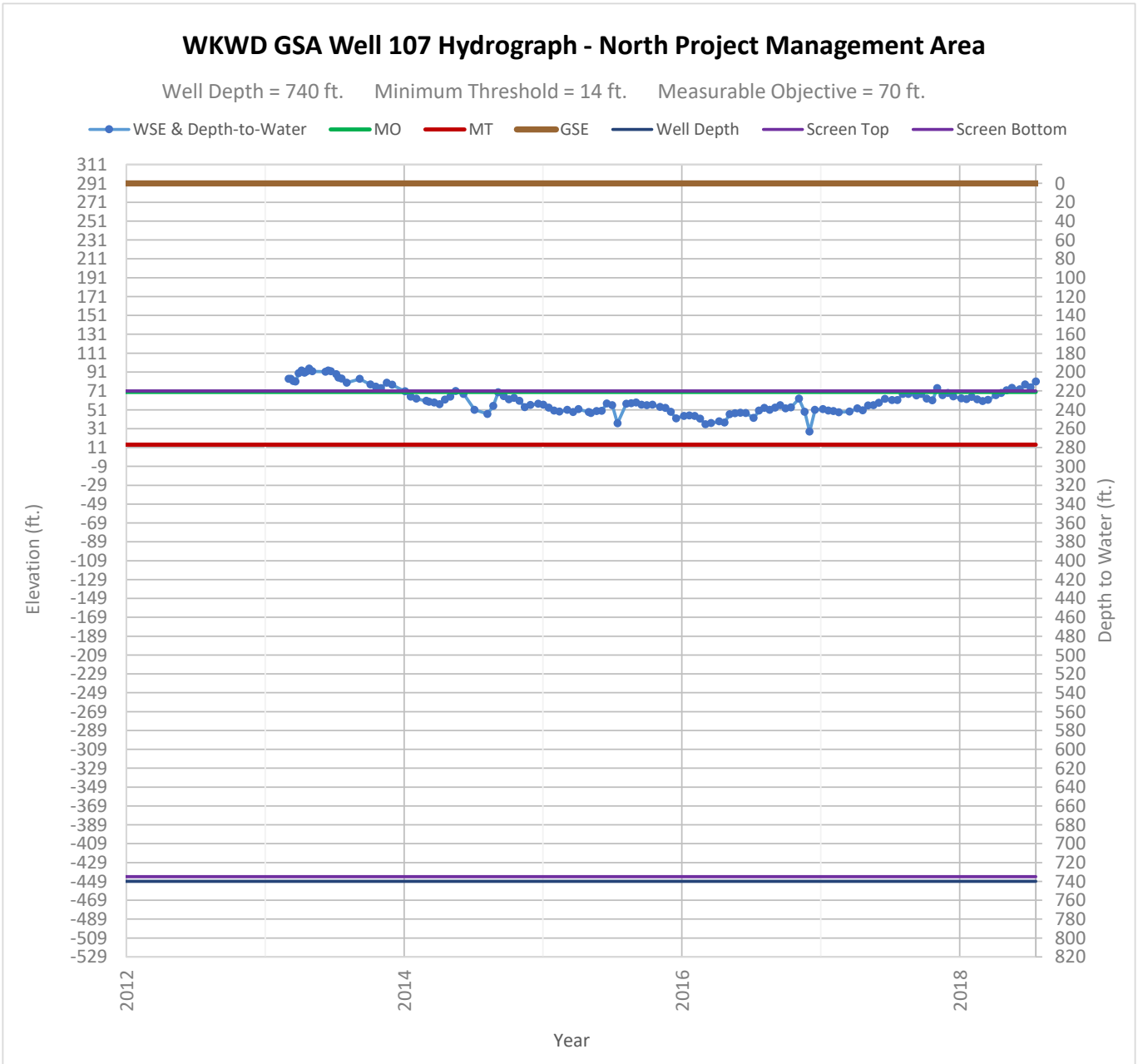

WKWD GSA Well 82 Hydrograph - South Project Management Area
Well Depth = 700 ft.
Minimum Threshold = -26 ft.
Measurable Objective = 159 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
327
307
287
267
247
227
207
187
167
147
127
107
87
67
47
27
7
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140
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180
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300
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360
380
400
420
440
460
480
500
520
540
560
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2004
2006
2008
2010
2012
2014
2016
2018

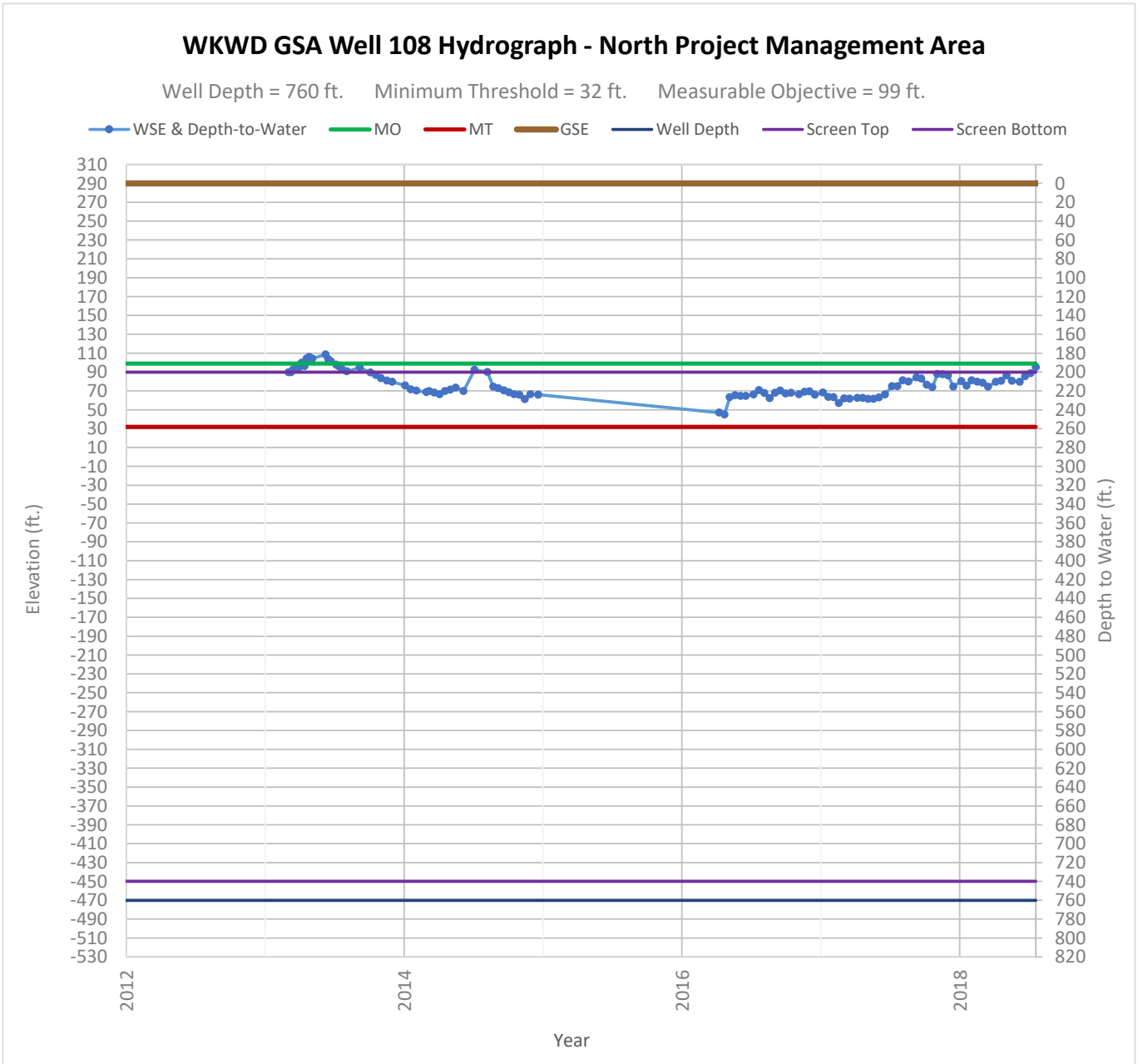

WKWD GSA Well 86 Hydrograph - South Project Management Area
Well Depth = 710 ft.
Minimum Threshold = 4 ft.
Measurable Objective = 133 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
334 314 294 274 254 234 214 194 174 154 134 114 94 74 54 34 14 -6 -26 -46 -66 -86 -106 -126 -146 -166 -186 -206 -226 -246 -266 -286 -306 -326 -346 -366 -386 -406 -426 -446 -466 -486 -506
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
2001 2003 2005 2007 2009 2011 2013 2015 2017


WKWD GSA Well 87 Hydrograph - South Project Management Area
Well Depth = 710 ft.
Minimum Threshold = -8 ft.
Measurable Objective = 132 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
334 314 294 274 254 234 214 194 174 154 134 114 94 74 54 34 14 -6 -26 -46 -66 -86 -106 -126 -146 -166 -186 -206 -226 -246 -266 -286 -306 -326 -346 -366 -386 -406 -426 -446 -466 -486 -506
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820
2001 2003 2005 2007 2009 2011 2013 2015 2017


WKWD GSA Well 88 Hydrograph - South Project Management Area
Well Depth = 710 ft.
Minimum Threshold = 23 ft.
Measurable Objective = 166 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year


WKWD GSA Well 100 Hydrograph - South Project Management Area
Well Depth = 560 ft.
Minimum Threshold = -82 ft.
Measurable Objective = 125 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
333
313
293
273
253
233
213
193
173
153
133
113
93
73
53
33
13
-7
-27
-47
-67
-87
-107
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-147
-167
-187
-207
-227
-247
-267
-287
-307
-327
-347
-367
-387
-407
-427
-447
-467
-487
-507
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
760
780
800
820
2004
2006
2008
2010
2012
2014
2016
2018


WKWD GSA Well 107 Hydrograph - North Project Management Area
Well Depth = 740 ft.
Minimum Threshold = 14 ft.
Measurable Objective = 70 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
311
291
271
251
231
211
191
171
151
131
111
91
71
51
31
11
-9
-29
-49
-69
-89
-109
-129
-149
-169
-189
-209
-229
-249
-269
-289
-309
-329
-349
-369
-389
-409
-429
-449
-469
-489
-509
-529
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
760
780
800
820
2012
2014
2016
2018


WKWD GSA Well 108 Hydrograph - North Project Management Area
Well Depth = 760 ft.
Minimum Threshold = 32 ft.
Measurable Objective = 99 ft.
WSE & Depth-to-Water
MO
MT
GSE
Well Depth
Screen Top
Screen Bottom
Elevation (ft.)
Depth to Water (ft.)
Year
2012
2014
2016
2018

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Appendix H

Little Santa Maria Valley Management Area Groundwater Sustainability Plan

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Attachments

Attachment 1 Soil Boring Logs
Attachment 2 2019 Fall Hydrographs

Abbreviations and Acronyms

Term	Definition
BBM	basin boundary modification
bgs	below ground surface
DWR	California Department of Water Resources
GSA	Groundwater Sustainability Agency
GSA area	West Kern Water District Groundwater Sustainability area
GSP	Groundwater Sustainability Plan
HCM	hydrogeologic conceptual model
KCWA	Kern County Water Agency
KGA	Kern Groundwater Authority
LSMV	Little Santa Maria Valley
MA	management area
mg/L	milligrams per liter
MOU	memorandum of understanding
NCCAG	Natural Communities Commonly Associated with Groundwater
SGMA	Sustainable Groundwater Management Act
Subbasin	Kern County Subbasin
TDS	total dissolved solids
WKWD	West Kern Water District

Section 1.0 Agency Information, Plan Area, and Communication

This appendix describes Sustainable Groundwater Management Act (SGMA) components required by regulation for the Little Santa Maria Valley (LSMV) Management Area (MA). The LSMV MA is in the West Kern Water District (WKWD) Groundwater Sustainability Agency (GSA)'s jurisdiction for their *Chapter Groundwater Sustainability Plan* (Chapter GSP). As part of the larger study, the LSMV MA needs to be distinguished from the WKWD GSA's Western MA.

This appendix also provides additional information about the LSMV MA, and refers to WKWD GSA's Chapter GSP for SGMA content required and covered in the Chapter GSP.

This appendix is organized in a similar way to the WKWD GSA's Chapter GSP. Some portions of this appendix directly refer to the Chapter GSP to address pertinent content, and some portions of this appendix add to or replace Chapter GSP content.

The following GSP content for the LSMV MA is fully covered in the WKWD GSA's Chapter GSP:

- Introduction and agency information
- Relationship to the Kern Groundwater Authority's Umbrella GSP and other subbasin GSAs
- WKWD background
- WKWD GSA contact information
- Management structure
- Legal authority

1.1 Plan Area

This section describes the LSMV MA's plan area components. The following GSP content for the LSMV MA is fully covered in the WKWD GSA's Chapter GSP:

- Existing water management programs
- Permitting new or replacement wells
- Conjunctive use programs in the subbasin
- Plan elements from California Water Code Section 10727.4
- Outreach and engagement
- Decision-making process
- Public engagement, stakeholder involvement, and GSP implementation progress

1.1.1 Introduction and Agency Information

The LSMV MA is covered as part of the WKWD GSA's Chapter GSP through an agreement among local landowners and WKWD. Per this agreement dated November 22, 2019, the Owner/Operator as Landowner has agreed to be responsible for actual costs incurred as a result of adding certain Owner/Operators' LSMV properties to WKWD's GSA area. These costs include directly attributable general and administrative costs and pro rata shares of consultant and service provider costs. According to the agreement, the Owner/Operator may reimburse WKWD for attributable expenditures or make direct payment to consultants or other service providers.

1.1.2 Plan Area Definition

The LSMV MA's plan area consists of a portion of the LSMV that is bounded according to criteria presented in Appendix G of the California Department of Water Resources' (DWR's) *Bulletin 118–Update 2003, California's Groundwater* (DWR, 2003). As described above, Landowners, in agreement with WKWD, added the LSMV MA to the WKWD GSA area. The LSMV MA also includes a portion of the hills surrounding the LSMV (Figure 1-1).

1.1.3 Existing Surface Water Monitoring Program

There is no natural surface water supply in the LSMV MA; additionally, there is no imported water supply available to the LSMV MA.

1.1.4 Existing Groundwater Monitoring Programs

From spring of 2018 to the present, landowners in the LSMV have monitored groundwater levels biannually in 20 wells. Water produced from all active wells is comingled and delivered through a single meter at a delivery point in the McKittrick Oil Field. This water is blended with treated oil field-produced water for use generating steam. As a result, the LSMV MA has well production metering data for all 20 wells combined but has no data about individual wells.

1.1.5 LSMV MA Description

The LSMV MA is a perched alluvial valley located 2 miles southwest of the town of McKittrick, in Kern County, California. The LSMV MA is in the Temblor Range on the west side of the southern San Joaquin Valley and is isolated from the Central Valley proper. The U.S. Geological Survey classifies the geomorphic province for the LSMV MA as dissected uplands (Faunt, 2009). Natural vegetation consists primarily of native grasses; land use in the valley and surrounding hills, other than producing oil and gasoline, is limited to ranching and surface mining of diatomaceous earth.

The LSMV MA is distinct and separate from the adjacent Western MA due to its higher elevation, local groundwater source, concentration of active and idle groundwater wells, water chemistry, and apparent isolation from the lands immediately east in the San Joaquin Valley portion of the WKWD GSA area.[1]

[1] The Western MA is described in WKWD Chapter GSP Section 4.6.4.

1.1.6 Wells in the LSMV MA

Figure 1-2 shows the general location of wells in the LSMV MA by type (i.e., agricultural, domestic, and industrial). The only known uses for water wells in the LSMV MA are industrial for oil field steam, and agricultural for cattle water.

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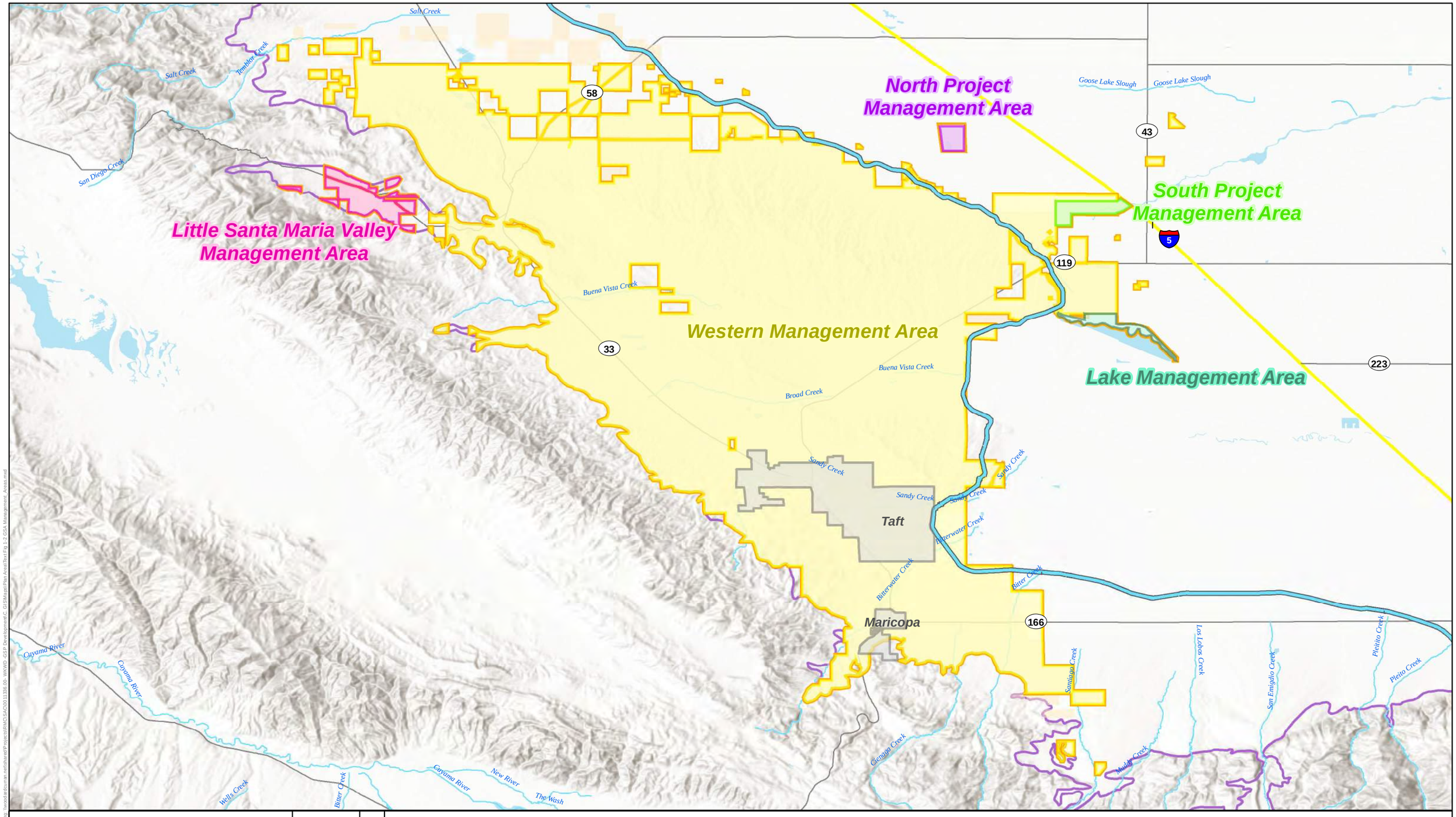


Figure 1-1: WKWD GSA MAs

West Kern Water District GSP

West Kern Water District Groundwater Sustainability Agency

December 2019

WOODARD &CURRAN

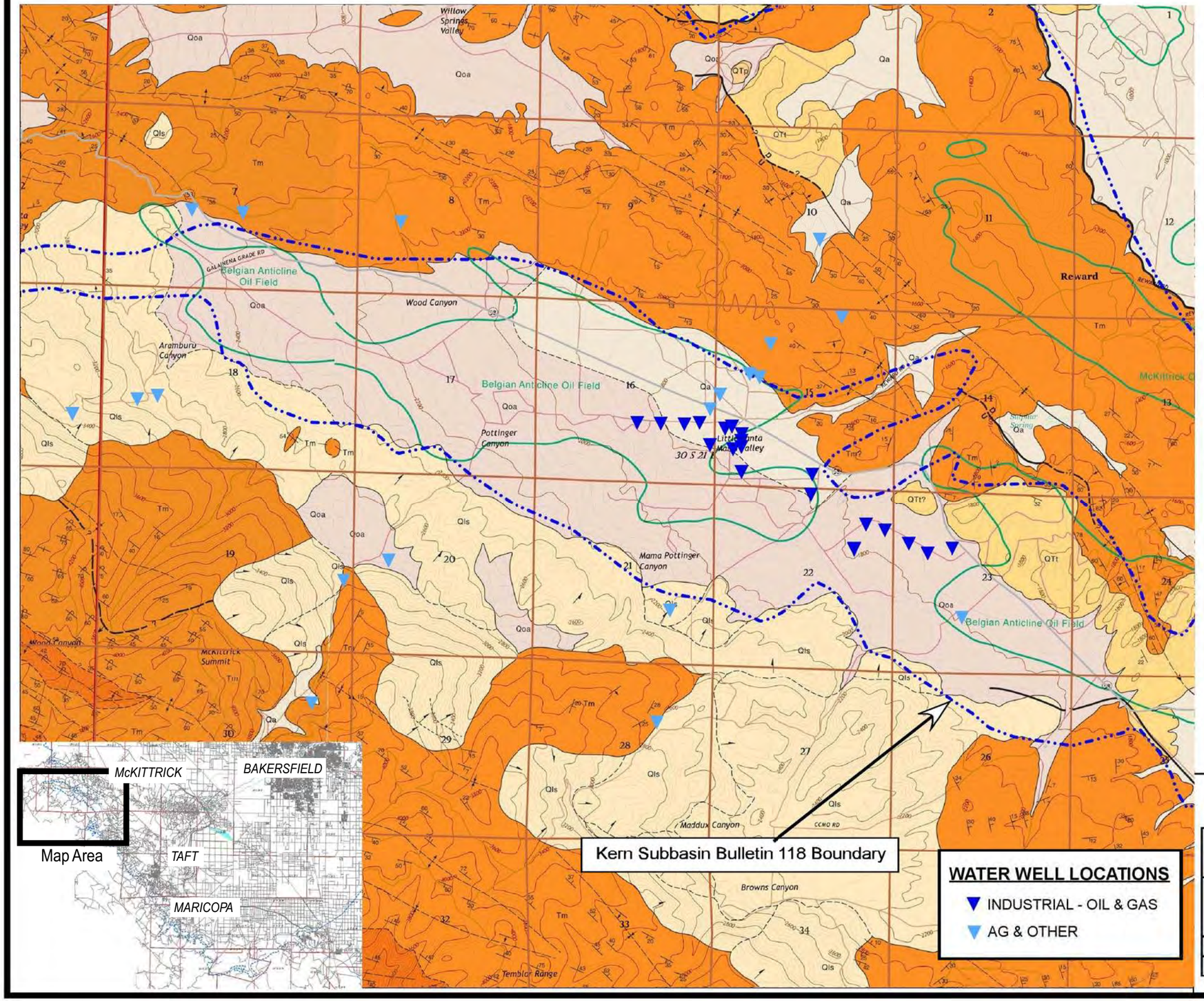
Legend

- WKWD GSA
- Kern County Subbasin
- Cities
- California Aqueduct
- Rivers/Streams
- North Project Management Area
- South Project Management Area
- Lake Management Area
- Western Management Area
- Little Santa Maria Valley Management Area

N

0 3 6 12 Miles

Figure Exported: 12/4/2019 By: cstapleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\001133600- WKWD -GSP Development\C- GIS\Maps\Plan Area\Text Fig 1-2 GSA Management Areas.mxd





LEGEND

Qa — SURFICIAL SEDIMENTS
Qa *Alluvial gravel and sand of valley issue*

Qls — LANDSLIDE RUBBLE
Qls *Landslide debris of cream white* **Tm** *debitus; merges into* **Qoa** *in western area.*

Qoa — OLDER SURFICIAL SEDIMENTS
Qoa *Dissected alluvial gravel in mostly* **Tm** *debitus*

UNCONFORMITY

QTt — TULARE FORMATION
Valley alluvial sediments, stream laid, weakly indurated;
age Pleistocene and possibly latest Pliocene
QTt *Gravel, sand and clay, light gray, pebbles almost entirely of Monterey Shale detritus; unconformity at base where in contact with* **Tm**

Te — ETCHEGOIN (?) FORMATION
Marine (?) clastic, weakly indurated; age Pliocene (?)
Te *Sandstone, light gray, medium grained, massive, friable, arkosic, locally impregnated with black tarry oil; about 30m thick at base of* **QTt**; *possibly injected (TH. Nilsen, oral comment)*

— UNCONFORMITY —

Tms / Tm / Tmg — MONTEREY SHALE
Marine, biogenic, lithified; age Miocene
Tmb *Buttridge Diatomite Member, white, soft, punky, faintly laminated, late Mohnian Stage, upper Miocene*
Tm *McLure Shale Member, siliceous shale, white weathered, thin bedded, platy; hard, commonly cherty; brittle, Mohnian Stage, upper Miocene; includes Antelope and McDonald shale in subsurface*
Tms *Sandstone, tan, semi-hard, arkosic; as lenses in* **Tm**
Tmg *Gould Shale Member, siliceous shale, semi-silicic shale and thin yellow dolomite beds; Luisian and Rezbian stages, middle Miocene*

Tts — TEMBLOR FORMATION
Marine clastic, moderately lithified; Saucesian-Zemorrian stages, lower Miocene-Oligocene
Tts *Sandstone, tan, massive, semi-hard, arkosic; base not exposed in quadrangle*
Tt *Grey clay shale, at southwest corner only.*

? ?	Holocene	QUATERNARY
? ?	Pliocene (?)	CENOZOIC
?	Miocene	TERTIARY
?	Oligocene	TERTIARY

1000 0 1000 2000 3000 4000 ft

LITTLE SANTA MARIA VALLEY
KERN COUNTY, CALIFORNIA

Figure 1-2
LSMV MA Well Locations

Authors: shl, bmh		Date: 29 November, 2019
	Scale: 1 in=3000 ft	

Section 2.0 Basin Settings: Hydrogeologic Conceptual Model

This section describes the LSMV MA's hydrogeologic conceptual model (HCM). The HCM provides a framework for understanding how water moves through the LSMV MA. The following GSP content for the LSMV MA is fully covered in the WKWD GSA's Chapter GSP:

- HCM definition
- Useful terms

2.1 Regional Geologic Features

As shown on Figure 2-1, the LSMV consists of alluvium deposited above an unconformity on the Tulare Formation or Miocene shales, and is roughly co-located with the Belgian Anticline oil field and is close to other major oil fields such as McKittrick and Midway-Sunset.

The LSMV is nearly surrounded by the Monterey Shale, which is water bearing only in fractures.

2.1.1 Regional Geologic and Structural Setting

The LSMV is a perched alluvial valley located 2 miles southwest of the town of McKittrick, in Kern County, California. The LSMV is in the Temblor Range and within the west side foldbelt that contains several oil fields, including the Belgian Anticline, McKittrick, and Midway-Sunset fields (Figure 2-1). Specifically, the LSMV MA water wells are located over portions of the Belgian Anticline oil field. The San Andreas Fault is approximately 4.5 miles to the southwest from the west end of the valley, and the McKittrick Thrust Fault is approximately 1 mile to the northeast from the east end of the valley.

The LSVM is approximately 7 miles long and 1.3 miles wide at its widest, and valley floor elevations range from 2,600 feet on the west end to 1,700 feet on the east. The surrounding hills have elevations ranging from over 4,000 feet in the west to approximately 1,800 feet in the east. The valley alluvium is bounded on the north and west by Miocene shales, to the south by Miocene shales and a series of landslides made up primarily of Miocene shale. To the east, where the valley narrows to approximately 1,700 feet, alluvium is bounded by the Plio-Pleistocene age Tulare Formation. Active oil wells are common in and around the valley, and in some cases are in close proximity to LSMV MA water wells.

2.1.2 Geologic History

The LSMV formed as the Temblor Range was uplifted and older rocks eroded. The foldbelt has been and continues to be tectonically active, and the result has been a variable stratigraphy (Bartow, 1991). In the LSMV area, a younger member of the Tulare Formation appears to be in contact with the underlying Miocene shales. The Pliocene marine formations present immediately to the east are missing, and Miocene shales are partially eroded. All of this suggests the valley was formed late, perhaps from the late Pleistocene to recent (Figure 2-2).

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LEGEND

Qa

SURFICIAL SEDIMENTS

Qa *Alluvial gravel and sand of valley areas*

Qls

LANDSLIDE RUBBLE

Qls *Landslide debis of cream white* **Tm** *detritus; merges into* **Qoa** *in western area*

Qoa

OLDER SURFICIAL SEDIMENTS

Qoa *Dissected alluvial gravel of mostly* **Tm** *detritus*

— *UNCONFORMITY* —

QTt

TULARE FORMATION

Valley alluvial sediments, stream laid, weakly indurated; age Pleistocene and possibly latest Pliocene

QTt *Gravel, sand and clay, light gray, pebbles almost entirely of Monterey Shale detritus: uncomformity at base where in contact with* **Tm**

Te

ETCHEGOIN (?) FORMATION

Marine (?) clastic, weakly indurated; age Pliocene (?)

Te *Sandstone, light gray, medium grained, massive, friable, arkosic, locally impregnated with black tarry oil; about 30m thick at base of* **QTt**: *possibly injected (T.H. Nilsen, oral commun)*

— *UNCONFORMITY* —

Tmb / Tm / Tms / Tmg

MONTEREY SHALE

Marine, biogenic, lithified; age Miocene

Tmb *Betridge Diatomite Member, white, soft, punky, faintly laminated, late Mohnian Stage, upper Miocene*

Tm *McLure Shale Member, siliceous shale, white weathered, thin bedded, platy, hard, commonly cherty, brittle; Mohnian Stage, upper Miocene; includes Antelope and McDonald shale in subsurface*

Tms *Sandstone, tan, semi-hard, arkosic; as lenses in* **Tm**

Tmg *Gould Shale Member, siliceous shale, semi-silicic shale and thin yellow dolomite beds. Luisian and Rezilian stages, middle Miocene*

Tts / Tt

TEMBLOR FORMATION

Marine clastic, moderately lithified; Saucesian-Zemorrian stages, lower Miocene-Oligocene

Tts *Sandstone, tan, massive, semi-hard, arkosic, base not exposed in quadrangle*

Tt *Grey clay shale, at southwest corner only*

CENOZOIC

QUATERNARY — Holocene; Pleistocene

TERTIARY — Pliocene; Miocene; Oligocene (?)

1461200 1471200 1481200 1491200 1501200 1511200 1521200

670000 660000 650000 640000 630000

Unnamed Folds

Little Santa Maria Valley

McKittrick Thrust Fault

San Andreas Fault

Recruit Pass Thrust

30 S 20 E

30 S 21 E

30 S 22 E

McKITTRICK

BAKERSFIELD

TAFT

MARICOPA

Map Area

1491200 1501200 1511200 1521200

Well Data Post

Figure 2-1: LSMV Geologic Map

Little Santa Maria Valley GSP

KERN COUNTY, CA

Scale = 1:36000

0 3000 6000 9000 ft

Coordinate System: California V 405 (NON-EXACT) EPSG: 26745
Horizontal Datum: North American Datum 1927 EPSG: 6267
Ellipsoid: Clarke 1866
X(Min,Max): 1439369.00 1531163.00
Y(Min,Max): 627023.00 681986.00
Latitude(Min,Max): 35.208592 35.383889
Longitude(Min,Max): -119.876809 -119.572445

Base Map

1/30/19 16:28:59

WNW

ESE

Along line of section, approximately 10.8 miles

A

A’

Landslide

Groundwater levels from Fall 2019 Survey

Recent Alluvium

Older Alluvium

Miocene Shales

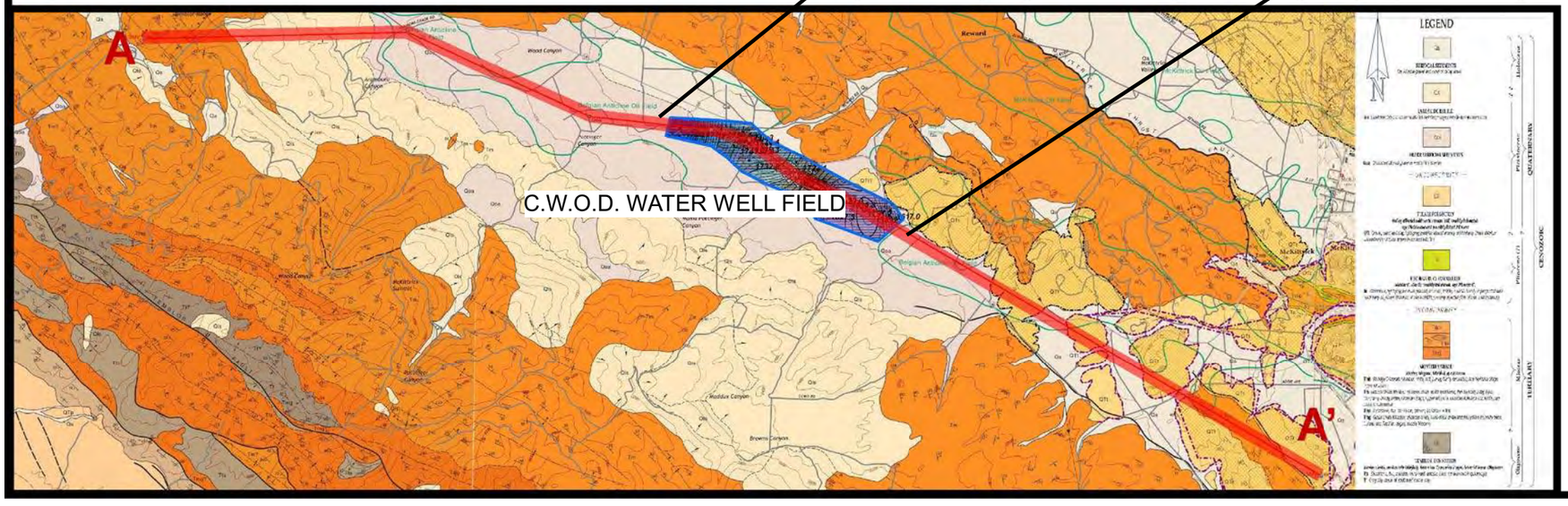
Tulare Fm?

Tulare Fm

Miocene Shales

Vertical Exaggeration 4:1

2000 ft



NOTE. Interpretation based upon e-logs from oil wells, water well depths, and surface geology. Exact depths to formation and alluvium contacts are estimated.

West Kern Water District GSP

Figure 2-2: Cross-Section A-A’

Little Santa Maria Valley
Kern County, CA

2.1.3 Geologic Formations/Stratigraphy

This section describes geologic formations and stratigraphy in the LSMV MA.

Stratigraphy

Formations in outcrop are Miocene and Plio-Pleistocene and younger in age. At the east end of the LSMV, the non-marine Tulare Formation sits unconformably on the marine Miocene Monterey Formation. Missing either by erosion or non-deposition are the intervening marine and marginal marine Pliocene strata commonly observed in the surface and subsurface immediately to the east, and the Etchegoin and San Joaquin formations. Figure 2-1 shows a stratigraphic column in the map legend. Figure 2-2 shows a cross section through the length of the LSMV. The figure also shows that alluvium in the LSMV is separated from the rest of the Kern County Subbasin by the Tulare Formation, and indicates alluvium and Tulare Formation depths.

Alluvial and Colluvial Deposits

The hills surrounding the LSMV are formed by landslides of Miocene shale material. Recent soil boring samples obtained from valley fill (Attachment 1) contain material that appears to be derived from the same Miocene sources, though further petrographic work is needed to confirm provenance.

Tulare Formation (East End of LSMV)

The east end of the LSMV is bounded by the Tulare Formation. In McKittrick Field (Township 30 south, Range 22 east, Section 20) approximately 4 miles to the east, two separate members (i.e., Main or Upper Tulare and Amnicola) have been identified and are oil producing. In the broader area, the Main or Upper Tulare consists primarily of debris-flow deposits, and the Amnicola is a fine-grained, clay-rich lacustrine deposit with a characteristic fossil assemblage (Miller, 1999). The facies of the Tulare Formation in the immediate vicinity of the LSMV need to be determined, but it appears perhaps some of the Upper and all of the Amnicola are missing (Nielsen and Campbell, 1996).

Miocene Marine Shales

The Miocene Monterey Formation is present both at the surface and in the subsurface in the LSMV. In the subsurface, four members have been identified, but a siliceous member is present at the surface around the LSMV and exhibits extensive natural fractures.

2.1.4 Faults and Structural Features

The LSMV MA contains a number of tectonic features already described in the WKWD Chapter GSP, and locally significant features are discussed below.

Synclines and Anticlines

The LSMV is located in the Temblor Range and within the foldbelt that contains several multiple anticlines, many of which define oil fields. Specifically, the LSMV water wells are located over portions of the Belgian Anticline Oil Field (Figure 2-1).

Major Faults

Faulting in LSMV alluvium itself is not observed, though faulting exists in the deeper formations (Division of Oil, Gas, and Geothermal Resources, 1998). Several major faults can be seen in the region on Figure 2-1, including the San Andreas and Temblor faults (strike-slip), the McKittrick Thrust, and the Recruit Pass Faults (Thrusts), as well as numerous unnamed folds. The LSMV is positioned in a structurally complex area.

Outcrops of Bedrock Inside the GSA Area

Bedrock and relatively impermeable or very poorly permeable formations that are excluded from the groundwater basin (i.e., Miocene shales and in some cases Tulare Formation) are included in the Kern Subbasin, which is at the eastern limit of the LSMV. Figure 2-2 shows that, within the GSA area of the LSMV, bedrock does not outcrop at the surface.

2.2 Basin Boundaries

2.2.1 Lateral Boundaries

As defined in Appendix G of *Bulletin 118–Update 2003, California's Groundwater* (DWR, 2003), the Kern Subbasin boundary wraps around the LSMV, roughly approximating the contact between the valley alluvium and the Miocene shales and landslides of the surrounding hills of the Temblor Range. These formations form the LSMV boundary.

2.2.2 Boundaries with Neighboring Subbasins

There are no neighboring basin boundaries in immediate contact with the LSMV. The LSMV is adjacent to uplands that are not part of the groundwater basin. Despite its elevation, isolation, and likely water source, the LSMV is presently a part of the Kern Subbasin.

2.2.3 Bottom of the Subbasin in the GSA Area

The bottom of the subbasin is formed by the same formation that forms the primary lateral boundary, the Miocene Monterey Formation. The depth to bottom was estimated by review of local well construction depths and oil well logs, which indicate that depth to Miocene shales is likely less than 500 feet bgs at its deepest. The bottom of the basin is shown in the cross section prepared from the northwest to the south east in Figure 2-2.

2.2.4 Additional Basin Boundary Information

WKWD intends to reapply for a basin boundary modification (BBM) to separate the LSMV from the Kern Subbasin. Prior to application, WKWD will further investigate the LSMV's unique characteristics to determine whether criteria for separation can be met.

2.3 Principal Aquifers and Aquitards

The only principal aquifer in the LSMV is the Quaternary alluvium in the center and lower portions of the valley. Its properties have not been determined. Within the alluvium, aquitards have not been defined or mapped.

2.3.1 Aquifers

Geologic maps of the surrounding hills indicate most of the southern boundary is formed by landslides of Miocene shale material. Recent soil boring samples obtained from valley fill (Attachment 1) contain material that appears to be derived from the same Miocene sources, though further petrographic work is needed to confirm provenance. The LSMV is bounded by marine shales, and it's proximity to the shales, along with the large amount of recent uplift suggest that most of the valley sediments are also locally derived. The soil boring descriptions note the prevalence of diatomite, diatomaceous clasts, and siliceous shale clasts in the gravels, sands and silts (Attachment 1). Groundwater was also encountered when advancing these soil borings.

2.3.2 Aquitards

Clay layers were noted in the soil boring descriptions, and their areal extent is unknown at this time. Water level monitoring indicates that there is no separate confined aquifer, as all monitored wells respond similarly in the LSMV in the monitoring record.

2.3.3 Aquifer Properties

Aquifer properties are not known at this time.

2.3.4 Natural Water Quality Characterization

Figure 2-3 shows general inorganic water chemistry analysis results from a single sample of the comingled water production described in Section 1.1.4. The sample was taken at the point of delivery. Analysis results indicate total dissolved solids (TDS) are 1,800 milligrams per liter (mg/L) with elevated sulfates at 560 mg/L. These results are typical of the fresh water produced on the west side of Kern County, and are distinct from water quality in the Kern Subbasin proper (Gillespie, 2017). These high TDS and sulphates are also typical of naturally occurring conditions in groundwaters that originate from marine units such as the Monterey Shale.

2.3.5 Topography, Surface Water, and Recharge Information

This section discusses the LSMV MA's topography, the absence of surface water, and recharge information.

Topography

The LSMV sits in a shallow basin surrounded by low-relief rolling hills. In general, the topography slopes east-southeast toward the San Joaquin Valley. The LSVM is approximately 7 miles long and 1.3 miles wide at its widest, and valley floor elevations range from 2,600 feet on the west end to 1,700 feet on the east. The surrounding hills have elevations from over 4,000 feet to the west to approximately 1,800 feet to the east.

Surface Water Bodies

The only streams that cross the LSMV are ephemeral (Figure 2-4).

Groundwater Discharge, and Areas of Recharge and Potential Recharge

It is not known to what degree discharge, if any, occurs to the east within the alluvium. The Tulare Formation, which is present on the eastern limit of the valley, may form a barrier to flow, effectively preventing discharge. Surface discharge occurs in an ephemeral stream located along Reward Road as indicated on aerial images where green vegetation follows the stream course. Green vegetation does not occur beyond the immediate vicinity of the stream bed (Figure 2-5).

Ephemeral streams exist in and around the perimeter of the LSMV, and during rare heavy rain events, limited surface groundwater replenishment may occur. The most likely source of recharge is through the naturally fractured shales that underlie and are in contact with the LSMV aquifer. In California south of the Diablo Range, precipitation on the west side of the San Joaquin Valley does not make significant contributions to usable groundwater (Davis and Coplen, 1989). Studies completed for other agencies also demonstrate the improbability of rain contributing to groundwater due to high potential evapotranspiration versus precipitation in the (Provost & Pritchard, 2015; Provost & Pritchard, 2018).

Based on this information, water is most likely recharged to the alluvium in the LSMV from mountain front recharge through fractured flow from marine shale surrounding the valley.

Soils

A soils map is in the WKWD Chapter GSP as Figure 2-6.

NALCO Champion

An Ecolab Company

Water Analysis Report

Attention: **Don Maxwell**

Customer: **E & B Nat Resources (1507098)**

Location Code: **111644**
Sample ID: **AA87869**
Batch ID: **2013-10-30_MFA_SW**
Collection Date: **10/21/2013**
Receive Date: **10/30/2013**
Report Date: **11/05/2013**

Region: **Abu-Pacific**
Location: **CWOD Lease**
System: **Production System**
Equipment: **Fresh Water Tank**
Lab ID: **ABU-1031**
Sample Point: **Fresh Water Tank Outlet**

Analyses	Result	Unit
Dissolved CO2	**17.6**	mg/L
Dissolved H2S	**0**	mg/L
Oxygen	**200**	ppb
pH	**7**	
Pressure	**100**	psi
Temperature	**88**	° F

Analyses	Result	Unit
Ionic Strength	**0.02**	
Resistivity	**3.409**	ohms - m
Total Dissolved Solids	**1880.278**	mg/L
Conductivity	**2933**	µS - cm3
Specfic Gravity	**1.005**	
Bicarbonate	**439**	mg/L

Cations	Result	Unit
Iron	**3.093**	mg/L
Manganese	**0.341**	mg/L
Barium	**0.021**	mg/L
Strontium	**0.753**	mg/L
Calcium	**88.05**	mg/L
Magnesium	**44.79**	mg/L
Sodium	**441.23**	mg/L

Anions	Result	Unit
CHLORIDE	**303**	mg/L
SULFATE	**560**	mg/L

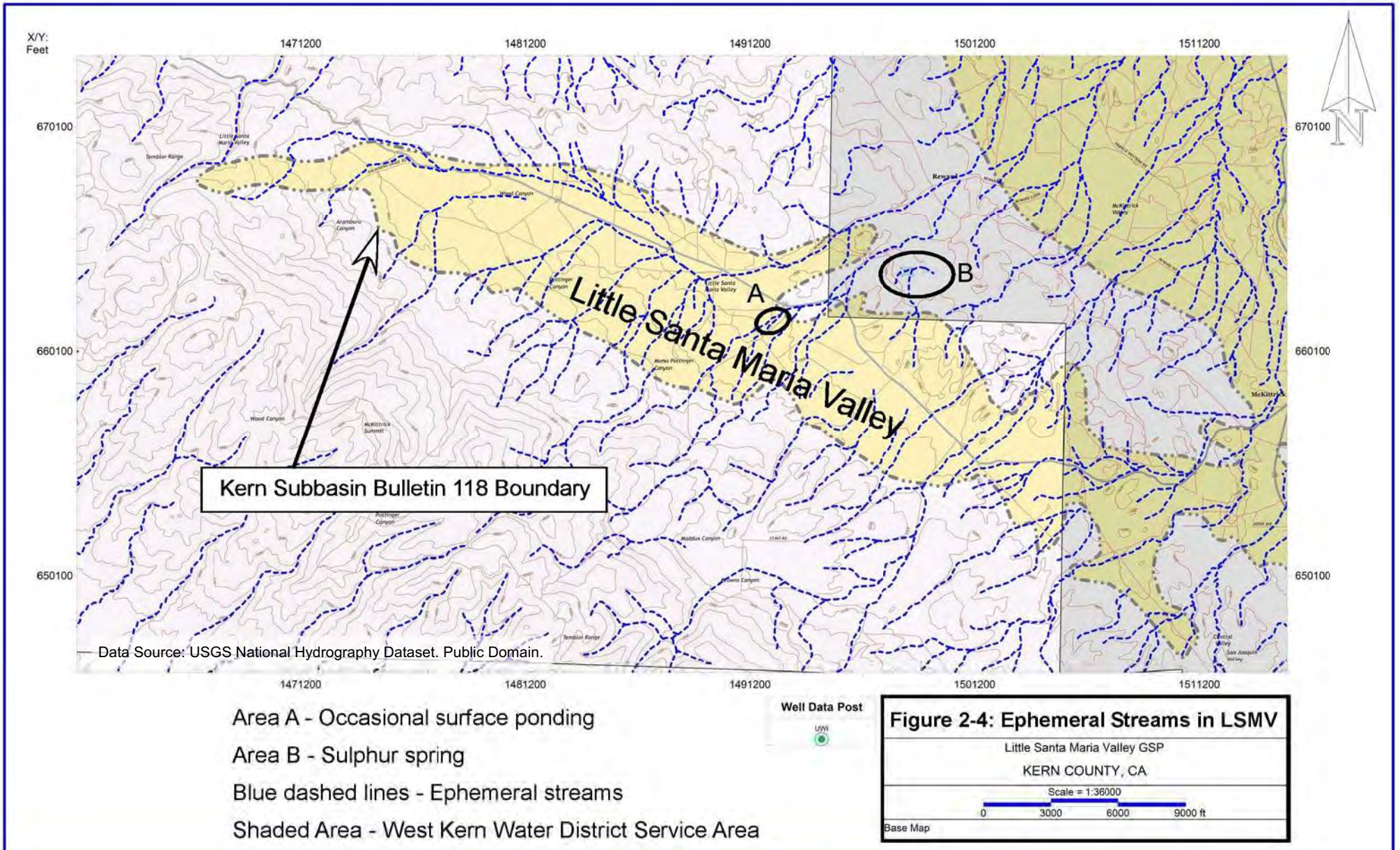
Scale Type	Result
Anhydrite CaSO4 SI	**-1.95**
Barite BaSO4 SI	**-0.07**
Calcite CaCO3 SI	**-0.13**
Celestite SrSO4 SI	**-1.54**
Gypsum CaSO4 SI	**-1.69**
Hemihydrate CaSO4 SI	**-1.45**

Saturation Index Calculation (Tomson-Oddo Model)

Comments:

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Figure 2-3. LSMV MA Groundwater Quality Monitoring Results


X/Y:
Feet
1471200
1481200
1491200
1501200
1511200
670100
660100
650100
Little Santa Maria Valley
A
B
Kern Subbasin Bulletin 118 Boundary
Data Source: USGS National Hydrography Dataset. Public Domain.
Area A - Occasional surface ponding
Area B - Sulphur spring
Blue dashed lines - Ephemeral streams
Shaded Area - West Kern Water District Service Area
Well Data Post
UWI
Figure 2-4: Ephemeral Streams in LSMV
Little Santa Maria Valley GSP
KERN COUNTY, CA
Scale = 1:36000
0
3000
6000
9000 ft
Base Map

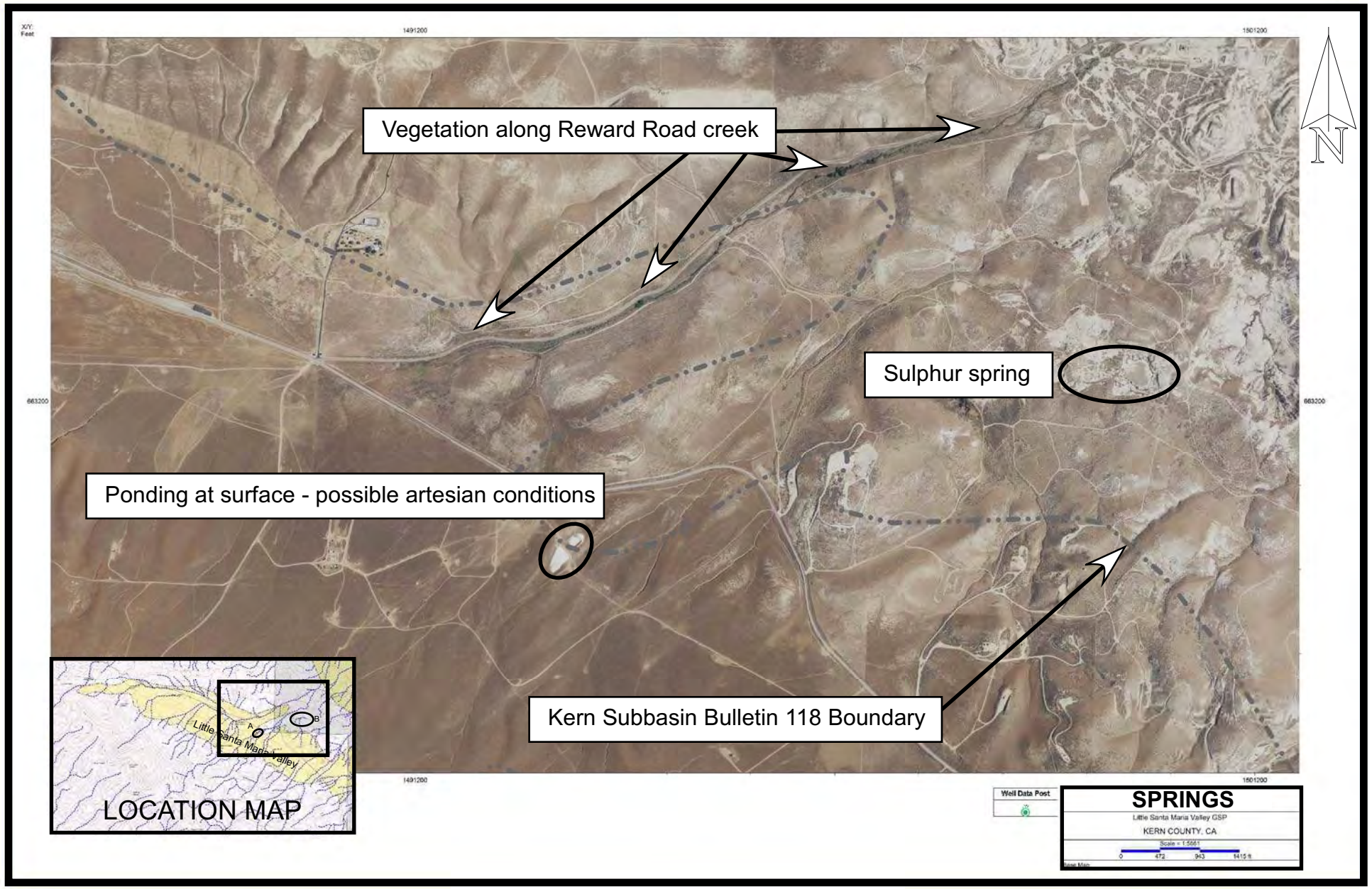


Figure 2-5. LSMV Springs and Discharge Locations

2.4 Hydrogeologic Conceptual Model Data Gaps

HCM data gaps are related to the nature of the LSMV's isolation from the Kern Subbasin. Further study should include investigating the following:

- Presence of concealed faults
- Transmissivity or lack of transmissivity in the Tulare Formation on the east end of the LSMV
- Physical relationship between alluvium and fractured Miocene shales
- More thorough characterization of water quality and source

Section 3.0 Basin Settings: Groundwater Conditions

This section describes the LSMV MA's groundwater conditions. Groundwater conditions information describe the trends, gradients, and movement of groundwater in the LSMV MA.

3.1 Groundwater Trends

This section discusses groundwater condition trends in the LSMV MA.

General Groundwater Elevation Hydrographs

Routine water level measurements have been made since spring of 2018 in LSMV MA water wells owned by local landowners. Hydrographs based on the last two years of data show water elevations averaging approximately 1,744 feet in the westerly upper portion of the LSMV MA and 1,627 feet in the easterly lower portion. Figure 3-1 shows the locations of monitoring wells. Figure 3-2 is a combined hydrograph showing all 20 wells monitored. In general, the hydrographs show limited change in elevation over the monitoring period of spring 2018 through fall 2019, as the groundwater elevation in some wells increased by up to 2 feet, and some decreased by as much as 3 feet.

Vertical Gradients

Vertical gradients are not known in the LSMV MA and are a data gap.

Groundwater Elevation Contour Maps

Figure 3-3 (spring 2019) and Figure 3-4 (fall 2019) show water level contours. Figure 3-3 shows that in the spring groundwater levels typically match topography in the LSMV MA, are higher in the west and lower in the east, and generally flatten out toward the eastern end of the monitored area. Figure 3-4 shows that in the fall groundwater elevations are similar in pattern to spring conditions, indicating that pumping in the LSMV MA did not have a seasonal effect on groundwater movement in 2019.

3.2 Historical Change in Storage

Figure 3-5 shows the 2019 change in water levels. Since monitoring began in spring of 2018, no earlier data are available. Figure 3-5 shows that groundwater levels changed slightly from spring to fall, with the majority of the monitored area increasing to over 2 feet in the central/north portion. The western portion of the monitored area also saw increases in elevation to over 1 foot. A small area in the northern portion of the LSMV saw slightly over 1 foot of decline during this period. Increased groundwater elevations in the vicinity of the Monterey Shale (orange on Figure 3-5) indicate that mountain front recharge may be occurring in the north/central portion of the area.

3.3 Groundwater Quality

The only known groundwater quality information available for the LSMV MA is discussed in Section 2.1.9, and is shown in Figure 2-3.

3.4 Land Subsidence

Land subsidence has not been monitored in the LSMV MA, and no data available.

3.5 Interconnected Surface Water Systems

Figure 2-4 shows that the only surface water in the LSMV MA is ephemeral streams, which dry up within days of rainfall; therefore, there is no connectivity between groundwater and surface water in the area.

3.6 Groundwater Dependent Ecosystems

There are no known groundwater dependent ecosystems in the LSMV MA. The Natural Communities Commonly Associated with Groundwater (NCCAG) dataset provided by DWR shows that there are two areas identified as potential wetlands in the LSMV MA. Aerial imagery reveals that the two locations indicated by NCCAG are not wetlands, and are similar to nearby areas. Therefore, there are no groundwater dependent ecosystems in the LSMV MA (Figure 3-6).

3.6.1 Data Gaps

Because no well monitoring was conducted prior to 2018, conditions in the LSMV MA prior to 2018 are unknown, and the LSMV MA's response to drought conditions is not known. Wells with vertically varying monitoring depths in close proximity are not available; as a result, the vertical gradient is not known. Additionally, land subsidence has not been monitored in the LSMV MA.

Because the LSMV MA is small in relation to the WKWD GSA's other MAs, the WKWD GSA does not plan to fill these data gaps. Measured conditions do not indicate overdraft in the LSMV MA, and groundwater production is limited in quantity. If additional monitoring becomes necessary due to changes in groundwater elevation in the future, WKWD GSA will evaluate an approach to fill these data gaps.

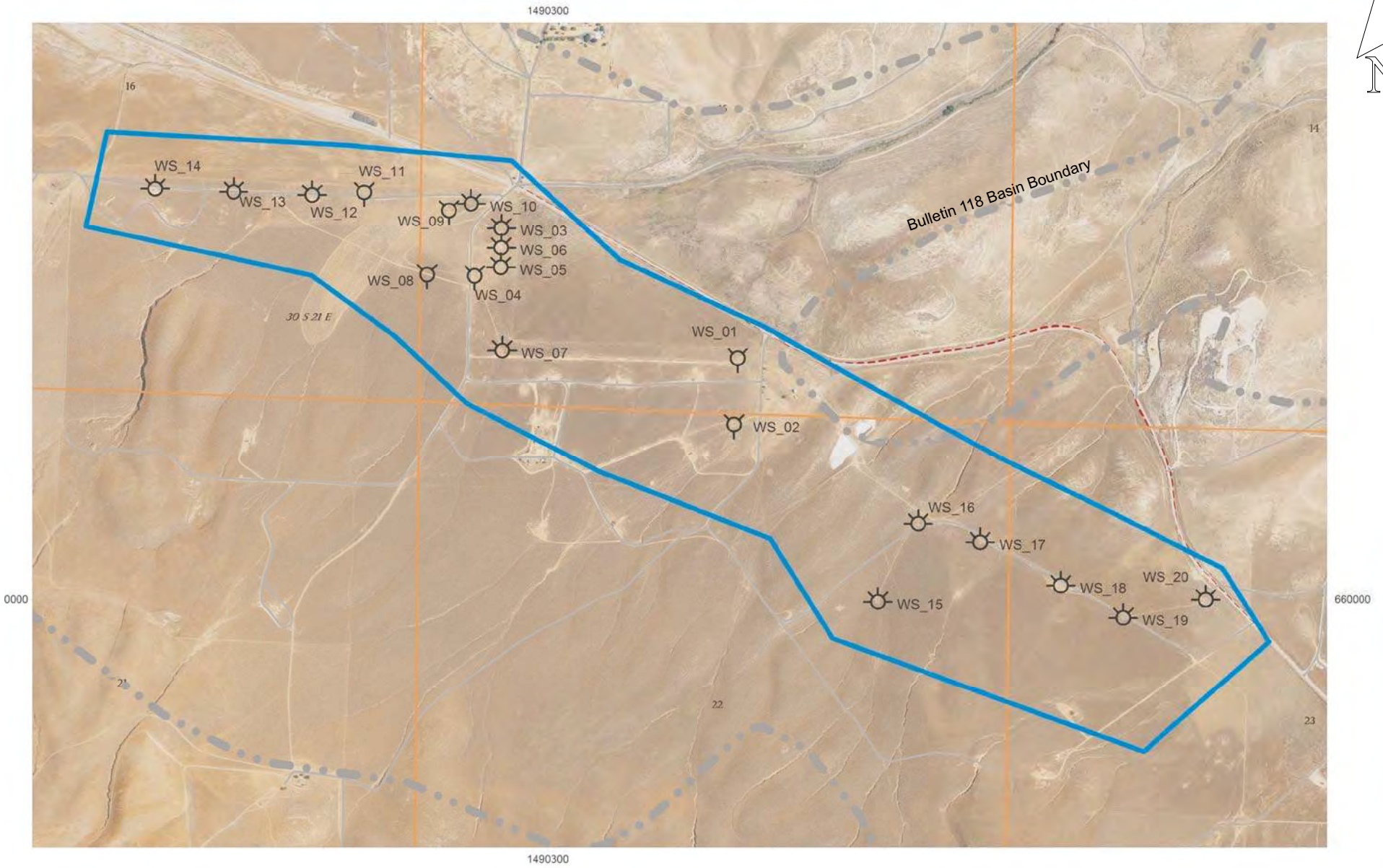


Figure 3-1. LSMV MA Monitoring Well Locations and Hydrographs

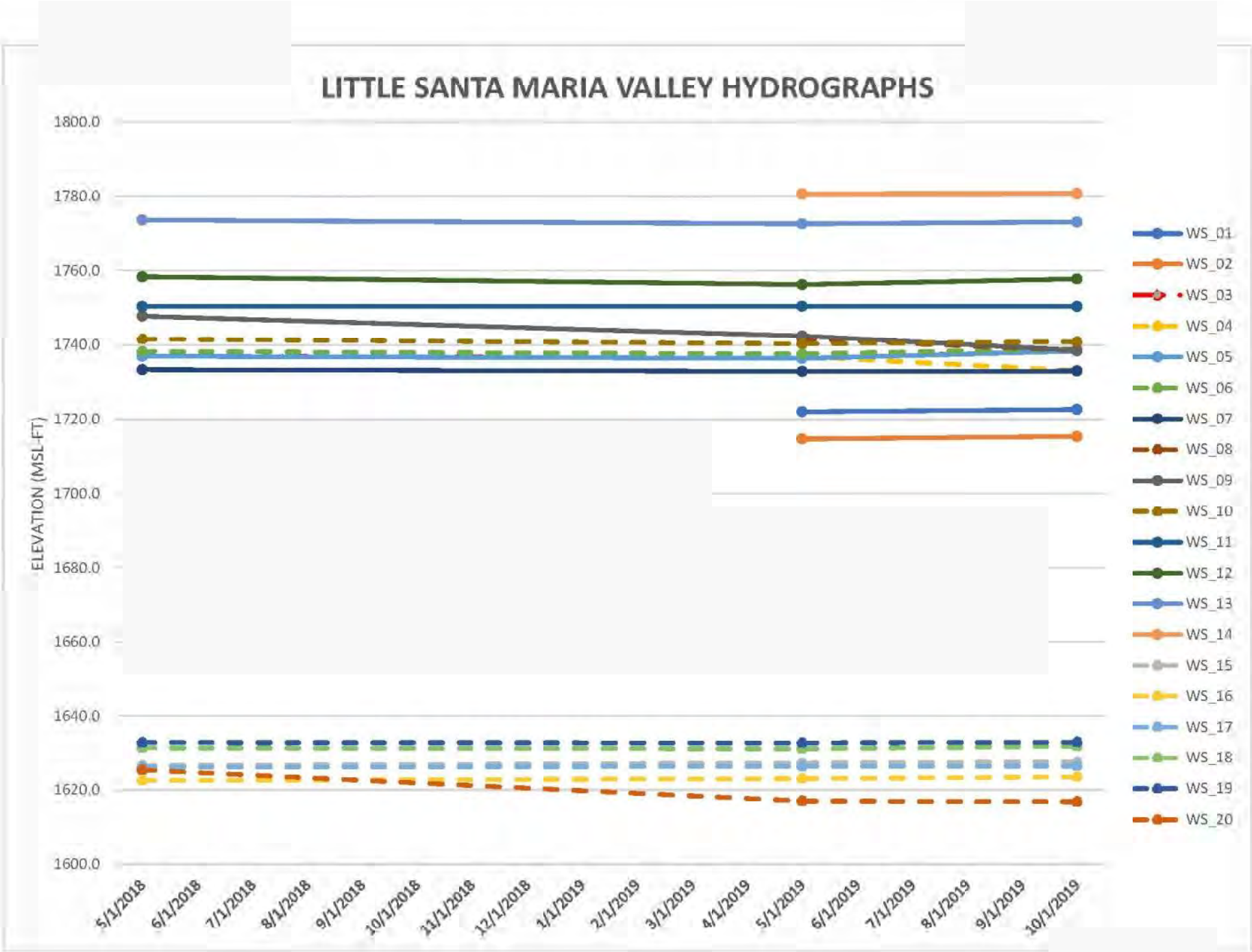


Figure 3-2. LSMV MA Combined Hydrographs

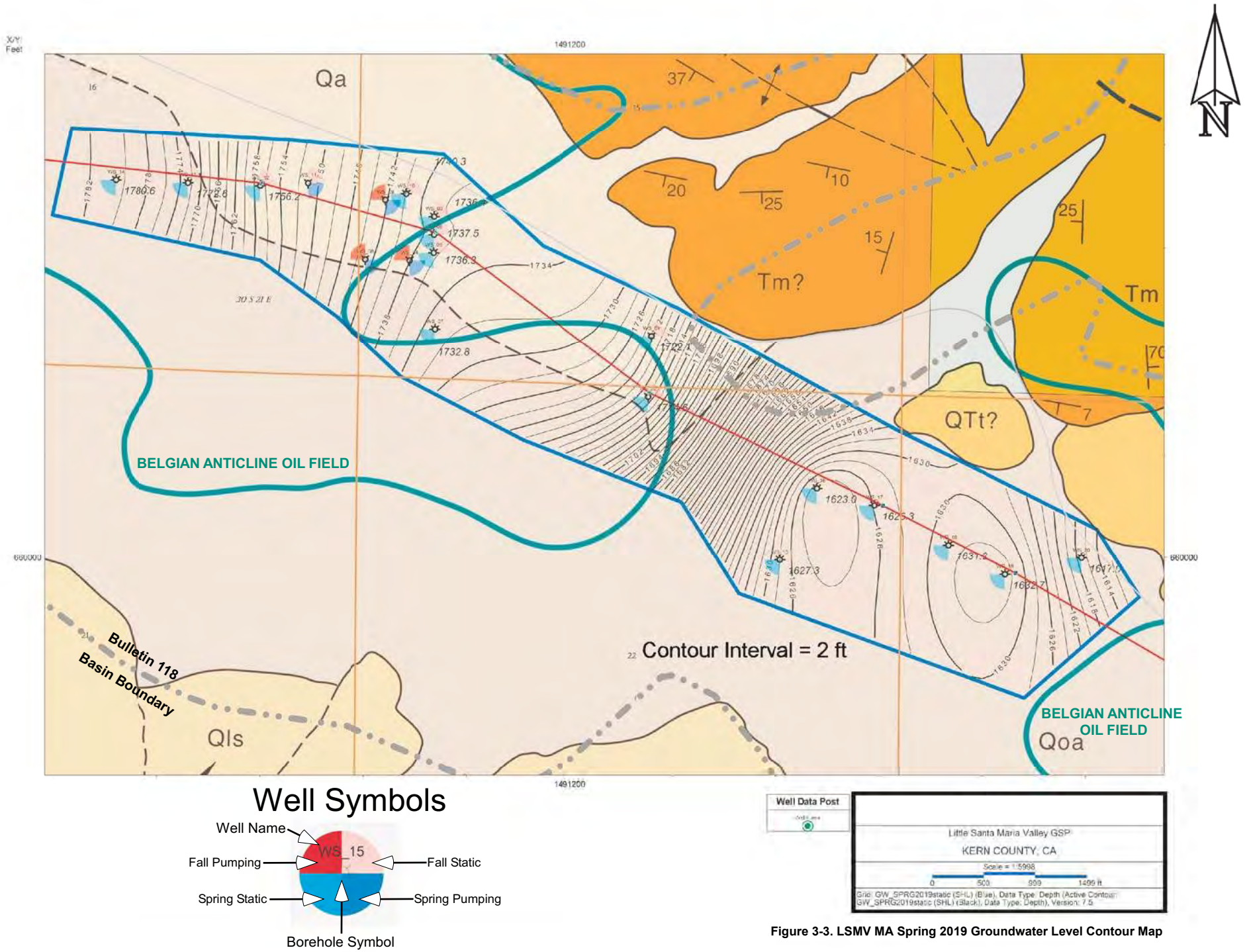


Figure 3-3. LSMV MA Spring 2019 Groundwater Level Contour Map

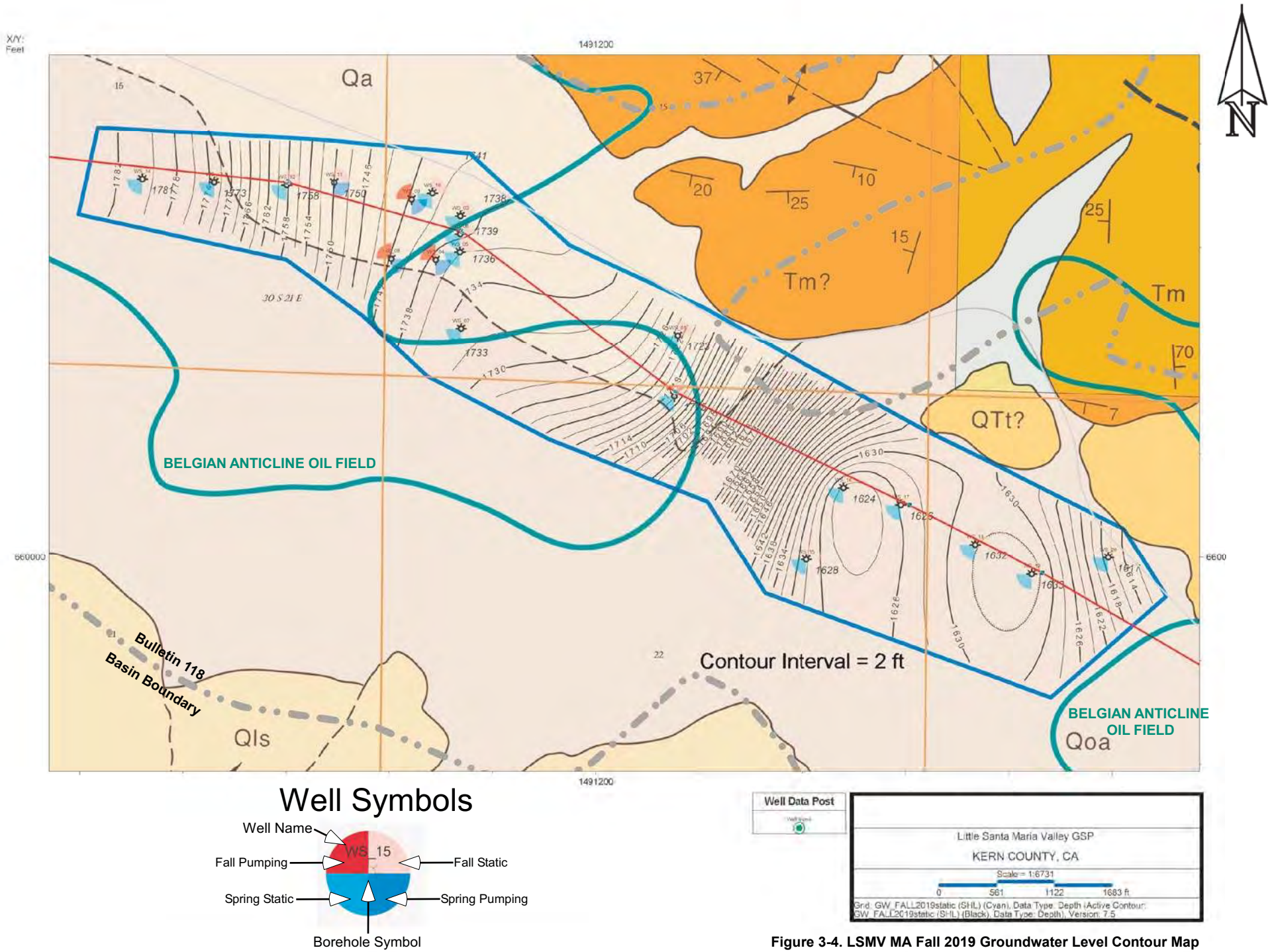


Figure 3-4. LSMV MA Fall 2019 Groundwater Level Contour Map

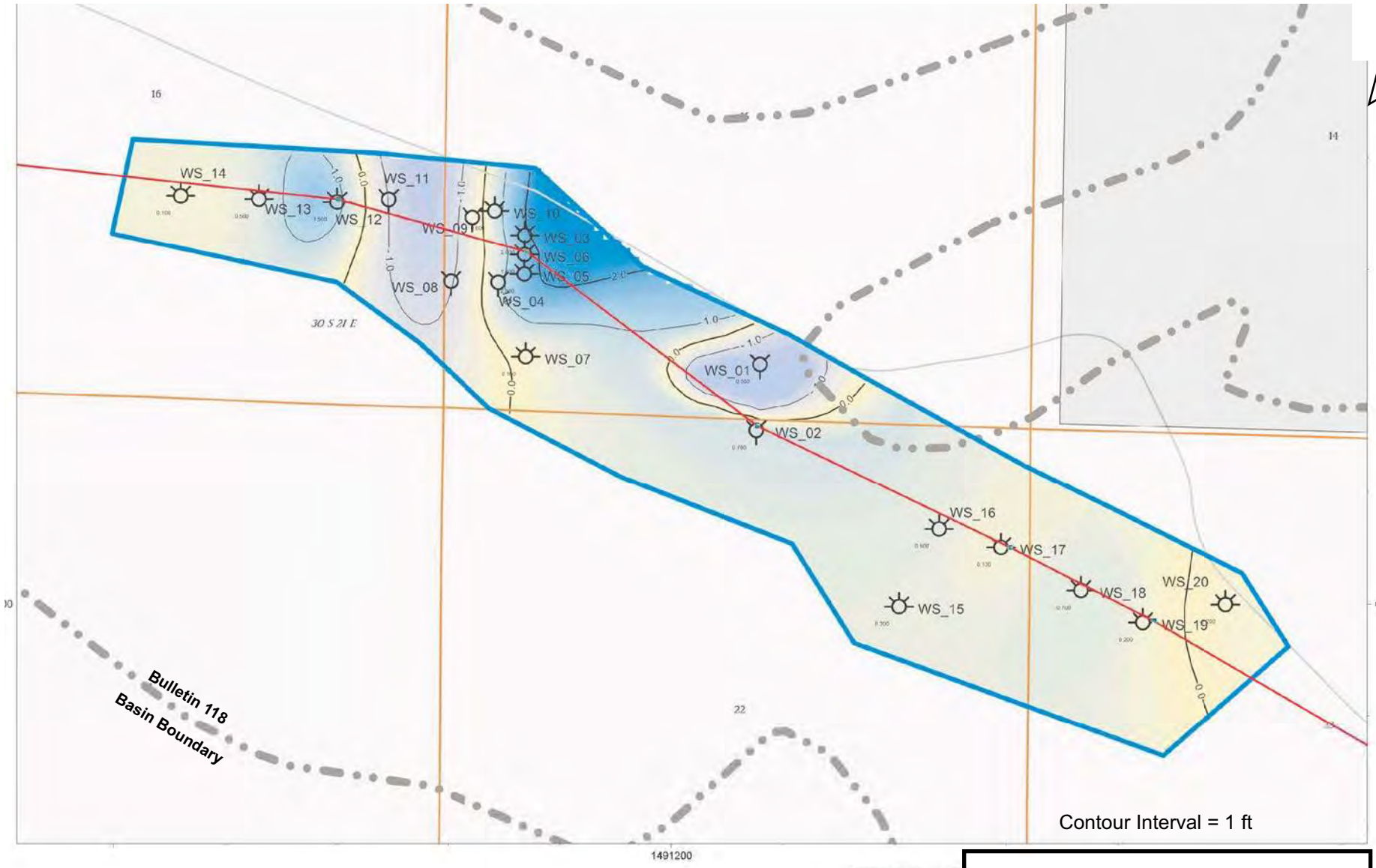


Figure 3-5. LSMV MA Change in Groundwater Levels, Spring 2019 to Fall 2019

Little Santa Maria Valley GSP

KERN COUNTY, CA

Scale = 1:7200

0 600 1200 1800 ft

Grid: 2019ChangeCont2Grid3 (SHL) (Red), Data Type: Depth (Active Contour: 2019ChangeCont2Grid3 (SHL) (Black), Data Type: Depth), Version: 7.5

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0 50 100 200 300 400 Feet

0 125 250 500 750 1,000 Feet

0 0.5 1 2 Miles

58

N

Figure 3-6: West Kern GW Basin
Little Santa Maria Valley Appendix

West Kern Water District GSP

West Kern Water District Groundwater Sustainbility Agency

December 2019

WOODARD &CURRAN

Legend

- WKWDGSA
- Kern County Subbasin
- Little Santa Maria Valley Management Area
- Western Management Area
- Rivers/Streams
- NCCAG Potential Wetlands
- NCCAG Potential Vegetation

Figure Exported: 12/10/2019 By: cstgibbon Using: \\woodardcurran.net\shared\Projects\BMC\SAC\011336.00 WKWD -GSP Development\C. GIS\Maps\L SMV\Figure3-6_.mxd

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Section 4.0 Water Budget

This section describes the LSMV MA's water budget. The water budget provides an understanding of water supply and use in the LSMV MA.

4.1.1 LSMV MA Historical Water Budget Estimates

The LSMV MA is hydrologically separate from the majority of the Kern County Subbasin. Because of this separation, the water budget for the LSMV MA cannot be extracted from the Kern Delta GSA's groundwater modeling efforts, which are used across the majority of the basin. A single water budget estimate for 2019 has been prepared for the LSMV MA due to the limited data collected, the small amount of water produced, limited recharge from precipitation, and unmeasurable mountain front recharge.

The 2019 water budget estimate for the LSMV MA is based on the following two measurements and calculations:

- Metered pumping from LSMV MA in 2019
- Estimated change of storage from spring to fall 2019

Figure 4-1 shows the locations of metered pumping from the 20 wells in use by local landowners. Figure 4-1 also shows that pumping averaged 20 acre-feet per month in 2016, and 10 acre-feet per month from 2017 to 2019. This indicates that current groundwater extraction in the LSMV MA is 120 acre-feet per year.

To complete the water budget, an estimate change of storage from spring to fall of 2019 was prepared. A volumetric calculation was performed based on the change in groundwater elevation shown in Figure 3-5. The volume of 140 acre-feet in aquifer space was multiplied by a specific yield of 0.08 to estimate that an approximately 10 acre-foot increase in water in storage was added to the LSMV MA from spring to fall of 2019.

Metered pumping averaged 120 acre-feet in 2019, and the estimated change in groundwater storage was 10 acre-feet from spring to fall 2019, indicating that pumping by landowners in the LSMV MA is sustainable. Continued monitoring and an expanded water budget will be needed for the 2025 GSP update to fill data gaps around projected water budgets.

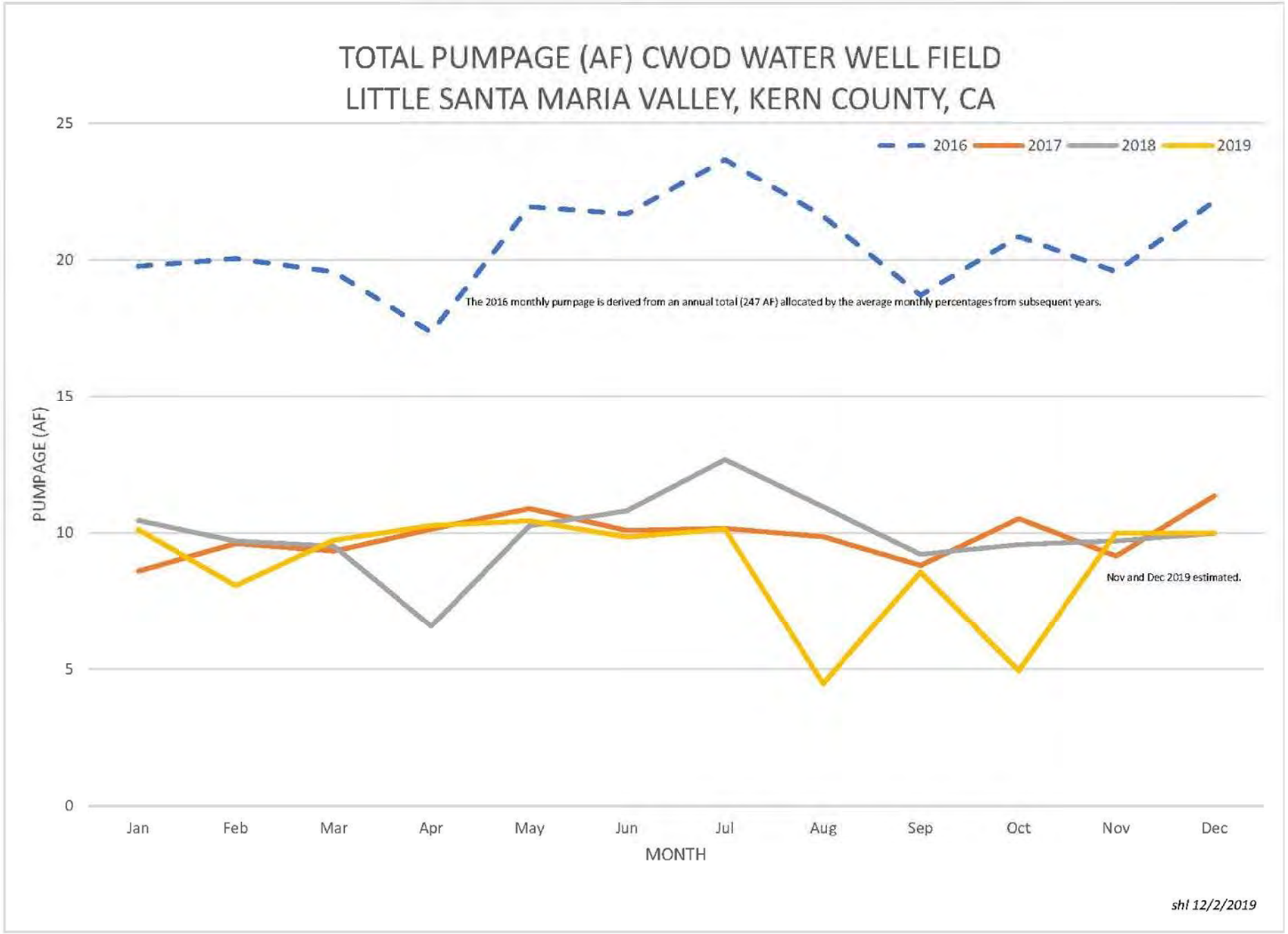


Figure 4-1. LSMV MA Well Field Pumping

Section 5.0 Undesirable Results Statements

Undesirable results were agreed to at the Kern County Subbasin level, and are included in both the Kern Groundwater Authority's Umbrella GSP, and WKWD GSA's Chapter GSP.

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Section 6.0 Monitoring Networks

This section describes the monitoring networks used in the LSMV MA. This section includes information about the objectives, rationales, and protocols used in the monitoring networks. This section also addresses how the GSP will monitor for the six sustainability indicators. The following GSP content for the LSMV MA is fully covered in the WKWD GSA's Chapter GSP:

- Monitoring network objectives
- Monitoring rationales
- Monitoring protocols

6.1 Groundwater Level Monitoring Network

Groundwater level monitoring is conducted through a groundwater well monitoring network. This section describes the following:

- How the level monitoring network was developed
- Criteria for selecting representative wells
- Monitoring frequency
- Spatial density
- Monitoring protocols
- Data gap identification and strategies to fill data gaps

6.1.1 Monitoring Wells Selected for Monitoring Network

The LSMV MA monitoring network includes almost all of the existing wells in LSMV MA. There are 25 known wells in LSMV, 20 of which are monitored by oil and gas industries and 5 of which are used for animal stock watering. Given the low number of wells in the area, there is limited spatial distribution and observation history; however, since 80 percent of the wells in the LSMV MA are monitored for level, data density is sufficient in the LSMV MA. All 20 monitored wells were selected for the monitoring network. Figure 6-1 shows the wells' locations.

6.1.2 Monitoring Frequency

Section 6.6.3 in the WKWD Chapter GSP describes the DWR best management practices for monitoring frequency. The Kern Groundwater Authority's Umbrella GSP requires Chapter GSPs to report monitoring twice per year: one round taken at a time from January 15 through March 30, and one round taken at a time from September 15 to November 15. More information about monitoring frequency is provided in the Umbrella GSP. To comply with GSP requirements, and to provide additional data for GSA planning and monitoring purposes, local landowners on behalf of the WKWD are committed to collecting groundwater level data biannually. This monitoring frequency will capture seasonal and long-term trends in groundwater levels.

6.1.3 Spatial Density

Section 6.6.4 in the WKWD Chapter GSP describes the DWR best management practices for spatial density of groundwater level monitoring networks. Of the recommended monitoring well densities in Table 6-3 of the WKWD Chapter GSP, the maximum density is 10 wells per 100 square miles. The LSMV MA itself is 3.05 square miles in size and has 20 monitoring wells, doubling the number of required wells for only one-twentieth of the area. Spatial density of the LSMV MA monitoring network exceeds minimum recommendations.

6.1.4 Representative Groundwater Level Monitoring Network

The LSMV MA groundwater level monitoring network consists of 20 wells, all of which are considered representative wells (Figure 6-1). Table 6-1 lists the wells in the groundwater level monitoring network and summarizes their construction information, their first and last measurement date, and other associated metadata.

The combination of monitoring well density and measurement frequency will provide useful information for determining flow directions, hydraulic gradients, and change in storage calculations. This information will be used in future water budgeting efforts for the LSMV MA.

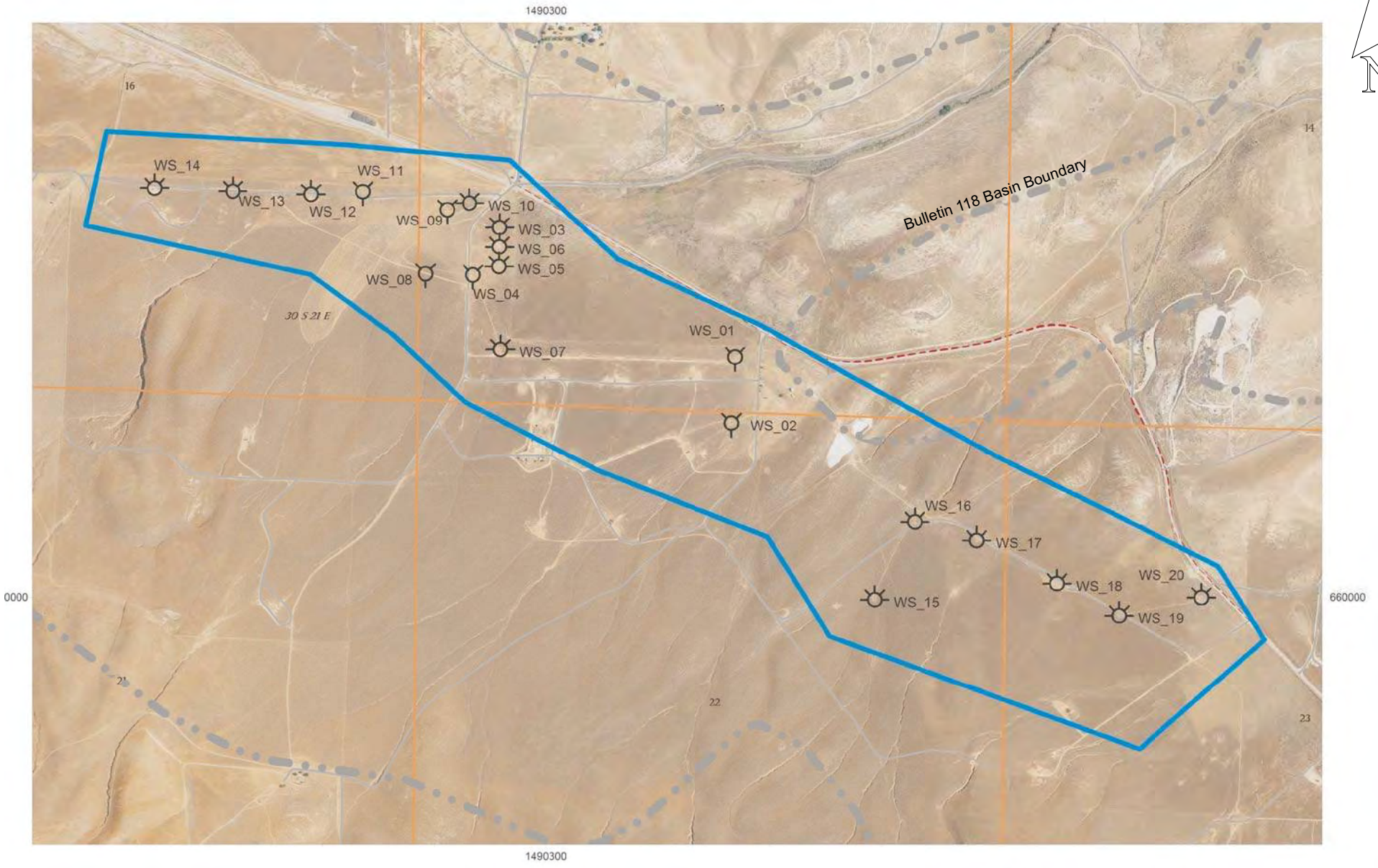


Figure 6-1. LSMV MA Groundwater Level Monitoring Network

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Table 6-1. Groundwater Level Monitoring Network Summary

Well	UWI-ID	X[a]	Y[a]	Status	GroundSurface Elevation (feet)	Total Well Depth (feet bgs)	Well Top Perforation (feet bgs)	Perforation Type	First Measurement Date	Last Measurement Date	Measurements
WS_1	30S21E15Qa	1491993.3	662147.89	Water Source—Active	1,757	495	n/a	n/a	5/13/2019	10/9/2019	2
WS_2	30S21E22B1	1491960.4	661558.49	Water Source—Active	1,764	658	n/a	n/a	5/13/2019	10/9/2019	2
WS_3	30S21E15Mc	1489888.5	663304.99	Water Source—Idle	1,763	509	n/a	n/a	5/3/2018	10/9/2019	3
WS_4	30S21E15Nb	1489650.2	662881.09	Water Source—Active	1,764	n/a	n/a	n/a	5/13/2019	10/9/2019	2
WS_5	30S21E15Nc	1489883.1	662955.69	Water Source—Idle	1,763	100[b]	5	Drilled	5/3/2018	10/9/2019	3
WS_6	30S21E15Md	1489886.6	663130.49	Water Source—Idle	1,763	156[b]	2	Drilled	5/3/2018	10/9/2019	3
WS_7	30S21E15Nd	1489895.6	662215.89	Water Source—Idle	1,787	n/a	n/a	n/a	5/3/2018	10/9/2019	3
WS_8	30S21E15Na	1489221.9	662891.49	Water Source—Active	1,773	n/a	n/a	n/a	5/13/2019	10/9/2019	2
WS_9	30S21E15Ma	1489417.5	663466.29	Water Source—Active	1,764	341	n/a	n/a	5/3/2018	10/9/2019	3
WS_10	30S21E15Mb	1489618.5	663524.69	Water Source—Idle	1,764	n/a	n/a	n/a	5/3/2018	10/9/2019	3
WS_11	30S21E16Jb	1488663.9	663628.49	Water Source—Active	1,770	384	n/a	n/a	5/3/2018	10/9/2019	3
WS_12	30S21E16Ja	1488201.8	663604.29	Water Source—Idle	1,785	n/a	n/a	n/a	5/3/2018	10/9/2019	3
WS_13	30S21E16Kb	1487502.4	663631.89	Water Source—Idle	1,810	n/a	n/a	n/a	5/3/2018	10/9/2019	3
WS_14	30S21E16Ka	1486802.3	663660.19	Water Source—Idle	1,855	n/a	n/a	n/a	5/13/2019	10/9/2019	2
WS_15	30S21E22H1	1493238.3	659977.79	Water Source—Idle	1,780	520	n/a	n/a	5/3/2018	10/9/2019	3
WS_16	30S21E22Aa	1493597.1	660671.89	Water Source—Idle	1,755	95[b]	84	Louvered Pipe	5/3/2018	10/9/2019	3
WS_17	30S21E22Ab	1494152.1	660507.29	Water Source—Idle	1,759	378	94	Louvered Pipe	5/3/2018	10/9/2019	3
WS_18	30S21E23Ea	1494868.1	660121.79	Water Source—Idle	1,752	403	100	Louvered Pipe	5/3/2018	10/9/2019	3
WS_19	30S21E23Eb	1495422.6	659835.99	Water Source—Idle	1,741	592	n/a	n/a	5/3/2018	10/9/2019	3
WS_20	30S21E23F1	1496160.8	659996.99	Water Source—Idle	1,727	552	n/a	n/a	5/3/2018	10/9/2019	3

Notes:
[a]NAD27 California Zone V
[b]Estimated depth from camera survey in April 2018
bgs = below ground surface

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6.1.5 Representative Monitoring

As described in WKWD Chapter GSP Section 6.6.6, SGMA specifies two categories of wells: representative wells and monitoring wells. Given that the 20 selected wells represent long-term, regional changes in the LSMV MA and are suitable to monitor sustainability, all monitoring network wells are considered representative wells.

6.1.6 Monitoring Protocols

Monitoring protocols for the groundwater level monitoring network are included in the Kern Groundwater Authority's Umbrella GSP. The WKWD GSA will continue its program of ongoing monitoring using current protocols until coordination of monitoring protocols described in the Umbrella GSP are completed.

6.1.7 Data Gaps

Spatial distribution of existing production wells does not expand to the boundaries of the LSMV MA. Given the number of wells and limited groundwater extraction in the region, the current number and density of monitoring wells is adequate.

6.2 Groundwater Storage Monitoring Network

Groundwater levels are used in the LSMV MA to monitor by proxy for change in groundwater storage. The WKWD GSA will use information collected from its groundwater level monitoring network to monitor for changes in storage.

6.3 Seawater Intrusion Monitoring Network

The WKWD GSA area is geographically and geologically isolated from the Pacific Ocean, and any other large source of saline water. As a result, the Subbasin is not at risk for seawater intrusion.

6.4 Degraded Groundwater Quality Monitoring Network

Groundwater levels are used in the LSMV MA to monitor by proxy for change in groundwater quality. The WKWD GSA will use information collected from its groundwater level monitoring network to monitor for changes in groundwater quality.

6.5 Land Subsidence Monitoring Network

Groundwater levels are used in the LSMV MA to monitor by proxy for change in subsidence. The WKWD GSA will use information collected from its groundwater level monitoring network to monitor for changes in subsidence.

6.6 Depletions of Interconnected Surface Water Monitoring Network

Groundwater levels are used in the LSMV MA to monitor by proxy for change in depletions of interconnected surface water. The WKWD GSA will use information collected from its groundwater level monitoring network to monitor for changes in interconnected surface water.

Section 7.0 Minimum Thresholds, Measurable Objectives, and Interim Milestones

This section defines the sustainability criteria that LSMV MA will use to avoid undesirable results during GSP implementation. SGMA requires the application of minimum thresholds, measurable objectives, and interim milestones to all representative monitoring sites identified in a GSP. These values will guide the LSMV MA and groundwater users within LSMV MA as they identify sustainable values for sustainability indicators and progress indicators over the GSP's 20-year plan implementation period.

7.1 Management Areas

The LSMV MA is its own MA within the WKWD GSA area, and has distinct minimum thresholds, measurable objectives, and interim milestones. Additional information about the sustainability indicators for other MAs (i.e., the Lake MA, North Project MA, South Project MA, and Western MA) are described in Section 7.1.1 of the WKWD Chapter GSP.

7.2 Chronic Lowering of Groundwater Levels

The undesirable result for chronic lowering of water levels is the point at which significant and unreasonable impacts occur over the planning and implementation horizon, as determined by depth/elevation of water, and affect the reasonable and beneficial use of, and access to, groundwater by overlying users. The LSMV MA has only two years of groundwater level data. The limited temporal extent of these groundwater level data do not provide a period of record that can be used to identify how the principal aquifer will respond during a drought. Because of the limited monitoring period, the LSMV MA will need to update its sustainable management criteria during the 2025 GSP update.

7.2.1 Minimum Thresholds, Measurable Objectives, and Interim Milestones

Minimum thresholds and measurable objectives were established in the LSMV MA to allow for an appropriate margin of operational flexibility that would allow for recovery of water as regularly conducted during normal operations.

Measurable objectives for the LSMV MA were calculated from the average groundwater levels observed between 2018 and 2019. Over the two-year observation period, groundwater levels do not fluctuate more than 10 feet even in wells that were pumping during measurement.

To provide an operational flexibility range, the minimum threshold was calculated to be lower than the measurable objective based on a fraction of the wetted portion of the well. Figure 7-1 illustrates the wetted portion of the well, 20 percent of which was subtracted from the fall 2019 groundwater levels to determine the minimum threshold. Calculated as the distance between the fall 2019 water surface elevation and the total well depth, 20 percent of the wetted portion of the well was subtracted from the fall 2019 water levels. Based on this methodology, the minimum threshold ranges between 15 and 122 feet below fall 2019 groundwater levels.

Total well depth was unavailable for eight wells. In these cases, the average fraction of wetted well portion was used (i.e., 71 feet) below fall 2019 levels. Since all representative wells are currently at or above the measurable objective, interim milestones were not established for the LSMV MA.

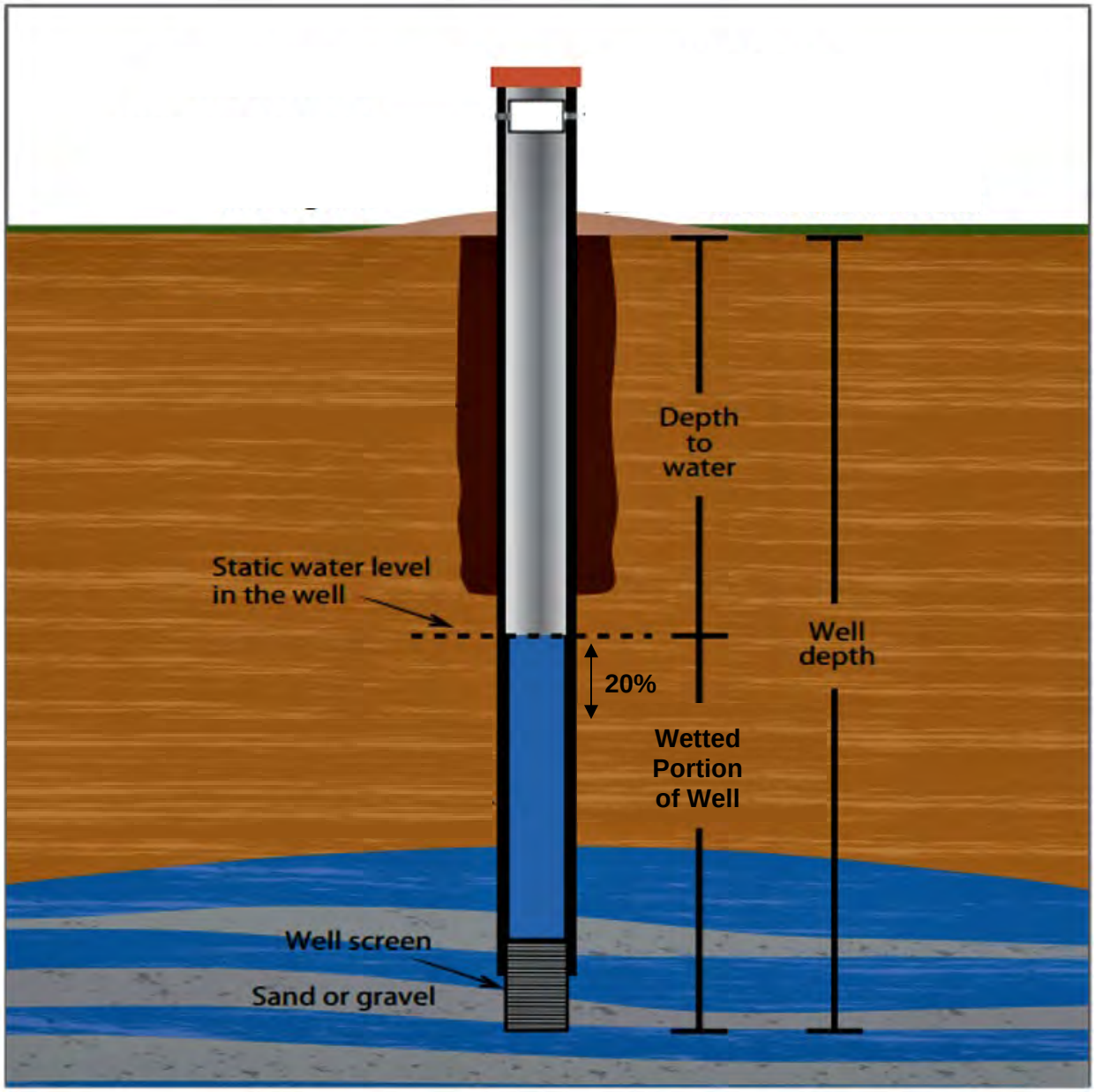


Figure 7-1. Wetted Portion of Well to Calculate Minimum Thresholds

7.2.2 Selected Minimum Thresholds and Measurable Objectives, Figures, and Tables

This section summarizes information about the data used to determine minimum thresholds and measurable objectives for each representative well. Figure 7-2 is an example hydrograph with the applied minimum threshold and measurable objective, and Table 7-1 summarizes data for each well.

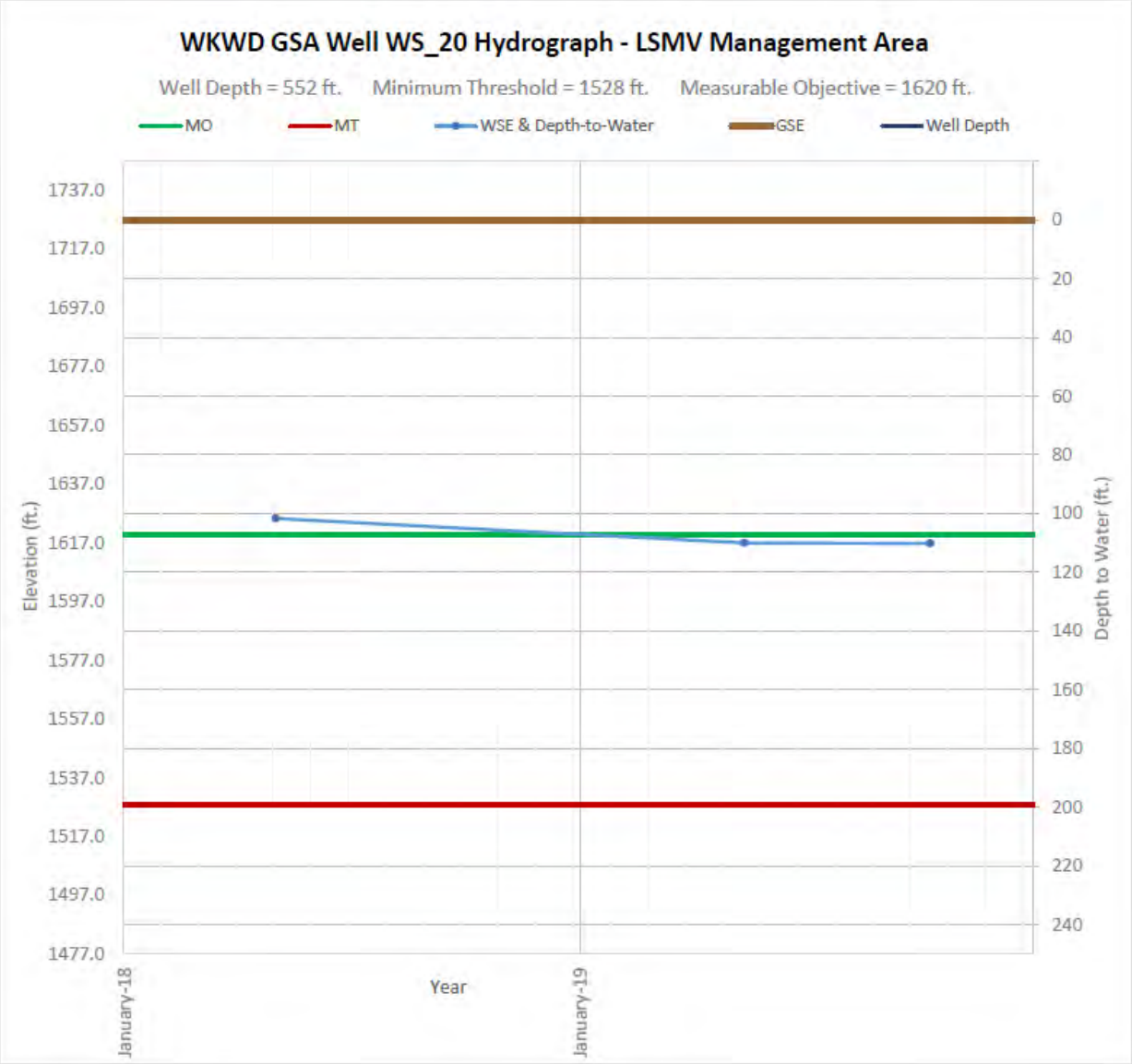


Figure 7-2. LSMV MA Example Hydrograph with Thresholds

Table 7-1. LSMV MA Minimum Thresholds, Measurable Objectives, and Interim Milestones

Representative Well	Minimum Threshold (feet above mean sea level)	Measurable Objective (feet above mean sea level)
WS_01	1,631	1,722
WS_02	1,593	1,715
WS_03	1,641	1,737
WS_04	1,662	1,735
WS_05	1,723	1,737
WS_06	1,713	1,738
WS_07	1,662	1,733
WS_08	1,667	1,740
WS_09	1,675	1,743
WS_10	1,670	1,741
WS_11	1,677	1,750
WS_12	1,687	1,757
WS_13	1,702	1,773
WS_14	1,710	1,781
WS_15	1,554	1,627
WS_16	1,552	1,623
WS_17	1,577	1,626
WS_18	1,575	1,631
WS_19	1,536	1,633

7.3 Reduction of Groundwater Storage

Groundwater levels are used in the LSMV MA to monitor by proxy for change in groundwater storage. The WKWD GSA will use information collected from its groundwater level monitoring network to monitor for changes in storage.

7.4 Seawater Intrusion

The WKWD GSA area is geographically and geologically isolated from the Pacific Ocean, and any other large source of saline water. As a result, the Subbasin is not at risk for seawater intrusion.

7.5 Degraded Water Quality

Groundwater levels are used in the LSMV MA to monitor by proxy for change in groundwater quality. The WKWD GSA will use information collected from its groundwater level monitoring network to monitor for changes in groundwater quality.

7.6 Subsidence

Groundwater levels are used in the LSMV MA to monitor by proxy for change in subsidence. The WKWD GSA will use information collected from its groundwater level monitoring network to monitor for changes in subsidence.

7.7 Depletions of Interconnected Surface Water

Groundwater levels are used in the LSMV MA to monitor by proxy for change in depletions of interconnected surface water. The WKWD GSA will use information collected from its groundwater level monitoring network to monitor for changes in interconnected surface water.

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Section 8.0 Projects, Management Actions, and Adaptive Management Strategies

This section describes projects and management actions planned for implementation in the WKWD Chapter GSP that apply to the LSMV MA.

8.1 Management Actions

There are two planned management actions for the LSMV MA in addition to continuing monitoring activities: filing for a BBM with DWR, and simultaneous continued monitoring and sustainable management as part of the WKWD's Chapter GSP.

8.1.1 File for Basin Boundary Modification

This management action will expand understanding of the LSMV MA by exploring the scientific rationale for filing for a BBM. If criteria for modification are met, the WKWD GSA will request removal of the LSMV MA from the Kern County Subbasin. In the WKWD GSA's 2018 BBM application, the emphasis was regional in nature and covered most of the west side from Wheeler Ridge to the Kern-Kings county line. The BBM application was based on precedent and broad geologic characteristics. At the time, not enough was understood about the LSMV MA, particularly the nature of its isolation from the rest of the subbasin. Consequently, DWR denied that component of the 2018 BBM application.

While more is now known as a result of work begun during the 2018 BBM application process and during preparation of this addendum, additional research and data gathering is under way to improve the upcoming BBM application for the LSMV MA.

8.1.2 Continued Monitoring and Sustainable Management as Part of the WKWD GSA

If criteria for modification are not met, and a BBM application is not submitted, or if the upcoming BBM application is denied, WKWD and the operator of the LSMV well field will continue existing water management programs and develop additional programs if required. Routine reporting of pumping to the WKWD GSA, continuing the current groundwater level monitoring program, coordination, and developing water management tools and strategies are among the anticipated activities.

WKWD GSA will work with the KGA to add the monitoring identified in this appendix to the KGA's Umbrella monitoring list as a part of implementation in 2020.

8.2 Adaptive Management Strategies

If monitoring indicates that sustainability is at risk in the LSMV MA, the WKWD GSA will work with local stakeholders to develop a plan (likely as part of a five-year update to the Chapter GSP) to address reductions in levels and potential effects on other sustainability indicators.

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Section 9.0 GSP Implementation

Implementation of monitoring and management actions will occur on a similar timeline to the WKWD Chapter GSP. Sections of WKWD Chapter GSP that cover the LSMV MA include the following:

- Annual reports
- Five-year Chapter GSP update
- Implementation schedule

9.1 GSA and GSP Implementation Costs and Funding Source

This section describes implementation costs and how implementation will be funded in the LSMV MA.

9.1.1 GSP Implementation Costs

Below is a rough cost estimate for implementing monitoring and reporting/collaboration with WKWD.

- Water level monitoring: approximately $2,400 per year, including staff time to perform monitoring in the field, and to update hydrographs
- Water metering monitoring: approximately $4,000 per year, including staff time to physically read meters
- Prepare BBM: approximately $35,000 in 2021
- Participate in annual reports: approximately $5,000, including an estimated 40 hours of staff time to prepare figures and analysis for use in the WKWD GSA's annual report
- Participate in five-year update: approximately $25,000 in 2024

9.1.2 GSP Implementation Funding

Per the agreement dated November 22, 2019, the Owner/Operator as Landowner has agreed to be responsible for actual costs incurred as a result of adding certain Owner/Operators' LSMV properties to WKWD's GSA area. These costs include directly attributable general and administrative costs and pro rata shares of consultant and service provider costs. According to the agreement, the Owner/Operator may reimburse WKWD for attributable expenditures or make direct payment to consultants or other service providers.

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Attachment 1

Soil Boring Logs

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BOREHOLE LOG WS-6 Boring

PROJECT NUMBER 2041-18001
CLIENT E & B Natural Resources
PROJECT NAME Little Santa Maria Valley Soil Investigation

DRILLING DATE 5/3/2018
DRILLING COMPANY Yellow Jacket Drilling
DRILLING METHOD Sonic with core sampler

LOGGED BY Darylyn Tachella
TOTAL DEPTH 166 feet

Depth (ft)	Graphic Log	USCS	Material Description	Additional Observations
		ML	Top soil-sandy silt: 10YR 6/2 (light brownish gray), dry, loose/soft, fine sand, slightly plastic	Clasts are shale & chert; little diatomite observed in boring
5			Sandy silt: 10YR 6/2 (light brownish gray), dry, medium stiff, moderately cemented, moderate subangular blocky structure, fine sand, moderately plastic, prevalent white precipitate, strong HCl reaction	Moist at 6'
		ML-CL	Sandy silt/clay: 10YR 6/3 (pale brown), dry, stiff, fine to coarse sand, trace gravel, subrounded to angular, moderately plastic, some orange oxidation mottles	Moist by 11' Prevalent oxidation mottling 9-14'
10				
15				
		ML	Sandy silt: 7.5YR 5/4 (brown), moist, medium stiff, mostly coarse sand, some gravel, angular to subrounded, low plasticity, weak HCl reaction	
20				
			▽	Wet & soft below 23'. Sounder DTW ~25'
25				
				Gravel layer 27.5-28.5'
30				Coarse sand & gravel layer 31-31.5'
				Trace organics ~33.75'
35				
			Silty sand with gravel: 10YR 7/4 (very pale brown), moist to dry, loose, mostly medium to coarse sand, subrounded to angular, moderate HCl reaction	
40		SM		
		ML	Sandy silt with gravel: 7.5 or 10YR 6/4 (light brown), moist, medium stiff, fine to coarse sand, gravel less than 1", angular to subrounded, low plasticity, weak HCl reaction	
45				
		SM	Silty sand with gravel: 10YR 6/6 (brownish yellow), moist to wet, medium dense, mostly coarse sand, fine to coarse gravel, subangular to angular, slightly plastic, no HCl reaction	
50				
		ML	Sandy silt with gravel: 10YR 5/6 (yellowish brown), moist to wet, medium stiff,	

produced by ESlog.ESdat.net on 11 May 2018

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BOREHOLE LOG WS-6 Boring

Depth (ft)	Graphic Log	USCS	Material Description	Additional Observations
55			some weak to moderate cementation of clasts, fine to coarse sand, fine to coarse gravel, few cobbles up to 4", angular to subrounded, low plasticity, weak to no HCl reaction	
60				
65				Lighter colored fines with strong HCl reaction
70				
75				
80				
85				
90				
95				
100				Possibly a boulder within surrounding material
105			Breccia: dry, angular, shale & chert clasts in matrix, dissociated	
110		ML	Sandy silt with gravel: 10YR 6/4 (light yellowish brown), moist to wet, medium stiff, fine to coarse sand, fine to coarse gravel, subrounded to angular, slightly plastic	
115				

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BOREHOLE LOG WS-6 Boring

Depth (ft)	Graphic Log	USCS	Material Description	Additional Observations
120				
125		SM/ ML	Alternating sandy silt with gravel & silty sand with gravel: 10YR 6/4 (light yellowish brown), moist to wet, medium stiff, fine to coarse sand, fine to coarse gravel, subrounded to angular, slightly plastic	
130				
135				
140				
145				
150		SM	Silty sand with gravel: 10YR 6/6 (brownish yellow), wet, loose, gravel up to 2.5", subangular, not plastic, no HCl reaction	
155		ML	Sandy silt with gravel: 10YR 5/4 (yellowish brown), moist, stiff to very stiff, fine to coarse sand, gravel up to 2", subrounded to angular, slightly plastic	
160				Before abandonment depth to water was measured at 35' and rising
165				
170				
175				
180				

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BOREHOLE LOG WS-18 Boring

PROJECT NUMBER 2041-18001
CLIENT E & B Natural Resources
PROJECT NAME Little Santa Maria Valley Soil Investigation

DRILLING DATE 5/2/2018
DRILLING COMPANY Yellow Jacket Drilling
DRILLING METHOD Sonic with core sampler

LOGGED BY Darylyn Tachella
TOTAL DEPTH 206 feet

Depth (ft)	Graphic Log	USCS	Material Description	Additional Observations
			0-5' cleared with conductor casing; samples begin at 5'	Soils have moderate to strong reaction with HCl unless otherwise noted
5		SM	Silty sand with gravel: 10YR 5/6 (yellowish brown), dry, loose, fine to coarse, subangular, slightly plastic, gravel up to 1.5"	Clasts are primarily diatomite
		GW	Gravel with sand; 10YR 5/6 (yellowish brown), dry, loose to medium dense, fine to coarse sand, some silt, gravel subround to angular, up to 1.5", slightly plastic	Diatomaceous clasts
10		SM	Silty sand with gravel: 10YR 6/6, 6/4 (brown-yellow), dry to moist, loose, sand fine at top to coarse at bottom, angular to subangular sand, gravel rounded to subangular up to 2", slightly to not plastic	
		ML	Gravelly silt: 10YR 6/4 (light yellowish brown), moist, soft, some cohesiveness, some coarse subangular sand, medium gravel up to 1", subangular, very slightly plastic, sand % increasing downward	
15		GM	Silty gravel with sand: 10YR 5/4 (yellowish brown), dry, loose, fine to coarse sand, fine to coarse gravel up to 2", subangular to subrounded, slightly plastic	One cobble observed
		ML	Sandy silt with gravel: 10YR 5/4 (yellowish brown), moist, medium stiff, semi-consolidated/ cohesive, coarse sand, fine to medium gravel up to 1.5", slightly plastic	
20		SM	Silty sand with gravel: 10YR 6/4 (light yellowish brown), dry to moist, loose, few consolidated pieces, fine to coarse sand, fine to medium gravel up to 1.5", subrounded to angular, very slightly plastic	
25				
		CL	Sandy clay with gravel: moist, stiff, some cohesive pieces, mostly coarse sand, fine to coarse gravel up to 2", angular to subrounded, low plasticity	
30		SM	Silty sand with gravel: 10YR 6/4 (light yellowish brown), moist, loose, medium to coarse sand, fine to medium gravel up to 1.5", angular to subrounded, not plastic, sand & gravel fining downward	
35				
		CL	Sandy clay: 10YR 4/4 (dark yellowish brown), moist, hard, mostly coarse sand, trace gravel, low plasticity, no HCl reaction	Cohesive 40-41'
40				
		ML	Sandy silt with gravel: 10YR 5/6 (yellowish brown), dry, loose & soft, mostly coarse sand, fine gravel, angular to subrounded, slightly plastic	
45		SM		

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BOREHOLE LOG WS-18 Boring

Depth (ft)	Graphic Log	USCS	Material Description	Additional Observations
50		SM	Silty sand with gravel: 10YR 6/4 (light yellowish brown), dry, loose, medium to coarse sand, fine to coarse gravel up to 2", subangular, slightly plastic	
55				Few clasts of chert began to be observed ~56'
60		ML	Gravelly silt with sand: 10YR 6/6 (brownish yellow), moist, loose, medium to coarse sand, fine to coarse gravel, angular to subrounded, low plasticity	
		SM	Silty sand with gravel: 10YR 6/4 (light yellowish brown), dry, loose, fine to coarse sand, fine to coarse gravel up to 2", subangular, slightly plastic	
65				
		ML	Sandy silt with gravel: 10YR 5/6 (yellowish brown), moist, loose, medium to coarse sand, fine to coarse gravel, angular to subrounded, slightly plastic	
70				
75				
80				
		CL	Sandy clay: 10YR 4/6 (dark yellowish brown), dry, hard, fine to medium sand, some gravel, angular to subangular, low plasticity, moderate subangular blocky structure	Clasts observed still primarily diatomaceous
85		ML	Sandy silt with gravel: 10YR 5/8 (yellowish brown), moist, loose, fine to coarse sand, gravel up to 1", subangular to angular, slightly plastic	
90				Cohesive
		SM	Silty sand with gravel: 10YR 6/6 (brownish yellow), loose, moist, medium to coarse sand, gravel up to 1.5", angular to subrounded, slightly plastic	
95				
		ML	Sandy silt with gravel: 10YR 5/6 (yellowish brown), hard, cohesive, fine to coarse sand, fine to coarse gravel, angular to subrounded, low plasticity, weak structure	
100				Loose
		SM	Silty sand with gravel: 10YR 5/6 (yellowish brown), dry to moist, loose to medium dense, cohesive, mostly medium sand, fine to coarse gravel, angular to	
105				

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BOREHOLE LOG WS-18 Boring

Depth (ft)	Graphic Log	USCS	Material Description	Additional Observations
110			subrounded, slightly plastic	
115		ML	Sandy silt with gravel: 10YR 5/6, 6/4 (yellowish brown), dry to moist, hard, cohesive, mostly fine to medium sand, fine to coarse gravel, subrounded to angular	Clasts are siliceous shale and diatomite
120		SM	Silty sand with gravel: 10YR 6/4 (light yellowish brown), dry to moist to wet, loose to medium dense, weak to strong cementation, weak HCl reaction, medium to coarse sand, fine to coarse gravel, subangular to angular	Clasts are mostly shale. Soil wet at ~123', sounder DTW ~125'
125		ML	Gravelly silt with sand: 10YR 6/6 (brownish yellow), moist, stiff, moderate to strong cohesiveness, medium to coarse sand, fine to coarse gravel, subrounded to angular	Significant decrease in diatomaceous clasts below 125'
130			Sandy silt with gravel: 10YR 5/6 (yellowish brown), moist, very stiff, moderate to strong cohesiveness, medium to coarse sand, fine to coarse gravel, mostly less than 1", subrounded to angular	
135				
140				Silt fraction is borderline fine sand by 139'
145				Weak reactions with HCl below 145'
150		CL	Sandy clay with gravel: 10YR 5/6 (yellowish brown), dry, hard, gravel up to 1", subrounded to angular, low plasticity	Moderate planar structure 148-151'
155				
160		ML	Sandy silt with gravel: 10YR 6/4 (light yellowish brown), moist, hard, fine to coarse sand, gravel mostly less than 1", subrounded to angular, low plasticity	Total depth of conductor casing: 160'

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BOREHOLE LOG WS-18 Boring

Depth (ft)	Graphic Log	USCS	Material Description	Additional Observations
165				
170				
175				
		SM	Silty sand with gravel: 10YR 5/6 (yellowish brown), moist, hard/very dense, fine to coarse sand, gravel less than 1", subrounded to subangular, low plasticity	More fine sand near 176', coarsening downward to 186'
180				
185				
		ML	Sandy silt: 10YR 5/6 (yellowish brown), dry to moist, hard, weak to moderate subangular blocky structure, fine to coarse sand, some gravel, subrounded to subangular, low plasticity	
190				Extremely hard 190-196'
195				
		SM	Silty sand with gravel: 10YR 6/6 (brownish yellow), dry, hard/very dense, fine to coarse sand, gravel up to 1.5", subrounded to angular, low plasticity	
200				
205				
				Before abandonment depth to water was measured at 145' and rising
210				
215				
220				

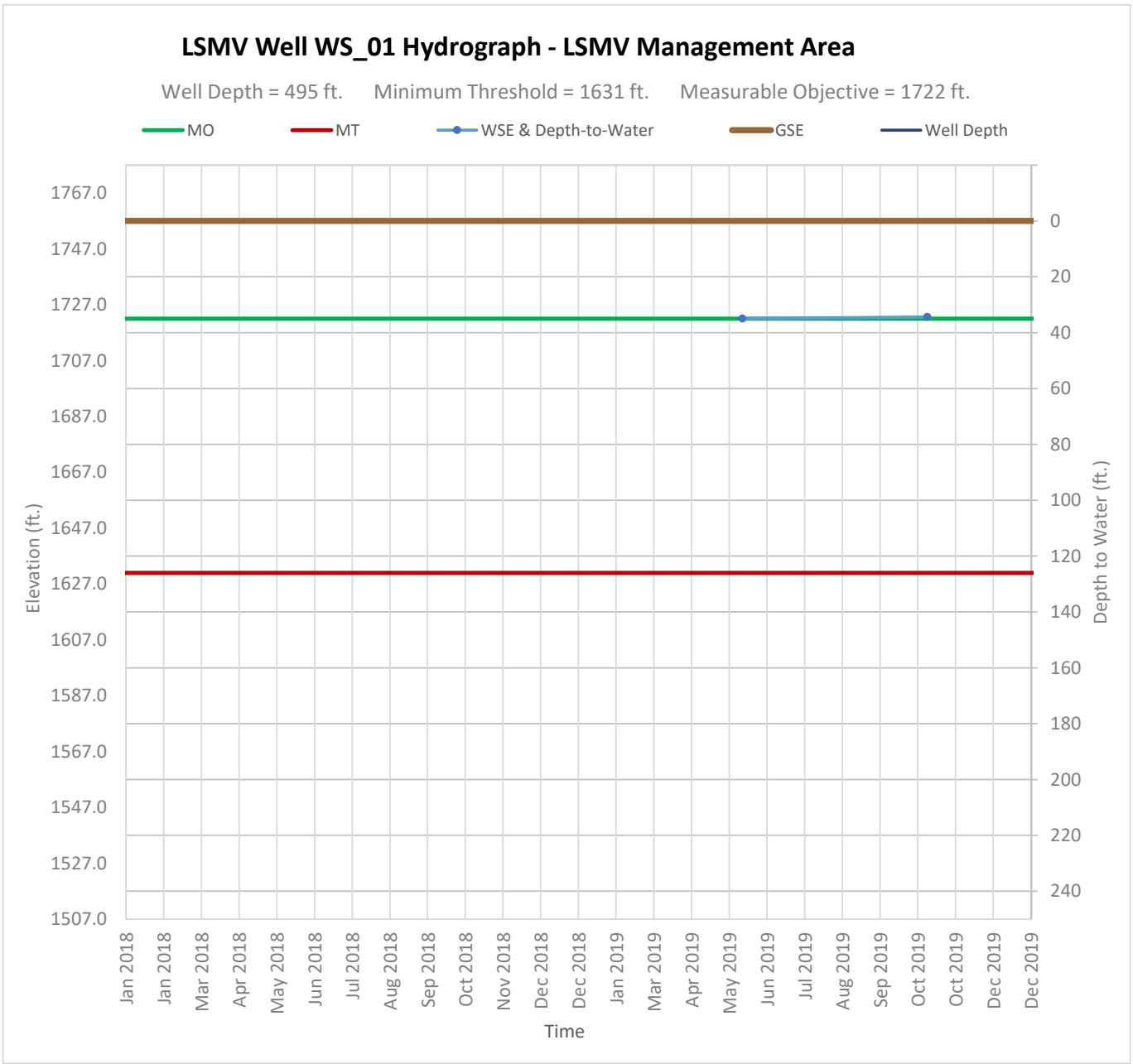
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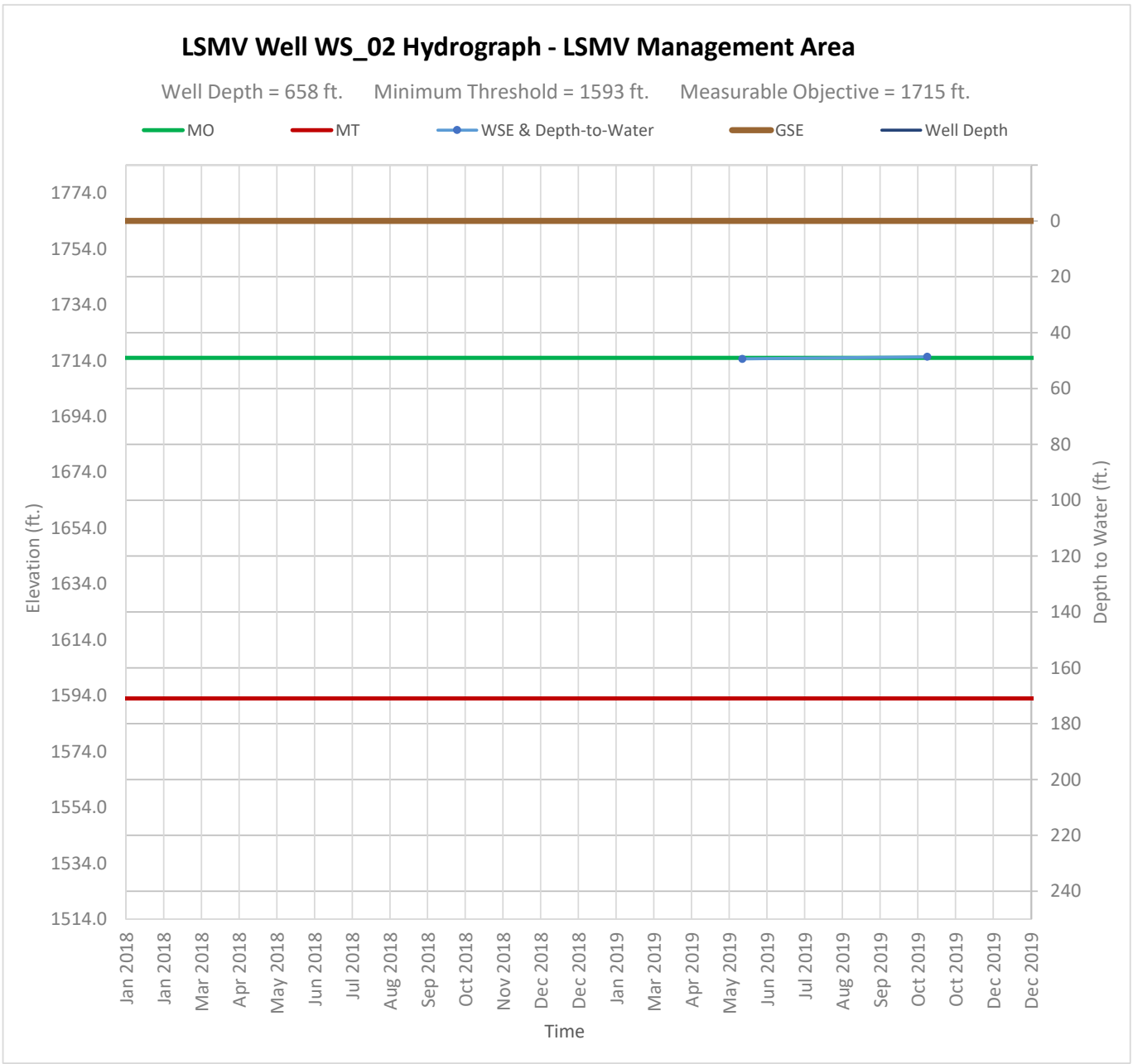
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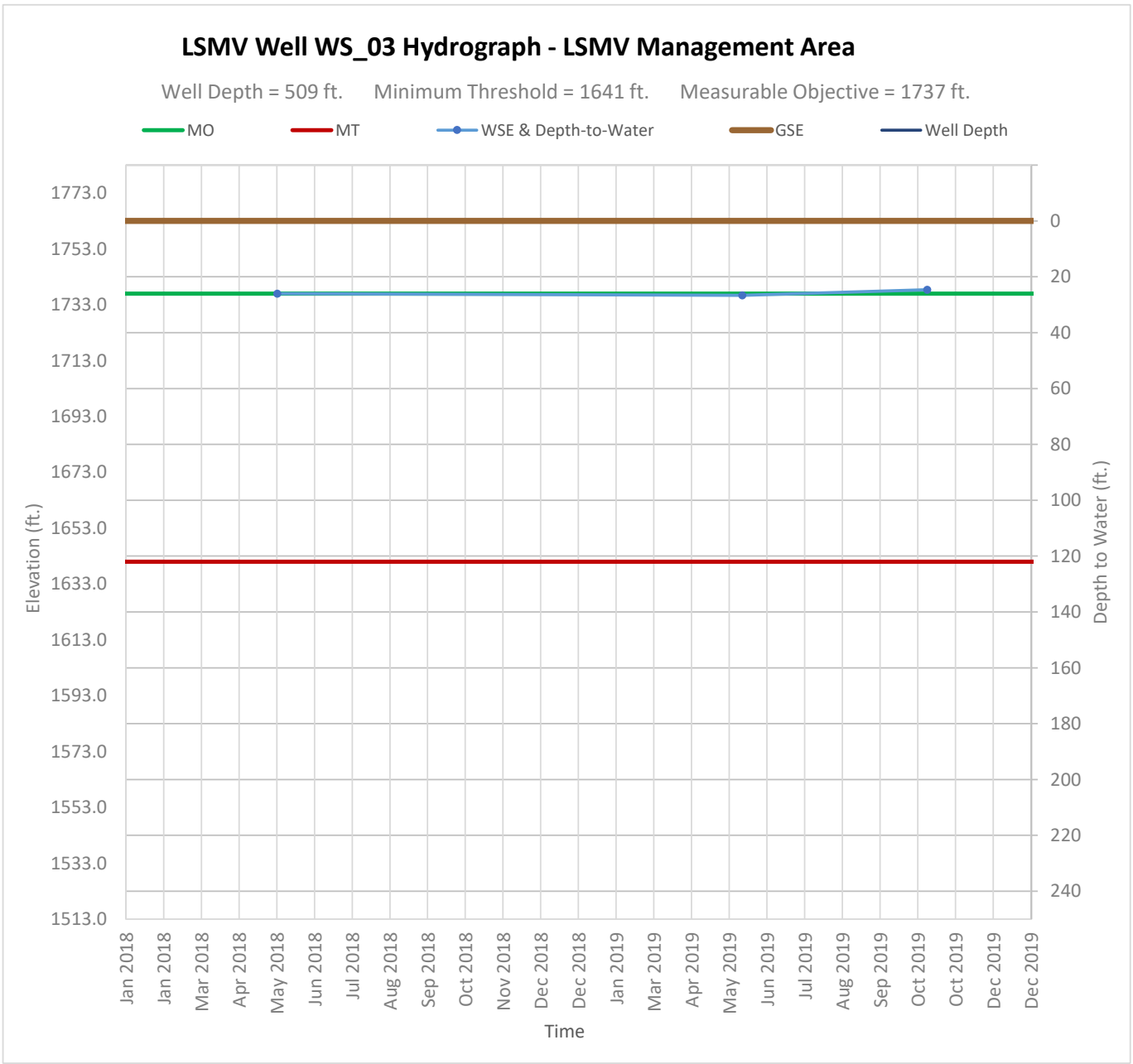
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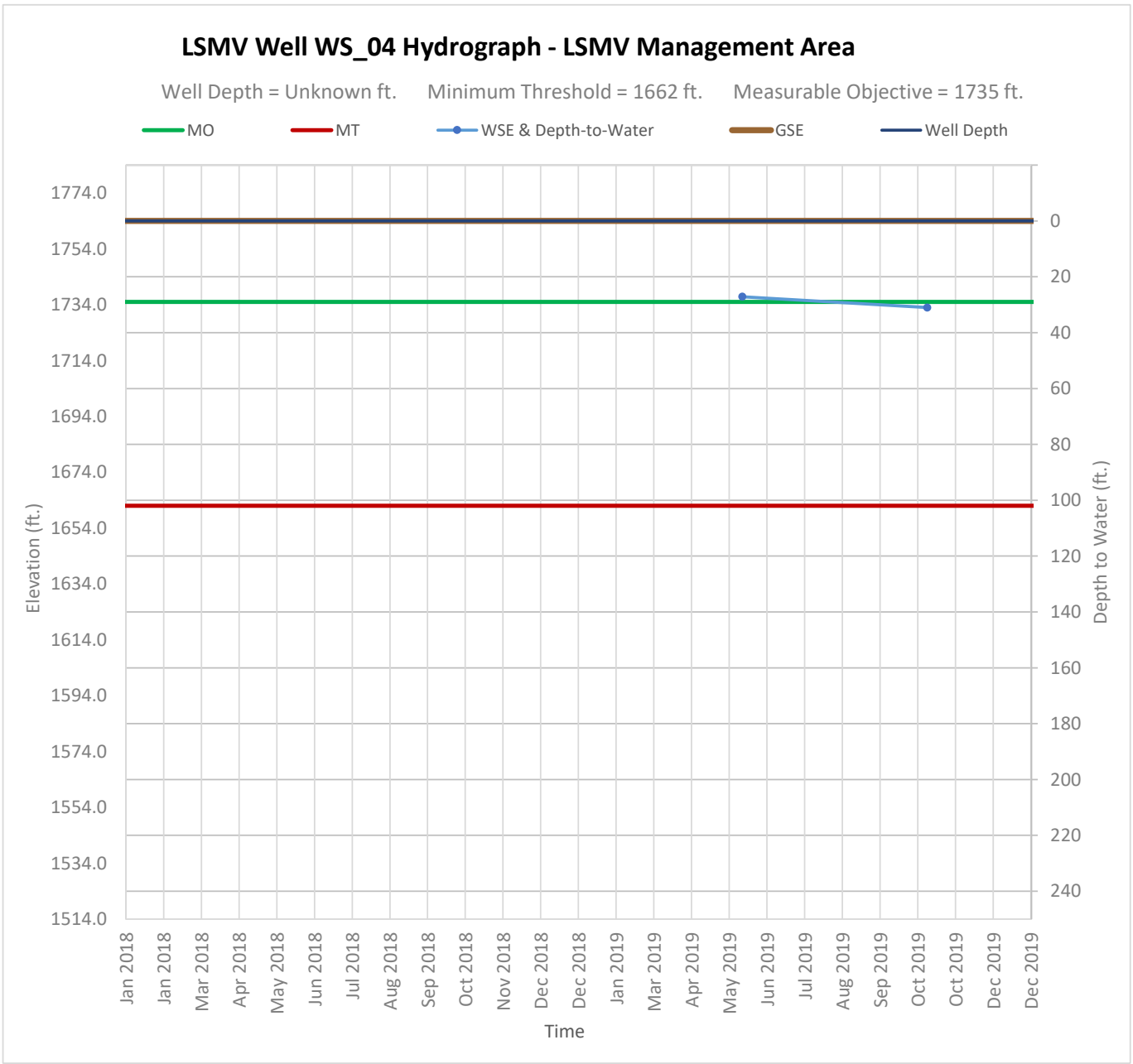
Hydrographs with Minimum Thresholds and Measurable Objectives

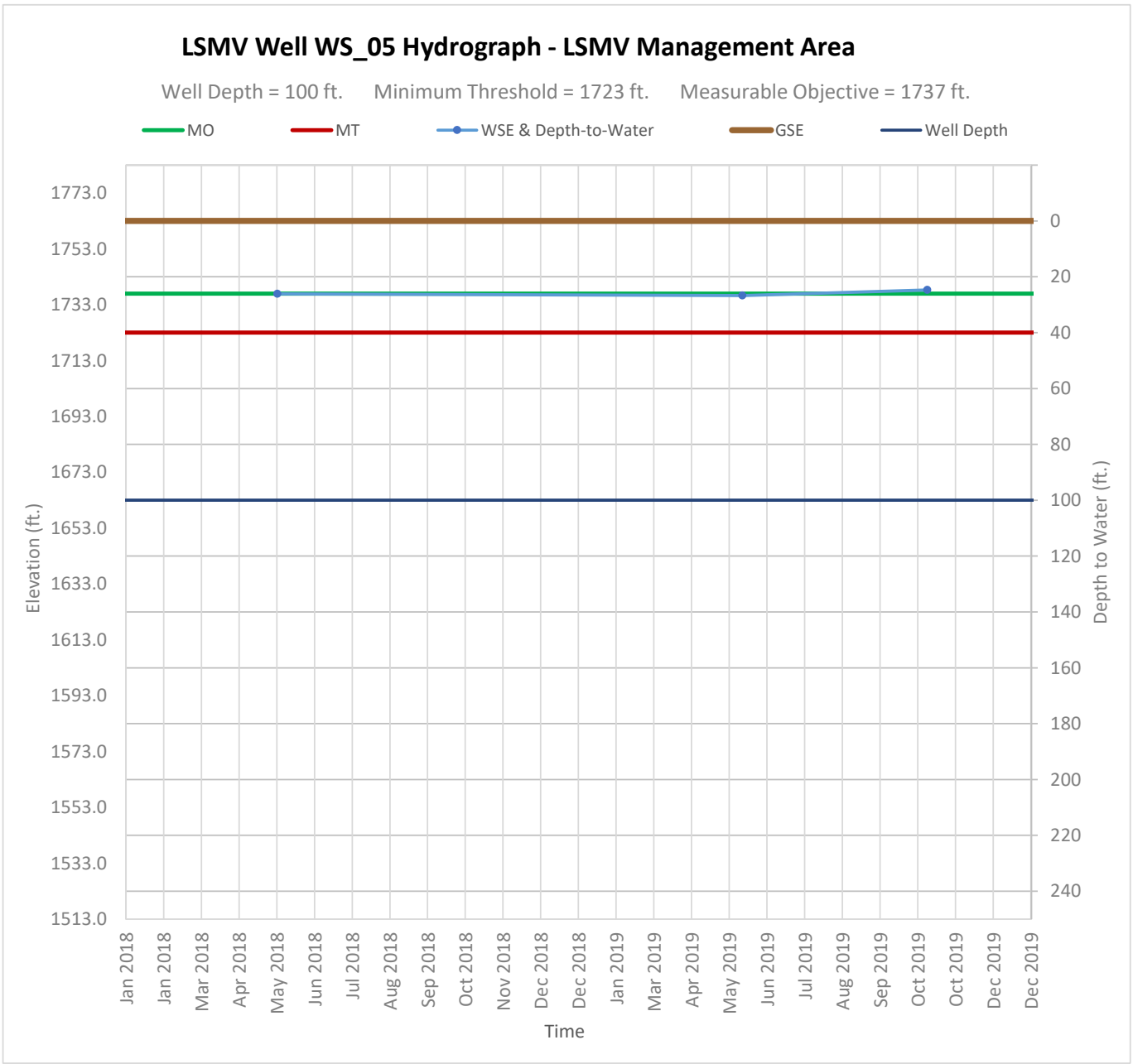
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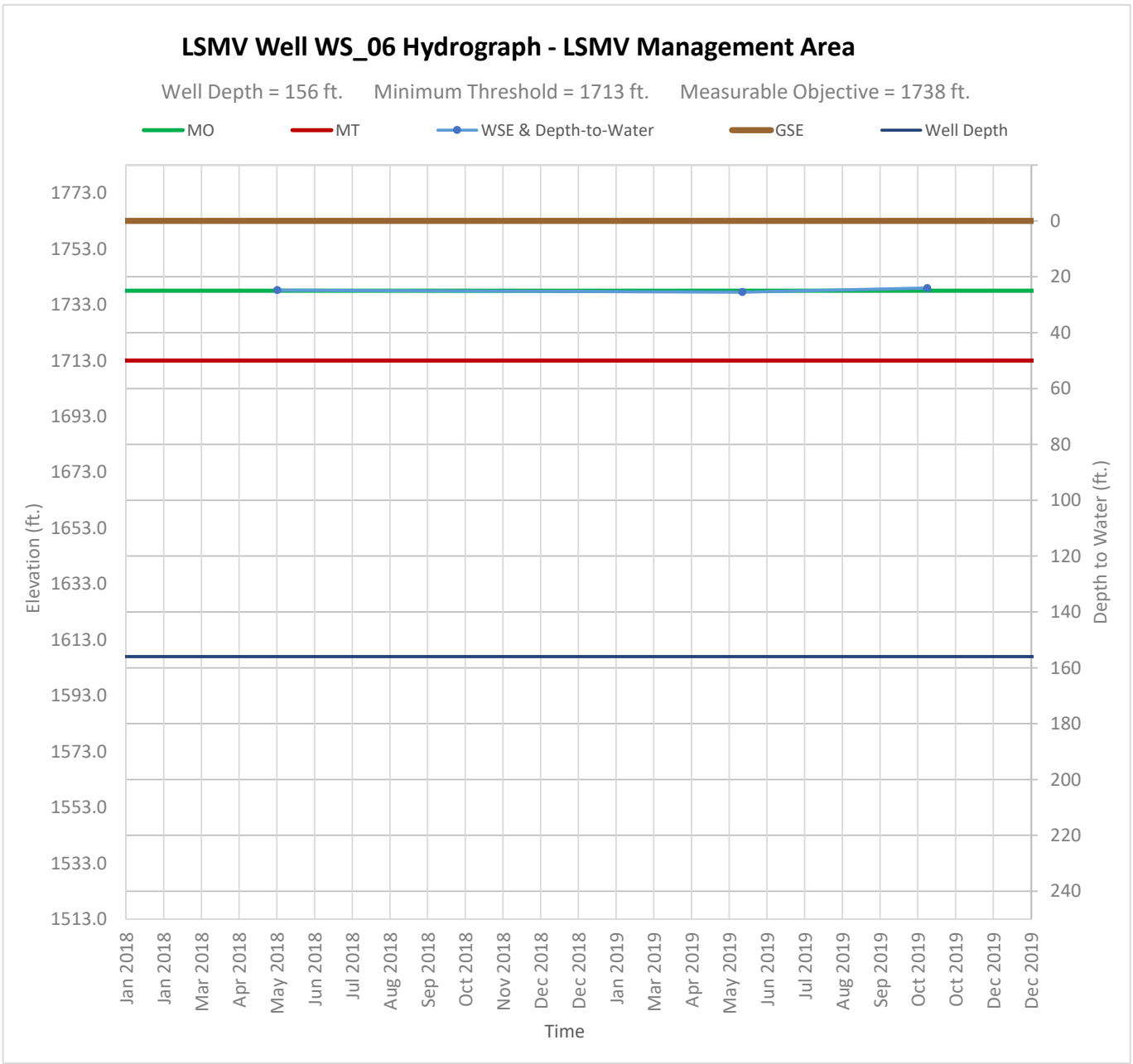

LSMV Well WS_01 Hydrograph - LSMV Management Area
Well Depth = 495 ft.
Minimum Threshold = 1631 ft.
Measurable Objective = 1722 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1767.0
1747.0
1727.0
1707.0
1687.0
1667.0
1647.0
1627.0
1607.0
1587.0
1567.0
1547.0
1527.0
1507.0
Depth to Water (ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
Jan 2018
Jan 2018
Mar 2018
Apr 2018
May 2018
Jun 2018
Jul 2018
Aug 2018
Sep 2018
Oct 2018
Nov 2018
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Aug 2019
Sep 2019
Oct 2019
Oct 2019
Dec 2019
Dec 2019
Time

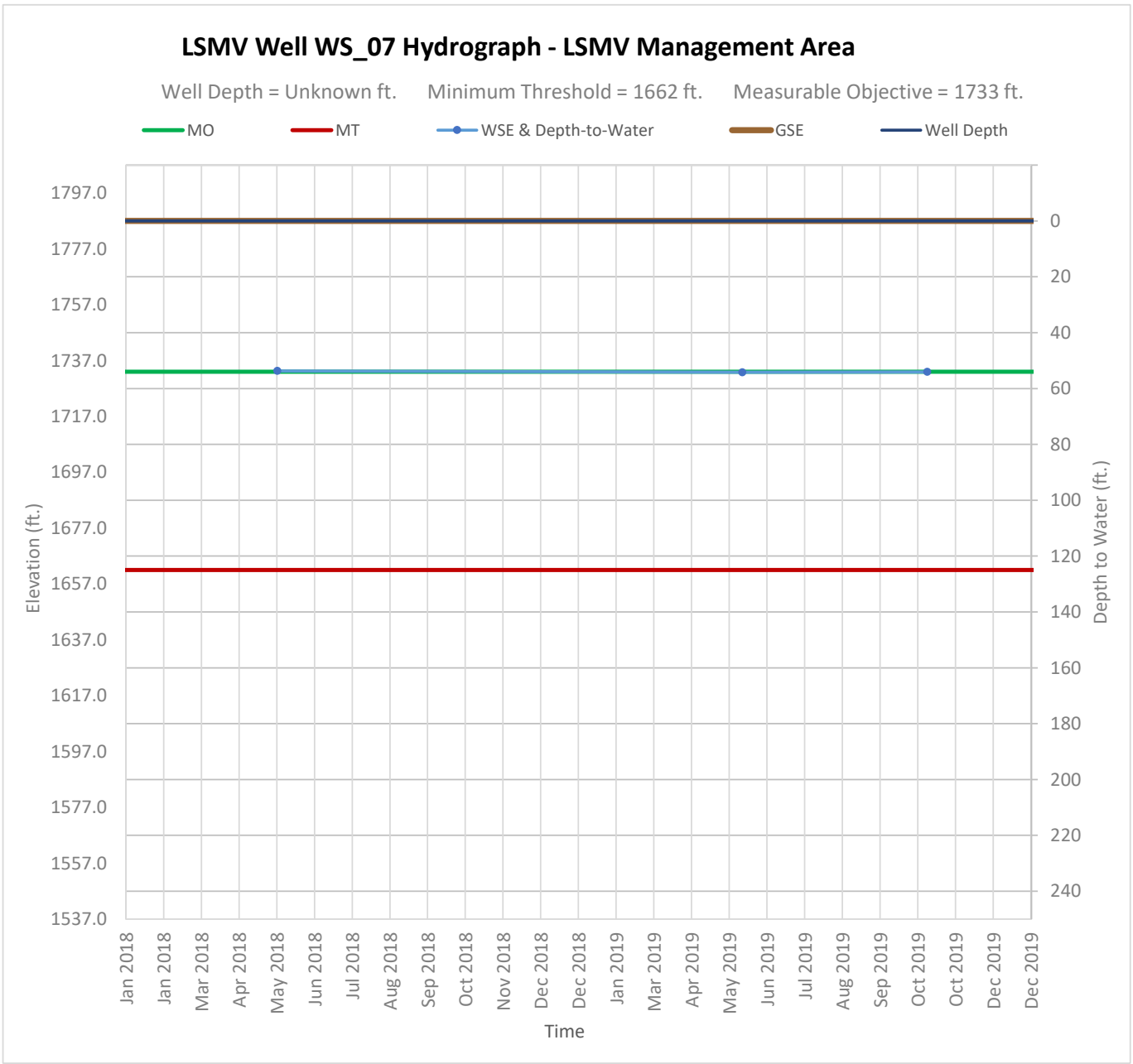

LSMV Well WS_02 Hydrograph - LSMV Management Area
Well Depth = 658 ft.
Minimum Threshold = 1593 ft.
Measurable Objective = 1715 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1774.0
1754.0
1734.0
1714.0
1694.0
1674.0
1654.0
1634.0
1614.0
1594.0
1574.0
1554.0
1534.0
1514.0
Depth to Water (ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
Jan 2018
Jan 2018
Mar 2018
Apr 2018
May 2018
Jun 2018
Jul 2018
Aug 2018
Sep 2018
Oct 2018
Nov 2018
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Oct 2019
Oct 2019
Dec 2019
Dec 2019
Time

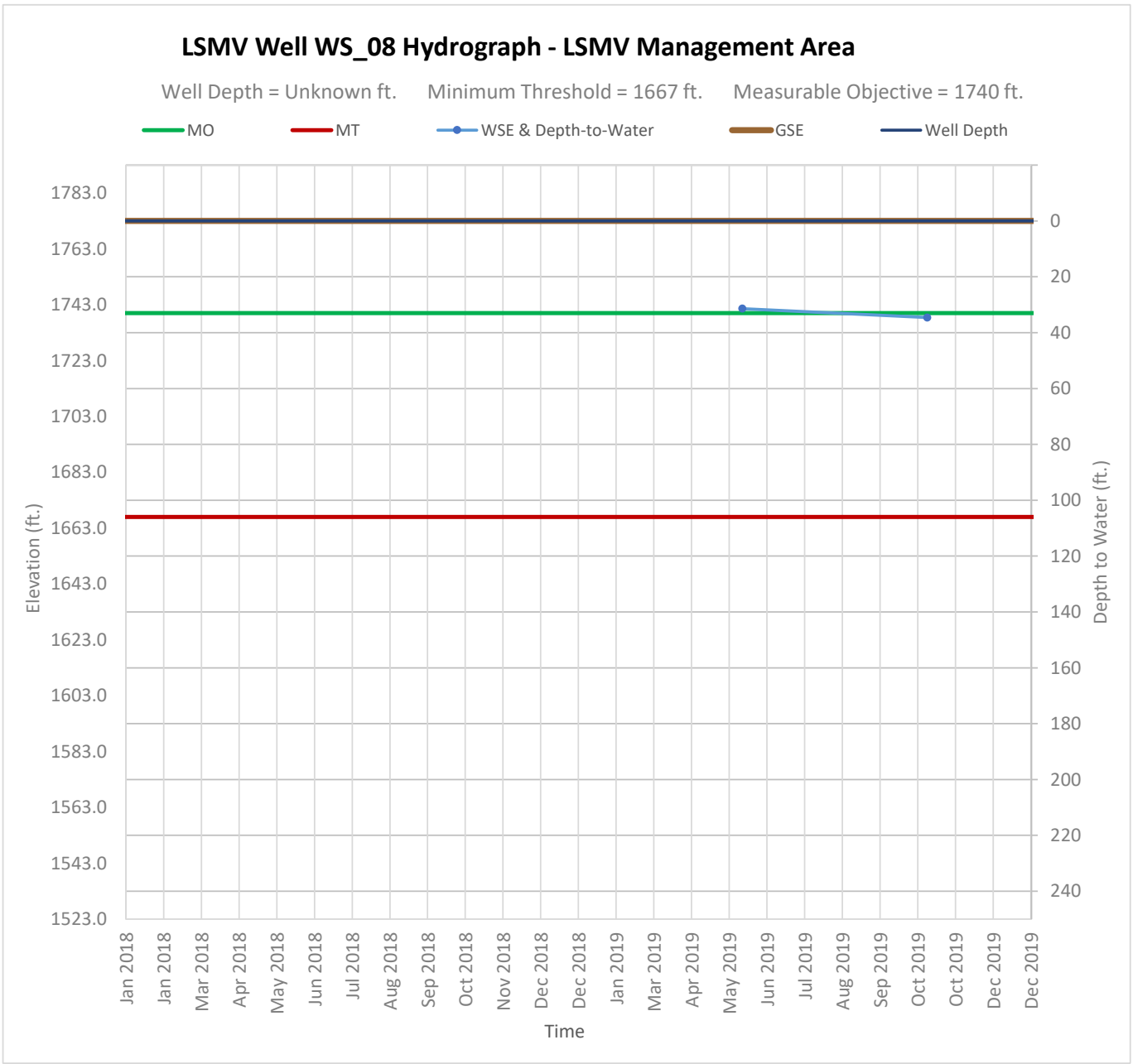

LSMV Well WS_03 Hydrograph - LSMV Management Area
Well Depth = 509 ft. Minimum Threshold = 1641 ft. Measurable Objective = 1737 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1773.0
1753.0
1733.0
1713.0
1693.0
1673.0
1653.0
1633.0
1613.0
1593.0
1573.0
1553.0
1533.0
1513.0
Depth to Water (ft.)
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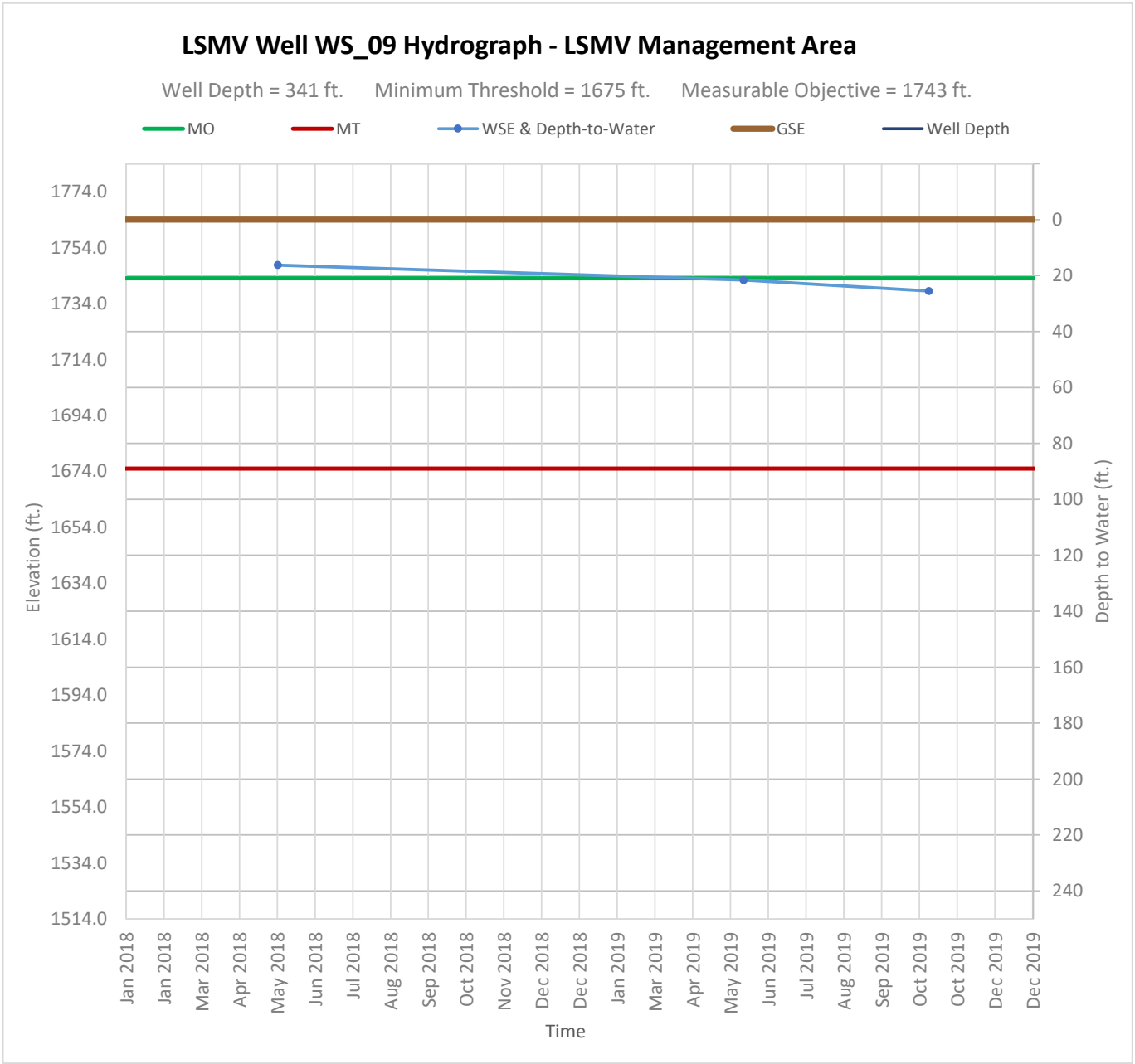

LSMV Well WS_04 Hydrograph - LSMV Management Area
Well Depth = Unknown ft.
Minimum Threshold = 1662 ft.
Measurable Objective = 1735 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1774.0
1754.0
1734.0
1714.0
1694.0
1674.0
1654.0
1634.0
1614.0
1594.0
1574.0
1554.0
1534.0
1514.0
Depth to Water (ft.)
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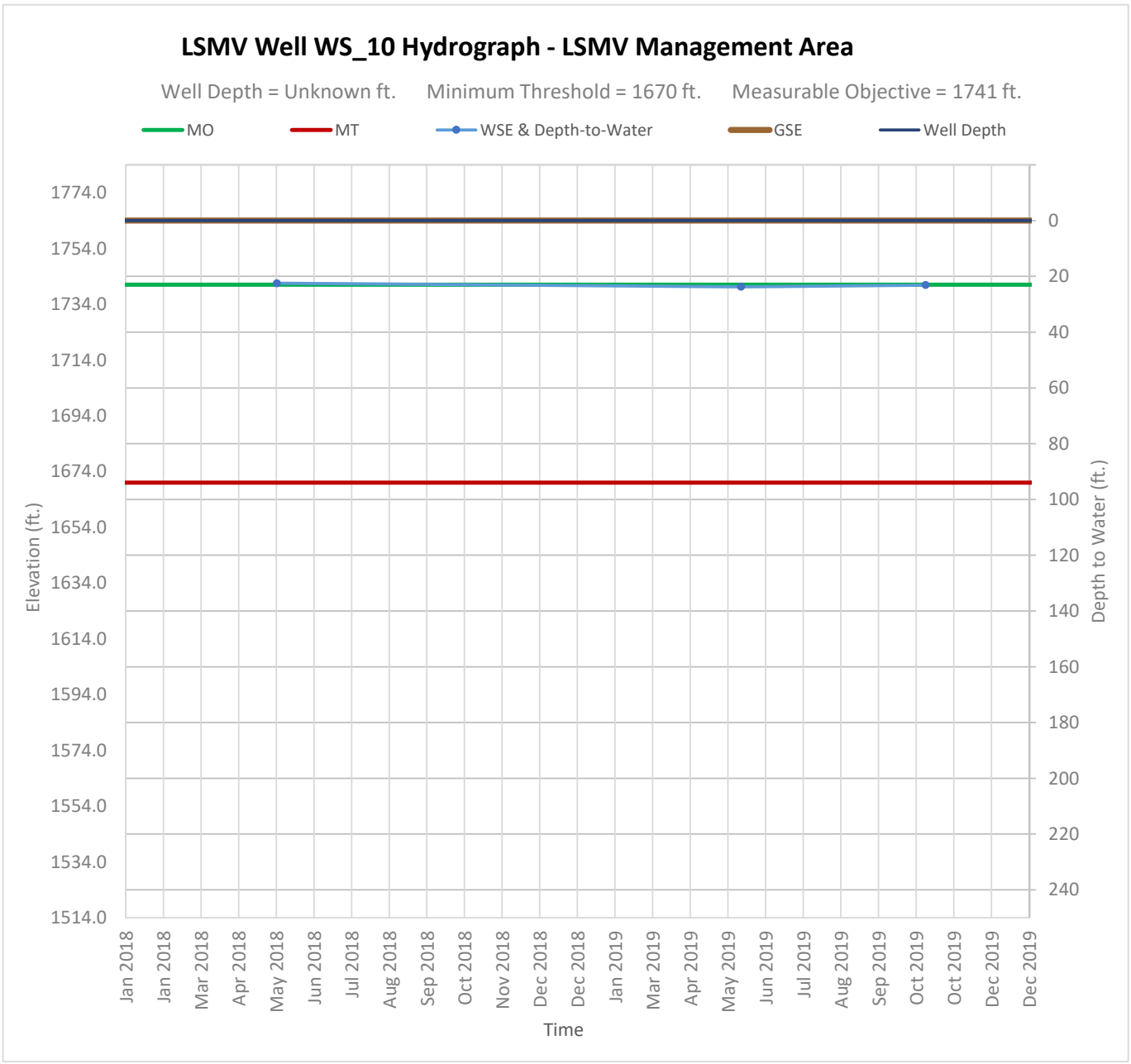

LSMV Well WS_05 Hydrograph - LSMV Management Area
Well Depth = 100 ft. Minimum Threshold = 1723 ft. Measurable Objective = 1737 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1773.0
1753.0
1733.0
1713.0
1693.0
1673.0
1653.0
1633.0
1613.0
1593.0
1573.0
1553.0
1533.0
1513.0
Depth to Water (ft.)
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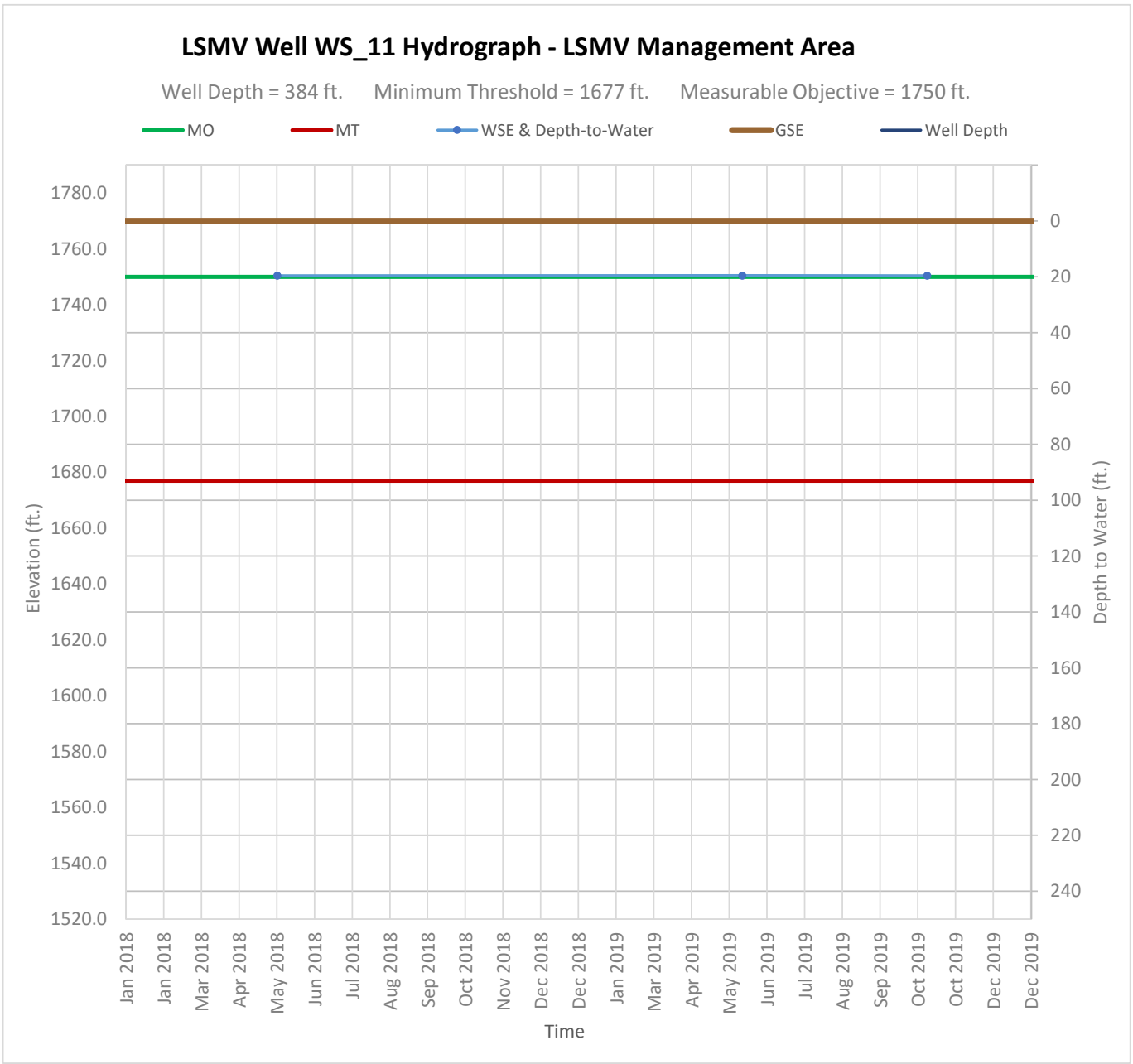

LSMV Well WS_06 Hydrograph - LSMV Management Area
Well Depth = 156 ft. Minimum Threshold = 1713 ft. Measurable Objective = 1738 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1773.0
1753.0
1733.0
1713.0
1693.0
1673.0
1653.0
1633.0
1613.0
1593.0
1573.0
1553.0
1533.0
1513.0
Depth to Water (ft.)
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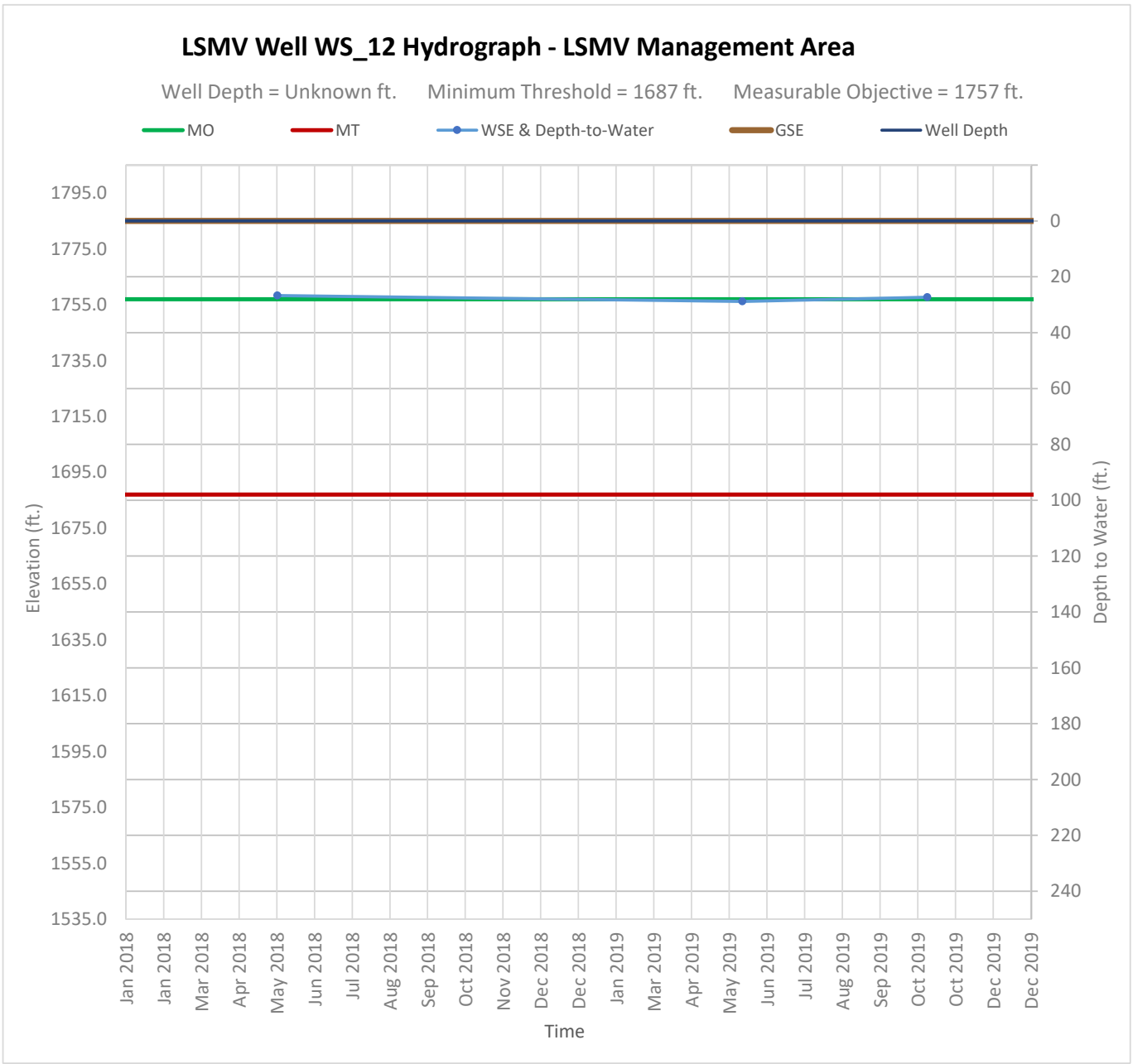

LSMV Well WS_07 Hydrograph - LSMV Management Area
Well Depth = Unknown ft.
Minimum Threshold = 1662 ft.
Measurable Objective = 1733 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1797.0
1777.0
1757.0
1737.0
1717.0
1697.0
1677.0
1657.0
1637.0
1617.0
1597.0
1577.0
1557.0
1537.0
Depth to Water (ft.)
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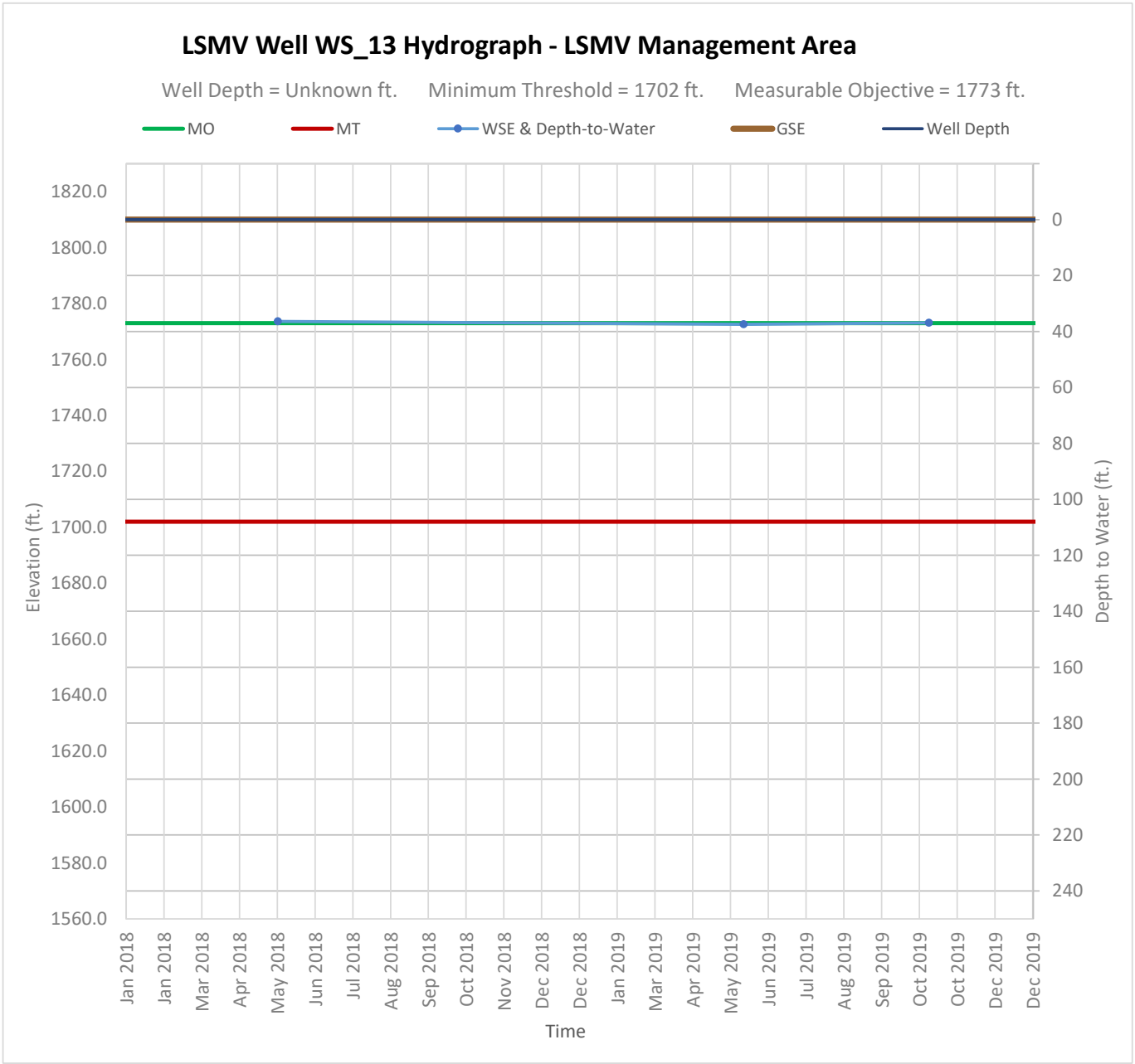

LSMV Well WS_08 Hydrograph - LSMV Management Area
Well Depth = Unknown ft.
Minimum Threshold = 1667 ft.
Measurable Objective = 1740 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1783.0
1763.0
1743.0
1723.0
1703.0
1683.0
1663.0
1643.0
1623.0
1603.0
1583.0
1563.0
1543.0
1523.0
Depth to Water (ft.)
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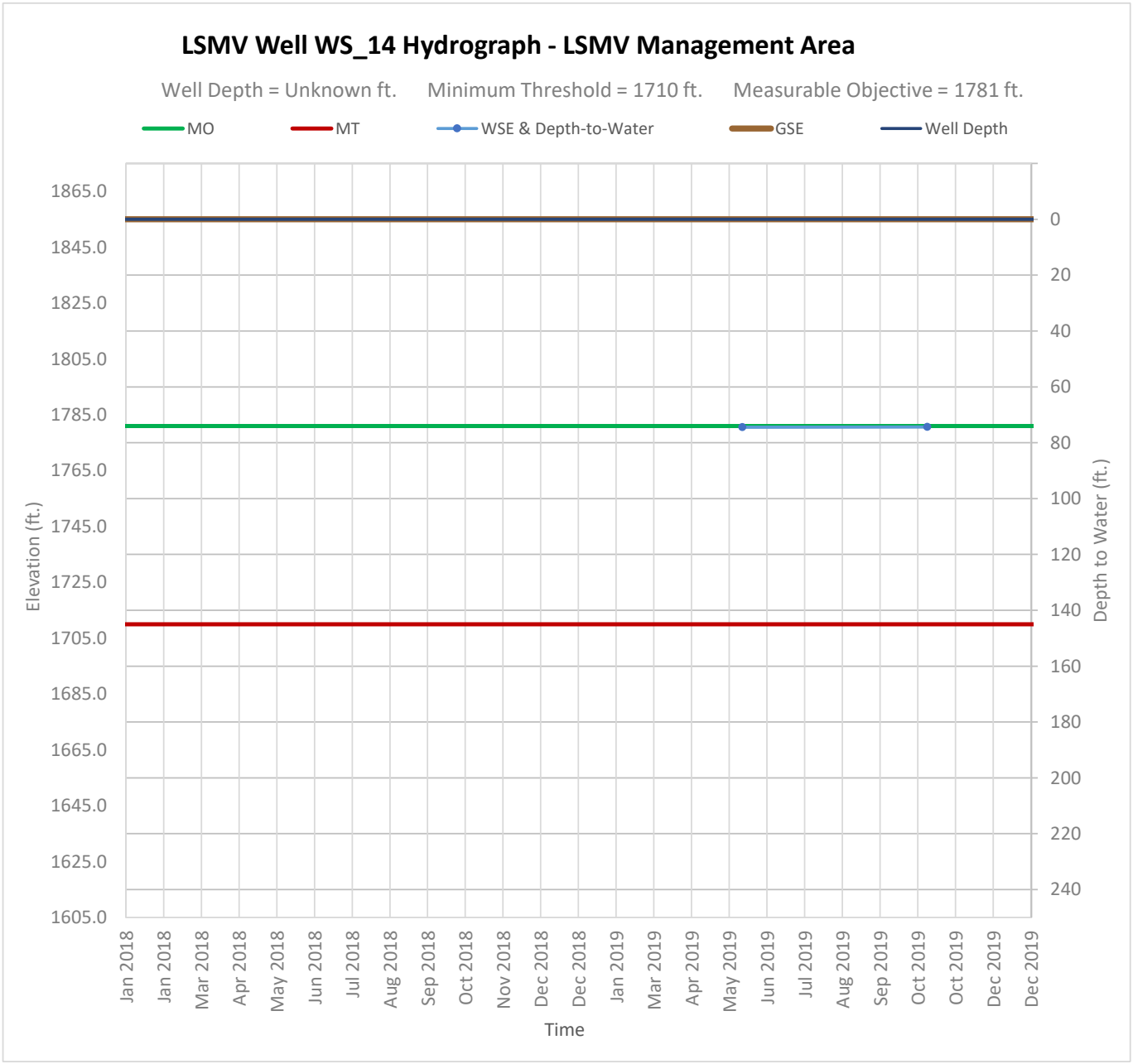

LSMV Well WS_09 Hydrograph - LSMV Management Area
Well Depth = 341 ft.
Minimum Threshold = 1675 ft.
Measurable Objective = 1743 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1774.0
1754.0
1734.0
1714.0
1694.0
1674.0
1654.0
1634.0
1614.0
1594.0
1574.0
1554.0
1534.0
1514.0
Depth to Water (ft.)
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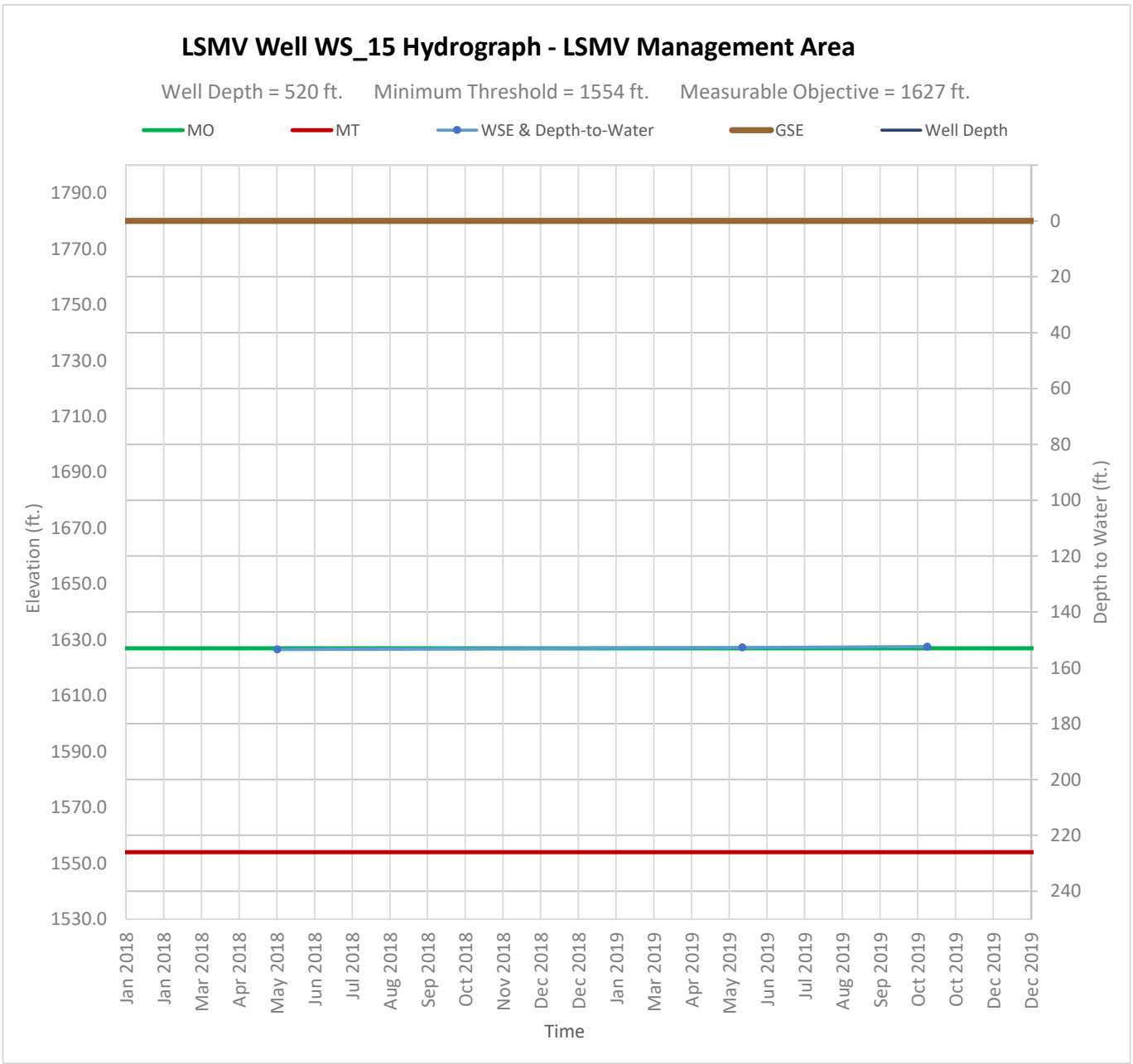

LSMV Well WS_10 Hydrograph - LSMV Management Area
Well Depth = Unknown ft.
Minimum Threshold = 1670 ft.
Measurable Objective = 1741 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1774.0
1754.0
1734.0
1714.0
1694.0
1674.0
1654.0
1634.0
1614.0
1594.0
1574.0
1554.0
1534.0
1514.0
Depth to Water (ft.)
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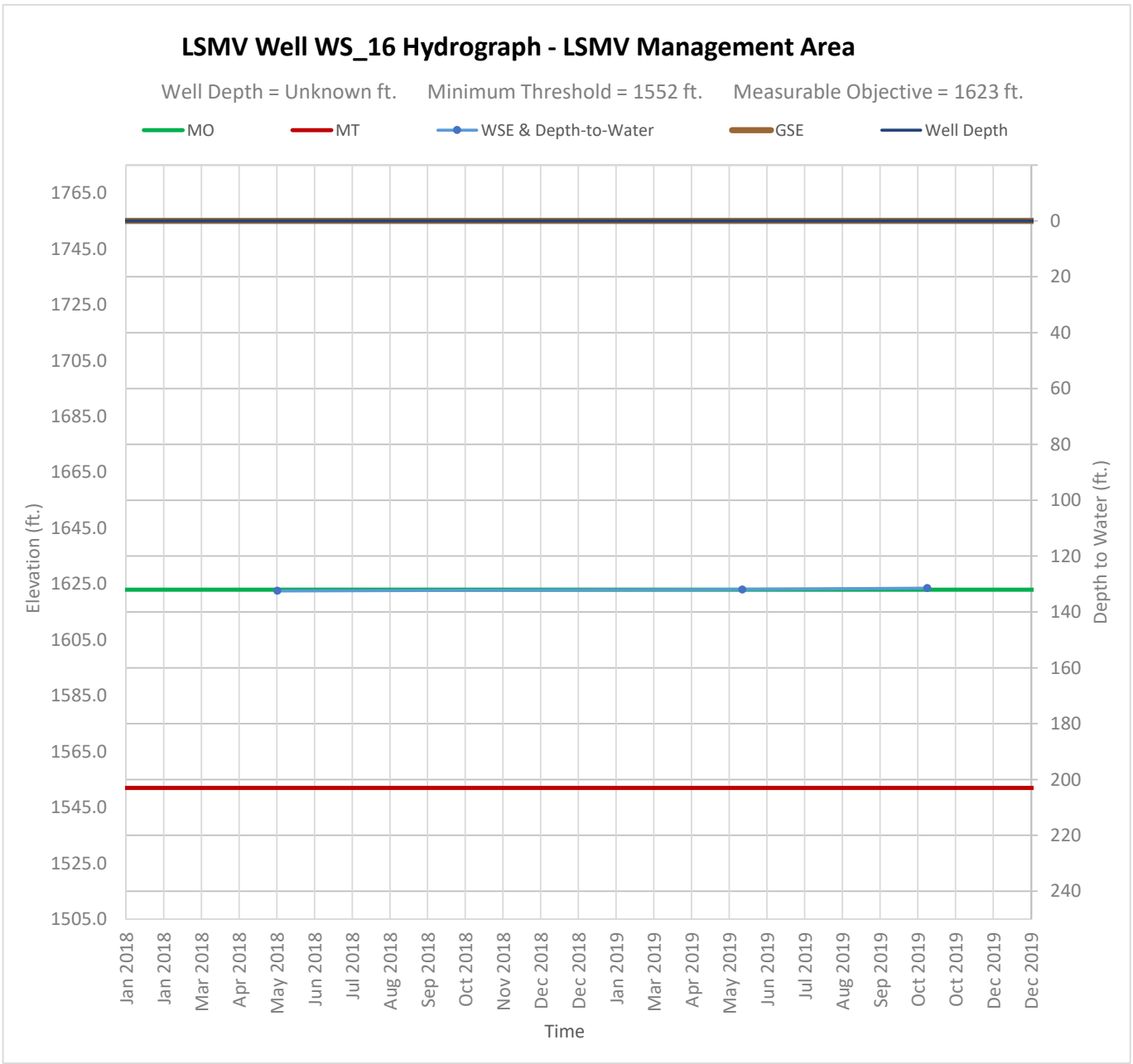

LSMV Well WS_11 Hydrograph - LSMV Management Area
Well Depth = 384 ft. Minimum Threshold = 1677 ft. Measurable Objective = 1750 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1780.0
1760.0
1740.0
1720.0
1700.0
1680.0
1660.0
1640.0
1620.0
1600.0
1580.0
1560.0
1540.0
1520.0
Depth to Water (ft.)
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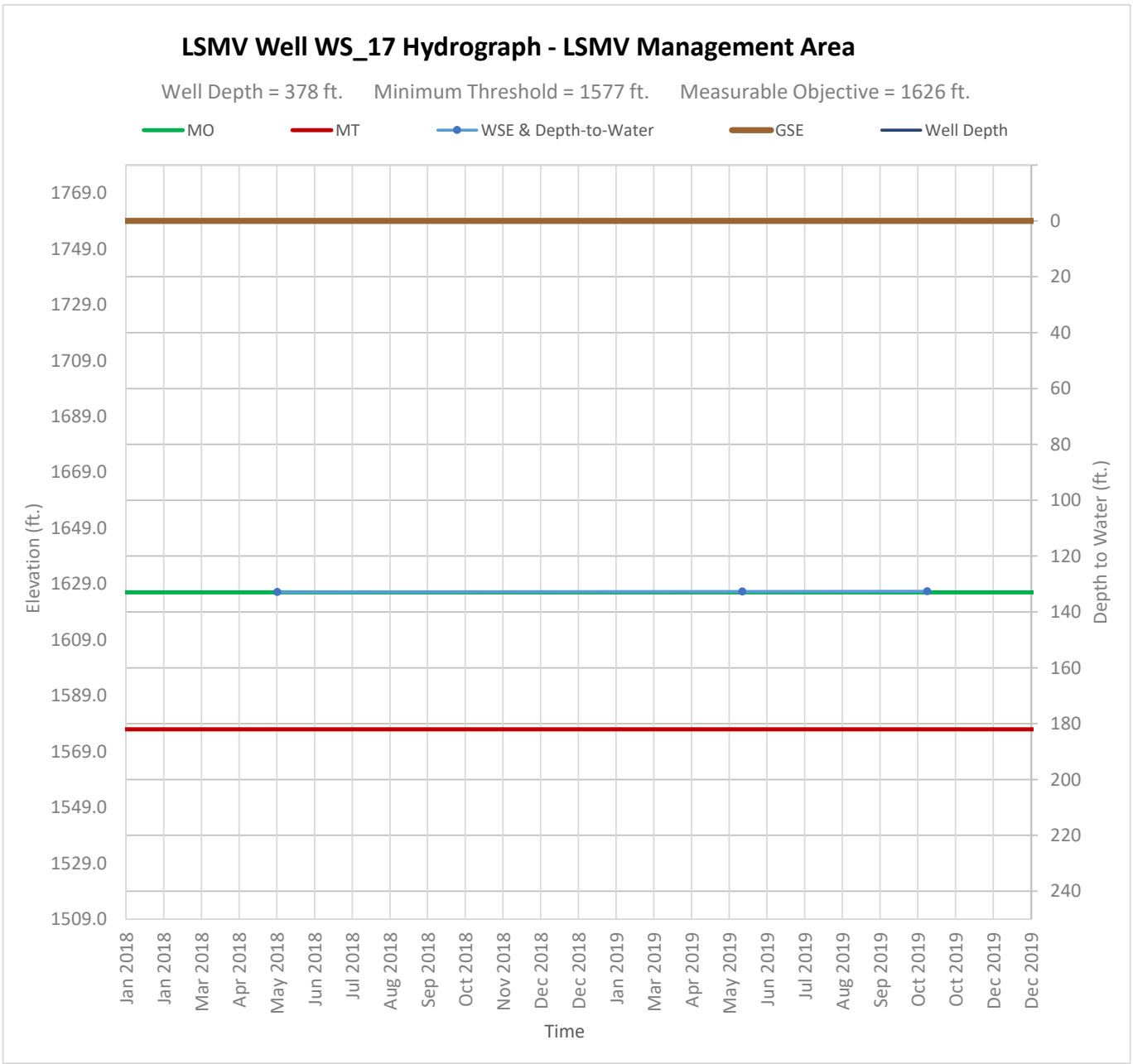

LSMV Well WS_12 Hydrograph - LSMV Management Area
Well Depth = Unknown ft.
Minimum Threshold = 1687 ft.
Measurable Objective = 1757 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1795.0
1775.0
1755.0
1735.0
1715.0
1695.0
1675.0
1655.0
1635.0
1615.0
1595.0
1575.0
1555.0
1535.0
Depth to Water (ft.)
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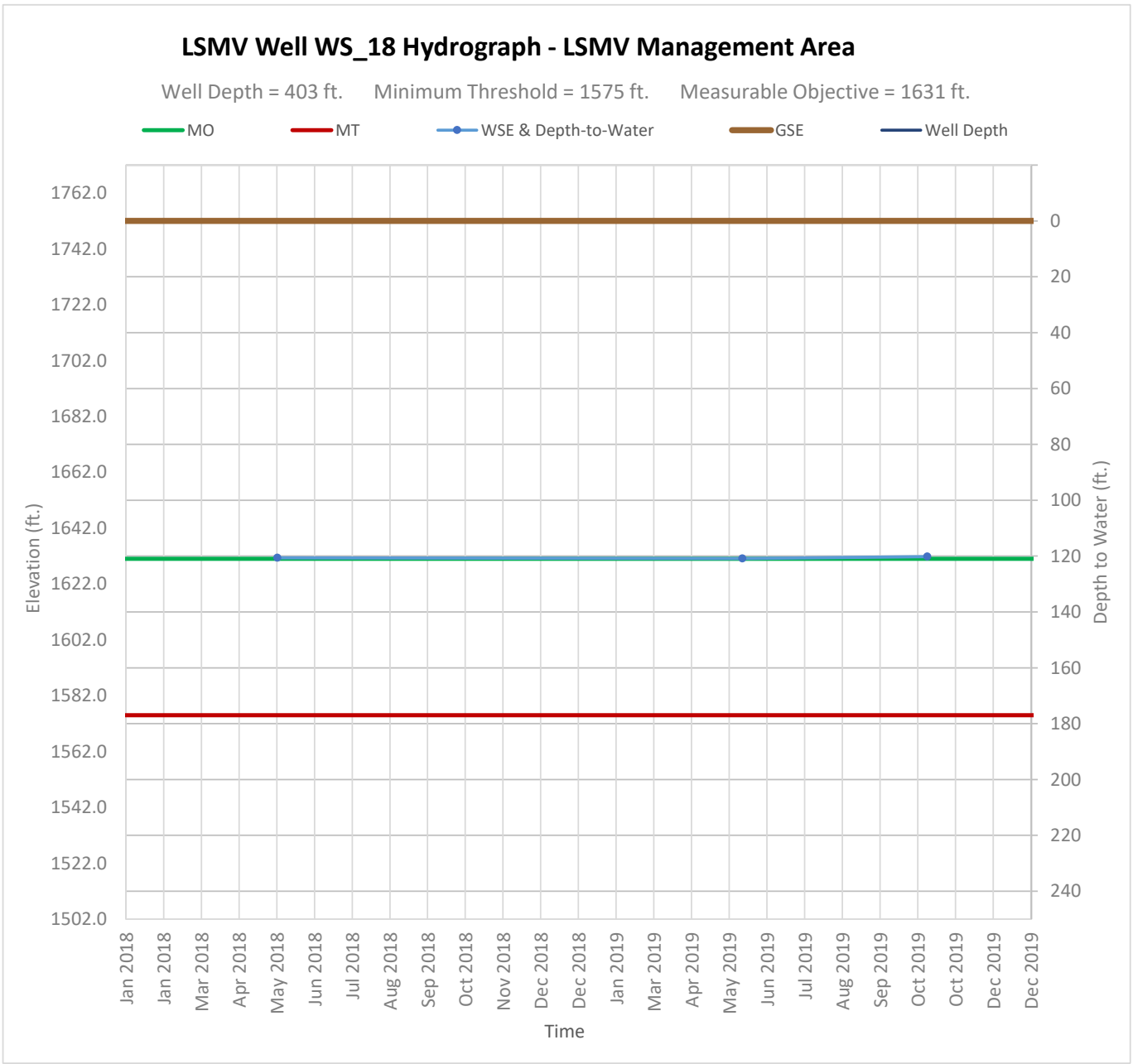

LSMV Well WS_13 Hydrograph - LSMV Management Area
Well Depth = Unknown ft.
Minimum Threshold = 1702 ft.
Measurable Objective = 1773 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
Depth to Water (ft.)
1820.0
1800.0
1780.0
1760.0
1740.0
1720.0
1700.0
1680.0
1660.0
1640.0
1620.0
1600.0
1580.0
1560.0
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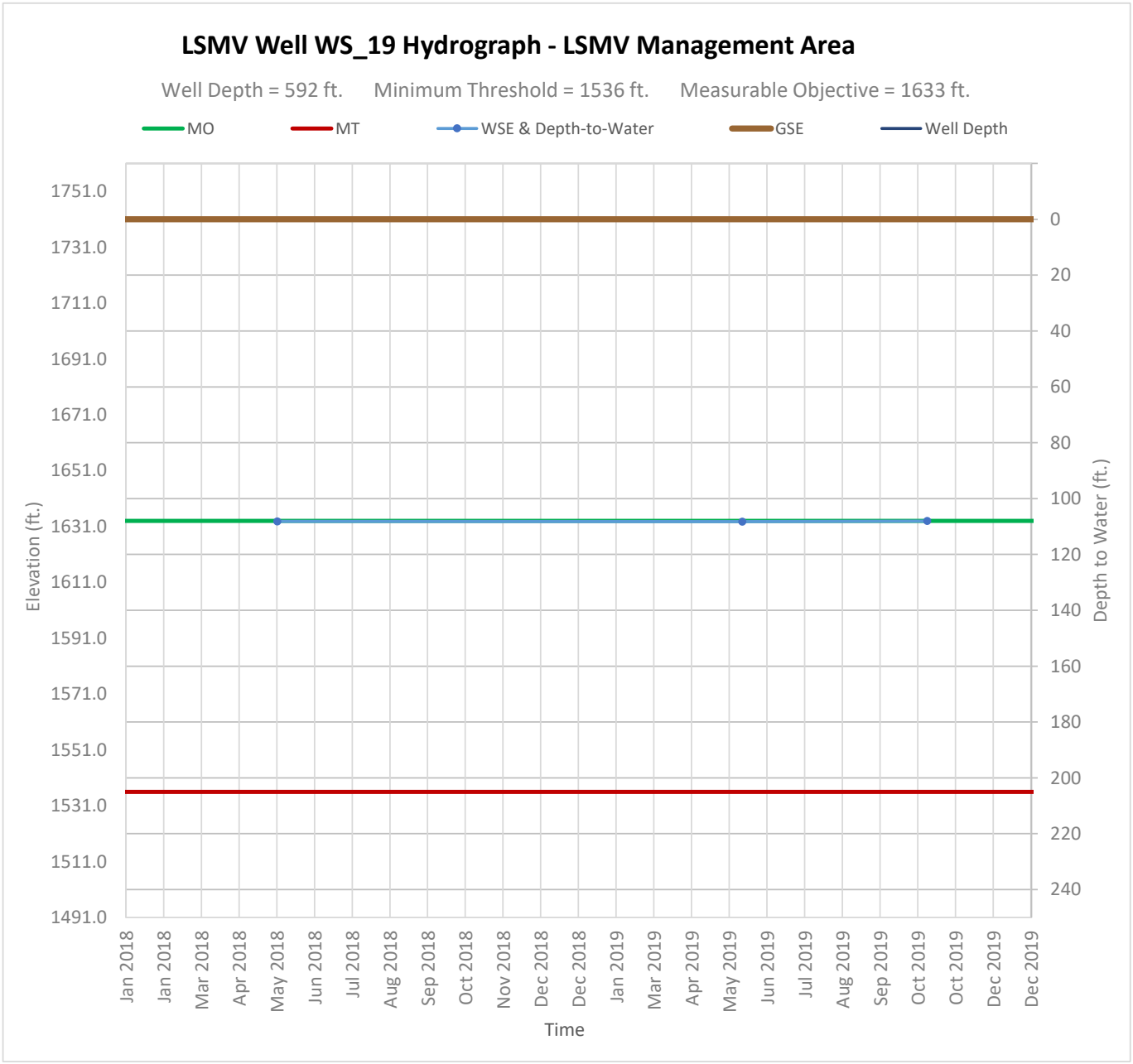

LSMV Well WS_14 Hydrograph - LSMV Management Area
Well Depth = Unknown ft.
Minimum Threshold = 1710 ft.
Measurable Objective = 1781 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1865.0
1845.0
1825.0
1805.0
1785.0
1765.0
1745.0
1725.0
1705.0
1685.0
1665.0
1645.0
1625.0
1605.0
Depth to Water (ft.)
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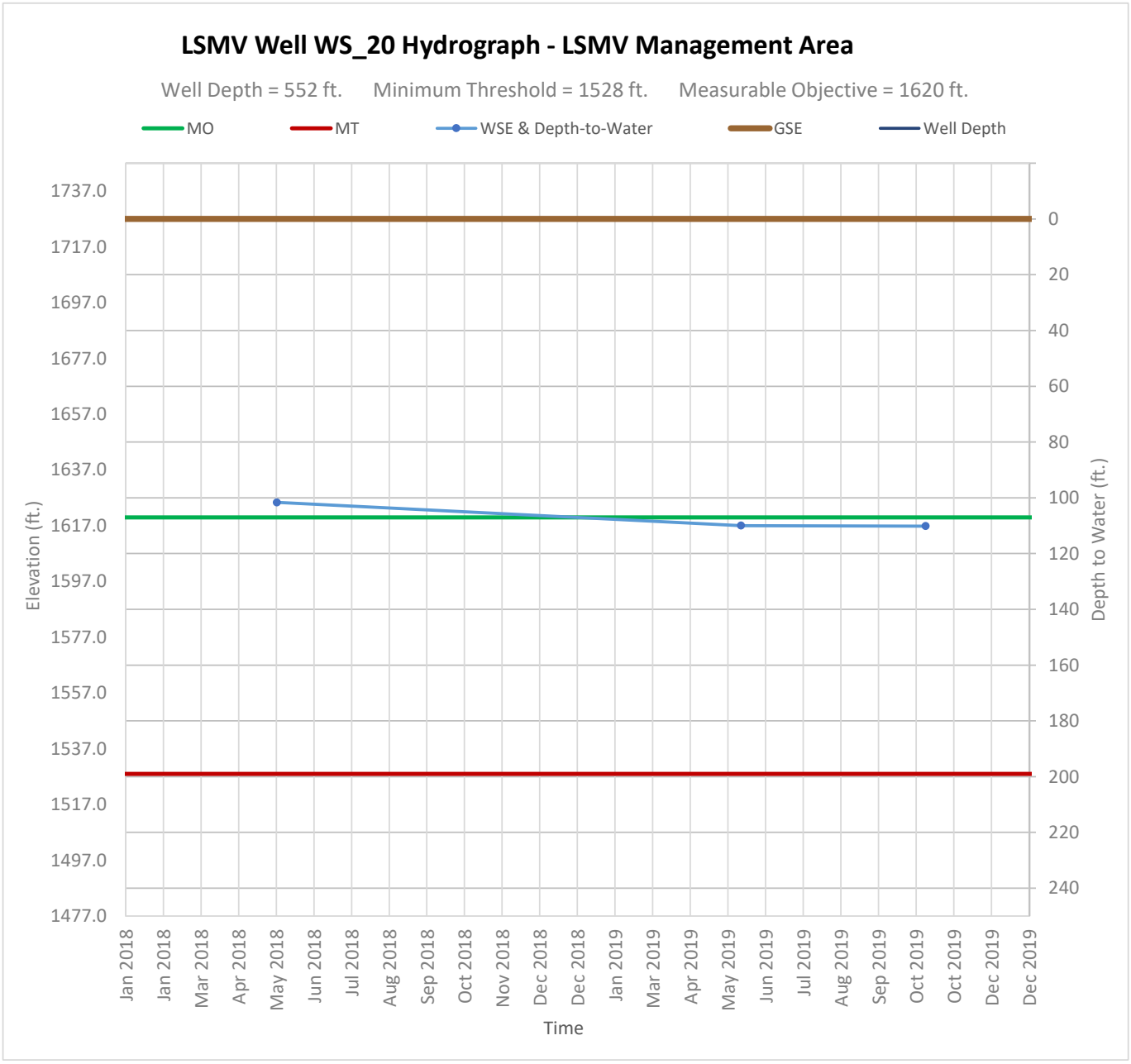

LSMV Well WS_15 Hydrograph - LSMV Management Area
Well Depth = 520 ft. Minimum Threshold = 1554 ft. Measurable Objective = 1627 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1790.0
1770.0
1750.0
1730.0
1710.0
1690.0
1670.0
1650.0
1630.0
1610.0
1590.0
1570.0
1550.0
1530.0
Depth to Water (ft.)
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LSMV Well WS_16 Hydrograph - LSMV Management Area
Well Depth = Unknown ft.
Minimum Threshold = 1552 ft.
Measurable Objective = 1623 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1765.0
1745.0
1725.0
1705.0
1685.0
1665.0
1645.0
1625.0
1605.0
1585.0
1565.0
1545.0
1525.0
1505.0
Depth to Water (ft.)
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Jul 2019
Aug 2019
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LSMV Well WS_17 Hydrograph - LSMV Management Area
Well Depth = 378 ft. Minimum Threshold = 1577 ft. Measurable Objective = 1626 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1769.0
1749.0
1729.0
1709.0
1689.0
1669.0
1649.0
1629.0
1609.0
1589.0
1569.0
1549.0
1529.0
1509.0
Depth to Water (ft.)
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LSMV Well WS_18 Hydrograph - LSMV Management Area
Well Depth = 403 ft. Minimum Threshold = 1575 ft. Measurable Objective = 1631 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1762.0
1742.0
1722.0
1702.0
1682.0
1662.0
1642.0
1622.0
1602.0
1582.0
1562.0
1542.0
1522.0
1502.0
Depth to Water (ft.)
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Jul 2019
Aug 2019
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LSMV Well WS_19 Hydrograph - LSMV Management Area
Well Depth = 592 ft. Minimum Threshold = 1536 ft. Measurable Objective = 1633 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1751.0
1731.0
1711.0
1691.0
1671.0
1651.0
1631.0
1611.0
1591.0
1571.0
1551.0
1531.0
1511.0
1491.0
Depth to Water (ft.)
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LSMV Well WS_20 Hydrograph - LSMV Management Area
Well Depth = 552 ft.
Minimum Threshold = 1528 ft.
Measurable Objective = 1620 ft.
MO
MT
WSE & Depth-to-Water
GSE
Well Depth
Elevation (ft.)
1737.0
1717.0
1697.0
1677.0
1657.0
1637.0
1617.0
1597.0
1577.0
1557.0
1537.0
1517.0
1497.0
1477.0
Depth to Water (ft.)
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Appendix I

Kern Groundwater Authority Subsidence Monitoring Recommendations

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T E C H N I C A L M E M O R A N D U M

TO: Kern County Subbasin

FROM: GEI Consultants, Inc.

DATE: October 25, 2019

RE: IMPROVEMENTS TO REGIONAL SUBSIDENCE MONITORING IN THE KERN COUNTY SUBBASIN

This memorandum was prepared, in coordination with subbasin stakeholders, to discuss improvements to fill data gaps in the Kern County Subbasin subsidence monitoring network. It prioritizes areas of interest, at a subbasin-level, that require additional subsidence monitoring. It also includes the design approach and parameters to be monitored, and references DWR guidelines regarding subsidence monitoring design.

Background and Purpose

The development of a network to monitor sustainability indicators, including subsidence, is one of the requirements of the Groundwater Sustainability Plans (GSPs) to be submitted to the Department of Water Resources (DWR) for compliance with the Sustainable Groundwater Management Act (SGMA).

In the public draft of the Kern Groundwater Authority GSP (KGA GSP) (KGA, 2019), existing land surface elevation and land subsidence monitoring is identified, along with data gaps within the existing network. The KGA GSP describes the process and rationale for identifying subsidence areas of interest (AOIs) to address data gaps, the current monitoring network, and the location of future monitoring points. The GSP includes the following objectives for monitoring, which are applicable to land subsidence:

1. Demonstrate progress toward achieving measurable objectives described in the management area and throughout the Subbasin;
2. Monitor impacts to the beneficial uses and users of groundwater, surface land uses, and critical infrastructure; and
3. Monitor changes in groundwater conditions (or land subsidence) relative to measurable objectives and minimum thresholds.

The monitoring network is designed to monitor impacts to surface land uses or critical infrastructure as stated in the Subbasin-wide definition of undesirable results for land subsidence (KGA, 2019 emphasis added):

> *The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure.*
>
> *This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.*

One of the purposes for improving the subsidence monitoring network is to collect additional data at each AOI to fill data gaps so that sustainable management criteria (SMCs) can be set. As more data are gathered for the AOIs, Kern County Subbasin GSAs and stakeholders can establish SMCs to avoid undesirable results stemming from subsidence.

AOI Screening and Monitoring Approach

The first step in the subsidence monitoring approach is to identify AOIs based on the presence of critical infrastructure or other surface land uses. These AOIs can then be evaluated based on the decision-making criteria listed below to determine if monitoring is required. This process is illustrated in Figure 1.

An AOI requires monitoring if the following three criteria apply:

1. Infrastructure or surface land uses are susceptible to land subsidence.
2. Significant land subsidence has been observed in screening from Interferometric Synthetic-Aperture Radar (InSAR) or other remote sensing techniques.
3. The subsidence is caused by groundwater extraction.

Where data gaps exist in evaluating the criteria, additional investigation may be necessary. For example, further investigation at AOI-2 is necessary to evaluate if groundwater extraction is causing subsidence.

Monitoring Parameters

If the area is identified as an AOI that requires monitoring, then the following actions should be taken:

A. Groundwater level monitoring near the AOI,

B. Ground-truthing of subsidence detected by InSAR (CGPS, extensometer, or level surveying), and

C. Monitoring of the critical infrastructure.

As depicted in Figure 1, the process for establishing monitoring points includes locations with susceptible critical infrastructure where InSAR and/or other historical and recent monitoring has detected recent subsidence that is likely caused by groundwater extraction.

Regional Coordination

Regional coordination of monitoring is key to the design of the network in the subbasin because regional groundwater extraction is a main driver of subsidence. In addition, many of the critical infrastructure are regional and may require coordination for access within the vicinity and data sharing.

Subsidence associated with oil and gas activities may also occur in the subbasin. However, any subsidence potentially associated with oil and gas activities is regulated by the California Division of Oil, Gas, and Geothermal Resources (DOGGR) under the California Public Resources Code and is therefore separate from SGMA requirements. Coordination between groundwater and oil and gas stakeholders may be needed where there is potential for both activities to cause subsidence that impacts critical infrastructure.

Figure 1 on next page

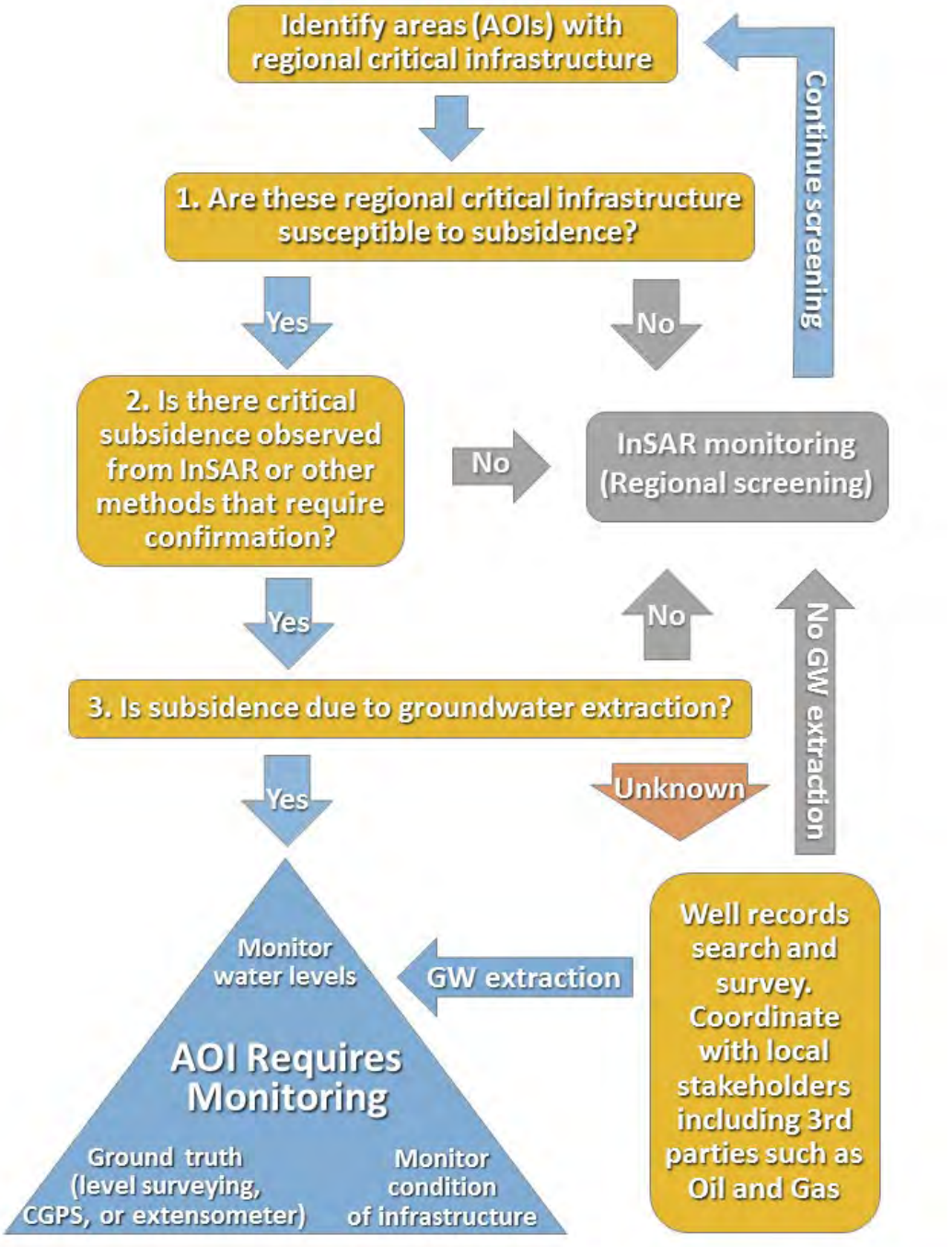


Figure 1. Subsidence Monitoring Decision Making Process and Criteria.

Improvements to Monitoring Network

Timeline and Approach

Five AOIs were identified, in order of priority, to improve the subbasin monitoring network (AOI-1 to AOI-5). Two of these areas are located along the Friant-Kern Canal (FKC), two are along the California Aqueduct, and one area is for monitoring changes in land surface elevation along the northern boundary of the subbasin where a significant amount of subsidence has been reported in the InSAR data.

It is anticipated that these sites will be evaluated in order of priority and may take up to several years to design and implement monitoring points.

Each monitoring site design will consider the following:

1. Confirm groundwater extraction is the cause of subsidence (if necessary),
2. Land siting and ownership,
3. Site access,
4. Monitoring design (CGPS or extensometer),
5. Confirmation that data for all three monitoring parameters can be collected (a. groundwater elevations, b. subsidence, and c. condition of infrastructure), and
6. Connection to the monitoring network and data sharing.

The subsidence monitoring network AOIs are presented on Figure 2. AOI-1 was selected to monitor along the FKC where subsidence has been detected near the northern boundary of the subbasin. AOI-2 was selected where the California Aqueduct has had historical impacts partially attributed to subsidence. AOI-3 along the FKC south of Poso Creek has had subsidence detected and reported by the North Kern WSD. AOI-4 along the California Aqueduct has had subsidence reported by DWR Division of Engineering (DOE) and InSAR, and AOI-5 along the northern boundary of the subbasin is not associated with critical infrastructure but is the location of high cumulative subsidence at the boundary of the subbasin and may be indicative of conditions in the neighboring subbasins which have the potential to impact the conditions of the Kern County Subbasin.

Groundwater Elevations

A key parameter in evaluating subsidence as a sustainability indicator for groundwater management is understanding groundwater level changes with respect to subsidence, particularly regional changes in water level. Figure 3 presents the regional water level monitoring points (RMWs) from the draft GSP with respect to the five AOIs for subsidence monitoring. The following are observations of RMWs within AOI vicinity:

- AOI-1 has a few surrounding RMWs; however, none are within 1 mile of the FKC.
- AOI-2 has one RMW within a mile of the Aqueduct and the AOI.
- AOI-3 has one RMW in the central portion about 1 mile from FKC.
- AOI-4 has two RMWs within the vicinity of the Aqueduct.
- AOI-5 has no RMWs within 1 mile.

Recommendation

Where possible, subsidence monitoring stations should be installed within 1 mile of a reliable RMW. If necessary, a new RMW may be installed to provide a point at which groundwater level may be collected in proximity to the land surface elevation monitoring point.

AOIs listed on subsequent pages

AOI-1. FKC Milepost 120 to 130

This high priority area is located along the FKC between Mileposts 120 to 130 (Figure 2), east-northeast of the City of McFarland. The purpose of this AOI is to monitor subsidence along the FKC and its related infrastructure. At times, InSAR monitoring has reported up to 5 inches per year of subsidence in areas surrounding this segment of the FKC. At present, no significant impacts to the FKC have been reported along this portion of the canal's alignment. According to leveling survey data from Friant Water Authority (FWA, 2019), the FKC invert may have subsided from 2 ft to 3 ft below original as-built elevations between Mileposts 120 to 135. Continued lowering of the canal invert can decrease freeboard from the original as-built conditions, which may contribute to reduction in emergency storage capabilities and delivery options of the Canal.

In contrast, beyond the subbasin's northern boundary, subsidence has caused significant impacts to the FKC conveyance capabilities between Mileposts 101 to 108.

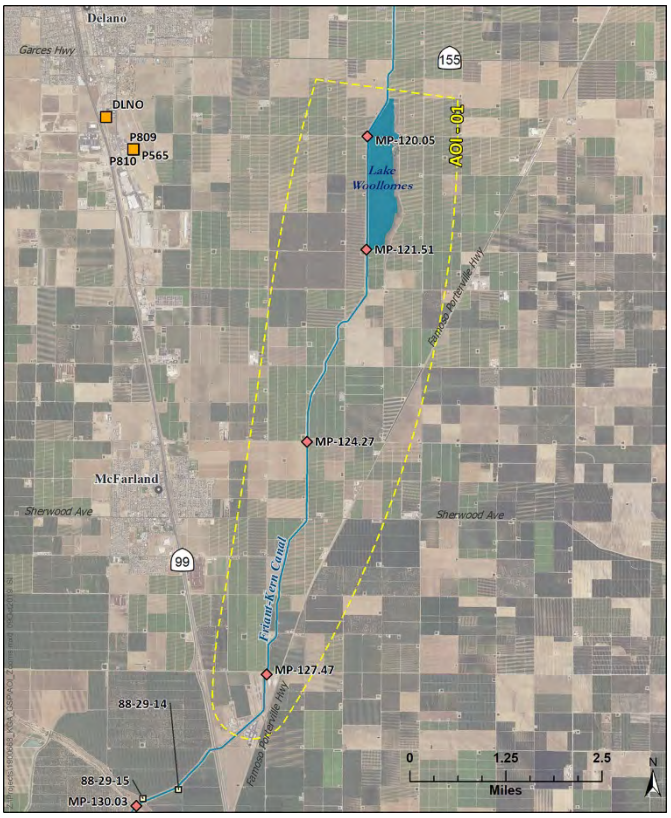


Figure 4. AOI-1. FKC Milepost 120 to 130
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR, and previous level surveying was performed by FWA at the mileposts labeled on Figures 2 and 4. There are no other active monitoring points except for InSAR along this stretch.

New Monitoring Approach

A new CGPS station that monitors at the ground surface any subsurface subsidence, regardless of the depth interval, is recommended because the only known cause of subsidence in this area is attributed to groundwater extraction. This CGPS data will complement any manual level surveys that may incorporate the FWA reported measuring points. CGPS data may also provide on-demand data as needed.

Coordination of Monitoring

Subsidence monitoring along the FKC benefits local stakeholders, CVP contractors, and the FWA. It is anticipated that this monitoring can be coordinated with FWA to share data as well as potentially share resources and cost.

Any level surveying along the canal from the United States Bureau of Reclamation (USBR) Friant-Kern benchmarks (Figure 2) will require coordination with the FWA.

AOI-2. California Aqueduct Milepost 196 to 215

This high priority area is the segment of the California Aqueduct where an embankment failure occurred at Milepost 208 in June 2011 (DWR, 2017). This failure is partially attributed to subsidence. The cause of this subsidence is unknown and is therefore a subject of monitoring at this location. This area is along the Aqueduct between Mileposts 196 to 215 in the western central subbasin (Figure 2). In addition to embankment failure, other consequences of subsidence include loss in freeboard in the Aqueduct. This area has experienced at least 2 feet of subsidence since the Aqueduct was constructed.

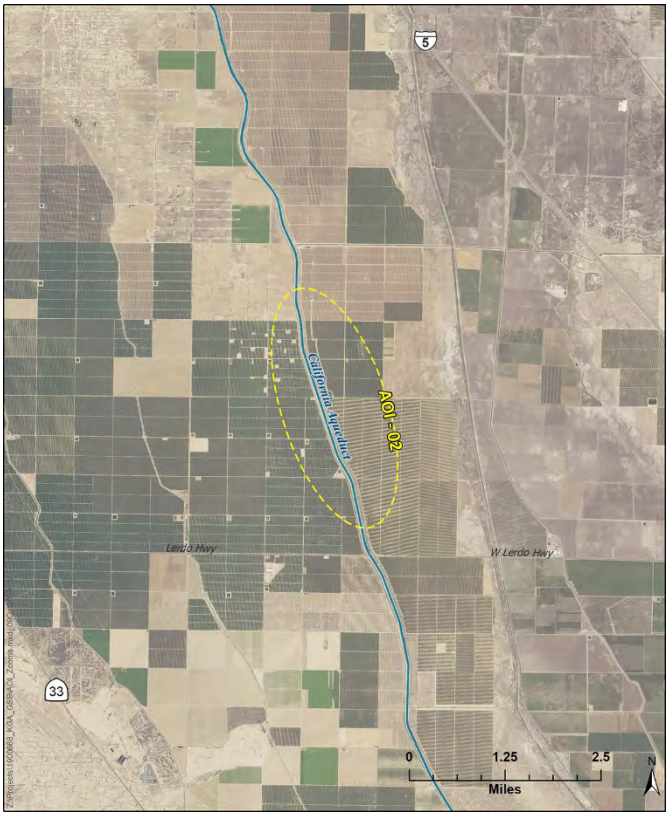


Figure 5. AOI-2. CA Aqueduct Milepost 196 to 215
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR and is monitored with level surveys every three to seven years by the DWR's DOE. There are no other active monitoring points along this stretch.

New Monitoring Approach

The source of subsidence, either by groundwater extraction activities or other activities, will be investigated by performing well records searches from DWR well completion records, the Kern County Public Health Department well permit records, and the DOGGR's databases. If necessary, a field well survey may be performed. Coordination may be needed with local stakeholders to confirm the magnitude of groundwater extracted within 1 mile of this portion of the Aqueduct's alignment and the volume of fluids extracted and injected by oil and gas activities within 1 mile of this alignment. A third potential source for subsidence in this area could be hydrocompaction, which was identified during the initial design and construction of the Aqueduct. Pre-consolidation of soil was performed during initial construction so hydrocompaction is likely not significant, however, it cannot be ruled out at this time.

If it is determined that groundwater extraction is playing a role in subsidence for this area, a monitoring point should be installed away from the footprint of the Aqueduct to avoid potential signatures of hydrocompaction if any exist. If there is question of whether some of the subsidence is related to nearby oil and gas activities, then an extensometer should be installed in the interval where groundwater production occurs. An extensometer will provide data of subsidence pertaining to intervals with groundwater production, whereas a CGPS would capture any subsidence regardless of the depth interval.

Coordination of Monitoring

Subsidence monitoring along the Aqueduct benefits local stakeholders, State Water Project (SWP) contractors, and the DWR's DOE. It is anticipated that this monitoring can be coordinated with DWR to share data as well as potentially share resources and cost.

AOI-3. FKC Milepost 130 to 137

This medium priority area is located along the FKC between Mileposts 130 to 137 (Figure 2), southwest of Famoso and Poso Creek. The purpose of this AOI is to monitor subsidence along the FKC infrastructure where InSAR and local stakeholders have reported subsidence in the surrounding area. As with AOI-1, no significant impacts to the FKC have been reported along this stretch. According to leveling survey data from the FWA (2019), the FKC invert may have subsided from 2 ft to 3 ft below original as-built elevation between Mileposts 120 to 135. Continued lowering of the canal invert can decrease freeboard from the original as-built conditions, which may contribute to reduction in emergency storage capabilities and delivery options of the Canal.

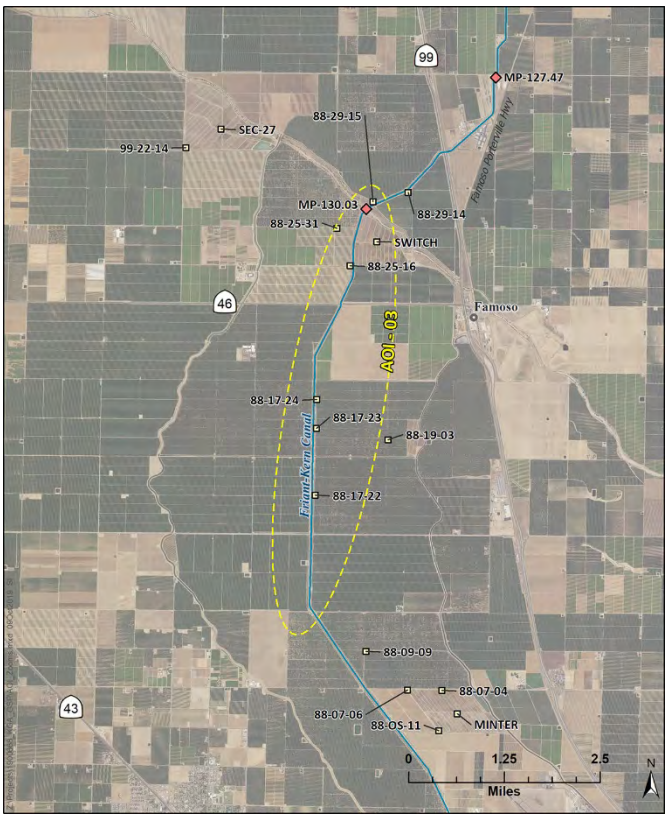


Figure 6. AOI-3. FKC Milepost 130 to 137
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR, and previous level surveying was performed by the FWA at Mileposts labeled on Figure 2. Local districts monitor this stretch regularly as labeled on Figures 2 and 6. Currently there are no continuous monitoring points along this stretch.

New Monitoring Approach

A CGPS station that monitors from the ground surface, any subsurface subsidence regardless of the depth interval, is recommended because the only known cause of subsidence in this area is attributed to groundwater extraction. This CGPS data will complement manual level surveys from local district surveys. CGPS data will also provide nearly on-demand data as needed.

Where possible, this station should be tied in to benchmark surveys performed by local districts.

Coordination of Monitoring

Subsidence monitoring along the FKC benefits local stakeholders, CVP contractors, and the FWA. It is anticipated that this monitoring can be coordinated with FWA to share data as well as potentially share resources and cost.

Any level surveying along the canal from USBR Friant-Kern benchmarks (Figures 2 and 6) will require coordination with the FWA.

AOI-4. California Aqueduct Milepost 267 to 271

This medium priority area is located along the Aqueduct between Milepost 267 to 271 near Old River Road. InSAR data report subsidence southwest and along I-5 and southwest toward the Aqueduct along Old River Road. A former CGPS station (BKR1/2) located about 5 miles north of the Aqueduct along Old River Road also reported significant subsidence; however, this station has since been decommissioned (2016).

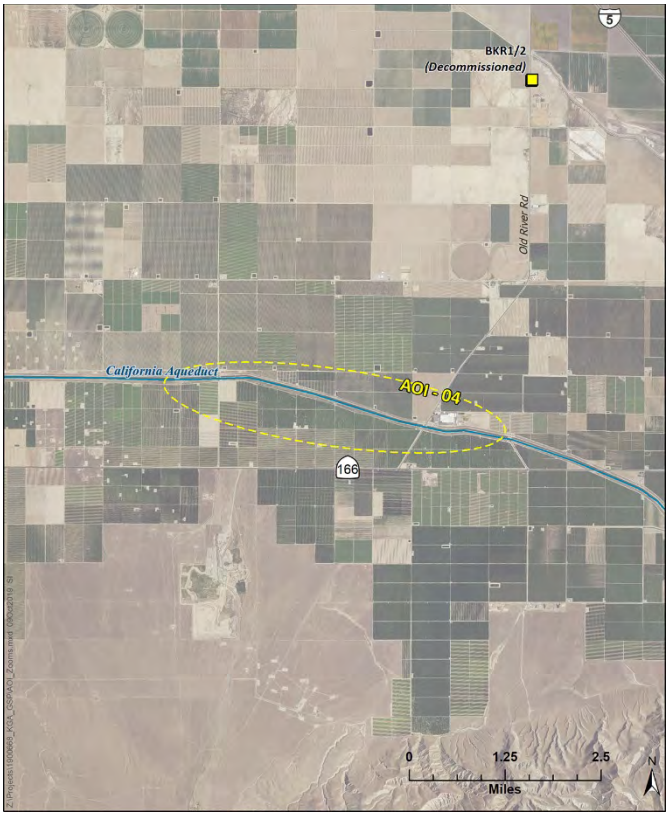


Figure 7. AOI-4. CA Aqueduct Milepost 267 to 271
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR, and is monitored by level surveying every three to seven years by the DWR's DOE. There are no other active monitoring points along this stretch.

New Monitoring Approach

Groundwater extraction is potentially the source of subsidence, so a continuous monitoring station such as a CGPS or extensometer will be installed. Other potential sources could be oil and gas extraction and hydrocompaction. A DOGGR records search may provide sufficient information to understand the extent of oil and gas extraction in this area. Although hydrocompaction may not be significant because of pre-consolidation practices during Aqueduct construction, nonetheless, in order to avoid potential signatures of hydrocompaction, a monitoring point should be installed away from the footprint of the Aqueduct. If feasible during the siting study, the site location may be selected to the north between the Aqueduct and former BKR1/2.

Where possible, this station should be tied in to benchmark surveys performed by local districts.

Coordination of Monitoring

Subsidence monitoring along the Aqueduct benefits local stakeholders, SWP contractors, and the DWR's DOE. It is anticipated that this monitoring can be coordinated with DWR to share data as well as potentially share resources and cost.

AOI-5. Central-Northern Boundary of Subbasin

This medium priority area is in the northern quarter of T25S-R24E and T25S-R25E. Currently, this AOI does not have recognized susceptible critical infrastructure. It has significant subsidence reported both historically (USGS level surveys) and recently (InSAR). A CGPS station in this area will provide a needed ground truthing point to confirm InSAR readings and will act as a useful monitoring point to gauge progress of groundwater management along the border of the subbasin in relation to neighboring subbasins to the north.



Figure 8. AOI-5 Central-Northern Boundary of Subbasin
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR. There are no other active monitoring points along this stretch.

New Monitoring Approach

Groundwater extraction is potentially the source of subsidence, so a CGPS or extensometer monitoring station should be installed. Where possible, this station should be tied in to benchmark surveys performed by local districts.

Coordination of Monitoring

Subsidence monitoring along the subbasin boundary benefits local stakeholders in Kern County subbasin and adjacent subbasins. In the future, data may be shared with neighboring GSAs for coordination.

Monitoring and Design Guidelines

According to the BMP (DWR, 2016), Leveling surveys and CGPS surveys must follow, at a minimum, guidelines in the *CalTrans Survey Manual*: https://dot.ca.gov/programs/right-of-way/surveys-manual-and-interim-guidelines. Extensometer resources from USGS are also listed in the BMP (DWR, 2016).

In addition to CalTrans guidance, UNAVCO has provided many CGPS design specifications on their website. UNAVCO offers a robust CGPS monument design (deep drill based monument [DDBM] that minimizes interference in data recording from soil expansion and temperature effects. Attachments 1 and 2 include example specifications for CGPS stations from CalTrans and UNAVCO, respectively. Attachment 3 includes sample extensometer designs for reference.

Rough Costs to Consider

For subbasin-wide monitoring to be implemented with the recommended AOIs in this memorandum, Kern Subbasin stakeholders will coordinate how the work will be implemented. Below is a brief summary of rough costs expected for the installation of each monitoring solution. Costs do not include ongoing management and maintenance of the stations. Actual costing will be confirmed during procurement and the planning process.

Level Surveying and Benchmarks (not proposed in this memo, but is an alternative approach).

- Install benchmarks where none available along linear features every 1/8 to 1/4 mile in area of interest.
- Each ~$500 to $2500 installation
- Initial Survey (5 to 8 monuments per day). ~$1500-$2500 per day (includes reporting).
- Subsequent Surveys (8 to 10 monuments per day). ~$1500-$2500 per day (includes reporting).

CORS CGPS Station

- ~$30k to $100k depending on equipment (purchase and installation). This may not include programming and digital network setup.
- DWR may be able to provide technical assistance, and at a minimum, review design specifications if DWR concurrence is wanted. DWR has not at this time offered any current specifications or assistance in developing designs.
- Optional outside consulting may be recommended for design and programming.

Extensometer

Drilling and installation costs ~$200k to $300k (design and operation not included).

Conclusions

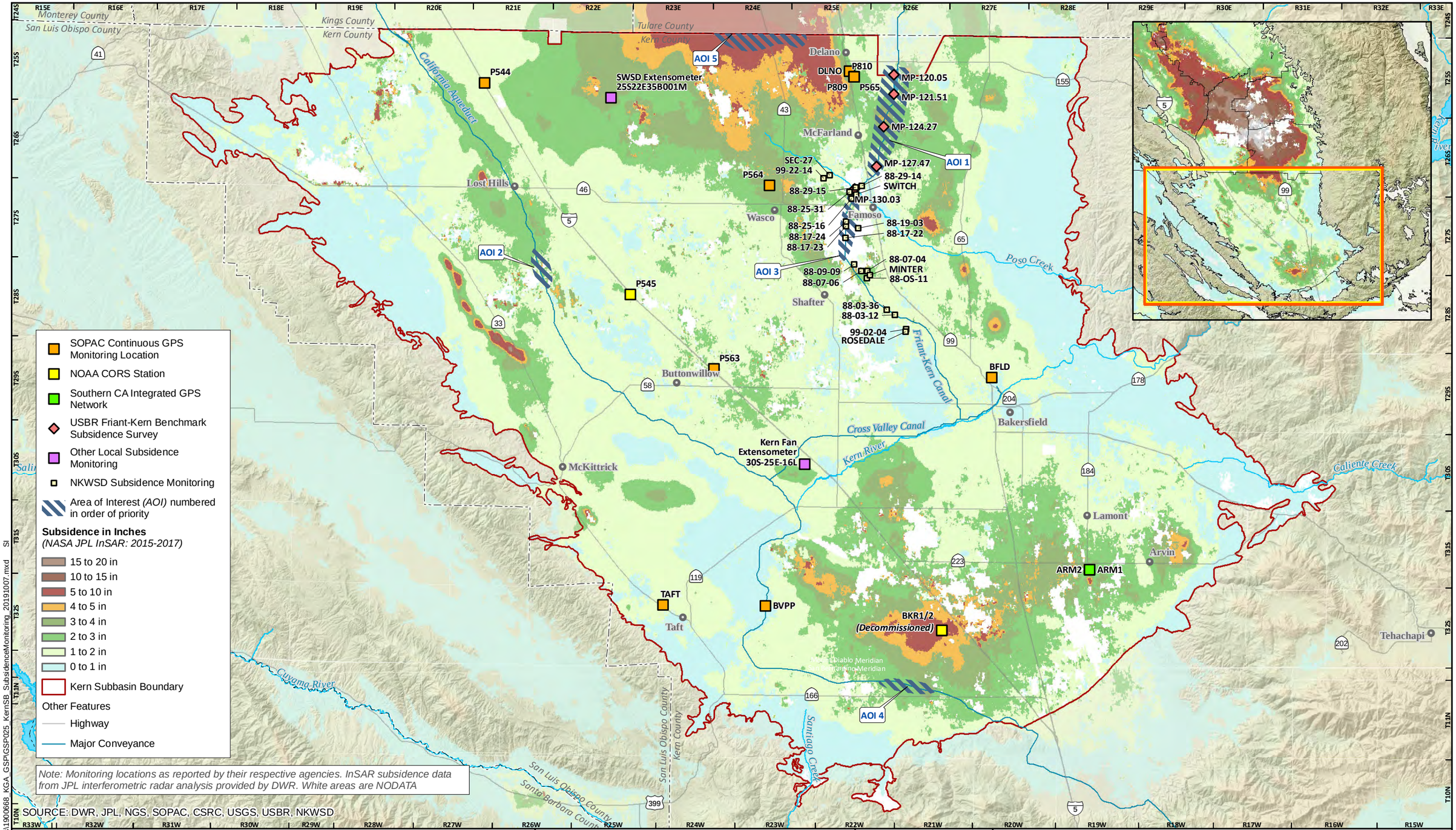
This memorandum was prepared, in coordination with subbasin stakeholders, to improve the Kern County Subbasin subsidence monitoring network. It prioritizes areas of interest, at a subbasin-level, that require additional subsidence monitoring. Figures 2 and 3 present the AOIs for future monitoring points and associated water level monitoring wells (RMWs). AOIs are listed in order of highest priority for investigation and monitoring installation. Figures 4 to 8 present aerial images of these areas. In AOIs where groundwater extractions and oil and gas activities may be contributing to subsidence, extensometers will be installed in lieu of CGPS points in order to monitor the depth interval of groundwater extractions. Where subsidence monitoring is required, monitoring water levels and the condition of infrastructure is necessary. Where groundwater extraction is not causing subsidence, the AOI can be screened by the region-wide InSAR subsidence monitoring network.

References

DWR. 2016. Monitoring Networks and Identification of Data Gaps. Best Management Practices (BMP) for the Sustainable Management of Groundwater. December.

DWR. 2017. California Aqueduct Subsidence Study. San Luis Field Division. San Joaquin Field Division. June.

Kern Groundwater Authority (KGA). 2019. Groundwater Sustainability Plan of Kern County Subbasin. Public Draft. August.



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

REGIONAL SUBSIDENCE MONITORING NETWORK

OCTOBER 2019 **DRAFT** FIGURE 2

07-Oct-2019 Z:\Projects\1900668_KGA_GSP\GSP025_KernSB_SubsidenceMonitoring_20191007.mxd SI



0.137 in = 1 mile

0 7 14 21 Miles

0.48 in

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

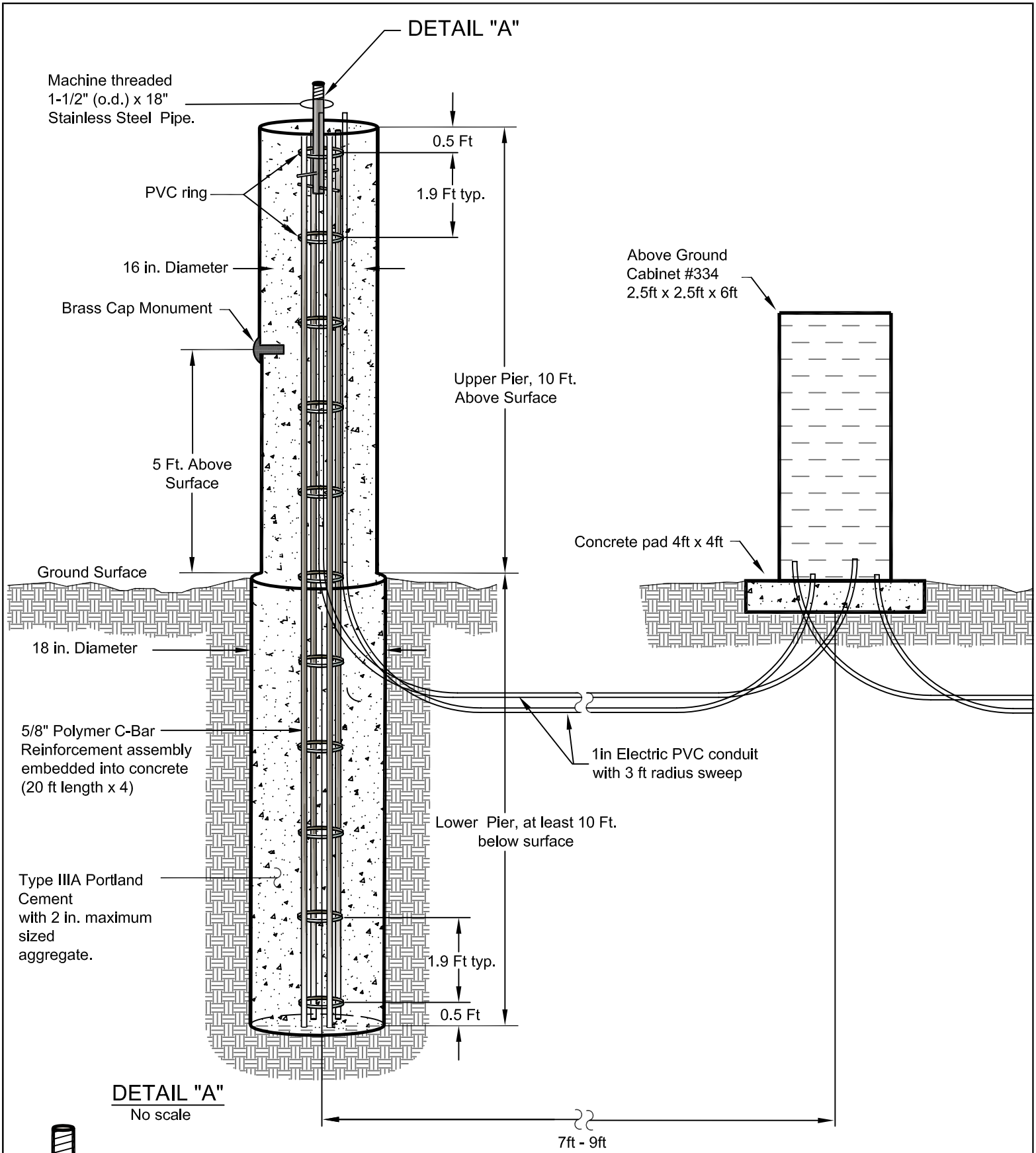
REGIONAL GROUNDWATER LEVEL MONITORING NETWORK

JULY 2019 DRAFT FIGURE 3

\\sac1s-fs01\GIS\Projects\1900668_KGA_GSP\GSP032_MTMO_MonNetwork_20190826.mxd AB/SI MM Export with AOIs. PDF edit for RMW-098 26Aug2019

Attachment 1. CGPS CDOT Design

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Caltrans
855 M Street, Suite 200, Fresno, CA 92721

Monument CVSRN

TAFT MS
Station Name

CENTRAL VALLEY SPATIAL REFERENCE NETWORK

C V S R N

Design By: GC	Revision: Feb 20, 2007
Drawn By: PNP	Scale: None
File: Monument TAFT	
Date:Feb 20, 2007	Sheet 1 of 1

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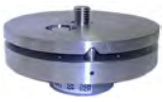
Attachment 2. CGPS UNAVCO Design and Resources

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Deep Drilled Braced Monument Overview

Article ID: 300 | Rating: Unrated | Last Updated: Wed, Oct 26, 2011 at 6:49 PM

Deep Drilled Braced Monument

Back to comparison table	Mount Commonly Used	Stability	Cost	Install Time	Labor	Substrate	Site Impact
	 SCIGN mount	high	$7,500-15,000	2-4 d	3-4	BR, U	high

The deep drilled braced monument (UNAVCO DDBM*) provides for a high degree of stability and longevity and can be anchored in bedrock or unconsolidated material. It is in the form of a tripod, each leg extending into the ground up to about 40 feet and welded at the top with gusset reinforcements. If site access is an issue and bedrock is available, the short drilled braced monument is the next best alternative to this type. The UNAVCO DDBM is used throughout the PBO network. It is based on the SCIGN design used at older installations in the SCIGN, BARGEN, PBO and PANGA networks.

* Modified from the original SCIGN DDBM design of Duncan Agnew and Frank Wyatt.



Site ASHM of the BARGEN network, Nevada, Utah, and California.

Pros

- high stability
- longevity
- can be installed in either bedrock or unconsolidated materials

Cons

- labor and tool intensive (requires a drilling rig and crew)
- expensive (can be $7,500 to $15,000, depending on drilling)
- time intensive (requires 2-4 days)
- may not be able to install in some remote locations... depends upon ease of site access
- large construction disturbance footprint

Design and Construction

A drilling contractor is required to install this monument. The cost of installation can typically range between $6,000 and $10,000 depending upon factors such as the type of drilling rig used, distance the drill rig and crew need to travel to site (mobilization/de-mobilization), foundation material (ground) being drilled, etc.

- Driller's Instructions (.pdf)

Documents

- Deep Drilled Braced Monument Technical Drawings in .pdf format:
  - Full
  - Above Surface
  - Top
  - Construction
  - Site Layout
  - Sub-surface
- Deep Drilled Braced Monument Alignment Tool Diagrams in .pdf format:
  - sign-01-01-010.pdf
  - sign-01-01-020.pdf
  - sign-01-01-030.pdf
  - sign-01-02-010.pdf
  - sign-01-02-020.pdf
  - sign-01-02-030.pdf

Installation Photos

- Construction Photos

Approximate Cost

$7,500-15,000 depending principally on drilling (substrate, distance drill rig needs to travel to and from the site)

This cost is for the monumentation only; the antenna mount (e.g. SCIGN mount) is not included.

Materials

- 21-foot 1.25" diameter schedule 40 stainless steel pipe, threaded (5 per site)

- 10-foot 1.25" diameter schedule 40 stainless steel pipe, threaded (5 per site)
- 1.25" schedule 40 stainless steel threaded adapters (5 per site)
- 3 weld gussets
- threaded adapter (if using the SCIGN antenna mount; see below)
- 2.5" diameter schedule 40 PVC (for each leg and for center post)
- foam wrapper (for each leg and for center post)
- rebar (for each leg and for center post)
- duct tape (for foam)
- concrete (provided by drillers)
- water (provided by drillers)
- welding rod
- gas for the generator (if there is no AC hookup)
- string, paint, nails, and wood stakes (for marking legs)

Tools

- generator (if there is no AC hookup)
- compass
- reel measuring tape (30m/100ft)
- leg alignment tool
- mallet
- large vice grips (2 or more)
- grinder
- vertical and angle level(s)
- welder
- file, pick, brush, gloves, helmet, long-sleeved shirt, hat (for welding)

Mount Commonly Used



The SCIGN mountis the antenna mount most commonly used with the deep drilled braced monument, although it is only required when using the SCIGN radome. Otherwise, any other leveling mount, such as the SECO 2072-series antenna mount, is acceptable.

GPS Deep Drilled Braced Monument Installation
Driller Instructions

Overview

The deep drilled braced GPS monument (DDBM) is designed to create a highly rigid and immobile structure isolated from surface soil movement and cemented in place at depth. The monument consists of 5 legs (stainless steel pipes) placed into drilled holes, and welded together above the surface to create a "tripod" frame. Of the 5 legs, the center leg is vertical and the 4 other legs are installed at angles to brace the vertical leg.

The Plate Boundary Observatory (PBO) project will require the installation of at least 600 of these DDBM monuments throughout the Western US and Alaska. We hope to locate a small number of highly skilled contractors throughout the Western US and Alaska to install these monuments during the next five years. This scope of work is for a one-time installation project consisting of a small number (1-5) of these installations. This will allow us to evaluate the contractor for possible future work within PBO. Please provide a quote for services based upon the scope of work outlined below.

Material

Contractor to supply to the following material:

1) A sufficient amount of grout to fill 5-35 foot deep holes (4.5"-6" diameter) will be used. Contractor will assure the following:

   a) Type I, II Portland cement and Class F Flyash shall be used for grout materials.
   b) Flyash shall replace 10-15% of the volume of Portland cement.
   c) Grout shall be proportioned to have a water to cementitious material ratio of 0.50.
   d) If using pre-packaged grout, grout shall be 1118 Grout supplied by Surecrete, Seattle, WA, or an approved equal meeting these specifications. Grout 1119 should be used for applications when water is present in the hole.

2) Water sufficient to mix grout. Final mix should be consistency of a milk shake.

All other material will be supplied by UNAVCO.

Construction Procedure

<u>Drilling/Casing/Pipe Placement</u>

1) Drill rig type and size selection shall be determined by contractor such that equipment used is most suited to site geology and hole precision requirements.

2) UNAVCO shall provide to the contractor a summary of expected site conditions such as surface topography and subsurface material.

3) Contractor shall drill 5 holes of 4.5" diameter to minimum depths of 35 ft.
   a) Center hole shall be drilled at vertical orientation plus/minus 2 degrees.
   b) Four angled holes shall be drilled at 35 degrees from vertical plus/minus 2.5 degrees.

4) Holes drilled at precise locations specified by UNAVCO engineering staff. Frequent measurement of hole inclination during drilling shall be made to ensure holes are drilled to exact specifications. The centerlines of all 5 holes shall intersect at a single point plus/minus 3". This point of intersection shall be located 62" above the surface, at the center leg. On level ground, each of the 4 angled legs will enter the ground at 43.5" from the center leg.

5) All holes shall be drilled straight enough so that PVC casing can be installed in the top 15.5 ft of each hole, and that the steel pipe can be freely lowered, not forced, for its entire 35 ft length.

6) Hole depth is to be determined by actual measurement after drilling. If necessary, loose material may need to be removed from the bottom of the holes to achieve required depth.

7) 2.5" PVC casing (wrapped with insulation) shall be installed in upper 15.5 ft of each hole immediately after drilling. It may be necessary to use drill rig to push casing into hole.

8) Contractor shall assist UNAVCO staff in placement of steel piping immediately after drilling and casing installation. 1.25" schedule 40 steel pipe shall be installed inside casing in each hole to a depth of 32-38 ft.

9) A single 5 foot vertical hole shall be drilled for the equipment enclosure.

10) UNAVCO is responsible for siting and alignment.

11) Contractor shall assist in the clearing of cuttings from the hole, during the drilling operation.

Grout Installation

1) Contractor shall provide grouting material and water for mixing.

2) All five legs are to be cemented in place with expansive grout.

3) Contractor shall prepare the pumpable grout to a "milkshake" consistency. Jobsite conditions may affect actual quantities of water needed.

4) Following steel pipe installation, contractor shall pump grout down steel pipes until grout fills pipe and pipe-casing annulus, and is seen emerging from top of annulus. Due to small clearances within pipe and at pipe-casing annulus, high pressures may be encountered during grout placement.

5) Contractor shall place grout such that no air bubbles are introduced. Ensuring a continuous flow of grout through pipe and back up through annulus requires proper grout handling, mixing, and pumping equipment and procedures.

6) Contractor shall neatly finish grout at surface of casing such that water will not puddle around monument legs.

Site Documentation and Cleanup

Contractor shall assist UNAVCO personnel in compiling site documentation including:

1) Depths of holes. All drilling documentation including drilled, measured, tamped, and shimmed pipe depths shall be recorded by contractor.

2) Grout information. Time of day, grout sack ID#, grout amount sifted, mixed, pumped, and lost shall all be monitored by contractor and reported to UNAVCO engineer for recording.

3) Contractor shall be responsible for removal of hazardous materials (i.e. hydraulic fluid, diesel fuel and/or contaminated soil) and debris. Site shall be left in suitable condition.

4) Contractor shall be responsible for containing and disposing of excess grouting material and debris such as cement bags, trash, and cigarette butts.

5) Contractor shall be responsible for leveling and raking of areas that were disturbed by drill rig and support vehicles at the site.

Miscellaneous

1) Contractor is responsible for hotel and per diem for the drilling crew.

2) Contractor shall assist UNAVCO personnel in any tasks related to GPS site installation such as pipe/coupling preparation, installation of pipe and insulation piping.

3) UNAVCO will mark for Underground Services Alert.

4) UNAVCO will provide maps, directions and relevant access information for drilling access.

5) Contractor's equipment and tools are the sole responsibility of the contractor. UNAVCO will not reimburse the contractor for any lost or damaged equipment.

All work shall be done to highest professional standards.

GPS/GNSS Receiver Comparison Table

	Receiver	Multi-GNSS ?	Available as special buy	Available on loan	Serviceable at UNAVCO	File Size (24 hr, 15 s	Memory	Time lasts recording at 15 s	Power draw w/ antenna	Time lasts on 18amphr battery
	Alert Geomatics/XEOS Resolute Polar	Y	Y	Y	N	4.2MB	8GB	5.2 years	1.2 - 2W	1 Week
	Ashtech ProFlex 500 CORS	Y	Y	N	Y	N/A	8MB + Ext. USB	N/A	<5W	>1.5 days
	Javad Sigma	Y	N	N	N	N/A	up to 2 GB	N/A	4 W	1.9 days
	Leica GR25	Y	Y	N	N	1.6 MB 1.2 MB (zip)	up to 32 GB SD card	54 years on an 32 GB card	N/A	N/A
	Leica GR10	Y	Y	N	N	1.6 MB 1.2 MB (zip)	up to 32 GB SD card	54 years on an 32 GB card	3.5 W	2.5 days

	Septentrio PolaRx5	Y	Y	N	N	N/A	up to 32 GB	N/A	2-4 W	4.5 days
	Septentrio PolaRx4	Y	Y	N	N	N/A	up to 7.4 GB	N/A	6.1W	1.25 days
	Septentrio AsteRx3 HDC	Y	Y	N	N	N/A	N/A	N/A	N/A	N/A
	Septentrio AsteRx2el HDC	N	Y	N	N	N/A	N/A	N/A	N/A	N/A
	Topcon NetG5	Y	Y	N	Y	6.8 MB (default messages)	up to 32 GB	~10 years	4 W	1.9 days
	Topcon Net-G3 and Net-G3A	Y	Y	N	Y	6.8 MB (default messages)	up to 8 GB CF card	3.2 years	4 W	1.9 days
	Topcon GB-1000	Y	N	Y	Y	4.6 MB	1 GB internal, 1 GB CF card	1.2 years	3.9+ W	1.9 days

	Trimble NetR9	Y	Y	Y	Y	0.9 MB	8 GB Internal + External USB	24 years at 8 GB	3.8 W	2.4 days
	Trimble NetR8	Y	N	Y	Y	0.9 MB	4 GB	12 years	4.3 W	1.8 days
	Trimble NetR5	Y	N	N	Y	1.4 MB	256 MB	6 months	4.8 W	1.6 days
	Trimble NetRS	N	N	Y	Y	800 kb	1 GB	3.5 years	3.4 W	2.25 days
	Trimble R7	N	N	Y	Y	1 MB	up to 2 GB CF card	- 4 mo.- 5.5 yearsor 512 files	3.7 W	2 days
	Trimble 5700	N	N	Y	Y	1 MB	up to 2 GB CF card	- 4 mo. - 5.5 yearsor 512 files	3 W	2.5 days

	Trimble 4800/5800/R8	N	N	N	N	-	0 MB	requires external data collection	varies: 6+ W - 2.5 W	1.25 - 3 days
No longer supported	**Receiver**	**GNSS ?**	**Available as special buy**	**Available on loan**	**Serviceable at UNAVCO**	**File Size (24 hr, 15 s)**	**Memory**	**Time lasts recording at 15 s**	**Power Draw**	**Time lasts on 18amphr battery**
	Allen Osborne TurboRogue	N	N	N	N	2.2 MB turbo binary 900 kb conan binary	low	low	high	low
	Ashtech Z-12	N	N	N	N	1.8 MB	32 MB or less	18 days or less	12 W	15 hrs
	Ashtech MicroZ & ICGRS	N	N	N	Y	3.8 MB	- 32-128 MB	8 days - 1 month	8 W	23 hrs
	Canadian Marconi AllStar	N	N	N	N		0 MB	requires external data collection		
	Trimble 4000	N	N	N	N	1.8 MB	10 MB or less	5 days	10 W	18 hrs

	Trimble 4700	N	N	N	N		0 MB	requires external data collection	4.5 W	1.7 days

Available as special buy: Special pricing is available to UNAVCO members and associate members on select equipment. For more information see the GNSS Equipment Purchase Information page.
Available on loan: UNAVCO maintains a large pool of GPS and related equipment, available on loan to member and associate member institutions and NSF-funded programs. To submit a request, fill out the Online Support Request Form .
Serviceable at UNAVCO: UNAVCO is licensed to repair select GNSS receivers and antennas. For more information see the Equipment Repairs page.
File size (24 hr, 15 s): File size for a 24 hour-long file collected at a 15 second sample rate. File size is approximate and varies based on # of satellites tracked and frequencies recorded. File sizes shown here were taken from site data in the UNAVCO data archive.
Memory: Memory for receivers from the dealer may vary; values are given for UNAVCO-owned receivers.
Time last recording at 15 s: Estimated length of time the receiver can record at its given internal memory at a sample rate of 15 seconds.
Power draw: Estimated power draw in Watts. The power draw varies depending on the other equipment e.g. antenna(s) connected to the receiver.
Time lasts on 18 amphr battery: Estimated length of time the receiver can operate on the 12 volt, 18 amphr battery standard for UNAVCO campaign systems, without a solar panel. Time will vary based on temperature and battery health.

UNAVCO Resources: GNSS Antennas

Dual frequency (L1/L2) Choke Ring Antennas provide geodetic-quality GNSS measurements for surveying, map
Typical dual-frequency choke ring antennas maintain a stable phase center that has less than 1 mm of drift. T
on the geodetic research standard and features aluminum choke rings and a Dorne Margolin antenna elemen
have a low power consumption, and have excellent multipath rejection characteristics. Less-expensive but alsc
available as well. The UNAVCO Facility currently supports the following GNSS antennas.

GPS/GNSS Antennas Used by UNAVCO

	Trimble Choke Ring	MENU • NGS antenna calibration (Trimble GNSS Choke Ring, TRM59800.00 SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=TRM59800.00_SCIT.atx) • NGS antenna calibration (TRM29659.00 SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=TRM29659.00_SCIT.atx) • Note: Trimble GNSS Choke Ring TRM59800.80 is a TRM29659.00 reworked with a wide-band low noise amplifier (LNA) for GNSS. The TRM59800.00 and TRM59800.80 elements are identical in construction, the two antenna types are assumed to show similar phase center corrections. The TRM59800.80 calibrations are copies of the TRM59800.00 calibrations.
	Ashtech Choke Ring	• NGS antenna calibration (ASH701945G_M SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH701945G_M_SCIT.atx) • NGS antenna calibration (ASH701945E_M SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH701945E_M_SCIT.atx) • NGS antenna calibration (ASH701945C_M SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH701945C_M_SCIT.atx) • NGS antenna calibration (ASH701945B_M SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH701945B_M_SCIT.atx) • NGS antenna calibration (ASH700936D_M NONE) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH700936D_M_NONE.atx) • Preliminary Report on Data Quality with a Trimble 5700 GPS Receiver and an Ashtech Choke Ring Antenna (2002) (http://kb.unavco.org/kb/article.php?id=237)

	Trimble Zephyr Geodetic	• NGS antenna calibration (TRM41249.00 NONE) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=TRM41249.00_NONE.atx) • NGS antenna calibration (TRM57971.00_NONE) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=TRM57971.00_NONE.atx) • Trimble Zephyr Geodetic - Dimensions (from Trimble) (http://kb.unavco.org/kb/article.php?id=240) • The Design and Performance of the Zephyr Geodetic Antenna (Trimble publication) (http://kb.unavco.org/kb/article.php?id=241)
	Trimble Zephyr	• NGS antenna calibration (TRM39105.00) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM39105.00)
	Topcon PG-A1	• NGS antenna calibration (TPSPG_A1+GP) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TPS&Antenna=TPSPG_A1,GP) • Topcon PG-A1 Antenna Dimensions (.pdf) (http://kb.unavco.org/kb/assets/102/TPSPG_A1GP.pdf)
no photo available	AOA TurboRogue SNR-800	• NGS antenna calibration (AOAD/M_T) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=AOA&Antenna=AOAD/M_T)
no photo available	Trimble L1/L2 microcentered geodetic with groundplane	• NGS antenna calibration (TRM33429.20+GP) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM33429.20,GP)
no photo available	Trimble Permanent L1/L2	• NGS antenna calibration (TRM23903.00) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM23903.00)
no photo available	Trimble Geodetic Compact L1/L2	• NGS antenna calibration (w/ ground plane) (TRM22020.00+GP) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM22020.00,GP) • NGS antenna calibration (w/o ground plane) (TRM22020.00-GP) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM22020.00-GP)

MENU

no photo available	Trimble 4000SST L1/L2 Geodetic	• NGS antenna calibration (TRM14532.00) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM14532.00)
no photo available	Trimble 4000SSE Kinematic L1/L2	• NGS antenna calibration (TRM14532.10) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM14532.10) MENU
	UNAVCO/Micro Pulse L1	• NGS antenna calibration (MPL1370W) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=MPL&Antenna=MPL1370W) • UNAVCO/Micro Pulse L1 - How to make UNAVCO's L1 antenna (http://kb.unavco.org/kb/article.php?id=635)

Setting up GPS/GNSS Antennas

- Introduction to GNSS Antenna Set-up Methods for Campaigns (http://kb.unavco.org/kb/article.php?id=71)
  An introduction for inexperienced surveyors including antenna height measurement methods and g
- How to use declination to align the GNSS antenna to true north (http://kb.unavco.org/kb/article.php?id=61)
  Antennas are typically aligned to true north to keep measurements both within and between campa that the location of the antenna phase center is modeled correctly.
- Geographic Magnetic Calculator (http://www.resurgentsoftware.com/GeoMag.html)
  Link to software you can download and use to calculate the declination in your study area.

Development and Testing of GPS/GNSS Antennas

- Choke Ring Antenna Calibrations (http://kb.unavco.org/kb/article.php?id=311)
- Equipment Power Usage Testing (http://kb.unavco.org/kb/article.php?id=235)
- Antenna Phase Center Plots (.pdf) (http://kb.unavco.org/kb/assets/242/phaseplots.pdf) (L1 and L2 phase center p Trimble Zephyr Geodetic, Trimble Zephyr, and Leica Choke Ring antennas)
- Iridium & GPS Antenna Interference Test (2008) (http://kb.unavco.org/kb/article.php?id=110)
- Assessing the Impact of the SCIGN Radome on Geodetic Parameter Estimates (2007) (http://kb.unavco.or
- Development of an antenna and multipath calibration system for Global Positioning System sites (2 (http://kb.unavco.org/kb/article.php?id=254)
- UNAVCO 2004 GPS Campaign System Testing in Support of the Plate Boundary Observatory (PBO) ((http://kb.unavco.org/kb/article.php?id=5)
- UNAVCO 2003 GPS Receiver and Antenna Testing in Support of the Plate Boundary Observatory (PB (http://kb.unavco.org/kb/article.php?id=15)
- Multipath characteristics of GPS signals as determined from the Antenna and Multipath Calibration (http://kb.unavco.org/kb/article.php?id=253)
- Preliminary report on data quality with a Trimble 5700 GPS receiver and an Ashtech Choke Ring Ant (http://kb.unavco.org/kb/article.php?id=237)

UNAVCO Resources: Permanent GNSS Station Enclosures

Article ID: 381 | Rating: 1/5 from 2 votes | Last Updated: Wed, Aug 24, 2016 at 8:36 PM

UNAVCO Resources: Permanent GNSS Station Enclosures

UNAVCO has installed and supports a large variety of equipment enclosures for both AC and DC GNSS sites, from enclosures specifically designed for solar systems (the SunWize battery enclosure) to simple storage containers modified to accommodate cable pass-throughs. We can work to find the most suitable enclosure given the budget and the location of each permanent or semi-permanent GNSS installation. Below is a list of enclosures used within the last several years in UNAVCO-supported projects; click on the photographs to see sample content lists and more photos of actual installations. For standard UNAVCO campaign enclosures, check out UNAVCO Campaign GNSS Systems .

	SunWize Premium F-Series Battery Enclosure	The SunWize F-Series 4-battery enclosure is used throughout the Plate Boundary Observatory network, as well as in several other permanent GPS station networks in the US. Benefits include reasonable strength (the enclosure is made of aluminum), security (two key locks secure the enclosure), both internal and external knockouts for passing wires and cables, weatherproof seals, and a generous amount of space. Drawbacks include cost ($700-$1000 as of February 2009), size (if on-site space is limited or if equipment must be shipped), and mounting requirements (enclosure is designed to be mounted on a post, which must be cemented into the ground and strong enough to support batteries).
	Hardigg Case	Hardigg (now owned by Pelican Products) makes rugged, well-sealed plastic enclosures which are stackable, easy to handle, and UV resistant. Connectors are recessed within the ribs of the case to reduce the risk of damage during shipping.

	JOBOX	JOBOX chests, made by Delta Consolidated Industries, Inc. , are durable, weatherproof metal enclosures that UNAVCO has used in several long-term installations, including the EarthScope-sponsored Rio Grande Rift network. Chests are secured with key locks. The major drawback of the JOBOX is weight; boxes are heavy and cumbersome, thus not ideal for shipping and for transporting by foot over long distances. Cost of the box shown here is approximately $300-400 (as of February 2009).
	Pelican Case (large)	The Pelican case is easily portable, can be used to transport equipment, and is weatherproof. The case shown here, as deployed in the EarthScope-sponsored Rio Grande network, contains 2 100 amphr batteries in addition to the GPS receiver. The case is difficult to destroy and can be locked with padlocks. Cost is approximately $250-$300 (February 2009). Smaller cases are available (see below), and have been used in networks with year-round, reliable sunlight where large battery banks are not required.
	Pelican Case (small)	Like the larger Pelican cases (above), the smaller Pelican case is weatherproof and can be used to transport equipment. A smaller case is ideal if space is not an issue--specifically, if the requirement for amount of power stored is small (e.g. in a year-round sunny environment, as is common near the equator). The case is difficult to destroy and can be locked with padlocks. Networks utilizing small Pelican cases include Afar, Ethiopia, and Sierra Negra, Galapagos. Cost for the case shown here is approximately $125 (February 2009).
	Commercial Electrical Enclosure	Electrical boxes can be often purchased 'locally,' in major cities, rather than being shipped. Boxes may include knock-outs for passing cables through and locking options, like the box shown here. Electrical boxes are often sturdy, made of either strong plastic or of metal, and may or may not be weatherproof. Networks utilizing local electrical enclosures include Calabria, Italy and Bangladesh. Typical price range is about $100-$300.

	Storage Container	A heavy-duty storage container, such as the Contico Tuff Box, designed for the back of a truck or other outdoor use may work well for an equipment enclosure. They are generally low cost (about $70 for the container shown here, as of February 2009), available in most US cities, rugged, and lockable with padlocks. The case shown here fits four sealed 100 Amphr batteries along with the GPS and communications equipment. Used as enclosures in the Peatland Bog, Minnesota network.

Cellular Modem Summary

Article ID: 357 | Rating: Unrated | Last Updated: Wed, Oct 28, 2009 at 3:12 PM

Cellular Modem Summary

Cellular modems need to be very robust as the inherent disadvantages of the analog cellular phone system become especially evident with high speed data transfers. Cellular coverage could be of a quality not compatible with high speed data transfers and handshaking protocols. Often more than one cellular provider offers coverage in an area and it is worthwhile to investigate several options. A good voice communication does not translate into an acceptable data communication. Your choice of cellular modem and cellular phone should be able to run off 12VDC, even if AC power is available, to facilitate DC (battery) backup.

Suggested Minimum Requirements

- 12 VDC power
- V.32, V.32bis communication protocols
- V.42, MNP error correction/data compression
- RTS/CTS hardware flow control
- High speed baud rates (2.4-19.2 kbps)
- Compatible with CCITT and Bell standards
- Support industry-standard AT command set
- Compatible with RS-232 Control Signals

Information on radio modems used by UNAVCO

Proxicast LANCell Gateway



Used throughout the Plate Boundary Observatory (PBO) network, Western U.S.

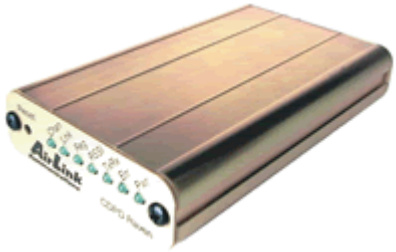
- UNAVCO summary of Proxicast cellular modems and networking

ZyXEL U-1496P



- ZyXEL U-1496P Portable Cellular Modem Summary Page

Raven II CDPD



- How to use the Raven II CDPD modem with the Lantronix MSS100 serial-to-ethernet device

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Attachment 3. Extensometer Design

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SAMPLE DESIGN
FOR REFERENCE

PAGE No.	DRAWING No.	DRAWING TITLE
1	100	TITLE SHEET
2	300	TYPICAL RAT HOLE
3	301	GRADING AND FOUNDATION PAD
4	302	EXTENSOMETER UNIT
5	303	BUILDING
6	304	SCHEMATIC DIAGRAM OF EXTENSOMETER

REV	DATE	DESCRIPTION	SUB	APP'D

APPROVED BY:

_____ DATE: _____

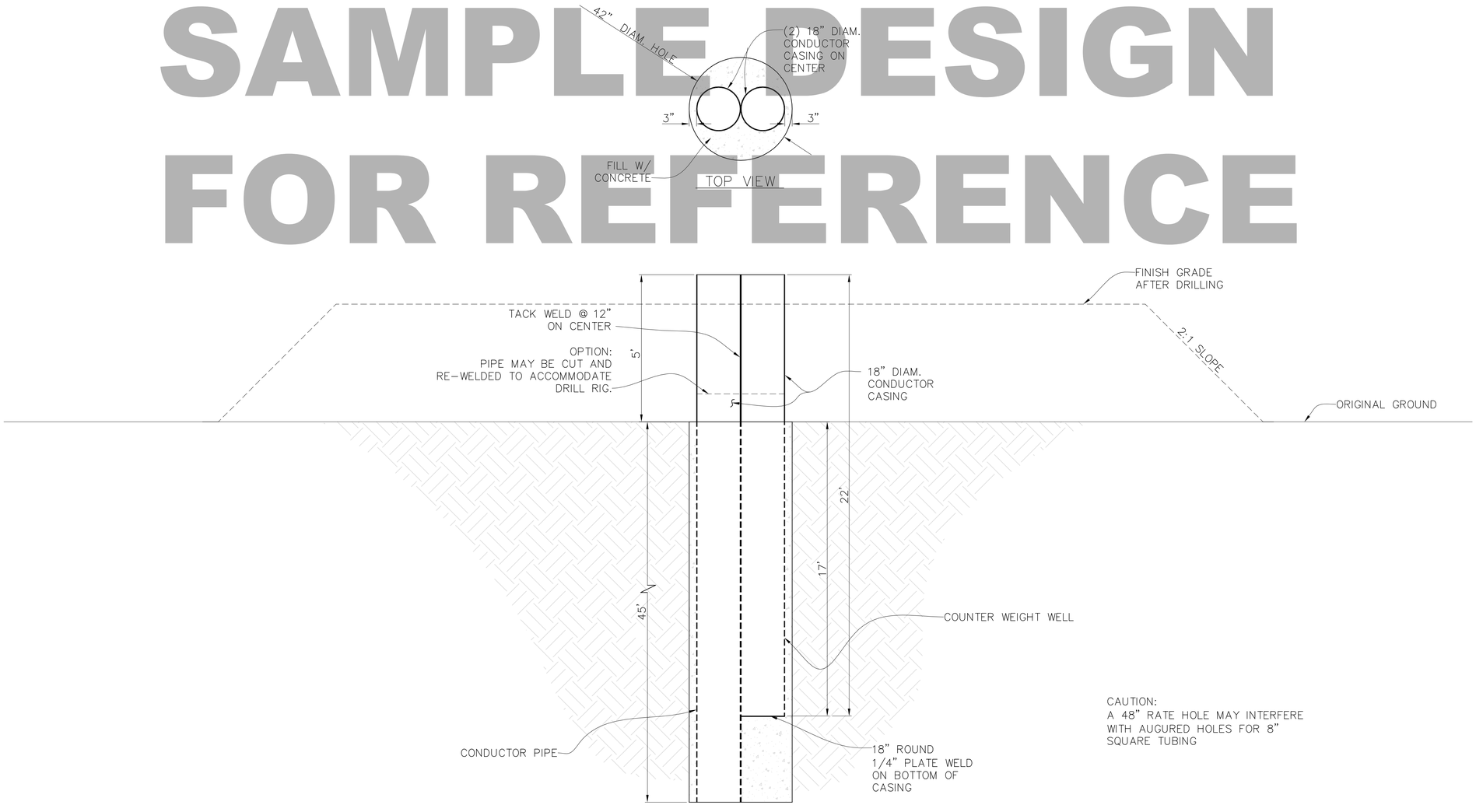
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EXTENSOMETER CONSTRUCTION
TITLE SHEET

DRAWING NUMBER
100

SAMPLE DESIGN
FOR REFERENCE



CAUTION:
A 48" RATE HOLE MAY INTERFERE WITH AUGURED HOLES FOR 8" SQUARE TUBING

TYPICAL 42" RAT HOLE

REV	DATE	DESCRIPTION	SUB	APP'D

APPROVED BY:

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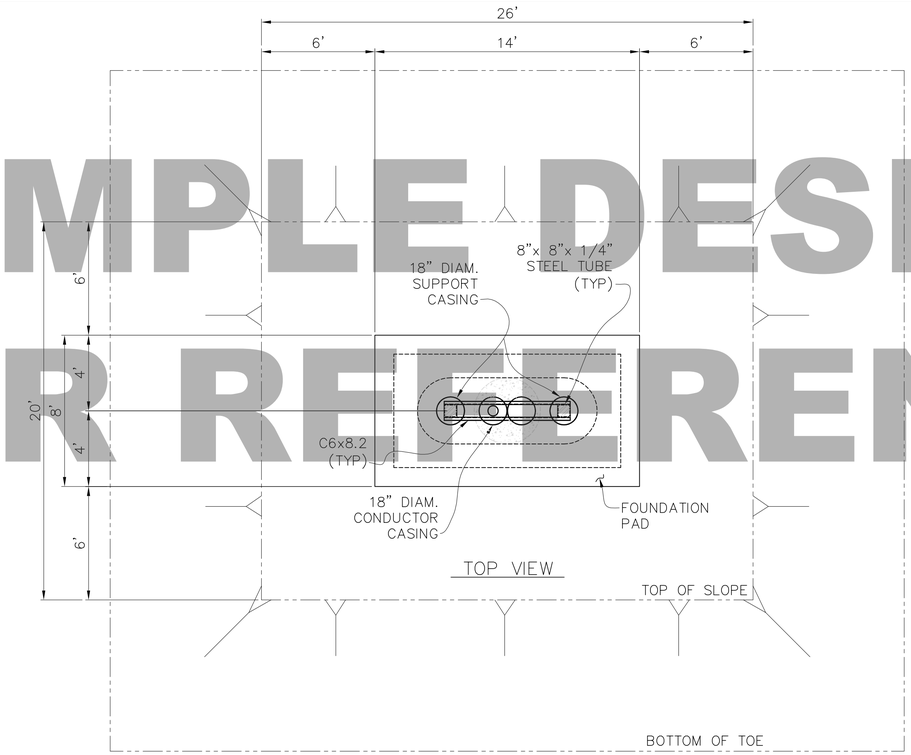
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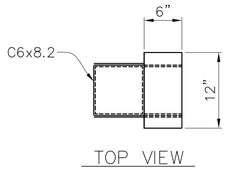
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EXTENSOMETER CONSTRUCTION
TYPICAL RAT HOLE

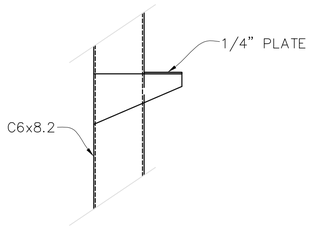
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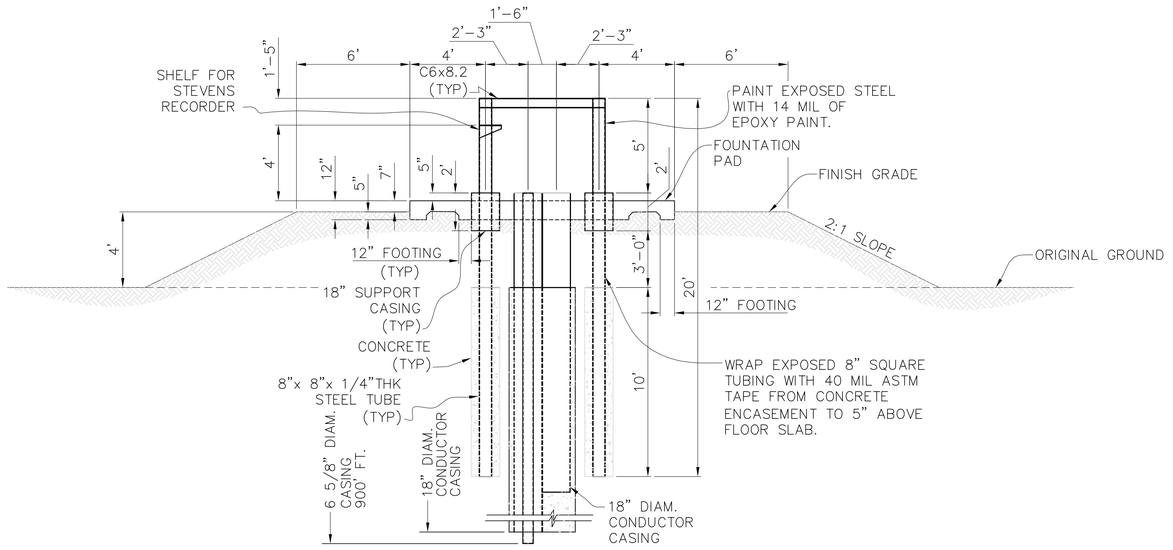




TOP VIEW



SHELF FOR STEVENS RECORDER



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DATE:

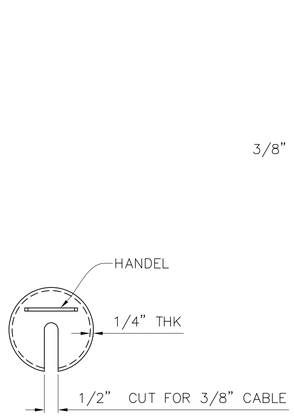
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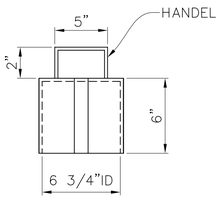
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EXTENSOMETER CONSTRUCTION
GRADING AND FOUNDATION PAD

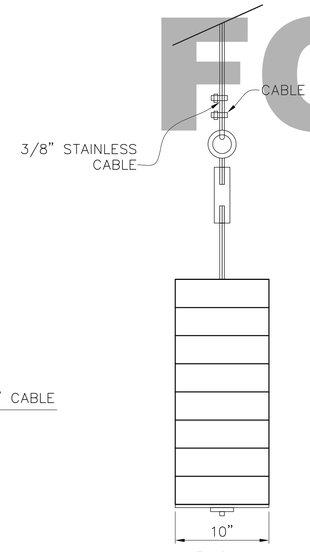
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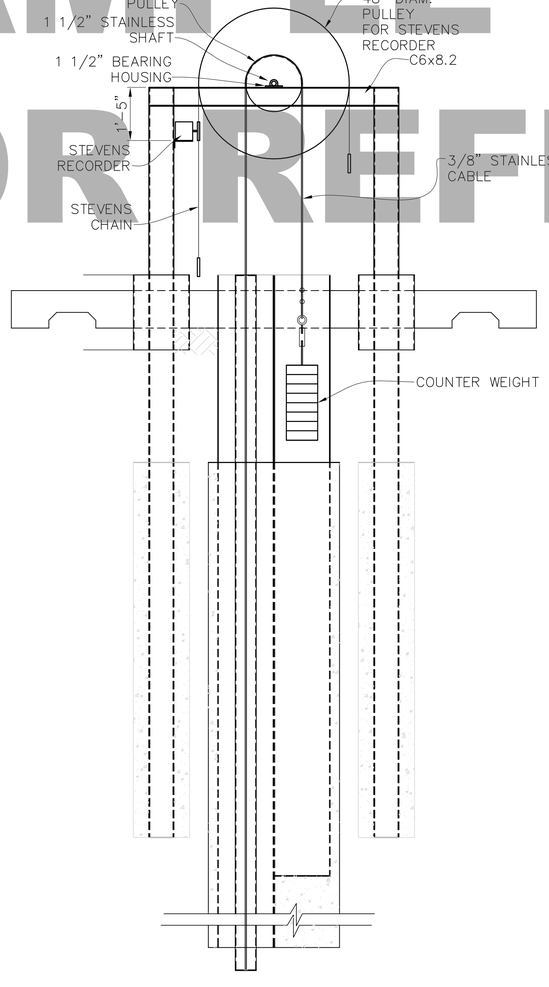




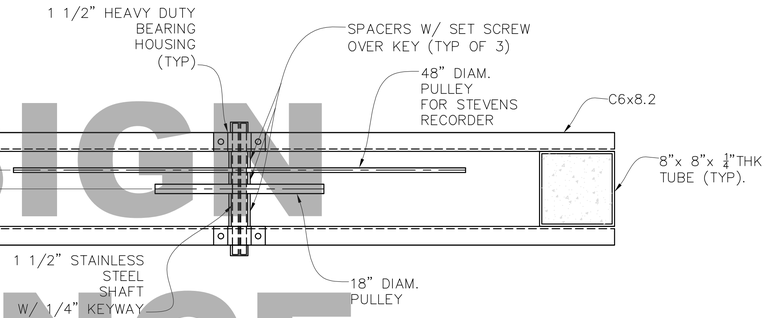
CASING CAP



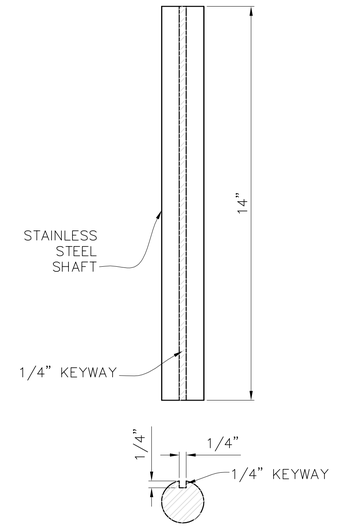
540 lbs
COUNTER WEIGHT



PULLEY ASSEMBLY



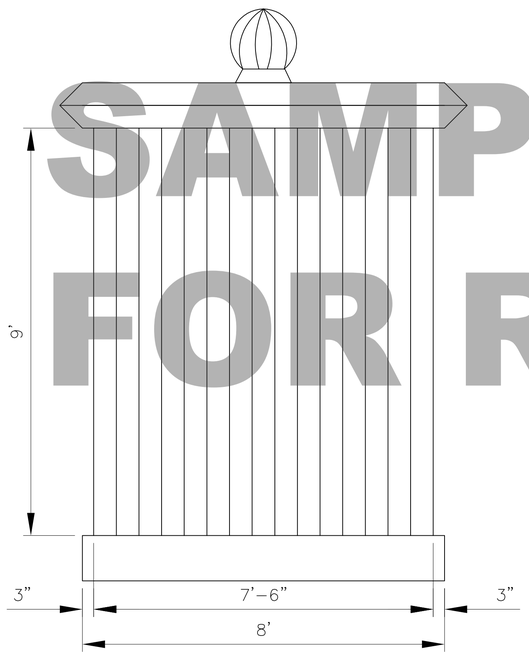
TOP VIEW



1 1/2" SHAFT

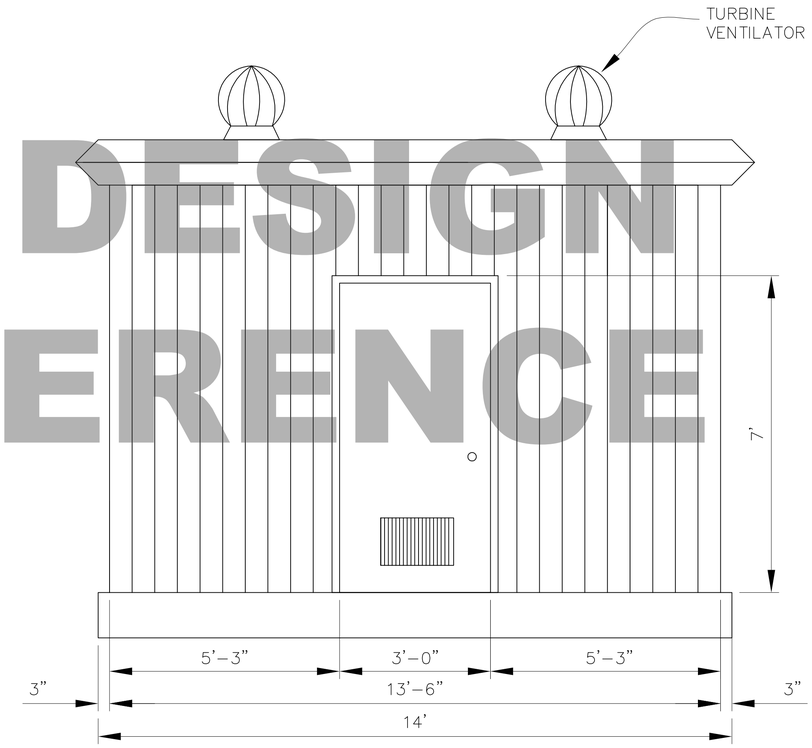
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SAMPLE DESIGN
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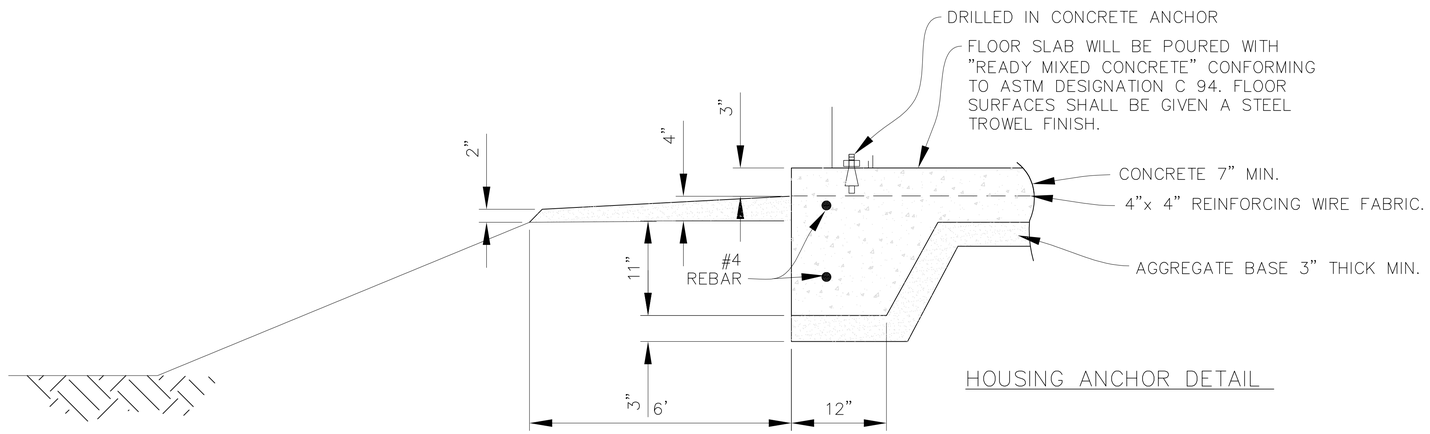


ENDWALL

ARMCO STEELOX BUILDING SYSTEMS TEC-LINE
1 BUILDING OR EQUIVALENT



SIDE VIEW



HOUSING ANCHOR DETAIL

REV	DATE	DESCRIPTION	SUB	APP'D

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DATE: _____

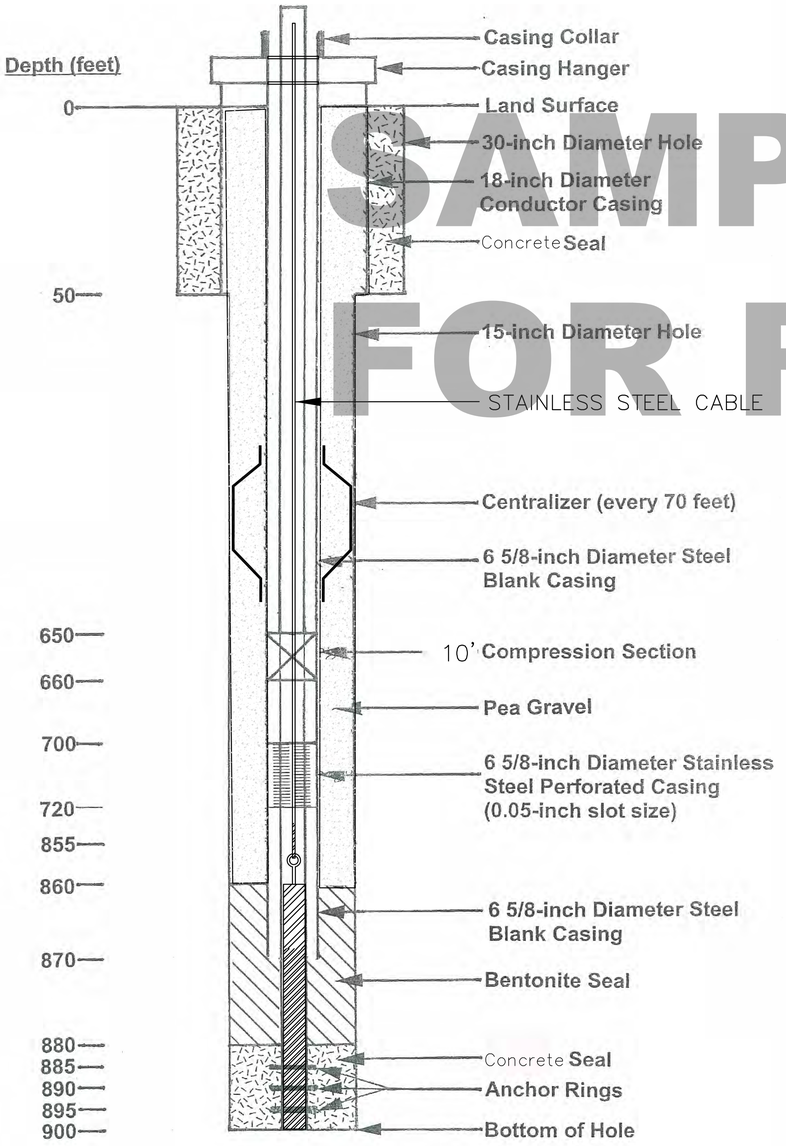
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EXTENSOMETER CONSTRUCTION
BUILDING

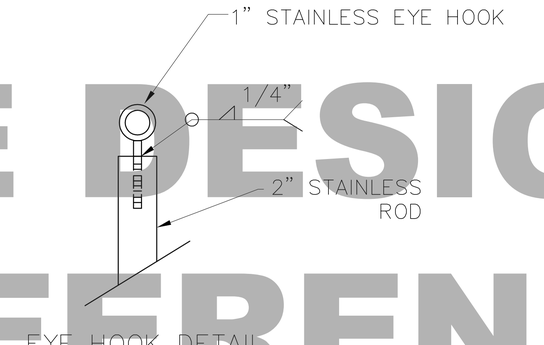
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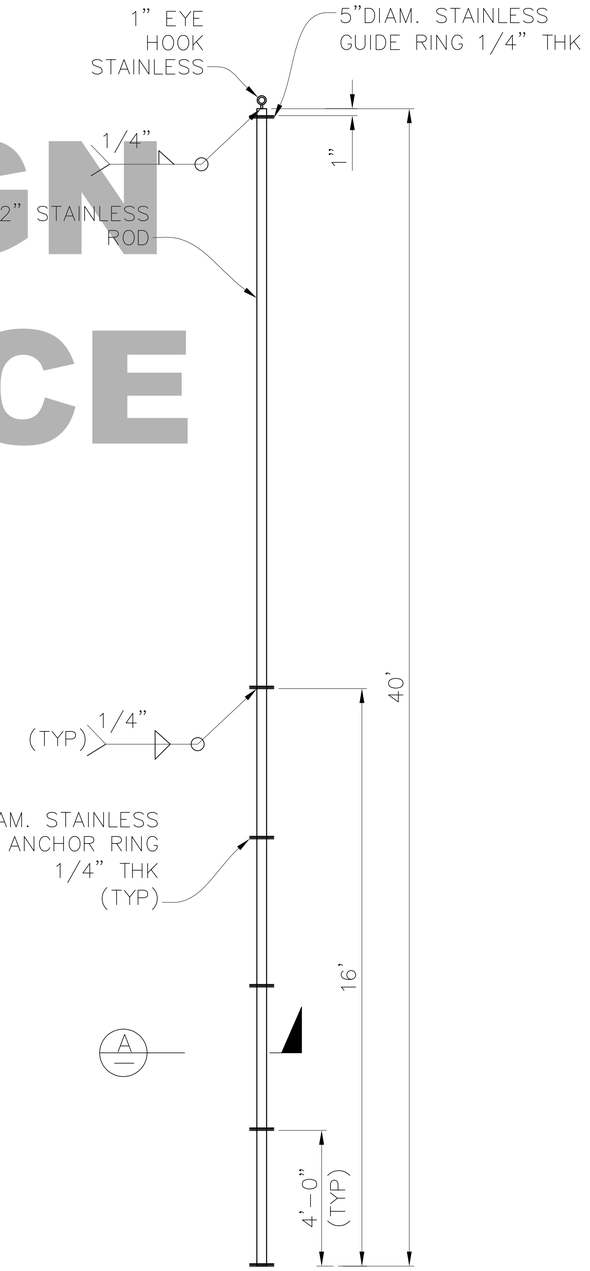
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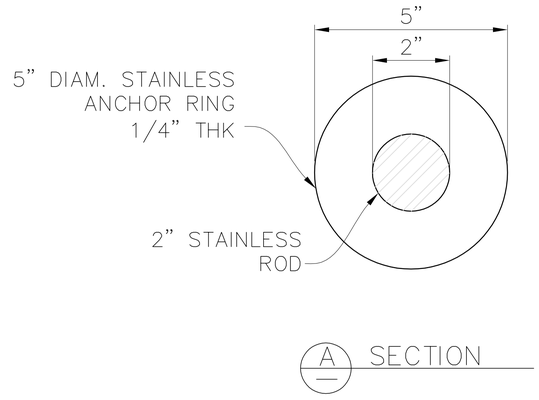
SAMPLE DESIGN
FOR REFERENCE



SCHEMATIC DIAGRAM OF EXTENSOMETER







REV	DATE	DESCRIPTION	SUB	APP'D

APPROVED BY: _____ DATE: _____

APPROVED

EXTENSOMETER CONSTRUCTION
SCHEMATIC DIAGRAM OF EXTENSOMETER

DATE

DRAWING NUMBER
304

aquilogic, Inc.
environment • water • strategy

245 Fischer Avenue, Suite D-2
Costa Mesa, CA 92626
Tel. +1.714.770.8040
Web: www.aquilogic.com

CHAPTER GROUNDWATER SUSTAINABILITY PLAN
WESTSIDE DISTRICT WATER AUTHORITY
Kern County, California

Prepared for:
Kern County Groundwater Authority
1800 30th Street, Suite 280
Bakersfield, California 93301

Project No.: 043-04

January 2020

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
§ 354.			**Introduction to Plan Contents**					
			This Article describes the required contents of Plans submitted to the Department for evaluation, including administrative information, a description of the basin setting, sustainable management criteria, description of the monitoring network, and projects and management actions.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
SubArticle 1.			**Administrative Information**					
§ 354.2.			**Introduction to Administrative Information**					
			This Subarticle describes information in the Plan relating to administrative and other general information about the Agency that has adopted the Plan and the area covered by the Plan.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.4.			**General Information**					
			Each Plan shall include the following general information:					
(a)			An executive summary written in plain language that provides an overview of the Plan and description of groundwater conditions in the basin.	30:55	ES			
(b)			A list of references and technical studies relied upon by the Agency in developing the Plan. Each Agency shall provide to the Department electronic copies of reports and other documents and materials cited as references that are not generally available to the public.	155:158	7.0			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10733.2 and 10733.4, Water Code.					
§ 354.6.			**Agency Information**					
			When submitting an adopted Plan to the Department, the Agency shall include a copy of the information provided pursuant to Water Code Section 10723.8, with any updates, if necessary, along with the following information:					
(a)			The name and mailing address of the Agency.	30:55,69	ES,1.5.4			
(b)			The organization and management structure of the Agency, identifying persons with management authority for implementation of the Plan.	30:55 58:63	ES,1.3			
(c)			The name and contact information, including the phone number, mailing address and electronic mail address, of the plan manager.	30:55,69	ES,1.5.4			
(d)			The legal authority of the Agency, with specific reference to citations setting forth the duties, powers, and responsibilities of the Agency, demonstrating that the Agency has the legal authority to implement the Plan.	30:56	ES,1.2			
(e)			An estimate of the cost of implementing the Plan and a general description of how the Agency plans to meet those costs.	63	1.3.6			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.8, 10727.2, and 10733.2, Water Code.					
§ 354.8.			**Description of Plan Area**					

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
			Each Plan shall include a description of the geographic areas covered, including the following information:					
(a)			One or more maps of the basin that depict the following, as applicable:					
	(1)		The area covered by the Plan, delineating areas managed by the Agency as an exclusive Agency and any areas for which the Agency is not an exclusive Agency, and the name and location of any adjacent basins.	30:55 64:65	ES,1.4.2	1a:3b		
	(2)		Adjudicated areas, other Agencies within the basin, and areas covered by an Alternative.	64:65	1.4.2	1a:3b		
	(3)		Jurisdictional boundaries of federal or state land (including the identity of the agency with jurisdiction over that land), tribal land, cities, counties, agencies with water management responsibilities, and areas covered by relevant general plans.	64:65, 75	1.4.2,2.3	2b, 10a:10c		
	(4)		Existing land use designations and the identification of water use sector and water source type.	76:77		10b:10c, 11a:11d		
	(5)		The density of wells per square mile, by dasymetric or similar mapping techniques, showing the general distribution of agricultural, industrial, and domestic water supply wells in the basin, including de minimis extractors, and the location and extent of communities dependent upon groundwater, utilizing data provided by the Department, as specified in Section 353.2, or the best available information.	88		18		1.2 wells/sq.mile, no municipal use
(b)			A written description of the Plan area, including a summary of the jurisdictional areas and other features depicted on the map.	64:65	1.4.2	1a:1b,2a:2b,3a:3b		
(c)			Identification of existing water resource monitoring and management programs, and description of any such programs the Agency plans to incorporate in its monitoring network or in development of its Plan. The Agency may coordinate with existing water resource monitoring and management programs to incorporate and adopt that program as part of the Plan.	122:125 135:140	2.8.2,3.0			
(d)			A description of how existing water resource monitoring or management programs may limit operational flexibility in the basin, and how the Plan has been developed to adapt to those limits.	124:125	2.8.2			Not applicable, will not limit.
(e)			A description of conjunctive use programs in the basin.	149:153	5.3			
(f)			A plain language description of the land use elements or topic categories of applicable general plans that includes the following:					
	(1)		A summary of general plans and other land use plans governing the basin.	65	1.4.3			
	(2)		A general description of how implementation of existing land use plans may change water demands within the basin or affect the ability of the Agency to achieve sustainable groundwater management over the planning and implementation horizon, and how the Plan addresses those potential effects	76:77	2.4			
	(3)		A general description of how implementation of the Plan may affect the water supply assumptions of relevant land use plans over the planning and implementation horizon.	65:67 75:77	2.3,2.4	10a;10c, 11a:11d		

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(4)		A summary of the process for permitting new or replacement wells in the basin, including adopted standards in local well ordinances, zoning codes, and policies contained in adopted land use plans.	66:67	1.4.5			
	(5)		To the extent known, the Agency may include information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management.	66:67	1.4.3			
(g)			A description of any of the additional Plan elements included in Water Code Section 10727.4 that the Agency determines to be appropriate.	66:67	1.4.3			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10720.3, 10727.2, 10727.4, 10733, and 10733.2, Water Code.					
§ 354.10.			**Notice and Communication**					
			Each Plan shall include a summary of information relating to notification and communication by the Agency with other agencies and interested parties including the following:					
(a)			A description of the beneficial uses and users of groundwater in the basin, including the land uses and property interests potentially affected by the use of groundwater in the basin, the types of parties representing those interests, and the nature of consultation with those parties.	31:32 67:69 93:95 130:132	ES,1.5.2, 2.6.4	20b		Groundwater naturally degraded. Basin Plan Amendement Pending.
(b)			A list of public meetings at which the Plan was discussed or considered by the Agency.	67:69	1.5.2			
(c)			Comments regarding the Plan received by the Agency and a summary of any responses by the Agency.	67:69	1.5			Appendix A
(d)			A communication section of the Plan that includes the following:					
	(1)		An explanation of the Agency's decision-making process.	67:69	1.5			
	(2)		Identification of opportunities for public engagement and a discussion of how public input and response will be used.	67:69	1.5			
	(3)		A description of how the Agency encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin.	67:69	1.5			
	(4)		The method the Agency shall follow to inform the public about progress implementing the Plan, including the status of projects and actions.	67:69	1.5			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.8, 10728.4, and 10733.2, Water Code					
SubArticle 2.			**Basin Setting**					
§ 354.12.			**Introduction to Basin Setting**					

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
			This Subarticle describes the information about the physical setting and characteristics of the basin and current conditions of the basin that shall be part of each Plan, including the identification of data gaps and levels of uncertainty, which comprise the basin setting that serves as the basis for defining and assessing reasonable sustainable management criteria and projects and management actions. Information provided pursuant to this Subarticle shall be prepared by or under the direction of a professional geologist or professional engineer.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.14.			**Hydrogeologic Conceptual Model**					
(a)			Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.	31:32 77:87	2.5	3a:3c, 12a:12e,13, 17a:17c		
(b)			The hydrogeologic conceptual model shall be summarized in a written description that includes the following:					
	(1)		The regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.	30:55 77:87	ES,2.5	12b		
	(2)		Lateral basin boundaries, including major geologic features that significantly affect groundwater flow.	77:87	2.5			
	(3)		The definable bottom of the basin.	77:87	2.5	16		
	(4)		Principal aquifers and aquitards, including the following information:					
		(A)	Formation names, if defined.	77:87	2.5	13,15b		
		(B)	Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.	77:87	2.5	13		
		(C)	Structural properties of the basin that restrict groundwater flow within the principal aquifers, including information regarding stratigraphic changes, truncation of units, or other features.	77:87	2.5			
		(D)	General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.	31:32 77:87	ES,2.5	15a,20b, 21:22		Groundwater naturally degrded. Basin Plan Amendment pending
		(E)	Identification of the primary use or uses of each aquifer, such as domestic, irrigation, or municipal water supply.	77:87	2.5			
	(5)		Identification of data gaps and uncertainty within the hydrogeologic conceptual model	77:87	2.5			
(c)			The hydrogeologic conceptual model shall be represented graphically by at least two scaled cross-sections that display the information required by this section and are sufficient to depict major stratigraphic and structural features in the basin.	77:87	2.5	12a:12c, 17a:17c		
(d)			Physical characteristics of the basin shall be represented on one or more maps that depict the following:					

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(1)		Topographic information derived from the U.S. Geological Survey or another reliable source.	77:87	2.5	4		
	(2)		Surficial geology derived from a qualified map including the locations of cross-sections required by this Section.	77:87	2.5	12b:12c, 17a:17c		
	(3)		Soil characteristics as described by the appropriate Natural Resources Conservation Service soil survey or other applicable studies.	77:87	2.5	14a:14c		
	(4)		Delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.	77:87	2.5	3c, 12a		
	(5)		Surface water bodies that are significant to the management of the basin.	77:87	2.5	10a		
	(6)		The source and point of delivery for imported water supplies.	118	2.7	27a:27c		
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10727.2, 10733, and 10733.2, Water Code.					
§ 354.16.			**Groundwater Conditions**					
			Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:					
(a)			Groundwater elevation data demonstrating flow directions, lateral and vertical gradients, and regional pumping patterns, including:					
	(1)		Groundwater elevation contour maps depicting the groundwater table or potentiometric surface associated with the current seasonal high and seasonal low for each principal aquifer within the basin.	88:91	2.6.2	19a:19b		Identified gap to be addressed
	(2)		Hydrographs depicting long-term groundwater elevations, historical highs and lows, and hydraulic gradients between principal aquifers.	121:122		20a		
(b)			A graph depicting estimates of the change in groundwater in storage, based on data, demonstrating the annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions, including the annual groundwater use and water year type.	121:122	2.7.2			
(c)			Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.	128				Not applicable, 40 miles inland
(d)			Groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes.	31:32 107:122 130:132	ES,2.7, 2.15.5			Groundwater naturally degraded due to geology
(e)			The extent, cumulative total, and annual rate of land subsidence, including maps depicting total subsidence, utilizing data available from the Department, as specified in Section 353.2, or the best available information.	132:133		28a:28b		
(f)			Identification of interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems, utilizing data available from the Department, as specified in Section 353.2, or the best available information.	128	2.12.2			

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
(g)			Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or the best available information.	129:130	2.12.3.1			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.2, 10727.4, and 10733.2, Water Code.					
§ 354.18.			**Water Budget**					
(a)			Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form.	110:122	2.7	24b:24d		KGA "Checkbook" Method
(b)			The water budget shall quantify the following, either through direct measurements or estimates based on data:					
	(1)		Total surface water entering and leaving a basin by water source type.	110:122	2.7			
	(2)		Inflow to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.	110:122	2.7			KGA "Checkbook" method, CV2SIM-Kern pending
	(3)		Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow.	110:122	2.7			KGA "Checkbook" method, CV2SIM-Kern pending
	(4)		The change in the annual volume of groundwater in storage between seasonal high conditions.	110:122	2.7			
	(5)		If overdraft conditions occur, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.	107:122	2.7			
	(6)		The water year type associated with the annual supply, demand, and change in groundwater stored.	110:122	2.7			
	(7)		An estimate of sustainable yield for the basin.	120:121	2.7.6	24b:24d		
(c)			Each Plan shall quantify the current, historical, and projected water budget for the basin as follows:					
	(1)		Current water budget information shall quantify current inflows and outflows for the basin using the most recent hydrology, water supply, water demand, and land use information.	107:122	2.7	24b:24d,25		KGA Umbrella GSP
	(2)		Historical water budget information shall be used to evaluate availability or reliability of past surface water supply deliveries and aquifer response to water supply and demand trends relative to water year type. The historical water budget shall include the following:					
		(A)	A quantitative evaluation of the availability or reliability of historical surface water supply deliveries as a function of the historical planned versus actual annual surface water deliveries, by surface water source and water year type, and based on the most recent ten years of surface water supply information.	75:76 110:122	2.3,2.7	24b:24d,25		

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
		(B)	A quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the tools and methods used to estimate and project future water budget information and future aquifer response to proposed sustainable groundwater management practices over the planning and implementation horizon.	110:122	2.7	24b:24d		
		(C)	A description of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability of the Agency to operate the basin within sustainable yield. Basin hydrology may be characterized and evaluated using water year type.	30:55 110:122	ES,2.7	24a:24d		
	(3)		Projected water budgets shall be used to estimate future baseline conditions of supply, demand, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components. The projected water budget shall utilize the following methodologies and assumptions to estimate future baseline conditions concerning hydrology, water demand and surface water supply availability or reliability over the planning and implementation horizon:					
		(A)	Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology. The projected hydrology information shall also be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.	80:81 107:122	2.5.4,2.7			KGA Umbrella GSP pending CV2SIM-Kern
		(B)	Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand. The projected water demand information shall also be applied as the baseline condition used to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate.	107:122	2.7	24b:24d		KGA"Checkbook" method pending CV2SIM-Kern
		(C)	Projected surface water supply shall utilize the most recent water supply information as the baseline condition for estimating future surface water supply. The projected surface water supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply identified in Section 354.18(c)(2)(A), and the projected changes in local land use planning, population growth, and climate.	80:81 107:122	2.5.4,2.7	24b:24d,25		KGA "Checkbook" pending CV2SIM-Kern
(d)			The Agency shall utilize the following information provided, as available, by the Department pursuant to Section 353.2, or other data of comparable quality, to develop the water budget:					
	(1)		Historical water budget information for mean annual temperature, mean annual precipitation, water year type, and land use.	107:122	2.7			
	(2)		Current water budget information for temperature, water year type, evapotranspiration, and land use.	107:122	2.7			

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(3)		Projected water budget information for population, population growth, climate change, and sea level rise.	107:122	2.7			
(e)			Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, climate change, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow. If a numerical groundwater and surface water model is not used to quantify and evaluate the projected water budget conditions and the potential impacts to beneficial uses and users of groundwater, the Plan shall identify and describe an equally effective method, tool, or analytical model to evaluate projected water budget conditions.	30:55 110:122	ES,2.7	24b,24d		KGA "Checkbook" method pending CV2SIM-Kern
(f)			The Department shall provide the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) and the Integrated Water Flow Model (IWFM) for use by Agencies in developing the water budget. Each Agency may choose to use a different groundwater and surface water model, pursuant to Section 352.4.	110:122	2.7			KGA "Checkbook" method pending CV2SIM-Kern
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10721, 10723.2, 10727.2, 10727.6, 10729, and 10733.2, Water Code.					
§ 354.20.			**Management Areas**					
(a)			Each Agency may define one or more management areas within a basin if the Agency has determined that creation of management areas will facilitate implementation of the Plan. Management areas may define different minimum thresholds and be operated to different measurable objectives than the basin at large, provided that undesirable results are defined consistently throughout the basin.	126	2.10	1a:1b,2a		KGA Umbrella GSP
(b)			A basin that includes one or more management areas shall describe the following in the Plan:					
	(1)		The reason for the creation of each management area.	126	2.10			
	(2)		The minimum thresholds and measurable objectives established for each management area, and an explanation of the rationale for selecting those values, if different from the basin at large.	141:145	4.0	29a:30f		
	(3)		The level of monitoring and analysis appropriate for each management area.	141:145	4.0			
	(4)		An explanation of how the management area can operate under different minimum thresholds and measurable objectives without causing undesirable results outside the management area, if applicable.	127:134 141:145	2.12:2.13, 4.0			Will coordinate with adjacent GMAs
(c)			If a Plan includes one or more management areas, the Plan shall include descriptions, maps, and other information required by this Subarticle sufficient to describe conditions in those areas.	58:63 141:145	1.3,4.0	1a:1b, 2a:2b		
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10733.2 and 10733.4, Water Code.					
SubArticle 3.			**Sustainable Management Criteria**					
§ 354.22.			**Introduction to Sustainable Management Criteria**					

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
			This Subarticle describes criteria by which an Agency defines conditions in its Plan that constitute sustainable groundwater management for the basin, including the process by which the Agency shall characterize undesirable results, and establish minimum thresholds and measurable objectives for each applicable sustainability indicator.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.24.			**Sustainability Goal**					
			Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline. The Plan shall include a description of the sustainability goal, including information from the basin setting used to establish the sustainability goal, a discussion of the measures that will be implemented to ensure that the basin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved within 20 years of Plan implementation and is likely to be maintained through the planning and implementation horizon.	126:140	2.11:3.0			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10721, 10727, 10727.2, 10733.2, and 10733.8, Water Code.					
§ 354.26.			**Undesirable Results**					
(a)			Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.	127:133	2.12:2.13			
(b)			The description of undesirable results shall include the following:					
	(1)		The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.	30:55 127:133	ES, 2.12:2.13			Groundwater natrually degraded. Simulated under flow toward axis of the basin beoynd the control of the WDWA.
	(2)		The criteria used to define when and where the effects of the groundwater conditions cause undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.	127:133	2.12:2.13			
	(3)		Potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results.	127:133	2.12:2.13			
(c)			The Agency may need to evaluate multiple minimum thresholds to determine whether an undesirable result is occurring in the basin. The determination that undesirable results are occurring may depend upon measurements from multiple monitoring sites, rather than a single monitoring site.	141:145	4.0	29a:30f		

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(d)			An Agency that is able to demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin shall not be required to establish criteria for undesirable results related to those sustainability indicators.	141:145	4.0			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10721, 10723.2, 10727.2, 10733.2, and 10733.8, Water Code.					
§ 354.28.			**Minimum Thresholds**					
(a)			Each Agency in its Plan shall establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site established pursuant to Section 354.36. The numeric value used to define minimum thresholds shall represent a point in the basin that, if exceeded, may cause undesirable results as described in Section 354.26.	141:145	4.0	29a:30f		GW naturally gegraded,GW elev.data identified as a data gap to be addressed
(b)			The description of minimum thresholds shall include the following:					
	(1)		The information and criteria relied upon to establish and justify the minimum thresholds for each sustainability indicator. The justification for the minimum threshold shall be supported by information provided in the basin setting, and other data or models as appropriate, and qualified by uncertainty in the understanding of the basin setting.	141:145	4.0	29a:30f		
	(2)		The relationship between the minimum thresholds for each sustainability indicator, including an explanation of how the Agency has determined that basin conditions at each minimum threshold will avoid undesirable results for each of the sustainability indicators.	141:145	4.0	29a:30f		
	(3)		How minimum thresholds have been selected to avoid causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals.	141:145	4.0	29a:30f		
	(4)		How minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests.	141:145	4.0	29a:30f		
	(5)		How state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the Agency shall explain the nature of and basis for the difference.	141:145	4.0	29a:30f		
	(6)		How each minimum threshold will be quantitatively measured, consistent with the monitoring network requirements described in Subarticle 4.	141:145	4.0	29a:30f		Will coordinate with adjacent GMA's.
(c)			Minimum thresholds for each sustainability indicator shall be defined as follows:					
	(1)		Chronic Lowering of Groundwater Levels. The minimum threshold for chronic lowering of groundwater levels shall be the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results. Minimum thresholds for chronic lowering of groundwater levels shall be supported by the following:					
		(A)	The rate of groundwater elevation decline based on historical trends, water year type, and projected water use in the basin.	141:145	4.0	29a:30f		Minimal pumping due to naturally degraded GW.

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
		(B)	Potential effects on other sustainability indicators.	141:145	4.0	29a:30f		
	(2)		Reduction of Groundwater Storage. The minimum threshold for reduction of groundwater storage shall be a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results. Minimum thresholds for reduction of groundwater storage shall be supported by the sustainable yield of the basin, calculated based on historical trends, water year type, and projected water use in the basin.	141:145	4.0	29a:30f		
	(3)		Seawater Intrusion. The minimum threshold for seawater intrusion shall be defined by a chloride concentration isocontour for each principal aquifer where seawater intrusion may lead to undesirable results. Minimum thresholds for seawater intrusion shall be supported by the following:					
		(A)	Maps and cross-sections of the chloride concentration isocontour that defines the minimum threshold and measurable objective for each principal aquifer.					Not applicable, 40 miles inland
		(B)	A description of how the seawater intrusion minimum threshold considers the effects of current and projected sea levels.					Not applicable, 40 miles inland
	(4)		Degraded Water Quality. The minimum threshold for degraded water quality shall be the degradation of water quality, including the migration of contaminant plumes that impair water supplies or other indicator of water quality as determined by the Agency that may lead to undesirable results. The minimum threshold shall be based on the number of supply wells, a volume of water, or a location of an isocontour that exceeds concentrations of constituents determined by the Agency to be of concern for the basin. In setting minimum thresholds for degraded water quality, the Agency shall consider local, state, and federal water quality standards applicable to the basin.	31:32 95:114 130:132 141:145	ES, 2.6, 2.12.5, 4.0	15a,16,20b		Groundwater naturally degraded due to geology.Basin Plan Amendment pending.
	(5)		Land Subsidence. The minimum threshold for land subsidence shall be the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results. Minimum thresholds for land subsidence shall be supported by the following:					
		(A)	Identification of land uses and property interests that have been affected or are likely to be affected by land subsidence in the basin, including an explanation of how the Agency has determined and considered those uses and interests, and the Agency's rationale for establishing minimum thresholds in light of those effects.	132:133 141:145	2.12.6,4.0	28a:28b		
		(B)	Maps and graphs showing the extent and rate of land subsidence in the basin that defines the minimum threshold and measurable objectives.	132:133 141:145	2.12.6,4.0	28a:28b		
	(6)		Depletions of Interconnected Surface Water. The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results. The minimum threshold established for depletions of interconnected surface water shall be supported by the following:					
		(A)	The location, quantity, and timing of depletions of interconnected surface water.	120:134	2.12	27d:27f		

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				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
		(B)	A description of the groundwater and surface water model used to quantify surface water depletion. If a numerical groundwater and surface water model is not used to quantify surface water depletion, the Plan shall identify and describe an equally effective method, tool, or analytical model to accomplish the requirements of this Paragraph.	127:134	2.12			
(d)			An Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence.	127:134 141:145	1.12.4, 4.0	29a:30f		GW elev. will serve as proxy for GW storage.
(e)			An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators.	127:134 141:145	1.12.4, 4.0			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.2, 10733, 10733.2, and 10733.8, Water Code.					
§ 354.30.			**Measurable Objectives**					
(a)			Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.	141:145	4.0	29a:30f		
(b)			Measurable objectives shall be established for each sustainability indicator, based on quantitative values using the same metrics and monitoring sites as are used to define the minimum thresholds.	141:145	4.0	29a:30f		
(c)			Measurable objectives shall provide a reasonable margin of operational flexibility under adverse conditions which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty.	141:145	4.0	29a:30f		
(d)			An Agency may establish a representative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence.	121:122 141:145	2.7.7,4.0	29a:30f		GW elevation will be used as proxy for GW storage
(e)			Each Plan shall describe a reasonable path to achieve the sustainability goal for the basin within 20 years of Plan implementation, including a description of interim milestones for each relevant sustainability indicator, using the same metric as the measurable objective, in increments of five years. The description shall explain how the Plan is likely to maintain sustainable groundwater management over the planning and implementation horizon.	121:122 141:145	2.11,4.0	29a:30f		
(f)			Each Plan may include measurable objectives and interim milestones for additional Plan elements described in Water Code Section 10727.4 where the Agency determines such measures are appropriate for sustainable groundwater management in the basin.	141:145	4.0	29a:30f		

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				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
(g)			An Agency may establish measurable objectives that exceed the reasonable margin of operational flexibility for the purpose of improving overall conditions in the basin, but failure to achieve those objectives shall not be grounds for a finding of inadequacy of the Plan.	141:145	4.0	29a:30f		Not applicable, no MOs that exceed regional margin of operational flexibility
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10727.2, 10727.4, and 10733.2, Water Code.					
SubArticle 4.			**Monitoring Networks**					
§ 354.32.			**Introduction to Monitoring Networks**					
			This Subarticle describes the monitoring network that shall be developed for each basin, including monitoring objectives, monitoring protocols, and data reporting requirements. The monitoring network shall promote the collection of data of sufficient quality, frequency, and distribution to characterize groundwater and related surface water conditions in the basin and evaluate changing conditions that occur through implementation of the Plan.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.34.			**Monitoring Network**					
(a)			Each Agency shall develop a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation.	132:133 135:140 141:145	2.12,3.0, 4.0	29a:30f		Appendix G
(b)			Each Plan shall include a description of the monitoring network objectives for the basin, including an explanation of how the network will be developed and implemented to monitor groundwater and related surface conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial density to evaluate the affects and effectiveness of Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:					
	(1)		Demonstrate progress toward achieving measurable objectives described in the Plan.	135:145	3.0,4.0			Will cordinate with adjacent GMA's
	(2)		Monitor impacts to the beneficial uses or users of groundwater.	135:145	3.0,4.0			
	(3)		Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds.	135:145	3.0,4.0			
	(4)		Quantify annual changes in water budget components.	135:145	3.0,4.0			
(c)			Each monitoring network shall be designed to accomplish the following for each sustainability indicator:					
	(1)		Chronic Lowering of Groundwater Levels. Demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features by the following methods:					
		(A)	A sufficient density of monitoring wells to collect representative measurements through depth-discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer.	135:140	3.0,4.0			One well every ~19 square miles

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
		(B)	Static groundwater elevation measurements shall be collected at least two times per year, to represent seasonal low and seasonal high groundwater conditions.	135:145	3.0,4.0			
	(2)		Reduction of Groundwater Storage. Provide an estimate of the change in annual groundwater in storage.	135:145	3.0,4.0			
	(3)		Seawater Intrusion. Monitor seawater intrusion using chloride concentrations, or other measurements convertible to chloride concentrations, so that the current and projected rate and extent of seawater intrusion for each applicable principal aquifer may be calculated.					Not applicable, 40 miles inland
	(4)		Degraded Water Quality. Collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues.	31:32 95:114 130:132 141:145	ES, 2.12.5, 4.0	15a,16,2ob		GW naturally degraded due to geology. Basin Plan Amendment pending.
	(5)		Land Subsidence. Identify the rate and extent of land subsidence, which may be measured by extensometers, surveying, remote sensing technology, or other appropriate method.	132:134 139:140	2.12.6, 3.1:3.2	28a:28b		
	(6)		Depletions of Interconnected Surface Water. Monitor surface water and groundwater, where interconnected surface water conditions exist, to characterize the spatial and temporal exchanges between surface water and groundwater, and to calibrate and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. The monitoring network shall be able to characterize the following:					
		(A)	Flow conditions including surface water discharge, surface water head, and baseflow contribution.	127:128	2.12			Depletion of interconnected GW not identified
		(B)	Identifying the approximate date and location where ephemeral or intermittent flowing streams and rivers cease to flow, if applicable.	72:75	2.1			
		(C)	Temporal change in conditions due to variations in stream discharge and regional groundwater extraction.	72:75	2.1			
		(D)	Other factors that may be necessary to identify adverse impacts on beneficial uses of the surface water.	72:75	2.1			Not applicable, use Aqueduct water
(d)			The monitoring network shall be designed to ensure adequate coverage of sustainability indicators. If management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the basin setting and sustainable management criteria specific to that area.	135:140	3.0,4.0		2	Appendix G
(e)			A Plan may utilize site information and monitoring data from existing sources as part of the monitoring network.	135:140	3.0,4.0		2	Appendix G
(f)			The Agency shall determine the density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends based upon the following factors:					
	(1)		Amount of current and projected groundwater use.	88:92 110:122	2.6.2, 2.7	24b:24d		~3,000AFY, currently

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(2)		Aquifer characteristics, including confined or unconfined aquifer conditions, or other physical characteristics that affect groundwater flow.	77:84	2.5.5	15b:15c		
	(3)		Impacts to beneficial uses and users of groundwater and land uses and property interests affected by groundwater production, and adjacent basins that could affect the ability of that basin to meet the sustainability goal.	127:134	2.12.3:2.13			Minimal pumping due to naturally degraded GW
	(4)		Whether the Agency has adequate long-term existing monitoring results or other technical information to demonstrate an understanding of aquifer response.	124:125	2.8.2			Identified data gap
(g)			Each Plan shall describe the following information about the monitoring network:					
	(1)		Scientific rationale for the monitoring site selection process.	135:145	3.0,4.0			
	(2)		Consistency with data and reporting standards described in Section 352.4. If a site is not consistent with those standards, the Plan shall explain the necessity of the site to the monitoring network, and how any variation from the standards will not affect the usefulness of the results obtained.	135:145	3.0,4.0			AppendixG
	(3)		For each sustainability indicator, the quantitative values for the minimum threshold, measurable objective, and interim milestones that will be measured at each monitoring site or representative monitoring sites established pursuant to Section 354.36.	135:145	3.0,4.0	29a:30f		
(h)			The location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used.	135:145	3.0,4.0	29a:30f		
(i)			The monitoring protocols developed by each Agency shall include a description of technical standards, data collection methods, and other procedures or protocols pursuant to Water Code Section 10727.2(f) for monitoring sites or other data collection facilities to ensure that the monitoring network utilizes comparable data and methodologies.	135:145	3.0,4.0			Appendix G
(j)			An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish a monitoring network related to those sustainability indicators.	135:145	3.0,4.0			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.2, 10727.4, 10728, 10733, 10733.2, and 10733.8, Water Code					
§ 354.36.			**Representative Monitoring**					
			Each Agency may designate a subset of monitoring sites as representative of conditions in the basin or an area of the basin, as follows:					
(a)			Representative monitoring sites may be designated by the Agency as the point at which sustainability indicators are monitored, and for which quantitative values for minimum thresholds, measurable objectives, and interim milestones are defined.	135:145	3.0,4.0			Appendix G
(b)			(b) Groundwater elevations may be used as a proxy for monitoring other sustainability indicators if the Agency demonstrates the following:					

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				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(1)		Significant correlation exists between groundwater elevations and the sustainability indicators for which groundwater elevation measurements serve as a proxy.	121:122 135:145	2.7.2, 3.0,4.0			
	(2)		Measurable objectives established for groundwater elevation shall include a reasonable margin of operational flexibility taking into consideration the basin setting to avoid undesirable results for the sustainability indicators for which groundwater elevation measurements serve as a proxy.	135:145	3.0,4.0			
(c)			The designation of a representative monitoring site shall be supported by adequate evidence demonstrating that the site reflects general conditions in the area.	135:145	3.0,4.0			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10727.2 and 10733.2, Water Code					
§ 354.38.			**Assessment and Improvement of Monitoring Network**					
(a)			Each Agency shall review the monitoring network and include an evaluation in the Plan and each five-year assessment, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin.	124:125 154:155	2.8.2,6.0			Appendix G, one well every ~19sq. miles
(b)			Each Agency shall identify data gaps wherever the basin does not contain a sufficient number of monitoring sites, does not monitor sites at a sufficient frequency, or utilizes monitoring sites that are unreliable, including those that do not satisfy minimum standards of the monitoring network adopted by the Agency.	124:125 154:155	2.8.2,6.0			
(c)			If the monitoring network contains data gaps, the Plan shall include a description of the following:					
	(1)		The location and reason for data gaps in the monitoring network.	135:145	3.0,4.0			
	(2)		Local issues and circumstances that limit or prevent monitoring.	135:145	3.0,4.0			
(d)			Each Agency shall describe steps that will be taken to fill data gaps before the next five-year assessment, including the location and purpose of newly added or installed monitoring sites.	135:145	3.0,4.0			
(e)			Each Agency shall adjust the monitoring frequency and density of monitoring sites to provide an adequate level of detail about site-specific surface water and groundwater conditions and to assess the effectiveness of management actions under circumstances that include the following:					
	(1)		Minimum threshold exceedances.	135:145	3.0,4.0			
	(2)		Highly variable spatial or temporal conditions.	135:145	3.0,4.0			
	(3)		Adverse impacts to beneficial uses and users of groundwater.	135:145	3.0,4.0			
	(4)		The potential to adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of sustainability goals in an adjacent basin.	135:145	3.0,4.0			Minimum pumping due to naturally degraded GW
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.2, 10728.2, 10733, 10733.2, and 10733.8, Water Code					
§ 354.40.			**Reporting Monitoring Data to the Department**					

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
			Monitoring data shall be stored in the data management system developed pursuant to Section 352.6. A copy of the monitoring data shall be included in the Annual Report and submitted electronically on forms provided by the Department.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10728, 10728.2, 10733.2, and 10733.8, Water Code.					
SubArticle 5.			**Projects and Management Actions**					
§ 354.42.			**Introduction to Projects and Management Actions**					
			This Subarticle describes the criteria for projects and management actions to be included in a Plan to meet the sustainability goal for the basin in a manner that can be maintained over the planning and implementation horizon.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.44.			**Projects and Management Actions**					
(a)			Each Plan shall include a description of the projects and management actions the Agency has determined will achieve the sustainability goal for the basin, including projects and management actions to respond to changing conditions in the basin.	146:153	5.0			
(b)			Each Plan shall include a description of the projects and management actions that include the following:					
	(1)		A list of projects and management actions proposed in the Plan with a description of the measurable objective that is expected to benefit from the project or management action. The list shall include projects and management actions that may be utilized to meet interim milestones, the exceedance of minimum thresholds, or where undesirable results have occurred or are imminent. The Plan shall include the following:					
		(A)	A description of the circumstances under which projects or management actions shall be implemented, the criteria that would trigger implementation and termination of projects or management actions, and the process by which the Agency shall determine that conditions requiring the implementation of particular projects or management actions have occurred.	141:153	4.0,5.0			
		(B)	The process by which the Agency shall provide notice to the public and other agencies that the implementation of projects or management actions is being considered or has been implemented, including a description of the actions to be taken.	67:69	1.5			
	(2)		If overdraft conditions are identified through the analysis required by Section 354.18, the Plan shall describe projects or management actions, including a quantification of demand reduction or other methods, for the mitigation of overdraft.	141:153	4.0,5.0			
	(3)		A summary of the permitting and regulatory process required for each project and management action.	141:153	4.0,5.0			

Article 5.			Plan Contents for Westside Districts Water Authority (WDWA) Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(4)		The status of each project and management action, including a time-table for expected initiation and completion, and the accrual of expected benefits.	141:153	4.0,5.0			
	(5)		An explanation of the benefits that are expected to be realized from the project or management action, and how those benefits will be evaluated.	141:153	4.0,5.0			
	(6)		An explanation of how the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.	141:153	4.0,5.0			
	(7)		A description of the legal authority required for each project and management action, and the basis for that authority within the Agency.	141:153	4.0,5.0			
	(8)		A description of the estimated cost for each project and management action and a description of how the Agency plans to meet those costs.	141:153	4.0,5.0			
	(9)		A description of the management of groundwater extractions and recharge to ensure that chronic lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater levels or storage during other periods.	141:153	4.0,5.0			
(c)			Projects and management actions shall be supported by best available information and best available science.	141:153	4.0,5.0			
(d)			An Agency shall take into account the level of uncertainty associated with the basin setting when developing projects or management actions.	141:153	4.0,5.0			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10727.2, 10727.4, and 10733.2, Water Code.					

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ACRONYMS AND ABBREVIATIONS

~	Approximately
>	Greater than
<	Less than
%	Percent
1,2-DCP	1,2-dichloropropane
40 CFR	Title 40 of the Code of Federal Regulations
AB	Assembly Bill
AF	acre-feet
AF/acre	acre-feet per acre
AFY	acre-feet per year
AGR	Agriculture
Amec	Amec Foster Wheeler
AWMP	Agricultural Water Management Plan
bgs	below ground surface
BMWD	Berrenda Mesa Water District
BPAW	Basin Plan Amendment Workplan
BWSD	Belridge Water Storage District
BVWSD	Buena Vista Water Storage District
°C	degrees Celsius
Ca	calcium
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	California Code of Regulation
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CGS	California Geological Survey
CIMIS	California Irrigation Management Information System
Cl	chloride
cm	centimeters
CRC	California Resource Corporation
COC	constituents of concern
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CVP	Central Valley Project
CWC	California Water Code
DAC	disadvantaged community
DAU	Detailed Analysis Unit
DBCP	1,2-dibromo-3-chloropane
DDWD	Devil's Den Water District
DO	dissolved oxygen
DOGGR	California Division of Oil, Gas, and Geothermal Resources
DPH	California Department of Public Health
DQO	data quality objectives
DRWD	Dudley Ridge Water District
DTSC	Department of Toxic Substances Control
DWR	California Department of Water Resources

EOR	enhanced oil recovery
ETAW	evapotranspiration of applied water
ETo	evapotranspiration
°F	degrees Fahrenheit
FAO	Food and Agriculture Organization of the United Nations
feet/year	feet per year
FS	Feasibility Study
GAMA	Groundwater Ambient Monitoring and Assessment
GEI	GEI Consultants
General Plan	Kern County General Plan
GMA	groundwater management area
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	Hydrogeologic Conceptual Model
I-5	Interstate-5
ILRP	Irrigated Lands Regulatory Program
inches/year	inches per year
IND	Industrial
KCWMD	Kern County Waste Management District
KCPNRD	Kern County Planning and Natural Resources Department
KCS	Kern County Subbasin
KCWA	Kern County Water Agency
KGA	Kern Groundwater Authority
LER	Lokern Ecological Reserve
LHSL	Lost Hills Sanitary Landfill
LHWD	Lost Hills Water District
LUST	leaking underground storage tank
MCL	maximum contaminant level
mg/L	milligrams per liter
mg/L-N	milligrams per liter as nitrogen
mmohs/cm	millimohs per centimeter
MNP	Monitoring Network Plan
MO	measurable objective
MSL	mean sea level
MT	minimum threshold
MUN	Municipal
Na	sodium
NA	not available
NO_3	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NWIS	National Water Information System
pH	potential of hydrogen
POE	point of entry
POU	point of use

ppb	parts per billion
ppt	parts per trillion
QA/QC	quality assurance/quality control
RO	reverse osmosis
RWQCB	Regional Water Quality Control Board
SB	Senate Bill
SGMA	Sustainable Groundwater Management Act
SMCL	secondary maximum contaminant level
SO4	sulfate
SpC	specific conductance
State	State of California
s.u.	standard unit
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWSD	Semitropic Water Storage District
TCP	1,2,3-trichloropropane
TDS	total dissolved solids
ug/L	micrograms per liter
UIC	Underground Injection Control
umhos/cm	micromhos per centimeter
uS/cm	microsiemens per centimeter
USDA	United States Department of Agriculture
USDW	Underground Source of Drinking Water
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Valley	Central Valley
WDR	waste discharge requirement
WDWA	Westside District Water Authority
WKWD	West Kern Water District
WWQC	Westside Water Quality Coalition
WY	Water Year

EXECUTIVE SUMMARY

On September 16, 2014, the State of California enacted into law three legislative bills (Senate Bill [SB] 1168 [Pavely], SB 1319 [Pavely], and Assembly Bill [AB] 1739 [Dickinson]). These bills are collectively known as the Sustainable Groundwater Management Act (SGMA). In simple terms the goal of SGMA is the sustainable management and use of the State of California's (State's) groundwater resources in a way that does not cause undesirable results.

To achieve the sustainable management of groundwater, SGMA requires that all groundwater basins identified by the State as high or medium priority, and subject to conditions of critical overdraft, be managed under a Groundwater Sustainability Plan (GSP) by January 31, 2020. The Kern County Subbasin (KCS, subbasin, or Subbasin) has been identified as a critically over drafted High Priority Basin subject to SGMA. As such, a special entity called the Kern Groundwater Authority (KGA) was formed on April 26, 2017. An amended and restated Joint Powers Agreement between Kern County and the general members of the KGA provided the necessary legal authority for the KGA to prepare, submit, and implement the required GSP.

Because of the many independent Water Districts within the KCS, which serve a variety of differing water users, it was decided to prepare a general GSP for the KGA, referred to in this Chapter GSP as the "KGA Umbrella GSP" or "Plan". Within this framework individual Water Districts or groups of Water Districts in the KGA are to prepare more detailed individual "Chapter GSPs", which discuss local groundwater conditions that, although are often related to adjoining Water Districts, have hydrogeology or other factors which may be distinct to their respective management area(s). Additionally, the Chapter GSPs provide the ability for the KGA to identify which of the undesirable results identified in SGMA may apply to a specific area of the KCS, and how these results would best be monitored and mitigated over both the short- and long-term, in order to meet KGA and SGMA sustainability goals.

This Chapter GSP focuses on a select subset of Water Districts within the KGA. Those participating Districts, referred to as the Westside Districts Water Authority (WDWA), are:

1. Lost Hills Water District (LHWD);
2. Belridge Water Storage District (BWSD); and
3. Berrenda Mesa Water District (BMWD).

Commensurate with SGMA, and based on the current level of understanding of the WDWA within the KCS basin setting, the purpose of this Chapter GSP is to describe in plain language the groundwater conditions that currently exist within the WDWA. This Chapter GSP also identifies hydrologic data gaps and focused remedies, and presents a proposed groundwater management plan that, if determined to be technically and economically feasible, has the potential to achieve and maintain the sustainability goals of the WDWA and, by extension, those

of the KGA over the required SGMA implementation horizon. Due the complex and interrelated nature of the hydrology and consumptive use of the water resources within the KGA, details and data from the KGA GSP, and some data from individual adjacent GSPs and/or Groundwater Sustainability Agencies (GSAs), may be included in this Chapter GSP. Issues related to preliminary coordination with adjacent Districts, if any, will be addressed during the first five-year reassessment period after acceptance of the KGA Plan.

The WDWA currently covers approximately 227,193 acres, or roughly 355 square miles of western Kern County, California. Of this total, approximately 88,989 acres (~140 square miles) is irrigated. Preliminary numerical modeling by the KGA indicates that the WDWA has a historic annual water demand of approximately 285,000 acre-feet per year (AFY), which is projected to escalate to approximately 316,000 AFY by 2040 due to climate change. Historically, significantly more than 95% of the water used for irrigation in the WDWA has been surface water, with most of the supply coming from the State Water Project (SWP) and other supplemental sources delivered via the California Aqueduct (Aqueduct). This volume of water consists of a combination of SWP "Table A" and "Article 21" water along with purchased supplemental import water, although not all supplemental water is SWP water. When available, a combined 100 percent (%) WDWA allocation from the SWP is around 332,218 AFY. Current surface water deliveries (all WDWA sources) are approximately 266,290 AFY. The WDWA preliminary minimum estimated volume of groundwater available that would not cause an undesirable result (i.e. "Native Yield"), is approximately 34,079 AFY. This volume is based on basic water supply inputs. When additional water budget inputs, such as those proposed in Project Management Action #3, are considered this volume may be higher (~68,158 AFY). Groundwater is primarily utilized for blending when California Aqueduct (Aqueduct) water supply is low. Current groundwater pumping in the WDWA is on the order of 3,000 AFY. It is emphasized that groundwater in the WDWA is of poor quality and unsuitable for practical use without blending or treatment. As such, brackish groundwater is considered to be "outside" the water budget unless blended or treated.

Unique hydrogeologic characteristics of the WDWA that set it apart from the other Water Districts in the KCS are:

1. The WDWA is isolated from other groundwater basins and adjoining water districts along its entire western boundary by the Temblor Mountain Range, its primary source of subsurface groundwater inflow. On the north and east, groundwater underflow towards the axis of the basin is impeded or slowed by a series of roughly north-south oriented geologic anticlines and synclines (up folds and down folds). To the south groundwater flow is impeded by geologic structural ridges that include spurs of the Temblor Range and the Elk Hills Anticline. This geologic setting has contributed to the poor groundwater quality in the WDWA and

limits necessary groundwater coordination to just a few downgradient management areas to the north and east.

2. Groundwater is naturally degraded and of poor quality throughout most of the WDWA due to the presence of geologic sediments derived from marine environments, some of which contain saline connate water. These conditions make groundwater in the WDWA unsuitable for practical beneficial use, without treatment or blending with better quality water.
3. Irrigation demand is met almost entirely by water delivered via the Aqueduct. Groundwater is estimated to make up less than 2% of the water used for irrigation by private well owners due to its poor quality. Current pumping for the purpose of blending with the Aqueduct-delivered water supply is estimated to be approximately 3,000 AFY.
4. The most significant amount of brackish groundwater discharge from the WDWA modeled by the KGA is in the form of natural subsurface groundwater underflow to the north, towards the former Tulare Lake bed, a beneficial use exemption area, and eastward towards the axis of the Valley. The total combined volume of modeled underflow discharge to these areas is estimated to be approximately 111,000 AFY. Given the limited amount of pumping in the WDWA, underflow out of the WDWA is the most significant contributor to estimated groundwater deficits (change in groundwater storage) in the WDWA. This natural phenomenon is beyond the control of the WDWA.
5. Pumping for consumptive use in downgradient adjacent water districts has resulted in noticeable differences in groundwater elevations between the WDWA and these areas. The adjacent pumping has likely increased the velocity and volume of underflow out of the WDWA along shared administrative boundaries to the east and southeast. While the WDWA plans to coordinate with adjacent water districts during the implementation of the GSP, activities in adjacent districts which may affect WDWA groundwater elevations are beyond the direct control of the WDWA.
6. In 2016, due to the near ubiquitous poor quality of groundwater in the KCS west side, the Westside Water Quality Coalition (WWQC) prepared a Basin Plan Amendment Workplan (BPAW), which is inclusive of a significant percentage of the irrigated lands within the WDWA. The BPAW recommends delisting municipal and unlimited agriculture as a designated beneficial use for perched groundwater and deeper unconfined/semi-confined groundwater above the sub-regional Corcoran Clay (or its equivalent) due to naturally poor groundwater quality. The draft BPAW has been provided to the CV-SALTS Technical Committee and the Regional Water Quality Control Board (RWQCB) for preliminary review and input. The final determination by the RWQCB on the BPAW application will be reported in the relevant GSP annual update report.

A brief description of the member districts of the WDWA follows.

Lost Hills Water District

The LHWD was formed in 1963 to provide irrigation water from the SWP to the District. The LHWD boundaries begin just south of the town of Lost Hills and extend north and west to the Kings-Kern County line. Key landmarks include the California Aqueduct and Interstate 5 (I-5), the latter of which bisects the District diagonally from northwest to southeast. Adjacent Water Districts include Dudley Ridge Water District (DRWD) to the north (Kings County, Tulare Lake Subbasin), the BWSD to the south, the Semitropic Water Storage District (SWSD) and a portion of the Buena Vista Water Storage District (BVWSD) to the east, and the BWSD to the west.

The LHWD is comprised of approximately 74,357 acres, of which 70,453 acres are considered farmable. Not all of this acreage is currently being utilized for agricultural purposes. As of 2015, the net area under irrigated cultivation is approximately 27,900 acres. Agricultural activities rely primarily on surface water from the Aqueduct. In addition to agriculture, oil and gas production is an important non-irrigated land use within the LHWD. Groundwater use in the LHWD is mostly limited to periods of contracted surface water shortfalls and is generally relied upon for the purpose of blending. During periods of drought the LHWD also relies on groundwater coordination with adjacent Water Districts or growers as well as for surface water transfers, supplemental water purchases and nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the District, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. Groundwater quality is documented to be naturally degraded due to elevated concentrations of total dissolved solids (TDS). Groundwater is considered unsuitable for most uses and is non-beneficial for a majority of crops, and in some cases livestock. The LHWD supplies no municipal water from surface water or groundwater.

Berrenda Mesa Water District

Like the LHWD, the BMWD was formed in 1963 by landowners for the purpose of providing a reliable supply of irrigation water to the BMWD from the SWP. To the north of the BMWD lies the adjacent Devil's Den Water District (DDWD) (Kern County, outside of the KCS), to the south is the BWSD, to east are Undistricted Lands and the LHWD, and to the west is the Temblor Mountain Range.

Of the approximate 55,440 acres within the BMWD, all but 6,400 acres are considered farmable. The estimated net acreage currently being farmed is around 35,240 acres, of which 24,204 acres is irrigated by surface water from the SWP. Remaining lands are used for dry land farming or livestock grazing. At 100% delivery, the volume of contract water available to the BMWD is approximately 92,600 acre-feet (AF). Current water demand is approximately 88,000 AFY.

During times of drought, when contract water deliveries are reduced, in addition to groundwater blending, the BMWD can recover previously stored (i.e. banked) surface water from the Pioneer and Berrenda Mesa Projects. These two banking projects are located outside of the District, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf.

Groundwater use is limited in the BMWD due to elevated concentrations of TDS. The BMWD supplies no municipal water either from groundwater or surface water supply.

Belridge Water Storage District

The BWSD was formed by landowners in 1962 to provide surface water from the SWP for irrigation. The BWSD is bounded on the north by the LHWD and BMWD along with some currently Undistricted Lands, to the south by additional currently Undistricted Lands and the West Kern Water District (WKWD), to the east by the BVWSD, and to the west by the Temblor Mountain Range.

The principal source of water supply for the BSWD is surface and other imported water delivered by the Aqueduct, with agriculture as the main consumer. Of the 91,397 acres within the BWSD, approximately 88,223 acres are considered farmable, although not all of this land is currently being used for agriculture. As of 2015, there were approximately 36,885 acres being irrigated in the BWSD. In addition to agriculture, a percentage of the BWSD annual import allocation, when available, is delivered for industrial use in oil recovery operations in the North and South Belridge oil fields.

During periods of drought the BWSD relies chiefly on groundwater blending and coordination with adjacent Water Districts or growers for water transfers, supplemental water purchases and transfers from nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the District, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. The BWSD supplies no municipal water either from groundwater or surface water supply.

Public Meetings and Stakeholder Engagement

The KGA maintains a website (www.kerngwa.com) where it routinely posts information related to the GSP preparation process and proactively solicits stakeholder engagement and input. KGA

Coordination Meetings with stakeholders are typically held on the first Monday of every month. A partial list of items that are made available on the KGA website includes:

- Agendas and dates for upcoming and past public meetings;
- Stakeholder surveys;
- Relevant documents and reports for public review and input;
- Presentations, research, and white papers; and
- KGA contact information.

Additionally, the WDWA members have their own individual websites that provide information that is focused on the status of WDWA operations and GSP development within their respective district areas. The WDWA-member websites are:

- LHWD: www.lhwd.org
- BWSD: www.belridgewsd.com
- BMWD: www.bmwd.org

WDWA public outreach activities to date include:

- The WDWA participated in a KGA sponsored public workshop at the Kern County Agricultural Center in Bakersfield, California on May 14, 2019. The evening workshop was open to all community members and stakeholders. The workshop afforded interested parties the opportunity to interact one-on-one with WDWA staff and consultants who were there to answer and discuss questions or concerns related to the WDWA Chapter GSP, potential undesirable results and groundwater sustainability. The forum afforded the public an opportunity to also learn more about other KGA Chapter GSPs and the SGMA process.
- A second public KGA workshop was held on the evening of September 26, 2019 at the Kern County Agricultural Center in Bakersfield, California. This workshop took place during the KGA Umbrella GSP 90-day public review period and provided another opportunity for interested parties to communicate with WDWA staff and consultants regarding SGMA, the WDWA Chapter GSP, potential undesirable results and groundwater sustainability in the WDWA.
- A public meeting (WDWA regularly scheduled Board meeting) was held on June 5, 2019 at the BWSD offices. The purpose of this meeting was to discuss WDWA-specific issues related to this Draft Chapter GSP, such as current and projected water budgets, potential undesirable results, groundwater quality and Measurable Thresholds (MTs) and Measurable Objectives (MOs). The meeting updated Board members, the public and stakeholders on the status of the WDWA GSP Chapter findings, costs and the SGMA process. Initial comments received from the public or other stakeholders were incorporated into the Chapter GSP prior to the next scheduled update on August 21, 2019.

- A second update meeting with the WDWA Board and members of the public to discuss the Draft Chapter GSP was held on August 21, 2019 at the BWSD offices. In addition to presenting the latest information on the draft WDWA Chapter GSP, the WDWA Board approved submittal of the draft Chapter GSP for inclusion in the KGA Umbrella GSP prior to a 90-day public review period for the KGA Umbrella GSP. Initial comments received from stakeholders were incorporated in the update Chapter GSP presented at this meeting.
- The Draft Chapter GSP components and status were presented at three other regularly scheduled WDWA Board meetings open to the public, and at two public KGA Board Meetings held in Bakersfield on August 28, 2019 and December 18, 2019.
- The WDWA Manager received one direct comment letter during the 90-day public comment period for the KGA Draft Umbrella GSP. Relevant and applicable comments pertaining to the WDWA were incorporated in this version of the Chapter GSP. A copy of the letter is provided in the appendices of this report. Five other, more global, comment letters related to the Draft KGA Umbrella GSP and addressed to the KGA GSP Manager were also reviewed for relevant or applicable comments for incorporation that might pertain to the WDWA. It should be noted that the WDWA does not supply groundwater for municipal supply. Copies of those letters are on file with the KGA. Based on Fish & Wildlife comments the Lokern Ecological Reserve was identified and discussed in the Chapter GSP.

Basin Setting

The Central Valley of California (Valley) covers about 20,000 square miles and is bounded by the Cascade Mountain Range to the north, the Sierra Nevada Mountain Range (Sierra Nevada) to the east, the Tehachapi Mountains to the south, and the Coast Ranges (e.g., Temblor Range) and San Francisco Bay area to the west. The Valley is divided into three groundwater hydrologic regions according to the California Department of Water Resources (DWR's) Bulletin 118: (1) the northern one-third of the Valley is within the Sacramento River Basin; (2) the central one-third is within the San Joaquin River Basin; and (3) the southern one-third is within the Tulare Lake Basin, which in turn contains the KCS and the WDWA (DWR, 2016; GEI Consultants [GEI] 2019).

The WDWA, which is the focus of this Chapter GSP, covers approximately 227,193 acres (i.e. 355 square miles) along the extreme western side of the KCS. Of this total, approximately 89,989 acres, or about 140 square miles, is currently irrigated. The WDWA is bounded on the north by the Kings-Kern County line and the DRWD, on the south by the WKWD, on the east by various Undistricted Lands, the SWSD, and BVWSD, and on the west by the Temblor Mountain Range.

Topography

Topography in the WDWA is mostly gentle and flat, with steeper foothills of the Temblor Range lying at the western edge. Elevations range from approximately 250 feet above mean sea level (MSL) in the east-southeast to 1,200 feet above MSL in the southwest. Typical slopes within the WDWA range from 25 to 50 feet per mile. The California Aqueduct, which runs along the eastern edge and through other parts of the WDWA, is at an approximate elevation of 310 feet above MSL. The western portion of the WDWA, known as the Antelope Plain, is enclosed by the Coastal (Temblor) Range on the west and north and by various geologic structural arches (anticlinal folds) on the east and south.

Climate

The climate in the WDWA is generally hot and dry and is characterized as inland Mediterranean. The main growing season for the KCS runs from May through October, although various crops are grown year-round. Historic wet season precipitation averages around 5.2 inches per year (inches/year). The length of the frost-free season is currently about nine months, or approximately 270 days per year. Surface water delivered by the SWP is the chief source of supply for irrigation in the WDWA (GEI, 2019; Amec Foster Wheeler [Amec], 2015).

Basin Setting and Geology

The KCS is located in the southern most extent of the Tulare Lake Basin Hydrologic Region. The KCS encompasses a surface area of around 1,792,000 acres (2,800 square miles) and is underlain by approximately 32,000 feet (6 miles) of marine and continental sediments (Page, 1986; DWR, 2006; Amec, 2015; GEI, 2019). Near the end of the Late Cretaceous, tectonic movements elevated the Coast Ranges to the west of the Valley and created a marine embayment. During the Tertiary, seas episodically advanced and retreated within the embayment, resulting in deposits comprised of both continental and marine sediments. Structural deformation along the early and present-day San Andreas fault zone resulted in the formation of a series of anticlinal folds that form many of the prolific oil fields along the west side of the KCS (Farrar and Bertoldi, 1988; GEI, 2019).

During Pleistocene and Holocene times, the seas retreated, and continental deposits from alluvial and fluvial systems were deposited over Tertiary-age marine deposits. Some of these marine deposits contained naturally occurring connate (saline) water which have subsequently migrated into adjacent and overlying continental deposits (Page, 1986). Within the WDWA in general, eroded marine deposits are common and contribute to the overall poor, and mostly unusable, groundwater quality in the western KCS (GEI, 2019).

Surface Water

Ephemeral streams that originate on the east-facing slopes of the Temblor Range drain eastward toward the Antelope Plain and from there towards the Valley floor. The stormwater runoff in these channels is not controlled and typically percolates within the Antelope Plain and does not reach the bed of the former Tulare Lake to the northeast or the axis of the Valley as surface flow. The 10-year, 24-hour, storm event for the area ranges from 3.0 to 3.5 inches of precipitation (National Oceanic and Atmospheric Administration [NOAA], 2013; Amec, 2015; GEI, 2019).

Lined irrigation canals and drainage facilities are the principal surface and imported water conveyance features in the WDWA. Chief among these are the California Aqueduct, and its Coastal Aqueduct inter-tie.

Partially overlapping with a small area in the LHWD, and adjacent to the WDWA on the east, is the Kern National Wildlife Refuge (KNWR). The KNWR is another important natural surface water feature in the KCS that variably depends primarily on precipitation and seasonal irrigation to maintain several different wildlife habitats at the KNWR. The portion of the KNWR that overlaps with the WDWA is designated as dry "Uplands Habitat", which relies on precipitation for its sole water source.

To the south, in the Belridge WSD, are portions of the 3,100 acre Lokern Ecological Reserve (LER). Within the WDWA the LER consists of small, scattered and generally non-contiguous parcels. A review of Google Earth imagery shows those portions of the LER in the WDWA are likely Valley sink scrub, and/or Valley saltbrush scrub habitat (aka Alkali Scrub). The scattered parcels are more or less centered on either side of the Aqueduct and along the dry Kern River Flood Channel between the 7th Standard Road to the north and Lokern Road (Highway 58) to the south. Typical native plant species in Valley sink scrub, as described by the California Department of Fish and Wildlife, are iodine bush and seepweed, with the understory dominated by non-native species. Those portions of the LER in the WDWA appear to consist entirely of dry, non-irrigated scrub lands that, with no operational wells, rely on annual precipitation as its source of water.

Larger, more contiguous blocks of the LER are present further south of the WDWA roughly between the towns of Lokern and Tubman. The California Department of Fish and Wildlife website describes the LER at large as consisting of marsh, valley sink scrub, and valley saltbush scrub habitat. Although not likely present in the WDWA, vegetation in the marsh habitat includes tule, cattail and other common marsh species.

Current uses for surface and imported water in the WDWA include:

- Agriculture;
- Industrial and Process Water; and
- Groundwater Recharge (banking).

Agriculture on the west side of Kern County has become a mainstay of the State and local economy. In response to a myriad of factors including climate change, imported surface water availability, emerging farm technologies, and product market forces; the land use and crop selection on the west side of the KCS has evolved. A majority of the irrigated acreage in the WDWA is currently supplied by Aqueduct water and is utilized for growing permanent crops such as almonds, pistachios, citrus, and pomegranates.

Principal Aquifers and Aquitards

The thickness of the aquifer systems beneath the WDWA vary greatly from a few hundreds of feet to around 2,500 feet in thickness (DWR, 2003). From oldest to youngest, the principal water bearing zones in western Kern County include the Etchegoin Formation, the Tulare Formation, older alluvium and terrace deposits, and younger alluvium and floodplain deposits. Groundwater occurs in three loosely constrained aquifer packages within the WDWA. These are:

- Shallow perched groundwater;
- Unconfined/semi-confined groundwater; and
- Confined groundwater.

The occurrence of perched groundwater in the WDWA is sporadic, limited in quantity, and is recognized as having poor quality due to elevated TDS. It therefore has no beneficial use, nor does it contribute to or support groundwater dependent ecosystems.

Unconfined/semi-confined aquifers represent the principal aquifer packages for groundwater in the WDWA. These zones exist below occasional shallow perched groundwater in the upper and lower Tulare. The Tulare Formation was deposited as a series of coalescing alluvial fans and debris flows shed from the Temblor Mountain Range. As such it contains interbedded and interlensing sequences of fine-grained silt and clay mixed with gravels and sands. The unconfined/semi-confined aquifer zone extends from approximately 50 feet below ground surface (bgs), downward to the top of the so called modified “E-Clay” that is considered to be equivalent to the Corcoran Clay. This sub-regional aquitard, where present, is typically found at approximately 500 feet bgs or deeper.

Confined groundwater conditions exist below the Corcoran Clay and its generally accepted equivalent on the Westside, the modified E-Clay. Studies by the United States Geological Survey (USGS) (2009) indicate that the Corcoran Clay extends from the Valley floor westward to approximately the east-facing flank of the Lost Hills Anticline. The modified E-Clay is poorly constrained and is not known to extend significantly into the Antelope Plain, which constitutes a majority of the interior surface area of the WDWA. Depths to confined groundwater are variable but are usually deeper than 500 feet bgs. Concentrations of TDS in the confined groundwater zones (typically Etchegoin Formation and deeper) can initially range between 250 to 434 milligrams per liter (mg/L), but often degrade over time, suggesting the volume of better-quality water is limited. Sediments in this stratigraphic package consist of unconsolidated to consolidated, interbedded medium to coarse sand, silt, and clay (Amec, 2015; GEI, 2019). The presence or lack thereof of a well-defined and contiguous confining layer beneath the Antelope Plain separating shallow and deeper groundwater zones, and Westside complex structural geology could explain the general poor quality of groundwater throughout the WDWA, as well as the occurrence of better-quality groundwater in certain areas. Together with the documented low volumes of groundwater pumping in the WDWA it may also explain why, with the possible exception of oilfield areas, there does not appear to be any significant inelastic land subsidence in the WDWA.

Groundwater Quality

In the WDWA management area, marine-derived geologic sediments have contributed to the documented naturally poor and unsuitable quality of groundwater. Along the western side of the KCS, including the WDWA, unconfined/semi-confined groundwater is characterized geochemically as sodium/calcium-sulfate (Na/Ca-SO_4) water with TDS concentrations often exceeding 2,000 mg/L. Other deeper groundwater aquifers beneath the WDWA, and elsewhere in the KCS, are referred to as sodium-chloride (Na-Cl) water, which exhibits high to very high levels of TDS and is likely saline connate water (Amec, 2015; GEI, 2019).

In 2016, the WWQC prepared a Basin Plan Amendment Workplan (BPAW) which is inclusive of a significant portion of the irrigated lands within the WDWA. The BPAW recommends delisting municipal and unlimited agriculture as a designated beneficial use for perched and deeper unconfined/semiconfined groundwater due to natural poor groundwater quality. Confined groundwater sources immediately east of the Lost Hill Anticline would remain unchanged with regards to current designated use, pending further monitoring. The draft BPAW has been provided to the CV-SALTS Technical Committee and the Regional Water Quality Control Board (RWQCB) for review and input. Final determination by the RWQCB on the request for a change in designated beneficial uses will be included in the relevant annual update to the KGA Umbrella GSP.

The occurrence of high TDS groundwater in the west side of the KCS has recently been further documented in a preliminary groundwater salinity mapping study conducted by the USGS (Metzger and Landon, 2018). In the study, the distribution of groundwater salinity for 31 oil fields and adjacent aquifers across major oil-producing areas of central and southern California were mapped. The objective of the study was to describe the distribution of groundwater near oil fields having TDS less than 10,000 mg/L by using existing TDS data from petroleum and groundwater wells to map concentrations and document data gaps. Within the KCS, the study reported much higher TDS in groundwater from Westside oil field wells and groundwater wells, when compared with east side groundwater wells and oil wells. Metzger and Landon (2018), among others, suggest that higher TDS in the Westside could be related to a combination of natural conditions (Westside sediments derived from marine deposits containing saline connate water) and anthropogenic factors such as infiltration from former oil field produced water evaporation ponds and/or agricultural drainage ponds. This higher TDS water is consistent with historical reports completed prior to widespread agricultural development and is documented for more than 60 miles from north to south in the west side of the KCS (KCDEH, 1980; KCDEH and KCWA, 1982; GEI, 2019).

Lateral Boundaries and Bottom of the Basin

To the west of the WDWA the consolidated rocks that form the Temblor Range mountain front is both a boundary of the KCS, and a barrier to westward groundwater flow. Structural impediments to downgradient eastward groundwater flow from the Antelope Plain are poorly constrained but may include post-depositional folding of then-soft sediments and faulting. These fold belt structures include, among others, the Belridge, Lost Hills, and Kettleman Anticlines, and the Buttonwillow and Semitropic ridges and associated north-south oriented synclines. Page (1986) and the DWR (2006) also identified the anticlinal folds, and specifically Lost Hills Anticline, as restrictions that slow or impede groundwater flow towards the Valley axis. To the south, groundwater flow is impeded by geologic structures that include spurs of the Temblor Range and the Elk Hills Anticline. This condition likely applies to other geologic structures within the WDWA.

In simplest form, the geologic bottom of the sedimentary Subbasin can be identified as the depth at which crystalline basement rock is encountered. Alternatively, and more applicable with regards to the conditions within the WDWA and the objectives of SGMA, the bottom of the groundwater Subbasin is more aptly defined by applying criteria of Title 40 of the Code of Federal Regulations (40 CFR) §146.4. The bottom of the Subbasin varies vertically and laterally with:

- Depth to commercially producible minerals or hydrocarbons;
- Depth to exempted aquifers;

- The depth that makes recovery of water for drinking water purposes no longer economically or technologically feasible; and
- The depth at which groundwater cannot now, or in the future, serve as a source of drinking water (GEI, 2019).

Recognizing that the hydrogeology of the Subbasin is highly variable, and that it is not possible at this time to predict the future maximum depth at which groundwater might be economically recoverable, or at which groundwater TDS concentrations below 10,000 mg/L may be economically treatable for drinking water, the KGA umbrella GSP has proposed the following combination of criteria for determining the hydrologic bottom of the Subbasin. The criteria take into account existing relevant and applicable rules and regulations. Utilizing this approach, the bottom of the Subbasin may be described as the combination of the itemized list below (i.e., item A, and either item B or C) (GEI, 2019).

A. Depth to commercially producible minerals or hydrocarbons (40 CFR §146.4) (where it applies to discrete areas of the Subbasin), or the depth to an exempted aquifer which has been approved by the United States Environmental Protection Agency (US EPA) and California Division of Oil, Gas, and Geothermal Resources (DOGGR) according to the criteria of 40 CFR §146.4; and either:
B. Depth to water at a TDS that is no longer economically or technologically feasible for groundwater beneficial use; or
C. Depth to waters of TDS greater than 10,000 mg/L (40 CFR §144.3), these being referred to here as not suitable as an Underground Source of Drinking Water (USDW).

In the WDWA, oil is produced from geologic structures that are comprised of some of the same formations that produce brackish groundwater elsewhere in the WDWA. The Tulare and Etchegoin Formations are two examples of this condition. In addition to containing hydrocarbons, many of these oil-bearing zones also contain naturally degraded formation water (i.e. produced water). Based on the presence of hydrocarbons in these structures, many of the associated formations are also designated as exempt aquifers by the DOGGR and the US EPA, within the administrative limits of the individual oil field. Examples of oil fields with aquifer exemptions include, among many others, the Lost Hills Oil Field and the Belridge Oil Field complex. Both oil field produced water and WDWA groundwater are naturally degraded by elevated concentrations of TDS and other constituents. With few exceptions, these conditions are found throughout the WDWA.

There have been numerous groundwater studies conducted in the west side of the KCS over the past 90 years. Several of these were conducted in the 1930s and 1950s prior to wide-spread development of agriculture. With rare exception all such studies have documented the poor quality of groundwater due to the presence of marine derived geologic sediments. Because

groundwater in the WDWA is degraded to a level where it is unsuitable for most practical beneficial use without blending or treatment, it is proposed the base of groundwater suitable for general beneficial use in the WDWA is where TDS concentrations exceed 2,000 mg/L. Groundwater quality is discussed further in **Section 2.6.5** of this Chapter GSP.

Groundwater Trends

Groundwater elevation data in the WDWA is scarce due to the minimal amount of annual groundwater pumping. Groundwater elevation data has been identified as a data gap that will be addressed during the first five-year reassessment period. However, based on the limited data available, groundwater trends in the WDWA appear to be generally downward, albeit likely not at rates currently simulated in the KGA C2VSim-Kern groundwater model. Groundwater trends in the WDWA are governed principally by drought and downgradient subsurface outflows that may be accelerated by irrigation withdrawals in adjacent water districts. Groundwater flow direction in the WDWA is believed to be primarily eastward from the Temblor Range toward the floor of the Valley, and northeastward along the northern boundary of the WDWA towards the former bed of Lake Tulare. Subsurface flow is thought to be both impeded, and sometimes sourced by, runoff from the aforementioned structural ridges and anticlines that separate the Antelope Plain from the axis of the Valley floor. In the north, geologic gaps between the Lost Hills Anticline and the South Dome of the Kettleman Hills Anticline may provide pathways for restricted groundwater migration. In the south, geologic gaps around the Belridge Anticline complex and the more easterly Buttonwillow and Semitropic ridges may be pathways for groundwater to move towards the Valley. Further study of WDWA geology and groundwater trends will be conducted during the first five-year reassessment period (i.e. 2020-2025).

Climate Change

Current climate modeling indicates that by 2050 there may be a significant reduction in the amount of winter snowpack in the Sierra Nevada. The gradual late-spring to mid-summer snowpack melt has historically allowed for organized management of this important resource, which currently provides around 65% of California's water supply. If current predictions are realized, it is possible that runoff from the Sierra Nevada Range will occur earlier in the year, and a majority of precipitation may come in the form of rain instead of snow. The ability to harvest and store the runoff for use later in the growing season may become a critical issue for Valley agriculture and by extension, the State's economy, in the next decade. Assuming no change to cropping patterns, and no new water storage or reuse projects, predicted climate change will likely result in increased competition for all water resources. In the KCS at large, it is expected that reliance on groundwater will increase in order to augment potential further reductions to deliveries from the SWP and the CVP. Adaptive planning and management actions that may mitigate these conditions include demand reduction measures, continued conservation,

improvements in groundwater and surface water storage, and the innovative treatment and conjunctive reuse of all water resources. This Chapter GSP has included many of these concepts in its sustainability planning (**Section 6.0**).

Beneficial Use and Users

As noted previously, a BPAW which proposes delisting unlimited agricultural and municipal use of perched and unconfined/semiconfined groundwater over a significant portion of the WDWA is under regulatory review. Current beneficial uses of groundwater for the WDWA are established in the Tulare Lake Basin Plan. The WDWA is within Detailed Analysis Unit (DAU) 259. Existing designated beneficial uses of groundwater in the WDWA include:

- Municipal (MUN);
- Agriculture (AGR); and
- Industrial (IND).

There currently is no MUN pumping of groundwater in the WDWA. Because of the ubiquitous presence of elevated concentrations of TDS, the use for AGR is primarily limited to blending with higher-quality Aqueduct water when those deliveries are reduced. Industrial use is mainly limited to oil field operations, such as water for well drilling or enhanced oil recovery (EOR) via steam generation and reinjection, etc.

Water Budget

All GSAs in the Kern County subbasin (Subbasin) coordinated and collaborated on the development of a groundwater model (Model) to evaluate historical, baseline and projected groundwater conditions. The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop the Model on behalf of the Subbasin. The contract required that Todd Groundwater use the C2VSim model provided by DWR. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (see Attachment H in Umbrella GSP). Basin-wide water budget results from the Model are provided in Attachment H and show the Subbasin, as a whole, has a total storage deficit of approximately 324,326 AFY over the baseline period.

The Subbasin's dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a GSA-level water accounting system (Checkbook) using Subbasin specific values for supply, demand and net results. The Model results reflect Subbasin-wide conditions and do not allocate water shortages/surpluses, nor do

the results allocate the "ownership" of water. As a result, the GSAs, through a coordinated effort, developed the Checkbook that estimates current conditions for each GSA that are generally consistent with the Model results under baseline condition. The Checkbook and Model budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability in the interest of developing a Subbasin coordinated approach.

To ensure the individual water budgets reflected actual conditions, the KGA members developed the Checkbook budget and coordinated water accounting methodology. The result of that effort indicates a current baseline shortage/deficit for KGA members of approximately-256,281 AFY. This reflects the difference between a total demand for KGA members of 1,939,409 AFY, and a total supply of 1,683,128 AFY. Of the shortage/deficit of the KGA, the WDWA's portion of the KGA shortage/deficit is a surplus of +33,167 AFY. Or a difference in demand of 285,000 AFY and a water supply of 318,167 AFY.

As is mentioned above, each estimate includes data gaps and has varying degrees of accuracy and/or reliability. The Checkbook is complimentary to the Model and reflects the allocation of water supply benefits and obligations independent of geographic constraints within the Subbasin. This was important to recognize and ensure the coordination of the various groundwater banking projects and water management programs amongst the various GSAs within the groundwater basin.

It should be noted that the six unique WDWA hydrogeologic conditions (e.g. naturally degraded groundwater quality etc.), relative to the rest of the Subbasin, rend WDWA groundwater unusable unless it is blended or treated.

With regard to the WDWA, agricultural activities are the largest source of water demand. These activities rely almost exclusively on imported water delivered by the Aqueduct; groundwater pumping is minimal. Sources of surface water include SWP Table A and Article 21 water and purchased supplemental imported water, although not all supplemental water is SWP water. Because of a lack of representative groundwater data, the water budget for the WDWA is currently based on two independent and contrasting surrogate approaches that bookend the range of potential water supply: (1) the Checkbook Approach and (2) C2VSim-Kern. The Checkbook Approach is a typical approach based on a simple accounting of preliminary supply and demand and, as noted previously, is also used by other GMAs in the KGA. The KGA Checkbook approach combines SWP water, imported water, a preliminary value of groundwater Native Yield, and a current value of precipitation to estimate the available water supply. Groundwater pumping is not explicitly accounted for in the Checkbook but is rather considered a portion of the Native Yield. The Checkbook value of Native Yield is intended to encompass all groundwater recharges and discharges that apply to the WDWA but does not explicitly include

groundwater underflow, which is a critical component of the WDWA water budget. It is also important to understand that the term, "Native Yield", implies *suitable groundwater quality*, a condition that does not generally apply to the WDWA.

The WDWA Native Yield for the purpose of the preliminary Brackish Water Checkbook is conservatively estimated to be 0.15 acre-feet per acre (af/ac) multiplied by all WDWA acreage (i.e. 227,193 acres). This results in a volume of approximately 34,079 AFY. The currently estimated Checkbook precipitation factor is based on KGA and CIMIS data for the WDWA. It utilizes a factor of 0.2 af/ac. multiplied by the number of irrigated acres (88,989 acres) in the WDWA. This results in a volume of approximately 17,798 AFY that can potentially meet a portion of crop demand. Unique to the WDWA is the fact that all sources of groundwater (i.e. underflow, natural recharge etc.) are eventually degraded due to the geology and are rendered unsuitable for most direct use. Therefore, brackish groundwater in the WDWA is considered as "outside" the water balance unless blended or treated. If the poor water quality, minimal levels of pumping in the WDWA, the volume of KGA-modeled underflow (~111,000 AFY) leaving the WDWA, and potential reuse of oil field produced water (considered outside the water budget) are accounted for, a Native Yield range of 0.15 af/ac. to 0.30 af/ac. is supportable. If applied, it would result in a potential Native Yield of 34,079 AFY to 68,158 AFY, depending on the volume of oil field produced water, which together with brackish groundwater could be utilized for blending or treatment for conjunctive reuse. This volume represents approximately 30%-60% of the current total KGA-modeled brackish groundwater underflow leaving the WDWA. Project Management Action (PMA) #3, discussed in **Section 5.3.1,** proposes to treat brackish groundwater and potentially, oil field produced water for irrigation and other beneficial reuses.

The WDWA Brackish Water Checkbook is at best an illustration of potential groundwater resources and is only capable of providing an estimate of the current operational water budget, as well as preliminary 2030 and 2040 water supply operational budgets. The projected future estimates encompass phased pumping of naturally degraded groundwater for the twin purposes of landowner blending, including anticipated increased pumping for this purpose in response to climate change, and for pumping and treatment as part of a proposed conjunctive reuse management action discussed in **Section 5.0** of this Chapter GSP (i.e. PMA #3). It is stressed that the Checkbook approach groundwater volumes (i.e. Native Yield) should not be construed as a current or future groundwater allocation.

The second approach to estimating the WDWA water budget is based on groundwater numerical modeling conducted by the KGA with C2VSim-Kern. The C2VSim-Kern is considered a preliminary, albeit more detailed water budget than the Checkbook approach. It is emphasized that the subject KGA model is intended to be a KCS-wide assessment of groundwater conditions and is not specifically calibrated to the WDWA service area. Additional reconciliation of basin

water budgeting efforts is a high priority for all of the GSAs within the KCS as part of GSP implementation.

C2VSim-Kern is based on a Beta version of the DWR California Central Valley Groundwater-Surface Water Simulation Model, C2VSimFG-BETA (2018). KGA updated the managed supply and demand components of the model for the purpose of calculating preliminary volumetric flow rates for water budget components for the individual GMAs within the KCS. Like the Checkbook approach, the KGA model does not take into account that groundwater in the WDWA is naturally degraded and is unsuitable for most uses without blending or treatment. Currently, C2VSim-Kern modeling results for the WDWA are available only for historical conditions (1995-2014), which were used to develop the current-conditions water budget. It should be noted, that the C2VSim-Kern model simulations of historical conditions overstate the amount of groundwater pumping that has and is occurring in the WDWA. It is expected that the C2VSim-Kern modeling results for WDWA "future scenarios", which will include groundwater pumping volumes more aligned WDWA projections, will be available as part of future data assessment efforts. Details of the preliminary WDWA groundwater budget are provided in **Section 2.7** of this report.

Neither of these two approaches (Brackish Water Checkbook or KGA Model) currently provides a definitive illustration of the WDWA water budget and neither considers that the WDWA groundwater is naturally degraded and therefore outside the water budget However, in the absence of any alternative methodology they do provide a framework for revising the KGA water budget components based on additional data collected in the coming years. Given this, the Brackish Water Checkbook approach presented in this Chapter GSP is currently the more representative estimate of a "water balance" for the WDWA. Additional reconciliation of basin water budgeting efforts is a high priority for all of the GSAs within the basin as part of KGA Umbrella GSP implementation.

Sustainable Yield

Sustainable yield, as defined by SGMA, means the maximum quantity of water, calculated over a base period representative of long-term conditions in a basin, and including any temporary surplus; which can be withdrawn annually from a groundwater supply without causing an undesirable result. This definition implies that the groundwater supply is of *suitable quality* for beneficial use without significant treatment (i.e., the groundwater supply is not brackish or otherwise naturally degraded). Data to support an assessment of detailed Sustainable Yield is not currently available for the WDWA. This data gap will be addressed by implementing a Network Monitoring Plan (MNP) during the first 5-year reassessment period. Based on the

basin-wide estimates promulgated by the KGA, the normalized (native) sustainable yield for the KCS at large is estimated to be 0.15 af/ac. This factor was applied to all acreage (developed and undeveloped) in the WDWA (KGA, 2019; Todd Groundwater Consultants [Todd], 2019), resulting in a WDWA Native Yield of approximately 34,079 AFY that could be potentially harvested in a phased fashion through 2040 for blending and potential treatment and conjunctive reuse by the WDWA. The KGA Native Yield is considered to be a preliminary minimum estimate pending (1) continued refinement and calibration of theC2VSim-Kern model, (2) WDWA-specific sampling, and (3) modeling updates conducted by the KGA during the first five-year reassessment period. Data collected during the first five-year reassessment period will be utilized to model and refine the estimated sustainable yield for the WDWA. This information will be reported in relevant future update reports.

Water Budget Baseline and Projected Conditions

Due to the previously mentioned lack of reliable groundwater data, the water budget presented herein is considered preliminary. The water budget will be refined by incorporation of updated KGA C2VSim-Kern modeling results and new data acquired by the implementation of the MNP discussed in **Section 3.0** of this Chapter GSP. For the purpose of this submittal, the WDWA is assessing the two approaches noted above, namely, the Checkbook approach and the draft KGA C2VSim-Kern hydrologic model, to represent the key water budget components described below, with adjustments to account for known inaccuracies of the current model.

WDWA Estimated Groundwater Inflows

Based on current KGA modeling with C2VSim-Kern for the period WY 1995-2014, total groundwater recharge is ~92,300 AFY:

- Underflow from the Coastal Ranges: ~55,300 AFY
- Underflow from adjacent Districts: ~800 AFY
- Water loss from imported water canals: ~8,800 AFY
- Areal recharge (deep percolation): ~24,200 AFY
- Water loss from ephemeral stream flow: ~3,200 AFY

WDWA Estimated Groundwater Discharges

Because the primary source of water for agriculture in the WDWA is the SWP and various supplemental purchases of imported water, the volume of discharge due to extraction by pumping wells has historically averaged less than 2% of annual demand (pumping is currently estimated to be 3,000 AFY). However, the current C2VSim-Kern historical simulation overstates groundwater pumping by nearly a factor of ten. The total estimated discharge for the current

C2VSim-Kern historical model simulation, which includes the overstated pumping, is 138,540 AFY. The KGA-modeled discharge volumes for the Westside are approximately:

- ~111,000 AFY for underflow out of the WDWA; and
- ~28,000 AFY by pumping extraction.

Overdraft, under the current C2VSim-Kern model simulation, is estimated to be ~46,200 AFY (rounded up to 47,000 AFY to account for model uncertainty). However, because groundwater pumping is overstated in the model, the estimated overdraft is likely significantly less (~22,000 AFY). KGA-calculated climate change estimates adjust the areal recharge (deep percolation) downwards from 24,200 AFY to 18,900 AFY, while the WDWA simultaneously estimates an increase in pumping extractions for the purpose of blending from the current 3,000 AFY to 5,400 AFY by 2030. The deficit under this scenario would be approximately 29,400 AFY (conservatively rounded to 30,000 AFY). This conservative estimate is still lower than the current modeled overdraft of ~46,200 AFY. It should be reiterated and noted that:

1. WDWA groundwater is naturally degraded, is generally unsuitable for most use, and is therefore considered outside of the water budget unless used for blending or treated.
2. The WDWA meets almost all of its demand through the use of surface water delivered by the Aqueduct.
3. Even if the WDWA were to theoretically cease all pumping extractions, a deficit would still be realized under the C2VSim-Kern model simulations due entirely to the projected downgradient groundwater underflow of approximately 111,000 AFY leaving the WDWA, a phenomenon outside the control of the WDWA.

Sustainability Goals

Sustainable management in the KCS will result from continuation of current water management practices and the implementation of projects and management actions at the member-agency level to maintain their respective use of groundwater within the sustainable yield of the Subbasin, operate at or above established measurable objectives, and operate above established minimum thresholds. The sustainable yield, measurable objectives, and minimum thresholds have been developed based on available technical information and will be reviewed, updated, and reported as additional data are collected, as required by SGMA. The overarching goal of the KGA is to bring the subbasin into sustainability and maintain sustainability over the implementation and planning horizon.

Sustainability goals for the WDWA are designed to support those proposed in the KGA Umbrella GSP while simultaneously acknowledging and addressing: 1.) the previously listed unique hydrogeologic characteristics of the WDWA. 2.) identified data gaps and, 3.) the potential for

undesirable results within the WDWA. The goals will be achieved through the implementation of coordinated measurable objectives (MOs), such as specific administrative policies, projects and plans designed to enhance the sustainability of groundwater resources within the WDWA and the KCS at large. The sustainability goals for the WDWA are:

- Collect representative hydrologic information to more fully characterize and model the occurrence, condition, and elevation of groundwater beneath the WDWA through the implementation of a comprehensive Monitoring Network Plan (MNP);
- Leverage, to the extent feasible, the harvesting and treatment of naturally degraded groundwater underflow leaving the WDWA for the twin benefits of conjunctive reuse and mitigation of potential adverse effects to better quality water in adjacent downgradient districts; and
- Mitigate the potential for the chronic lowering of groundwater levels and significant reduction of groundwater in storage through the coordinated implementation of minimum thresholds (MTs) and MOs within WDWA areas that are adjacent to other downgradient GMAs.

Monitoring Network Objectives

Data related to representative aquifer characteristics and groundwater monitoring within the WDWA has, until most recently, been limited and non-contemporaneous. This is likely due to the limited amount of annual groundwater pumping in the WDWA. The lack of groundwater elevation data has been identified as an important data gap that must be filled for effective implementation of this Chapter GSP over the short-term, and for the assessment and planning of future adaptive management strategies over the long-term and SGMA implementation horizon. Associated groundwater components that rely on representative groundwater level monitoring include, among others, groundwater in storage and changes in storage, water budgets, and land subsidence. Objectives and elements of the MNP will address the need for representative data and will help reduce uncertainty for the purpose of sustainability planning. The MNP, once fully implemented, will help achieve the following objectives:

- Acquisition of representative groundwater data sufficient to assess and document short-term, seasonal, and long-term groundwater trends related to WDWA water budgets, groundwater pumping volumes, groundwater in storage, groundwater elevation, and potential future land subsidence;
- Ability to assess changes in groundwater conditions relative to identified MOs and MTs; and
- Coordination with adjacent GMAs by way of scheduled sampling events, updating MTs and MOs that mutually lead to groundwater sustainability, and regularly scheduled status meetings to ensure sustainability outcomes.

The MNP will include a minimum of 21 primary wells for monitoring, and will be based, to the extent feasible, on existing locations currently being monitored by the Westside Water Quality Coalition (WWQC). The preliminary monitoring locations were selected to cover all three aquifer zones (perched, unconfined/semi-confined, and confined). To the extent feasible selected wells will be used for both groundwater elevation and water quality monitoring. The initial distribution of wells across the WDWA is as follows:

- LHWD: 8 wells
- BMWD: 4 wells
- BWSD: 6 wells

The area of the WDWA is approximately 355 square miles. The well density of the proposed MNP is around one well per every 19.72 miles. While there is currently no established number for monitoring well density in a basin or management area, for comparison the monitoring well density for a basin recommended by the California Statewide Groundwater Elevation Monitoring (CASGEM) Groundwater Elevation Monitoring Guidelines ranges between one to 10 wells per 100 square miles. The current proposed groundwater monitoring network is capable of providing representative data to define short-term, seasonal, and long-term data trends in groundwater and associated surface conditions. Based on the density of the monitoring well network there will be sufficient data to utilize groundwater elevation changes as a surrogate for evaluating potential changes in groundwater in storage. To ensure reliable groundwater-level data, monitoring events will be scheduled in the late fall and early spring when many irrigation wells are typically idled. Monitoring activities will follow KGA guidance protocols.

Minimum Thresholds and Measurable Objectives

Pursuant to SGMA, MTs/ MOs shall be established for each sustainability indicator, based on quantitative analysis using the same metrics and monitoring sites as those utilized to define MTs. In accordance with the KGA Plan, the following general definitions apply to this Chapter GSP (California Code of Regulation [CCR] Title 23):

- MTs: Numeric values for each sustainability indicator used to define an undesirable result.
- MOs: Interim milestones in increments of five years, to achieve the sustainability goals for the WDWA, and by extension, the KGA, within 20 years of the Plan implementation.

Minimum Thresholds and Measurable Objectives for the WDWA Groundwater Management Area

Based on an assessment of the six potential undesirable results identified in SGMA, there are three co-related elements (lowering of groundwater elevation, change in groundwater storage,

and inelastic land subsidence) that require monitoring and/or focused MTs and MOs in order to sustainably manage the groundwater resources of the WDWA. The WDWA will conduct sentry monitoring to track groundwater elevations and quality along its northern and eastern boundary where groundwater leaves the WDWA as underflow. This underflow has been identified as the most significant contributor to the modeled groundwater deficit in the WDWA. Preliminary MTs and MOs have been proposed for these areas and are discussed further in **Section 4.0.**

Land Subsidence

Irrigation pumping, an activity sometimes correlated to land subsidence, has been limited in the WDWA due to its naturally degraded water quality. The potential for land subsidence will be monitored by the WDWA in coordination with a KCS-wide subsidence monitoring plan administered by the KGA. Special emphasis will be placed on monitoring between Aqueduct Mileposts 195 and 215. In 2011, an Aqueduct embankment failure of unknown cause at the time was documented at Milepost 208. Changes in topographic surface elevations will be reported at a minimum every five years in the relevant GSP update report. The MT for inelastic land subsidence in the KGA will be established and reviewed in consultation with adjacent GMA's and will be based on future KGA InSAR and other geodetic land survey data that may be collected by the WDWA in coordination with adjacent districts to the east. Data will be utilized to assess for potential inelastic subsidence and the potential for undesirable results to critical infrastructure. Subsidence associated with local oil field activities is under the oversight of DOGGR. Subsidence in the WDWA caused by oil field activities and by pumping in adjacent GMAs is outside the control of the WDWA. To the extent feasible the WDWA will coordinate the sharing of land-subsidence data with DOGGR and local oil producers that are party to the KGA Umbrella GSP.

Reduction of Groundwater Elevation/Groundwater Storage

Because changes in groundwater storage cannot be measured directly, the WDWA will utilize changes in groundwater elevations as a proxy to assess potential changes in groundwater storage. According to the draft C2VSim-Kern model, a principal cause of the groundwater deficit in the WDWA is the discharge of poor-quality groundwater (~111,000 AFY) from the WDWA as underflow toward the axis of the basin. By comparison, current groundwater pumping extractions in the WDWA are approximately 3,000 AFY. Said another way, even if all pumping extractions were to cease in the WDWA, it would still be in deficit and would experience reductions in groundwater elevation and changes in groundwater storage due to the preliminary modeled volume of underflow leaving the WDWA. The rate of underflow leaving the WDWA may be further influenced by groundwater extraction being conducted in some of the adjacent down-gradient GMAs. These conditions are beyond the control of the WDWA. Therefore, the WDWA has proposed two coordination sentry zones along shared boundaries with adjacent GMAs to monitor groundwater level elevations at the north and east boundaries of the WDWA.

Based on hydrologic conditions and preliminary simulated hydrographs, these zones each have separate preliminary MOs and MTs.

The preliminary MTs are:

- Sentry Zone #1 (well 25S21E-01): ~-115 feet below MSL
- Sentry Zone #2 (well 27S22E-30H- aka well #7106-63): ~59 feet above MSL
- Sentry Zone #2 (well 28S21E16 (sim centroid): ~56 feet above MSL
- Sentry Zone #2(well 28S21E13H): ~59 feet above MSL

The preliminary MOs are:

- Sentry Zone #1 (well 25S21E-01): ~-62 feet below MSL
- Sentry Zone #2 (well 27S22E-30H- aka well # 7106-63): ~101 feet above MSL
- Sentry Zone #2 (well 28S22E16 (sim centroid): ~112 feet above MSL
- Sentry Zone #2 (well 28S21E13H): ~127 feet above MSL

These MTs and MOs are preliminary and subject to review and change at a minimum every five years based on newly acquired data, and subsequent coordination discussions with adjacent GMAs. Proposed changes will be reported in the relevant GSP update report. There are currently no MTs or MOs proposed at this time for interior WDWA areas outside of the specified sentry coordination zones. The rationale for this approach is the aforementioned minimal historic pumping, and natural groundwater underflow over which the WDWA has no control. Data collected as part of the MNP for this Chapter GSP will be utilized to coordinate with adjacent downgradient GMAs and to assess whether the proposed MTs need updating. Planned coordination with adjacent management areas and data collected as part of the MNP for this Chapter GSP will be utilized to assess whether and how this approach may need to be revised.

Projects, Management Actions, and Adaptive Management

To meet WDWA sustainability goals, and ensure the ability to reduce current uncertainty related to the characterization of MTs, MOs, groundwater elevation monitoring, and other sustainability indicators, the WDWA will address the data gaps identified in this Chapter GSP through:

- The preparation and implementation of a comprehensive MNP during the first five-year reassessment period to collect data and document short-term, seasonal, and long-term groundwater trends related to the WDWA. The MNP will be designed to collect the necessary data to establish or update MTs and MOs, as needed in order to refine WDWA

water budgets, and sustainably manage and assess the potential for the chronic lowering of groundwater levels and significant reduction of groundwater in storage over the implementation horizon of the GSP;
- Coordination of water resources and data with adjacent GMAs; and
- The identification and assessment of potential projects and WDWA-specific management actions designed to support the sustainability goals of the WDWA, and by extension, the KGA.

To further enhance its sustainable and adaptive management strategies the WDWA is evaluating the feasibility of an innovative project that will integrate the treatment and conjunctive reuse of naturally degraded brackish groundwater and oil field produced water. Based on preliminary planning the project will ultimately harvest and treat approximately 40% oil field produced water and 60% brackish groundwater underflow for multiple beneficial uses including, among other things:

- A potential new water supply for adjacent and nearby disadvantaged communities (DACs) in order to improve water reliability and drought resiliency;
- A reliable supplemental source of better-quality water that, together with imported water, can be used for irrigation;
- Provide potential environmental flows to the adjacent Kern National Wildlife Refuge; and
- Protect groundwater quality adjacent to the WDWA by reducing the volume of naturally degraded groundwater underflow migrating to the northeast and east from the WDWA toward potentially better-quality groundwater in the axis of the Valley and adjacent management areas. This objective will be accomplished via strategic and sustainable monitoring and focused pumping for treatment and conjunctive reuse.

GSP Reporting and Periodic Evaluations

SGMA reporting standards, as enumerated in Section 352.4 of CCR 23, Subchapter 2, Groundwater Sustainability Plans, shall apply to all WDWA Chapter GSP reporting. Additional reporting details are provided below. Data from the various monitoring and well installation activities, if any, will be provided to the appropriate State and County databases (e.g., well installation information and groundwater level and water quality monitoring). Data will also be coordinated with adjacent GMAs and the KGA, which will coordinate with the KCS database. All data collected by the WDWA will be provided and summarized in the various reports detailed in this section.

Pursuant to SGMA, the WDWA will prepare Annual Reports for inclusion in the KGA GSP. The Annual Reports will comport with KGA guidance and will be submitted by the KGA by April 1st of each year following adoption of the Plan. The Annual Reports shall include the following topics:

- Groundwater elevation data and contour maps;
- Key well hydrographs;
- Groundwater extractions;
- Surface water supplies;
- Total water use;
- Change in groundwater storage; and
- Implementation progress.

Periodic reevaluation reports will be prepared a minimum of every five years for inclusion in the Plan. The five-year reassessments will be submitted electronically by the KGA to the DWR via the online reporting system and format provided by the Agency per Section 10733.2, Water Code and Section 353.2 and 356.4, of CCR 23, Subchapter 2, Groundwater Sustainability Plans. The submittal of updates or amendments to this Chapter GSP will be accompanied by a transmittal letter signed by the Plan Manager, or duly authorized representative. A coordinated data management system for the KCS is necessary to improve the accuracy, usefulness and confidence in groundwater data reported by the individual GMA's and GSA's within the KGA. Data system perimeters, inputs and a coordinated data system methodology will be established and reported in the relevant KGA update report. In the meantime, the WDWA will continue to rely on established State data bases for updating and reporting new data.

1.0 INTRODUCTION AND PURPOSE OF THE CHAPTER GSP

1.1 General Information

On September 16, 2014, the State of California (State) enacted into law three legislative bills (Senate Bill [SB] 1168 [Pavely], SB 1319 [Pavely], and Assembly Bill [AB] 1739 [Dickinson]). These bills are collectively known as the Sustainable Groundwater Management Act (SGMA). In simple terms, the goal of SGMA is the sustainable management and use of the State's groundwater resources in a way that does not cause undesirable results. SGMA defines undesirable results as:

- Chronic lowering of groundwater levels;
- Significant and unreasonable reduction of groundwater stored in aquifers;
- Seawater intrusion;
- Significant and unreasonable degraded water quality;
- Significant and unreasonable land subsidence; and
- Depletions of interconnected surface water that have significant and unreasonable impacts on the beneficial use of surface water.

1.2 Legal Authority

To achieve the sustainable management of groundwater, SGMA requires that all groundwater basins identified by the State as high or medium priority, and subject to conditions of critical overdraft, be managed under a Groundwater Sustainability Plan (GSP) by January 31, 2020. The Kern County Subbasin (KCS, subbasin, or Subbasin) has been identified as a critically over drafted High Priority Basin subject to SGMA. As such, a special entity called the Kern Groundwater Authority (KGA) was formed on April 26, 2017. An amended and restated Joint Powers Agreement between Kern County and the general members of the KGA provided the necessary legal authority for the KGA to prepare, submit, and implement the required GSP. Recently, due to potential liability concerns regarding groundwater rights, Kern County supervisors decided to cede their leadership role in SGMA-related issues to the Kern County Water Agency (KCWA). Reportedly, the State Water Board, in a letter to Kern County, has stated that the withdrawal of Kern County from direct involvement in the SGMA process for the subbasin will not trigger the State's intervention nor jeopardize local control of sustainable groundwater use.

Because of the many independent Water Districts within the KCS, which serve a variety of differing water users, it was decided to prepare a general GSP for the KGA, referred to in this Chapter GSP as the "KGA Umbrella GSP" or "Plan". Within this framework individual Water Districts or groups of Water Districts (groundwater management areas [GMAs]) in the KGA are

to prepare more detailed individual "Chapter GSPs", which discuss local groundwater conditions that, although are often related to adjoining Water Districts, have hydrogeology or other factors that may be distinct to their respective management area(s). Additionally, the Chapter GSPs provide the ability for the KGA to identify which of the undesirable results identified in SGMA may apply to a specific area of the KCS, and how these results would best be monitored and mitigated over both the short- and long-term, in order to meet KGA and SGMA sustainability goals. The individual GMAs have also entered into a Coordination Agreement, the components of which are:

1. Groundwater Elevation Data
2. Groundwater Extraction Data
3. Surface Water Supply
4. Total Water use
5. Change in Groundwater Storage
6. Water Budget
7. Sustainable Yield

This Chapter GSP focuses on a select subset of Water Districts within the KGA. Those participating Districts, referred to as the Westside District Water Authority (WDWA), are:

1. Lost Hills Water District (LHWD)
2. Belridge Water Storage District (BWSD)
3. Berrenda Mesa Water District (BMWD)

Figure 1a presents the current extent of the KGA administrative area, member agencies, and adjacent groundwater sustainability agencies (GSAs) in the KCS. **Figure 1b** presents the KGA member agencies. **Figure 2a** shows details of the WDWA. A list of the other agencies and groups in alphabetical order that are participating in the KCS are:

- Arvin-Edison Water Storage District;
- Buena Vista Water Storage District (BVWSD);
- Cawelo Water District;
- City of Bakersfield;
- Delano Cutout;
- Henry Miller Water District;
- Kern-Tulare Water District;
- Kern Water Bank Authority;
- North Kern Water Storage District;
- Olcese Water District;
- Pioneer Project;

- Rosedale-Rio Bravo Water Storage District;
- Semitropic Water Storage District (SWSD);
- Shafter-Wasco Irrigation District;
- Southern San Joaquin Municipal Utility District;
- Undistricted Lands of Kern County (or "unmanaged" on certain figures);
- West Kern Water District (WKWD); and
- Wheeler Ridge-Maricopa Water Storage District.

Commensurate with SGMA, and based on the current level of understanding of the WDWA within the KCS basin setting, the purpose of this Chapter GSP is to describe in plain language the groundwater conditions that currently exist within the WDWA. This Chapter GSP also identifies hydrologic data gaps and focused remedies, and presents a proposed groundwater management plan that, if determined to be technically and economically feasible, has the potential to achieve and maintain the sustainability goals of the WDWA and, by extension, those of the KGA, over the SGMA implementation horizon. Due the complex and interrelated nature of the hydrology and consumptive use of the water resources within the KGA, details and data from the KGA GSP, and some data from individual adjacent GSPs and/or GSAs, may be included in this Chapter GSP. Issues related to coordination with adjacent Districts, if any, will be addressed during the first five-year reassessment period after acceptance of the KGA Plan.

1.3 WDWA Agency Information and Contacts

The WDWA currently covers approximately 227,193 acres, or roughly 355 square miles of western Kern County, California. Of this total, approximately 89,989 acres (140 square miles) is irrigated. Preliminary numerical modeling by the KGA indicates that the WDWA has a historic annual water demand of approximately 297,000 acre-feet per year (AFY). However, the KGA modeled water demand appears to be overestimated. WDWA data shows that current demand is approximately 285,000 AFY, which is projected to escalate to approximately 316,000 AFY by 2040 due to climate change. Significantly more than 95% of the water used for irrigation in the WDWA has historically been delivered via the Aqueduct from SWP Table A and Article 21 water and supplemental import water purchases, although not all supplemental water is from the SWP. When available, a combined 100 percent (%) contract allocation from the SWP is around 332,218 AFY. Current surface water deliveries (all WDWA sources) are estimated by the WDWA to be approximately 266,290 AFY. This volume does not include supplemental water purchases and transfers by individual growers. Current estimated recharge by precipitation is 17,798 AFY, and minimum "Native Yield is approximately 34,079 AFY. This results in an estimated total water supply of 318,167 AFY. The WDWA water budget is described in more detail in **Section 2.7**. Groundwater is estimated to have made up less than 2% of the water used for irrigation by private well owners due to the general poor quality of groundwater in the WDWA. Groundwater pumping in the WDWA is approximately 3,000 AFY. The main use of groundwater in the WDWA

has been for blending to augment supply when Aqueduct deliveries have been reduced by drought or other factors.

A brief description of the WDWA participating members follows. More detailed information regarding each member is provided on their respective District websites, and in their specific 2015 Agricultural Water Management Plan (AWMP) reports. The AWMP reports are prepared to comply with the requirements of California SB X7-7 (Water Conservation Act of 2007), and are available online at the relevant District's website.

1.3.1 Lost Hills Water District

The LHWD was formed in 1963 to provide irrigation water from the SWP to the District. The LHWD boundaries begin just south of the town of Lost Hills and extend north and west to the Kings-Kern County line. Key landmarks include the California Aqueduct and Interstate 5 (I-5), which bisect the District diagonally from northwest to southeast. Adjacent Water Districts include Dudley Ridge Water District (DRWD) to the north (Kings County, Tulare Lake Subbasin), the BWSD to the south, the SWSD to the east, and the BMWD to the west.

The LHWD is governed by a five-member Board of Directors, all of which must be landowners or be designated as a representative of a landowner. Day-to-day administration of the District is the responsibility of the General Manager, who reports directly to the Board of Directors. The LHWD has two offices. The main administration office is located at 1405 Commercial Way, Bakersfield, California. The operations office is located in the town of Lost Hills. The website address is: www.lhwd.org.

The LHWD is comprised of approximately 74,357 acres, of which 70,453 acres are considered farmable. Not all of this acreage is currently being utilized for agricultural purposes. As of 2015, the net area under irrigated cultivation is approximately 27,900 acres. Agricultural activities rely primarily on surface water from the SWP. In addition to agriculture, oil and gas production is an important non-irrigated land use within the LHWD. A small portion of the LHWD surface water supply is sometimes delivered as industrial water to agricultural processors and oil field production customers. Other non-farmable service areas within the LHWD include Service Area 6E, which has been excluded from the water service area, and Service Area 8 which includes lands that were annexed by the District, for which a water delivery system is not yet available. During times of reduced allocations, the District relies on coordination with adjacent water districts and landowners for water transfers, supplemental water purchases and water banking (e.g., Berrenda and Pioneer Projects). The District owns and operates over 23 miles of concrete- or geomembrane-lined canals, 42 miles of pipelines, and an additional 27 miles of unlined canals, most of which are out of use.

Groundwater use in the LHWD is mostly limited to periods of SWP and other supplemental source delivery shortfalls, and is principally relied upon for the purpose of blending. During periods of drought or other shortages the LHWD relies on coordination with adjacent Water Districts or growers for water transfers, supplemental import water purchases, and nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the WDWA, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. Groundwater quality is naturally degraded in many areas due to elevated concentrations of total dissolved solids (TDS) and other minerals. Groundwater is considered unsuitable for most uses and is non-beneficial for a majority of crops, and in some cases livestock. There are three groundwater monitoring wells in the LHWD with extended historic groundwater-level monitoring data. These wells are monitored for groundwater elevation and a focused suite of water quality analytes on a now-regular schedule (last few years) by the KGA and are also part of the California Statewide Groundwater Elevation Monitoring (CASGEM) Program. The subject wells are discussed further in **Section 2.6**.

The LHWD supplies no municipal water from surface water or groundwater. The town of Lost Hills is served by two groundwater supply wells owned and operated by the Lost Hills Utility District (LHUD). These wells are located 12 miles east of the town and are outside of the WDWA (Provost & Prichard, 2015).

1.3.2 Berrenda Mesa Water District

Like the LHWD, the BMWD was formed in 1963 by landowners for the purpose of providing a reliable supply of irrigation water to the BMWD from the SWP. To the north of the BMWD lies the adjacent Devil's Den Water District (DDWD) (Kern County, outside of the KCS), to the south is the BWSD, to east are Undistricted Lands and the LHWD, and to the west is the Temblor Range (**Figure 2**).

The BMWD is also governed by a five-member Board of Directors, all of which must be landowners or be designated as a representative of a landowner. Day-to-day administration of the District is the responsibility of the General Manager, who reports directly to the Board of Directors. The administration office for the BMWD is located at 14823 Highway 33, Lost Hills, California. A field office for the District is located in nearby unincorporated Blackwell's Corner, California, located at the intersection of Highways 33 and 46. The website address for the BMWD is: www.bmwd.org.

Of the approximate 55,440 acres within the BMWD, all but 6,400 acres are considered farmable. The estimated net acreage currently being farmed is around 35,240 acres, of which 24,204 acres is irrigated by surface water from the SWP. Remaining lands are used for dry-land farming or

livestock grazing. At 100% delivery, the volume of contract water available to the BMWD from the SWP is approximately 92,600 acre-feet (AF). Current water demand is approximately 88,000 AFY. During periods of drought or other shortages the BMWD relies on coordination with adjacent Water Districts or growers for water transfers, supplemental import water purchases, and nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the WDWA, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. Other alternative management techniques include discretionary deficit irrigation implemented by individual growers.

Groundwater use is limited in the BMWD due to elevated levels of TDS. The BMWD supplies no municipal water either from groundwater or surface water supply (Provost & Prichard, 2015b).

1.3.3 Belridge Water Storage District

The BWSD was formed by landowners in 1962 to provide surface water from the SWP for irrigation. The BWSD is bounded on the north by the LHWD and BMWD along with some currently Undistricted Lands, to the south by additional currently Undistricted Lands and the WKWD, to the east by the Buena Vista Water Storage District (BVWSD), and to the west by the Temblor Range (**Figure 2**).

Similar to the LHWD and BMWD, the BWSD is also governed by a five-member Board of Directors, all of which must be landowners or be designated as a representative of a landowner. Day-to-day administration of the District is the responsibility of the General Manager, who reports directly to the Board of Directors. The administration office for the BWSD is located at 21908 Seventh Standard Road, McKittrick, California. The website address for the BWSD is: http://www.belridgewsd.com.

The principal source of water supply for the BWSD is surface water from the SWP, with agriculture as the main consumer. Of the 91,396 acres within the BWSD, approximately 88,223 acres are considered farmable, although not all of this land is currently being used for agriculture. As of 2015, approximately 36,885 net acres are irrigated. In addition to agriculture, a percentage of the BWSD annual allocation from the SWP is delivered for industrial use in oil recovery operations in the North and South Belridge oil fields.

Groundwater use in the BWSD has historically been limited, primarily due to the readily available source of good quality water provided by the SWP and various supplemental import sources, versus the naturally degraded groundwater found in the WDWA. The main use of groundwater by private well owners in the BWSD is for blending with SWP water. During periods of drought or other shortages the BWSD relies on coordination with adjacent Water Districts or

growers for water transfers, supplemental import water purchases, and nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the WDWA, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. Other alternative management techniques include discretionary deficit irrigation implemented by individual growers. Representative historic groundwater data are limited within the BWSD because of the aforementioned availability of other better quality water sources, and because until recently, records from privately owned wells in the WDWA at large were generally sporadic or not available. The BWSD supplies no municipal water either from groundwater or surface water supply (BWSD AWMP, 2015).

1.3.4 WDWA Undistricted Lands

There are approximately 341,048 acres of Undistricted Lands within the KCS (**Figure 2b**). Of these, approximately one third (113,682 acres) are located within the WDWA. These lands consist of a mixture of uses, including, among other things, mountain-front slopes, non-irrigated lands, grazing land, oil field production, quarry operations, and limited agriculture. Groundwater use among these different categories varies widely. Mountain-front slopes, grazing and non-irrigated lands, which comprise a large portion of the Undistricted Lands within the WDWA, use no groundwater and instead rely on precipitation. The limited agriculture and quarry uses in the WDWA are believed to use little or no groundwater based on typical operational practices. Oil field activities may utilize some groundwater from water wells for field activities (e.g. well drilling, enhanced oil recovery "make-up water" etc.). Oil fields also generate produced water as part of oil extraction activities. Produced water contains residual oil, elevated TDS derived from geologic formations, and other constituents common to crude oil production. A majority of produced water from oil field operations is either reinjected into the same zone it was extracted from for enhanced oil recovery (EOR), or is sequestered in deeper exempt aquifers pursuant to the United States Environmental Protection Agency (US EPA) Underground Injection Control (UIC) Program which, along with other oilfield activities in California, is administered by the Division of Oil, Gas, and Geothermal Resources (DOGGR).

The potential for impacts to the occurrence or quality of groundwater posed by oil field operations, and those undistricted lands that are not part of the WDWA Chapter GSP, are beyond the control of the WDWA. Recently, in response to potential water rights liability and County staff resource considerations, Kern County decided it would no longer oversee these lands with regard to SGMA compliance. Going forward, the KGA will oversee these lands within the KCS for the purpose of SGMA compliance, provided they are covered by a KCS GSP. The KGA has initiated an effort to enroll these landowners into an appropriate existing GSP group. Those Undistricted Lands that do not join the KGA or other GSP will be responsible for individually

complying with all relevant SGMA requirements (KGA, 2019). The Kern County Public Health Services Department (KCPHSD) has retained its jurisdictional authority over, among other things, groundwater well permitting and destruction in the County. The Kern County Environmental Health Services Department develops guidelines for the protection of groundwater quality and well construction standards.

1.3.5 Non-Managed Monitoring Areas

Non-Managed Monitoring Areas are lands defined within the KCS and included in an adopted GSP, in which underlying groundwater has not been significantly developed or used historically and is not actively pumped, excepting *de minimis* extractors[1], and whose consumptive use of groundwater (e.g., evapotranspiration [ETo]) is less than or equal to the consumptive use of native vegetation. As such, lands within a Non-Managed Monitoring Area are typically native/range land. All lands designated as Non-Managed Monitoring Areas will be monitored by satellite imaging or equivalent technology that provides a comparative estimate of the amount of consumptive water use relative to native vegetation (KGA, 2019).

If non *de minimis* groundwater extraction, or if water consumed increases above the baseline of native vegetation ETo, is either proposed or is documented within a Non-Managed Monitoring Area, the lands overlying these areas will be reclassified as "Actively Managed Lands" and will become subject to the groundwater monitoring, sustainability criteria, water budget requirements of the governing GSP, and any applicable water management actions (e.g., water use restrictions) under the governing GSP. Upon reclassification as Actively Managed Lands, failure to comply with the requirements for Actively Managed Lands under the governing GSP may result in the subject lands being removed from coverage under the GSP (KGA, 2019). Any such lands would be subject to SWRCB regulations.

1.3.6 Chapter GSP Development Costs

Development and implementation costs for the KGA Umbrella GSP incurred to date are currently being shared by the individual member water districts. Costs are being allocated under a Special Activity Agreement. The agreement is basically a two-tiered system that allows for cost-sharing either by a direct pro rata approach (i.e., split 16 ways by the member water districts) for such items as KGA administration costs, or by allocating costs based on a water district's (or Management Area's) percentage of total acreage overlying the area of fresh groundwater in the KCS. This method is applied to various required scientific studies, such as the KCS numerical groundwater flow model. Costs for the development of the WDWA Chapter GSP are being allocated on a direct pro rata basis between the three member agencies of the WDWA (LHWD, BWSD, and BMWD) (WDWA, 2019).

[1] *De minimis* extractors are defined under SGMA; California Water Code (CWC) §1072 (e).

1.3.7 Chapter GSP Implementation Funding

Estimates for the implementation and administration of the Chapter GSP are currently being assessed as part of the GSP development activities. The sources of implementation funding, while not specially identified at this time, may likely include a combination of State and Federal low-interest financing and grants for specific projects, as well as base and incremental water tolls paid by member landowners of the various respective Water Districts that comprise the WDWA (WDWA, 2019).

1.4 Description of Plan Area

1.4.1 Geographic Areas Covered

As noted previously, the WDWA encompasses approximately 227,193 acres, or roughly 355 square miles along northwestern edge of Kern County, California. The WDWA is bounded on the north by the Kings-Kern County line (an administrative boundary); on the south by areas of Undistricted Lands and the WKWD; on the east by some scattered Undistricted Lands, the SWSD, and BVWSD; and on the west by some Undistricted Lands and the Temblor Range.

As discussed in **Section 1.3.4**, Undistricted Lands are those lands within the WDWA that are not currently a part of a recognized GSA, but may be assimilated through separate agreements by the KGA. These areas are primarily associated with grazing lands and oil and gas operations such as the Belridge and Lost Hills Oil Fields. The KGA is currently working with these interested stakeholders to execute the necessary agreements to include them in the KGA GSP framework. Oil and gas operators within the WDWA include among others, California Resource Corporation (CRC), Chevron U.S.A, Inc., and Aera Energy, LLC.

1.4.2 Plan Area Setting

Geography and geology of the western KCS are discussed in further detail in **Section 2.0**. Within the WDWA; there are currently no adjudicated areas. A small dryland portion of the LHWD overlaps on the Kern National Wildlife Refuge (KNWR). The KNWR parcels within the LHWD are designated “Upland Habitat” areas, which rely on annual precipitation as its sole source of water (i.e. no operational wells). To the south, in the Belridge WSD, are portions of the 3,100 acre Lokern Ecological Reserve (LER). Within the WDWA the LER consists of small, scattered and generally non-contiguous parcels. A review of Google Earth imagery shows those portions of the LER in the WDWA are likely Valley sink scrub, and/or Valley saltbrush scrub habitat (aka Alkali Scrub). The scattered parcels are more or less centered on either side of the Aqueduct and along the dry Kern River Flood Channel between the 7th Standard Road to the north and Lokern Road (Highway 58) to the south. Typical native plant species in Valley sink scrub, as described by the California Department of Fish and Wildlife, are iodine bush and seepweed, with the understory dominated by non-native species. Those portions of the LER in the WDWA appear to consist

entirely of dry, non-irrigated scrub lands that, with no operational wells, rely on annual precipitation as its source of water. Other discrete State, Federal and County parcels in the WDWA are primarily associated with rangeland and mineral extraction activities (e.g. oil, gas, and gypsum).

As stated previously, the majority of water within the WDWA that is utilized for agricultural purposes is delivered as surface water via the Aqueduct. The WDWA distributes this water through a network of infrastructure facilities including, but not limited to, lined main canals, pipelines, pump stations, and control structures. Some of this surface water, when available, is provided to oil field operators and others for industrial use. As noted previously, the use of groundwater by landowners in the WDWA is generally limited and is mostly used for blending. The town of Lost Hills obtains its municipal water supply from two wells located approximately 12 miles to the east of the LHWD, an area outside of the WDWA. Existing land use is predominately agricultural, followed by currently undistricted oil field operations, some natural range and grazing uses, and fallow lands.

1.4.3 Existing General Plans

The Kern County Planning and Natural Resources Department (KCPNRD) provides consolidated land use planning and development guidance and programs for the County's industry, businesses, and residents through the Kern County General Plan (General Plan). The General Plan is a policy document designed to provide long-range guidance to County officials and stakeholders regarding the priorities, growth, and resources of the unincorporated jurisdictional portions of the County, of which the WDWA is a part. Metropolitan areas, such as the City of Bakersfield, are part of separate planning areas. The stated objectives of the subject General Plan are:

- Encourage economic development;
- Adopt policies and goals that reflect the County's commitment to consult and cooperate with State, Federal, and local agencies to plan for the long-term future of Kern County;
- Ensure protection of environmental resources, the development of adequate infrastructure with specific emphasis on conserving agricultural areas, adequate water supplies, and addressing air quality issues;
- Periodically revise the General Plan to reflect ongoing activities, changes to rules and regulations, and demographic changes in the County in order to ensure that the interests of the County in the health, safety, and welfare of residents and visitors are reflected in current policies and goals; and
- Maintain compliance with the provisions of State Planning and Zoning Laws as they pertain to General Plan requirements (KCPNRD, 2009).

Implementation of the WDWA Chapter GSP will provide additional drought resiliency and flexibility for agriculture and sustainability to water planning in Kern County. As such, it will not adversely affect water supply assumptions in the current General Plan and, by coordinating with adjacent GMAs and the KGA at large; will satisfy the requirements of SGMA.

1.4.4 Existing Groundwater Ordinances

Well drillers have been required by State law (CWC 13751) to submit well logs to the State since 1949. Public entity and other groundwater well owners within the WDWA are subject to all relevant and applicable rules and regulations regarding groundwater well drilling, development, monitoring, well abandonment, water use, and recycling, unless otherwise exempted by the State. An existing Kern County Ordinance, enacted in 1998, which requires a conditional use permit for groundwater exports both external and internal to the County, applies only to the southeastern drainage of the Sierra Nevada and the Tehachapi Mountains; and, thus, is not applicable to groundwater management in the WDWA. It should be noted that, based on a review of State records, it appears not all private well owners in Kern County have fully complied with well data reporting requirements.

1.4.5 Well Drilling, Replacement, and Abandonment

Kern County and the State Division of Water Resources (DWR) have respective water well permitting, wellhead protection and well construction and abandonment requirements that are germane to protection of groundwater quality and this Chapter GSP. Well drilling and monitoring requirements specific to the WDWA will be documented in the WDWA Monitoring Network Plan (MNP), which will be developed and implemented in coordination with adjacent management areas during the first 5-yeat reassessment period. Both sets of requirements (Kern County and State) for well permitting, construction and abandonment will apply in relation to applicable site-specific conditions and permitted drilling activities conducted in support of this Chapter GSP. Kern County well requirements can be found at: https://kernpublichealth.com/water-wells. State of California well drilling requirements can be found in DWR Bulletin 74, located, along with other details, at: https://water.ca.gov/Programs/Groundwater-Management/Wells.

A general summary of the process for permitting new or replacement wells in the WDWA is:

- Compliance with the most current version of the WDWA MNP and KGA protocols with regards to sediment logging, well and water quality testing and reporting;
- Compliance with Kern County Public Health requirements for well permitting, wellhead protection and well inspection; and
- Compliance with all applicable requirements as detailed in California Well Standards (Bulletin 74) for water wells, monitoring wells and cathodic protection wells.

Oil and gas wells in the WDWA are drilled under the purview of the DOGGR and US EPA rules and regulations.

1.5 Notice of Intent and Stakeholder Outreach and Communication

Stakeholder outreach and communication is central to the successful outcome of the KGA GSP. As such, the KGA has implemented a wide-ranging outreach program designed to maximize stakeholder involvement in order to ensure a transparent and inclusive GSP process. The subsections below provide further information on this important topic.

1.5.1 GSP Participating Agencies

A list of KGA-participating Water Districts is provided in **Section 1.2**. In addition to regulatory oversight by the California Department of Water Resources (DWR) for GSP development and implementation, participating agencies include, among others, the State Water Resources Control Board (SWRCB), Regional Water Quality Control Board (RWQCB), United States Geological Survey (USGS), and the KCWA. The KGA and the WDWA recognize that maintaining a close collegial relationship with the various State and Federal regulatory agencies with oversight on water management and SGMA in the KCS are essential to achieving proposed sustainability objectives. Private landowners are also supporting the GSP effort by providing, among other things, historic and current groundwater well and hydrogeologic data, as well as relevant planning and land-use information.

1.5.2 Public Meetings and Stakeholder Engagement

The KGA maintains a website (www.kerngwa.com) where it routinely posts information related to the GSP preparation and development process and actively solicits stakeholder engagement and input. KGA Coordination Meetings with stakeholders are typically held on the first Monday of every month. A partial list of items that are made available on the KGA website includes:

- Agendas and dates for upcoming and past public meetings;
- Stakeholder surveys;
- Relevant documents and reports for public review and input;
- Presentations, research, and white papers; and
- KGA contact information.

Additionally, the WDWA maintains a website for growers and the community at: www.westsidedwa.org. Member Water Districts within the WDWA have their own individual websites that provide information that is focused on Water District operations and GSP development within their respective management areas. As previously noted, the WDWA-member websites are:

- LHWD: www.lhwd.org
- BWSD: www.belridgewsd.com
- BMWD: www.bmwd.org

WDWA public outreach activities to date include:

- The WDWA participated in a KGA sponsored public workshop in Bakersfield, California at the Kern County Agricultural Center on May 14, 2019. The evening workshop was open to all community members and stakeholders. The workshop afforded interested parties the opportunity to interact one-on-one with WDWA staff and consultants who were there to answer and discuss questions or concerns related to the WDWA Chapter GSP, and afford the public an opportunity to learn more about other KGA Chapter GSPs, WDWA undesirable results, and the SGMA process.
- A second public KGA workshop was held the evening of September 26, 2019 at the Kern County Agricultural Center in Bakersfield, California. This workshop took place during the KGA Umbrella GSP 90-day public review period and provided another opportunity for interested parties to communicate with WDWA staff and consultants regarding SGMA, the WDWA Chapter GSP, undesirable results and groundwater sustainability in the WDWA.
- A public meeting (WDWA regularly scheduled Board meeting) to discuss WDWA-specific issues related to this Draft Chapter GSP, such as current and projected water budgets, groundwater quality and Measurable Thresholds (MTs) and Measurable Objectives (MOs) was held on June 5, 2019 at the BWSD offices. The meeting updated the Board members, the public and stakeholders on the status of the WDWA GSP Chapter findings, undesirable results, GSP costs and the SGMA process.
- The Draft Chapter GSP components and key findings and conclusions were presented a second time to the public at a regularly scheduled WDWA Board meeting on August 21, 2019 at the offices of the BWSD. At the meeting the WDWA Board approved submittal of the WDWA Chapter GSP to the KGA for inclusion in the formal 90-day KGA Umbrella GSP public review process. Prior comments were addressed in the draft Chapter GSP prior to this update presentation.
- The Draft Chapter GSP components and status were presented at three other regularly scheduled WDWA Board meetings open to the public, and at two public KGA Board meetings held in Bakersfield on August 21, 2019 and December 18, 2019.
- The WDWA Manager received one direct comment letter (Wonderful Orchards) during the 90-day public comment period for the KGA Draft Umbrella GSP. Relevant and applicable comments pertaining to the WDWA were incorporated in this version of the Chapter GSP. A copy of the letter is provided in Appendix A. Five other more global comment letters related to the Draft KGA Umbrella GSP (The Nature Conservancy, California Fish & Wildlife, Hancock Farmland Services, Westchester Group, and Leadership Council for Justice and

Accountability) addressed to the KGA GSP Manager were also reviewed for relevant or applicable comments for incorporation that might pertain to the WDWA. It should be noted that the WDWA does not provide groundwater for municipal supply. Copies of those letters are on file with the KGA. Based on Fish & Wildlife comments the Lokern Ecological Reserve was identified and discussed in the Chapter GSP.

The WDWA will continue stakeholder outreach during the implementation and planning horizon with periodic updates at its Board meetings, which are open to the general public, and by making SGMA annual reports and other relevant information available on its website.

1.5.3 SGMA Checklist and Notice of Intent to Develop a GSP

The SGMA check list for preparation of this Chapter GSP is provide in the front portion of this report. A copy of the KGA Notice of Intent (NOI) to prepare a GSP is provided in **Appendix B**. The NOI outlines the organization of the KGA and the general approach for developing the Plan. The NOI was submitted to the DWR on December 20, 2017. A complete list of undistricted lands to date that have opted into the WDWA Chapter GSP is included as **Appendix C.**

1.5.4 Kern Groundwater Authority GSP Managers

The KGA GSP Managers are:

Mr. Terry Erlewine, Basin Coordinator
Kern Groundwater Authority
1800 30th Street, Suite 280
Bakersfield, California 93301
Email: terlewine@ppeng.com
Telephone: 530.220.0752

Ms. Patricia Poire, Planning Manager
Kern Groundwater Authority
1800 30th Street, Suite 280
Bakersfield, California 93301
Email: ppoire@kerngwa.com
Telephone: 661.479.7171

1.5.5 WDWA Chapter GSP Manager

The WDWA Chapter GSP Manager is:

Mr. Phil Nixon, General Manager, WDWA
1405 Commercial Way, Suite 125
Bakersfield, California 93309
Email: pnixon@lhwd.org
Telephone: 661.633.9022

The KGA is responsible for making decisions on issues related to the GSP and KCS at large. Individual Water Districts and GMAs are responsible for taking the day to day decisions necessary to simultaneously meet the needs of their individual members and those actions related to meeting the sustainability objectives detailed in their respective Chapter GSPs.

Decisions related to the funding and implementation of items specific to the WDWA Chapter GSP are considered for adoption by the Boards of the respective WDWA member districts and the WDWA at large.

1.6 Chapter GSP Organization

This Chapter GSP for the WDWA is organized into the following sections.

- *Section 1.0 Introduction and Purpose of the Chapter GSP*
  This section discusses the regulatory requirements of the SGMA, participating Water Districts that comprise the KGA, and the subset of those agencies that make up the WDWA, which is the subject of this Chapter GSP.
- *Section 2.0 Basin Setting*
  This section includes a description, based on the current understanding of the subbasin, of the physical characteristics of the subbasin and the dynamic groundwater and local water budget conditions. A Hydrogeologic Conceptual Model (HCM) for the area covered by this Chapter GSP discusses hydrogeologic conditions, current and projected water budgets, identified data gaps, how these gaps will be addressed, the qualitative and quantitative understanding of the subbasin, and how the local aquifers might react to stress over time. The HCM takes into account how conditions in the WDWA may affect, or be affected by, adjacent Water Districts.
- *Section 3.0 Sustainability Goals and Undesirable Results*
  This section discusses and describes the suite of sustainability goals that, once fully implemented, will result in the absence of undesirable results identified in the WDWA within the statutory deadlines described in the SGMA.
- *Section 4.0 WDWA Monitoring Network*
  This section describes existing monitoring wells in the WDWA and the improved monitoring network that will be developed during the implementation of the Monitoring Network Plan (MNP) and reassessment periods after GSP approval. Development of the improved monitoring network will result in representative data sufficient to document attainment of identified WDWA sustainability goals, the monitoring for undesirable results, and the ability to provide for adaptive management of groundwater, both within the WDWA and as coordinated with adjacent GMAs.
- *Section 5.0 Minimum Thresholds and Measurable Objectives*
  This section describes relevant sustainability indicators and the numerical value(s) for each sustainability indicator used to define undesirable results, and the specific, quantifiable objectives for the maintenance or improvement of specified groundwater conditions.
- *Section 6.0 Projects, Management Actions, and Adaptive Management*
  This section describes the necessary sustainability projects and management actions that are currently being planned for implementation beginning in the first five-year reassessment

period to address identified data gaps within the WDWA. The objective is to coordinate with other adjacent GMAs in order help achieve the stated sustainability goals for the WDWA and KCS.

- *Section 7.0 GSP Reporting and Periodic Evaluations*
  This section discusses the coordinated data management system that will be used to store GSP data and required reports pursuant to the SGMA, as wells as report submittal schedules.
- *Section 8.0 References*
  This section contains relevant technical references relied upon to prepare this Chapter GSP.
- *Tables, Figures, and Appendices*
  These appendices s contain figures, tables, guidance protocols and other documents relevant to this Chapter GSP.

2.0 BASIN SETTING

2.1 WDWA Plan Setting within the Kern Groundwater Authority

The Central Valley of California (Valley) covers about 20,000 square miles and is bounded by the Cascade Mountain Range to the north, the Sierra Nevada Mountain Range (Sierra Nevada) to the east, the Tehachapi Mountains to the south, and the Coast Ranges (e.g., Temblor Range) and San Francisco Bay area to the west. The Valley is an expansive agricultural region drained by the Sacramento and San Joaquin rivers. The Valley averages about 50 miles in width and extends around 400 miles from the Tehachapi Mountains in the south, to near the town of Redding, California in the north. The Valley is divided into three groundwater hydrologic regions according to DWR's Bulletin 118: (1) the northern one-third of the Valley is within the Sacramento River Basin; (2) the central one-third is within the San Joaquin River Basin; and (3) the southern one-third is within the Tulare Lake Basin, which in turn contains the KCS and the WDWA (DWR, 2016; GEI Consultants [GEI], 2019) (**Figure 3a and 3b**). Conceptual inflow of groundwater into the WDWA is presented on **Figure 3c**. The groundwater conditions in the KCS at large are described in the KGA umbrella GSP.

Unique hydrogeologic characteristics of the WDWA that set it apart from the other water districts in the KCS are:

1. The WDWA is isolated from other groundwater basins and adjoining water districts along its entire western boundary by the Temblor Mountain Range, its primary source of subsurface groundwater inflow. On the north and east, groundwater underflow towards the axis of the basin is impeded or slowed by a series of roughly north-south oriented geologic anticlines and synclines (up folds and down folds). To the south groundwater flow is impeded by geologic structural ridges that include spurs of the Temblor Range and the Elk Hills Anticline. This geologic setting has contributed to the poor groundwater quality in the WDWA and limits necessary groundwater coordination to just a few downgradient management areas to the north and east.
2. Groundwater is naturally degraded and of poor quality throughout most of the WDWA due to the presence of geologic sediments derived from marine environments, some of which contain saline connate water. These conditions make groundwater in the WDWA unsuitable for practical beneficial use, except for blending with better quality water.
3. Irrigation demand is met almost entirely by surface and imported water delivered via the California Aqueduct (Aqueduct). Groundwater is estimated to make up less than 2% of the water used for irrigation by private well owners due to its poor quality. Current pumping for the purpose of blending with Aqueduct water is estimated to be approximately 3,000 AFY.
4. The most significant amount of discharge from the WDWA simulated by the KGA model is in the form of subsurface groundwater flow to the north towards the former Tulare Lake bed,

a beneficial use exemption area, and eastward towards the axis of the Valley. The total combined volume of underflow discharge to these areas is estimated to be approximately 111,000 AFY. Given the limited amount of pumping in the WDWA, underflow out of the WDWA is the most significant contributor to estimated groundwater deficits (change in groundwater storage) in the WDWA. This phenomenon is beyond the control of the WDWA.

5. Pumping for consumptive use in adjacent water districts has resulted in noticeable differences in groundwater elevations between the WDWA and these areas, and has likely increased the velocity and volume of underflow out of the WDWA along shared administrative boundaries to the east and southeast. Pumping activities in adjacent downgradient water districts are beyond the control of the WDWA.
6. In 2016, due to the near ubiquitous poor quality of groundwater in the KCS West Side, the Westside Water Quality Coalition (WWQC) prepared a Basin Plan Amendment Workplan (BPAW), which is inclusive of a significant percentage of the irrigated lands within the WDWA. The BPAW recommends delisting municipal and unlimited agriculture as a designated beneficial use for perched groundwater and deeper unconfined/semi-confined groundwater above the sub-regional Corcoran Clay (or its equivalent) due to natural poor groundwater quality. The draft BPAW has been provided to the CV-SALTS Technical Committee and the Regional Water Quality Control Board (RWQCB) for preliminary review and input. The final determination by the RWQCB on the BPAW application will be reported in the relevant GSP annual update report.

The WDWA, which is the focus of this Chapter GSP, covers approximately 227,193 acres (355 square miles) along the western side of the KCS. Of this total, approximately 89,989 acres, or about 140 square miles, is currently irrigated. The WDWA is bounded on the north by the Kings-Kern County line (administrative boundary) and the DRWD, on the south by the WKWD, on the east by various Undistricted Lands, the SWSD, and BVWSD, and on the west by the Temblor Mountain Range.

Topography in the WDWA is mostly gentle and flat, with steeper foothills of the Temblor Range lying at the western edge (**Figure 4**). Elevations range from approximately 250 feet above mean sea level (MSL) in the east-southeast to 1,200 feet above MSL in the southwest. Typical slopes within the WDWA range from 25 to 50 feet per mile. The California Aqueduct, which runs along the eastern edge and through other parts of the WDWA, is at an approximate elevation of 310 feet above MSL. The elevation of I-5, which transects portions of the WDWA, varies from approximately 225 to 240 feet above MSL. East of I-5, the ground surface is nearly flat. The western portion of the WDWA is known as the Antelope Plain and is enclosed by the Temblor Range on west and north, and by various geologic structural arches (folds) on the east and south.

2.2 Climate

The climate in the WDWA is generally hot and dry and is characterized as inland Mediterranean. The main growing season for the KCS runs from May through October, although various crops are grown year-round. The length of the frost-free season is currently about nine months, or approximately 270 days per year. Surface water delivered by the SWP and supplemental purchases of supplemental import water, not all of which are SWP water, are the chief sources of supply for irrigation (Amec, 2015; GEI, 2019).

The WDWA is characteristic of the southern Valley climate with temperatures in the summer often exceeding 100 degrees Fahrenheit (°F), and winter low temperatures occasionally falling below freezing. Summers are generally hot and dry, and winters are semi-arid with ground fog a common occurrence. The rainy season usually occurs from November through April, when nine-tenths of the annual precipitation falls (Provost & Prichard, 2015a). The average annual KCS precipitation for the period extending from 1998 through 2012 was approximately 5.2 inches per year (inches/year). KCS reference ETo rates range from 52.4 to 65.8 inches/year, with an average of 58.3 inches/year. Rainfall is considered sufficient for grazing purposes, but not for large-scale agricultural purposes. The SWP was specifically designed to offset the lack of regional precipitation (Amec, 2015; GEI, 2019).

Monthly reference ETo and precipitation data for the WDWA for the most recent 10-year period, water year (WY) 2009-2018, were obtained from the California Irrigation Management Information System (CIMIS) website for the Blackwells Corner (Station 54) and Belridge (Station 146) stations (**Figure 5**). These stations were chosen for the continuity of their respective data sets and because their locations, near the northern and southern extent of the WDWA, provided representative data for extrapolation across the WDWA.

For the Blackwells Corner station during the 10-year period, the average annual ETo rate ranged from 59.4 inches/year in 2011 to 70.2 inches/year in 2014 (**Figure 6**). The average monthly ETo ranged from 1.6 inches in December to 10.0 inches in July. The average annual precipitation rate ranged from 2.5 inches/year in 2013 to 8.4 inches/year in 2011. The average monthly precipitation ranged from 0.01 inches in June to 0.98 inches in January (**Figure 7**). During the 10-year period, the maximum monthly precipitation of 3.4 inches occurred in May 2014.

For the Belridge station during the same 10-year period, the average annual ETo rate ranged from 51.4 inches/year in 2011 to 61.9 inches/year in 2014 (**Figure 8**). The average monthly ETo ranged from 1.5 inches in December to 8.2 inches in July. The average annual precipitation rate ranged from 1.1 inches/year in 2014 to 9.3 inches/year in 2011. The average monthly precipitation ranged from 0.02 inches in August/September to 1.0 inches in December (**Figure**

9). During the 10-year period, the maximum monthly precipitation of 5.3 inches occurred in December 2010.

2.3 Surface Water

The major surface water feature in the WDWA, is the California Aqueduct (**Figure 10a**). Ephemeral streams that originate on the east-facing slopes of the Temblor Range drain eastward toward the Valley floor. The stormwater runoff in these channels is not controlled and typically percolates within the Antelope Plain and does not reach the bed of the former Tulare Lake or the axis of the Valley as surface flow. The 10-year, 24-hour storm event for the area ranges from 3.0 to 3.5 inches of precipitation (National Oceanic and Atmospheric Administration [NOAA], 2013; Amec, 2015).

A small northeastern portion of the LHWD overlaps with a dry Upland Habitat Area of the KNWR (**Figure 10b**). The KNWR at large covers approximately 11,250 acres, most of which lie within the adjacent SWSD. Established in 1960, habitats within the KNWR consist of:

- Seasonal Wetlands of which a significant portion are irrigated via deliveries from the Central Valley Project (CVP);
- Moist Soil Units are wetland habitats that are divided into irrigated and seasonal units;
- Seasonal Marsh are areas within the KNWR that maintain water depths of between 4 feet and a few inches and do not typically receive summer irrigation;
- Riparian Areas are located along former or seasonal stream courses within the KNWR; and
- Upland Areas are drier and are not irrigated during the summer and rely solely on precipitation as their source of water. Upland areas within the KNWR are generally closed to the public and are located in the northeast and northwest portions (LHWD portion) of the refuge.

To the south, in the Belridge WSD, are portions of the 3,100 acre Lokern Ecological Reserve (LER). Within the WDWA the LER consists of small, scattered and generally non-contiguous parcels (**Figure 10c**). A review of Google Earth imagery shows those portions of the LER in the WDWA are likely Valley sink scrub, and/or Valley saltbrush scrub habitat (aka Alkali Scrub). Those portions of the LER in the WDWA appear to consist entirely of dry, non-irrigated scrub lands that, with no operational wells, rely on annual precipitation as its source of water.

Larger, more contiguous blocks of the LER are present further south of the WDWA roughly between the towns of Lokern and Tubman. The California Department of Fish and Wildlife website describes the LER at large as consisting of marsh, valley sink scrub, and valley saltbush scrub habitat. Although not likely present in the WDWA, vegetation in the marsh habitat includes tule, cattail and other common marsh species.

Irrigation canals and drainage facilities are the principal surface water conveyance features in the WDWA. Chief among these are the California Aqueduct, and its Coastal Aqueduct inter-tie.

Current designated uses for surface water provided by the SWP in the WDWA include:

- Agriculture;
- Industrial and process water; and
- Groundwater recharge (i.e. banking).

Other uses of California Aqueduct and CVP water adjacent to the WDWA include irrigation, non-contact recreation, wildlife habitat, and warm freshwater habitat.

The topographic highlands that source naturally occurring surface water runoff in the WDWA consist of several small watersheds that range from less than 10 square miles to around 100 square miles in area. Surface water runoff flow in the WDWA is considered unreliable and of poor (brackish) quality. As a result, it is unsuitable for beneficial use, does not support most agricultural uses, and requires blending with better quality water for irrigation. A USGS 1959 survey of water quality in highland streams and springs, which predates much of the later agricultural development of the Westside, found the following (Amec, 2105):

Surface Water	EC (umhos/cm)	TDS (mg/L)
USGS Streams	590 – 3,100	540 – 3,200
USGS Springs	542 – 16,100	362 – 10,900

Notes:
EC: electrical conductivity
umhos/cm: micromhos per centimeter
mg/L: milligrams per liter

By contrast, the average concentration of TDS in surface water imported via the Aqueduct indicates that this water is of markedly better quality. Sample data from Kettleman Check 21 between 2008 and spring 2013 found EC averaging around 449 umhos/cm, and an average TDS concentration of 252 mg/L (Amec, 2015). A general definition of freshwater is TDS concentrations of less than 500 mg/L.

2.4 Land Use

Prior to the development of the Kern County Westside for agriculture, much of the land in the area was dry, native rangeland. A USGS (1959) report on groundwater conditions in the vicinity of Avenal and McKittrick described the area as: "*…uninhabited desert*" (GEI, 2019). Since that time, along with oil and gas, Westside agriculture has become a mainstay of the State and local

economy. In response to a myriad of factors including climate change, imported water availability, emerging farm technologies, and product market forces, Westside land use, crop selection and agricultural practices have evolved. A majority of the 89,989 acres presently under cultivation in the WDWA are utilized for growing permanent crops such as almonds, pistachios, citrus, and pomegranates. Scattered State, Federal, and County parcels are adjacent or present in the WDWA. A preponderance of such parcels, aside from the aforementioned portions of the KNWR and the LER, are related to rangeland or mineral extraction activities like those in the Shale Hills, Pyramid Hills, and Lost Hills Anticline areas. **Figures 11a through 11d** provide WDWA land use for the years 1992 and 2014.

2.5 Hydrogeologic Conceptual Model

The HCM is the framework for the iterative development of water budgets, numerical and analytical models, and assessment of groundwater monitoring networks. Details from a subset of previous reports and investigations relating to the regional geologic and structural setting of the KCS, as well as the occurrence, quantity, and quality of groundwater in the WDWA are described below. This information, along with data provided in the KGA Umbrella GSP and KGA groundwater modeling, is the foundation for the HCM. An HCM differs from a numerical or analytical model in that it does not quantify or compute actual specific quantities of water flowing through or moving into or out of the basin via the surface or subsurface. Its purpose is to provide a general understanding of the physical setting and processes related to groundwater sources, occurrence and movement in the WDWA (**Figure 12a**). Therefore, it does not provide specific data on the water balance for the WDWA. In general, recharge to the WDWA occurs via mountain-front underflow, water loss as a result of leakage from imported water canals, areal deep percolation, and water loss from ephemeral streams. Based on the preliminary KGA C2V Sim-Kern groundwater model, by far the largest component of discharge in the WDWA is groundwater underflow (~111,000 AFY) migrating toward down-gradient GMAs. Pumping for the purpose of blending in the WDWA is presently estimated at around 3,000 AFY. A more detailed discussion of KCS geology is provided in the KGA umbrella GSP. A summary of the physical setting follows.

2.5.1 Kern County Subbasin Geology

The KCS is located in the southern most extent of the Tulare Lake Basin Hydrologic Region. The KCS encompasses a surface area of around 1,792,000 acres (2,800 square miles) and is underlain by approximately 32,000 feet (6 miles) of marine and continental sediments (Page, 1986; DWR, 2006; Amec, 2015; GEI, 2019). **Figure 12b** provides a geologic map of the KCS. **Figures 12c-12e** provides conceptual KGA geologic cross sections for the vicinity of the WDWA.

Near the end of the Late Cretaceous, tectonic movements elevated the Coast Ranges to the west of the Valley and created a marine embayment. During the Tertiary, seas episodically advanced and retreated within the embayment, resulting in deposits comprised of both continental and marine sediments. Structural deformation along the early and present-day San Andreas fault zone resulted in the formation of a series of geologic faults and anticlinal folds that form many of the prolific oil fields along the west side of the KCS (Farrar and Bertoldi, 1988; GEI, 2019). During and since marine deposition, sediments derived from erosion of igneous and metamorphic rocks and consolidated marine sediments in the surrounding mountains to the east and west were transported into the Valley by streams. The continental sediments at the southern end of the Valley have an average thickness of about 2,400 feet (Planert and Williams, 1995). The continental sediments consist mostly of basin-fill or lake and marsh deposits of interlensing sand and gravel interbedded with clay and silt. Within the WDWA, sediments deposited by coalescing alluvial fans and debris flows are common. Depending on location, deposits of fine-grained materials (mostly clay and silt) comprise as much as 50% of the thickness of the basin-fill sediments (Planert and Williams, 1995; GEI, 2019).

During Pleistocene and Holocene times, the seas retreated, and continental deposits from alluvial and fluvial systems were deposited over Tertiary-age marine deposits (Page, 1986). Some of these marine deposits contained naturally occurring connate (saline) water which have subsequently migrated into adjacent and overlying continental deposits (Page, 1986). Overall, the continental deposits make up a significant portion of the regional aquifer system within the eastern and central parts of the Valley. Within the WDWA, and Westside in general, eroded marine deposits are common and contribute to the overall poor groundwater quality that has been documented throughout the western KCS (GEI, 2019). According to several reports, the Pleistocene Epoch saw the development of brackish and freshwater lakes within the basin, resulting in thick deposits of silts and clay and associated minerals, as found throughout the upper Tulare Formation. In particular, the Corcoran Clay has been mapped over much of the central and eastern San Joaquin Valley. The Corcoran Clay has been correlated to equivalent clays beneath the Kern and Buena Vista dry lake beds in the southern part of the KCS; as well as the Tulare Lake sediments on the northern boundary of Kern County (Wood and Dale, 1964; Croft, 1972; GEI, 2019). This clay, when present, acts as an aquitard that isolates accessible shallow poor-quality water from slightly higher quality water of the deeper regional aquifer system. On the Westside, including beneath the WDWA, and those other areas west of the Lost Hills Anticline, this clay appears to be either poorly constrained or absent (**Figure 13**).

Since the Pleistocene, stream channels, lakes, and rivers have dominated the deposition of sediments in the Valley. Alluvial fans have continued to form on both sides of the Valley, especially on the eastern side. Over time, shifting stream channels have created overlapping and coalescing sediment fans, forming broad sheets of inter-fingering, wedge-shaped lenses of

gravel, sand, and finer sediments which make up the shallow continental water-bearing deposits of the regional aquifer system (Page, 1986). During this time, fine-grained floodplain, lake, and marsh conditions were predominate on the western side of the Valley resulting in aquifers with less reliable hydraulic properties (Amec, 2015; GEI, 2019).

2.5.2 Surficial Geology

The surficial geology of the KCS has been documented in a variety of previous investigations (Bartow, 1991; Page, 1986; California Geological Survey [CGS], 2010; GEI, 2019). Based on published studies, the center of the basin consists mainly of Pleistocene to recent unconsolidated and semi-consolidated alluvial lake, playa (alkali/salt flat), and terrace deposits. Older Pleistocene alluvium is present in the eastern portion of the basin on top of Pliocene-Pleistocene deposits of sandstone, shale, and gravel deposits, including the Kern River Formation. The Pliocene-Pleistocene sediments also include the Tulare Formation. The Tulare and Etchegoin Formations are known to be variably a source of both brackish groundwater (unconfined/semi-confined) and oil within the WDWA. Small remnants of older continental sediments along the southeastern flank of the KCS, consist of undivided Tertiary-age sandstone, shale, conglomerate, breccia (clastic rock with a matrix of sand and/or mud), and lake deposits. Miocene-age sandstone, shale, conglomerate, and fanglomerate, plus smaller remnants of older marine sediments are also present. These remnant units include the Santa Margarita Formation, Round Mountain Silt, and Olcese Sand (Amec, 2015; GEI, 2019).

The geologic structure of the western KCS is distinguished by numerous northwest-trending folds that are subparallel to the nearby right-lateral San Andreas Fault. Most of the mapped folds are anticlines that occur in the older sediments and appear as anticlinal ridges that crop out approximately 30 to 50 feet or more above the surrounding topography. Some of these features include the Buttonwillow Ridge, Semitropic Ridge, and the Lost Hills and Elk Hills Anticlines (Bartow, 1991; GEI, 2019). Many anticlines and associated synclines in the Westside are known to be concealed beneath younger Quaternary age sediments. Similarly, several northwest-trending faults are concealed by the younger sediments and some have also been mapped within outcrop islands of older sediments (GEI, 2019).

2.5.3 Surface Soils

Surface soils for western Kern County have been described in various studies and reports (United States Department of Agriculture [USDA], 1986; USDA, 1988; USDA, 2018; Amec 2015). In the WDWA, surface soils are somewhat poorly drained basin clays and silty loams derived predominately from the erosion of sediments deposited in former continental environments. These soil types are considered to be a contributing factor to the overall natural poor quality of groundwater in the WDWA. Near surface soils in western Kern County generally include the following soil type series (USDA, 1988, Amec, 2015):

Series	pH (s.u.)	Salinity (mmhos/cm)
Buttonwillow	7.9 – 8.4	< 4
Kimberlina	6.6 – 8.4	<2 – 8
Lethent	>7.8 – 9.0	4 – 16
Lokern	6.6 – 9.0	<2 – 16
Milham	7.4 – 8.4	<2 – <8
Nahrub	>7.4 – >7.8	4 – 16
Panoche	7.4 – 8.4	<2 – 16
Twisselman	7.9 – 9.0	<2 – >16
Yribarren	7.9 – 8.4	<2 – <8

Notes:
mmhos/cm: millimhos per centimeter
s.u.: standard unit
pH: potential of hydrogen

Soil maps for the three individual Water Districts that comprise the WDWA, are presented in **Figures 14a through 14c**. The USDA's list of landscape soil types is provided in **Appendix D**.

2.5.4 WDWA Management Area Hydrogeology

WDWA hydrogeology is unique from other areas of the KGA. A key distinction is, with the exception of small, localized areas of higher-quality groundwater, the groundwater beneath the WDWA is almost exclusively naturally brackish, with TDS levels generally exceeding the drinking water maximum contaminant level (MCL) of 500 mg/L (**Figure 15a**). Overall, TDS concentrations routinely exceed 2,000 mg/L in many areas. The sediments that comprise the subsurface in the WDWA have accumulated since the Cretaceous. A large portion of the sediments were either eroded into, or deposited by, an inland sea bounded by an ancient fore-arc ridge to the west and the Sierra Nevada Range to the east. Naturally occurring saline connate water still exists in some of these sediments today. These saline waters, along with naturally occurring salts and other minerals in surface soil and shallow sediments, are the primary sources of the elevated TDS concentrations detected in WDWA groundwater (Amec, 2015; GEI, 2019). **Figure 15b** provides a general stratigraphic column, which depicts the transitional nature of the environments of sediment deposition in the KCS. Elevated concentrations of other constituents, such as arsenic, boron, and nitrates (most naturally occurring), have also been detected in parts of the WDWA. Data indicate that these minerals are likely the result of depositional concentration as the former marine embayments and lakes that previously covered much of the WDWA retreated and evaporated. Isolated pockets of fresh groundwater exist within relatively thin layers of continental sediments deposited on top of the marine sediment layers. Due the predominance of surrounding brackish groundwater conditions, these pockets of higher-quality water have been known to degrade after only a few months or years of pumping. Available data

appear to indicate that poor-quality water is migrating from the WDWA down-gradient to the north and east, towards areas of higher-quality water found in adjacent GMAs, such as SWSD and BVWSD. Impediments to this underflow are likely presented by various geologic structures including folding and faulting. One such example is the Buttonwillow Syncline.

The Pliocene-Pleistocene Tulare Formation represents a west-to-east change in depositional environments across the Subbasin. The Tulare Formation in the western part of the Subbasin contains up to 2,200 feet of interbedded, oxidized to reduced sands, gypsiferous clays, and gravels derived predominantly from erosion of Coast Range sources. Up to 250 feet of Pleistocene-age older alluvium/stream and terrace deposits occur as lenticular deposits of clay, silt, sand, and gravel that are loosely consolidated to cemented, and are exposed mainly at the margins of the Subbasin and along the crests of some Valley anticlines. Collectively, these sediments are typically moderately to highly permeable and can initially yield large quantities of water to wells (DWR, 2003; Amec, 2015; GEI, 2019). These deposits are reportedly often indistinguishable from the underlying Tulare Formation, and together, form the principal (unconfined/semi-confined) aquifer system in the WDWA.

The younger Holocene-age lacustrine, alluvium and flood plain deposits vary in character and thickness across the WDWA and consist of silt, silty clay, sandy clay, and clay interbedded with poorly permeable sand layers. The flood plain deposits are reported to be difficult to distinguish from underlying fine-grained alluvium and the total thickness of both units may be as much as 1,000 feet (DWR, 2003; GEI, 2019).

2.5.5 Principal Aquifers, Physical Properties and Aquitards

The thickness of the aquifer systems beneath the WDWA and Westside are thought to vary greatly from a few hundreds of feet to around 2,500 feet in thickness (DWR, 2003; GEI, 2019). From oldest to youngest, the principal water-bearing zones in western Kern County include the Etchegoin, and Tulare Formations, Older Alluvium and Terrace Deposits, and Younger Alluvium and Floodplain Deposits. Groundwater occurs in three loosely constrained aquifer packages within the WDWA. These are:

- Shallow perched groundwater;
- Unconfined/semi-confined groundwater; and
- Confined groundwater.

Perched groundwater was reported historically in the WDWA, especially along the eastern side of the WDWA management area. Its presence is attributed to a shallow clay layer known as the “A-Clay”. Depth to perched water was historically measured at 3 feet to 24 feet below ground surface (bgs). Perched water samples analyzed from six tile drains between 1986 and 2012

found average TDS concentrations of 13,250 mg/L, in addition to elevated concentrations of boron and other elements (Amec, 2015).

In late 2018, the Westside Water Quality Coalition (WWQC) reportedly attempted to record water-level data from several previously monitored perched zone piezometers; a majority of which were found to be dry (WDWA, 2019). The change in perched groundwater levels from 1989 to present indicates its occurrence is greatly reduced and sporadic. This condition is believed to be due to a change in crop types, recent drought conditions, and the increased efficacy of irrigation methods. For example, approximately 97% of crop irrigation in the WDWA now utilizes drip or micro-irrigation technology. The evolution in crop types away from the cotton and row crops being grown in the mid-1990s to predominately nut and other permanent crops today, coupled with more modern irrigation methods, may have reduced the volume of direct recharge via irrigation return flows. These return flows are believed to have been a likely contributor to perched groundwater in those areas where geologic conditions favored the accumulation of perched groundwater. Given the unreliability of the occurrence, the de minimis available volume of perched water, and its documented high salinity and mineral content, it is considered to be non-beneficial for Municipal (MUN), Agriculture (AGR), and most, if not all, Industrial (IND) use in the WDWA. Consequently, perched water wells will not be used to establish sustainability minimum thresholds (MTs) or measurable objectives (MOs) in the WDWA. It will however continue to be monitored along the eastern boundary of the WDWA. If future planned monitoring identifies a change in status of perched groundwater, these findings will be presented in future reassessment reports.

Unconfined/semi-confined aquifers represent the principal aquifer packages for groundwater in the WDWA. These zones generally exist well below the afore-described potential shallow perched groundwater zones in the upper and lower Tulare Formation or deeper. Groundwater quality in these sediments is regarded as poor to very poor due to significant concentrations of naturally occurring TDS, which often exceed 2,000 mg/L. The unconfined/semi-confined aquifer zone extends variably from approximately 50 feet bgs, downward to the top of the so called modified “E-Clay” that may be equivalent to the Corcoran Clay. This aquitard, where present, is typically found at approximately 500 feet bgs or deeper. Most groundwater in the unconfined/semi-confined zone in the WDWA is found at depths greater than 75 ft. bgs.

Where the modified E-Clay is present, confined groundwater conditions can exist below this horizon. Studies by the USGS in 2009 indicate that this confining layer extends from the Valley floor westward to approximately the east-facing flank of the Lost Hills Anticline. The modified E-Clay is poorly constrained and not known to extend with any significance into the Antelope Plain. This area constitutes a majority of the surface area of the WDWA, and occupies the structural trough between the Temblor Range and the west facing flank of the Lost Hills Anticline. Depths to confined groundwater, where present, are variable, but are usually deeper

than 500 feet bgs. Concentrations of TDS from confined groundwater reportedly range between 250 to 434 mg/L, but are known to sometimes degrade over time. Sediments in this stratigraphic package consist of unconsolidated, interbedded medium to coarse sand, silt, and clay (Amec, 2015; GEI, 2019). The presence, or lack thereof of a well-defined and contiguous confining layer beneath the Antelope Plain separating shallow and deeper groundwater zones, and complex structural geology, could explain the general poor quality of groundwater throughout the WDWA, as well as the occurrence of better quality groundwater in certain areas. Together with the documented low volumes of groundwater pumping in the WDWA it may also explain why, with the possible exception of oilfield areas, there does not appear to be any significant inelastic land subsidence in the WDWA.

Physical properties of aquifers within the KCS are derived from both well pumping tests and calibrated groundwater flow models. These data are summarized in the KGA Umbrella GSP. Physical properties include hydraulic conductivity (i.e. transmissivity), which is a function of the ability of an aquifer to transmit water through a given saturated thickness of aquifer, and specific yield (unconfined aquifers) and storage coefficient (confined aquifers). Specific yield and the storage coefficient are functions of the ability of an aquifer to store and release water. **Figure 15c** provides the range of horizontal conductivity for the principal aquifer types in the KCS (i.e. Unconfined/Semi-confined, and Confined). These ranges are typical of the silty sands and clean medium to coarse sands found in KCS aquifers, and are collaborated by various calibrated groundwater flow models predicated on field test data.

The Corcoran Clay varies from fine grained silts and clays to coarse sands in parts. The USGS estimated horizontal conductivities for the silts to medium sands within the range of 0.0024 to 33 feet per day. The vertical conductivity for these sediments was estimated at between 6.6 x 10^{-6} and 1.5 x 10^{-3} feet per day.

2.5.6 Lateral Boundaries and Structural Impediments to Groundwater Flow

The following federal regulations are foundational to the subsections pertaining to the lateral and basal extents of the effective groundwater Subbasin:

- Title 40 of the Code of Federal Regulations (40 CFR) §144.3
- 40 CFR §146.4

Title 40 of the Code of Federal Regulations defines an underground source of drinking water (USDW) in §144.3, as an aquifer or its portion which (GEI, 2019):

a. 1. supplies any public water system; or
2. contains a sufficient quantity of ground water to supply a public water system; and
i. currently supplies drinking water for human consumption; or

ii. contains fewer than 10,000 mg/L total dissolved solids; and

b. is not an exempted aquifer.

It should also be noted that the area of the effective groundwater Subbasin can be separated from the jurisdictional boundaries of the Subbasin by the criteria for exempted aquifers per 40 CFR §146.4; which includes, but is not limited to, areas in which the presence of commercially producible minerals or hydrocarbons are present in the aquifer, such as those found within the WDWA at the Belridge, South Belridge, Monument Junction, Lost Hills, and many other oil and gas fields in the WDWA (GEI, 2019).

To the west of the WDWA, the consolidated rocks that form the Coastal (Temblor) Range mountain front is both a boundary of the KCS and a barrier to westward groundwater flow. Structural impediments to downgradient eastward groundwater flow from the Antelope Plain are poorly constrained, but may include post-depositional folding of then-soft sediments. These fold belt structures include among others, the Belridge, Lost Hills, and Kettleman Anticlines, and the Buttonwillow and Semitropic Ridges (Bartow, 1991) and associated synclines. To the south, groundwater flow is impeded by geologic ridges that include spurs of the Temblor Range and the Elk Hills Anticline. Page (1986) and the DWR (2006) also identified the anticlinal folds and specifically Lost Hills, as restrictions that slow or impede groundwater flow downgradient and eastward towards the Valley axis. This condition likely applies to other folds and anticlines in the Subbasin beneath the WDWA. It is believed that several of these anticlines are associated with faults that trend subparallel to the San Andreas Fault and, if confirmed by future studies, they may also affect groundwater flow. Based on current draft C2VSim-Kern hydrologic modeling by the KGA, there appears to be some underflow towards the immediate north and the former bed of Lake Tulare. In that direction, Subbasin boundaries include the separate Kettleman Plain, the former Tulare Lake bed, which is a beneficial use exemption area, and the Tule subbasin (GEI, 2019).

2.5.7 Bottom of the Basin

In simplest form, the geologic bottom of the sedimentary Subbasin can be identified as the depth at which crystalline basement rock is encountered. Alternatively, and more applicable with regards to the objectives of SGMA, the bottom of the groundwater Subbasin is more aptly defined by applying criteria of 40 CFR §146.4. The bottom of the Subbasin varies vertically and laterally with the following criteria:

- Depth to commercially producible minerals or hydrocarbons, or primacy productive limits;
- Depth to exempted aquifers;
- The depth that makes recovery of water for drinking water purposes no longer economically or technologically feasible; or

- The depth at which groundwater cannot now, or in the future, serve as a source of drinking water.

Recognizing that the hydrogeology of the WDWA is highly variable, and that it is not possible at this time to predict the future maximum depth at which groundwater might be economically recoverable, or at which groundwater TDS concentrations below 10,000 mg/L may be economically treatable for drinking water. The following combinations of criteria are proposed for determining the hydrologic bottom of the Subbasin. The criteria take into account existing relevant and applicable rules and regulations. Utilizing this approach, the bottom of the Subbasin (i.e., base of "fresh water") may be described as the combination of the itemized list below (i.e., item A, and either item B or C) (GEI, 2019):

A. Depth to commercially producible minerals or hydrocarbons (40 CFR §146.4) (where it applies to discrete areas of the Subbasin), or the depth to an exempted aquifer which has been approved by the US EPA and DOGGR according to the criteria of 40 CFR §146.4; and either:
B. Depth to water with a TDS concentration that is no longer economically or technologically feasible for groundwater beneficial use; or
C. Depth to waters of TDS greater than 10,000 mg/L (40 CFR §144.3), these being referred to here as not suitable as an USDW.

In the WDWA, concentrations of TDS routinely exceed 2,000 mg/L, making the groundwater unsuitable for practical beneficial use in the WDWA. The base of fresh groundwater in the KCS (**Figure 16**) has historically been defined by Page (1973), as the depth at which specific conductance (SpC) is 3,000 umhos/cm or microsiemens per centimeter (uS/cm). This value is considered to be generally equivalent to a TDS concentration of 2,000 mg/L. These values are reported in this Chapter GSP because they are considered a limiting factor for irrigation and other practical beneficial uses in the WDWA. The conversion factor from SpC to TDS used for this determination was 0.67, which is midway between the typical range of 0.55 to 0.75 (Hem, 1985), and is dependent on the composition of groundwater. Available groundwater data indicates that, with few exceptions, most of the accessible groundwater of sufficient quantity to be economically viable within the WDWA meets or exceeds this threshold (Amec, 2015; GEI, 2019). Further, in support of this concept, the WWQC is in the process of submitting a BPAW for regulatory review that proposes delisting agriculture and municipal beneficial uses for perched and unconfined/semiconfined aquifers over a significant portion of the WDWA.

In reference to item "A" above, in the WDWA oil and gas is produced from geologic structures that are comprised of some of the same formations that produce brackish groundwater elsewhere in the WDWA. The Tulare and Etchegoin Formations are two examples of this

condition. The uppermost hydrocarbon producing zones are variable, but can be a shallow as 400 feet below ground surface. In addition to containing hydrocarbons, many of these oil-bearing zones also contain naturally degraded formation water (i.e. produced water). Based on the presence of hydrocarbons in these structures many of the associated formations are also designated as exempt aquifers by the DOGGR and the US EPA, within the administrative limits of the individual oil field. Examples of oil fields with aquifer exemptions include, among many others, the Lost Hills Oil Field and the Belridge Oil Field complex. Both oil field produced water and WDWA groundwater are naturally degraded by elevated concentrations of TDS and other minerals and compounds. Brackish groundwater conditions are found throughout a majority of the WDWA.

The depth to groundwater with a TDS of 10,000 mg/L, also known as the base of the USDW, is predicated on recent research in the KCS (Gillespie et. al., 2017; Kong, 2016). As described by Gillespie et al. (2017), the base of USDW is identified by geochemical analysis of discrete water samples and geophysical log (E-log) analysis. Gillespie found that salinity in the western KCS are much higher, and the depth to the base of USDW is more variable, than elsewhere in the KCS. These findings may be due to the geological complexity of the western KCS. Gillespie and others cite numerous wells with TDS between 3,000 mg/L and 10,000 mg/L in the non-marine Tulare Formation and overlying alluvium in the western KCS. Although lacking an extensive data set, Page (1973) reported very little data with specific conductance of less than 3,000 umhos/cm (i.e., ~2,000 mg/L) in the western KCS. TDS concentrations in the WDWA are often found to be much higher than 2,000 mg/L, supporting the conclusion there is very little “fresh water” on the western side of the KCS as corroborated further by other sources (Metzger and Landon, 2018; Amec, 2015 etc.). Therefore, the base and lateral extent of groundwater suitable for general beneficial use in the WDWA is proposed as where TDS concentrations exceed 2,000 mg/L.

2.5.8 Geologic Cross-Sections

The two geologic cross-sections provided in this Chapter GSP are based on driller descriptive logs and well completion forms filed with Kern County. The datum for both cross-sections is ground surface. Cross-sections presenting the structure and hydrogeology of the KCS at large are provided in the KGA umbrella GSP. The WDWA cross-section location map is provided on **Figure 17a**.

WDWA cross-section A-A’ (**Figure 17b**) extends from near the northeastern edge of the LHWD, southwards to near the southern boundary of the BWSD. Stratigraphy depicted on this cross-section matches that described in **Section 2.0** and is generally comprised of interbedded and interlensing series of silts, sands, and clays. Of note are the apparent fine-grained (silt and clay) layers that are evident in several of the wells (e.g., Well No.7108-69). Based on the similar geochemistry of groundwater found across the WDWA it is not clear if any of these fine-grained

or clayey sediments are fully competent confining layers. This condition will be assessed further as part of the Chapter MNP data collection.

Cross-section B-B' (**Figure 17c**) extends from west to east, from well 026S020E07E001M to a location near the boundary between LHWD and the adjacent SWSD (well 026S021E14EH002M). This cross-section exhibits the same sediment types as those in the Section A-A', and transects the Lost Hills anticline.

2.5.9 Data Gaps

The limited use of groundwater in the WDWA has resulted in data gaps related to the availability of DWR data, well construction information, and continuous and representative groundwater level and pumping data over historic and contemporaneous intervals. Historic studies by the USGS and others have provided sufficient hydrogeologic data and background to construct a preliminary HCM. The current HCM and WDWA water budget presented in this report are based on the preliminary KGA CV2Sim-Kern hydrologic model and the "Brackish Water Checkbook" approach from which an estimate of available water supply was derived. Once additional representative hydrogeologic data has been collected, the existing preliminary groundwater modeling will be further refined by the KGA to include the incorporation of local groundwater elevation, groundwater in storage, cropping, and groundwater pumping and water quality data. The WDWA will also refine and report its HCM and water budget information as new data become available. Until then, the WDWA will rely upon the Brackish Water Checkbook approach for estimating available water and Native Yield. Data gaps will be addressed through the implementation of the focused network monitoring plan described further in **Section 3.0** of this Chapter GSP.

2.6 Groundwater Conditions

Groundwater within the WDWA has been documented by numerous studies to be of poor quality and unsuitable for most practical beneficial use without blending or treatment. Because of the dynamic nature of the occurrence and movement of groundwater in the subsurface, it is recognized that groundwater conditions are transient through time and are subject to change. Factors that can affect groundwater conditions and quality include, but are not limited to, volume of precipitation, quality and quantity of direct recharge, topography, climate (ETo), soil geochemistry, aquifer thickness and physical properties, and subsurface geologic impediments or restrictions to groundwater flow. Land use, and anthropogenic activities (e.g., evaporation ponds) are other factors that might further degrade existing brackish groundwater quality. Data to more fully quantify groundwater elevation and occurrence within the WDWA will be addressed as a priority during the first five-year reassessment period. However, current KGA C2VSim-Kern modeling indicates that the principal source of discharge, and thus the most significant change in storage in the WDWA, is not pumping extractions. Instead it is natural

subsurface groundwater underflow towards the axis of the Valley. This condition may be accelerated by pumping in adjacent downgradient water districts. Both conditions are beyond WDWA control.

2.6.1 Description of Historic and Current Groundwater Conditions

Historic and current groundwater data that is representative of local conditions is a recognized data gap in the WDWA. Although there are many well installations recorded in various agency databases, for the most part a majority of these are lacking the continuous information necessary to fully characterize groundwater conditions. **Figure 18** presents the universe of known well installations as derived from various regulatory agency databases, and a 2015 groundwater assessment conducted by Amec on behalf of the WWQC. In total there are approximately 409 known well sites in the WDWA. This number represents a well density of approximately 1.2 wells per square mile.

Available water quality data in the WDWA confirms that a significant portion of groundwater is brackish and of poor, unsuitable quality. The trend for groundwater elevation levels are downward although, based on the limited data available, appear generally to be at a rate that is less pronounced than as modeled by the KGA and documented elsewhere in the KCS. This is likely due to the limited pumping in the WDWA which is currently estimated at 3,000 AFY, and the fact that natural downgradient groundwater underflow is believed to be the most significant discharge factor in the current C2VSim-Kern model simulation.

Information regarding historic and recent groundwater elevations in the WDWA is limited because many wells are often completed in more than one aquifer, and it is rare that pumping volume or water-level data is collected in a systematic and coordinated way using a common set of sampling protocols and data recording standards that are implemented on a set schedule. In addition, public availability of gauged pumping volumes has been, and still is, difficult to obtain, as most wells are privately owned. Another contributing factor to this data gap is the fact that, historically in the WDWA, groundwater was generally considered a secondary source when compared to the ready availability of good-quality surface water from the SWP for the purpose of irrigation. This factor may have further militated against consistent detailed record keeping. Currently, based on the best available information, the aforementioned data gaps related to the need for additional representative data persist. Steps to decisively remedy this data gap pursuant to SGMA will be addressed in the WDWA MNP, described in **Section 3.0**.

2.6.2 Groundwater Trends

Groundwater elevation data in the WDWA are scarce due to the minimal amount of annual groundwater pumping. Groundwater elevation data has been identified as a data gap that will be addressed during the first five-year reassessment period. However, based on the data

available, including historic maps generated prior to widespread development of the WDWA, groundwater trends in the WDWA appear to be generally downward, albeit not at the rates currently simulated in the KGA groundwater model. Groundwater trends in the WDWA are governed principally by drought and downgradient subsurface outflows that may be accelerated by irrigation withdrawals in adjacent water districts. Groundwater flow direction in the WDWA is believed to be primarily eastward toward the floor of the Valley, with some northeastward flow along the northern boundary of the WDWA towards the former bed of Lake Tulare. Subsurface flow is reportedly impeded by geologic synclinal troughs, and sometimes sourced by runoff from the aforementioned anticlinal ridges that separate the Antelope Plain from the axis of the Valley floor. Seismic profiles and other geologic data made publicly available in applications for oil field aquifer exemptions in the WDWA show that gaps do exist in and around anticlinal ridges and synclinal down-folds that could present pathways for groundwater underflow. For example, in the north, geologic gaps between the Lost Hills Anticline and the South Dome of the Kettleman Hills Anticline could provide pathways for subsurface groundwater migration. In the southeast, geologic gaps around the Belridge Anticline complex, and the more easterly Buttonwillow and Semitropic Ridges, may also be pathways for restricted groundwater movement towards the Valley (**Figures 19a and 19b**). A possible obstruction to groundwater flow further eastward may be the Buttonwillow Syncline. Further study of groundwater trends and flow will be conducted during the first five-year reassessment period (i.e. 2020-2025).

An alternative interpretation for the occurrence and condition of groundwater in the WDWA is based on the presence of buried complex geologic structures that are known to exist beneath the Antelope Plain. Many of these features are visible only by viewing geophysical seismic data. It is possible that these structures may have some added influence over the distribution and quality of groundwater in the WDWA beyond what is currently known. The WDWA plans to assess these conditions by reviewing new data, including publicly available seismic data, during the first five-year reassessment period. Findings of this evaluation will be included in the HCM as appropriate and reported in the relevant SGMA update report

Preliminary C2VSim-Kern modeling conducted by the KGA indicates that the WDWA management area is variably recharged by underflow from the east-facing slopes of Coastal Mountain Ranges, seepage losses from the mostly ephemeral streams after significant storm events, deep percolation of precipitation above calculated ETo, by direct recharge returns of imported water from crop (surface water) application, and incidental losses from irrigation canals and ditches.

Pumping extractions under current conditions in the WDWA are minimal (estimated at ~3,000 AFY), primarily due to the poor groundwater quality and the availability of better quality Aqueduct import water. The simulated estimate of WDWA groundwater recharge is sufficient

to cover pumping extraction volumes. However, as noted previously, based on the preliminary KGA C2VSim-Kern model, the largest component of discharge in the WDWA is natural underflow (111,000 AFY) downgradient towards the axis of the Valley. Recharge via agricultural applications of surface water (i.e., deep percolation of agricultural return flow), although still an important source of recharge in the WDWA, is believed to be somewhat less than in the past because of the now-widespread use of modern drip and micro-irrigation technology by growers.

The general lack topographic of definition of stream drainage channels in the WDWA management area indicates that these are likely seasonal losing streams, and that most stream flow never leaves the Antelope Plain as surface water flow; with the possible exception of during extreme precipitation events (GEI 2019). Deep percolation of rainfall may be a source of recharge, but only during periods that significantly exceed the current 5.2 inches of average annual rainfall. The average ETo of approximately 58.3 inches/year, and long-term precipitation data for the KCS, suggest that direct percolation of precipitation in the Antelope Plain is not a significant source of recharge in the WDWA (Amec, 2015; GEI, 2019). There is no evidence for widespread, continuous saturated conditions extending from the surface to first regional groundwater aquifer in the WDWA.

As noted previously, representative groundwater elevation data within the WDWA is limited. The KCWA now (last few years) monitors three groundwater monitoring wells within the LHWD area as part of the CASGEM Program. In addition to these three wells, the WDWA has proposed to monitor another 18 (total of 21) well locations throughout the WDWA. In coordination with the WWQC, the WDWA MNP will implement monitoring on a biannual (Spring and Fall) basis going forward.

A hydrograph for one of the three aforementioned KCWA CASGEM wells (25S/21E-01R001M), located in the extreme northeast of the LHWD, was selected to assess for current and projected groundwater trends due to its continuous record of groundwater elevations for the period 1976 through 2017. **Figure 20a** shows the hydrograph for the period 1975-2018 for well 25S/21E-01R001M. This well is located basin-ward on the boundary between the WDWA and the SWSD. The general groundwater elevation trend in this well has been downward since approximately 1992. Monitoring data are more or less continuous, with some minor gaps starting in 1976 and extending periodically to other short intervals where data was not collected. Groundwater elevations range from a low of 6.2 feet above MSL in 2017, to a high of 84 feet above MSL in 1987. For the period 2007 through 2017, the average downward trend was approximately 5.3 feet per year (feet/year). The reported top of the well screen intervals is approximately 409 feet below MSL (624 feet bgs), which suggest that groundwater in 2017 was standing at approximately 400 feet above the top of the first well screen. Projecting a linear decline rate of 5.3 feet/year outwards to 2040 indicates that groundwater levels would be approximately -62 feet below MSL in 2030 and at 2040 approximately -115 feet below MSL.

Three other well hydrographs and linear decline graphs were generated for the period 1995 through 2004 by CV2SimFG-BETA to help assess groundwater elevation trends along the shared boundary of the WDWA with the BVWSD. One hydrograph is located in the center of Section 16, Township 28S, Range 21E (**Section 4.1.1)**. Based on the simulation data, the projected rate of decline for a well at this location for the specified period would be approximately 5.6 feet/year. The projected water level in 2030 would be approximately 112 feet above MSL, and in 2040 it would be approximately 56 feet above MSL. A second hydrograph is a relatively new well located at Township 27S, Range 22E, Section 30 (**Section 4.1.1**). The projected decline rate for this well based on reported groundwater elevations was determined to be approximately 4.2 feet/year. The projected water level in 2030 is estimated to be approximately 101 feet above MSL. The 2040 level is approximately 59 feet above MSL. The third hydrograph is for a well located 28S21E30H. The projected decline rate is approximately 6.8 ft. year. Estimated water level in 2030 is 127 feet above MSL. The projected 2040 water level is approximately 59 feet above MSL. These projected water levels inform the selection of the preliminary MOs and MTs, which are discussed further in **Section 4.0**.

2.6.3 Projected 2016-2065 Climate Change

Current climate modeling indicates that by 2050 there may be a significant reduction in the amount of winter snowpack in the Sierra Nevada Mountain Range. The gradual late-spring to mid-summer snowpack melt has historically allowed for an organized management of this important resource, which currently provides around 65% of California's water supply. If the current predictions are realized, it is possible that runoff from the Sierra Nevada will occur earlier in the year, and a majority of precipitation may come in the form of rain instead of snow. The ability to harvest and store the runoff for use later in the growing season may become a critical issue for Valley agriculture, and by extension, the State's economy in the coming decades. Assuming no change to cropping patterns, and no new water storage or reuse projects, predicted climate change will likely result in increased competition for all water resources.

In the KCS at large, it is expected that demand reduction measures and reliance on groundwater will increase in order to augment any potential further reductions to deliveries from imported surface water. In the Sacramento River Delta, which is a source of SWP water, less summer Sierra Nevada runoff equates to calculated reductions in Valley surface water deliveries. A corresponding rise in sea level caused by glacier and ice sheet melt off and a rise in ocean temperatures, could also affect water quality for irrigation by increasing the salinity in the Sacramento Delta. In the WDWA, where SWP water is the primary contractual supply of irrigation water and groundwater is used primarily for blending, it is anticipated that SWP deliveries may be further reduced and could become less reliable, while ETo will increase with rising temperatures.

Total (100%) designated SWP allocations to the WDWA, when available, are on the order of 332,218 AFY. However, current KGA preliminary modeling with C2VSim-Kern for the baseline period 1995 to 2014 indicates SWP deliveries averaged around (~272,000 AFY). A preliminary KGA-modeled climate-change scenario for the WDWA covering the period 2016 to 2065 assumes SWP deliveries would be reduced to approximately 61% of the current total Table A allocation (i.e., ~204,698 AFY). Preliminary KGA C2VSim-Kern modeled projections of climate change influences may result in the following groundwater budget components:

Inflows

- Underflow from Coastal Ranges: 55,600 AFY
- Water loss from imported water canals: 8,800 AFY
- Areal recharge (deep percolation): 18,900 AFY
- Water loss from ephemeral stream flow: 3,200 AFY
- Total inflow: 86,500 AFY

Outflows

- Underflow out of the WDWA: 111,000 AFY
- Pumping Extraction: 5,400 AFY
- Total outflow: ~116,400 AFY

Modeled groundwater underflow out of the WDWA and not pumping is by far the most significant factor contributing to change in groundwater storage. This natural phenomenon is outside the control of the WDWA. Due to the poor quality of groundwater, irrigation demand in the WDWA is and will continue to be met almost entirely by Aqueduct water. To help ameliorate the modeled groundwater outflows over the GSP implementation horizon, the WDWA will continue to utilize conservation and demand reduction measures, intra-area water trading, advanced irrigation technology, deficit irrigation methods, and the potential innovative conjunctive reuse of degraded groundwater and oilfield produced water. Data derived from the MNP will be used to update the KGA water budget model for the WDWA in order to coordinate forward looking and sustainable water management strategies and projects with adjacent GMAs.

As a first step towards future sustainability and climate change resiliency, the WDWA is considering an innovative approach to treat and reuse oil field produced water and naturally degraded groundwater to increase flexibility and diversity in its water portfolio. This project is discussed further in **Section 6.0**.

2.6.4 Beneficial Uses and Users

Current designated beneficial uses of groundwater for the WDWA are established in the Tulare Lake Basin Plan. The WDWA is within Detailed Analysis Unit (DAU) 259. Existing designated beneficial uses of groundwater in DAU 259 include:

- MUN
- AGR
- IND

It should be clarified that although MUN is a designated beneficial use for groundwater within the WDWA, there is no MUN use in the WDWA at this time. For these designated beneficial uses, the Tulare Lake Basin Plan specifies numeric water quality criteria for certain water quality parameters and provided narrative water quality for other parameters. In the Tulare Lake Basin Plan, the designated water quality criteria for MUN are described as (Amec, 2015):

> *"At a minimum, waters designated MUN shall not contain concentrations of chemical constituents in excess of maximum contaminant levels (MCLs)…or secondary Maximum Contaminant Levels (SMCLs)…"*

The Tulare Lake Basin Plan also identified the following narrative water quality criteria for groundwater (Amec, 2015):

> *"Ground waters shall not contain chemical constituents in concentrations that adversely affect beneficial uses."*

> *"Ground waters shall not contain taste or odor-producing substances in concentrations that cause nuisance or adversely affect beneficial uses."*

The US EPA drinking water SMCL for TDS is 500 mg/L. The California Department of Public Health (DPH) has established a range of TDS and EC in drinking water (Section 64449, Title 22, CFR). The DPH SMCLs are:

Constituent	Recommended	Upper Level	Short-Term
TDS	500 mg/L	1,000 mg/L	1,500 mg/L
EC	900 umhos/cm	1,600 umhos/cm	2,200 umhos/cm

Aside from potential hazards to irrigated crops, adverse effects from the consumption of water with elevated TDS include nuisance aesthetic concerns such as bad taste or unpleasant odor, and cosmetic effects, such as skin or tooth discoloration. Physical effects to infrastructure, such as staining, corrosion, pitting, and scaling of pipes, valves, and other water equipment is also common. Consumption of highly brackish to saline waters can result in severe health effects.

Based on available data, a majority of the groundwater in the WDWA contains elevated levels of TDS that make it unsuitable for MUN use without additional treatment (Amec, 2015).

The SWP, along with other supplemental sources of surface water, delivers the vast majority of the water used for AGR activities, such as crop irrigation in the WDWA. Groundwater in the WDWA is of sufficiently poor mineral quality to severely impair AGR beneficial uses, and often exceeds published water quality criteria for MUN and AGR-Irrigation (severe restrictions; Food and Agriculture Organization of the United Nations [FAO], 1994). The Tulare Lake Basin Plan has designated beneficial uses of AGR that, for the most part, do not currently exist and cannot be sustained in the WDWA due to poor groundwater quality. Groundwater in the WDWA requires significant blending to be usable for AGR-Irrigation. As noted in **Section 2.1** and elsewhere in this Chapter GSP, the WWQC has transmitted a Draft Basin Plan Amendment Workplan (BPAW) to the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) Technical Committee and the Regional Water Quality Control Board (RWQCB) for their preliminary review and input, prior to final submittal to the RWQCB (**Figure 20b**) for a regulatory determination. The BPAW currently recommends the following:

- Delist the beneficial use of MUN and domestic supply in perched and unconfined/semi-confined groundwater in a portion of the WWQC, which also includes a significant portion of the WDWA; and
- Delist the beneficial use of AGR water supply in perched and unconfined/semiconfined groundwater in those same areas.

Principal land use within the WDWA, aside from open undeveloped rangeland, consists of two general categories:

- AGR: farming, livestock, etc.
- IND: primarily oil and gas production

Users that could be potentially affected by use of groundwater in the WDWA include:

- AGR users;
- IND users (i.e., principally oil and gas); and
- MUN and individual domestic users.

There is no public water supply use of groundwater in the WDWA, nor is there likely to be over the duration of Plan implementation because of the ubiquitous extent of naturally degraded groundwater, and the remoteness of the WDWA where the predominate land uses are agriculture, oil and gas production and grazing. The ready supply of other water sources of better quality, such as Aqueduct water, and groundwater from adjacent management areas also make it unlikely that WDWA groundwater would be used for local public water system supply.

According to the DWR well completion reporting and the CASGEM Program, historically there have been a few well completions recorded as "domestic" within the WDWA. However, it is unknown if this well designation is accurate or, if so, whether any of these wells are still in use. The majority of active groundwater wells in the WDWA were completed for the following purposes:

- Irrigation/stock, etc.;
- Industrial; and
- Monitoring/observation.

2.6.5 Groundwater Quality

A literature review was conducted to ascertain and document water quality. Among the various technical reports reviewed were USGS studies as well as data culled from the State GeoTracker and EnviroStor databases, which identify contaminant releases to soil and groundwater. The SWRCB's Human Right to Water Quality Portal was accessed to identify common contaminants that are typically found to be in concentrations that are out of compliance with drinking water standards. The evaluation also included data from local Water Districts and the State Drinking Water Information System (SDWIS).

This characterization of groundwater quality was conducted to comply with California Code of regulations (CCR) Title 23-Waters: Sub-article 2§ 354.16(d)-Groundwater Conditions. Of the regulated *drinking water* constituents considered, the most common water quality constituents encountered in the WDWA are; Arsenic, Nitrate, Boron, Hexavalent Chrome, Pesticides (Synthetic Organics), and TDS. To the extent applicable, the constituents evaluated and the methodology utilized are consistent with guidance provided in:

- Assembly Bill 1249 (AB 1249), which states *"…if the Integrated Regional Water Management (IRWM) region has areas of nitrate, arsenic, or hexavalent chromium contamination, the (IRWM) Plan must include a description of location, extent, and impacts of the contamination; actions undertaken to address the contamination, and a description of any additional actions needed to address the contamination*" (Water Code §10541.(e)(14).
- Division of Drinking Water (DDW) Human Right to Water (HR2W) portal, which identifies the contaminants for which public water systems have received MCL violations.
- Water Quality Control Plan for the Tulare Lake Basin (Basin Plan), dated May 2018, which is the SWRCB's implementation plan for Water Code §106.3. The amended basin Plan requires permitees to *"…address the immediate needs of those drinking groundwater that exceeds the drinking water standard for nitrate*".

Much of this information, including maps of public water systems within the KCS, is contained in the KGA Umbrella GSP. Because of the naturally degraded quality of groundwater in the WDWA, district groundwater is not utilized as a source for public supply.

The quality of groundwater varies greatly across the KCS. Most of this difference is due to natural conditions related to the mineral content of the sediments and lithology and geologic structure of the Subbasin. In the WDWA management area, marine-derived formations have contributed to the documented poor and unsuitable quality of groundwater. Along the western side of the KCS, including the WDWA, unconfined/semi-confined groundwater is characterized geochemically as Na/Ca-SO_4 water with TDS concentrations most often above 2,000 mg/L. Other deeper groundwater aquifers beneath the WDWA, and elsewhere in the KCS, are referred to as sodium-chloride (Na-Cl) water, which exhibits high to very high levels of TDS and is likely saline connate water (Amec, 2015; GEI, 2019).

Groundwater beneath the WDWA exhibiting TDS concentrations above 2,000 mg/L are naturally degraded and are considered unsuitable for all practical beneficial use. This includes waters found in, or produced from, oil field hydrocarbon-bearing zones, and US EPA designated exempt aquifers regardless of depth. In addition to TDS, other minerals and compounds that can affect groundwater quality present in WDWA groundwater are described in the subsections below.

It should be noted that generally accepted concentrations of TDS for defining water quality are:

- Fresh Water: up to 500 mg/L
- Brackish Water: 500 mg/L to 30,000 mg/L
- Saline: 30,000 mg/L to 40,000 mg/L
- Hypersaline: greater than 40,000 mg/L

In its 2003 update to California Water Bulletin 118, the DWR provided the following information with regard to the range of TDS values and related suitability for agricultural use (DWR, 2003):

- TDS: <500 mg/L, no restrictions
- TDS: 500 mg/L to 1,250 mg/L, slight restrictions on use
- TDS: 1,250 mg/L 2,500 mg/L, moderate restrictions on use
- TDS: >2,500 mg/L, severe restrictions on use

2.6.5.1 Arsenic

Arsenic has a primary drinking water MCL of 10 micrograms per liter (ug/L) (parts per billion [ppb]), and an agricultural goal of 100 ppb. Reports published by the Department of Pesticide Regulation and USGS studies indicate that the major source of arsenic in the KCS is naturally occurring. A significant source of arsenic in KCS groundwater is derived from erosion and mobilization of arsenic found in geologic sediments. Throughout the southern San Joaquin

Valley arsenic rich minerals, such as arsenopyrite, a common constituent of shales, the mineral apatite, and phosphorites are the most frequent sources of arsenic leaching to groundwater. **Figure 21** presents the KCS regional distribution of arsenic in wells for the years 2001 to 2007 (GEI, 2019). The distribution of elevated arsenic concentrations in the KCS is localized and appear to be associated with natural clay deposition in and around the former Tulare Lake, Kern Lake, and Buena Vista Lake areas, where the process of evaporative concentration likely acted to further increase naturally occurring concentrations in associated clays and silts (DWR, 2003; Amec, 2015). A study by the USGS reported that arsenic is the trace element most often present at elevated concentrations in the KCS, with concentrations ranging from 10ppb to 30 ppb.

2.6.5.2 Nitrate

Nitrate (NO_3) has an acute drinking water MCL of 10 mg/L (ppm) nitrate-nitrogen. There is no agricultural goal. Nitrate is a form of nitrogen that can be produced naturally by the atmosphere or by decomposing organic matter. Naturally occurring nitrate concentrations are generally less than 10 milligrams per liter as nitrogen (mg/L-N), and generally do not exceed 20 mg/L-N in groundwater (Hounslow, 1995; Todd, D.K. [Todd], 2008; Amec, 2015). Elevated nitrate concentrations are also attributable to the application of nitrogen fertilizers, runoff from feedlots or dairies, percolation of wastewater and food processing waste, and leachate from septic systems (Harter et al., 2012). Groundwater recharge from septic systems is not thoroughly measured or estimated in the KCS, but this potential source is believed to be a minor contributor in the WDWA due to the sparse population and remoteness of towns and individual dwellings. Recharge from wastewater generated by food processing, confined animal facilities, and other industries can also be significant but, like some other wastes, are generally regulated under individual waste discharge requirements (WDRs) (Amec, 2015). Treated wastewater is regulated by the various RWQCBs under site/facility-specific WDRs. Point source discharges from facilities, including stormwater discharges to surface water are regulated by the National Pollutant Discharge Elimination System (NPDES) under the Federal Clean Water Act (Amec, 2015).

Wells in the San Joaquin Valley, including those on the western side of the KCS, have higher nitrate concentrations in shallower zones, likely the result of return-flow percolation due to past agricultural activities and irrigation practices. Recent improvements to irrigation technology and the evolution to permanent crops like nut trees in the WDWA have significantly reduced the amount of agricultural return flows and fertilizer application. Public water supplies are required to treat raw water to meet all established drinking water MCLs. Within the WDWA, there are no public water systems sourced by district groundwater. The water supply for the town of Lost Hills is from outside the WDWA and is managed by LHUD (Amec, 2015). **Figure 22** presents

nitrate as nitrogen detected in KGA wells and proximity of septic tanks for the years 2009 to 20019 (GEI, 2019).

2.6.5.3 Boron

Currently, there is no Federal or State drinking water MCL for boron. However, the State does have a notification level of 1,000 ug/L, and there is an agricultural goal of 700 ug/L. Since the WDWA is largely dedicated to agriculture, the agricultural goal is used as a reference point in this Chapter GSP. The agricultural goal is intended to protect various agricultural uses of water including various crop types and stock watering. The agricultural level is a baseline to compare against and should not be used to represent an acceptable maximum level for the KCS. According to USGS Scientific Investigations Report 2011-5218, boron is commonly found in the southern part of the KCS. It generally occurs in association with basin-fill sediments of marine origin like those in the southern and western sides of the Subbasin. Brackish and saline connate waters, common to the WDWA, are also known to contain elevated concentrations of naturally occurring boron. Other sources of boron include leaching from wastewater, and fertilizer/pesticides (Amec, 2015; GEI 2019).

2.6.5.4 Hexavalent Chromium

Currently, there is no Federal drinking water MCL for hexavalent chromium. A court-challenged State drinking water MCL of 10ug/L is in the legislative process to be re-adopted. In the meantime, the Federal MCL of 50 ppb for total chromium applies. Anthropogenic sources of hexavalent chromium include commercial and industrial activities such as discharges of chrome-plating liquid wastes, various pigments, wood preservatives, and leaching from landfills and hazardous waste sites. Chromium is also prevalent in soils and plants. The process of leaching chromium into groundwater is believed to be similar to that for arsenic described in a previous section above. The occurrence and concentrations of hexavalent chromium detected to date in the KCS (i.e., in the range of ~5 ug/L to 13 ug/L [or ppb]) indicate that many of the existing detections are likely result of natural conditions (Amec, 2015). There is no Agricultural Water Quality Goal for hexavalent chromium. A review of the GeoTracker and EnviroStor databases found no open contamination hexavalent chromium cleanup sites or point source releases in the WDWA.

2.6.5.5 Pesticides (Synthetic Organic Chemicals)

In a Groundwater Assessment Report prepared for the WDWA and the Western Supplemental Area in 2015 (Undistricted Lands), it was reported that a review of available relevant databases for pesticide detections in the study area determined pesticides were infrequently detected in groundwater samples, and these were generally below established corresponding MCLs. The following table summarizes the review of the GeoTracker and Groundwater Ambient Monitoring and Assessment (GAMA) databases for the pesticides atrazine, simazine, 1,2-dichloropropane

(1,2-DCP), Diuron, 1,2,3-trichloropropane (TCP), and 1,2-dibromo-3-chloropane (DBCP) (Amec,2015).

Pesticide	Wells with Data	Wells with Detections	MCL (mg/L)
Atrazine	24	1(E)	0.001
Simazine	30	1(E)	0.004
TCP	21	0	0.000005
Diuron	15	0	NA
DBCP	31	0	0.0002
1,2-DCP	25	1	0.005

Note:
(E): estimated value at or below established reporting limit

The US EPA cancelled registrations for DBCP use, with the exception of Hawaii, in 1977. Its use was subsequently banned in the continental United States in 1979. In 1985, the registration for use in Hawaii was also cancelled. The State MCL for DBCP is 0.2 ug/L (ppb). There is no Agricultural Water Quality Goal for this chemical.

To date, there have been no reported detections of TCP in the WDWA. The drinking water MCL for TCP is 5 parts per trillion (ppt.), which became effective in January 2018. In Kern County, 18 water systems have a combined total of 124 wells impacted with TCP. This number represents approximately 52% of all wells for these specific water systems. Typically released to the environment through industrial processes and leaching of soil fumigants, residual concentrations of these chemicals are still reportedly being detected in soil and groundwater in the KCS. These detections are expected to attenuate over time (Amec, 2015; SWRCB, 2019). As stated previously, there is no municipal supply use of groundwater in the WDWA.

2.6.5.6 Total Dissolved Solids, Sodium and Chloride

Based on current drinking water standards, the recommended SMCL for TDS is 500 ppm, with an upper limit of 1,000 ppm. The SMCL for chloride is 250 ppm, with an upper limit of 500 ppm. There are no drinking water standards for sodium. Agricultural Water Quality Goals set by the United Nations Food and Agriculture Organization (FAO) for TDS, sodium and chloride are 450 ppm, 69 ppm and 106 ppm, respectively. Chloride concentrations in the WDWA often exceed FAO limits. This is likely due to leaching from geologic sediments, the presence of saline connate water in the WDWA and anthropogenic impacts from oil industry evaporation ponds. The naturally occurring concentration of TDS in groundwater in the WDWA typically exceeds 2,000 Mg/L (ppm), the level at which it is considered unsuitable for practical beneficial use in the WDWA.

2.6.5.7 United States Geological Survey

A USGS study designed to assess the groundwater quality of the western KCS, prior to widespread agricultural development, sampled 45 supply wells between 1930 and 1955. Water uses of the 45 study wells were described as follows:

Number of Wells	Well Use
2	Industrial
3	Domestic
6	Idle/Unused
13	Stock
21	Irrigation

In a subsequent report that discussed the study data, USGS (1959) provided the following results for EC, TDS, boron and sulfate. Based on these data, most of the groundwater tested beneath the USGS study area exceeded current water quality criteria for MUN, AGR-Irrigation, AGR-Livestock, and AGR-Poultry (Amec, 2015).

EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)
890 – 8,370	537 – 7,040	0.4 – 18	48 – 3,930

In 1963, a multi-depth monitoring well cluster was installed near the Kern County National Wildlife Refuge (25S/21E-01N). The well cluster was part of a wider USGS study to characterize vertical groundwater quality in the KCS. The various individual well screens that made up the subject well cluster were as follows (Amec, 2015):

- Well 1N15: 10 feet to 20 feet bgs
- Well 1N57: 56 feet to 62 feet bgs
- Well 1N95: 90 feet to 100 feet bgs
- Well 1N194: 189 feet to 199 feet bgs

Each well in the cluster was sampled in August 1990. The data are summarized in the table below.

Well	EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)	Arsenic (ug/L)
1N15	1,750	1,270	0.87	220	6
1N57	12,000	9,280	9.4	4,600	16
1N95	6,250	4,260	2.1	1,500	10
1N194	4,540	2,620	1.3	420	8

These data, together with data from other studies identified in this Chapter GSP, reinforce the finding that the groundwater in the WDWA is, with few exceptions, brackish and of poor quality and is unsuitable for current designated uses including MUN and AGR-related uses. The relatively better water quality found in the shallow zone well (1N15) may be attributable to imported fresh surface water used to artificially maintain surface water levels and quality at the Kern County National Wildlife Refuge (Amec, 2015). Deeper groundwater zones appear to be representative of sub-regional conditions, as evidenced by comparison other study data.

A USGS (1995) report provided data on 15 perched groundwater wells in eastern LHWD and BWSD. Concentration of TDS ranged from 1,130 mg/L to 37,300 mg/L. Boron detections ranged from 0.8 mg/L to 70 mg/L. Sulfate and arsenic concentrations ranged from 160 mg/L to 34,000 mg/L and 1.0 ug/L to 20 ug/L, respectively (Amec, 2015). The data show that perched water, where present, in eastern LHWD and BWSD, generally exceed current water quality criteria for MUN, AGR-Irrigation, ARG-Livestock, and ARG Poultry (Amec, 2015).

As part of a separate USGS KCS study, groundwater data below the Westside (hydrographic unit 18030012) were obtained from the National Water Information System (NWIS) (USGS/NWIS) (Amec, 2015). This data set was comprised of 59 wells for which some general mineral data had been collected between 1930 and 1992. The data is summarized as follows (Amec, 2015):

EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
1,080 – 102,000	544 – 91,900	58 – 70	100 – 27,000	59 – 44,000

These data reiterate the conclusion that, with few exceptions, a majority of the groundwater, including oil field produced water beneath the WDWA on a sub-regional basis is brackish, and of little, if any, beneficial use without blending or treatment.

2.6.5.8 California Department of Water Resources

As a technical basis for the adoption of WDRs for oil field operations, the SWRCB contracted with the DWR for a hydrologic assessment of selected oil fields within the Westside, including several located in the WDWA. The following subsections provide a summary of those and other assessments with in the WDWA (Amec, 2015).

Vicinity of Lost Hills Water District

In the 1956 Geologic and Waste Disposal Investigation, Lost Hills Oil Field, the DWR identified 12 supply wells: 10 stock wells and 2 domestic wells. The ranges of general mineral concentrations were reported as follows (Amec, 2015):

Wells	EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
Stock	2,750 – 8,410	1,860 – 6,780	2.9 – 10	470 – 3,630	230 – 1,460
Domestic	3,600 – 6,100	2,700	5.2	920 – 2,700	500 – 542

These data indicate that groundwater in the vicinity of the Lost Hills Oil Field is of poor quality and generally not suitable for use without expensive treatment. Chloride and boron concentrations from all but one well (26S/21E-12F), are sufficient to be classified as injurious for irrigation use (Amec, 2015).

A RWQCB (1990) report of groundwater quality samples collected from Tulare Lake Basin tile drains, including four in the LHWD, found TDS concentrations in these drains ranging from 11,000 mg/L to 14,000 mg/L. Concentrations of boron ranged from 29 mg/L to 63 mg/L (Amec, 2015). Based on the reported data, the LHWD tile drain water samples do not meet the criteria for beneficial use for MUN or AGR.

In 2012, as part of DWR's Agricultural Drainage Monitoring Program, the DWR collected samples from two tile drains in the LHWD. The concentration of TDS from the subject drains (DWR 5467 and DWR 6467) ranged between 12,520 mg/L and 23,300 mg/L. Boron was detected at concentrations between 26.6 mg/L to 43.5 mg/L (DWR, 2013; Amec, 2015). The results are comparable to those from the 1990 study described immediately above. Neither data set meets the beneficial use criteria for MUN or ARG use.

Vicinity of Berrenda Mesa Water District

In the 1957 Geologic and Waste Disposal Investigation, Blackwells Corner Oil Field, and Geologic and Waste Disposal Investigation, Welcome Valley Oil Field, the DWR identified nine irrigation wells and one stock well for study. The ranges of general mineral concentrations were reported as follows (Amec, 2015):

Wells	EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
Stock	8,370 – 15,700	5,450 – 10,400	11 – 18	1,180 – 4,870	2,200 – 4,870
Irrigation	2,030 – 3,450	1,370 – 2,660	1.0 – 2.7	600 – 1,450	166 – 288

In their report the DWR concluded that, *"These concentrations are excessive for drinking water"* (Amec, 2015). In addition, these concentrations would also be excessive for most if not all AGR use without treatment or blending with better quality water.

Vicinity of Belridge Water Storage District

In the 1957, Geologic and Waste Disposal Investigation, North and South Belridge Oil Fields the DWR was able to sample two water wells in the vicinity of the Belridge Oil Fields; an industrial supply well in the oil field and a nearby stock well. The ranges of general mineral concentrations were reported as follows (Amec, 2015):

Wells	EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
Stock	5,450	3,863	3.3	1,775	766
Industrial	4,730	2,848 – 2,950	0.4 – 7.6	462 – 464	830 – 870

2.6.5.9 Regional Water Quality Control Board

The RWQCB has oversight on several facilities and sites within the WDWA and Westside at large. A selection of these facilities and sites are described below.

Vicinity of Lost Hills Water District

As of 2015, the RWQCB regulated two facilities in the vicinity of the LHWD. These are the former Chevron USA oil field ponds, and the irrigation drainage evaporation ponds operated by the LHWD. The former Chevron ponds are located along the eastern flank of the Lost Hills Oil Field, north of the town of Lost Hills and Highway 46. Down-gradient monitoring in 2012 detected the following concentrations in groundwater (Amec, 2015):

Wells	EC (umhos/cm)	TDS (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
Chevron	4,600 – 30,000	4,100 – 30,000	1,500 – 23,000	880 – 7,900

These data exceed the criteria for MUN and AGR use, and the poor water quality is consistent with other studies and locations discussed in this Chapter GSP.

The LHWD evaporation ponds consist of six cells covering about 534 acres. In the LHWD 2018 Biannual Wildlife Monitoring Report, it was stated that the ponds were dry for that year due to a lack of discharge by the LHWD. Shallow and deep groundwater monitoring samples collected in 2009/2010 reported the following concentrations (Amec, 2015):

Wells	EC (umhos/cm)	Sulfate (mg/L)	Chloride (mg/L)
LHWD Shallow	13,000 – 171,000	NA	NA
LHWD Deep	2,500 – 50,600	500 – 20,000	980 – 23,000

Note: NA: not available

These data show that groundwater at this location is very brackish and has been impacted, likely both by the nearby ponds and the naturally poor quality of groundwater found throughout the WDWA. As such, this groundwater would be unsuitable for any beneficial use without expensive advanced water treatment technology capable of desalination such as reverse osmosis (RO) or other membrane technology. Because of the location of the ponds on the eastern boundary of the LHWD there is also the likelihood that brackish, poor quality groundwater, has migrated down-gradient towards the adjacent SWSD. If confirmed, coordinated monitoring and management of the brackish water will be required during the implementation of the KGA GSP to mitigate the potential for further undesirable results to better quality water to the east of the WDWA.

Vicinity of Berrenda Mesa Water District

The RWQCB oversees the Lost Hills Sanitary Landfill (LHSL), operated by Kern County, and the cleanup of the Antelope Pump Station, managed by Chevron. The LHSL is located along the southwestern flank of the Lost Hills Anticline, while the Antelope Pump Station is located in the west-central part of the BMWD. Monitoring of shallow groundwater at the LHSL was reported by Kern County Waste Management District (KCWMD) in 2012. This report found TDS in the range of 3,400 mg/L to 4,300 mg/L, chloride concentrations in the range of 620 mg/L to 1,200 mg/L, and sulfate concentrations in the range of 1,400 mg/L to 1,500mg/L.

Monitoring of shallow groundwater at the Antelope Pump Station and reported by Chevron in 2012, found EC values in the range of 1,175 umhos/cm to 2,416 umhos/cm. For comparison, a value of 3,000 umhos/cm equates to approximately 2,000 mg/L of TDS.

Vicinity of Belridge Water Storage District

In the vicinity of the BWSD, the RWQCB regulates several sites. Among these are:

- Aera Energy's former South Belridge Oil Field Ponds;
- Clean Harbors Disposal Facility;
- Exxon/Mobil Hill Lease; and
- Valley Water Management Ponds.

Aera's former oil field ponds are located on the southern edge of the BWSD on State Highway 33. Adjacent areas to the north include the other member Districts of the WDWA, while to the east are the BVWSD and Undistricted Lands. To the west lies the Temblor Range, and to the south is the WKWD. Monitoring wells in shallow groundwater are maintained to assess groundwater quality both beneath, and down-gradient of the former ponds.

Data from a 2012 sampling event included the following (Amec, 2015):

Wells	EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)
Aera	3,000 – 70,000	2,400 – 45,000	2.4 - 110	520 – 3,000

At the Clean Harbors Buttonwillow facility groundwater is monitored in three zones identified by the company. The zones are described as the Upper Perched Zone (80 to 140 feet bgs), Intermediate Perched Zone (185 to 201 feet bgs), and Lower Water Table (260 to 290 feet bgs). Adjacent down-gradient areas to this facility include the town of McKittrick, California, and the WKWD. A 2012 groundwater monitoring event provided the following results (Cameron-Cole, 2013; Amec, 2015):

Wells	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
Upper	1,390 – 3,980	4.7 – 11.8	559 – 2,100	185 – 2,400
Intermediate	2,230 – 2,670	4.8 – 6.9	980 – 1,560	162 – 555
Lower	2,100 -3,200	6.2 – 9.4	806 – 1,280	385 – 527

The Exxon/Mobil Hill Lease is located in the western part of the BWSD along State Highway 33. Shallow groundwater is monitored both beneath and down-gradient of the Hill Lease. A 2012 monitoring event reported the following (Cardno ERI, 2013; Amec, 2015):

Wells	EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)
Hill Lease	4,000 – 25,000	4,160 – 19,300	2.5 – 48.7	830 – 2,000

The Valley Water Management (VWM) Ponds located near the Belridge oil field complex were recently found to be in non-compliance with several regulations by the RWQCB. Members of the VWM cooperative are reportedly working with the RWQB to come into compliance in order to avoid further enforcement, including the recent imposition of a Cease and Desist Order from the RWQCB.

As with the totality of other data sets discussed elsewhere in this subsection, these data support the conclusion that the groundwater quality beneath the BWSD is largely naturally degraded and is sometimes impacted by localized anthropogenic activity (e.g., evaporation ponds). That said; the groundwater beneath the WDWA is almost exclusively unsuitable for MUN and most, if not all, AGR or other beneficial use without blending and/or desalination. There is also the potential for these primarily naturally degraded groundwaters to migrate outside the WDWA where it would produce or perpetuate an undesirable result in adjacent GMAs. To mitigate any undesirable result related to poor water quality originating from the WDWA, the WDWA will work in close cooperation with oil producers and down-gradient, adjacent GMAs during the

implementation of the KGA GSP to conduct sentry monitoring as part of the WDWA MNP in order to assess for changes in groundwater quality on its boundaries.

2.6.5.10 Kern County Water Agency

As part of a recent study, Amec (2015) requested the KCWA groundwater data from across the Westside. A review of data for 66 wells found that EC values ranged from 370 umhos/cm to 55,600 umhos/cm. Boron ranged from 0.48 mg/L to 14 mg/L, and sulfate ranged from 130 mg/L to 1,300 mg/L (Amec, 2015). The breadth and scope of this review again documents and confirms that, with few exceptions, the water quality beneath the WDWA is predominately brackish to saline and of poor quality.

2.6.5.11 Adjacent Areas and Other Studies

The Dudley Ridge Water District (DRWD), located outside and generally down-gradient to parts of the WDWA, is immediately north of the LHWD in Kings County. Like the WDWA, the groundwater beneath the DRWD is similarly degraded by naturally occurring TDS and salts. A DWR (1964) Feasibility Study (FS) to evaluate the viability of providing SWP surface water to the DRWD found that, *"There are some producing water wells in the extreme northern portion of the District which provide a small portion of the present water supply. Most wells that have been drilled, however, have been abandoned due to poor yield and poor quality of groundwater..."* (Amec, 2015). A subsequent siting study and monitoring program conducted by Amec on behalf of the Los Angeles County Sanitation District for its bio-solids composting facility on the eastern side of the DRWD, found TDS and sulfate concentrations in groundwater ranging from of 5,920 mg/L to 26,800 mg/L and 2,930 mg/L to 11,600 mg/L, respectively.

Starrh & Starrh Growers provided Amec with 2010 data from a then newly installed well in the southern part of the WDWA. The summarized results are provided below (Sanden, 2012; Amec, 2015).

Wells	EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)	Arsenic (mg/L)
Starrh & Starrh	3,000	2,300	7.1	1,000	16

The Starrh & Starrh well data is consistent with a majority of the other groundwater data in the WDWA and indicates this water is unsuitable for MUN without membrane desalination, and is also unsuitable for many sustained AG uses without blending.

Adjacent, and generally down-gradient to the east of the WDWA; the SWSD is susceptible to undesirable results from naturally degraded brackish groundwater migrating out of the WDWA and towards the SWSD. In a recent SWSD AWMP, the SWSD stated that, *"In general, groundwater in the west has higher TDS content relative to the eastern part of the District.*

Groundwater of poor quality, typically a sodium chloride or sodium chloride-sulfate type with high concentrations of dissolved solids and chlorides, can be found extensively along the western side of the San Joaquin Valley" (Provost & Prichard, GEI 2013; Amec, 2015).

As described elsewhere in this section, the BVWSD, located to the east and south east of the WDWA, and portions of the WKWD located to the south of the WDWA, are also potentially susceptible to groundwater quality undesirable results by migration of brackish groundwater originating from the WDWA.

In 2013, Amec, on behalf of the WWQC, sampled a total of 21 wells. Twenty samples were collected from the WDWA, and one sample from the adjacent down-gradient DRWD. The wells were of various depths and screen intervals and were distributed across the WDWA as follows (Amec, 2015):

- LHWD (4 wells)
- BMWD (6 wells)
- BWSD (10 wells)
- DRWD (1 well

The results for this sampling event are summarized below (Amec, 2015):

Wells	EC (umhos/cm)	TDS (mg/L)	Boron (mg/L)	Sulfate (mg/L)	Arsenic (mg/L)
LHWD	2,700 – 5,800	2,000 – 4,000	0.8 – 3.3	470 – 1,300	<2 – 10
BMWD	1,800 – 3,200	1,300 -2,600	1.6 – 6.7	450 – 1,200	<2 – 22
BWSD	2,900 – 21,000	1,800 – 18,000	3.3 – 47	510 – 2,200	2 – 33
DRWD	4,500	3,000	1.2	1,200	14

In addition, water hardness was also evaluated. The results for the hardness analysis are provided below (Amec, 2015):

Wells	Hardness (mg/L)
LHWD	790 – 1,200
BMWD	470 – 890
BWSD	510 – 5,600
DRWD	960

It was concluded that all 21 samples exceeded the State MCLs for drinking water for EC and TDS. The results for hardness in this study would classify all of the samples as being very hard water. Hardness values above 120 mg/L typically require softening in order to prevent scaling deposits in pipes and water heaters (Amec, 2015).

The occurrence of high TDS groundwater in the Westside has recently been further documented in a preliminary groundwater salinity mapping study conducted by the USGS (Metzger and Landon, 2018). In the study, the distribution of groundwater salinity for 31 oil fields and adjacent aquifers across major oil-producing areas of central and southern California were mapped. The objective of the study was to describe the distribution of groundwater near oil fields having TDS less than 10,000 mg/L by using existing TDS data from petroleum and groundwater wells to map concentrations and document data gaps. Within the KCS, the study reported much higher TDS in groundwater from Westside oil field wells and groundwater wells, when compared with east side groundwater wells and oil wells. Metzger and Landon (2018), among others, suggest that higher TDS in the Westside of the KCS could be related to a combination of natural conditions (Westside sediments derived from marine deposits with some saline connate water) and anthropogenic factors such as, among other things, infiltration of TDS from former oil field disposal ponds and/or agricultural drainage ponds. Naturally occurring higher TDS water is consistent with historical reports (several reports from before wide-spread agricultural development) and is documented for more than 60 miles from north to south in the KCS (KCDEH, 1980; KCDEH and KCWA, 1982; GEI, 2019).

2.6.5.12 Contamination Plumes

An evaluation of contamination plumes was conducted via the GAMA Groundwater Information System. The GAMA contains information from other State data bases such as the Department of Toxic Substances Control (DTSC) EnviroStor, and the SWRCB GeoTracker. This section presents the potentially impacted sites as were listed in the regulatory databases it should be noted that it is not the intent of this Chapter GSP to evaluate or confirm whether any of these sites are impacting beneficial use. It is important to recall that information provided in this Chapter GSP has documented that groundwater in the WDWA is primarily naturally degraded and is not suitable for most uses, including drinking water, nor is there any public water system use. The following programs from GAMA were reviewed:

- WDR;
- Underground Storage Tank (UST);
- Leaking Underground Storage Tank (LUST);
- Cleanup Program Sites;
- DTSC Hazardous Waste Sites;
- Department of Pesticide Regulation;
- Oil and Gas Sites; and
- Integrated Lands Regulatory Program.

Although the GeoTracker database did not show any sites with WDRs, in the WDWA, there are many sites in the KCS and WDWA that operate on WDRs issued by the Central Valley Regional

Water Quality Control Board (CVRWQCB or RWQCB). Facilities with WDR's typically include water treatment facilities, wastewater treatment facilities, oil and gas produced water treatment facilities, confined animal facilities and sites that are under active groundwater remediation. The GeoTracker also does not identify any confined animal facilities in the KCS, even though CIWQS shows there are approximately 264 such sites in Kern County. A non-profit Central Valley Dairy Monitoring program was formed in 2010 to develop a monitoring and research program to study the ecological effects of dairies in the Valley. This group recently submitted a report summarizing the findings of their monitoring. One of the recommendations was to develop and administer a web-based portal and data management system. Sites that were or are currently being studied under the oversight of the RWQCB were discussed in **Section 2.6.5.9**

Oil field wells permitted under the DOGGR and the US EPA UIC Program were not included on the figures or the related site table described below because the UIC requires that oil operators confine injected produced water to the approved zone to ensure that injected fluid does not impact off site underground sources of drinking water. Produced oil field water is discussed further in **Section 2.7.4.**

Figure 23a shows the location of sites extracted from the EnviroStor and GeoTracker data bases. **Figure 23b** presents Permitted Discharge Locations, of which there are approximately 44 in the WDWA, a majority of which appear to be related to oil field produced water treatment facilities. **Appendix E** lists the data acquired from the aforementioned regulatory sources in this section. Data was included on the subject table only if they applied to the following criteria (GEI, 2019):

1. Potential media was described as "groundwater", "other groundwater", or "unknown"
2. Contaminate of concern was described or classified as "unknown"
3. Site was classified as "not closed", and had one of the following modifiers:
    - Active cleanup
    - Active land use restrictions
    - Open remediation
    - Open site assessment
    - Open-eligible for closure
    - Inactive-action required
    - Under review
    - Open-inactive
    - Inactive permitted
    - Inactive unpermitted

2.7 Water Budget

2.7.1 KCS and KGA Water Budget Development

All GSAs in the Kern County subbasin (Subbasin) coordinated and collaborated on the development of a groundwater model (Model) to evaluate historical, baseline and projected groundwater conditions. The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop the Model on behalf of the Subbasin. The contract required that Todd Groundwater use the C2VSim model provided by DWR. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (see Attachment H in Umbrella GSP). Basin-wide water budget results from the Model are provided in Attachment H and show the Subbasin, as a whole, has a total storage deficit of approximately 324,326 AFY over the baseline period.

The Subbasin's dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a GSA-level water accounting system (Checkbook) using Subbasin specific values for supply, demand and net results. The Model results reflect Subbasin-wide conditions and do not allocate water shortages/surpluses, nor do the results allocate the "ownership" of water. As a result, the GSAs, through a coordinated effort, developed the Checkbook that estimates current conditions for each GSA that are generally consistent with the Model results under baseline condition. The Checkbook and Model budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability in the interest of developing a Subbasin coordinated approach.

To ensure the individual water budgets reflected actual conditions, the KGA members developed the Checkbook budget and coordinated water accounting methodology. The result of that effort indicates a current baseline shortage/deficit for KGA members of approximately-256,281 AFY. This reflects the difference between a total demand for KGA members of 1,939,409 AFY, and a total supply of 1,683,128 AFY. Of the shortage/deficit of the KGA, the WDWA's portion of the KGA shortage/deficit is a surplus of +33,167 AFY. Or a difference in demand of 285,000 AFY and a water supply of 318,167 AFY.

As is mentioned above, each estimate includes data gaps and has varying degrees of accuracy and/or reliability. The Checkbook is complimentary to the Model and reflects the allocation of water supply benefits and obligations independent of geographic constraints within the Subbasin. This was important to recognize and ensure the coordination of the various groundwater banking projects and water management programs amongst the various GSAs within the groundwater basin.

As with other GSA-level budgets, the preliminary WDWA estimates also include data gaps and have varying degrees of accuracy and/or reliability that will be addressed by the collection, analysis, and reporting of additional representative data. However, it should be noted that the six unique WDWA hydrogeologic conditions (e.g. naturally degraded groundwater quality etc.), relative to the rest of the KCS, rend WDWA groundwater unusable unless it is blended or treated.

2.7.2 WDWA-Specific Water Budget Development and Issues

With regard to the WDWA, agricultural activities are the largest source of water demand, and such activities rely almost exclusively on surface and other imported water from the Aqueduct. There is currently a lack of representative groundwater elevation data in the WDWA. This data gap is due to the limited amount of annual groundwater pumping, which is directly attributable to naturally poor water quality. As discussed in **Section 2.7.1**, the water budget for the WDWA is currently based on the two independent and contrasting surrogate approaches described below that bookend the range of potential water supply: (1) The Checkbook Approach and (2) The Modeling Approach.

The Checkbook Approach is a typical approach based on an accounting of preliminary supply and demand and, as previously noted, is used by other GMAs in the KGA. The KGA Checkbook approach combines SWP water, alternative imported water (i.e. total Aqueduct water), a preliminary value of groundwater "Native Yield", and a currently estimated value of precipitation in areas of irrigated acreage, to estimate the available water supply. The Checkbook value of "Native Yield" is intended to encompass all groundwater recharges and discharges that apply to the WDWA but does not explicitly include groundwater underflow, which as discussed below is a critical element of the WDWA water budget. Furthermore, it is important to understand that the term, "Native Yield*",* implies *suitable groundwater quality,* a condition that does not generally apply to the WDWA. Due to the six aforementioned unique hydrogeologic characteristics of the WDWA discussed in the **Executive Summary** and **Section 2.1**, with geologic sediments of marine origin contributing directly to naturally degraded groundwater, and degraded brackish groundwater underflow chief among them, groundwater quality in the WDWA is poor and unsuitable for most uses. For example, virtually all groundwater pumping is and has been minimal and is used for the sole purpose of blending with better quality imported surface water when the supply of Aqueduct water is low.

All of the groundwater in the Native Yield in the modified WDWA Checkbook is comprised of naturally degraded brackish groundwater that is considered unsuitable for most use without blending or treatment and is therefore *"outside"* of the water budget. The Checkbook approach is a simplified illustration of potential groundwater resources and is only capable of providing an estimate of the current operational water budget, as well as preliminary 2030 and 2040 water

supply operational budgets. The projected estimates are sufficient to encompass phased groundwater pumping for the twin purposes of landowner blending, including anticipated increased pumping in response to climate change, as well as pumping and treatment for a proposed conjunctive reuse management action discussed in **Section 5.0** of this Chapter GSP.

The second Water Budget approach used in this Chapter GSP is based on available modeling conducted by the KGA. As noted above, it should be emphasized that the subject numerical groundwater model, C2VSim-Kern, is intended as a Subbasin-wide assessment of groundwater conditions and is not specifically calibrated to the WDWA service area. The C2VSim-Kern model is based on an uncalibrated Beta version of the DWR California Central Valley Groundwater-Surface Water Simulation Model, known as the C2VSimFG-BETA. The C2VSim-Kern modeling results are available for historical conditions for the WDWA, which were used to develop the current conditions water budget. C2VSim-Kern modeling results are also available for future baseline conditions and future conditions that include water projects proposed by all KCS GSAs, but these results are only available for the KCS at large; WDWA-specific results are not currently available (see **Section 2.7.2.2**). These scenarios will continue to be updated and adjusted for the KCS as a whole during the first GSP reassessment period. Additional pumping to support the planned treatment conjunctive reuse of brackish groundwater is described in **Section 2.7.2.1 and Section 5.3**.

Neither of these two approaches (Brackish Water Checkbook or C2VSim-Kern) explicitly considers the poor water quality in the WDWA or provides a definitive illustration of the WDWA-specific water budget but, in the current absence of sufficient groundwater elevation data in the WDWA, they do provide a framework for revising the water budget components based on data collected in the coming years. **Figure 24a** presents the C2VSim-Kern model zone map for the water budget area. **Figures 24b, 24c, and 24d** show graphic presentations of both approaches to estimating a preliminary WDWA groundwater budget, and current and projected groundwater pumping.

It should be noted that the C2VSim-Kern historical model overstates the amount of groundwater pumping that has and is occurring in the WDWA. For the purpose of comparison, the relatively low actual groundwater pumping (i.e. currently 3,000 AFY) is used in the following and ongoing discussions, and the overstated pumping volume from the C2VSim-Kern historical model is retained for the time being in those respective current-condition water budget estimates, as described below in **Sections 2.7.2.1 and 2.7.2.2**. Given this, the Brackish Water Checkbook approach is presently the more representative estimate of a water balance for the WDWA. Additional reconciliation of basin water budgeting efforts is a high priority for all of the GSAs as part of GSP implementation.

2.7.2.1 Brackish Water Checkbook Approach

The WDWA Checkbook approach combines SWP surface water, various supplemental surface water supplies (i.e. other Aqueduct water), a preliminary value of operational Native Yield, and a current value of precipitation to estimate the available water supply. Groundwater pumping is not explicitly accounted for in the Checkbook but is rather considered a portion of the Native Yield. As noted above, the Checkbook value of Native Yield is intended to encompass all groundwater recharges and discharges that apply to the WDWA but does not include groundwater underflow. The WDWA Native Yield for the purpose of the preliminary Checkbook is conservatively estimated to be 0.15 af/ac., multiplied by all WDWA acreage (i.e. 227,193 acres). This results in a volume of approximately 34,079 AFY. Unique to the WDWA is the fact that all sources of groundwater (e.g. underflow, recharge etc.) are eventually degraded due to the geology and are unsuitable for most use. Therefore, the brackish groundwater is necessarily considered as "*outside*" the water balance unless blended or treated. If the poor water quality, minimal levels of pumping in the WDWA, and volume of modeled degraded underflow (~111,000 AFY; see **Section 2.7.2.2**) leaving the WDWA are accounted for, a Native Yield of up to 0.30 af/ac may be supportable. If applied, it would result in a potential Native Yield range of 34,079 AFY to 68,158 AFY that could be utilized for blending or treatment for conjunctive reuse. This volume represents approximately 30%-60% of the current total C2VSim-Kern estimate of brackish groundwater underflow leaving the WDWA (**Figures 24b, 24c and 24d**).

The currently estimated Brackish Water Checkbook precipitation factor was based on KGA and CIMIS data for the WDWA. It utilizes a factor of 0.2 af/ac. multiplied by the number of irrigated acres (88,989 acres) in the WDWA. This results in a volume of approximately 17,798 AFY that can potentially meet a portion of crop demand.

The volume of available surface water includes SWP Table "A" water (204,698 AFY), Article 21 water (23,878 AFY), as well as purchased alternative imported water (37,714 AFY), which includes just WDWA purchases from outside the basin, but excludes WDWA intra-basin purchases/transfers and intra-basin purchases/transfers by individual landowners. All of this water is delivered to WDWA via the California Aqueduct. Together, this results in a currently available surface water supply of approximately 266,290 AFY. The surface water supply for current conditions was not adjusted for the preliminary 2030 and 2040 water budgets. Rather, if delivered volumes of surface water decrease over this time horizon it was assumed that management actions would be taken by the WDWA and is growers to reduce demand or increase supply.

As noted above, groundwater pumping is not explicitly accounted for in the Checkbook, but illustrations of current and projected pumping are shown on **Figures 24b, 24c, and 24d**. Pumping in the WDWA is not expected to approach the preliminary range of brackish Native

Yield until 2040. Current conditions (**Figure 24b)** indicate only 3,000 AFY of brackish groundwater is utilized to meet demand, and this water is used primarily for blending with Aqueduct water. In 2030 (**Figure 24c),** a projected pumping increase to 5,400 AFY is anticipated for the purpose of blending in order to account for climate change, in addition to another 20,000 AFY of brackish groundwater underflow being pumped for treatment and conjunctive reuse as described in Proposed Management Action (PMA) No. 3. In 2040 (**Figure 24d),** the full potential range of brackish Native Yield of 34, 079 to 68,158 AFY is utilized: 5,400 AFY for blending, and the remainder for proposed PMA No. 3 feedstock water for treatment and conjunctive reuse. This amount of feedstock pumping is considered a maximum value, because it is anticipated that some percentage of oilfield-produced water will be available for treatment and reuse in conjunction with brackish groundwater underflow. In the WDWA, total water demand is essentially equivalent to crop demand. For current conditions, demand is estimated to be 285,000 AFY (**Figure 24b**). To account for climate change, estimated demand is conservatively increased to 300,000 AFY in 2030 (**Figure 24c**) and 316,000 AFY in 2040 (**Figure 24d**).

The Brackish Water Checkbook method provides a preliminary estimate of available water supply. It should be emphasized that the values stated above provide a framework for data-based updates in the coming years and are not intended to be used for allocation purposes. Future allocations, if any, will be addressed through a stakeholder process.

2.7.2.2 Modeling Approach

Groundwater modeling conducted for the KGA utilizing the C2VSim-Kern model provided estimated volumetric flow rates for key water budget components. It should be noted again that the subject model is intended to be a Subbasin-wide assessment of groundwater conditions and is not specifically calibrated to the WDWA service area at this time. Additional reconciliation of water budgeting efforts for the Subbasin and the WDWA is a priority as part of GSP implementation. The managed supply and demand components of the model were updated with data provided by KGA-member water management agencies and other KCS GSAs to develop C2VSim-Kern. The details of the model updates, as well as the KCS-level modeling results, are described in a Technical Memorandum prepared by Todd Groundwater, *Historical and Projected Future Water Budget Development* (Attachment H in the KGA Umbrella GSP).

Water demand in the WDWA is dominated by irrigated agriculture. The C2VSim-Kern model calculates crop demand based on crop type and distribution, climate, and soil type. In the WDWA, water supply is predominately (approximately 95-98%) delivered via the California Aqueduct, which includes SWP water and other supplemental import (i.e. Aqueduct) water. Based on available data, less than 2% of the WDWA water demand is met by groundwater pumping, which is utilized primarily for the purpose of blending.

According to the C2VSim-Kern model, there is currently an imbalance in the WDWA between agricultural water supply and demand, resulting in an average agricultural shortage (deficit) of 80,000 AFY for the WY 1995-2014 period. This equates to an estimated shortage of 8.4 inches/year per irrigated acre. By way of contrast, available data indicate that actual demand more or less tracks with average Aqueduct deliveries for this same period. Locally, this imbalance indicates that either: (1) a substantial amount of deficit irrigation or other water management techniques are being implemented by the growers in the WDWA and/or (2) the crop demand is overestimated by the C2VSim-Kern model. A preliminary review of the model data indicates that an overestimation of crop types and associated demand (i.e. pumping) likely account for a majority of this disparity in the model. This phenomenon, and other refinements to the numerical model, will be assessed further during the first five-year reassessment period and reported in a future reassessment report. As noted previously, current WDWA Aqueduct surface water deliveries, less intra-basin WDWA purchases and individual land-owner intra-basin purchase and transfers are approximately 266,290 AFY. Total current demand WDWA is estimated at 285,000 AFY.

Current Conditions

Based on KCS-level C2VSim-Kern modeling for the period WY 1995-2014 (i.e. current conditions), total groundwater recharge is approximately 92,341 AFY:

- Underflow from the Coastal Ranges: ~ 55,264 AFY
- Underflow into the WDWA from adjacent Districts: ~837 AFY
- Water loss from imported water canals: ~8,844 AFY
- Areal recharge (deep percolation): ~24,227 AFY
- Water loss from ephemeral stream flow: ~3,169 AFY

Areal recharge (i.e., deep percolation in C2VSim-Kern) is the distributed recharge to groundwater from the unsaturated zone. It is equal to percolation out of the root zone plus or minus flow out of or into unsaturated zone storage. Percolation out of the root zone is a combination of applied water and precipitation in excess of ET.

As noted previously in this report, C2VSim-Kern is overestimating the volume of WDWA pumping extractions under current conditions. Because the primary source of water for agriculture in the WDWA is via the Aqueduct, the volume of discharge due to extraction by pumping wells has historically averaged less than 2% of annual demand. Pumping is currently estimated at approximately 3,000 AFY. The overestimated pumping volumes in the model will be addressed in future model simulations. The total estimated groundwater discharge for the current-conditions model simulation is approximately 138,540 AFY. The individual C2VSim-Kern discharge volumes, which will be refined as new data become available, are:

- 98,581 AFY for underflow out of the WDWA towards the down-gradient axis of the Valley;
- 12,403 AFY for underflow to non-districted areas to the north, south, and west; and
- 27,556 AFY by pumping extraction (significantly overstated in the current model).

The current C2VSim-Kern overdraft for the WDWA, which uses the overstated higher value of pumping, is estimated to be -46,200 AFY (rounded up here to 47,000 AFY to account for uncertainty in the model). This deficit in the water budget is met in the C2VSim-Kern model by approximately 46,000 AFY that enters the groundwater flow system from groundwater storage. Because groundwater pumping is overstated in C2VSim-Kern, the current simulated change in groundwater storage is also overstated and is likely significantly lower (i.e.~22,000 AFY). Taking into account future conditions due to climate change (i.e. reduced precipitation and recharge) and an associated increase in pumping extraction from the current 3,000 AFY to 5,400 AFY, the change in storage could conservatively increase to approximately 30,000 AFY. This adjusted estimate of change in groundwater storage is still significantly less than that derived from the current C2VSim-Kern model. Because actual discharge by pumping extraction is approximately 3,000 AFY, the majority of the modeled change in groundwater storage for the WDWA is due to downgradient groundwater underflow out of the WDWA towards adjacent management areas generally to the north and east. Said another way; even if all pumping were to cease in the WDWA, a deficit (and resultant decrease in groundwater storage) would still exist due solely to groundwater underflow leaving the WDWA toward the axis of the basin. This natural phenomenon, which is possibly being accelerated by pumping in adjacent downgradient GMAs, is beyond the control of the WDWA.

C2VSim-Kern Future Conditions

A total of six C2VSim-Kern future-conditions model scenarios were developed by Todd Groundwater for the KGA for the KCS as a whole (KGA Umbrella GSP Attachment H). Future-conditions scenarios are not available for the WDWA at this time. Three of these KCS scenarios are for “baseline” conditions, i.e. scenarios that do not consider water management actions:

- Future Baseline Conditions: Repeat historical hydrology with expected future water supply;
- 2030 Climate Conditions: Adjust historical hydrology for 2030 climatic conditions and expected water supply; and
- 2070 Climate Conditions: Adjust historical hydrology for 2070 climatic conditions and expected water supply.

The other three future-conditions scenarios are the same as above but include proposed water management actions (i.e. SGMA and other projects). Future-conditions results for the KCS as a whole are:

- Future Baseline Conditions;

- No Projects: shortage/deficit of -324,326 AFY
- With Projects: surplus of +85,578 AFY

- 2030 Climate Conditions;
  - No Projects: shortage/deficit of -372,120 AFY
  - With Projects: surplus of +46,829
- 2070 Climate Conditions;
  - No Projects: shortage/deficit of -472,336 AFY
  - With Projects: shortage/deficit of -45,969 AFY

It should be noted that C2VSim-Kern is uncalibrated, particularly with regard to the groundwater flow system (i.e. geologic complexity, aquifer storage parameters, and hydraulic conductivity). The lack of calibration may significantly affect the modeled change in groundwater storage and groundwater underflow. For purposes of this Chapter GSP, it is assumed that this issue will be addressed in the coming years and any changes will be reported in the relevant update report.

2.7.3 Surface Water

All significant surface and imported water delivered by the Aqueduct to the WDWA is utilized for agricultural irrigation, except for minor amounts diverted for industrial use, when available. The supplies sourced from the Aqueduct are primarily SWP water, along with some supplemental import water purchases, although not all supplemental water is from the SWP. Current annual surface water deliveries (i.e. all Aqueduct sources) are estimated at approximately 266,290 AFY. The C2VSim-Kern average annual Aqueduct deliveries to the WDWA for the WY 1995-2014 period are approximately 272,000 AFY. The C2VSim-Kern evapotranspiration of applied water (ETAW) for this period is 241,000 AFY, for a balance of 31,000 AFY potentially available for groundwater recharge. For comparison purposes, the C2VSim-Kern ETAW in 1989 was 287,000 AFY and in 2015 it was 257,000 AFY. **Figure 25** presents annual surface water deliveries to the combined WDWA.

2.7.4 Source and Point of Delivery of Imported Water Supply

The sources of imported surface water used for irrigation in the WDWA are the SWP and other supplemental surface water delivered via the Aqueduct to the member water districts of the WDWA. Member water-district infrastructure for delivery of Aqueduct water is detailed in their individual AWMPs, which are available on their respective websites.

2.7.4.1 State Water Project (SWP)

Two types of contract water are available from the SWP, including a contract supply of “Table A Water”, and surplus “Article 21 Water”. Table A Water takes its name from an exhibit to the contract between the DWR and the SWP contracting agencies that serves as the basis for

allocating surface water among the agencies. Due to a variety of factors, including hydrologic conditions, reservoir storage capacity, and projected runoff, the SWP cannot deliver full Table A Water allocations in most years. Accordingly, a percent allocation is set each year and is applied to each contractor's Table A Water amount. Deliveries to the WDWA from the SWP are via the California Aqueduct (GEI, 2019).

While the reliability of SWP water is less than was anticipated when the contracts were executed, a contract amendment, introduced in the Monterey Agreement of 1994, put agricultural and urban contractors on equal footing with respect to the allocation of water supply during shortages. Prior to the amendment, agricultural contractors were burdened with a larger share of any shortages (Amec, 2015; GEI, 2019).

Article 21 Water cannot be scheduled and must be taken when declared to be available. The following conditions govern the availability of Article 21 Water:

- Available only when deliveries do not interfere with Table A allocations and SWP operations;
- Available only when excess water is determined to be available by DWR;
- Available only when conveyance capacity is not being used for SWP purposes or scheduled SWP deliveries; and
- Cannot be stored within the SWP system. In other words, contractors must be able to use the Article 21 water directly or store it in their own system.

Article 21 Water is typically only available during the December through March wet months of the year (GEI, 2019). **Figures 27a** through **27c** present the infrastructure utilized for the delivery of import water to the three members of the WDWA. Average Article 21 deliveries to the combined WDWA member water districts over the period between 1995 and 2017 were approximately 23,878 AFY (KGA, 2019).

2.7.4.2 Central Valley Project (CVP)

In 1973, DWR completed the initial facilities of the SWP, including the main line of the California Aqueduct. Portions of the SWP were constructed for use in conjunction with the facilities of the CVP. As the State and Federal projects developed, a group of water users planned the Cross Valley Canal as a means of taking delivery of CVP water conveyed through the California Aqueduct. The KCWA was formed in the 1960s to contract with the DWR for the importation of SWP water to Kern County. The California Aqueduct, the SWP's principal conveyance feature, transports water from the Delta along the western side of the San Joaquin Valley to the KCS. Individual water districts holding contracts with KCWA have turnouts directly from the Aqueduct into their service areas or receive water via the Cross Valley Canal. The Cross Valley Canal was completed in 1975 and, in 1976, the water users entered into three-party contracts with DWR and the Department of Reclamation. Under these contracts, CVP water available to Reclamation

in the Sacramento River Delta can be pumped by the SWP's Harvey O. Banks Pumping Plant into the California Aqueduct for delivery to the Tupman turnout, where this water is diverted into the Cross Valley Canal. This Federal water conveyance, which is subordinate to conveyance of SWP water, can then be delivered to water users in the KCS (GEI, 2019).

2.7.5 Oil field Produced Water

There are currently 16 oil and gas fields or portions thereof in the WDWA (**Figure 26**). Productive oil and gas reservoirs (pools) include:

- Tulare Formation (Pleistocene);
- Etchegoin Formation (Pliocene);
- Monterey Formation (Miocene);
- Temblor Formation (Oligocene); and
- Kreyenhagen Formation (Eocene).

Oil field produced water in western Kern County typically contains entrained oil, elevated TDS, and other constituents. Because of this, oil field produced water is unsuitable for any beneficial use without extensive treatment. Produced water is managed by either recycling it for enhanced oil recovery (EOR) operations, such as steam/cyclic steam flooding or water flooding, or by exempted disposal in deeper zones. Both of these activities are under the regulatory oversight of the DOGGR and the US EPA. Produced water used for steam or water flood EOR is typically reinjected under permit into the same geologic zone from which it was produced (e.g., Tulare or Etchegoin Formations) to help maintain oil reservoir pressures and sweep residual oil towards planned oil extraction wells. During this process, a portion of the water that is recycled is inevitably lost to the geologic formations within the field or to the process of steam generation, etc. In addition, so called "*make up water*", from freshwater sources like the Aqueduct, may be added to the process depending on field conditions. Reinjection of produced water back into the zone from which it was extracted potentially helps to mitigate the rate of local land subsidence. It is important to clarify that the type of EOR discussed here is not hydraulic fracturing.

Disposal of brackish and saline oil field produced water in Western Kern County has typically employed two methods: (1) evaporation ponds; or (2) reinjection into exempt aquifers identified for this purpose pursuant to regulations of the Federal UIC Program. The UIC is administered in California under the oversight of the DOGGR and the US EPA. Due to water quality concerns, many of the produced water disposal ponds in Kern County have been closed. Consequently, reinjection into exempt aquifers has become the primary method of produced water disposal. Aquifers identified for permitted disposal reinjection are by design isolated from nonexempt underground sources of drinking water. As with the EOR methods described above, disposal-well reinjection does not involve, nor is it in this case related to, hydraulic fracturing.

As part of the aquifer exemption (AE) process, oil producers are required to complete a detailed geologic study of the zones selected for reinjection. When reviewing applications for AE permits, DOGGR consults with the SWRCB and/or the relevant RWQCB. A key requirement of this multi-agency review for AE approval is to ensure that oil field reinjection activities do not impact designated underground sources of drinking water.

In summary, a significant percentage of the oil field produced water in the WDWA is either recycled into the same geologic zones it was produced from for the purpose of EOR or is sequestered in deeper zones that are isolated from underground sources of drinking water. Like groundwater in the WDWA in general, produced oil field water is naturally degraded and exhibits elevated levels of TDS. The concentrations of TDS and crude oil residual in untreated produced water make it unsuitable for any beneficial use without treatment.

Oil field activities, including land subsidence associated with the extraction of oil and gas, are under the oversight of DOGGR, and are therefore outside the control of the WDWA. This element will be assessed further as part of the WDWA MNP and the KGA land subsidence monitoring plan. Data and findings will be reported during the first five-year reassessment period. **Table 1** provides a summary of produced water statistics for the selected oil and gas fields found within the WDWA.

2.7.6 Sustainable Yield

Unique to the WDWA is the fact that all sources of groundwater (e.g. underflow, recharge etc.) are eventually degraded due to the geology and are unsuitable for most uses. Therefore, the brackish groundwater is considered as "*outside*" the water balance unless blended or treated. As defined by SGMA, Sustainable Yield means the maximum quantity of water, calculated over a base period representative of long-term conditions in a basin, and including any temporary surplus; which can be withdrawn annually from a groundwater supply without causing an undesirable result, such as a significant change in groundwater storage or impacts to water quality. The WDWA relies almost entirely on imported surface water to meet current and projected demand. Groundwater use in the WDWA is chiefly limited to blending because of the documented poor quality of WDWA groundwater. Current pumping is on the order of 3,000 AFY. A vast majority of the C2VSim-Kern-modeled change in groundwater storage for the WDWA is therefore not related to groundwater pumping. Instead it is due to brackish groundwater underflow moving downgradient out of the WDWA towards adjacent management areas generally to the north and east. This natural condition, which could potentially impact water quality in adjacent downgradient GMAs, is possibly being accelerated by pumping in adjacent downgradient GMAs and is beyond the control of the WDWA.

The WDWA normalized sustainable yield (i.e. Native Yield) for the purpose of the preliminary Brackish Water Checkbook approach discussed in **Section 2.7** is conservatively estimated to be 0.15 af/ac., multiplied by all WDWA acreage (i.e. 227,193 acres). This results in a volume of approximately 34,079 AFY. If the poor water quality, minimal levels of pumping in the WDWA, the volume of C2VSim-Kern-modeled underflow (~111,000 AFY) leaving the WDWA, and the potential treatment and potential reuse of oil field produced water are accounted for, a Native Yield range of 0.15 af/ac. to 0.30 af/ac. may be supportable. If applied, it would result in a potential Native Yield of 34,079 AFY to 68,158 AFY that could be utilized for blending or treatment for conjunctive reuse. This volume, depending on the amount of oilfield-produced water utilized, represents approximately 30%-60% of the current total C2VSim-Kern-modeled brackish groundwater underflow leaving the WDWA.

2.7.7 Groundwater Storage

The assessment of the quantity and extent of groundwater in the subsurface, and the amount of water that can be sustainably extracted for use, is dependent on the understanding and monitoring of a myriad of factors of a complex natural system; none of which can be determined with absolute certainty. This is because all of these systems are interrelated in some fashion and most are transitory through time. As a result, the WDWA will use directly observable groundwater elevation data as a proxy for determining change in groundwater storage.

Key hydraulic properties used to define changes in storage of groundwater within the saturated parts of an unconfined aquifer system are specific yield and specific retention (irreducible storage). Specific yield and specific retention are functions of sediment porosity and moisture retention characteristics (Faunt et al., 2015; Todd, 2008). Specific yield plus specific retention is equal to sediment porosity. These two properties represent and govern the reversible uptake and release of water to and from storage in unconfined aquifers. In its simplest form, specific yield is a volumetric fraction of the bulk aquifer volume, representing the amount of water that an aquifer yields when it drains under the force of gravity, the results of which are observable by changes in water table elevations. Storativity is defined as the amount of water an aquifer releases from, or takes into, storage per unit surface area of the aquifer per unit of change in head. In unconfined aquifers, storativity is equal to specific yield.

The availability of storage capacity changes with the amount of groundwater withdrawn or recharged. For unconfined aquifers, which comprise a majority of the well completions in the WDWA, a change in storage is expressed as the product of the volume of the aquifer lying between the water table (i.e., groundwater elevation) at the beginning and end of a period of time and the average specific yield of the formation (Todd, 2008). Based on the current preliminary KGA model, the average WDWA groundwater-in-storage during the WY 1995-2014

period is estimated to be 42,400,000 AF. One acre-foot is equivalent to approximately 325,851 US gallons of water.

2.7.8 Water Budget Baseline and Projected Conditions

As previously noted, there is a general lack of representative water budget data available for the WDWA, including changes in groundwater storage. This condition will be remedied by implementation of the MNP discussed in **Section 4.0**. The MNP will collect representative groundwater elevation data for the purpose of, among other things, assessing for lowering of groundwater levels, calculation of changes in groundwater storage and monitoring for land subsidence. The WDWA water budget will be assessed and revised during the first five-year reassessment period as additional representative data become available. For the purpose of this initial submittal, the WDWA is relying on the Brackish Water Checkbook approach to estimate total water supply and demand **(Section 2.7.2.1).** Additionally, the Brackish Water Checkbook and C2VSim-Kern model are being used as a framework for revising the water budget components based on data collected in the coming years. Because of the reliance on Aqueduct water as the primary source of irrigation, the historic use of groundwater has been primarily for blending due to high levels of TDS. Assuming projected climate change estimates are realized, it is likely that projected water budget components over the GSP implementation period of 2040 and beyond will change and evolve as will groundwater and land use management practices. It is expected that pumping volumes for the purpose of blending would increase to approximately 5,400 AFY by 2030 and beyond, up from the current 3,000 AFY.

2.8 Existing/Ongoing Water Resources Programs/Policies

Knowledge of existing and ongoing water resource programs and a close working relationship with the respective lead agencies are key to successful groundwater sustainability planning and management. The sections below discuss some of the key programs utilized to help coordinate data between the various KGA Chapter GSPs.

2.8.1 Existing Monitoring Programs

Various public agencies currently collect and coordinate groundwater monitoring data for wells within the KCS. Based on current conditions, these programs and proposed MNP monitoring activities will not limit the operational flexibility in the WDWA. Where applicable, several databases were utilized to prepare the Basin Setting and other sections of this Chapter GSP for the WDWA. Chief among these are the following:

2.8.1.1 Local Agency Monitoring Programs

Within the WDWA, there are two local groundwater monitoring programs. As reported elsewhere in this Chapter GSP, those agencies are the KCWA, which manages and maintains the

CASGEM Program, and the WWQC, which includes the WDWA. The WWQC began an annual groundwater monitoring program in 2018. These programs will be used as the primary basis of the WDWA MNP described in more detail in **Section 4.0** of this Chapter GSP.

2.8.1.2 Groundwater Ambient Monitoring and Assessment Program (GAMA)

GAMA was implemented in 2000 by the SWRCB to integrate existing groundwater monitoring programs in order to better assess and monitor groundwater quality. The GAMA Basin Priority Project assessed public water system wells to identify and understand risks to drinking water supply. Historically, the program has sampled over 2,900 public and domestic drinking water supply wells. Relevant data from this program will be utilized to compare with the future MNP data for this Chapter GSP in order to quantify and interpret historic and contemporary groundwater level and quality trends.

2.8.1.3 GeoTracker and EnviroStor Databases

GeoTracker is a SWRCB database which allows the agency to manage and share data related to sites that currently impact groundwater or have the ability to adversely impact groundwater resources. Data available on GeoTracker include records of Leaking Underground Storage Tank (LUST) sites, Department of Defense sites, and various permitted activities such as land disposal sites, and oil and gas production sites. GeoTracker is unique in that it collects data from multiple agencies, making it very useful.

The EnviroStor database is managed by the DTSC. EnviroStor provides records of site cleanup activities beginning in 2009 or later. EnviroStor only maintains records of sites where the DTSC is the lead agency and is typically focused on soil cleanups, many of which could have impacted groundwater as a secondary condition. Both GeoTracker and EnviroStor were utilized to assess for potential anthropogenic impacts to groundwater in the WDWA.

2.8.1.4 California Statewide Groundwater Elevation Monitoring Program (CASGEM)

The CASGEM program was created by the State legislature as part of the 2009 California Comprehensive Water Package, which established a coordinated statewide program to collect groundwater elevations and facilitate cooperation between local monitoring agencies and the DWR. The CASGEM database was utilized to search for representative groundwater level and well completion data within the WDWA.

2.8.1.5 Irrigated Lands Regulatory Program (ILRP)

The goal of the ILRP is to protect receiving waters (natural surface waters) from impairment associated with agricultural runoff, tile drain flows, and stormwater flows from irrigated crops and fields. To augment existing surface water data collected by the program, the ILRP was to have started collecting groundwater data beginning in late 2018. The focus of the groundwater

sampling will be to assess water quality related to individual domestic wells. The WWQC, of which the WDWA is a member, has been cooperating with ILRP surface water sampling efforts since its inception in 2003. While the number of individual domestic wells within the WDWA is believed to be limited, the requirements and goals of the ILRP will be considered in the **Section 4.0**.

2.8.1.6 Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS)

CV-SALTS is a stakeholder-managed program whose main objective is to facilitate salt and nitrate management and reduction strategies in the Valley. The objectives and goals of the CV-SALTS program are foundational to those of SGMA and the KCS GSP. Key CV-SALTS goals are:

- Ensure safe drinking water supply;
- Achieve balanced salt and nitrate loading of surface water and groundwater; and
- Implement the long-term restoration and management of impaired water bodies.

Sampling, when required, is conducted in association with explicit WDRs specified by the State and relevant RWQCBs. These typically include, among other things, sampling for chloride, sodium, nitrate/nitrite, and EC. As mentioned, because of the naturally occurring elevated levels of TDS found throughout the WDWA, the WWQC has engaged the CV-SALTS Technical Committee to review its recent draft BPAW prior to submittal to the State. The subject plan recommends the de-listing of MUN and AGR as beneficial uses for perched and unconfined/semi-confined groundwater found beneath a portion of the WDWA. The WDWA plans to coordinate the Chapter GSP MNP with the ongoing sampling activities being conducted by the WWQC to support the BPAW.

2.8.2 Monitoring Data Gaps and Uncertainty

A coordinated (and standardized) database and calibrated groundwater numerical flow model is necessary to ensure that all relevant data is input in a timely manner for the purpose of ongoing sustainability planning. Planning discussions within the KGA at large regarding this topic are ongoing. To achieve coordinated monitoring, data must be collected and reported by local well owners in a systematic way on contemporaneous schedules. To the extent feasible and practical, until a KCS-wide data system is identified, components of the above referenced existing programs and databases will be utilized to help address identified data gaps. It is not anticipated that these plans will significantly limit the flexibility of operations in the WDWA as they will be implemented in cooperation with well owners, adjacent groundwater management areas, existing programs such as the WWQC, and established water banking operations being utilized by the WDWA and its member landowners. Minimum sampling parameters include:

- Groundwater elevation;
- Annual extraction (pumping) volumes; and

- Groundwater quality.

These data, along with surface water supply volumes provided by the WDWA members, will be utilized to assess identified data gaps, and the potential for undesirable results in order to update WDWA water budget components, including precipitation, ETo, sustainable yield and groundwater storage. It is important to note that per SGMA requirements, water budgets must include current, historic, and future conditions. Projected water budgets will be used to estimate and refine future conditions of supply, demand in response to Umbrella GSP implementation, and to identify any new or evolving data gaps or uncertainties pertaining to these water budget components.

Within the WDWA, existing monitoring for representative groundwater occurrence and elevation levels is recognized as a key data gap. A WDWA-specific MNP will be designed to address, to the extent feasible, uncertainties that would affect the efficacy of the implementation of the KGA Plan and, therefore, the WDWA's ability to assess whether the WDWA is being managed sustainably. Identified data gaps within the WDWA management area are:

- Representative groundwater occurrence, groundwater elevations, groundwater trends, groundwater quality and flow directions, and annual extraction volumes; and
- WDWA-specific water budget components and modeling.

2.9 Plans to Address Identified Data Gaps

Preparation and implementation of a comprehensive MNP will directly address the identified data gaps by coordinating a systematic and contemporaneous collection of representative groundwater monitoring and pumping data in consultation with adjacent GMAs. The data will be utilized to update water budget and model components.

2.10 Groundwater Management Area

For the purpose of this Chapter GSP, the WDWA is considered a single combined GMA. The rationale for this approach is threefold:

1. The similar hydrogeologic conditions found across the WDWA and the occurrence of poor-quality brackish groundwater identified throughout the WDWA;
2. The ability to cost effectively leverage and better coordinate future monitoring and adaptive management actions due to the similarities of organizational structure among the WDWA member Districts, as well as similar groundwater use by stakeholders that are served by the WDWA; and

3. The ability to streamline communications, coordination, and planning of sustainability objectives and management actions between the WDWA and adjacent KGA GMAs that are implementing their individual Chapter GSPs.

As designated, the WDWA will operate under a single set of MTs and MOs which, while focused on the WDWA, are also designed to coordinate, to the extent feasible, with adjacent GMAs. As part of the SGMA-required annual update and five-year reassessment process, the status of the WDWA GMA will be re-evaluated and adjusted, as needed. In the unlikely event of internal conflicts between individual member districts of the WDWA, the WDWA Board will consider and resolve the item pursuant to its established rules.

2.11 WDWA Sustainability Goals

Sustainable management in the KCS will result from the implementation of projects and management actions at the member-agency level to maintain its respective use of groundwater within the sustainable yield of the Subbasin, operate at or above established measurable objectives, and operate above established minimum thresholds. The sustainable yield, measurable objectives, and minimum thresholds have been developed based on available technical information and will be reviewed and updated as additional data are collected, as required by SGMA.

Sustainability goals for the WDWA are designed to support the goals proposed in the KGA umbrella GSP, address identified and projected issues and hydrogeologic data gaps, and mitigate the potential for undesirable results within the WDWA. The goals will be achieved through the implementation of coordinated MTs and MOs, such as specific administrative policies, projects, and plans designed to enhance the sustainability of groundwater resources within the WDWA, and by association the KGA at large. It is not anticipated that County land use plans, as currently formulated, will affect the ability of WDWA to achieve its planned sustainability goals, nor will WDWA activities, as part of the GSP, adversely affect County land use planning. The coordination process established in development of the KGA Umbrella GSP and memorialized in the KCS Coordination Agreement will ensure that the KCS is managed as a cohesive unit, and that the individual GMAs within the KCS work collaboratively towards sustainability.

The sustainability goals for the WDWA are:

- Collect additional representative hydrogeologic information to more fully characterize and model the occurrence, condition, and elevation of groundwater beneath the WDWA through the implementation of a comprehensive MNP;
- Leverage, to the extent feasible, the harvesting and treatment of naturally degraded groundwater underflow leaving the WDWA for the twin benefits of conjunctive reuse and

mitigation of potential adverse effects to better quality water in adjacent downgradient districts; and

- Mitigate the potential for the chronic lowering of groundwater levels and significant reduction of groundwater in storage through the coordinated implementation of minimum thresholds (MTs) and MOs within WDWA areas that are adjacent to other downgradient GMAs.

2.12 WDWA Undesirable Results

Based on the current understanding of available WDWA data, an assessment of the six undesirable results identified in SGMA found that two of these do not directly apply to the WDWA. These being:

- Seawater intrusion; and
- Depletion of interconnected surface water.

Of the remaining four, further assessment is provided in the following subsections. The four potential undesirable results are:

- Chronic lowering of groundwater levels;
- Significant reduction of groundwater in storage;
- Degraded water quality;
- Land subsidence.

2.12.1 Seawater Intrusion

The WDWA is located more than 40 miles inland from the Pacific Ocean. Seawater intrusion to aquifers is not feasible, and will not affect groundwater quality within the WDWA, which is naturally brackish. Therefore, seawater intrusion is not considered further in this Chapter GSP.

2.12.2 Depletion of Interconnected Surface Water

Interconnected surface water systems are defined by the State as surface waters that are known to be hydraulically connected by a "*…continuous saturated zone*" to an underlying aquifer (DWR, 2016). As such, there are no interconnected natural surface water systems in monitored areas associated within the WDWA. Various small creeks and drainages within the WDWA are ephemeral and only carry water for brief times during the wet season, usually only immediately after intense precipitation events. The dryland portion of the KNWR that overlaps with the WDWA is not irrigated and relies on seasonal precipitation for habitat maintenance. The scant volume of annual precipitation, and high level of ETo in the WDWA, militates against the likelihood of interconnected surface water systems. Further, recent WWQC monitoring activities have found that the presence of perched groundwater in the WDWA is greatly reduced and

sporadic. As such, depletion of interconnected natural surface water and associated groundwater dependent ecosystems are not considered a recognized or feasible undesirable result. Therefore, no MTs or MOs will be established at this time. Further assessment will be conducted as part of the proposed monitoring Network Plan. Any changes in this finding will be reported in the relevant GSP update report.

2.12.3 Chronic Lowering of Groundwater Levels

The chronic lowering of groundwater levels is the point at which significant and unreasonable impacts over the GSP implementation horizon, as determined by the depth/elevation of water, affects the reasonable and beneficial use of, and access to, groundwater by overlying users. In the KGA, an exceedance is triggered when the MT for groundwater levels are exceeded by at least three adjacent management areas that collectively represent at least 15% of the subbasin or, if non-contiguous GMAs, comprising 30% or more of the subbasin, as measured by the acreage of each management area that exceed their respective MTs (GEI/KGA, 2019).

Groundwater levels in the WDWA are being reduced primarily by the volume of underflow migrating downgradient towards the axis of the basin. Within the WDWA extractions by pumping have been limited due to the demonstrated naturally degraded quality of groundwater which is of little practical beneficial use. There is presently a lack of representative data in the WDWA sufficient to assess for potential chronic lowering of groundwater elevations with a high level of certainty, especially along the downgradient eastern border of the WDWA. A review of currently available data, including, but not limited to, various recorded WDWA well pumping volumes and the individual AWMP reports for the WDWA, indicate there has been little historic reliance on groundwater for the purpose of irrigation in the WDWA due to the availability of Aqueduct and other imported surface water.

The current estimated volume of pumping for irrigation is less than 2% of total demand (i.e., ~3,000 AFY). Of further relevance is the C2VSim-Kern modeled water budget for the WDWA, has identified approximately 111,000 AFY of brackish groundwater underflow migrating from the WDWA towards adjacent downgradient GMAs. The WDWA is studying the feasibility of a project to harvest a portion of the lost underflow by focused pumping for treatment and conjunctive reuse. If determined to be viable, this project could substantially increase the quality and quantity of groundwater retained in the WDWA water budget. In the interim, while MNP data are being collected and the C2VSim-Kern model is refined and calibrated, the WDWA proposes to utilize a groundwater well hydrograph and a series of CV2SimFG-BETA simulated hydrographs to determine historic and projected groundwater trends along its eastern boundary. These data will also be used to establish provisional informational MOs and MTs for the area of the WDWA directly adjacent to the aforementioned down-gradient GMAs. Based on the limited pumping in the WDWA, there are no MTs or MOs proposed for groundwater

elevation for the remaining interior areas of the WDWA at this time. This approach allows for sentry monitoring along the WDWA's downgradient northern and eastern borders with the objective of sustainable management via the harvesting and treatment of a portion of the groundwater underflow as it leaves the WDWA. If reuse is determined to be feasible, it will significantly reduce the potential for an undesirable result related to the accelerated chronic lowering of groundwater levels and significant reduction of groundwater in storage.

2.12.3.1 Groundwater Dependent Ecosystems

The following factors weigh against the presence of groundwater dependent ecosystems in the WDWA:

- The sporadic occurrence and further diminution of the already limited amount of perched water in the WDWA due to drought, physiographic and hydrogeologic conditions and less agricultural surface runoff as a result of improved irrigation and water conservation methods;
- The overall general depth to the unconfined/semiconfined groundwater zone (~200 feet bgs);
- The lack of interconnected surface water systems in the WDWA; and
- The predominately brackish quality of groundwater.

As stated elsewhere in this Chapter GSP a small portion of the WDWA in the LHWD overlaps with the Kern National Wildlife Refuge. These lands are designated as "Uplands Habitat". As such, the area is dry rangeland and, with no operating wells, relies solely on precipitation for its only source of water. To the south, in the Belridge WSD, are portions of the 3,100 acre Lokern Ecological Reserve (LER). Within the WDWA the LER consists of small, scattered and generally non-contiguous parcels (**Figure 10c**). A review of Google Earth imagery shows those portions of the LER in the WDWA are likely Valley sink scrub, and/or Valley saltbrush scrub habitat (aka Alkali Scrub). Those portions of the LER in the WDWA appear to consist entirely of dry, non-irrigated scrub lands that, with no operational wells, rely on annual precipitation as its source of water.

Larger, more contiguous blocks of the LER are present further south of the WDWA roughly between the towns of Lokern and Tubman. The California Department of Fish and Wildlife website describes the LER at large as consisting of marsh, valley sink scrub, and valley saltbush scrub habitat. Although not likely present in the WDWA, vegetation in the marsh habitat includes tule, cattail and other common marsh species.

Further assessment of these areas will be conducted as part of the proposed monitoring Network Plan. Any change to current conditions regarding groundwater dependent ecosystems in the WDWA will be discussed in the relevant annual updates and five-year reassessment

reports as required by SGMA. In the meantime, impacts to groundwater dependent ecosystems will not be evaluated further, and no MTs or MOs are warranted at this time. **Figures 27d through 27f** provide the additional supporting information pertaining to groundwater dependent ecosystems in the KCS.

2.12.4 Significant Reduction of Groundwater in Storage

Change in groundwater in storage cannot be measured directly. In its simplest form, a change in groundwater in storage is reflected by a change in groundwater elevations. A significant reduction in groundwater storage is the point at which significant and unreasonable impacts, as determined by the estimated amount of groundwater in the subbasin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended drought period, which is proposed to be 10 years for the purpose of the KGA GSP. Within the KGA, an undesirable result is determined when groundwater elevations, which act as the proxy for groundwater storage, are depleted to elevations lower than the respective groundwater-level MTs in at least three adjacent management areas that collectively represent at least 15% of the Subbasin or, if non-contiguous GMAs, comprising 30% or more of the Subbasin, as measured by the acreage of each management area that exceed their respective MTs (GEI/KGA, 2019).

The current KGA C2VSim-Kern simulated water budget for the WDWA indicates that changes in groundwater storage in the WDWA management area are largely attributable to non-pumping activities, such as the downgradient underflow of brackish groundwater from the WDWA towards adjacent GMAs and the axis of the KCS. As such, this natural condition, which may be accelerated by pumping in adjacent downgradient GMAs, is beyond the control of the WDWA. As described in **Section 2.11.3**, additional groundwater elevation data and numerical modeling is required, especially along the WDWA's downgradient eastern and northern borders, in order to fully assess this important hydrologic parameter with a high level of certainty. Data gaps related to groundwater elevation (a proxy for change in storage) will be addressed by the collection of representative groundwater elevation data during the first five-year reassessment period. In the interim, the MTs and MOs for this component will be assessed as presented in **Section 3.3.2**.

2.12.5 Degraded Water Quality

Degraded groundwater quality is defined in SGMA as the point at which significant and unreasonable impacts occur over the GSP planning and implementation horizon, as caused by water management actions that affect the reasonable and beneficial use of, and access to, groundwater by overlying users. In the KGA, this is determined when the MT for a groundwater quality constituent of concern is exceeded in at least three adjacent management areas that collectively represent at least 15% of the subbasin or, if non-contiguous GMAs, comprising 30% or more of the subbasin, as measured by the acreage of each management area exceed their respective MTs (KGA, 2019).

Due to the overall naturally degraded quality of WDWA groundwater, as documented by the various groundwater studies presented in this Chapter GSP, no water quality MTs or MOs are proposed for the interior areas west of the California Aqueduct in the WDWA. Groundwater within the WDWA has been documented to be predominately degraded by elevated concentrations of TDS due primarily to the presence of naturally occurring basin-fill sediments derived from marine dispositional environments and associated saline connate waters. These conditions have been documented to exist before widespread development of the west side of the KCS and are outside the control of the WDWA. Because of the poor quality water, agriculture within the WDWA relies primarily on surface water and other imported water provided by the Aqueduct for irrigation. Historically, the primary use of brackish groundwater has been for blending, when deliveries from the Aqueduct are low. Groundwater with TDS concentrations in excess of 2,000 mg/L, which is common in the WDWA, is considered unsuitable for designated beneficial uses without blending or treatment. Because of the presence of naturally occurring brackish groundwater beneath a majority of the WDWA, the WWQC has prepared a BPAW for regulatory review that recommends delisting the designated agriculture and municipal beneficial use for perched and unconfined/semiconfined groundwater under a significant portion of the WDWA.

The current KGA C2VSim-Kern model water budget for the WDWA estimates there is a significant volume of combined natural downgradient groundwater underflow (~111,000 AFY) migrating from the WDWA towards adjacent down-gradient GMAs and the axis of the KCS. This underflow is predominantly brackish. This condition, which may be accelerated by groundwater pumping in adjacent downgradient GMAs, is beyond the control of the WDWA. The downgradient migration of brackish groundwater has the potential to cause an undesirable result by impacting better quality groundwater found in adjacent downgradient GMAs. Therefore, assessment of groundwater quality within the WDWA will focus on sentry monitoring of the boundary between the WDWA and affected down-gradient GMAs to the, northeast, east and southeast in the KCS. The purpose of the sentry monitoring will be to provide timely notification to adjacent GMAs in the event that existing water quality related to TDS concentrations changes significantly. Sentry monitoring will be implemented for groundwater quality along the boundary area that lies generally east of the California Aqueduct in the WDWA. The sentry monitoring activities will be detailed in the MNP and will be coordinated with the relevant adjacent GMAs.

As part of GSP implementation groundwater quality will be assessed in any new wells drilled in the interior of WDWA to help inform planning and implementation of future sustainable management practices and projects.

2.12.6 Land Subsidence

In the KGA, an undesirable result for land subsidence is defined by significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a coordinated basin wide GSP subsidence monitoring plan (KGA, 2019).

Based on recent satellite-based Interferometer Synthetic Aperture Radar (InSAR) data for the period 2007 to 2011, two localized areas of land subsidence were identified in the WDWA: one is adjacent; and just west of the portion of the Aqueduct that lies immediately north and south of the town of Lost Hills (approximately Aqueduct mile post 195-203 and milepost 205-215). Subsidence here is estimated to range between 4 inches to 15 inches. This portion of the Aqueduct coincides with an embankment failure in June 2011 at Milepost 208. This incident was confirmed by surveying, but a specific cause was not identified at the time of the breach. It is important to emphasize that agricultural groundwater pumping in this area has historically been limited due to poor groundwater quality. The other area of subsidence is located approximately midway between town of McKittrick and State Highway 46 and is likely associated with the Belridge Anticline oil field complex. InSAR subsidence there has reportedly ranged from 4 inches to over 25 inches (**Figure 28a**).

A subsequent update to the earlier KGA InSAR data for the period 2015 to 2016 found improved conditions, with the areas adjacent to the town of Lost Hills (e.g. Mileposts 195-215) mostly displaying only minimal subsidence (approximately 2 inches to 6 inches). The areas around the Belridge Anticline oil field also improved somewhat, with the exception of areas immediately proximal to the oil fields, which appear to have remained more or less unchanged from the findings of the earlier InSAR survey (**Figure 28b**). The rebound of topographic surface elevation indicated by the latter InSAR survey in several areas suggests that some of the WDWA subsidence may have a reversible (elastic) component that benefited from the increased winter precipitation during 2015 to 2016.

There currently is no definitive evidence that the subsidence adjacent to the aqueduct near Lost Hills (i.e., Mile Posts 195-215), or elsewhere in the WDWA, is attributable to a single factor. Given that groundwater pumping in the WDWA is limited, the measured subsidence may be the result of a combination of factors, including, but not limited to, oil well extraction, sub-regional geologic structural forces, such as geologic folding or compression, and/or loss of soil moisture in the shallow subsurface via accelerated ETo due to prolonged drought. Still other factors include existing deficiencies in the aqueduct structure itself that could result in shallow differential settlement. Assessment by a combination of iterative geodetic techniques over time (e.g. InSAR, established continuous geo-positioning system (CGPS) data, and depth-specific extensometer monitoring will likely be necessary to more definitively identify the cause of the

embankment failure at Mile Post 208, and to monitor for potential future subsidence in the identified area of interest between Mile Posts 195-215.

Inelastic land subsidence related to the potential dewatering of the Corcoran Clay or other clay layers by water-well pumping is recognized as a potential undesirable result in that portion of the WDWA east of the California Aqueduct, between the WDWA boundary with the SWSD and the BVWSD. To monitor for this type of land subsidence going forward, the WDWA will rely on future InSAR studies and other iterative subsidence monitoring techniques (e.g. CGPS, extensometer, etc.) to be implemented over time in coordination with adjacent management areas as part of the KCS-wide land subsidence monitoring program administered by the KGA.

The WDWA will establish a preliminary MO and MT for land subsidence for those areas closest to the Aqueduct in coordination with adjacent GMAs during the first five-year reassessment report. The subject areas are more or less along the downgradient eastern boundary between the WDWA, the Semitropic Water Storage District and the Buena Vista Water Storage District. This includes the area between Aqueduct Mileposts 195 and 215. Based on current InSAR data results, and the limited amount of groundwater pumping in WDWA, subsidence MTs or MOs for areas interior to the WDWA will not be established at this time. Instead, the WDWA will monitor InSAR data and other geodetic subsidence data adjacent to its eastern boundary in order to make any necessary adjustments to its current MT/MO network for land subsidence. It should be noted that subsidence associated with oil and gas activities is under the oversight of DOGGR pursuant to the California Public Resources Code. The WDWA will coordinate and share subsidence data with those operators that are a party to the KGA Umbrella GSP, but oil field related subsidence is outside the control of the WDWA.

2.13 Effects Beyond the WDWA Chapter Area

Assessment of identified undesirable results that could potentially extend beyond the boundaries of the WDWA will be coordinated with adjacent GMAs, as needed, to ensure the integrated and sustainable management of the WDWA and, by extension, adjacent GMAs and the KGA. For example, although these natural systems and conditions are outside the control of the WDWA, underflow of brackish groundwater found to be migrating downgradient from the WDWA, towards areas of better-quality groundwater in response to regional groundwater flow patterns and adjacent GMA pumping, will be assessed in cooperation with the Dudley Ridge (Kings County) and the Semitropic, and Buena Vista GMAs. To help ameliorate the potential for impacts to adjacent water quality, the WDWA will share groundwater level and water quality data with these adjacent management areas, and will work to coordinate relevant groundwater monitoring activities so that sentry monitoring occurs at the WDWA boundaries contemporaneously with sampling activities being conducted at the SWSD and BVWSD. These data will then become the foundation for other WDWA initiated, or joint management actions

with adjacent GMAs, such as detailed groundwater numerical flow modeling to better track and predict brackish water occurrence and migration.

3.0 WDWA MONITORING NETWORK

To reduce the current level of uncertainty pertaining to groundwater conditions and occurrence within the WDWA, a Monitoring Network Plan (MNP) will be prepared and implemented during the first five-year reassessment period after adoption of KGA GSP. The MNP, which will be reassessed and updated as needed based on data results, will be specifically designed to address data gaps and sustainability indicators identified in this Chapter GSP. The MNP will simultaneously promote coordination with adjacent GMAs and GSAs through the collection of representative data necessary to evaluate changing groundwater conditions that may occur during the planning and implementation horizon of the WDWA Chapter GSP. **Figure 29a** presents the proposed MNP wells. **Table 2** presents well construction details for the proposed MNP monitoring wells. To the extent possible, wells included in the MNP will serve as monitor points for both groundwater quality and groundwater elevation and include wells currently being monitored by the Westside Water Quality Coalition (WWQC). New monitoring wells, if any, will funded by the WDWA. Any new wells constructed expressly for the MNP will be permitted, constructed or abandoned pursuant to relevant Kern County and State requirements. To the extent feasible, costs for new wells and monitoring may be shared with the WWQC and/or other adjacent GMAs/GSAs.

3.1 Monitoring Network Objectives and Rationale

As reported in this Chapter GSP, data related to representative aquifer characteristics and groundwater elevation monitoring within the WDWA is limited and have been identified as an important data gap that must be filled for effective implementation of this Chapter GSP over the short-term, and for the assessment and planning of future adaptive management strategies over the long-term and SGMA implementation horizon. Associated groundwater components that rely on representative groundwater level monitoring include, among others, water budget components, and the identified undesirable results of chronic lowering of groundwater levels, reduction of groundwater in storage and land subsidence. Although not identified as requiring a specific MT/MO, due to previously discussed physiographic and hydrogeologic conditions (**Section 2.12.2**), monitoring of perched groundwater will also be conducted in coordination with the WWQC in order to asses for potential changes in the status of depletion of interconnected natural surface water or undesirable results to groundwater dependent ecosystems. Objectives and elements of the MNP will address the need for representative data and help reduce uncertainty for the purpose of sustainability planning. The MNP, once fully implemented, will help achieve the following objectives:

- Acquisition of representative groundwater level and water quality data sufficient to assess and document short-term, seasonal, and long-term groundwater trends related to WDWA

water budgets, groundwater pumping volumes, changes to groundwater in storage, groundwater elevation, and potential future land subsidence;

- Ability to assess for changes in groundwater conditions relative to identified MOs and MTs; and
- Coordination with adjacent management areas by way of contemporaneous scheduled sampling events, mutually sustainable MTs and MOs, and regularly scheduled status meetings to ensure sustainable outcomes.

The rationale for selecting monitoring wells for inclusion in the MNP are:

- Ability to economically meet the overall MNP objectives; and
- Ability to provide representative data based on physical location, age of well construction and aquifer screened intervals.

The MNP shall incorporate the data quality objective (DQO) process as outlined in the US EPA Guidance on Systematic Planning Using the DQO Process. The MNP shall also include a data quality assurance/quality control (QA/QC) plan to guide the collection and assessment of data. Monitoring will include the use of a standardized database and well data collection form. A summary of MNP protocols and a sample well data collection form is provided in **Appendix F**. MNP field activities will be based on the methodologies described in the USGS National Field Manual for the Collection of Water Quality Data as well as Kern County and State well permitting, construction and abandonment regulations. At a minimum, the following sampling analytical methods and monitoring frequency will be implemented as part of the MNP:

Groundwater Sampling Analysis							
Frequency			Indicator Parameter	Reporting Units	Field Measurement	Laboratory Analysis	Analysis Method
Initial Sample	5-Year	Semi-Annual	EC	umhos/cm	•		Field Instrument
			pH	s.u.	•		Field Instrument
			Dissolved Oxygen (DO)	mg/L	•		Field Instrument
			Temperature	°C	•		Field Instrument
		Annual	Nitrate as Nitrogen	mg/L		•	Method 300.0
			TDS	mg/L		•	Method 2540C
			General Minerals – Anions (carbonate, bicarbonate, chloride, sulfate)	mg/L		•	Method 2320B
			General Minerals – Cations (boron, calcium, sodium, magnesium, potassium)	mg/L		•	Method 200.7

Note: C°: degrees Celsius

3.1.1 Monitoring Protocols

Monitoring protocols are designed to detect changes in groundwater elevation levels, groundwater quality, and act as a proxy to assess for changes in groundwater storage. In addition, MNP data will be utilized to assess for potential inelastic subsidence and groundwater flow that may directly affect groundwater levels, quality, or changes caused by groundwater extraction in adjacent GMAs. The WDWA will comport with all KGA-established monitoring protocols and will coordinate its monitoring activities and well access/agreements with adjacent GMAs, GSAs and other established monitoring programs, such as the WWQC **(Appendix G and Appendix H)**. Note: some well access agreements are pending.

3.1.2 Description of Monitoring Network

The modeled overdraft in the WDWA is largely attributed to groundwater underflow leaving the WDWA to the northeast and east. The most critical sustainability criteria to be monitored by the MNP are chronic lowering of groundwater levels associated with groundwater underflow leaving the WDWA, associated groundwater quality that might affect downgradient GMAs, reduction (changes) in groundwater in storage and the potential for significant inelastic land subsidence. The direct measurement of groundwater levels along the northeast and east boundary of the WDWA that is shared with adjacent down-gradient management areas is best suited to provide representative data for this purpose. The geochemical composition of naturally degraded water that may impact better water quality in adjacent down-gradient management area will also be assessed as part of the sentry monitoring implemented as part of the MNP. The location of proposed monitoring wells (including MT/MO regional monitoring wells) in this Chapter are intended to be preliminary and are subject to change in number and/or location as data becomes available. For example, additional monitoring well location(s) in the northeast of the LHWD may be necessary to better characterize groundwater conditions in the area where groundwater underflow is believed to be migrating from the WDWA toward the former bed of Lake Tulare. Data collected as part of the GSP implementation will be utilized to assess the need for MNP modifications and to optimally site new monitoring locations for best technical and economic benefit.

3.1.2.1 Chronic Lowering of Groundwater Levels

Monitoring of representative groundwater levels are an important and obvious metric for determining changes to groundwater storage and thus WDWA and KCS sustainability. The recording of groundwater levels along the northern and eastern boundary between the WDWA and downgradient management areas will also provide insight into changes in groundwater in storage and potential land subsidence. The rationale for focusing the sentry monitoring wells in the MNP along the north and eastern boundaries of the WDWA are:

- The western and southern sides of the WDWA are isolated from other groundwater basins and districts by the Temblor Mountain Range and geologic structures such as the Elk Hills Anticline;
- There is minimal pumping in the WDWA (~3,000 AFY);
- A majority of WDWA groundwater underflow is towards the northeast and east (modeled to be ~111,000 AFY); and
- Groundwater quality in the WDWA is naturally degraded with TDS concentrations often exceeding 2,000 mg/L, making it unsuitable for practical beneficial uses in the WDWA.

The initial MNP will include a minimum of 21 primary wells for monitoring, including three locations currently monitored by the WWQC. The monitoring locations were selected to cover the aquifer zones associated with economic (agricultural) pumping activities (unconfined/semi-confined, and confined). The wells are distributed across the WDWA as follows:

- LHWD: 8 wells
- BMWD: 4 wells
- BWSD: 6 wells

The areal extent of the WDWA is approximately 355 square miles. The well density of the proposed MNP is around one well per every 19.72 square miles. While there is currently no established number for monitoring well density in a basin or management area, for comparison the monitoring well density for a basin recommended by the CASGEM Groundwater Elevation Monitoring Guidelines ranges between one to 10 wells per 100 square miles. The current proposed groundwater monitoring network is therefore capable of collecting representative data of sufficient quantity to define short-term, seasonal and long-term data trends in groundwater and associated surface conditions. To ensure reliable groundwater level data, monitoring events will be scheduled in the late fall and early spring when many irrigation wells are typically idled.

3.1.2.2 Reduction in Groundwater in Storage

Changes in groundwater in storage cannot be measured directly. For the proposed MNP groundwater elevations will be used as a proxy indicator for calculating estimated changes in groundwater in storage. The MNP monitoring well network will be used to gather groundwater elevations and generate groundwater elevation contour maps and discern groundwater flow direction. Based on the density of the proposed monitoring well network there will be sufficient data to utilize groundwater elevation changes as a surrogate for evaluating potential changes in groundwater in storage.

3.1.2.3 Land Subsidence

Land subsidence in the WDWA will be monitored utilizing various iterative geodetic techniques over time including InSAR, surveying of permanent benchmarks, CGPS monitoring, and installation of well extensometers. Special emphasis will be placed on the previously identified area of interest between Aqueduct Mileposts 195-215. CGPS continuously collects geodetic data related to land surface monitoring at established stations within the KCS. CGPS is a reliable method for assessing changes related to geologic processes such a folding or faulting. Extensometers measure a depth- discrete interval in the subsurface. Extensometer data is useful for identifying changes in land elevation that may be caused by groundwater extractions in a specific ground water bearing zone, and together with CGPS and InSAR help provide a more complete understanding of factors contributing to subsidence (GEI 2019). InSAR is a proven technology and is capable of reliably detecting variations of land surface elevations over time on the order of millimeters, particularly when the surveyed elevations of so called "persistent scatterers" of InSAR signals are utilized to ground-truth the results. Persistent scatterers include hard fixed surfaces such as buildings, roadways and intersections, InSAR reflective corners, tanks and other permanent infrastructure that provide a stable reflective surface of known elevation for InSAR signals. Subsidence monitoring and reporting activities in the WDWA will be coordinated with adjacent GMAs and the KGA Land Subsidence Monitoring Plan for the KCS. In the KGA, an undesirable result for land subsidence is defined by significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin-wide coordinated GSP subsidence monitoring plan (KGA, 2019). Oil field related activities, including subsidence, is under the oversight of DOGGR and are therefore outside the control of the WDWA. However, the WDWA will coordinate and share data with DOGGR and oil field operators that are a party to the KGA Umbrella GSP. With few exceptions InSAR data for non-oil field areas in the WDWA indicate there is little or no significant inelastic subsidence at this time. InSAR data and other geodetic data for the WDWA will be evaluated a minimum of every five years.

3.2 Assessment and Improvement of the Monitoring Network and Timelines

As envisioned, the WDWA MNP will be dual-phased. Phase I would be implemented during the initial five-year reassessment period of 2020 to 2025 and would consist of preparing the detailed MNP for review and approval, coordination with adjacent GMAs and the WWQC, and implementation of the subject monitoring activities. A key component of the Phase I MNP will be the assimilation of the initial proposed 21 monitoring wells into the MNP. These locations are spatially located throughout the WDWA boundary areas. If it is determined after further review that some of these wells are either not needed or are unacceptable adjustments will be made to the MNP to better characterize targeted groundwater conditions. All substantive changes to the

MNP will be reported in the relevant update report. The goal of Phase I is to identify and sample a sufficient number of wells to establish representative data within and along the northeast and east boundary of the WDWA where groundwater underflow is migrating from the WDWA. To ensure reliable groundwater level data, monitoring events will be scheduled in cooperation with the WWQC and adjacent GMAs in the late fall and early spring. Phase I will also include completion of the technical and economic feasibility studies for the proposed Project Management Action No.3, (PMA No.3) described in **Section 5.3** of this Chapter GSP. PMA No.3 proposes to harvest a combination of brackish groundwater and oil field produced water for treatment and conjunctive reuse.

Phase II will utilize the Phase I data during the second five-year reassessment period (2030 to 2035) to adjust the monitoring network as needed and coordinate as necessary with adjacent GMAs in order to better maximize the cost effective collection of representative data. A central objective of Phase II is to provide the data necessary to plan and implement adaptive management strategies and projects, such as PMA No.3, which are designed to achieve long term sustainable management of the groundwater resources in the WDWA. Undistricted lands within the WDWA that are subsequently incorporated into the KGA GSP framework will be assessed for potential as additional monitoring locations.

4.0 MINIMUM THRESHOLDS AND MEASURABLE OBJECTIVES

Pursuant to SGMA, MOs and MTs shall be established for each sustainability indicator, based on quantitative analysis using the same metrics and monitoring sites as those utilized to define MTs. In accordance with the KGA Plan, the following general definitions apply to this Chapter GSP (CCR Title 23). **Figures 29b and 29c** depict the KGA regional MO and MT groundwater elevations for the KGA. The lack of representative data is a recognized data gap in the WDWA. Hydrographs related to MTs/MOs are preliminary and will be updated based on data collected during the first reassessment period.

- MTs: Numeric values for each sustainability indicator used to define an undesirable result.
- MOs: Interim milestones in increments of five years, to achieve the sustainability goals for the WDWA, and by extension, the KGA, within 20 years of the Plan implementation.

4.1 Minimum Thresholds for the WDWA Groundwater Management Area

Based on an assessment of the six potential undesirable results identified in SGMA, there are three co-related elements that require monitoring or MTs to sustainably manage the groundwater resources of the WDWA. Two potential undesirable results (Seawater Intrusion and Depletion of Interconnected Surface Water) were determined to be not applicable to the WDWA. A sixth element, Degraded Water Quality, is predominately the result of naturally occurring sub-regional geologic conditions. Therefore, it is not feasible to set direct MOs or MTs for this condition as the WDWA has no control over this natural phenomenon. However, the quality of groundwater underflow leaving the WDWA as it migrates toward the axis Valley will be monitored as a surrogate to assess for potential undesirable results to neighboring (down-gradient) management areas.

The three indicators that require monitoring and/or MOs and MTs are:

- Chronic lowering of groundwater levels;
- Reduction in groundwater storage; and
- Potential for localized land subsidence.

4.1.1 Chronic Lowering of Groundwater Levels/Significant Reduction of Groundwater in Storage

Fluctuations in groundwater levels and changes to groundwater in storage are linked to the extent that if sustainable groundwater level elevations are achieved, significant reductions in groundwater storage are avoided. There has been little historic reliance on groundwater for the purpose of irrigation or other uses in the WDWA due to poor groundwater quality. Therefore,

the potential for a significant lowering of groundwater levels or reduction in storage due to WDWA pumping extractions is believed to be minimal. It is unlikely this condition will change through at least 2040. Current estimates of WDWA groundwater well extraction is less than 2% of total demand (i.e. ~3,000 AFY). According to the current and projected KGA C2VSim-Kern model results, a principal cause of the lowering of groundwater levels in the WDWA, and by extension changes to groundwater in storage and projected groundwater deficits, is groundwater underflow (~111,000 AFY) migrating downgradient northeast and east toward the axis of the Valley. This condition, if confirmed by future data, indicates that a significant portion of changes to groundwater storage in the WDWA are not caused by pumping. It is believed that rate of underflow migrating from the WDWA could also be influenced by groundwater extractions being conducted in some of the adjacent downgradient GMAs. Therefore, the subject conditions of sub-regional downgradient underflow and most specifically adjacent pumping are outside the control of the WDWA. The WDWA has proposed two sentry coordination zones with adjacent GMAs to monitor groundwater elevations along the north and east boundaries of the WDWA where underflow exits the WDWA. Based on known hydrologic conditions, and preliminary simulated hydrographs these zones each have separate preliminary MTs and MOs. These are depicted in **Figures 30a through 30f**.

The preliminary MTs are:

- Sentry Zone #1 (well 25S21E-01): ~-115 feet below MSL
- Sentry Zone #2 (well 27S22E-30H- 7106-63): ~59 feet above MSL
- Sentry Zone#2 (well 28S21E-16 sim centroid): ~ 56 feet above MSL
- Sentry Zone #2 (well 28S21E-13H): ~59 feet above MSL

Because groundwater underflow is beyond the control of the WDWA, these MTs are preliminary and will be revised as necessary as additional groundwater elevation data is acquired. The proposed MTs are subject to review and revision at a minimum of every five years based on new data and subsequent coordination discussions with adjacent GMAs. Proposed changes will be reported in the relevant GSP update report. There are currently no MTs proposed for the WDWA areas not within the specified coordination zones at this time. The rationale for this approach is the aforementioned minimal historic pumping, and natural groundwater underflow over which the WDWA has no control. Data collected as part of the MNP for this Chapter GSP will be utilized to coordinate with adjacent downgradient GMAs and to assess whether the proposed MTs need updating or supplementing with additional MT/MO monitoring locations.

4.1.2 Land Subsidence

Irrigation pumping has been limited in the WDWA due to its naturally degraded quality. Land subsidence will be monitored by the WDWA in coordination with a land subsidence monitoring plan to be administered by the KGA. Special emphasis will be placed on monitoring Aqueduct

Mileposts 195-215. In 2011, an Aqueduct embankment failure of unknown cause was documented at Milepost 208. Changes in topographic surface elevations will be reported at a minimum every five years in the relevant GSP update report. The MT for inelastic land subsidence will be established and reviewed in consultation with adjacent GMA's and will be based on future InSAR and other geodetic land survey data. This data will be utilized to assess for potential inelastic subsidence and the potential for undesirable results to critical infrastructure. Subsidence in the WDWA caused by oil field activities and by pumping in adjacent GMAs is outside the control of the WDWA. To the extent feasible, the WDWA will coordinate the sharing of land-subsidence data with DOGGR and local oil producers that are party to the KGA Umbrella GSP.

4.1.3 Degraded Groundwater Quality

Given the ubiquitous occurrence of naturally degraded groundwater quality throughout the WDWA, groundwater is considered to be unsuitable for general use without treatment or blending with better quality water. The WDWA has no control over this phenomenon, therefore, no MT's or MO's are proposed at this time for this condition. To assist adjacent downgradient GMAs in their sustainability planning, the WDWA will conduct sentry monitoring within the WDWA lands east of the California Aqueduct adjacent to the shared boundaries with the GMAs northeast and east of the WDWA. The sentry monitoring data will be utilized to assess for any significant changes in groundwater quality (e.g., TDS) that might be migrating to the north or east from the WDWA as underflow. This condition, in conjunction with the aforementioned sentry data, will be re-assessed a minimum of every five years. Any proposed changes will be reported in the relevant GSP update report.

4.2 Measurable Objectives for the WDWA Groundwater Management Area

4.2.1 Chronic Lowering of Groundwater Levels/Significant Reduction of Groundwater in Storage

As discussed in **Section 5.1.1** and elsewhere in this report, the existing KGA C2VSim-Kern model has identified natural downgradient underflow (~111,000 AFY) as a principal cause of discharge and groundwater deficits (change in storage) in the WDWA. The rate of groundwater underflow migrating out of the WDWA may be accelerated by pumping activities in adjacent downgradient GMAs. Collectively these conditions are outside the control of the WDWA. Therefore, the WDWA has proposed two sentry coordination zones near the WDWA boundary with adjacent GMAs to monitor water level elevations to the north and east. Representative data will be collected for use in modeling changes to groundwater storage, and to act as a sentry for naturally degraded water quality migrating from the WDWA. The objective is to assess the potential for undesirable results to groundwater levels, and by proxy changes in groundwater

storage, within the WDWA. In addition, the data will be used to assess groundwater quality migrating into adjacent down-gradient management areas. The coordination zones each have separate preliminary MTs and MOs that will be re-evaluated, as needed, in coordination with the subject downgradient GMAs/GSAs and the KGA.

The preliminary MOs are:

- Sentry Zone #1 (well 25S21E-01): -62 feet below MSL
- Sentry Zone #2 (well27S22E-30H- 7106-63): 101 feet above MSL
- Sentry Zone #2 (well 28S21E-16 sim centroid): ~112 feet above MSL
- Sentry Zone #2 (well 28S21E-13H): ~127 feet above MSL

As discussed, these MOs and associated hydrograph simulations are preliminary and subject to review and change at a minimum every five years based on new data and subsequent coordination discussions with adjacent GMAs. Proposed changes will be reported in the relevant GSP update report. There are currently no MOs proposed for the areas not within the specified sentry coordination zones (i.e. areas internal to the WDWA) at this time. The rationale for this approach is the aforementioned poor quality groundwater and the low volume of historic pumping, which is expected to continue for the foreseeable future (2040). As stated, additional MT/MO monitoring locations may be proposed and reported in relevant GSP update reports based on MNP monitoring data collected during the first reassessment period.

4.2.2 Land Subsidence

The MO for inelastic land subsidence is to avoid significant impacts to critical infrastructure. Land subsidence will be monitored by an iterative approach that includes satellite-based InSAR and various focused geodetic land survey methodology as part of the KGA-wide land subsidence monitoring plan. In the WDWA, special emphasis will be placed on Aqueduct Mileposts 195-215. In 2011, an Aqueduct embankment failure was documented at Milepost 208. The monitoring activities will be conducted in coordination with adjacent GMAs via the monitoring plan administered by the KGA. Changes in topographic surface elevations will be reported in the relevant GSP update report. Oil field activities, including field subsidence, are under the oversight of DOGGR. Therefore, land subsidence in the WDWA caused by oil field activities, and by groundwater pumping in adjacent GMAs is outside the control of the WDWA. To the extent feasible, the WDWA will share subsidence data with DOGGR and those oil operators party to the KGA Umbrella GSP. The MO for inelastic land subsidence will be set in consultation with adjacent GMAs and the KGA and will be based on data that will be collected and reported during the first five-year reassessment period.

4.2.3 Degraded Groundwater Quality

As explained elsewhere in this Chapter GSP, because of the widespread occurrence of naturally degraded groundwater quality in the WDWA, there are no proposed MOs for this indicator. Instead, the WDWA will conduct sentry monitoring along its down-gradient (northeastern and eastern) boundaries in order to assess for significant changes to existing concentrations of TDS in groundwater underflow leaving the WDWA. A pending Basin Plan Amendment Workplan being submitted by the WWQC requests delisting of beneficial use designations for MUN and AGR for perched and unconfined/semi-confined groundwater over a portion of the WDWA.

5.0 PROJECTS, MANAGEMENT ACTIONS, AND ADAPTIVE MANAGEMENT

Groundwater quality in the WDWA is largely naturally degraded by elevated concentrations of TDS and other minerals that make it unsuitable for beneficial use. Further, due to the degraded quality of this groundwater, pumping extractions in the WDWA are estimated to be minimal (~3,000 AFY). The most significant source of discharge from the WDWA is groundwater underflow (~111,000 AFY) towards the north and east. This condition is a natural phenomenon that is outside the control of the WDA, and which may also be influenced by groundwater extractions in some adjacent GMAs. To the extent feasible and practical, Projects and Management Actions (PMAs) have been developed to address sustainability goals, undesirable results and MTs/ MOs for the WDWA. Recognizing that the hydrogeologic characteristics of the WDWA are transitory through time and that adaptive management is an iterative process, the PMAs have been selected and developed with consideration to climate change and drought resiliency, as well as coordination with adjacent GMAs. The initial proposed PMAs are:

1. Collect Representative Hydrogeologic Data
2. Water Resource Coordination
3. Conjunctive Reuse of Naturally Degraded Brackish Groundwater

5.1 PMA No.1 - Collect Representative Hydrogeologic Data

Historically, because of the brackish and naturally degraded quality of groundwater in the WDWA, growers have relied almost exclusively on surface water from the SWP for their irrigation needs. Groundwater is used primarily for blending when annual SWP deliveries are less than expected. As a result, there is currently little representative hydrogeologic data in the WDWA. This lack of data represents a significant data gap that must be addressed in order to refine the current understanding of the WDWA HCM, including key elements such as native yield/sustainable yield, groundwater elevations, pumping, and changes to groundwater in storage as well as the overall water budget.

5.1.1 Description of PMA No.1

As reported in this Chapter GSP, representative data related to aquifer characteristics and groundwater elevation monitoring within the WDWA is limited. This important data gap will be filled by implementation of the MNP. The MNP, once fully implemented, will help achieve the following objectives:

- Acquisition of additional representative groundwater elevation data sufficient to assess and document short-term, seasonal, and long-term groundwater trends related to WDWA,

native yield/sustainable yield, proposed sentry MTs/MOs, water budgets, groundwater pumping volumes, groundwater in storage, groundwater elevation, and potential future land subsidence;
- Ability to assess for changes in groundwater storage and conditions relative to identified MOs and MTs; and
- Coordination with adjacent management areas by way of scheduled sampling events, mutually sustainable MTs and MOs, and regularly scheduled status meetings to ensure sustainable outcomes.

5.1.2 Expected Benefits of PMA No.1

The expected benefits to be realized from the coordinated collection of groundwater data within the WDWA are:

- The ability to generate representative data for use in updating native yield/sustainable yield, sentry MTs/MOs and various water budget elements;
- Improved numerical groundwater modeling results; and
- Better forecasting and planning of adaptive management projects and management actions.

The PMA No.1 will also directly support WDWA MTs/MOs by providing foundational data to monitor and manage adaptive management projects that are designed and implemented to ameliorate the potential for significant reduction of groundwater elevations and groundwater in storage.

5.1.3 Timetable and Metrics for PMA No.1

Public noticing of proposed sampling activities or other field implemented as part of the MNP will be made on the WDWA member websites in advance of any field work. Permitting, if necessary, will comply with State and local requirements.

The PMA No.1 will be implemented beginning with implementation of the GSP and subsequent acceptance of the MNP. It will directly support WDWA MT/MOs by providing foundational data to monitor and manage adaptive management projects that are designed and implemented to ameliorate the potential for significant reduction of groundwater elevations and groundwater in storage. Metrics include sufficient representative water level data, pumping data, and additional water quality data.

5.1.4 Costs of PMA No.1

The cost of implementing PMA No 1. will be apportioned between the member water districts of the WDWA. It is possible that some costs might also be shared by adjacent management areas, and/or the WWQC as part of coordination agreements that are currently being negotiated.

Detailed costs and the MNP document will be developed and implemented during the first five-year reassessment period. If cost sharing with adjacent areas is implemented it will increase efficiency and flexibility in data collection and will reduce costs to the WDWA. Preliminary annual monitoring and reporting costs are estimated at $150,000 to $175,000. A more refined estimate of monitoring costs will be available and reported once the MNP is finalized for implementation.

5.2 PMA No.2 - Water Resource Coordination

5.2.1 Description of PMA No.2

The landowners in the WDWA have historically made significant investment in efficient irrigation technologies and methods that promote water conservation and sustainable management. They have also coordinated amongst themselves as individuals or via the various water districts to implement focused reduction demand measures, and trade or purchase surplus water when deliveries from the SWP have been reduced. It is assumed that these effective approaches and arrangements will continue after GSP implementation. In addition, the WDWA will work cooperatively and in close consultation with its landowners, the KGA and adjacent GMAs/GSAs to coordinate groundwater resource monitoring, testing and reporting as part of its overall strategy for the sustainable management of all its available water resources.

5.2.2 Expected Benefits of PMA No.2

Expected benefits from PM No.2 include:

- More reliability and flexibility in water availability;
- Drought resiliency; and
- Sustainable water strategies for both short- and long-term planning horizons.

5.2.3 Timetable and Metrics for PMA No.2

The implementation of the different Water Resource Coordination Programs varies; some as described above are already in place and ongoing. Others, like a KCS-wide groundwater coordination program would likely begin with planning by the KGA during the first five-year reassessment period after KCS Plan implementation. Groundwater coordination between the WDWA and its immediately adjacent GMAs, although already in place, would likely be structured to begin with meetings shortly after the Umbrella GSP approval. Metrics for PMA No.2 include regularly scheduled coordination meetings, a common data base system, frequent sharing of relevant water resource data (surface and groundwater) and discussion and planning of coordinated groundwater management actions and projects where feasible. Public noticing for SGMA related activities will be via WDWA district websites.

5.2.4 Costs of PMA No.2

Costs related to spot purchase or trading of supplemental water between individual growers is typically transactional between the relevant parties and thus not directly part of the WDWA operations. Purchase of supplemental water by the WDWA or individual member water districts is generally conducted on an as-needed (and available basis). Therefore, these transactions are not standard and subject to future market forces and an estimate of cost cannot be made at this time. The cost of this type of purchase would be within the WDWA or individual water district budget. The costs of each such unit of water would ultimately be borne by the respective recipient (i.e. pass-through cost). All such data would be reported in the member district AWMP report. Costs related to groundwater testing and monitoring will be determined once the MNP is finalized.

5.3 PMA No.3 - Conjunctive Reuse of Naturally Degraded Brackish Groundwater

To further enhance the sustainable and adaptive management strategies for the WDWA, the WDWA is evaluating the feasibility of an innovative, phased project that will integrate the treatment and conjunctive use of brackish groundwater and oil field produced water for potential multiple beneficial uses including, among other things:

- A new water supply for adjacent and nearby disadvantaged communities (DACs) in order to improve water reliability and drought resiliency;
- A reliable supplemental source of better-quality water that, together with the Aqueduct supplies, can be used for irrigation and other uses;
- Provide for potential environmental flows to the adjacent Kern National Wildlife Refuge; and
- Protect groundwater quality adjacent to the WDWA and reduce potential changes to groundwater storage by reducing the volume of naturally degraded groundwater migrating north and east from the WDWA toward better-quality groundwater in the axis of the Valley via the focused pumping, treatment and conjunctive reuse of modeled groundwater underflow leaving the WDWA (provided adjacent GMAs address their existing pumping-related groundwater gradient issues through their individual GSP management actions).

5.3.1 Description of PMA No.3

The supporting rationale for PMA No. 3 is multifaceted and relies on the unique hydrogeologic characteristics of the WDWA previously enumerated in this Chapter GSP, proven and available water treatment technologies that allow for innovative solutions to seemingly complex water quality challenges, and the potential for a variety of beneficial reuse opportunities derived from a degraded resources of little to no current practical use. Unlike other existing and proposed

State water supply projects, PMA No.3 would also have the added benefit of being planned, constructed and operated under local control.

Sub-regionally, most of the groundwater in the WDWA is of poor to very poor quality, with TDS concentrations routinely greater than 2,000 mg/L, making it unsuitable for practical beneficial use within the WDWA without blending or treatment. The poor water quality is caused by geologic sediments of marine origin, some of which contain saline connate water. The principal source of modeled deficit in the WDWA is due to natural downgradient underflow out of the WDWA towards the northeast (former Tulare Lake bed, a designated beneficial use exemption area), and eastward towards the axis of the basin. Historically, WDWA growers have, among other water management techniques, used Aqueduct water (significantly more than 95%) to meet their water supply demand. Groundwater withdrawals have been minimal (~3,000 AFY), and have been used largely for the purpose of blending. However, climate variability has placed stress on the reliability of imported water. During the recent extended drought period (2007 to 2016), actual deliveries from the SWP to the WDWA averaged less than 50% of the stipulated allocation. The proposed drought resiliency infrastructure project (Project), when fully implemented, would provide for treatment and conjunctive reuse of a mixture of oil field produced water, and naturally degraded groundwater that is currently escaping the WDWA as underflow.

Membrane technologies and associated system control software to treat brackish and saline water are well established and the cost of treatment is declining. Many of these proven technologies are now “off the shelf” and modular, allowing for cost-effective facility upscaling as part of planned project phasing, or as operational conditions change. The Project proposes to utilize a modular treatment system in order to right-size the project and maximize and maintain the balance between project economics and desired benefits. As envisioned, the PMA No. 3 would include at least two similar construction phases over the next 10-20 years, each with an array of brackish groundwater underflow-capture wells located along the eastern or northern boundaries of the WDWA. These wells along with some oilfield produced water would eventually provide the source water for two or more distributed modular treatment systems. When fully operational, the Project, as currently planned, could produce up to 50,000 AFY of new, high-quality water for multi-beneficial reuse options.

Potential sources of feed water for the project include degraded brackish groundwater underflow from the WDWA and surplus oil field produced water. Current groundwater underflow that migrates from the WDWA, downgradient towards the axis of the basin, has been preliminarily estimated by the KGA C2VSim-Kern model at approximately 111,000 AFY. Because of the brackish quality of this water, it is considered to be non-beneficial without treatment or blending.

The oil fields of West Kern County generate approximately 10 to 12 barrels of brackish or saline produced water for every barrel of oil. A large portion of the produced water is recycled and used at the oil fields for steam flooding for EOR, and other oil field operations. However, any remaining surplus volume of produced water requires disposal. Due to water quality concerns, many of the produced water disposal ponds in Kern County have been closed. This leaves permitted reinjection into typically deeper zones under the oversight of the DOGGR and the Federal UIC program as the primary method for disposal of produced waters. The Project would, if determined to be feasible, divert a portion of this surplus produced water for additional treatment and conjunctive reuse.

5.3.2 Expected Benefits of PMA No.3

When operational, the Project will result in multiple potential beneficial uses, including many of the "One Water" concepts enumerated in the State's California Water Action Plan:

1. Increase drought resiliency, regional and local water self-reliance, and flexible integrated water management;
2. Potentially help protect, maintain and restore important ecosystems (e.g., Kern National Wildlife Refuge);
3. Provide a potential alternative water source for use by local DACs;
4. Increase WDWA operational flexibility and regulatory efficiency; and
5. Help mitigate the rate of subsidence through the treatment, potential banking and conjunctive reuse of surplus oilfield produced water.

The Project will also directly support WDWA MTs/MOs by providing a new reliable local source of better quality water for conjunctive reuse that is derived from groundwater that is currently considered unsuitable for beneficial use and is typically lost to underflow from the WDWA, or is injected deep underground as part of oilfield produced water disposal where it beyond practical reach for reuse.

5.3.3 Timetable and Metrics for PMA No.3

Preliminary planning for a Project Engineering feasibility study (FS) for the first phase of the project has already begun. It is expected there will be at a minimum two phases of distributed treatment facility construction. The FS will examine the viability of the project for regulatory acceptance, potential for undesirable results (e.g. significant subsidence), and for the economics of treating both brackish groundwater and oil field produced waters in a distributed modular facility via the use of readily available membrane technologies, such as reverse osmosis (RO).

Treatment technologies to be assessed would include pre-treatment, pH adjustment and filtration followed by either a single-pass RO configuration, a double-pass RO, or a RO modification called a closed-circuit RO. Treated water quality would, at a minimum, meet Basin Plan requirements.

Project FS components include:

- Evaluating existing hydrogeologic data pertaining to brackish groundwater and oil field produced water quality, water use, and volumes;
- Development of preliminary engineering options and costs for siting the treatment facility, source wells, water treatment, energy demand, concentrate disposal, and treated water transmission;
- Examination of the potential for undesirable results (e.g. subsidence); and
- Assessment of permitting and public notification requirements (California Environmental Quality Act [CEQA], etc.).

Sustainable objectives and metrics will be developed to comport with those identified in the KGA Umbrella GSP and the WDWA Chapter GSP. Data gaps will be filled, as needed, through water sample analysis, geophysics (e.g. airborne, surface, borehole), aquifer pumping tests, and groundwater flow and solute transport modeling.

The FS will include information on the study area, as well as water supply, source water, and RO concentrate characteristics and treatment facilities. A project alternative analysis will be performed leading to a recommended plan for implementation including a preliminary construction schedule and financing plan, a revenue program, and a net present worth analysis. Findings and status of the FS implementation would be reported in the first five-year GSP reassessment. It is a goal to have the first modular treatment system online before the end of the second five-year reassessment period (by 2030). Public noticing for this project would be implemented pursuant to relevant and applicable rules and regulations and would be distributed via the websites of the stakeholder water districts and other methods, as required. Permitting (CEQA, construction, etc.) will also comply with relevant and applicable rules and regulations.

5.3.4 PMA No.3 Issues, Outcomes and Costs

Key issues to be addressed during the FS include those related to technical feasibility, project phasing, regulatory and public acceptance, potential project-related undesirable results, the development of an engineering cost/benefit analysis, State or other funding alternatives and permitting (e.g. CEQA, etc.). The FS will seek to identify the preferred project alternative by examining the CEQA required “no project alternative”, in addition to several different construction and RO configurations, combined with varying approaches for concentrate (brine)

disposal. End-users of the new water supply will be identified, including local DACs, agricultural, oil field, and environmental users.

Ultimately, this project directly supports WDWA water resources and provides the benefit of a new water supply to the State. Specific benefits include:

- Ability to wheel water of acceptable quality to neighboring management areas that may be facing shortage;
- Increased regional and local water self-reliance, flexibility and integrated management;
- Drought resiliency;
- Ability to decrease agricultural reliance on diversions from the Delta via the Aqueduct; and
- Increase operational and regulatory efficiency for improved drought resiliency.

Only broad order-of-magnitude cost ranges are available at this time. More refined cost estimates will be generated by the proposed FS. Rough order-of-magnitude costs for the initial phase of the project range from $50 million to $60 million +/- 20% depending on site location and number of capture wells to be installed. Refined costs will be generated by the aforementioned FS. Project costs and funding are among key feasibility factors. Funding sources could include a combination of State, WDWA and other stakeholder or private funding.

6.0 GSP REPORTING AND PERIODIC EVALUATIONS

SGMA reporting standards, as enumerated in Section 352.4 of CCR 23, Subchapter 2, Groundwater Sustainability Plans, shall apply to all WDWA Chapter GSP reporting and WDWA Chapter GSP amendments. Additional reporting details are provided below. Data from the various monitoring and well installation activities will be provided to the appropriate State and County databases (e.g., well installation information and groundwater level and water quality monitoring). Data will also be coordinated with adjacent GMAs, and will be maintained in the appropriate State data bases (e.g. GeoTracker), and a WDWA data base that is coordinated with the KGA. All data collected by the WDWA will be provided and summarized in the various reports detailed in this section (**Appendix G and Appendix H**).

6.1 GSP Reporting and Data Management

Pursuant to SGMA, the WDWA will prepare Annual Reports for inclusion in the KGA GSP. The Annual Reports will be prepared consistent with KGA guidance and formats. The compiled reports from the individual Chapter GSPs/ GSAs will submitted by the KGA by April 1st of each year following adoption of the Umbrella GSP. The Annual Reports shall, at a minimum, include the following topics:

- Groundwater elevation data and contour maps;
- Key well hydrographs;
- Groundwater extractions;
- Surface water supplies;
- Total water use;
- Change in groundwater storage; and
- Implementation progress.

Periodic reevaluation reports will be prepared a minimum of every five years for inclusion in the Umbrella GSP. The five-year reassessments will be submitted electronically by the KGA to the DWR via the online reporting system and format provided by the Agency per Section 10733.2, Water Code and Section 353.2 and 356.4, of CCR 23, Subchapter 2, Groundwater Sustainability Plans. The submittal of updates or amendments to this Chapter GSP will be accompanied by a transmittal letter signed by the Plan Manager, or duly authorized representative. A coordinated data management system for the KCS is necessary to improve the accuracy, usefulness and confidence in groundwater data reported by the individual GMA's and GSA's within the KGA. Data system perimeters, inputs and a coordinated data system methodology will be established and reported in the relevant KGA update report. In the meantime, the WDWA will continue to rely on established State data bases for updating and reporting new data.

7.0 REFERENCES

A spreadsheet of the report references is provided in **Appendix I**.

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TABLES

Table 1: Summary of Water Produced and Steam/Water Injection From Selected Westside Oil Fields

WDWA Chapter GSP, Kern County, California

Oil Field Name	Total Water Produced (bbl)	Steam and Water Injection (bbl)					Injection vs. Produced (%)
		Cyclic Steam	Steam Flood	Waste Disposal	Water Flood	Total	
2017							
Antelope Hills	584,269	--	--	--	--	--	
Antelope Hills, North	2,615,568	56,162	422,445	256,262	0	734,869	28.1%
Beer Nose	440	--	--	--	--	--	
Belridge, North	30,630,602	0	0	131,580	14,871,355	15,002,935	49.0%
Belridge, South	313,822,415	1,204,415	30,576,027	61,136,536	49,343,907	142,260,885	45.3%
Blackwells Corner	44,198	0	0	18,557	0	18,557	42.0%
Canal	148,663	0	0	16,653	0	16,653	11.2%
Carneros Creek	51,113	--	--	--	--	--	
Chico-Martinez	240,034	0	0	0	0	0	
Cymric	122,464,701	19,025,632	6,811,102	1,388,551	0	27,225,285	22.2%
Devils Den	62,304	0	0	330	0	330	0.5%
Lost Hills	94,900,949	376,060	7,583,279	4,564,475	27,610,275	40,134,089	42.3%
Lost Hills, Northwest	469,801	0	0	57,027	0	57,027	12.1%
McDonald Anticline	1,083,898	0	0	258,878	0	258,878	23.9%
Monument Junction	766,809	--	--	--	--	--	
Welcome Valley	0	--	--	--	--	--	
2016							
Antelope Hills	646,192	--	--	--	--	--	
Antelope Hills, North	2,969,212	314,652	1,498,797	770,356	--	2,583,805	87.0%
Beer Nose	0	--	--	--	--	--	
Belridge, North	31,492,411	--	--	473,613	35,295,713	35,769,326	113.6%
Belridge, South	313,203,446	3,420,411	76,430,146	152,384,388	116,636,040	348,870,985	111.4%
Blackwells Corner	38,585	--	--	39,529	--	39,529	102.4%
Canal	131,651	--	--	60,207	--	60,207	45.7%
Carneros Creek	47,129	--	--	--	--	--	
Chico-Martinez	697,367	--	--	--	--	--	
Cymric	119,034,697	45,957,558	18,693,944	5,321,968	--	69,973,470	58.8%
Devils Den	55,028	--	--	1,545	--	1,545	2.8%
Lost Hills	95,762,945	1,050,368	23,781,662	15,458,729	71,122,221	111,142,980	116.1%
Lost Hills, Northwest	296,924	--	--	291,268	--	291,268	98.1%
McDonald Anticline	921,774	--	--	894,776	--	894,776	97.1%
Monument Junction	769,457	--	--	--	--	--	
Welcome Valley	0	--	--	--	--	--	
2015							
Antelope Hills	793,876	--	--	--	--	--	
Antelope Hills, North	3,501,910	352,069	1,384,315	1,151,904	--	2,888,288	82.5%
Beer Nose	36	--	--	--	--	--	
Belridge, North	32,892,698	5,628	34,156	539,208	34,191,254	34,770,246	105.7%
Belridge, South	311,688,218	5,063,904	76,736,192	154,744,582	109,791,229	346,335,907	111.1%
Blackwells Corner	294,401	--	--	43,292	--	43,292	14.7%
Canal	176,827	--	--	95,221	--	95,221	53.8%
Carneros Creek	35,717	--	--	--	--	--	
Chico-Martinez	1,721,165	145,560	1,946,046	--	--	2,091,606	121.5%
Cymric	110,069,856	42,040,449	16,890,712	5,156,436	--	64,087,597	58.2%
Devils Den	73,804	--	--	25,553	--	25,553	34.6%
Lost Hills	105,205,630	1,402,177	26,196,774	15,807,276	87,626,667	131,032,894	124.5%
Lost Hills, Northwest	365,633	--	--	365,611	--	365,611	100.0%
McDonald Anticline	932,738	--	--	896,442	--	896,442	96.1%
Monument Junction	878,820	--	--	--	--	--	
Welcome Valley	0	--	--	--	--	--	

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WDWA Chapter GSP, Kern County, California

Oil Field Name	Total Water Produced (bbl)	Steam and Water Injection (bbl)					Injection vs. Produced (%)
		Cyclic Steam	Steam Flood	Waste Disposal	Water Flood	Total	
2014							
Antelope Hills	1,115,384	--	--	--	--	--	
Antelope Hills, North	3,356,056	795,908	1,123,285	1,168,408	--	3,087,601	92.0%
Beer Nose	661	--	--	--	--	--	
Belridge, North	30,314,930	40,845	559,049	654,750	31,687,307	32,941,951	108.7%
Belridge, South	309,281,921	4,391,253	72,027,807	144,650,162	117,953,288	339,022,510	109.6%
Blackwells Corner	207,684	--	--	207,682	--	207,682	100.0%
Canal	224,706	--	--	124,257	--	124,257	55.3%
Carneros Creek	24,232	--	--	--	--	--	
Chico-Martinez	1,300,120	271,242	1,706,121	240,322	--	2,217,685	170.6%
Cymric	113,284,536	39,268,791	18,197,110	5,156,531	--	62,622,432	55.3%
Devils Den	57,806	--	--	12,600	--	12,600	21.8%
Lost Hills	111,083,620	1,919,634	25,467,477	16,927,599	96,660,948	140,975,658	126.9%
Lost Hills, Northwest	393,339	--	--	392,373	--	392,373	99.8%
McDonald Anticline	1,070,158	--	--	1,031,542	--	1,031,542	96.4%
Monument Junction	731,049	--	--	--	--	--	
Welcome Valley	0	--	--	--	--	--	

Notes:
---: not available
%: percent
bbl: barrel
GSP: Groundwater Sustainability Plan
vs.: versus
WDWA: Westside District Water Authority
1 acre-foot = 325,851 gallons
1 barrel = 42 gallons
Source: Annual Report of California Oil and Gas Production Statistics, State of California Department of Conservation Division of Oil, Gas, and Geothermal Resources (DOGGR

Table 2: Well Data for Proposed Monitoring Network Plan(MNP)[1]

WDWA Chapter GSP, Kern County, California

State Well Name	PLSS	Aquifer Zone	Well Priority	Location	DWR Record	Other Well Name	Well Use	Date Installed	Latitude	Longitude	Depth (feet)	Screen Top (feet)	Screen Base (feet)	Notes
025S020E30A002M	025S020E30A	Unconfined	Primary	Satellite	Yes	USGS L2-2	Test	12/17/1987	35.7301387	-119.8507339	232	211	221	USGS well cluster.
025S021E01R001M	025S021E01R	Confined	Primary	Satellite	Yes	--	Irrigation	11/9/1954	35.77630219	-119.6536076	760	624	760	
025S021E26P001M	025S021E26P	Unconfined	Primary	Satellite	Yes	--	Irrigation	9/19/1975	35.71956493	-119.6797936	402	195	402	
Unknown	026S017E13F	Unconfined	Primary	Satellite	No	Berrenda Mesa 1	Unknown	Unknown	35.668823	-120.090742	--	--	--	
026S018E14N001M	026S018E14N	Unconfined	Primary	Satellite	Yes	--	Not Specified	1/1/1949	35.65821474	-120.0101995	334	135	300	USGS well. Month/day of completion uncertain.
026S019E29E001M	026S019E29E	Confined	Primary	Satellite	Yes	--	Irrigation	6/15/2009	35.63648337	-119.9486288	1,205	715	1,185	Well cluster. See completion report for exact locations.
026S020E07E001M	026S020E07E	Unconfined	Primary	Satellite	Yes	Lost Hills 5	Test/Irrigation	Not Specified	35.680238	-119.867359	--	--	--	Well type unknown.
026S021E14H002M	026S021E14H	Unconfined	Primary	Satellite	Yes	Lost Hills 3	Irrigation	8/4/1954	35.66720121	-119.672432	300	--	--	USGS well. Date of completion uncertain. DWR record not legible.
027S021E10A001M	027S021E10A	Unconfined/ Confined	Primary	Satellite	Yes	Lost Hills Tulare Water Well	Industrial	3/20/2001	35.60032877	-119.6903123	865	420 790	670 845	Chevron well. APN 069-011-34.
Unknown	027S021E19K	Unconfined	Primary	Satellite	No	AeraBelridge_19M1	Unknown	Unknown	35.56449384	-119.760961	237	170	230	Possible monitoring well.
Unknown	028S021E18J	Unconfined	Primary	Surveyed	No	MW12	Unknown	7/31/2014	35.4882413	-119.7453854	205	145	205	Possible monitoring well.
029E022E05B001M	029S022E05B	Unconfined	Primary	Approximate DWR	Yes	AeraBelridge_5B2	Monitoring	10/26/1986	35.441076	-119.630256	274	191	211	
029S022E09K001M	029S022E09K	Unconfined	Primary	Satellite	Yes	Starrh_9K_No2	Irrigation	2/2/2003	35.41948121	-119.6160593	500	258	500	
025S020E27B003M	025S020E27B	Unconfined	Primary	Approximate DWR	Yes	--	Domestic	1/4/1972	35.73073885	-119.8000475	271	141	271	
025S020E32B001M	025S020E32B	Unconfined	Primary	Satellite	Yes	--	Irrigation	10/22/2008	35.71609757	-119.8497694	490	110	470	
026S021E21N001M	026S021E21N	Unconfined	Alternative	Satellite	Yes	USGS-353851119432201	Monitoring	Unknown	35.64632656	-119.7223854	570	300	570	USGS well. Date of completion unknown.
028S022E29D001M	028S022E29D	Unconfined	Alternative	Approximate NWIS	No	USGS-352800119380001	Monitoring	11/4/2014	35.4701944	-119.6361944	305	--	--	USGS well. Date of completion uncertain.
028S022E29D002M	028S022E29D	Unconfined	Alternative	Approximate NWIS	No	USGS-352800119380002	Monitoring	11/4/2014	35.47025	-119.6361667	400	--	--	USGS well. Date of completion uncertain.
Unknown	27-22-30-SE	Confined	Primary	Satellite	No	7106-62	Irrigation	1/16/2017	35.543765	-119.636505	680	240 600	540 680	
Unknown	25-21-03-NE	Confined	Primary	Satellite	No	7108-69	Irrigation	7/25/2016	35.788706	-119.698322	1,000	820	980	
Unknown	25-21-16-SW	Confined	Primary	Satellite	No	Snake	Irrigation	12/13/2010	35.747119	-119.725136	505	--	--	

Notes:

1. All MNP wells in the table will be sampled for groundwater elevation twice yearly (fall and spring). In the spring, all the MNP wells will be sampled via field instruments for EC, pH, DOC, and temperature. In the fall, all the MNP wells, in additional to all of the spring parameters, will be sampled and analyzed in a certified lab for nitrate-nitrogen, TDS, general mineral ions and cations. All monitoring will be conducted pursuant to KGA Monitoring Protocols.

APN: Assessor's Parcel Number

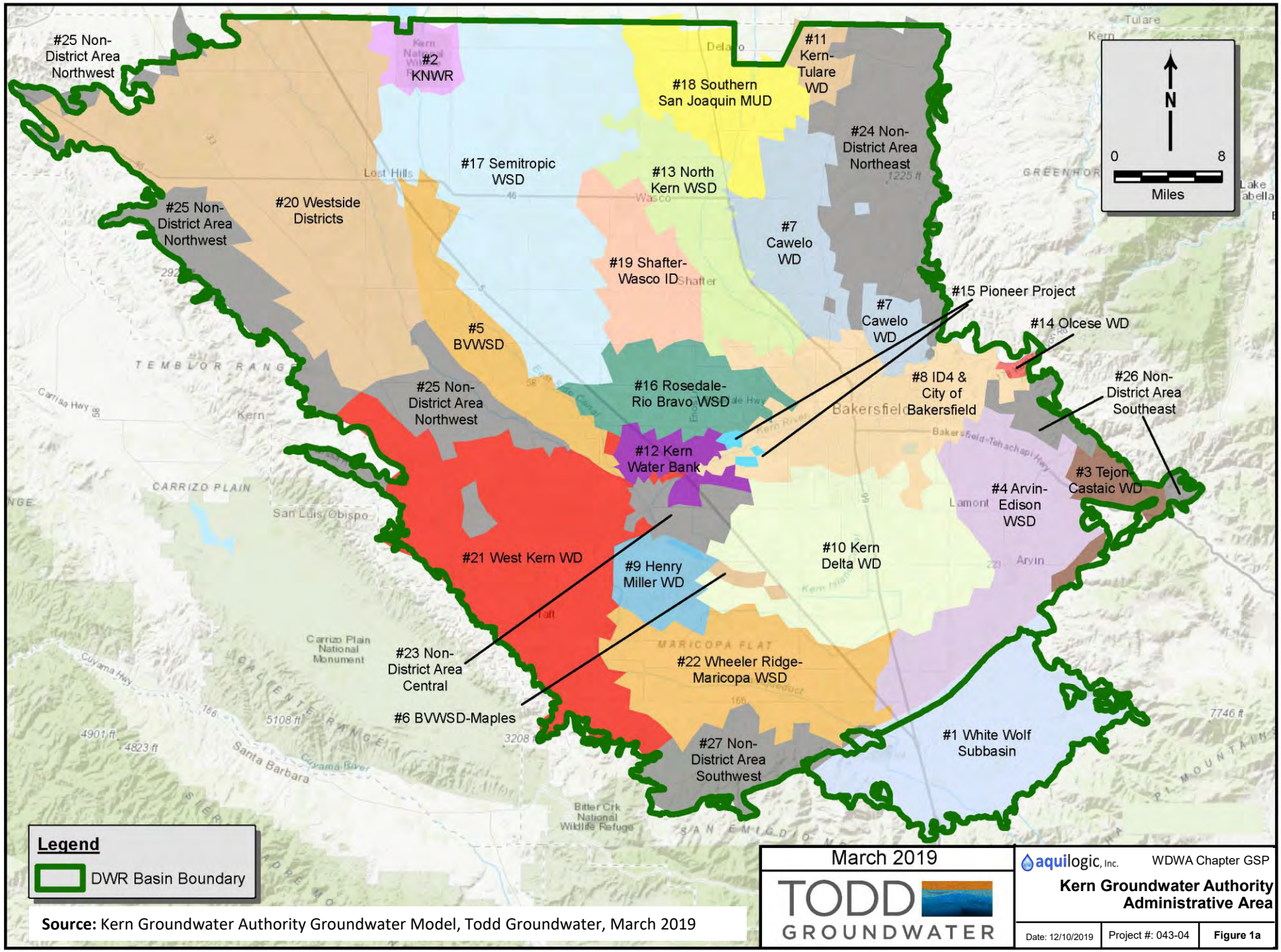
DWR: California Department of Water Resources

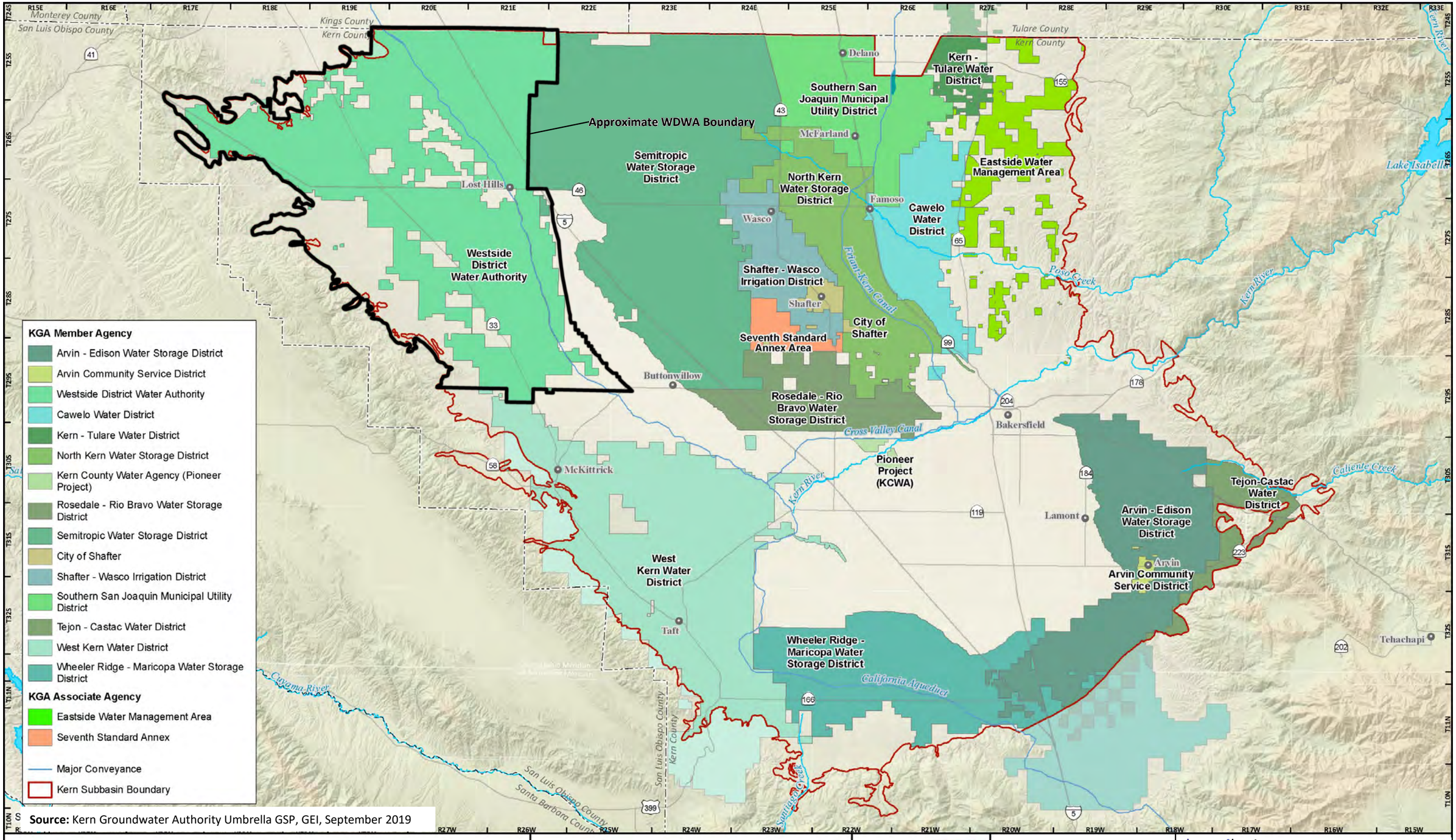
NWIS: National Water Information System

PLSS: The Public Land Survey System

USGS: United States Geological Survey

FIGURES


#25 Non-District Area Northwest
#2 KNWR
#18 Southern San Joaquin MUD
#11 Kern-Tulare WD
#24 Non-District Area Northeast
#17 Semitropic WSD
#13 North Kern WSD
#20 Westside Districts
#25 Non-District Area Northwest
#7 Cawelo WD
#19 Shafter-Wasco ID
#15 Pioneer Project
#7 Cawelo WD
#14 Olcese WD
#5 BVWSD
#8 ID4 & City of Bakersfield
#26 Non-District Area Southeast
#25 Non-District Area Northwest
#16 Rosedale-Rio Bravo WSD
#12 Kern Water Bank
#3 Tejon-Castaic WD
#4 Arvin-Edison WSD
#10 Kern Delta WD
#21 West Kern WD
#9 Henry Miller WD
#23 Non-District Area Central
#22 Wheeler Ridge-Maricopa WSD
#6 BVWSD-Maples
#27 Non-District Area Southwest
#1 White Wolf Subbasin
N
0
8
Miles
Legend
DWR Basin Boundary
Source: Kern Groundwater Authority Groundwater Model, Todd Groundwater, March 2019
March 2019
TODD GROUNDWATER
aquilogic, Inc.
WDWA Chapter GSP
Kern Groundwater Authority Administrative Area
Date: 12/10/2019
Project #: 043-04
Figure 1a



Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

0 3.5 7 14 21

Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

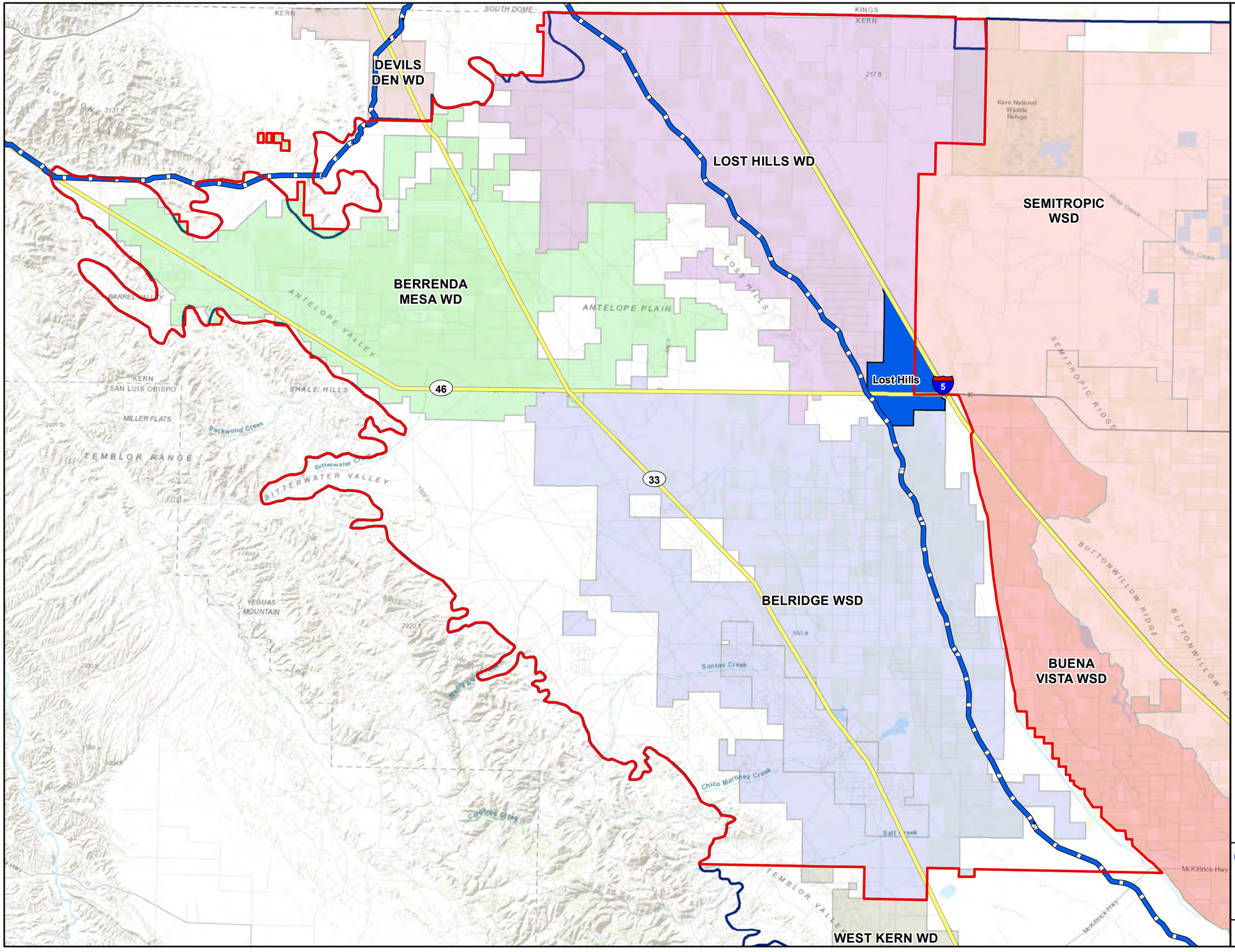
Notes:
KGA: Kern Groundwater Authority
WDWA: Westside District Water Authority

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WDWA Chapter GSP

Kern Groundwater Authority Member Agencies

Date: 12/3/2019 | Project #: 043-04 | **Figure 1b**



- WDWA Boundary
- California Aqueduct
- Lost Hills Town Boundary
- Kern County Groundwater Sub-Basin
- Undistricted Area

Notes:
WDWA: Westside District Water Authority

0 4
Miles

aquilogic, Inc.

WDWA Chapter GSP

Location of the WDWA Northwest Kern County

Date: 8/23/2019	Project #: 043-04	**Figure 2a**

Kern Groundwater Authority

GSA Management Areas and White Area Parcels Review

Approximate WDWA Boundary

SJV Kern County GW Subbasin (DWR B118, 2019)

White Area Parcels

By Agency

- County
- Federal
- State

Areas Covered by Agencies

- District Boundary and Managment Areas (parcels)

Notes:
KGA: Kern Groundwater Authority
WDWA: Westside District Water Authority

Delano
Wasco
Shafter
Bakersfield
Lamont
Arvin
Taft
Lost Hills
Carrizo Plain National Monument

EST. 1968 PROVOST& PRITCHARD CONSULTING GROUP An Employee Owned Company

N

0 5 10 Miles

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WDWA Chapter GSP

KGA Undistricted Lands

Date: 12/10/2019	Project #: 043-04	**Figure 2b**

Source: Kern Groundwater Authority, Provost and Pritchard, 2019



Source: Bulletin 118 Update, Department of Water Resources, 2003

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California Groundwater Hydrologic Regions

Date: 12/3/2019	Project #: 043-04	**Figure 3a**



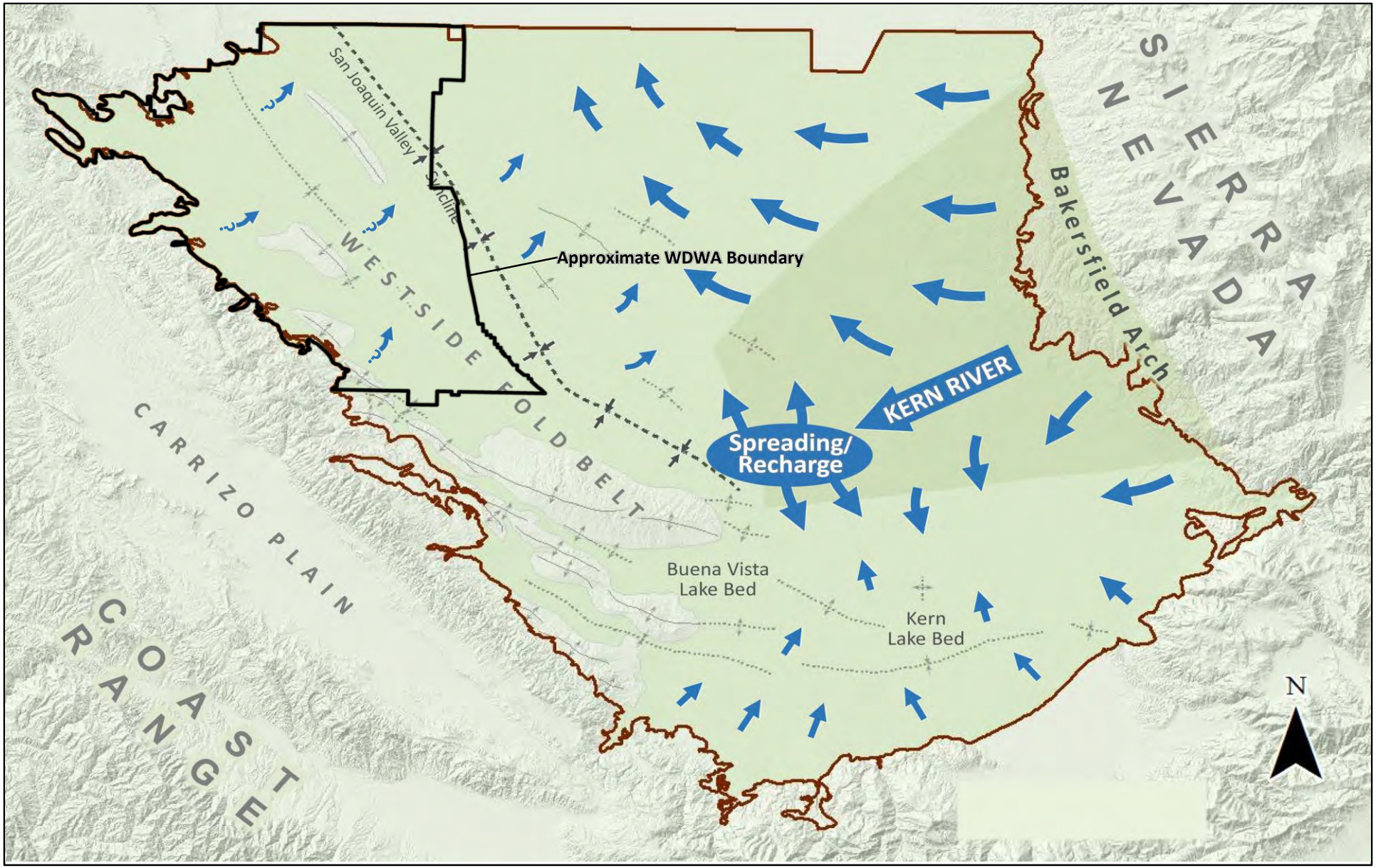
Source: Bulletin 118 Update, Department of Water Resources, 2016

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Groundwater Basins and Subbasins within the Tulare Lake Hydrologic Region

Date: 12/3/2019	Project #: 043-04	**Figure 3b**



Source: GEI, 2019

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Conceptual Groundwater Recharge Sources

Date: 12/10/2019	Project 043-04	**Figure 3c**



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

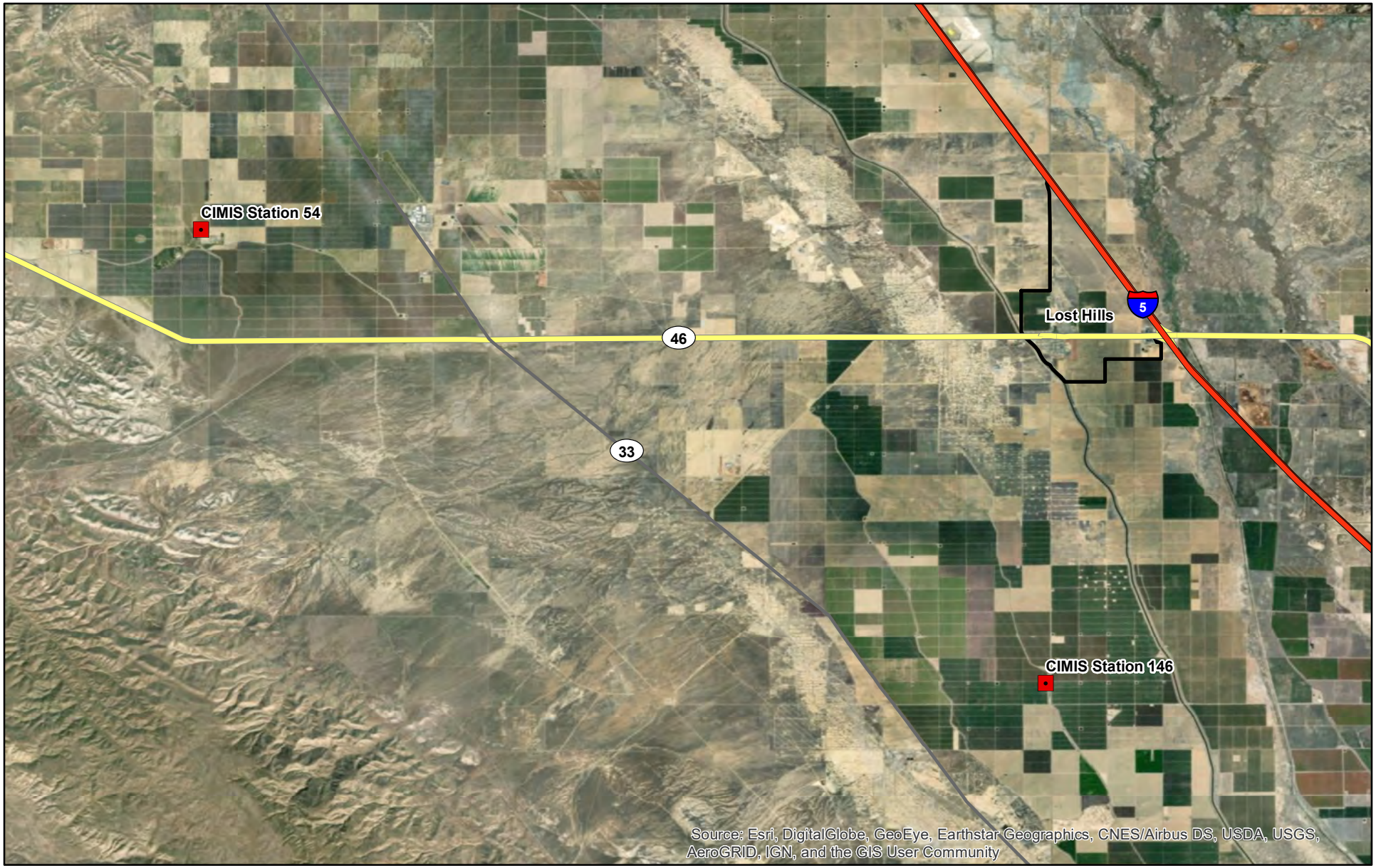
Notes:
KGA: Kern Groundwater Authority
WDWA: Westside District Water Authority

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WDWA Chapter GSP

WDWA/KGA Topographic Features

Date: 12/3/2019	Project #: 043-04	**Figure 4**



CIMIS Station Locations

Lost Hills Town Boundary

0 3

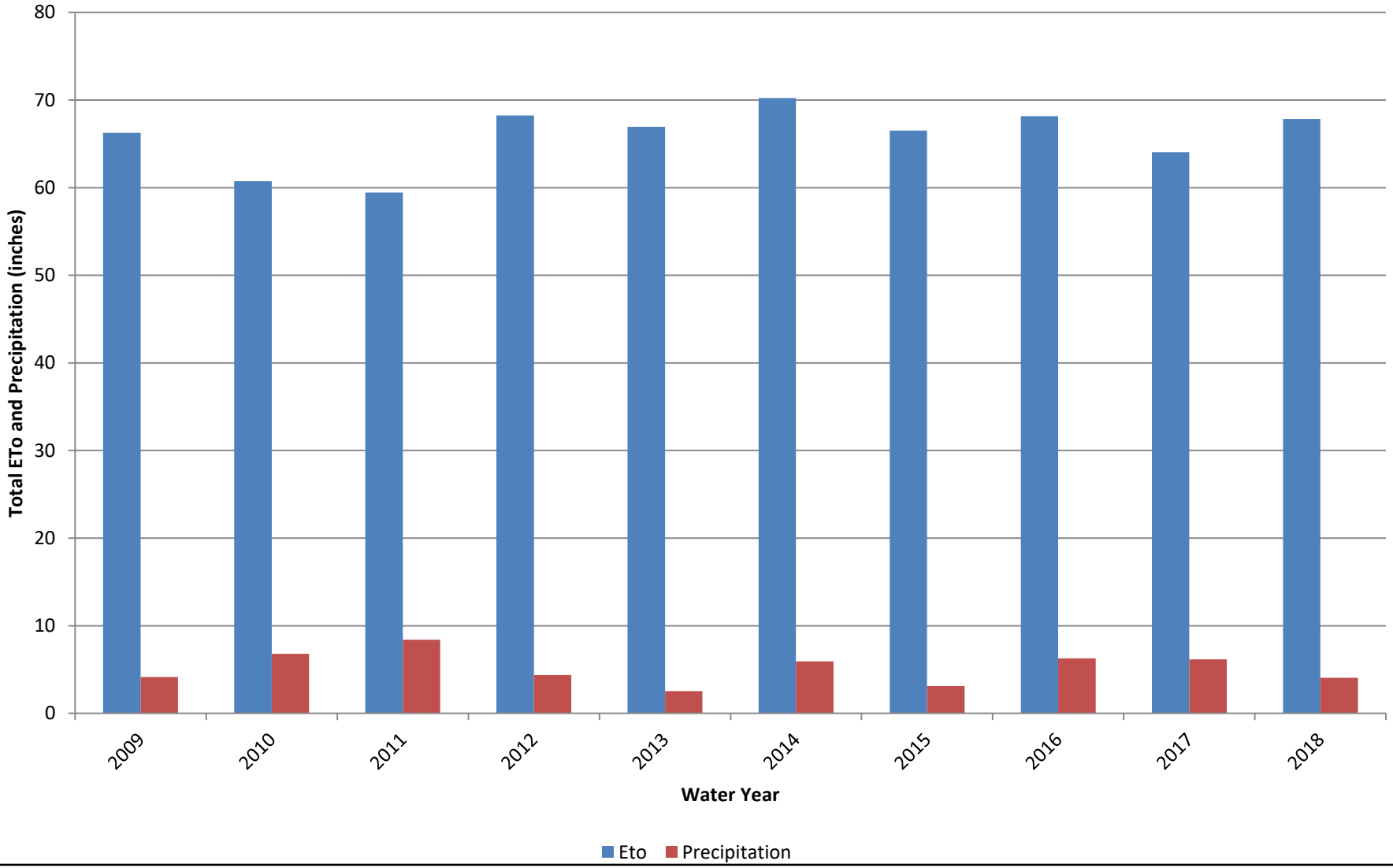
Miles

aquilogic, Inc.

WDWA Chapter GSP

CIMIS Station Locations

Date: 8/23/2019	Project #: 043-04	**Figure 5**



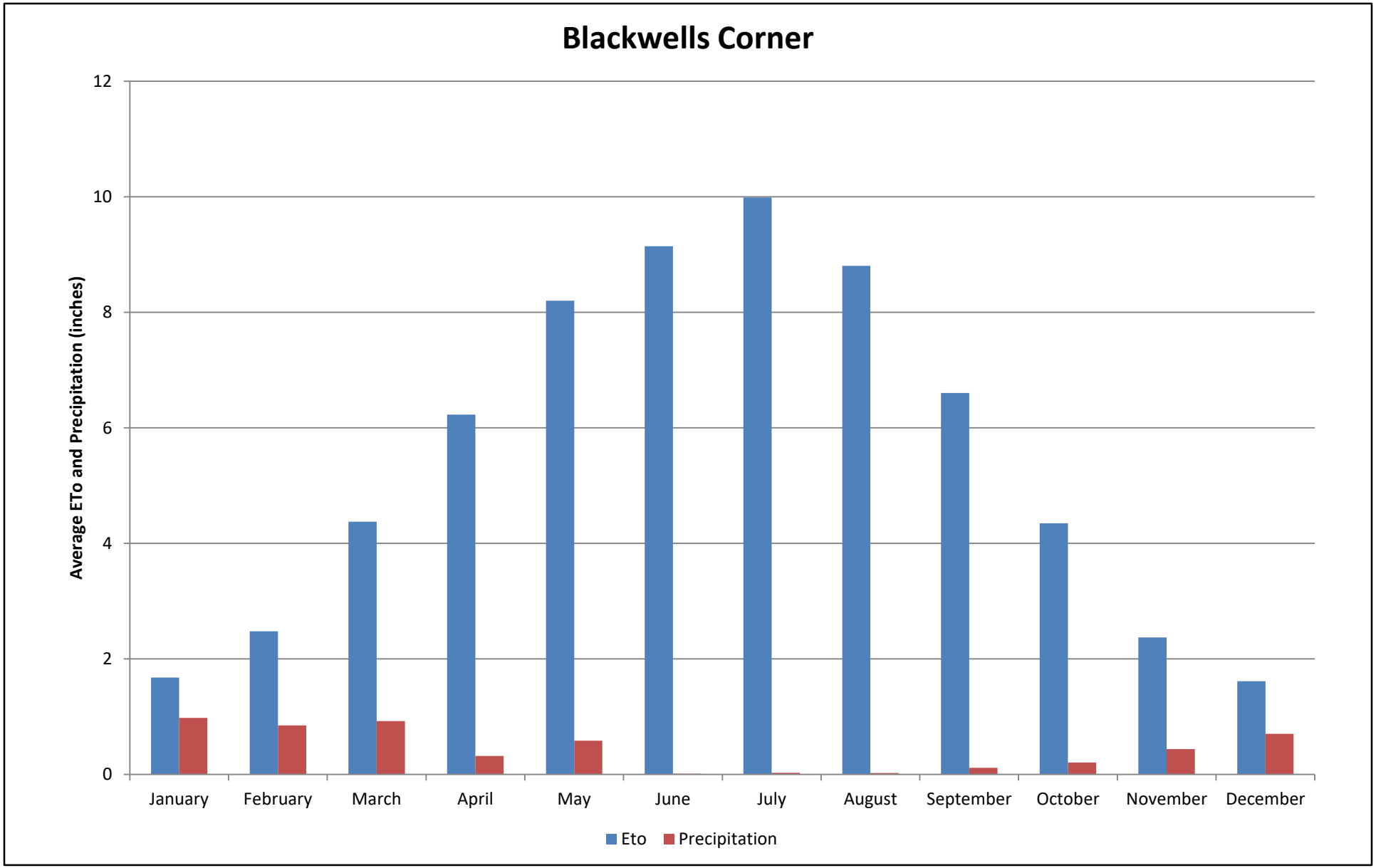
Notes:
ETo: Evapotranspiration

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WDWA Chapter GSP

CIMIS Station #54 – Blackwells Corner
Total ETo and Precipitation

Date: 12/3/2019	Project #: 043-04	**Figure 6**



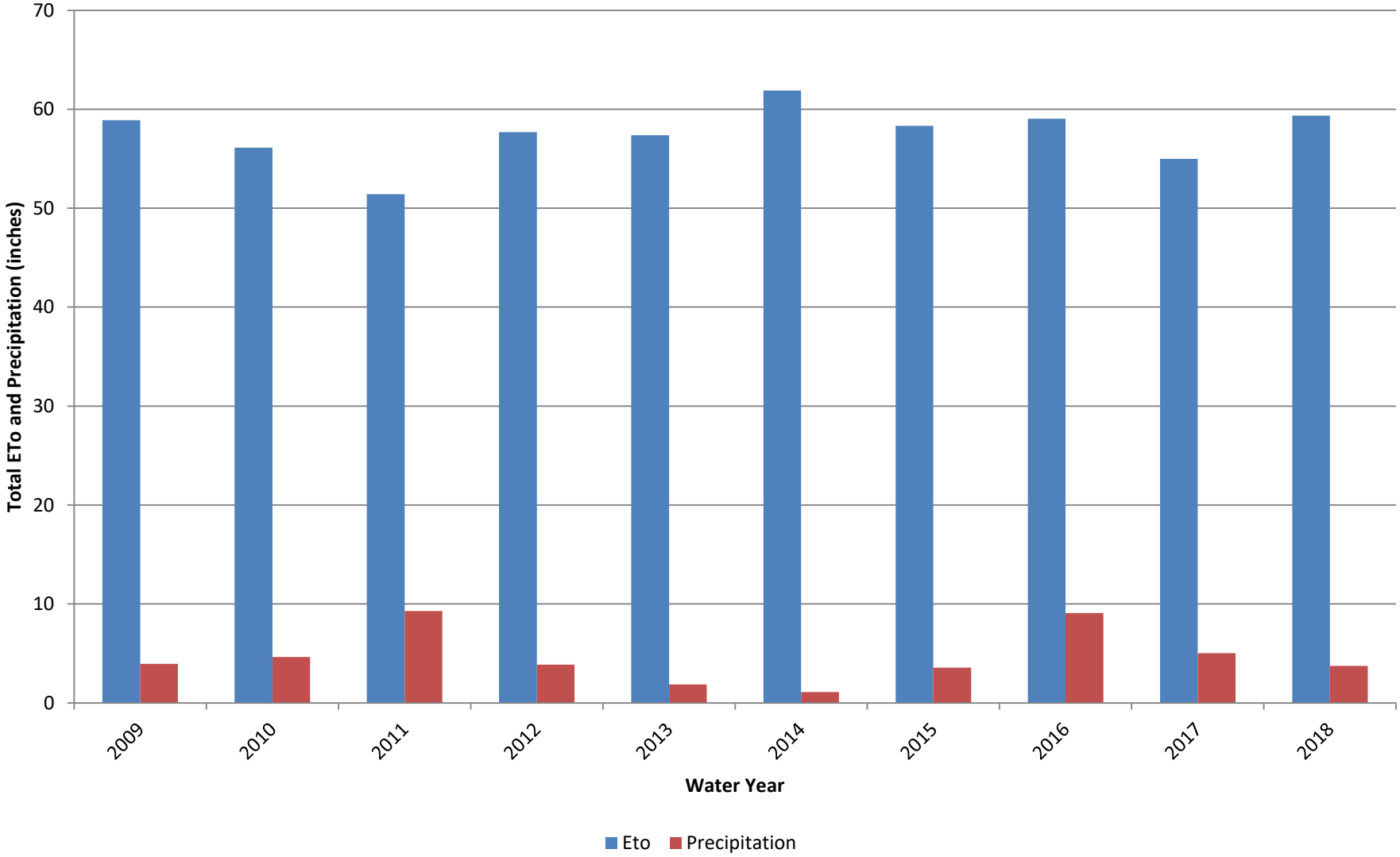
Notes:
ETo: Evapotranspiration

aquilogic, Inc.

WDWA Chapter GSP

CIMIS Station #54 – Blackwells Corner
Average ETo and Precipitation

Date: 12/3/2019	Project #: 043-04	**Figure 7**



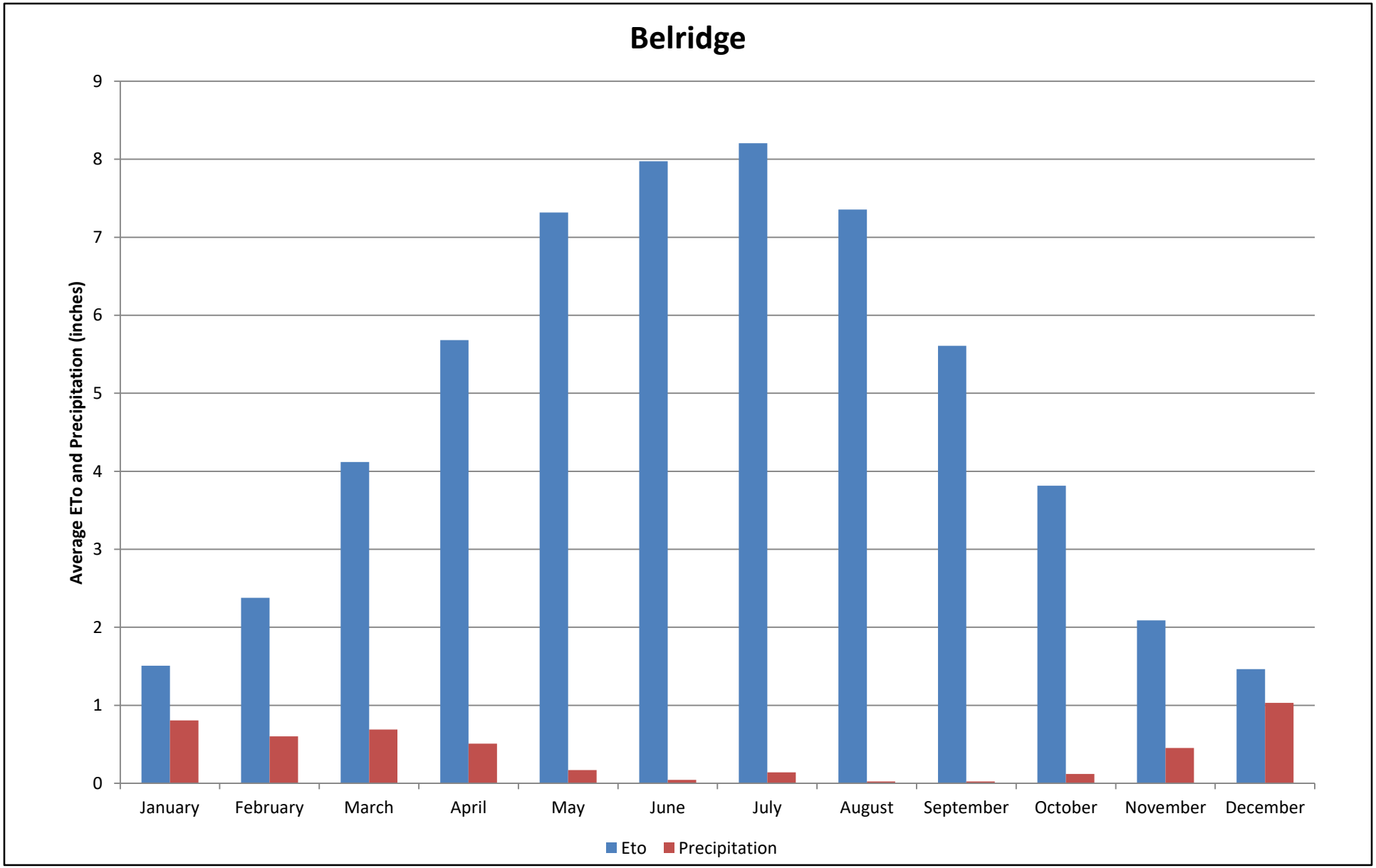
Notes:
ETo: Evapotranspiration

aquilogic, Inc.

WDWA Chapter GSP

CIMIS Station #146 – Belridge
Total ETo and Precipitation

Date: 12/3/2019	Project #: 043-04	**Figure 8**



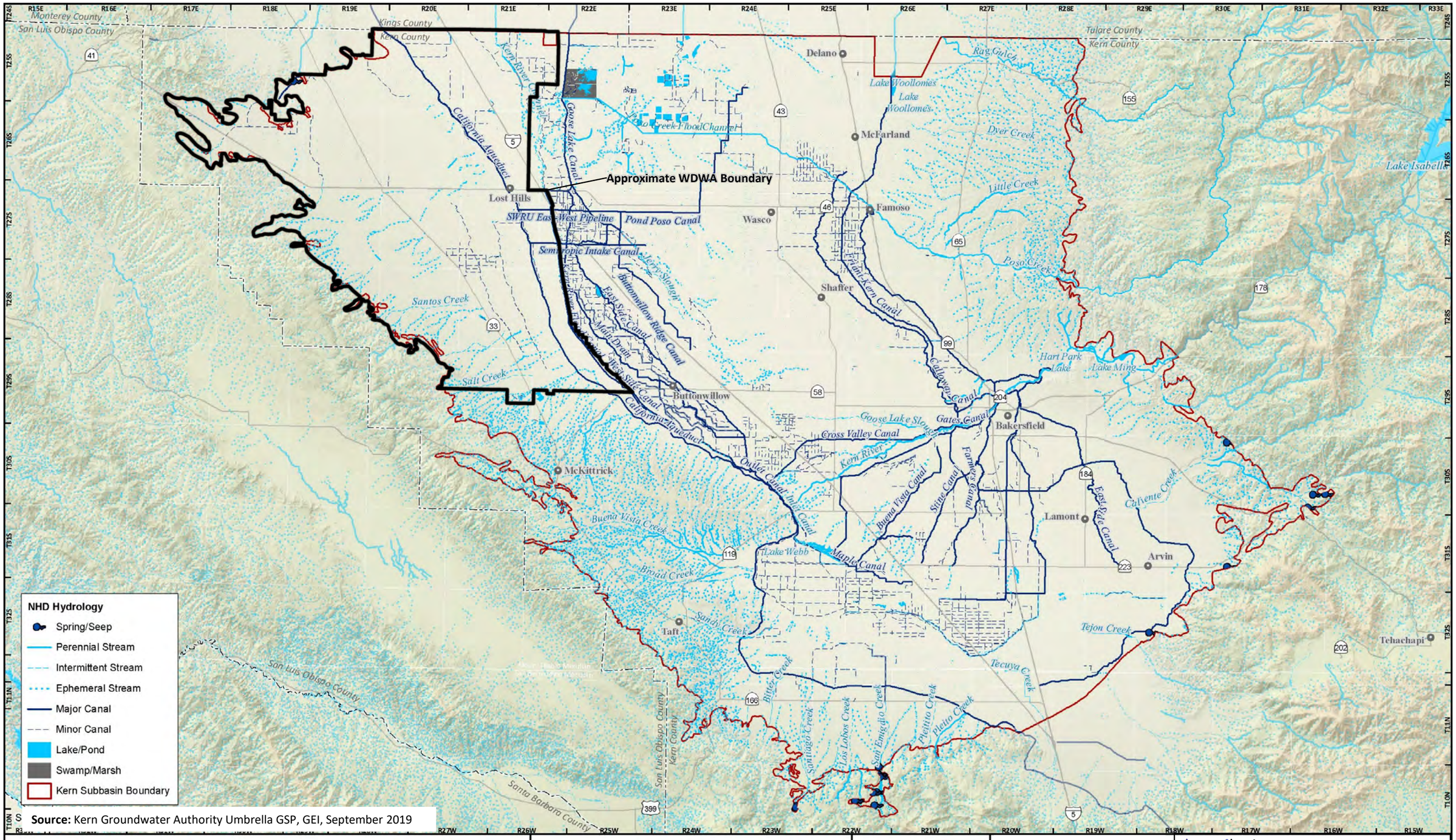
Notes:
ETo: Evapotranspiration

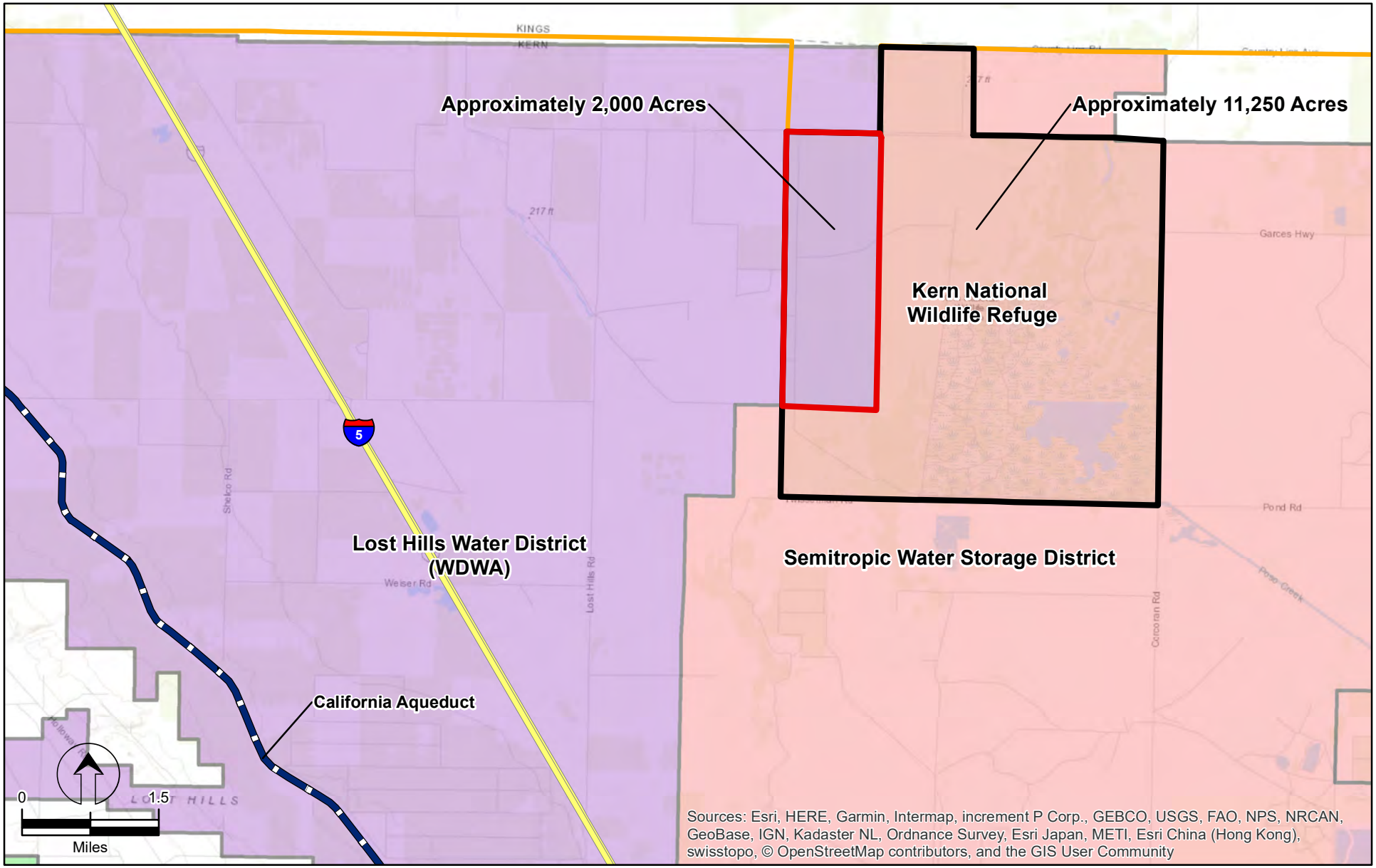
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WDWA Chapter GSP

CIMIS Station #146 – Belridge
Average ETo and Precipitation

Date: 12/3/2019	Project #: 043-04	**Figure 9**


Approximate WDWA Boundary
Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
Delano
McFarland
Wasco
Famoso
Lost Hills
Shaffer
Buttonwillow
Bakersfield
McKittrick
Taft
Arvin
Lamont
Tehachapi
Lake Isabella
Lake Woollomes
Lake Woollomes
Rag Gulch
Dyer Creek
Little Creek
Poso Creek
Hart Park Lake
Lake Ming
Lake Webb
Tejon Creek
Caliente Creek
Santos Creek
Salt Creek
Buena Vista Creek
Broad Creek
Sandy Creek
Bitter Creek
Santiago Creek
Los Lobos Creek
Pleito Creek
Tecuya Creek
Kern River
Goose Lake Slough
Cross Valley Canal
California Aqueduct
Goose Lake Canal
Kern River Channel
Lo Creek Flood Channel
SWRU East-West Pipeline
Pond Poso Canal
Semitropic Intake Canal
Merry Slough
Buttonwillow Ridge Canal
East Side Canal
Main Drain
West Side Canal
Outlet Canal
Buena Vista Canal
Stine Canal
Farmers Canal
Maple Canal
Friant-Kern Canal
Calloway Canal
Gates Canal
East Side Canal
San Luis Obispo County
Kern County
Santa Barbara County
NHD Hydrology
Spring/Seep
Perennial Stream
Intermittent Stream
Ephemeral Stream
Major Canal
Minor Canal
Lake/Pond
Swamp/Marsh
Kern Subbasin Boundary
Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019
0 3.5 7 14 21
Miles
N
W
E
S
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
Notes:
KGA: Kern Groundwater Authority
WDWA: Westside District Water Authority
aquilogic, Inc.
WDWA Chapter GSP
WDWA/KGA
Surface Water Features
Date: 12/3/2019
Project #: 043-04
Figure 10a



Lost Hills WD
Semitropic WSD
Undistricted Lands
Kern County Groundwater Sub-Basin
California Aqueduct

Kern National Wildlife Refuge
Area of Overlap - Kern National Wildlife Refuge and Lost Hills Water District

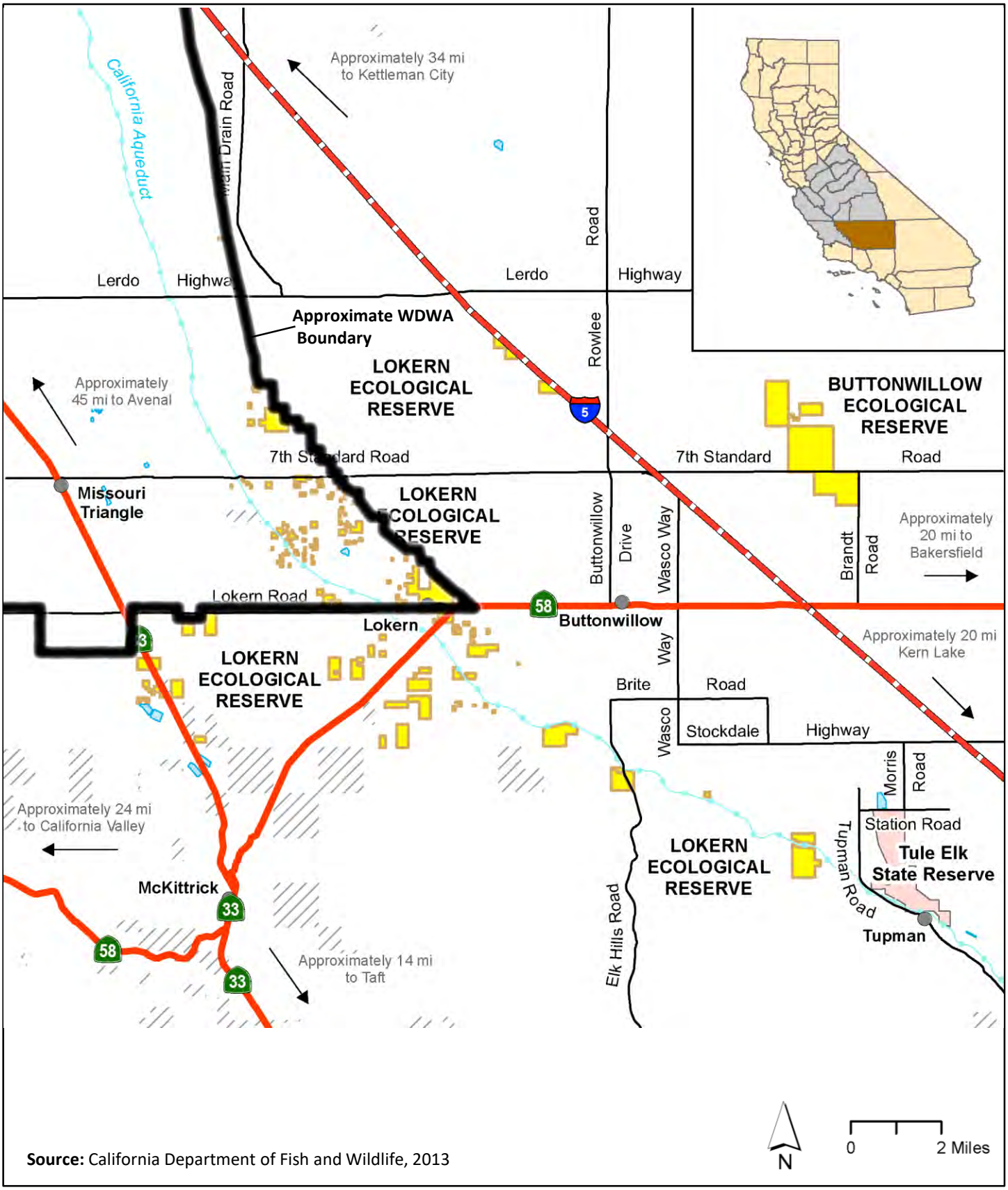
Notes:
WDWA: Westside District Water Authority

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Jurisdictional Boundary of Federal or State Land (Kern National Wildlife Refuge)

Date: 12/4/2019	Project #: 043-04	**Figure 10b**



Source: California Department of Fish and Wildlife, 2013

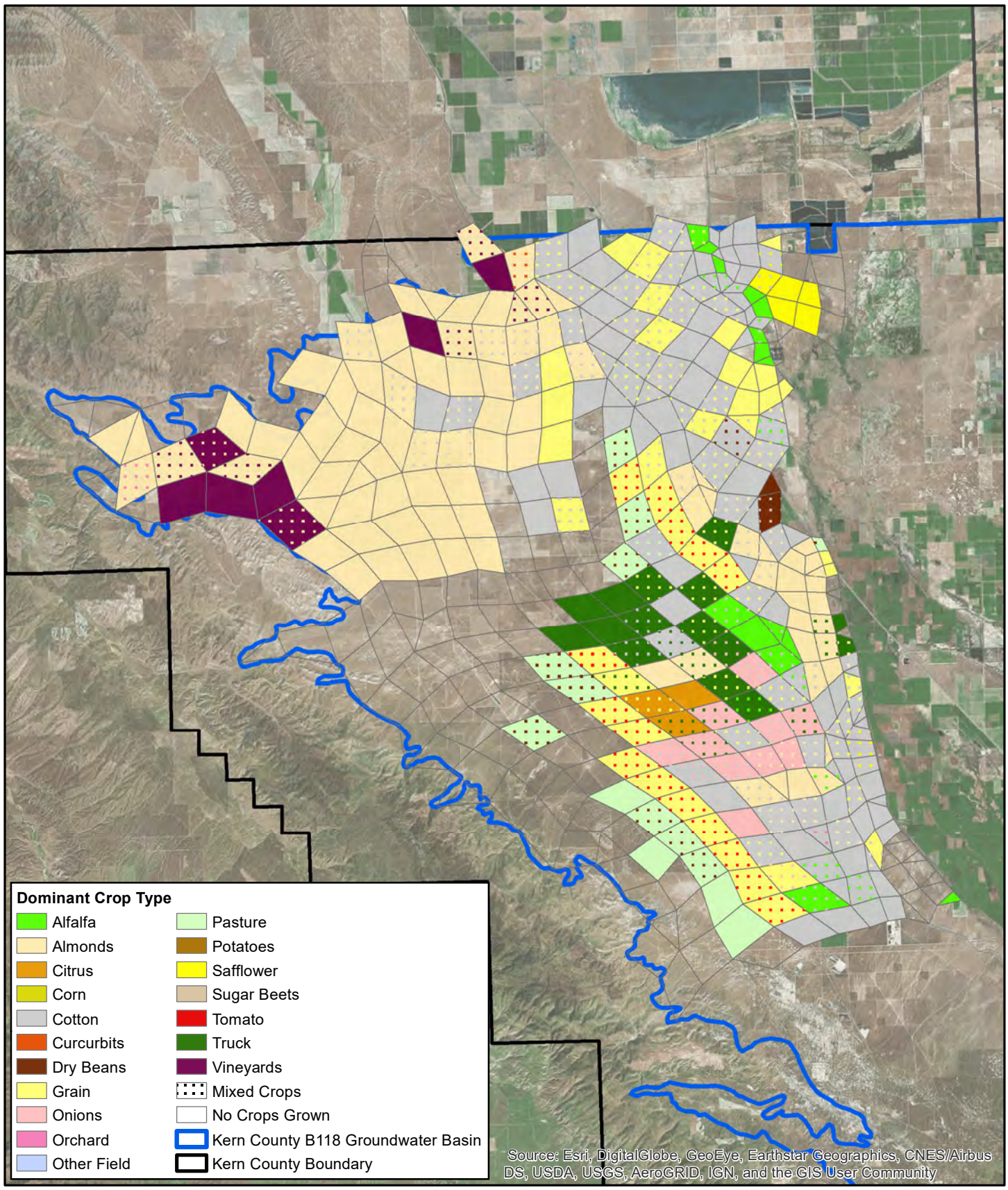
Ecological Reserve
State Reserve
Bureau of Land Management
Interstate Highway
State Highway
Local Road

aquilogic, Inc.

WDWA Chapter GSP

Jurisdictional Boundary of Federal or State Land (Lokern Ecological Reserve)

Date: 12/4/2019	Project #: 043-04	**Figure 10c**



Source:
KGA - Todd Groundwater Model, 2019

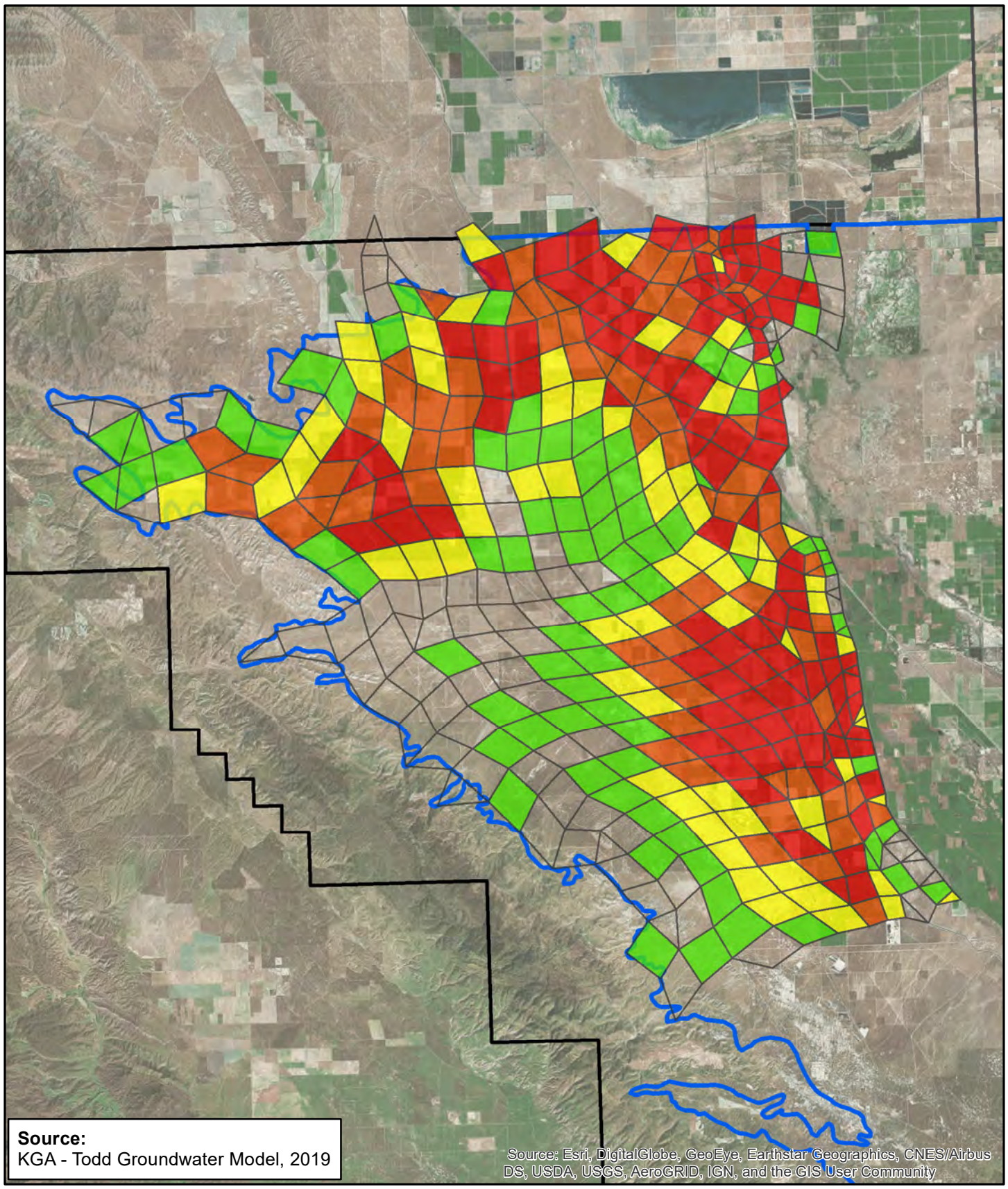
0 5
Miles

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WDWA Chapter GSP

Dominant Crop Type - NW Kern County 1992

Date: 3/26/2019	Project #: 043-04	**Figure 11a**



No Cropped Area
0.01% - 25% Cropped Area
25.01% - 50% Cropped Area
50.01% - 75% Cropped Area
75.01% - 100% Cropped Area

Kern County B118 Groundwater Basin
Kern County Boundary

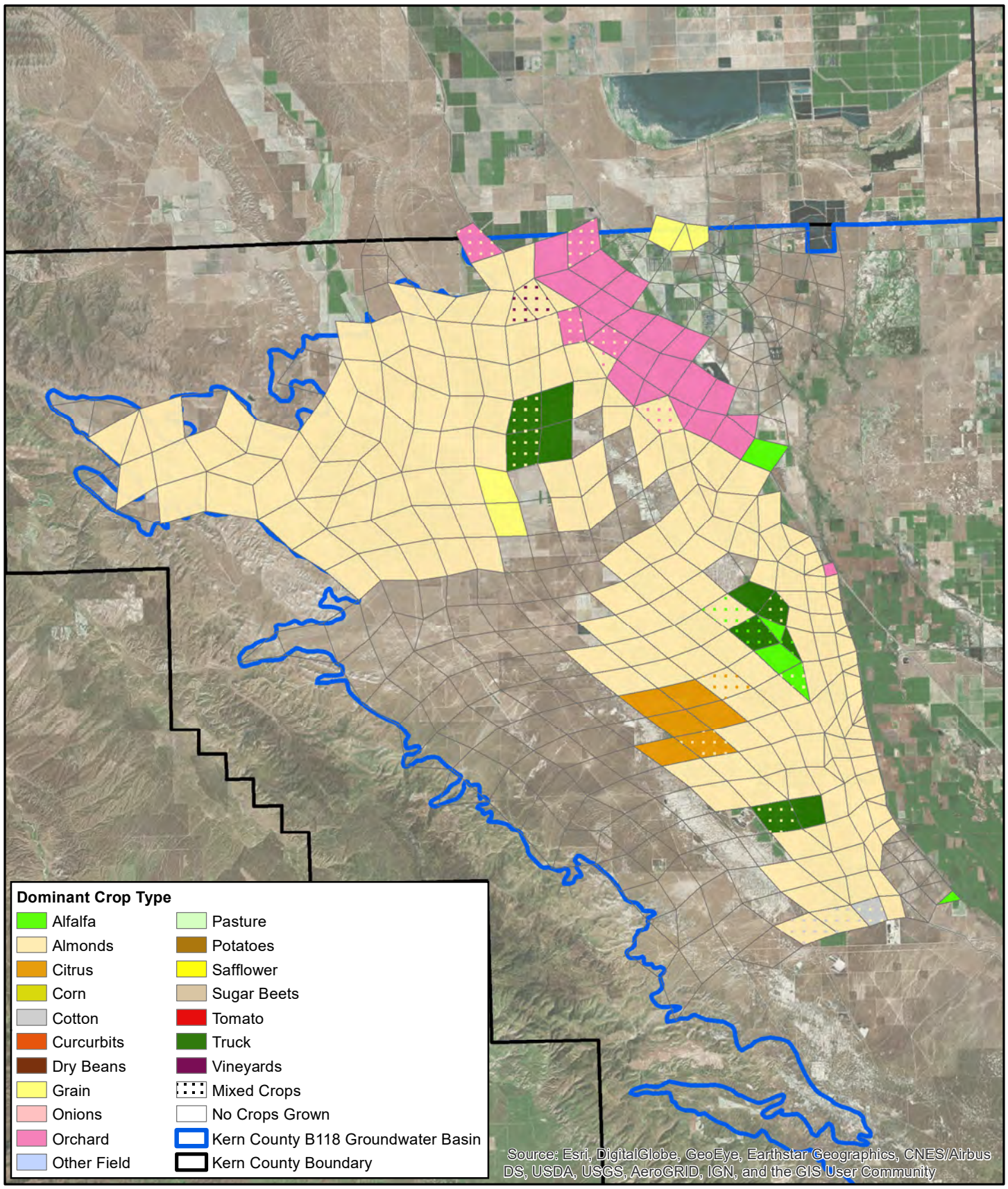
0 5
Miles

aquilogic, Inc.

WDWA Chapter GSP

Percentage of Cropped Area
NW Kern County - 1992

Date: 3/26/2019	Project #: 043-04	**Figure 11b**



Source:
KGA - Todd Groundwater Model, 2019

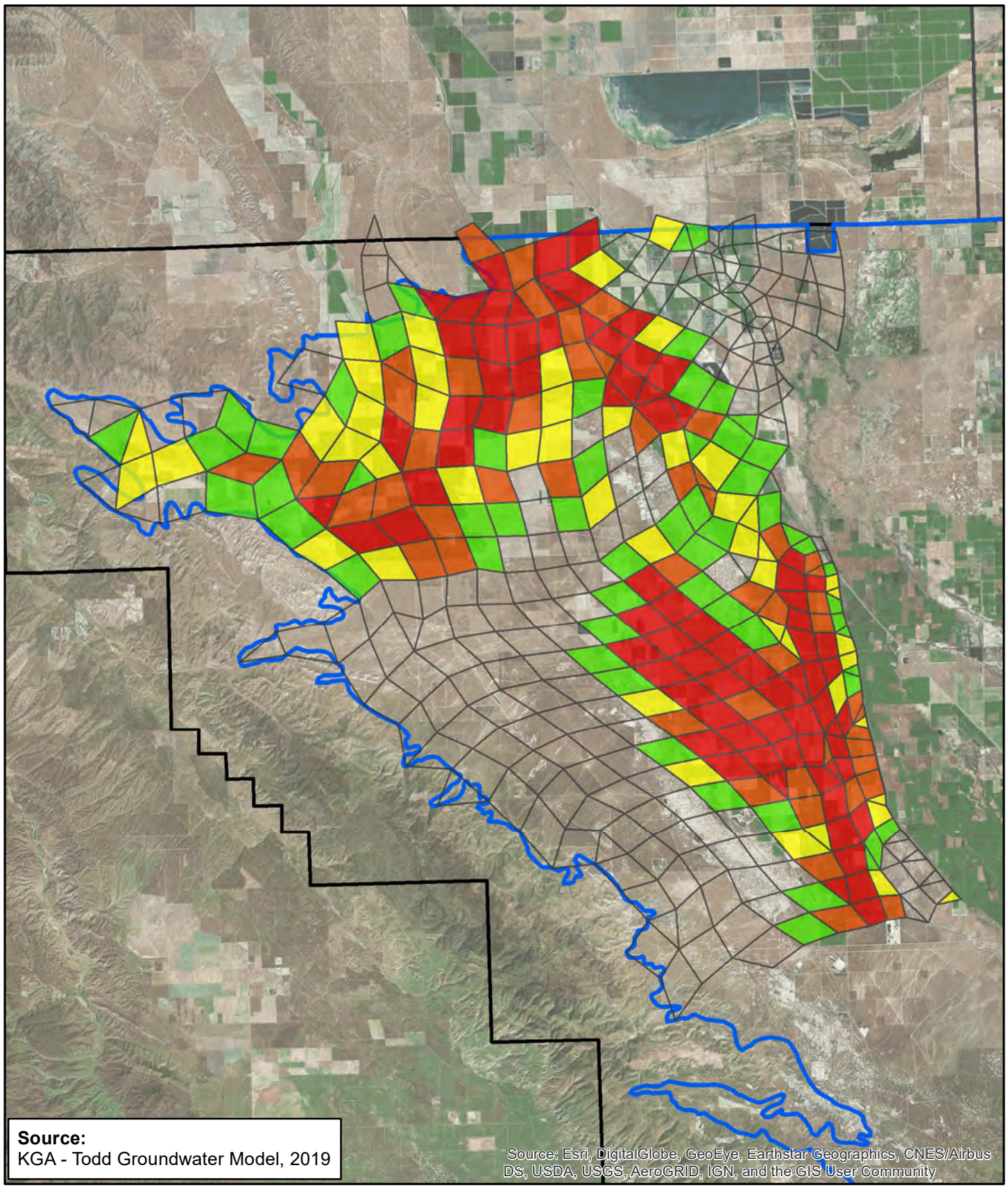
0 5
Miles

aquilogic, Inc.

WDWA Chapter GSP

Dominant Crop Type - NW Kern County 2014

Date: 3/26/2019	Project #: 043-04	**Figure 11c**



No Cropped Area
0.01% - 25% Cropped Area
25.01% - 50% Cropped Area
50.01% - 75% Cropped Area
75.01% - 100% Cropped Area

Kern County B118 Groundwater Basin
Kern County Boundary

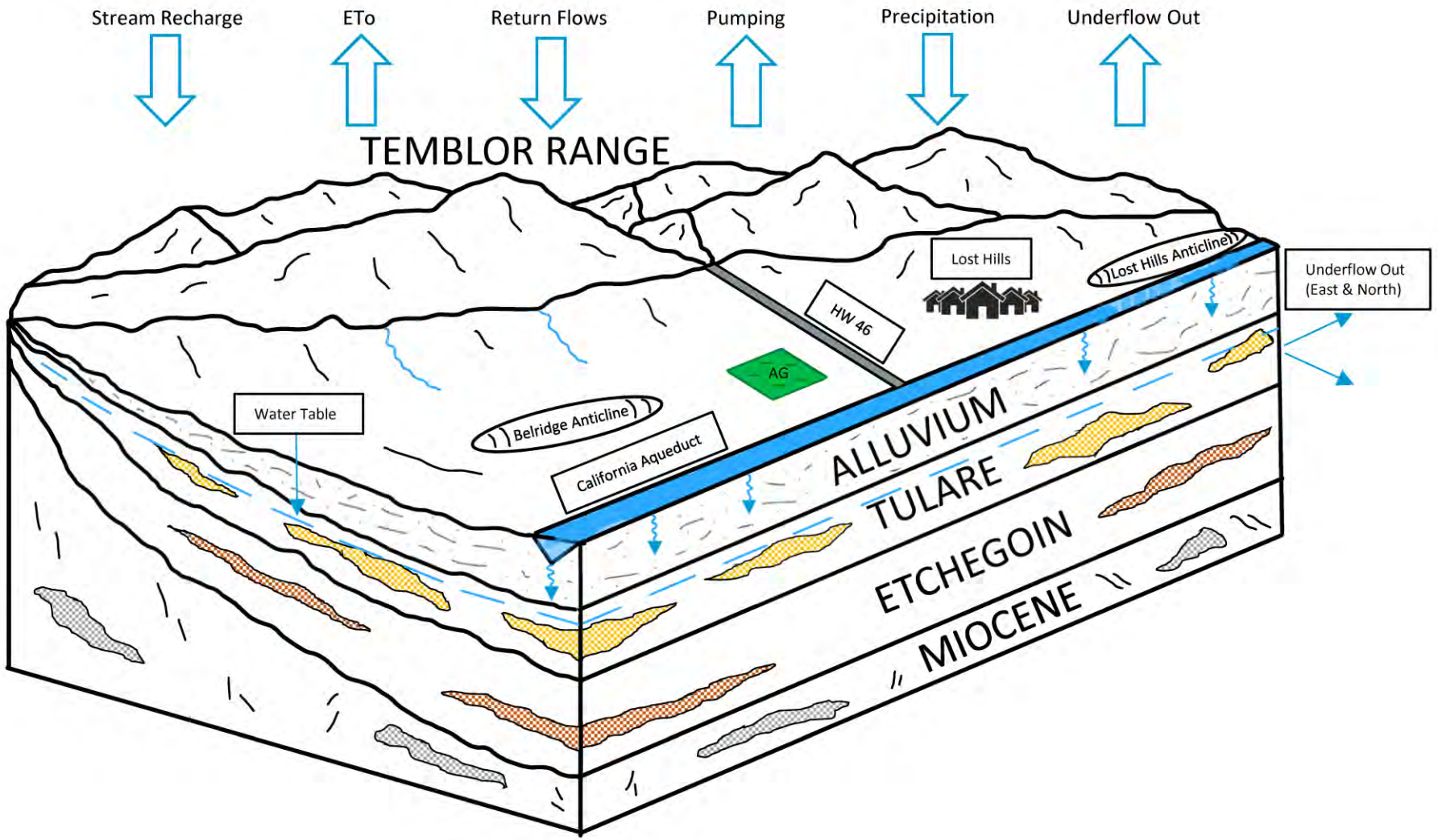
0 5
Miles

aquilogic, Inc.

WDWA Chapter GSP

Percentage of Cropped Area
NW Kern County - 2014

Date: 3/26/2019	Project #: 043-04	**Figure 11d**

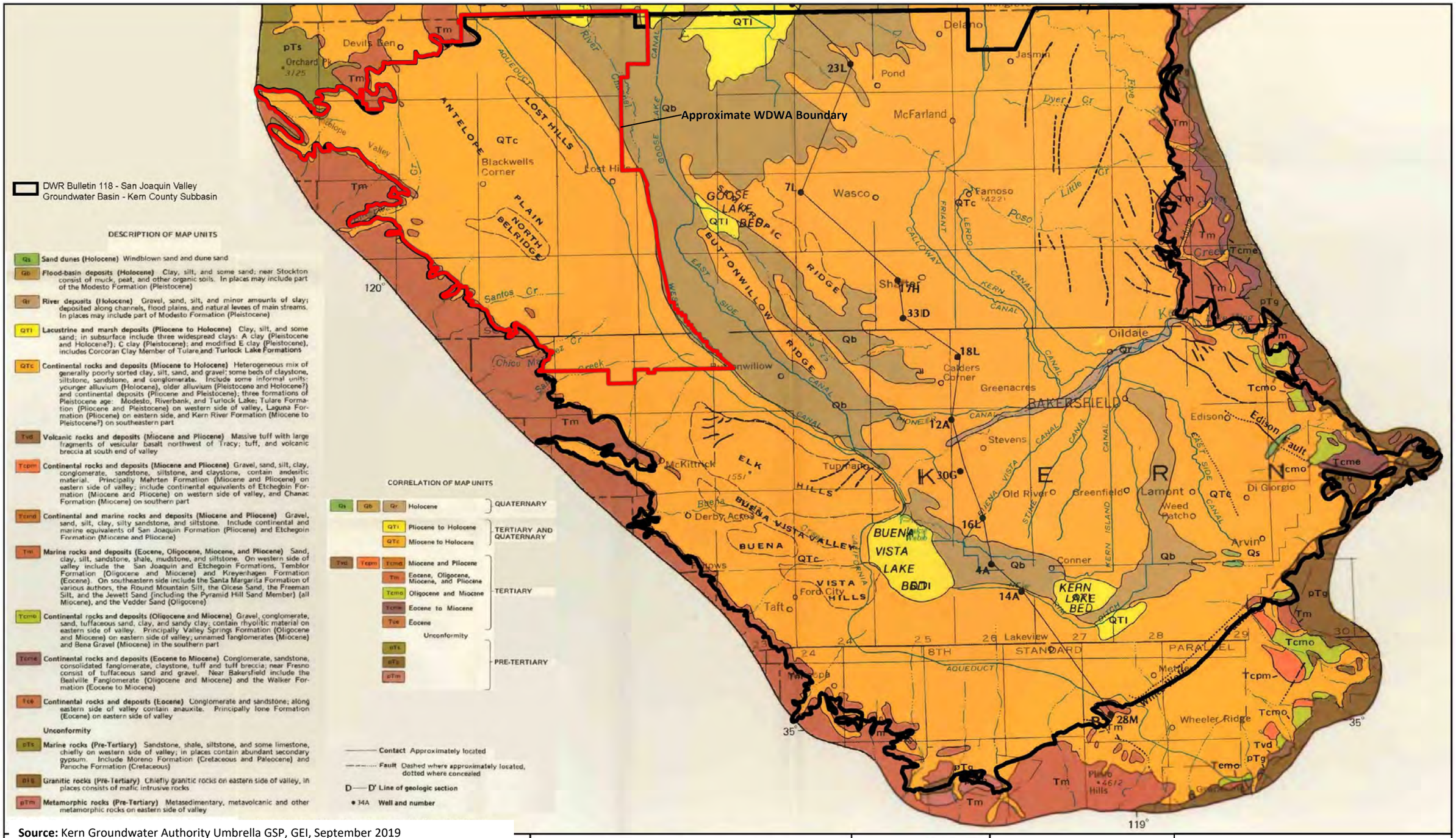


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WDWA Chapter GSP

Conceptual Hydrogeologic Diagram

Date: 12/3/2019	Project #: 043-04	**Figure 12a**



Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

10 5 0 10
Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

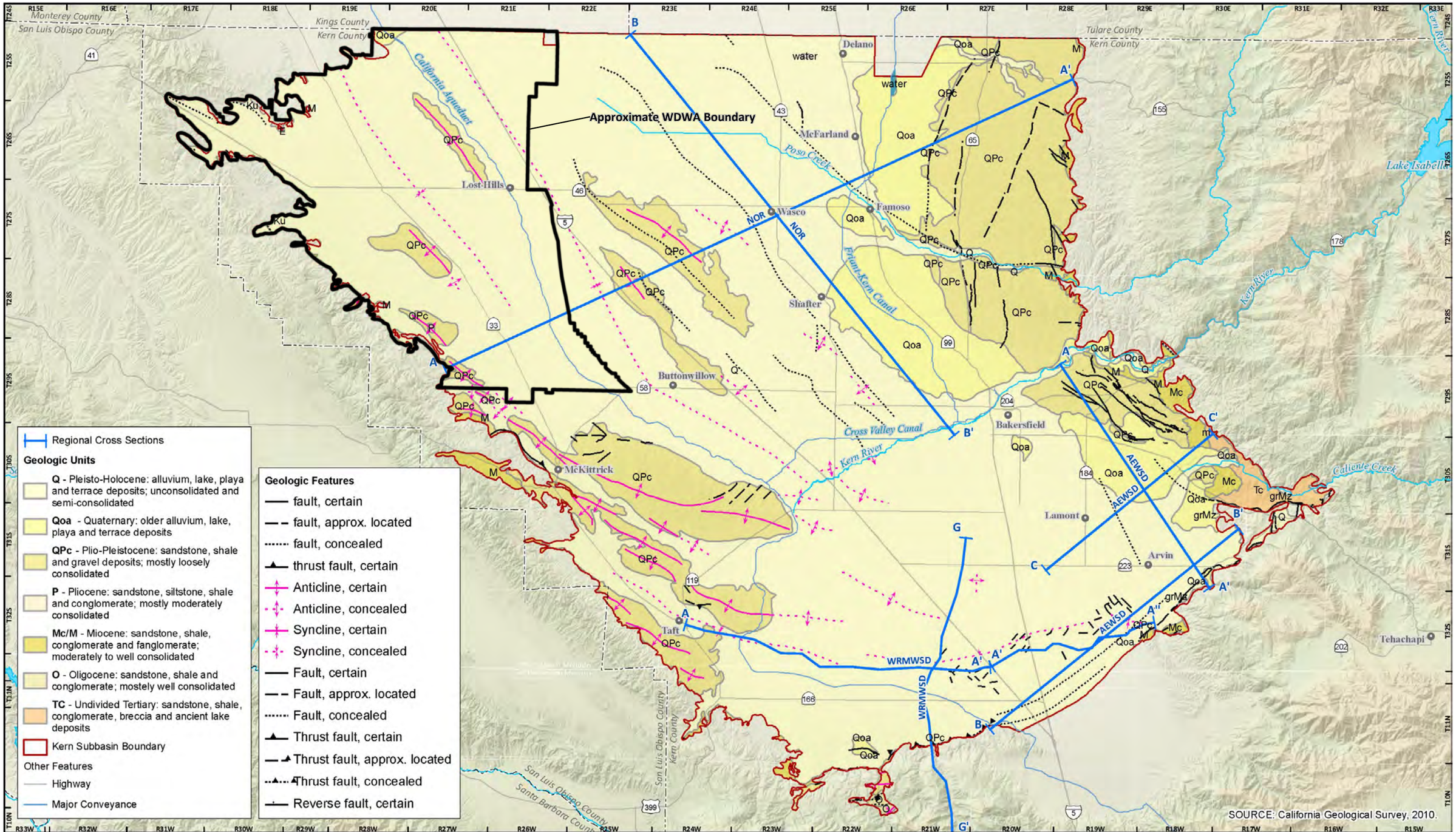
Notes:
WDWA: Westside District Water Authority

aquilogic, Inc.

WDWA Chapter GSP

Geology in the Kern County Groundwater Subbasin

Date: 12/3/2019	Project #: 043-04	**Figure 12b**



Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

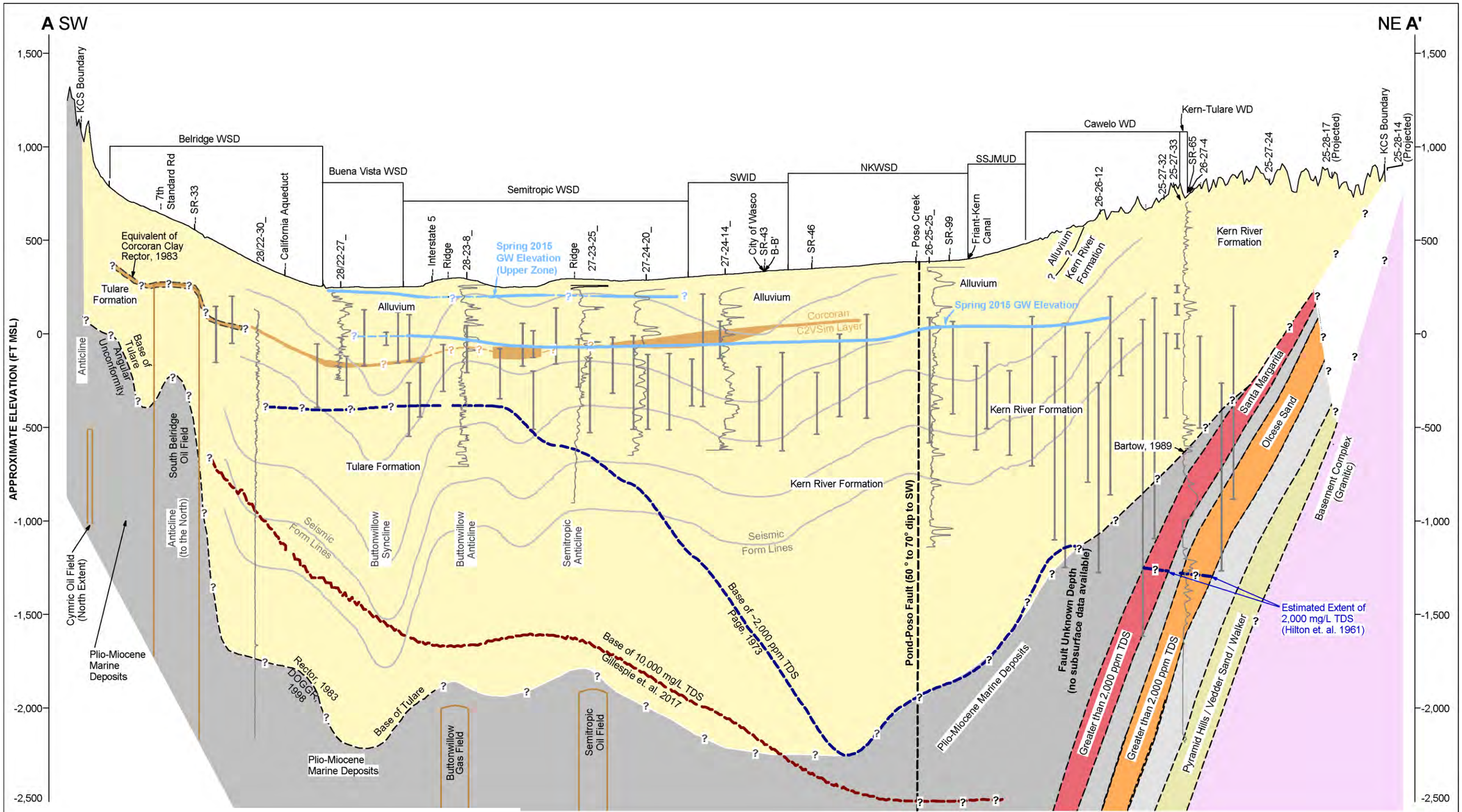
Notes:
KGA: Kern Groundwater Authority
WDWA: Westside District Water Authority

aquilogic, Inc.

WDWA Chapter GSP

Conceptual KGA Cross-Sections A-A' and B-B' Location Map

Date: 12/3/2019 | Project #: 043-04 | **Figure 12c**



Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

Approximate Scale
0 1.8 3.7 Miles
Vertical Exaggeration = 39x

Well Perforated Intervals
Resistivity (ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model
Alluvium / Kern River Formation / Tulare Formation
Plio-Miocene Marine Deposits (Etchegoin/San Joaquin)
Oil Field Primacy Extents (Approximate) (DOGGR, 1998)

Kern Groundwater Authority
Basin Setting

Kern County, CA

Notes:
KGA: Kern Groundwater Authority
WDWA: Westside District Water Authority

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WDWA Chapter GSP

Conceptual KGA West - East Cross-Section A-A'

Date: 12/3/2019 | Project #: 043-04 | **Figure 12d**

B NW

SE B'

APPROXIMATE ELEVATION (FT MSL)

1,500
1,000
500
0
-500
-1,000
-1,500
-2,000
-2,500

Kern County Subbasin Northern Boundary

Approximate Extent of Bakersfield Arch

Kern River GSA

Semitropic WSD

NKWSD

SWID

NKWSD

RRBWSD

ID4

ID4

25-23-27_

Spring 2015 GW Elevation (Upper Zone)

-- Poso Creek

26-24-8_

26-24-21_

City Of Wasco

-- SR-46

-- A-A' SR-43

27-25-19_

27-25-28_

28-25-3_

-- City Of Shafter

28-25-12_

-- 7th Standard Rd

-- SR-58

-- CV Canal -- Kern River

Alluvium

Corcoran C2VSim Layer

Spring 2015 GW Elevation

Alluvium

Tulare Formation

Base of 10,000 mg/L TDS
Gillespie et. al. 2017

Base of ~2,000 ppm TDS
Page, 1973

Seismic Form Lines (PGA, 1991)

Seismic Form Lines, Apparent Dip
(Chevron Oil Company, Aug. 1966, Line T-874)

Kern River Formation

Mio-Pliocene Marine Deposits

Rose Oil Field approximately -7000 feet msl

Shafter North Oil Field approximately -7100 feet msl

Seventh Standard Oil Field approximately -7100 feet msl

Rosedale Oil Field approximately -5100 feet msl

NOTE: Although contacts with the Top of San Joaquin Formation (Mio-Pliocene Marine Deposits) are reported in Oil and Gas records for some of this cross section, facies changes are likely occurring and can cause difficulty in correlation along the cross section.

Miles
0 1.4 2.9
Vertical Exaggeration = 31x

Well Perforated Intervals
Resistivity (0-100 ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model
Alluvium / Kern River Formation / Tulare Formation
Mio-Pliocene Marine Deposits

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

NKWSD-SWID Basin Setting

Kern County, CA

Notes:
KGA: Kern Groundwater Authority
WDWA: Westside District Water Authority

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WDWA Chapter GSP

Conceptual KGA North - South Cross-Section B-B'

Date: 12/3/2019 | Project #: 043-04 | **Figure 12e**

Approximate WDWA Boundary

USGS Corcoran Clay Thickness (ft)
USGS Corcoran Clay Depth (ft)
USGS Extent of Corcoran Clay
Kern Subbasin Boundary
Other Features
Highway
Major Conveyance

Notes:
These data comprise a regional representation of the Corcoran Clay. Data developed at a local level (e.g. Kern Fan Area, Buttonwillow Ridge and Semitropic Ridge) likely differ in clay extent and thickness.

SOURCE: Corcoran Clay Extents - Page, 1986; Faunt et al, PP-1766 (2012)

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

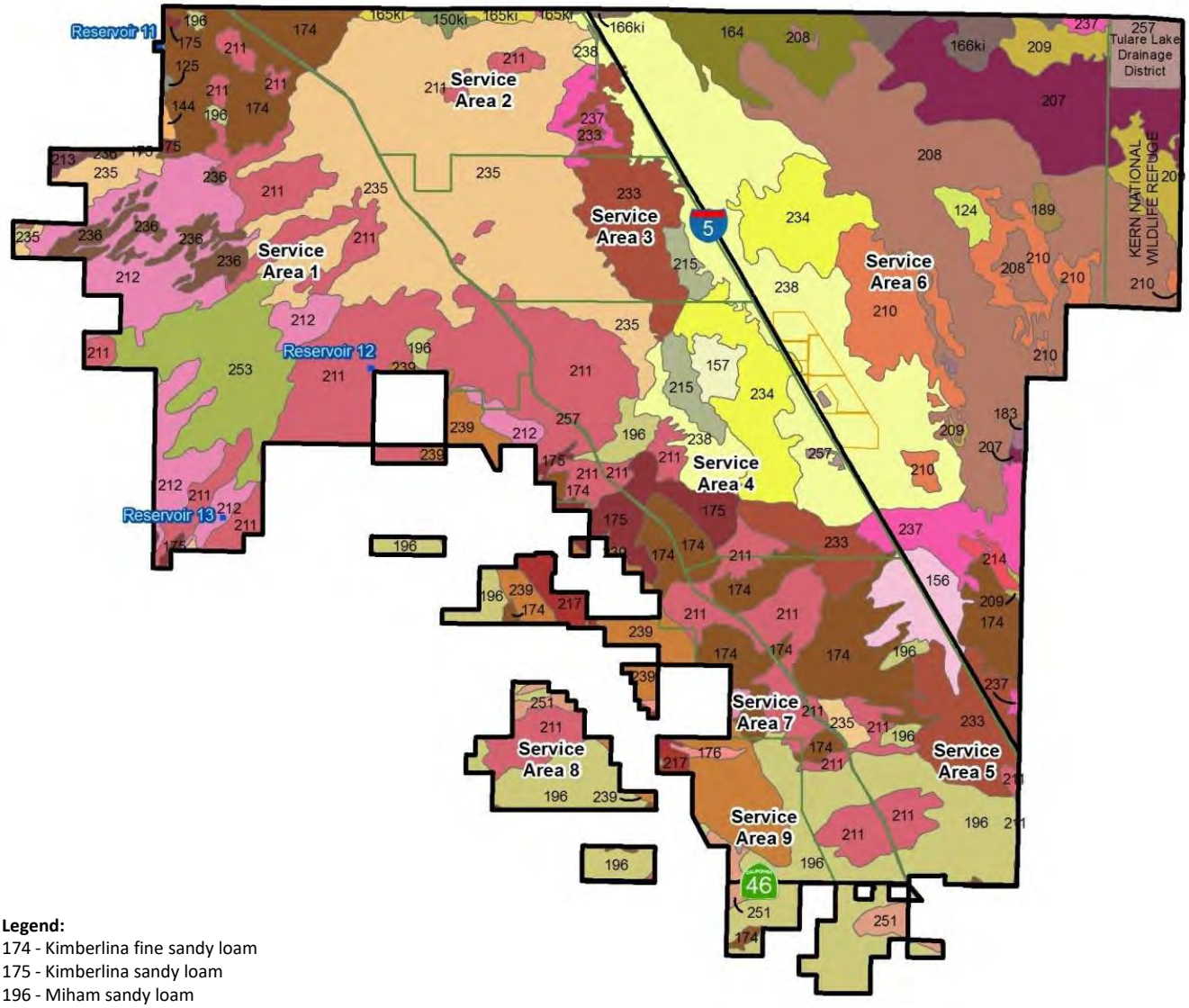
Notes:
WDWA: Westside District Water Authority

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Corcoran Clay in the Kern County Groundwater Subbasin

Date: 12/3/2019 | Project #: 043-04 | **Figure 13**



Legend:

- 174 - Kimberlina fine sandy loam
- 175 - Kimberlina sandy loam
- 196 - Miham sandy loam
- 211 - Panoche clay loam
- 212 - Panoche clay
- 233 - Twisselman sandy loam (saline-alkali)
- 234 - Twisselman sandy loam
- 235 - Twisselman clay
- 253 - Yribarren clay loam

Notes:
A more complete list of U.S. Department of Agriculture soil types is provided in Appendix B.

Source: 2015 Update to the 2012 Agricultural Water Management Plan, Lost Hills Water District, December 2015

0 0.5 1 1.5 2 Miles

EST. 1968
PROVOST& PRITCHARD CONSULTING GROUP
An Employee Owned Company
1800 30th St. Suite 280
Bakersfield, CA . 93301
(661) 616-5900

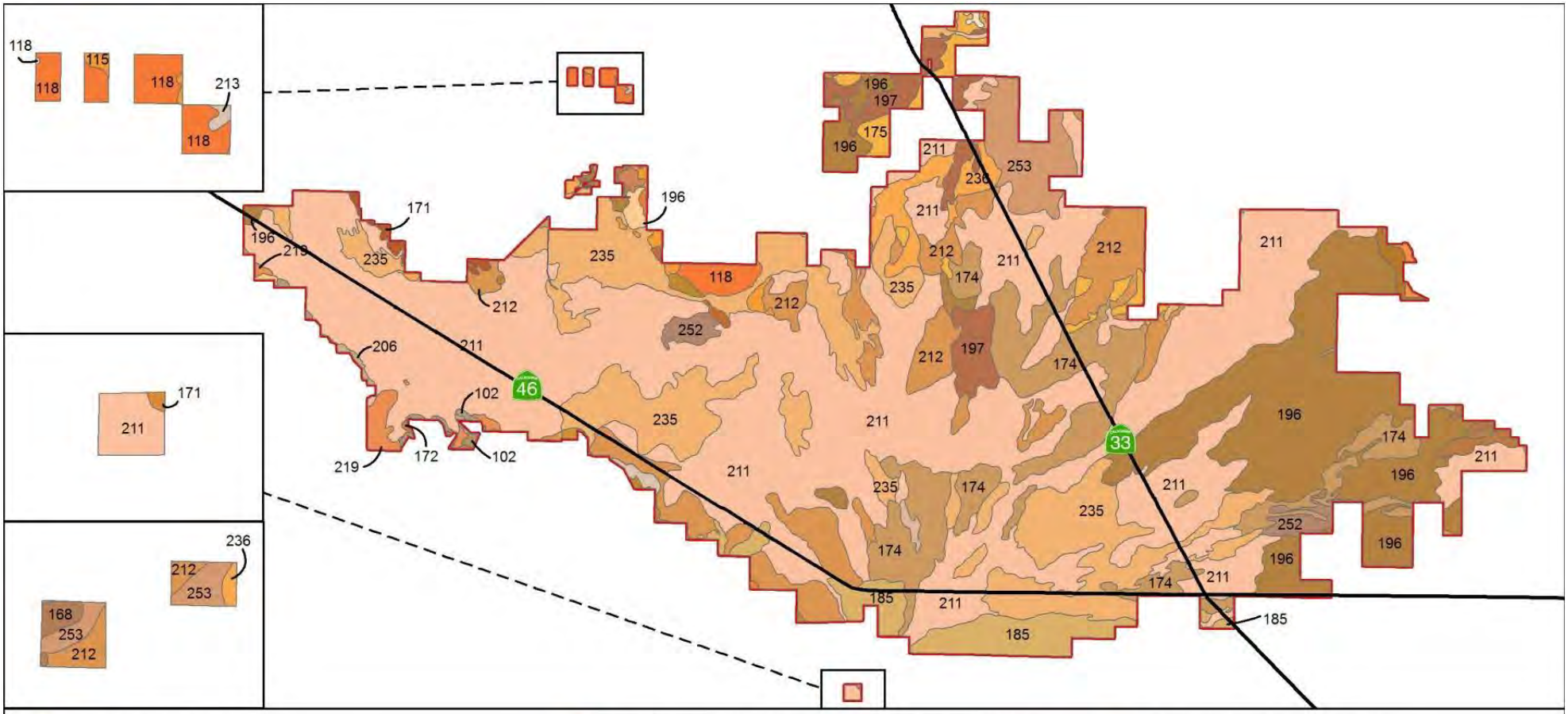
Highway
LHWD Boundary
Pond
Rservoir

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WDWA Chapter GSP

Lost Hills Water District
Surface Soil Types

Date: 12/3/2019	Project #: 043-04	**Figure 14a**



101: Aido clay, 9 to 30% slopes
102: Aido clay 30 to 50% slopes
115: Bitterwater sandy loam, 9 to 15% slopes
118: Bitterwater-Delgado association, 9 to 30% slopes
119: Bitterwater-Delgado association, 30 to 75% slopes
129: Carollo-Twisselman saline alkali association, 2 to 15 p ercent slopes
129: Carollo-Twisselman saline alkali association, 2 to 15% slopes
144: Delgado sandy loam, 5 to 30% slopes
163: Hillbrick-Rock outcrop complex, 50 to 75% slopes
166: Kecksroad silty clay loam, 5 to 15% slopes
167: Kecksroad silty clay loam, 15 to 50% slopes
168: Kettleman loam, 9 to 15% slopes
169: Kettleman loam, 15 to 50% slopes
171: Kettleman-Delgado-Rock outcrop complex, 15 to 50 percen t slopes
171: Kettleman-Delgado-Rock outcrop complex, 15 to 50% slopes
172: Kilmer-Hillbrick complex, 15 to 50% slopes
174: Kimberlina fine sandy loam, 0 to 2% slopes
175: Kimberlina sandy loam, 2 to 5% slopes
177: Kimberlina gravelly sandy loam, 2 to 5% slopes
185: Lewkalb, saline alkali-Milham-Kimberlina complex, 0 to 5% slopes
186: Lodo variant clay loam, 15 to 50% slopes
196: Milham sandy loam, 0 to 2% slopes
197: Milham sandy loam, 2 to 5% slopes
206: Nacimiento-Kilmer complex, 30 to 50% slopes
211: Panoche clay loam, 0 to 2% slopes
212: Panoche clay loam, 2 to 5% slopes
213: Panoche clay loam, 5 to 9% slopes
217: Pits
219: Polonio loam, 2 to 9% slopes
220: Pottinger very shaly clay loam, 2 to 9% slopes
235: Twisselman clay, 0 to 2% slopes
236: Twisselman clay, 2 to 5% slopes
239: Typic Gypsiorthids-Kimberlina association, 0 to 5 percent slopes
239: Typic Gypsiorthids-Kimberlina association, 0 to 5% slopes
251: Yribarren loam, 0 to 2% slopes
252: Yribarren clay loam, 0 to 2% slopes
253: Yribarren clay loam, 2 to 5% slopes
257: Water

0 1 2 Miles

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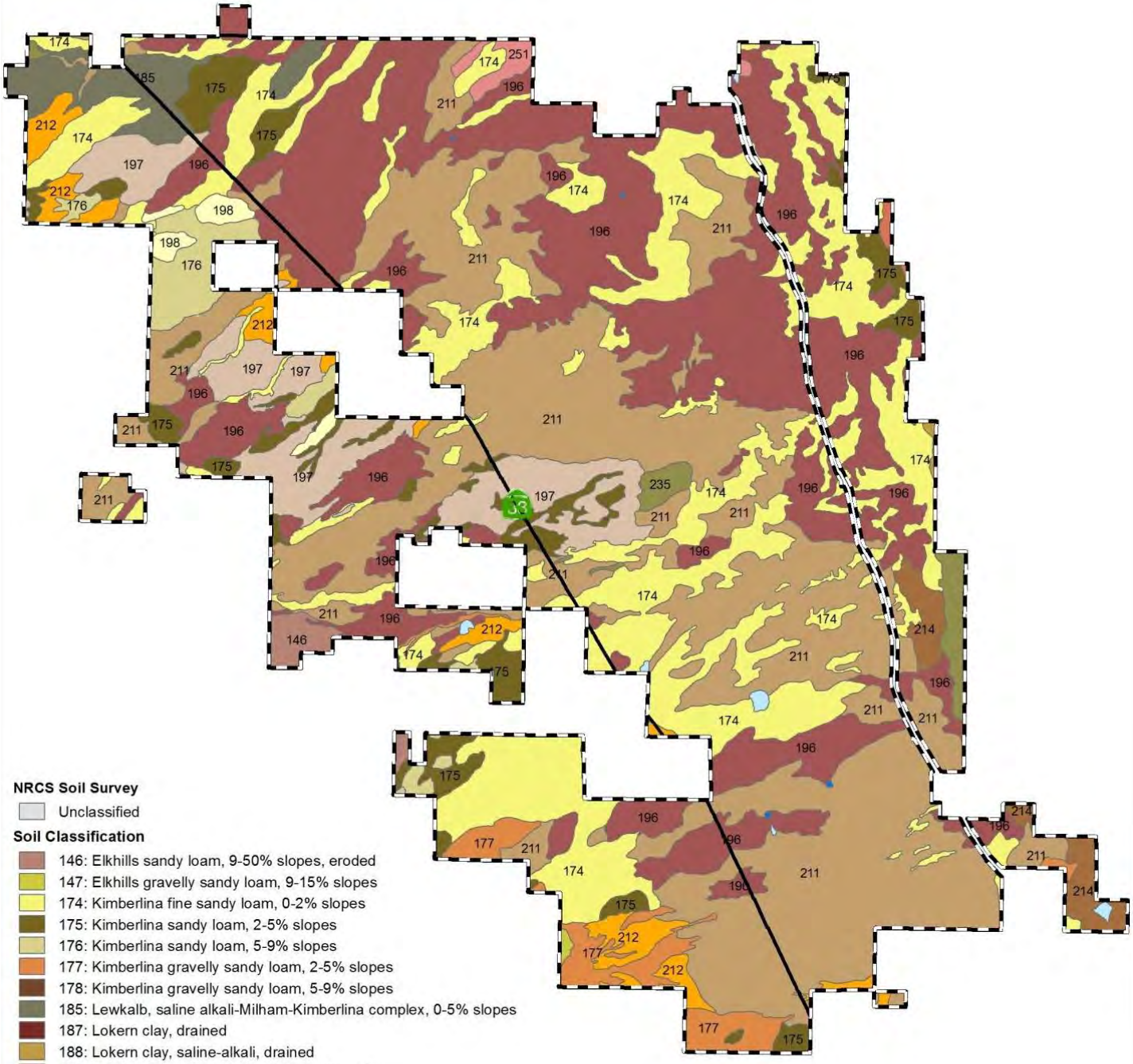
Source: 2015 Update to the 2012 Agricultural Water Management Plan, Berrenda Mesa Water District, December 2015

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WDWA Chapter GSP

Berrenda Mesa Water District Surface Soil Types

Date: 12/3/2019	Project #: 043-04	**Figure 14b**



Source: 2015 Update to the 2012 Agricultural Water Management Plan, Belridge Water Storage District, December 2015

0 1 2 Miles

EST. 1968
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Belridge W.S.D. Boundary
Reservoir
Highway

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WDWA Chapter GSP

Belridge Water Storage District
Surface Soil Types

Date: 12/3/2019	Project #: 043-04	**Figure 14c**

Approximate WDWA Boundary

Delano
McFarland
Wasco
Shafter
Lost Hills
Buttonwillow
Bakersfield
McKittrick
Taft
Lamont
Arvin
Tehachapi
Isabella Lake
Poso Creek
Kern River
Caliente Creek
Tejon Creek
Cuyama River
San Emigdio Creek
Pleito Creek
Salinas River
Twitchell

River, Creek or Ephemeral Stream
Lake
Highway
Kern Subbasin Boundary

TDS Concentrations

- Recommended SMCL (<= 500 mg/L)
- Upper SMCL (<= 1000 mg/L)
- Short Term MCL (<=1,500 mg/L)
- Above MCL (>1,500 mg/L)

NOTES:

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2018

8 4 0 8
Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

Notes:
WDWA: Westside District Water Authority

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TDS Groundwater Quality Results in the Kern County Groundwater Subbasin 2011 - 2017

Date: 12/3/2019 | Project #: 043-04 | **Figure 15a**

Age	Geologic Units of Interest	General Description	
Recent	Alluvium	Discontinuous beds of sand, silt, clay and gravel, becoming finer grained toward the valley.	
Pleistocene	Older Alluvium		
	Tulare Formation	Interbedded gravel, sand, silt, and clay.	
	Corcoran Clay	Silt and clay. Lacustrine.	
	Tulare Formation	Kern River Formation Alluvial Fan Deposits. Interbedded gravel, sand, silt, and clay. Fresh water production on east side of the valley.	Interbedded gravel, sand, silt, and clay. Siltstone, clayey, diatomaceous with thin lenticular sand beds.
Pliocene	San Joaquin Formation		
Miocene	Etchegoin Formation	AE	Clay and silt to sand, gravel, and sandstone
	Santa Margarita Sandstone	Chanac Formation AE Conglomerate with lenses of coarse sand and clays Non-Marine Clastic. Limited fresh water production on east side.	Fine to coarse white sand, gravel, and sandstone.
	Round Mountain Silt	Brown siltstone, diatomaceous	
	Olcese Sand	Light gray sandstone with a few pebble and siltstone beds.	
	Freeman-Jewett Silt	Brown siltstone with interbedded ash.	
Oligocene	Pyramid Hills and Vedder Sands	Interbedded sandstone and siltstone	

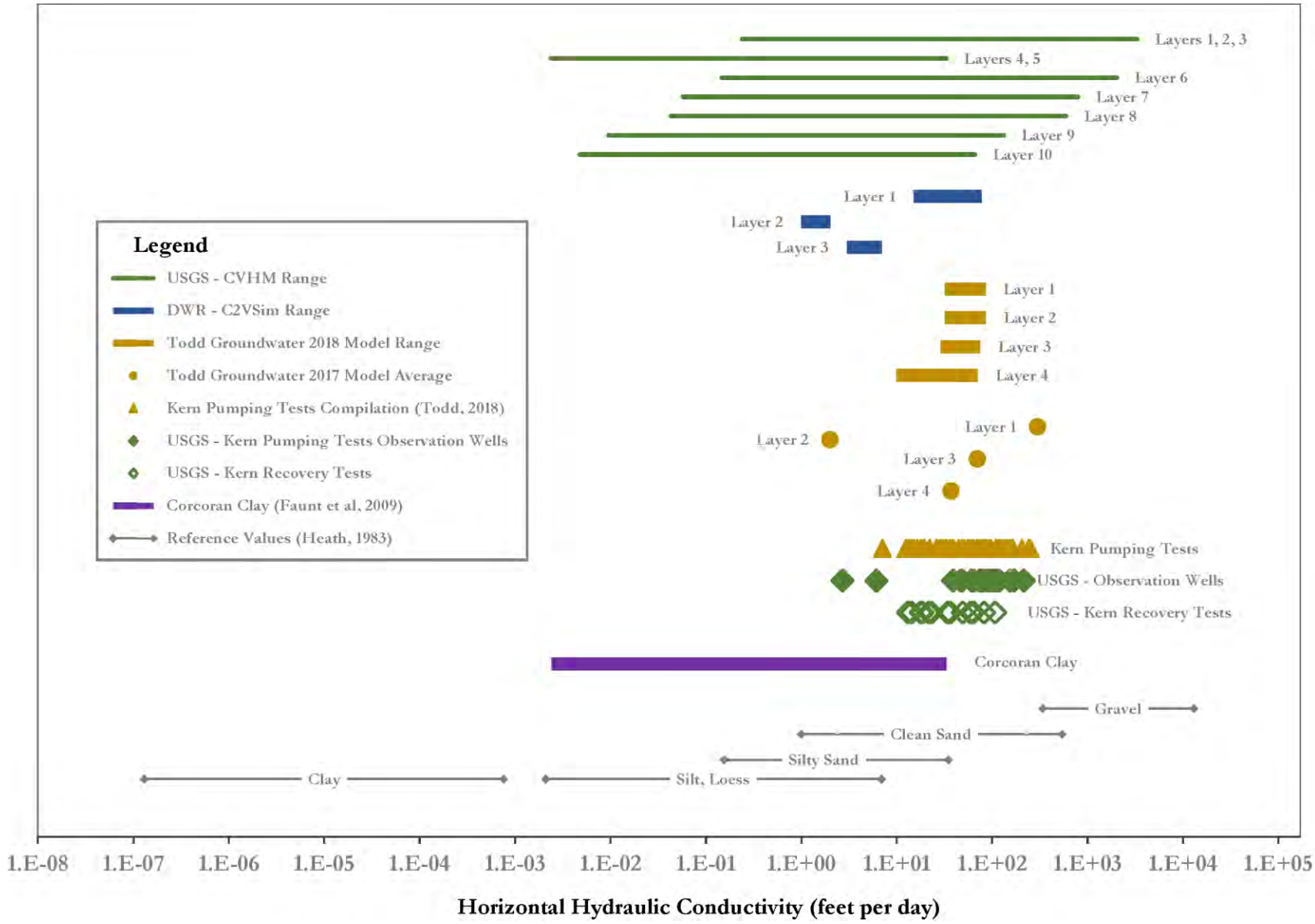
Notes:
AE: UIC Aquifer Exemption
Source: Kern Groundwater Authority, 2019

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WDWA Chapter GSP

Generalized Hydrostratigraphy
Kern County Subbasin

Date: 12/3/2019	Project #: 043-04	**Figure 15b**



Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

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WDWA Chapter GSP

Hydraulic Conductivity Values

Date: 12/3/2019	Project #: 043-04	**Figure 15c**

Approximate WDWA Boundary

NOTES:

(Approximate) Elevation of base of fresh water (Specific conductance generally less than 3,000 micomhos per centimeter) or ~2,000 mg/L TDS.

Hydrocarbon elevations from primacy productive limits represent difference between average surface elevation and minimum depth of productive limit.

Elevation to hydrocarbons and the top of exempted aquifers are generalized. Refer to the report table for details. Exemptions are subject to change as applications are approved.

Per 40 CFR §144.3, exempted aquifers are not USDWs. Based on criteria of 40 CFR §146.4, primacy productive limits are not suitable USDWs.

USDW: Underground Source of Drinking Water (Source: Code of Federal Regulations).

Datum is Mean Sea Level

- Elevation Contour of Specific Conductance 3,000 micromhos per centimeter (Page-1973)
- Elev — Aquifer Exemption (max Elevation)
- Elev — Primacy Productive Limits (Hydrocarbon max Elevation)
- Kern Subbasin Boundary

Other Features

- Highway
- Major Conveyance

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

in Valley, California (R.W. Page 1973)

0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

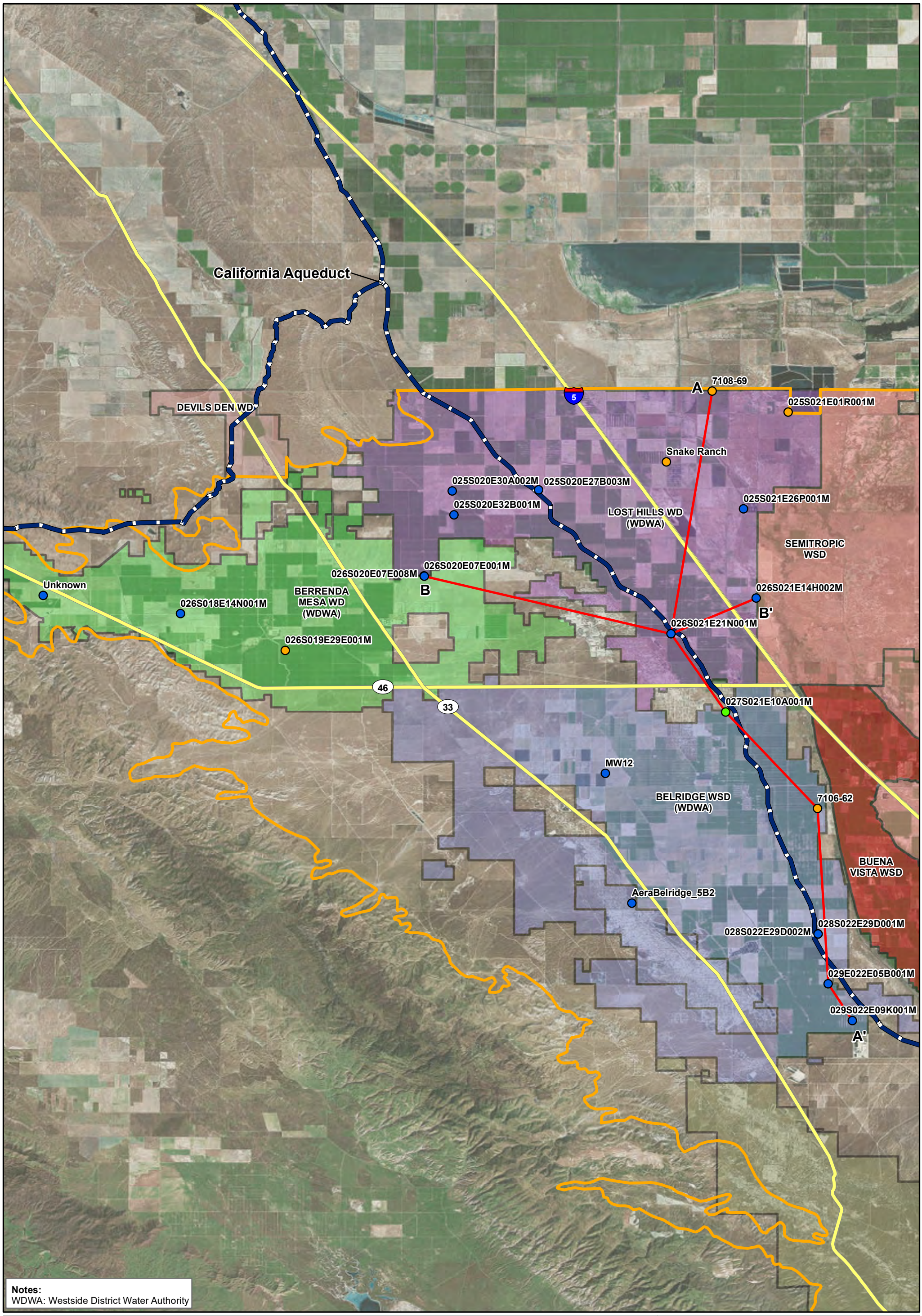
Notes:
WDWA: Westside District Water Authority

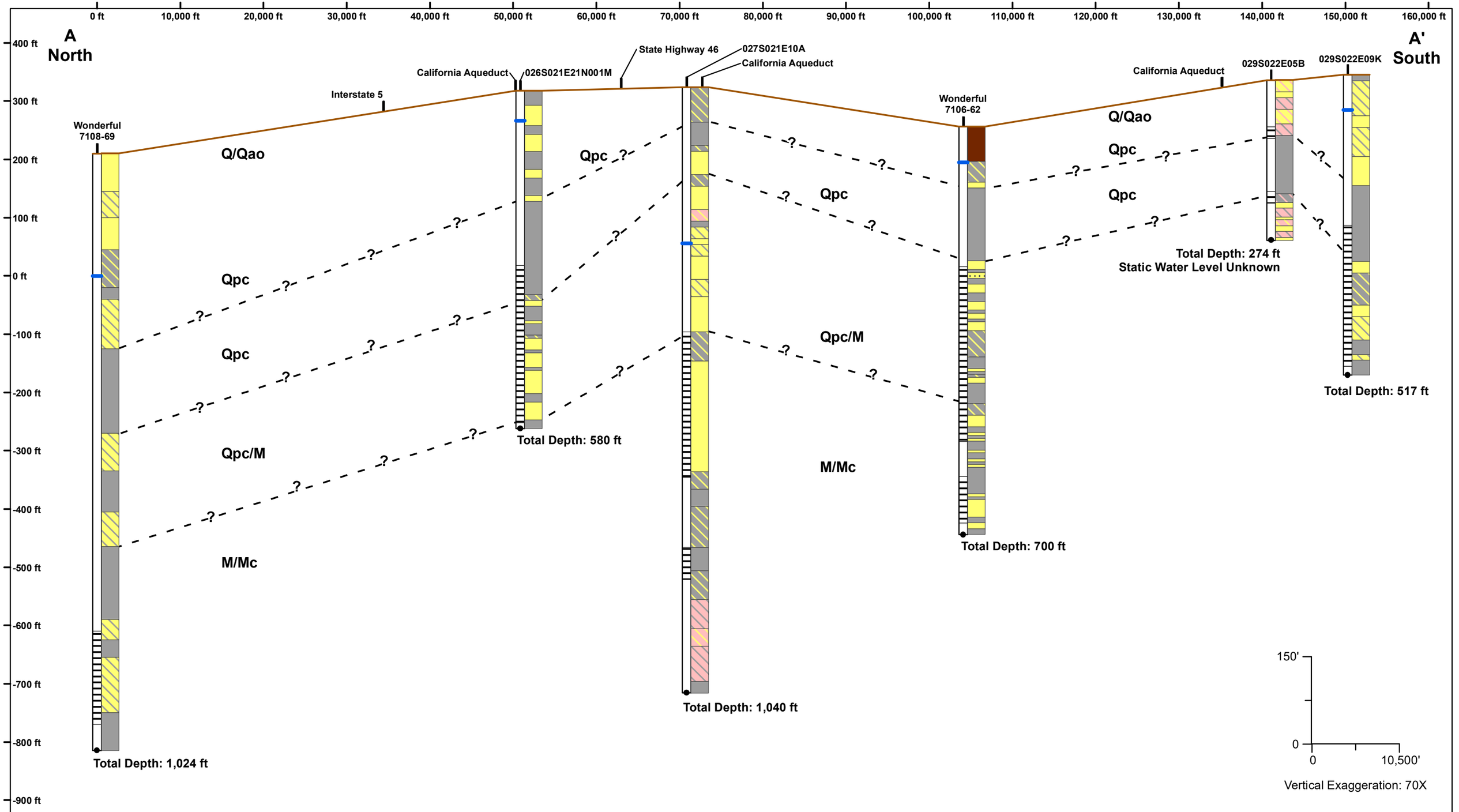
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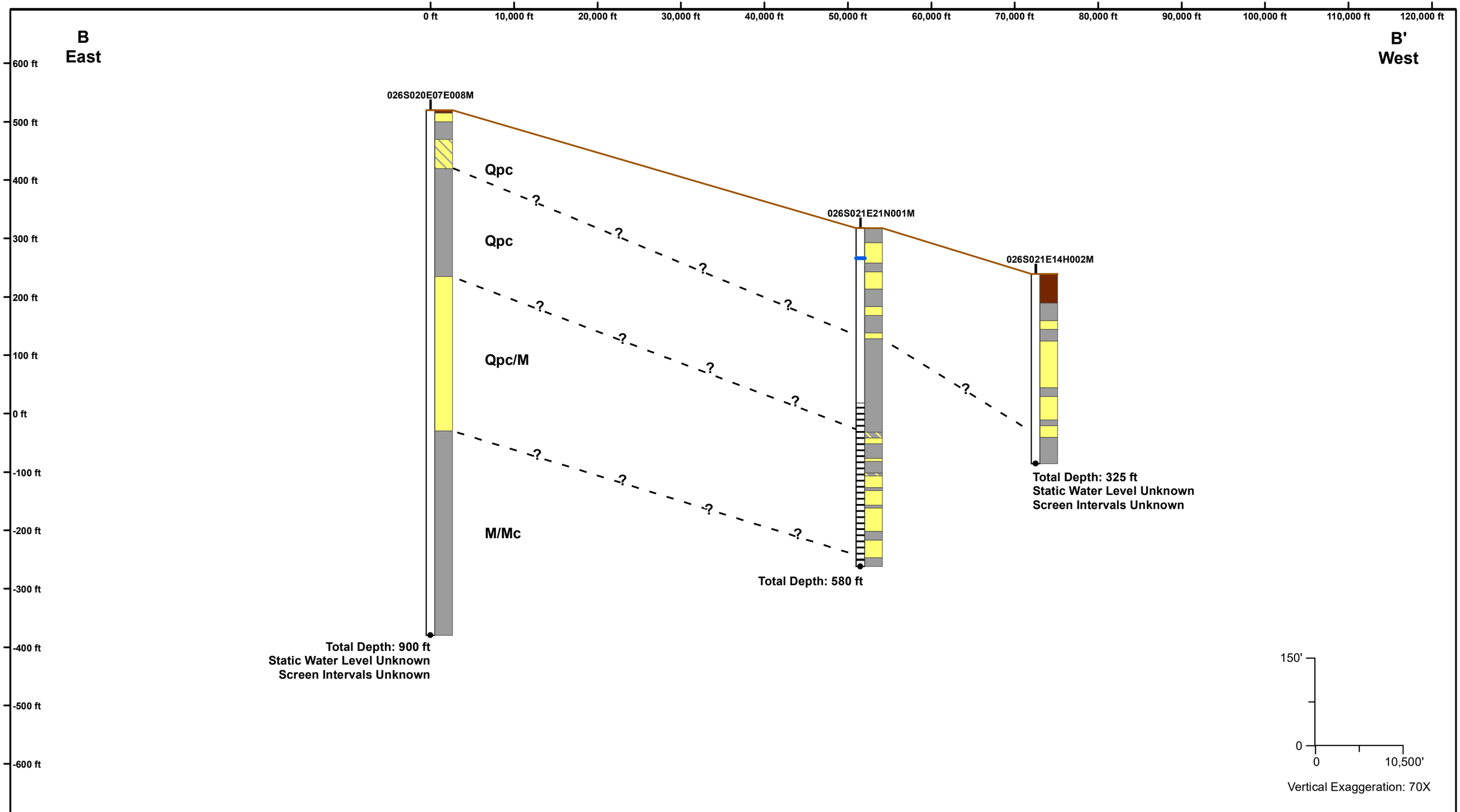
WDWA Chapter GSP

Base of Fresh Groundwater in the Kern County Groundwater Subbasin (Page 1973)

Date: 12/3/2019 | Project #: 043-04 | **Figure 16**


California Aqueduct
DEVILS DEN WD
5
7108-69
A
025S021E01R001M
Snake Ranch
025S020E30A002M
025S020E27B003M
025S020E32B001M
LOST HILLS WD
(WDWA)
025S021E26P001M
SEMITROPIC
WSD
026S020E07E008M
B
026S020E07E001M
Unknown
026S018E14N001M
BERRENDA
MESA WD
(WDWA)
026S021E14H002M
B'
026S021E21N001M
026S019E29E001M
46
33
027S021E10A001M
MW12
BELRIDGE WSD
(WDWA)
7106-62
BUENA
VISTA WSD
AeraBelridge_5B2
028S022E29D001M
028S022E29D002M
029E022E05B001M
029S022E09K001M
A'
Notes:
WDWA: Westside District Water Authority
Cross-Section Location
Aquifer Zone
Perched
Unconfined
Confined/Semi-confined
Confined
Water Districts in Kern County
Belridge WSD
Berrenda Mesa WD
Buena Vista WSD
Devils Den WD
Lost Hills WD
Semitropic WSD
West Kern WD
Undistricted Lands
Kern County Groundwater Sub-Basin
California Aqueduct
0
3.5
Miles
aquilogic, Inc.
WDWA Chapter GSP
Selected Wells and
Cross-Section Locations
Date: 3/27/2019
Project #: 043-04
Figure 17a


A
North
A'
South
0 ft
10,000 ft
20,000 ft
30,000 ft
40,000 ft
50,000 ft
60,000 ft
70,000 ft
80,000 ft
90,000 ft
100,000 ft
110,000 ft
120,000 ft
130,000 ft
140,000 ft
150,000 ft
160,000 ft
400 ft
300 ft
200 ft
100 ft
0 ft
-100 ft
-200 ft
-300 ft
-400 ft
-500 ft
-600 ft
-700 ft
-800 ft
-900 ft
Wonderful
7108-69
Interstate 5
California Aqueduct
026S021E21N001M
State Highway 46
027S021E10A
California Aqueduct
Wonderful
7106-62
California Aqueduct
029S022E05B
029S022E09K
Q/Qao
Qpc
Qpc
Qpc/M
M/Mc
Qpc
Qpc
Qpc
Qpc/M
M/Mc
Total Depth: 1,024 ft
Total Depth: 580 ft
Total Depth: 1,040 ft
Total Depth: 700 ft
Total Depth: 274 ft
Static Water Level Unknown
Total Depth: 517 ft
150'
0
0
10,500'
Vertical Exaggeration: 70X
Land Surface
Well Screen Interval
Static Water Level
Inferred Correlation
Clay
Sand
Top Soil
Sandy Clay
Silty Clay
Clayey Sand
Silty Sand
Clayey Silt
Sandy Silt
Sand/Gravel
Notes:
Q: Recent Alluvium
Qao: Pleistocene Older Alluvium
QPc: Pliocene/Pleistocene
M/Mc: Miocene
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WDWA Cross-Section A - A'
Date: 12/10/2019
Project #: 043-04
Figure 17b



Land Surface
Well Screen Interval
Static Water Level
Inferred Correlation
Clay
Sand
Top Soil
Sandy Clay
Silty Clay
Clayey Sand
Silty Sand
Clayey Silt
Sandy Silt
Sand/Gravel

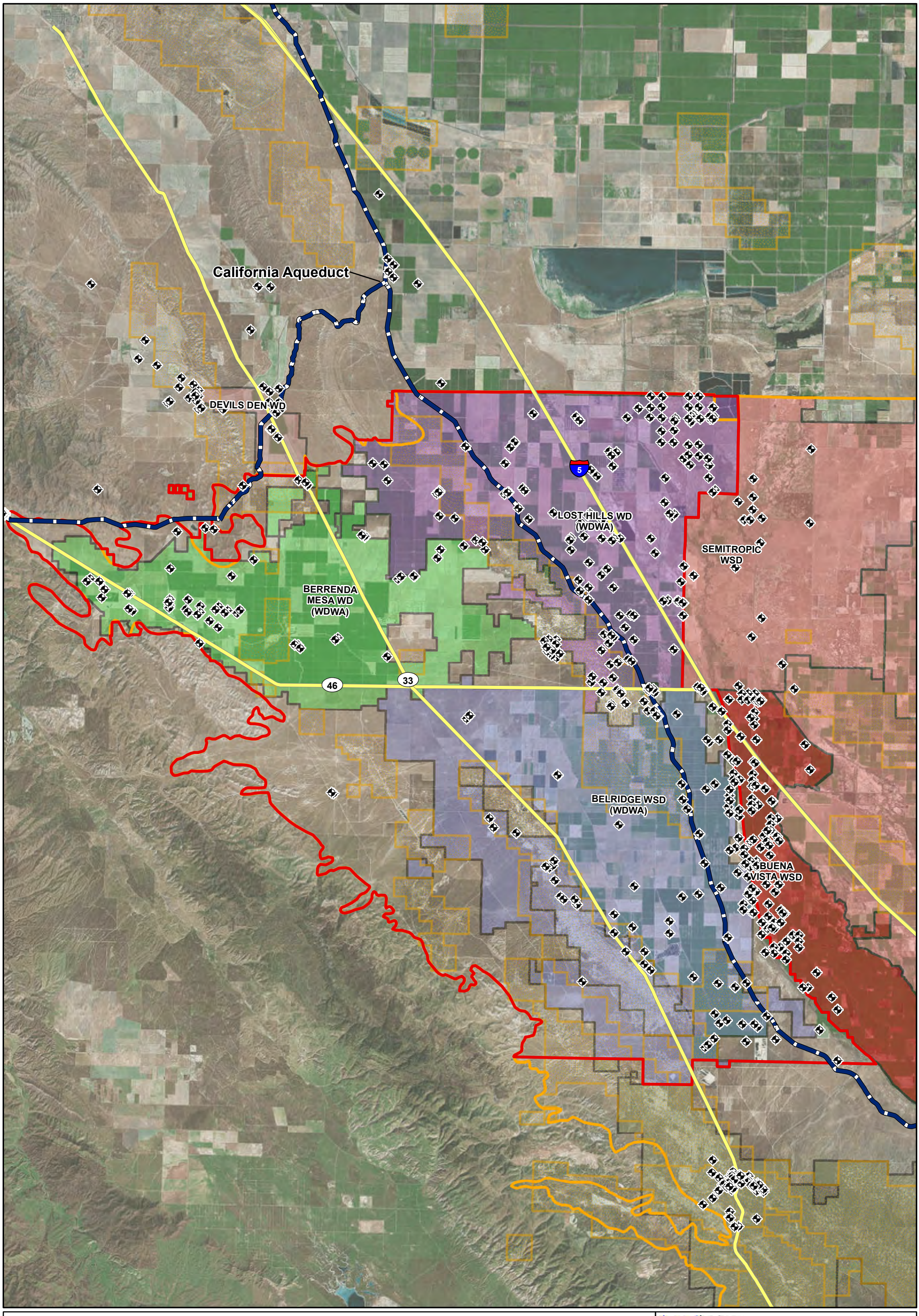
Notes:
M/Mc: Miocene
Q: Recent Alluvium
Qao: Pleistocene Older Alluvium
QPc: Pliocene/Pleistocene

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WDWA Chapter GSP

WDWA Cross-Section B - B'

Date: 12/10/2019 | Project #: 043-04 | **Figure 17c**



- Well Locations
- Belridge WSD
- Berrenda Mesa WD
- Buena Vista WSD
- Devils Den WD
- Lost Hills WD
- Semitropic WSD
- West Kern WD
- WDWA Boundary
- Undistricted Lands
- Kern County Groundwater Sub-Basin
- California Aqueduct

Notes:
Approximate WDWA Well Density: 1.2 wells/mi^2
WDWA: Westside District Water Authority
Well locations exclude oil and gas wells

0 3.5
Miles

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WDWA Well Density

Date: 6/3/2019 | Project #: 043-04 | **Figure 18**

Approximate WDWA Boundary

Spring 2015 Upper Zone Groundwater Surface Elevation

Kern Subbasin Boundary

Other Features

Highway

Major Conveyance

Notes:
Due to limited data, Contours are incomplete and the extent of the Upper Zone is not fully defined.

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

Notes:
WDWA: Westside District Water Authority

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Spring 2015 Upper Zone Groundwater Elevation

Date: 8/23/2019 | Project #: 043-04 | **Figure 19a**

Approximate WDWA Boundary

Upper Production Zone Contours Presented on Separate Figure

Well Location

Production Zone Boundary (Above (West) and Below (East) Corcoran)

Fall 2015 Groundwater Surface Elevation

Kern Subbasin Boundary

Other Features

Highway

Major Conveyance

Notes:
Contours are generated at a subbasin scale to depict overall regional trends and flow directions. High resolution site-specific data may not be reflected in this dataset. Refer to chapter-level GSPs for any local modifications.

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

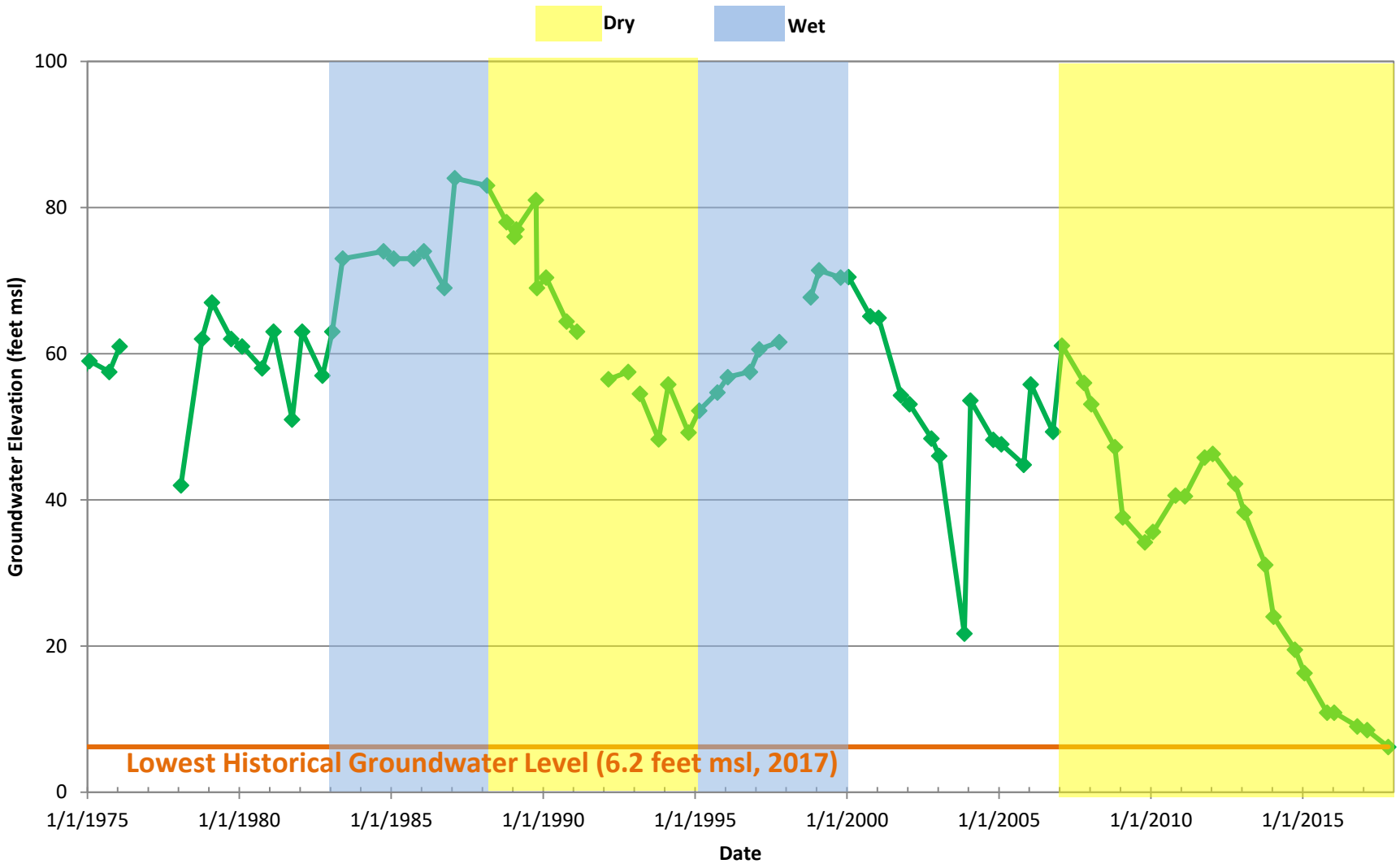
Notes:
WDWA: Westside District Water Authority

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Fall 2015 Regional Groundwater Elevation

Date: 12/10/2019 | Project #: 043-04 | **Figure 19b**



Note:
Confined well
Well screen: 624 feet to 760 feet below ground surface
Ground surface elevation: 215 feet mean sea level

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Hydrograph Well 25S/21E-01R001M

Date: 12/3/2019	Project #: 043-04	**Figure 20a**

KINGS COUNTY

FRESNO COUNTY

Tulare Lake Bed Beneficial Use Exemption Area

ONTEREY COUNTY

Approximate WDWA Boundary

SAN LUIS OBISPO COUNTY

KERN COUNTY

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Sources: Esri, DeLorme, USGS, NPS

Westside Water Quality Coalition Jurisdiction

Proposed Basin Plan Amendment Perched Groundwater

Proposed Basin Plan Amendment Unconfined/Semi-Confined Groundwater

County Line

Miles
0 2.5 5 10

Kilometers
0 2.5 5 10

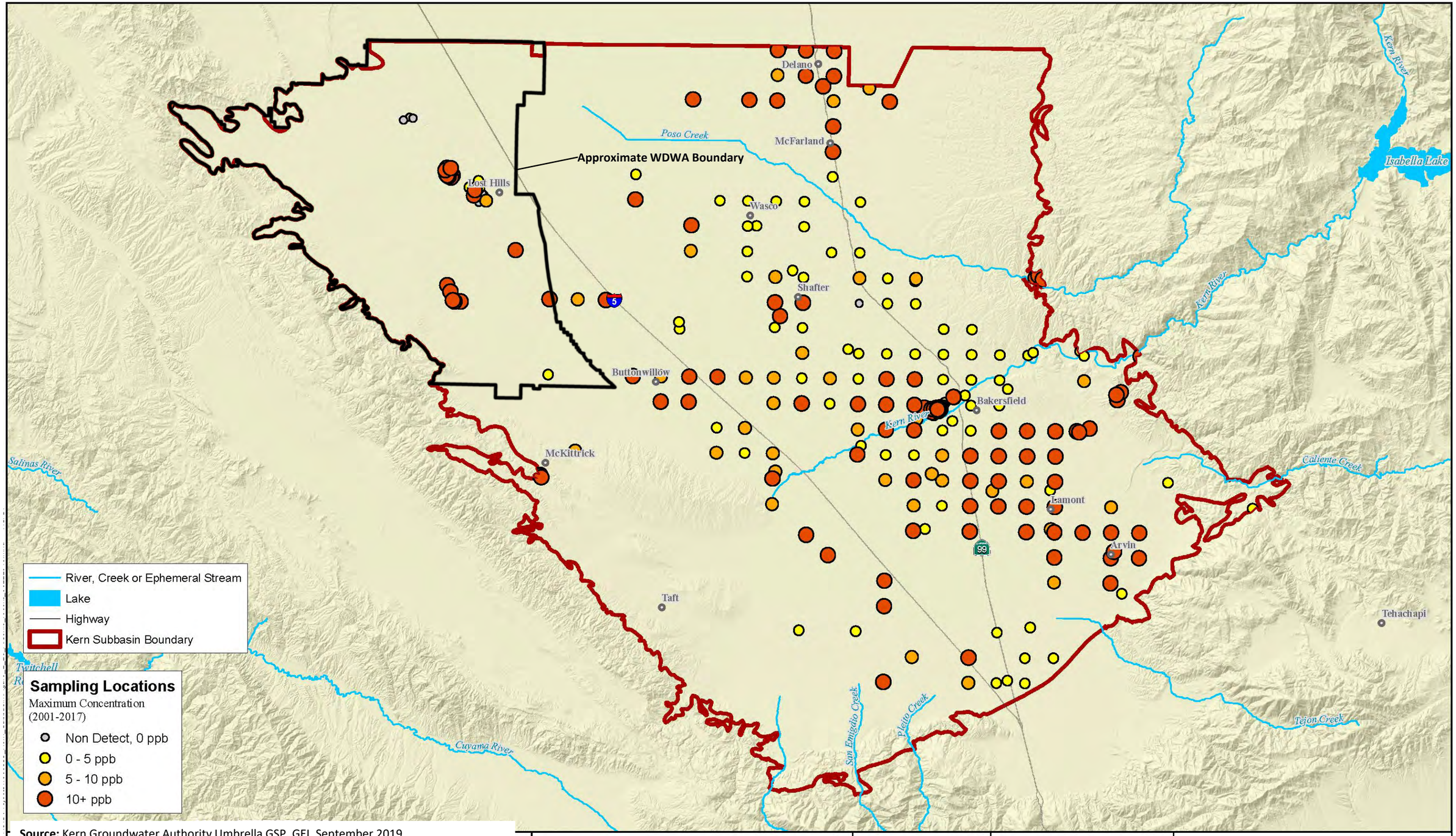
Notes:
WDWA: Westside District Water Authority
WWQC: Westside Water Quality Coalition
Source: Proposed Basin Plan Amendment Area, Wood, 2018

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WDWA Chapter GSP

WWQC Proposed Basin Plan Amendment Area

Date: 12/10/2019	Project #: 043-04	**Figure 20b**



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

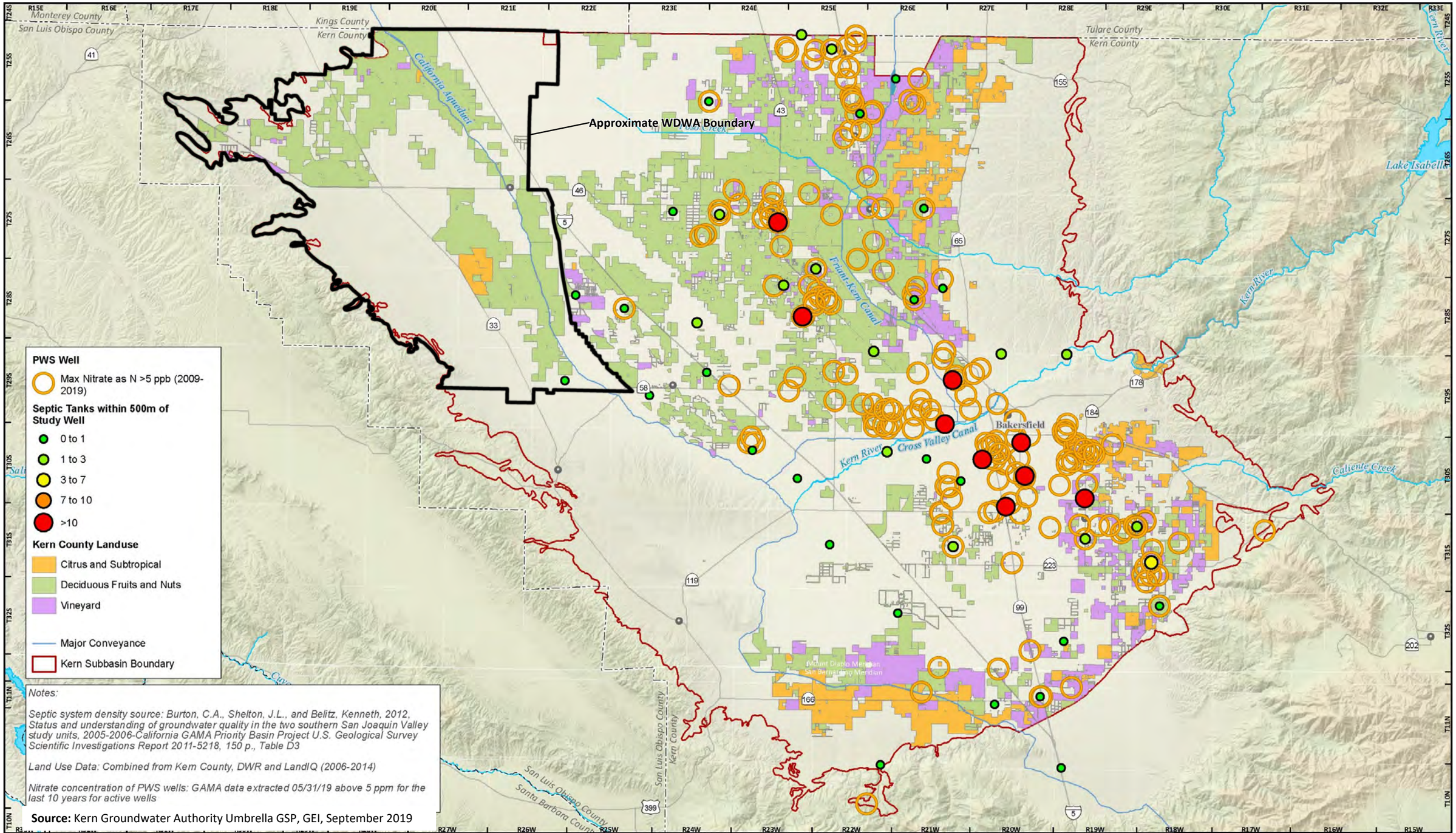
Notes:
WDWA: Westside District Water Authority

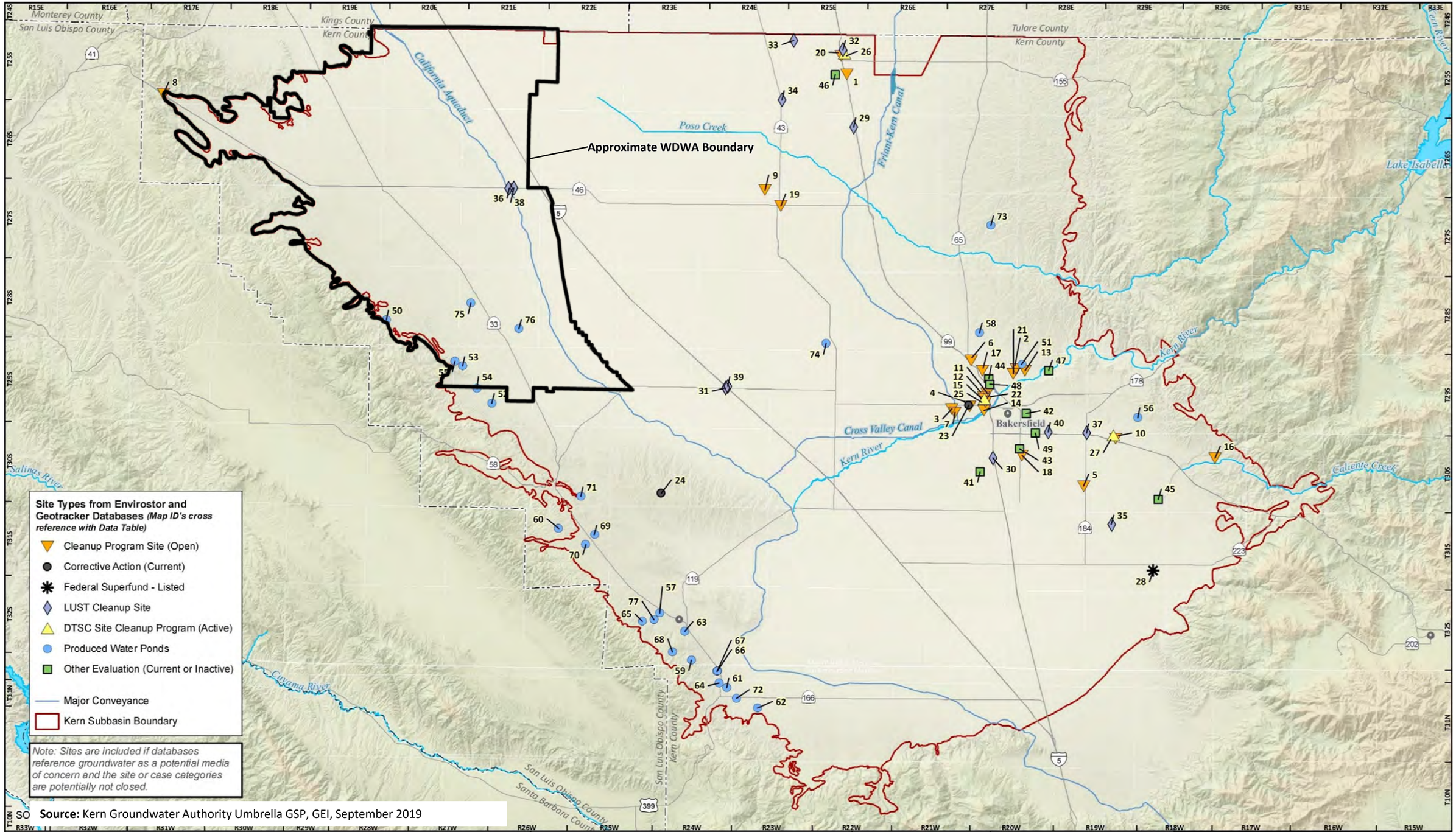
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WDWA Chapter GSP

WDWA/KGA Arsenic Concentrations in the Kern County Groundwater Subbasin 2001 - 2017

Date: 8/23/2019 | Project #: 043-04 | **Figure 21**


Approximate WDWA Boundary
PWS Well
Max Nitrate as N >5 ppb (2009-2019)
Septic Tanks within 500m of Study Well
0 to 1
1 to 3
3 to 7
7 to 10
>10
Kern County Landuse
Citrus and Subtropical
Deciduous Fruits and Nuts
Vineyard
Major Conveyance
Kern Subbasin Boundary
Notes:
Septic system density source: Burton, C.A., Shelton, J.L., and Belitz, Kenneth, 2012, Status and understanding of groundwater quality in the two southern San Joaquin Valley study units, 2005-2006-California GAMA Priority Basin Project U.S. Geological Survey Scientific Investigations Report 2011-5218, 150 p., Table D3
Land Use Data: Combined from Kern County, DWR and LandIQ (2006-2014)
Nitrate concentration of PWS wells: GAMA data extracted 05/31/19 above 5 ppm for the last 10 years for active wells
Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019
Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
California Aqueduct
Friant-Kern Canal
Kern River
Cross Valley Canal
Lake Isabella
Bakersfield
Caliente Creek
Mount Diablo Meridian
San Bernardino Meridian
0 3.5 7 14 21
Miles
DRAFT
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
Notes:
WDWA: Westside District Water Authority
aquilogic, Inc.
WDWA Chapter GSP
Kern Subbasin Nitrate Wells and Septic Tanks
Date: 8/23/2019
Project #: 043-04
Figure 22



DRAFT

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

Notes:
WDWA: Westside District Water Authority

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Envirostor and Geotracker Sites in the Kern County Groundwater Subbasin

Date: 8/26/2019 | Project #: 043-04 | **Figure 23a**

Approximate WDWA Boundary

Confined Animal Facility

Other Waste Discharge Requirement Facility

Major Conveyance

Kern Subbasin Boundary

Notes:
Many WDR facilities have no coordinate information and so, may or may not actually fall within the extent of the subbasin. Future work to locate these facilities by other means may result in a greater number of them falling within the subbasin extent.

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

0 3.5 7 14 21
Miles

DRAFT

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

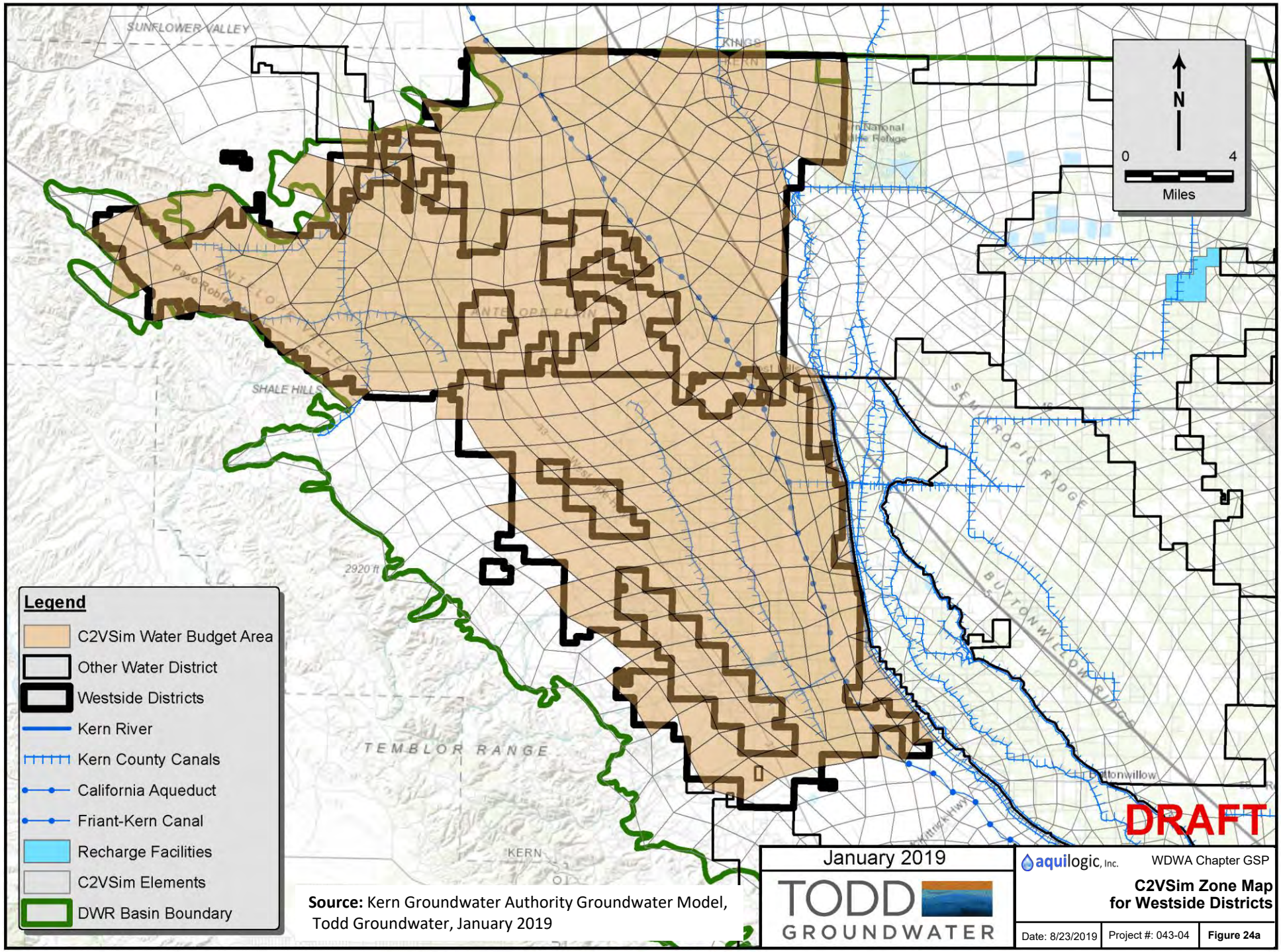
Notes:
WDWA: Westside District Water Authority

aquilogic, Inc.

WDWA Chapter GSP

Waste Discharge Requirement Sites in the Kern County Groundwater Subbasin

Date: 8/26/2019 | Project #: 043-04 | **Figure 23b**



Source: Kern Groundwater Authority Groundwater Model, Todd Groundwater, January 2019

January 2019

TODD GROUNDWATER

aquilogic, Inc.

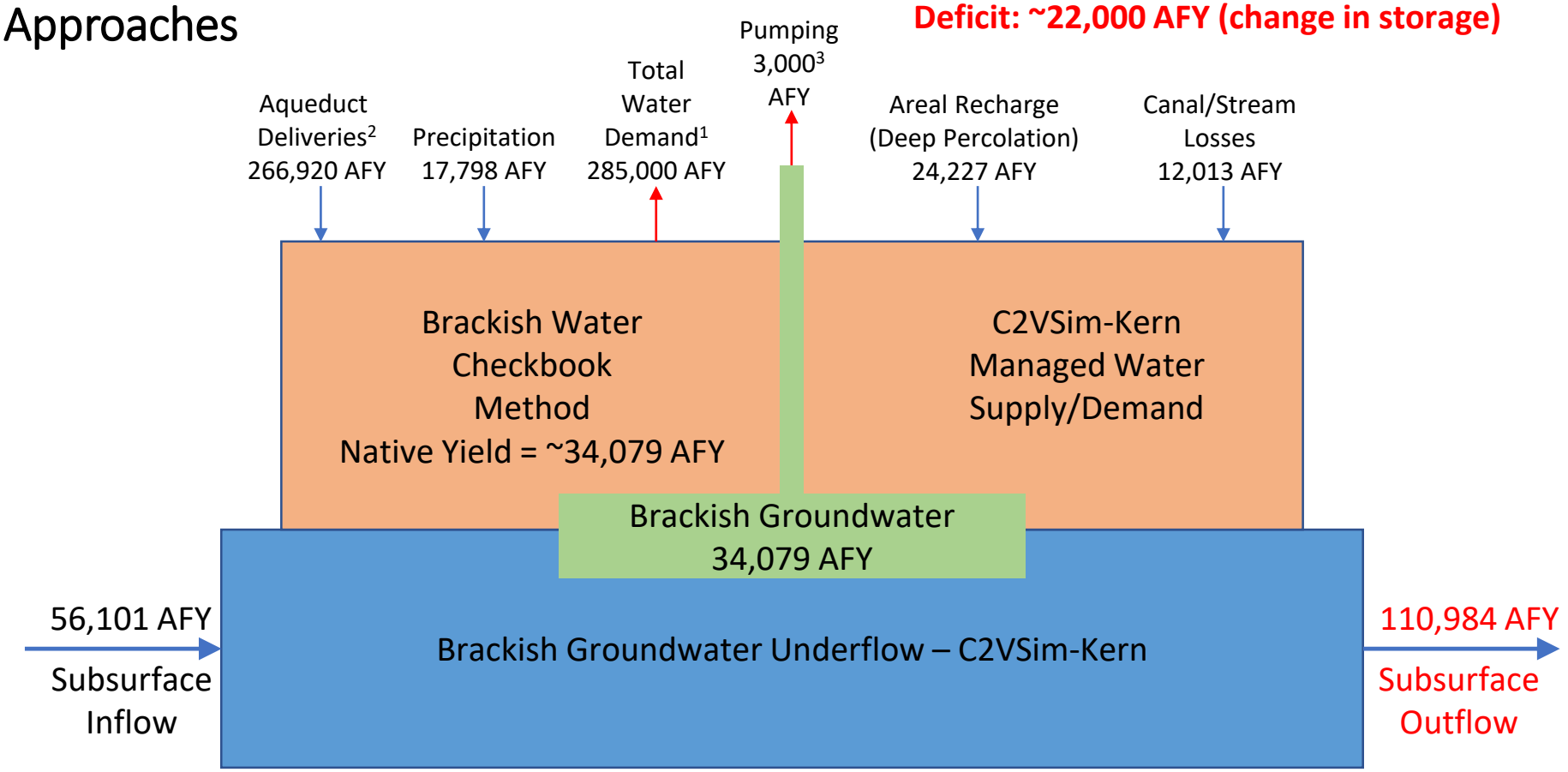
WDWA Chapter GSP

C2VSim Zone Map for Westside Districts

Date: 8/23/2019	Project #: 043-04	**Figure 24a**

Illustration of the Differences Between Approaches

C2VSim-Kern Total Recharge: +92,341 AFY
C2VSim-Kern Total Discharge: -138,540 AFY[4]
Pumping Adjustment: +24,556 AFY
Deficit: ~22,000 AFY (change in storage)



Notes:
WDWA: Westside District Water Authority
1. WDWA calculated demand
2. Includes alternative supply, not all of which may be SWP
3. WDWA estimated pumping for blending
4. Includes ~111,000 AFY of brackish underflow out of the WDWA

aquilogic, Inc.

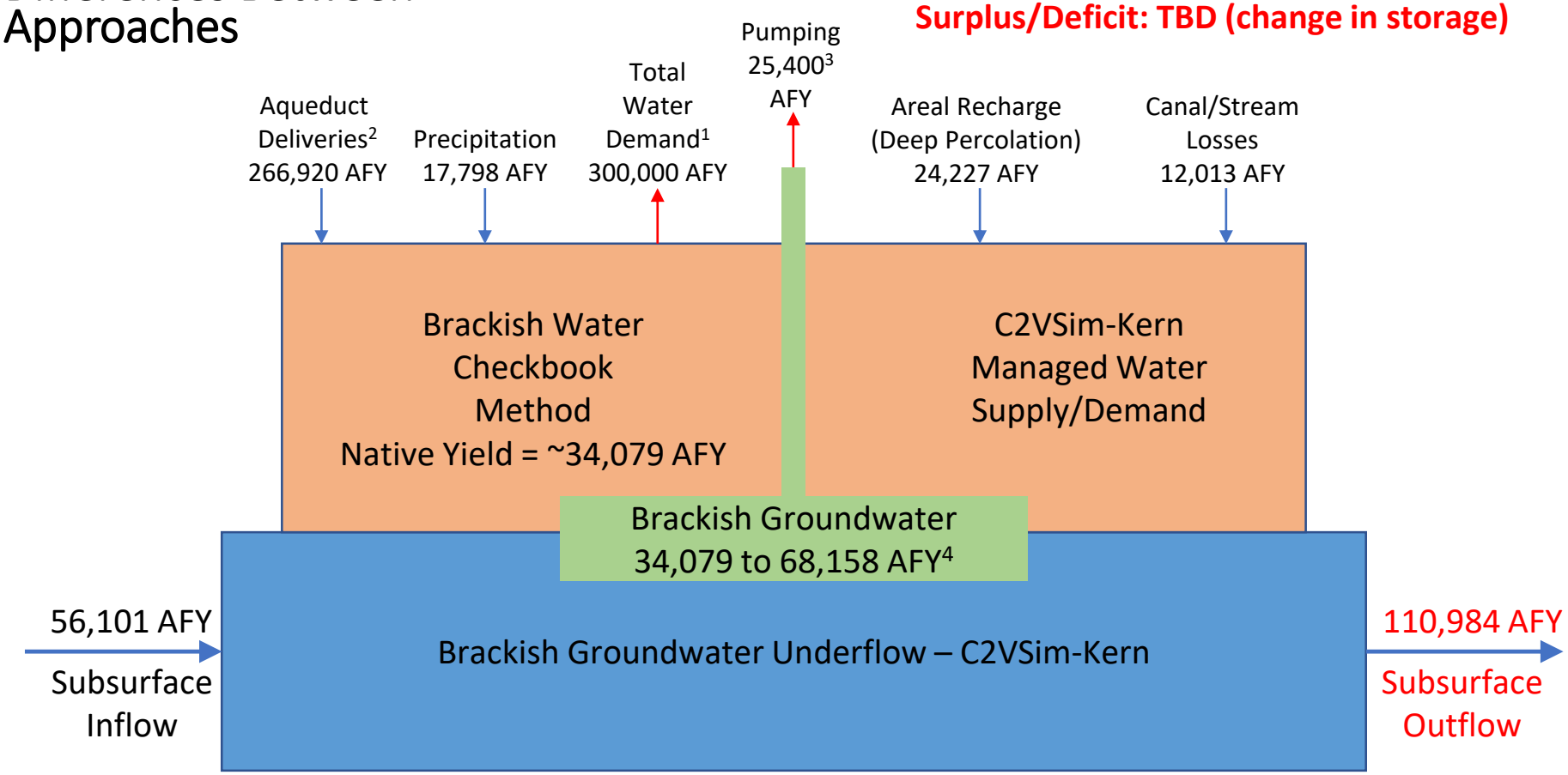
WDWA Chapter GSP

Preliminary WDWA Groundwater Budget Current Conditions

Date: 12/3/2019	Project #: 043-04	**Figure 24b**

Illustration of the Differences Between Approaches

PENDING MODEL UPDATES
C2VSim-Kern Total Recharge: TBD
C2VSim-Kern Total Discharge: TBD[5]
Surplus/Deficit: TBD (change in storage)



Notes:
WDWA: Westside District Water Authority
1. WDWA calculated demand + climate change effect
2. Includes alternative supply, not all of which may be SWP
3. WDWA estimated pumping (~5,400 AFY) + potential feedwater for PMA No. 3
4. ~30% to ~60% of modeled brackish underflow out of the WDWA for blending and conjunctive reuse
5. Includes ~111,000 AFY of brackish underflow out of the WDWA

aquilogic, Inc.

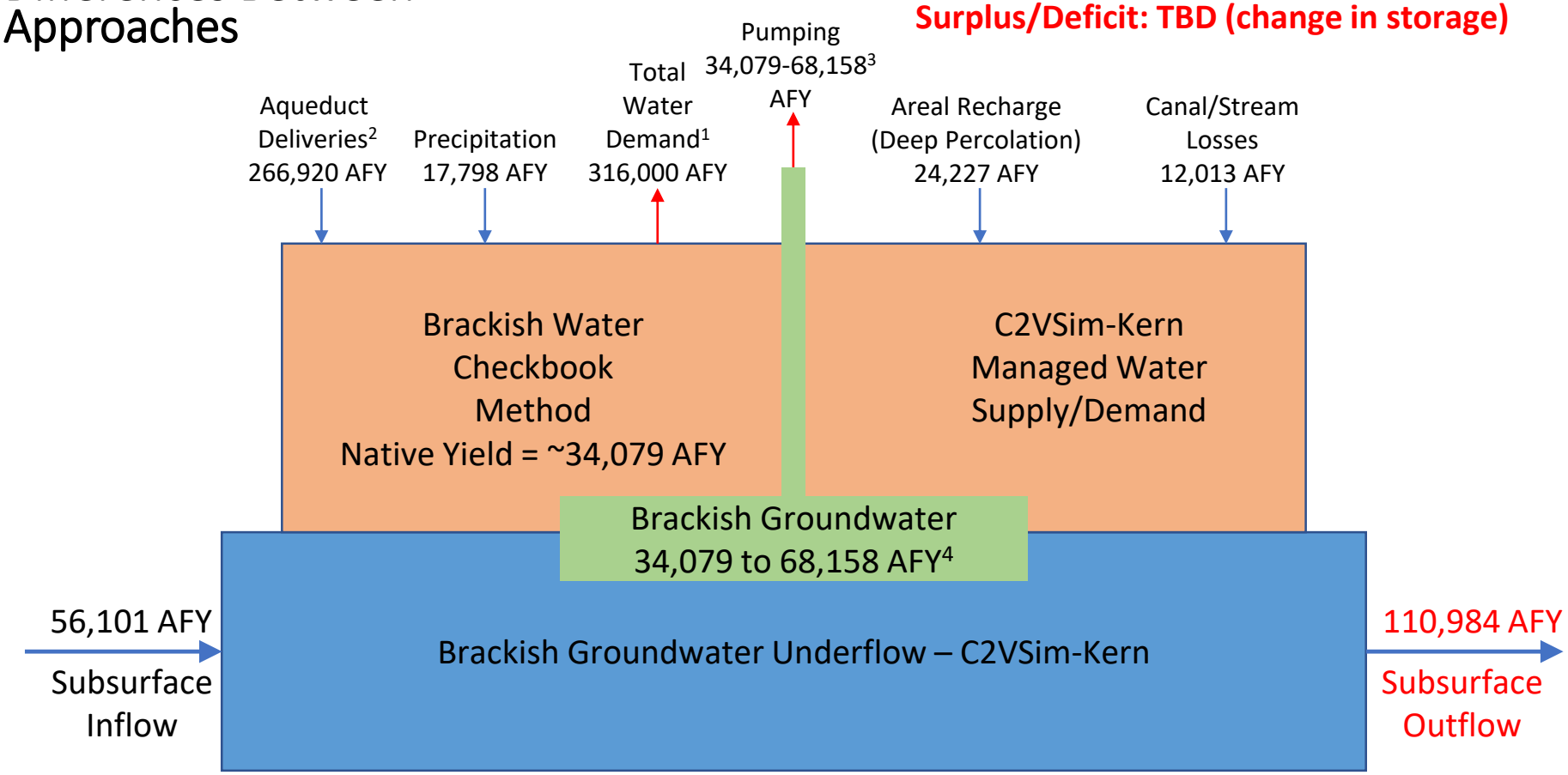
WDWA Chapter GSP

Preliminary WDWA Groundwater Budget 2030 Conditions

Date: 12/3/2019	Project #: 043-04	**Figure 24c**

Illustration of the Differences Between Approaches

PENDING MODEL UPDATES
C2VSim-Kern Total Recharge: TBD
C2VSim-Kern Total Discharge: TBD[5]
Surplus/Deficit: TBD (change in storage)



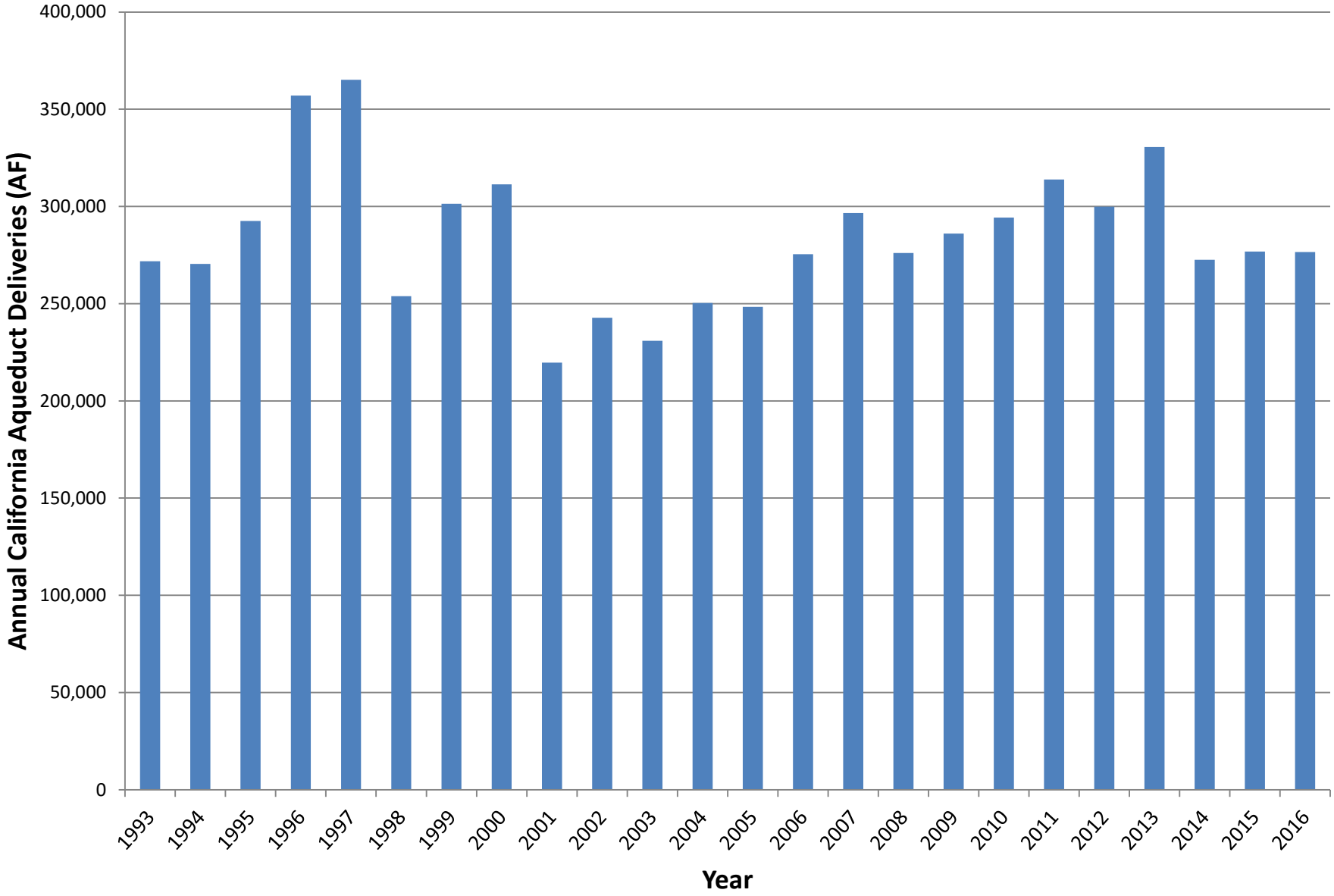
Notes:
WDWA: Westside District Water Authority
1. WDWA calculated demand + climate change effect
2. Includes alternative supply, not all of which may be SWP
3. WDWA estimated pumping (~5,400 AFY) + potential feedwater for PMA No. 3
4. ~30% to ~60% of modeled brackish underflow out of the WDWA for blending and conjunctive reuse
5. Includes ~111,000 AFY of brackish underflow out of the WDWA

aquilogic, Inc.

WDWA Chapter GSP

Preliminary WDWA Groundwater Budget 2040 Conditions

Date: 12/3/2019	Project #: 043-04	**Figure 24d**

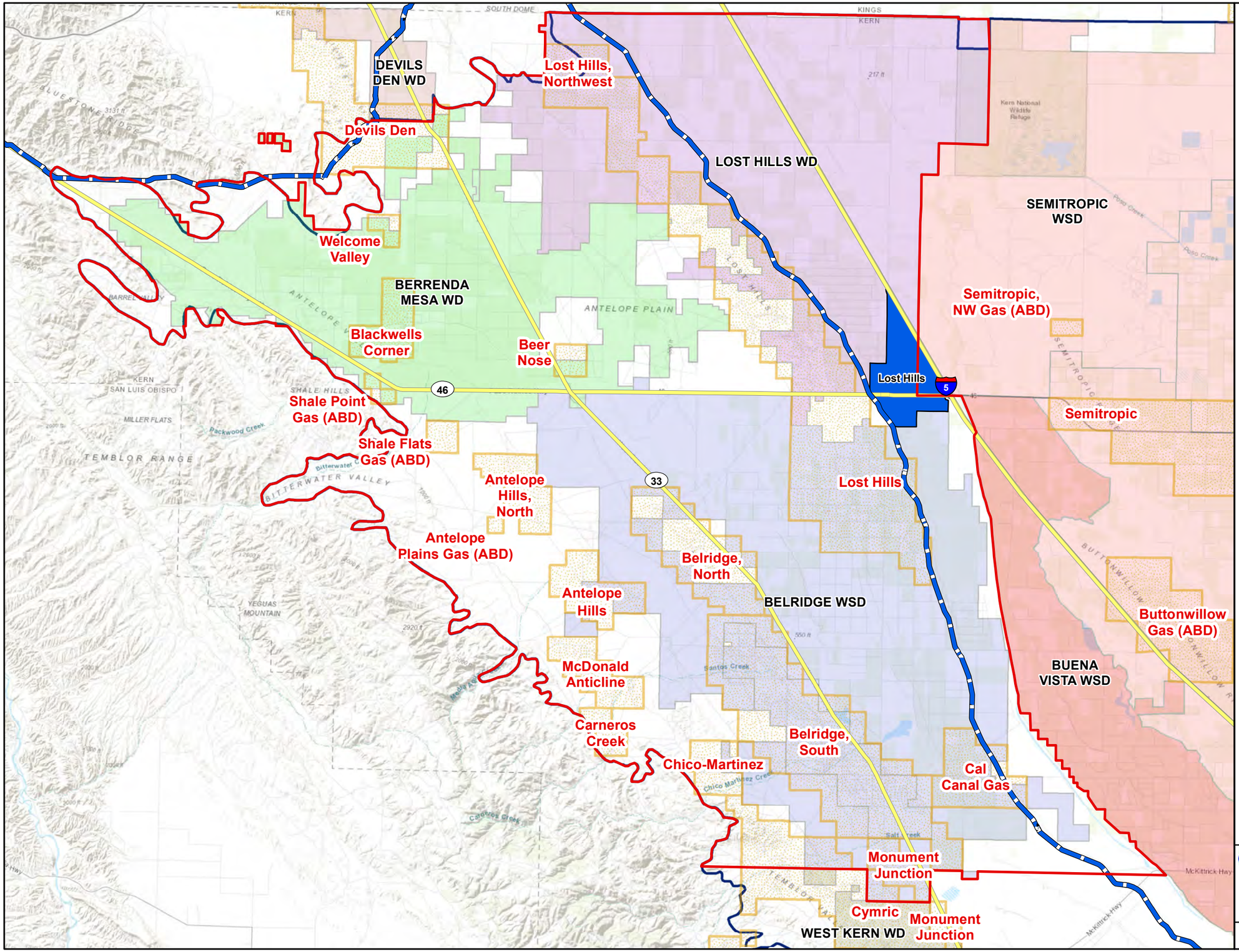


aquilogic, Inc.

WDWA Chapter GSP

Combined Annual California Aqueduct Deliveries for the Westside District Water Authority from 1993 to 2016

Date: 12/3/2019	Project #: 043-04	**Figure 25**

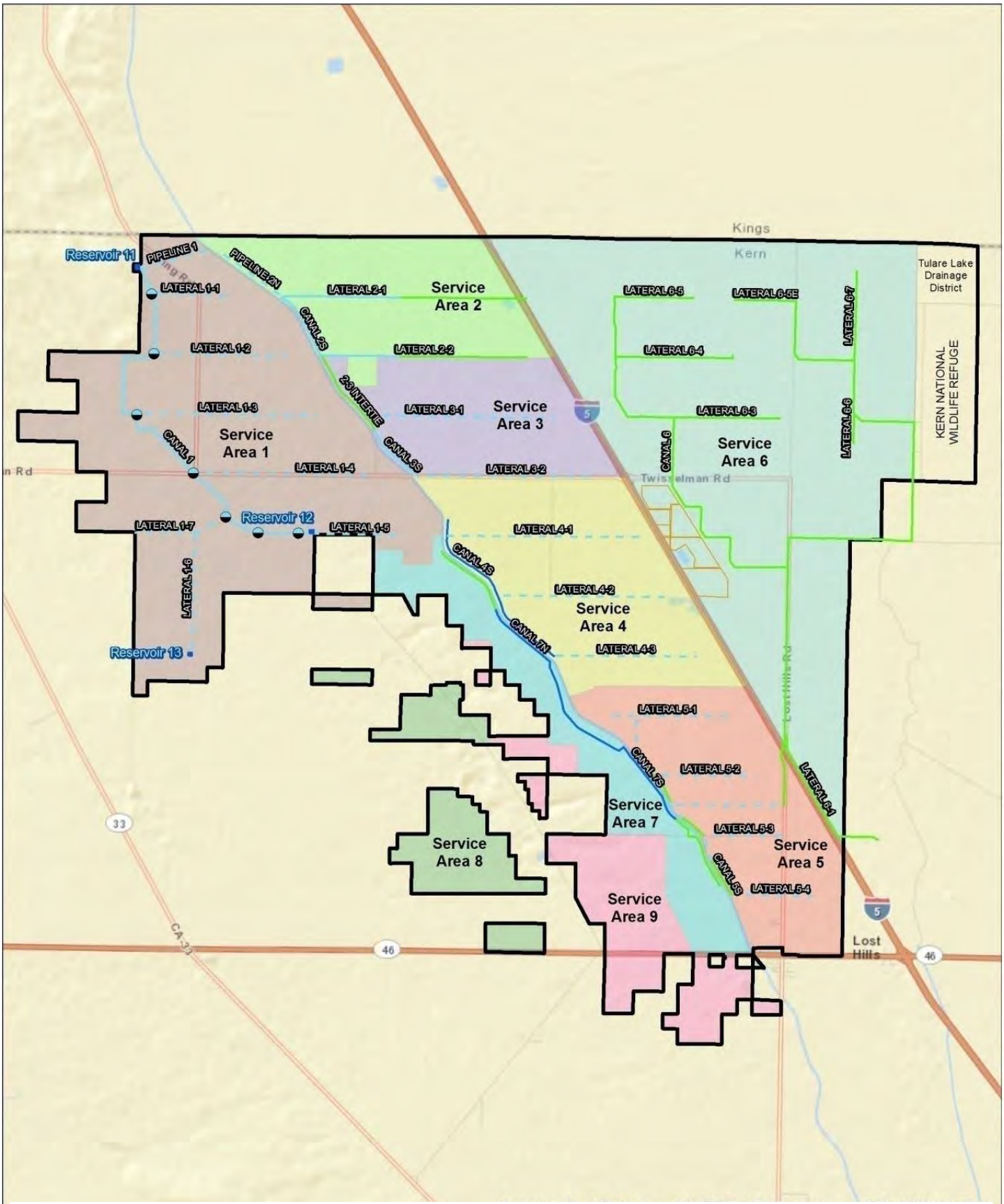


aquilogic, Inc.

WDWA Chapter GSP

Oilfields in the WDWA

Date: 6/7/2019	Project #: 043-04	**Figure 26**



Source: 2015 Update to the 2012 Agricultural Water Management Plan, Lost Hills Water District, December 2015

0 0.5 1 1.5 2 Miles

EST. 1888 PROVOST& PRITCHARD CONSULTING GROUP
An Employee Owned Company

1800 30th St. Suite 280
Bakersfield, CA . 93301
(661) 616-5900

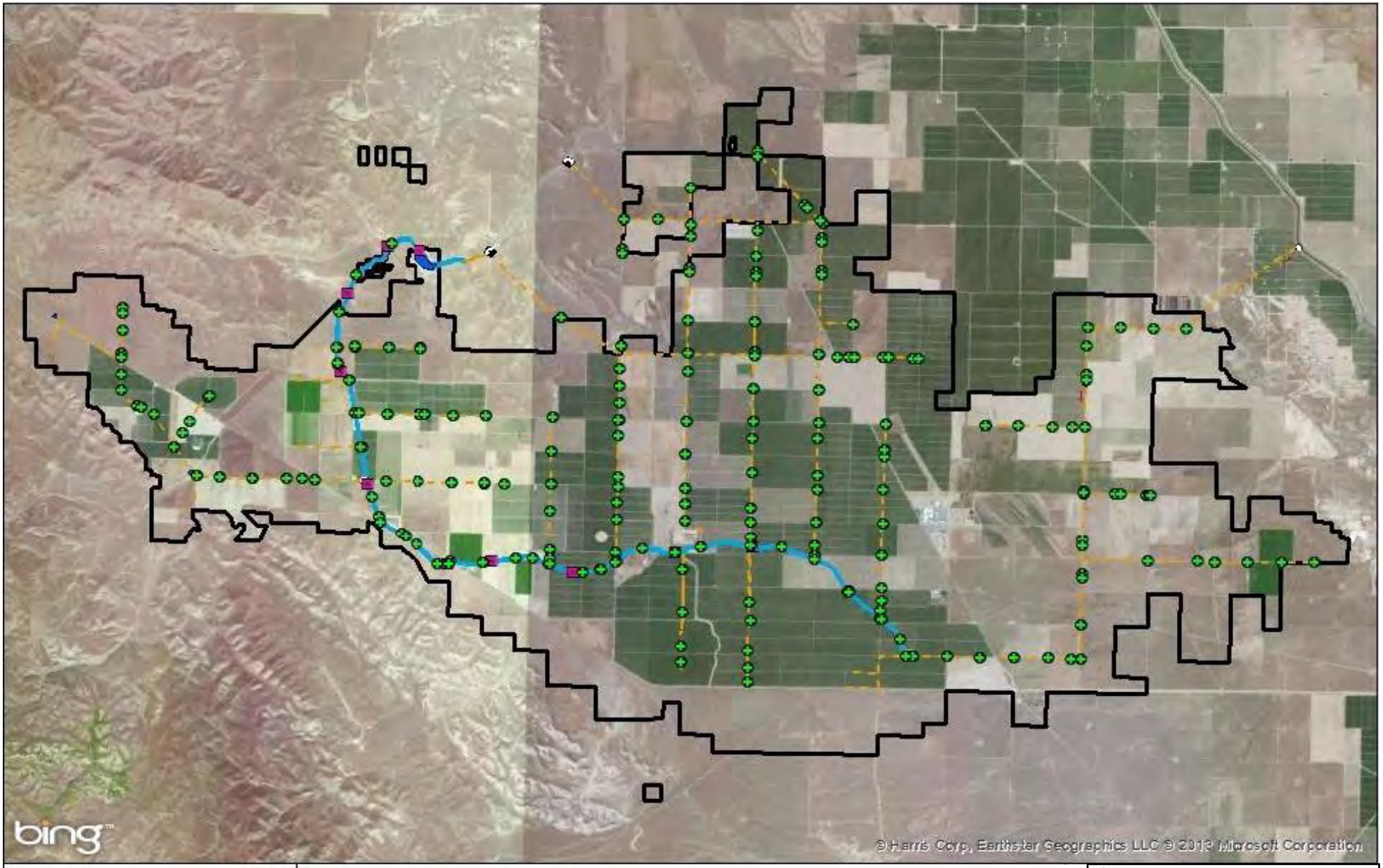
LHWD Boundary
Ponds
Canal Checks
Concrete Lined Canal
Plastic Lined Canal
Dirt Canal
Pipeline

aquilogic, Inc.

WDWA Chapter GSP

Lost Hills Water District
Water Infrastructure

Date: 12/3/2019	Project #: 043-04	**Figure 27a**



0 1 2 Miles

PROVOST & PRI CHARD
1800 30th Street, Suite 280
Bakersfield, CA 93301
(661) 616-5900

Arrows Service
Reservoir
Pump Station
Valve or Turnout
Check Weir
Pipeline

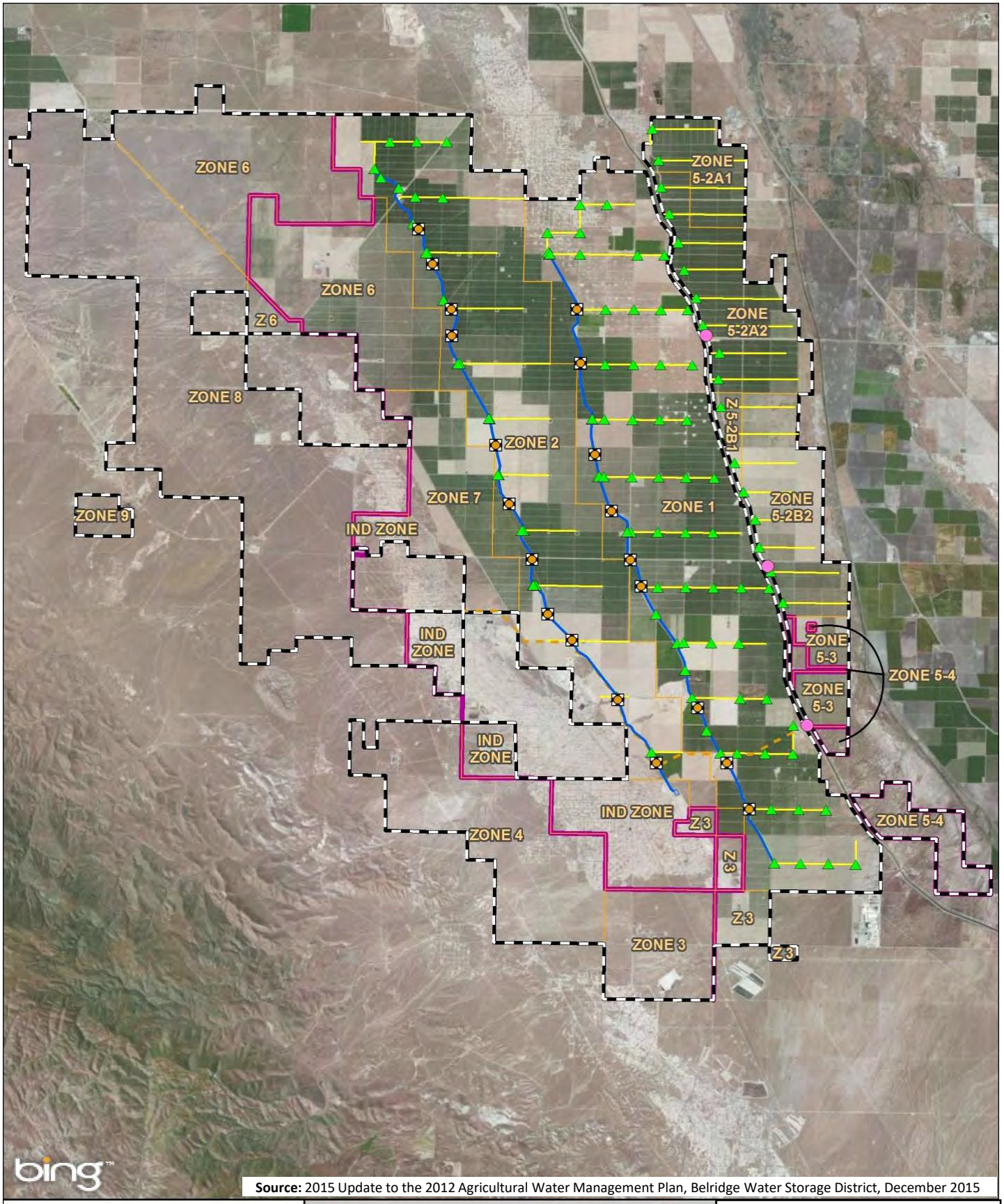
Source: 2015 Update to the 2012 Agricultural Water Management Plan, Berrenda Mesa Water District, December 2015

aquilogic, Inc.

WDWA Chapter GSP

Berrenda Mesa Water District Water Infrastructure

Date: 12/3/2019	Project #: 043-04	**Figure 27b**



Source: 2015 Update to the 2012 Agricultural Water Management Plan, Belridge Water Storage District, December 2015

0 1 2 Miles

EST. 1968
PROVOST& PRITCHARD CONSULTING GROUP
An Employee Owned Company
1800 30th Street, Suite 280
Bakersfield, CA 93301
(661) 616-5900

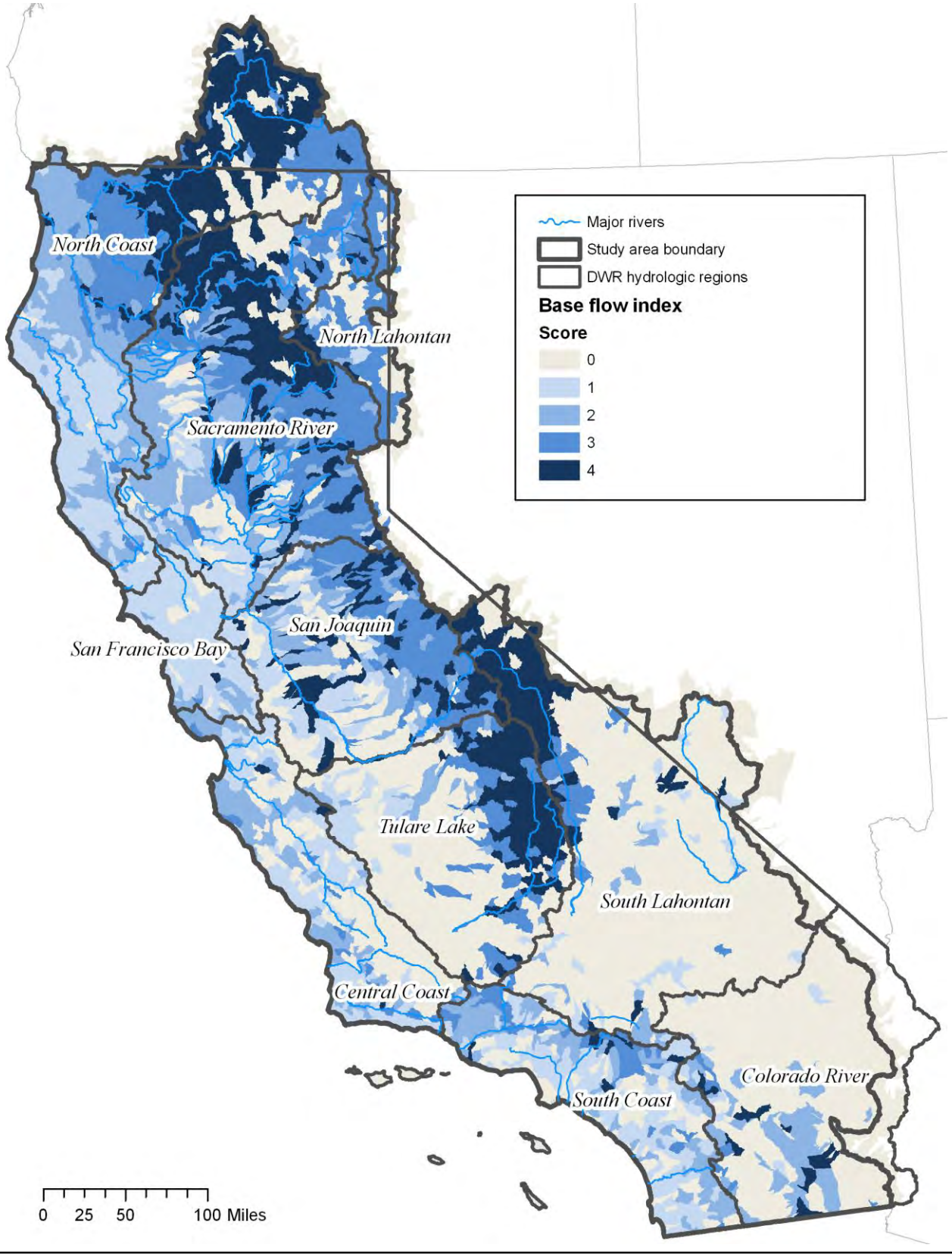
- Aqueduct Turnout
- Canal Check Structure
- Turnout
- Belridge W.S.D. Boundary
- Reservoir
- Canal
- Industrial Pipeline
- Lateral
- Service Area

aquilogic, Inc.

WDWA Chapter GSP

Belridge Water Storage District Water Infrastructure

Date: 12/3/2019	Project #: 043-04	**Figure 27c**



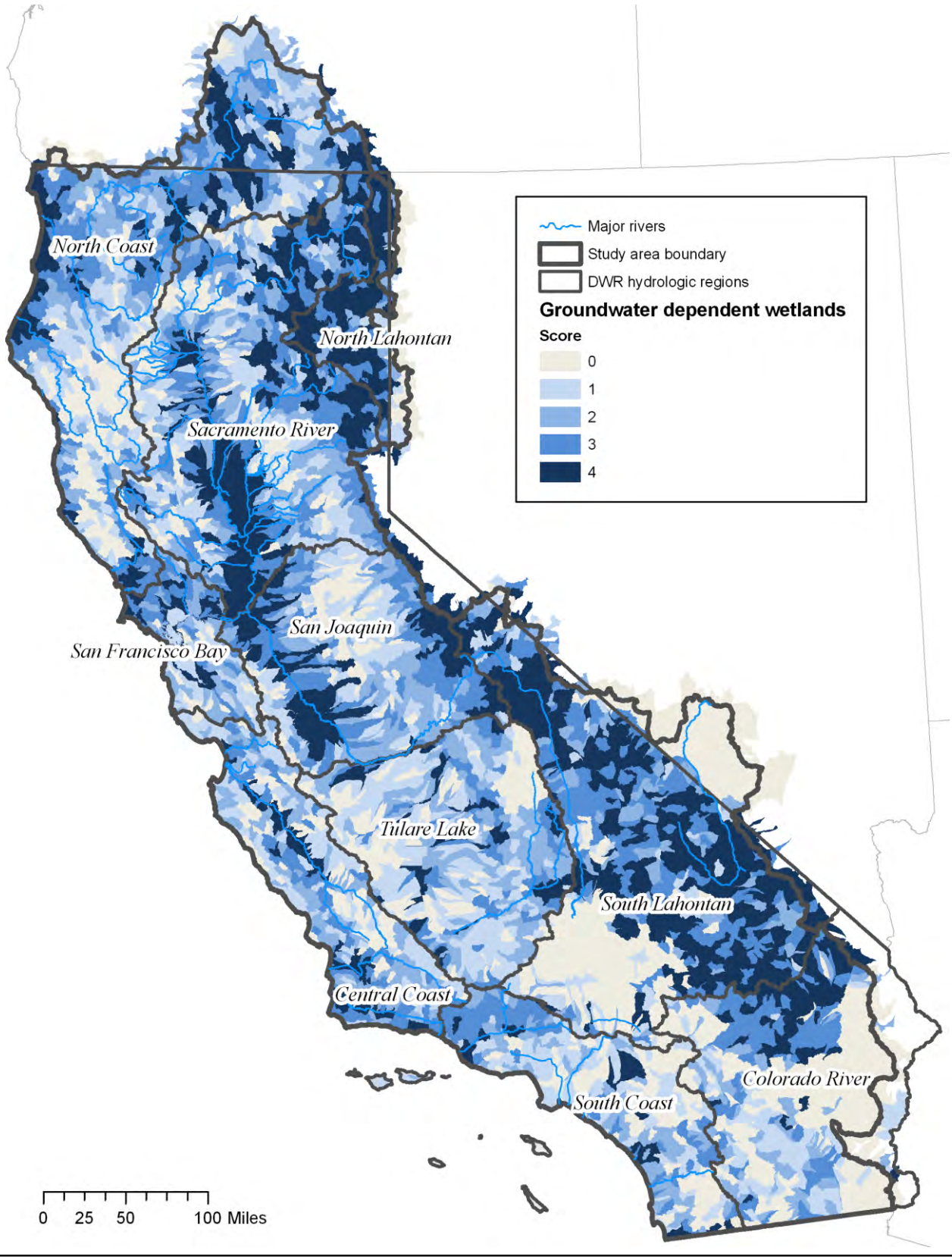
Source: Howard and Merrifield, 2010

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WDWA Chapter GSP

Base Flow

Date: 12/3/2019	Project #: 043-04	**Figure 27d**



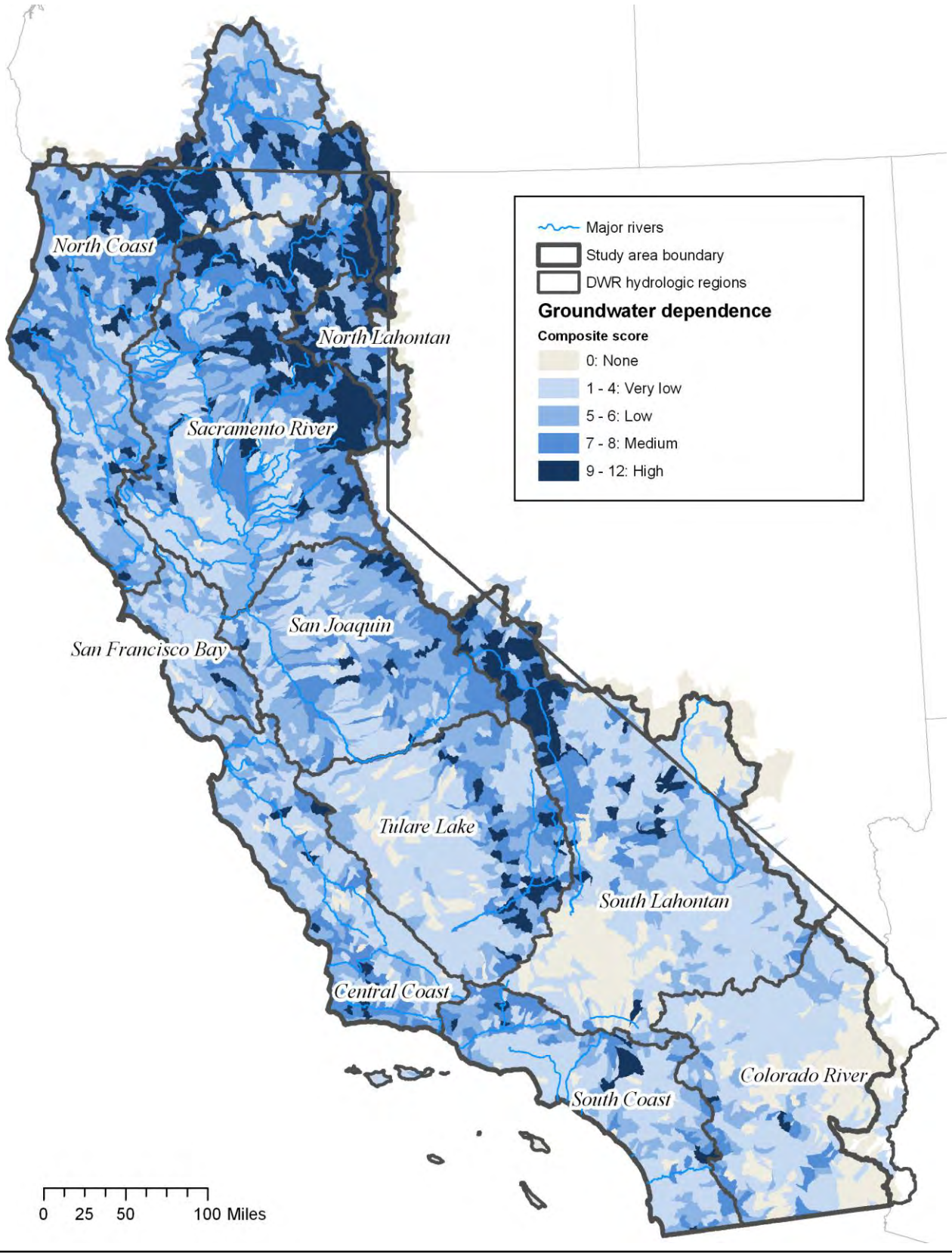
Source: Howard and Merrifield, 2010

aquilogic, Inc.

WDWA Chapter GSP

Groundwater Dependent Wetlands

Date: 12/3/2019	Project #: 043-04	**Figure 27e**



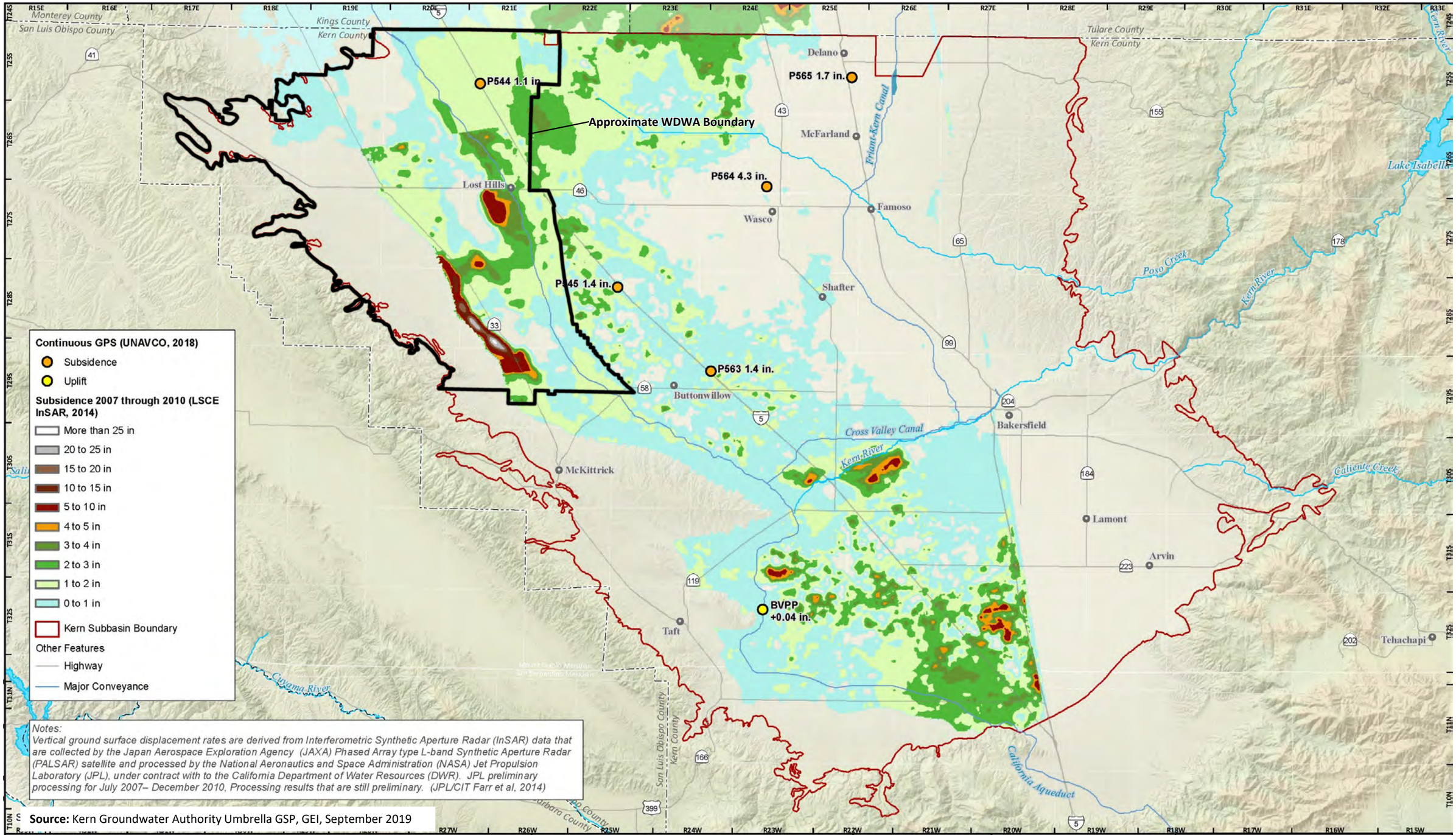
Source: Howard and Merrifield, 2010

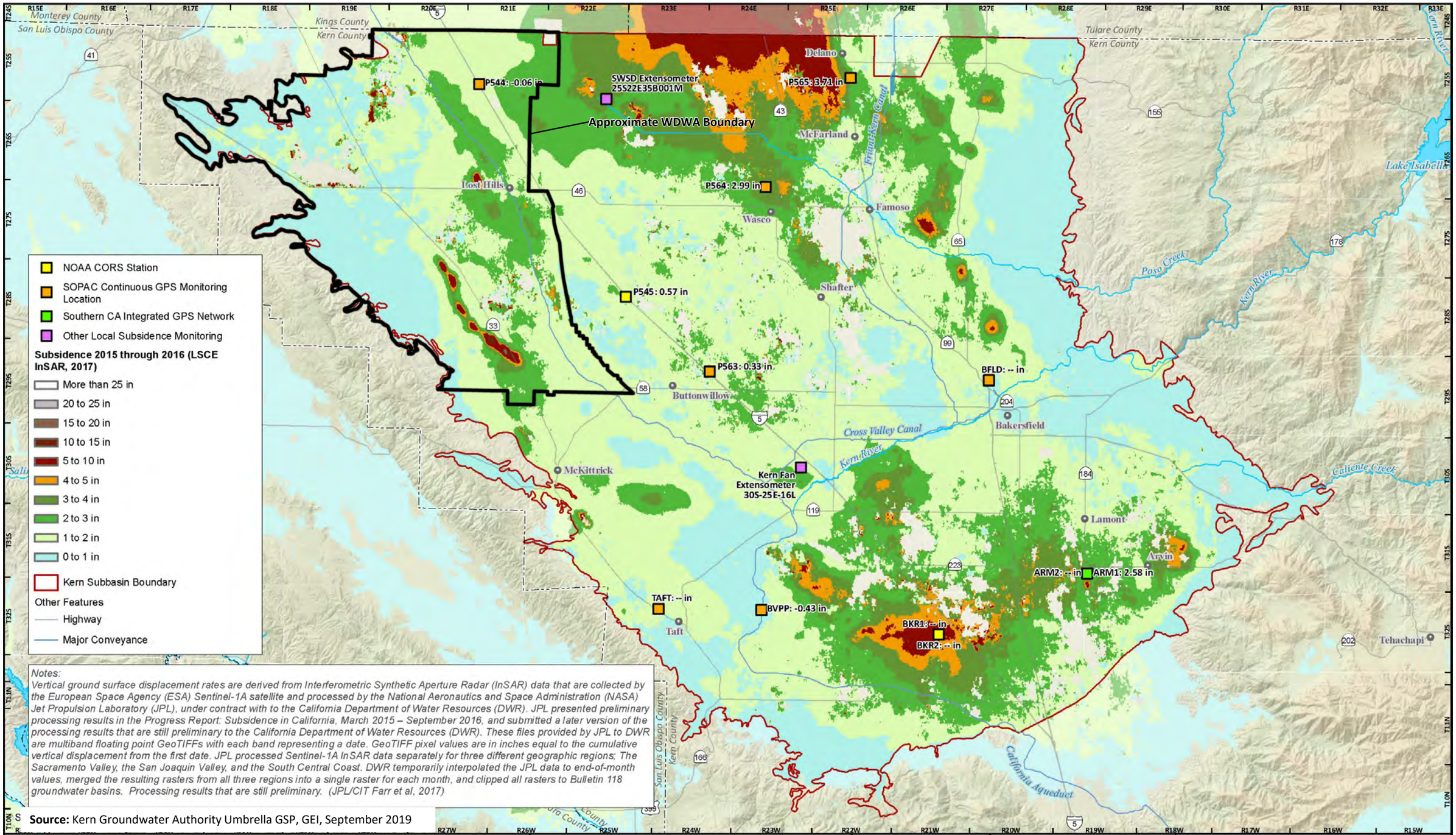
aquilogic, Inc.

WDWA Chapter GSP

Groundwater Dependence

Date: 12/3/2019	Project #: 043-04	**Figure 27f**


Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
Delano
McFarland
Wasco
Shafter
Famoso
Lost Hills
Buttonwillow
Bakersfield
McKittrick
Taft
Lamont
Arvin
Tehachapi
Friant-Kern Canal
Cross Valley Canal
Kern River
Poso Creek
Caliente Creek
Lake Isabella
California Aqueduct
Cuyama River
San Luis Obispo County
Kern County
P544 1.1 in.
P565 1.7 in.
Approximate WDWA Boundary
P564 4.3 in.
P545 1.4 in.
P563 1.4 in.
BVPP
+0.04 in.
Continuous GPS (UNAVCO, 2018)
Subsidence
Uplift
Subsidence 2007 through 2010 (LSCE InSAR, 2014)
More than 25 in
20 to 25 in
15 to 20 in
10 to 15 in
5 to 10 in
4 to 5 in
3 to 4 in
2 to 3 in
1 to 2 in
0 to 1 in
Kern Subbasin Boundary
Other Features
Highway
Major Conveyance
Notes:
Vertical ground surface displacement rates are derived from Interferometric Synthetic Aperture Radar (InSAR) data that are collected by the Japan Aerospace Exploration Agency (JAXA) Phased Array type L-band Synthetic Aperture Radar (PALSAR) satellite and processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), under contract with to the California Department of Water Resources (DWR). JPL preliminary processing for July 2007– December 2010, Processing results that are still preliminary. (JPL/CIT Farr et al, 2014)
Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019
0 3.5 7 14 21
Miles
N
W
E
S
DRAFT
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
Notes:
WDWA: Westside District Water Authority
aquilogic, Inc.
WDWA Chapter GSP
Subsidence in the Kern County Groundwater Subbasin 2007 - 2011
Date: 8/23/2019
Project #: 043-04
Figure 28a



Notes:
Vertical ground surface displacement rates are derived from Interferometric Synthetic Aperture Radar (InSAR) data that are collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), under contract with to the California Department of Water Resources (DWR). JPL presented preliminary processing results in the Progress Report: Subsidence in California, March 2015 – September 2016, and submitted a later version of the processing results that are still preliminary to the California Department of Water Resources (DWR). These files provided by JPL to DWR are multiband floating point GeoTIFFs with each band representing a date. GeoTIFF pixel values are in inches equal to the cumulative vertical displacement from the first date. JPL processed Sentinel-1A InSAR data separately for three different geographic regions; The Sacramento Valley, the San Joaquin Valley, and the South Central Coast. DWR temporarily interpolated the JPL data to end-of-month values, merged the resulting rasters from all three regions into a single raster for each month, and clipped all rasters to Bulletin 118 groundwater basins. Processing results that are still preliminary. (JPL/CIT Farr et al, 2017)

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

0 3.5 7 14 21
Miles

DRAFT

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

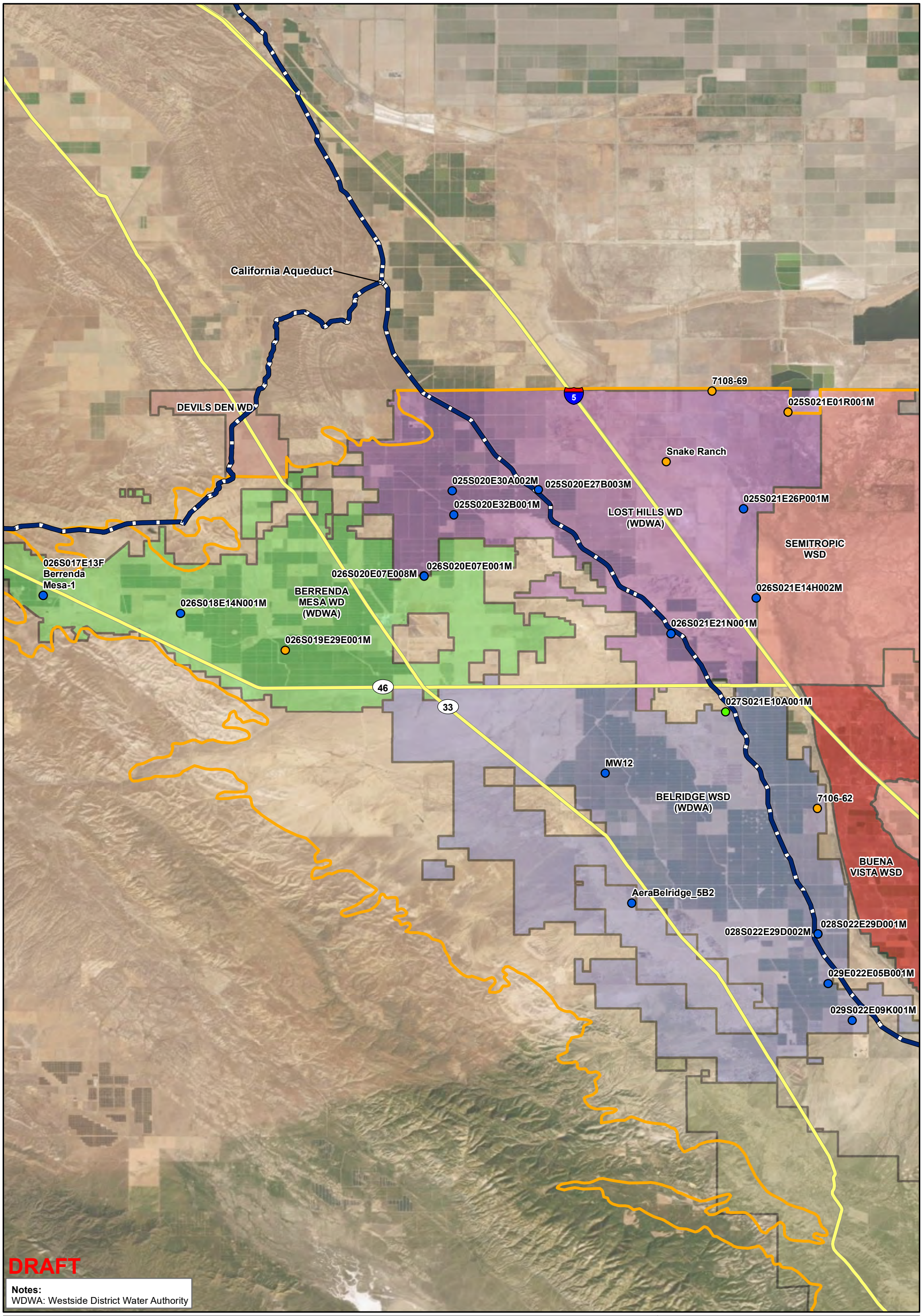
Notes:
WDWA: Westside District Water Authority

aquilogic, Inc.

WDWA Chapter GSP

Subsidence in the Kern County Groundwater Subbasin 2015 - 2016

Date: 8/23/2019 | Project #: 043-04 | **Figure 28b**


California Aqueduct
DEVILS DEN WD
7108-69
025S021E01R001M
5
Snake Ranch
025S020E30A002M
025S020E27B003M
025S020E32B001M
LOST HILLS WD
(WDWA)
025S021E26P001M
SEMITROPIC
WSD
026S017E13F
Berrenda
Mesa-1
026S020E07E008M
026S020E07E001M
026S021E14H002M
BERRENDA
MESA WD
(WDWA)
026S018E14N001M
026S021E21N001M
026S019E29E001M
46
33
027S021E10A001M
MW12
BELRIDGE WSD
(WDWA)
7106-62
BUENA
VISTA WSD
AeraBelridge_5B2
028S022E29D001M
028S022E29D002M
029E022E05B001M
029S022E09K001M
DRAFT
Notes:
WDWA: Westside District Water Authority
Aquifer Zone
Perched
Unconfined
Confined/Semi-confined
Confined
Water Districts in Kern County
Belridge WSD
Berrenda Mesa WD
Buena Vista WSD
Devils Den WD
Lost Hills WD
Semitropic WSD
West Kern WD
Undistricted Lands
Kern County Groundwater Sub-Basin
California Aqueduct
0
3.5
Miles
aquilogic, Inc.
WDWA Chapter GSP
Monitoring Network Plan
Proposed Locations
Date: 12/6/2019
Project #: 043-04
Figure 29a

Kern Subbasin Boundary
MTMO Groundwater Level Monitoring Network
Measurable Objective (MO) Groundwater Elevation Contour *(ft NAVD88)*
Kern Groundwater Authority GSA
KERN RIVER GSA
BELRIDGE W.S.D.
BERRENDA MESA W.D.
BUENA VISTA W.S.D.
CAWELO W.D.
DEVILS DEN W.D.
DUDLEY RIDGE W.D.
HENRY MILLER W.D.
LOST HILLS W.D.
SEMITROPIC W.S.D.
WHEELER RIDGE-MARICOPA W.S.D.
ARVIN-EDISON W.S.D.
DELANO-EARLIMART I.D.
SHAFTER-WASCO I.D.
KERN-TULARE W.D
SOUTHERN SAN JOAQUIN M.U.D
TEJON CASTAIC W.D
NORTH KERN W.S.D
SHAFTER-WASCO I.D additional M.A
ROSEDALE RIO BRAVO W.S.D
WEST KERN W.D
KERN WATER BANK AUTHORITY
OIL AND GAS LANDS
WHEELER RIDGE W.S.D Additional M.A
EASTSIDE WATER MANAGEMENT AREA
CAWELO W.D Additional M.A
SEMITROPIC W.S.D additional M.A
ROSEDALE RIO BRAVO W.S.D additional M.A
ARVIN-EDISON W.S.D additional M.A.
BELRIDGE W.S.D additional M.A

Approximate WDWA Boundary

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

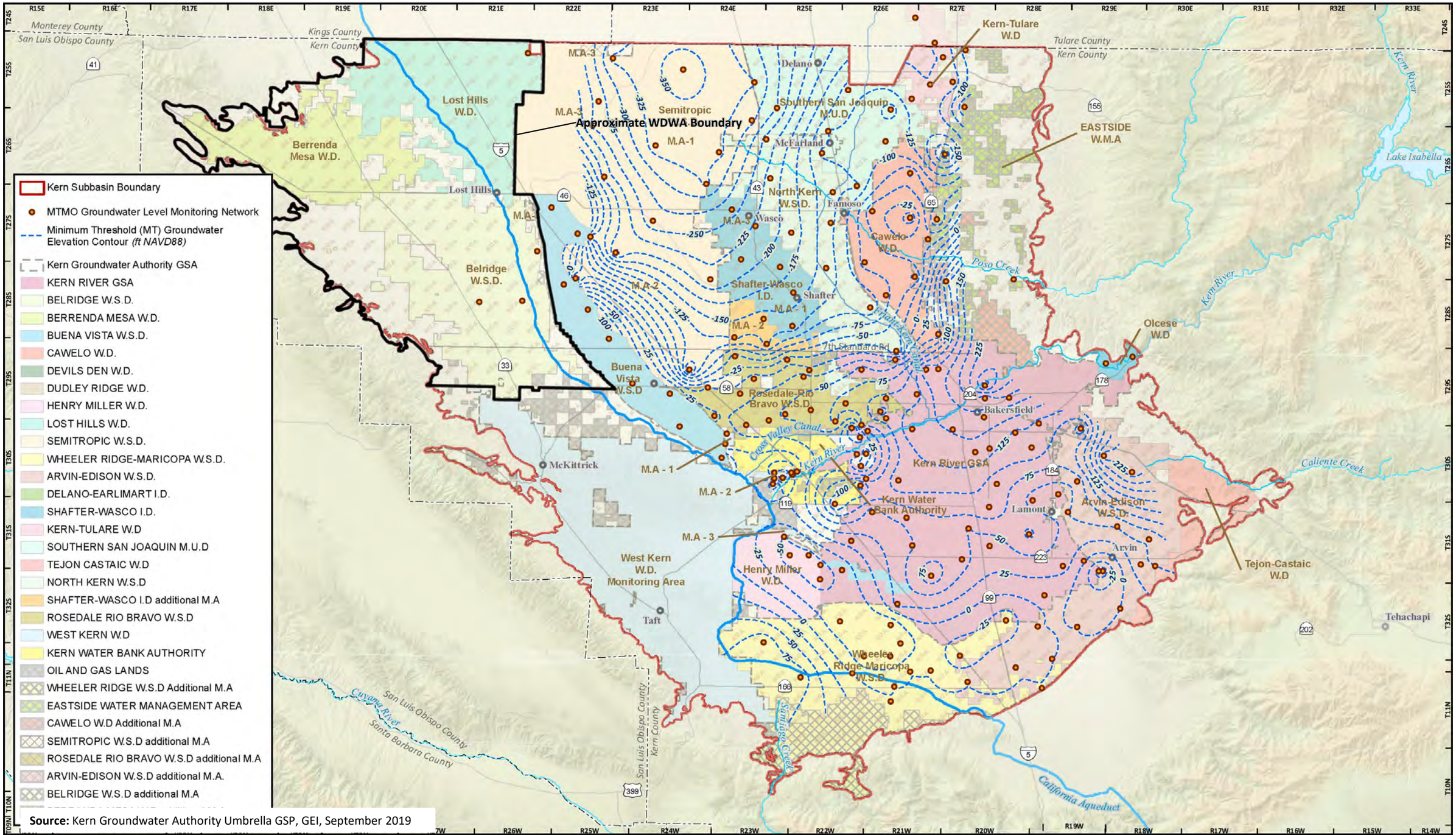
Notes:
KGA: Kern Groundwater Authority
WDWA: Westside District Water Authority

aquilogic, Inc.

WDWA Chapter GSP

Regional Measurable Objective Groundwater Elevation Contours

Date: 12/3/2019 | Project #: 043-04 | **Figure 29b**



Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

0 3.5 7 14 21
Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

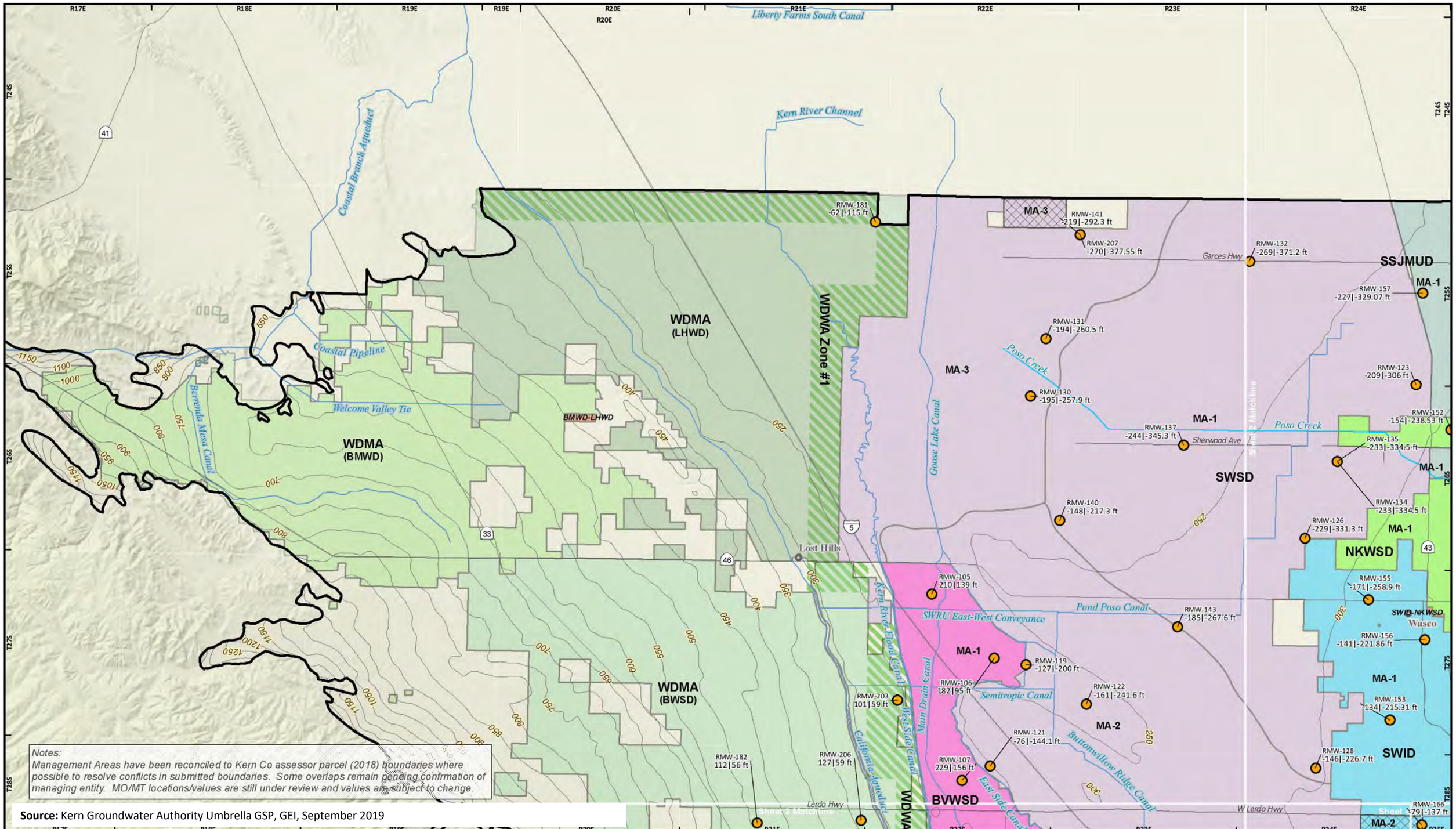
Notes:
KGA: Kern Groundwater Authority
WDWA: Westside District Water Authority

aquilogic, Inc.

WDWA Chapter GSP

Regional Minimum Threshold Groundwater Elevation Contours

Date: 12/3/2019 | Project #: 043-04 | **Figure 29c**



Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

Well ID
MO | MT MSL

District

Unresolved Boundary Overlap

Undistricted (Colored where associated with District)

DRAFT

0 1.5 3 6
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

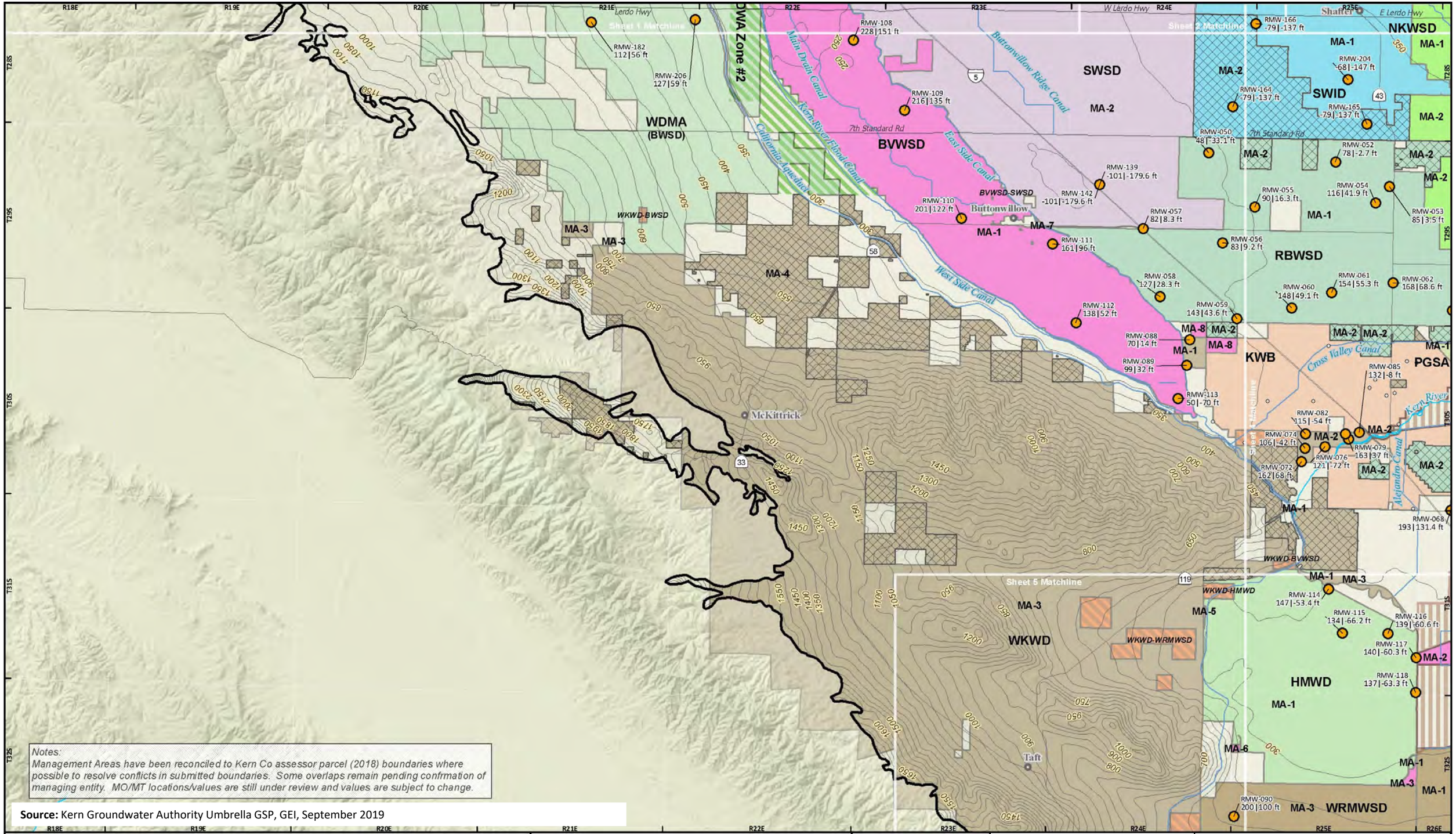
Notes:
Average decline slope:
4.2 – 5.6 ft/year
WDWA: Westside District Water Authority

aquilogic, Inc.

WDWA Chapter GSP

WDWA Proposed MO and MT Coordination Zones

Date: 8/23/2019 | Project #: 043-04 | **Figure 30a**



Notes:
Management Areas have been reconciled to Kern Co assessor parcel (2018) boundaries where possible to resolve conflicts in submitted boundaries. Some overlaps remain pending confrmation of managing entity. MO/MT locations/values are still under review and values are subject to change.

Source: Kern Groundwater Authority Umbrella GSP, GEI, September 2019

Well ID
MO | MT MSL

District

Unresolved Boundary Overlap

Undistricted (Colored where associated with District)

DRAFT

0 1.5 3 6
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

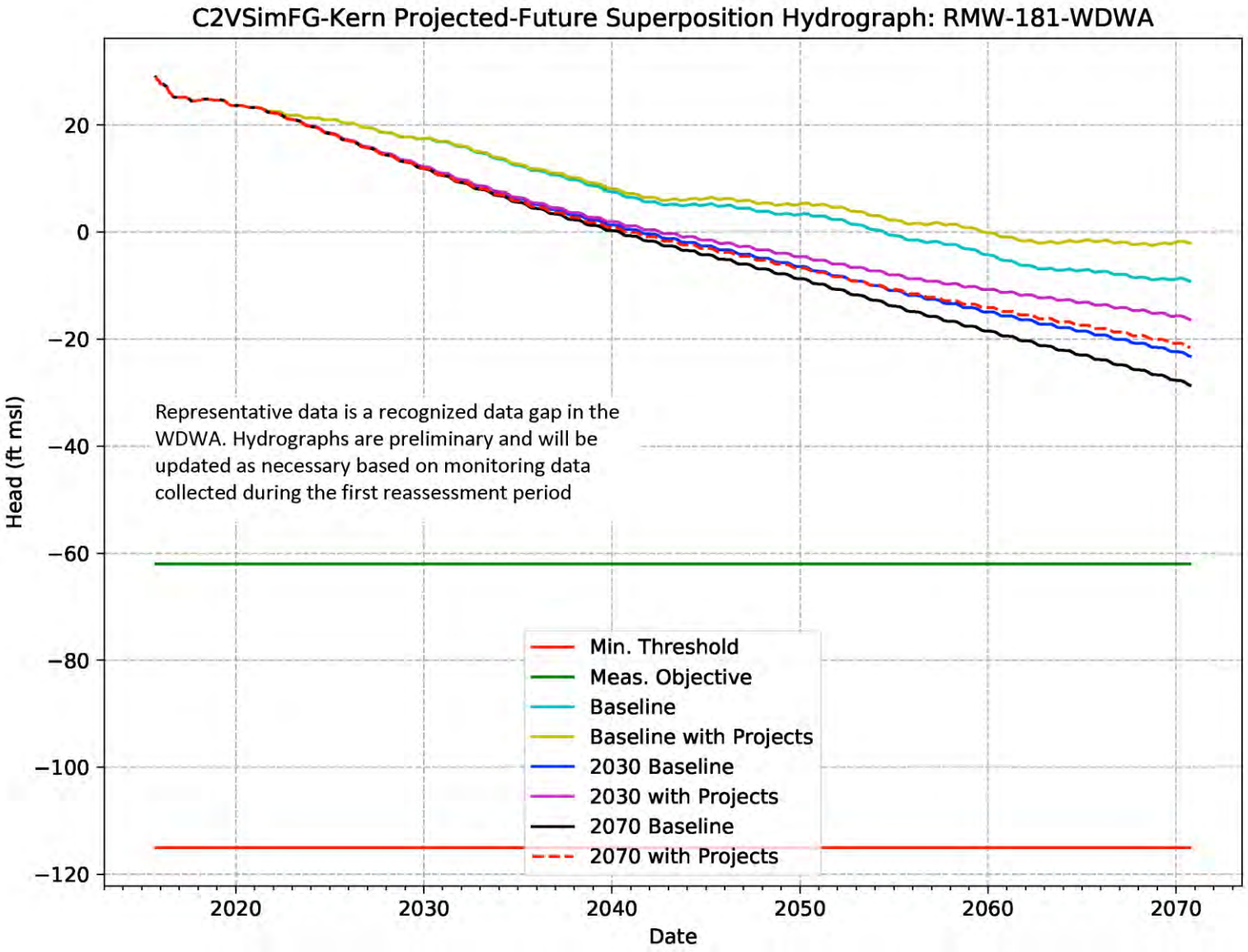
Notes:
*Preliminary, subject to change
Average decline slope:
4.2 – 5.6 ft/year
WDWA: Westside District Water Authority

aquilogic, Inc.

WDWA Chapter GSP

WDWA Proposed MO and MT Coordination Zones

Date: 8/23/2019 | Project #: 043-04 | **Figure 30b**



Notes:
MO: Measurable objective
MT: Minimum threshold
WDWA: Westside District Water Authority
Source: KGA/Todd Groundwater 2019

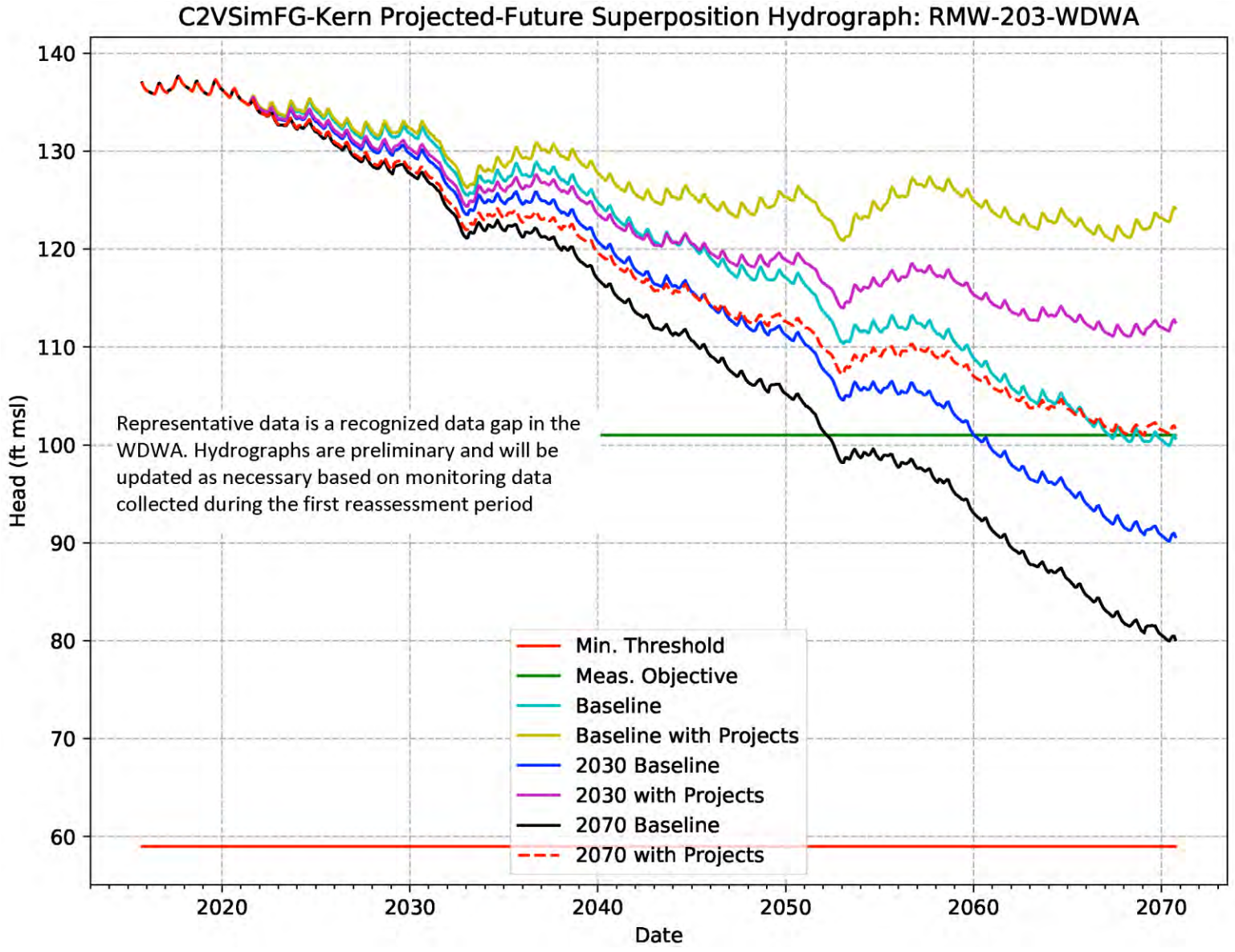
MO: -62 ft. below MSL
MT: -115 ft. below MSL

aquilogic, Inc.

WDWA Chapter GSP

MOs and MTs – Well 25S21E-01R01

Date: 12/9/2019	Project #: 043-04	**Figure 30c**



Notes:
MO: Measurable objective
MT: Minimum threshold
WDWA: Westside District Water Authority
Data from 2016.
Source: KGA/Todd Groundwater 2019

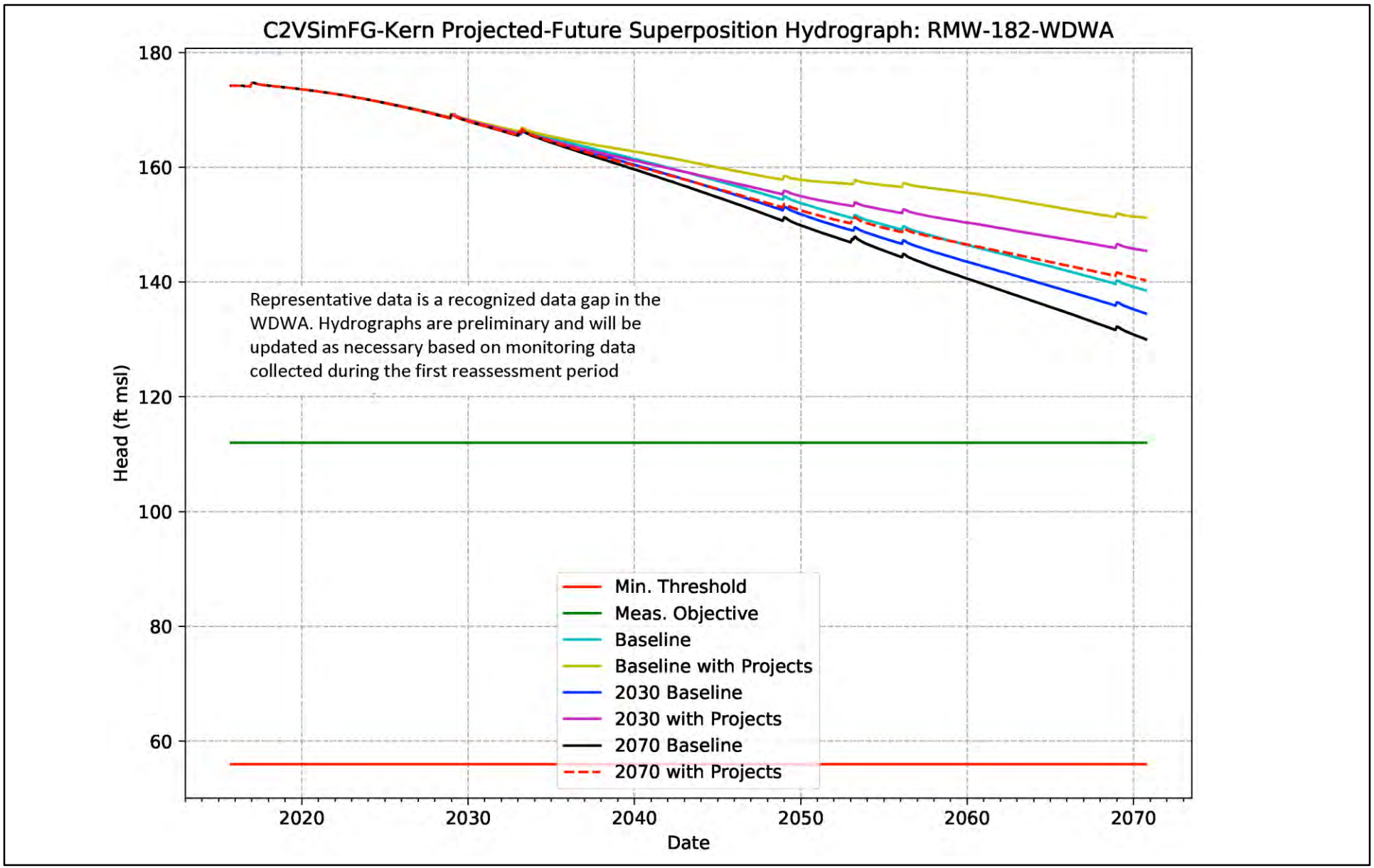
MO: 101 ft. above MSL
MT: 59 ft. above MSL

aquilogic, Inc.

WDWA Chapter GSP

T27S, R22E,Sec.30
MOs and MTs – Well 7106-63

Date: 12/9/2019	Project #: 043-04	**Figure 30d**



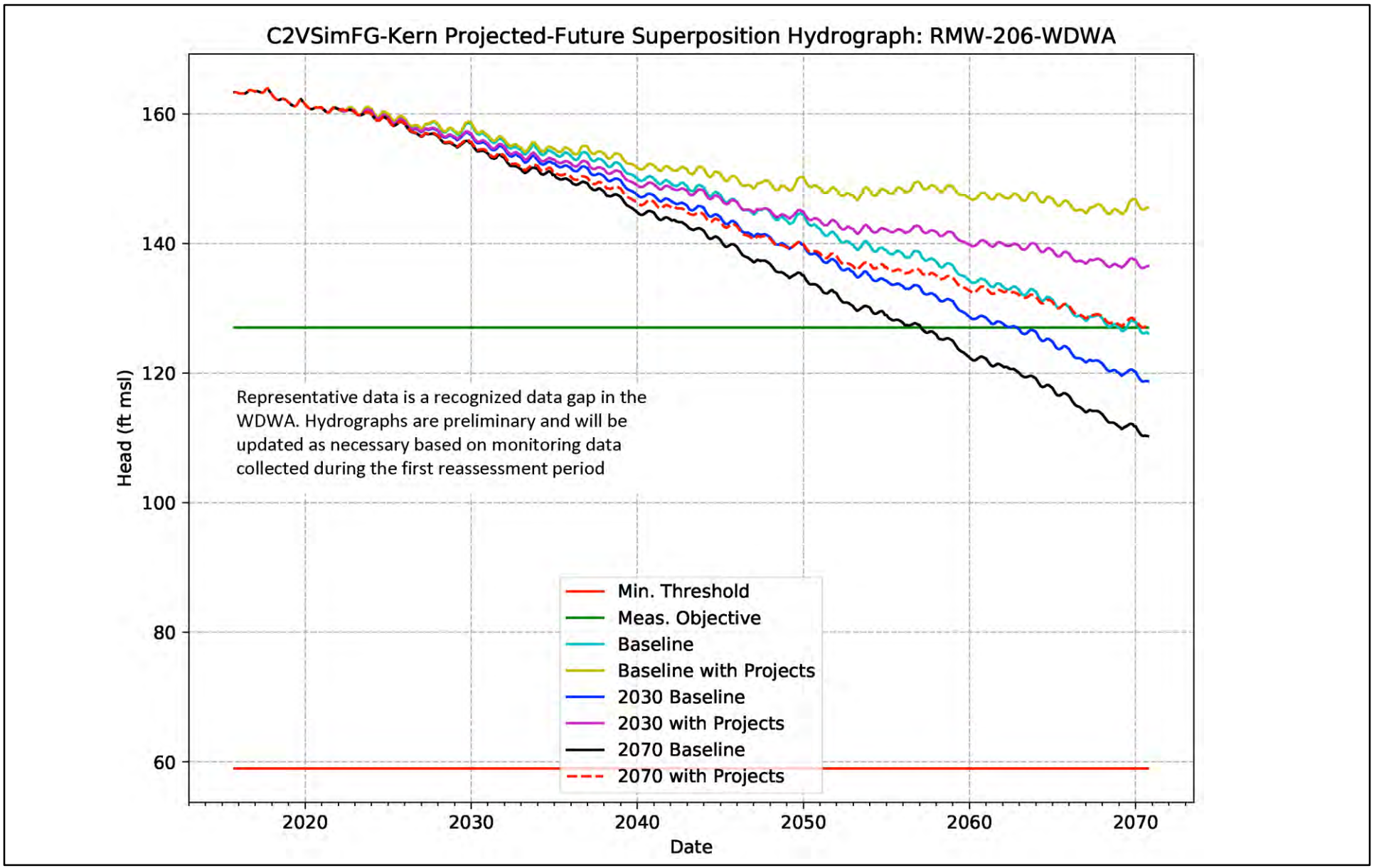
Notes:
MO: Measurable objective
MT: Minimum threshold
WDWA: Westside District Water Authority
Source: KGA/Todd Groundwater 2019

MO: 112 ft. above MSL
MT: 56 ft. above MSL

aquilogic, Inc.

T28S, R21E,Sec.16
MOs and MTs – C2VSim

Date: 12/9/2019	Project #: 043-04	**Figure 30e**



Notes:
MO = Measurable objective
MT = Minimum threshold
WY = Water year
Simulated data range of WY 1995-2004, and projections based on that range, for an average water-level decline of 6.8 feet per year.

MO: 127 ft. above MSL
MT: 59 ft. above MSL

aquilogic, Inc.

WDWA Chapter GSP

Well 028S021E13H
MOs and MTs

Date: 12/9/2019	Project #: 043-04	**Figure 30f**

APPENDICES

APPENDIX A CHAPTER COMMENT LETTER

Wonderful orchards
Wonderful citrus

November 27, 2019

Phil Nixon
Westside District Water Authority
1405 Commercial Way, Ste. 125
Bakersfield, CA 93309

VIA EMAIL: pnixon@lhwd.org

Re: Comments on Draft Kern Groundwater Authority Umbrella Groundwater Sustainability Plan and Westside Management Area Plan

Dear Mr. Nixon and Board of Directors,

Wonderful Orchards LLC and Wonderful Citrus LLC (collectively, "Wonderful") appreciate all the hard work that has gone into preparing the draft Groundwater Sustainability Plan ("Umbrella GSP") and Management Area Plans ("MAPs") by the Kern Groundwater Authority ("KGA") and its member agencies ("Members") including Westside District Water Authority.

Wonderful, and our related entities, farm and process almonds, pistachios, various citrus varietals, pomegranates and nursery stock in Central California, including Kern County. As a major agricultural entity in the Central Valley, we understand just how important it is to formulate a GSP that meets the sustainability needs of the groundwater basin well into the future.

In order to best execute the GSP's goal to achieve sustainability by 2040, we encourage all GSAs and Members in the subbasin to initiate stakeholder-driven processes and to work together cooperatively to develop coordinated, subbasin-wide management actions and implementation strategies. To that end, we request that the following comments be considered prior to the Umbrella GSP and MAPs being finalized and implemented.

Quantification of Native Yield[1]

It is imperative that the final GSP properly address the quantification of native yield. The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource.

For example, a district or pumper located adjacent to the foothills does not necessarily have a superior claim to native yield over someone located in the center of the basin just because they are geographically closer to the source of mountain front recharge. Similarly, a district or

[1] Native yield as defined in Section 4.2.1 of Appendix J to the GSP.

pumper located in a cone of depression does not necessarily have a superior claim to native yield just because groundwater is flowing toward them. Surface water entering the groundwater via seepage in natural channels, including the Kern River and small streams, may be attributable to the native yield depending upon the circumstances of that seepage. A thorough technical and legal analysis is necessary to determine appropriate sources contributing to the native yield and to quantify these supplies.

Allocation of Native Yield

In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield. Currently, the GSP references native yield in terms of acre-feet per gross acre for water budget purposes. Appendix J of the GSP indicates the subbasin native yield is approximately 0.144 acre-feet per acre. It is our understanding that subsequent to the release of the draft GSP, all MAPs and other GSPs in the basin agreed to utilize the same number for their water budgets. If referencing native yield this way is necessary, the GSP should clarify that it is for initial water budget purposes ONLY, is non-precedent setting, and is not a determination of individual landowner allocations or groundwater rights. Alternatively, in the 2020 plans subbasin native yield could be described as a total volume of water and not associated with a given gross or net area.

In addition, GSAs should initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations of native yield that are coordinated across the subbasin. The allocation methodology should be consistent with various legal considerations drawn from applicable case law and be generally consistent with groundwater rights, recognizing that GSAs do not have statutory authority to make a final determination of water rights. An equal-per-gross acre approach to allocations is not likely to be consistent with established water rights doctrine, which must recognize many equitable considerations in addition to acreage owned, to determine a legally defensible allocation. Further information regarding allocation methodology can be found in *Groundwater Pumping Allocations Under California's Sustainable Groundwater Management Act – Environmental Defense Fund and New Current Water & Land, July 2018*.

Groundwater Markets

Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next.

Pumping Restrictions

Wonderful understands that there are instances where it may be necessary to restrict pumping in order to achieve basin-wide sustainability. If this becomes a necessity, the GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity.

As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled).

Groundwater Recharge and Banking

GSAs must develop clear policies and conditions that protect existing investment in groundwater banking and banked inventory, and without interference with existing rules and regulations. GSAs must also find a way to incentivize additional investment, such as on-farm recharge, and allow flexibility for recharged or banked water to be freely transferrable (subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results). Where possible, GSPs should also identify management areas that may benefit from additional recharge and banking. We also recommend that GSAs work to develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).

Measurement and Data Management

Finally, GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions.

Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).

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Wonderful appreciates the opportunity to provide feedback on the GSP and MAPs. We would be happy to discuss these comments at your convenience. Thank you for your consideration.

Sincerely,

Rob C. Yraceburu
President
Wonderful Orchards LLC

David W. Krause
President
Wonderful Citrus LLC

APPENDIX B KERN GROUNDWATER AUTHORITY NOTIFICATION OF INTENT TO DEVELOP A GROUNDWATER SUSTAINABILITY PLAN

KERN
GROUNDWATER AUTHORITY

December 20, 2017

Mr. Trevor Joseph
Sustainable Groundwater Management Section Chief
California Department of Water Resources
P. O. Box 94236
Sacramento, CA 94236

Re: Notification of Intent to Develop a Groundwater Sustainability Plan

Dear Mr. Joseph:

The purpose of this letter is to notify you that the Kern Groundwater Authority Groundwater Sustainability Agency (KGA) intends to develop a Groundwater Sustainability Plan (GSP) pursuant to Water Code Section 10727.8 for its service area within the Kern County Subbasin (Basin Number 5-22.14, DWR Bulletin 118). The KGA is an exclusive GSA whose formation was posted by DWR on April 21, 2016.

The KGA is engaged in several coordination and outreach efforts across the Kern County Subbasin, as well as within the more specific service area of the KGA. The KGA actively participates in technical and planning meetings and forums with other GSAs in the Kern County Subbasin, recognizing that the findings of the KGA's GSP will need to be coordinated with other GSP development efforts occurring in parallel within the Kern County Subbasin. In addition to the monthly KGA Board of Directors meetings, the KGA holds monthly public meetings to review and discuss on-going planning activities in support of the GSA and GSP development process. These meetings welcome public input and feedback to the GSA and the GSP development process.

The KGA will also be holding educational workshops specifically intended for the interested parties and general public living, working and operating farms and businesses in the KGA service area. These additional workshops will have an educational focus to inform attendees on the overall role and purpose of the GSA, describe the method and process to develop the GSP, and solicit input on the development of the GSP. An initial workshop in 2018 will focus on public involvement and seek input on approaches, such as an Advisory Committee, to regularly acquire input from a wide variety of public stakeholders, and from disadvantaged communities in particular. One of the key goals of the public workshops will be to hear comments and feedback from the public that can be used to further inform the GSP development process.

1800 30th Street, Suite 280, Bakersfield, CA 93301 • Tel: (661) 616-6500 • Fax: (661) 616-5890 • www.kerngwa.com

The KGA has established a website at: http://kerngwa.com/. This website is already actively in use and will continue to provide the public with key information regarding the GSA and GSP development process including the dates of public meetings and workshops. The KGA website also makes our resource planning and GSP documents available to the public.

If you have any questions regarding our GSP development process, please don't hesitate to contact me at the phone number or email below.

Sincerely,



Terry L. Erlewine
Kern Groundwater Authority

Cc: City of Delano
City of Wasco
City of Shafter
City of Arvin
County of Kern
City of McFarland

APPENDIX C LIST OF WDWA UNDISTRICTED LANDS

APN's/Tax Assessor	Acreage	BWSD/BMWD/LHWD
068-120-02	40.26	BWSD
043-380-05	10.1	BMWD
043-380-02	18.54	BMWD
086-190-01	146.71	BWSD
069-250-10	163.99	BWSD
069-250-19	2.26	BWSD
069-250-20	199.47	BWSD
086-070-11	191.44	BWSD
086-070-05	68.79	BWSD
069-250-17	2.32	BWSD
069-250-18	137.04	BWSD
068-120-54	160	BWSD
068-100-13	39.53	BWSD
068-100-35	483.17	BWSD
068-120-35	161.28	BWSD
068-120-49	78.88	BWSD
068-120-56	160.93	BWSD
068-230-08	335.90	BWSD
098-141-15	82.45	BWSD
086-272-14	4.66	BWSD
086-272-32	1.18	BWSD
043-140-05	20.07	BMWD
043-150-21	20.1	BMWD
043-150-23	53.31	BMWD
043-150-20	80.4	BMWD
057-112-05	6	BMWD
057-112-12	66	BMWD
069-220-14	29.83	BWSD
085-160-20	20.03	BWSD
043-330-30	80.67	BMWD
057-080-20	40.17	BMWD
057-080-25	62.99	BMWD
057-080-26	61.49	BMWD
068-120-01	54.48	BWSD
068-120-29	53.97	BWSD
068-120-30	108.49	BWSD
069-011-09	18.13	BWSD
069-011-58	38.47	BWSD
069-104-03	0.66	BWSD
085-160-19	20.48	BWSD
085-170-36	58.18	BWSD
085-170-37	19.03	BWSD
057-162-19	320.52	BMWD
057-162-23	20.75	BMWD
057-180-36	525.32	BMWD
057-230-13	302.46	BMWD
057-230-15	19.93	BMWD
057-230-21	59.96	BMWD
057-250-28	80.58	BMWD
057-250-29	40.34	BMWD
057-250-30	323.32	BMWD

APN's/Tax Assessor	Acreage	BWSD/BMWD/LHWD
057-250-18	40.34	BMWD
058-010-24	207.87	LHWD
058-101-07	162.57	LHWD
043-370-29	121.09	BMWD
043-260-20	38.76	BMWD
098-020-03	10.03	BWSD
098-020-07	10.11	BWSD
098-020-09	10.03	BWSD
043-140-08	40.17	BMWD
043-140-17	20.07	BMWD
086-280-32	10.1	BWSD
086-280-33	10.41	BWSD
086-280-35	10.13	BWSD
086-330-23	10.41	BWSD
099-130-12	2.49	BWSD
099-130-13	2.53	BWSD
099-130-14	4.96	BWSD
043-260-55	39.23	BMWD
043-260-27	39.84	BMWD
043-320-03	5.05	BMWD
043-320-04	104.85	BMWD
043-320-05	9.55	BMWD
043-320-06	40.42	BMWD
043-320-02	40.63	BMWD
043-320-01	97.6	BMWD
043-320-07	13.76	BMWD
043-103-21	39.1	BMWD
068-100-05	26.11	BWSD
068-100-06	18.14	BWSD
068-100-07	20.91	BWSD
068-100-04	87.56	BWSD
068-100-28	80.84	BWSD
068-100-29	81.99	BWSD
068-100-30	284.74	BWSD
043-330-06	137	LHWD
043-250-04	60	LHWD
068-100-15	642.79	BWSD
068-110-08	642.82	BWSD
068-120-53	161.18	BWSD
068-210-17	248.40	BWSD
068-220-08	80.56	BWSD
068-220-35	312.84	BWSD
068-220-36	320.60	BWSD
069-111-11	8.86	BWSD
085-070-45	59.54	BWSD
085-120-09	156.05	BWSD
085-120-20	78.02	BWSD
085-120-26	85.78	BWSD
085-140-01	633.06	BWSD
085-170-08	40.07	BWSD
085-210-17	17.08	BWSD

APN's/Tax Assessor	Acreage	BWSD/BMWD/LHWD
098-141-22	79.74	BWSD
068-090-13	322.06	BWSD
068-110-12	646.50	BWSD
069-111-09	101.70	BWSD
085-050-07	243.46	BWSD
085-070-40	25.60	BWSD
085-120-25	81.05	BWSD
085-210-40	131.48	BWSD
086-040-12	0.95	BWSD
057-202-24	19.32	LHWD
068-100-18	162.26	BWSD
068-100-34	161.24	BWSD
068-120-33	482.29	BWSD
068-220-01	644.20	BWSD
085-070-46	21.64	BWSD
085-110-16	79.58	BWSD
085-120-22	10.52	BWSD
085-130-08	639.64	BWSD
085-140-10	163.62	BWSD
085-140-17	79.53	BWSD
085-170-21	41.41	BWSD
085-210-18	621.47	BWSD
085-220-21	271.86	BWSD
085-230-05	643.99	BWSD
057-220-12	84.71	LHWD
057-220-40	50.92	LHWD
057-220-62	159.94	LHWD
058-110-15	19.89	LHWD
068-100-19	320.76	BWSD
068-120-51	401.76	BWSD
068-210-16	410.20	BWSD
068-220-13	644.33	BWSD
068-220-43	15.12	BWSD
068-230-01	338.21	BWSD
085-050-14	78.60	BWSD
085-060-20	91.69	BWSD
085-070-18	195.06	BWSD
085-070-44	68.52	BWSD
085-230-25	146.62	BWSD
098-141-20	161.71	BWSD
057-031-12	159.96	BMWD
057-202-23	19.09	LHWD
068-120-14	79.31	BWSD
085-050-09	83.27	BWSD
085-120-15	308.20	BWSD
085-120-16	39.40	BWSD
085-140-02	43.54	BWSD
085-140-15	159.25	BWSD
085-140-18	159.42	BWSD
085-220-22	355.99	BWSD
057-202-58	42.25	LHWD

APN's/Tax Assessor	Acreage	BWSD/BMWD/LHWD
058-110-13	478.79	LHWD
068-080-17	93.90	BWSD
068-080-49	73.25	BWSD
068-230-02	320.71	BWSD
068-230-10	321.05	BWSD
069-112-19	40.00	BWSD
085-070-15	60.73	BWSD
085-070-39	116.26	BWSD
085-120-07	70.38	BWSD
085-120-12	140.27	BWSD
085-140-23	166.45	BWSD
085-140-34	20.41	BWSD
085-230-07	636.70	BWSD
085-230-34	4.87	BWSD
043-133-01	320.94	BMWD
058-110-26	92.15	LHWD
058-110-27	5.06	LHWD
068-080-20	90.75	BWSD
068-090-14	636.23	BWSD
068-210-18	363.03	BWSD
068-220-44	81.32	BWSD
085-070-19	41.87	BWSD
085-070-42	22.06	BWSD
085-120-03	19.56	BWSD
085-120-17	39.72	BWSD
085-120-19	38.07	BWSD
085-150-03	81.35	BWSD
085-210-43	535.20	BWSD
085-230-01	166.62	BWSD
085-230-26	488.86	BWSD
068-120-16	643.93	BWSD
069-111-12	227.82	BWSD
085-120-11	78.69	BWSD
085-120-21	79.29	BWSD
085-140-14	161.66	BWSD
085-140-33	61.20	BWSD
085-170-19	40.90	BWSD
098-141-24	75.10	BWSD
043-133-02	80	BMWD
043-133-06	40	BMWD
057-202-12	60	BMWD
057-220-22	80	BMWD
057-220-25	80	BMWD
057-250-07	160	BMWD
057-250-14	240	BMWD
057-250-09	160	BMWD
058-180-45	302.25	BWSD
069-410-27	240	BWSD
085-060-17	234	BWSD
085-070-22	35.83	BWSD
085-140-29	48.12	BWSD

APN's/Tax Assessor	Acreage	BWSD/BMWD/LHWD
085-140-37	23.68	BWSD
085-140-38	63.68	BWSD
085-140-41	20	BWSD
085-140-42	60	BWSD
085-160-02	20	BWSD
085-160-03	20	BWSD
085-160-04	40	BWSD
085-160-21	40	BWSD
085-170-38	20	BWSD
085-170-39	220	BWSD
085-170-40	20	BWSD
085-170-41	60	BWSD
086-320-02	320	BWSD
098-120-29	80	BWSD
098-120-30	80	BWSD
098-120-16	80	BWSD
098-141-16	20	BWSD
098-141-17	59.09	BWSD
099-261-25	68.69	BWSD
099-261-26	273.06	BWSD
099-261-31	297.6	BWSD
099-290-03	640	BWSD
099-290-06	640	BWSD
099-261-20	160	BWSD
099-261-17	629.88	BWSD
102-010-26	243.25	BWSD
102-010-27	230.41	BWSD
058-180-44	1.1	BWSD
099-290-05	39.34	BWSD
099-290-16	278.83	BWSD
099-290-17	319.17	BWSD
099-261-32	318.36	BWSD

APPENDIX D UNITED STATES DEPARTMENT OF AGRICULTURE LANDSCAPE CHARACTERISTICS

USDA Landscape Characteristics

Topography Characteristic			% of the District				Effect on Water Operations and Drainage
Rolling Land			(20% of Irrigated land)				Land is adaptable to sprinkler and micro irrigation systems. There are no effects on water operations and drainage because of the existence of pressurized irrigation systems
Flat Land			(80% of irrigated land)				Land is adaptable to flood and other types of irrigation systems
Soil Unit	**Soil Name / Characteristic / Classification**	**Description**	**Percent of District**	**Depth (in)**	**Clay (%)**	**Permeability (in/hr)**	**Effect on Water Operations and Drainage**
115	Bitterwater sandy loam, 9 to 15 percent slopes	Deep, well drained soil is on foothills. Formed in residuum derived dominantly from sandstone.	0.00	0-23	5-10	1.98 - 5.95	No irrigation operations impact
				23-60	5-10	1.98 - 5.95	
				60-70	---	1.98 - 5.95	
124	Buttonwillow clay, partially drained	Deep, somewhat poorly drained soil is in basins. Formed in alluvium derived dominantly from granitic rock. Slope is 0-2 percent.	0.29	0-28	40-55	0.06 - 0.2	No irrigation operations impact
				28-55	8-15	1.98 - 5.95	
				55-64	35-50	0.06 - 0.2	
125	Cajon loamy sand, 0 to 2 percent slopes	Deep, somewhat excessively drained soil is on alluvial fans. Formed in alluvium derived dominantly from granitic rock.	0.05	0-9	5-18	5.95 - 19.98	No irrigation operations impact
				9-44	0-5	5.95 - 19.98	
				44-60	5-10	5.95 - 19.98	
129	Carollo-Twisselman saline alkali association, 2 to 15 percent slopes	Carollo (60% of area), clay loam, saline-alkali. Moderately deep and well drained soil is on hill tops. Formed in residuum derived dominantly from shale.	0.01	0-2	27-32	0 - 0.06	No irrigation operations impact
				2-15	40-60	0 - 0.06	
				15-30	30-40	0 - 0.06	
		Twisselman (40% of area), clay, saline-alkali. Deep and well drained soil is on side slopes and drainageways. Formed in alluvium derived dominantely from sedimentary rock.		0-9	40-60	0 - 0.06	
				9-60	35-60	0 - 0.06	
				30-60	---	0 - 0.2	
144	Delgado sandy loam, 5 to 30 percent slopes	Shallow, somewhat excessively drained soil is on hills. Formed in residuum derived dominantly from sedimentary rock.	0.06	0-2	8-20	1.98 - 5.95	No irrigation operations impact
				2-10	8-20	1.98 - 5.95	
				10-14	---	0.2 - 1.98	
150ki	Panoche loam, 0 to 2 percent slopes	Component is on alluvial fans. Parent material consists of alluvium derived from sedimentary rock. Natural drainage class is well drained.	0.16	0-7	18-27	0.57 - 1.98	No irrigation operations impact
				7-60	18-35	0.57 - 1.98	
156	Garces silt loam	Deep, well drained, saline-alkali soil is on basin rims. Formed in alluvium derived dominantly from granitic rock.	1.19	0-2	10-18	0.2 - 0.57	No irrigation operations impact
				2-9	27-35	0 - 0.06	
				9-23	20-35	0 - 0.06	
				23-37	20-27	0	
				37-60	10-27	0.2 - 0.57	
157	Garces silt loam, moderately wet	Deep, well drained, saline-alkali soil is on basin rims. Formed in alluvium derived dominantly from granitic rock.	0.40	0-2	10-18	0.2 - 0.57	No irrigation operations impact
				2-9	27-35	0 - 0.06	
				9-23	20-35	0 - 0.06	
				23-37	20-27	0	
				37-60	10-27	0.2 - 0.57	
164	Houser fine sandy loam, partially drained	Deep, somewhat poorly drained, saline-alkali soil is on basin rims. Formed in alluvium derived dominantly from granitic rock. Slope is 0-1 percent.	1.77	0-4	5-20	1.98 - 5.95	No irrigation operations impact
				4-60	40-60	0 - 0.06	
165ki	Twisselman silty clay. Slopes are 0 to 1 percent	Component is on alluvial fans. Parent material consists of alluvium derived from sedimentary rock. Natural drainage class is well drained.	0.27	0-9	40-60	0.06 - 0.2	No irrigation operations impact
				9-60	35-60	0.06 - 0.2	
166ki	Twisselman silty clay, saline-alkali	Component is on alluvial fans. Parent material consists of alluvium derived from sedimentary rock. Natural drainage class is well drained.	0.80	0-9	40-60	0.06 - 0.2	No irrigation operations impact
				9-60	35-60	0.06 - 0.2	
174	Kimberlina fine sandy loam, 0 to 2 percent slopes	Deep, well-drained soil on alluvial fans & plains. Formed in alluvium derived dominantly from granitic & sedimentary rock.	7.44	0-9	6-18	1.98 - 5.95	No irrigation operations impact
				9-45	10-18	1.98 - 5.95	
				45-71	10-25	0.57 - 1.98	
175	Kimberlina sandy loam, 2 to 5 percent slopes	Deep, well-drained soil on alluvial fans & plains. Formed in alluvium derived dominantly from granitic & sedimentary rock.	1.46	0-9	6-18	1.98 - 5.95	No irrigation operations impact
				9-45	10-18	1.98 - 5.95	
				45-71	10-25	0.57 - 1.98	
176	Kimberlina sandy loam, 5 to 9 percent slopes	Deep, well-drained soil on alluvial fans & plains. Formed in alluvium derived dominantly from granitic & sedimentary rock.	0.12	0-9	6-18	1.98 - 5.95	No irrigation operations impact
				9-45	10-18	1.98 - 5.95	
				45-71	10-25	0.57 - 1.98	
183	Lethent silt loam	Deep, moderately well drained, saline-alkali soil on basin rims. Formed in alluvium derived dominantly from granitic & sedimentary rock.	0.07	0-3	20-27	0.2 - 0.57	No irrigation operations impact
				3-53	35-55	0 - 0.06	
				53-60	10-30	0.06 - 0.2	
189	Lokern clay, saline-alkali, partially drained	Deep, somewhat poorly drained soil is on basins. Formed in alluvium derived from mixed rock sources, mainly granitic rock. Slope is 0-2 percent.	0.16	0-7	40-55	0.06 - 0.2	No irrigation operations impact
				7-21	40-60	0.06 - 0.2	
				21-48	40-60	0.57 - 1.98	
				48-66	10-26	0.57 - 1.98	
196	Milham sandy loam, 0 to 2 percent slopes	Deep, well-drained soil on alluvial fans, plains, & low terraces. Formed in alluvium derived dominantly from granitic & sedimentary rock.	7.95	0-10	5-20	1.98 - 5.95	No irrigation operations impact
				10-49	20-35	0.2 - 0.57	
				49-60	5-25	0.57 - 1.98	
197	Milham sandy loam, 2 to 5 percent slopes	Deep, well drained soil on alluvial fans, plains, & low terraces. Formed in alluvium derived dominantly from granitic & sedimentary rock.	0.01	0-10	5-20	1.98 - 5.95	No irrigation operations impact
				10-49	20-35	0.2 - 0.57	
				49-60	5-25	0.57 - 1.98	
207	Nahrub clay, drained	Deep, somewhat poorly drained soil; is in basins. Derived dominately from granitic and sedimentary rock.	3.54	0-18	40-50	0 - 0.06	No irrigation operations impact
				18-52	35-50	0 - 0.06	
				52-61	15-30	0.57 - 1.98	
208	Nahrub clay, partially drained	Deep, somewhat poorly drained soil; is in basins. Derived dominately from granitic and sedimentary rock.	9.90	0-18	40-50	0 - 0.06	No irrigation operations impact
				18-52	35-50	0 - 0.06	
				52-61	15-30	0.57 - 1.98	
209	Nahrub, drained-Lethent complex	Located in basins. 75% Nahrub clay & 25% Lethent silt loam; intermingled	1.42	0-18	40-50	0 - 0.06	No irrigation operations impact
				18-52	35-50	0 - 0.06	
				52-61	15-30	0.57 - 1.98	
210	Nahrub, partially drained-Lethent complex	Located in basins. 75% Nahrub clay & 25% Lethent silt loam; intermingled	3.21	0-18	40-50	0 - 0.06	No irrigation operations impact
				18-52	35-50	0 - 0.06	
				52-61	15-30	0.57 - 1.98	
211	Panoche clay loam, 0 to 2 percent slopes	Deep, well-drained soil on alluvial fans & plains. Formed in alluvium derived dominately from granitic or sedimentary rock.	13.64	0-16	27-35	0.57 - 1.98	No irrigation operations impact
				16-60	18-35	0.57 - 1.98	
212	Panoche clay loam, 2 to 5 percent slopes	Deep, well-drained soil on alluvial fans & plains. Formed in alluvium derived dominately from granitic or sedimentary rock.	4.51	0-16	27-35	0.57 - 1.98	No irrigation operations impact
				16-60	18-35	0.57 - 1.98	
213	Panoche clay loam, 5 to 9 percent slopes	Deep, well-drained soil on alluvial fans & plains. Formed in alluvium derived dominately from granitic or sedimentary rock.	0.10	0-16	27-35	0.57 - 1.98	No irrigation operations impact
				16-60	18-35	0.57 - 1.98	
214	Panoche clay loam, saline-alkali, 0 to 2 percent slopes	Deep, well drained soil on alluvial fans & plains. Formed in alluvium derived dominately from granitic or sedimentary rock.	0.19	0-16	27-35	0.57 - 1.98	No irrigation operations impact
				16-60	18-35	0.57 - 1.98	
215	Panoche clay loam, saline-alkali, moderately wet, 0 to 2 percent slopes	Deep, well drained soil on alluvial fans & plains. Formed in alluvium derived dominately from granitic or sedimentary rock.	0.77	0-16	27-35	0.57 - 1.98	No irrigation operations impact
				16-60	18-35	0.57 - 1.98	
233	Twisselman sandy loam, saline-alkali, 0 to 2 percent slopes	Deep, well-drained soil on alluvial fans & basin rims. Formed in alluvium derived dominately from sedimentary rock. Drainage has been altered due to extensive irrigation.	5.14	0-8	5-20	1.98 - 5.95	No irrigation operations impact
				8-60	35-60	0 - 0.06	
234	Twisselman sandy loam, saline-alkali, moderately wet, 0 to 2 percent slopes	Deep, well-drained soil on alluvial fans & basin rims. Formed in alluvium derived dominately from sedimentary rock. Drainage has been altered due to extensive irrigation.	3.42	0-8	5-20	1.98 - 5.95	No irrigation operations impact
				8-60	35-60	0 - 0.06	
235	Twisselman clay, 0 to 2 percent slopes	Deep, well-drained soil on alluvial fans. Formed in alluvium derived dom-inantly from sedimentary rock.	12.88	0-14	40-60	0.06 - 0.2	No irrigation operations impact
				14-60	35-60	0.06 - 0.2	
236	Twisselman clay, 2 to 5 percent slopes	Deep, well-drained soil on alluvial fans. Formed in alluvium derived dom-inantly from sedimentary rock.	1.06	0-14	40-60	0.06 - 0.2	No irrigation operations impact
				14-60	35-60	0.06 - 0.2	
237	Twisselman clay, saline-alkali, 0 to 2 percent slopes	Deep, well-drained soil on basin rims. Formed in alluvium derived dom-inantly from sedimentary rock. Drainage has been altered due to extensive irrigation.	1.88	0-9	40-60	0 - 0.06	No irrigation operations impact
				9-60	35-60	0 - 0.06	
238	Twisselman clay, saline-alkali, moderately wet, 0 to 2 percent slopes	Deep, well-drained soil on basin rims. Formed in alluvium derived dom-inantly from sedimentary rock. Drainage has been altered due to extensive irrigation.	9.65	0-14	40-60	0 - 0.06	No irrigation operations impact
				14-60	35-60	0 - 0.06	
239	Typic Gypsiorthids-Kimberlina association, 0 to 5 percent slopes	Deep and well drained. Formed in alluvium derived dominantly from sedimentary rock.	2.94	0-9	6-18	1.98 - 5.95	No irrigation operations impact
				9-45	10-18	1.98 - 5.95	
				45-71	10-25	0.57 - 1.98	
251	Yribarren loam, 0 to 2 percent slopes	Deep, well drained soil on alluvial fans & plains. Formed in alluvium derived dominantly by sedimentary rock.	0.65	0-7	20-27	0.57 - 1.98	No irrigation operations impact
				7-19	35-55	0 - 0.06	
				19-22	15-35	0 - 0.06	
				22-60	15-30	0.2 - 0.57	
253	Yribarren clay loam, 2 to 5 percent slopes	Deep, well-drained soil on alluvial fans & plains. Formed in alluvium derived dominantly by sedimentary rock.	2.90	0-7	20-27	0.57 - 1.98	No irrigation operations impact
				7-19	35-55	0 - 0.06	
				19-22	15-35	0 - 0.06	
				22-60	15-30	0.2 - 0.57	

APPENDIX E LIST OF REGULATORY CLEANUP SITES

Table 2-5
GeoTracker and EnviroStor Sites with Potential Groundwater Media
Kern Groundwater Authority
Kern County, California
(Updated January 2019)

New Map ID	Site / Facility Name	ENVIROSTOR/ Geotracker ID	Source	Program Type	Status	Address	City	Zip	CALEnviroscreen Score	X Coord	Y Coord	Constituents of Concern
1	CROP PRODUCTION SERVICES (CPS) DELANO	SL185724257	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	930 WOOLOMES AVE	DELANO	93215-9553	---	-119.2422	35.7466	VOCs and Pesticides, NITRATE, OTHER CHLORINATED HYDROCARBONS, OTHER SOLVENT OR NON-PETROLEUM HYDROCARBON
2	CHEVRON USA (AKA: CHEVRON REFINERY & WAIT TANK YD)	SL205064267	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	2525 NORTH MANOR STREET	BAKERSFIELD	93308	---	-119.0087	35.4238	BENZENE, CRUDE OIL, LEAD, OTHER PETROLEUM
3	PG&E KERN POWER PLANT (FORMER:COFFEE RD. OVERPASS)	SLT5FP024290	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	2401 COFFEE ROAD	BAKERSFIELD	93308-5748	---	-119.094919	35.37920074	BENZENE, CRUDE OIL, OTHER PETROLEUM
4	BAKERSFIELD REFINERY	SL205314279	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	6451 ROSEDALE HIGHWAY	BAKERSFIELD	93308	---	-119.071219	35.38198244	BTEX, TPH, MTBE / TBA / OTHER FUEL OXYGENATES, OTHER SOLVENT OR NON-PETROLEUM HYDROCARBON
5	KERN OIL & REFINING	SL372524510	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	7724 E PANAMA LANE	BAKERSFIELD	93307-9210	---	-118.9169	35.2954	BTEX, TPH, MTBE / TBA / OTHER FUEL OXYGENATES, PAHs
6	BAKERSFIELD AIRPORT BUSINESS PARK (CHEVRON LAND/D)	SL0602981532	Geotracker	CLEANUP PROGRAM SITE	OPEN - VERIFICATION MONITORING	UNICORN RD. AT HWY 99/65	BAKERSFIELD	93308	---	-119.0698	35.4328	CRUDE OIL
7	SUNLAND REFINING CORPORATION	SL205224272	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	2152 COFFEE ROAD	BAKERSFIELD	93308-5746	---	-119.0911102	35.37550916	CRUDE OIL, GASOLINE, MTBE / TBA / OTHER FUEL OXYGENATES
8	CHEVRON - ANTELOPE PUMP STATION	SL0602985189	Geotracker	CLEANUP PROGRAM SITE	OPEN - ASSESSMENT & INTERIM REMEDIAL ACTION	STATE ROUTE 46	LOST HILLS	93249	---	-120.164723	35.71251	CRUDE OIL, WASTE OIL / MOTOR / HYDRAULIC / LUBRICATING
9	WASCO AIRPORT	SLT5FQ444336	Geotracker	CLEANUP PROGRAM SITE	OPEN - VERIFICATION MONITORING	PALM AVE & MCCOMBS	WASCO	93280	---	-119.3505	35.6184	DDD / DDE / DDT, OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
10	J. R. SIMPLOT - EDISON	SLT5FS324450	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	430 PEPPER DR.	EDISON	93220	---	-118.8745	35.3485	DIBROMOCHLOROPROPANE (DBCP), FERTILIZER, PESTICIDES/HERBICIDES
11	SAN JOAQUIN REFINING CO - FRUITVALE REFINERY	SL205714283	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	STANDARD STREET	BAKERSFIELD	93308	---	-119.048	35.3972	DIESEL
12	BAKERSFIELD REFINERY - AREA 3	T10000001848	Geotracker	CLEANUP PROGRAM SITE	OPEN - VERIFICATION MONITORING	3663 GIBSON STREET	BAKERSFIELD	93308	---	-119.0527654	35.39330068	DIESEL, GASOLINE
13	WEST COAST OIL REFINERY, BAKERSFIELD	SL0602978387	Geotracker	CLEANUP PROGRAM SITE	OPEN - INACTIVE	1157 CHINA GRADE LOOP	BAKERSFIELD	93308	---	-118.9975	35.4225	DIESEL, GASOLINE, LEAD
14	APEX BULK COMMODITIES	T10000011271	Geotracker	CLEANUP PROGRAM SITE	OPEN - ASSESSMENT & INTERIM REMEDIAL ACTION	2111 BRICYN LANE	BAKERSFIELD	93308	---	-119.05178	35.37789	DIESEL, OTHER PETROLEUM
15	SAN JOAQUIN DRUM	SLT5FR634417	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	3930 GILMORE AVE	BAKERSFIELD	93308-6214	---	-119.05165	35.39017952	METALS/HEAVY METALS, PESTICIDES/HERBICIDES, VOLATILE ORGANIC COMPOUNDS
16	J. R. SIMPLOT - BENA (AKA: BENA FERTILIZER)	SLT5FS304448	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	NONE	EDISON	93220	---	-118.7406	35.3276	NITRATE, OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
17	WESTERN FARM SERVICE INC-1610 NORRIS ROAD BAKERSFIELD	SL186364605	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	1610 NORRIS RD	BAKERSFIELD	93308-2234	---	-119.0541923	35.42200027	OTHER CHLORINATED HYDROCARBONS
18	GARRIOTT CROPDUSTERS	SLT5FQ134306	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	2010 S UNION AVE	BAKERSFIELD	93307-4154	---	-119.0003209	35.32892143	OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
19	SIMPLOT WASCO	SLT5FS184436	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	541 HWY 46	WASCO	93280-1433	---	-119.3289256	35.60078769	OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
20	WIP - DELANO, PCE	SL0602943992	Geotracker	CLEANUP PROGRAM SITE	OPEN - INACTIVE		DELANO	93215	---	-119.2496	35.7672	PCE
21	WITCO REFINERY (OILDALE)	SLT5FQ474339	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	1134 MANOR STREET	BAKERSFIELD	93308-3553	---	-119.0129	35.419	PETROLEUM/FUELS/OILS
22	SABRE REFINERY	SLT5FQ334326	Geotracker	CLEANUP PROGRAM SITE	OPEN - INACTIVE	W. BAKERSFIELD-ROSEDALE AREA	BAKERSFIELD	93308	---	-119.05	35.3876	TOTAL PETROLEUM HYDROCARBONS (TPH)
23	BIG WEST OF CALIFORNIA LLC	80001738	EnviroStor	CORRECTIVE ACTION (CURRENT)	REFER: RWQCB	6451 ROSEDALE HWY	BAKERSFIELD	93308	81-85%	-119.072547	35.383247	BTEX, MTBE
24	OCCIDENTAL OF ELK HILLS INC	80001254	EnviroStor	CORRECTIVE ACTION (CURRENT)	ACTIVE - LAND USE RESTRICTIONS, POST CLOSURE RCRA PERMIT	28590 HIGHWAY 119	TUPMAN	93276	76-80%	-119.484792	35.281959	Metals, Petroleum, PCBS, Radioactive isotopes, Volatile Organics
25	ASSURED TRANSPORTATION SITE	15420001	EnviroStor	DTSC SITE CLEANUP PROGRAM (ACTIVE)	ACTIVE	3228 GIBSON ST	BAKERSFIELD	93308	81-85%	-119.051671	35.3904494	Halogenated Organic Compounds, Tetrachloroethylene (PCE)
26	DELANO PCE PLUME	60001327	EnviroStor	DTSC SITE CLEANUP PROGRAM (ACTIVE)	ACTIVE	MAIN STREET AND 10TH AVENUE	DELANO	93215	66-70%	-119.2456698	35.76910534	Tetrachloroethylene (PCE)
27	J R SIMPLOT, EDISON	15070030	EnviroStor	DTSC SITE CLEANUP PROGRAM (ACTIVE)	ACTIVE - LAND USE RESTRICTIONS	430 PEPPER DRIVE	EDISON	93220	81-85%	-118.8778	35.35147831	Organochlorine pesticides (8081 OCPS), Volatile Organics (8260B VOCS)
28	BROWN AND BRYANT, INC., ARVIN FACILITY	15280011	EnviroStor	FEDERAL SUPERFUND - LISTED	ACTIVE	600 S DERBY ST	ARVIN	93203	81-85%	-118.8231039	35.20314691	DINOSEB and Volatile Organics (8260B VOCS)

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29	FASTLANE MINI MART	T0602912732	Geotracker	LUST CLEANUP SITE	OPEN - ELIGIBLE FOR CLOSURE	201 ELMO HWY	MCFARLAND	93250	---	-119.2322588	35.68861163	Gasoline
30	HOWARDS MINI MARKET	T10000000635	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	3300 PLANZ ROAD	BAKERSFIELD	93309	---	-119.0392612	35.325438	Diesel, Gasoline
31	JEFFRIES BROS, OASIS	T10000007369	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	35750 HWY 58	BUTTONWILLOW	93206	---	-119.39992	35.39946	Benzene, Diesel, Ethylbenzene, Gasoline, MTBE / TBA / Other Fuel Oxygenates, Naphthalene, Toluene, Xylene
32	LOGRECCO PROPERTY	T0602925877	Geotracker	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	1330 HIGH STREET	DELANO	93215	---	-119.247728	35.773859	Gasoline
33	NORTH KERN STATE PRISON	T0602900672	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	2737 CECIL AVE W	DELANO	93216	---	-119.3145731	35.7831358	Gasoline
34	POND MERCANTILE	T0602900113	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	29310 POND RD.	POND	93280	---	-119.3292703	35.71777716	Gasoline
35	RIBIER MARKET	T0602900267	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	11228 EDISON RD S	LAMONT	93241	---	-118.8792731	35.25343586	gasoline
36	ROBERTSONS MARKET	T0602902377	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	21124 HWY 46(FORMERLY 62160 HWY 46)	LOST HILLS	93249	---	-119.6964148	35.6153236	Diesel, Gasoline
37	SAMCO FOOD STORE NO. 3	T10000009045	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	8101 EAST BRUNDAGE LANE	BAKERSFIELD		---	-118.91375	35.35406	Diesel, Gasoline
38	TAYLOR AUTOMATED FUELS	T0602900529	Geotracker	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	61700 HWY 46, (NW CORNER OF HWY 46 AND LOST HILLS RD)	LOST HILLS	93249	---	-119.6900572	35.61639925	Gasoline
39	TRAVEL CENTERS OF AMERICA	T10000010004	Geotracker	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	27769 LAGOON DRIVE	BUTTONWILLOW	93206	---	-119.39723	35.40124	Benzene, Diesel, Gasoline, MTBE / TBA / Other Fuel Oxygenates, Naphthalene, Toluene, Xylene
40	WHOLESALE FUELS, INC.	T10000007773	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	2200 EAST BRUNDAGE LANE	BAKERSFIELD	93307	---	-118.96564	35.35471	Benzene, Ethylbenzene, Gasoline, MTBE / TBA / Other Fuel Oxygenates, Naphthalene, Toluene, Xylene
41	BAKERSFIELD DISCOVERY PROJECT	60001630	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - ACTION REQUIRED	PACHECO ROAD AND STINE ROAD	BAKERSFIELD	93318	66-70%	-119.056751	35.310412	Tetrachloroethylene (PCE), Trichloroethylene (TCE)
42	BAKERSFIELD PLATING WORKS	15340012	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: OTHER AGENCY	527 EAST 19TH	BAKERSFIELD	93305	81-85%	-118.9954948	35.37490554	Metals (cadmium, chromium III/VI. Copper. Lead, Nickel)
43	BC CHEMICALS	15280041	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: RWQCB	1511 SOUTH UNION AVENUE	BAKERSFIELD	93307	91-95%	-119.0036166	35.33598464	Arsenic
44	CALTRANS SERVICE YARD	60001605	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - NEEDS OTHER EVALUATION (CURRENT OR INACTIVE)	1200 OLIVE DRIVE	OILDALE	93308	86-90%	-119.046228	35.413042	PCE, TCE
45	EASTLAND FLYING SERVICE	15070006	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - NEEDS OTHER EVALUATION (CURRENT OR INACTIVE)	16849 MT. VIEW ROAD	LAMONT	93241	76-80%	-118.816845	35.28164	Carbaryl, 8141A OPPS, Toxaphene
46	KERN COUNTY DUMP	15490017	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: RWQCB	SE OF XING OF STRADLEY & WOOLOMES AVES	DELANO	93215	96-100%	-119.25779	35.74616	Tetrachloroethylene, trichloroethylene, Dichlorodifluoromethane, 1,1 Dichloroethane
47	KERN COUNTY GUN CLUB	15860001	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: OTHER AGENCY	2818 CHINA GRADE LOOP	BAKERSFIELD	93308	76-80%	-118.965412	35.422405	Lead, Other Organic Solids, Polynuclear aromatic hydrocarbons
48	RAIN FOR RENT	60001771	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - NEEDS OTHER EVALUATION (CURRENT OR INACTIVE)	3404 STATE STREET	OILDALE	93308	96-100%	-119.044861	35.406524	Unknown
49	SPARKLE/BRUNDAGE CLEANERS	60002071	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	BACKLOG	1517 W. BRUNDAGE ROAD	BAKERSFIELD	93304	96-100%	-118.9824817	35.3539159	Tetrachloroethylene, trichloroethylene
50	CARNEROS CREEK, THETA	L10009422184	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	CARNEROS CREEK OIL FIELD	LOST HILLS		---	-119.85852	35.46844	Crude Oil
51	CHEVRON USA INC-KERN RIVER-SAN JOAQUIN	T10000007105	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	KERN RIVER OIL FIELD	MALTHA		---	-119.001769	35.428919	Crude Oil
52	CYMRIC OIL FIELD, BOWLES LEASE	T10000006948	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	SW OF LOKEN RD / LOST HILLS RD	MCKITTRICK	93251	---	-119.71424	35.37855	Crude Oil
53	CYMRIC OIL FIELD, LEHI-RICHARDSON LEASE	T10000007036	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	CYMRIC OIL FIELD	MCKITTRICK		---	-119.754775	35.418844	Crude Oil
54	CYMRIC OIL FIELD, OVERLAND ANDERSON LEASE	T10000007035	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NE TAFT (S20, T29S, R21E, MDB&M)	MCKITTRICK	93251	---	-119.73454	35.3944	Crude Oil
55	CYMRIC OIL FIELD, USL LEASE	T10000007037	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	CYMRIC OIL FIELD	MCKITTRICK		---	-119.765	35.42378	Crude Oil
56	EDISON OIL FIELD, RACETRACK LEASE	T10000007136	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	EDISON OIL FIELD	EDISON		---	-118.84515	35.37177	Other inorganic / salt, TDS, Crude Oil
57	J&K, MIDWAY-SUNSET OIL FIELD, JADE KERN PROJECT LEASE	T10000006764	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	KRISTIN STREET NE 1/4, SEC 15 T32S R23E MDB&M	TAFT	93268	---	-119.48427	35.14988	Crude Oil
58	KERN FRONT NO. 2	T10000007097	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	KERN FRONT OIL FIELD	SACO		---	-119.05882	35.46374	Crude Oil

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59	MIDWAY-SUNSET OIL FIELD, BERRY & EWING LEASE	T10000007297	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.44121	35.09873	Crude Oil
60	MIDWAY-SUNSET OIL FIELD, C. E. HOUCHIN ET AL LEASE	T10000006771	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	SEC 9, T31S, R22E, MDB&M	FELLOWS	93224	---	-119.62194	35.24141	Crude Oil
61	MIDWAY-SUNSET OIL FIELD, FULTON LEASE	T10000007030	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTHEAST OF MARICOPA (S1, T11N, R24W, SBB&M)	MARIPOSA	93252	---	-119.39335	35.06877	Crude Oil
62	MIDWAY-SUNSET OIL FIELD, HAVENSTRITE LEASE	T10000006789	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.35188	35.0463	Crude Oil
63	MIDWAY-SUNSET OIL FIELD, JAMESON TRUST LEASE	T10000006947	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	7026 DARNOCH WAY	WEST HILLS	91307	---	-119.45068	35.13032	Crude Oil
64	MIDWAY-SUNSET OIL FIELD, JAMESON TRUST LEASE	L10002548641	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.40374	35.0736	Crude Oil
65	MIDWAY-SUNSET OIL FIELD, LOCKWOOD LEASE	T10000007029	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	WEST OF TAFT	TAFT	93628	---	-119.5077454	35.14047576	Crude Oil
66	MIDWAY-SUNSET OIL FIELD, MOCO 35 LEASE (PLASTIC-LINED POND 3)	T10000007039	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTH OF MARICOPA (S35, T12N, R24W, MDB&M)	MARICOPA	93252	---	-119.4057919	35.08717628	Crude Oil
67	MIDWAY-SUNSET OIL FIELD, MOCO 35 LEASE (PONDS 1&2, SAND PITS)	T10000007031	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTH OF MARICOPA (S35, T12N, R24W, MDB&M)	MARIPOSA	93252	---	-119.4065	35.08679	Crude Oil
68	MIDWAY-SUNSET OIL FIELD, NATIONAL USL LEASE	T10000007032	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	TWO MILES SOUTHWEST OF TAFT (S35, T32S, R23E, MDB&M)	TAFT	93268	---	-119.46687	35.10715	Crude Oil
69	MIDWAY-SUNSET OIL FIELD, SHALE 14 LEASE	T10000007033	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	1.5 MILES SOUTHEAST OF DERBY ACRES (S14, T31S, R22E)	DERBY ACRES	93224	---	-119.57365	35.23502	Crude Oil
70	MIDWAY-SUNSET OIL FIELD, W & S LEASE	T10000007034	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	2 MILES SOUTHEAST OF DERBY ACRES (S14, T31S, R22E)	DERBY ACRES	93224	---	-119.5852	35.22457	Crude Oil
71	MIDWAY-SUNSET OIL FIELD, WEBBER LEASE	T10000006776	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	LDD ENERGY - NE ¼ SECTION 34, T30S, R22E, MDB&M	FELLOWS	93224	---	-119.59296	35.27708	Crude Oil
72	MIDWAY-SUNSET, HOYT LEASE	T10000006779	Geotracker	PRODUCED WATER PONDS	UNDER REVIEW	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.37986	35.05688	Crude Oil
73	POSO CREEK, POSO	T10000007301	Geotracker	PRODUCED WATER PONDS	INACTIVE - UNPERMITTED	LINN OPERATING INC - NW OF BRONZE HILL RD. & WHITE CROWN DR.	MCFARLAND	93250	---	-119.0452	35.58195	Crude Oil
74	RIO BRAVO OIL FIELD, KERNCO LEASE	T10000006733	Geotracker	PRODUCED WATER PONDS	OPEN - INACTIVE	NW OF 7TH STANDARD RD / TRANSPORT LN S1/2 OF THE NE1/4 OF SECTION 34, T28S, R25E, MDB&M	SHAFTER	93263	---	-119.2656	35.44952	Crude Oil
75	S. BELRIDGE OIL FIELD, HILL LEASE	SL0602935481	Geotracker	PRODUCED WATER PONDS	INACTIVE - PERMITTED	SEC 19, T28S, R21E, MDB&M	SOUTH BELRIDGE OIL FIELD		---	-119.7453854	35.4882413	Other inorganic, Salt
76	SOUTH BELRIDGE OIL FIELD, SOUTH WASTEWATER DISPOSAL FACILITY	SL0602990565	Geotracker	PRODUCED WATER PONDS	INACTIVE - PERMITTED	SOUTH BELRIDGE OIL FIELD	SPICER CITY		---	-119.6796305	35.46115366	Other inorganic / salt
77	VAUGHN-MIDWAY-SUNSET OIL FIELD, USL 15	T10000006813	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTHWEST IF MIDOIL RD / THOMAS ST	TAFT	93268	---	-119.49199	35.14231	Crude Oil

Source: DTSC Envirostor: https://www.envirostor.dtsc.ca.gov/public/ and SWRCB Geotracker: http://geotracker.waterboards.ca.gov/

APPENDIX F WDWA MONITORING NETWORK PLAN (MNP) PROTOCOLS AND SAMPLING FORM

Monitoring Network & Protocols

Monitoring Network shall be developed to be capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:

1) Demonstrate progress toward achieving measurable objectives described in the Plan
2) Monitor impacts to the beneficial uses and users of groundwater
3) Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds
4) Quantify annual changes in water budget components

Monitoring Network shall be designed to ensure adequate coverage of sustainability indicators. If management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the basin setting and sustainable management criteria specific to that area. To the extent possible, the use of existing monitoring data and infrastructure should be utilized to meet the needs for characterization, historical record documentation and continued monitoring requirements.

Monitoring Network shall describe the scientific rationale for the monitoring site selection and for each sustainability indicator, the quantitative values for the minimum threshold, measurable objective and interim milestones shall be indicated at each monitoring site.

Monitoring Protocols developed shall include a description of technical standards, data collection methods, and other procedures or protocols for monitoring sites or other data collection facilities to ensure that the monitoring network utilizes comparable data and methodologies. There is no definitive rule for the density of groundwater monitoring points needed in a basin. The table below provides guidance for the density of monitoring wells per hundred square miles. One important item to consider is how the definitions of undesirable results will be impacted to provide the necessary information to indicate compliance.

Reference	Monitoring Well Density (wells per 100 miles2)
Heath (1976)	0.2 - 10
Sophocleous (1983)	6.3
Basins pumping more than 10,000 acrefeet/year per 100 miles	4.0
Basins pumping between 1,000 and 10,000 acre-feet/year per 100 miles	2.0
Basins pumping between 250 and 1,000 acre-feet/year per 100 miles	1.0
Basins pumping between 100 and 250 acre-feet/year per 100 miles	0.7

Measuring Groundwater Levels

Given the significant variations in groundwater elevations throughout the Kern subbasin which are due to variations in hydrologic conditions, no single groundwater elevation surface should be considered a representation of groundwater flow directions in this basin.

Requirements for well selections:

- A long-term access agreement that includes year-round site access to allow for increased monitoring frequency
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact, type of information to be collected, latitude, longitude and elevation
- Monitoring location should also track all modifications to the site in a modification log

The following data collection protocols are to be followed within the Kern subbasin:

- Groundwater level data shall be sufficient to produce seasonal maps of potentiometric surfaces or water table surfaces throughout the basin that clearly identify changes in groundwater flow direction and gradient.
- Use the Well Data form provided (see attached)
- Groundwater level data shall be collected from each principal aquifer in the basin
- Collection of data between the approved time frames only
    - January 15th to March 30th
    - September 15th to November 15th
- A weighted water level meter or other CASGEM approved measuring device will be used to measure the depth to groundwater
- Depth to groundwater must be measured relative to an established Reference Point on the well casing. If no mark or reference point is apparent, the person performing the measurement should measure the depth to groundwater from the north side of the top of the well casing
- The elevation of the Reference Point of the well must be referenced to the North American Vertical Datum of 1988. The accuracy of the reference point should be consistent with CASGEM established guidelines.
- Each well's Reference Point will be cataloged to ensure identical procedures are followed for subsequent measurements.
- The data collector should remove the appropriate cap, lid or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement should follow a period of time to allow the water level to equilibrate.
- Depth to groundwater must be measured to the accuracy associated with the approved monitoring method or device.
- The water level meter shall be decontaminated after measuring each well.
- The data collector shall calculate the groundwater elevation as:
    - GWE = RPE – DTW
    - GWE = Groundwater Elevation

    - RPE = Reference Point Elevation
    - DTW = Depth to Water
- The data collector must ensure that all measurements are consistent units of feet, tenths of feet or hundredths of feet. Measurements and Reference Point Elevations should not be recorded in feet and inches.

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Groundwater Quality

Groundwater quality monitoring networks shall be designed to demonstrate that the degraded water quality sustainability indicator is being observed for the purpose of meeting the definition of the sustainability goal.

Requirements for well selections:

- A long-term access agreement that includes year-round site access to allow for increased monitoring frequency
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact, type of information to be collected, latitude, longitude and elevation
- Monitoring location should also track all modifications to the site in a modification log
- The use of existing water quality data within the basin should be done to the greatest extent possible
- Monitoring network should consist largely as a supplemental monitoring locations where known groundwater contamination plumes are under existing regulatory management

The following data collection protocols are to be followed within the Kern subbasin:

- Monitor groundwater quality data from each principal aquifer in the basin
- Data should be sufficient for mapping movement of degraded water quality
- Data should be sufficient to assess groundwater quality impacts to beneficial uses and users
- Data should be sufficient to evaluate whether management activities are contributing to water quality degradation.
- All analyses should be performed by a laboratory certified under the State Environmental Laboratory Accreditation Program
- Samples will be collected according to the standards listed in the Standard Methods for the Examination of Water and Wastewater, USGS National Field Manual for the Collection of Water Quality Data
- Prior to sampling, the sampler must contact the laboratory to schedule laboratory time, obtain appropriate sampler containers, and clarify any sample holding times or sample preservation requirements
- Each well used for groundwater quality monitoring must have a unique identifier. This identifier must appear on the well housing or the well casing to avoid confusion
- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead. Samples are not to be taken/collected from storage tanks, at the end of long pipe runs or after any water treatment infrastructure

- Samples will be taken/collected only after the appropriate volume of water has been purged from the casing and field parameters have stabilized
- Sampler will clean the sampling port and/or sampling equipment. The sampling port and/or sampling equipment must be free of any contaminants
- Groundwater elevation in the well should be measured following the protocols described in the groundwater level measuring protocols
- Field parameters of pH, electrical conductivity and temperature should be collected for each sample. Lab pH analysis are typically unachievable due to short hold times.
- All field instruments should be calibrated daily and evaluated for drift throughout the day
- Sample containers should be labeled prior to sample collection. The sample label must include:
    - Sample ID (well ID)
    - Sample date and time
    - Sample personnel
    - Sample location
    - Preservative used
    - Analytes and analytical method
- Samples shall be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection
- Samples requiring preservation must be preserved as soon as practically possible
- Samples to be analyzed for metals should be field-filtered prior to preservation. Do not collect an unfiltered sample in a preserved container
- Samples will be chilled and maintained at 4 C to prevent degradation of the sample
- Samples will be shipped under a chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions
- Custody Seal will be used by the field technician if a third-party transportation service is used
- A Field Sampling Log will include:
    - Sampler's identification
    - Well identification
    - Climatic conditions
    - Depth to water prior to purging
    - Type of purging and sampling device
    - Purging rate and volume
    - Relative well yield volume
    - Field parameter measurements (pH, temperature, EC, DO)
    - Type and number of samples collected
    - Date and time collected

Change in Groundwater Storage

Since the groundwater storage is not a directly measurable condition, it does rely heavily on the collection of accurate groundwater levels. The changes in groundwater levels reflect changes in storage and can thus be estimated with assumptions of thickness of units, porosity, and connectivity. These observations will be essential for use in calculating the water budget.

A water budget is a foundational tool used to compile water flows (supplies) and outflows (demands). It is an accounting of the total groundwater and surface water entering and leaving a basin or user-defined area. The difference between flows and outflows is a change in the amount of water stored.

Coordination of Water Budget Data to comply with groundwater storage:

- Surface water supply
- Total water use
- Water budget
- Sustainable yield

The change in the annual volume of groundwater storage between seasonal high conditions shall be quantified in the water budget.

Land Subsidence

Land subsidence protocols are to be set up to identify the rate and extent of land subsidence, which maybe measured by extensometers, surveying, remote sensing technology, or other appropriate method. To the extent possible, the use of existing data should be utilized.

Prior to development of a specific subsidence monitoring network a screening level analysis should be conducted. The screening of subsidence occurrence should include:

- Review of the HCM and understanding of grain-size distributions and potential for subsidence to occur
- Review of any known regional or correlative geologic conditions where subsidence has been observed.
- Review of historic range of groundwater levels in the principal aquifers of the basin
- Review of historic records of infrastructure impacts, including but not limited to damage to pipelines, canals, roadways or bridges or well collapse potentially associated with land surface elevation changes
- Review of remote sending results such as InSAR or other land surface monitoring data
- Review of existing CGPS surveys

This basin has decided to work together on this protocol with a consultant to obtain the required data.

WDWA MNP SAMPLING FORM

aquilogic

STATE WELL NUMBER	COUNTY	REFERENCE POINT ELEV.	DATE

NO MEASUREMENT	QUESTIONABLE MEASUREMENT
☐ Measurement discontinued	☐ Caved or deepened
☐ Pumping	☐ Pumping
☐ Pump house locked	☐ Nearby pump operating
☐ Tape hung up	☐ Casing leaky or wet
☐ Can't get tape in casing	☐ Pumped recently
☐ Unable to locate well	☐ Air or pressure gauge measurement
☐ Well has been destroyed	☐ Other
☐ Special	☐ Recharge operation at nearby well
☐ Casing leaky or wet	☐ Oil in casing
☐ Temporarily inaccessible	

TIME	DEPTH TO WATER	PUMP DEPTH	TOP OF SCREEN

COMMENTS/OBSERVATIONS:

APPENDIX G LIST OF MNP AND MT/MO WELLS

Local Well Name	State Well Number	Monitoring Network Type	Reference Point Elevation (feet)	Reference Point Description	Ground Surface Elevation (feet)	Elevation Method	Elevation Accuracy	Well Use Type	Well Status
USGS L2-2	25S20E30A002M	SGMA Representative	382.9	Ground surface elevation	382.9	Digital Elevation Model	Unknown	Other	Active
Unknown	25S21E01R001M	SGMA Representative	213.0	Ground surface elevation	213.0	Digital Elevation Model	Unknown	Irrigation	Active
Unknown	25S21E26P001M	SGMA Representative	222.5	Ground surface elevation	222.5	Digital Elevation Model	Unknown	Unknown	Active
Berrenda Mesa 1	26S17E13F	SGMA Representative	880.4	Ground surface elevation	880.4	Digital Elevation Model	Unknown	Unknown	Active
Unknown	26S18E14N001M	SGMA Representative	659.3	Ground surface elevation	659.3	Digital Elevation Model	Unknown	Irrigation	Active
Unknown	26S19E29E001M	SGMA Representative	750.1	Ground surface elevation	750.1	Digital Elevation Model	Unknown	Irrigation	Active
Lost Hills 5	26S20E07E001M	SGMA Representative	519.9	Ground surface elevation	519.9	Digital Elevation Model	Unknown	Irrigation	Active
Lost Hills 3	26S21E14H002M	SGMA Representative	239.3	Ground surface elevation	239.3	Digital Elevation Model	Unknown	Industrial	Active
Lost Hills Tulare Water Well	27S21E10A001M	SGMA Representative	324.2	Ground surface elevation	324.2	Digital Elevation Model	Unknown	Unknown	Active
AeraBelridge_19M1	27S21E19K	SGMA Representative	520.1	Ground surface elevation	520.1	Digital Elevation Model	Unknown	Unknown	Active
MW12	28S21E18J	SGMA Representative	578.5	Ground surface elevation	578.5	Digital Elevation Model	Unknown	Monitoring	Active
AeraBelridge_5B2	29E22E05B001M	SGMA Representative	335.4	Ground surface elevation	335.4	Digital Elevation Model	Unknown	Irrigation	Active
Starrh_9K_No2	29S22E09K001M	SGMA Representative	344.5	Ground surface elevation	344.5	Digital Elevation Model	Unknown	Domestic	Active
Unknown	25S20E27B003M	SGMA Representative	309.9	Ground surface elevation	309.9	Digital Elevation Model	Unknown	Irrigation	Active
Unknown	25S20E32B001M	SGMA Representative	407.0	Ground surface elevation	407.0	Digital Elevation Model	Unknown	Monitoring	Active
USGS-353851119432201	26S21E21N001M	SGMA Representative	320.6	Ground surface elevation	320.6	Digital Elevation Model	Unknown	Monitoring	Active
USGS-352800119380001	28S22E29D001M	SGMA Representative	299.3	Ground surface elevation	299.3	Digital Elevation Model	Unknown	Monitoring	Active
USGS-352800119380002	28S22E29D002M	SGMA Representative	299.3	Ground surface elevation	299.3	Digital Elevation Model	Unknown	Irrigation	Active
7106-62	27S22E30R	SGMA Representative	256.8	Ground surface elevation	256.8	Digital Elevation Model	Unknown	Irrigation	Active
7108-69	25S21E03C	SGMA Representative	214.1	Ground surface elevation	214.1	Digital Elevation Model	Unknown	Irrigation	Active
Snake	25S21E16N	SGMA Representative	222.2	Ground surface elevation	222.2	Digital Elevation Model	Unknown	Irrigation	Active

Local Well Name	Latitude	Longitude	Coordinates Method	Coordinates Accuracy	Principal Aquifer	Well Completion Type	Well Depth (feet bgs)	Well Completion Report Number
USGS L2-2	35.73014	-119.85073	Digital aerial photo	Unknown	Unconfined	Part of a nested/multi-completion well	232	298414
Unknown	35.77630	-119.65361	Digital aerial photo	Unknown	Confined	Single Well	760	21427
Unknown	35.71956	-119.67979	Digital aerial photo	Unknown	Unconfined	Single Well	402	112332
Berrenda Mesa 1	35.66882	-120.09074	Digital aerial photo	Unknown	Unconfined	Single Well		WCR not available
Unknown	35.65821	-120.01020	Digital aerial photo	Unknown	Unconfined	Part of a nested/multi-completion well	334	Not indicated on WCR
Unknown	35.63648	-119.94863	Digital aerial photo	Unknown	Confined	Single Well	1205	e0095227
Lost Hills 5	35.68024	-119.86736	Digital aerial photo	Unknown	Unconfined	Single Well		WCR not available
Lost Hills 3	35.66720	-119.67243	Digital aerial photo	Unknown	Unconfined	Single Well	300	Not indicated on WCR
Lost Hills Tulare Water Well	35.60033	-119.69031	Digital aerial photo	Unknown	Unconfined/ Confined	Single Well	865	748832
AeraBelridge_19M1	35.56449	-119.76096	Digital aerial photo	Unknown	Unconfined	Single Well	237	WCR not available
MW12	35.48824	-119.74539	Digital aerial photo	Unknown	Unconfined	Single Well	205	WCR not available
AeraBelridge_5B2	35.44108	-119.63026	Digital aerial photo	Unknown	Unconfined	Single Well	274	154332
Starrh_9K_No2	35.41948	-119.61606	Digital aerial photo	Unknown	Unconfined	Single Well	500	e011328
Unknown	35.73074	-119.80005	Digital aerial photo	Unknown	Unconfined	Single Well	271	86416
Unknown	35.71610	-119.84977	Digital aerial photo	Unknown	Unconfined	Single Well	490	E074216
USGS-353851119432201	35.64633	-119.72239	Digital aerial photo	Unknown	Unconfined	Single Well	570	149592
USGS-352800119380001	35.47019	-119.63619	Digital aerial photo	Unknown	Unconfined	Single Well	305	WCR not available
USGS-352800119380002	35.47025	-119.63617	Digital aerial photo	Unknown	Unconfined	Single Well	400	WCR not available
7106-62	35.54377	-119.63651	Digital aerial photo	Unknown	Confined	Single Well	680	e0318219
7108-69	35.78871	-119.69832	Digital aerial photo	Unknown	Confined	Single Well	1000	e0332650
Snake	35.74712	-119.72514	Digital aerial photo	Unknown	Confined	Single Well	505	WCR not available

Local Well Name	Well Location Description	Additional Comments	County	Top Perforation - Interval 1	Bottom Perforation - Interval 1	Top Perforation - Interval 2	Bottom Perforation - Interval 2	Top Perforation - Interval 3	Bottom Perforation - Interval 3
USGS L2-2	None given on WCR		Kern	211	221				
Unknown	300 ft NW of SE corner Sec 1		Kern	624	760				
Unknown	SE/4 T25 R21E Sec26		Kern	195	402				
Berrenda Mesa 1			Kern						
Unknown	4.2 mi SE of Kecks Corner, SW corner of section		Kern	135	300				
Unknown	1.5 mi north Hwy 46, 3.75 mi west on Hwy 33		Kern	715	1185				
Lost Hills 5			Kern						
Lost Hills 3	None given on WCR	WCR not legible	Kern			790	845		
Lost Hills Tulare Water Well	APN 69 11 34		Kern	420	670				
AeraBelridge_19M1			Kern	170	230				
MW12			Kern	145	205				
AeraBelridge_5B2	1643 ft W, 90 ft S of NE corner 5-29/22		Kern	80	100	191	211		
Starrh_9K_No2	APN 99 230 9		Kern	230	500				
Unknown	252 ft south of Twisselman. 600 ft east of San Luis Canal		Kern	141	271				
Unknown	3/4 mi west of Holloway Rd, 1 mi south of Twisselman		Kern	110	470				
USGS-353851119432201	440 ft N of GPRd., 1000 ft west of CA Aqueduct		Kern	300	570				
USGS-352800119380001			Kern						
USGS-352800119380002			Kern			600	680		
7106-62	APN 69 240 52		Kern	240	540				
7108-69	APN 44 90 1		Kern	820	980				
Snake			Kern						

Local Well Name	Top Perforation - Interval 4	Bottom Perforation - Interval 4	Top Perforation - Interval 5	Bottom Perforation - Interval 5	Top Perforation - Interval 6	Bottom Perforation - Interval 6	Top Perforation - Interval 7	Bottom Perforation - Interval 7	Top Perforation - Interval 8
USGS L2-2									
Unknown									
Unknown									
Berrenda Mesa 1									
Unknown									
Unknown									
Lost Hills 5									
Lost Hills 3									
Lost Hills Tulare Water Well									
AeraBelridge_19M1									
MW12									
AeraBelridge_5B2									
Starrh_9K_No2									
Unknown									
Unknown									
USGS-353851119432201									
USGS-352800119380001									
USGS-352800119380002									
7106-62									
7108-69									
Snake									

Local Well Name	Bottom Perforation - Interval 8	Top Perforation - Interval 9	Bottom Perforation - Interval 9	Top Perforation - Interval 10	Bottom Perforation - Interval 10	Sustainability Indicator - Groundwater Levels	Sustainability Indicator - Groundwater Storage	Sustainability Indicator - Seawater Intrusion
USGS L2-2						Yes	Yes	No
Unknown						Yes	Yes	No
Unknown						Yes	Yes	No
Berrenda Mesa 1						Yes	Yes	No
Unknown						Yes	Yes	No
Unknown						Yes	Yes	No
Lost Hills 5						Yes	Yes	No
Lost Hills 3						Yes	Yes	No
Lost Hills Tulare Water Well						Yes	Yes	No
AeraBelridge_19M1						Yes	Yes	No
MW12						Yes	Yes	No
AeraBelridge_5B2						Yes	Yes	No
Starrh_9K_No2						Yes	Yes	No
Unknown						Yes	Yes	No
Unknown						Yes	Yes	No
USGS-353851119432201						Yes	Yes	No
USGS-352800119380001						Yes	Yes	No
USGS-352800119380002						Yes	Yes	No
7106-62						Yes	Yes	No
7108-69						Yes	Yes	No
Snake						Yes	Yes	No

Local Well Name	Sustainability Indicator - Water Quality	Sustainability Indicator - Land Subsidence	Sustainability Indicator - Interconnected Surface Waters
USGS L2-2	No	No	No
Unknown	No	No	No
Unknown	No	No	No
Berrenda Mesa 1	No	No	No
Unknown	No	No	No
Unknown	No	No	No
Lost Hills 5	No	No	No
Lost Hills 3	No	No	No
Lost Hills Tulare Water Well	No	No	No
AeraBelridge_19M1	No	No	No
MW12	No	No	No
AeraBelridge_5B2	No	No	No
Starrh_9K_No2	No	No	No
Unknown	No	No	No
Unknown	No	No	No
USGS-353851119432201	No	No	No
USGS-352800119380001	No	No	No
USGS-352800119380002	No	No	No
7106-62	No	No	No
7108-69	No	No	No
Snake	No	No	No

Local Well Name	State Well Number	Monitoring Network Type	Reference Point Elevation (feet)	Reference Point Description	Ground Surface Elevation (feet)	Elevation Method	Elevation Accuracy	Well Use Type	Well Status
Unkown	25S21E01R001M	SGMA Representative	213.0	Ground surface elevation	213.0	Digital Elevation Model	Unknown	Irrigation	Active
C2VSim-Kern location	28S21E16	SGMA Representative	491.0	Simulated monitor locatio	491.0	Digital Elevation Model	Unknown	Other	Inactive
7106-63	27S22E30H	SGMA Representative	250.0	Ground surface elevation	250.0	Digital Elevation Model	Unknown	Irrigation	Active
Aera Belridge 13A1	28S21E13H	SGMA Representative	346.3	Top of casing	344.0	Surveyed to a benchmark	Unknown	Monitoring	Active

Local Well Name	Latitude	Longitude	Coordinates Method	Coordinates Accuracy	Principal Aquifer	Well Completion Type	Well Depth (feet bgs)	Well Completion Report Number
Unkown	35.77630	-119.65361	Digital aerial photo	Unknown	Confined	Single Well	760	21427
C2VSim-Kern location	35.49187	-119.71627	USGS quad	Unknown	SIM Layers 1, 2, & 3	Single Well	0	NA
7106-63	35.55051	-119.63684	Digital aerial photo	Unknown	Confined	Single Well	680	e0316813
Aera Belridge 13A1	35.49556	-119.65800	Surveyed	Unknown	Unconfined/Semi-Confined	Single Well	90	Unkown

Local Well Name	Well Location Description	Additional Comments	County	Top Perforation - Interval 1	Bottom Perforation - Interval 1	Top Perforation - Interval 2	Bottom Perforation - Interval 2	Top Perforation - Interval 3	Bottom Perforation - Interval 3
Unkown	300 ft NW of SE corner Sec 1		Kern	624	760				
C2VSim-Kern location	Centroid of Section 16	Simulated location, not a w	Kern						
7106-63	069-240-51		Kern	260	460	520	660		
Aera Belridge 13A1	Unkown	WCR not available	Kern	70	90				

Local Well Name	Top Perforation - Interval 4	Bottom Perforation - Interval 4	Top Perforation - Interval 5	Bottom Perforation - Interval 5	Top Perforation - Interval 6	Bottom Perforation - Interval 6	Top Perforation - Interval 7	Bottom Perforation - Interval 7	Top Perforation - Interval 8
Unkown									
C2VSim-Kern location									
7106-63									
Aera Belridge 13A1									

Local Well Name	Bottom Perforation - Interval 8	Top Perforation - Interval 9	Bottom Perforation - Interval 9	Top Perforation - Interval 10	Bottom Perforation - Interval 10	Sustainability Indicator - Groundwater Levels	Sustainability Indicator - Groundwater Storage	Sustainability Indicator - Seawater Intrusion
Unkown						Yes	Yes	No
C2VSim-Kern location						Yes	Yes	No
7106-63						Yes	Yes	No
Aera Belridge 13A1						Yes	Yes	No

Local Well Name	Sustainability Indicator - Water Quality	Sustainability Indicator - Land Subsidence	Sustainability Indicator - Interconnected Surface Waters
Unkown	Yes	No	No
C2VSim-Kern location	No	No	No
7106-63	Yes	No	No
Aera Belridge 13A1	Yes	No	No

APPENDIX H WELL ACCESS AGREEMENTS AND WELL COMPLETION REPORTS

MONITORING WELL ACCESS AGREEMENT

This Monitoring Well Access Agreement ("Agreement") is made and entered into by and between the Westside District Water Authority (hereafter "District") and Wonderful Nut Orchards, LLC (hereafter "Landowner"), both of whom shall be referred to individually as a "Party" to this Agreement and collectively as the "Parties" to this Agreement.

RECITALS

WHEREAS, the District is a member of the Kern Groundwater Authority ("KGA") which has adopted or will adopt a Groundwater Sustainability Plan ("GSP") to comply with the Sustainable Groundwater Management Act ("SGMA"); and

WHEREAS, the District developed and is responsible for implementing a chapter of the KGA GSP; and

WHEREAS, SGMA requires the long-term monitoring of groundwater levels and water quality; and

WHEREAS, to comply with this requirement, the District may need access rights from Landowners within its service area to monitor groundwater elevations and water quality; and

WHEREAS, real property owned by Landowner as set forth on Exhibit A attached hereto ("Landowner's Land") contains one or more groundwater wells in the District GSP chapter area for which the District is required to monitor for groundwater elevation and water quality monitoring activities; and

WHEREAS, Landowner has agreed to grant the District limited access onto Landowner's Land, subject to the terms and conditions as set forth in this Agreement.

NOW, THEREFORE, the Parties have entered into this Agreement to allow the District to access to Landowner's Land under the following terms and conditions:

TERMS AND CONDITIONS

1. Incorporation of Recitals. The foregoing recitals are incorporated herein as terms and conditions of this Agreement.

2. Right of Entry. Landowner grants to the District and its employees, agents, consultants, and contractors a non-exclusive year-round license to enter onto Landowner's Land (as generally described in Exhibit A) for the sole purpose of obtaining groundwater elevation and water quality data from Landowner's well(s). Unless otherwise agreed to by the Parties in a written amendment to this Agreement, the Parties agree that the District's access to Landowner's Land shall be limited to wells described in Exhibit A's "Monitoring Well Locations" and in compliance with any conditions listed under "Access Instructions."

3. Access and Control. Except as otherwise provided in this Agreement, Landowner retains the exclusive right of access to and control over the Landowner's Land. Nothing contained in this Agreement shall be construed as affording the public a right of access to any portion of the Landowner's Land or precluding Landowner's right to grant access to third parties across the Landowner's Land, provided that such access is not inconsistent with this Agreement.

4. Duration of Right. The Parties agree that this Agreement shall remain in effect until either of the following occurs: (a) Termination of the Agreement by either Party, or (b) Change in Ownership of Landowner's Land.

a. Termination by a Party. The Parties agree that this Agreement may be terminated at any time, with or without cause, by either Party upon sixty (60) days written notice to the other Party.

b. Landowner's Land: Change in Ownership. The Parties agree that this agreement shall terminate upon any change in ownership of Landowner's Land. Thereafter, the District acknowledges that it will need to enter into a new access agreement with the new owner(s) of Landowner's Land.

5. No Easement. The Parties agree that this Agreement does not grant the District a possessory right, easement, or other land interest with respect to Landowner's Land.

6. Costs. The Parties agree that all groundwater elevation and water quality monitoring performed by the District under this Agreement shall be funded by the District.

7. No Storage. The right of entry does not include permission to store soil or any measurement apparatus on the Landowner's Land. All materials and tools shall be removed from the Landowner's Land on the date of entry.

8. Use of Collected Data. The data collected as a result of well monitoring will be used to fulfill District's SGMA-related reporting requirements. The District will exclude landowner specific information and only site the location of the well and data.

9. Maintenance of Landowner's Land. The Parties acknowledge that this Agreement grants the District a non-exclusive year-round license to access Landowner's Land for the limited purpose of obtaining groundwater elevation and water quality data from Landowner's well(s). Accordingly, except as provided in section 10 of this Agreement below ("Damage/Restoration"), the Parties agree that the District (including its employees, agents, consultants, and contractors) is under no obligation to maintain or otherwise repair the Landowner's Land.

10. Damage/Restoration. The District (including its employees, agents, consultants, and contractors) shall take all reasonable precautions to avoid damaging Landowner's Land. If any damage is caused to Landowner's Land by the District in the course of performance of this Agreement, the District shall notify the Landowner immediately. In addition, the District will at its sole cost and expense work with the Landowner to take all action reasonably necessary to repair the damage and restore the areas of Landowner's Land to the condition that existed immediately prior to the damage caused by the District.

11. Schedule or Notice of Access. The District may develop a schedule of dates/times it will access Landowner's Land for the purposes of well monitoring. If the District does not provide a schedule, it shall undertake reasonable efforts to notify the Landowner in advance of accessing Landowner's Land pursuant the access rights granted under this Agreement.

12. Indemnity. The District agrees to defend, indemnify, and hold harmless Landowner and Landowner's past, present and future parents, subsidiaries and affiliates, and their respective directors, officers, shareholders, partners, members, managers, employees, agents, trustees, attorneys, representatives, affiliates, predecessors in interest, successors and assigns (collectively, the "Landowner Parties") for any costs, claims, damages, losses or other liabilities arising out of the District's (including any employees, agents, consultants, and contractors) actions on Landowner's Land under this Agreement, with the exception that the District shall not be responsible for defending, indemnifying, or holding harmless Landowner with regard to costs, claims, damages, losses, or other liabilities arising out of the sole negligence or intentional misconduct of Landowner.

13. Insurance. Prior to entering onto Landowner's Land, District shall provide to Landowner a certificate that the District or District's consultant a certificate evidencing general liability insurance in the amount of at least $500,000 Dollars aggregate limit.

14. If District or any of its contractors, invitees or other agents shall cause any release of any hazardous substances on, in or above Landowner's Land, or otherwise violate any applicable environmental law, District, at its sole cost and expense, shall promptly remediate such release to the satisfaction of Landowner and any governmental body having jurisdiction. If District fails to do the foregoing, Landowner may do such work at the cost and expense of the District.

15. District shall not permit or allow any mechanic's lien, materialmen's lien or other similar lien to attach to or be enforced against any portion of Landowner's Land arising out of District's exercise of rights under this agreement.

16. In no event shall Landowner be liable to District for any direct, indirect or consequential damages incurred by District resulting from District's use of, or inability to use, Landowner's Land for the purpose set forth herein.

17. District shall not assign, sublease, license or apportion its rights under this Agreement, in whole or in part, to any other party without Landowner's prior written consent, which consent may be withheld in Landowner's sole and absolute discretion.

18. Written Notices. Written notices between the Parties shall be sent via U.S. mail to the addresses listed below the parties' respective signatures.

19. Entire Agreement. This Agreement contains the entire understanding of the Parties and supersedes all prior agreements and understandings among the Parties related to the subject matter of this Agreement.

20. Amendment. Amendments to this Agreement shall become effective upon execution of a written amendment signed by both Parties.

21. Severability. If any provision of this Agreement is held to be unenforceable for any reason, it shall be adjusted, rather than voided, if possible, to achieve the intent of the Parties, and the balance of the Agreement shall remain in full force and effect.

22. Governing Law. This Agreement shall be interpreted and enforced pursuant to the laws of the state of California.

23. Effective Date. This Agreement shall become effective as of the latest date of execution below.

DISTRICT

By_____

Name, Title Kris Lawrence, Regulatory Coordinator

Date: 1-15-20

Address: 1405 Commercial Way, Suite 125, Bakersfield, CA 93309

LANDOWNER

_____

By: Rob Yraceburu, President

Date: January 16, 2020

Address: 6801 E. Lerdo Highway
Shafter, CA 93263

EXHIBIT A

Parcel (Referenced in the attached Agreement as "Landowner's Land")
Landowner Name, Contact Name:_ ***Wonderful Nut Orchards, LLC***   APN(s): 044-090-09

Monitoring Well Locations

[Insert directions to where (on Landowner's Land) the monitoring well(s) subject to this Agreement are located.]

25S21E01R001M → About 300' NW of the SE Corner of Section 1, Twp 25S, Range 21E.

Access Instructions

[Insert Landowner's Land access instructions here. Examples include parking restrictions, gate codes, animals to be aware of etc.]

stay under 10 mph to avoid stirring up dust.

MONITORING WELL ACCESS AGREEMENT

This Monitoring Well Access Agreement ("Agreement") is made and entered into by and between the Westside District Water Authority (hereafter "District") and Wonderful Nut Ranches III, LLC (hereafter "Landowner"), both of whom shall be referred to individually as a "Party" to this Agreement and collectively as the "Parties" to this Agreement.

RECITALS

WHEREAS, the District is a member of the Kern Groundwater Authority ("KGA") which has adopted or will adopt a Groundwater Sustainability Plan ("GSP") to comply with the Sustainable Groundwater Management Act ("SGMA"); and

WHEREAS, the District developed and is responsible for implementing a chapter of the KGA GSP; and

WHEREAS, SGMA requires the long-term monitoring of groundwater levels and water quality; and

WHEREAS, to comply with this requirement, the District may need access rights from Landowners within its service area to monitor groundwater elevations and water quality; and

WHEREAS, real property owned by Landowner as set forth on Exhibit A attached hereto ("Landowner's Land") contains one or more groundwater wells in the District GSP chapter area for which the District is required to monitor for groundwater elevation and water quality monitoring activities; and

WHEREAS, Landowner has agreed to grant the District limited access onto Landowner's Land, subject to the terms and conditions as set forth in this Agreement.

NOW, THEREFORE, the Parties have entered into this Agreement to allow the District to access to Landowner's Land under the following terms and conditions:

TERMS AND CONDITIONS

1. Incorporation of Recitals. The foregoing recitals are incorporated herein as terms and conditions of this Agreement.

2. Right of Entry. Landowner grants to the District and its employees, agents, consultants, and contractors a non-exclusive year-round license to enter onto Landowner's Land (as generally described in Exhibit A) for the sole purpose of obtaining groundwater elevation and water quality data from Landowner's well(s). Unless otherwise agreed to by the Parties in a written amendment to this Agreement, the Parties agree that the District's access to Landowner's Land shall be limited to wells described in Exhibit A's "Monitoring Well Locations" and in compliance with any conditions listed under "Access Instructions."

3. Access and Control. Except as otherwise provided in this Agreement, Landowner retains the exclusive right of access to and control over the Landowner's Land. Nothing contained in this Agreement shall be construed as affording the public a right of access to any portion of the Landowner's Land or precluding Landowner's right to grant access to third parties across the Landowner's Land, provided that such access is not inconsistent with this Agreement.

4. Duration of Right. The Parties agree that this Agreement shall remain in effect until either of the following occurs: (a) Termination of the Agreement by either Party, or (b) Change in Ownership of Landowner's Land.

a. Termination by a Party. The Parties agree that this Agreement may be terminated at any time, with or without cause, by either Party upon sixty (60) days written notice to the other Party.

b. Landowner's Land: Change in Ownership. The Parties agree that this agreement shall terminate upon any change in ownership of Landowner's Land. Thereafter, the District acknowledges that it will need to enter into a new access agreement with the new owner(s) of Landowner's Land.

5. No Easement. The Parties agree that this Agreement does not grant the District a possessory right, easement, or other land interest with respect to Landowner's Land.

6. Costs. The Parties agree that all groundwater elevation and water quality monitoring performed by the District under this Agreement shall be funded by the District.

7. No Storage. The right of entry does not include permission to store soil or any measurement apparatus on the Landowner's Land. All materials and tools shall be removed from the Landowner's Land on the date of entry.

8. Use of Collected Data. The data collected as a result of well monitoring will be used to fulfill District's SGMA-related reporting requirements. The District will exclude landowner specific information and only site the location of the well and data.

9. Maintenance of Landowner's Land. The Parties acknowledge that this Agreement grants the District a non-exclusive year-round license to access Landowner's Land for the limited purpose of obtaining groundwater elevation and water quality data from Landowner's well(s). Accordingly, except as provided in section 10 of this Agreement below ("Damage/Restoration"), the Parties agree that the District (including its employees, agents, consultants, and contractors) is under no obligation to maintain or otherwise repair the Landowner's Land.

10. Damage/Restoration. The District (including its employees, agents, consultants, and contractors) shall take all reasonable precautions to avoid damaging Landowner's Land. If any damage is caused to Landowner's Land by the District in the course of performance of this Agreement, the District shall notify the Landowner immediately. In addition, the District will at its sole cost and expense work with the Landowner to take all action reasonably necessary to repair the damage and restore the areas of Landowner's Land to the condition that existed immediately prior to the damage caused by the District.

11. Schedule or Notice of Access. The District may develop a schedule of dates/times it will access Landowner's Land for the purposes of well monitoring. If the District does not provide a schedule, it shall undertake reasonable efforts to notify the Landowner in advance of accessing Landowner's Land pursuant the access rights granted under this Agreement.

12. Indemnity. The District agrees to defend, indemnify, and hold harmless Landowner and Landowner's past, present and future parents, subsidiaries and affiliates, and their respective directors, officers, shareholders, partners, members, managers, employees, agents, trustees, attorneys, representatives, affiliates, predecessors in interest, successors and assigns (collectively, the "Landowner Parties") for any costs, claims, damages, losses or other liabilities arising out of the District's (including any employees, agents, consultants, and contractors) actions on Landowner's Land under this Agreement, with the exception that the District shall not be responsible for defending, indemnifying, or holding harmless Landowner with regard to costs, claims, damages, losses, or other liabilities arising out of the sole negligence or intentional misconduct of Landowner.

13. Insurance. Prior to entering onto Landowner's Land, District shall provide to Landowner a certificate that the District or District's consultant a certificate evidencing general liability insurance in the amount of at least $500,000 Dollars aggregate limit.

14. If District or any of its contractors, invitees or other agents shall cause any release of any hazardous substances on, in or above Landowner's Land, or otherwise violate any applicable environmental law, District, at its sole cost and expense, shall promptly remediate such release to the satisfaction of Landowner and any governmental body having jurisdiction. If District fails to do the foregoing, Landowner may do such work at the cost and expense of the District.

15. District shall not permit or allow any mechanic's lien, materialmen's lien or other similar lien to attach to or be enforced against any portion of Landowner's Land arising out of District's exercise of rights under this agreement.

16. In no event shall Landowner be liable to District for any direct, indirect or consequential damages incurred by District resulting from District's use of, or inability to use, Landowner's Land for the purpose set forth herein.

17. District shall not assign, sublease, license or apportion its rights under this Agreement, in whole or in part, to any other party without Landowner's prior written consent, which consent may be withheld in Landowner's sole and absolute discretion.

18. Written Notices. Written notices between the Parties shall be sent via U.S. mail to the addresses listed below the parties' respective signatures.

19. Entire Agreement. This Agreement contains the entire understanding of the Parties and supersedes all prior agreements and understandings among the Parties related to the subject matter of this Agreement.

20. Amendment. Amendments to this Agreement shall become effective upon execution of a written amendment signed by both Parties.

21. Severability. If any provision of this Agreement is held to be unenforceable for any reason, it shall be adjusted, rather than voided, if possible, to achieve the intent of the Parties, and the balance of the Agreement shall remain in full force and effect.

22. Governing Law. This Agreement shall be interpreted and enforced pursuant to the laws of the state of California.

23. Effective Date. This Agreement shall become effective as of the latest date of execution below.

DISTRICT

By_____

Name, Title Kris Lawrence, Regulatory Coordinator

Date: 1-15-20

Address: 1405 Commercial Way, Suite 125, Bakersfield, CA 93309

LANDOWNER

_____

By: Rob Yraceburu, President

Date: January 16, 2020

Address: 6801 E. Lerdo Highway
Shafter, CA 93263

EXHIBIT A

Parcel (Referenced in the attached Agreement as "Landowner's Land")
Landowner Name, Contact Name:_ ***Wonderful Nut Ranches III, LLC***
APN(s): 085-200-26

Monitoring Well Locations

[Insert directions to where (on Landowner's Land) the monitoring well(s) subject to this Agreement are located.]

Aera 13A1 → 1335 ft south and 1100 feet west of intersection of Lerdo Highway and Starrh Road

Access Instructions

[Insert Landowner's Land access instructions here. Examples include parking restrictions, gate codes, animals to be aware of etc.]

stay under 10 mph to avoid stirring up dust.

MONITORING WELL ACCESS AGREEMENT

This Monitoring Well Access Agreement ("Agreement") is made and entered into by and between the Westside District Water Authority (hereafter "District") and Wonderful Nut Ranches I, LLC (hereafter "Landowner"), both of whom shall be referred to individually as a "Party" to this Agreement and collectively as the "Parties" to this Agreement.

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WHEREAS, the District developed and is responsible for implementing a chapter of the KGA GSP; and

WHEREAS, SGMA requires the long-term monitoring of groundwater levels and water quality; and

WHEREAS, to comply with this requirement, the District may need access rights from Landowners within its service area to monitor groundwater elevations and water quality; and

WHEREAS, real property owned by Landowner as set forth on Exhibit A attached hereto ("Landowner's Land") contains one or more groundwater wells in the District GSP chapter area for which the District is required to monitor for groundwater elevation and water quality monitoring activities; and

WHEREAS, Landowner has agreed to grant the District limited access onto Landowner's Land, subject to the terms and conditions as set forth in this Agreement.

NOW, THEREFORE, the Parties have entered into this Agreement to allow the District to access to Landowner's Land under the following terms and conditions:

TERMS AND CONDITIONS

1. Incorporation of Recitals. The foregoing recitals are incorporated herein as terms and conditions of this Agreement.

2. Right of Entry. Landowner grants to the District and its employees, agents, consultants, and contractors a non-exclusive year-round license to enter onto Landowner's Land (as generally described in Exhibit A) for the sole purpose of obtaining groundwater elevation and water quality data from Landowner's well(s). Unless otherwise agreed to by the Parties in a written amendment to this Agreement, the Parties agree that the District's access to Landowner's Land shall be limited to wells described in Exhibit A's "Monitoring Well Locations" and in compliance with any conditions listed under "Access Instructions."

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b. Landowner's Land: Change in Ownership. The Parties agree that this agreement shall terminate upon any change in ownership of Landowner's Land. Thereafter, the District acknowledges that it will need to enter into a new access agreement with the new owner(s) of Landowner's Land.

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12. Indemnity. The District agrees to defend, indemnify, and hold harmless Landowner and Landowner's past, present and future parents, subsidiaries and affiliates, and their respective directors, officers, shareholders, partners, members, managers, employees, agents, trustees, attorneys, representatives, affiliates, predecessors in interest, successors and assigns (collectively, the "Landowner Parties") for any costs, claims, damages, losses or other liabilities arising out of the District's (including any employees, agents, consultants, and contractors) actions on Landowner's Land under this Agreement, with the exception that the District shall not be responsible for defending, indemnifying, or holding harmless Landowner with regard to costs, claims, damages, losses, or other liabilities arising out of the sole negligence or intentional misconduct of Landowner.

13. Insurance. Prior to entering onto Landowner's Land, District shall provide to Landowner a certificate that the District or District's consultant a certificate evidencing general liability insurance in the amount of at least $500,000 Dollars aggregate limit.

14. If District or any of its contractors, invitees or other agents shall cause any release of any hazardous substances on, in or above Landowner's Land, or otherwise violate any applicable environmental law, District, at its sole cost and expense, shall promptly remediate such release to the satisfaction of Landowner and any governmental body having jurisdiction. If District fails to do the foregoing, Landowner may do such work at the cost and expense of the District.

15. District shall not permit or allow any mechanic's lien, materialmen's lien or other similar lien to attach to or be enforced against any portion of Landowner's Land arising out of District's exercise of rights under this agreement.

16. In no event shall Landowner be liable to District for any direct, indirect or consequential damages incurred by District resulting from District's use of, or inability to use, Landowner's Land for the purpose set forth herein.

17. District shall not assign, sublease, license or apportion its rights under this Agreement, in whole or in part, to any other party without Landowner's prior written consent, which consent may be withheld in Landowner's sole and absolute discretion.

18. Written Notices. Written notices between the Parties shall be sent via U.S. mail to the addresses listed below the parties' respective signatures.

19. Entire Agreement. This Agreement contains the entire understanding of the Parties and supersedes all prior agreements and understandings among the Parties related to the subject matter of this Agreement.

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21. Severability. If any provision of this Agreement is held to be unenforceable for any reason, it shall be adjusted, rather than voided, if possible, to achieve the intent of the Parties, and the balance of the Agreement shall remain in full force and effect.

22. Governing Law. This Agreement shall be interpreted and enforced pursuant to the laws of the state of California.

23. Effective Date. This Agreement shall become effective as of the latest date of execution below.

DISTRICT

By_____

Name, Title Kris Lawrence, Regulatory Coordinator

Date: 1-15-20

Address: 1405 Commercial Way, Suite 125, Bakersfield, CA 93309

LANDOWNER

_____

By: Rob Yraceburu, President

Date: January 16, 2020

Address: 6801 E. Lerdo Highway
Shafter, CA 93263

EXHIBIT A

Parcel (Referenced in the attached Agreement as "Landowner's Land")
Landowner Name, Contact Name: ***Wonderful Nut Ranches I, LLC***
APN(s): 069-240-51

Monitoring Well Locations

[Insert directions to where (on Landowner's Land) the monitoring well(s) subject to this Agreement are located.]

7106-63 → 3.58 mile N/Lerdo Hwy – 1 mile W/ Main Drain Road,

Access Instructions

[Insert Landowner's Land access instructions here. Examples include parking restrictions, gate codes, animals to be aware of etc.]

stay under 10 mph to avoid stirring up dust.

T25S/R20E-27B3

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

ORIGINAL
File with DWR

Do Not Fill In
No 86416

State Well No. _____
Other Well No. _____

County Kern Owner's number, if any
Township, Range, and Section T25S R20E, Sec. 27
Distance from cities, roads, railroads, etc. 2521 south of Twisselman; 600' east of San Luis Canal

(3) TYPE OF WORK *(check):*
New Well ☒ Deepening ☐ Reconditioning ☐ Destroying ☐
If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE *(check):*
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:
Rotary ☐
Cable ☒
Other ☐

(6) CASING INSTALLED:
STEEL: OTHER:
SINGLE ☒ DOUBLE ☐

From ft.	To ft.	Diam.	Gage or Wall	If gravel packed: Diameter of Bore	From ft.	To ft.
Up 1'	271	8"	#10			

Size of shoe or well ring: 8"x4"½" steel shoe Size of gravel:
Describe joint Buttwelded

(7) PERFORATIONS OR SCREEN:
Type of perforation or name of screen Mills

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.
141	156	6	2	2½" x 3/8"
161	166	6	2	"
269	271	6	2	"

(8) CONSTRUCTION:
Was a surface sanitary seal provided? Yes ☐ No ☒ To what depth ft.
Were any strata sealed against pollution? Yes ☐ No ☒ If yes, note depth of strata
From ft. to ft.
From ft. to ft.
Method of sealing

(9) WATER LEVELS: 75-80 gpm (Air Lift)
Depth at which water was first found, if known 118 ft.
Standing level before perforating, if known 103 ft.
Standing level after perforating and developing 92 ft.

(10) WELL TESTS:
Was pump test made? Yes ☐ No ☒ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Temperature of water Was a chemical analysis made? Yes ☐ No ☒
Was electric log made of well? Yes ☐ No ☒ If yes, attach copy

(11) WELL LOG:
Total depth 271 ft. Depth of completed well 271 ft.
Formation: *Describe by color, character, size of material, and structure*

			ft.
0	3	Sandy soil	
3	10	Brown sandy clay	
10	12	Small cobbles and clay	
12	87	Brown joint clay	
87	90	Sandy clay	
90	113	Creamy joint clay	
113	120	Clayey packed sand	
120	140	Brown sandy clay	
140	141	Joint clay	
141	155	Brown sandy clay	
155	162	Creamy joint clay	
162	165	Small cobbles	
165	198	Brown sandy joint clay	
198	238	Brown joint clay	
238	244	Sandy joint clay	
244	245	Coarse sand	
245	248	Sandy joint clay	
248	253	Fine brown sand	
253	269	Joint clay	
269	270	Medium fine sand	
270	271	Joint clay	

UNCONFINED

CONFIDENTIAL
Water Code Sec. 13752

Work started 12/16/71, Completed 1/4/72 19

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Bill Belknap GLJr.
(Person, firm, or corporation) (Typed or printed)
Address P. O. Box 846
Reedley, California 93654
[SIGNED] Bill Belknap vh
(Well Driller)
License No. 106833 Dated 1/11/72, 19

SKETCH LOCATION OF WELL ON REVERSE SIDE

DWR 188 (REV. 9-68)

25179-950 9-68 50M TRIP △D OSP

ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do not fill in

No. 298414

Notice of Intent No. _____

Local Permit No. or Date

State Well No. 25S/20E-30A2

Other Well No. _____

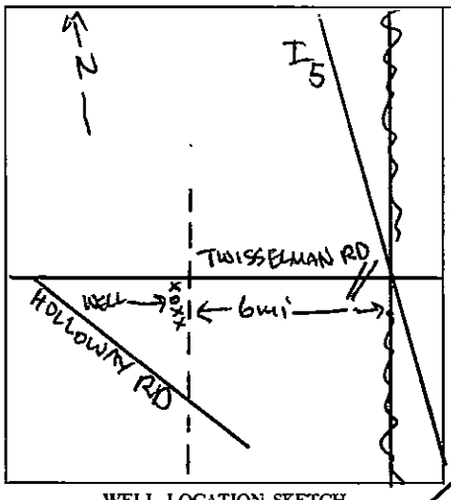
(2) LOCATION OF WELL (See instructions):

County Kern Owner's Well Number L2-2

Well address if different from above _____

Township 25S Range 20E Section 30A

Distance from cities, roads, railroads, fences, etc. _____



WELL LOCATION SKETCH

(3) TYPE OF WORK:

New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:

Domestic [ ]
Irrigation [ ]
Industrial [ ]
Test Well [X]
Municipal [ ]
Other [ ]
(Describe)

(5) EQUIPMENT:

Rotary [X] Reverse [ ]
Cable [ ] Air [ ]
Other [ ] Bucket [ ]

(6) GRAVEL PACK:

Yes [X] No [ ] Size 12x20

Diameter of bore 10

Packed from 198 to 226 ft.

(7) CASING INSTALLED:

Steel [ ] Plastic [X] Concrete [ ]

From ft.	To ft.	Dia. in.	Gage or Wall
0	226	5	SDR17

(8) PERFORATIONS:

Type of perforation or size of screen

From ft.	To ft.	Slot size
211	221	.03

(9) WELL SEAL:

Was surface sanitary seal provided? Yes [X] No [ ] If yes, to depth 198 ft.

Were strata sealed against pollution? Yes [ ] No [ ] Interval _____ ft.

Method of sealing bentonite grout

(10) WATER LEVELS:

Depth of first water, if known _____ ft.

Standing level after well completion 59 ft.

(11) WELL TESTS:

Was well test made? Yes [ ] No [X] If yes, by whom? _____

Type of test Pump [ ] Bailer [ ] Air lift [ ]

Depth to water at start of test _____ ft. At end of test _____ ft.

Discharge _____ gal/min after _____ hours Water temperature _____

Chemical analysis made? Yes [ ] No [X] If yes, by whom? _____

Was electric log made Yes [X] No [ ] If yes, attach copy to this report

(12) WELL LOG:

Total depth 232 ft. Completed depth 226 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	37	sandy clay
37	80	yellow clay
80	84	coarse sand
84	121	silty clay
121	125	clean sand
125	127	sandy clay
127	138	blue sand
138	142	blue clay
142	166	blue sand, some clay
166	197	clay and sand
197	211	stiff brown clay
211	214	sand and gravel
214	220	clay
220	230	silty sand

Work started _____ 19____ Completed 12/17 1987

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Signed _____ (Well Driller) HYDROLOGIC TECHNICIAN

NAME U.S. GEOLOGICAL SURVEY (Person, firm, or corporation) (Typed or printed)

Address SAME AS OWNER

City _____ ZIP _____

License No. _____ Date of this report _____

CONFIDENTIAL
NOT FOR PUBLIC USE
WATER CODE SEC. 13752

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 1 of 1

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. **E074216**

DWR USE ONLY --- DO NOT FILL IN

25S/20E-32

STATE WELL NO./ STATION NO.

LATITUDE / LONGITUDE

APN/TRS/OTHER

Owner's Well No. AMA Pistachio

Date Work Began 10/20/2008, Ended 10/22/2008

Local Permit Agency Kern County

Permit No. WP 11298 Permit Date 9/23/2008

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD REVERSE FLUID WATER/POL

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	3	TOP SOIL
3	11	SAND
11	81	CLAY
81	91	SAND/GRAVEL/ROCKS
91	176	CLAY
176	179	FINE SAND
179	200	BRN/BLUE CLAY
200	205	SAND
205	216	BLUE CLAY
216	224	FINE SAND
224	238	BLUE CLAY
238	244	SAND
244	250	BLUE CLAY
250	259	SAND/GRAVEL/ROCKS
259	270	BRN.CLAY
270	275	SAND/GRAVEL/ROCKS
275	290	BRN.CLAY
290	295	SAND
295	318	BRN.CLAY
318	342	SAND/GRAVEL/ROCKS
342	370	BRN.CLAY
370	374	SAND
374	380	BRN.CLAY
380	387	SAND/ROCKS
387	444	BRN.CLAY
444	446	SAND
446	488	BLUE CLAY
488	494	SAND
494	495	HARD ROCK

TOTAL DEPTH OF BORING 495 (Feet)

TOTAL DEPTH OF COMPLETED WELL 490 (Feet)

WELL OWNER

WELL LOCATION

Address 3/4 Mile W of Holloway Rd 1 Mile S of Twissleman

City CA

County KERN

APN Book 044 Page 080 Parcel 42

Township 25 S Range 20 E Section 32

Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
✓ Irrigation ___ Industrial

___ MONITORING
___ TEST WELL
___ CATHODIC PROTECTION
___ HEAT EXCHANGE
___ DIRECT PUSH
___ INJECTION
___ VAPOR EXTRACTION
___ SPARGING
___ REMEDIATION
___ OTHER (SPECIFY)

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	110	26	✓				STEEL	12	5/16	
110	470	26		✓			STEEL	12	5/16	.125 FF
470	490	26	✓				STAINLESS	12	5/16	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	50	✓			
50	490				GRAVEL

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Myers Well Drilling, Inc
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

11745 2nd Ave. Hanford CA 93230
ADDRESS CITY STATE ZIP

Signed ___ 10/23/08 865822
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

25/21-1R1 10-25-57

DUPLICATE
File Original, Duplicate and Triplicate with the
REGIONAL WATER POLLUTION CONTROL BOARD No.
(Insert appropriate number)

Love Tate well #1

WATER WELL DRILLERS REPORT

(Sections 7076, 7077, 7078, Water Code)

STATE OF CALIFORNIA

LOCATION ~~NOT SATISFACTORY. Do Not Fill In~~

No. 21427

State Well No. 25/21-1R1 (G5)

Other Well No. 25-21E-1

(2) LOCATION OF WELL:

County Kern Owner's number, if any—

R. F. D. or Street No. About 300' NW. of the South East Corner of Section 1, Twp 25 S, Range 21 E. MDB&M.

(3) TYPE OF WORK (*check*):

New well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (*check*):

Domestic ☐ Industrial ☐ Municipal ☐

Irrigation ☒ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☒

Cable ☐

Dug Well ☐

(6) CASING INSTALLED:

SINGLE ☒ DOUBLE ☐

From ft.	to ft.	Diam.	Gage or Wall
0	8'	24"	10
0	480'	14"	5/16
480'	760'	12"	1/4"

Type and size of shoe or well ring

Describe joint Welded

If gravel packed

Diameter of Bore	from ft.	to ft.
22"	500'	760

Size of gravel: X 6 x20

(7) PERFORATIONS:

Type of perforator used Saw

Size of perforations 100 M in., length, by in.

From ft.	to ft.	Perf. per row	Rows per ft.
624	760'	15	"

(8) CONSTRUCTION:

Was a surface sanitary seal provided? ☐ Yes ☐ No. To what depth ft.

Were any strata sealed against pollution? ☐ Yes ☐ No If yes, note depth of strata

From ft. to ft.

Method of Sealing

(9) WATER LEVELS:

Depth at which water was first found ft.

Standing level before perforating ft.

Standing level after perforating ft.

(10) WELL TESTS:

Was a pump test made? ☐ Yes ☐ No If yes, by whom?

Yield: gal./min. with ft. draw down after hrs.

Temperature of water Was a chemical analysis made? ☐ Yes ☐ No

Was electric log made of well? ☐ Yes ☐ No

(11) WELL LOG:

Total depth 830' ft. Depth of completed well 760' ft.

Formations *Describe by color, character, size of material, and structure.*

ft. to	ft.	
0	15	Soil & Clay
15	17	Sand
17	25	Clay, Grey
25	60	Bron Sand
60	65	Brown ~~XXXX~~ Clay,
65	85	Brown Sand
85	135	Sand W/ strs of Clay.
135	145	Grey Sand.
145	155	~~XXXX~~ Sand Cparse
155	165	Clay.
165	240	Sand W/ strs of Clay
240	335	Silty Sand,
335	340	Hard Clay.
340	350	Sand Grey
350	352	Very Hard Clay,
352	390	Sand Silty,
	385	Very Hard Clay.
385	400	Sand grey
400	460	Sand W/strs of Hard Shells.
460	470	Blue Clay.
470	540	Silty Sand.
540	620	Blue Clay.
620	650	Sand w/ strs of Blue Clay.
650	750	Sand Grey
750	760	Blue Clay.
760	810	Sand Very Fine.
810	830	Blue Clay.

CONFIDENTIAL
Section 7076.1, Water Code

Work started Oct 11/54 19 . Completed Oct 26/54'

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Arthur T. Ball
(Person, firm, or corporation) (*Typed or printed*)

Address Route #1 Box #5

Lemoore, Calif

[SIGNED] Arthur T. Ball
Well Driller

License No. 125446 Dated Nov 9th, 1954

93889 2-54 SOM. QUIN Q. SPO DWR FORM NO. 246 (REV. 3-54)

*The free Adobe Reader may be used to view and complete this form. However, software must be purchased to complete, save, and reuse a saved form.

File Original with DWR 7108-69

Page _____ of _____

State of California
Well Completion Report

Refer to Instruction Pamphlet

No. 80332650

Owner's Well Number Snake Ranch Well #6

Date Work Began 07/22/2016 Date Work Ended 1/16/2017

Local Permit Agency Kern County Public Health Services

Permit Number ~~17228~~ 17231 Permit Date 7/21/16

DWR Use Only – Do Not Fill In

State Well Number/Site Number

Latitude N Longitude W

APN/TRS/Other

Geologic Log

Orientation ⊙ Vertical ○ Horizontal ○ Angle Specify _____

Drilling Method Reverse Circulation Rotary Drilling Fluid Bentonite mud

Depth from Surface Feet	to Feet	Description Describe material, grain size, color, etc
0	63	Coarse Sand
63	110	Clay, GRY with Coarse Sand
110	135	Coarse Sand
135	165	Coarse Sand
165	196	Clay, GRY with Fine Sand
196	228	Clay, GRY with Medium Sand
228	250	Clay, GRY Soft
250	281	Clay, GRY with Coarse Sand
281	302	Clay, GRY with Medium Sand
302	333	Clay, GRY with Fine Sand
333	387	Clay, GRY Soft
387	450	Clay, GRY Soft
450	482	Clay, GRY Soft
482	514	Clay, GRY Medium to Firm
514	546	Clay, GRY Soft to Medium
546	576	Clay, GRY Firm
576	615	Clay, GRY Firm
615	674	Clay, GRY Medium to Firm
674	738	Clay, GRY Firm
738	769	Clay, GRY Firm
769	801	Clay, GRY Firm
801	832	Clay, GRY with Fine Sand
832	864	Clay, GRY Firm
864	897	Clay, GRY Soft to Medium
897	928	Clay, GRY with Fine Sand
928	961	Clay, GRY Soft to Medium
961	989	Clay, GRY Firm
989	1,024	Clay, GRY Firm
		**Note all above sample measurements were take
		from 11' Kelly Bushing above the ground level

Total Depth of Boring _____ Feet

Total Depth of Completed Well _____ Feet

Well Owner

Name Wonderful Nut Orchards

Mailing Address 6801 E. Lerdo Hwy

City Shafter State Ca Zip 93263

Well Location

Address _____

City _____ County Kern

Latitude 35 Deg. 78 Min. 3 Sec. N Longitude -119 Deg. 698 Min. 26 Sec. W

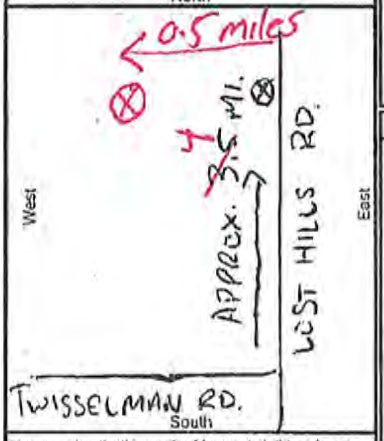
Datum NAD27 Dec. Lat. 35 Dec. Long. -119

APN Book 44 Page 90 Parcel ~~19~~ 1

Township 25S Range 21E Section ~~10~~ 3

Location Sketch

(Sketch must be drawn by hand after form is printed.)



Illustrate or describe distance of well from roads, buildings, fences, rivers, etc., and attach a map. Use additional paper if necessary. Please be accurate and complete.

Activity

⊙ New Well
○ Modification/Repair
○ Deepen
○ Other _____
○ Destroy
Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

⊙ Water Supply
☐ Domestic ☐ Public
☑ Irrigation ☐ Industrial
○ Cathodic Protection
○ Dewatering
○ Heat Exchange
○ Injection
○ Monitoring
○ Remediation
○ Sparging
○ Test Well
○ Vapor Extraction
○ Other _____

Water Level and Yield of Completed Well

Depth to first water 20 (Feet below surface)

Depth to Static Water Level 210 (Feet) Date Measured 01/16/2017

Estimated Yield * 1,450 (GPM) Test Type Step-Drawndown

Test Length 1.0 (Hours) Total Drawdown 132 (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)
0	50	38	Conductor	Low Carbon Steel	.250	32		
0	760	28	Blank	Low Carbon Steel	.375	16		
760	780	28	Comp Sec	Low Carbon Steel	.375	18		
780	820	28	Blank	Low Carbon Steel	.375	16		
820	980	28	Screen	Low Carbon Steel	.375	16	Louver	0.060
980	1,000	28	Blank	Low Carbon Steel	.375	16		

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
0	720	Cement	11 Sack Slurry
720	1,020	Filter Pack	6x9 Silica

Attachments

☐ Geologic Log
☐ Well Construction Diagram
☐ Geophysical Log(s)
☐ Soil/Water Chemical Analyses
☐ Other _____

Attach additional information, if it exists

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name Clayton Ludington

Person, Firm or Corporation

1311 Calaveras Park Dr Bakersfield CA 93311

Address City State Zip

Signed _____ 997775

C-57 Licensed Water Well Contractor Date Signed C-57 License Number

DWR 188 REV. 1/2005

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

25/21-26 P1

ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do Not Fill In

No 112332

State Well No. _____

Other Well No. _____

(2) LOCATION OF WELL:

County Kern Owner's number, if any

Township, Range, and Section SE/4 T25 R21E Sec26

Distance from cities, roads, railroads, etc.

(3) TYPE OF WORK (check):

New Well [X] Deepening [ ] Reconditioning [ ] Destroying [ ]

If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic [ ] Industrial [ ] Municipal [ ]
Irrigation [X] Test Well [ ] Other [ ]

(5) EQUIPMENT:

Rotary Rev [X]
Cable [ ]
Other [ ]

(6) CASING INSTALLED:

STEEL [X] OTHER:
SINGLE [X] DOUBLE [ ]

If gravel packed

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	From ft.	To ft.
0	402	14"	1/4	26"	0	450

Size of shoe or well ring: Bull Nose Size of gravel: 4/16 x 4

Describe joint 30'

(7) PERFORATIONS OR SCREEN:

Type of perforation or name of screen Saw

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.
195	402	7	3	1/8" x 3

(8) CONSTRUCTION:

Was a surface sanitary seal provided? Yes [X] No [ ] To what depth 60 ft.

Were any strata sealed against pollution? Yes [ ] No [ ] If yes, note depth of strata

From ft. to ft.

From ft. to ft.

Method of sealing

(9) WATER LEVELS:

Depth at which water was first found, if known ft.

Standing level before perforating, if known ft.

Standing level after perforating and developing ft.

(10) WELL TESTS:

Was pump test made? Yes [ ] No [ ] If yes, by whom?

Yield: gal./min. with ft. drawdown after hrs.

Temperature of water Was a chemical analysis made? Yes [ ] No [ ]

Was electric log made of well? Yes [ ] No [ ] If yes, attach copy

(11) WELL LOG:

Total depth 450 ft. Depth of completed well 402 ft.

Formation: *Describe by color, character, size of material, and structure*

ft. to	ft.	Formation	
0	2	top soil	
2	8	clay	
8	18	sand	
18	27	clay	
27	55	sand	
55	60	clay	
60	75	sand	
75	116	clay	
116	131	sand	
131	145	clay	
145	150	sand	
150	160	clay	
160	170	sand	
170	190	clay	
190	193	sand	
193	195	clay	
195	210	sand	(15)
210	218	clay	
218	225	sand	(7)
225	244	clay	
244	257	sand	(7)
257	264	clay	
264	277	sand	(13)
277	291	clay	
291	310	sand	(19)
310	350	clay	
350	355	sand	(5)
355	361	clay	
361	366	sand	(5)
366	407	clay	
407	418	sand	(11)
418	422	clay	91 ft sand
422	431	sand	(9)
431	450	clay	(Corcoran Clay)

UNCONFINED

Work started Sept 9 19 75, Completed Sept 12 19 75

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Grabow Well Drilling Co. Inc
(Person, firm, or corporation) (Typed or printed)

Address 12522 - 9th Ave, Hanford, Calif 93230

[SIGNED] Jean E. Grabow
(Well Driller)

License No. 288489 Dated Sept 19, 19 75

SKETCH LOCATION OF WELL ON REVERSE SIDE

67139-750 8-72 30M TRIP OT OSP

26/18-14N1

REGION 5

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

BASIN

DWR NO. 26/18-14N1 B & M

OTHER NOS.

COUNTY Kern

NEAR Kern's Corners
Santa Fe "Alley

WELL LOG

LOCATION 4.2 mi SE/o Kerns Corners 7.5
S.W. corner of section

DRILLED BY L.E. Williams ADDRESS

DRILLING METHOD Cable tool GRAVEL PACKED Yes DATE COMPLETED 1949

SIZE OF CASING DEPTH 14" STRUCK WATER AT

PERFORATIONS 135-300 SIZE No.

WATER LEVEL BEFORE PERFORATING AFTER
Log of 26/18-14G1 on file at USGS

TEST DATA: DISCHARGE G. P. M. DRAWDOWN FT. HOURS RUN

OTHER DATA AVAILABLE: WATER LEVEL RECORD 1487 (6/51) ANALYSIS

SURFACE ELEV. 670 DATUM MSL SOURCE OF INFORMATION USGS

DEPTH	ELEV. OF BOTTOM OF STRATUM	MATERIAL	THICKNESS	SP. YIELD %	
0-29		Top soil			
135		Yellow clay, gravel streaks			
140		Gravel (water)			
160		Yellow clay			
185		Gravel			
210		Clay			
242		Gravel			
293		Clay			
300		Gravel			
333		Sandstone			
334		Blue shale			

FOR FIELD COPIES USE ALTERNATE LINES

LOG OBTAINED BY R.C. Ford DATE 4/6/52 SHEET 1 OF 1

FORM 263

*The free Adobe Reader may be used to view and complete this form. However, software must be purchased to complete, save, and reuse a saved form.

File Original with DWR

State of California

Well Completion Report

Refer to Instruction Pamphlet

No. e0095227

Page 1 of 2

Owner's Well Number TH-2

Date Work Began 04/20/2009 Date Work Ended 6/15/2009

Local Permit Agency Kern County Environmental Health Services

Permit Number WP 11571 Permit Date 1/6/09

DWR Use Only – Do Not Fill In

26S/19E-29

State Well Number/Site Number

N W

Latitude Longitude

APN/TRS/Other

Geologic Log

Orientation ◉ Vertical ○ Horizontal ○ Angle Specify

Drilling Method Rotary Drilling Fluid Polymer mud

Depth from Surface Feet	to Feet	Description Describe material, grain size, color, etc
50	130	Sand Gravel
130	160	Sand Clay
160	240	Sand Clay Gravel
240	270	Sand Clay
270	300	Sand Gravel
300	330	Sand
330	400	Sand Gravel
400	930	Sand Clay
930	970	Sand
970	990	Sand Clay
990	1,020	Sand Gravel
1020	1,090	Clay Sand
1090	1,225	Sand Gravel

Total Depth of Boring 1225 Feet

Total Depth of Completed Well 1205 Feet

Well Owner

Well Location

Address 1-1/2 Mile North Hwy 46 3-3/4 Mile West on Hwy 33

City Lost Hills County Kern

Latitude ___ Deg. ___ Min. ___ Sec. N Longitude ___ Deg. ___ Min. ___ Sec. W

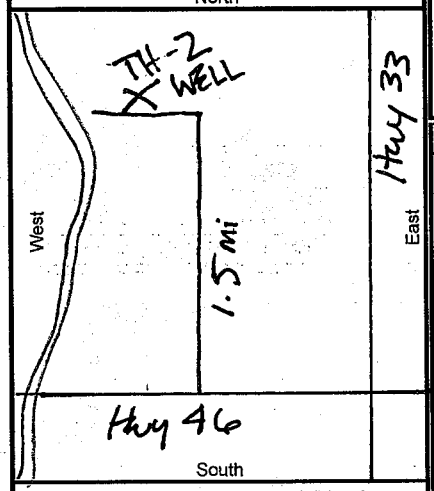
Datum ___ Decimal Lat. ___ Decimal Long. ___

APN Book 057 Page 190 Parcel 26

Township 26S Range 19E Section 29

Location Sketch

(Sketch must be drawn by hand after form is printed.)



Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. Please be accurate and complete.

Activity

◉ New Well
○ Modification/Repair
○ Deepen
○ Other
○ Destroy
Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

◉ Water Supply
☐ Domestic ☐ Public
☑ Irrigation ☐ Industrial
○ Cathodic Protection
○ Dewatering
○ Heat Exchange
○ Injection
○ Monitoring
○ Remediation
○ Sparging
○ Test Well
○ Vapor Extraction
○ Other

Water Level and Yield of Completed Well

Depth to first water 395 (Feet below surface)

Depth to Static Water Level 395 (Feet) Date Measured 06/10/2009

Estimated Yield * 1,500 (GPM) Test Type Step-Drawndown

Test Length 12.0 (Hours) Total Drawdown 285 (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)
0	50	36	Conductor	A53 Grade B	5/16	32		
0	715	26	Blank	Copper Bearing	5/16	14		
715	750	26	Perf	Moss Ful Flo	5/16	14	Louver	0.070
750	880	26	Perf	Standard Flo	5/16	14	Louver	
880	900	26	Perf	Moss Ful Flo	5/16	14	Louver	0.070
900	920	26	Perf	Standard Flo	5/16	14	Louver	

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
0	50	Cement	Annular Seal
0	1,205	Filter Pack	Path #12 SRI

Attachments

☐ Geologic Log
☐ Well Construction Diagram
☐ Geophysical Log(s)
☐ Soil/Water Chemical Analyses
☐ Other

Attach additional information, if it exists.

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name Bakersfield Well & Pump Co.
Person, Firm or Corporation

7212 Fruitvale Ave. Bakersfield CA 93308
Address City State Zip

Signed [signature] 7/21/2009 440537
Licensed Water Well Contractor Date Signed C-57 License Number

DWR 188 REV. 1/2006

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

26/21— 1443

Clay	0 to 27	27
Sand	27 to 117	90
Clay	117 to 197	80
Sand	197 to 212	15
Clay	212 to 251	39
Sand	251 to 280	29
Clay	280 to 327	47

Drilled by Sage Bros

MICROFILMED Roll 12

26/[illegible]-20 26/21-21M

Do Not Fill In

ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

No 149592

State Well No. _____

Other Well No. _____

(2) LOCATION OF WELL:

County /Kern Owner's number, if any

Township, Range, and Section

Distance from cities, roads, railroads, etc. 440ft N of GPRd. 1000ft W. of Calif. Aquaduct

(3) TYPE OF WORK (check):

New Well ☒ Deepening ☐ Reconditioning ☐ Destroying ☐

If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☒ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary Rev. ☒
Cable ☐
Other ☐

(6) CASING INSTALLED:

STEEL: X OTHER:

SINGLE ☒ DOUBLE ☐

If gravel packed

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	From ft.	To ft.
0	570	14	1/4	28	0	580

Size of shoe or well ring: bull nose Size of gravel: 5/16x4

Describe joint

(7) PERFORATIONS OR SCREEN:

Type of perforation or name of screen Louver

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.
300	570	8	4 1/2	1/8x2 3/8

(8) CONSTRUCTION:

Was a surface sanitary seal provided? Yes ☐ No ☐ To what depth ft.

Were any strata sealed against pollution? Yes ☐ No ☐ If yes, note depth of strata

From ft. to ft.

From ft. to ft.

Method of sealing

(9) WATER LEVELS:

Depth at which water was first found, if known ft.

Standing level before perforating, if known ft.

Standing level after perforating and developing ft.

(10) WELL TESTS:

Was pump test made? Yes ☐ No ☐ If yes, by whom?

Yield: gal./min. with ft. drawdown after hrs.

Temperature of water Was a chemical analysis made? Yes ☐ No ☐

Was electric log made of well? Yes ☐ No ☐ If yes, attach copy

(11) WELL LOG:

Total depth 580 ft. Depth of completed well 570 ft.

Formation: *Describe by color, character, size of material, and structure*

ft. to	ft.	
0-8		top soil
8-25		clay
25-60		sand
60-75		clay
75-105		sand
105-135		clay
135-150		sand
150-182		clay
182-191		sand
191-350		clay
350-352		sand 2
352-363		clay
363-373		sand 10
373-394		clay
394-402		sand 8
402-414		clay
414-415		sand 1
415-421		clay
421-422		sand 1
422-427		clay
427-445		sand 18
445-447		clay
447-474		sand 27
474-475		clay
475-477		sand 2
477-480		clay
480-520		sand 40
520-534		clay
534-565		sand 31
565-580		clay

UNCONFINED

Work started Mar. 23 19 76 Completed Mar. 25 19 76

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Grabow Well Drilling Co.
(Person, firm, or corporation) (*Typed or printed*)

Address 12522-9th Ave.
Hanford, Calif.

[SIGNED] Glen Grabow
(Well Driller)

License No. 288489 Dated Mar. 31, 19 76

SKETCH LOCATION OF WELL ON REVERSE SIDE

ORIGINAL
File with DWR

Page 1 of 1

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

DWR USE ONLY — DO NOT FILL IN
27S/21E-10
STATE WELL NO./STATION NO
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. LOST HILLS TULARE WATER WELL No. 748832

Date Work Began 3-20-01, Ended

Local Permit Agency KERN COUNTY ENVIRONMENTAL HEALTH

Permit No. EH -757 Permit Date 2-20-01

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD REVERSE CIRCULATION FLUID POLY BORE

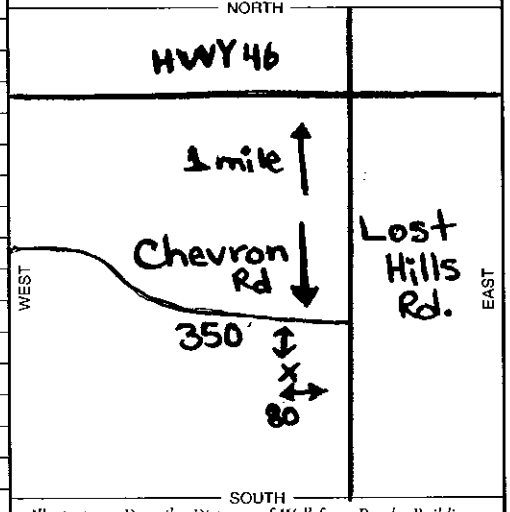
DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
50	60	CLAY & SAND
60	100	CLAY
100	110	SAND & CLAY
110	150	SAND
150	170	SAND & CLAY
170	210	SAND
210	230	SAND & SILT
230	240	CLAY
240	260	CLAY & SAND
260	270	SAND
270	290	SAND & CLAY
290	300	SAND
300	310	SAND & SM GRAVEL
310	330	SAND
330	360	SAND & CLAY
360	420	SAND
420	470	SAND & CLAY
470	590	SAND
590	630	FINE SAND
630	660	SAND
660	690	SAND & CLAY
690	720	CLAY
720	790	SAND & CLAY
790	830	CLAY
830	880	SAND & CLAY
880	930	CLAY & SHALE
930	960	SAND & SHALE
960	1020	SAND, SHALE, & CLAY
1020	1040	CLAY

TOTAL DEPTH OF BORING 1040 (Feet)
TOTAL DEPTH OF COMPLETED WELL 865' (Feet)

WELL LOCATION

Address 1 MILE SOUTH OF HWY 46 WEST SIDE OF LOST HILLS RD
City LOST HILLS
County KERN
APN Book 069 Page 011 Parcel 34
Township 27 S Range 21 E Section 10 A
Latitude ___ DEG. ___ MIN. ___ SEC. NORTH Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH



*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivery, etc and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.***

ACTIVITY (✓)
X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USES (✓)
WATER SUPPLY
___ Domestic X Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 268 (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 268 (Ft.) & DATE MEASURED 5-8-01
ESTIMATED YIELD * 1500 (GPM) & TEST TYPE CONSTANT FLOWMETER
TEST LENGTH 24 (Hrs.) TOTAL DRAWDOWN 162 (Ft.)
** May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	50	42			x		ASTM 139	32	3/8	
+ 2	420	28	x				316 L SS	16	5/16	
420	670	28		x			SS FUL FLO	16	5/16	.050
670	790	28	x				316 L SS	16	5/16	
790	845	28		x			SS FUL FLO	16	5/16	.050
845	865	28	x				316 L SS	16	5/16	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	360	x			
360	870				8 x 20 CCSI

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME BAKERSFIELD WELL & PUMP (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

7212 FRUITVALE AVE. ADDRESS BAKERSFIELD CITY CA. STATE 93308 ZIP

Signed [signature] WELL DRILLER/AUTHORIZED REPRESENTATIVE 6-14-01 DATE SIGNED 440537 C-57 LICENSE NUMBER

DWR 188 REV 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

*The free Adobe Reader may be used to view and complete this form. However, software must be purchased to complete, save, and reuse a saved form.

File Original with DWR

State of California

Well Completion Report

Refer to Instruction Pamphlet

No. e0316813

7106-63

Page 1 of 2

Owner's Well Number 74

Date Work Began 07/11/2016 Date Work Ended 7/15/2016

Local Permit Agency Kern

Permit Number 17252 Permit Date

DWR Use Only – Do Not Fill In

State Well Number/Site Number

Latitude N Longitude W

APN/TRS/Other

Geologic Log

Orientation ◉ Vertical ○ Horizontal ○ Angle Specify

Drilling Method Reverse Rotary Drilling Fluid

Depth from Surface Feet	to Feet	Description (Describe material, grain size, color, etc)
	0	Heavy Top Soil
	50	Sand
	61	Blue Clay
	64	Sand
	104	Blue Clay
	111	Sand
	118	Sand & Clay
	124	Sand
	141	Blue Clay
	146	Sand
	175	Clay
	180	Sand
	193	Blue Clay
	205	Sand
	213	Blue Clay
	224	Sand
	237	Blue Clay
	244	Sand
	253	Blue Clay
	263	Fine Sand
	282	Clay
	290	Sand
	297	Clay
	301	Sand
	305	Clay
	310	Sand
	317	Clay
	336	Sand
	344	Brown Clay
	370	Sand

Total Depth of Boring 700 Feet

Total Depth of Completed Well 680 Feet

Well Owner

Name Wonderful Nut Orchards Well - 30-1-4

Mailing Address 6801 E. Lerdo Hwy

City Shafter State CA Zip 93263

Well Location

Address 3.58 mile N/Lerdo Hwy - 1 mile W/ Main Drain Rd.

City Lost Hills County Kern

Latitude Deg. Min. Sec. N Longitude Deg. Min. Sec. W

Datum Dec. Lat. Dec. Long.

APN Book 069 Page 240 Parcel 51

Township Range Section

Location Sketch

(Sketch must be drawn by hand after form is printed.)

North

West East

South

Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. Please be accurate and complete.

Activity

◉ New Well

○ Modification/Repair

○ Deepen

○ Other

○ Destroy

Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

◉ Water Supply

☐ Domestic ☐ Public

☑ Irrigation ☐ Industrial

○ Cathodic Protection

○ Dewatering

○ Heat Exchange

○ Injection

○ Monitoring

○ Remediation

○ Sparging

○ Test Well

○ Vapor Extraction

○ Other

Water Level and Yield of Completed Well

Depth to first water (Feet below surface)

Depth to Static Water Level (Feet) Date Measured

Estimated Yield * (GPM) Test Type

Test Length (Hours) Total Drawdown (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)
0	700	28						
0	260		Blank	PVC	1.024	17.4		
260	460		Perf	PVC	1.024	17.4		0.050
460	520		Blank	PVC	1.024	17.4		
520	660		Perf.	PVC	1.024	17.4		0.050
660	680		Blank	PVC	1.024	17.4		

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
0	150	Cement	
150	680		1/4 X #8

Attachments

☐ Geologic Log

☐ Well Construction Diagram

☐ Geophysical Log(s)

☐ Soil/Water Chemical Analyses

☐ Other

Attach additional information, if it exists.

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name Anthony J. Prieto Water Well Drilling, Inc.
Person, Firm or Corporation

891 Golden State Blvd. Selma CA 93662
Address City State Zip

Signed Anthony J. Prieto 07/20/2016 C-57 425883
C-57 Licensed Water Well Contractor Date Signed C-57 License Number

DWR 188 REV. 1/2006

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

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State of California

Well Completion Report

Refer to Instruction Pamphlet

No. xxxxxxx

Page 2 of 2

Owner's Well Number _____

Date Work Began _____ Date Work Ended _____

Local Permit Agency Kern

Permit Number _____ Permit Date _____

DWR Use Only – Do Not Fill In

State Well Number/Site Number

N Latitude Longitude W

APN/TRS/Other

Geologic Log

Orientation ○ Vertical ○ Horizontal ○ Angle Specify _____

Drilling Method _____ Drilling Fluid _____

Depth from Surface Feet	to Feet	Description (Describe material, grain size, color, etc.)
	378	Clay
	381	Sand
	387	Clay
	391	Sand
	419	Clay
	434	Sand
	444	Clay
	462	Sand & Clay
	467	Clay
	470	Sand
	475	Clay
	515	Sand & Clay
	523	Clay
	541	Sand
	548	Clay
	556	Sand
	559	Clay
	570	Sand
	588	Clay
	593	Sand
	606	Clay
	611	Sand
	618	Sandy Clay
	631	Sand
	645	Sandy Clay
	662	Sand
	669	Sandy Clay
	676	Clay
	684	Sand 697 Sandy Clay
	691	Clay 700 Stopped Drilling

Total Depth of Boring _____ Feet

Total Depth of Completed Well _____ Feet

Well Owner

Name Wonderful Nut Orchard Well 30-1-4

Mailing Address _____

City _____ State _____ Zip _____

Well Location

Address _____

City _____ County _____

Latitude _____ Deg. _____ Min. _____ Sec. N Longitude _____ Deg. _____ Min. _____ Sec. W

Datum _____ Dec. Lat. _____ Dec. Long. _____

APN Book _____ Page _____ Parcel _____

Township _____ Range _____ Section _____

Location Sketch

(Sketch must be drawn by hand after form is printed.)

North

West East

South

Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. **Please be accurate and complete.**

Activity

○ New Well
○ Modification/Repair
  ○ Deepen
  ○ Other _____
○ Destroy
  Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

○ Water Supply
  ☐ Domestic ☐ Public
  ☐ Irrigation ☐ Industrial
○ Cathodic Protection
○ Dewatering
○ Heat Exchange
○ Injection
○ Monitoring
○ Remediation
○ Sparging
○ Test Well
○ Vapor Extraction
○ Other _____

Water Level and Yield of Completed Well

Depth to first water _____ (Feet below surface)

Depth to Static Water Level _____ (Feet) Date Measured _____

Estimated Yield * _____ (GPM) Test Type _____

Test Length _____ (Hours) Total Drawdown _____ (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)

Annular Material

Depth from Surface Feet	to Feet	Fill	Description

Attachments

☐ Geologic Log
☐ Well Construction Diagram
☐ Geophysical Log(s)
☐ Soil/Water Chemical Analyses
☐ Other _____

Attach additional information, if it exists.

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name Anthony J. Prieto
Person, Firm or Corporation

_____ CA _____
Address City State Zip

Signed Anthony J. Prieto 07/20/2016
C-57 Licensed Water Well Contractor Date Signed C-57 License Number

DWR 188 REV. 1/2006

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

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7106-62

State of California

Well Completion Report

Refer to Instruction Pamphlet

No. e0318219

Page 1 of 2

Owner's Well Number 78

Date Work Began 07/19/2016 Date Work Ended 7/25/2016

Local Permit Agency Kern

Permit Number WP 17253 Permit Date 7/19/16

DWR Use Only – Do Not Fill In

State Well Number/Site Number

N W

Latitude Longitude

APN/TRS/Other

Geologic Log

Orientation ◉ Vertical ○ Horizontal ○ Angle Specify

Drilling Method Reverse Rotary Drilling Fluid

Depth from Surface Feet	to Feet	Description (Describe material, grain size, color, etc)
	0	Heavy Top Soil
	50	Sand
	71	Clay
	75	Sand
	94	Clay
	104	Sand
	196	Blue Clay
	234	Sand
	245	Clay
	251	Sand & Gravel
	261	Blue Clay
	272	Sand
	288	Clay
	295	Sandy Clay
	302	Clay
	311	Sand
	315	Clay
	321	Sand
	329	Clay
	336	Sand
	351	Clay
	364	Sandy Clay
	371	Brown Clay
	395	Sand
	414	Clay
	417	Sandy Clay
	420	Sand
	423	Clay
	425	Sand
	427	Clay

Total Depth of Boring 700 Feet

Total Depth of Completed Well 680 Feet

Well Owner

Name Wonderful Nut Orchards - Well 30-4

Mailing Address 6801 E. Lerdo Hwy

City Shafter State CA Zip 93263

Well Location

Address 3.08 mile N /Lerdo Hwy - 1 mile W/Main Drain Rd.

City Shafter County Kern

Latitude Deg. Min. Sec. N Longitude Deg. Min. Sec. W

Datum Dec. Lat. Dec. Long.

APN Book 069 Page 240 Parcel 52

Township 27S Range 22E Section 30

Location Sketch

(Sketch must be drawn by hand after form is printed.)

North

West East

South

Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. Please be accurate and complete.

Activity

◉ New Well

○ Modification/Repair

○ Deepen

○ Other

○ Destroy

Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

◉ Water Supply

☐ Domestic ☐ Public

☑ Irrigation ☐ Industrial

○ Cathodic Protection

○ Dewatering

○ Heat Exchange

○ Injection

○ Monitoring

○ Remediation

○ Sparging

○ Test Well

○ Vapor Extraction

○ Other

Water Level and Yield of Completed Well

Depth to first water (Feet below surface)

Depth to Static Water Level (Feet) Date Measured

Estimated Yield * (GPM) Test Type

Test Length (Hours) Total Drawdown (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)
0	700	28						
0	240		Blank	PVC	1.024	17.4		
240	540		Perf.	PVC	1.024	17.4		0.050
540	600		Blank	PVC	1.024	17.4		
600	680		Perf.	PVC	1/024	17.4		0.050

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
0	205	Cement	
205	680		1/4 X #8

Attachments

☐ Geologic Log

☐ Well Construction Diagram

☐ Geophysical Log(s)

☐ Soil/Water Chemical Analyses

☐ Other

Attach additional information, if it exists.

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name Anthony J. Prieto Water Well Drilling, Inc.
Person, Firm or Corporation

891 So.Golden State Blvd. Selma CA 93662
Address City State Zip

Signed Anthony J. Prieto 08/01/2016 C-57 425883
C-57 Licensed Water Well Contractor Date Signed C-57 License Number

DWR 188 REV. 1/2006

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

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State of California

Well Completion Report

Refer to Instruction Pamphlet

No. xxxxxxx

Page 2 of 2

Owner's Well Number _____

Date Work Began _____ Date Work Ended _____

Local Permit Agency Kern

Permit Number WP 17253 Permit Date _____

DWR Use Only – Do Not Fill In

State Well Number/Site Number

N Latitude W Longitude

APN/TRS/Other

Geologic Log

Orientation ○ Vertical ○ Horizontal ○ Angle Specify _____

Drilling Method _____ Drilling Fluid _____

Depth from Surface Feet	to Feet	Description Describe material, grain size, color, etc
	429	Coarse Sand
	433	Clay
	437	Sand
	459	Clay
	474	Sand
	477	Clay
	480	Sand
	483	Blue Clay
	497	Coarse Sand
	516	Clay
	524	Sand
	532	Clay
	534	Sand
	538	Clay
	554	Sand
	559	Clay
	573	Sand
	577	Hard Clay
	580	Sand
	585	Clay
	611	Hard Clay
	616	Blue clay
	629	Sand
	637	Clay
	640	Sand
	669	Clay
	680	Sand
	686	Clay
	700	Stopped Drilling

Total Depth of Boring _____ Feet

Total Depth of Completed Well _____ Feet

Well Owner

Name Wonderful Nut Orchards Well 30-4

Mailing Address _____

City _____ State _____ Zip _____

Well Location

Address _____

City _____ County _____

Latitude _____ Deg. _____ Min. _____ Sec. N Longitude _____ Deg. _____ Min. _____ Sec. W

Datum _____ Dec. Lat. _____ Dec. Long. _____

APN Book _____ Page _____ Parcel _____

Township _____ Range _____ Section _____

Location Sketch

(Sketch must be drawn by hand after form is printed.)

North

West East

South

Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. Please be accurate and complete.

Activity

○ New Well
○ Modification/Repair
○ Deepen
○ Other _____
○ Destroy
Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

○ Water Supply
☐ Domestic ☐ Public
☐ Irrigation ☐ Industrial
○ Cathodic Protection
○ Dewatering
○ Heat Exchange
○ Injection
○ Monitoring
○ Remediation
○ Sparging
○ Test Well
○ Vapor Extraction
○ Other _____

Water Level and Yield of Completed Well

Depth to first water _____ (Feet below surface)

Depth to Static Water Level _____ (Feet) Date Measured _____

Estimated Yield * _____ (GPM) Test Type _____

Test Length _____ (Hours) Total Drawdown _____ (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)

Annular Material

Depth from Surface Feet	to Feet	Fill	Description

Attachments

☐ Geologic Log
☐ Well Construction Diagram
☐ Geophysical Log(s)
☐ Soil/Water Chemical Analyses
☐ Other _____

Attach additional information, if it exists.

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name Anthony J. Prieto

Person, Firm or Corporation

Address _____ City _____ CA State _____ Zip _____

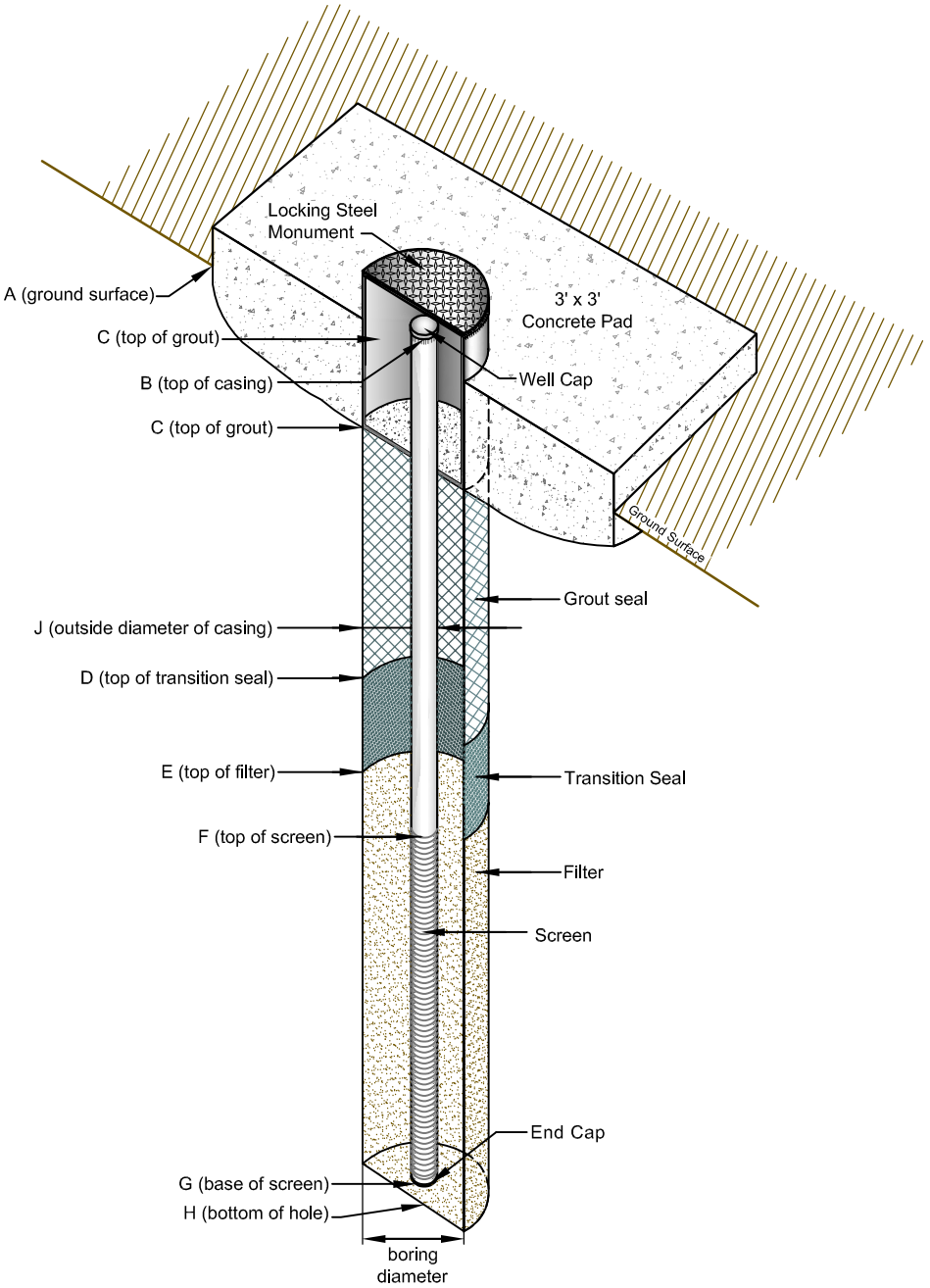
Signed Anthony J. Prieto 08/01/2016

C-57 Licensed Water Well Contractor Date Signed

C-57 License Number

DWR 188 REV. 1/2006

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



Well Number	Elevation [1] (ground surface)	Elevation [1] (top of casing)	Depth Below Ground Surface (feet)						Diameter (inches)	
	A	B	C	D	E	F	G	H	I	J
13A1	344.0	346.3	0	57	63	70.0	89.3	95	10	4
13A2	343.5	345.8	0	106	112	125.0	144.5	150	10	4
20J1 [2]	558.1	560.5	0	289	295	299.9	319.4	322	10	4
20J2 [2]	558.0	560.4	0	376	395	400.1	419.6	422	10	4
21C1R	503.4	505.8	0	200	205	210.0	229.5	235	10	4
21C2R	503.7	506.2	0	300	335	340.0	359.4	362	10	4
22N1 [2]	510.3	512.6	0	298	304	315.0	334.5	340	10	4
22N2 [2]	510.0	512.7	0	386	392	400.3	419.8	423	10	4
23D1	438.9	441.4	0	105	110	115.1	134.2	140	10	4
23D2	438.5	441.1	0	165	170	175.2	194.8	200	10	4
24J1	359.7	362.4	0	89	95	100.0	119.5	123	10	4
24J2	359.7	362.3	0	164	175	180.0	199.5	203	10	4
25J1R	371.4	373.9	0	118	124	130.0	149.2	155	10	4
25J2R	371.0	373.7	0	255	260	270.2	289.3	295	10	4
22N1A [2,3]	--	--	0	306	310	315.0	334.5	342	10	4

Well Construction	
Casing	4-inch Schedule 80 PVC
Screen	4-inch Schedule 80 PVC, 0.02-inch slot size
Filter Material	No. 3 sand
Transition Seal	Hydrated bentonite pellets
Grout Seal	Cement grout with 5% bentonite by weight and bentonite grout
Surface Finish	10" locking steel stovepipe, centered in a 3x3 concrete pad

Notes:

1. Elevation in feet above mean sea level (NAD27).
2. Grout seal consists of bentonite grout and neat cement grout installed at different intervals. See Table 1 for grout seal intervals.
3. Decommissioned due to melted casing. Backfilled with neat cement and upper 15' removed.

MONITORING WELL CONSTRUCTION DIAGRAM
Aera Belridge 2013 Well Installation
South Belridge Oil Field
Kern County, California

By: DB	Date: 12/02/2013	Project No. 0053750000
amec		Figure 2

Plot Date: 12/02/13 - 2:16pm, Plotted by: diana.babshoff
Drawing Path: N:\5000s\005375\acad\2013\2013-10_WellInstallation\, Drawing Name: _fig02_SBelridge_MonWellConstDiagram.dwg

WP 14158 13A1
Permit/Well #WP 14159 13A2

Kern County Public Health Services Department,
Environmental Health Division
2700 "M" Street, Suite 300, Bakersfield, CA 93301
Phone (661) 321-3000 FAX (661) 862-8701
www.co.kern.ca.us/eh/

Starting Date 5-20-13

APPLICATION FOR WATER WELL PERMIT

APPLICATION MUST BE SUBMITTED AT LEAST TEN (10) WORKING DAYS PRIOR TO THE PROPOSED STARTING DATE

Mark Type of Permit: ☑ Construct New ☐ Reconstruct/Modify ☐ Deepen ☐ Destroy

Type of Well

☐ Domestic/Private (1)
☐ Domestic (2-4 connections)
☐ Domestic (5 or more connections)
☐ Agricultural
☐ Test Hole
☑ Monitoring
☐ Cathodic Protection
☐ Vadose
☐ Other _____

MARK ONE OF THE BOXES BELOW FOR THE PARTY RESPONSIBLE FOR PAYMENT OF FEES

OWNER'S INFORMATION			PROPERTY/FACILITY INFORMATION		
☐ Name: Aera Energy LLC, Attn: Ken Knight			☐ Name: Paramount Farming Company		
Address: 10000 Ming Avenue, P.O. Box 11164			Address: 33141 E. Lerdo Highway		
City: Bakersfield	State: CA	Zip: 93389	City: Bakersfield	State: CA	Zip: 93308
Phone: 661.665.5094	e-mail: KKnight@aeraenergy.com		APN: 085-200-26	T: 28S R: 21E	Sec: 13
CONTRACTOR'S INFORMATION					
☑ Environmental Contractor: AMEC Environment & Infrastructure, Inc.			☐ Drilling Contractor: Cascade Drilling, LP		
Address: 1281 East Alluvial Avenue, Ste. 101			Address: 555 South Harbor Blvd.		
City: Fresno	State: CA	Zip: 93720	City: La Habra	State: CA	Zip 90631
Contact : Leslie Purvis	Phone: 559.892.2921		Contact: Mike Gray	Phone: 562.929.8176	
e-mail: leslie.purvis@amec.com			e-mail: MGray@cascadedrilling.com		

LOCATION OF WELL: **TOTAL ACRES** _____

Attach a plot plan with the exact location of water well with respect to the following items: property lines, adjoining properties, water bodies or courses, drainage pattern, roads, existing wells, structures, sewers or private disposal systems. Include dimensions. Draw a 200' radius circle from well site location. For monitoring wells provide a description of the facility to be monitored, including: location of tanks, proposed monitoring and placement, nearest street or intersection, location of any water wells or surface water within 500' radius of facility.

Provide detailed directions to site:

Wells are located 1,335 feet south and 1,100 feet west of the intersection of Lerdo Highway and Starrh Road.

Starrh Road is located 2 miles east of the intersection of Lerdo Highway and Lost Hills Road.

See attached site plan for general well locations.

WELL CONSTRUCTION INFORMATION

WP 14158 WP 14159

METHOD: ☐ Reverse Rotary ☒ Rotary ☐ Air Rotary ☐ Hollow Stem Auger ☐ Other: _____

WELL NAME / NUMBER	13A1	13A2	
MAXIMUM WELL DEPTH	95 feet	150 feet	
SEALING MATERIAL	Neat Cement	Neat Cement	
SEAL DEPTH (HARD ROCK/UNCONSOLIDATED)	0 feet - 60 feet	0 feet - 115 feet	
CASING MATERIAL & GAUGE	Schedule 80 PVC	Schedule 80 PVC	
CASING - INSIDE DIAMETER	4-inch	4-inch	
SCREEN/PERFORATION DEPTH	70 feet - 90 feet	125 feet - 145 feet	
CONDUCTOR DEPTH	N/A	N/A	
CONDUCTOR DIAMETER	N/A	N/A	
DEPTH TO GROUNDWATER	N/A	71 feet	
LOCKING WELL CAP	Yes	Yes	
BOREHOLE DIAMETER	8-inch	8-inch	
SCREEN MATERIAL & GAUGE	Schedule 80 PVC	Schedule 80 PVC	
TYPE OF BENTONITE PLUG & DEPTH	60 feet Hydrated Bentonite Pellets	115 feet Hydrated Bentonite Pellets	
FILTER PACK MATERIAL & SIZE	# 3 Sand	# 3 Sand	
SCREEN SLOT SIZE & LENGTH	0.020 - inch/20 feet	0.020 - inch/20 feet	
SEALANT PLACEMENT METHOD	Tremie Pipe	Tremie Pipe	

WELL DESTRUCTION INFORMATION

WELL NUMBER			
WELL DEPTH			
CASING MATERIAL			
SEALANT MATERIAL			
SEALANT PLACEMENT METHOD			

GENERAL CONDITIONS FOR DESTRUCTION:

1. A well destruction application must be filed with this Division if a well is being destroyed that is not in conjunction with a test hole permit.
2. Destruction procedures must be followed as per UT-50.
3. Placement of the seal must be witnessed by a representative of this Division. Forty-eight hour advanced notice is required for an appointment.

SPECIAL CONDITIONS:

13A1
13A2

GENERAL CONDITIONS FOR ALL PERMITS:

Permit applications may be submitted to the Planning Department by county staff for zoning, access, and flood plain clearances prior to approval of the Environmental Health Division (EHD). If you are drilling within city's limits, you will have to receive approval from their Planning Department:

1. Permit applications must be submitted to EHD at least ten (10) working days prior to the proposed starting date.
2. Well site approval is required before beginning any work related to water well construction. It is unlawful to continue work past the stage at which an inspection is required unless inspection is waived or completed.
3. Other required inspections include: setting conductor casing, E-Logs, all seals, and final construction features.
4. In areas where a water well penetrates more than one aquifer, and one or more of the aquifers may contain water which is of a quality which may degrade the other aquifer(s) penetrated if allowed to commingle, an E-Log shall be required to determine the location of the confining clay layer(s) and assist in the placement of any required annular seal(s).
5. A phone call to the Division Hotline at (661) 862-8788 is required 48 hours before the placement of any seals or plugs.
6. Approval of water quality and final construction features is required before the water well is put into use.
7. Construction under this permit is subject to any instructions by EHD representatives.
8. Any misrepresentation or noncompliance with required permit conditions, or regulations, will result in issuance of a "Stop Work Order."
9. A copy of the Department of Water Resources Driller's Report and water quality analyses must be submitted to EHD within sixty (60) days after completion of the work.
10. "Dry" holes must be properly destroyed within two (2) weeks of drilling. A water well destruction application must be filed with EHD.
11. The permit is void one (1) year after date of issuance if work has not been started and reasonable progress toward completion made. Fees are not refundable or transferable.
12. Lead appurtenances shall not be used in construction of any private or public water supply system. The use of solders containing more than 2/10 of 1% lead is prohibited in making joints and fittings in any private or public potable water system.
13. Drilling of a water well shall be performed by a C-57 contractor licensed in accordance with the provisions of the Contractors License Law (Chapter 9, Division 3, of the Business and Professions Code) unless exempted by that act, and registered to drill within the County of Kern.
14. Permittee shall assume entire responsibility for all activities and uses under this permit and shall indemnify, defend and save the County of Kern and/or Kern County Water Agency, its officers, agents, and employees, free and harmless from any and all expense, cost or liability in connection with or resulting from the exercise of this permit, including, but not limited to, property damage, personal injury, and wrongful death.

☑ I UNDERSTAND THAT FUTURE DEVELOPMENT PERMITS MAY NOT BE ISSUED (KCOC 17.04.120) UNLESS RECORDED LEGAL ACCESS TO THE PROPERTY CAN BE DEMONSTRATED.

I certify that I am the owner of the above-described property, or the authorized representative of such owner, and that all the information I have furnished is current and accurate to the best of my knowledge, and I intend to construct the water well as represented above. I understand that all work is to be done in accordance with Kern County Ordinance Code Chapter 14.08, Bulletin 74-81 and all subsequent bulletins and the conditions of the Permit Application, including any conditions which may be added or changed by EHD upon review of this Application and issuance of the Permit. I further understand that any permit issued pursuant to this application is subject to such further conditions as may be deemed necessary to ensure compliance with the permit regulations.

X Owner's Signature _____ Date 5-6-13 Authorized Agent or Agency _____ Date _____

THIS APPLICATION BECOMES A PERMIT WHEN APPROVED

For internal use only

Permit Approved: [signature]	Total Fee: 1,425 Date Paid: 5-8-13
Date: 5/16/13	Receipt #: 196251 ☐ Cash ☑ Check (# 304101)
Expiration Date:	Fee received by: [signature]
Zone: A	E-Log Required: ☐ Yes ☐ No
Flood Plain Approval Required: ☐ Yes ☑ No	Faxed to KCWA on _____ by _____

REASONS FOR DENIAL OR CONDITIONS OF PERMIT:

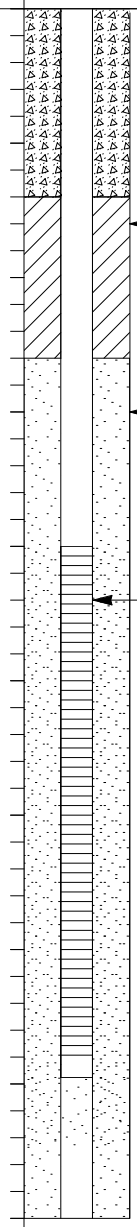
PROJECT: Aera Belridge Well Installation	**Log of Well No. 13A1**
BORING LOCATION:	GROUND SURFACE ELEVATION AND DATUM:
DRILLING CONTRACTOR: Cascade Drilling	DATE STARTED: 6/14/13 / DATE FINISHED: 6/14/13
DRILLING METHOD: DM	TOTAL DEPTH (ft.): 95.0 / SCREEN INTERVAL (ft.): 70-89.26
DRILLING EQUIPMENT: Star 50k	DEPTH TO WATER ATD: / CASING:
SAMPLING METHOD: Grab	LOGGED BY: Alex Olsen
HAMMER WEIGHT: / DROP:	RESPONSIBLE PROFESSIONAL: / REG. NO.

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/ 6 inches	PID Reading (ppm)	DESCRIPTION: NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
					Surface Elevation:	
1–4						First 5 feet hand augered
5–9					CLAY (CL): ~100% fines, low plasticity, trace fine sand	Type II/V Portland Neat Cement Grout with 5% Bentonite
10–19					Becomes ~90% fines, ~10% fine sand	4-inch diameter schedule 80 PVC
20–24					POORLY GRADED SAND (SP): ~100% medium to coarse sand, trace gravel	
25–29					CLAY (CL): ~90% fines, ~10% fine to medium sand, trace gravel	
30–39					POORLY GRADED SAND (SP): ~100% medium to coarse sand, trace gravel	
40–50					CLAY (CL): ~90% fines, ~10% fine to medium sand, trace gravel, low placticity, low toughness	

PROJECT: Aera Belridge Well Installation

Log of Well No. 13A1 (cont'd)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/ 6 inches	PID Reading (ppm)	DESCRIPTION: NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
51–110					CLAY (CL): ~80% fines, ~20% fine to coarse sand, trace gravel, low plasticity, low toughness	Hydrated Pel-plug Bentonite Chips; #3 Lapis Lustre sand; 0.02-inch slot 4-inch diameter schedule 80 PVC
					CLAY with SAND (CL): ~80% fines, ~20% fine to coarse sand, trace gravel, low plasticity, low toughness	
					Bottom of hole at 95 feel below ground surface	



ORIGINAL

File with DWR

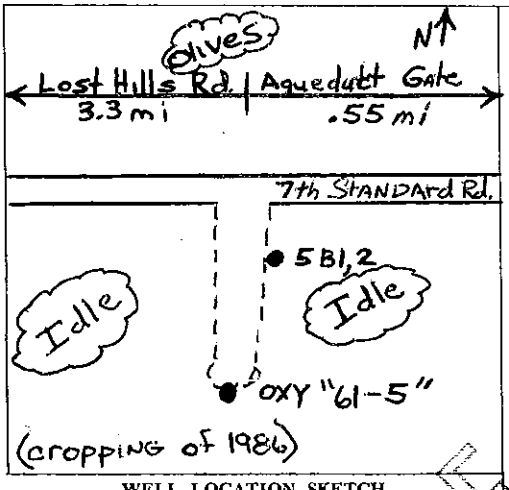
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not fill in
No. 154332
State Well No. 29/22-5
Other Well No.

N e of Intent No.
L . Permit No. or Date

(2) LOCATION OF WELL (See instructions): 5B shallow

County Kern Owner's Well Number 5B Deep
Well address if different from above Belridge Field
Township 29 S. Range 22 E. Section 5 NW 1/4 NE 1/4
Distance from cities, roads, railroads, fences, etc. 1643' W., 90' S. of NE cor. 5-29/22, 75' S. centerline 7th Standard Rd., 3.3 miles E. of Lost Hills Rd.



WELL LOCATION SKETCH

(3) TYPE OF WORK:

New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:

Domestic ☐
Irrigation ☐
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other Monitors ☒

(5) EQUIPMENT: Percussion

Rotary ☐ Hammer Reverse ☒
Cable ☐ Air ☒
Other ☐ Bucket ☐

(6) GRAVEL PACK: Monterey

Yes ☒ No ☐ Size #8
Diameter of bore 10 1/4"
Packed from 175'28" to 274'154" ft.

(7) CASING INSTALLED:

Steel ☐ Plastic ☒ Concrete ☐

(8) PERFORATIONS: .020"

Type of perforation or size of screen

	From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
Shallow	0	80	2"	sch 40	80	100	.020"
	100	110	2"	sch 40			
Deep	0	191	2"	sch 40	191	211	.020"
	211	221					

(9) WELL SEAL:

Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 20 ft.
Were strata sealed against pollution? Yes ☒ No ☐ Interval 153-173 ft.
Method of sealing Bentonite Pellets 1/4"

(10) WATER LEVELS:

Depth of first water, if known ft.
Standing level after well completion ft.

(11) WELL TESTS:

Was well test made? Yes ☐ No ☐ If yes, by whom?
Type of test Pump ☐ Bailer ☐ Air lift ☐
Depth to water at start of test ft. At end of test ft
Discharge gal/min after hours Water temperature
Chemical analysis made? Yes ☐ No ☐ If yes, by whom?
Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

(12) WELL LOG:

Total depth 274 ft. Depth of completed well 274 ft.

from ft. to ft. Formation (Describe by color, character, size or material)

See attached

Two - 2" wells completed in the same borehole

Work started Sept 1986 Completed Oct 3 1986

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

SIGNED Steve Story (Well Driller)
NAME Layne-Western Co. Inc. (Person, firm, or corporation) (Typed or printed)
Address P.O. Box 3216
City Bakersfield, CA Zip
License No. 452609 C-57 Date of this report 12-1-86

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

CONFIDENTIAL
PUBLIC USE
UNDER WATER CODE SEC. 13752

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

State No. 29s/22e-5B2

WELL DATA

BRANCH

Depths	REMARKS	REMARKS color	S in.
CUTTINGS AT 5' INTERVALS; NO MUD; Dual-wall percussion hammer			
5-15	VF SAND, silty; rare clasts of CR shale; common whitish carbonate flecks	Lt. yellow brown	VIS
20	M-C SAND, silty	"	VIS
25	C SAND with much F gvl (mostly broken chips of CR shale); prominant silt	"	VIS
30-50	Clayey sandy SILT; occ'l clasts of CR shale	"	VIS
55	F SAND, silty; " " " " "	"	MS
60-70	F-M SAND, silty	"	MS
75	WS silty VF SAND and IS C SAND and GRAVEL	Lt. brown	—
80-85	Clayey SILT with appreciable scattered sand	Lt. yellow brown	—
90-95	Silty CLAY	"	—
100-135	Predominantly CLAY; variable sand & silt in strx	"	—
140	Clayey SILT	Dk "	—
145-195	CLAY, as 100-135	Lt "	—
200-205	Silty CLAY with abundant scattered sand grains	Lt brown	—
210	[Due casing blockage and running sand, NO sample]	—	—
* 215	M SAND; subrd-subang; prominent mica and mafics; common orangish feldspar(?); occ'l nubbins of compacted yellowish-brown F sand; Sierran	Gray	WS
220	As 215, but coarse grained	"	"
225	Mixed: (1) as 220; (2) compact clayey sandy silt	—	—
230	As 225 (2)	Tan	—
235	VF-C SAND, silty, clayey; compact; abundant irregular stainings of black manganese and yellow/red limonite. A paleosol? Grayish where unstained; generally a blackish aspect.	—	VIS
* 240	C SAND & GVL; sand as at 220 (with mica, mafics & orange feldspar?); but gravel is subrounded CR shale lozenges to 3 cm & chert.	Gray	IS
245	Clayey sandy SILT; compact; sand to VF size; abundant irregular stains & nodules of orange limonite. Paleosol?	Gray (where unstained)	—
250	Mixed: (1) Clayey sandy SILT, sim. to 245; (2) compact clayey SILT with limonite stainings; (3) C SAND & GVL as 240.	Gray	IS
255	M-C SAND; subrd-subang; mica, mafics, orange feldspar(?); occ'l CR gravel to 10 mm	"	MS
260	Silty CLAY and sandy clayey SILT	Lt. brown	—
265	clayey SILT; compact; main mass is greenish-gray but there are irregular mottles of yellowish-brown	Greenish-gray	—
269	Clayey silty VF SAND	Blwish-gray	VIS
* 270	VF SAND, some silt; abundant mafics & black mica	"	WS
274	TD; no sample		

* Sample retained

Sorting code: WS, well sorted; MS, moderately sorted; IS, ill sorted; VIS, very ill sorted.

Depths not adjusted to the γ-log

COMPLETION SCHEDULE:

Set the deep 2" piezometer (-5B2) with screen 191-211 having a 10' capped bullnose below. Monterey no. 8 sand backfill to 173'. Set isolating seal of 1/4" Volclay tablets 153-173'. For schedule above 153', see form for companion piezometer 29/22-5B1 (in the same borehole).

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DWR 429 Continuation

ORIGINAL
File with DWR

Page 1 of 1

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. E011328

DWR USE ONLY — DO NOT FILL IN
29S/22E-09
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. STARRH#1
Date Work Began 4/28/03, Ended 5/5/03
Local Permit Agency K.C.E.H.S.D.
Permit No. 1544 Permit Date 1/31/03

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

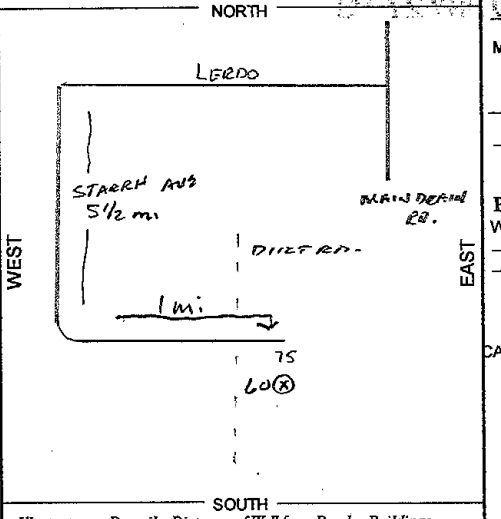
DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	10	BROWN TOP SOIL -CLAY
10	160	MEDIUM BROWN SAND
160	257	BROWN CLAY
257	317	MEDIUM BROWN SAND
317	391	BROWN CLAY - SAND
391	421	BROWN MEDIUM SAND
421	520	BROWN CLAY - SAND

TOTAL DEPTH OF BORING 520 (Feet)
TOTAL DEPTH OF COMPLETED WELL 500 (Feet)

WELL LOCATION

Address STARRH AVE.
City BUTTON WILLOW CA 93263
County KERN
APN Book 099 Page 230 Parcel 09
Township 29 S Range 22 E Section 9
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH



Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
✓ Irrigation — Industrial
MONITORING —
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 30 (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	50	42			✓		STEEL	26"	.250	
0	230	24	✓				STEEL	16"	.312	
230	500	24		✓			STEEL	16"	.312	.080 X 32

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	50	✓			
520	0			✓	1/4" GRAVEL

ATTACHMENTS (✓)

✓ Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME Farm Pump and Irrigation
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
P.O. Box 1477 Shafter CA 93263
ADDRESS CITY STATE ZIP
Signed [signature] 05/05/03 602148 C-57
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

APPENDIX I REFERENCES SPREADSHEET

* Required fields

Reference Type *	Author *	Publish Date *	Title *	Access Date	Publication	Report Number	File name or URL *
Report	Amec Foster Wheeler	1/1/2015	Groundwater Assessment Report, Westside	1/1/2019	Amec Foster Wheeler		
Report	Bartow, J. Alan	1/1/1991	The Cenozoic Evolution of the San Joaquin V	1/1/2019	United States Geological Survey Professi	1501	
Unknown/Other	California Code of Regulations	1/1/2016	Title 23, Waters, Division 2, Department of V	1/1/2019	California Code of Regulations		
Report	California Department of Water Re	1/1/1964	Feasibility of Serving the Dudley Ridge Wate	1/1/2019	California Department of Water Resourc	Bulletin No. 119-14	
Report	California Department of Water Re	1/1/1993	Shallow Groundwater Study, Buena Vista W	1/1/2019	California Department of Water Resources (DWR)		
Unknown/Other	California Department of Water Re	1/1/2003	California Groundwater, Bulletin 118, Grour	1/1/2019	California Department of Water Resourc	Bulletin 118	
Report	California Department of Water Re	1/1/2006	San Joaquin Valley Groundwater Basin, Kerr	1/1/2019	California Department of Water Resources (DWR)		
Report	California Department of Water Re	1/1/2008	Lost Hills/Semitropic, 2008 Areas of Shallow	1/1/2019	California Department of Water Resources (DWR)		
Report	California Department of Water Re	1/1/2013	California Water Data Library	1/1/2019	California Department of Water Resources (DWR)		http://wdl.water.ca.gov/waterdatalibrary/
Report	California Department of Water Re	1/1/2016	California's Groundwater, Bulletin118, Inter	1/1/2019	California Department of Water Resourc	Bulletin 118	
Unknown/Other	California Department of Water Re	1/1/2018	DWR Central Valley Groundwater-Surface W	1/1/2019	California Department of Water Resources (DWR)		
Report	California Division of Oil, Gas, and (	1/1/1981	Application for Primacy in the Regulation of	4/1/2019	California Division of Oil, Gas, and Geothermal Resources (DOGGR)		
Report	California Division of Oil, Gas, and (	1/1/1998	California Oil & Gas Fields, Volume 1 – Cent	1/1/2019	California Division of Oil, Gas, and Geothermal Resources (DOGGR)		
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Management Area Plan

Wheeler Ridge – Maricopa Management Area
Kern County Subbasin



Prepared for

Wheeler Ridge-Maricopa

Water Storage District

December 2019

Prepared by

eki environment & water

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List of Abbreviations

AEWSD	Arvin-Edison Water Storage District
AF	acre-feet
AFY	acre-feet per year
AWMP	Agricultural Water Management Plan
BMP	Best Management Practice
BOS	bottom of screen
C2VSim	California Central Valley Groundwater-Surface Water Simulation Model
C2VSim-CG	California Central Valley Groundwater-Surface Water Simulation Model – Coarse Grid
C2VSim-FG	California Central Valley Groundwater-Surface Water Simulation Model – Fine Grid
Cal EPA	California Environmental Protection Agency
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	California Code of Regulations
CDEC	California Data Exchange Center
CDMG	California Division of Mines and Geology
cfs	cubic feet per second
CGS	California Geological Survey
CIMIS	California Irrigation Management Information System
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
CWC	California Water Code
DAC	Disadvantaged Community
DDW	Division of Drinking Water
DEM	Digital elevation model
DMS	Data Management System
DOGGR	Division of Oil, Gas and Geothermal Resources
DTSC	Department of Toxic Substances Control
DWR	California Department of Water Resources
EC	electrical conductance
EKI	EKI Environment & Water, Inc.
ET	evapotranspiration
ETo	reference evapotranspiration
FKC	Friant-Kern Canal
ft	feet
ft bgs	feet below ground surface
ft msl	feet above mean sea level
ft/day	feet per day
ft^2/day	feet squared per day
gal	gallons
GAMA	Groundwater Ambient Monitoring and Assessment
GDE	groundwater dependent ecosystem

GIS	Geographic Information System
gpd/ft	gallons per day per foot
gpd/ft^2	gallons per day per foot squared
gpm	gallons per minute
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWMP	Groundwater Management Plan
HCM	Hydrogeologic Conceptual Model
ILRP	Irrigated Lands Regulatory Program
in	inches
in/hr	inches per hour
in/mo	inches per month
IRWMP	Integrated Regional Water Management Plan
ITRC	Irrigation Training & Research Center
JPA	Joint Powers Agreement
JPL	Jet Propulsion Laboratory
KCPHSD	Kern County Public Health Services Department
KCWA	Kern County Water Agency
KDWD	Kern Delta Water District
KGA	Kern Groundwater Authority
KRWCA	Kern River Watershed Coalition Authority
LUST	leaking underground storage tank
MCL	Maximum Contaminant Level
METRIC	Mapping EvapoTranspiration at high Resolution with Internalized Calibration
mg/L	milligrams per liter
M&I	municipal and industrial
NASA	National Aeronautics and Space Administration
NCCAG	Natural Communities Commonly Associated with Groundwater
ND	not detected
NLCD	National Land Cover Database
NRCS	Natural Resources Conservation Service
PLSS	Public Land Survey System
P/MA	Project / Management Action
RMS	Representative Monitoring Site
RMSE	root mean squared error
SCEP	Stakeholder Communication and Engagement Plan
SDAC	Severely Disadvantaged Community
SGMA	Sustainable Groundwater Management Act
SSURGO	Soil Survey Geographic Database
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWSA	Surface Water Service Area
TCWD	Tejon Castac Water District

TDS	total dissolved solids
TNC	The Nature Conservancy
TOS	top of screen
TRS	township-range-section
ug	micrograms
ug/L	micrograms per liter
umhos/cm	microsiemens per centimeter
USBR	United States Bureau of Reclamation
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WDRs	Waste Discharge Requirements
WKWD	West Kern Water District
WRMWSD	Wheeler Ridge-Maricopa Water Storage District

EXECUTIVE SUMMARY

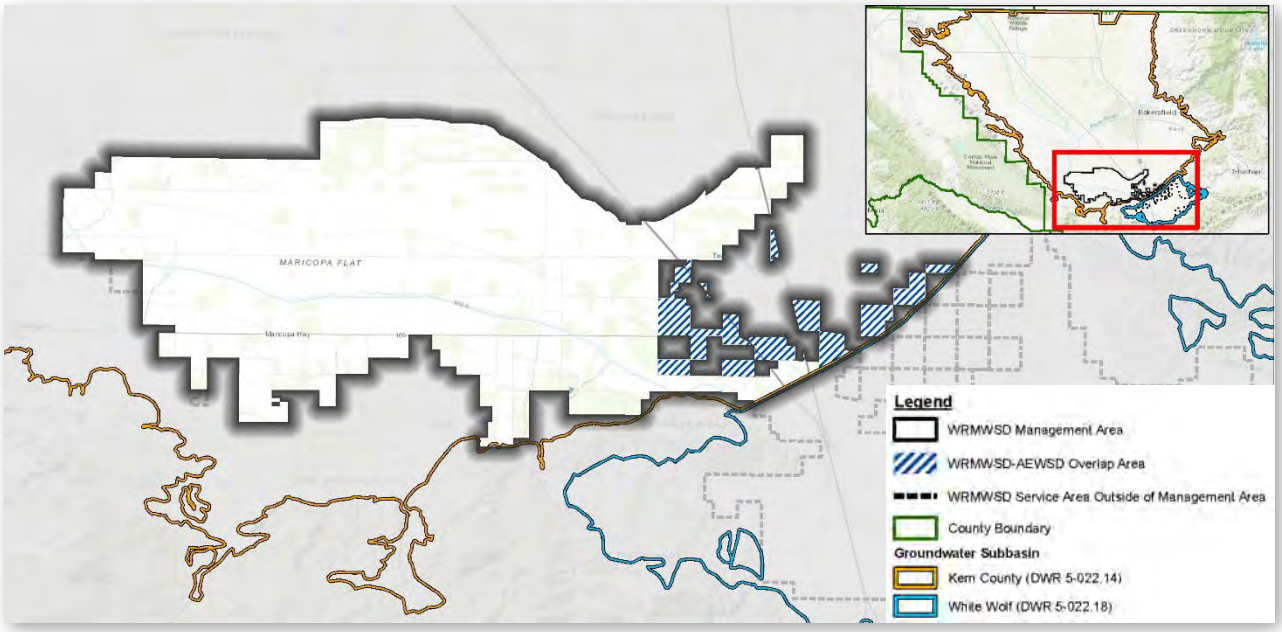
☑ 23 CCR § 354.4(a)

ES.1. Introduction

On 16 September 2014, the California legislature enacted the Sustainable Groundwater Management Act (SGMA) whose primary purpose is to achieve and/or maintain sustainability within the state's high and medium priority groundwater basins. Key tenets of SGMA are the concept of local control, use of best available data and science, and active engagement and consideration of all beneficial uses and users of groundwater. As such, SGMA empowers certain local agencies to form Groundwater Sustainability Agencies (GSAs) whose purpose is to manage basins sustainably through the development and implementation of Groundwater Sustainability Plans (GSPs). Under SGMA, GSPs are required to contain certain elements, the most significant of which include: a Sustainability Goal; a description of the area covered by the GSP ("Plan Area"); a description of the Basin Setting, including hydrogeologic conceptual model, historical and current groundwater conditions, and a water budget; locally-defined sustainability criteria; monitoring networks and protocols for sustainability indicators; and a description of projects and/or management actions that will be implemented to achieve or maintain sustainability. SGMA also requires a significant element of stakeholder outreach to ensure that all beneficial uses and users of groundwater are given the opportunity to provide input into the GSP development and implementation process.

This GSP Management Area Plan ("MA Plan") has been prepared by Wheeler Ridge-Maricopa Water Storage District (WRMWSD) and covers an area called the "Wheeler Ridge-Maricopa Management Area" or "Management Area" (see figure below). The Management Area underlies the WRMWSD service area, excluding the area (approximately 2,809 acres) also overlain by the West Kern Water District, and is located in the southern portion of the Kern County Subbasin of the San Joaquin Valley Groundwater Basin (Department of Water Resources [DWR] Basin No. 5-022.14; referred to herein as the "Kern Subbasin"). The Kern Subbasin is one of 21 basins and subbasins identified by the DWR as being critically overdrafted, a designation that triggers an accelerated timetable for GSP development by 2020 and achievement of sustainability by 2040.

The Kern Groundwater Authority (KGA) GSA, of which WRMWSD is a member, is the largest of the 11 GSAs that have been formed within the Kern Subbasin. The KGA GSA was formed in 2017 upon adoption of a Joint Powers Agreement by all members and is governed by a 16-member Board of Directors that includes a representative of each member agency. The KGA GSA is preparing an "Umbrella GSP" that, in addition to providing content for the entire KGA GSA area, includes individual Management Area Plans that contain more detailed information for each member agency's service area. Areas of the Kern Subbasin that are outside of the KGA GSA GSP are covered under five separate, coordinated GSPs that have been developed by other GSAs.



Wheeler Ridge-Maricopa Management Area

The Arvin-Edison Water Storage District (AEWSD) jurisdictional boundary overlaps approximately 5,318 acres of the Management Area (see figure above), and WRMWSD serves surface water to approximately 3,186 acres in this area. AEWSD is a participating member of the KGA GSA and is developing a separate Management Area Plan for its jurisdictional area within the Kern Subbasin in close coordination with WRMWSD. For purposes of SGMA monitoring and management, WRMWSD and AEWSD have agreed that AEWSD will cover the overlap areas. However, WRMWSD will continue in the future to serve surface water to those lands within the overlap area that have historically received District supplies in accordance with the District's water delivery contracts with landowners.

The KGA Umbrella GSP and this MA Plan for the Wheeler Ridge-Maricopa Management Area have been developed to meet SGMA regulatory requirements[1] while reflecting local needs and preserving local control over water resources. Together, these documents provide a path to maintain the long-term sustainability of locally-managed groundwater resources now and into the future.

ES.2. Sustainability Goal

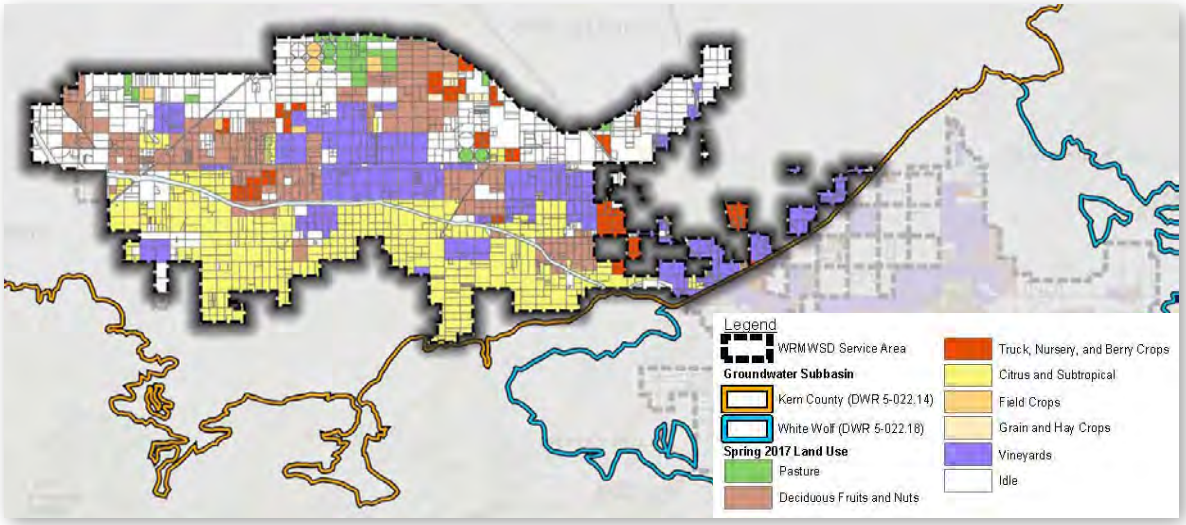
The sustainability goal for the Wheeler Ridge-Maricopa Management Area is to maintain an economically-viable groundwater resource for the beneficial use of the Management Area's landowners and water users by utilizing the area's groundwater resources within the local sustainable yield. Long-term groundwater sustainability, i.e., the absence of undesirable results within 20 years of the applicable statutory deadline, will be achieved and maintained through the implementation of projects and management actions as described herein to both increase water supplies and reduce demands within the Management Area.

[1] Regulations for GSP development are contained within Title 23 of the California Code of Regulations (CCR) Division 2 Chapter 1.5 Subchapter 2.

The local sustainability goal, above, is consistent with and in addition to the basin-wide sustainability goal being adopted by all GSAs in the Kern Subbasin.

ES.3. Plan Area

The Wheeler Ridge-Maricopa Management Area covers 91,430 acres in the southwestern portion of the Kern Subbasin. Located at the far southern end of the state's Central Valley, the Kern Subbasin is the largest groundwater basin in the state and is bounded on the north by the Tulare Lake Subbasin, the Tule Subbasin, the Kettleman Plain Subbasin and on the south by the White Wolf Subbasin. The Wheeler Ridge-Maricopa Management Area is bordered on the north by the Kern Delta Water District and Henry Miller



Spring 2017 Land Use

Water District, on the west by West Kern Water District, and on the east by (and overlapped with) the Arvin-Edison Water Storage District. To the south are "non-districted" lands, some of which have requested inclusion in this MA Plan and whose information is included in an Appendix hereto.

Most lands within the Wheeler Ridge-Maricopa Management Area are developed for irrigated agriculture, especially in the central and southern portions of the Management Area (see figure above). These agricultural lands use a combination of imported surface water provided by WRMWSD and groundwater from private wells for their water supply. WRMWSD has a water supply contract through Kern County Water Agency for State Water Project water which is obtained through turnouts off the California Aqueduct which runs through the District. WRMWSD has invested considerably over the years to import, convey, and distribute water to its customers within the Management Area (and also to customers in the portion of the District that is in the White Wolf Subbasin). Through its conjunctive management of water supplies, WRMWSD has provided a substantial net benefit to groundwater conditions within its service area.[2]

[2] WRMWSD supplies surface water to certain lands with WRMWSD water supply contracts within the eastern portion of the Wheeler Ridge-Maricopa Management Area that overlaps with the Arvin-Edison Water Storage District (AEWSD) service area and Arvin-Edison Management Area. WRMWSD will continue to serve surface water to those lands within the overlap area that have contracts with and have historically received water from WRMWSD.

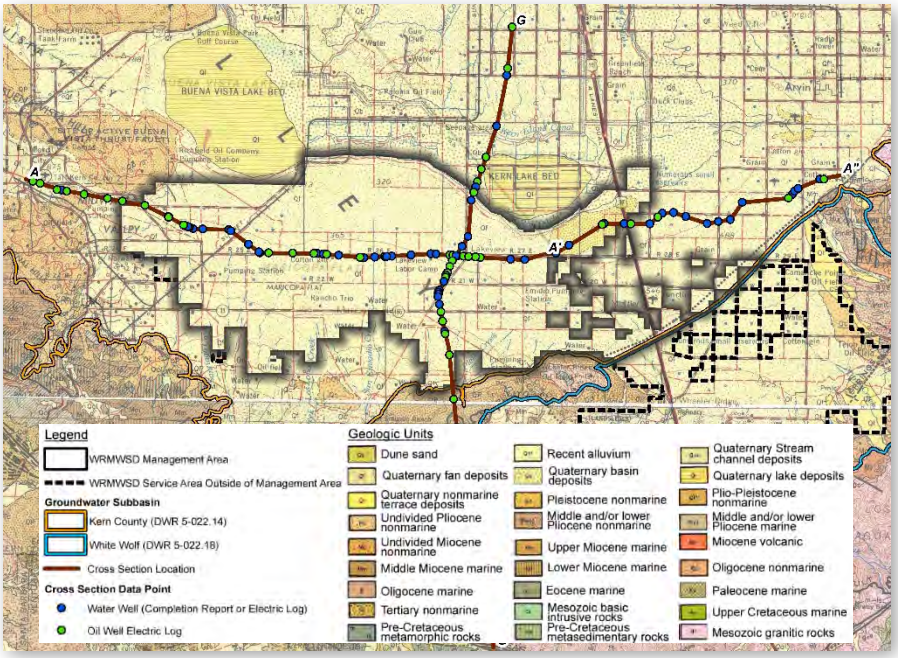
Two small public water systems exist within the Management Area, serving small populations of residents or workers at various commercial/agricultural facilities. Most of the Management Area is designated by the U.S. Census Bureau as either Disadvantaged Community (DAC) or Severely Disadvantaged Community (SDAC). In the preparation of this MA Plan the interests of DACs have been considered.

ES.4. Stakeholder Outreach Efforts

WRMWSD has developed and adopted a Stakeholder Communication and Engagement Plan (SCEP) for the Wheeler Ridge-Maricopa Management Area to fulfill notice and communication requirements and enable the interests of all beneficial users of groundwater within the Management Area during the development and implementation of the MA Plan. The goal of the outreach efforts described in the SCEP is to encourage open and transparent engagement by diverse stakeholders and gain knowledge and perspectives provided by basin stakeholders. Public participation has been welcomed throughout the MA Plan development process. Venues for public stakeholder engagement and input throughout the MA Plan development process have included: Wheeler Ridge-Maricopa Management Area SGMA Landowner Workshops, WRMWSD Board meetings, KGA GSA Board meetings, and KGA GSA Stakeholder Workshops and Meetings. Other outreach to Management Area stakeholders throughout the MA Plan development process has included: distribution and collection of a Stakeholder Survey and an Agricultural Stakeholder Survey, and various letters from WRMWSD and KGA to landowners. WRMWSD has also conducted extensive coordination with other KGA members and GSAs in the Kern Subbasin.

ES.5. Hydrogeologic Conceptual Model

The Wheeler Ridge-Maricopa Management Area is located in the southwestern portion of the Kern Subbasin, south of the Kern River. The Kern Subbasin occupies a large structural trough filled with thick sedimentary deposits of continental and marine origin. The local geology underlying the Management Area reflects its location near the edge of the basin, proximal to the San Emigdio Mountains which are a source for the sediments washed down into the basin.



Surficial Geology and Cross-Section Locations

The "principal aquifer" is defined in the Management Area as the aquifer materials encountered within the depths of production wells in the area (i.e., the top 2,600 feet) and is comprised of fluvial and alluvial deposits of Mio/Pliocene to Recent age. In the northeastern portion of the Management Area, a regionally-extensive clay layer (the "E"-Clay) is found at intermediate depths and creates more confined

conditions in the underlying sediments. Aquifer conditions in general are more unconfined to semi-confined in the shallower zones and southern and western areas and more confined in the deeper zones and northern areas. The White Wolf Fault forms the southern boundary of the Kern Subbasin and has been demonstrated to be a significant impediment to groundwater flow as evidenced by higher groundwater levels on the upgradient (southern) side.

Due to its location near the edge of the basin, the southern half of the Management Area has fairly coarse and permeable soils that are conducive to recharge from precipitation and excess applied water[3] . The northern half of the Management Area is underlain by finer soils with lower recharge potential, and in some locations perched groundwater is present due to low permeability soils and sediments close to the surface. The Management Area also receives recharge from percolation of natural surface water flows in several creeks that flow from the uplands in the south into the Management Area.

ES.6. Existing Groundwater Conditions

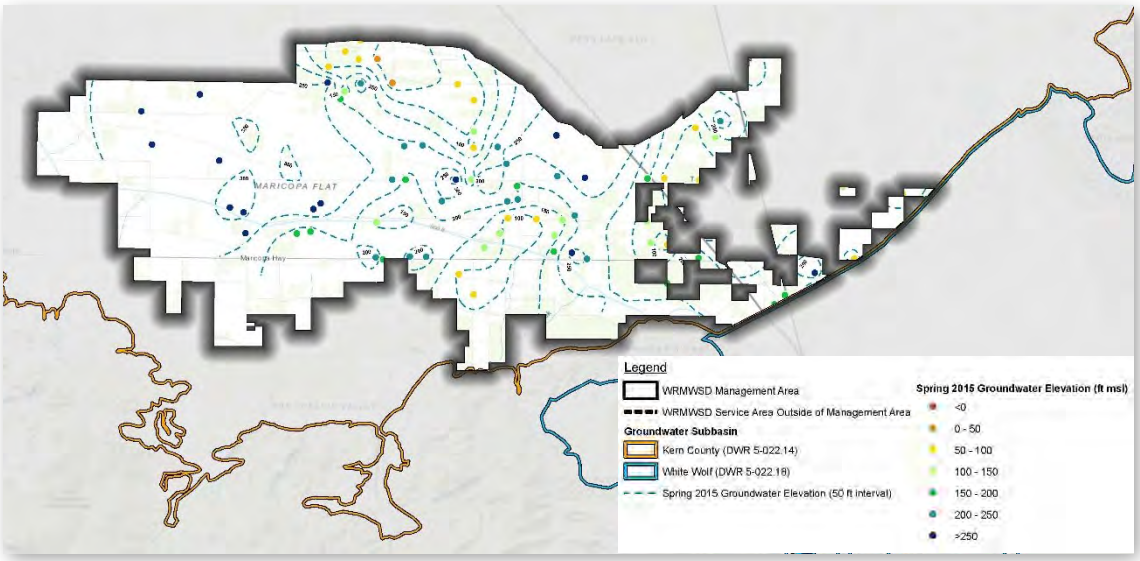
Information on groundwater conditions within the Management Area is presented in this MA Plan with respect to the six "Sustainability Indicators" defined under SGMA, which include the following:

- Chronic lowering of groundwater levels
- Reduction in groundwater storage
- Seawater intrusion
- Degraded water quality
- Land subsidence
- Depletion of interconnected surface water

[3] Irrigation practices are generally highly efficient within the Wheeler Ridge-Maricopa Management area; however, recharge of applied water includes some irrigation inefficiency as well as water applied for leaching purposes and other non-consumptive operational uses.

Water Levels: Groundwater levels within the Management Area are presented using contour maps depicting recent (2015) seasonal high (spring) and seasonal low (fall) conditions, as well as hydrographs from 16 wells throughout the Management Area that have long records. The available data indicate groundwater flow directions are variable throughout the Management Area, with groundwater levels generally higher in the west and lower in the southern central and north central areas. Relative highs and lows appear to be controlled, at least in part, by the distribution of groundwater pumping versus surface water deliveries, with the exception of the south central where groundwater levels in 2015 were relatively low despite being within the District's Surface Water Service Area. Depths to groundwater in Spring 2015 range from approximately 100 to 560 feet below ground surface (ft bgs)[4]. The fact that most groundwater levels are greater than 100 ft bgs indicates that connections to surface water and the existence of groundwater dependent ecosystems (GDEs) are unlikely. Hydrographs show the long-term positive effects of WRMWSD's surface water importation in raising groundwater levels, tempered by the effects of the recent severe drought.

Groundwater Storage: Changes in groundwater storage over selected time periods of interest were analyzed by comparing water levels at the beginning and end of the period. The water levels show the positive impacts of water importation and the variability caused by wet and dry climate periods. Over the period from Fall 1994 through Fall 2014 (the KGA historical water budget period of interest), the average annual change in storage was +3,286 acre-feet per year (AFY), indicating sustainable conditions although annual changes in groundwater storage ranged from +83,000 AFY to -46,000 AFY. Spatially, the changes in storage (directly related to changes in water level) are more positive in the WRMWSD Surface Water Service Area compare to areas that rely solely on groundwater for supply.



Spring 2015 Groundwater Elevations

[4] A perched groundwater zone exists along the northern boundary of the Management Area, where depth to groundwater has historically been encountered as shallow as 20 ft bgs. This perched zone is hydraulically disconnected from the underlying principal aquifer system and does not yield significant or economic quantities of groundwater to wells, springs, or surface water systems (see **Section 8.2 Groundwater Elevations and Flow Direction**).

Water Quality: Agricultural use is the dominant beneficial use within the Management Area, and groundwater quality is generally suitable for agricultural uses. That being said, in some instances concentrations of nitrate, arsenic, total dissolved solids (TDS), boron, iron, manganese and sulfate have been detected in groundwater within or near the Management Area above drinking water standards and/or agricultural water quality goals. Future monitoring efforts will include routine collection of water quality data throughout the Management Area; these data will be periodically reviewed and water quality trends will be evaluated as part of future GSP implementation efforts. Further, water quality issues related to potential constituents or concern are regulated separately under the Irrigated Lands Regulatory Program (ILRP), Central Valley-Salinity Alternatives for Long-term Sustainability (CV-SALTS), and the State Water Resources Control Board (SWRCB).

Land Subsidence: Some amount of land subsidence has been documented within the Wheeler Ridge-Maricopa Management Area over both historical (1949-2005) and recent (2015-2016) timeframes. Subsidence due to aquitard depressurization following groundwater withdrawal tends to be greater in the north central area, with some localized subsidence historically in the far western area and more recently in the south-central area. Subsidence has the potential to affect critical infrastructure including gravity-driven water conveyance systems (canals) and has been monitored and observed along the California Aqueduct. However, subsidence has been historically managed by DWR through maintenance and improvements to its facilities and no reaches of the Aqueduct in this area have less than the minimum recommended freeboard.

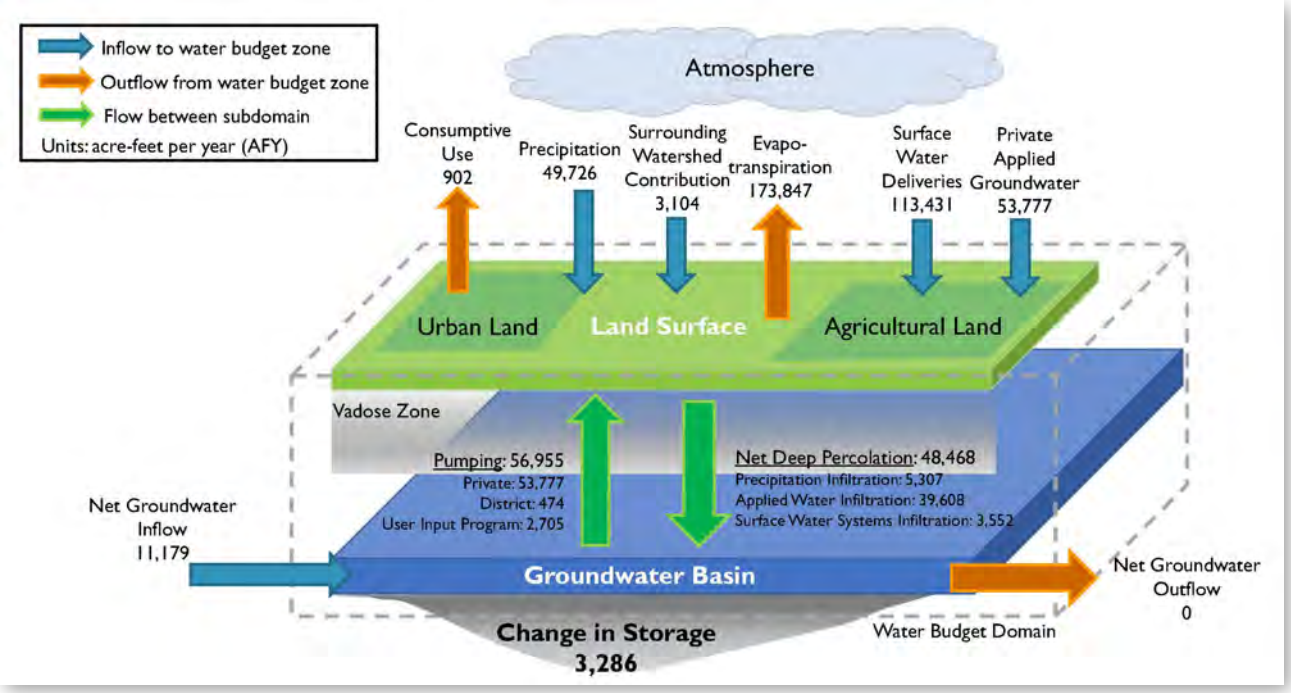
Interconnected Surface Waters: Due to the great depth to groundwater in the principal aquifer (i.e., greater than 100 ft bgs in most places), it appears that there are no interconnection surface water systems within the Management Area. Similarly, while the DWR dataset of Natural Communities Commonly Associate with Groundwater (NCCAG) shows some areas along the northern boundary of the Management Area as NCCAG, due to the great depth to groundwater in the principal aquifer, these areas do not appear to be GDEs.

Seawater Intrusion: The Management Area is located far from coastal areas. As a result, seawater intrusion is not considered to be an issue for this area.

ES.7. Water Budget

For the Kern Subbasin as a whole, the basin GSAs coordinated on two basin-wide water budget approaches, as described in the KGA Umbrella GSP: (1) development of a numerical model based on the California Central Valley Groundwater/Surface Water Simulation Model (C2VSim) to estimate the basin-wide water budget, and (2) development of a "checkbook" water accounting approach that estimates supply, demand, and shortages using certain management assumptions. In addition, on a local Management Area basis, a spreadsheet water budget model was developed and calibrated to observed water level/storage changes to provide locally-refined water budget information. While the numerical model and checkbook water accounting approaches are described in the Coordination Agreement and Appendices thereto, the calibrated spreadsheet model is the basis for the detailed historical and current water budget information presented herein (see figure below) but is not a determination of water rights. Based on the 1995 to 2014 historical water budget time period (DWR water years [WY] 1995 through 2014; October 1994 through September 2014) The sustainable yield for the Management Area is conservatively estimated to be at a minimum approximately 60,300 AFY under current supply and demand conditions (approximately 0.65 AFY/acre over the 91,430-acre Management Area). Because it is based on

a calculation of pumping to achieve net zero decrease in groundwater storage, this sustainable yield is defined in such a way as to avoid the occurrence of Undesirable Results for relevant Sustainability Indicators (discussed further below), and is consistent with the assumptions for "native yield" and effective precipitation being used basin-wide and also reflects the contribution to groundwater from return flow of applied imported surface water.



Illustrated Historical Water Budget (WY 1995-2014)

Over this historical period, the average annual change in groundwater storage in the Management Area was +3,286 AFY.

Water budget information under projected (future) conditions was also developed using the calibrated spreadsheet water budget model, with DWR-provided inputs for climate variables (i.e., precipitation and evapotranspiration) and water supply assumptions (i.e., changes to imported water supplies). The projected water budget assesses the magnitude of the net water supply deficit under future conditions that would need to be addressed through Projects and Management Actions (P/MAs) to prevent Undesirable Results and achieve the Sustainability Goal. Consistent with the basin-wide efforts, three projected water budget scenarios were developed for this analysis: a Baseline Scenario, a 2030 Climate Change Scenario, and a 2070 Climate Change Scenario. For the projected Baseline condition, the long-term average change in groundwater storage was estimated to be -14,665 AFY for both the analytical spreadsheet model and basin-wide "checkbook" method (see table below). The projected deficit under the 2030 Climate Change Scenario (-21,429 AFY) was used as the basis to develop P/MAs for the Management Area.

Comparison of Change in Storage Estimates (AFY) from Three Water Budget Estimation Methods

Period / Scenario	Basin-wide Numerical Model	Local Analytical Spreadsheet Model	Basin-wide "Checkbook" Water Accounting Approach
Historical Period (WY 1995 – 2014)	-8,654	3,286	Not Applicable
Current Period (WY 2015)	-45,191	-42,898	Not Applicable
Projected Period (50 years; 2021 – 2070) Baseline with no Projects	**-5,423**	**-14,665**	**-14,665**
Projected Period (50 years; 2021 – 2070) 2030 Climate Change with no Projects	-9,712	-21,429	Not Applicable
Projected Period (50 years; 2021 – 2070) 2030 Climate Change with Projects	9,780	53	Not Applicable
Projected Period (50 years; 2021 – 2070) 2070 Climate Change with no Projects	-17,952	-33,326	Not Applicable
Projected Period (50 years; 2021 – 2070) 2070 Climate Change with Projects	1,571	47	Not Applicable

Each estimate presented above includes data gaps and has varying degrees of accuracy and/or reliability. As part of MA Plan implementation, these numbers will be refined as additional information is developed.

ES.8. Sustainable Management Criteria

Sustainable Management Criteria (SMCs) are the metrics by which groundwater sustainability is judged under SGMA. Key terms related to SMCs under SGMA include the following:

Undesirable Results: Undesirable Results are the significant and unreasonable occurrence of conditions, for any of the six Sustainability Indicators defined under SGMA, that adversely affect groundwater use in the basin. Definitions of Undesirable Results for the basin have been developed through a coordinated effort of the basin GSAs and are described in the KGA GSA Umbrella GSP. The basin-wide definitions of Undesirable Results allow for local definition of Minimum Thresholds and the combination thereof that is considered significant and unreasonable. Therefore, the broad basin-wide Undesirable Results definitions were refined locally for the Wheeler Ridge-Maricopa Management Area to better reflect local groundwater conditions and beneficial uses.

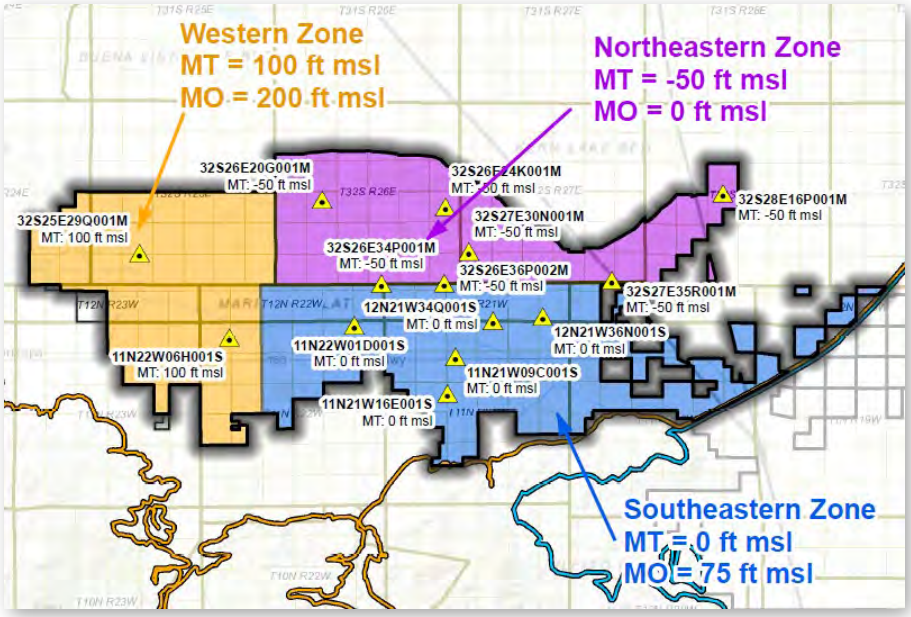
Minimum Thresholds: Minimum Thresholds (MTs) are the numeric criteria for each Sustainability Indicator that, if exceeded in a locally-defined combination of monitoring sites, may constitute an Undesirable Results for that indicator. Where appropriate, the Minimum Thresholds for the Sustainability Indicators have been set using groundwater levels as a proxy.

Measurable Objectives: Measurable Objectives (MOs) are a specific set of quantifiable goals for the maintenance or improvement of groundwater conditions. Measurable Objectives use the same units and metrics as the Minimum Thresholds and are thus directly comparable.

Interim Milestones: Interim Milestones are a set of target values representing measurable groundwater conditions in increments of five years over the 20-year statutory deadline for achieving sustainability.

Chronic Lowering of Groundwater Levels is arguably the most fundamental Sustainability Indicator, as it influences several other key Sustainability Indicators, including Reduction of Groundwater Storage and Land Subsidence. MTs and MOs for Chronic Lowering of Groundwater Levels were developed through temporal analysis of long-term groundwater level data. Briefly, at each of 15 locations with long-term records, an initial MT estimate was calculated considering historical lows, recent groundwater level trends, and the variability or range in groundwater levels. Initial MOs were set based on Fall 2015 levels. These initial individual estimates were then generalized into three Sustainability Zones to allow flexibility in the ultimate monitoring locations. An evaluation of these generalized MTs against known well construction information was performed to understand the potential impacts on wells (i.e., potential dewatering of shallow wells). MTs and MOs were presented on multiple occasions in public meetings to allow for stakeholder input.

Significant Groundwater Storage exists within the Wheeler Ridge-Maricopa Management Area, and it is estimated that it would take roughly 100 years of zero recharge to deplete the usable storage under current extraction rates. As such, it was determined to be sufficiently protective to define the SMCs for Reduction of Groundwater Storage based on the use of SMCs for Chronic Lowering of Groundwater Levels as a proxy.



Minimum Thresholds (MT) and Measurable Objectives (MO) for Chronic Lowering of Groundwater Levels

No SMCs for Degraded Water Quality are defined within the Wheeler Ridge-Maricopa Management Area because, based the existing beneficial uses and users of groundwater within, there are no Undesirable Results for Degraded Water Quality occurring, and the MTs for Chronic Lowering of Groundwater Levels are anticipated to be protective in terms of preventing migration of poor-quality water. Monitoring for water quality will continue to be conducted at a set of Representative Monitoring Sites, and if a nexus between these constituent concentrations and water levels and groundwater management actions is established, then the SMCs for water quality will be revisited.

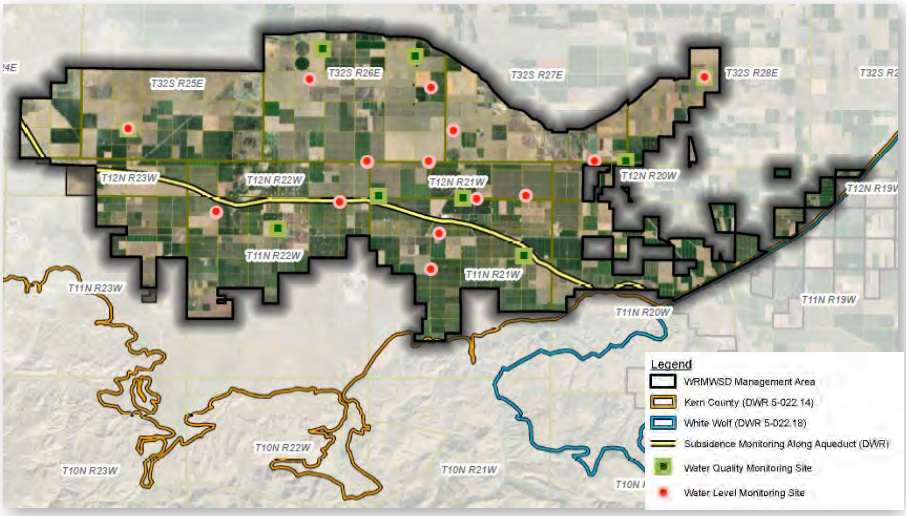
The SMCs for Land Subsidence are based on observed rates of subsidence from ground-based surveys along the California Aqueduct between 1975 and 2019. Specifically, the MT is set as the maximum rate of

subsidence that was observed during that period extended through the GSP implementation timeframe. The rationale for this MT rate of subsidence is that such subsidence has been historically managed by DWR through maintenance and improvements to its facilities and no reaches of the Aqueduct in this area have less than the minimum recommended freeboard. The MO is defined as the amount of land subsidence that would occur if the Minimum Threshold rate were to continue through 2030 and then cease.

As discussed above, Depletion of Interconnected Surface Water has not been observed within the Wheeler Ridge-Maricopa Management Area and is not applicable due to the great depths to groundwater in the principal aquifer. Likewise, Seawater Intrusion does not exist within the Kern Subbasin. Therefore, no SMCs for these Sustainable Indicators are defined in this MA Plan.

ES.9. Monitoring Network

The objective of the Wheeler Ridge-Maricopa Management Area Monitoring Network is to collect sufficient data to allow for assessment of the Sustainability Indicators relevant to the Management Area, and potential impacts to the beneficial uses and users of groundwater. The proposed Monitoring Network was developed to ensure sufficient spatial distribution and spatial density. The network consists of 14 Representative Monitoring Sites for groundwater levels and (by proxy) groundwater storage, nine sites for monitoring groundwater quality (although as discussed above, no SMCs are defined for this Sustainability Indicator), and 40 sites along the California Aqueduct for monitoring land subsidence. The SGMA-compliance network for the Management Area supplements other monitoring networks and programs in the basin such as DWR California Statewide Groundwater Elevation Monitoring (CASGEM), Central Valley-Salinity Alternatives for Long-term Sustainability (CV-SALTS), Kern County Water Agency [KCWA] semiannual groundwater monitoring program, etc. and basin-wide monitoring networks related to SGMA compliance such as the KGA's land subsidence network.

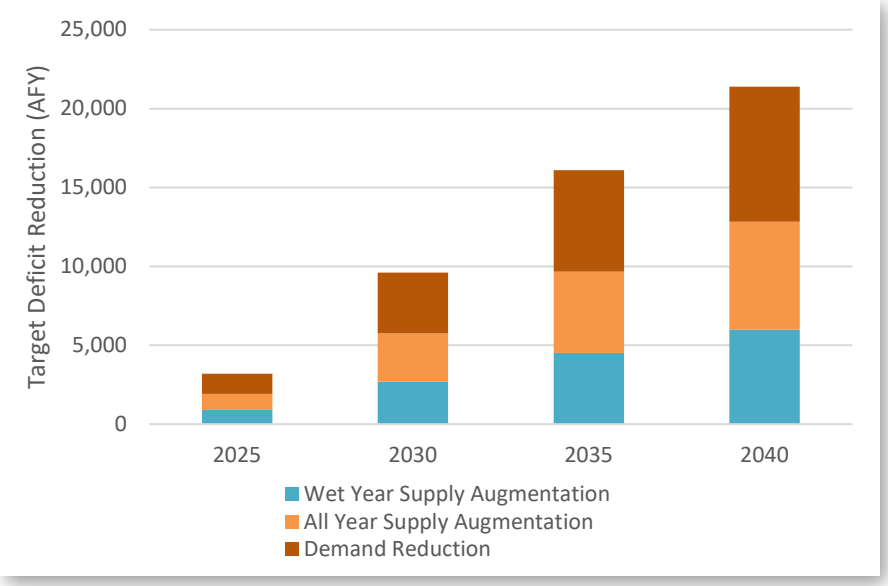


Monitoring Networks for Water Levels, Water Quality and Land Subsidence

Data collected from the SGMA-compliant Monitoring Network will be uploaded to the Data Management System maintained for the basin and reported to the DWR in accordance with the Monitoring Protocols developed for the basin as described in the KGA Umbrella GSP. In addition, local data will be stored and managed in a Wheeler Ridge-Maricopa Management Area-specific DMS. Additional data collected as part of WRMWSD's other regular monitoring programs may be used in conjunction with data collected from the SGMA-compliant Monitoring Network to meet compliance with GSP Emergency Regulations regarding Annual Reporting or as otherwise deemed necessary for the Management Area.

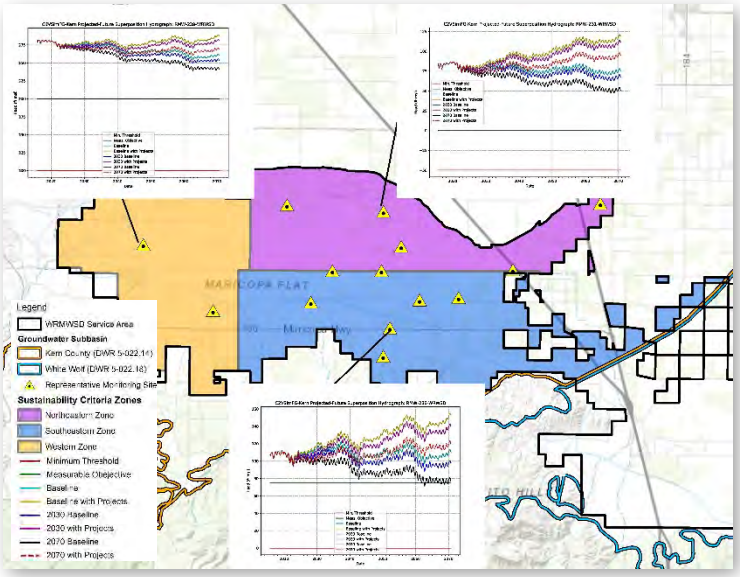
ES.10. Project and Management Actions

Achieving sustainability in the Wheeler Ridge-Maricopa Management Area will require implementation of P/MAs to address projected water budget deficits. As such, WRMWSD has developed a portfolio of P/MAs, each with specific expected benefits, implementation triggers, and costs. A preliminary "glide path" has been developed that results in closing of the currently identified projected "deficit"[5] of approximately -21,400 AFY by 2040. Accelerated implementation of P/MAs will be triggered if observed groundwater conditions deteriorate, as measured against defined SMCs at the representative monitoring sites.



Project & Management Action Implementation Glide Path

The Projects in WRMWSD's P/MA portfolio have supply augmentation as their primary expected benefit, and are grouped into the following categories:



Simulated Hydrographs Showing Achievement of Sustainability with Planned P/MAs

- Projects to Enhance Recharge / Banking;
- Projects to Increase Water Management Flexibility; and
- Projects to Develop New Supplies.

The Management Action in the P/MA portfolio have water demand reduction as their primary expected benefit and are grouped into the following categories:

- Management Actions to Raise Funds to Support SGMA Compliance; and
- Management Actions / Policies to Reduce Groundwater Pumping.

The supply augmentation and demand reduction P/MAs listed above comprise a diverse portfolio of options that can be

[5] The net deficit to be addressed by the 2040 GSP implementation deadline is the estimated deficit under the 2030 Climate Change scenario.

implemented as necessary by WRMWSD to achieve sustainability from a total water quantity perspective. Simulation results from the basin-wide numerical (C2VSim) model indicate that P/MA implementation along the planned glide path will successfully achieve sustainability and avoid Undesirable Results for Groundwater Levels (and by proxy for the other applicable Sustainability Indicators) (see figure above). The glide path provides a general guide to how quickly these benefits are to be realized. However, the exact schedule and order of implementation is not known, and further analysis will be conducted to prioritize the P/MAs in consideration of factors including permitting, engineering feasibility, cost effectiveness and other factors. In general, P/MAs being considered for implementation will be discussed during regular WRMWSD Board Meetings, which are open to the public. Additional stakeholder outreach efforts will be conducted prior to and during P/MA implementation, as required by law.

ES.11. GSP Implementation

Key GSP implementation activities to be undertaken over the next five years include:

- Monitoring and data collection;
- Projects & Management Action (P/MA) implementation, including policy development to support GSP implementation;
- Technical and non-technical coordination with other water management entities within the Kern County Subbasin (Kern Subbasin);
- Continued outreach and engagement with stakeholders;
- Annual reporting;
- Enforcement and response actions, as necessary; and
- Evaluation and updates, as necessary, of the Wheeler Ridge-Maricopa MA Plan as part of the required periodic evaluations (i.e., “five-year updates”).

ES.12. GSP Implementation Costs and Funding

Costs to implement this MA Plan can be divided into several groups, as follows:

- Costs of local groundwater management activities;
- WRMWSD’s proportional share of costs for basin-wide groundwater management activities; and
- Costs to implement P/MAs, including capital/one-time costs and ongoing costs.

The estimated costs to WRMWSD for local groundwater management activities is approximately $261,000 per year, the estimated proportional share of costs for basin-wide groundwater management activities is approximately $120,000 per year, and the estimated costs to implement P/MAs is approximately $3.5 million per year in the first five years, increasing to between approximately $4.5 million to $7.1 million per year in the subsequent 15 years.

Sources of funding for SGMA compliance activities will include primarily regular fees and assessments from customers and rate payers. This primary source of revenue will be supplement to the greatest extent possible through loans and grants, and possibly by additional fees imposed as an incentive to discourage

unsustainable water use practices. All efforts by WRMWSD to raise revenue through fees and charges will be conducted pursuant to applicable laws and regulations (e.g., Proposition 218 and related laws).

ES.13. Conclusion

The passage of SGMA in 2014 ushered in a new era of mandatory groundwater management in California's most intensively used groundwater basins. The law was followed by promulgation of a robust regulatory framework for GSA formation and GSP development and implementation. The law and regulations emphasize the use of best available science, local control and decision making, and active engagement of affected stakeholders. Because of the breadth and scope of the groundwater sustainability problem in California and the legislative and regulatory response to it, SGMA presents significant challenges both for local implementing agencies and groundwater users alike. Achieving and maintaining sustainability in the face of uncertain future water supply conditions while addressing and balancing the needs of all beneficial uses and users will require significant effort, creative solutions, and unprecedented collaboration. As the implementing agency within the Wheeler Ridge-Maricopa Management Area, WRMWSD is committed to facing these challenges in a manner that upholds the interests of its landowners and other beneficial uses and users of groundwater.

INTRODUCTION

1. PURPOSE OF THIS GROUNDWATER SUSTAINABILITY PLAN

The purpose of this Groundwater Sustainability Plan (GSP) Management Area Plan (MA Plan) is to, in combination with the Kern Groundwater Authority (KGA) Groundwater Sustainability Agency (GSA) and the other GSAs in the Kern County Subbasin (Kern Subbasin), meet the regulatory requirements set forth in the three-bill legislative package consisting of Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley), and SB 1319 (Pavley), collectively known as the Sustainable Groundwater Management Act (SGMA)[6]. SGMA defines sustainable groundwater management as the "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results". Undesirable results are defined by SGMA as any of the following effects caused by groundwater conditions occurring throughout the basin:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply;
- Significant and unreasonable reduction of groundwater storage;
- Significant and unreasonable seawater intrusion;
- Significant and unreasonable degraded water quality;
- Significant and unreasonable land subsidence; and/or
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

The Kern Subbasin has been identified by the California Department of Water Resources (DWR) as critically overdrafted. WRMWSD's MA Plan has been developed in coordination with the KGA GSA to meet SGMA regulatory requirements by the 31 January, 2020 deadline for critically-overdrafted basins while reflecting local needs and preserving local control over water resources. WRMWSD's MA Plan, in coordination with the KGA Umbrella GSP and the other GSPs in the Kern Subbasin, provides a path to achieve and document sustainable groundwater management within 20 years following Plan adoption, and preserves the long-term sustainability of locally-managed groundwater resources now and into the future. This MA Plan was approved for inclusion in the KGA GSA Umbrella GSP by the WRMWSD Board on 11 December 2019 (**Appendix J**).

[6] Nothing in this Management Area Plan or in the related Groundwater Sustainability Plan determines or alters surface water rights or groundwater rights under common law, any provision of law that determines or grants surface water rights, or otherwise (see, California Water Code section 10720.5(b)). This Management Area Plan and the related Groundwater Sustainability Plan shall be construed consistent with Section 2 of Article X of the California Constitution and nothing provided in this Chapter modifies rights or priorities to use or store groundwater except as expressly stated in California Water Code section 10720.5(a). The District reserves and retains all rights to the use of water to the extent provided by law.

2. SUSTAINABILITY GOAL

☑ **23 CCR § 354.24**

The sustainability goal for the Wheeler Ridge-Maricopa Management Area is to maintain an economically-viable groundwater resource for the beneficial use of the Management Area's landowners and water users by utilizing the area's groundwater resources within the local sustainable yield. Long-term groundwater sustainability, i.e., the absence of undesirable results within 20 years of the applicable statutory deadline, will be achieved and maintained through the implementation of projects and management actions as described herein to both increase water supplies and reduce demands within the Management Area.

The local sustainability goal, above, is consistent with and in addition to the basin-wide sustainability goal being adopted by all GSAs in the Kern Subbasin, shown below (as of 9 August 2019).

> "The sustainability goal of the Kern County Subbasin is to:
>
> - Achieve sustainable groundwater management in the Kern County Subbasin through the implementation of projects and management actions at the member agency level of each GSA
> - Maintain its groundwater use within the sustainable yield of the basin
> - Operate within the established sustainable management criteria, which are based on the collective technical information presented in the GSPs in the Subbasin.
> - Implement projects and management actions that include a variety of water supply development and demand management actions
> - Collectively bring the Subbasin into sustainability and to maintain sustainability over the implementation and planning horizon.
>
> Further, the Subbasin sustainability goal includes a commitment to monitor and report groundwater conditions, as required by SGMA, and to continue coordination among the KGA member agencies and all other GSA's in the Subbasin to identify the potential for, or presence of, undesirable results and actions to prevent undesirable results. The coordination process established in the development of this GSP and memorialized in the Coordination Agreement will ensure that the Subbasin is managed as a shared groundwater resource and that the districts within the Subbasin work collaboratively towards achieving and maintaining sustainable groundwater use."

3. AGENCY INFORMATION

3.1. Name and Mailing Address of the Agency

☑ 23 CCR § 354.6(a)

The Wheeler Ridge-Maricopa Water Storage District Management Area (Wheeler Ridge-Maricopa Management Area)[7] is the portion of the Kern County Subbasin of the San Joaquin Valley Groundwater Basin (Department of Water Resources [DWR] Basin No. 5-022.14) that underlies the WRMWSD. WRMWSD is member of the Kern Groundwater Authority Groundwater Sustainability Agency (KGA GSA or Agency) per a Joint Power Agreement (JPA) executed on 22 March 2017. Information regarding the Agency's mailing address is provided in the KGA "Umbrella" GSP.

The mailing address for the WRMWSD is:

12109 Highway 166
Bakersfield, California 93313-9630

The mailing address for the KGA GSA is:

Kern Groundwater Authority
(c/o Provost & Pritchard Consulting Group)
1800 30th Street, Suite 280
Bakersfield, CA 93301

3.2. Organization and Management Structure of the Agency

☑ 23 CCR § 354.6(b)

Per the JPA executed on 22 March 2017, the KGA GSA Board is composed of one representative from each of the general member agencies[8], including: Arvin Community Services District (ACSD), Arvin-Edison Water Storage District (AEWSD), Cawelo Water District (CWD), Kern County Water Agency (KCWA), Kern-Tulare Water District (KTWD), Kern Water Bank Authority (KWBA), North Kern Water Storage District (NKWSD), Rosedale-Rio Bravo Water Storage District (RRBWSD), Semitropic Water Storage District (SWSD), Shafter-Wasco Irrigation District (SWID), Southern San Joaquin Municipal Utility District (SSJMUD), Tejon-Castac Water District (TCWD), West Kern Water District (WKWD), Westside District Water Authority (WDWA) and WRMWSD, and the City of Shafter.

To facilitate the implementation of the KGA GSA GSP, the Agency is divided into management areas formed by the portion of the Kern Subbasin that underlies the boundaries of each general member agency. Each general member agency will prepare a refined Management Area Plan for their management area.

[7] In this document, the term "Wheeler Ridge-Maricopa Management Area" is used in its entirety the first time the area is being referenced in each paragraph; subsequent references to this area in each paragraph use the term "Management Area".
[8] See executed JPA for a full list of member agencies to the KGA.

The WRMWSD Board of Directors also represents the Wheeler Ridge-Maricopa Management Area and it is formed by nine directors. A current list of WRMWSD Directors can be found on the District's website at https://wrmwsd.com/board-of-directors/.

The KGA GSA was formed by a resolution of the Board of Directors of the Kern Groundwater Authority on 26 April 2017. The KGA GSA is governed by a Board of Directors that includes a representative of each member agency. Information regarding current KGA GSA Board members can be found on the KGA's website at http://www.kerngwa.com/.

3.3. MA Plan Manager

☑ **23 CCR § 354.6(c)**

The Plan Manager for this MA Plan is Sheridan Nicholas, Engineer-Manager of the WRMWSD. Mr. Nicholas can be reached at:

Sheridan Nicholas
Engineer-Manager
Wheeler Ridge-Maricopa Water Storage District
12109 Highway 166
Bakersfield, California 93313-9630
661-858-2281 office phone
email: snicholas@wrmwsd.com

The KGA GSP Plan Manager is Patricia Poire. Ms. Poire can be reached at:

Patricia Poire, Planning Manager
Telephone: (661) 479-7171
Fax: (661) 479-7172
Email: ppoire@kerngwa.com

3.4. Legal Authority of the GSA

☑ **23 CCR § 354.6(d)**

The KGA GSA applied for and was granted GSA status under SGMA Section 10723(c). Please refer to the KGA Umbrella GSP for further discussion of the legal authority of the KGA GSA, demonstrating that it has the legal authority to implement the GSP.

3.5. Estimated Cost of Implementing the GSP and the GSA's Approach to Meet Costs

☑ **23 CCR § 354.6(e)**

Information on estimated costs to implement the GSP within the Wheeler Ridge-Maricopa Management Area, and the WRMWSD's plan to meet those costs is provided in **Section 19 *Plan Implementation Costs***.

4. GSP ORGANIZATION

This MA Plan is organized as follows:

- Sections 1 through 4 comprise the **Introduction**, including the following sections:
  - Section 1. Purpose of this Groundwater Sustainability Plan
  - Section 2. Sustainability Goal
  - Section 3. Agency Information
  - Section 4. GSP Organization
- Section 5 provides the **Description of the Plan Area**.
- Sections 6 through 10 present the **Basin Setting**, including the following sections:
  - Section 6. Introduction to Basin Setting
  - Section 7. Hydrogeologic Conceptual Model
  - Section 8. Current and Historical Groundwater Conditions
  - Section 9. Water Budget Information
  - Section 10. Management Areas
- Sections 11 through 15 present the **Sustainable Management Criteria**, including the following sections:
  - Section 11. Introduction to Sustainable Management Criteria
  - Section 12. Sustainability Goal
  - Section 13. Undesirable Results
  - Section 14. Minimum Thresholds
  - Section 15. Measurable Objectives and Interim Milestones
- Section 16 presents the **Monitoring Network**.
- Section 17 presents the **Projects and Management Actions**.
- Sections 18 through 20 present **Plan Implementation**, including the following sections:
  - Section 18. WRMWSD Plan Implementation
  - Section 19. Plan Implementation Costs
  - Section 20. Plan Implementation Schedule
- **References and Technical Studies** are included at the end of this document.
- Supporting information is provided in appendices as follows:
  - Appendix A. GSP Submittal Checklist
  - Appendix B. Parcels Outside of WRMWSD Covered by MA Plan
  - Appendix C. Summary of Stakeholder Communications and Engagement

- Appendix D. Detailed Responses to Selected Comments Received Regarding the MA Plan
- Appendix E. Potential Additional Water Quality Data Sources
- Appendix F. Analysis of Temporal Characteristics of Available Groundwater Quality Data
- Appendix G. Methods and Data Used in the Water Budget Spreadsheet Model Approach
- Appendix H. WRMWSD Long-term Monitoring Access Agreement
- Appendix I. DWR California Aqueduct Subsidence Study (June 2017), Plates 20 – 24; DWR California Aqueduct Benchmark Survey Data, 2016-2019
- Appendix J. Board Resolution

PLAN AREA

5. DESCRIPTION OF THE PLAN AREA

☑ 23 CCR § 354.8

This section presents a description of the Plan Area for the Wheeler Ridge-Maricopa Management Area[9], and a summary of the relevant jurisdictional boundaries and other key land use features potentially relevant to the sustainable management of groundwater in the Management Area. This section also describes the water monitoring programs, water management programs, and general plans relevant to the Management Area and their influence on the development and execution of this Groundwater Sustainability Plan (GSP) Management Area Plan (MA Plan).

5.1. Summary of Jurisdictional Areas and Other Features

5.1.1. Area Covered by the Plan

☑ 23 CCR § 354.8(a)(1)
☑ 23 CCR § 354.8(b)

As discussed previously in **Section 3.2** ***Organization and Management Structure of the Agency***, this MA Plan is a locally refined subcomponent of the "Umbrella" GSP prepared by the Kern Groundwater Authority (KGA) Groundwater Sustainability Agency (GSA). This MA Plan covers a portion of the KGA GSA area, specifically the portion underlying Wheeler Ridge-Maricopa Water Storage District (WRMWSD). The area covered by this MA Plan, referred to herein as the "Wheeler Ridge-Maricopa Management Area" and shown on **Figure PA-1**, includes all WRMWSD lands within the Kern County Subbasin (Department of Water Resources [DWR] Basin 5-022.14) (referred to herein as the Kern Subbasin or basin) excepting 2,809 acres that occur within the West Kern Water District (WKWD). Lands within the WRMWSD service area that are located in the White Wolf Subbasin are managed under a separate GSP being prepared by the White Wolf GSA. The Arvin-Edison Water Storage District (AEWSD) jurisdictional boundary also partially overlaps the Management Area, both in the Kern Subbasin and the White Wolf Subbasin; AEWSD is a participating member of the KGA GSA and is developing a separate Management Area Plan for its jurisdictional area within the Kern Subbasin in close coordination with WRMWSD. For purposes of SGMA monitoring and management, WRMWSD and AEWSD have agreed that AEWSD will cover the overlap areas.

The Wheeler Ridge-Maricopa Management Area is in the southern-southeastern portion of the Kern Subbasin. The basin is bounded on the north by the Tulare Lake Subbasin (DWR Basin 5-022.12), the Tule Subbasin (DWR Basin 5-022.13), and the Kettleman Plain Subbasin (DWR Basin 5-022.17), and on the south by the White Wolf Subbasin (DWR Basin 5-022.18).

[9] In this document, the term "Wheeler Ridge-Maricopa Management Area" is used in its entirety the first time the area is being referenced in each paragraph; subsequent references to this area in each paragraph use the term "Management Area".

The Wheeler Ridge-Maricopa Management Area encompasses 91,430 acres of the KGA GSA. There are 10 other GSAs that are located within the Kern Subbasin[10]: Buena Vista Water Storage District (BVWSD), Cawelo GSA, Greenfield County Water District, Henry Miller Water District (HMWD), Kern River GSA, McFarland GSA, Olcese GSA, Pioneer GSA, Semitropic Water Storage District, and West Kern Water District (WKWD). These GSAs were formed by several other GSA-eligible public agencies in the basin and in some cases are preparing separate GSP documents that will be coordinated with the GSP prepared by the KGA GSA. The rest of the basin is comprised of undistricted lands (i.e. "white lands"), some of which have executed management agreements with nearby water districts or other public agencies.

5.1.2. Adjudicated Areas

☑ 23 CCR § 354.8(a)(2)
☑ 23 CCR § 354.8(b)

The basin is not adjudicated, and no portion of the basin is being managed pursuant to an alternative.

5.1.3. Jurisdictional Boundaries

☑ 23 CCR § 354.8(a)(3)
☑ 23 CCR § 354.8(b)

The Wheeler Ridge-Maricopa Management Area is entirely within Kern County and the Kern County Water Agency. As shown on **Figure PA-1**, water agencies that partially overlie the Management Area are AEWSD and the WKWD[11]. Additional water agencies and public water systems in the vicinity of the Management Area include: BVWSD, HMWD, Kern Delta Water District (KDWD), Opal Fry and Son Water System, and Mettler County Water District (MCWD).

According to the information made available by DWR[12] in support of the development of GSPs, there are no tribal lands nor state lands within or in the vicinity of the Wheeler Ridge-Maricopa Management Area. Federal lands within the Management Area include approximately 500 acres of national public lands managed by the U.S. Bureau of Land Management, located in the northern portion of the District (see **Figure PA-2**). Tribal, federal and state lands within the KGA GSA are identified in the KGA Umbrella GSP.

DWR further presents information regarding U.S. Census Blocks, Tracts and Places that are defined as Disadvantaged Communities (DAC) or Severely Disadvantaged Communities (SDAC). **Figure PA-3** shows DAC/SDAC areas within the Wheeler Ridge-Maricopa Management Area. As shown on **Figure PA-3**, a majority of the Management Area is considered either a severely disadvantaged or a disadvantaged community based on the Census Block Group and Census Tract characterizations (see **Figure PA-3**).

The Wheeler Ridge-Maricopa Management Area is located entirely within the Kern County General Plan area (see **Figure PA-7**). This plan is described in further detail below in **Section *5.3 Land Use Elements or Topic Categories of Applicable General Plans*** .

[10] SGMA Portal: https://sgma.water.ca.gov/portal/gsa/all, retrieved on 11/30/2018.
[11] WKWD overlaps a portion of WRMWSD, however, the GSA formed by this district (WKWD GSA) does not include such area.
[12] SGMA Data Viewer: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer

5.1.4. Existing Land Use and Water Use

☑ 23 CCR § 354.8(a)(4)
☑ 23 CCR § 354.8(b)

As shown on **Figure PA-4**, agriculture is the primary land use within the Wheeler Ridge-Maricopa Management Area, followed by idle/non-irrigated lands. As of Spring 2017, approximately 63,620 acres (71%) are classified as irrigated agricultural lands within the Management Area, ~23,950 acres (27%) are classified as non-irrigated agricultural/native lands, and ~2,260 acres (3%) are classified as urban areas and artificial channels.

Agricultural water demands are met with surface water and/or groundwater depending on location within the Wheeler Ridge-Maricopa Management Area. The District has a contract for 197,088 acre-feet per year (AFY) of Table A water from the State Water Project (SWP) through the Kern County Water Agency (KCWA) (WRMWSD, 2015). **Figure PA-5** shows the parcels within the District's surface water service area (SWSA). The reminder of the Management Area relies solely on groundwater to meet demands; surface water customers are not precluded from pumping underlying groundwater for beneficial use.

Imported surface water is served only to agricultural water users for irrigation. All municipal/industrial (M&I) and domestic demands are met by groundwater pumping. The potable consumption of groundwater in the Management Area is limited to domestic well owners.

Land use designations under the Kern County General Plan are discussed in **Section 5.3.1** ***Kern County General Plan*** and shown on **Figure PA-7**.

5.1.5. Well Density per Square Mile

☑ 23 CCR § 354.8(a)(5)
☑ 23 CCR § 354.8(b)

Figure PA-6 shows the density of wells per square mile within the Wheeler Ridge-Maricopa Management Area, based on Well Completion Report records compiled by DWR[13] and refined information on active domestic wells obtained from the Community Water Center.[14] According to these records, approximately 121 production wells, 27 active domestic wells, and one public supply wells have been installed within the Public Land Survey System (PLSS) sections[15] that fall partially or entirely within the Management Area.

The WRMWSD Data Management System (DMS) identifies 559 wells within the Wheeler Ridge-Maricopa Management Area; 100 of these wells are known to be active, 49 inactive or abandoned, and the status of 410 wells is unknown. Of the active wells, 79 are production wells, 14 are domestic/Municipal & Industrial (M&I) wells, and seven are monitoring wells. As part of GSP preparation efforts, the District is attempting to reconcile the information in its DMS with the DWR records. These data reconciliation efforts are expected to continue as part of GSP implementation.

[13] DWR Well Completion Report Map Application website: https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37, accessed 08/17/2018.
[14] Community Water Center Drinking Water Vulnerability Tool, obtained 24 May 2019.
[15] Each PLSS section represents approximately 1 square mile of area (i.e., 640 acres).

The closest urban communities to the Wheeler Ridge-Maricopa Management Area are Maricopa and Mettler but there are no communities dependent on groundwater within the Management Area. The only potable groundwater consumption comes from the domestic wells.

5.1.6. Lands Outside of District Covered by MA Plan

Under SGMA (CWC § 10724), counties are presumed to be the GSA for areas that are not otherwise covered by another GSA, unless the county specifically opts out of this GSA role. In the Kern Subbasin, the County of Kern opted out of this role in early 2019 which resulted in lands outside of the other GSA boundaries being "uncovered". To address this, the KGA sent notices to these "undistricted" land owners offering an opportunity to sign an agreement for coverage under the Management Area Plans of nearby KGA members. Three landowners with a total of four parcels outside of the District totaling approximately 1,122 acres accepted the offer to gain coverage under the WRMWSD MA Plan. Given the late time at which these offers were made and accepted following the County's withdrawal, KGA determined that it would not be possible to cover these undistricted lands in the KGA member's Management Area Plans to the same degree of detail as lands that were covered by KGA members from the start; instead, KGA determined that it would be appropriate to include the lands in an appendix to the Management Area Plans, providing basic information about each parcel including the owner, APN, area, land/water use, and well information. As such, **Appendix B** includes a table of these lands[16] with the above information as well as a figure showing their locations. It is the intention of KGA and its members to include additional information for these lands (if they still need GSP coverage) in their 2025 Management Area Plan updates.

5.2. Water Resources Monitoring and Management Programs

5.2.1. Existing Monitoring and Management Programs

☑ **23 CCR § 354.8(c)**

Existing Monitoring Programs

Existing groundwater monitoring in the Wheeler Ridge-Maricopa Management Area includes:

- The California Statewide Groundwater Elevation Monitoring (CASGEM) Program is a program that tracks long-term groundwater elevation trends in groundwater basins throughout California. The program's mission is to establish a permanent, locally-managed program of regular and systematic monitoring in all of California's alluvial groundwater basins, including within the Management Area. In 2011, the District submitted to DWR an application to be the CASGEM Monitoring Entity for the District's service area (except the overlap areas with AEWSD and WKWD), but a full CASGEM monitoring plan has not been completed. Therefore, all wells monitored within the District are designated as "voluntary wells" under the CASGEM program at this point.
- The Groundwater Ambient Monitoring and Assessment (GAMA) Program is California's comprehensive groundwater quality monitoring program that was created by the State Water Resources Control Board (SWRCB) in 2000. The GAMA Program monitors groundwater quality trends throughout California, including within the Management Area.[17]

[16] All four undistricted parcels included in **Appendix B** are unirrigated.
[17] GAMA Website: https://www.waterboards.ca.gov/water_issues/programs/gama/about.html.

- The Monitoring and Reporting Program (MRP) from the Irrigated Lands Regulatory Program (ILRP), establishes the specific surface and groundwater monitoring, reporting, and electronic data deliverable requirements for irrigated lands used for commercial purposes within the Tulare Lake Basin Area (The ILRP is further described in the section below "Existing Management Programs"). The purpose of this MRP is to determine the effects of irrigated lands waste discharges on water quality and assess the effectiveness of ILRP management actions. Data collected and reports are available in the GAMA database (Central Valley Regional Water Quality Control Board [CVRWQCB], 2013).
- Central Valley-Salinity Alternatives for Long-term Sustainability (CV-SALTS) is a collaborative stakeholder driven and managed program to develop sustainable salinity and nitrate management planning for the Central Valley. The Kern Subbasin is a Priority 2 basin for nitrate management. Consequently, the nitrate control program schedule is set to begin in 2021 as described in the KGA Umbrella GSP.
- The District conducts periodic groundwater level monitoring and groundwater quality sampling in selected wells throughout the Management Area as part of its on-going water resources management efforts, including the AEWSD-WRMWSD overlap portion of the Management Area.

CASGEM groundwater elevations (and groundwater elevations from wells in the WRMWSD and AEWSD monitoring networks) have been used to characterize groundwater level conditions (see **Section 8.2 *Groundwater Elevations and Flow Direction***)[18]. Water quality data from the above sources have been used to assess groundwater quality conditions (see **Section 8.5 *Groundwater Quality***).

Existing surface water monitoring in the Wheeler Ridge-Maricopa Management Area includes the following:

- The WRMWSD is establishing a network of five stream gauges in the San Emigdio mountains, three of which are on streams that flow into the Management Area and two of which flow into the White Wolf Subbasin.
- The California Data Exchange Center (CDEC) provides a centralized database to store, process, and exchange real-time hydrologic information gathered by various cooperators throughout the State[19]. The CDEC has three monitoring points within or in the vicinity of the Management Area.

Another surface water monitoring program in the basin is the United States Geological Survey (USGS) National Water Information System; however, there are not monitoring points within or in the vicinity of the Wheeler Ridge-Maricopa Management Area.

[18] While they collect groundwater level data on a regular basis, WRMWSD is not an official CASGEM monitoring entity for the Kern Subbasin.
[19] CDEC Website: http://cdec.water.ca.gov/cdecstation2/

Land subsidence data in the vicinity of WRMWSD is available through the following sources:

- University Navstar[20] Consortium (UNAVCO) Plate Boundary Observatory's continuous and conventional Global Positioning System (GPS) network; and
- Remote sensing studies by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL).
- USGS San Joaquin Valley Land Subsidence Network. A subsidence monitoring network in the San Joaquin Valley was implemented in the 1960s to help quantify the extent and magnitude of the subsidence that was first discovered in the 1950s. To identify existing and future subsidence, a new monitoring network is currently being developed[21].
- The DWR's San Luis Field Division and the San Joaquin Field Division conducted a land subsidence study along the California Aqueduct (DWR, 2017) to understand the magnitude, location and effects of past and present land subsidence. For this study, data from 940 survey benchmarks along the California Aqueduct that have been monitored at 1-year and 7-year intervals by the San Luis Field Division, and 1,009 benchmarks monitored at 3-year and 7-year intervals by the San Joaquin Field Division was used.

The WRMWSD will incorporate information from these existing regional and local programs to inform GSP development and implementation. The Wheeler Ridge-Maricopa Management Area Monitoring Network is further described in **Section 16 *Monitoring Network***.

Existing Management Programs

Existing groundwater management programs within the Wheeler Ridge-Maricopa Management Area include:

- The Wheeler Ridge-Maricopa Management Area falls within the South County Subregion of the Kern County Integrated Regional Water Management Region (Kern Region) and is therefore included in the November 2011 Kern Integrated Regional Water Management Plan (Kern IRWMP; Kennedy/Jenks Consultants, 2011). The Kern Region covers approximately 5,690 square miles of Kern County and a small portion of southern Kings County. The Kern Region is separated into nine subregions, in acknowledgement of the variation in geography, agency boundaries, and water management strategies. These subregions are: (1) Greater Bakersfield, (2) Kern Fan, (3) Mountains/Foothills, (4) Kern River Valley, (5) North County, (6) South County, (7) West Side, (8) KCWA1 and (9) the County of Kern.

  The key issues, needs, challenges, and priorities for the South County subregion, according to the Kern IRWMP (2011), include the following:

  - Decreased Imported Water Supply;
  - Water Quality/Groundwater Contamination;
  - Urban Growth Encroachment on Key Recharge Areas; and

[20] Navstar is a network of U.S. satellites that provide GPS services.
[21] From USGS California Water Science Center website: https://ca.water.usgs.gov/projects/central-valley/land-subsidence-san-joaquin-valley.html

- Water Rights.

A 2019 Kern IRWMP update that is consistent with the 2016 IRWM Guideline requirements was recently approved by DWR (9 December 2019) and is now entering a 30-day Public Comment Period that is expected to be completed in mid-January 2020. Subsequent adoption of the 2019 Plan update is anticipated to occur in February 2020.

- The WRMWSD has an existing Groundwater Management Plan (GWMP). Although this MA Plan extends and supersedes the groundwater management efforts outlined in the GWMP, a brief summary of this GWMP is included below for completeness.

- The WRMWSD GWMP was developed in 2007 and aimed to increase reliability and sustainability of water supply by conjunctively integrating groundwater with imported surface water supply. Specifically, the WRMWSD GWMP (2007) set forth the following groundwater management objectives to guide future water management actions:
  - Prevent a return to historical overdraft conditions;
  - Maintain groundwater quality;
  - Monitor water levels, water quality, and groundwater storage; and
  - Estimate groundwater use and future groundwater demands on the basin.
- The ILRP, initiated in 2003 and last modified in 2013 to include groundwater provisions, is a program whose objective is to protect both groundwater and surface water from irrigated agricultural waste dischargers throughout the Central Valley. The ILRP is implemented through CVRWQCB Orders, also called Waste Discharge Requirements (WDRs). Order R5-2013-0120 (Order) regulates discharges in the Tulare Lake Basin. Under this order, third parties are responsible for fulfilling regional requirements and conditions (e.g. surface and groundwater monitoring). WRMWSD is a member of the Kern River Watershed Coalition Authority (KRWCA) which is a third-party coalition that formed in 2014 to respond to the Order. Key elements of the ILRP are: Surface water/Groundwater Quality Monitoring Plan, Sediment and Erosion Control Plan, Nitrogen Management Plan and Mitigation Monitoring. The overall goals of the ILRP for the Tulare Lake Basin Area are:
  - To restore and/or maintain the highest reasonable quality of state waters;
  - Minimize waste discharge from irrigated agricultural lands that could degrade state waters quality;
  - Maintain the economic viability of agriculture in California's Central Valley; and
  - Ensure that irrigated agricultural discharges do not impair access by Central Valley communities and residents to safe and reliable drinking water.

  In accordance with these goals, the objectives are the following:
  - Restore and/or maintain appropriate beneficial uses established in CVWQCB plans by ensuring that all state waters meet applicable water quality objectives; and

- Encourage implementation of management practices that improve water quality in keeping with the first objective, without jeopardizing the economic viability for all sizes of irrigated agricultural operations.

- The District prepared an Agricultural Water Management Plan (AWMP) in accordance with the requirements of Senate Bill (SB) X7-7 and Governor's Executive Order B-29-15 and it was last modified in December 2015. The purpose of this AWMP is to describe and document the District's existing and proposed agricultural water management programs and activities aimed to provide reliable agricultural water supply for its landowners. The document provides a description and quantification of water supply sources for agricultural users (surface and groundwater), a water reliability assessment, and efficient water management practices (WRMWSD, 2015).

5.2.2. Operational Flexibility Limitations

☑ 23 CCR § 354.8(d)

The above water resource monitoring programs are not expected to limit operational flexibility in the basin. In fact, some of these management and monitoring programs will be integral to the on-going monitoring and reporting that will be conducted pursuant to this MA Plan (see **Section 16 *Monitoring Network***).

For example, the IRWMP and GSP development are complimentary management processes. To the extent that the issues identified for the greater IRWMP region affect the Wheeler Ridge-Maricopa Management Area, these issues will be discussed in the following sections of this MA Plan. The implementation of this MA Plan will contribute to the sustainable use of water supplies within the IRWMP region and the IRWMP is not expected to limit operational flexibility in the Management Area.

Most of the groundwater management objectives identified in the WRMWSD GWMP are consistent with the issues and objectives identified in the following sections of this MA Plan. The implementation of this MA Plan will contribute to the sustainable groundwater use within the Wheeler Ridge-Maricopa Management Area. Therefore, this GSP compliments and supersedes the GWMP.

5.2.3. Conjunctive Use in the Wheeler Ridge-Maricopa Management Area

☑ 23 CCR § 354.8(e)

Since 1971, WRMWSD has imported SWP surface water, supporting the conjunctive use of surface water and groundwater resources within the Wheeler Ridge-Maricopa Management Area, which has been the primary cause of the recovery and stability of groundwater levels observed in the area (see **Section 8 *Current and Historical Groundwater Conditions***). WRMWSD banks water in and returns it from out-of-District water banks (e.g., the Pioneer Water Bank; see **Section 9.2.1 *Surface Water Inflows and Outflows***) through its own conveyance network and the California Aqueduct. As of December 2018, the District has a combined 200,700 acre-feet (AF) stored in its banking projects. The California Aqueduct is also used for intra-District conveyance, wherein delivered water supplies are blended with groundwater, the proportion of which varies depending on the season and the water year type.

5.3. Land Use Elements or Topic Categories of Applicable General Plans

☑ 23 CCR § 354.8(f)

The following sections describe topic categories of general plans and other planning documents with specific relevance to the Wheeler Ridge-Maricopa Management Area MA Plan. Other planning documents developed for Kern County and the Wheeler Ridge-Maricopa Management Area vicinity (e.g., habitat conservation plans, hazard mitigation plans, etc.) are further described in the Umbrella GSP.

5.3.1. Kern County General Plan

☑ 23 CCR § 354.8(f)(1)

The Wheeler Ridge-Maricopa Management Area is located within the Kern County General Plan area (Kern County, 2009). The current Kern County General Plan was first adopted in 2004 and has undergone several amendments, the most recent amendment approved in 2009 (General Plan). The County is currently working to update its General Plan through 2040, with completion of the "2040 General Plan" expected in 2019. This section identifies relevant policies in the current General Plan that could: (1) affect water demands in the Management Area (e.g., due to population growth and development of the built environment), (2) influence the GSP's ability to achieve sustainable groundwater use, and (3) affect implementation of General Plan land use policies.

Figure PA-7 shows the current General Plan land use designations within the Wheeler Ridge-Maricopa Management Area. The land use designations include primarily intensive and extensive agriculture, residential, mineral and petroleum, resource management, federal land, and seven other designations that account for less than 1% of the Management Area. These designations are generally consistent with the predominantly agricultural land use within the Management Area as shown in **Figure PA-4**.

The Land Use, Open Space, and Conservation Element (Chapter 1) of the General Plan includes the following goals, policies, and implementation measures that are related to groundwater or land use management, and that could potentially influence the implementation of this GSP.

Physical and Environmental Constraints

- **Implementation Measure C.** Cooperate with the Kern County Water Agency to classify lands in the County overlying groundwater according to groundwater quantity and quality limitations.

Public Facilities and Services

- **Goal 5.** Ensure that adequate supplies of quality (appropriate for intended use) water are available to residential, industrial, and agricultural users within Kern County.
- **Goal 7.** Facilitate the provision of reliable and cost-effective utility services to residents of Kern County.
- **Policy 2.** The efficient and cost-effective delivery of public services and facilities will be promoted by designating areas for urban development which occur within or adjacent to areas with adequate public service and facility capacity.

- **Policy 2.a.** Ensure that water quality standards are met for existing users and future development.

Residential

- **Goal 6.** Promote the conservation of water quantity and quality in Kern County.
- **Goal 7.** Minimize land use conflicts between residential and resource, commercial, or industrial land uses.

Industrial

- **Goal 2.** Promote the future economic strength and well-being of Kern County and its residents without detriment to its environmental quality.

Resource

- **Policy 7.** Areas designated for agricultural use, which include Class I and II and other enhanced agricultural soils with surface delivery water systems, should be protected from incompatible residential, commercial, and industrial subdivision and development activities.
- **Policy 10.** To encourage effective groundwater resource management for the long-term economic benefit of the County the following shall be considered:
- **Policy 10.a.** Promote groundwater recharge activities in various zone districts.
- **Policy 10.c.** Support the development of groundwater management plans.
- **Policy 10.d.** Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water and groundwater and desalination.

General Provisions

- **Goal 1.** Ensure that the County can accommodate anticipated future growth and development while maintaining a safe and healthful environment and a prosperous economy by preserving valuable natural resources, guiding development away from hazardous areas, and assuring the provision of adequate public services.
- **Policy 40.** Encourage utilization of community water systems rather than the reliance on individual wells.
- **Policy 41.** Review development proposals to ensure adequate water is available to accommodate projected growth.
- **Policy 45.** New high consumptive water uses, such as lakes and golf courses, should require evidence of additional verified sources of water other than local groundwater. Other sources may include recycled stormwater or wastewater.
- **Implementation Measure U.** The Kern County Environmental Health Services Department will develop guidelines for the protection of groundwater quality which will include comprehensive well construction standards and the promotion of groundwater protection for identified degraded watersheds.

☑ 23 CCR § 354.8(f)(2)
☑ 23 CCR § 354.8(f)(3)

The above goals, policies and implementation measures established by the General Plan are complementary to sustainable groundwater management of the Wheeler-Ridge Management Area relative to future land use development and conservation (i.e., the General Plan encourages development of the County's groundwater supply to ensure that existing users have access to high quality water, and states that future growth should be accommodated only while ensuring that adequate high-quality water supplies are available to existing and future users). Successful implementation of this MA Plan will help to ensure that the Management Area groundwater supply is managed in a sustainable manner by avoiding undesirable results as defined under SGMA. Therefore, implementation of General Plan policies is not expected to affect the ability of the Management Area to achieve groundwater sustainability.

Likewise, implementation of this MA Plan is not anticipated to significantly affect the water supply assumptions or land use plans within the General Plan over the planning horizon. Given that the General Plan is being updated concurrently with the development of this MA Plan, and the County is engaged in the process of GSP development through its participation in the KGA GSA, it is anticipated that the 2040 General Plan would take into account this MA Plan and utilize consistent water supply assumptions over the 2040 planning horizon. As required by California Government Code § 65352.5(d), the GSA will coordinate with and provide the necessary information to land use planning agencies that are adopting or amending their general plan.

5.3.2. Well Permitting Process

☑ 23 CCR § 354.8(f)(4)

Well permits within the Wheeler Ridge-Maricopa Management Area are issued by the Kern County Public Health Services Department Water Well Program. The Water Well Program issues permits to construct, reconstruct and destroy water wells. All wells must be constructed in accordance with Kern County Ordinance Code Section 14.08, and DWR Bulletins 74-81 and 74-90, except as modified by subsequent revisions. The ordinance requires, among other things, that domestic and agricultural wells be installed a minimum distance from potential pollution and contaminant sources, water quality be tested for new and reconstructed wells, an NSF 61 approved flowmeter be installed, and the final well construction be inspected by County staff. It is expected that as part of GSP implementation, the Water Well Program may be more closely coordinated with KGA GSA activities to support long-term sustainability within the Management Area and the Basin at large. Recently, the Kern County Public Health Services Department (KCPHSD) released a supplemental well application for wells intended to be installed on overdrafted basins. This new form additionally requires water district and GSA information, granting GSAs review power. Starting in 2019, it is WRMWSD's policy to provide a written response to KCPHSD and the well applicant when supplemental well application forms are received.

5.4. Additional GSP Elements

☑ 23 CCR § 354.8(g)

Per California Water Code (CWC) Section (§) 10727.4, a GSP shall include, where appropriate and in collaboration with the appropriate agencies, all of the following:

Control of saline water intrusion

Because the Wheeler Ridge-Maricopa Management Area is located far from coastal areas, seawater intrusion is not considered to be an issue.

Wellhead protection

The Kern County Public Health Services Department Water Well Program issues permits to construct, reconstruct and destroy water wells (see **Section 5.3.2 *Well Permitting Process***).

Migration of contaminated groundwater

There are no known active contaminated groundwater sites within the Wheeler Ridge-Maricopa Management Area. The Central Valley Regional Water Quality Control Board's (CVRWQCB) GeoTracker and California Department of Toxic Substances Control (DTSC) EnviroStor databases show two closed Cleanup Program sites, one closed Leaking Underground Storage Tank (LUST) site, and four sites listed as "inactive – Needs Evaluation". These sites are discussed further in **Section 8.5 *Groundwater Quality*** below.

Well abandonment and well destruction program

The Kern County Public Health Services Department Water Well Program issues permits to construct, reconstruct and destroy water wells (see **Section 5.3.2 *Well Permitting Process***).

Replenishment of groundwater extractions

The District actively manages the groundwater basin within its boundaries through conjunctive use and other programs (see **Section 5.2.3 *Conjunctive Use in the Wheeler Ridge-Maricopa Management Area***).

Conjunctive use and underground storage

The District actively manages the groundwater basin within its boundaries through conjunctive use and other programs (see **Section 5.2.3 *Conjunctive Use in the Wheeler Ridge-Maricopa Management Area***).

Well construction policies

The Kern County Public Health Services Department Water Well Program issues permits to construct, reconstruct and destroy water wells (see **Section 5.3.2 *Well Permitting Process***).

Groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects

The District constantly pursues water conservation through its water management practices. Currently its efficient water management practices for agricultural users are described in the WRMWSD Agricultural Water Management Plan (WRMWSD, 2015). This plan is summarized in **Section 5.2.1 *Existing Monitoring and Management Programs***.

The District also operates a "User Input pump-in program" to facilitate conveyance of groundwater pumped by landowners through its distribution system to other lands within the WRMWSD service area owned by that same landowner.

Efficient water management practices

The District constantly pursues gaining efficiency through its water management practices. Currently its efficient water management practices for agricultural users are described in the WRMWSD Agricultural

Water Management Plan (WRMWSD, 2015). This plan is summarized in **Section 5.2.1** ***Existing Monitoring and Management Programs***.

Relationships with State and federal regulatory agencies

As described above, WRMWSD maintains a water supply contract with DWR for its SWP surface water supply that remains in effect until 2035. Currently, the Contractors and DWR are in the validation process of approving a contract extension to 2085.

Land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity

Applicable land use planning documents and processes are discussed in **Section 5.3** ***Land Use Elements or Topic Categories of Applicable General Plans***.

Impacts on Groundwater Dependent Ecosystems

This topic is discussed in **Section 8.8** ***Groundwater Dependent Ecosystems***.

5.5. Notice and Communication

☑ **23 CCR § 354.10**

The Wheeler Ridge-Maricopa Management Area adopted its Stakeholder Communication and Engagement Plan (SCEP) in August 2018 to fulfill notice and communication requirements. The SCEP is included herein as **Appendix C**. Following the public process described herein, this MA Plan was approved for inclusion in the KGA GSA Umbrella GSP by the WRMWSD Board on 11 December 2019, as documented in **Appendix J**.

5.5.1. Beneficial Uses and Users of Groundwater

☑ **23 CCR § 354.10(a)**

As part of the SCEP, beneficial uses and users of groundwater in the basin were identified, including various holders of overlying groundwater rights (agricultural users, domestic users, commercial/industrial users, etc.), public water systems, local land use planning agencies, environmental users of groundwater, surface water users, the federal government, and DACs/SDACs (see SCEP Section 3). Additionally, a Stakeholder Constituency "Lay of the Land" exercise was developed which identified stakeholders in the Wheeler Ridge-Maricopa Management Area, key interests and issues, and the level of engagement expected with each stakeholder (see SCEP Table 1). This exercise will be updated during MA Plan implementation.

5.5.2. Public Meetings Summary

☑ **23 CCR § 354.10(b)**

The list below identifies public meetings, workshops, and direct outreach specific to SGMA and WRMWSD's MA Plan development and progress.

WRMWSD Board Meetings

The WRMWSD Board meets every month at its offices. Regular SGMA and MA Plan development updates are provided by Staff and/or WRMWSD's consultant, and stakeholders are provided the opportunity to provide input on the GSP development and implementation process. **Appendix C** includes a list of meeting dates where SGMA topics have been discussed at the WRMWSD Board Meeting. This information will be updated throughout MA Plan development and/or implementation.

Stakeholder Workshops

WRMWSD has hosted and/or participated in workshops intended to educate local landowners and other stakeholders within the Wheeler Ridge-Maricopa Management Area regarding SGMA, including:

- WRMWSD Sustainable Groundwater Management Act (SGMA) Landowner Workshop #1 – 05/24/2018
- Kern Subbasin Open House – 14 May 2019
- WRMWSD SGMA Landowner Workshop #2 – 12 June 2019
- Kern Subbasin GSP Public Review Open House – 26 September 2019

This list will be populated throughout MA Plan implementation. While stakeholders were very engaged during the workshops, no direct feedback was provided for input into the MA Plan.

Direct Outreach

Through the distribution of letters and surveys, WRMWSD has made numerous efforts to secure local stakeholder input during the SGMA process:

- KGA stakeholder survey distribution and respondence (May 2018 – July 2018);
- KGA agricultural stakeholder survey distribution and respondence (December 2018 – January 2019);
- Public water system data request (October 2018 – January 2019); and
- KGA Landowner Letter (June 2019).

Results from these outreach efforts have been compiled and reviewed. Data and information received from respondents has been incorporated into the WRMWSD DMS and into this MA Plan, as appropriate. The list above will be updated throughout MA Plan development and/or implementation.

5.5.3. Comments Received Regarding the MA Plan

☑ 23 CCR § 354.10(c)

As described in the above sections and in the remainder of this section, WRMWSD has conducted extensive engagement of stakeholders through the MA Plan development process. During this time, input and feedback from the public has been encouraged. **Table PA-1** below summarizes the comments and input received and how that input was incorporated into the MA Plan. In some cases, more detailed responses can be found in **Appendix D**.

Table PA-1 Comments and Input Received from Public During MA Plan Development

Source	Date	Type of Input	How Input was Incorporated
Chevron	19 November 2019	Email to WRMWSD with comments on Public Draft MA Plan	WRMWSD has taken the comments of Chevron into consideration in defining the bottom of the basin (**Section 7.1.3**). See **Appendix D** for additional information.
Farmland Reserve	27 November 2019	Letter to WRMWSD with comments on WRMWSD Public Draft MA Plan	Clarifying text added to the **Executive Summary** and **Section 9.1.3**. Detailed responses are included in **Appendix D.**
Wonderful Orchards / Wonderful Citrus	27 November 2019	Letter to WRMWSD with comments on KGA Public Draft GSP and WRMWSD Public Draft MA Plan	Clarifying text added to the **Executive Summary** and **Sections 8.1**, **9.1.3**, **18.2** and **18.4**. Detailed responses are included in **Appendix D.**

WRMWSD welcomes further comments during MA Plan implementation. **Table PA-1** will be updated as more comments are received during MA Plan implementation.

5.5.4. Communication

☑ **23 CCR § 354.10(d)**

The SCEP outlines WRMWSD's communication goals.

Decision-Making Process

☑ **23 CCR § 354.10(d)(1)**

The SCEP Section 2.2 outlines the WRMWSD decision-making process. Briefly, the process involves decision making by the WRMWSD Board of Directors during District Board meetings which are open to the public. In addition, the KGA GSA Board of Directions makes decisions of the KGA GSA at its public Board meetings. The KGA GSA Board is supported by a Coordination Committee composed of representatives of each KGA GSA board member, whose role is to provide recommendations to the KGA GSA Board on technical and other matters.

Public Engagement Opportunities

☑ **23 CCR § 354.10(d)(2)**

The SCEP Section 6 discusses public engagement opportunities and SCEP Sections 5 and 6 discuss how public input and responses will be handled. These opportunities include WRMWSD Board meetings, the planned public hearing at which the Draft MA Plan will be available for public comments, and the various stakeholder workshops and surveys, discussed below.

Stakeholder Involvement

☑ **23 CCR § 354.10(d)(3)**

The SCEP Section 5 outlines WRMWSD's goals, including open and transparent engagement with diverse stakeholders. Additionally, SCEP Section 4 outlines describes the Stakeholder Survey which the District used to gain additional knowledge on stakeholders within the Management Area. Only three entities have responded to the survey to date.

District staff have made numerous outreach efforts to landowners within the District regarding well access for monitoring. This effort has represented a constructive effort to improve local knowledge of well conditions and to engage landowners in SGMA implementation efforts.

Public Notification

☑ **23 CCR § 354.10(d)(4)**

The SCEP Section 5 and 6 details the methodology that is being followed to inform the public regarding all MA Plan updates, status, and actions.

5.5.5. Interagency Coordination

WRMWSD has actively engaged in both intrabasin and interbasin coordination efforts through multiple avenues during the GSP development process, including:

KGA Board/Coordination Committee Meetings

Prior to enactment of the SGMA, the KGA was established to provide a framework for the active, comprehensive management of the groundwater basin underlying the valley portion of Kern County, to preserve and maintain local control of groundwater resources and provide long term surety for all basin users. With passage of the SGMA, the KGA seeks to coordinate local groundwater management efforts and is working with its members to determine the most cost effective and efficient way of meeting the new requirements of the SGMA. During 2016-2018 the KGA Board of Directors met monthly at the Kern County office in Bakersfield. These monthly meetings have continued into 2019, now at the Great Bakersfield Chamber. Meeting agendas and other information can be found at http://www.kerngwa.com.

The KGA Coordination Committee meets monthly at the Rosedale-Rio Bravo WSD office. Meeting agendas and other information can be found at http://www.kerngwa.com/.

Kern Managers Meetings

Managers of member agencies to the KGA as well as representatives from other Kern GSAs (Kern River GSA, HMWD, etc.) meet weekly at Rosedale-Rio Bravo WSD to discuss Basin-wide SGMA topics ranging from monitoring network coordination to Basin-wide modeling efforts and sustainable management criteria development.

South of Kern River Coordination Meetings

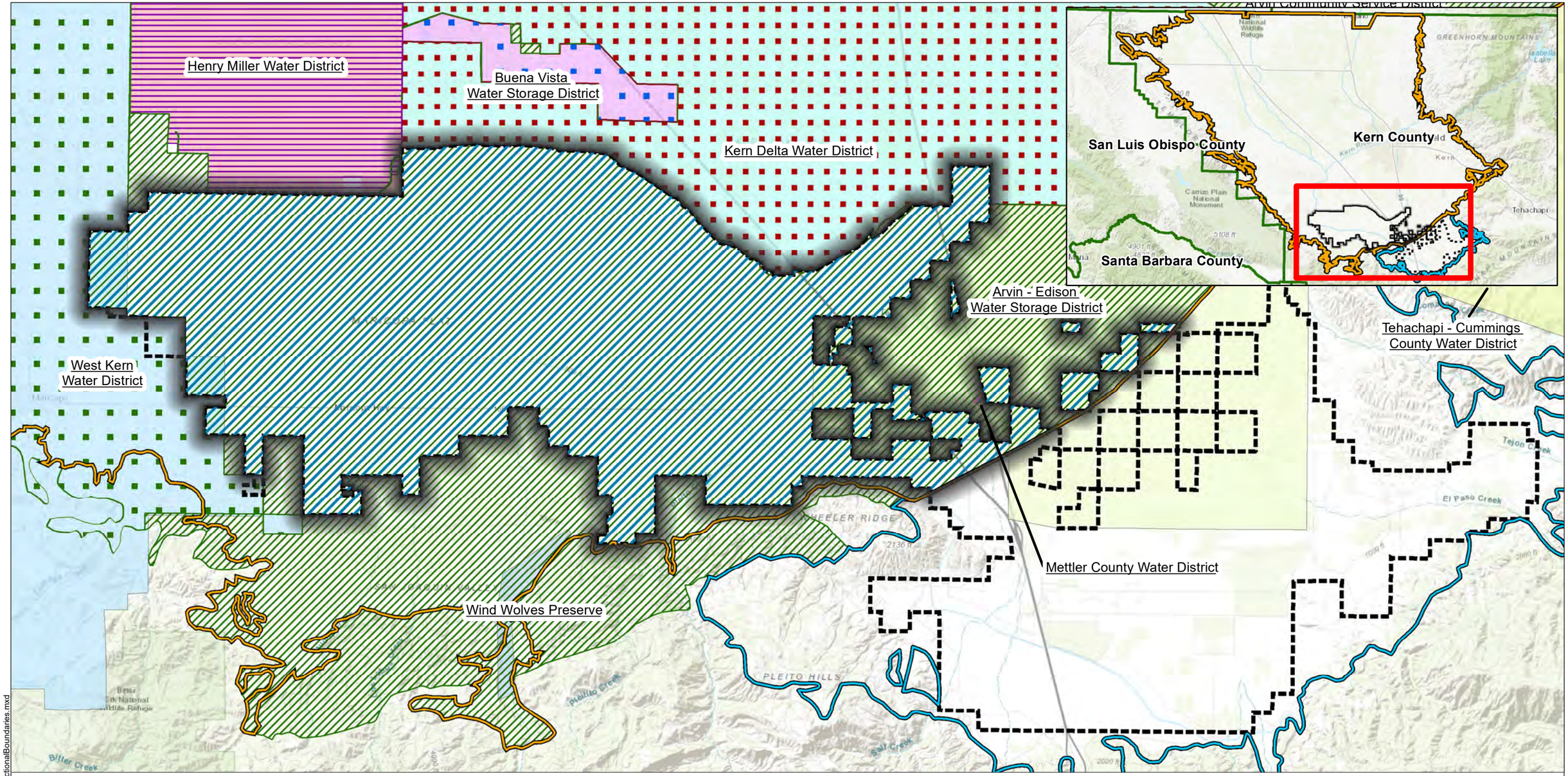
WRMWSD and neighboring agencies in the "south of Kern River" portion of the Basin have periodically convened to coordinate on major GSP development topics, including methodologies and data sources used to develop the Basin Setting, Water Budget, and Sustainability Criteria sections of their respective GSPs/Management Area Plans and the development of projects and management actions.

White Wolf Basin GSA

The White Wolf GSA was formed in 2017 by three water districts: WRMWSD, AEWSD, Tejon-Castac Water District (TCWD), as well as Kern County (as a non-voting member). Prior to that, the GSA parties coordinated in an effort to subdivide the Kern Subbasin into two separate subbasins and remove the critical-overdraft status from the newly formed White Wolf Subbasin. By December of 2016, both goals were accomplished, and the White Wolf GSA is currently in the process of developing a GSP. The White Wolf GSA meets quarterly at WRMWSD's offices.

5.5.6. Interbasin Coordination

WRMWSD has actively participated in interbasin coordination with the neighboring White Wolf Subbasin (DWR 5-022.18), Tule Subbasin (DWR 5-022.13), and Tulare Lake Subbasin (DWR 5-022.12) throughout the GSP development process through its membership with the KGA. Coordination topics have included subsidence concerns along the California Aqueduct, delineation of the White Wolf Fault, and cross-boundary flows between subbasins.



Legend

- WRMWSD Management Area
- WRMWSD Service Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

GSA Name

- Buena Vista Water Storage District
- Henry Miller Water District
- Kern Groundwater Authority GSA
- Kern River GSA
- West Kern Water District

Abbreviations

DWR = California Department of Water Resources
GSA = Groundwater Sustainability Agency
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. The WRMWSD Plan Area is the WRMWSD Management Area.
3. The pastel filled and labeled areas represent public and private water systems neighboring the WRMWSD Management Area.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. DWR groundwater basins are based on the boundaries released on 11 February 2019.

N

0 2.5 5

(Scale in Miles)

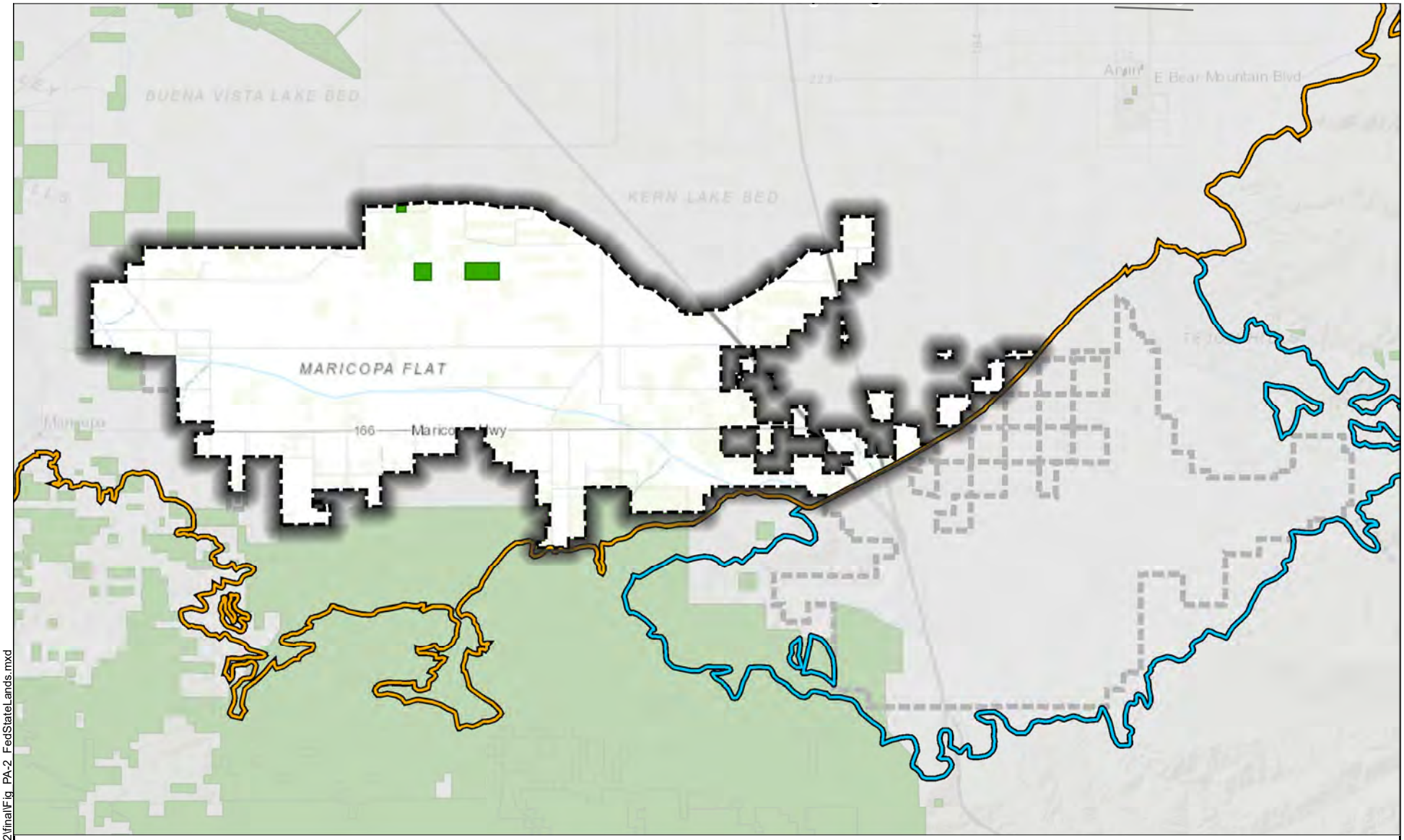
Wheeler Ridge-Maricopa Water Storage District
Plan Area and Relevant Boundaries

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure PA-1

eki environment & water

Path: X:\B70103\Mapsfor_GSP\2019\11\Final\Fig_PA-1_JurisdictionalBoundaries.mxd



Legend

- WRMWSD Service Area
- Federal Lands - BLM

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Abbreviations

BLM = United States Bureau of Land Management
DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. No State lands locate within the Wheeler Ridge-Maricopa Management Area.

Sources

1. Basemap is ESRI's ArcGIS Online world aerial map, obtained 10 December 2019.
2. Federal lands information downloaded on 04 October 2018 from the SGMA Data Viewer: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer. Last updated 2016.

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(Scale in Miles)

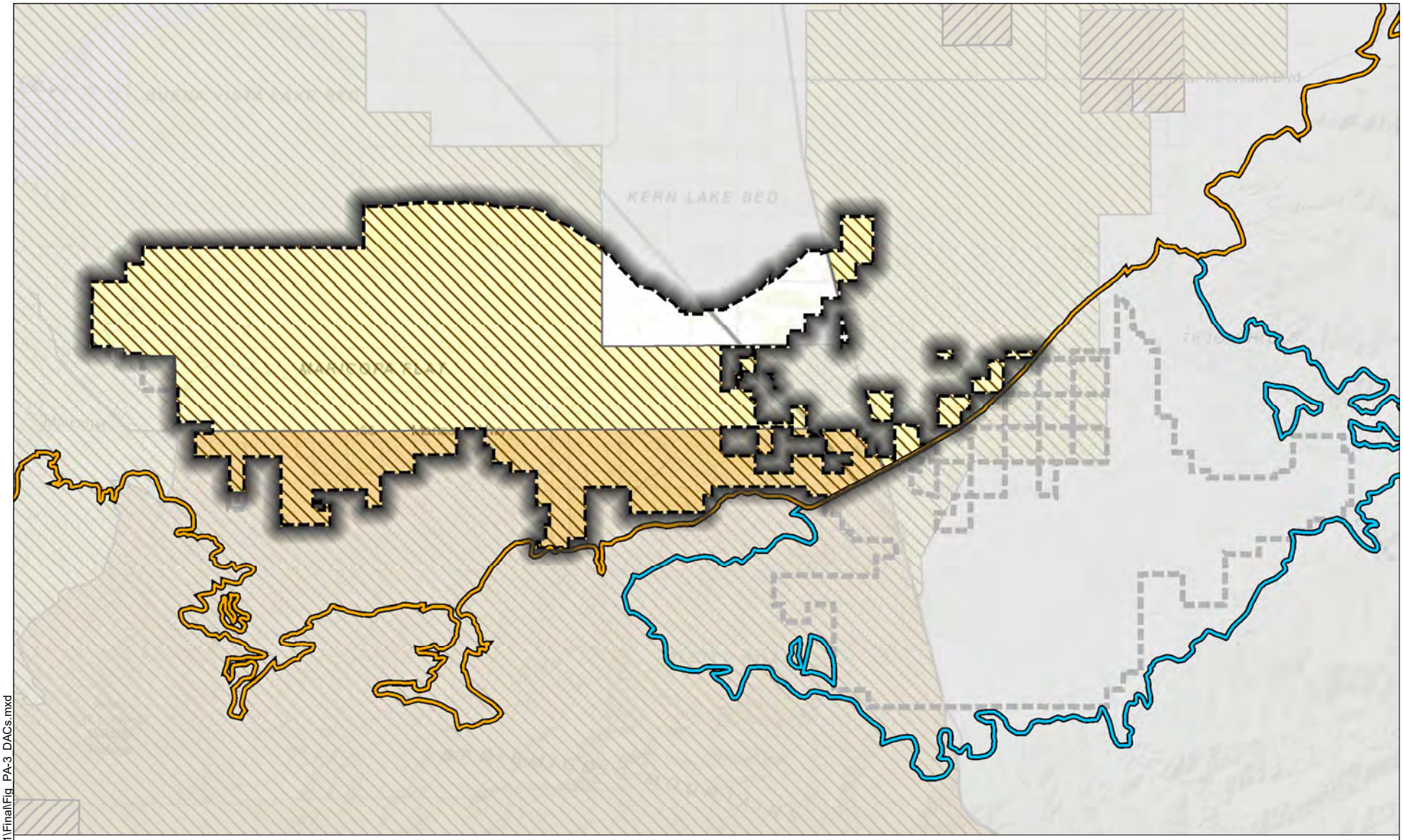
Federal and State Lands

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure PA-2

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\12\final\Fig PA-2 FedStateLands.mxd



Legend

WRMWSD Service Area

Groundwater Subbasin

Kern County (DWR 5-022.14)

White Wolf (DWR 5-022.18)

Disadvantaged Community Census Block Group

Severely Disadvantaged Community

Disadvantaged Community

Disadvantaged Community Census Tract

Severely Disadvantaged Community

Disadvantaged Community

Abbreviations

BLM = United States Bureau of Land Management
DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world aerial map, obtained 22 November 2019.
2. Disadvantaged communities information downloaded on 04 October 2018 from the SGMA Data Viewer: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer. Last updated 2016.

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(Scale in Miles)

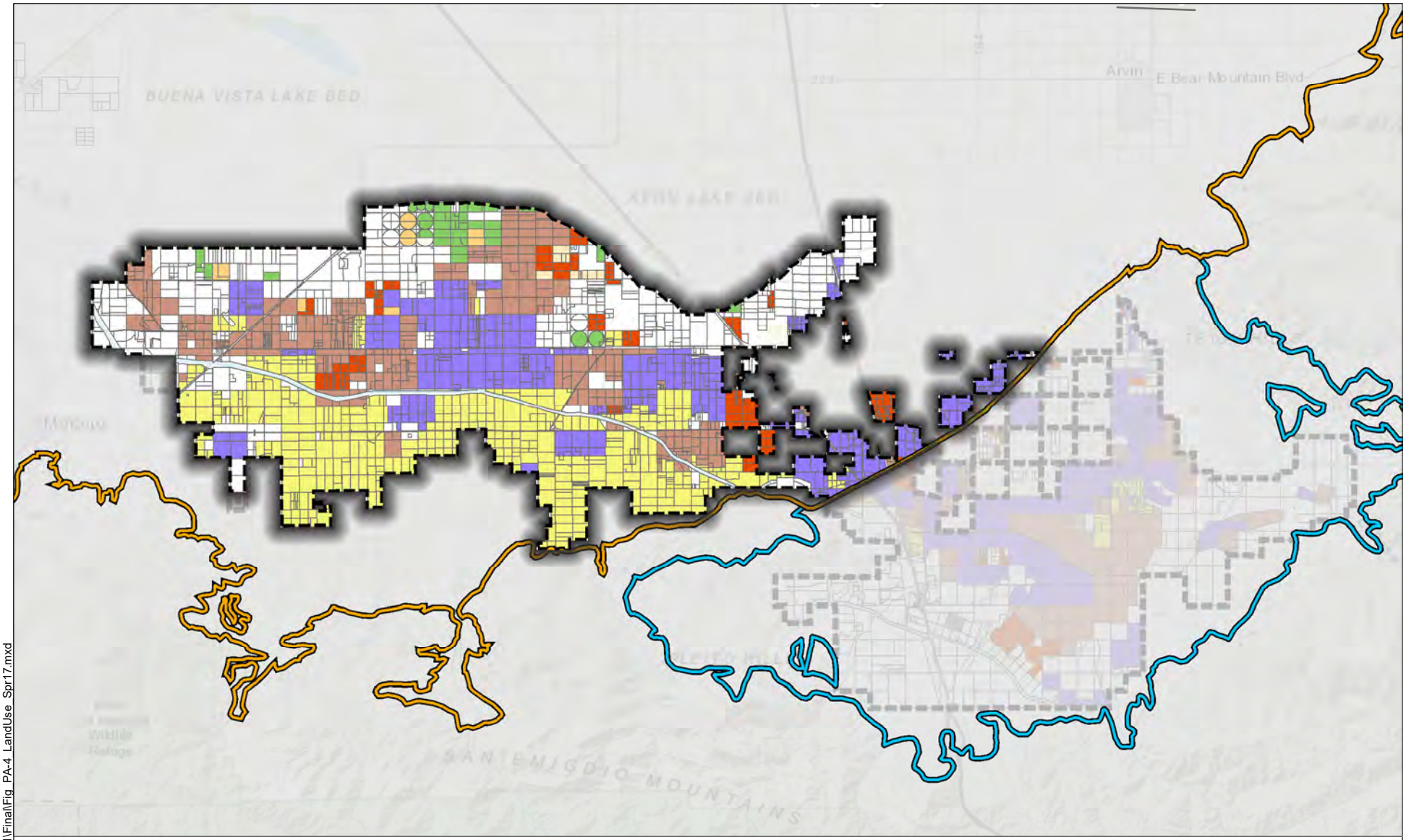
Disadvantaged Communities

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure PA-3

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\Fig PA-3 DACs.mxd



Legend

- WRMWSD Service Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Spring 2017 Land Use

- Pasture
- Deciduous Fruits and Nuts
- Truck, Nursery, and Berry Crops
- Citrus and Subtropical
- Field Crops
- Grain and Hay Crops
- Vineyards
- Idle

Abbreviations

DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world aerial map, obtained 22 November 2019.
2. Spring 2017 land use data received from WRMWSD staff on 21 November 2017.

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(Scale in Miles)

Spring 2017 Land Use

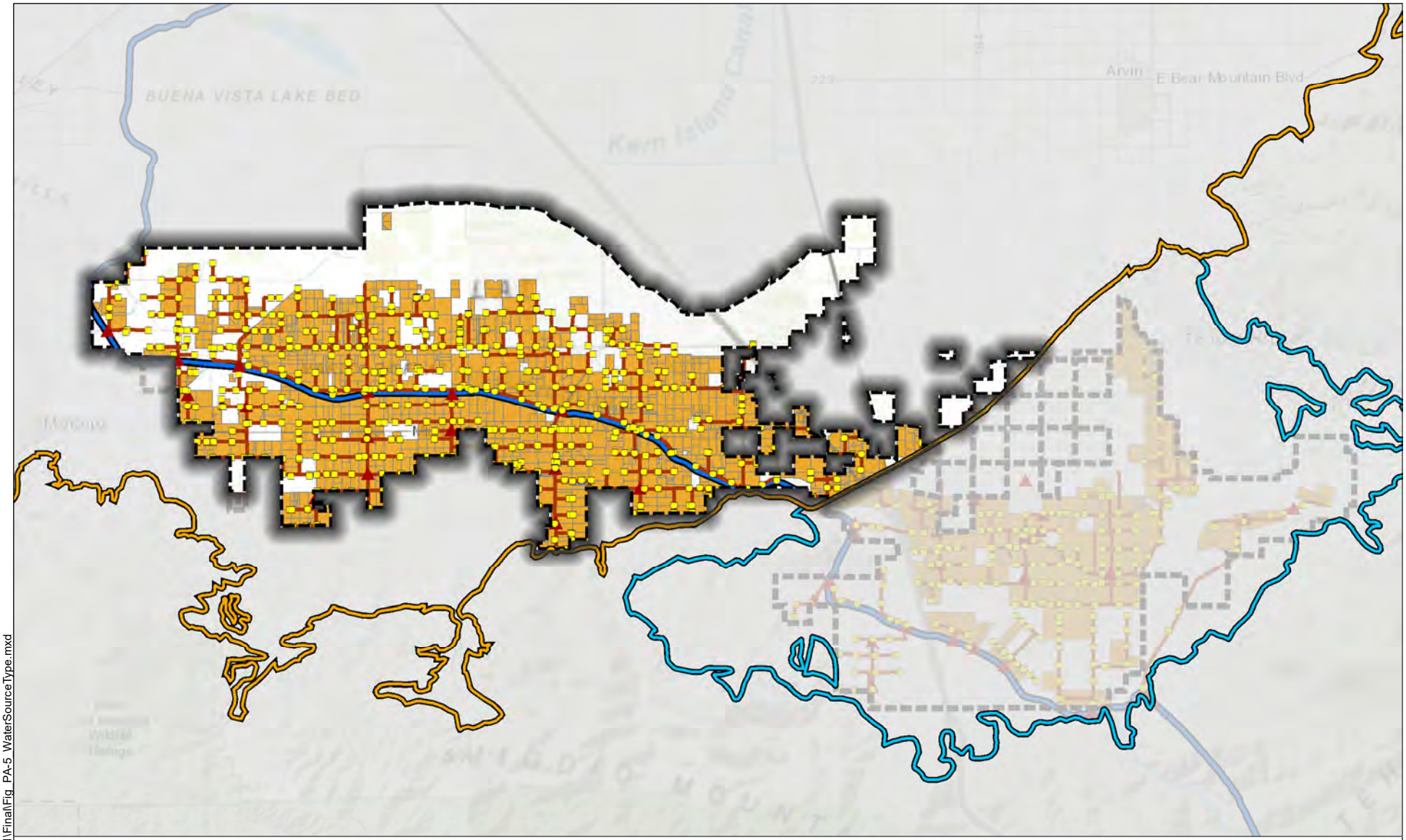
Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure PA-4

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\Fig_PA-4_LandUse_Spr17.mxd

19



Legend

- WRMWSD Service Area
- Pipeline

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Surface Water Feature

- California Aqueduct
- WRMWSD Surface Water Service Area

WRMWSD Infrastructure

- Turnout
- Pumping Plant

Abbreviations

DWR = California Department of Water Resources
NHD = National Hydrography Dataset
SWSA = surface water service area

Abbreviations

WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Users outside the SWSA rely exclusively on groundwater, however, users on the SWSA are not precluded of using groundwater.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 10 December 2019.
2. Surface water features and California Aqueduct location from NHD.
3. District infrastructure data and Surface Water Service Area acquired from WRMWSD staff on 21 November 2017.

N

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(Scale in Miles)

WRMWSD Facilities and Surface Water Service Area

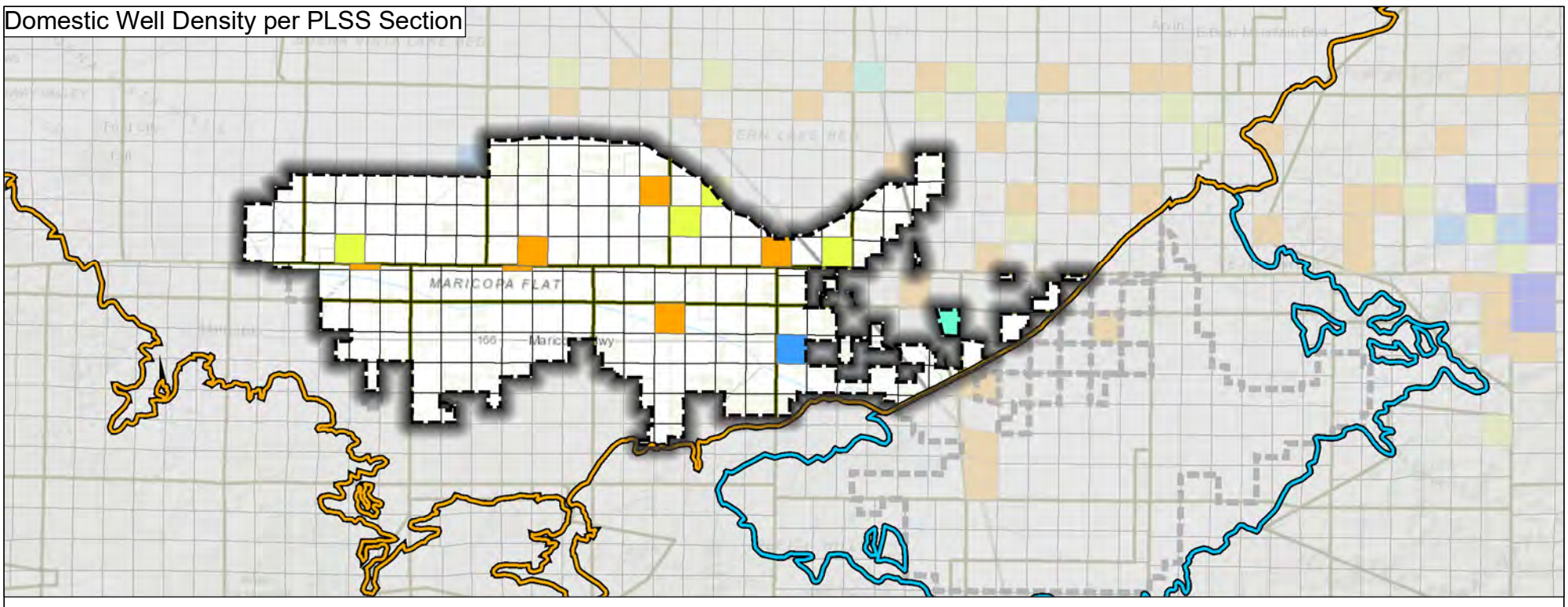
Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure PA-5

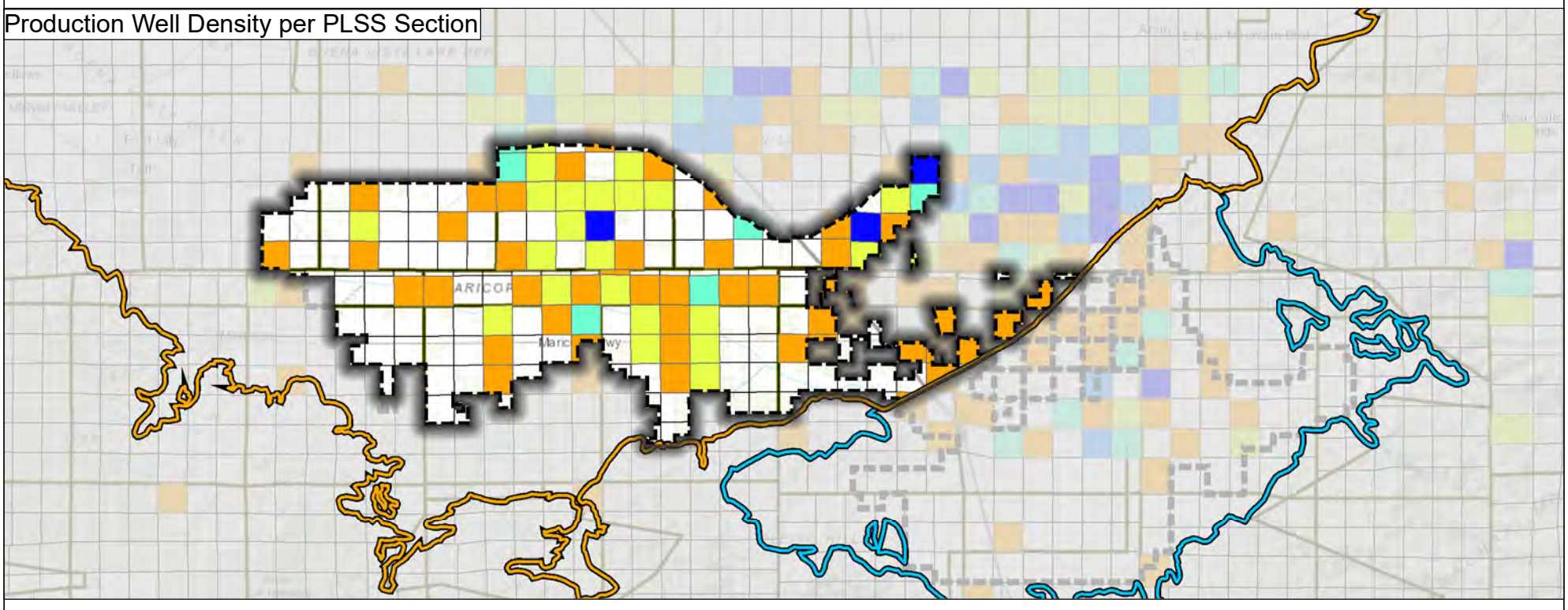
eki environment & water

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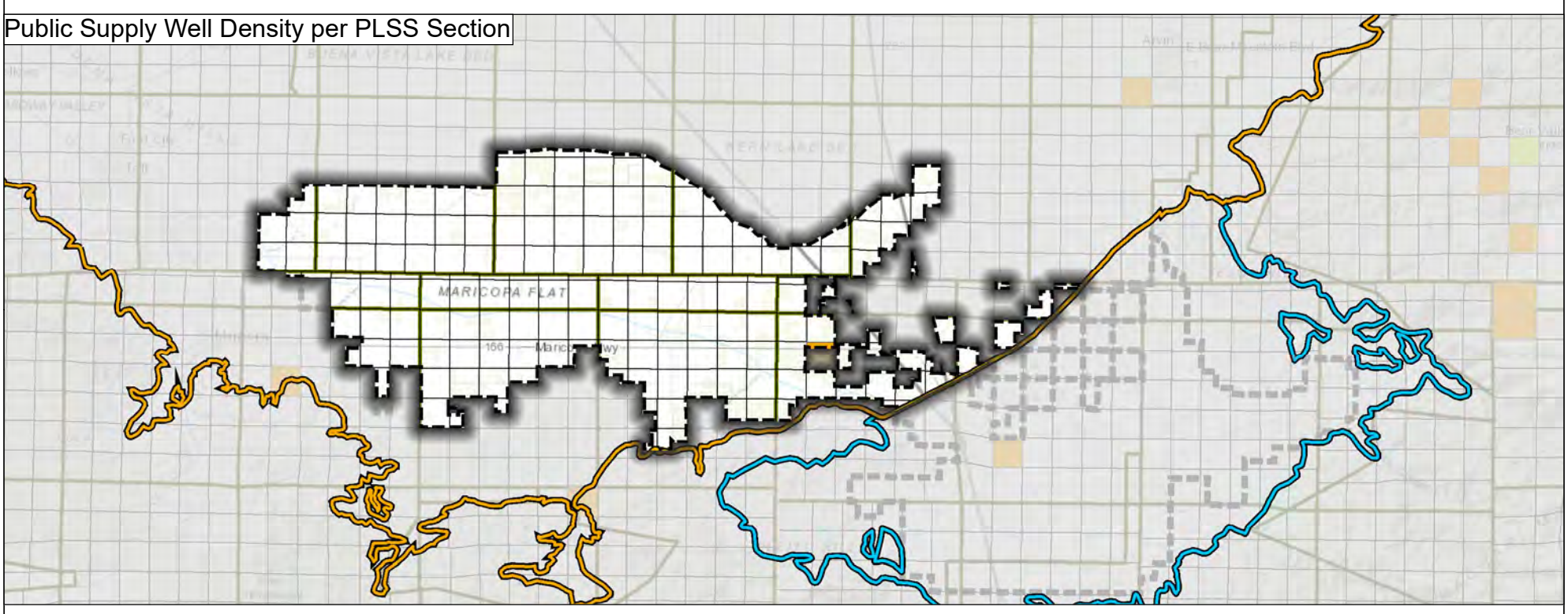
Domestic Well Density per PLSS Section



Production Well Density per PLSS Section



Public Supply Well Density per PLSS Section



Legend

- WRMWSD Service Area
- PLSS Sections
- PLSS Township

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Well Density per PLSS Section

- 0
- 1
- 2
- 3
- 4
- >4

Abbreviations

DWR	= California Department of Water Resources
MA	= management area
PLSS	= Public Land Survey System
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Potable water is supplied in the WRMWSD MA by private domestic wells, there is no public water supply, therefore, it is considered that there are not communities dependent on groundwater.

N

0 5 10

(Scale in Miles)

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. WRMWSD boundary is from DWR's water agencies shapefile and updated based on input from WRMWSD staff on 12 April 2017.
3. Well Count per square mile (PLSS section) from Well Completion Report Map Application, obtained on 8 October 2018, website: https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37

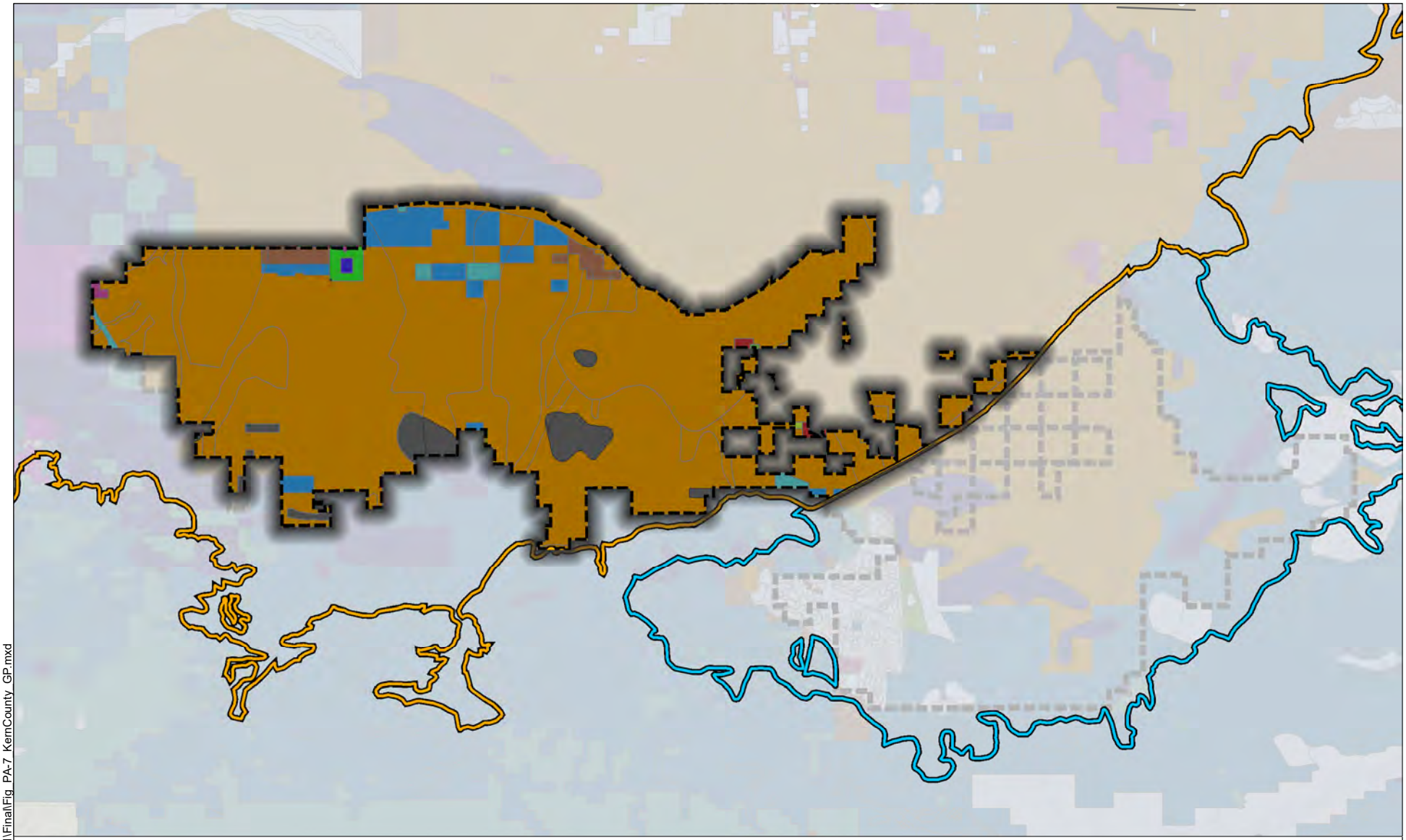
Well Density by PLSS Section from DWR Well Completion Reports

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.00

Figure PA-6

eki environment & water

Path: X:\B70103\Mapsfor_GSP\2019\11\Final\Fig_PA-6_Well_Density.mxd



Legend

WRMWSD Service Area

Groundwater Subbasin

Kern County (DWR 5-022.14)

White Wolf (DWR 5-022.18)

Land Use Designation

Extensive Agriculture; Extensive Agriculture (Min. 20 Acre Parcel Size)

Heavy Industrial

Highway Commercial

Intensive Agriculture; Intensive Agriculture (Min. 20 Acre Parcel Size)

Light Industrial

Low Medium Density Residential

Mineral and Petroleum; Mineral and Petroleum (Min. 5 Acre Parcel Size)

Residential/ Other

Resource Management

Service Industrial

Solid Waste Facilities

State or Federal Land

Abbreviations

DWR = California Department of Water Resources

WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. The legend shows land use designations only within the Management Area.

Sources

1. Kern County General Plan information obtained on 16 August 2018 from the Kern County website.

N

0 5 10

(Scale in Miles)

Kern County General Plan - Land Use Designation

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure PA-7

eki environment & water

Path: X:\B70103\Maps\for_GSP\2019\11\Final\Fig_PA-7_KernCounty_GP.mxd

BASIN SETTING

6. INTRODUCTION TO BASIN SETTING

☑ **23 CCR § 354.12**

This section presents Basin Setting information for the Wheeler Ridge-Maricopa Management Area[22]. As discussed previously in ***Section 5 Description of the Plan Area,*** the Management Area consists of the portion of the Wheeler Ridge-Maricopa Water Storage District (WRMWSD) service area within the Kern County Subbasin (Kern Subbasin) that is not overlapped by the West Kern Water District (WKWD) Groundwater Sustainability Agency (GSA; **Figure HCM-1**). In some cases, Basin Setting information for areas proximal to, but outside of, the Management Area is provided for context. Basin Setting information includes the Hydrogeologic Conceptual Model, Groundwater Conditions, and Water Budget.

[22] In this document, the term "Wheeler Ridge-Maricopa Management Area" is used in its entirety the first time the area is referenced in each paragraph; subsequent references to this area in each paragraph use the term "Management Area".

7. HYDROGEOLOGIC CONCEPTUAL MODEL

☑ 23 CCR § 354.14(a)

This section presents the hydrogeologic conceptual model (HCM) for the Wheeler Ridge-Maricopa Management Area. As described in the Hydrogeological Conceptual Model Best Management Practices (BMP) document (California Department of Water Resources [DWR], 2016), an HCM provides, through descriptive and graphical means, an understanding of the physical characteristics of an area that affect the occurrence and movement of groundwater, including geology, hydrology, land use, aquifers and aquitards, and water quality. This HCM serves as a foundation for subsequent Basin Setting analysis including water budgets and numerical models, monitoring network development, and the development of sustainable management criteria. The HCM information presented herein is supplemental to the HCM provided in the Kern Groundwater Authority (KGA) Umbrella Groundwater Sustainability Plan (GSP) and provides refined detail on HCM topics specific to the Management Area.

7.1. General Description

☑ 23 CCR § 354.14(b)

7.1.1. Geological and Structural Setting

☑ 23 CCR § 354.14(b)(1)

The Wheeler Ridge-Maricopa Management Area is located at the southern end of the San Joaquin Valley which is the portion of California's Central Valley that is south of the San Joaquin/Sacramento River Delta. The San Joaquin Valley is a structural trough filled with tens of thousands of feet of Cenozoic continental and shallow marine sedimentary deposits shed from the surrounding mountains which include the Sierra Nevada Mountains to the east, the Temblor Range and Coast Range Mountains to the west, and the San Emigdio and Tehachapi Mountains to the south (Davis et al., 1959). The structural trough is asymmetric, with its axis located west of the valley's centerline at land surface (Scheirer, 2013). Locally, to the north of the Management Area, the Maricopa Depocenter is a structural depression which has accumulated thicker deposits than the surrounding areas. The Buena Vista Hills are located to the northwest of the Management Area. The reader is referred to the Basin-wide geologic and structural setting discussion included in the KGA Umbrella GSP for additional information and map figures.

Due to its location near the North American and Pacific plate boundary, the southern San Joaquin Valley underwent complex patterns of tectonic evolution during the Cenozoic era, including phases of extension, uplift, subsidence, faulting, and flexure (Goodman and Malin, 1992). The White Wolf Fault cuts through the District and forms the boundary between the Kern Subbasin to the north and the White Wolf Subbasin to the south. The White Wolf Fault is a recently active southward-dipping high-angle reverse fault that has resulted in significant displacement of stratigraphic units on either side of the fault trace (California Division of Mines, 1955; Hagan, 2001).

The general geologic setting of the Wheeler Ridge-Maricopa Management Area consists of multiple alluvial fans derived from sediments washed into the basin from the surrounding highlands, coarser near their source and finer towards the basin interior. These fan deposits wash up against Quaternary lake and

basin deposits that border the Management Area to the north. The basin deposits, including those beneath the Buena Vista Lake Bed, Kern Lake Bed, and the slough that connects them, are generally fine-grained due to the low energy depositional environment in which they were formed. The "E Clay", a significant regional aquitard (Croft, 1972), underlies the western portion of the southern Central Valley including portions of the Management Area. The E Clay is several tens of feet thick in this area and becomes thinner and shallower towards the east, pinching out in the vicinity of the City of Arvin. On the northern edge of the Management Area, shallow clay layers and fine-grained soils create areas of perched groundwater that is separate from the main groundwater system. Two hydrogeologic cross-sections through the Management Area that further illustrate the subsurface structural relationships are discussed further in **Section 7.2 *Cross-Sections***.

7.1.2. Lateral Basin Boundaries

☑ 23 CCR § 354.14(b)(2)

This MA Plan covers only the Wheeler Ridge-Maricopa Management Area (see **Figure HCM-1**) which is within the larger Kern Subbasin. With the exception of its southeastern edge, the Management Area does not coincide with any part of the Kern Subbasin boundary, and therefore a complete discussion of the lateral basin boundaries is not provided herein, but rather in the KGA Umbrella GSP.

The southeastern edge of the Wheeler Ridge-Maricopa Management Area is coincident with the White Wolf Fault which is the boundary between the Kern Subbasin and the White Wolf Subbasin. As discussed above, the White Wolf Fault is a south-dipping reverse fault, with the northern block down-dropped relative to the southern block. There is also a component of left-lateral slip on the fault (California Division of Mines, 1955). The total vertical displacement is estimated to be over 10,000 feet and is greatest at the southwestern end and less to the northeast (California Division of Mines, 1955). As evidenced by surface rupture during the major earthquake of 21 July 1952, the White Wolf Fault is active, and its displacement plane extends to the ground surface, affecting the youngest sedimentary deposits.

Based on multiple lines of evidence, the fault acts as a significant barrier to groundwater flow, which is the basis for the Kern Subbasin boundary (Erler & Kalinowski, Inc., 2016). These lines of evidence include substantial groundwater elevation differences across the fault (based on analysis of available water level data and reports prepared by others), aquifer testing data from wells close to the fault that showed boundary effects, and groundwater modeling studies.

7.1.3. Bottom of the Basin

☑ 23 CCR § 354.14(b)(3)

As discussed above, the southern San Joaquin Valley is a deep structural trough filled with a thick sequence of Tertiary sediments including sandstone, siltstone, shale, and conglomerate. As described below, multiple sources of information can be relied on to define the "bottom of the basin" for purposes of the Sustainable Groundwater Management Act (SGMA), including elevation maps of the basement bedrock surface, information on the base of fresh water, the presence, location and depth of oil and gas fields, and depth of groundwater extraction. Each of these is discussed below, with depth information presented as feet below ground surface (ft bgs) or feet above mean sea level (ft msl), based on the original source information. A summary comparison, including a unit normalization, is included in **Table HCM-1**.

Depth to Basement Bedrock

The depth of pre-Tertiary basement rocks which form the impermeable floor of the San Joaquin Valley groundwater basin generally increases from east to west within the southern end of the San Juaquin Valley. Within the Wheeler Ridge-Maricopa Management Area, the elevation of the top of the basement rock surface ranges from between -21,000 to -22,000 ft msl in the western area and -16,000 to -20,000 ft msl in the eastern area (Scheirer, 2013). Given the land surface elevations, discussed further in **Section 7.3 *Physical Characteristics*** below, the depth to bedrock ranges from less than 16,500 ft bgs in the eastern area to approximately 23,000 ft bgs in the far western area.

Base of Fresh Water

Despite the substantial thickness of sedimentary strata overlying impermeable basement rock within this structural basin, in the case of the Central Valley it is more appropriate to consider geochemical properties (i.e., water quality) in determining the definable bottom of the basin (DWR, 2016). Documentation of the DWR's C2VSim model states that "although the Central Valley sedimentary basins are very thick, the fresh water aquifer in each basin is very thin" (Brush et al., 2016).

Page (1973) mapped the elevation of the base of fresh water in the Kern Subbasin using a criterion for fresh water of specific conductance (also known as electrical conductivity or EC) of less than 3,000 micromhos per centimeter (umhos/cm). This EC is equivalent to a total dissolved solids (TDS) concentration of approximately 2,000 milligrams per liter (mg/L). The Page (1973) base of fresh water map only characterizes the northernmost portion of the Wheeler Ridge-Maricopa Management Area and is therefore less informative in this case. O'Bryan (1992) used the same criteria as Page to map the base of fresh water in areas farther south in the San Joaquin Valley, including most of the Management Area. O'Bryan shows that the base of fresh water ranges from -1,000 ft msl in the western portion of the Management Area to below -5,000 ft msl near the Rio Viejo oil field in the east-central portion of the Management Area (**Figure HCM-2**). These elevations translate to a range of depths of approximately 1,300 ft bgs to 5,600 ft bgs.

Base of Fresh Water from Oil Field Information

For over a century, oil and gas exploration and development has taken place throughout the Kern Subbasin, tapping various Tertiary sedimentary deposits. Such activity continues to this day and has resulted in the accumulation of a substantial body of knowledge concerning the regional geology, including stratigraphy, structural features, hydrocarbon occurrence, and the geochemical character of groundwater. **Figure HCM-3** shows the locations of oil fields in and around the Wheeler Ridge-Maricopa Management Area, as mapped by the Division of Oil, Gas, and Geothermal Resources (DOGGR). The San Emidio Nose oil field, located in the central portion of the Management Area, contains two "pools" (subareas with distinct production characteristics and rules) – the Main Area and the Northwest Area. The base of fresh water indicated on the field data sheets for these pools ranges from 4,500 ft bgs to 5,000 ft bgs in the Main Area to 3,800 ft bgs to 5,000 ft bgs in the Northwest Area (DOGGR, 1998). The DOGGR base of fresh water determination is based primarily on salinity derived from borehole electric log (e-log) data. The Rio Viejo oil field, located just north of the San Emigdio Nose oil field, has a base of fresh water of 5,500 ft bgs. The Yowlumne oil field, located in the western portion of the Management Area, has a base of fresh water between 1,600 ft bgs and 4,000 ft bgs. The Los Lobos oil field overlies a small portion of the southwestern corner of the Management Area and has a base of fresh water between 500 and 3,000 ft bgs. The Midway-Sunset oil field overlies portions of the far western edge of the Management

Area, and is largely in an area without fresh water, except in the far southeastern tip of the oil field near Santiago Creek where fresh water is found down to approximately 500 ft bgs.

Deepest Groundwater Extractions

The HCM BMP states that "the definable bottom of the basin should be at least as deep as the deepest groundwater extractions" (DWR, 2016). Based on well construction information from 191 wells within the Wheeler Ridge-Maricopa Management Area, all wells have depths less than 2,600 ft bgs and approximately 90% of wells have depths less than 1,800 ft bgs.

Another indication of the "bottom" of the basin in the Wheeler Ridge-Maricopa Management Area comes from the basin representation within groundwater flow models, specifically the Department of Water Resources C2VSim basin model (Brush et al., 2016).[23] The C2VSim model (C2VSim-CG, version R374) divides the Central Valley alluvial basin vertically into three layers, the top two of which are pumped (i.e., could be considered to define the vertical extent of the basin). C2VSim-CG layer thickness data for 33 model nodes within and near the Management Area show that the combined thickness of Layers 1 and 2 (i.e., the unconfined and confined pumped layers) ranges from 1,252 ft to 3,910 ft, averaging 1,834 feet (ft). The updated version of C2VSim[24] which utilizes a finer grid (C2VSim-FG, Beta version) uses the same layering scheme, but has a refined grid/mesh, adjusts the thickness of Layers 1 through 3 and adds an additional deeper Layer 4. C2VSim-FG layer thickness data for 103 model nodes within the Management Area show a combined thickness of Layers 1 and 2 ranging from 597 ft to 1,807 ft, averaging 1,446 ft (see **Figure HCM-4**). These combined Layer 1 and 2 thicknesses correspond to the total depth of the pumped zone in this model.

Given the above information, the controlling factor for the definable "bottom of the basin" is determined to be the depth of the base of fresh water. Within the Wheeler Ridge-Maricopa Management Area, the bottom of the basin ranges in elevation from -1,000 ft msl in the western portion to below -5,000 ft msl near the Rio Viejo oil field in the east-central portion, corresponding to depths of approximately 1,300 ft bgs to 5,600 ft bgs. In the certain areas where pools within the Yowlumne, San Emigdio Nose, and Rio Viejo oil fields are shallower than the previously mentioned depths, the bottom of the basin is defined as the (shallower) depth of fresh water from the DOGGR oil field data. It is recognized, however, that the maximum depth of wells is only about 2,600 feet, with 90% of wells screened to depths of 1,800 feet or less, and therefore a substantial volume of groundwater above the "bottom of the basin" has not been tapped by water wells.

[23] http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/index_C2VSIM.cfm

[24] C2VSim-FG, Beta version is currently uncalibrated, and various potential concerns have been identified regarding this model's parameterization of the Kern and White Wolf Subbasins, including representation of the White Wolf Fault (location and hydraulic properties), hydraulic properties of the aquifers, etc. as discussed in detail in the letter to DWR from the White Wolf GSA, of which WRMWSD is a member, on 9 July 2018.

Table HCM-1. Information Relevant to Definition of the Bottom of the Basin

Type of Information	Source(s)	Parameter Range within Wheeler Ridge-Maricopa Management Area	
		Elevation Range (ft msl)	Depth Range (ft bgs)
Bedrock Basement Composite Surface	Scheirer, 2013	Western Area: -22,000 to -21,000 Eastern area: -20,000 to -16,000	Western Area: 21,500 to 23,000 Eastern area: 16,500 to 20,500
Base of Fresh Water	O'Bryan, 1992	Western Area: -3,000 to -1,000 Eastern area: -5,000	Western Area: 1,300 to 4,000 Eastern area: 5,300 to 5,600
Oil Field Base of Fresh Water Information	DOGGR, 1998	Yowlumne oil field: -3,400 to -1,000 San Emigdio Nose oil field: -4,400 to -3,200 Rio Viejo oil field: -5,100	Yowlumne oil field: 1,600 to 4,000 San Emigdio Nose oil field: 3,800 to 5,000 Rio Viejo oil field: 5,500
Deepest GW Extractions from Well Construction Information	WRMWSD Well Database	90% of wells BOS elevation > -1,400 100% of wells BOS elevation > -2,000	90% of wells less than 1,800 feet deep 100% of wells less than 2,600 feet deep
Deepest GW Extractions from Regional Groundwater Model	Brush et al., 2016; DWR, 2018	C2VSim-CG (R374): -357 to -1,447 C2VSim-FG (Beta): -129 to -1,342	C2VSim-CG (R374): 1,252 to 3,910 C2VSim-FG (Beta): 597 to 1,807

Note:
1. Shaded cells indicate estimated values based on approximate ground surface elevation.

7.1.4. Principal Aquifers and Aquitards

☑ **23 CCR § 354.14(b)(4)**

Principal aquifers are defined in the GSP Emergency Regulations as "aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water

systems" (23 CCR § 351(aa)). In an area with significant groundwater development, such as the Wheeler Ridge-Maricopa Management Area, it is therefore reasonable to equate the principal aquifer(s) with the aquifer(s) from which wells pump water. This in turn can be deduced through examination of the depths of production wells.

As discussed previously and shown on **Figure HCM-5**, well construction information from 191 wells within the Wheeler Ridge-Maricopa Management Area indicates that all wells have depths[25] less than 2,600 ft bgs, and approximately 90% of wells have depths less than 1,800 ft bgs. Therefore, the principal aquifer is considered to be the aquifer materials encountered within the top 2,600 ft bgs. The surficial geology within the Management Area is discussed further below in **Section 7.3 *Physical Characteristics***, and the stratigraphic relations and well log information along the lines of section are presented on cross-sections A-A'-A'' and G-G', discussed further below in **Section 7.2 *Cross-Sections***.

Formation Names and Occurrence

☑ **23 CCR § 354.14(b)(4)(A)**

The stratigraphy within the depth zone of the principal aquifer includes (from shallowest to deepest; youngest to oldest): Quaternary (Recent to Pleistocene) Alluvium deposits and the late Tertiary (Pliocene/Pleistocene) Tulare Formation. Underlying the Tulare Formation (and generally well below the depth of the principal aquifer) are Miocene and Pliocene marine sedimentary rocks of the San Joaquin and Etchegoin Formations. Owing to their similar continental origin and fluvial mode of deposition, the Quaternary Alluvium and Plio/Pleistocene Tulare Formation can be difficult to distinguish from one another. The Alluvium and Tulare Formations are generally unconsolidated, although consolidation increases with age and depth.

The Alluvium unit, sometimes divided into Younger (Recent) and Older (Pleistocene) units (e.g., Wood and Dale, 1964), is composed generally of unconsolidated sands and gravels of fluvial origin, coarser towards its base, and is somewhat coarser than the underlying deposits (Croft, 1972). The Tulare Formation is correlative to and interfingers with the Kern River Formation which underlies the Quaternary Alluvium on much the eastern side of the Kern Subbasin. In the vicinity of the southwestern border of the San Joaquin Valley, the Tulare Formation is exposed in the foothills and is folded or tilted. It consists of poorly sorted lenticular beds of sand and conglomerate with interbeds of siltstone and mudstone. The fluvial origin of the Tulare Formation results in channel-like bodies of coarse-grained materials which can provide anisotropic hydraulic connections, although these channels are largely unmapped. Underlying the Tulare Formation (generally well below the depth of the principal aquifer) are the Etchegoin Formation and, towards the east, the Miocene Chanac to the east of the Wheeler Ridge-Maricopa Management Area.

A significant regional aquitard within the Tulare Formation, the Pleistocene E Clay (Croft, 1972), underlies the northern portion of the center of the Wheeler Ridge-Maricopa Management Area (**Figure HCM-6**). The E Clay, correlative with and sometimes referred to as the "Corcoran Clay", is one of several flood-basin, lacustrine and marsh deposits within the southern San Joaquin Valley. It is often described as "blue clay" in well driller logs (Croft, 1972). The E Clay dips generally southwestward, and beneath the Management Area the base of the E Clay ranges in elevation from approximately -200 ft msl in the

[25] The depth of wells is determined from well construction information using the following data, in order of preference (if data are available): bottom of screen depth, completed depth, or total depth.

northeastern portion to -400 ft msl in the north-central portion. The depth to top of the E Clay ranges is approximately 250 ft bgs in its most southwestern extent beneath the Management Area (DWR, 2008). The E Clay, where present, acts as a confining unit for the underlying groundwater; above the E Clay (and where it does not exist) groundwater occurs under unconfined conditions (Croft, 1972). As shown on **Figure HCM-6**, the E Clay is not known to extend all the way underneath the Management Area to the western or southern extents, and thus is not known to consistently confine the underlying aquifer. Another similar regional aquitard unit, the "A Clay", exists at shallower depths to the north of the Management Area but does not underlie it. The A Clay may be the cause of perched groundwater conditions observed in this area (Croft, 1972).

It should be noted that despite the variably confined conditions in this area, it is not deemed appropriate to define separate unconfined and confined principal aquifers because (1) the regional aquitards are not extensive throughout the Wheeler Ridge-Maricopa Management Area; and (2) many wells are screened over large vertical intervals including above and below the regional aquitard (where it is present), thus creating a vertical hydraulic connection.

Physical Properties of Aquifer(s) and Aquitard(s)

☑ **23 CCR § 354.14(b)(4)(B)**

Given the range of lithologies and grain sizes within the formations that comprise the principal aquifer (i.e., ranging from gravels and sands, to silts and clays, generally poorly-sorted and interbedded), the physical properties of the aquifer vary widely both laterally and with depth. In general, wells drilled into the principal aquifer tap into sufficient coarse-grained material to be productive enough to support overlying agricultural demands. Wood and Dale (1964) developed a map of "yield factors" for the Edison-Maricopa area. The yield factor is defined as the specific capacity (gallons per minute per foot of drawdown) per 100 feet of aquifer screened by a well (i.e., units of gpm/100ft^2). The Wood and Dale (1964) map (**Figure HCM-7**) shows that most of the central portion of the Wheeler Ridge-Maricopa Management Area has yield factors between 1 and 5 gpm/100ft^2, with some areas to the west having lower yield factors, and some areas to the east having higher yield factors of 6 to 10 gpm/100ft^2. Well testing data collected in 2017 from 19 wells located in the north-central portion of the Management Area indicates specific capacity ranging from 10.8 gallons per minute per foot of drawdown (gpm/ft) to 61.4 gpm/ft, averaging 28.1 gpm/ft.

While the yield factors of Wood and Dale (1964) provide insight into the relative productivity of wells, they do not directly translate into aquifer hydraulic properties. Multiple-well aquifer pumping test data, which is necessary to accurately determine hydraulic conductivity and storage parameters, is generally not available. Another potential source of information regarding hydraulic properties is extraction of parameters from calibrated numerical groundwater models, although this information must be used with caution, particularly in areas such as Wheeler Ridge-Maricopa Management Area where the model parameters are not based on local calibration.[26] As mentioned previously, the DWR's C2VSim model covers the Management Area and is therefore one such source of hydraulic property information. **Table**

[26] Numerical models that are regional (i.e., large scale) in extent should be assumed to possess a high degree of uncertainty with respect to local parameter values. Nonetheless, where local measurements are not available, such model parameters can serve as an approximation for unknown values.

HCM-2, below, shows a summary of hydraulic property information for C2VSim nodes in Layers 1 and 2 within the Management Area, based on the R374 version of the coarse grid (CG) model and the "beta" version of the fine grid (FG) model. **Figure HCM-8** shows selected hydraulic property values for the 103 C2VSim-FG nodes within the Management Area, including hydraulic conductivity for Layers 1 and 2, specific yield for Layer 1, and specific storage for Layer 2.

Table HCM-2. Hydraulic Properties Extracted from C2VSim Models

Parameter	C2VSim-CG (R374)	C2VSim-FG (Beta version)
Number of Nodes within Wheeler Ridge-Maricopa Management Area	9	103
Layer 1 Node Properties: Average (Minimum to Maximum)		
Hydraulic Conductivity (ft/day)	33.6 (30.0 to 41.4)	20.8 (8.7 to 37.3)
Specific Yield (-)	0.27 (0.11 to 0.40)	0.082 (0.075 to 0.087)
Specific Storage (-)	N/A	N/A
Layer 2 Node Properties: Average (Minimum to Maximum)		
Hydraulic Conductivity (ft/day)	20.7 (8.7 to 49.9)	15.6 (2.2 to 71.2)
Specific Yield (-)	0.122 (0.122 to 0.123)	0.080 (0.071 to 0.097)
Specific Storage (-)	1.8E-05 (9E-06 to 4.6E-05)	0.0014 (0.0002 to 0.0021)

Abbreviations:
ft/day = feet per day
NA = not applicable

As shown in the table above, the upper unconfined zone, represented by Layer 1 in both the coarse-grid and (uncalibrated) fine-grid versions of C2VSim, is somewhat more permeable than the confined zone represented by Layer 2. The specific yield of Layer 1 is much greater in the Wheeler Ridge-Maricopa Management Area in C2VSim-CG than in C2VSim-FG; however, these values may change in C2VSim-FG upon completion of model calibration.

Another numerical groundwater model that covers the entire Central Valley is the U.S. Geological Survey's (USGS's) Central Valley Hydrologic Model (CVHM) (Faunt, ed., 2009). The CVHM model is based on the USGS MODFLOW software package and simulates integrated subsurface and surface water flow processes, including agricultural water demand based on climate and land use information, for the period from October 1961 through September 2003. Hydraulic properties for each 1 square mile model grid cell were assigned based on the spatially interpolated (using kriging) distribution of coarse-grained deposits that was ascertained through review and lithologic coding of thousands of well logs. **Figure HCM-9** shows the horizontal hydraulic conductivity of active cells of CVHM model layers 3, 4, 6, and 8 which correspond, respectively and approximately, to (Layer 3) the upper unconfined, saturated portion of the principal aquifer, (Layer 4) the Corcoran Clay, and (Layers 6 and 8), the confined portion of the principal aquifer. As

shown on **Figure HCM-9**, the hydraulic conductivity of Layer 3 is high (generally in the 250 feet per day [ft/d] to 500 ft/d range), which is much higher than in C2VSim. For the confined aquifer represented in CVHM by Layers 6 and 8, hydraulic conductivity ranges from 5 ft/d to 50 ft/d.

From the information discussed above, it is clear that considerable uncertainty exists in the values for aquifer properties including hydraulic conductivity and specific yield. This is not unexpected, given the heterogeneous nature of the Tulare Formation. As a further indication of the variability in these parameters, Dale et al. (1966) provided estimates of permeability (analogous to hydraulic conductivity) of the various types of continental deposits in the Kern River alluvial fan area, and they range over several orders of magnitude. Permeability for gravel and clay is stated in Dale et al. (1966) to range between 10 and 100 gallons per day per foot squared (gpd/ft^2)[27], for fine sand and silt from 0.001 to 10 gpd/ft^2, for medium and coarse sand from 100 to 1,000 gpd/ft^2, and for the gravel (dominated) lentil from 1,000 to 10,000 gpd/ft^2. As such, an accurate spatial distribution of hydraulic properties remains a significant data gap, although one that may be filled via further local investigation and/or model calibration.

Structural Properties of the Basin that Restrict Groundwater Flow Within the Principal Aquifer(s)

☑ 23 CCR § 354.14(b)(4)(C)

The White Wolf Fault that forms the southeastern border of the Wheeler Ridge-Maricopa Management Area and the Kern Subbasin is known to act as a significant barrier to (lateral) groundwater flow from the White Wolf Subbasin northwards into the Kern Subbasin, especially at lower groundwater levels (Erler & Kalinowski, Inc., 2016). As discussed above, the E Clay acts as a regional aquitard that limits vertical flow to some extent between the unconfined and confined portions of the aquifer in the northern portion of the Management Area. It should be noted, however, that many wells are screened through this aquitard and therefore serve as a hydraulic connection between the two zones. The Plieto Fault is a southward dipping thrust fault located roughly two to six miles south of the Management Area that separates Miocene and older rocks on the south from Pliocene and Quaternary rocks on the north. The fault is active in Recent times and is roughly coincident with the southern boundary of the Kern Subbasin (as defined in 2016).

General Water Quality of the Principal Aquifer(s)

☑ 23 CCR § 354.14(b)(4)(D)

General groundwater quality within most of the Wheeler Ridge-Maricopa Management Area is categorized by Wood and Dale (1964) as "west-side waters" (see **Figure HCM-10**). Small areas on the far eastern side are categorized as "transition waters" and "axial waters". The Wood and Dale (1964) groundwater quality categories reflect differences in the chemical characteristics of streams that recharge groundwater and differences in the rock types through which groundwater moves. The "west-side waters" have sulfate as the predominant anion and with intermediate cation composition. Total ionic concentrations, indicated by the size of the pie charts on **Figure HCM-10**, are highest in the west, which reflects that the source of water is marine rocks of the Coast Range Mountains. The "transition" waters represent the transition from water emanating chiefly from the Sierra Nevada Mountains to the east and

[27] One gpd/ft^2 is equal to 0.133 ft/day.

"axial" and "west-side" waters whose chemical composition reflects geochemical processes occurring in the central and western San Joaquin Valley, respectively. The "transition" waters have bicarbonate as the predominant anion and an intermediate cation composition. Further discussion of specific constituents of particular relevance to the beneficial uses within the Management Area, including maps of the distribution of these constituents, is provided in **Section 8.5 *Groundwater Quality***.

Primary Uses of Each Aquifer

☑ **23 CCR § 354.14(b)(4)(E)**

The predominant use of groundwater from the principal aquifer in the Wheeler Ridge-Maricopa Management Area is for irrigated agriculture. This includes groundwater pumped by individual landowners for use on their crops, as well as groundwater pumped by WRMWSD and subsequently distributed to WRMWSD customers. There are also several domestic wells in the Management Area, mostly in the east-central portion. WRMWSD also supplies small quantities of water (approximately 1% of total water deliveries) to several industrial entities. **Figure HCM-11** shows the distribution of wells within the Management Area by well type (i.e., agricultural, domestic, industrial, monitoring, and unknown). As shown on **Figure HCM-11**, the density of wells is much lower in the western half of the Management Area, presumably due to the relatively lower yields and poorer water quality in that area.

7.1.5. Data Gaps and Uncertainty

☑ **23 CCR § 354.14(b)(5)**

Key data gaps and uncertainties identified during development of this HCM for the Wheeler Ridge-Maricopa Management Area include:

- Uncertainty in hydraulic properties (hydraulic conductivity, specific yield) of the principal aquifer;
- Uncertainty in the degree of hydraulic connection between the unconfined and confined zones of the principal aquifer where the E Clay is present;
- Uncertainty about well construction details, including well screen intervals, for many in-District wells (i.e., many available well logs are old and no longer legible, or the well logs cannot be accurately mapped to the correct well location); and
- Uncertainty about well status (i.e., whether or not certain wells are active).

7.2. Cross-Sections

☑ **23 CCR § 354.14(c)**

Two hydrogeologic cross-sections (A-A'-A'' and G-G') were developed for this HCM (see **Figure HCM-12** and **Figure HCM-14**, respectively). The locations of the cross-sections with respect to the surficial geology are shown on **Figure HCM-12**. The cross-sections extend laterally slightly beyond the boundaries of the Wheeler Ridge-Maricopa Management Area and extend vertically down to an elevation of -15,000 ft msl. As such the cross-sections include the entire thickness of aquifer materials that are or could reasonably be tapped for groundwater supply purposes (i.e., down through the Pliocene and younger

continental/alluvial deposits of the Tulare Formation) and include the entire zone above the Page (1973) and O'Bryan (1992) base of fresh water surfaces. The cross-sections include the following:

- Land surface elevation extracted from the USGS 10-meter digital elevation model (DEM);
- Surficial geologic units after Chapman and Saleeby (2012), Bartow and McDougall (1984), and Wood and Dale (1964), and other geologic references, discussed further below;
- The locations and State Well IDs of water wells proximal to the cross-section lines, that were used to infer lithology based on inspection of well logs. The locations of water supply wells included on the cross-sections are also shown on **Figure HCM-12**;
- The locations an American Petroleum Institute (API) ID numbers of DOGGR oil wells proximal to the cross-section lines from which the elevations of various stratigraphic markers were extracted from well records;
- Subsurface geologic units, after Chapman and Saleeby (2012), Bartow and McDougall (1984), Wood and Dale (1964), and other geologic references (i.e., lithologic information from water well and DOGGR oil well records);
- Base of fresh water, after O'Bryan (1992);
- Locations of relevant boundaries and landmarks, including the WRMWSD jurisdictional boundary, the Kern Subbasin boundary, the centerlines of various roadways, etc.; and
- The Spring and Fall 2015 groundwater elevations as measured in wells screened in the principal aquifer.

As shown on the cross-sections and discussed previously, all groundwater supply wells with known construction information within the Wheeler Ridge-Maricopa Management Area are less than 2,800 feet in total depth, whereas the Tulare Formation extends significantly deeper. The base of fresh groundwater (after O'Bryan, 1992) is generally deeper than groundwater supply wells in the Management Area. Wells are typically not drilled deeper than needed to obtain the desired quantity of water. Therefore, while usable groundwater may be present below the depths currently tapped by groundwater wells, it may not be economical to do so, especially given that water quality tends to be poorer at greater depths, even above the nominal base of fresh water.

Cross-Section A-A'-A''

Cross-sections A-A'-A'' extends for approximately 37 miles in a west-east direction through the center and extending out of the Wheeler Ridge-Maricopa Management Area. The cross-section starts between the bases of the Little Signal Hills and Buena Vista Hills to the west of the Management Area, where the ground surface is highest in elevation (approximately 1,000 ft msl). The cross-section then crosses through Maricopa Flat in the center of the Management Area, passes through the south-central portion of the Arvin-Edison Management Area, and ends near the southeastern boundary of the Kern Subbasin and the northeastern corner of the White Wolf Subbasin. After declining in elevation from the hills in the west, the ground surface along the cross-section remains approximately constant near 400 to 500 ft msl.

The surficial geologic unit traversed by the cross-section is "Qa", Undifferentiated Surficial Deposits (Pleistocene/Holocene). This deposit is approximately 500 to 700 feet in thickness within the Wheeler Ridge-Maricopa Management Area. Underlying the Qa unit is the Plio-Pleistocene Tulare Formation, which

thickens from west to east and extends down to approximately 5,000 feet in the eastern portion of the Management Area. The contact with the Kern River Formation on the east is approximated and gradational. Underlying the Tulare Formation are the Pliocene San Joaquin Formation, the Miocene/Pliocene Etchegoin Formation, and the Miocene Monterey Formation.

The groundwater elevation in Spring and Fall 2015 is shown to be several hundred feet below the land surface which is within the Pleistocene/Holocene surficial deposits. The base of fresh water is shown to increase in depth from west to east, roughly in line with the base of the Tulare Formation.

Cross-Section G-G'

Cross-section G-G' extends for approximately 26 miles in a north-south direction through the center of the Wheeler Ridge-Maricopa Management Area. The northern end of the cross-section is roughly seven miles north of the Management Area within the Kern Delta Water District (KDWD) service area at an elevation of approximately 300 ft msl. Moving southward the land surface elevation rises through the Management Area and then more steeply as it nears the Plieto Fault Zone and the southern boundary of the Kern Subbasin. Further south, the cross-section extends up into the San Emigdio Mountains, reaching an elevation at its southern end of approximately 5,000 ft msl. The portion of the cross-section within the Management Area has similar stratigraphy as in cross-section A-A', including the Undifferentiated Surficial Deposits, underlain by the Tulare, San Joaquin, Etchegoin, and the Monterey Formations. The groundwater levels in Spring and Fall 2015 are relatively flat, showing a slight decrease to the south. The base of fresh water is found at elevations between -4,000 and -5,000 ft msl. On the southern end of the cross-section, outside of the Management Area and Subbasin, the structural regime is dominated by the Plieto Fault which has raised older (Miocene and older) marine sedimentary units upwards on the south relative to the younger continental rocks on the north side. Another prominent feature in this area is the Devil's Kitchen Syncline.

7.3. Physical Characteristics

☑ 23 CCR § 354.14(d)

7.3.1. Topographic Information

☑ 23 CCR § 354.14(d)(1)

Figure HCM-15 shows the topography within the Wheeler Ridge-Maricopa Management Area. Topography generally slopes to the north in the western and central portions of the Management Area and to the northwest in the eastern portion. Elevations within the Management Area range from approximately 300 ft msl in the central low spot to 1,000 ft msl in the southern highlands of the San Emigdio Mountains.

7.3.2. Surficial Geology

☑ 23 CCR § 354.14(d)(2)

Figure HCM-12 shows the surficial geology within the Wheeler Ridge-Maricopa Management Area, based on the Geologic Map of California, Bakersfield Sheet (CDMG, 1964) and associated map explanation. The predominant surficial geologic unit of Management Area is "Qf" (i.e., Recent alluvial fan deposits in the Great Valley). These deposits were deposited by streams entering the San Joaquin Valley from the uplands

to the south and west. A small portion of Cross-Section A-A'-A'' cuts through "Qs" (Recent dune sand) in the northeastern extent of the Management Area and just south of the Kern Lake Bed.

Along the northern boundary of the Wheeler Ridge-Maricopa Management Area, "Qf" alluvial fan deposits transition to fine-grained "Qb" Quaternary basin deposits that connect two areas of "Ql" Quaternary lake deposits associated with the Buena Vista Lake Bed and Kern Lake Bed. These recent "Basin" deposits ("Qb") are relatively less permeable and were deposited under lower-energy floodplain or marsh environments. The basin and lake deposits may contribute to local perched water conditions in that area in the very shallow subsurface (i.e., approximately the top 20 feet). These perched zones are often composed of poor-quality water (Central Valley Regional Water Quality Control Board [CVRWQCB], 2009) and do not yield significant or economic quantities of water to wells, springs, or surface water systems, and therefore are not considered part of the principal aquifer.

Just south of the Wheeler Ridge-Maricopa Management Area and along the boundary of the Kern Subbasin, "Qc", Quaternary (Pleistocene) non-marine deposits, and "QP", Quaternary (Pliocene-Pleistocene) non-marine deposits are prevalent. The "Qc" deposits consist of older alluvium, including slightly consolidated and dissected fan deposits. The "QP" deposits underlie the Recent Alluvium throughout the Management Area.

7.3.3. Soil Characteristics

☑ **23 CCR § 354.14(d)(3)**

Soils within the Wheeler Ridge-Maricopa Management Area are shown on **Figure HCM-16**, based on the U.S Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic Database (SSURGO) for western Kern County. Soils are generally of intermediate texture, with the predominant type being loam with lesser amounts of fine sandy loam, sandy loam, loamy sand, and other. As shown on **Figure HCM-16**, saturated hydraulic conductivity of soils is generally in the range of 2 to 4 inches per hour (4 to 8 ft/d) in the southern area, decreasing towards the north. As shown on **Figure HCM-17**, soils are predominantly in the B Hydrologic Soil Group in the south and the C Hydrologic Soil Group in the north. These B and C Hydrologic Soil Groups indicate moderate and slow infiltration rates, respectively, and moderately low and moderately high runoff potential, respectively. The northernmost portion of the Management Area, where the "Qf" alluvial fan deposits transition to fine-grained "Qb" Quaternary basin deposits, has soils belonging to the D Hydrologic Soil Group, with very slow infiltration rates and high runoff potential.

7.3.4. Recharge and Discharge Areas

☑ **23 CCR § 354.14(d)(4)**

Figure HCM-18 shows the existing and potential recharge and discharge areas within the Wheeler Ridge-Maricopa Management Area. The groundwater system underlying the Management Area is recharged from several sources, including deep percolation of excess irrigation water applied to agricultural lands (i.e., due to inherent irrigation inefficiency), and seepage/shallow subsurface inflow from natural surface water channels entering the Management Area from the uplands. Recharge of precipitation via deep percolation likely occurs primarily during particularly wet time periods and rarely if ever during normal and dry periods. Discharge of groundwater is predominantly through groundwater pumping from wells. Because water levels are far below the land surface, no significant springs, seeps, or

wetlands exist within the Management Area. Outside of the Management Area, recharge areas include spreading grounds associated with other water banking operations and agricultural lands, and discharge areas are primarily to groundwater supply and recovery wells.

SAGBI Soil Recharge Potential

Figure HCM-19 shows groundwater recharge suitability on agricultural lands within the Wheeler Ridge-Maricopa Management Area based on the UC Davis California Soil Resource Lab's Soil Agricultural Groundwater Banking Index (SAGBI) dataset. This dataset ranks agricultural lands for groundwater recharge suitability based on soil types and five key factors: deep percolation potential, root zone residence time, topography, chemical limitations, and soil surface conditions. The SAGBI dataset ranks a majority of lands within the southern two thirds of the Management Area as having "Good" suitability for groundwater recharge, whereas areas in the northern third are classified as "Moderately Good" or "Very Poor". As discussed in **Section 17 *Projects and Management Actions***, WRMWSD plans to study and pursue in-District banking and recharge efforts as part of its portfolio approach to supply augmentation projects. Any additional future groundwater recharge facilities proposed within the Management Area will be screened against the SAGBI dataset along with other local sources of information to determine their potential suitability for groundwater recharge operations.

7.3.5. Surface Water Bodies

☑ **23 CCR § 354.14(d)(5)**

Surface water bodies significant to the management of the Wheeler Ridge-Maricopa Management Area include both natural surface water features as well as man-made features. **Figure HCM-20** shows the natural surface water features in the vicinity of the Management Area.

To the south of the Wheeler Ridge-Maricopa Management Area, approximately 309 square miles of upland watershed area drains into the area, providing occasional surface water inflows and likely some shallow subsurface inflow. Several creeks whose headwaters are in the Tehachapi and San Emigdio mountains drain northward into the Management Area, including (from west to east) Bitterwater Creek, Cienega Creek, Bitter Creek, Santiago Creek, Muddy Creek, Los Lobos Creek, San Emigdio, and Pleito Creeks. Several smaller unnamed watersheds along the southern valley margin also drain into the Management Area. In addition, several other watersheds and creeks, including El Paso Creek, Pastoria Creek, Grapevine Creek, and Tecuya Creek drain into the White Wolf Subbasin which ultimately drains into the Kern Subbasin. The mapped extents of these creeks mostly terminate along the southern edge of the Management Area, implying that channelized flow does not continue further into the basin, but rather seeps out into the subsurface. The mountain watersheds that drain into the Management Area receive substantially greater precipitation than the Management Area itself and therefore surface/shallow subsurface inflows from these watersheds are likely a considerable source of recharge.

The USGS historically operated a stream gauge on San Emigdio Creek[28], south of the Wheeler Ridge-Maricopa Management Area but the gauge has not been in operation since 1981. WRMWSD is establishing a network of five stream gauges in the San Emigdio mountains, three of which are on streams

[28] https://waterdata.usgs.gov/nwis/inventory/?site_no=11195500

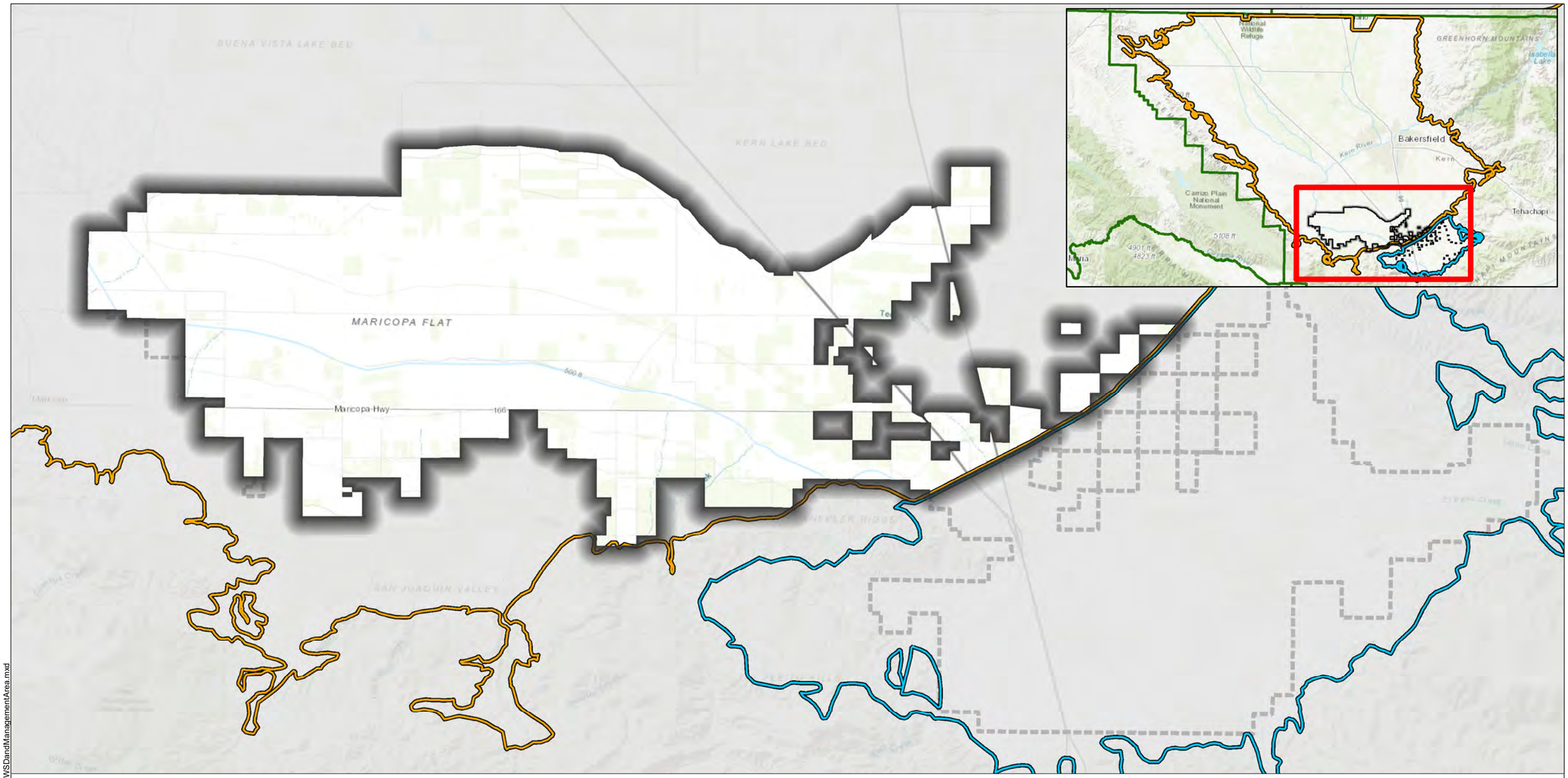
that flow into the Management Area and two of which flow into the White Wolf Subbasin. No streamflow data are yet available from these gauges.

7.3.6. Source and Point of Delivery for Imported Water Supplies

☑ 23 CCR § 354.14(d)(6)

WRMWSD conjunctively manages its surface water and groundwater supplies. The District imports State Water Project (SWP) water through a contract with Kern County Water Agency (KCWA) for 197,088 acre-feet per year (AFY) of Table A Allocation (WRMWSD, 2015). During wet years, the District also receives "Article 21" wet period, surplus water from the SWP. Pursuant to transfer agreements with partner agencies (e.g., Buena Vista Water Storage District, Tehachapi-Cummings Community Water District, etc.), the District has also obtained additional imported water from the SWP, the Central Valley Project (CVP), and other sources. Additionally, the District banks water with the Kern Water Bank, Pioneer Project, and Berrenda Mesa Project in wet years and recovers banked water during dry years.[29] **Figure PA-5** shows the District's facilities and infrastructure used for the conveyance and distribution of imported water supplies. The California Aqueduct runs through the District from west to southeast, and the District has approximately twenty pump stations along the Aqueduct that feed SWP water into the District pipelines, distributing water to the District's Surface Water Service Area.

[29] Table 28 of the WRMWSD Agricultural Water Management Plan provides a complete listing of water transfer and exchange partners.



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- County Boundary

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Abbreviations

DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
3. WRMWSD Management Area boundary was received by WRMWSD staff on 3 July 2018 and excludes overlap area with West Kern Water District Groundwater Sustainability Agency.

N

0 2.5 5
(Scale in Miles)

Wheeler Ridge-Maricopa Water Storage District and Management Area

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure HCM-1

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Path: X:\B70103\Maps\for_GSP\2019\11\Final\Fig HCM-1 WRMWSDandManagementArea.mxd

(a) Base of Fresh Water Based on Page, 1973

(b) Base of Fresh Water Based on O'Bryan, 1992

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Base of Fresh Water Based on Page (ft msl)
- Base of Fresh Water Based on O'Bryan (ft msl)

Abbreviations

DWR	= California Department of Water Resources
ft msl	= feet above mean sea level
USGS	= United States Geological Survey
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

N

0 4 8

(Scale in Miles)

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Page RW, 1973. Base of Fresh Ground Water (approximately 3,000 micromhos) in the San Joaquin Valley, California. USGS Hydrologic Investigations Atlas HA-489.
3. O'Bryan, 1992. A Study of the Base of Fresh Water in the Southern San Joaquin Basin, California. Society of Petroleum Engineers.

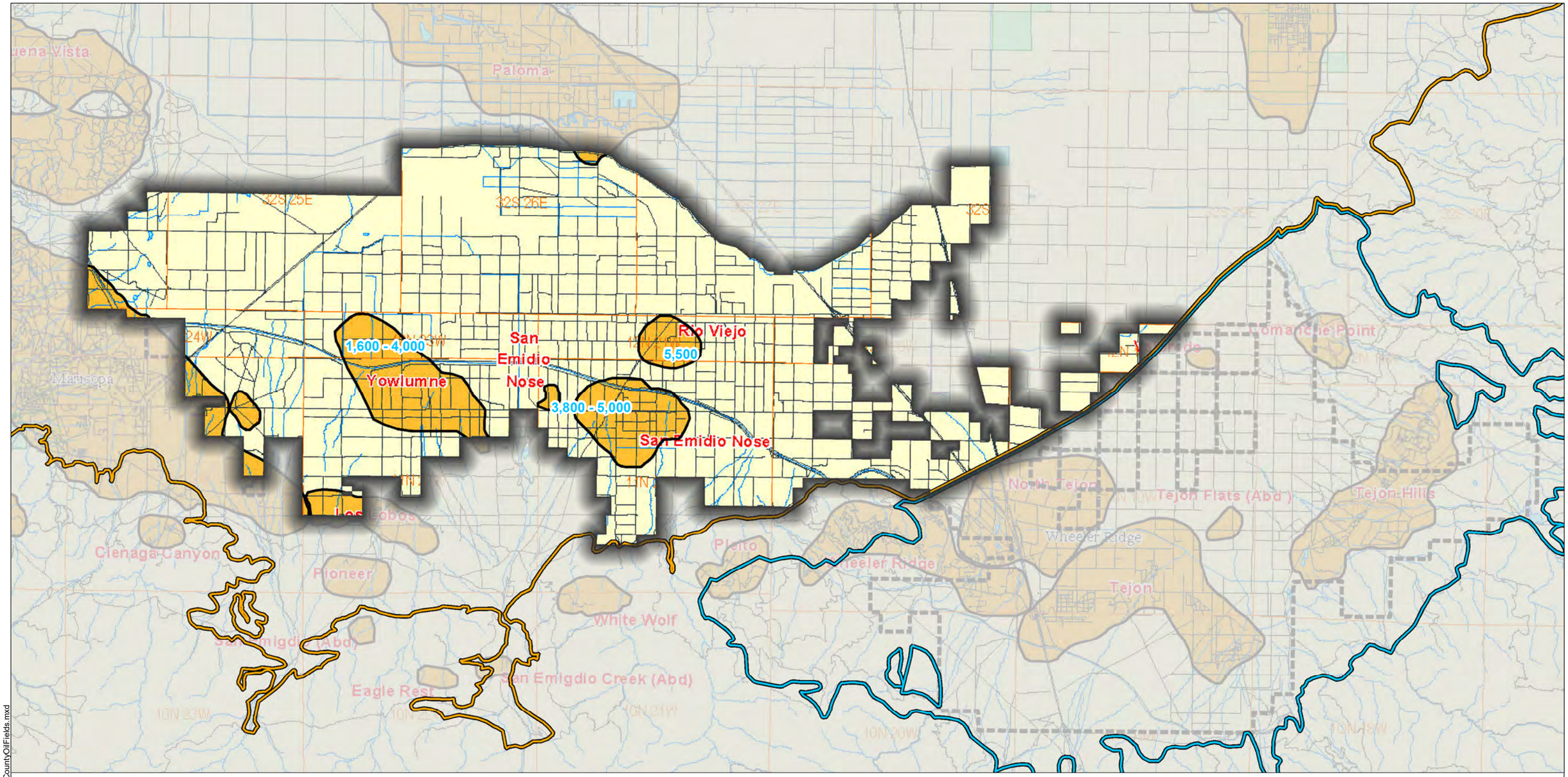
Base of Fresh Groundwater, Based on Page, 1973 (USGS) and O'Bryan, 1992

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure HCM-2

eki environment & water

Path: X:\B70103\Maps\for_GSP\2019\11\Final\FigHCM-2_BaseFreshGroundwater_Page_OBryan.mxd



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- DOGGR Oil Field
- xx Base of Fresh Groundwater (ft bgs)

Abbreviations

DOGGR	= California Division of Oil, Gas, and Geothermal Resources
DWR	= California Department of Water Resources
ft bgs	= feet below ground surface
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Base of Fresh Groundwater according to DOGGR field data sheets.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Oil fields map obtained from DOGGR website (ftp://ftp.consrv.ca.gov/pub/oil/maps/dist4/Dist4_fields.pdf)

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0 2.5 5

(Scale in Miles)

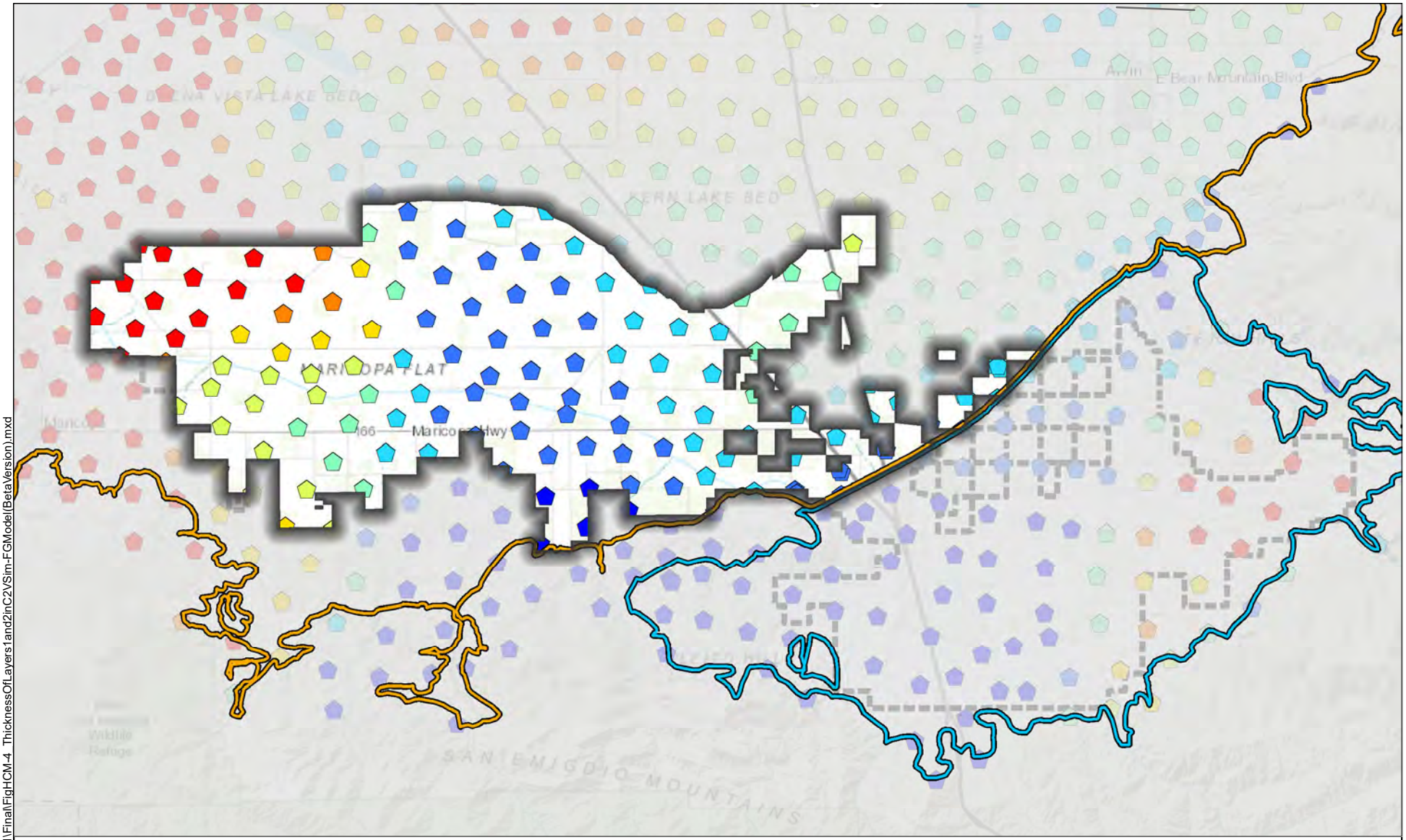
Kern County Oil Fields

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure HCM-3

eki environment & water

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Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Depth to Bottom of Layer 2 (ft bgs)

- <1,100
- 1,100 - 1,200
- 1,200 - 1,300
- 1,300 - 1,400
- 1,400 - 1,500
- 1,500 - 1,600
- 1,600 - 1,700
- >1,700

Abbreviations

C2VSim-FG	= California Central Valley Groundwater-Surface Water Simulation Model-Fine Grid
CNRA	= California Natural Resources Agency
DWR	= California Department of Water Resources
ft bgs	= feet below ground surface
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Total thickness of Layers 1 and 2 of C2VSim-FG Beta Model are shown.
3. Layer 1 and 2 total depths range from 597 to 1,807 ft bgs in C2VSim-FG Model within WRMWSD Management Area.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. C2VSim-FG Model data obtained from CNRA website: https://data.cnra.ca.gov/dataset/c2vsimfg-beta-model

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0 5 10

(Scale in Miles)

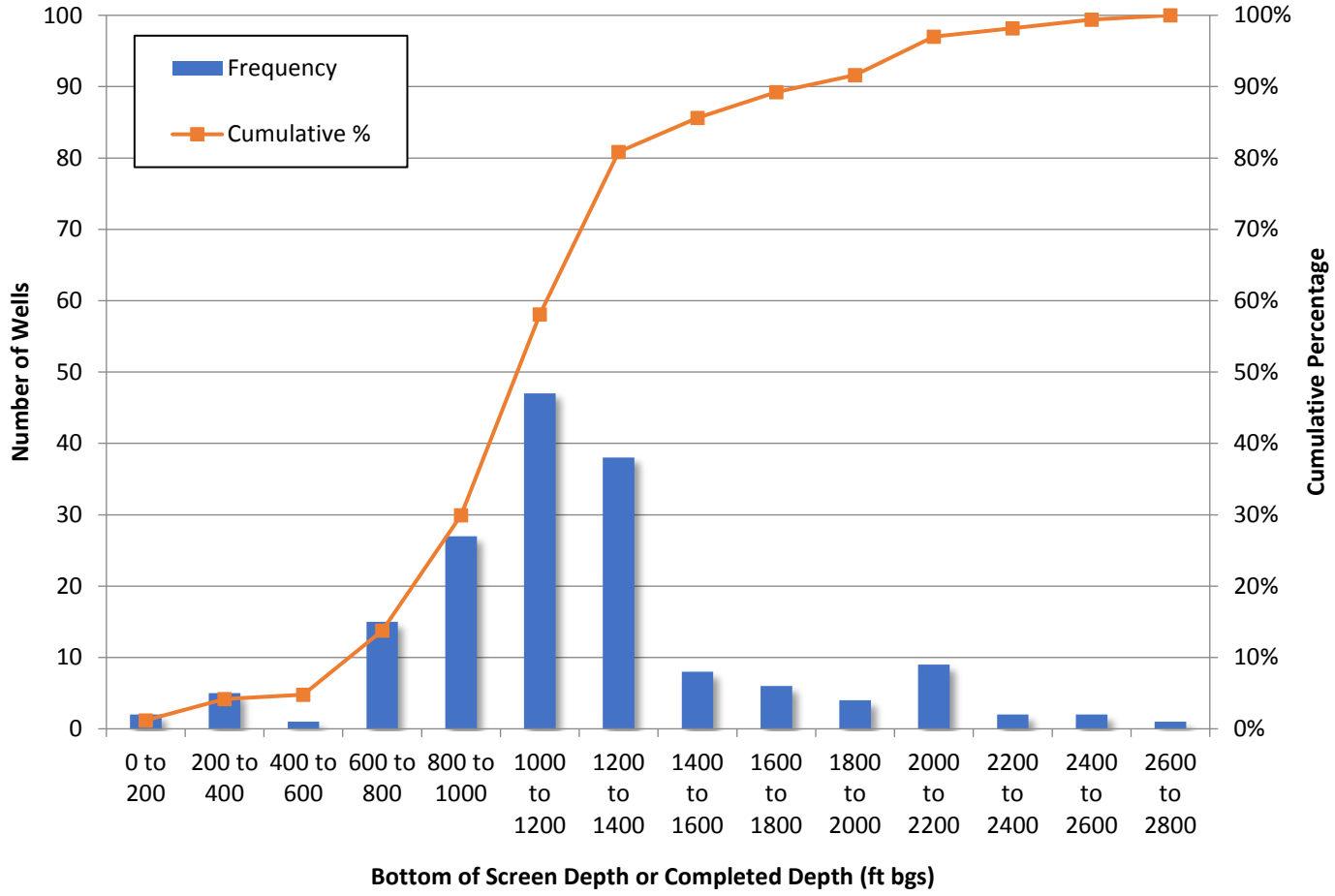
Thickness of Layers 1 and 2 in C2VSim-FG Model (Beta Version)

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure HCM-4

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Path: X:\B70103\Maps\for GSP\2019\11\Final\FigHCM-4 ThicknessOfLayers1and2inC2VSim-FGModel(BetaVersion).mxd



Abbreviations

BOS = bottom of screen
ft bgs = feet below ground surface

Notes

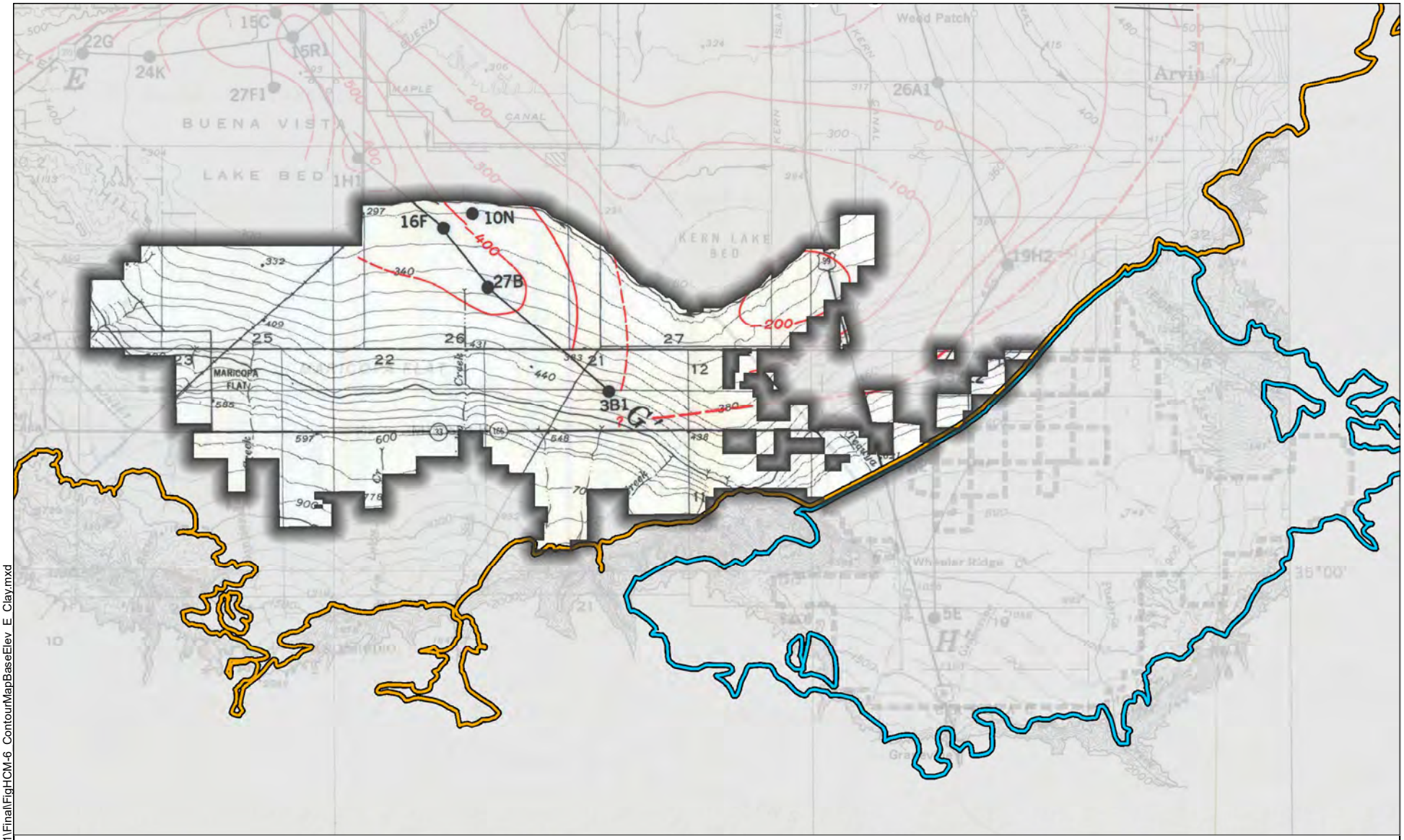
1. Well screen data is based on digitized well records of 167 wells in the Wheeler Ridge-Maricopa Management Area.
2. When BOS depth was not available, completed depth was used.

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Summary of Well Screen Depth Data

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure HCM-5



Path: X:\B70103\Maps\for GSP\2019\11\Final\FigHCM-6 ContourMapBaseElev_E Clay.mxd

Legend

- WRMWSD Management Area
- WRMWSD Service Area
- Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

"E Clay" Overlay Map Attributes

- Structure contour — Shows altitude of base of E clay. Dashed where approximately located. Contour interval 100 feet; datum is mean sea level
- Boundary of upper clay stratum of the E clay
- Boundary of lower clay stratum of the E clay
- Boundary of the E clay; stratum not determined
- 6F3 — Well, core hole, or auger hole and number
- Alinement of geologic section

Abbreviations

DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Overlay map shows elevation contours (red lines) of the base of the "E Clay". The contour interval is 100 feet and the datum is mean sea level.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Croft, M.G., 1972, Sub surface geology of the late Tertiary and Quaternary water-bearing deposits of the southern part of the San Joaquin Valley, California, USGS Water Supply Paper 199 H, 29 pp.

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0 5 10

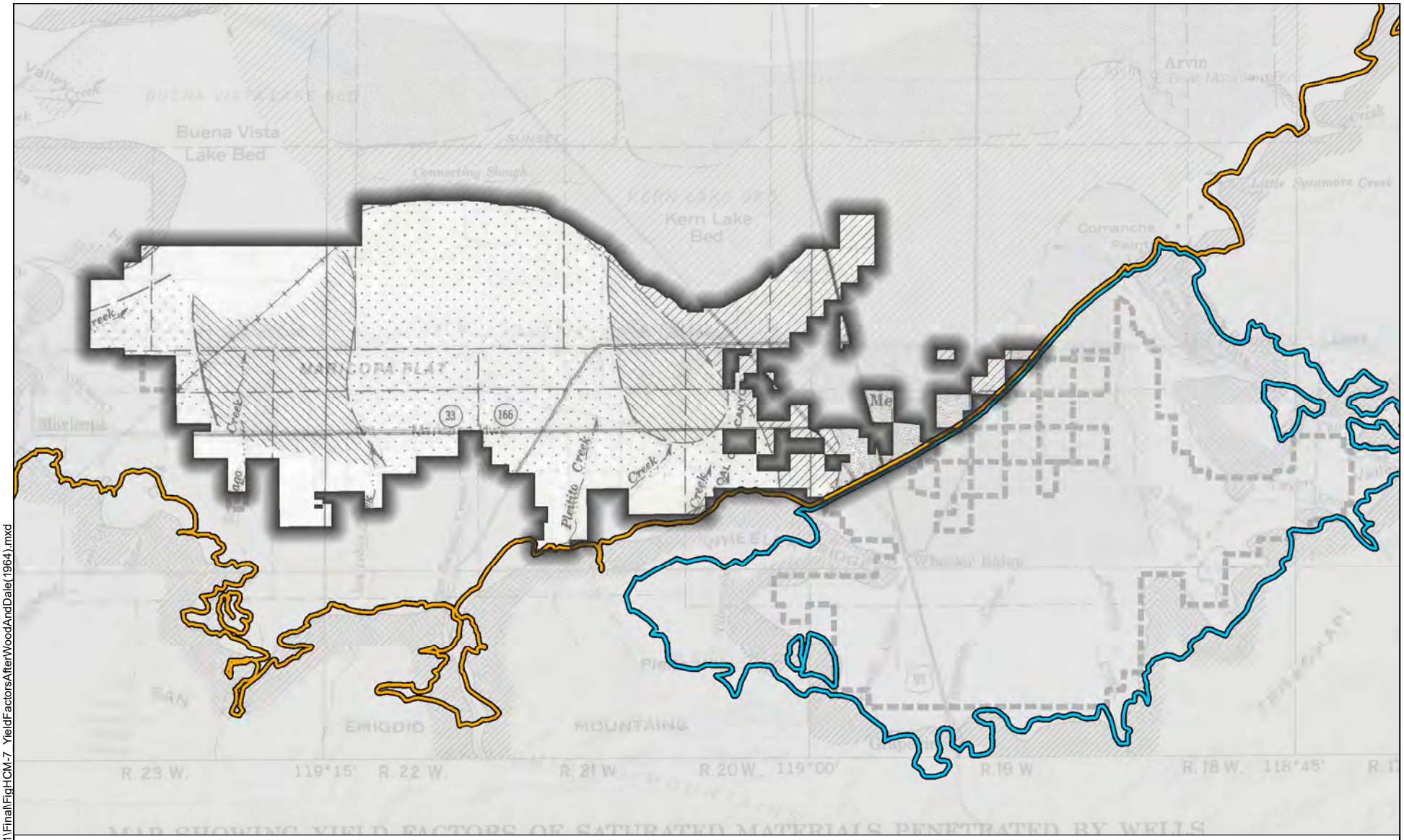
(Scale in Miles)

Contour Map of Base Elevation of "E Clay" Layer

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure HCM-6

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Path: X:\B70103\Maps\for GSP\2019\11\Final\FigHCM-7 YieldFactorsAfterWoodAndDale(1964).mxd

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Yield Factor (gpm/ft per 100 feet of aquifer)

- < 1
- 1 - 5
- 6 - 10
- 11 - 50
- > 50

Abbreviations

DWR	= California Department of Water Resources
gpm/ft	= gallons per minute per foot
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Yield factor is in gallons per minute per foot of drawdown per 100 feet of saturated materials penetrated by irrigation wells.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. P. R. Wood and R. H. Dale, 1964, Geology and Ground-Water Features of the Edison-Maricopa Area, Geological Survey Water-Supply Paper 1656.

N

0 5 10

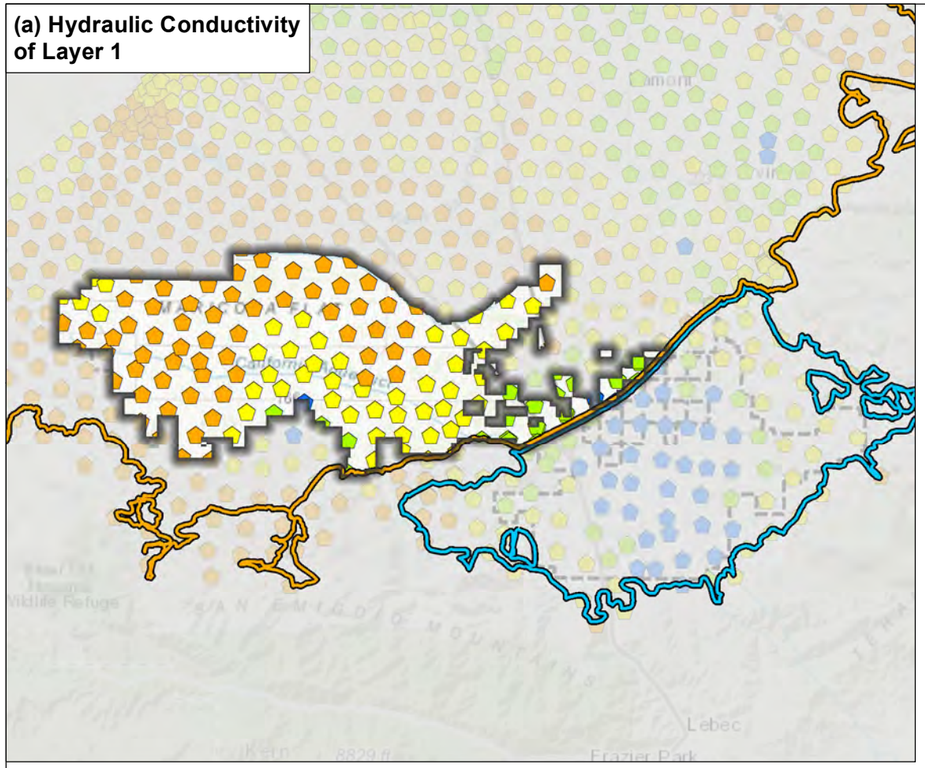
(Scale in Miles)

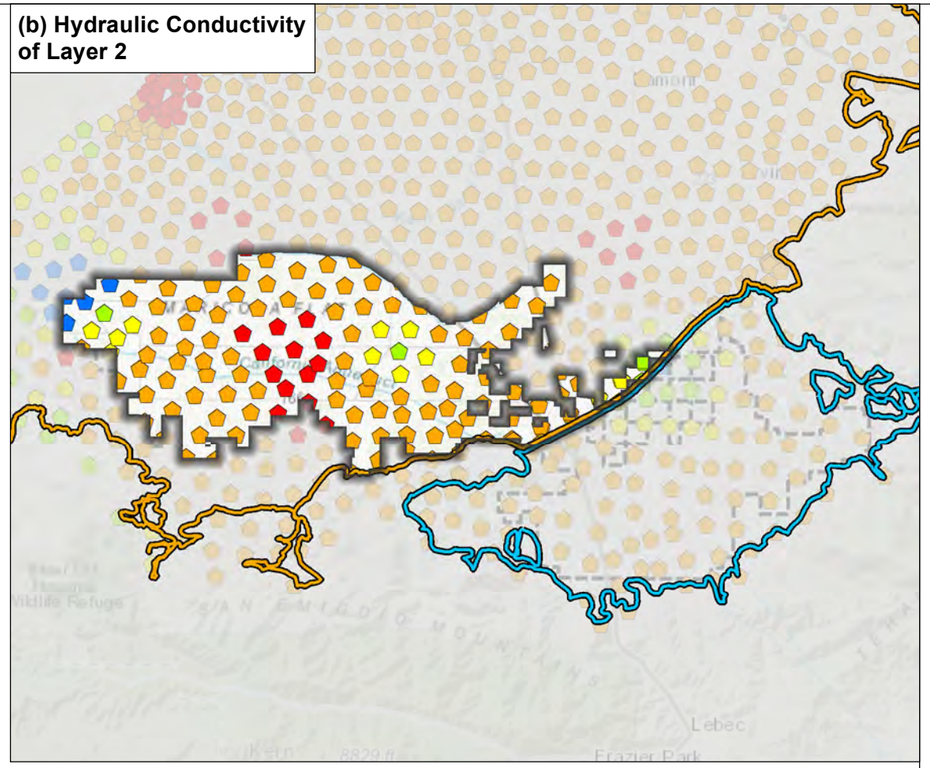
Yield Factors after Wood and Dale (1964)

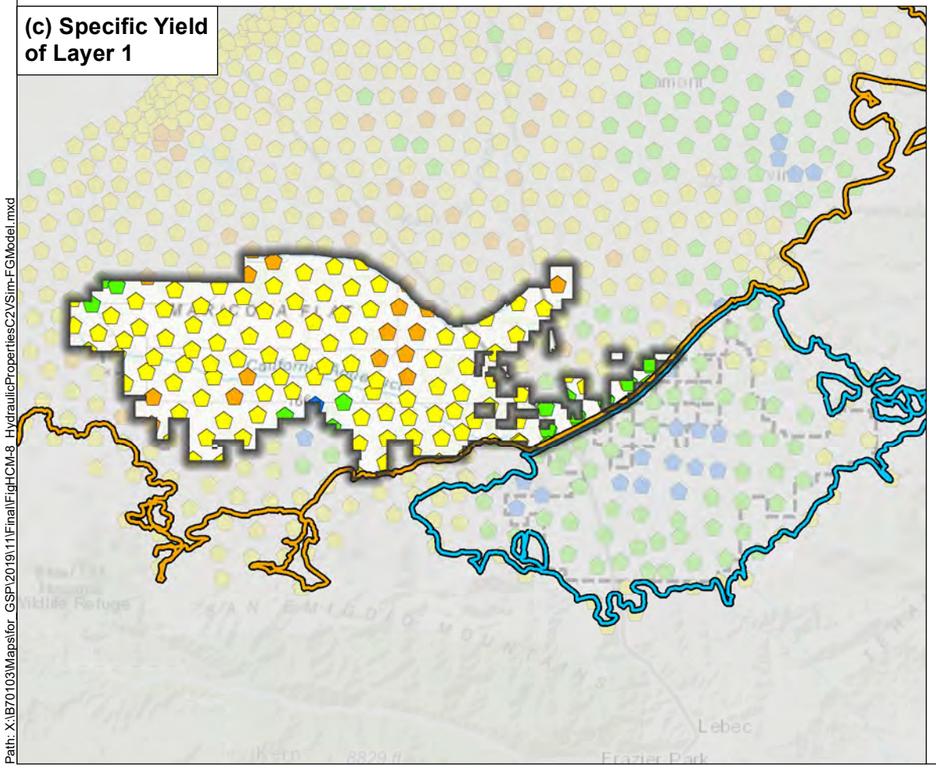
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

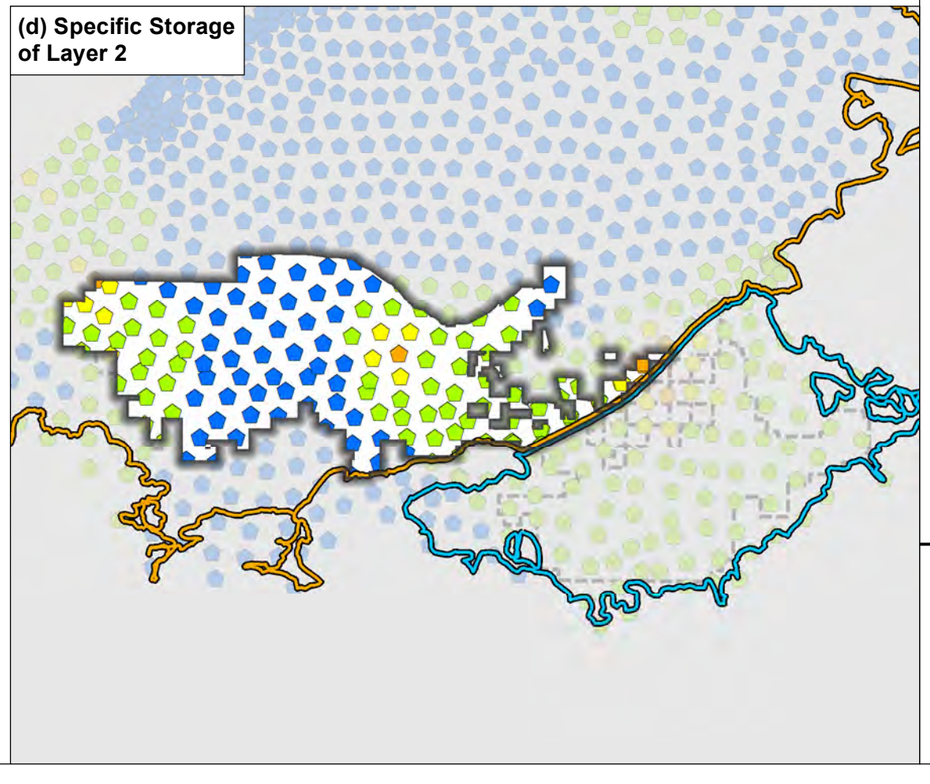
Figure HCM-7

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Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Hydraulic Conductivity (ft/day)

- 2 - 8
- 8 - 20
- 20 - 30
- 30 - 40
- > 40

Specific Yield [-]

- 0.070 - 0.080
- 0.080 - 0.085
- 0.085 - 0.090
- 0.090 - 0.100

Specific Storage

- < 0.0005
- 0.0005 - 0.001
- 0.001 - 0.0015
- 0.0015 - 0.0021

Abbreviations

C2VSim-FG = California Central Valley Groundwater-Surface Water Simulation Model - Fine Grid
CNRA = California Natural Resources Agency
ft bgs = feet below ground surface
ft/day = feet per day
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Layers 1 and 2 are the representative "pumped layers" of C2VSim-FG Beta Model.
3. Layer 1 and 2 total depths range from 600 to 1,810 ft bgs in C2VSim-FG Beta Model within WRMWSD Management Area.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. C2VSim-FG Model data obtained from CNRA website: https://data.cnra.ca.gov/dataset/c2vsimfg-beta-model

N

0 7 14

(Scale in Miles)

Hydraulic Properties in C2VSim-FG Model (Beta Version)

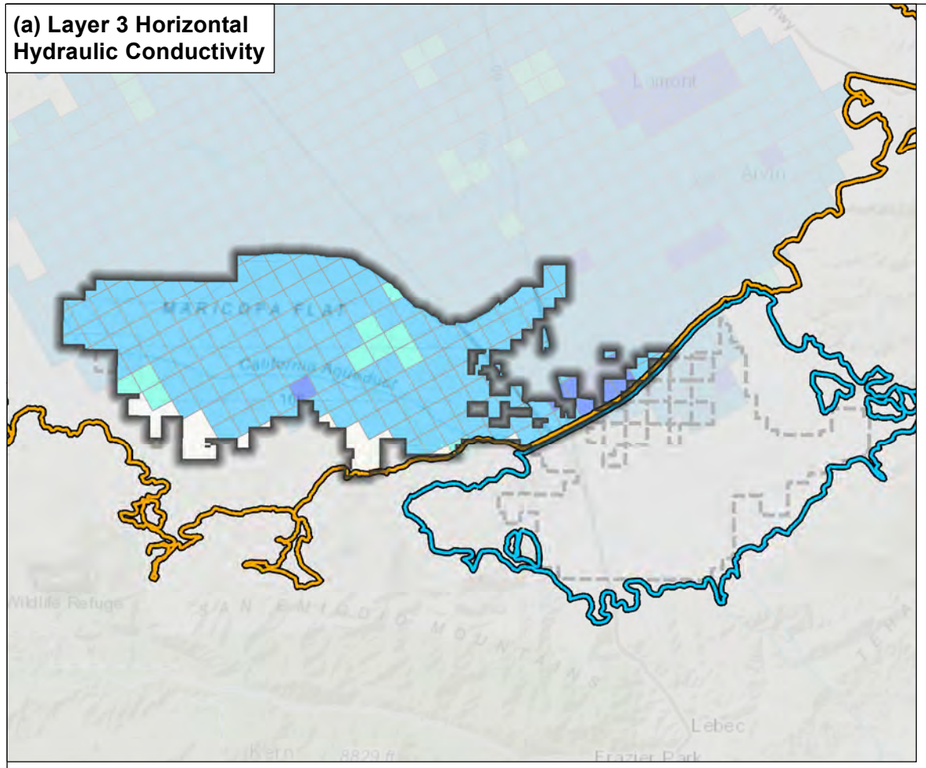
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure HCM-8

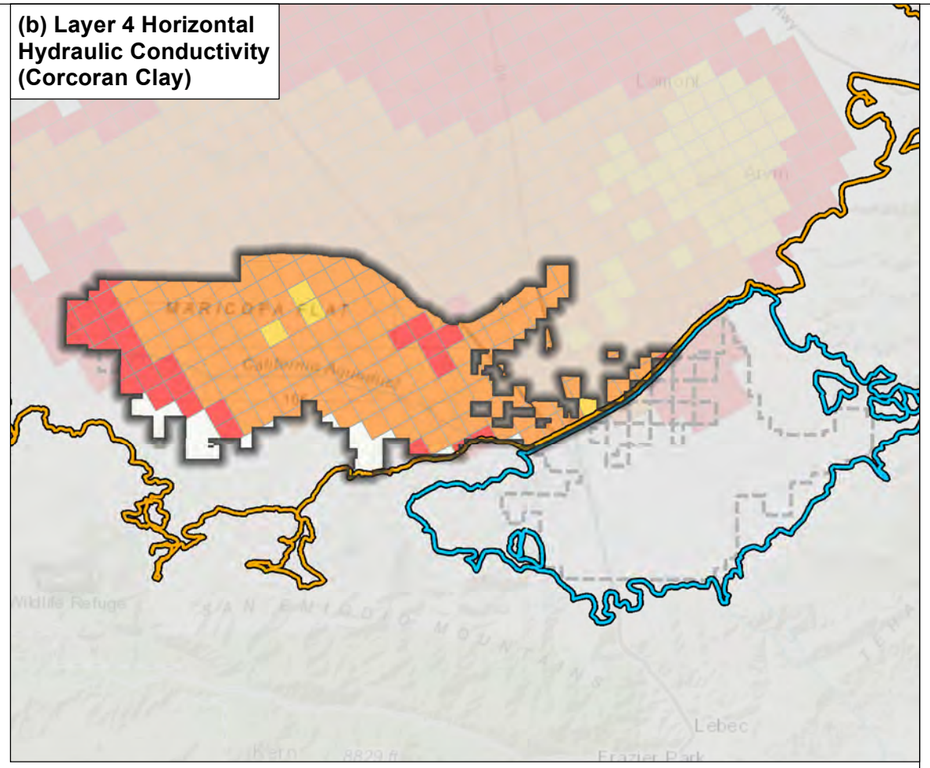
eki environment & water

Path: X:\B70103\Maps\for_GSP_2019\11\FinalFigHCM-8_HydraulicPropertiesC2VSim-FGModel.mxd

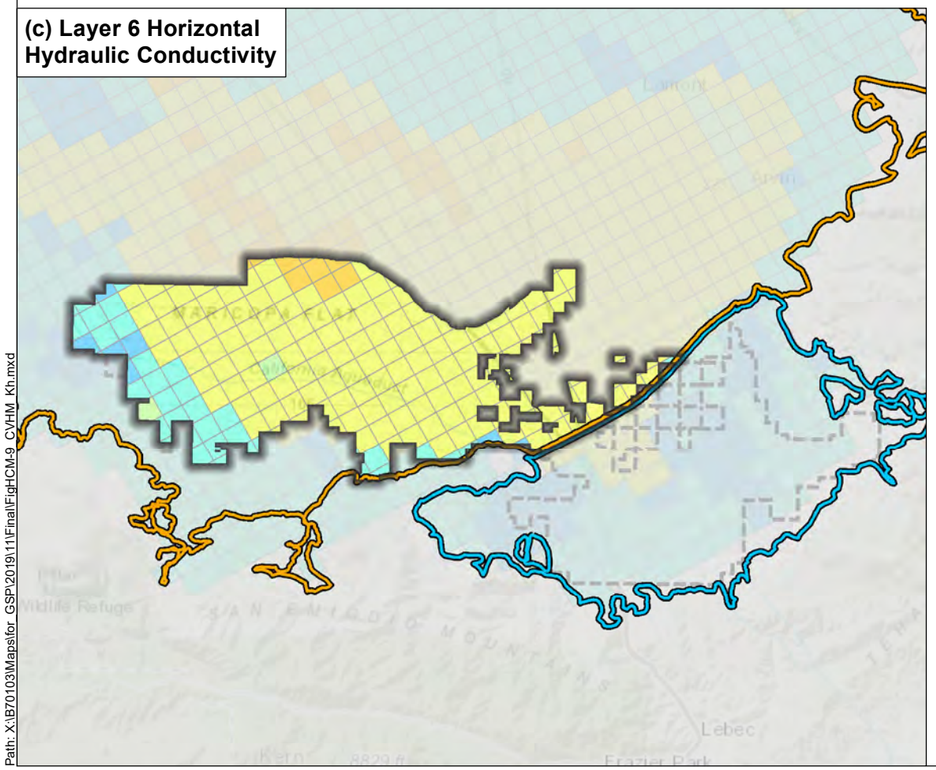
(a) Layer 3 Horizontal Hydraulic Conductivity



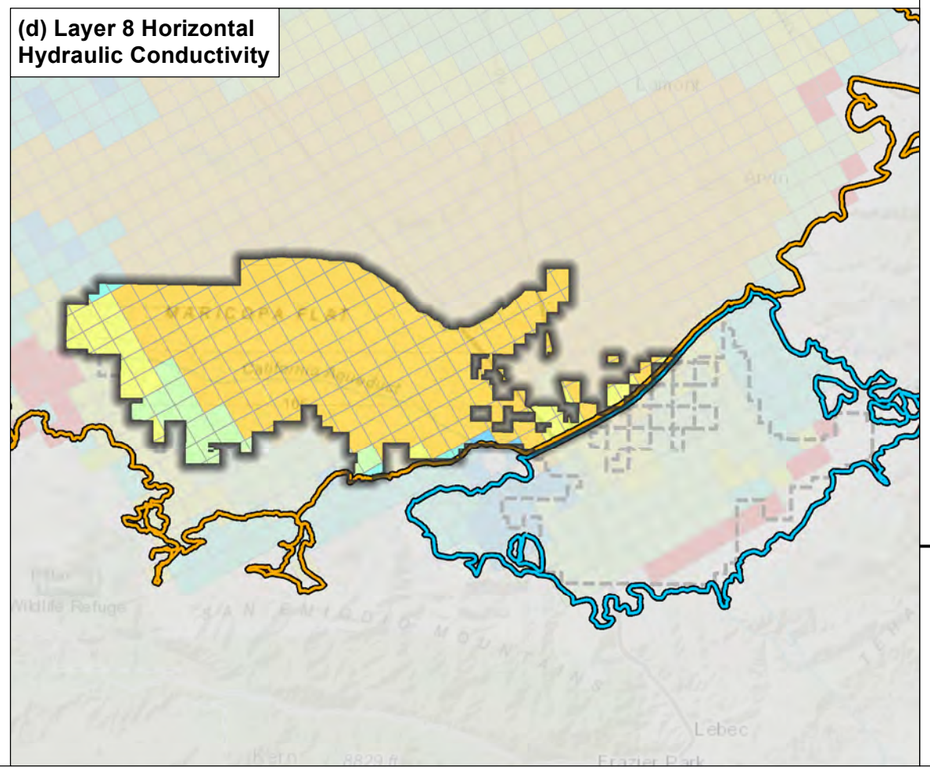
(b) Layer 4 Horizontal Hydraulic Conductivity (Corcoran Clay)



(c) Layer 6 Horizontal Hydraulic Conductivity



(d) Layer 8 Horizontal Hydraulic Conductivity



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Horizontal Hydraulic Conductivity (ft/d)

- < 0.5
- 0.5 - 5.0
- 5.0 - 25
- 25 - 50
- 50 - 100
- 100 - 250
- 250 - 500
- 500 - 1,000
- > 1,000

Abbreviations

CVHM	= Central Valley Hydrologic Model
DWR	= California Department of Water Resources
ft/d	= feet per day
USGS	= United States Geological Survey
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Percent coarse is used to approximate hydrogeologic properties of each layer in the CVHM model.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 10 December 2019.
2. CVHM aquifer properties were acquired from Faunt, C.C., ed., 2009, Groundwater Availability of the Central Valley Aquifer, California: USGS Professional Paper 1766, 225 p.

N

0 7 14

(Scale in Miles)

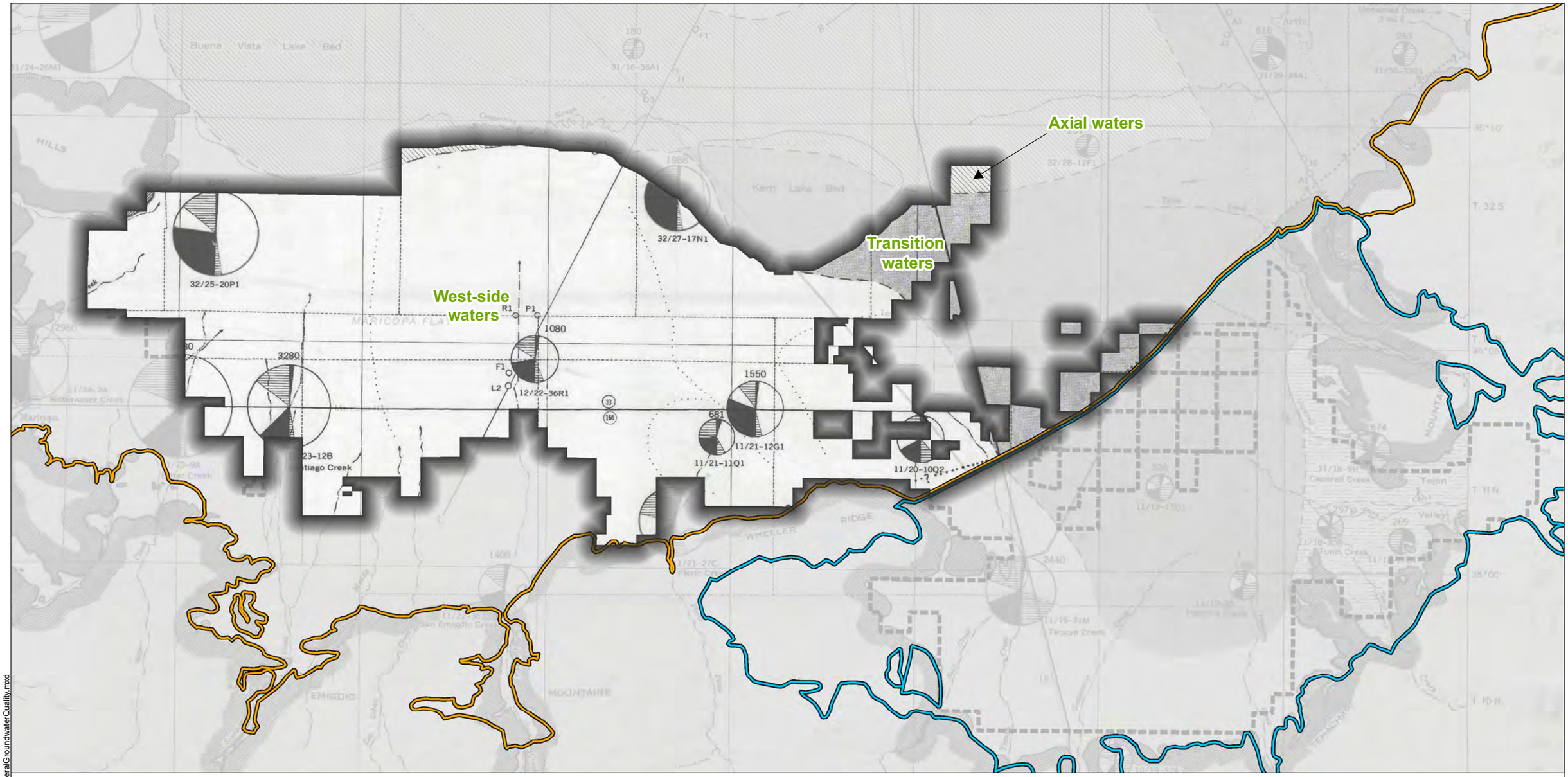
CVHM Horizontal Hydraulic Conductivity, Layers 3, 4, 6, 8

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure HCM-9

eki environment & water

Path: X:\B70103\Mapsfor GSP\2019\11\Final\FigHCM-9 CVHM Kh.mxd



Legend

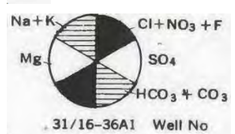
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

General Water Quality

- Probable boundary between groundwater subtypes
- Consolidated rocks bordering the valley
- Groundwater barrier (querried where uncertain)



Area of circle indicates mineral concentration (excluding silica), in parts per million



Abbreviations

DWR	= California Department of Water Resources
USGS	= The United States Geological Survey
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Map shows areas of different water quality (shading, hatching, and stippling), as shown by labels, and chemical composition of major ions (pie charts) the sizes of which are scaled by the total mineral concentration (excluding silica).

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Wood P.R. and R. H. Dale, 1964, Geology and Ground-Water Features of the Edison-Maricopa Area, Kern County, California. USGS Water Supply Paper 1656.

N

0 2.5 5

(Scale in Miles)

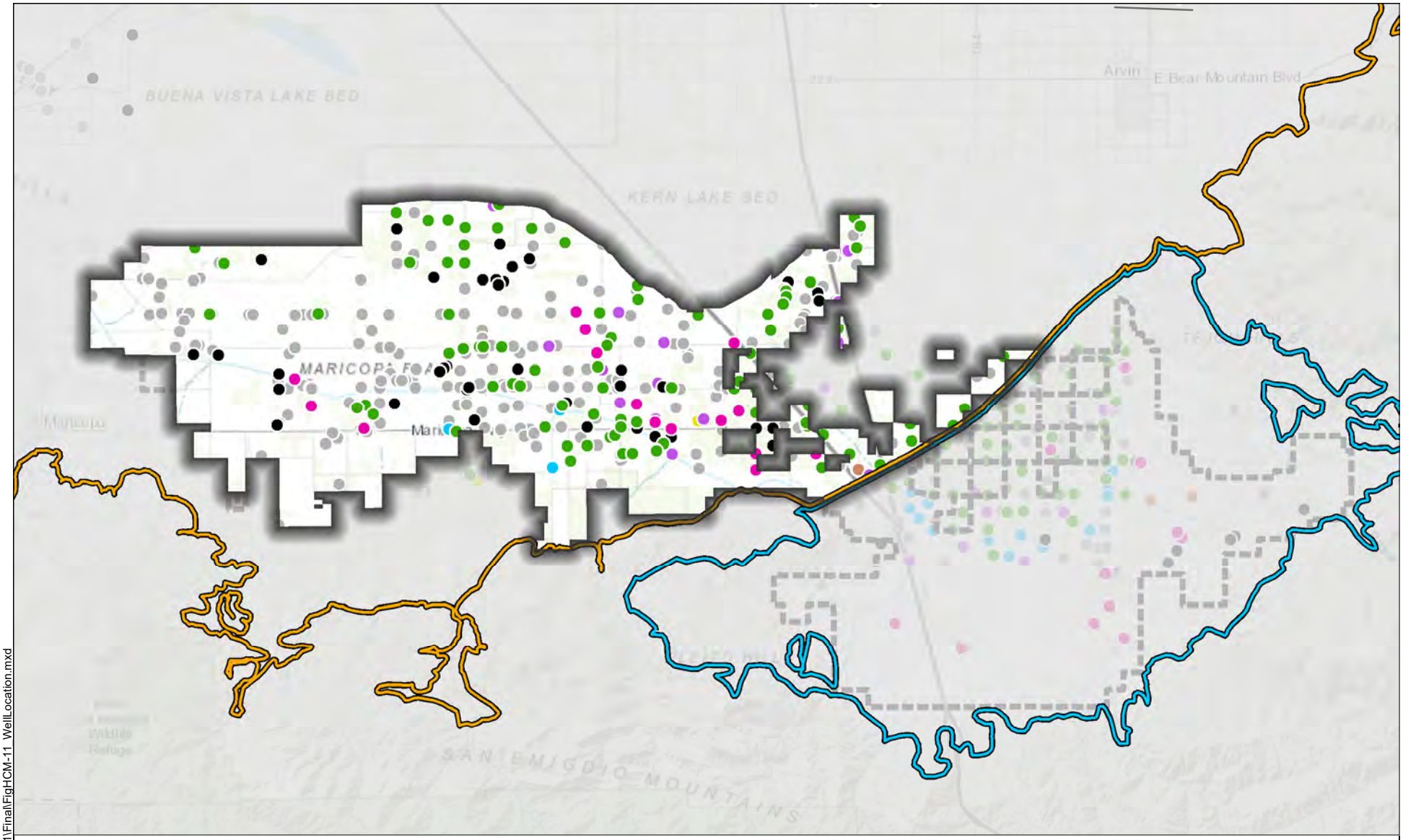
General Groundwater Quality

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure HCM-10

eki environment & water

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Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Well Type/Status

- Active Agricultural
- Active Domestic
- Active Industrial
- Active WRMWSD Production Well
- Monitoring Well
- Abandoned
- Dry Well
- Other

Abbreviations

DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Well type data received from WRMWSD on 20 November 2017.

N

0 5 10

(Scale in Miles)

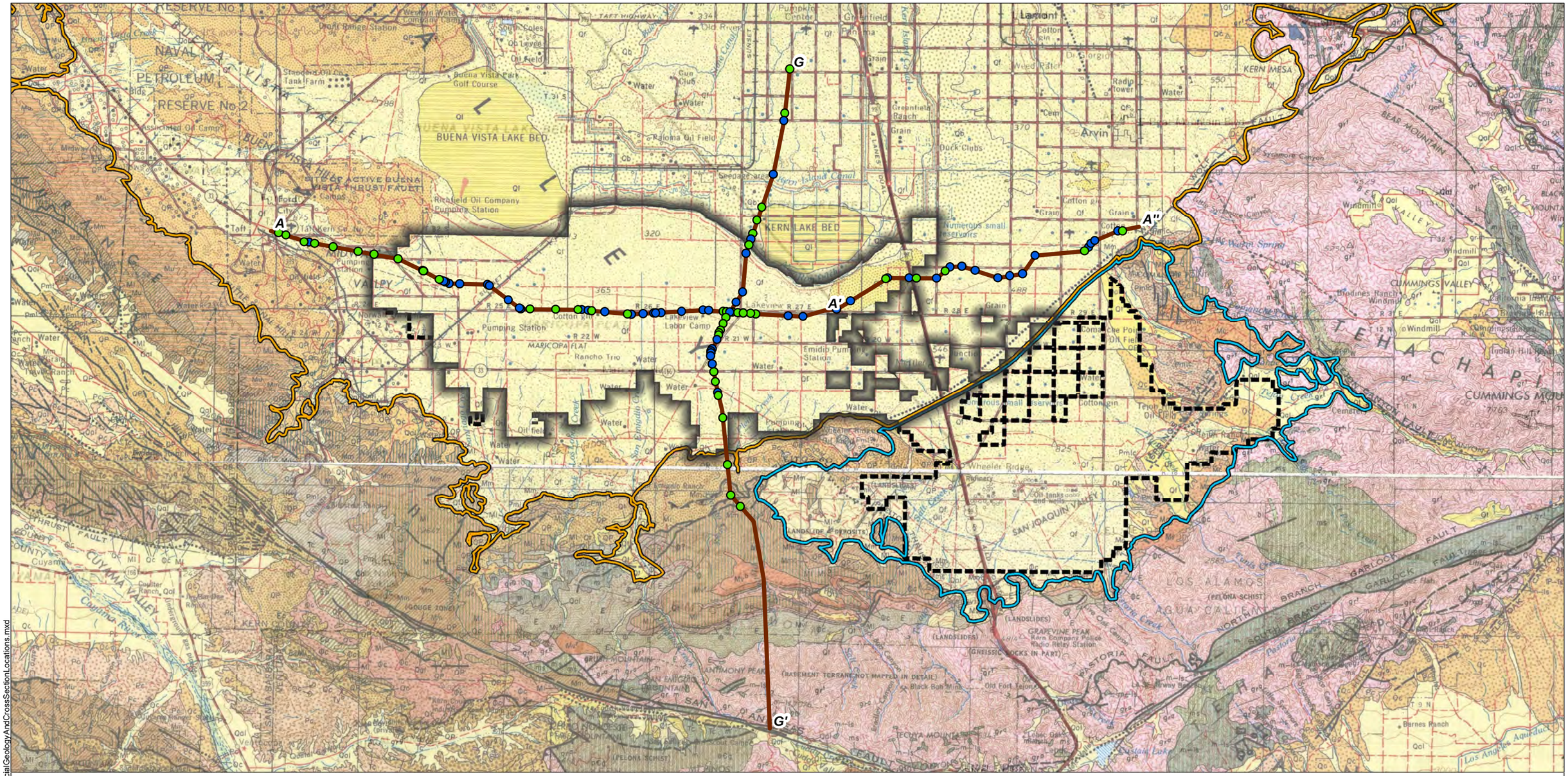
In-District Well Locations, Type, and Status

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure HCM-11

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigHCM-11 WellLocation.mxd



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Cross Section Location

Cross Section Data Point

- Water Well (Completion Report or Electric Log)
- Oil Well Electric Log

Geologic Units

- Dune sand
- Quaternary fan deposits
- Quaternary nonmarine terrace deposits
- Undivided Pliocene nonmarine
- Undivided Miocene nonmarine
- Middle Miocene marine
- Oligocene marine
- Tertiary nonmarine
- Pre-Cretaceous metamorphic rocks
- Recent alluvium
- Quaternary basin deposits
- Pleistocene nonmarine
- Middle and/or lower Pliocene nonmarine
- Upper Miocene marine
- Lower Miocene marine
- Eocene marine
- Mesozoic basic intrusive rocks
- Pre-Cretaceous metasedimentary rocks
- Quaternary Stream channel deposits
- Quaternary lake deposits
- Plio-Pleistocene nonmarine
- Middle and/or lower Pliocene marine
- Miocene volcanic
- Oligocene nonmarine
- Paleocene marine
- Upper Cretaceous marine
- Mesozoic granitic rocks

Abbreviations

DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
2. WRMWSD cross section locations and data type provided by WRMWSD staff on 25 January 2018 (A-A'-A") and 9 March 2018 (G-G').
3. Surface geology from California Division of Mines and Geology, Geologic Map of California, Olaf P. Jenkins Edition, Bakersfield Sheet (1964) and Los Angeles Sheet (1969).

N

0 4 8

(Scale in Miles)

Surficial Geology and Cross Section Locations

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure HCM-12

eki environment & water

Path: X:\B70103\Maps\for_GSP\20191212\final\FigHCM-12_SurficialGeologyAndCrossSectionLocations.mxd

Figure HCM-13 Geologic Cross-Section A-A’

December 2019

A

A'

15,000'

10,000'

5,000'

SEA LEVEL

- 5,000'

- 10,000'

- 15,000'

Notes and References:

1. Alan D. Chapman and Jason B. Saleeby, 2012, Geologic Map of the San Emigdio Mountains, Southern California: The Geological Society of America, Map and Chart Series MCH101 2012
2. Bartow, A. and McDougall, K., 1984, Tertiary stratigraphy of the southeastern San Joaquin Valley, California: U.S. Geological Survey Bulletin 1529-J
3. Wood, P. R. and Dale, R. H., 1964, Geology and ground-water features of the Edison-Maricopa area Kern County, California: U.S. Geological Survey Water Supply Paper 1656
4. Base of fresh water derived from contours by P.L. O'Bryan, 1992, A study of the base of fresh water in the Southern San Joaquin basin, California: Society of Petroleum Engineers, SPE 24084
5. Formation contacts inferred from electric logs. Deflections observed in select electric logs were compared to log motifs for mappable units in California Oil and Gas Fields, Vol. I, Central California: California Dept. of Conservation, Division of Oil, Gas, and Geothermal Resources Publication No. TR11, Fourth Ed., 1998
6. Drawn by Thomas Suggs, Wheeler Ridge-Maricopa Water Storage District, January 2019

WRMWSD Jurisdictional Boundary

City of Taft

02907272, 32S/24E-20

32S/24E-20R01

02975577, 32S/24E-21

alluvial fan deposits

Cl. CA Aqueduct

Cl. Gardner Field Rd

02933290, 32S/25E-30

32S/25E-31B0

32S/25E-29P01

32S/25E-28P01

Cl. Sunset Railroad

32S/25E-35N02

02981514, 32S/25E-35

02959519, 12N/22W-33

32S/26E-31R01

03031098, 13N/22W-35

12N/22W-25N01

Proj 700' to 32S/26E-5AN04

32S/26E-34P01

Proj 700' to 12N/21W-29N01

32S/26E-36P02

02956431, 12N/21W-28

Crosses Section G-G

Cl. Sunset Railroad

02954568, 12N/21W-34

02955327, 12N/21W-26

Proj 1500' to 12N/21W-27N02

12N/20W-30N01

Qs

I-5 Freeway

32S/27E-36F01 and 32S/27E-36L01

fan delta, lake and marsh deposits

32S/26E-30H02

Cl. Hwy 99

02959287, 32S/26E-33

32S/26E-28H01

32S/26E-27B01

32S/26E-22P01

Qa

32S/26E-25F01

32S/26E-30F01

32S/26E-19H02

West Edge of Percolation Pond

02932469, 32S/26E-21

32S/26E-15N01

Cl. Rancho Rd

alluvial fan deposits

32S/26E-14F01

Qa

Tm

QTt

Spring 2015 SWL

Fall 2015 SWL

Tsj

Te

Qs

QTt

Tsj

QTc

Te

Tm

Base of Fresh Water (EC = 3,000 mMhos/cm)

EXPLANATION OF SYMBOLS

Contact, dashed where approximate

Questioned contact

Base of fresh water

Static water level surface

02933290, 32S/25E-30

API number and well number

0 1 MILE

SCALE

4X VERTICAL EXAGGERATION

Qs **Sand dunes** (Holocene) Windblown sand and dune sand

Qa **Undifferentiated Surficial Deposits** (Pleistocene - Holocene) Unconsolidated to cemented, oxidized silt, sand, and gravel, cobbles, boulders, and minor clay; equivalent to the older alluvial fan, tilted alluvial fan, younger alluvium, flood basin deposits, and terrace deposits of Wood and Dale (1964)

QTt **Tulare Formation** (Pliocene - Pleistocene) Mostly unconsolidated clay, sand, pebble gravel with some beds of sandstone and conglomerate derived from both west-side and east-side sources; alluvial fan, flood plain, deltaic, lacustrine, and marsh deposits; includes Corcoran clay member

Tsj **San Joaquin Formation** (Pliocene) Silt and clay beds alternating with beds of sandstone and conglomerate; contains marine, brackish water and nonmarine fossils

Te **Etchegoin Formation** (Miocene - Pliocene) Marine and terrestrial sandstone, conglomerate, and claystone, tan to greenish gray, friable, fossiliferous

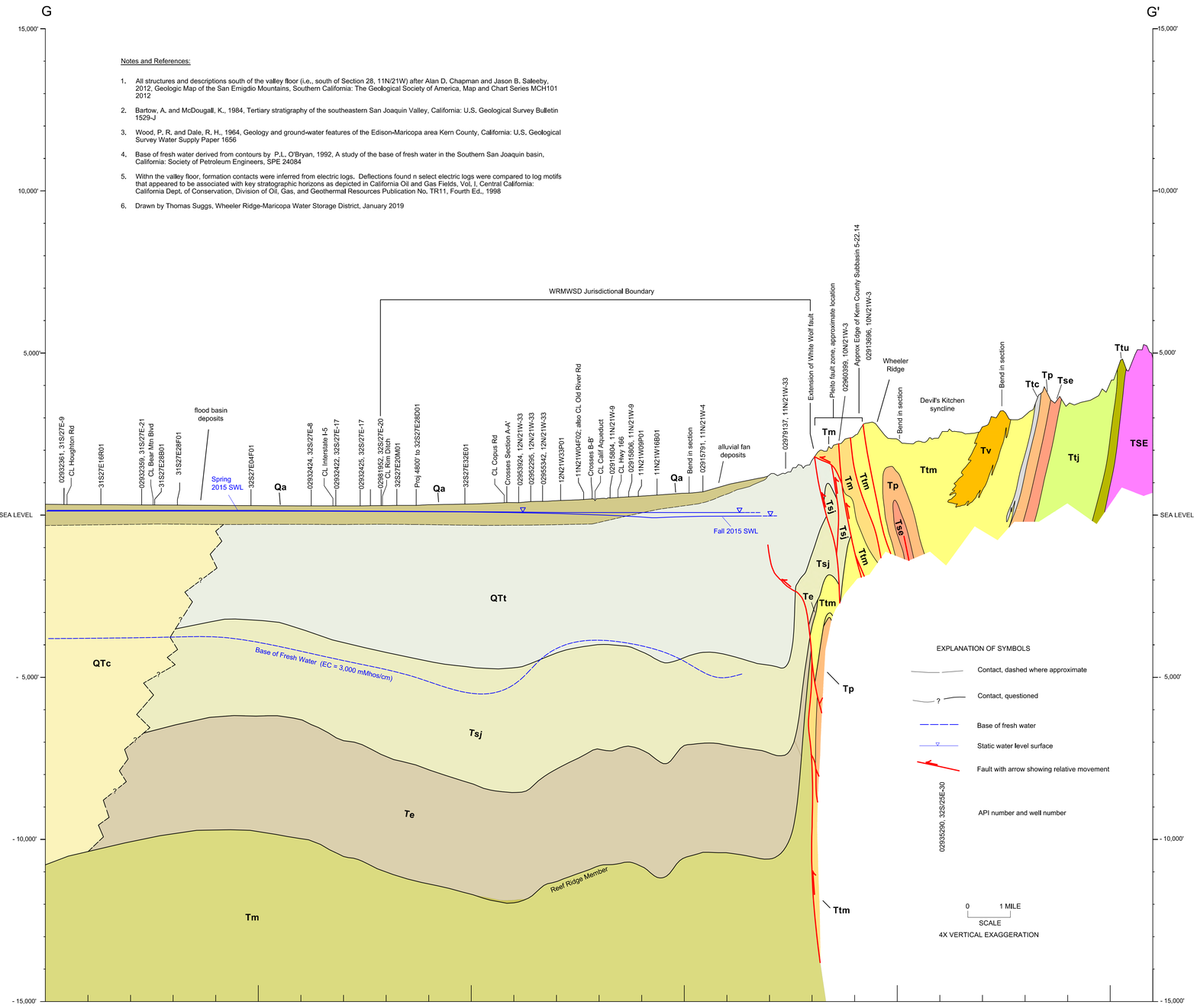
QTc **Kern River Formation / Chanac Formation** (Miocene - Pleistocene) Unconsolidated to semiconsolidated, generally poorly sorted clay, silt, sand, and gravel derived from the Sierra Nevada and Tehachapi Mountains; fluvial and alluvial deposits; grades westward into continental and marine deposits of Tulare, San Joaquin and Etchegoin formations

Tm **Monterey Formation** (Miocene) Marine biogenic shale, lithified, siliceous to semi-siliceous, gray to white, platy to fissile

GEOLOGIC CROSS SECTION A-A', SAN JOAQUIN VALLEY, CALIFORNIA

Figure HCM-14 Geologic Cross-Section G-G’

December 2019



GEOLOGIC CROSS SECTION G-G', SAN JOAQUIN VALLEY, CALIFORNIA

Qa — **Undifferentiated Surficial Deposits** (Pleistocene - Holocene) Unconsolidated to cemented, oxidized silt, sand, and gravel, cobbles, boulders, and minor clay; equivalent to the older alluvial fan, tilted alluvial fan, younger alluvium, flood basin deposits, and terrace deposits of Wood and Dale (1964)

QTc — **Kern River Formation / Chanac Formation** (Miocene - Pleistocene) Unconsolidated to semiconsolidated, generally poorly sorted clay, silt, sand, and gravel derived from the Sierra Nevada and Tehachapi Mountains; fluvial and alluvial deposits; grades westward into continental and marine deposits of Tulare, San Joaquin and Etchegoin formations

QTt — **Tulare Formation** (Pliocene - Pleistocene) Mostly unconsolidated clay, sand, pebble gravel with some beds of sandstone and conglomerate derived from both west-side and east-side sources; alluvial fan, flood plain, deltaic, lacustrine, and marsh deposits; includes Corcoran clay member

Tsj — **San Joaquin Formation** (Pliocene) Silt and clay beds alternating with beds of sandstone and conglomerate; contains marine, brackish water and nonmarine fossils

Te — **Etchegoin Formation** (Miocene - Pliocene) Marine and terrestrial sandstone, conglomerate, and claystone, tan to greenish gray, friable, fossiliferous

Tm — **Monterey Formation** (Miocene) Marine biogenic shale, lithified, siliceous to semi-siliceous, gray to white, platy to fissile

Ttm — **Temblor Formation** (Lower Miocene) Marine shale to sandstone

Tv — **Volcanic Rocks** (Lower Miocene) Extrusive basalt, olivine basalt, diabase, andesite, and dacite with fine feldspar phenocrysts, black to tan and light gray, massive

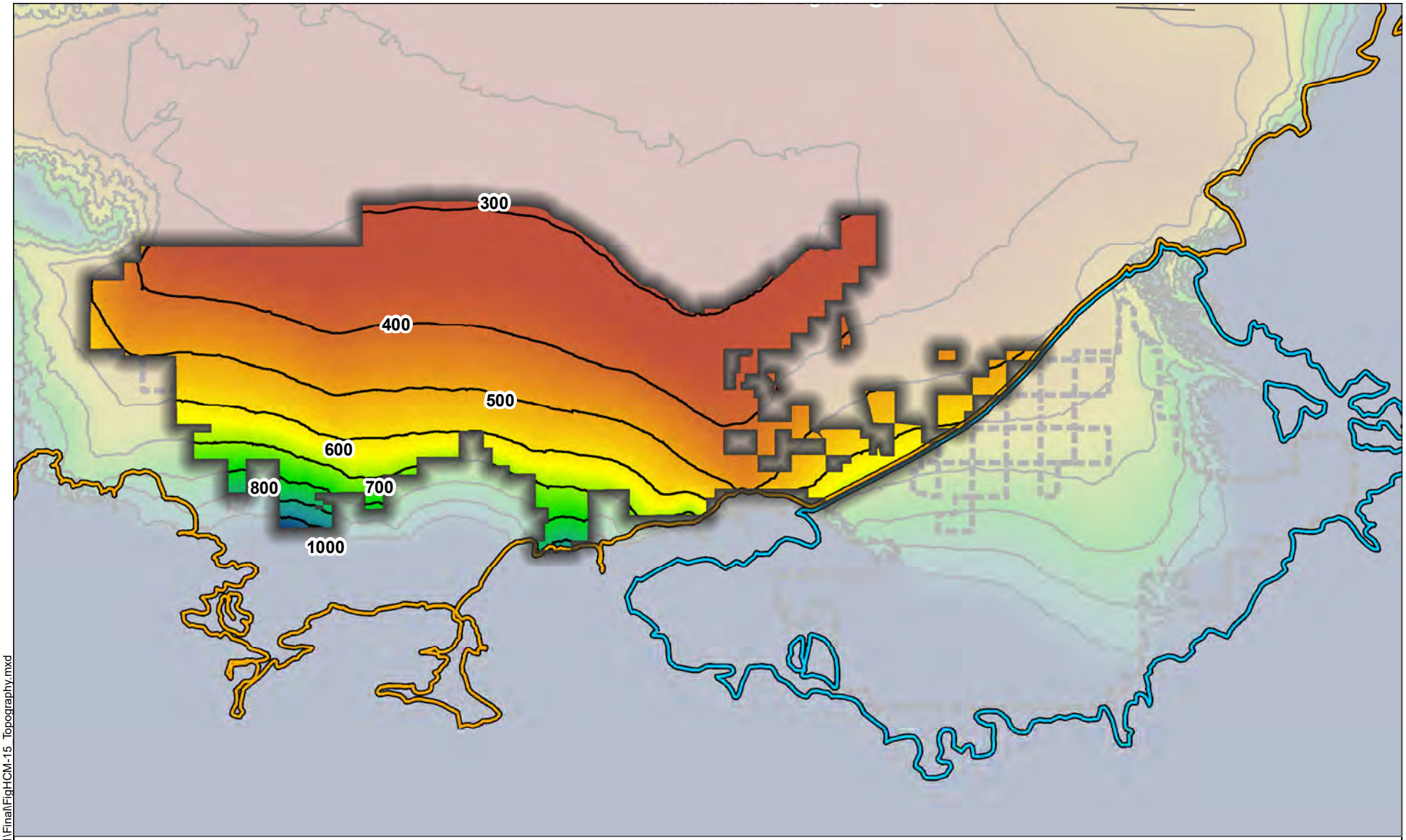
Ttc — **Tecuya Formation** (Lower Miocene - Oligocene) Marine variegated red, green, and gray sandstone, clay and conglomerate of granite, quartzite, and marble detritus

Tp — **Pleito Formation** (Lower Miocene - Oligocene) Marine claystone to sandstone, similar in composition to Ttm

Tse — **San Emigdio Formation** (Upper Eocene?) Marine claystone to siltstone

Ttj / Ttu — **Tejon Formation** (Eocene - Paleocene?) Ttj (Metralla Sandstone and Liveoak Shale Members) Tts (Uvas Member)

TSE — **Undiffentiated Tehachapi - San Emigdio Complex**



Path: X:\B70103\Maps\for GSP\2019\11\Final\FigHCM-15 Topography.mxd

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Elevation Contour (100-ft interval)

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Land Surface Elevation (ft msl)

High : 1100

Low : 330

Abbreviations

DWR	= California Department of Water Resources
ft msl	= feet above mean sea level
NED	= National Elevation Dataset
USGS	= United States Geological Survey
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Surface elevation data obtained from USGS NED (https://viewer.nationalmap.gov/basic/).

N

0 5 10

(Scale in Miles)

Topography

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure HCM-15

eki environment & water

(a) Soil Map Units

(b) Soil Saturated Hydraulic Conductivity

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Texture

- Fine Sandy Loam
- Loam
- Loamy Sand
- Sandy Clay Loam
- Sandy Loam
- Other

Soil Saturated Hydraulic Conductivity (in/hr)

- < 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Abbreviations

DWR	= California Department of Water Resources
in/hr	= inches/hour
NRCS	= Natural Resources Conservation Service
SSURGO	= Soil Survey Geographic Database
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Map units extracted from SSURGO data.
3. Only the soil units of greatest extent are included in their own category. Additonal soil units grouped as "Other".

N

0 4 8

(Scale in Miles)

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Soil data from SSURGO (https://gdg.sc.egov.usda.gov/GDGOrder.aspx#).

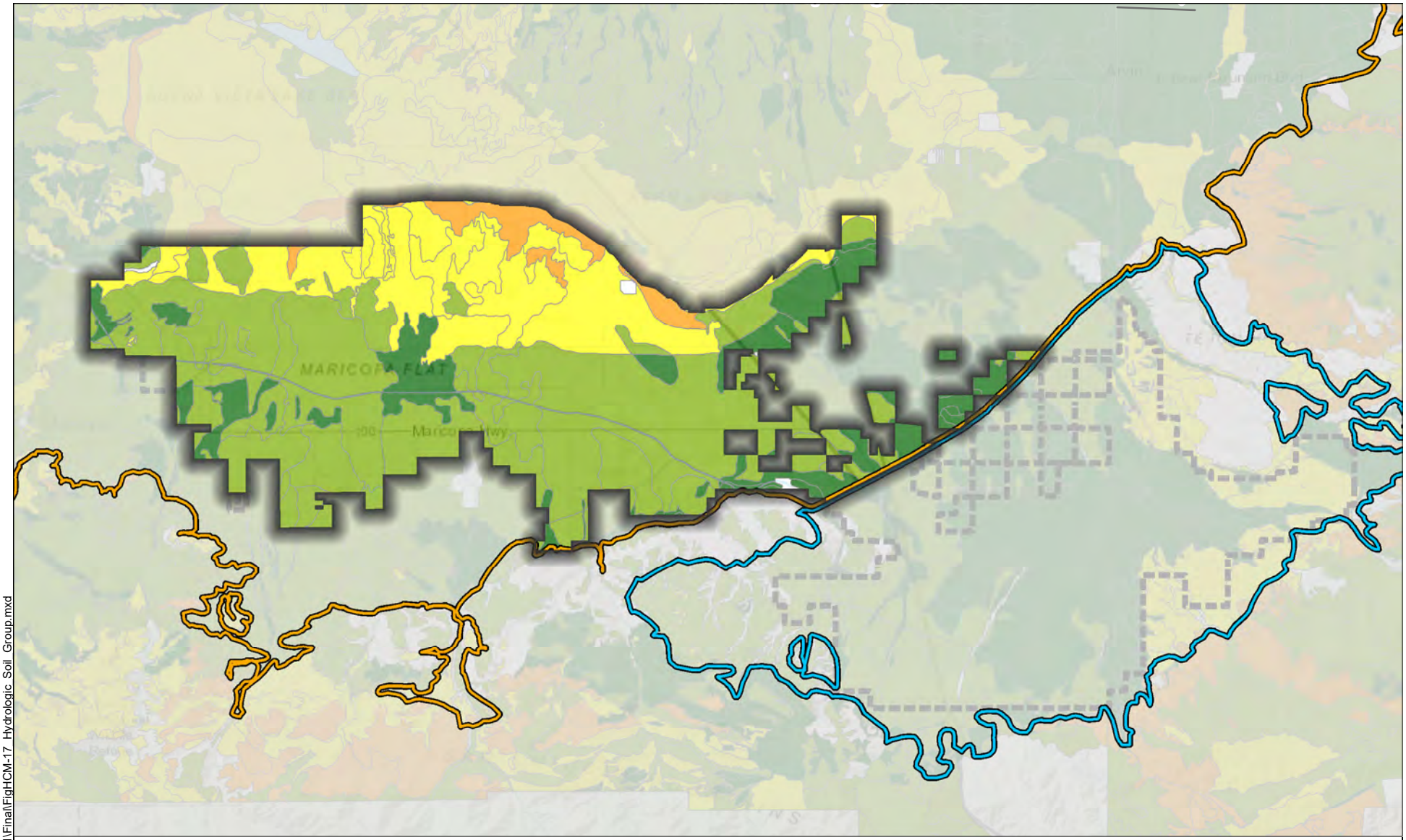
Soil Map Units and Saturated Hydraulic Conductivity

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure HCM-16

eki environment & water

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Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Hydrologic Soil Groups

- A
- B
- C
- D

Abbreviations

DWR	= California Department of Water Resources
SSURGO	= Soil Survey Geographic Database
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Hydrologic soil groups extracted from SSURGO data.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Soil data from SSURGO (https://gdg.sc.egov.usda.gov/GDGOrder.aspx#).

N

0 5 10

(Scale in Miles)

Hydrologic Soil Group

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure HCM-17

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigHCM-17 Hydrologic Soil Group.mxd

BUENA VISTA LAKE BED

KERN LAKE BED

MARICOPA FLAT

WHEELER RIDGE

PLEITO HILLS

Arvin

Maricopa

Bitterwater Creek

Bitter Creek

Cienaga Creek

Santiago Creek

Muddy Creek

Los Lobos Creek

San Emigdio Creek

Pleitito Creek

Pleito Creek

Salt Creek

Tecuya Creek

Grapevine

Pastoria Creek

Tunis Creek

El Paso Creek

Tejon Creek

TEJON HILLS

2824 ft

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Surface Water Feature

- California Aqueduct
- WRMWSD Surface Water Service Area
- Streams into WRMWSD

Well Type

- Active Agricultural
- Active Domestic
- Active Industrial
- Active WRMWSD Production

Abbreviations

DWR	= California Department of Water Resources
NHD	= National Hydrography Dataset
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 2 January 2020.
2. Surface water features and California Aqueduct location from NHD (https://viewer.nationalmap.gov/basic/).
3. Surface Water Service Area and well type and status data acquired from WRMWSD staff on 21 November 2017.

N

0 2.5 5

(Scale in Miles)

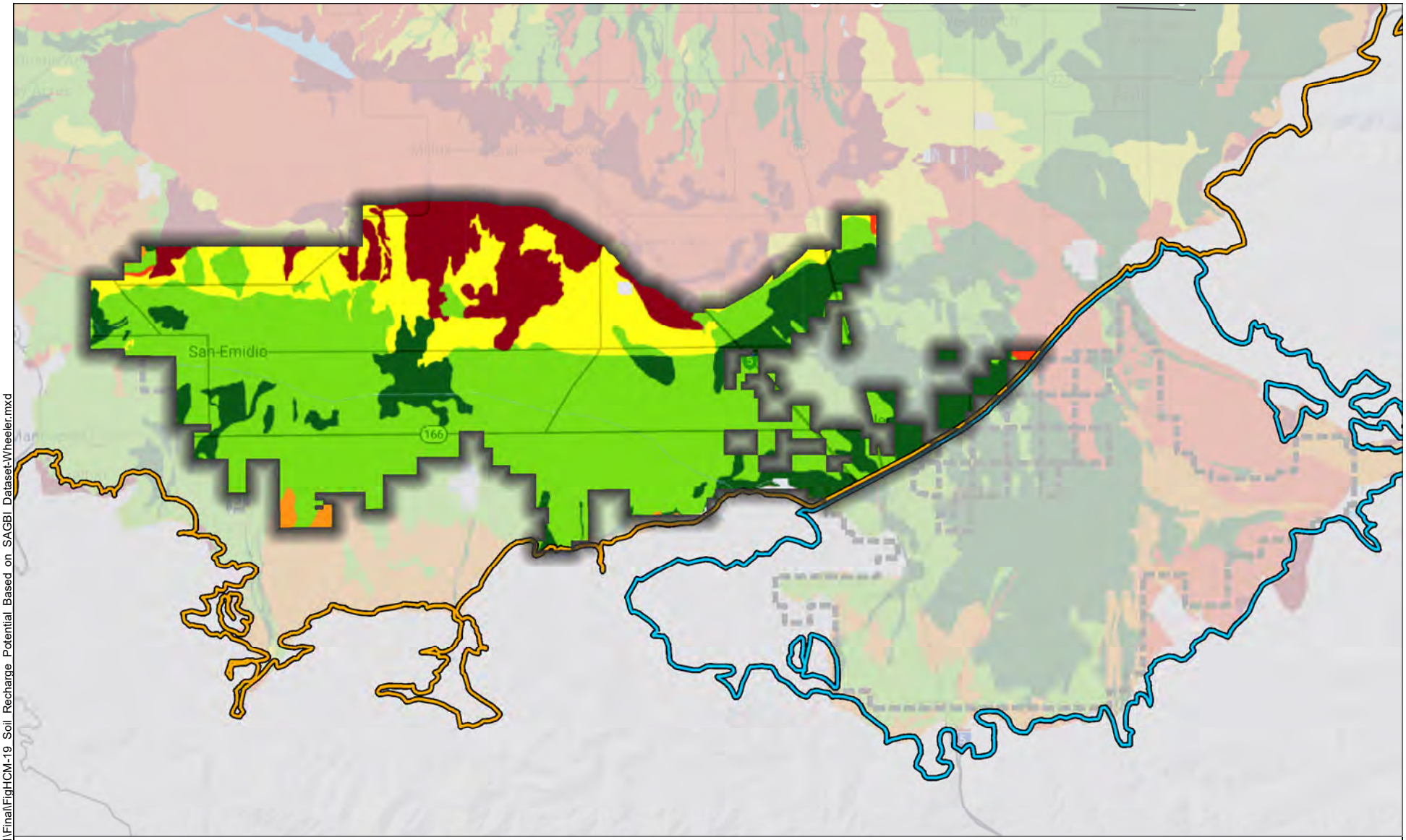
Recharge and Discharge Areas

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure HCM-18

eki environment & water

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Path: X:\B70103\Maps\for GSP\2019\11\Final\FigHCM-19 Soil Recharge Potential Based on SAGBI Dataset-Wheeler.mxd

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

SAGBI Rating

- Excellent
- Good
- Moderately Good
- Moderately Poor
- Poor
- Very Poor

Abbreviations

DWR	= California Department of Water Resources
SAGBI	= Soil Agricultural Groundwater Banking Index
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. The SAGBI dataset is a spatial mapping of a suitability index for groundwater recharge on agricultural land, based on five key factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. SAGBI data from https://casoilresource.lawr.ucdavis.edu/sagbi/.

N

0 5 10

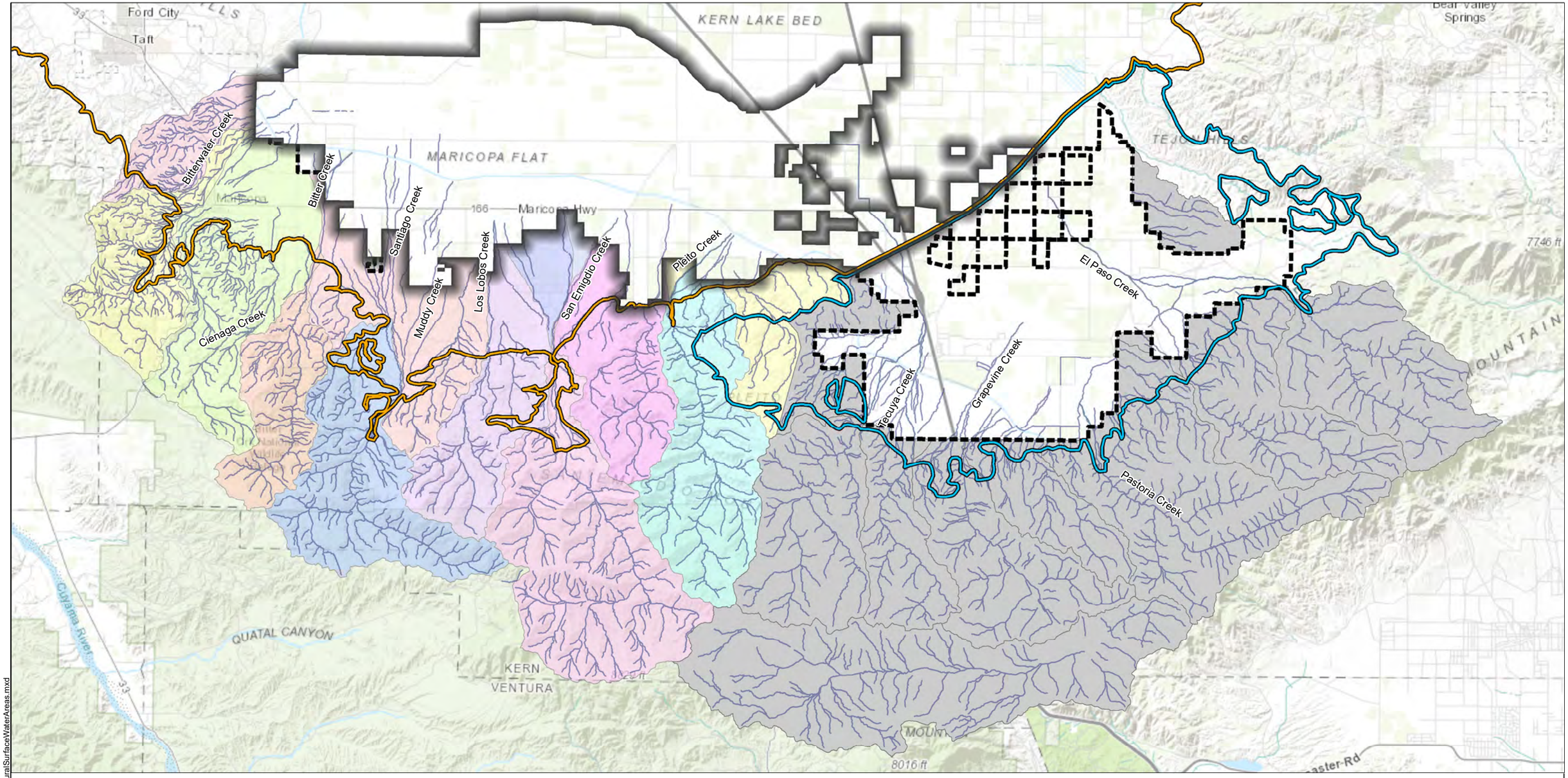
(Scale in Miles)

Soil Recharge Potential Based on SAGBI Dataset

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure HCM-19

eki environment & water



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Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Stream into WRMWSD

Abbreviations

DWR	= California Department of Water Resources
NHD	= National Hydrography Dataset
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Pastel filled areas are watersheds draining into the Wheeler Ridge-Maricopa Management Area, and gray filled areas are watersheds draining into WRMWSD's area in the White Wolf Subbasin.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Surface water features and watersheds from NHD (https://viewer.nationalmap.gov/basic/).

N

0 3.5 7

(Scale in Miles)

Natural Surface Water Features

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure HCM-20

eki environment & water

8. CURRENT AND HISTORICAL GROUNDWATER CONDITIONS

☑ 23 CCR § 354.16

This section presents information on historical and current groundwater conditions within the Wheeler Ridge-Maricopa Management Area based on available data. Sources of data used to inform the current conditions assessment are described within each data topic section and include data from District records, various state and federal databases, and other reports.

For the purposes of this assessment, "current conditions" refers to conditions in calendar year 2015 (i.e., the effective date of SGMA), which is consistent with how "current" is defined by the KGA in the KGA Umbrella GSP. For historical conditions, two periods are relevant. The first is DWR Water Years (WY) 1995 through 2015 (i.e., October 1994 through September 2015) which is the period being used by KGA and its member entities for historical water budget development. As discussed further below, this period is climatically close to normal/average, but includes a significantly dry (drought) period between 2012 and 2015, as well as other years that were drier or wetter than normal. The second historical period discussed herein is the period from 1971 through 2017/2018 which corresponds to the period since WRMWSD began its water importation operations. Consideration of this longer period allows assessment of the long-term effects of District operations and various sustainability indicators (i.e., groundwater levels, storage, and water quality). In some cases, certain other historical periods are also discussed in this section when either (a) the discussion is constrained by the time periods of available datasets (e.g., for land subsidence), or (b) the groundwater conditions characterization is improved by incorporation of data from other time periods.

8.1. Data Sources and Compilation

☑ 23 CCR § 352.6

Per the GSP Emergency Regulations (23 CCR § 352.6), each GSA "shall develop and maintain a data management system that is capable of storing and reporting information relevant to the development or implementation of the Plan and monitoring of the basin". In support of GSP development (i.e., HCM development, analysis of groundwater conditions, water budget development, and Plan Area information) a substantial number of data sources were compiled, organized, and processed, and stored within a District-specific DMS. The data compiled, which are described in greater detail in the sections that follow, included:

- Groundwater level measurements for in-District and nearby wells compiled by the District from its own records and state data sources such as the California Statewide Groundwater Elevation Monitoring (CASGEM) Program, 1924-2017;
- District records of in-District wells and associated Geographic Information System (GIS) shapefiles;
- Well construction information compiled by the District;
- GIS shapefiles of the District service area and surface water conveyance and distribution infrastructure;
- Annual district-wide land use survey and associated GIS shapefile, 2000-2017;
- Groundwater quality data, 1951-2016;

- District data for evapotranspiration (ET) as provided to the Kern Groundwater Authority (KGA) by the Cal-Poly Irrigation Training and Research Center (ITRC) at monthly intervals, 1993-2015 (excluding 2012).
- Surficial geology maps from the California Geological Survey (CGS; formerly known as the California Division of Mines and Geology);
- GIS shapefiles of watershed boundaries and surface water features from National Hydrography Dataset (NHD);
- Locations of known contamination sites from the State Water Resources Control Board (SWRCB) GeoTracker database;
- Aquifer parameter information from California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) for model nodes within the District5;
- Percent coarse information from the Central Valley Hydrologic Model (CVHM) for model elements within the AOI;
- Division of Oil, Gas, and Geothermal Resources (DOGGR) oil field reports for the District area;
- Soils data from the National Resources Conservation Service's (NRCS) Soil Survey Geographic Database (SSURGO);
- California water agency administrative boundary shapefiles from DWR;
- Various regional geologic reports, maps and cross-sections;
- Various land subsidence studies encompassing the District; and
- Base of fresh water studies.

All geospatial data were integrated into the ArcGIS software platform as a "geodatabase", a composite file structure (.gdb) which packages attribute data with associated geospatial information in a user-defined coordinate system.

Much of the data compiled for GSP development and analyses needed at least some pre-processing before the data could be integrated into ArcGIS. These pre-processing tasks included digitization, georeferencing, filtering, and linking georeferenced datasets to associated attribute data from other sources. For example, water level information in some instances did not have any coordinate or elevation information attributed to individual wells. To bring water level information into ArcGIS and create groundwater elevation maps, unique well identifiers based on the Public Land Survey System (PLSS) township information were assigned and then used to link water level records with their associated well coordinates derived from the well survey.

The result of these processing steps is a series of compiled spreadsheets containing, to the extent the information was available: (1) Well IDs, coordinates, and elevation information; (2) well construction information; (3) seasonal water level measurements for the period of collection (1924-2017); and (4) water quality information compiled by the District (1951-2016). These data were subsequently brought into ArcGIS and stored in a geodatabase created for the District along with other geospatial data sources used for HCM development and further assessment of groundwater conditions. Last, selected data types

(i.e., water level and water quality data at wells) were brought into a Microsoft Access database. Together these spreadsheets, geodatabase files, and Microsoft Access database comprise the working DMS for the District. Efforts to develop a coordinated Kern Subbasin DMS are planned as part of Plan Implementation (see **Section 18.3** ***Intrabasin Coordination***).

8.2. Groundwater Elevations and Flow Direction

☑ 23 CCR § 354.16(a)

Groundwater elevation data have been collected and compiled from WRMWSD monitoring records, datasets from other neighboring entities (i.e., Arvin-Edison Water Storage District [AEWSD], Kern Delta Water District [KDWD], and Kern County Water Agency [KCWA]), and the DWR's California Statewide Groundwater Elevation Monitoring (CASGEM) database. The multiple datasets were reconciled and processed for quality assurance/quality control prior to analysis for groundwater conditions. These data cleaning efforts included removal of erroneous data points identified through examination of hydrographs and removal of very shallow depth-to-water data points (less than 20 ft bgs) suspected of being affected by perched conditions along the northern boundary and to the north of the Wheeler Ridge-Maricopa Management Area. The resulting dataset used to inform this discussion of groundwater elevation conditions consists of over 100,000 groundwater elevation data points from over 1,600 wells over the period from 1936 to Spring 2018 throughout the Kern Subbasin.[30] For the purposes of this analysis the periods of Spring and Fall 2015 are used to represent seasonal high and low conditions under current land and water use, which is consistent with how other Management Area Plans under the KGA Umbrella GSP and other GSPs within the Kern Subbasin (i.e., Kern River GSA's GSP) are being prepared.

Lateral Gradients

Lateral gradients are discussed below in the context of groundwater elevation contour maps.

Vertical Gradients

Vertical gradients between the different zones within the principal aquifer (i.e., the unconfined zone above the E Clay versus the confined zone below the E Clay, where it exists) may develop due to variability in proximity to recharge sources and the intensity of pumping. Vertical gradients may also vary in time as the stresses affecting water levels are also temporally variable. Evaluation of vertical gradients can be accomplished by examination of water levels in well pairs where one well is representative of the upper, unconfined zone and the other well is representative of the lower, confined zone. This approach requires water level information from wells that: (a) have known well construction information, (b) are screened in different depth zones, (c) have contemporaneous measurements (i.e., water levels measured at least in the same year and season), and (d) are in close spatial proximity to each other (i.e., to minimize the influence of lateral gradients in water level). At this time, data that meets all of the above criteria are limited. Available data indicate that vertical gradients within the District are generally downwards but vary and between years and seasons. Compiling additional well screen interval information for associated groundwater elevation data would help fill to better define vertical gradients between different zones of the principal aquifer.

[30] Within the Wheeler Ridge-Maricopa Management Area, the dataset consists of roughly 11,000 groundwater elevation data points from 381 wells over the period from 1943 to 2018.

Groundwater Elevation Contour Maps

☑ 23 CCR § 354.16(a)(1)

Groundwater elevation contour maps for "current conditions" – Spring 2015 and Fall 2015 – are presented on **Figure GWC-1** and **Figure GWC-2**, respectively. The following generalities can be made based on groundwater elevation data compiled for wells within the Wheeler Ridge-Maricopa Management Area.

- Groundwater levels are consistently lowest in the southern central portion of the Management Area near the California Aqueduct, in the northernmost portion between the Buena Vista Lake Bed and Kern Lake Bed, and in the far eastern portion just north of the White Wolf Fault.
- Groundwater levels are highest in the western portion of the Management Area and just south of the Kern Lake Bed.
- The barrier effects of White Wolf Fault tend to cause higher groundwater levels on the upgradient (South) side just outside of the Management Area, due to "backing up" of water.
- Assuming groundwater flow is perpendicular to groundwater elevation contours, flow directions are highly variable throughout the Management Area. Generally, groundwater flows into the Management Area across the White Wolf Fault at a relatively low rate due to low transmissivity. Flow across the northern boundary is variable and may result in net inflow or outflow from season to season.
- Average lateral groundwater gradients across the northern boundary of the Management Area under current conditions were extracted from the Spring and Fall 2015 groundwater elevation contour maps (**Figure GWC-1** and **Figure GWC-2**) using GIS analysis. This boundary was divided into three sections – northwest (where data are very limited and gradients therefore uncertain), north-central, and northeast. The estimated lateral gradients across these three northern boundary sections in Spring 2015 were 0.005 feet per foot (ft/ft) 0.0016 ft/ft, and 0.0022 ft/ft, all in a northerly (outflow) direction. In Fall 2015, the gradients for these sections were 0.0049 ft/ft, 0.0033 ft/ft, and 0.0039 ft/ft, respectively, also all in an outflow direction. Average lateral gradients across the White Wolf Fault in Spring and Fall 2015 were approximately 0.01 ft/ft.
- An area of relatively high groundwater levels exists to the northeast of the Management Area, which may potentially be due to the impact of finer-grained "basin" deposits.

The relative highs and lows within the Wheeler Ridge-Maricopa Management Area appear to be controlled, at least in part, by the distribution of groundwater pumping versus surface water deliveries; with the notable exception of the south-central area with low groundwater elevations mentioned in the first bullet above, areas within the District's Surface Water Service Area (SWSA) (see **Figure GWC-3**) tend to exhibit higher groundwater elevations than areas outside of the SWSA that rely exclusively on groundwater.

Depth to Groundwater

As shown on **Figure GWC-4**, depth to groundwater for "current conditions" in Spring 2015 within the Wheeler Ridge-Maricopa Management Area varies from about 23 ft bgs to 559 ft bgs within the principal aquifer. Most of the Management Area had depths to water of between 100 and 350 ft bgs, with shallower depths interspersed in the northern portion and deeper depths concentrated in the south-central portion.

The shallowest depths to water (i.e., less than 50 ft bgs), were measured in wells along the far northern portion of the Management Area near the Kern Lake Bed and Buena Vista Lake Bed and may be indicative of perched groundwater atop the fine-grained "basin" deposits in that area. It appears that these shallow measurements are representative of perched water that is not connected to the principal aquifer system. The fact that depth to water in the principal aquifer system is in most cases more than 100 ft bgs indicates that interconnected surface water and groundwater-dependent ecosystems are unlikely to occur with respect to the principal aquifer in the Management Area. These topics are discussed further below in **Section 8.7 *Interconnected Surface Water Systems*** and **Section 8.8 *Groundwater Dependent Ecosystems***, respectively.

Long-Term Groundwater Elevation Trends

☑ 23 CCR § 354.16(a)(2)

Long-term trends in groundwater levels were evaluated based on examination of hydrographs for 16 wells throughout the Wheeler Ridge-Maricopa Management Area. Wells were selected for hydrograph analysis based on the length of record, their distribution throughout the Management Area, and their representativeness of conditions in their area. Hydrographs were developed for two periods: a long-term period from 1955 through February 2018 which captures the entire operational history of the District through the most recent available data (**Figure GWC-5**), and the more recent period from October 1994 through September 2015 which is consistent with the KGA period of interest (**Figure GWC-6**). As shown on **Figure GWC-5**, a majority of the wells with long-term records in the Management Area have shown increased groundwater levels over the long-term, reflecting the increased storage resulting from the WRMWSD's importation of surface water starting in 1971. Prior to 1971, groundwater levels in many wells were experiencing steep declines. Wells in the far eastern and northwestern portions of the Management Area show more moderate long-term increases or slight declines in groundwater level. The effects of drought cycles (e.g., late 1980s/early 1990s) are apparent in some but not all wells, with greater declines during dry periods and recovery during wet periods. As shown on **Figure GWC-6**, over the more recent period from October 1994 to September 2015, the same general behavior and spatial patterns are apparent, except that the long-term increase in water levels due to surface water importation is tempered by recent declines due to drought, especially in the central portion of the Management Area.

To evaluate long-term water level trends, linear regression of the water level data was used (recognizing that this method can be slightly biased by the data's temporal frequency and distribution). Over the period from 1971 (i.e., the start of surface water imports) through February 2018, trends ranged from -1.38 feet per year to +4.06 feet per year, with 12 out of 16 wells showing positive trends greater than 0.5 feet per year, and only two wells with negative trends. Over the period from Fall 1994 through Fall 2015 (i.e., the KGA period of interest), trends ranged from -2.06 feet per year to +3.86 feet per year, with 9 out of 16 wells showing positive trends greater than 0.5 feet per year, and six wells with negative trends.

Table GWC-1 below shows the DWR Water Year Hydrologic Classification Index for the San Joaquin Valley (i.e., water year type)[31,32]. Based on the DWR San Joaquin Valley Water Year Index for the 21 Water Years from 1995 through 2015, the period included five "critical" (dry) years, four dry years, two below normal

[31] http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST
[32] DWR defines a Water Year as extending from October 1 of the previous year to September 30 of the year in question. For example, Water Year 2005 extends from 1 October 2004 through 30 September 2005.

years, three above normal year, and seven wet years. The first third of this period was relatively wet, the middle third was a mix of wet and dry years, and the last third of the period was extremely dry. This climatic factor is reflected in the hydrographs which tend to exhibit water level increases in the 1990s, relative stability in the early 2000s, and then greater decreases starting in the late 2000s.

Table GWC-1. Summary of DWR Water Year Types, 1995 - 2015

Water Year	WY Index	Water Year	WY Index	Water Year	WY Index
1995	Wet	2002	Dry	2009	Below Normal
1996	Wet	2003	Below Normal	2010	Above Normal
1997	Wet	2004	Dry	2011	Wet
1998	Wet	2005	Wet	2012	Dry
1999	Above Normal	2006	Wet	2013	Critical
2000	Above Normal	2007	Critical	2014	Critical
2001	Dry	2008	Critical	2015	Critical

Groundwater Levels Relative to Well Screens

One factor to consider when setting minimum thresholds for chronic lowering of groundwater levels is the potential for dewatering of wells or well screens[33]. Based on available well construction information, the elevation of the top of well screen (TOS) varies substantially across the Wheeler Ridge-Maricopa Management Area, with differences of several hundred feet between neighboring wells (**Figure GWC-7**). In order to understand how wells may have been historically or currently impacted, groundwater levels were compared to known TOS elevation information.

Under the assumption that historical low water levels occurred in Fall 1971, just prior to the start of surface water imports by WRMWSD (which is generally supported by the long-term hydrographs shown on **Figure GWC-5**), historic groundwater elevation lows from Fall 1971 were compared to TOS data (**Figure GWC-8** (a))[34]. Wells in the western and northern portions of the Wheeler Ridge-Maricopa Management Area tended to be less impacted (i.e., not dewatered) than wells in the central portion of the Management Area.

To assess potential vulnerability due to drought under the current water supply regime (i.e., since surface water imports have been in effect), groundwater levels from Fall 2016[35] were compared to the TOS data

[33] DWR, 2017, Draft Best Management Practices for the Sustainable Management of Groundwater: Sustainable Management Criteria

[34] Groundwater elevation data used are interpolated values in order to include all wells for which the District has well screen data in the analysis, as opposed to only those with both well screen and Fall 1971 groundwater elevation records.

[35] Data from Fall 2016, near the end of the recent historic drought, were used to understand the extent of drought impacts.

(**Figure GWC-8**(b)). As this analysis was focused on assessing recent and future potential impact, only wells known to be active are shown.

Of the four active domestic wells for which the District has well screen data, one showed groundwater elevations more than 100 ft below the TOS elevation, two showed groundwater elevations between 50 and 100 feet below the TOS, and one showed groundwater elevations between 100 and 200 feet above the TOS. Of the 30 active agricultural production wells (including 28 private wells and two District-owned wells) for which the District has well screen data, groundwater levels were below the TOS for 10 wells and were within 50 ft of the TOS for four other wells.

Lack of complete well screen data[36] currently prevents a comprehensive analysis of impacts of lowering groundwater levels on wells in the Wheeler Ridge-Maricopa Management Area. To better understand the potential impacts of groundwater level changes on active wells in the Management Area, it would be necessary to acquire and compile data on well screen interval information for additional domestic, agricultural, and industrial wells. Additionally, it would be necessary to update data on well status (i.e., whether or not the well is active) to determine potential impacts to existing wells, as District data show that the status of some wells was most recently assessed in January 1991.

8.3. Change in Groundwater Storage

☑ **23 CCR § 354.16(b)**

Change in groundwater storage was estimated based on data for selected periods of interest. The method used to estimate storage change for these periods used water level data collected at the start and end of each period, spatially-variable specific yield information, and the following relationship, applied in a distributed manner:

$$\textit{Change in Storage} = [\textit{Ending Water Level} - \textit{Starting Water Level}] * \textit{Specific Yield} * \textit{Area}$$

Specifically, this approach was implemented by: (1) interpolating groundwater elevations for both years onto a 100-ft grid of pixels using the geostatistical spatial interpolation method known as kriging, (2) similarly interpolating the specific yield values from C2VSim-FG node data[37], (3) calculating the water level difference at each pixel, (4) multiplying the water level difference from (3) by the specific yield at each pixel, (5) multiplying the result from (4) by the area of each pixel (i.e., 100 ft x 100 ft = 10,000 ft^2), and (5) summing all calculated values over the area of the Wheeler Ridge-Maricopa Management Area. To avoid errors caused by comparison of interpolated data that is based on different well points, a paired-well approach was used, wherein wells were selected for inclusion only if they were present in both datasets or if they were in close proximity (less than 1 mile) to a well in the other dataset.

[36] District records indicate that there are thirteen active domestic wells in the Wheeler Ridge-Maricopa Management Area; the District has well screen data compiled for four of these wells. There are 74 active agricultural production wells within the Management Area, not including the District's own production wells, and the District has well screen data for 28 of these and is lacking well screen data for 46. There are three active District production wells in the Management Area (the District has thirteen additional active production wells in its area within the White Wolf Basin), and the District has well screen information for two of these wells. The District also lacks well screen information for the one active industrial well in the Management Area.

[37] As discussed previously, specific yield values in the C2VSim-FG model used in this calculation may change upon completion of the model calibration.

Table GWC-2, below, presents the results of this storage change estimation for selected time periods of interest. As shown in **Table GWC-2**, the total change in storage from 1971 through 2016 (i.e., since the start of District water imports through the latest available data) was 77,180 AF or approximately 1,715 AFY. The total change in storage from Fall 1994 through Fall 2015 (i.e., the recent KGA period of interest) was 27,180 AF or approximately 1,294 AFY. To put this annual change in storage value into context, it represents approximately 2.3% of the average annual rate of groundwater pumping within the Wheeler Ridge-Maricopa Management Area over that same period (approximately 57,000 AFY; discussed further below in **Section 9.3.2** ***Historical Water Budget***). This indicates that groundwater storage over the Management Area has shown long-term stability over the WY 1994 – 2015 period.[38]

Table GWC-2. Change in Storage for Selected Time Periods

Period	Relevance of Time Period	Total Change in Storage (AF)	Annual Rate of Change in Storage (AFY)
Spring 1971 – Spring 2016	Entire period of District Operations	77,180	1,715
Fall 1971 – Fall 1990	Entire Bookman-Edmonston Water Budget Period	358,993	18,894
Fall 1994 – Fall 2015	KGA water budget period of interest	27,180	1,294
Spring 2003 – Spring 2015	Longer normal/dry period	-80,939	-6,745
Spring 2003 – Spring 2012	Longer normal/wet period	81,839	9,093
Fall 2014 – Fall 2015	Short dry period	-76,197	-76,197

Figure GWC-9 shows the distribution of groundwater elevation change throughout the Wheeler Ridge-Maricopa Management Area for the periods from Spring 1971 through Spring 2016, Fall 1994 through Fall 2015, and Fall 2014 through Fall 2015 (groundwater elevation change is directly related to storage change). As shown on **Figure GWC-9**, from Spring 1971 through Spring 2016 groundwater levels increased throughout most of the Management Area, with the exception of the south- central portion and a small area along the west/central portion of the northern border. The area in the south-central portion

[38] Results from the basin-wide numerical modeling indicated a negative average annual storage change of approximately 7,900 AFY between Fall 1994 and Fall 2014.However, that estimate is considered less accurate than the locally-derived storage change estimates presented here because the basin-wide model has not undergone calibration of subsurface parameters on a local scale against actual local water level data.

appears to have been influenced by several low water level measurements that may be indicate short-term pumping-related levels rather than static levels, but because they were observed in several wells they were not considered outliers. Over the recent period from Fall 1994 through Fall 2015, changes in groundwater elevation were variable, with slight increases in the west, north-central, and east portions of the Management Area, and slight decreases along the southern central and northeastern areas. Over the period from Fall 2014 to Fall 2015, groundwater elevation changes were slightly positive in most areas, but negative in the south-central area.

Determination of the change in storage on a yearly basis using the method described above is more difficult due to a lack of consistent water level monitoring data. To address this issue, annual change in storage estimates were extracted from the output of the water budget model, described further in **Section 9 *Water Budget Information*** below. A graph of estimated annual change in storage between seasonal water level highs (i.e., from March of each year to March of the following year), is presented on **Figure GWC-10**. Also shown on **Figure GWC-10** is the Water Year type based on DWR's San Joaquin Valley Water Year Index[39]. As shown on **Figure GWC-10**, annual change in storage within the Wheeler Ridge-Maricopa Management Area ranged from an increase of 83,000 AF for the period from March 1998 – February 1999 to a decrease of 46,000 AF for the period between March 2013 and February 2014. Change in storage tends to be more negative during dry Water Years and more positive during wet Water Years. Change in groundwater storage is discussed further below in **Section 9.3.2 *Historical Water Budget***.

8.4. Seawater Intrusion

☑ **23 CCR § 354.16(c)**

Because the Wheeler Ridge-Maricopa Management Area is located far from coastal areas, seawater intrusion is not considered to be an issue.

8.5. Groundwater Quality

☑ **23 CCR § 354.16(d)**

8.5.1. Groundwater Quality Constituents of Concern

Groundwater quality constituents that may affect the supply and beneficial uses of groundwater in the Wheeler Ridge-Maricopa Management Area were identified by comparing the highest measured concentrations detected at an individual well for each constituent between 2012 and 2016 to applicable screening levels for the various beneficial uses (i.e., Maximum Contaminant Levels [MCLs] for domestic/Municipal & Industrial (M&I) use and various thresholds for irrigated agricultural use). Constituents for which at least 15% of samples exceeded the applicable screening level include TDS, nitrate, arsenic, boron, iron, manganese, and sulfate, as discussed below. Of the seven constituents

[39] The seasonal high groundwater condition occurs typically in late winter or spring and for the purposes of **Figure GWC-10** is assumed to occur in March. March groundwater levels are affected by both the amount of pumping during the prior summer (i.e., previous DWR Water Year) as well as the amount of precipitation during the winter months of the current DWR Water Year. In **Figure GWC-10**, the color of each bar is based on the Water Year type for the year the begins in the October between the March and February represented by the bar.

mentioned above, only nitrate and arsenic are regulated with a primary (i.e., health risk-based) MCL[40], while TDS, iron, manganese, and sulfate have secondary (i.e., aesthetically-based) MCLs[41]. Boron does not have a primary nor secondary MCL, but levels exceeding 0.50 mg/L can be harmful to sensitive crops (including oranges and grapes) and thus may cause a slight to moderate restriction of use to prevalent crops in the Management Area (United Nations Food and Agriculture Organization, 1985).

- Nitrate was detected above the primary MCL of 10 mg/L (as N) or 45 mg/L (as NO_3) in zero of 37 wells sampled between 2012 and 2016. Higher concentrations were measured in locations along the southeastern edge of the Management Area, near the White Wolf Fault, and several wells just southeast of the Management Area across the White Wolf Fault show nitrate exceedances (**Figure GWC-11**).
- Arsenic was detected above the primary MCL of 10 micrograms per liter (ug/L) in six (38%) of 16 wells sampled between 2012 and 2016, with most MCL exceedances in the northern and central portions of the Management Area (**Figure GWC-11**). Arsenic concentration varies over short distances, with relatively high values in close proximity to "non-detect" values. Arsenic is naturally-occurring in this area, derived from the granitic source rocks whose eroded sediments are present within the alluvial Tulare Formation (Thiros, 2010).
- Boron was detected at levels that may restrict a water's use for irrigation for common crops (i.e., above 0.5 mg/L; Ayers and Westcot, 1985) in 13 (87%) of 15 wells sampled between 2012 and 2016. Boron is commonly detected throughout the central portion of the Management Area (**Figure GWC-12**). Boron was also cited as the cause of a base of fresh water determination for nearby oil field pools (Jeppi, Main Area of the Edison oil field) (DOGGR, 1988).
- Sulfate is detected above the recommended secondary MCL of 250 mg/L throughout the Management Area; 34 (92%) of 37 wells sampled between 2012 and 2016 show sulfate concentrations above 250 mg/L. In many cases (41%, or 15 of 37 wells), the sulfate concentration exceeds the upper secondary MCL of 500 mg/L.
- TDS was detected above the recommended secondary MCL of 500 mg/L in 35 (95%) of 37 wells sampled between 2012 and 2016 and was present throughout the Management Area (**Figure GWC-13**). TDS exceeded the upper secondary MCL of 1,000 mg/L in 10 (27%) of 37 wells sampled between 2012 and 2016, primarily in the northern central portion of the Management Area. As shown on **Figure GWC-13**, recent water quality sampling has not occurred in the western portion of the Management Area, as groundwater use and monitoring have mostly ceased in this area due to a combination of poor water quality and relatively low yield. Historical water quality sampling from the 1960s shows high concentrations of TDS in the western portion of the Management Area, with TDS detected in most wells above the upper secondary MCL.

[40] Primary MCLs are drinking water standards set by the USEPA and California Environmental Protection and Agency (CalEPA) based on human health considerations.

[41] Secondary MCLs are non-health related standards set by the State Water Resources Control Board based on aesthetic characteristics of drinking water such as taste, odor, and color. For four common constituents – TDS, specific conductance, chloride and sulfate – the SWRCB sets three levels of secondary MCLs for consumer acceptance, referred to as (lowest to highest concentration): "recommended", "upper", and "short term".

- Both iron and manganese exceeded their respective secondary MCLs (300 ug/L and 50 ug/L, respectively) in some locations. Iron exceeded its secondary MCL in eight (33%) of 24 wells sampled between 2012 and 2016, and manganese exceeded its secondary MCL in six (25%) of 24 wells sampled between 2012 and 2016. Though these naturally-occurring constituents can impair the aesthetic quality of drinking water and at high enough concentrations can result in staining of fixtures or clothes washed therein, they are not likely to significantly affect beneficial uses of groundwater in the Management Area.
- The District has indicated that chloride and Uranium may be of concern; groundwater sample data collected between 2012 to 2016 showed no exceedances of MCLs (primary for Uranium and secondary for chloride) for either constituent. Because chloride can negatively affect crop health, recent (2012-2016) groundwater quality sample data were screened against a lower concentration threshold associated with sensitive rootstocks and cultivars for major tree and berry crops (Ayers and Westcot, 1985). Only one of 43 samples exceeded the lowest (most conservative) threshold concentration of 117 mg/L (3.3 milliequivalents per liter of chloride).

Recent District sampling has included primarily inorganic constituents such as major ions and metals, as well as volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). VOCs and SVOCs constituents are typically not a concern for agricultural beneficial uses, but some are harmful to humans if consumed at high enough concentrations (often at parts per million or parts per billion concentrations) and are thus regulated by the U.S. Environmental Protection Agency (EPA) and California EPA (specifically the State Water Resources Control Board [SWRCB]) in drinking water sources. Some of these compounds are, or have been historically, used in agriculture as pesticides, herbicides, fungicides, and can be transported to groundwater by deep percolation of excess applied water, although this is more of a concern for the older "legacy" chemicals and less so for the current generation of chemicals that are designed to avoid deep percolation. One compound in particular, 1,2,3-trichloropropane (1,2,3-TCP), which is an industrial solvent that was also historically a component in a soil fumigant, was recognized in 2006 as a "constituent of special interest" in Kern County (Shelton et al., 2006), and was recently assigned a (primary) MCL of 0.005 ug/L (five parts per trillion) by the California EPA[42], effective 14 December 2017. Limited data from the District's water quality sampling (43 samples since 2000) indicate that 1,2,3-TCP has not been detected in the Wheeler Ridge-Maricopa Management Area. Additionally, limited data from the USGS Groundwater Ambient Monitoring and Assessment (GAMA) program (Shelton et al., 2006) showed that 1,2,3-TCP was not detected in wells within the Management Area but was detected in 2006 in one location in the adjacent Arvin-Edison Management Area at a concentration of 0.40 ug/L, 80 times the MCL.

More generally, additional efforts to compile and characterize water quality data from additional data sources will continue as part of Plan Implementation. **Appendix E** includes a list and description of potential water quality datasets that may be analyzed to further assess groundwater quality conditions in the Arvin-Edison Management Area, including, for example, the CalEPA's Regulated Site Portal, Cortese List, GeoTracker, Drinking Water Watch, GAMA-PBP, California Pesticide Information Portal, USEPA's National Priorities List, and DOGGR's CalStim'D and WellFinder datatsets.

[42] https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/123-tcp/2017_1115_01S_app.pdf

8.5.2. Temporal Characteristics of Groundwater Quality

Historical water quality sampling data are limited both in spatial extent and temporal frequency within the Wheeler Ridge-Maricopa Management Area, thus making analysis of water quality trends and their potential nexus to groundwater elevations difficult. The most regularly monitored constituents of concern within the District include TDS, Arsenic, and Nitrate. For these constituents, time-series water quality data were plotted relative to groundwater level measurements for all wells with at least five historical water quality and groundwater level records (see **Appendix F**). For each constituent, there was no discernable relationship between groundwater levels and groundwater quality trends that could be consistently identified. Thus, additional data collection and analysis will be needed to further evaluate this potential relationship.

8.5.3. Point-Source Contamination Sites

In addition to the relatively widespread non-point source groundwater quality constituents of concern, there are a small number of point-source contamination sites that historically or currently affect shallow (possibly perched) groundwater within the Wheeler Ridge-Maricopa Management Area. These sites, shown on **Figure GWC-14**, are typically associated with certain industrial or commercial land uses (e.g., gas stations).

As shown on **Figure GWC-14**, there are a total of two closed Cleanup Program sites and one closed Leaking Underground Storage Tank (LUST) Cleanup site. The LUST Cleanup site was managed by Kern County and the two of the Cleanup Program sites were managed under the oversight of the CVRWQCB. There are no active cleanup sites within the Wheeler Ridge-Maricopa Management Area. The LUST Cleanup site has gasoline listed as a potential contaminant of concern and one of the Cleanup Program sites has crude oil listed as a contaminant of concern. **Table GWC-3** below summarizes these three closed sites within the Management Area.

As shown on **Figure GWC-14**, there are five inactive sites that need evaluation listed in the Department of Toxic Substances Control EnviroStor database within the Wheeler Ridge-Maricopa Management Area. Four of these are military sites, and one is a firing range that has been identified for State Response.

In addition to the closed and inactive sites discussed above, there are several open and closed Cleanup Program Sites, several closed LUST Cleanup sites, a few active Corrective Action and State Response Sites, and Certified Voluntary Cleanup Sites just outside of the Wheeler Ridge-Maricopa Management Area. Given the lack of open sites and the fact that groundwater is generally hundreds of feet below the surface and separated from near-surface contamination by numerous thin low permeability layers, the threat to groundwater from the closed sites is likely minor.

Table GWC-3. Summary of Active Point-Source Contamination Sites

Site ID (see **Figure GWC-14**)	Site Name	Site Type	Regulatory Oversight Agency	Potential Contaminants of Concern	Status
1	Tenneco - Rancho Loma Farm	Cleanup Program Site	CVRWQCB	None Listed	Completed - Case Closed
2	Robert Andrews Farms	LUST Cleanup Site	Kern County	Gasoline	Completed - Case Closed
3	Four Corners Pipeline Company	Cleanup Program Site	CVRWQCB	Crude Oil	Completed - Case Closed

8.5.4. Oil Field Injection Wells and Produced Water Ponds

As described in **Section 7.1.3 *Bottom of the Basin***, there are five oil fields that overlap the Wheeler Ridge-Maricopa Management Area – the San Emidio Nose, Yowlumne, Rio Viejo, Los Lobos, and Midway-Sunset oil fields. **Figure GWC-15** shows the locations of active underground injection wells (based on DOGGR data) and produced water ponds (based on data from the SWRCB's GeoTracker website) used for oil field operations in these areas. Within the Management Area there are 12 active injection wells, all but one of which are in the Yowlumne oil field (the other being in the Rio Viejo oil field). There are also a large number of injection wells in the Midway-Sunset oil field to the west of the Management Area. There are no produced water ponds within the Management Area, but there are many in the Midway-Sunset oil field.

Underground injection wells used to dispose of wastewater from oil and gas development are regulated in California by the USEPA, DOGGR, and SWRCB (see California Health and Safety Code § 25159.10 et seq). Produced water discharges to ponds are under the purview of SWRCB and CVRWQCB regulatory oversight and are subject to regulation under individual and general Waste Discharge Requirements (WDRs) amongst other requirements to ensure adequate protection against impacts to underlying groundwater resources. Pursuant to SB 4 (2013), the SWRCB established a Regional Groundwater Monitoring Program[43] to assess the potential effects on groundwater resources of well stimulation activities in oil and gas producing areas. The Regional Monitoring Program has been implemented through cooperative efforts between the SWRCB and the USGS, including collection of groundwater quality samples in selected wells in proximity to oil fields within the Kern Subbasin (Dillon et al., 2017).

[43] https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/regional_monitoring/

8.6. Land Subsidence

☑ 23 CCR § 354.16(e)

The Kern Subbasin has a documented history of land subsidence, including historical and recent subsidence in the southern portion of the Kern Subbasin, south of the Kern River, which includes the Wheeler Ridge-Maricopa Management Area (Lofgren, 1975; DWR, 2014). Subsidence in this area has been caused primarily by withdrawal of groundwater, with some areas also affected by hydrocompaction (Lofgren, 1975). Subsidence due to oil and gas production has also occurred in some areas but is minor in importance. **Figure GWC-16** depicts maps of areas of hydrocompaction and historical (1949-2005) and recent (2015-2016) subsidence, which are discussed below. The KGA Umbrella GSP provides additional information on subsidence throughout the Kern Subbasin and over time, and with particular reference to critical delivery system infrastructure such as the California Aqueduct and the Friant-Kern Canal.

Historical Subsidence

During the mid-20th century, when groundwater levels were declining rapidly before the importation of surface water supplies by WRMWSD and others began, subsidence was widespread throughout the area, with the greatest amounts – over nine feet between 1926 and 1970 – occurring just south of Kern Lake Bed northwest of Mettler (Lofgren, 1975). Subsidence amounts tended to decrease in all directions from this central "hot spot". This area of historical subsidence generally coincides with the presence of the regional E Clay aquitard and other shallower regional aquitards, which is also presumably an area that includes a greater proportion of other unnamed fine-grained compactible materials.

Between 1957 and 1965, the estimated rate of subsidence as a function of groundwater level decline varied widely from approximately 0.01 to 0.4 feet of subsidence per foot of head decline in the Wheeler Ridge-Maricopa Management Area (Lofgren, 1975).

Extending the historical record further into recent times, DWR has mapped subsidence in this portion of the Kern Subbasin between 1949 and 2005. The southern and northwestern areas of the Wheeler Ridge-Maricopa Management Area are shown in this dataset as having subsidence over that period of between zero and five feet and the northern central areas having subsidence between five and 15 feet (see **Figure GWC-16**). DWR has noted that between 7.5 and 9 feet of land subsidence was observed within the Management Area between 1965 and 1968 as a result of hydrocompaction upon the development of pre-construction ponds along the proposed alignment of the California Aqueduct Mileposts 255.7 – 274.3 (DWR, 2017).

Recent Subsidence

Subsidence due to water level decline has continued in recent times of groundwater level decline associated with dry climatic conditions; between May 2015 and September 2016 most areas within the Wheeler Ridge-Maricopa Management Area experienced between one and eight inches of subsidence, with some small areas between eight and twelve inches (see **Figure GWC-16**; based on Farr et al., 2016).[44] The continued recent subsidence, occurring at a time when groundwater levels are not necessarily below

[44] It should be noted that subsidence estimates based on interferometric synthetic aperture radar (InSAR) methods can be subject to errors when the period of time between measurements is short and when the land is subject to surface disturbance, as is typical in agricultural areas (personal communication, Michelle Sneed, USGS, 27 June 2018).

their historic minima, demonstrates that subsidence can continue to occur even after water levels are partially recovered. This continued subsidence could be elastic or could be inelastic subsidence resulting from the temporally-lagged, continued slow depressurization of compactible fine-grained materials (Lofgren, 1975).

As discussed further in **Section 13 *Undesirable Results*** the localized areas of increased subsidence in the near-vicinity of the alignment of the California Aqueduct within the Wheeler Ridge-Maricopa Management Area highlights the potential impacts of subsidence on critical infrastructure. Approximately 22 miles of the California Aqueduct runs through the Management Area, from approximately Milepost 256.14 (Check No. 31) to Milepost 278.13 (Teerink Pumping Plant). This portion of the California Aqueduct includes pools 32-35. DWR has documented subsidence by milepost of the California Aqueduct with a baseline of 1967 or 1969 ground surface elevation and estimated hydraulic impacts of differential settling (DWR, 2017). Within this section of the Aqueduct, measured values for survey benchmark locations within the Management Area show up to approximately 1.7 feet of settlement from the 1967/1969 baseline through 2013 (DWR, 2017), and up to approximately 9 inches of additional settlement between 2013 and 2017 (Walker, 2017). Subsidence measurements based on InSAR data between April 2014 and June 2016 indicate a localized area of subsidence in the south-central portion of the Management Area in close proximity to the California Aqueduct (**Figure GWC-17**).

8.7. Interconnected Surface Water Systems

☑ 23 CCR § 354.16(f)

As discussed above, groundwater levels in the principal aquifer are far below the ground surface within the Wheeler Ridge-Maricopa Management Area. Depths to groundwater are generally 100 or more feet below ground surface, and even deeper (greater than 350 ft bgs) in the southern areas where surface water streams enter the Management Area from the south. (see **Figure GWC-4**). The few water level data that show shallower groundwater in the northern portion of the Management Area are from wells that are not screened in the principal aquifer, but rather shallow monitoring wells monitoring perched conditions. Therefore, with respect to the principal aquifer, it is assumed there is no interconnected surface water. As such, depletion of interconnected surface water is not considered to be an issue in this area.

8.8. Groundwater Dependent Ecosystems

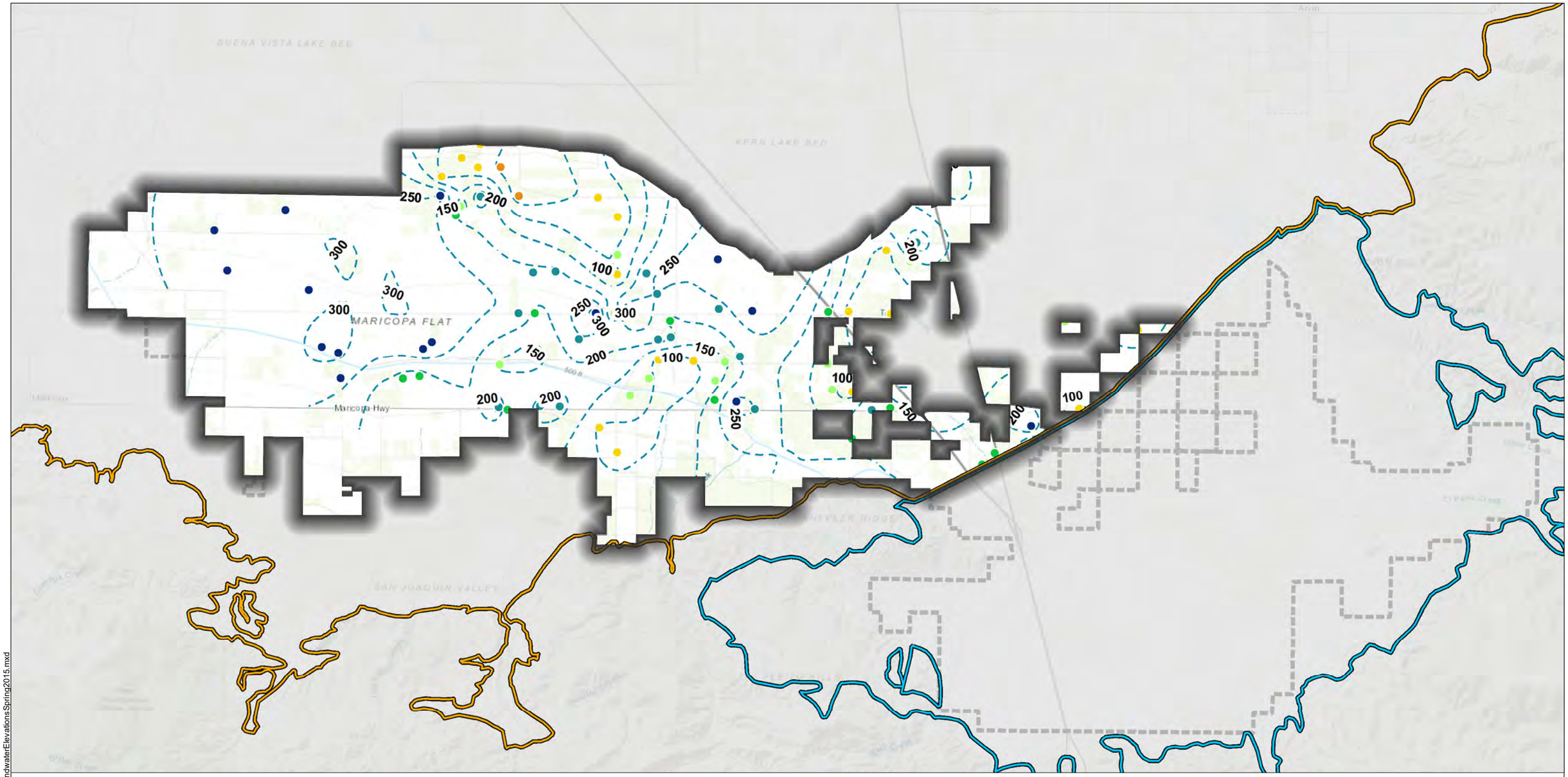
☑ 23 CCR § 354.16(g)

Groundwater dependent ecosystems (GDEs) are those natural communities that depend on near-surface groundwater as a source of water. Guidance for identification of GDEs developed by The Nature Conservancy (TNC) states that groundwater depths less than 30 feet below ground surface are "generally accepted as being a proxy" for confirming that potential GDEs are actually supported by groundwater (TNC, 2019)[45]. As discussed above, depths to groundwater in the principal aquifer are several hundred

[45] https://groundwaterresourcehub.org/public/uploads/pdfs/TNC_NCdataset_BestPracticesGuide_2019.pdf

feet below ground surface, and it is therefore highly unlikely that any ecosystems depend on groundwater from this aquifer system.

DWR has developed a map of "Natural Communities Commonly Associated with Groundwater" (NCCAG) for use by GSAs in identifying potential GDEs. **Figure GWC-18** shows the distribution of NCCAG within the Wheeler Ridge-Maricopa Management Area. As shown on **Figure GWC-18**, the primary area where NCCAG were identified is along the northern boundary of the Management Area near the Kern Lake Bed. These wetlands and vegetation may be connected to perched groundwater atop the fine-grained "basin" deposits in that area, where depth to groundwater is generally encountered at less than 20 ft bgs. This perched zone is not used for groundwater production within the Management Area. Water level data collected from monitoring wells screening the principal aquifer in the area indicate depth to water of approximately 120-200 ft bgs in the area as of Spring 2015, suggesting that the perched zone is fully disconnected from the underlying principal aquifer. Due to the great depth to the principal aquifer, these vegetation communities (i.e., mostly areas of iodine bush, quailbush, and tamarisk) are likely not dependent on groundwater from the principal aquifer system. Other potential GDE features identified by the NCCAG within the north-central portions of the Wheeler Ridge-Maricopa Management Area are vegetation communities that generally line artificial reservoirs, ditches, or other small open water bodies within the District. Based on groundwater level data collected from surrounding monitoring wells, depth to water is generally encountered at 140-300 ft bgs in these areas, indicating that these vegetation communities are not connected to the principal aquifer system and are therefore not considered to be GDEs. This judgement is consistent with the guidance developed by The Nature Conservancy (TNC, 2019).



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Spring 2015 Groundwater Elevation (50 ft interval)

Spring 2015 Groundwater Elevation (ft msl)

- <0
- 0 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- >250

Abbreviations

DWR	= California Department of Water Resources
ft	= feet
ft msl	= feet above mean sea level
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Groundwater elevation contours were created using an interpolation process called kriging and are less certain in areas with sparse data.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Water level data provided by Arvin-Edison Water Storage District, Kern Delta Water District, and WRMWSD.

N

0 2.5 5

(Scale in Miles)

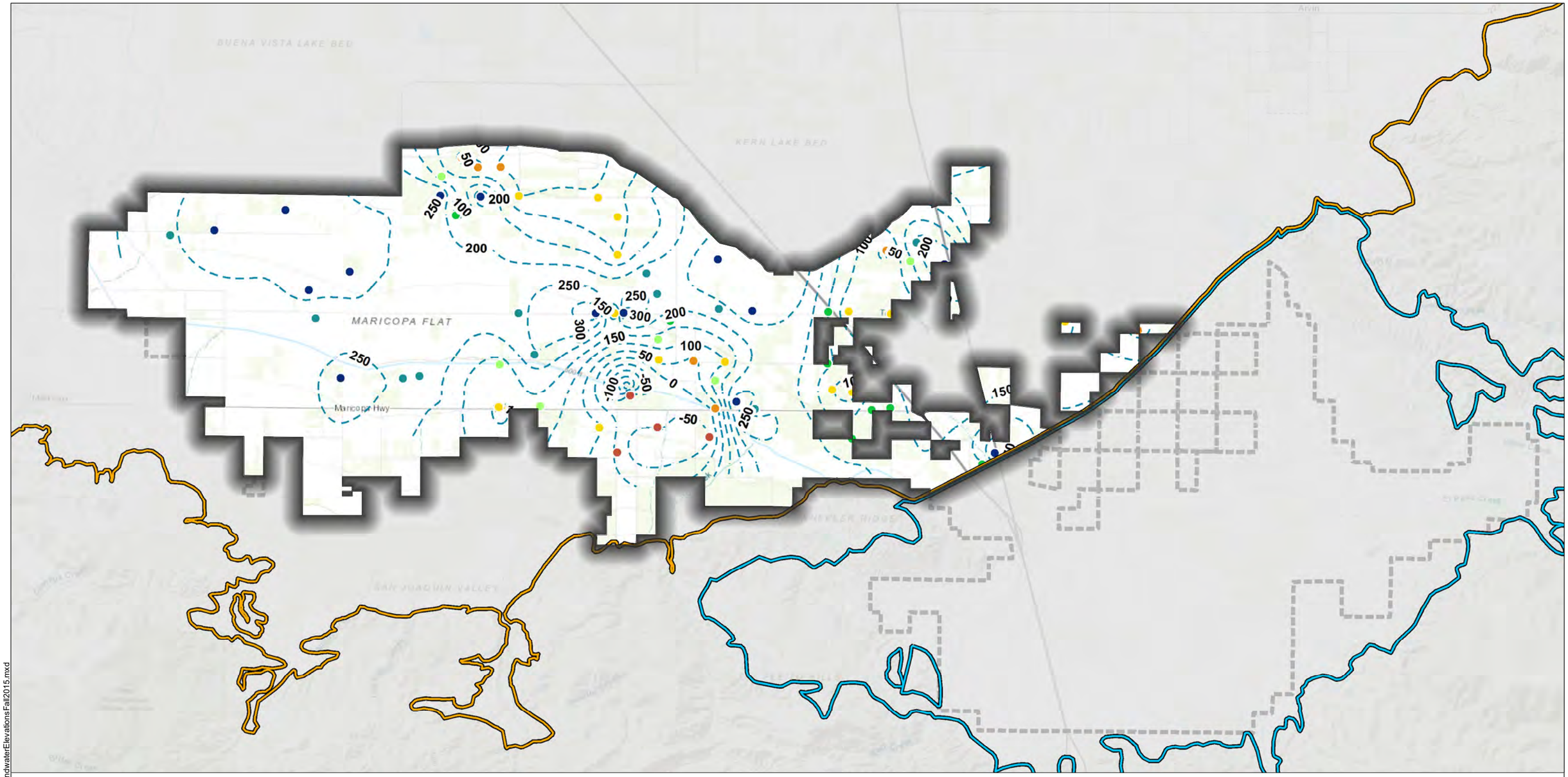
Groundwater Elevations Spring 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-1

eki environment & water

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Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Fall 2015 Groundwater Elevation (50 ft interval)

Fall 2015 Groundwater Elevation (ft msl)

- <0
- 0 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- >250

Abbreviations

DWR	= California Department of Water Resources
ft	= feet
ft msl	= feet above mean sea level
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Groundwater elevation contours were created using an interpolation process called kriging and are less certain in areas with sparse data.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Water level data provided by Arvin-Edison Water Storage District, Kern Delta Water District, and WRMWSD.

N

0 2.5 5

(Scale in Miles)

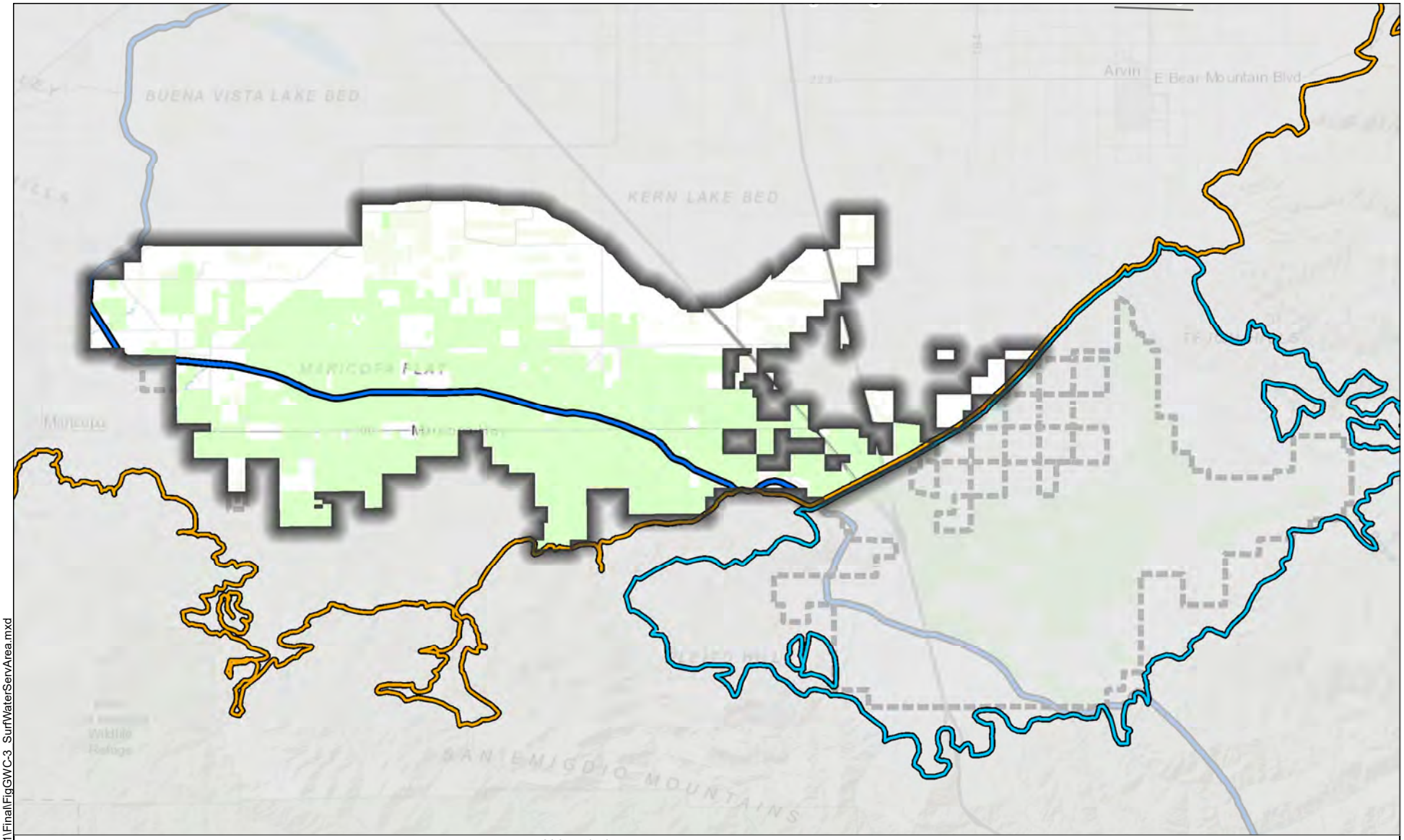
Groundwater Elevations Fall 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-2

eki environment & water

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Legend

- WRMWSD Management Area
- WRMWSD Service Area
- Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Surface Water Feature

- California Aqueduct
- WRMWSD Surface Water Service Area

Abbreviations

DWR = California Department of Water Resources
NHD = National Hydrography Dataset
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Surface water features and California Aqueduct location from NHD (https://viewer.nationalmap.gov/basic/).
3. Surface Water Service Area acquired from WRMWSD staff on 21 November 2017.

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(Scale in Miles)

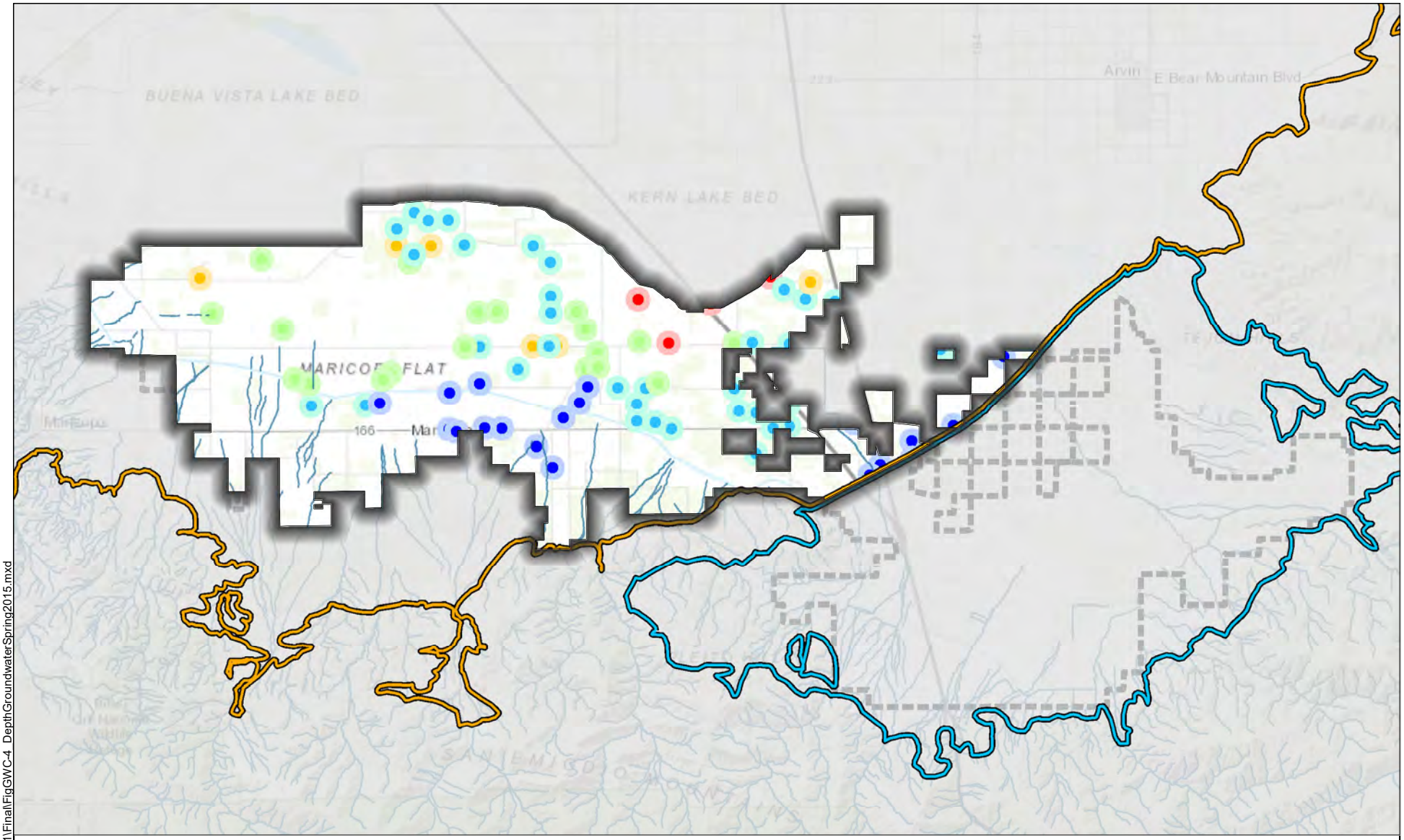
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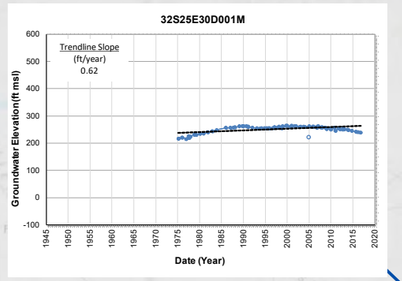
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

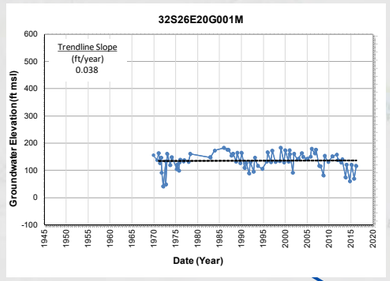
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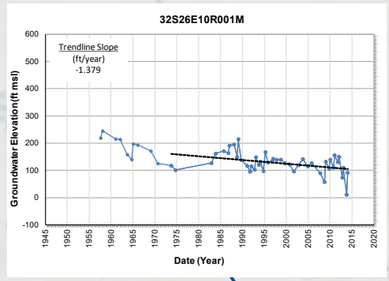
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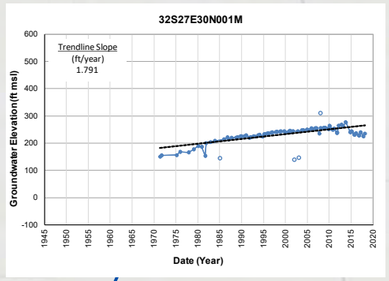
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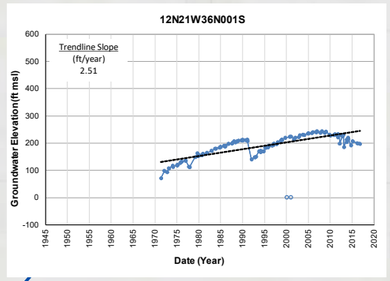

BUENA VISTA LAKE BED
KERN LAKE BED
Arvin
E Bear Mountain Blvd
MARICOPA FLAT
166
Legend
WRMWSD Management Area
WRMWSD Service Area Outside of Management Area
Groundwater Subbasin
Kern County (DWR 5-022.14)
White Wolf (DWR 5-022.18)
Stream into WRMWSD
Spring 2015 Depth to Groundwater (ft bgs)
0 - 50
50 - 100
100 - 200
200 - 350
> 350
Abbreviations
DWR = California Department of Water Resources
ft bgs = ft below ground surface
WRMWSD = Wheeler Ridge-Maricopa Water Storage District
Notes
1. All locations are approximate.
Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Depth to groundwater data provided by WRMWSD on 8 December 2017.
N
0
5
10
(Scale in Miles)
Depth to Groundwater
Spring 2015
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01
Figure GWC-4
eki environment & water
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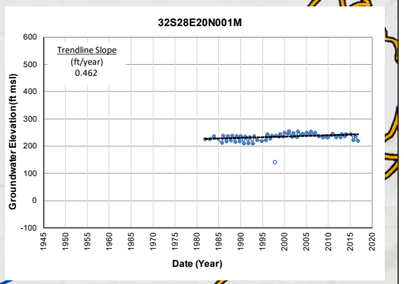


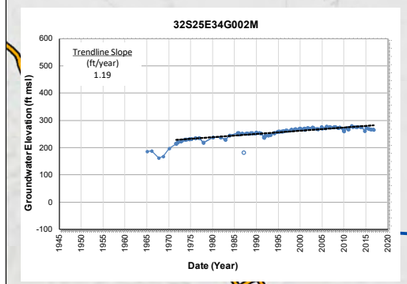


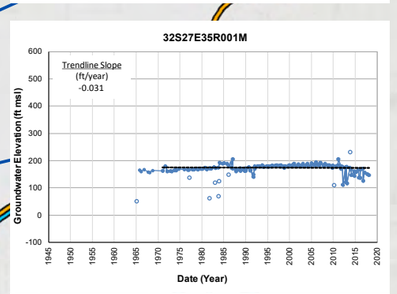


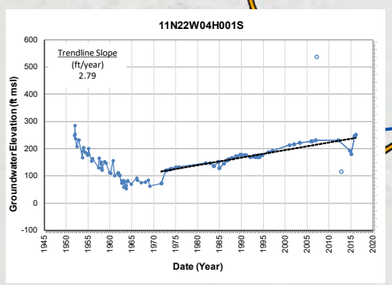


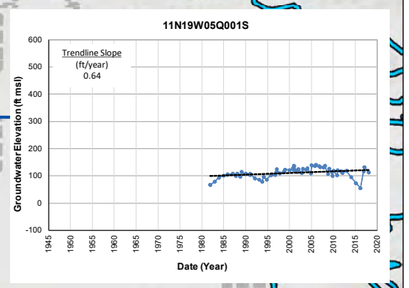


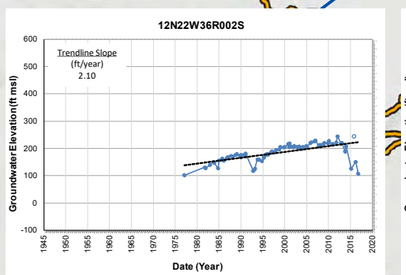


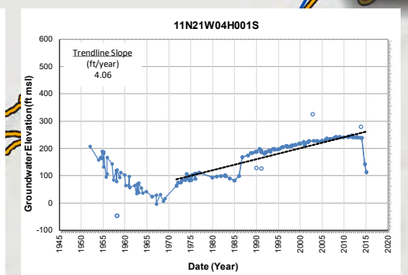


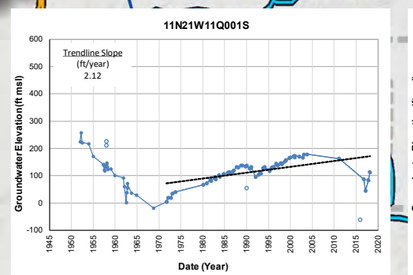


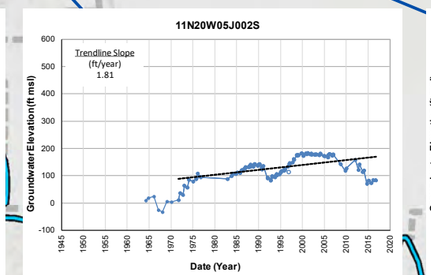


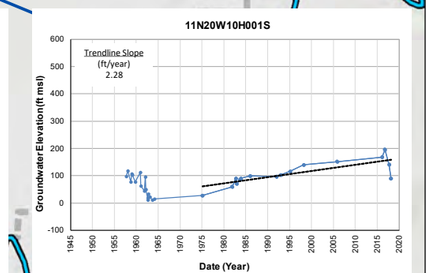












Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Groundwater Monitoring Well
- Groundwater Elevation Measurement
- Groundwater Elevation Measurement, Apparent Outlier

Abbreviations

DWR	= California Department of Water Resources
ft msl	= feet above mean sea level
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. The water level trend was calculating using linear regression on all non-outlier data between 1 January 1971 and 1 August 2018.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
3. Groundwater elevation data provided by WRMWSD on 8 December 2017.

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(Scale in Miles)

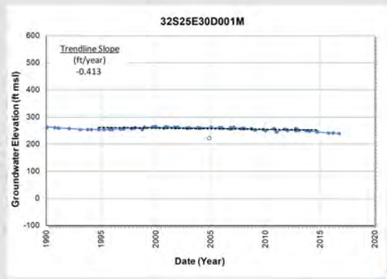
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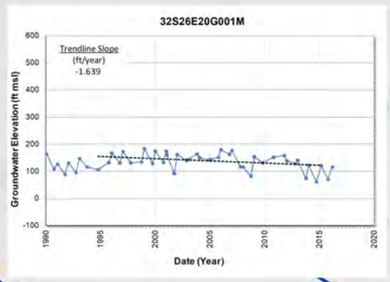
Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

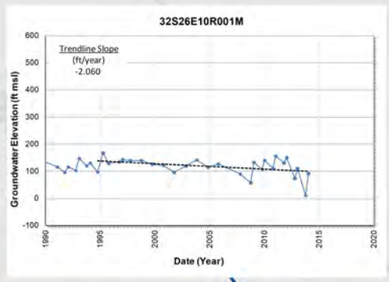
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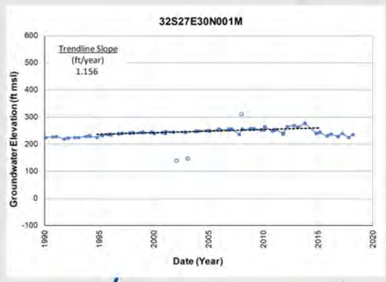
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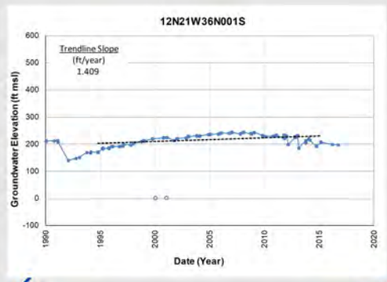
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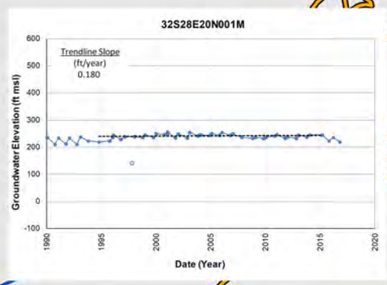


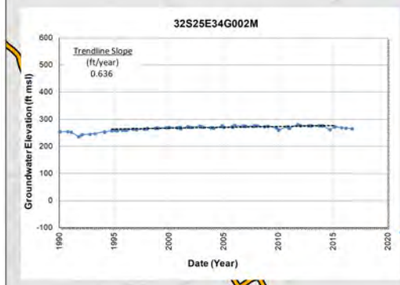


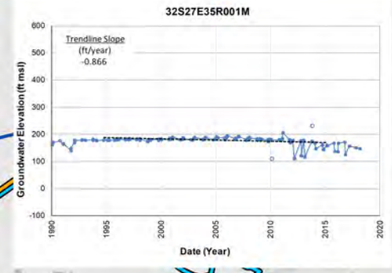


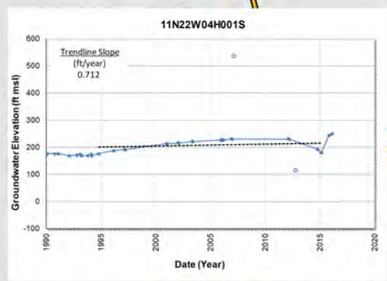




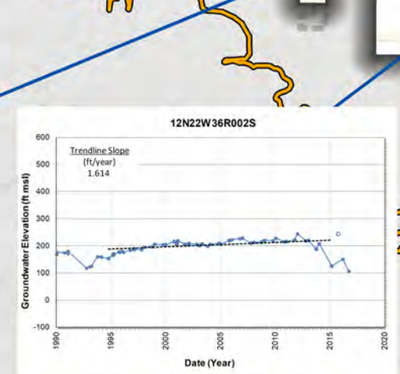


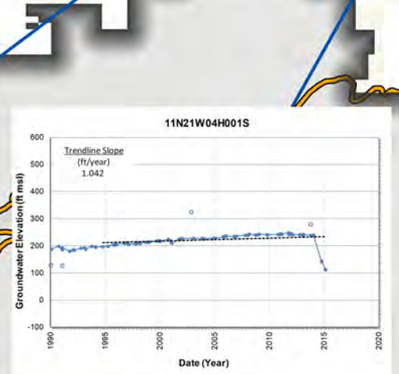


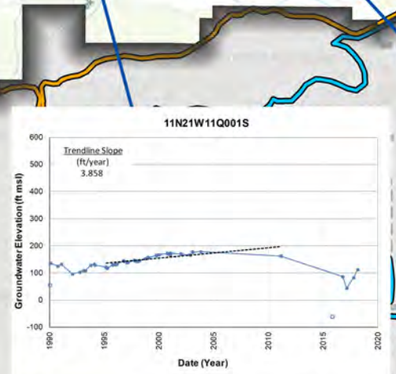


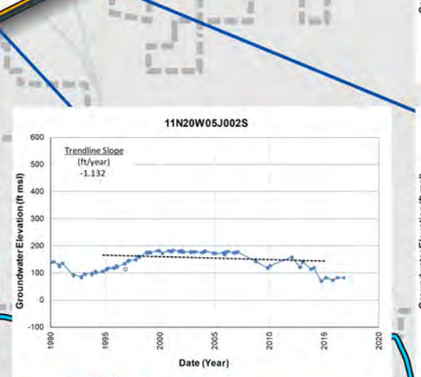


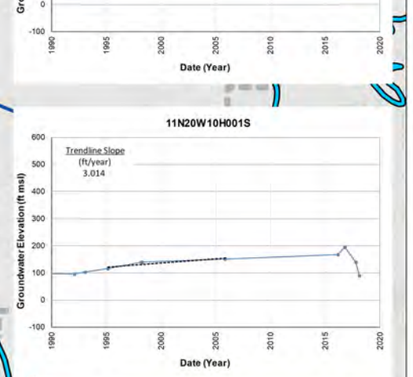












Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Groundwater Monitoring Well
- Groundwater Elevation Measurement
- Groundwater Elevation Measurement, Apparent Outlier

Abbreviations

DWR	= California Department of Water Resources
ft msl	= feet above mean sea level
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. The water level trend was calculating using linear regression on all non-outlier data between 1 October 1994 and 30 September 2015.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
3. Groundwater elevation data provided by WRMWSD on 8 December 2017.

N

0 3 6

(Scale in Miles)

Recent (1994-2015) Groundwater Elevation Hydrographs

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

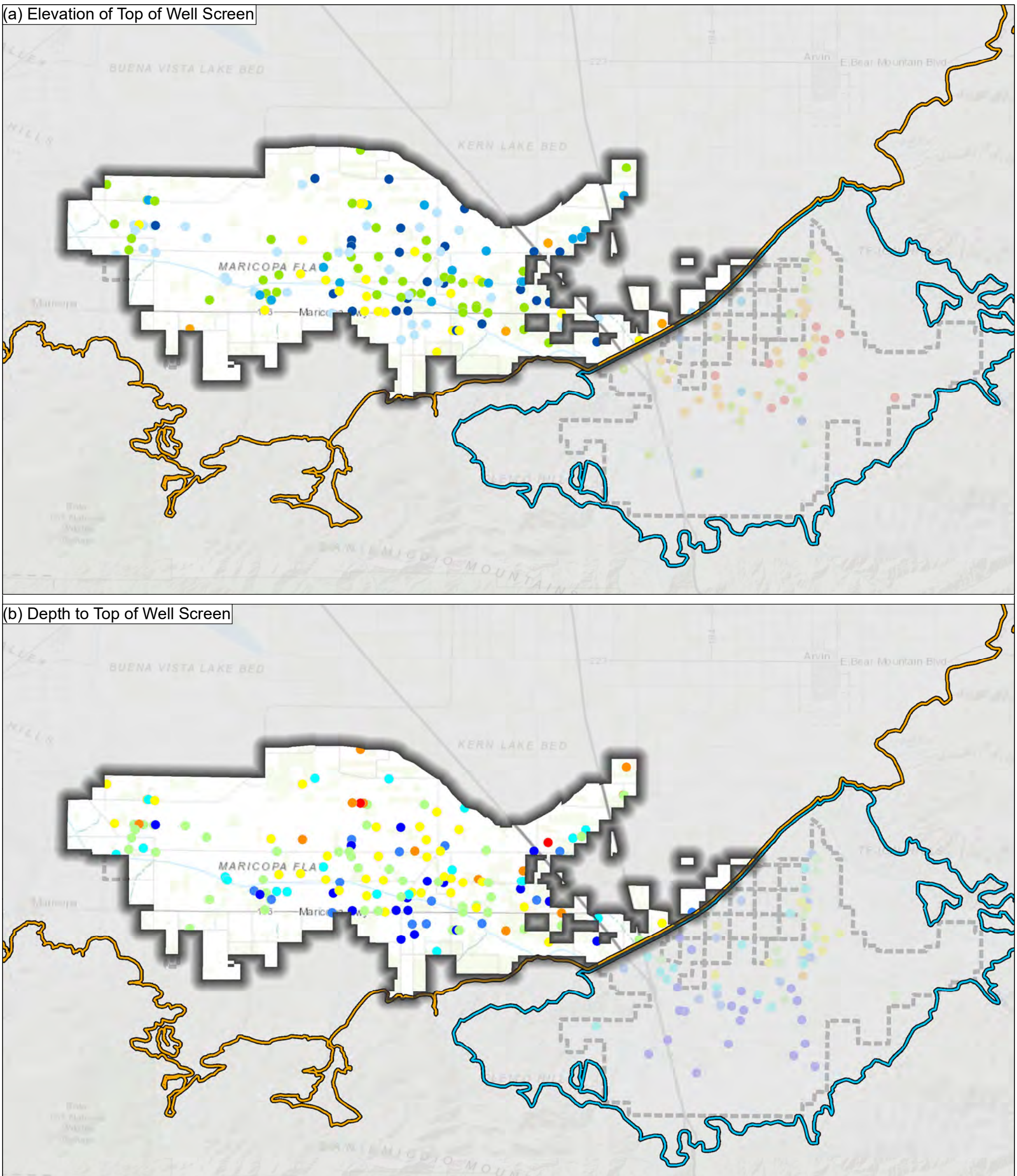
Figure GWC-6

eki environment & water

Path: X:\B70103\Maps\for_GSP\20191111\Final\FigGWC-6_GWEL_Hydrograph_Recent.mxd

(a) Elevation of Top of Well Screen

(b) Depth to Top of Well Screen



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Elevation of Top of Well Screen (ft msl)

- <-100
- -100 - 0
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- >400

Depth of Top of Well Screen (ft bgs)

- <100
- 100 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 600
- >600

Abbreviations

DWR = California Department of Water Resources
ft bgs = feet below ground surface
ft msl = feet above mean sea level
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

N

0 4 8

(Scale in Miles)

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Well screen data provided by WRMWSD staff on 20 November 2017.

Elevation and Depth to Top of Well Screen

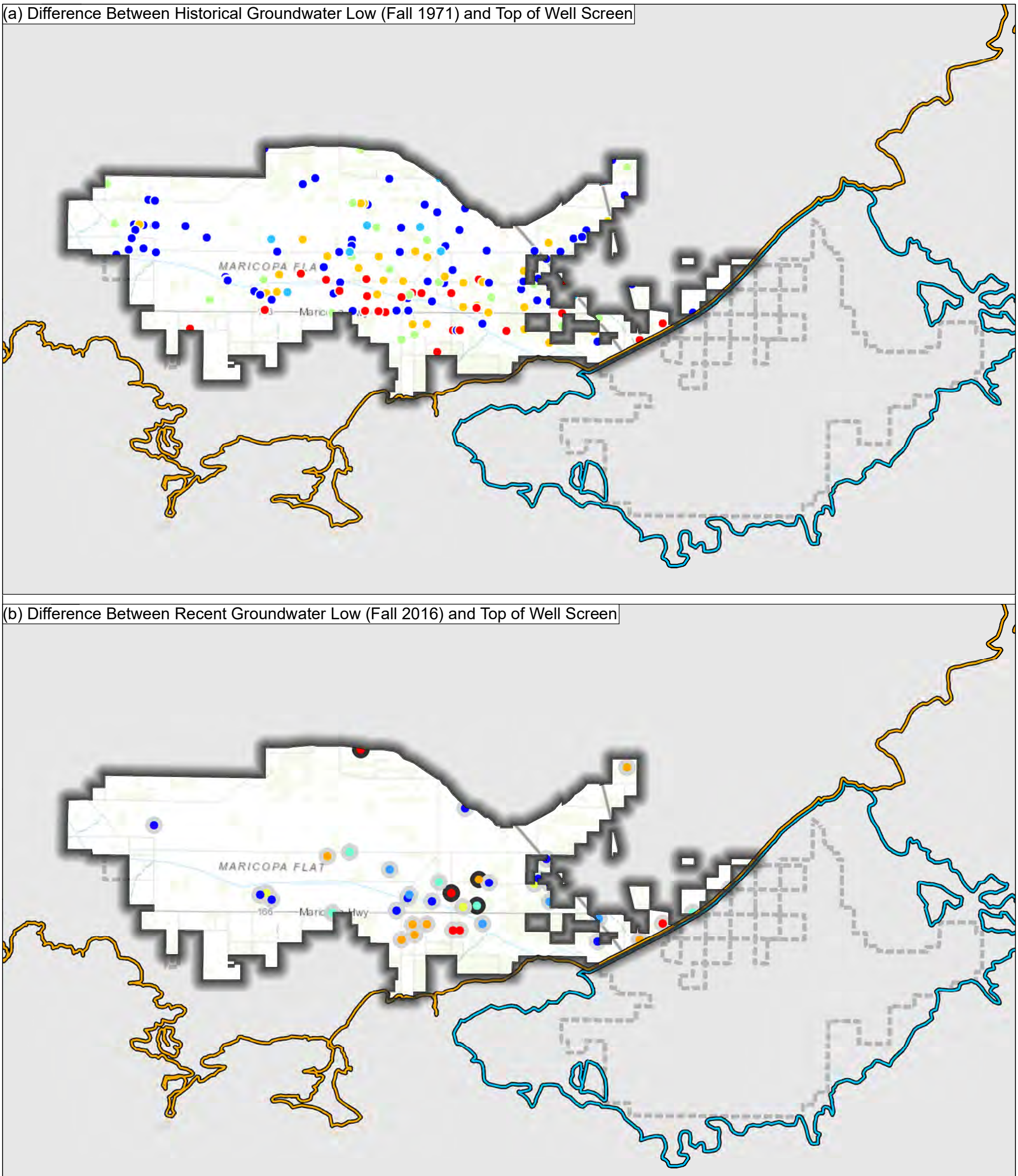
Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-7

eki environment & water

Path: X:\B70103\Maps\for GSP\20191\Final\FigGWC-7 Elevation Depth TOS.mxd

(a) Difference Between Historical Groundwater Low (Fall 1971) and Top of Well Screen



(b) Difference Between Recent Groundwater Low (Fall 2016) and Top of Well Screen

Legend

- WRMWSD Management
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-
- White Wolf (DWR 5-

Difference between Groundwater Elevation and Top of Well Screen (ft)

- <-100
- -100 - 0
- 0 - 50
- 50 - 100
- 100 - 200
- >200

Abbreviations

DWR = California Department of Water Resources
ft = feet
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

N

0 4 8

(Scale in Miles)

Notes

1. All locations are approximate.
2. Only active wells with available Fall 2016 groundwater elevation data are displayed for panel (b).

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Groundwater elevation and well screen data provided by WRMWSD staff on 20 November 2017.

Difference between Historical (Fall 1971) or Recent (Fall 2016) Groundwater Elevation and Top of Well Screen

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-8

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigGWC-8 Historical Recent GWlow TOS.mxd

(a) Change in Groundwater Elevation, Spring 1971 - 2016

(b) Change in Groundwater Elevation, Fall 1994 - 2015

(c) Change in Groundwater Elevation, Fall 2014 - 2015

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Starting Groundwater Elevation
- Ending Groundwater Elevation

Groundwater Elevation Change (ft)

220
100
0
-100
-200
-270

N

0 5 10

(Scale in Miles)

Abbreviations

DWR = California Department of Water Resources
USGS = United States Geological Survey
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Groundwater elevation change shown as feet change in each 100 ft by 100 ft call. Groundwater elevation data were interpolated using kriging for each year, and the difference was calculated using GIS tools.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Groundwater elevaiton data provided by WRMWSD staff on 8 December 2017.

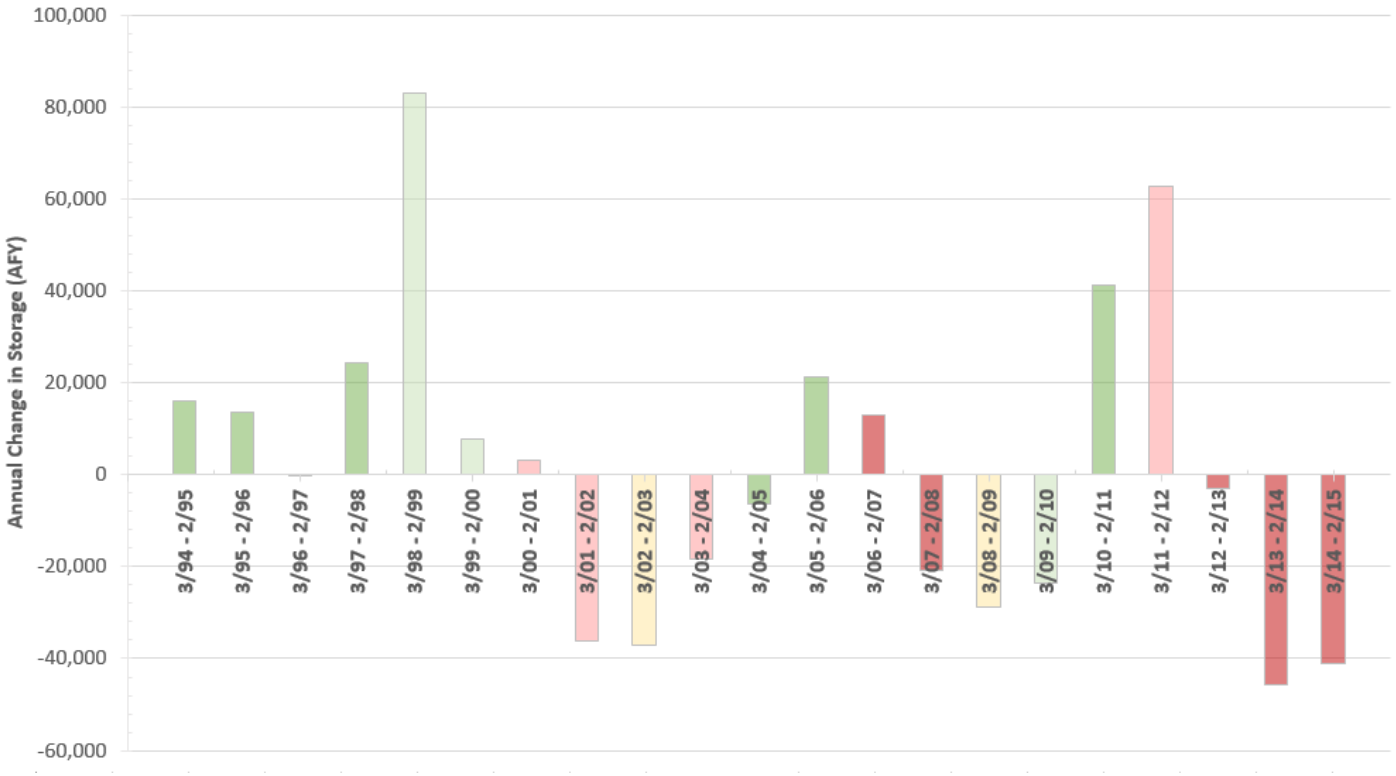
Groundwater Elevation Change
1971 - 2016, 1994 - 2015, and 2014 - 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-9

eki environment & water

Path: X:\B70103\Mapsfor_GSP\2019\11\Final\FigGWC-9_GW_ChangeinStorage.mxd



Legend

DWR Water Year Type

= Wet

= Above Normal

= Below Normal

= Dry

= Critical

Abbreviations

AFY = acre-feet per year

Notes

1. "Seasonal high" condition is defined as March – February of the following year.
2. The color of each bar is based on the Water Year type for the Water Year the begins in the October between the March and February represented by the bar.

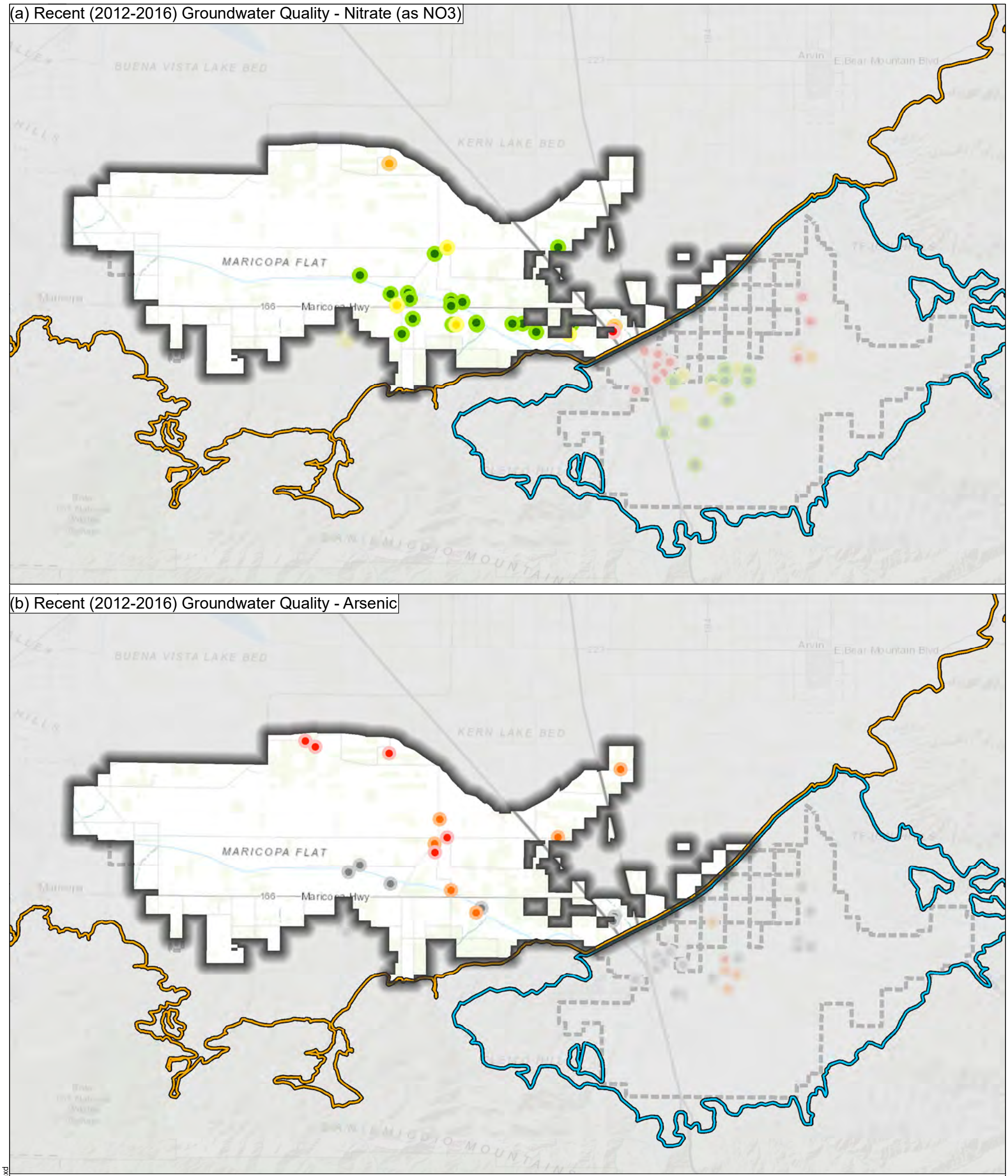
eki environment & water

Annual Change in Storage Between Seasonal Highs vs. DWR Water Year Type

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure GWC-10

(a) Recent (2012-2016) Groundwater Quality - Nitrate (as NO3)



(b) Recent (2012-2016) Groundwater Quality - Arsenic

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Nitrate (as NO3) Concentration (mg/L)

- ND
- 0.1- 9
- 9 - 22.5
- 22.5 - 45
- > 45

Dissolved Arsenic Concentration (ug/L)

- ND (< 7.8)
- 7.8 - 10
- > 10

Abbreviations

CCR	= California Code of Regulations
DWR	= California Department of Water Resources
MCL	= Maximum Concentration Level
mg/L	= miligrams per liter
ug/L	= micrograms per liter
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

N

0 4 8

(Scale in Miles)

Notes

1. All locations are approximate.
2. Constituent concentration is the maximum observed for each well between 2012 and 2016.
3. CCR 22-4 Table 64431-A lists primary MCL for nitrate as nitrogen at 10 mg/L, equivalent to 45 mg/L nitrate as NO3.
4. CCR 22-4 Table 64431-A lists Primary MCL for Arsenic at 10 ug/L.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Groundwater quality data was provided by WRMWSD staff on 20 November 2017.

Groundwater Quality – Nitrate and Arsenic Concentrations (2012 - 2016)

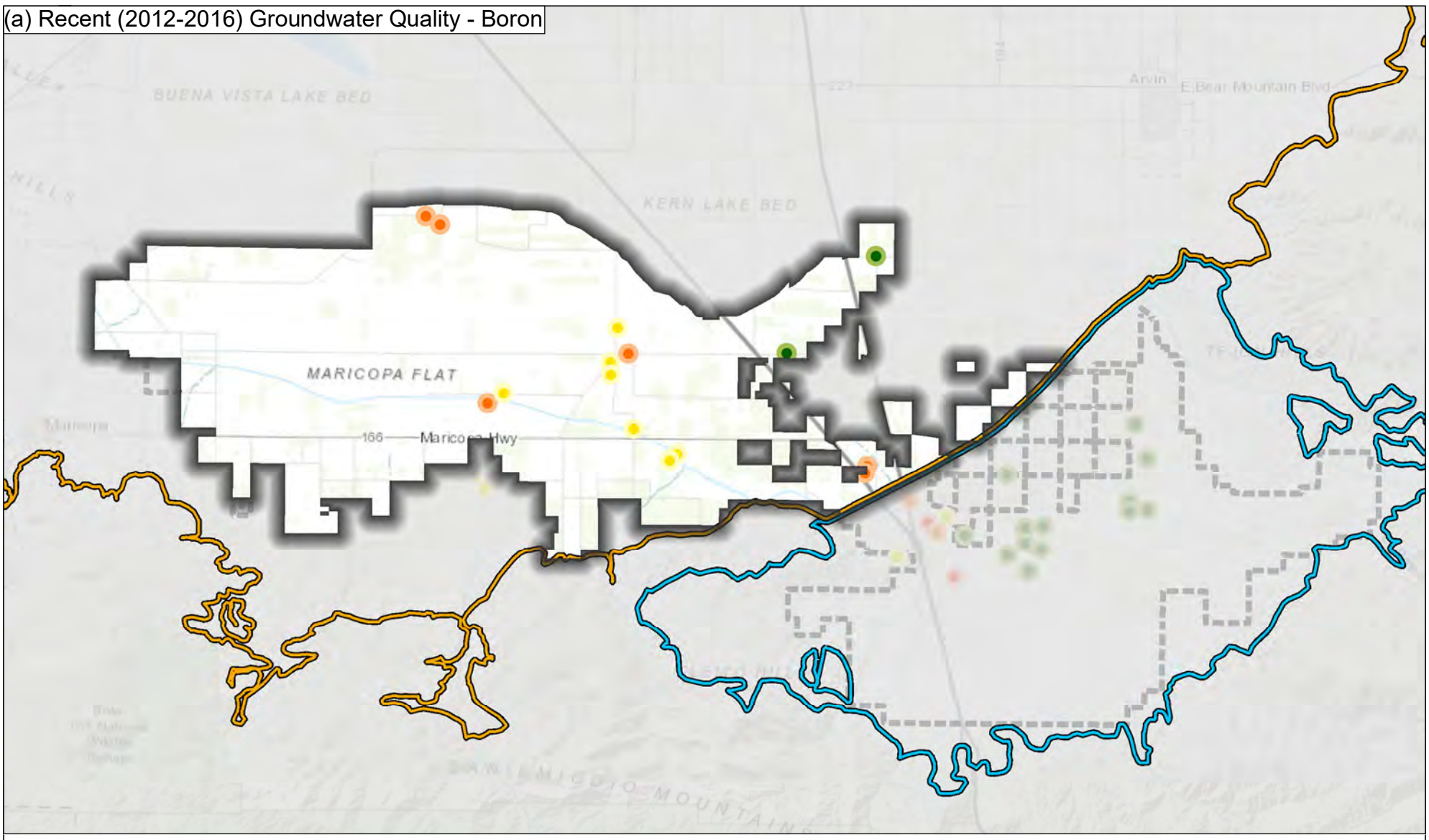
Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-11

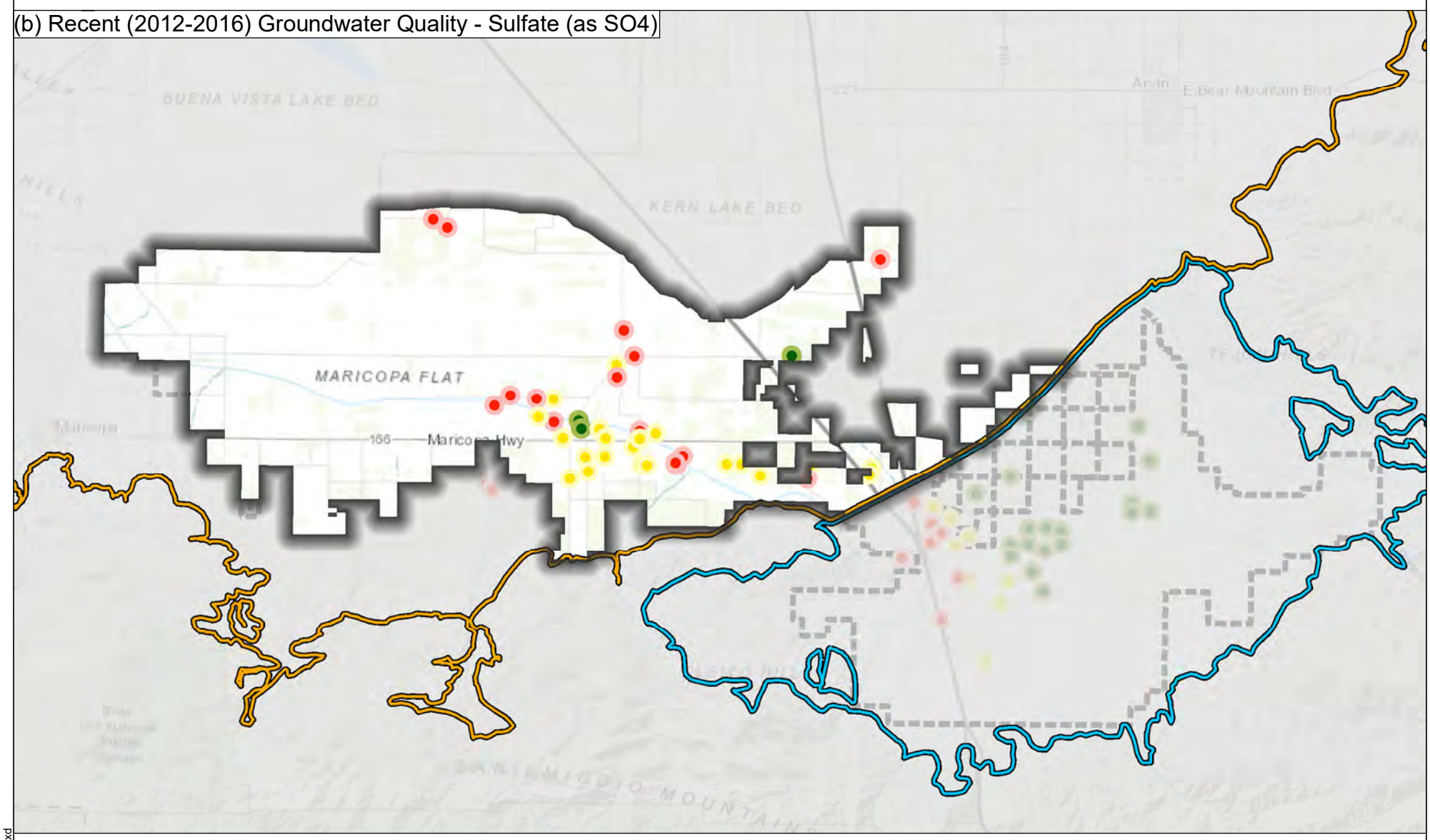
eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigGWC-11 NitrateArsenicConcentrations(2012-2016).mxd

(a) Recent (2012-2016) Groundwater Quality - Boron



(b) Recent (2012-2016) Groundwater Quality - Sulfate (as SO4)



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Dissolved Boron Concentration (mg/L)

- < 0.50
- 0.50 - 0.69
- 0.70 - 0.99
- > 1.0

Sulfate (as SO_4) Concentration (mg/L)

- < 250
- 250 - 499
- > 500

Abbreviations

CCR	= California Code of Regulations
DWR	= California Department of Water Resources
MCL	= Maximum Concentration Level
mg/L	= miligrams per liter
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

N

0 4 8

(Scale in Miles)

Notes

1. All locations are approximate.
2. Constituent concentration is the maximum observed for each well between 2012 and 2016.
3. Boron levels >0.5 mg/L can exhibit slight to moderate restrictions on agricultural productivity, depending on crop type.
4. CCR 22-4 Table 64449-B lists “Upper” Secondary MCL for sulfate at 500 mg/L.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Groundwater quality data was provided by WRMWSD staff on 20 November 2017.

Groundwater Quality – Boron and Sulfate Concentrations (2012 - 2016)

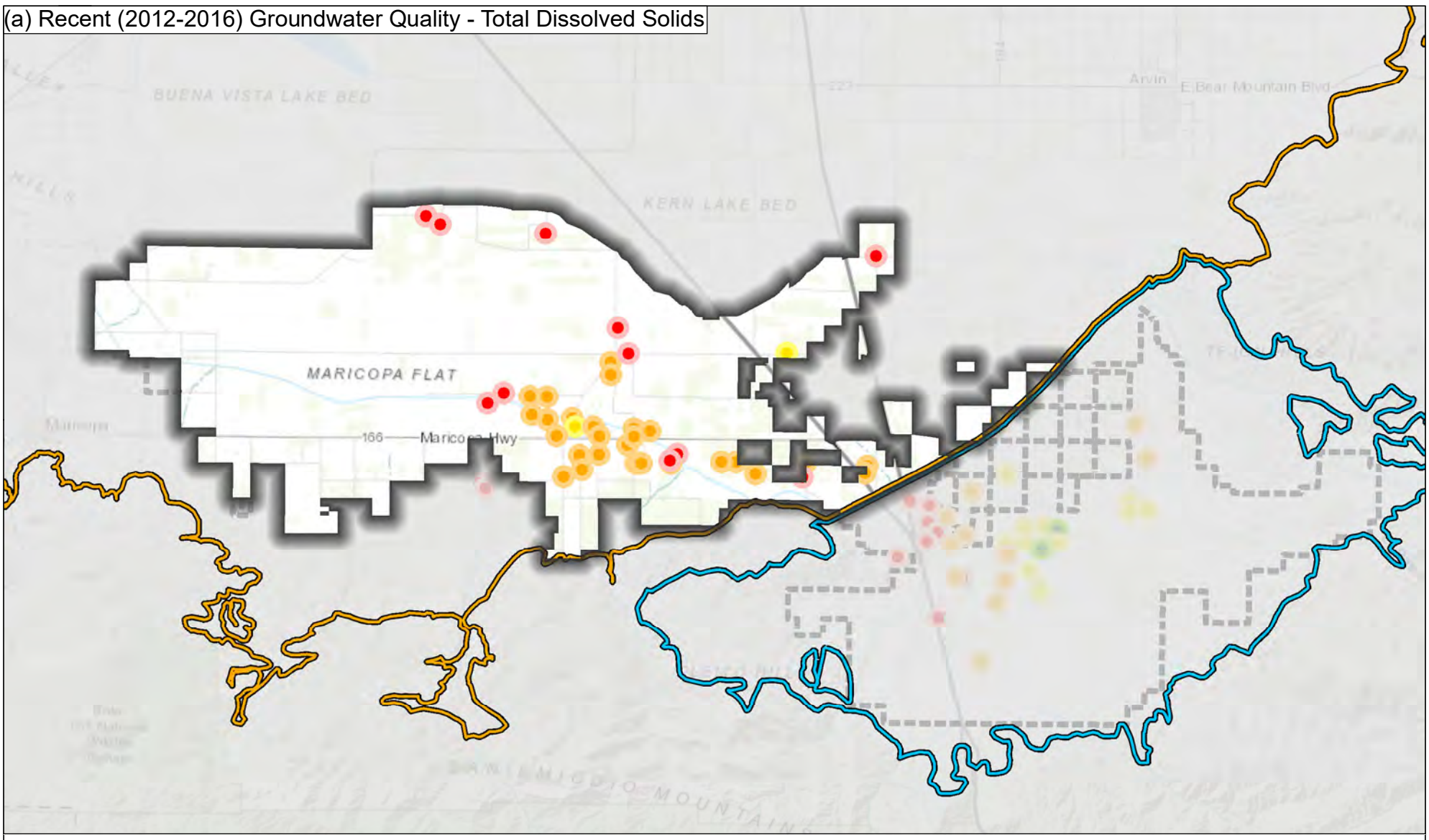
Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-12

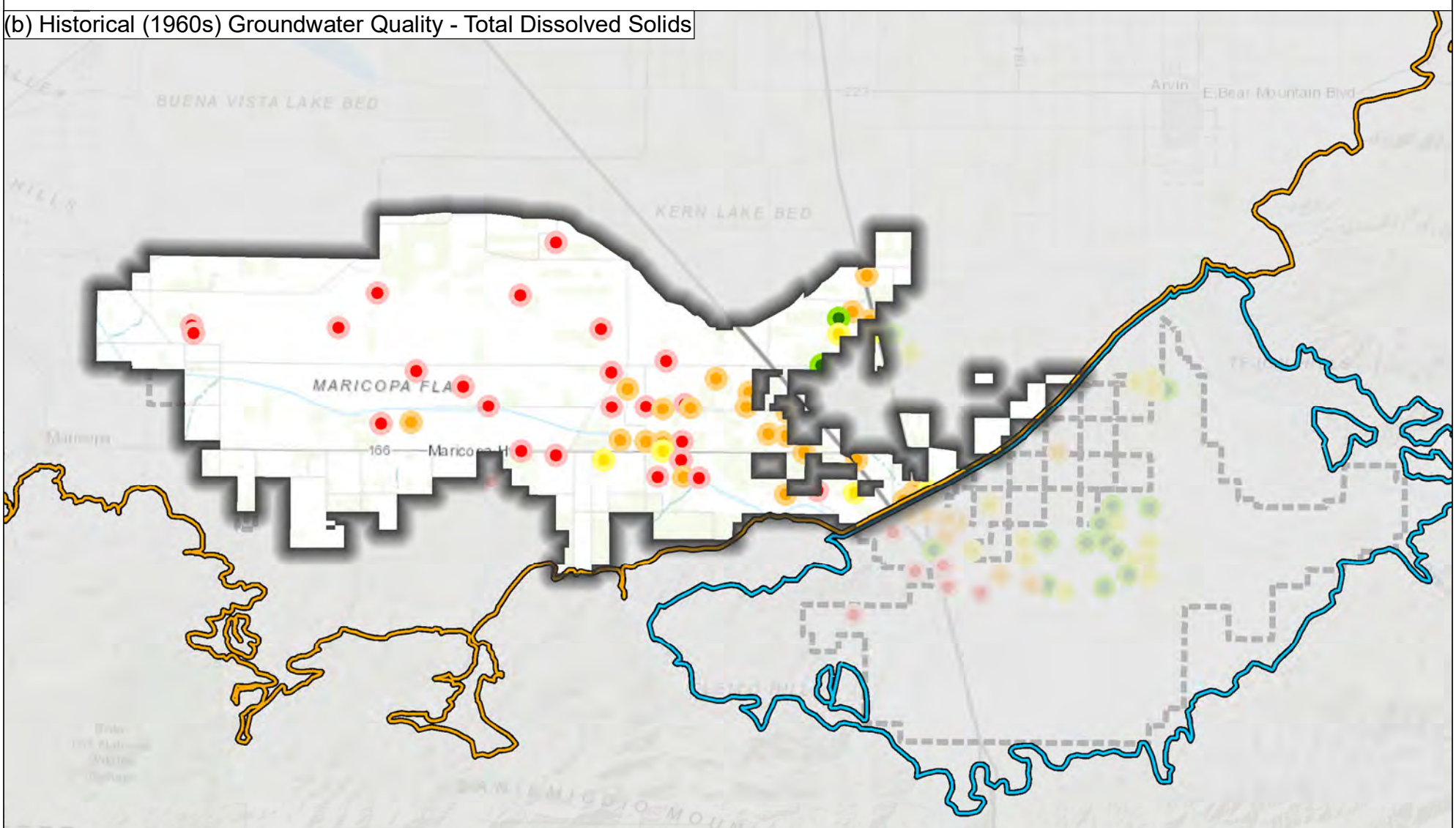
eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigGWC-12 BoronSulfateConcentrations(2012-2016).mxd

(a) Recent (2012-2016) Groundwater Quality - Total Dissolved Solids



(b) Historical (1960s) Groundwater Quality - Total Dissolved Solids



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Total Dissolved Solids Concentration (mg/L)

- <300
- 300 - 500
- 500 - 1,000
- >1,000

Abbreviations

CCR	= California Code of Regulations
DWR	= California Department of Water Resources
MCL	= Maximum Contaminant Level
mg/L	= miligrams per liter
TDS	= Total Dissolved Solids
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Constituent concentration is the maximum observed for each well between 2012 and 2016 (Figure GWC-13(a)) and between 1960 and 1969 (Figure GWC-13(b)).
3. CCR 22-4 Table 64449-B lists "upper" Secondary MCL for TDS at 1,000 mg/L and "lower". Secondary MCL for TDS at 500 mg/L.

N

0 4 8

(Scale in Miles)

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Groundwater quality data was provided by WRMWSD staff on 20 November 2017.

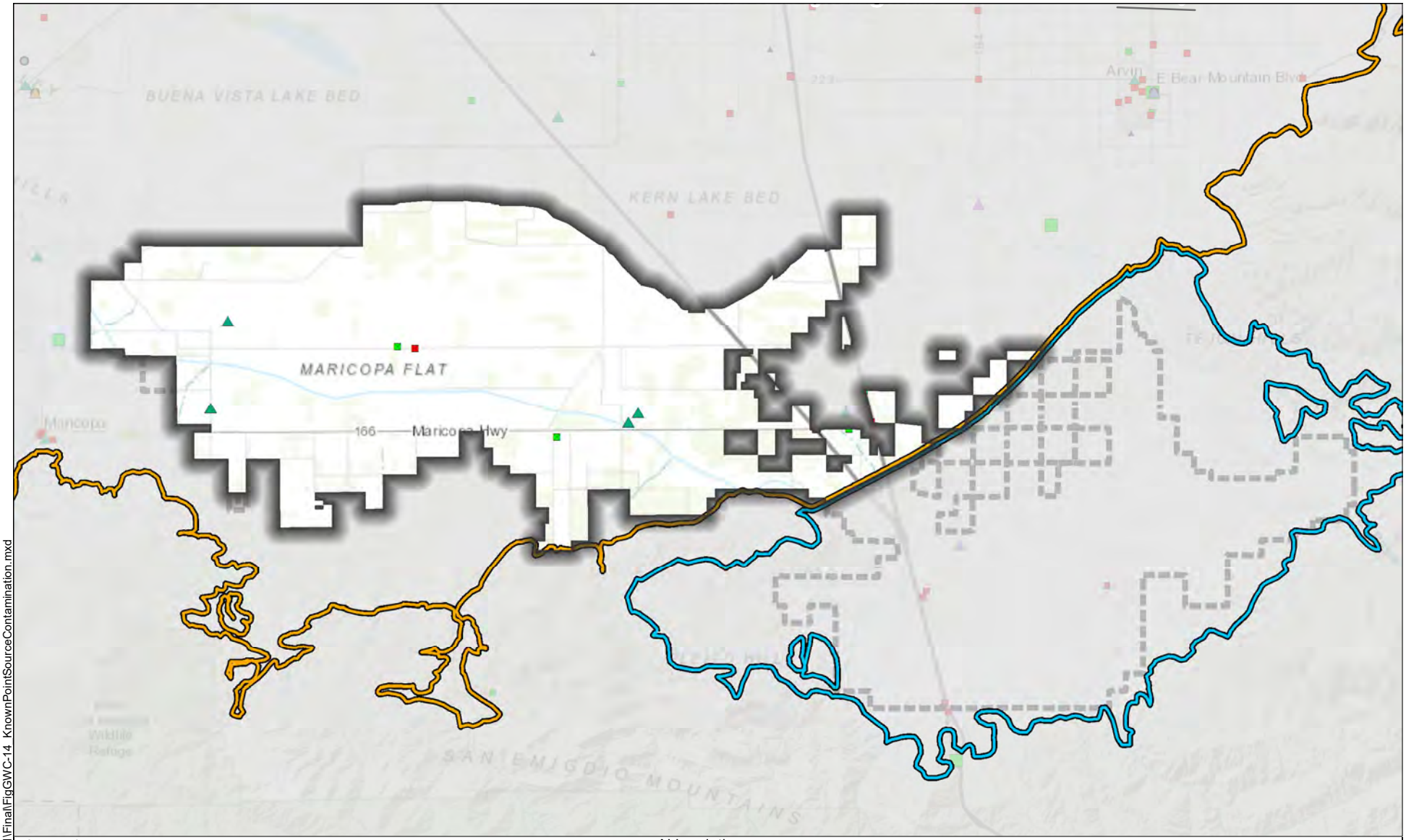
Groundwater Quality – Recent (2012 - 2016) and Historical (1960s) TDS Concentrations

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-13

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigGWC-13 RecentHistoricTDSconcentration.mxd



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

GeoTracker Sites

- Cleanup Program Site, Open
- Cleanup Program Site, Closed
- LUST Cleanup Site, Closed

EnviroStor Sites

- Active Corrective Action
- Active Federal Superfund
- Active State Response
- Corrective Action, Refer: EPA
- Inactive - Needs Evaluation
- Certified Voluntary Cleanup
- School Investigation, No Action or No Further Action
- Closed Hazardous Waste Site
- Hazardous Waste Site Undergoing Closure

Abbreviations

DWR	= California Department of Water Resources
LUST	= Leaking Underground Storage Tank
SWRCB	= State Water Resources Control Board
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Locations of contamination sites from SWRCB GeoTracker website (http://geotracker.waterboards.ca.gov/datadownload) accessed 27 February 2018 and Department of Toxic Substances Control EnviroStor website (https://www.envirostor.dtsc.ca.gov/public/) accessed 11 May 2018.

N

0 5 10

(Scale in Miles)

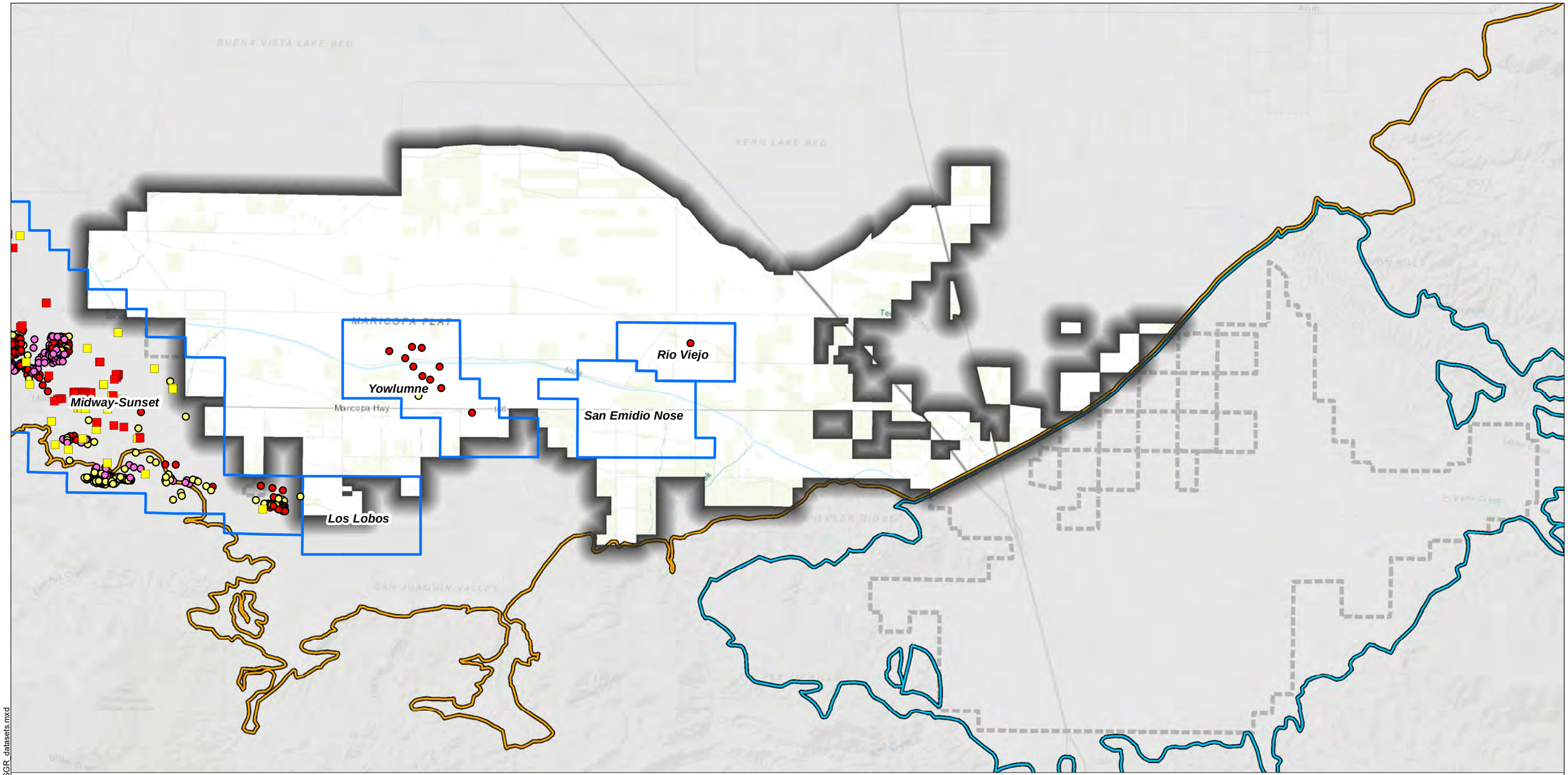
Known Point Source Contamination Sites

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure GWC-14

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigGWC-14 KnownPointSourceContamination.mxd



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- DOGGR Oil & Gas Fields

Produced Water Ponds

- Active
- Inactive

Injection Well Type (see Note 2)

- INJ
- Multi
- SC
- SF

Abbreviations

DWR	= California Department of Water Resources
DOGGR	= Division of Oil, Gas, and Geothermal Resources
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Wells shown are listed as "Active" and include injection (INJ), Cyclic Steam (SC), Steam Flood (SF), and Multi (injection and production).

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. DOGGR well data obtained 4 June 2019.
3. Produced water ponds data obtained 4 June 2019.

N

0 2.5 5

(Scale in Miles)

Locations of Oil Fields, Active Injection Wells, and Produced Water Ponds

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-15

eki environment & water

Path: X:\B70103\Maps\for_GSP\2019\11\Final\FigGWC-15_DOGGR_datasets.mxd

(a) Subsidence and Hydrocompaction

(b) Historical (1949-2005) Land Subsidence

(c) Recent (May 2015 - September 2016) Land Subsidence

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Subsidence Type (after Ireland et al., 1984)

- Subsidence Monitoring Station
- Area of subsidence due to hydrocompaction
- Area with subsidence due to water level decline of >1 foot
- Outline of valley

Subsidence (1949 - 2005)

- -30 to -25 feet
- -25 to -20 feet
- -20 to -15 feet
- -15 to -10 feet
- -10 to -5 feet
- -5 to 0 feet
- Highway
- California Aqueduct

Subsidence (May 2015 - Sept. 2016)

- No data
- -12 to -8 inches
- -8 to -4 inches
- -4 to -1 inches
- -1 to 1 inches
- California Aqueduct
- Highway

N

0 5 10

(Scale in Miles)

Abbreviations

DWR = California Department of Water Resources
USGS = United States Geological Survey
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Ireland et al., 1984. Land Subsidence in the San Joaquin Valley, California, as of 1980. USGS Professional Paper 437-1.
3. California Aqueduct location is from the National Hydrography Dataset.
4. Subsidence monitoring locations are from UNAVCO's Plate Boundary Observatory database.
5. Subsidence data is from DWR's Estimated Subsidence in the San Joaquin Valley between 1949-2005.
6. Subsidence data is from the California Institute of Technology Jet Propulsion Laboratory Progress Report: Subsidence in California, March 2015 - September 2016.

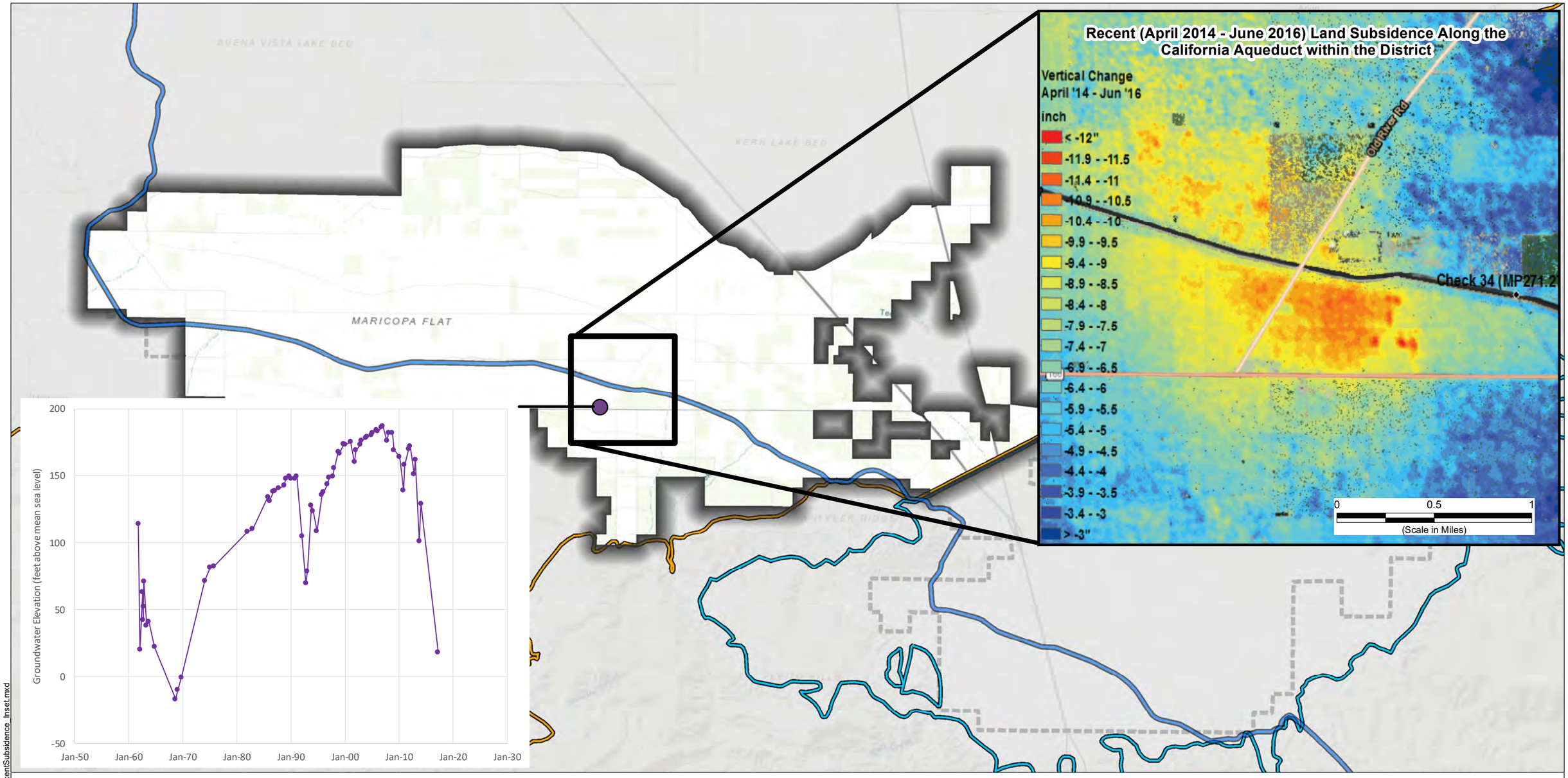
Historical (1949-2005) and Recent (2015-2016) Land Subsidence, and Hydrocompaction

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-16

eki environment & water

Path: X:\B70103\Mapsfor_GSP\2019\11\Final\FigGWC-16_HistoricRecentSubsidence.mxd



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- California Aqueduct

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- State Well 11N21W08A001S

Abbreviations

CASGEM	= California Statewide Groundwater Elevation Monitoring Program
DWR	= California Department of Water Resources
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Inset map shows the area of highest widespread subsidence observed along the southern portion of the California Aqueduct from April 2014 to June 2016. See Source 4.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Subsidence data is from the California Institute of Technology Jet Propulsion Laboratory Progress Report: Subsidence in California, March 2015 - September 2016.
3. Groundwater elevation data for acquired from CASGEM for State Well 11N21W08A001S on 19 December 2017.

N

0 2.5 5

(Scale in Miles)

Recent Land Subsidence Along the California Aqueduct With Groundwater Elevation Hydrograph

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-17

eki environment & water

Path: X:\B70103\Maps\for_GSP\2019\11\Final\FigGWC-17_RecentSubsidence_Inset.mxd

(a) NCCAG Wetland and Vegetation - Identified by DWR as Potential GDEs

(b) Removed from NCCAG Dataset

NCCAG features line artificial channels and open surface water bodies. DTW encountered at 140 - 300 ft bgs.

NCCAG features are in perched groundwater area, where DTW < 20 ft bgs. DTW of principal aquifer is 120 - 200 ft bgs.

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- NCCAG Wetland
- NCCAG Vegetation
- Removed NCCAG Vegetation or Wetland
- Stream into WRMWSD

Spring 2015 Depth to Groundwater (ft bgs)

- 0 - 50
- 50 - 100
- 100 - 200
- 200 - 350
- > 350

Abbreviations

DTW	= Depth to Water
DWR	= California Department of Water Resources
ft bgs	= feet below ground surface
NCCAG	= Natural Communities Commonly Associated with Groundwater
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

N

0 4 8

(Scale in Miles)

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. DWR NCCAG dataset was obtained from NC Dataset Viewer (https://gis.water.ca.gov/app/NCDatasetViewer/)

Natural Communities Commonly Associated with Groundwater (DWR)

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure GWC-18

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigGWC-18 NCCAG(DWR) v2.mxd

9. WATER BUDGET INFORMATION

☑ 23 CCR § 354.18(a)
☑ 23 CCR § 354.18(f)

All GSAs in the Kern County subbasin (Subbasin) coordinated and collaborated on the development of a groundwater model (Model[46]) to evaluate historical, baseline and projected groundwater conditions. The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop the Model on behalf of the Subbasin. The contract required that Todd Groundwater use the C2VSim model provided by DWR. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (see Attachment H in Umbrella GSP). Basin-wide water budget results from the Model are provided in Attachment H and show the Subbasin, as a whole, has a total storage deficit of approximately 324,326 acre-feet per year (AFY) over the baseline period.

The Subbasin's dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a GSA level water accounting system (Checkbook) using Subbasin specific values for supply, demand and net results. The Model results reflect Subbasin-wide conditions and do not allocate water shortages/surpluses, nor do the results allocate the "ownership" of water. As a result, the GSAs, through a coordinated effort, developed the Checkbook that estimates current conditions for each GSA that are generally consistent with the Model results under baseline condition. The Checkbook and Model budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability in the interest of developing a Subbasin coordinated approach.

To ensure the individual water budgets reflected actual conditions, the KGA members developed the Checkbook budget and coordinated water accounting methodology. The result of that effort indicates a current baseline shortage/deficit for KGA members of approximately -256,281 AFY.[47] This reflects the difference between a total demand for KGA members of 1,939,409 AFY, and a total supply of 1,683,128 AFY. Of the shortage/deficit of the KGA, the Wheeler Ridge-Maricopa Management Area's portion of the KGA shortage/deficit is -14,655 AFY. Or a difference in demand of 202,402 AFY and a water supply of 192,237 AFY.

As is mentioned above, each estimate includes data gaps and has varying degrees of accuracy and/or reliability. The Checkbook is complimentary to the Model and reflects the allocation of water supply benefits and obligations independent of geographic constraints within the Subbasin. This was important to recognize and ensure the coordination of the various groundwater banking projects and water management programs amongst the various GSA's within the groundwater basin.

[46] The "Model" is referred to elsewhere in this water budget discussion as the "numerical model".
[47] The water supplies available to each KGA member from the Pioneer and Kern Water Bank banking programs are incorporated into the listed total available supplies. Note that both programs only store surface supplies, and do not have consumptive demands that contribute to the listed shortages. For more detail on the banking projects, please see the respective management area plans.

These two Basin-level water budgeting efforts (i.e., the numerical model and the "checkbook" water accounting approach) are described in the Coordination Agreement and Appendices thereto. These Basin-level efforts are supplemented by the local water budget information presented in this section for the Wheeler Ridge-Maricopa Management Area. Consistent with DWR's GSP Emergency Regulations and DWR's Water Budget BMP (DWR, 2016b), this local water budget information provides an accounting of the total annual volume of water entering and leaving the Management Area, for historical, current, and projected future conditions.

The two Basin-level water budgeting efforts and the local water budget assessment discussed in detail in this section provide a range of results. **Table WB-1** below shows a comparison of results for change in groundwater storage from the three water budget approaches for several time periods. Change in groundwater storage is considered an appropriate term for comparison, as it amounts to an integration of all of the other inflow and outflow terms and represents the overall quantitative balance of the system.

The range of change in groundwater storage results shown in **Table WB-1** is due to several reasons. These include:

- Slight differences in the spatial area considered by the numerical model and the other two approaches (i.e., due to the fact that the model's grid cells/elements do not exactly align with the boundaries of the Wheeler Ridge-Maricopa Management Area);
- Slight differences in the way that project and management actions are implement over time;
- Inherently different levels of spatial resolution between methods, affecting the parameterization and subsequent calculation of subsurface flow across boundaries;
- Slight differences in the way in which land surface processes are treated (i.e., evapotranspiration demand, precipitation);
- Differences in the apportionment of native/natural water supplies stemming from the different perspectives and objectives of the multiple methods (i.e., the numerical model and local [analytical spreadsheet] model consider water supplies from a purely physical perspective whereas the Checkbook utilized a water accounting approach that assumes for management purposes a uniform Basin distribution).[48]

Despite these differences, each approach provides valuable information that can support effective groundwater management within the Basin and the Wheeler Ridge-Maricopa Management Area. As part of Plan Implementation, WRMWSD will continue to refine the water budget parameters based on additional data and modeling (see **Section 18 *WRMWSD Plan Implementation***).

[48] Nothing in this water budget information presented herein results in or is intended to be a determination of water rights.

Table WB-1. Comparison of Change in Groundwater Storage Estimates from Three Water Budget Estimation Methods

Period / Scenario	Basin-wide Numerical Model	Local Analytical Spreadsheet Model	Basin-wide "Checkbook" Water Accounting Approach
Historical Period (WY 1995 – 2014)	-8,654 (a)	3,286 (b)	NA
Current Period (WY 2015)	-45,191 (a)	-42,898 (b)	NA
Projected Period (50 years; 2021 – 2070) Baseline with no Projects	-5,423 (c)	-14,665 (d)	-14,665 (e)
Projected Period (50 years; 2021 – 2070) 2030 Climate Change with no Projects	-9,712 (f)	-21,429 (d)	NA
Projected Period (50 years; 2021 – 2070) 2030 Climate Change with Projects (2)	9,780 (g)	53 (h)	NA
Projected Period (50 years; 2021 – 2070) 2070 Climate Change with no Projects	-17,952 (i)	-33,326 (d)	NA
Projected Period (50 years; 2021 – 2070) 2070 Climate Change with Projects (2)	1,571 (j)	47 (h)	NA

Abbreviations
NA = not applicable

Notes:
(1) All values are in AFY.
(2) The Projected Period is 50 years in length. For the 2030 Climate Change scenarios, the Basin-wide numerical model approach includes a 20-year (2021-2040) "implementation period" and a 30-year (2041-2070) "sustainability period". The Analytical Spreadsheet Model results assumes projects and management actions are fully implemented for the entire 50-year projected period.

Sources:
(a) Table 1 of "FINAL_WRMWSD-Hist-WB.xlsx", received from Todd, 7 May 2019.
(b) Table WB-6
(c) Table 1 of "WRMWSD-Baseline-Nov14-FINAL.xlsx", received from Todd, 18 November 2019.
(d) Table WB-7
(e) "SKM_C25819111413180.pdf", received from KGA on 14 November 2019.
(f) Table 1 of "WRMWSD-2030-Nov14-FINAL.xlsx", received from Todd, 18 November 2019.
(g) Table 1 of "WRMWSD-2030_Projects-Nov14-FINAL.xlsx", received from Todd, 18 November 2019.
(h) Table WB-8
(i) Table 1 of "WRMWSD-2070-Nov14-FINAL.xlsx", received from Todd, 18 November 2019
(j) Table 1 of "WRMWSD-2070_Projects-Nov14-FINAL.xlsx", received from Todd, 18 November 2019

9.1. Water Budget Methods and Data Sources

☑ 23 CCR § 354.18(d)
☑ 23 CCR § 354.18(e)

This District-level water budget uses a **spreadsheet model approach** that quantifies each flow component and enforces mass balance principles for each "subdomain" that collectively comprise the water budget domain (i.e., the Wheeler Ridge-Maricopa Management Area). Details of this approach and the corresponding data sources employed within the water budget model are described further below.

9.1.1. Spreadsheet Model Approach

The spreadsheet model approach was developed for WRMWSD to serve as an independent estimate of the local historical, current, and projected water budget conditions within the Wheeler Ridge-Maricopa Management Area. The spreadsheet model approach uses a variety of data and analytical methods to quantify each water budget flow component. Processes and groups of processes are grouped into "subdomains" and "flow components". These water budget flow components are quantified on a monthly timestep for the period from January 1994 through December 2015.

Water Budget Subdomains

The water budget is divided into five internal subdomains, each influenced by a number of flow components and within which mass-balance is enforced (i.e., the sum of inflow components is balanced by the sum of outflow components and/or a change in storage component). **Figure WB-1** shows the water budget domain, and the following internal subdomains:

1. Artificial Channels and Pipelines;
2. Agricultural Lands;
3. Urban Lands;
4. Natural Channels; and
5. Groundwater System

In addition to the five internal subdomains, several external subdomains are incorporated into the spreadsheet model. These include the watersheds that contribute streamflow to streams entering the Wheeler Ridge-Maricopa Management Area, the atmosphere which is a source of precipitation and sink for evapotranspiration, the adjacent and connected portions of the groundwater basin, and the external surface water sources including out-of-basin and in-basin (but outside of the District) storage "accounts". The spreadsheet model does not explicitly account for the vadose (unsaturated) zone between the land surface and the (saturated) groundwater system, but instead incorporates temporal lag factors to account for the movement of water through this zone. An implicit assumption in this approach, therefore, is that the vadose zone does not experience any change in storage over time.

Water Budget Flow Components

Within and between each subdomain are 31 water budget flow components that route water through the Wheeler Ridge-Maricopa Management Area. **Figure WB-2** shows a conceptual diagram of the individual water budget flow components between subdomains as well as flow components that are external to the

overall water budget domain (i.e., serve only as an inflow or outflow to the entire system, rather than a flow between subdomains).

Certain components are based on "raw" data which are directly measured and based on historical records. These "raw" components are considered to have a relatively high degree of certainty. Other components are estimated using a variety of analytical methods (e.g., Darcy's Law to calculated subsurface flows across the domain's external boundaries) and are thus subject to uncertainty based on the parameters used in their estimation. Some components (i.e., groundwater pumping for agricultural use) constitute major proportions of the overall water budget and have thus been given significant attention. Others are relatively minor in magnitude (e.g., seepage from artificial channels) and are, to some degree, less significant to the overall water budget and less well defined. Details of the methods and data used in the spreadsheet model approach are provided in **Appendix G**.

Wheeler Ridge-Maricopa / Arvin-Edison Overlap Lands

The District also supplies surface water to certain lands within the portion of its service area that overlaps with the AEWSD service area. The total acreage of overlap lands within the Kern Subbasin is approximately 5,318 acres, and WRMWSD serves surface water to approximately 3,186 acres in this area. Although the overlap lands are being covered by AEWSD for SGMA monitoring and management purposes, WRMWSD will continue in the future to serve surface water to those lands within the overlap area that have historically received District supplies in accordance with the District's water delivery contracts with landowners. The water budget presented herein is quantified for the entire Wheeler Ridge-Maricopa Management Area, but also specifically identifies inflow and outflow quantities associated with these overlap lands. For the projected water budget "checkbook" accounting exercise conducted by all entities within the Kern Subbasin, the demands for the overlap lands are only included in the Arvin-Edison Management Area "checkbook" and the supplies for those lands include WRMWSD-provided surface water (included as an import to the Arvin-Edison "checkbook") and groundwater.

9.1.2. Data Sources

☑ **23 CCR § 354.18(d)**
☑ **23 CCR § 354.18(e)**

Per 23 CCR § 354.18(e), the best-available data were used to evaluate the water budget for the Wheeler Ridge-Maricopa Management Area and include the following:

- Precipitation Records from the various local climate stations including:
    - WRMWSD's own climate stations (WRM-2 Pumping Plant, SP-P2 Pumping Plant, Greenlee's Pasture, District Headquarters, PA-2 Pumping Plant, and Spillway Basin), *Monthly, January 1971 – December 2017*
    - Two additional climate stations (Lebec and Tejon Rancho) maintained by the National Oceanic and Atmospheric Administration (NOAA)[49]; *Monthly resolution, January 1971 – December 2015 (data availability varies by station)*

[49] See **Appendix G** for a detailed description of how climate stations are used to estimate precipitation on District lands and surrounding watersheds.

- Satellite Evapotranspiration (ET) Data from the California Polytechnic Institute's Irrigation Training and Research Center's "Mapping Evapotranspiration at High Resolution with Internalized Calibration" (ITRC-METRIC) Study, funded by the KGA[50]; *Monthly, January 1993 -December 2015* [51]

- WRMWSD Land Use Surveys from the District's internal land use records; *Seasonal*, *Spring 2001 – Spring 2017 (data availability varies by season)*

- WRMWSD Surface Water Delivery Records from the District's internal operations records; *Monthly resolution, January 1999 – December 2016*

- Historical Groundwater Level Records from selected wells within the District; *Seasonal resolution, Spring 1936 – Fall 2017 (data availability varies by well)*

- Streamflow Records for San Emigdio Creek (USGS stream gauge 11195500), *Monthly, April 1959 – September 1981*

9.1.3. Intended Purpose of Water Budget

The water budget spreadsheet model described herein (as well as the basin-wide numerical modelling approach to water budget estimation described in the Coordination Agreement and Appendices thereto) aims to assess the water budget from a purely quantitative, physical perspective, which is consistent with SGMA and the GSP Emergency Regulations (i.e., CWC § 10720.5 and 23 § CCR 354.18(a)). The spreadsheet model does not aim to evaluate the water budget from the perspective of water rights. As discussed above, the Checkbook "water accounting" approach described in the Coordination Agreement and Appendices thereto attempts to evaluate the water budget using certain management assumptions (e.g., a uniform "native yield" component to all lands within the Basin). However, nothing in this water budget information results in or is intended to be a determination of water rights within the Wheeler Ridge-Maricopa Management Area.

9.2. Water Budget Results

Results are presented below in terms of both annual values during the historical water budget period (DWR Water Years [WY] 1995 – 2014)[52], as well as long-term averages over that period. As such, some information presented here aligns with the requirements of the historical water budget described under **Section 9.3 *Current and Historical Water Budget***. below, and is not repeated there.

[50] Howes, D. 2017. 1993-2015 ITRC-METRIC ETc for Kern County. prepared for the Kern Groundwater Authority on behalf of the Cal Poly Irrigation Training and Research Center.
[51] There is no ITRC satellite ET data for calendar year 2012, as the LANDSAT satellite system employed in the ITRC-METRIC analysis was non-operational during this period. See **Appendix G** for further details.
[52] DWR Water Years run from October of the previous year to September of the current year (e.g. DWR Water Year 2015 is October 2014 – September 2015.

9.2.1. Surface Water Inflows and Outflows

☑ 23 CCR § 354.18(b)(1)

Table WB-2 presents an annual summary of the total surface water inflows to and outflows from the Wheeler Ridge-Maricopa Management Area between WY 1995 – 2015. These inflows include imported surface water, natural streamflow into the area, and precipitation. **Figure WB-3** shows the total surface water inflows by type. Total surface water inflows to the Management Area average approximately 166,000 AFY over WY 1995 – 2014 but have varied widely from year to year. On average, 68% of surface water inflows are from imported water supplies, and 30% are from direct precipitation, and 2% are from intermittent streamflow from surrounding watersheds.

Imported Water Supplies

WRMWSD has been importing surface water into its service area since 1971. Annual surface water imports (District-wide) from 1971 through WY 2015 have ranged from approximately 41,000 AFY to over 250,0000 AFY, and cumulatively a total of 7.49 million AF have been imported through September 2015 (see **Figure WB-4**)[53]. WRMWSD's primary source of imported water is the State Water Project (SWP), delivered via the California Aqueduct which runs through the District. WRMWSD has a contract with the Kern County Water Agency for 197,088 AFY of Table A water from the SWP. In addition to its Table A water allocation, in the District has access to Article 21 water when it is available (primarily during wet years). When surplus supplies are available, the District banks water in several out-of-District water banks[54]. Recovery of banked water during dry years is used to supplement SWP allocations. The District also actively and regularly pursues additional water supplies through banking programs, water transfers, and purchases. Imported surface water supplies have averaged approximately 113,000 AFY over WY 1995 – 2014 but vary substantially from year to year.

Natural Streamflow

As discussed in **Section 7.3.5 *Surface Water Bodies***, several creeks drain into the Wheeler Ridge-Maricopa Management Area from watersheds to the south and west (see **Figure HCM-20**). There are no stream gauges on these creeks that have data during the historical water budget period (WY 1995 – 2014). However, in 2018 the District installed gauges on five streams and will be establishing rating curves for these gauges over the next few years. Between April 1959 and September 1981, the USGS operated a stream gauge on San Emigdio Creek (USGS stream gauge 11195500)[55], located approximately four miles south of the District boundary. Data from this gauge were used as a proxy for all contributing watersheds (i.e., runoff as a function of precipitation was upscaled for the remaining watersheds by proportional area). During this gauge's period of record, average monthly discharge at this location ranged from 2.2 cubic feet per second (cfs) in October to 3.5 cfs in May. Annual average discharge ranged from 0.71 cfs in 1966 to 9.87 cfs in 1978. Annual peak flows ranged from a minimum of 16.0 cfs in 1968 to a maximum of 6,690 cfs in 1961. These data indicate a mildly seasonal pattern in streamflow at this location with substantial variability from year to year.

[53] Through 11 July 2019, WRMWSD has imported and delivered a total of 7,974,462 AF.
[54] WRMWSD has participated in the following groundwater banking and recovery projects: Kern Water Bank, 2800 Acres, Pioneer Project, and Berrenda Mesa Project (WRMWSD, 2015).
[55] https://waterdata.usgs.gov/ca/nwis/inventory/?site_no=11195500; upstream catchment area = 48.8 square miles.

Precipitation

Precipitation on lands within the Wheeler Ridge-Maricopa Management Area contributes some water to the overall water budget and is grouped herein with "surface water inflows". WRMWSD operates six rainfall measurement stations, four of them are within the Management Area. Data from the District's rain gauges are similar in magnitude and temporal pattern. Annual rainfall over the period of WY 1995 – 2014 ranged from approximately 1.5 inches in WY 2014 to over 16 inches in WY 1998, with an average of 6.5 inches per year. Overall, an average of approximately 49,700 AFY of precipitation fell on lands within the Management Area during this period. This water serves to wet the near surface soil and then either evaporates, contributes to crop water demand, or (when a rainfall event is intense enough or long enough) percolates through the root zone to eventually recharge groundwater. "Effective precipitation", i.e. the volume of precipitation that ultimately contributes to meeting evapotranspiration demands within the root zone, is estimated to be approximately 24,100 AFY (or 49% of total precipitation) within the Management Area.[56]

Surface Water Outflows

As shown in **Table WB-2**, natural surface water outflows from the Wheeler Ridge-Maricopa Management Area are essentially zero. This is because there are no natural stream channels that flow through the District to the north; any natural stream inflows percolate into the ground before reaching the northern District boundary.

The District uses its network of canals and pipelines to convey and deliver not only imported surface water, but also groundwater pumped by the District, and by District customers participating in its "User Input" groundwater pump-in program. These deliveries are made to customers throughout the WRMWSD service area, including some customers in the White Wolf Subbasin. At times, the District also uses the California Aqueduct for intra-District conveyance. Some of these conveyance facilities, including the California Aqueduct, cross the basin boundary between the Kern Subbasin and the White Wolf Subbasin. Therefore, outflows leaving the Wheeler Ridge-Maricopa Management Area through these conveyance facilities have been blended upstream and may include a variable percentage of groundwater depending on the given season and Water Year type.

Out-of-District Groundwater Storage

As described in **Section 5.2.3 *Conjunctive Use in the Wheeler Ridge-Maricopa Management Area***, WRMWSD also participates in several out-of-District groundwater storage and recovery programs both within and outside the Kern Subbasin. As of December 2018, the District has a combined 200,774 acre-feet (AF) stored and available to withdraw in its various banking projects outside the Management Area, including:

- 160,564 AF in the Kern Water Bank;
- 29,288 AF in the Pioneer Project; and
- 10,922 AF in the Berrenda Mesa water bank.

[56] Based on application of the U.S. Department of Agriculture-Soil Conservation Service method (USDA-SCS, 1970); see **Appendix G**.

These banked imported water supplies are not included in the quantification of total surface water inflows into the Wheeler Ridge-Maricopa Management Area or in the subsequent determination of change in groundwater storage, as they are currently being physically stored outside the Management Area boundaries. However, these banked supplies contribute to the overall storage within the Kern Subbasin. WRMWSD maintains rights to recover these banked supplies in the future per the contract terms specified in the individual agreements with the entities mentioned above.

9.2.2. Groundwater Inflows and Outflows

☑ 23 CCR § 354.18(b)(2)
☑ 23 CCR § 354.18(b)(3)

Table WB-3 and **Figure WB-5** provide an annual summary of inflows to and outflows from the groundwater system by water source type for WY 1995 – 2014. As evident from these two exhibits (as well as the groundwater hydrographs shown in **Figure GWC-5** and **Figure GWC-6**), the groundwater system is highly sensitive to climatic conditions and WRMWSD operations. As such, annual inflows and outflows vary widely depending on availability of surface water supplies to meet irrigation demands. Sources of inflow to the groundwater system include:

- Subsurface inflows across the District's northern boundary (from north to south), across its southern boundary (from southern foothills to north), and across the White Wolf Fault (from southeast to northwest);
- Infiltration of a portion of applied irrigation water;
- Infiltration of precipitation; and
- Infiltration from surface water systems (e.g., seepage from streams and channels).

Figure WB-6 provides a summary of long-term (WY 1995 – 2014) annual average inflows to and outflows from the groundwater system. Total inflows to the groundwater system averaged approximately 60,300 AFY. Approximately 20% of total inflows to the groundwater system came from subsurface groundwater inflows, 66% from infiltration of applied water, 6% from infiltration from surface water systems, and 9% from infiltration of precipitation.

Due to the District's position at the southern edge of the Kern Subbasin (near pre-development discharge areas) and the resulting low hydraulic heads which are further drawn down by pumping, there are virtually no subsurface outflows, losses to surface water systems, or evapotranspiration losses occurring from the groundwater system (see **Figure GWC-1**). As shown on **Figure WB-6**, total outflows from the groundwater system averaged approximately 57,000 AFY over WY 1995 – 2014 and were entirely related to groundwater extraction. Of this value, approximately 94% of groundwater extraction can be attributed to private agricultural pumpage, 5% to pumpage from private wells related to its "User Input" pump-in program, and the remaining 1% to pumpage from District wells.

9.2.3. Change in Groundwater Storage

☑ 23 CCR § 354.18(b)(4)

Figure WB-7, **Figure WB-8**, and **Table WB-4** present the annual and cumulative change in groundwater storage between seasonal high conditions, which are defined in this chapter to be March through February

of the following year. Note that this time window is distinct from DWR's definition of the Water Year, which runs from October of the previous year to September of the current year (e.g. DWR WY 2014 is October 2013 – September 2014); thus the values presented in **Table WB-4** are slightly different than the annual and cumulative change in storage estimates provided for DWR WY 1995 – 2014 in **Table WB-3**, **Table WB-5**, and **Table WB-6**.

Annual change in groundwater storage under the Wheeler Ridge-Maricopa Management Area averaged approximately +2,300 AFY between seasonal high conditions for the period of March 1994 – February 2015, with a cumulative change in storage of +47,700 AF over the same period. However, as seen in **Figure WB-7** and **Figure WB-8**, change in storage varied widely between years, from a -29,400 AF decrease in storage to a +51,000 AF increase in storage.

Figure WB-9, **Figure WB-10**, and **Table WB-5** compare the annual and cumulative change in storage in the Wheeler Ridge-Maricopa Management Area associated with each DWR Water Year from WY 1995 – 2014 to the water year type based on DWR's San Joaquin Valley Water Year Index. Annual change in groundwater storage under the Management Area averaged approximately +3,300 AFY from DWR WY 1995 – 2014, with a cumulative change in storage amounting to +65,700 AF over this period. These exhibits depict a clear relationship between change in groundwater storage to WY type, whereby change in storage becomes more positive with an increasing "wet" condition and more negative with an increasing "dry" condition. The net benefit of a "wet" period on groundwater conditions is especially evident in WYs 1995 – 2000, whereas the impact of a severe multi-year drought becomes increasingly evident in WYs 2012 – 2015.

9.2.4. Overdraft Conditions

☑ **23 CCR § 354.18(b)(5)**

The Kern Subbasin is designated by DWR in its latest version of *Bulletin 118 – California's Groundwater* as being in a condition of critical overdraft (DWR, 2016c). With respect to overdraft conditions and basins subject to those conditions, DWR has made the following statements:

- "A basin is subject to critical conditions of overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts." (DWR, 1980)
- Groundwater overdraft is "... the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions. Overdraft can be characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years. If overdraft continues for a number of years, significant adverse impacts may occur, including increased extraction costs, costs of well deepening or replacement, land subsidence, water quality degradation, and environmental impacts." (DWR, 2003)
- "Overdraft occurs where the average annual amount of groundwater extraction exceeds the long-term average annual supply of water to the basin. Effects of overdraft result can include seawater

> intrusion, land subsidence, groundwater depletion, and/or chronic lowering of groundwater levels".[57]

In evaluating basins for critical overdraft conditions in its most recent Bulletin 118 update, DWR considered the time period from WY 1989 – 2009. This period excludes the recent drought which began in 2012, includes both wet and dry periods, is at least 10 years in length, and includes precipitation close to the long-term average; these were all criteria used in selecting the time period.

The historical water budget information discussed herein covers the period from WY 1995 through 2014[58] (i.e., it does not cover the entire period used in DWR's evaluation). However, within the period covered by this water budget, the timeframe between WYs 1997 and 2009 (October 1996 through September 2009) meets all of the same criteria. During this 13-year period, the cumulative departure in statewide average precipitation increased by approximately 9% (DWR, 2016c Figure 1), indicating that, on average, each year was less than 1% wetter than the long-term average. Over this time period, the cumulative change in storage within the Wheeler Ridge-Maricopa Management Area increased by approximately 48,100 AF, averaging 3,700 AFY. Therefore, based on local historical water budget information, the Management Area as a whole does not show a deficit. According to the results of the "checkbook" water accounting approach for the projected baseline condition, the Management Area has a projected annual deficit of -14,665 AFY. The District has developed a suite of Projects and Management Actions (see **Section 17 Projects and Management Actions**) whose intended benefit is to prevent or eliminate any future net water budget deficit condition by the statutory deadline. As discussed in **Section 9** above, however, significant uncertainty exists regarding the actual magnitude of projected water budgets, and the water budget will be refined over time as additional data is collected. In the meantime, the planned P/MAs will be implemented according to the implementation plan outlined **Section 18 WRMWSD Plan Implementation**.

9.2.5. Water Year Types

☑ **23 CCR § 354.18(b)(6)**

Table WB-5 presents the annual total supplies, total demands, and change in groundwater storage in the Wheeler Ridge-Maricopa Management Area along with the DWR Water Year type (October – September) for the period from WY 1995 through 2015. Also shown on **Table WB-5** are the averages for total supplies, total demands and change in groundwater storage for each of the five Water Year types. **Figure WB-9** and **Figure WB-10** present the change in groundwater storage versus Water Year type on an annual and cumulative basis, respectively. The Water Year type is based on DWR's San Joaquin Valley Water Year Index. These exhibits depict a clear relationship between Water Year type and change in groundwater storage, whereby change in storage is more positive during wet and above normal Water Years and more negative during below normal, dry and critical Water Years. This variability can be traced largely to differences in supplies during different Water Year types, as the total demands are relatively constant.

[57] https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118/Critically-Overdrafted-Basins, accessed 1 July 2018.
[58] This timeframe is consistent with the water budgeting timeframes incorporated into basin-level modeling efforts for the Kern Subbasin.

The net benefit of a "wet" period on groundwater conditions is especially evident in Water Years 1995 – 2000, whereas the impact of a severe multi-year drought becomes increasingly evident in WYs 2012 – 2015.

Section 8.3 *Change in Groundwater Storage*, of the Groundwater Conditions section of this MA Plan, reported values for change in storage based on interpolated groundwater levels and specific yield values (see **Table GWC-2**). Some of those water level-based change in storage values were used in the calibration of the water budget spreadsheet model[59]. **Figure WB-11** shows a comparison of the spreadsheet model-based transient change in storage against the water level-based change in storage values for the entire District service area as well as for the Wheeler Ridge-Maricopa Management Area. As shown on **Figure WB-11**, the spreadsheet model matches the water level-based estimates well; the root-mean squared error (RMSE) for the annual rate of change for the three long-term periods (Fall 1994 – Fall 2015, Spring 2003 – Spring 2012, and Spring 2003 – Spring 2015) over the Management Area is approximately 4,300 AFY, which is a relatively small fraction (<4%) of the overall groundwater subdomain water budget magnitude (e.g., average annual groundwater inflows and outflows of approximately 60,300 AFY and 57,000 AFY, respectively).

9.2.6. Sustainable Yield

☑ **23 CCR § 354.18(b)(7)**

SGMA defines sustainable yield as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result" (CWC § 10721(w)). DWR's Water Budget BMP (DWR, 2016b), further states that "Water budget accounting information should directly support the estimate of sustainable yield for the basin and include an explanation of how the estimate of sustainable yield will allow the basin to be operated to avoid locally defined undesirable results. The explanation should include a discussion of the relationship or linkage between the estimated sustainable yield for the basin and local determination of the sustainable management criteria (sustainability goal, undesirable results, minimum thresholds, and measurable objectives)."

A key part of the codified definition and the BMP statement is the avoidance of Undesirable Results, defined as "significant and unreasonable" effects for any of the six SGMA sustainability indicators. For example, in regard to groundwater levels, declining levels during a drought do not constitute and Undesirable Result for Chronic Lowering of Groundwater Levels if extractions and groundwater recharge are managed as necessary to ensure that reduction in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods (CWC § 10721(x)(1)). Therefore, while the water budget should provide support for sustainable yield, determination of the sustainable yield for the Wheeler Ridge-Maricopa Management Area ultimately depends upon whether Undesirable Results are avoided within the time-frames required by SGMA.

A conservative estimate of the sustainable yield of the groundwater system underlying the Wheeler Ridge-Maricopa Management Area can be made by adding the average annual change in storage to the average annual groundwater extraction. This simplified approach provides a sustainable yield number

[59] The water budget spreadsheet model calibration was completed for the entire WRMWSD service area, inclusive of the area within the White Wolf Subbasin.

corresponding to the volume of groundwater that, if pumped over the water budget period of interest, would have resulted in zero change in storage – a reasonable metric for sustainability. Based on the average annual change in groundwater storage over the water budget period from WY 1995 – 2014 (i.e., +3,300 AFY) and the average annual groundwater extraction (i.e., 57,000 AFY), using this simple method the sustainable yield is conservatively estimated to be at a minimum approximately 60,300 AFY under current supply and demand conditions. This equates to an acreage-normalized sustainable yield of approximately 0.65 AFY/acre over the (92,343 acre) Wheeler Ridge-Maricopa Management Area.[60]

This number is conservative because SGMA itself does not require that the basin or any particular management area to be balanced at any particular point in time, as discussed above. As mentioned above, the sustainable yield estimate does not factor in the additional ~200,700 AF of imported District supplies currently stored within other groundwater banking facilities outside the District but within the Kern Basin (see **Section 9.2.1**).

This sustainable yield number is also inherently conservative in that it is based on a pumping rate that, under similar hydrologic conditions as the historical period, would result in no decrease in storage. As discussed in **Section 13.1** ***Undesirable Results for Chronic Lowering of Groundwater Levels*** and **Section 13.2** ***Undesirable Results for Reduction of Groundwater Storage***, the locally defined criteria for what constitutes an Undesirable Result for groundwater levels and change in storage is not strictly limited to a zero net decrease; rather, those criteria allow for some operation of the basin at groundwater levels and storage levels below current conditions. For the other relevant sustainability indicators (i.e., water quality degradation and land subsidence), a sustainable yield value that amounts to a zero change in storage would also be expected to avoid Undesirable Results. Therefore, this sustainable yield estimate takes into account Undesirable Results, as required by CWC § 10721(w).

Moreover, as described earlier in this section, WRMWSD has also participated in a Basin-wide numerical modeling effort in addition to developing a more refined local water budget for their Management Area. Results from the C2VSim-FG historical water budget model, extracted for model elements corresponding approximately to the Management Area, indicate an average annual groundwater extraction rate of approximately 107,200 AFY for the historical period of WY 1995 – 2014, and an average annual change in storage of -7,900 AFY during that same period. Under the same approach as described above, the C2VSim-FG historical water budget results indicate a sustainable yield estimate of 99,300 AFY within the Management Area, or 1.08 AFY/acre. It is important to note that this model is intended to be a Basin-wide assessment of groundwater conditions and, unlike the local water budget described above, is not specifically calibrated to the WRMWSD service area. Additional reconciliation of basin water budgeting efforts is a high priority for basin GSAs as part of GSP implementation.

[60] The acreage-normalized sustainable yield values presented herein should not be viewed as an "allocation" but rather is presented herein to facilitate comparisons to commonly-used agronomic quantities (e.g., crop water demands in AFY/ac).

9.3. Current and Historical Water Budget

9.3.1. Current Water Budget

☑ 23 CCR § 354.18(c)(1)

This section presents results for the "current" water budget, based on values extracted from the spreadsheet model for WY 2015. This is consistent with how "current" is being defined by the KGA in the KGA Umbrella GSP.

WY 2015 was classified as the third consecutive "Critical" (dry) Water Year and fourth consecutive "Dry" or "Critical" Water Year within the San Joaquin Valley and is thus representative of perhaps the worst drought condition in recent history within the region.

Table WB-6 and **Figure WB-12** provide a summary of total inflows and outflows to the Wheeler Ridge-Maricopa Management Area for WY 2015, while **Table WB-3** and **Figure WB-13** provide a summary of groundwater inflows and outflows.

Total inflows to the Wheeler Ridge-Maricopa Management Area amounted to approximately 150,000 AF in WY 2015, comprised of 36% precipitation, 56% surface water imports, 6% subsurface inflows, and 2% natural surface water inflows. This resulted in a total inflow to the groundwater system of approximately 57,600 AF, comprised of 15% subsurface inflow, 70% infiltration of applied water, 6% infiltration from surface water systems, and 9% infiltration of precipitation.

Total outflows from the Wheeler Ridge-Maricopa Management Area amounted to approximately 187,000 AF in WY 2015, comprised entirely (100%) of evapotranspiration (consumptive use by vegetation). This resulted in a total outflow from the groundwater system of approximately 103,000 AF, 100% of which is due to groundwater extraction.

As evident from these water budget values, the Wheeler Ridge-Maricopa Management Area (like nearly all areas in the Kern Subbasin and San Joaquin Valley as a whole) was impacted significantly by the extreme drought condition of WY 2015, resulting in a net loss of approximately -42,900 AF of groundwater storage during this timeframe. However, as evidenced by the recovery of water levels and storage following previous dry periods, the groundwater system is resilient, and the "current" (WY 2015) conditions are not indicative of a normal condition but rather represent the late stages of a major drought period from which the groundwater system has already started to recover (see **Figure GWC-6**).

9.3.2. Historical Water Budget

☑ 23 CCR § 354.18(c)(2)

Water budget results are presented for the historical water budget period in **Section 9.2 *Water Budget Results***, including associated figures and tables, and are not repeated here. Rather, this section focuses on providing: (a) a quantitative evaluation of historical surface water availability and reliability (23 CCR § 354.18(d)(2)(A)), (b) a quantitative assessment of the historical water budget (23 CCR § 354.18(d)(2)(B)), and (c) a description of how historical conditions have impacted the ability of the Wheeler Ridge-Maricopa Management Area to be operated within its sustainable yield (23 CCR § 354.18(d)(2)(C)).

Historical Surface Water Availability and Reliability

☑ 23 CCR § 354.18(c)(2)(A)

As described above, WRMWSD's only contracted source of surface water supply is its SWP supply contract with KCWA for 197,088 AFY of Table 1 water. Between WY 1995 – 2014, WRMWSD received an average allocation (entitlement) of approximately 73% of this contractual amount. **Figure WB-14** presents an annual breakdown of total imported SWP supplies relative to the District's existing SWP contract volumes.

This large inter-annual variability in supply indicates that, while SWP water remains the primary and most important source to the District, its reliability is not iron-clad, and has been impacted significantly in recent years due to natural drought, and by federal court rulings and other regulatory measures which have served to limit pumping of northern California supplies through the Delta to the southern part of the state. For this reason, the District actively and regularly pursues additional water supplies through transfers, purchases, exchanges, and banking programs.

Quantitative Assessment of Historical Water Budget

☑ 23 CCR § 354.18(c)(2)(B)

Based on the DWR San Joaquin Valley Water Year Index for the 20-year period from WY 1995 through 2014, this period included four "critical" (dry) years, four dry years, two below normal years, three above normal year, and seven wet years. The first third of this period was relatively wet, the middle third was a mix of wet and dry years, and the last third of the period was extremely dry. This climatic factor is clearly reflected in the water budget for the Wheeler Ridge-Maricopa Management Area, whereby the groundwater system shows consistent increases in storage with wetter conditions and decreases in storage under "drier" conditions (see **Figure WB-9**, **Figure WB-10**, and **Table WB-5**).

Table WB-6 and **Figure WB-15** provide a tabular and graphical breakdown of total inflows and outflows to the Wheeler Ridge-Maricopa Management Area for WY 1995 – 2014, with a summary of average annual total inflows and outflows provided in **Figure WB-16**. **Table WB-3** and **Figure WB-5** provide a tabular breakdown of inflows and outflows to the groundwater system underlying the Management Area for WY 1995–2014, with a summary of average annual groundwater inflows and outflows provided in **Figure WB-6**.

Total inflows to the Wheeler Ridge-Maricopa Management Area amounted to an average of 178,000 AFY for WY 1995 – 2014, including 64% from surface water imports, 28% from precipitation, 7% from subsurface inflows, and 2% from natural surface water inflows. This resulted in an average net inflow to the groundwater system of approximately 60,300 AFY, comprised of 66% of infiltration of applied water, 20% of subsurface inflow, 6% of infiltration from surface water systems, and 9% of infiltration of precipitation.

Total annual outflows from the Wheeler Ridge-Maricopa Management Area amounted to 175,000 AFY for WY 1995 – 2014, comprised nearly entirely (99.99%) of evapotranspiration (consumptive use by vegetation). This resulted in a net outflow from the groundwater system of approximately 57,000 AF, 100% of which comes from groundwater extraction.

Operation Within Sustainable Yield

☑ 23 CCR § 354.18(c)(2)(C)

Average annual change in groundwater storage under the Wheeler Ridge-Maricopa Management Area amounted to approximately +3,300 AFY between WY 1995 – 2014, resulting in a cumulative change in groundwater storage of 65,700 AF during this period. This cumulative storage change over a 20-year historical record, that includes the recent severe drought, indicates that the groundwater system is in a state of relative balance. Although some years in this period showed negative changes in storage as much as -34,000 AF, the calculated transient change in storage and water levels measured in wells within the Management Area (see **Figure WB-18**, **Figure GWC-5**, and **Figure GWC-6**) demonstrate that the groundwater system is sensitive to climatic variability and WRMWSD operations, with decreases in storage during drought followed by increases in storage during wet periods.

As discussed previously, through September 2015 WRMWSD has imported nearly 7.5 million AF of water into its service area since it began imports in 1971. Since that time, the groundwater system has experienced a long-term increase in storage of approximately 77,100 AF (see **Table GWC-2**) and groundwater elevations have increased in areas where imported surface water is delivered (see **Figure GWC-5**). Clearly District operations have resulted in a net benefit to the groundwater supply beneath the Wheeler Ridge-Maricopa Management Area, demonstrating successful groundwater management.

9.4. Projected Water Budget

☑ 23 CCR § 354.18(c)(3)

Projected water budgets are required as a way to estimate future conditions of water supply and demand within a basin, as well as the aquifer response to implementation of the Plan over the planning and implementation horizon. To develop the projected water budget, the same tools and methodologies that were used for the historical and current water budget were used, with updated inputs for climate variables (i.e., precipitation and ET) and water supply assumptions (i.e., imported water supplies). The chief purpose of this projected water budget analysis is to assess the magnitude of the net water supply deficit that would need to be addressed through Projects and Management Actions to prevent Undesirable Results (discussed further in **Section 13 *Undesirable Results*** and **Section 17 *Projects and* Management Actions**) and achieve the Sustainability Goal. This section describes the development and results of the projected water budget for the Wheeler Ridge-Maricopa Management Area.

9.4.1. Development of 50-Year Analog Period

☑ 23 CCR § 354.18(c)(3)(A)
☑ 23 CCR § 354.18(c)(3)(B)
☑ 23 CCR § 354.18(c)(3)(C)

Per 23 CCR § 354.18(c)(3)(A), the projected water budgets must use 50 years of historical precipitation, evapotranspiration, and streamflow information as the basis for evaluating future conditions under baseline and climate-modified scenarios. The process by which a 50-year period of precipitation, evapotranspiration and streamflow information was developed is based on the process adopted by all

GSAs within the Basin, as described in the KGA Umbrella GSP and the Coordination Agreement and Appendices thereto. That process is briefly summarized here.

To develop the required 50 years-worth of hydrologic input information, first an "analog period" was created from the 20 years-worth of historical information (WY 1995-2014) by combining the years in a specific way that, on average, maintained the long-term average hydrologic conditions. This approach, which was used for both the spreadsheet water budget model approach and the basin-wide C2VSim-FG modeling approach, allowed for the creation of a complete 50-year period to inform the projected water budget analysis, even when certain component datasets were not available for that length of time. The sequence of actual years that were combined to create the 50-year analog period is as follows:

- Analog Years 1-12: Based on actual years 2003-2014
- Analog Years 13-32: Based on actual years 1995-2014
- Analog Years: 33-50: Based on actual years 1995-2012

The above mapping of actual years to analog years within the required 50-year projected water budget period applies to precipitation and ET datasets. It also applies to imported surface water datasets with some additional modifications as described in the following section.

9.4.2. Development of Projected Water Budget Scenarios

☑ **23 CCR § 354.18(c)(3)(A)**
☑ **23 CCR § 354.18(c)(3)(B)**
☑ **23 CCR § 354.18(c)(3)(C)**

Using the 50-year analog period, three projected water budget scenarios were developed for this analysis: a baseline scenario, and 2030 climate change scenario, and a 2070 climate change scenario. Development of the three scenarios was done consistent with the agreed-upon process being used basin-wide. Details of the scenario development are contained within in the KGA Umbrella GSP and the Coordination Agreement and Appendices thereto and are briefly summarized here.

Baseline Scenario

Per 23 CCR § 354.18(c)(3)(C), the projected water budgets must use "the most recent water supply information as the baseline condition for estimating future surface water supply". Consistent with the process applied basin-wide, the information used to inform the baseline conditions for SWP supplies is based on information published by and/or obtained from DWR, including data from DWR's CalSim water resources planning model, historical SWP operations data, and impacts from new operations regulations pursuant to the 2008/2009 Long-Term Operations Criteria and Plan (OCAP) Biological Opinion (BO).[61,62]

[61] CalSim deliveries data from: https://data.cnra.ca.gov/dataset/sgma-climate-change-resources; SWP operational data from: https://water.ca.gov/Programs/State-Water-Project/Operations-and-Maintenance/Monthly-and-Annual-Operations-Reports; new operations regulations pursuant to the 2008-2009 OCAP BOs used as basis for calculation of SWP impacts by KGA's consultant.

[62] The District has a long history of actively striving to achieve sustainable groundwater use within the District. In fact, the District was specifically formed to contract for a substantial surface water supply because of declining groundwater levels. Since that time, groundwater levels within the District have stabilized, and in many areas have risen. In the 1990s, with regulatory shifts in the State Water Project, the District invested in groundwater storage facilities in order to capture and recharge wet

As part of the basin-wide approach to Baseline Scenario development, certain substitutions and/or adjustments to years were made to the 50-year analog period for certain water supplies because the available datasets did not cover the entire historical water budget time period (WY 1995-2014). These substitutions included the following:

- Adjusting years 2004-2007 for SWP supplies to account for the recent regulatory changes to SWP operations made effective in 2008 and 2009 (i.e., the OCAP BO[63]); and
- Replacing years 1995-2003 for SWP supplies with values from DWR's 2030-level CalSim study[64], increased by 3.03%, again to account for the OCAP BO.

The above substitutions and adjustments were made by KGA GSA consultants based upon their analysis of the DWR studies and were provided to all Districts as a basis for development of projected water budgets. As such, the information used for this analysis is consistent with the basin-wide approach.

2030 Climate Change Scenario

☑ 23 CCR § 354.18(d)(3)

In order to estimate the potential effects on the projected water budget of climate change during the GSP implementation period (i.e., between 2020 and 2040), a water budget scenario based on 2030 climate change factors published by DWR was developed. For this scenario, precipitation and ET were both adjusted based on the change factors published by DWR. SWP supply projections were taken from the DWR 2030-Level CalSim studies, except for years 2004-2007 which were taken as the actual SWP data, adjusted for the OCAP BO and reduced by 3.03%, and years 2008-2014 which were taken as the actual SWP data, reduced by 3.03%. Again, the assumptions upon which this scenario was based are from the KGA consultant's analysis of DWR information and are therefore consistent with the basin-wide approach.

2070 Climate Change Scenario

☑ 23 CCR § 354.18(d)(3)

In order to estimate the potential effects on the projected water budget of climate change towards the end of the planning and implementation horizon (i.e., 50 years out into the future), a water budget scenario based on 2070 "central tendency" climate change factors for the published by DWR was developed. It should be noted that estimates of climate change impacts on water supplies this far into the future have significant uncertainty. For this scenario, precipitation and ET were both adjusted based on the 2070 "central tendency" change factors published by DWR. SWP supply projections were taken from the DWR 2070-Level CalSim studies, except for years 2004-2007 which were taken as the actual SWP data, adjusted for the OCAP BO and reduced by 8.09%, and years 2008-2014 which were taken as the actual

year supplies to augment the District's contractual supplies. The Wenger decision in 2008, and the subsequent Biological Opinions, had a dramatic negative impact on the availability of the District's contractual supplies. Although the District does not agree with the decision nor the subsequent Biological Opinions, it has been forced to adapt to those negative impacts.

[63] https://www.fws.gov/sfbaydelta/Documents/SWP-CVP_OPs_BO_12-15_final_OCR.pdf https://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Operations,%20Criteria%20and%20Plan/nmfs_biological_and_conference_opinion_on_the_long-term_operations_of_the_cvp_and_swp.pdf

[64] Consistent set of CALSIM operations studies at current, 2030 and 2070 climate levels for Bay Delta Conservation Plan evaluation provided by DWR Bay Delta Office staff.

SWP data, reduced by 8.09%. Again, the assumptions upon which this scenario was based are from the KGA consultant's analysis of DWR (CalSim) information and are therefore consistent with the basin-wide approach.

9.4.3. Projected Water Budget Results

Results of the projected water budget analysis are summarized in **Table WB-7** for both the entire water budget domain and for the groundwater subdomain, as well as in **Figure WB-19**. As shown in **Table WB-7**, water budget components are presented as averages over the 20-year historical period and averages over the 50-year analog period for the Baseline, 2030 Climate Change, and 2070 Climate Change scenarios. Water budget components are grouped into inflows and outflows, relative to the domain or subdomain they pertain to (also see **Figure WB-2**). Also shown in **Table WB-7** is the average annual change in groundwater storage for the historical period and each projected scenario. Results from **Table WB-7** were subsequently used to inform the development of Projects and Management Actions (P/MAs) as further described in **Section 17** ***Projects and Management Actions***. Implementation of the P/MAs described in **Section 17** were then input into the 2030 and 2070 projected water budget model scenarios to assess their estimated impacts to the groundwater balance within the Wheeler Ridge-Maricopa Management Area. Results of this exercise are presented in **Table WB-8** and briefly mentioned below.

Baseline Scenario

In the Baseline Scenario, the water budget components that are not dependent on surface water imports differ only slightly from the historical period. The percent difference from the historical average period to the Baseline Scenario ranges from approximately -4.0% for M&I consumptive use (including evapotranspiration from urban lands) to natural surface water inflows to -1.2% for precipitation. This demonstrates that the 50-year analog period is a good representation of the historical conditions.

The water budget components that are dependent on surface water imports differ more significantly from the historical averages, due to the different assumptions about imported surface water availability under the Baseline Scenario, as discussed above. In particular, the surface water imports component is approximately 17.7% lower under the Baseline Scenario than it is under the historical period, due a projected decrease in SWP supplies due to factors including the OCAP BO.

Overall, the Baseline Scenario indicates a net "deficit" (i.e., outflows greater than inflows) of approximately -14,700 AFY.

2030 Climate Change Scenario

Under the 2030 Climate Change Scenario, changes in precipitation, natural surface water inflows, and M&I consumptive use relative to the Baseline Scenario are all relatively small (i.e., relative changes of 1.1% to 2.9% and absolute changes of approximately 0 AFY to 550 AFY). The most significant changes relative to the Baseline Scenario are a reduction in surface water imports of approximately -2,800 AFY (-3.0%) and an increase in evapotranspiration of approximately 4,700 AFY (+2.8%).

Overall, the 2030 Climate Change Scenario indicates a net deficit of approximately -21,400 AFY. Consistent with the approach being used by all KGA GSA members (and other GSAs in the basin), this estimated net deficit under the 2030 Climate Change Scenario is the amount that the Projects and Management Actions

are targeted to address by the GSP implementation deadline (i.e., January 2040).[65] As shown on **Table WB-8** and further described in **Section 17.1.4** ***Implementation Glide Path*** and in **Table PMA-2**, WRMWSD has proposed to address approximately 60% of the projected deficit of -21,400 AFY by the GSP implementation deadline (i.e. January 2040) through adoption of supply augmentation projects (i.e., ~12,900 AFY), and may address the remaining 40% of the projected deficit (i.e., ~8,600 AFY) through adoption of demand reduction management actions as necessary in order to achieve and maintain the sustainability goal within the Management Area.

It should be noted that the results from the numerical model show that, upon implementation of the planned Projects and Management Actions, the Wheeler Ridge-Maricopa Management Area achieves its sustainability goal (i.e., avoids Minimum Thresholds and Undesirable Results and achieves Measurable Objectives for Chronic Lowering of Groundwater Levels) (see **Section 17.8.2** ***Evaluation Relative to Water Level Sustainability Criteria***).

2070 Climate Change Scenario

Under the 2070 Climate Change Scenario, changes in precipitation, natural surface water inflows, and M&I consumptive use relative to the Baseline Scenario are somewhat greater than in the 2030 Climate Change Scenario, but still not significant (i.e., relative changes of -1.3% to 6.8% and absolute changes of approximately 0 AFY to -700 AFY). Surface water imports are lower by approximately -7,200 AFY (-7.7%) and evapotranspiration is greater by approximately +10,700 AFY (+6.2%).

Overall, the 2070 Climate Change Scenario indicates a net deficit of approximately -33,300 AFY. As shown on **Table WB-8** and further described in **Section 17.1.4** ***Implementation Glide Path*** and in **Table PMA-2**, WRMWSD has proposed to address approximately 56% of the projected deficit of -33,300 AFY by the end of the 50-year GSP planning and implementation horizon (i.e. January 2070) through adoption of supply augmentation projects (i.e., ~18,800 AFY), and may address the remaining 44% of the projected deficit (i.e., ~14,600 AFY) through adoption of demand reduction management actions as necessary in order to achieve and maintain the sustainability goal within the Management Area..

It should be noted that the results from the numerical model show that, upon implementation of the planned Projects and Management Actions, the Wheeler Ridge-Maricopa Management Area achieves its sustainability goal (i.e., avoids Minimum Thresholds and Undesirable Results and achieves Measurable Objectives for Chronic Lowering of Groundwater Levels) (see **Section 17.8.2** ***Evaluation Relative to Water Level Sustainability Criteria***).

[65] The District, as required by law, is planning on implementing Projects and Management Actions to address the potential impacts due to climate change. The District does note that making planning decisions based on models has real and substantial economic impacts on District landowners and residents and does not agree with this exercise.

TABLE WB-2

Annual Surface Water Inflows and Outflows by Source Type

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

DWR Water Year (Oct - Sept)	INFLOWS [AFY]						OUTFLOWS [AFY]				
	Total Imported Surface Water (b)	*Natural Inflows*				TOTAL SURFACE WATER INFLOWS	*Surface Water Exports*	*Surface Water Deliveries to Overlap Lands*	*Natural Outflows*		TOTAL SURFACE WATER OUTFLOWS
		Direct Precipitation			Streamflow into District				Streamflow out of District	Runoff of Excess Precip.	
		Non-Overlap Lands	Overlap Lands	TOTAL							
Historical Water Budget Period (DWR WY 1995 - 2014)											
1995	120,977	67,393	4,118	71,511	6,625	**199,113**	0	7,102	0	0	**0**
1996	150,040	61,041	3,730	64,771	2,279	**217,090**	0	8,842	0	0	**0**
1997	147,817	46,179	2,822	49,001	2,562	**199,380**	0	10,282	0	0	**0**
1998	108,888	118,987	7,271	126,258	8,904	**244,049**	0	6,446	0	0	**0**
1999	126,098	50,787	3,103	53,890	3,701	**183,689**	0	7,849	0	0	**0**
2000	132,736	34,843	2,129	36,972	2,451	**172,159**	0	8,406	0	0	**0**
2001	95,287	49,374	3,017	52,391	3,228	**150,907**	0	6,315	0	0	**0**
2002	93,727	27,223	1,664	28,887	1,252	**123,866**	0	6,639	0	0	**0**
2003	86,002	57,801	3,532	61,333	4,165	**151,500**	0	6,101	0	0	**0**
2004	97,212	34,477	2,107	36,583	2,298	**136,094**	0	6,965	0	0	**0**
2005	92,378	61,076	3,732	64,808	7,402	**164,588**	0	6,097	0	0	**0**
2006	104,769	43,555	2,662	46,216	2,608	**153,594**	0	6,518	0	0	**0**
2007	120,260	30,176	1,844	32,020	1,870	**154,149**	0	7,702	0	0	**0**
2008	121,328	16,782	1,026	17,808	1,555	**140,691**	0	6,114	0	0	**0**
2009	109,427	35,367	2,161	37,529	1,762	**148,718**	0	6,195	0	0	**0**
2010	110,195	49,311	3,013	52,324	1,113	**163,632**	0	5,742	0	0	**0**
2011	111,698	77,100	4,711	81,811	3,178	**196,687**	0	5,698	0	0	**0**
2012	123,256	35,585	2,175	37,760	2,073	**163,089**	0	6,669	0	0	**0**
2013	120,138	29,627	1,810	31,438	1,848	**153,424**	0	6,629	0	0	**0**
2014	96,394	10,560	645	11,205	1,211	**108,810**	0	4,920	0	0	**0**
TOTAL [AF]	2,268,628	937,243	57,272	994,516	62,087	3,325,230	0	137,229	0	0	**0**
AVERAGE	*113,431*	*46,862*	*2,864*	*49,726*	*3,104*	*166,262*	*0*	*6,861*	*0*	*0*	*0*
%	*68.2%*	*28.2%*	*1.7%*	*29.9%*	*1.9%*	-	-	-	-	-	**-**
Current Water Budget Period (DWR WY 2015											
2015	83,710	51,321	3,136	54,457	2,676	**140,842**	0	4,478	0	0	**0**
%	*59.4%*	*36.4%*	*2.2%*	*38.7%*	*1.9%*	-	-	-	-	-	**-**

Abbreviations

AFY = acre-feet per year
DWR = California Department of Water Resources
Precip. = precipitation
WRMWSD = Wheeler Ridge-Maricopa Water Storage District
WY = Water Year

Notes

(a) All values reported in acre-feet per year (AFY).
(b) Surface water import sources include State Water Project water, as well as recovered groundwater from out-of-district banking operations, including (1) Kern Water Bank, (2) Pioneer Project, (3) Berrenda Mesa Project, and (4) 2800 Acres. These sources are blended into the California Aqueduct prior to delivery to WRMWSD customers and thus cannot be independently quantified.

TABLE WB-3

Annual Inflows to and Outflows from the Groundwater System, and Change in Groundwater Storage

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

DWR Water Year (Oct - Sept)	INFLOWS [AFY]									OUTFLOWS [AFY]									CHANGE IN STORAGE	
										Groundwater Extraction										
	Subsurface Groundwater Inflow	Infiltration of Precipitation			Infiltration from Surface Water Systems	Infiltration of Applied Water			**TOTAL INFLOWS TO GROUND WATER SYSTEM**	Pumpage from District Wells	Pumpage from Private Wells - for User Input Program	Pumpage from Private Wells - for Private Use			Discharge to Surface Water Sources	Evapo-transpiration (c)	Subsurface Groundwater Outflow	**TOTAL OUTFLOWS FROM GROUND-WATER SYSTEM**	**Annual Change in Groundwater Storage [AFY]**	*Cumulative Change in Groundwater Storage Since WY 1995 [AF]*
		Non-Overlap Lands	Overlap Lands	TOTAL		Non-Overlap Lands	Overlap Lands	TOTAL				Non-Overlap Lands	Overlap Lands	TOTAL						
Historical Water Budget (DWR WY 1995 - 2014)																				
1995	22,957	7,720	472	8,192	6,307	44,921	2,745	47,666	**85,122**	139	0	60,375	3,689	64,065	0	0	0	**64,204**	**15,125**	*15,125*
1996	10,578	7,392	452	7,844	2,907	50,284	3,073	53,357	**74,685**	0	0	65,039	3,974	69,013	0	0	0	**69,013**	**-4,020**	*11,105*
1997	11,897	5,296	324	5,619	3,128	45,736	2,795	48,531	**69,175**	0	0	58,247	3,559	61,806	0	0	0	**61,806**	**4,946**	*16,051*
1998	30,923	14,826	906	15,732	8,090	54,583	3,335	57,918	**112,663**	63	0	54,550	3,333	57,883	0	0	0	**57,947**	**49,878**	*65,929*
1999	15,316	6,131	375	6,505	4,020	49,369	3,017	52,386	**78,227**	13	0	64,941	3,968	68,910	0	0	0	**68,922**	**22,381**	*88,310*
2000	11,239	4,059	248	4,307	3,041	41,460	2,533	43,993	**62,581**	0	0	58,444	3,571	62,016	0	0	0	**62,016**	**51**	*88,361*
2001	9,982	5,738	351	6,088	3,649	34,311	2,097	36,408	**56,128**	1,270	943	50,887	3,110	53,997	0	0	0	**56,210**	**862**	*89,223*
2002	4,055	2,345	143	2,489	2,104	28,855	1,763	30,618	**39,265**	0	191	66,780	4,081	70,860	0	0	0	**71,051**	**-31,814**	*57,409*
2003	12,794	4,630	283	4,913	4,383	28,581	1,746	30,327	**52,416**	0	0	50,809	3,105	53,913	0	0	0	**53,913**	**-6,413**	*50,997*
2004	7,565	2,793	171	2,963	2,922	30,847	1,885	32,732	**46,181**	0	0	54,865	3,353	58,217	0	0	0	**58,217**	**-21,726**	*29,271*
2005	23,988	4,976	304	5,280	6,915	28,923	1,767	30,690	**66,873**	8	0	32,635	1,994	34,629	0	0	0	**34,637**	**27,419**	*56,690*
2006	10,409	4,544	278	4,821	3,165	33,739	2,062	35,801	**54,196**	0	0	34,710	2,121	36,831	0	0	0	**36,831**	**18,718**	*75,408*
2007	10,819	3,367	206	3,573	2,587	32,411	1,981	34,392	**51,370**	0	0	45,592	2,786	48,378	0	0	0	**48,378**	**446**	*75,854*
2008	7,952	1,940	119	2,058	2,340	30,597	1,870	32,466	**44,817**	1,388	1,051	41,813	2,555	44,368	0	0	0	**46,807**	**-14,703**	*61,152*
2009	7,708	3,646	223	3,869	2,503	30,251	1,849	32,099	**46,179**	0	7,906	38,005	2,322	40,327	0	0	0	**48,233**	**-1,949**	*59,203*
2010	5,353	4,683	286	4,969	1,995	35,684	2,181	37,865	**50,181**	1,631	7,719	34,207	2,090	36,297	0	0	0	**45,648**	**6,846**	*66,049*
2011	12,006	7,792	476	8,268	3,610	37,448	2,288	39,736	**63,620**	236	1,398	25,539	1,561	27,100	0	0	0	**28,734**	**53,698**	*119,747*
2012	7,788	3,435	210	3,645	2,746	37,381	2,284	39,665	**53,844**	960	1,900	56,210	3,435	59,645	0	0	0	**62,505**	**3,863**	*123,611*
2013	7,143	3,340	204	3,544	2,570	38,071	2,326	40,397	**53,654**	1,131	8,260	65,658	4,012	69,670	0	0	0	**79,061**	**-24,061**	*99,550*
2014	5,110	1,373	84	1,457	2,071	33,098	2,023	35,121	**43,759**	2,636	24,728	54,289	3,317	57,607	0	0	0	**84,971**	**-33,839**	*65,711*
TOTAL	235,582	100,024	6,112	106,137	71,050	746,549	45,620	792,169	**1,204,937**	9,475	54,095	1,013,595	61,938	1,075,533	0	0	0	**1,139,104**	**65,711**	*65,711*
AVERAGE	*11,779*	*5,001*	*306*	*5,307*	*3,552*	*37,327*	*2,281*	*39,608*	**60,247**	*474*	*2,705*	*50,680*	*3,097*	*53,777*	*0*	*0*	*0*	***56,955***	**3,286**	-
%	*20%*	*8%*	*1%*	*9%*	*6%*	*62%*	*4%*	*66%*	-	*0.8%*	*5%*	*89%*	*5%*	*94%*	*0%*	*0%*	*0%*	-	-	-
Current Water Budget (DWR WY 2015)																				
2015	8,640	5,044	308	5,352	3,217	38,081	2,327	40,408	**57,618**	2,410	31,253	65,327	3,992	69,319	0	0	102	**103,084**	**-42,898**	-
%	*15%*	*8.8%*	*0.5%*	*9%*	*6%*	*66%*	*4%*	*70%*	-	*2.3%*	*30%*	*63%*	*4%*	*67%*	*0%*	*0%*	*0%*	-	-	-

Abbreviations

AF = acre-feet
AFY = acre-feet per year
DWR = California Department of Water Resources
ITRC = Cal Poly Irrigation Training & Research Center
WY = Water Year

Notes

(a) All values reported in acre-feet per year (AFY), except cumulative change in storage (reported in acre-feet).

(b) This value includes all groundwater extractions from WRMWSD wells for its long-term groundwater banking and recovery program. On certain years, this value also includes minor groundwater inputs to the District delivery system from private wells that have elected to participate in the District's groundwater "pump-in" program to augment delivery supplies in times of drought.

(c) There are years for which ITRC-measured evapotranspiration from non-irrigated lands exceeds the total measured rainfall to these lands. In these cases, residual water demands on non-irrigated lands are accounted for as a reduction in total infiltration ("inflows") rather than an explicit groundwater "outflow" due to evapotranspiration. This is based on the understanding that the groundwater table is fully disconnected from the root zone under the District. ITRC-measured residual water demands on non-irrigated lands are likely caused in part by evaporation from local surface water bodies (e.g., storage ponds) and/or are met by a reduction of root zone soil moisture, which is not explicitly accounted for in the water budget spreadsheet model.

TABLE WB-4

Annual and Cumulative Change in Groundwater Storage between Seasonal Highs (Mar - Feb)

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

Period of Reference [m/yy]	Annual Change in Groundwater Storage [AFY]	Cumulative Change in Groundwater Storage [AF]
3/94 - 2/95	676	676
3/95 - 2/96	2,314	2,989
3/96 - 2/97	4,749	7,738
3/97 - 2/98	12,156	19,894
3/98 - 2/99	49,356	69,251
3/99 - 2/00	4,753	74,004
3/00 - 2/01	5,654	79,658
3/01 - 2/02	-12,446	67,212
3/02 - 2/03	-27,481	39,732
3/03 - 2/04	-10,773	28,959
3/04 - 2/05	-8,647	20,312
3/05 - 2/06	19,552	39,864
3/06 - 2/07	21,652	61,517
3/07 - 2/08	-11,478	50,038
3/08 - 2/09	-12,299	37,740
3/09 - 2/10	-2,415	35,325
3/10 - 2/11	26,890	62,215
3/11 - 2/12	50,964	113,180
3/12 - 2/13	-8,233	104,946
3/13 - 2/14	-29,420	75,526
3/14 - 2/15	-27,863	47,664
TOTAL	47,664	47,664
AVERAGE	2,270	-

TABLE WB-5

Supplies, Demands, and Change in Groundwater Storage vs. DWR Water Year Type

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

DWR Water Year (Oct - Sept)	DWR Water Year Type (a)	Total Supplies [AFY] (b)	Total Demands [AFY] (c)	Annual Change in Groundwater Storage [AFY]
1995	W	222,070	210,575	15,125
1996	W	227,668	229,141	-4,020
1997	W	211,276	202,384	4,946
1998	W	274,972	210,421	49,878
1999	AN	199,005	191,299	22,381
2000	AN	183,398	186,354	51
2001	D	160,889	163,299	862
2002	D	127,921	165,102	-31,814
2003	BN	164,294	172,178	-6,413
2004	D	143,658	166,256	-21,726
2005	W	188,576	152,979	27,419
2006	W	164,003	142,920	18,718
2007	C	164,968	175,259	446
2008	C	148,643	158,517	-14,703
2009	BN	156,426	156,802	-1,949
2010	AN	168,985	150,323	6,846
2011	W	208,694	151,074	53,698
2012	D	170,877	178,157	3,863
2013	C	160,567	180,823	-24,061
2014	C	113,920	151,114	-33,839
2015	C	149,483	187,327	-42,898

Water Year Type (a)	Number of Years During WY 1995 - 2015 Period	Average Total Supplies [AFY] (b)	Average Total Demands [AFY] (c)	Average Annual Change in Groundwater Storage [AFY]
C	5	147,516	170,608	-23,011
D	4	150,837	168,204	-12,204
BN	2	160,360	164,490	-4,181
AN	3	183,796	175,992	9,760
W	7	213,894	185,642	23,681

Abbreviations

AFY = acre-feet per year
DWR = California Department of Water Resources
WY = Water Year

Notes:

(a) DWR Water Year Types are as follows: W = wet, AN = above normal, BN = below normal, D = dry, C = critical
(b) Total supplies equal the sum of inflow terms (see Table WB-6 for individual inflow components).
(c) Total demands equal the sum of outflow terms (see Table WB-6 for individual outflow components).
(d) The apparent residual of water-budget calculated change in groundwater storage to [Total Inflows - Total Outflows] can be attributed to the deep percolation lag effect in the water budget spreadsheet model, which serves to delay infiltration from reaching the groundwater system. See "Appendix E - Methods & Data Used in the Water Budget Spreadsheet Model Approach" for further details on how monthly storage change is calculated within the water budget spreadsheet model.

Sources:

(1) DWR Water Year Type is from DWR's Water Year Hydrologic Classification Indices for the San Joaquin Valley <http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST>.

TABLE WB-6

Annual Total Inflows, Outflows, and Change in Groundwater Storage

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

DWR Water Year (Oct - Sept)	INFLOWS [AFY]							OUTFLOWS [AFY]									CHANGE IN STORAGE	
	Subsurface Groudwater Inflow	Precipitation			Surface Water Imports	Natural Surface Water Inflows	**TOTAL INFLOWS**	Evapotranspiration (b)			M&I Consumptive Use	Surface Water Exports	*Surface Water Deliveries to Overlap Lands*	Natural Surface Water Outflow	Subsurface Groundwater Outflow	**TOTAL OUTFLOWS**	**Annual Change in Groundwater Storage [AFY]** (c)	*Cumulative Change in Groundwater Storage Since WY 1995 [AF]*
		Non-Overlap Lands	Overlap Lands	TOTAL				Non-Overlap Lands	Overlap Lands	TOTAL								
Historical Water Budget (DWR WY 1995 - 2014)																		
1995	22,957	67,393	4,118	71,511	120,977	6,625	**222,070**	197,340	12,059	209,399	1,176	0	7,102	0	0	**210,575**	**15,125**	*15,125*
1996	10,578	61,041	3,730	64,771	150,040	2,279	**227,668**	214,732	13,122	227,854	1,287	0	8,842	0	0	**229,141**	**-4,020**	*11,105*
1997	11,897	46,179	2,822	49,001	147,817	2,562	**211,276**	189,352	11,571	200,923	1,461	0	10,282	0	0	**202,384**	**4,946**	*16,051*
1998	30,923	118,987	7,271	126,258	108,888	8,904	**274,972**	196,980	12,037	209,017	1,405	0	6,446	0	0	**210,421**	**49,878**	*65,929*
1999	15,316	50,787	3,103	53,890	126,098	3,701	**199,005**	178,895	10,932	189,826	1,472	0	7,849	0	0	**191,299**	**22,381**	*88,310*
2000	11,239	34,843	2,129	36,972	132,736	2,451	**183,398**	174,416	10,658	185,074	1,280	0	8,406	0	0	**186,354**	**51**	*88,361*
2001	9,982	49,374	3,017	52,391	95,287	3,228	**160,889**	153,149	9,359	162,508	791	0	6,315	0	0	**163,299**	**862**	*89,223*
2002	4,055	27,223	1,664	28,887	93,727	1,252	**127,921**	154,768	9,457	164,225	877	0	6,639	0	0	**165,102**	**-31,814**	*57,409*
2003	12,794	57,801	3,532	61,333	86,002	4,165	**164,294**	161,512	9,870	171,382	797	0	6,101	0	0	**172,178**	**-6,413**	*50,997*
2004	7,565	34,477	2,107	36,583	97,212	2,298	**143,658**	155,848	9,523	165,371	885	0	6,965	0	0	**166,256**	**-21,726**	*29,271*
2005	23,988	61,076	3,732	64,808	92,378	7,402	**188,576**	143,465	8,767	152,231	747	0	6,097	0	0	**152,979**	**27,419**	*56,690*
2006	10,409	43,555	2,662	46,216	104,769	2,608	**164,003**	133,980	8,187	142,168	753	0	6,518	0	0	**142,920**	**18,718**	*75,408*
2007	10,819	30,176	1,844	32,020	120,260	1,870	**164,968**	164,208	10,034	174,242	1,016	0	7,702	0	0	**175,259**	**446**	*75,854*
2008	7,952	16,782	1,026	17,808	121,328	1,555	**148,643**	148,695	9,086	157,782	735	0	6,114	0	0	**158,517**	**-14,703**	*61,152*
2009	7,708	35,367	2,161	37,529	109,427	1,762	**156,426**	147,070	8,987	156,057	745	0	6,195	0	0	**156,802**	**-1,949**	*59,203*
2010	5,353	49,311	3,013	52,324	110,195	1,113	**168,985**	141,206	8,629	149,835	488	0	5,742	0	0	**150,323**	**6,846**	*66,049*
2011	12,006	77,100	4,711	81,811	111,698	3,178	**208,694**	142,031	8,679	150,710	364	0	5,698	0	0	**151,074**	**53,698**	*119,747*
2012	7,788	35,585	2,175	37,760	123,256	2,073	**170,877**	167,257	10,221	177,478	679	0	6,669	0	0	**178,157**	**3,863**	*123,611*
2013	7,143	29,627	1,810	31,438	120,138	1,848	**160,567**	169,857	10,379	180,237	586	0	6,629	0	0	**180,823**	**-24,061**	*99,550*
2014	5,110	10,560	645	11,205	96,394	1,211	**113,920**	141,951	8,674	150,625	488	0	4,920	0	0	**151,114**	**-33,839**	*65,711*
TOTAL	235,582	937,243	57,272	994,516	2,268,628	62,087	3,560,812	3,276,714	200,231	3,476,945	18,033	0	137,229	0	0	**3,494,978**	**65,711**	*65,711*
AVERAGE	*11,779*	*46,862*	*2,864*	*49,726*	*113,431*	*3,104*	***178,041***	*163,836*	*10,012*	*173,847*	*902*	*0*	*6,861*	*0*	*0*	***174,749***	**3,286**	-
%	*7%*	*26%*	*2%*	*28%*	*64%*	*2%*	-	*94%*	*6%*	*99.5%*	*0.5%*	*0%*	-	*0%*	*0%*	**-**	-	-
Current Water Budget (DWR WY 2015)																		
2015	8,640	51,321	3,136	54,457	83,710	2,676	**149,483**	175,651	10,734	186,384	840	0	4,478	0	102	**187,327**	**-42,898**	-
%	*6%*	*34%*	*2%*	*36%*	*56%*	*2%*	-	*94%*	*6%*	*99.5%*	*0.4%*	*0%*	-	*0%*	*0%*	**-**	-	-

Abbreviations

AF = acre-feet
AFY = acre-feet per year
DWR = California Department of Water Resources
M&I = municipal & industrial
WY = Water Year

Notes

(a) All values reported in acre-feet per year (AFY), except cumulative change in storage (reported in acre-feet).
(b) "Evapotranspiration" includes all estimated crop and vegetative evapotranspirative demands as well as evaporation of excess rainfall and from open water bodies within the District.
(c) Apparent residual of water-budget calculated change in groundwater storage to [Total Inflows - Total Outflows] can be attributed to the deep percolation lag effect in the water budget spreadsheet model, which serves to delay infiltration from reaching the groundwater system. See "Appendix A - Methods & Data Used in the Water Budget Spreadsheet Model Approach" for further details on how monthly storage change is calculated within the water budget spreadsheet model.

TABLE WB-7

Summary of Projected Water Budget Results without Project & Management Action Implementation

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

Total Water Budget Domain

Water Budget Category	Water Budget Component	Historical Period (WY 1995-2014)	Projected		
			Baseline (50-year Synthetic Hydrologic Period)	2030 Climate (scaled from Baseline Period)	2070 Climate (scaled from Baseline Period)
Inflows	(Net) Subsurface Inflow [(b)]	11,779	11,551	11,704	11,485
	Precipitation	49,726	49,144	49,707	48,485
	Surface Water Imports	113,431	93,328	90,541	86,119
	Natural Surface Water Inflows	3,104	3,044	3,095	3,022
	TOTAL INFLOWS	**178,041**	**157,067**	**155,046**	**149,111**
Outflows	Evapotranspiration [(c)]	173,847	171,023	175,767	181,702
	M&I Consumptive Use [(d)]	902	866	891	925
	Surface Water Exports	0	0	0	0
	Natural Surface Water Outflows	0	0	0	0
	Subsurface Groundwater Outflow	0	0	0	0
	TOTAL OUTFLOWS	**174,749**	**171,888**	**176,658**	**182,627**
Change in Groundwater Storage	**Equivalent to "Deficit"**	**3,286**	**-14,665**	**-21,429**	**-33,326**

Groundwater Subdomain

Water Budget Category	Water Budget Component	Historical Period (WY 1995-2014)	Projected		
			Baseline (50-year Synthetic Hydrologic Period)	2030 Climate (scaled from Baseline Period)	2070 Climate (scaled from Baseline Period)
Inflows	(Net) Subsurface Inflow[(b)]	11,779	11,551	11,704	11,485
	Infiltration of Precipitation	5,307	4,997	4,974	4,678
	Infiltration from Surface Water Systems	3,552	3,443	3,450	3,308
	Infiltration of Applied Water	39,608	33,132	32,618	30,935
	TOTAL GW INFLOWS	**60,247**	**53,123**	**52,745**	**50,406**
Outflows	Pumpage from District Wells	474	463	463	463
	Pumpage from Private Wells - User Input Program	2,705	2,563	2,563	2,563
	Pumpage from Private Wells - Private Use	53,777	64,918	71,330	80,894
	TOTAL GW OUTFLOWS	**56,955**	**67,944**	**74,357**	**83,921**
Change in Groundwater Storage	**Equivalent to "Deficit"**	**3,286**	**-14,665**	**-21,429**	**-33,326**

Notes

(a) All values reported in acre-feet per year (AFY).

(b) Projected GW Inflow terms based on Estimated Net Groundwater Inflows from Calibrated Historical Water Budget

(c) Evapotranspiration includes all estimated crop and vegetative evapotranspirative demands as well as evaporation of excess rainfall and from open water bodies within the District.

(d) M&I Consumptive Use includes evapotranspiration on Urban Lands (no other consumptive uses specified within the District), which is in part met by precipitation.

(e) Apparent residual of water-budget calculated change in groundwater storage to [Total Inflows - Total Outflows] can be attributed to the deep percolation lag effect in the water budget spreadsheet model, which serves to delay infiltration from reaching the groundwater system. See "Appendix E - Methods & Data Used in the Water Budget Spreadsheet Model Approach" for further details on how monthly storage change is calculated within the water budget spreadsheet model.

TABLE WB-8

Summary of Projected Water Budget Results with Project & Management Action Implementation

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

Total Water Budget Domain

Water Budget Category	Water Budget Component	Historical Period (WY 1995-2014)	Projected		
			Baseline (50-year Synthetic Hydrologic Period)	2030 Climate (scaled from Baseline Period)	2070 Climate (scaled from Baseline Period)
Inflows	(Net) Subsurface Inflow [(b)]	11,779	11,551	11,704	11,485
	Precipitation	49,726	49,144	49,707	48,485
	Surface Water Imports	113,431	93,328	90,541	86,119
	P&MA Augmented Supplies	-	**0**	**12,900**	**18,800**
	Natural Surface Water Inflows	3,104	3,044	3,095	3,022
	TOTAL INFLOWS	**178,041**	**157,067**	**167,946**	**167,911**
Outflows	Evapotranspiration [(c)]	173,847	171,023	175,767	181,702
	P&MA Demand Reduction	**-**	**0**	**-8,600**	**-14,600**
	M&I Consumptive Use [(d)]	902	866	891	925
	Surface Water Exports	0	0	0	0
	Natural Surface Water Outflows	0	0	0	0
	Subsurface Groundwater Outflow	0	0	0	0
	TOTAL OUTFLOWS	**174,749**	**171,888**	**168,058**	**168,027**
Change in Groundwater Storage	**Equivalent to "Deficit"**	**3,286**	**-14,665**	**53**	**47**

Groundwater Subdomain

Water Budget Category	Water Budget Component	Historical Period (WY 1995-2014)	Projected		
			Baseline (50-year Synthetic Hydrologic Period)	2030 Climate (scaled from Baseline Period)	2070 Climate (scaled from Baseline Period)
Inflows	(Net) Subsurface Inflow[(b)]	11,779	11,551	11,704	11,485
	Infiltration of Precipitation	5,307	4,997	5,031	4,757
	Infiltration from Surface Water Systems	3,552	3,443	3,477	3,345
	Infiltration of Applied Water	39,608	33,132	34,470	33,222
	TOTAL GW INFLOWS	**60,247**	**53,123**	**54,682**	**52,808**
Outflows	Pumpage from District Wells	474	463	463	463
	Pumpage from Private Wells - User Input Program	2,705	2,563	2,563	2,563
	Pumpage from Private Wells - Private Use	53,777	64,918	51,767	49,897
	TOTAL GW OUTFLOWS	**56,955**	**67,944**	**54,794**	**52,923**
Change in Groundwater Storage	**Equivalent to "Deficit"**	**3,286**	**-14,665**	**53**	**47**

Notes

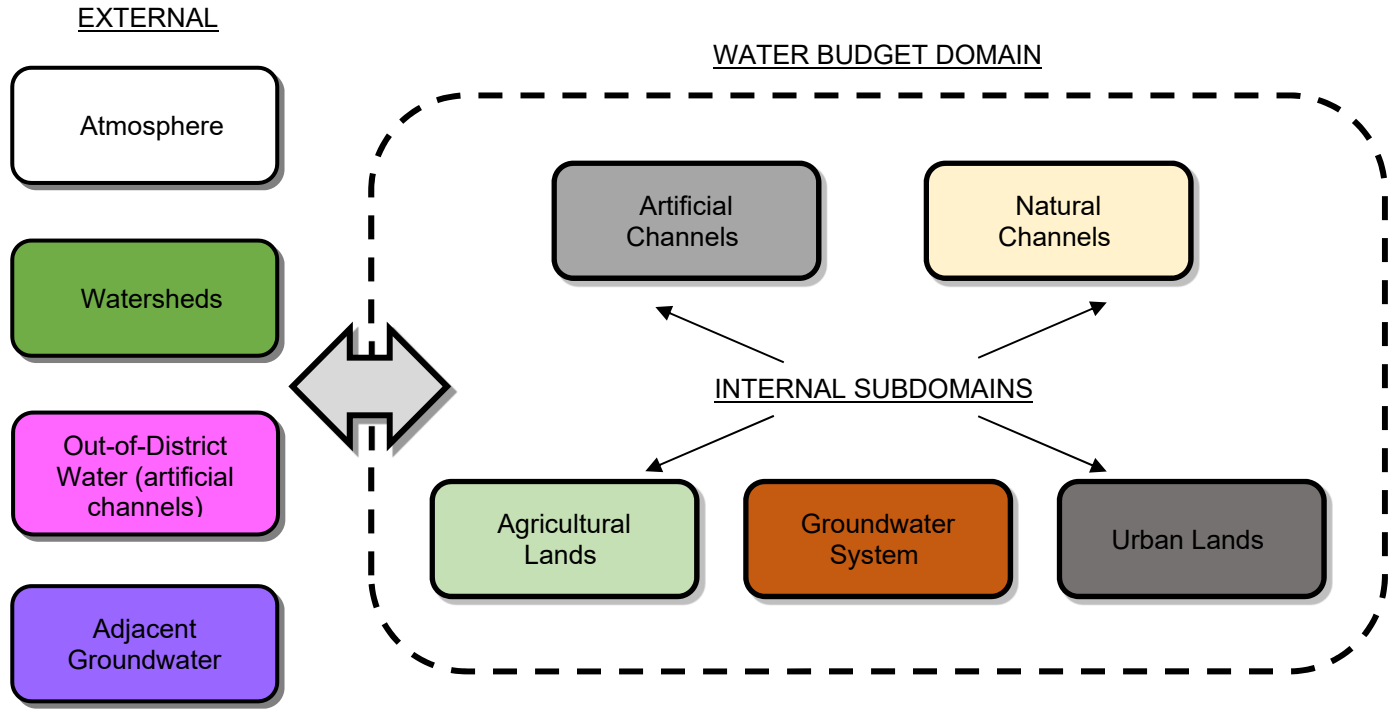
(a) All values reported in acre-feet per year (AFY).

(b) Projected GW Inflow terms based on Estimated Net Groundwater Inflows from Calibrated Historical Water Budget

(c) Evapotranspiration includes all estimated crop and vegetative evapotranspirative demands as well as evaporation of excess rainfall and from open water bodies within the District.

(d) M&I Consumptive Use includes evapotranspiration on Urban Lands (no other consumptive uses specified within the District), which is in part met by precipitation.

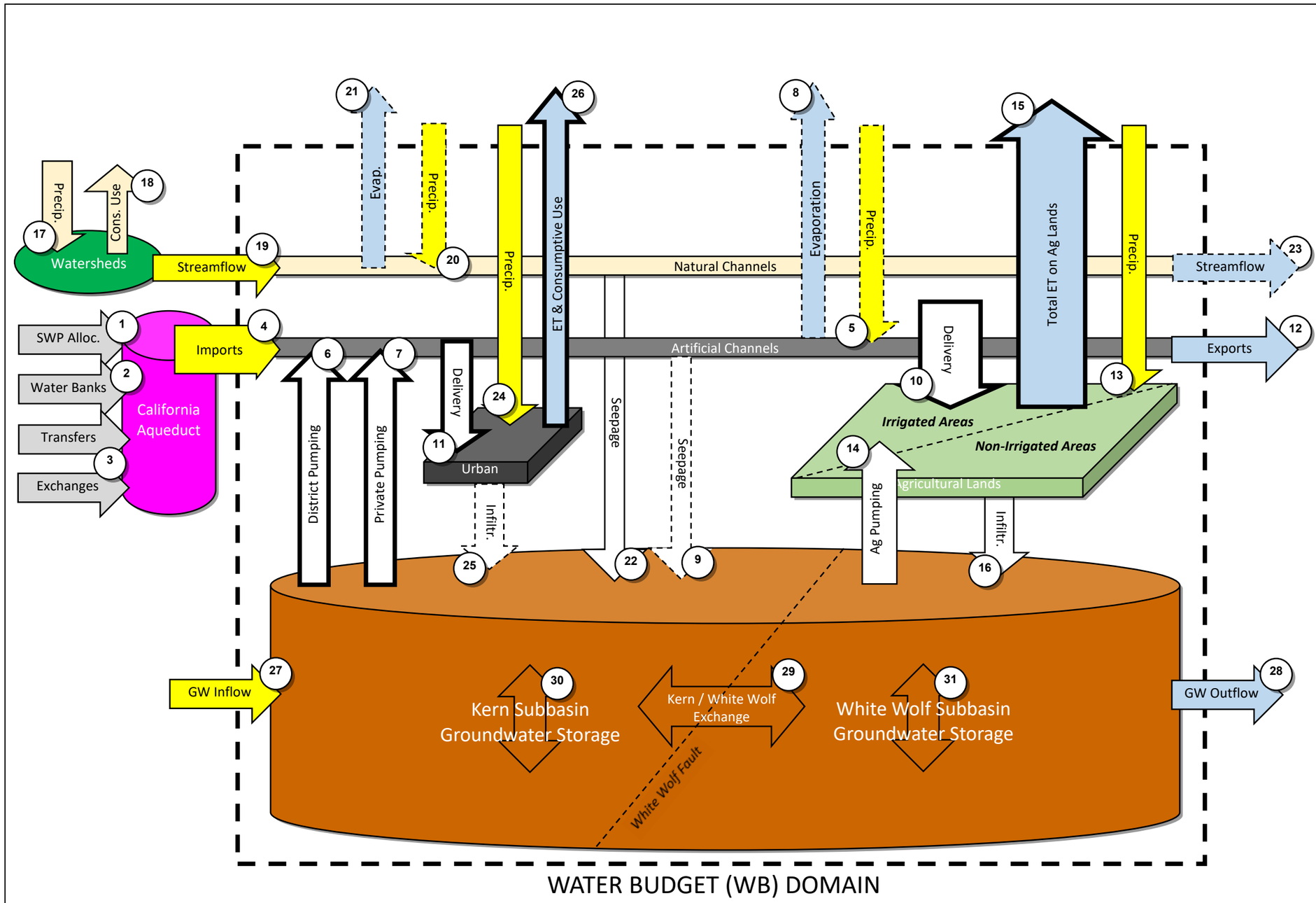
(e) Apparent residual of water-budget calculated change in groundwater storage to [Total Inflows - Total Outflows] can be attributed to the deep percolation lag effect in the water budget spreadsheet model, which serves to delay infiltration from reaching the groundwater system. See "Appendix E - Methods & Data Used in the Water Budget Spreadsheet Model Approach" for further details on how monthly storage change is calculated within the water budget spreadsheet model.



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Water Budget Domains and Subdomains

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01
Figure WB-1



Legend

- "Raw"
- Likely Negligible
- External
- Inflow to WB Domain
- Internal
- Outflow from WB Domain
- Currently Not Estimated in WB

Abbreviations:

Ag	=	agricultural
Cons.	=	consumptive
Evap.	=	evaporation
ET	=	evapotranspiration
GW	=	groundwater
Infiltr.	=	infiltration
M&I	=	municipal & industrial
Perc.	=	percolation
Precip.	=	precipitation
WB	=	water budget

Notes:

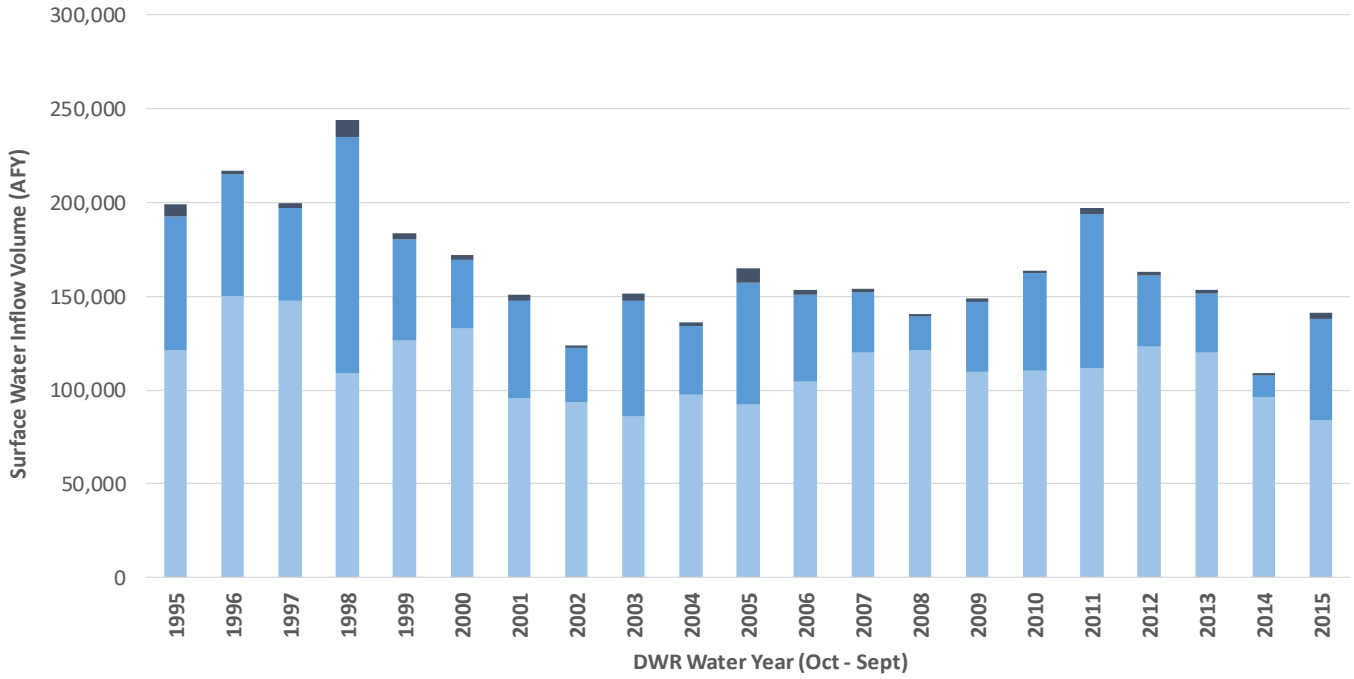
1. Components 4-28 are further parsed into their respective contributions to the Kern and White Wolf Subbasins within the water budget.

Water Budget Flow Components

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

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Figure WB-2



Legend

= Surface Water Imports

= Direct Precipitation

= Streamflow into District

Abbreviations

AFY = acre-feet per year

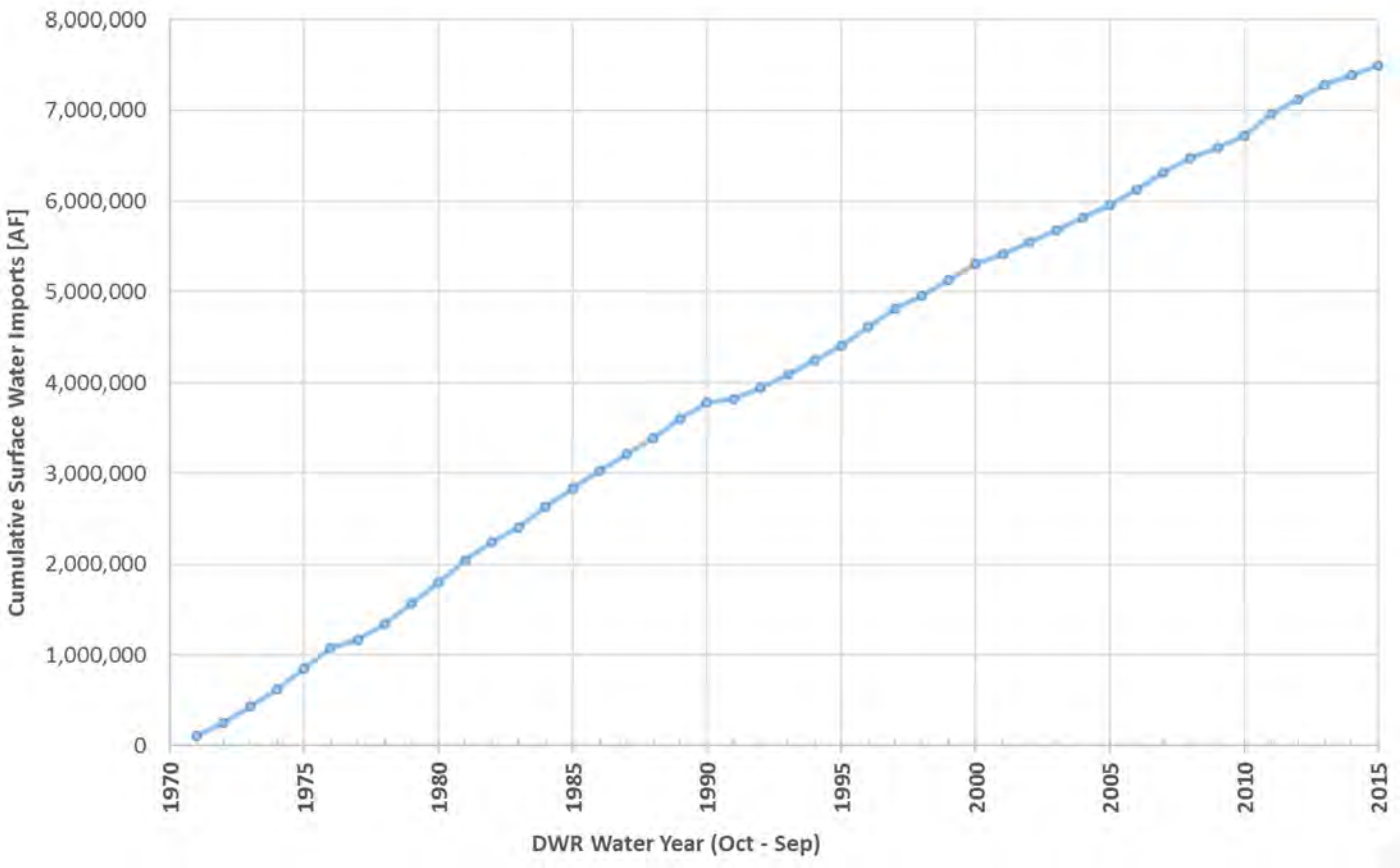
DWR = California Department of Water Resources

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Annual Surface Water Inflows by Source

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-3



Abbreviations

AF = acre-feet

DWR = California Department of Water Resources

Notes

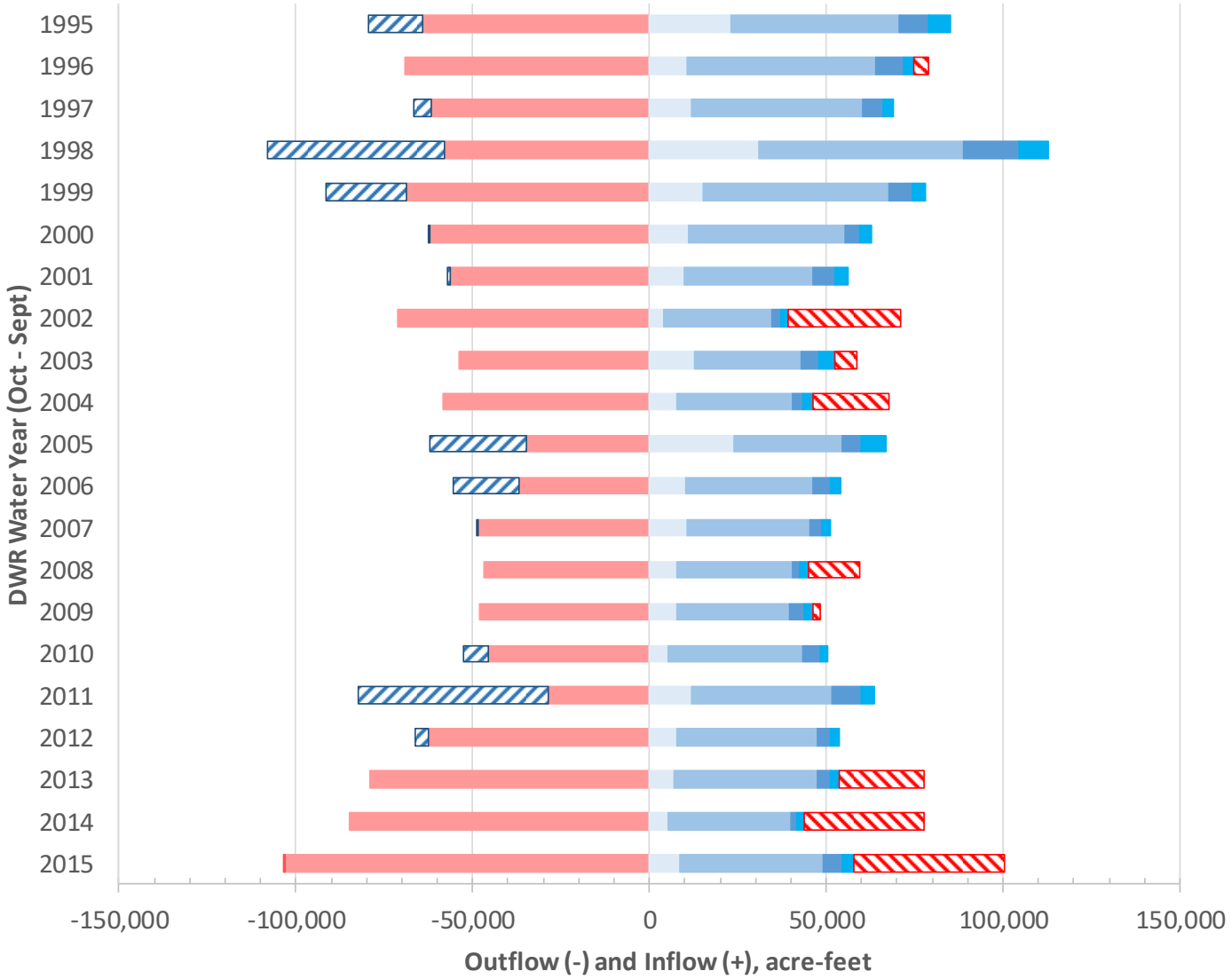
1. Annual volumes reported by DWR Water Year, which extends October (of the previous year) – September.

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Cumulative Surface Water Imports, 1971 - 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-4



Legend

Groundwater Inflows

= Subsurface GW Inflow

= Infiltration of Applied Water

= Infiltration of Precipitation

= Infiltration from Surface Water Systems

= Recharge from Spreading Basins

Groundwater Outflows

= Groundwater Extraction

= Subsurface GW Outflow

Change in Groundwater Storage

= Gain in GW Storage

= Reduction in GW Storage

Abbreviations

DWR = California Department of Water Resources

GW = groundwater

Notes

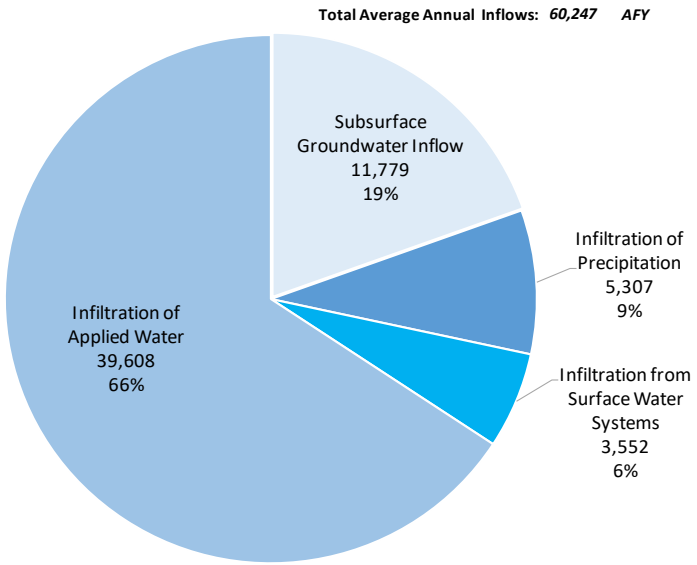
1. "Groundwater Extraction" includes all District, private, and municipal & industrial groundwater pumping.

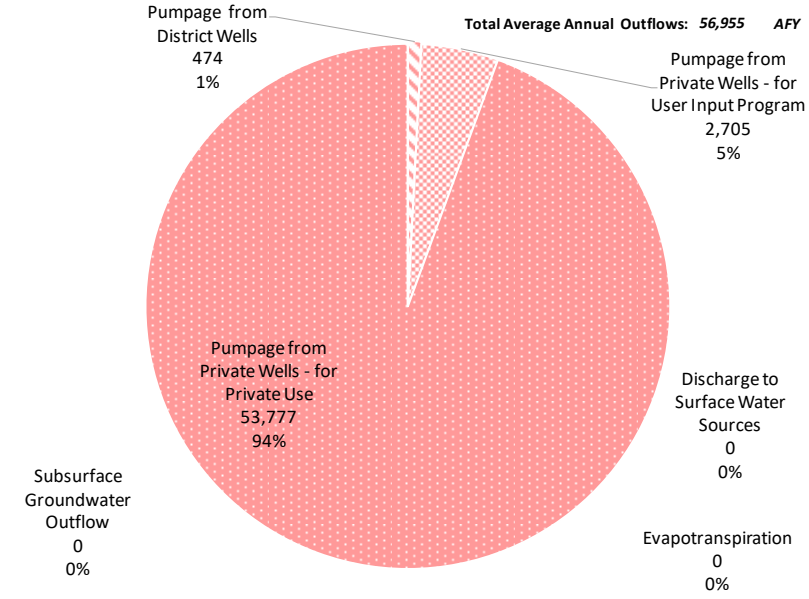
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Annual Groundwater Inflows and Outflows

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-5





Legend

Groundwater Inflows

- = Subsurface GW Inflow
- = Infiltration of Applied Water
- = Infiltration of Precipitation
- = Infiltration from Surface Water Systems
- = Recharge from Spreading Basins

Groundwater Outflows

- = Groundwater Extraction
- = Subsurface GW Outflow

Change in Groundwater Storage

- = Gain in GW Storage
- = Reduction in GW Storage

Abbreviations

AFY = acre-feet per year
GW = groundwater
WY = Water Year

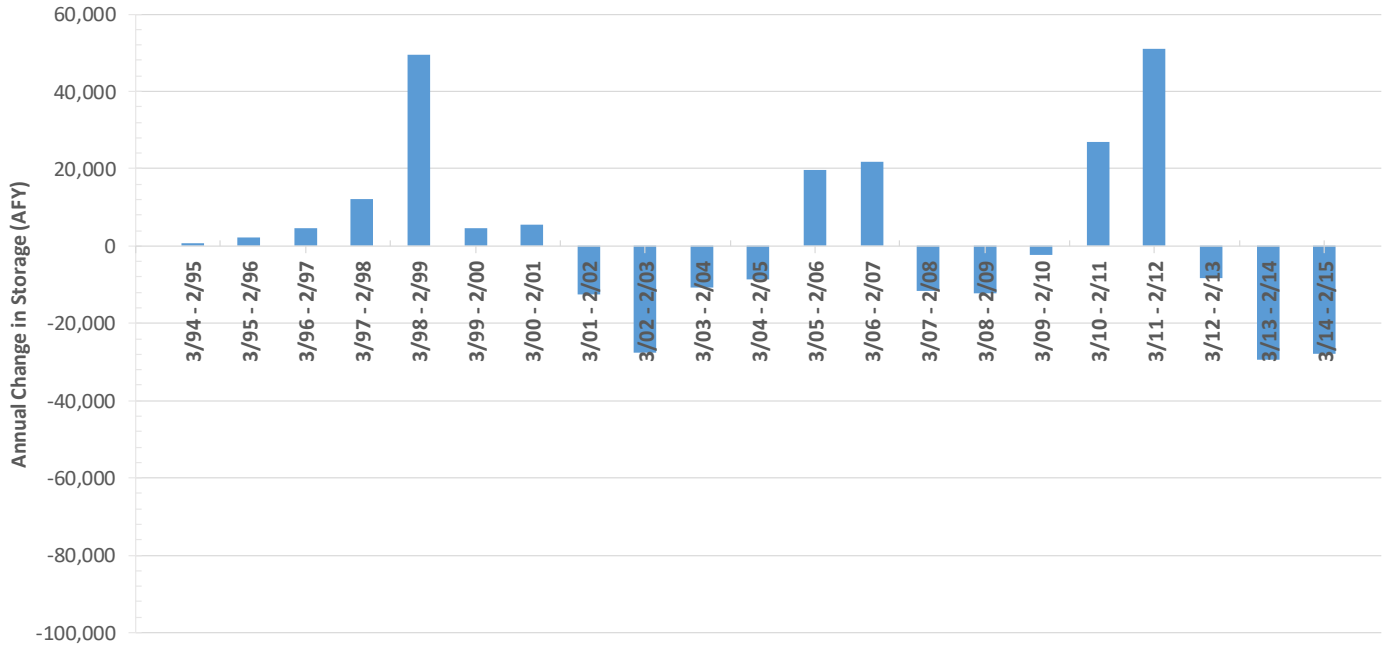
Notes

1. All values reported in acre-feet per year (AFY).
2. "Groundwater Extraction" includes all District and private groundwater pumping.

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Summary of Groundwater Inflows & Outflows, WY 1995 - 2014

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01
Figure WB-6



Abbreviations

AFY = acre-feet per year

Notes

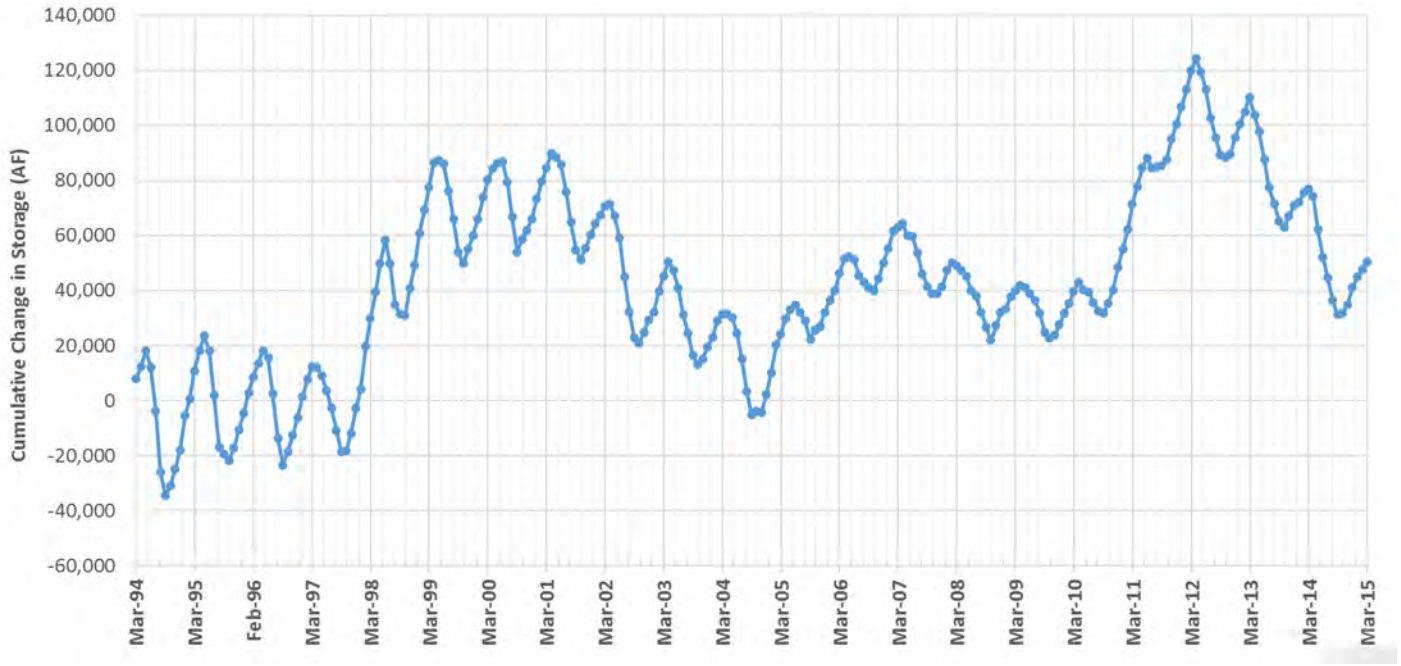
1. "Seasonal high" condition is defined as March – February of the following year.

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Annual Change in Storage Between Seasonal Highs

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-7



Abbreviations

AF = acre-feet

Notes

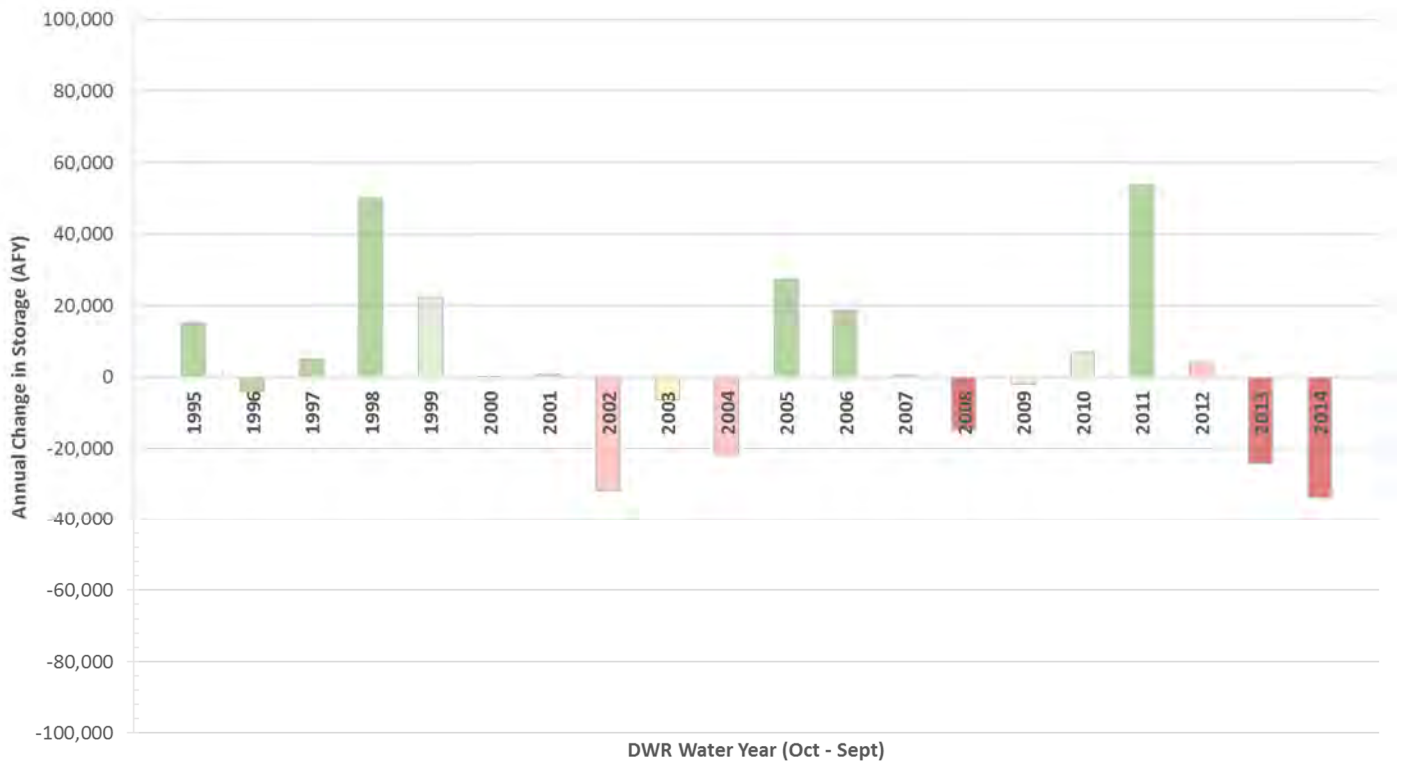
1. Values represent cumulative change in storage since the "seasonal high" condition of March 1994.

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Cumulative Change in Storage, March 1994 - February 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-8



Legend

DWR Water Year Type

= Wet

= Above Normal

= Below Normal

= Dry

= Critical

Abbreviations

AFY = acre-feet per year

Sources

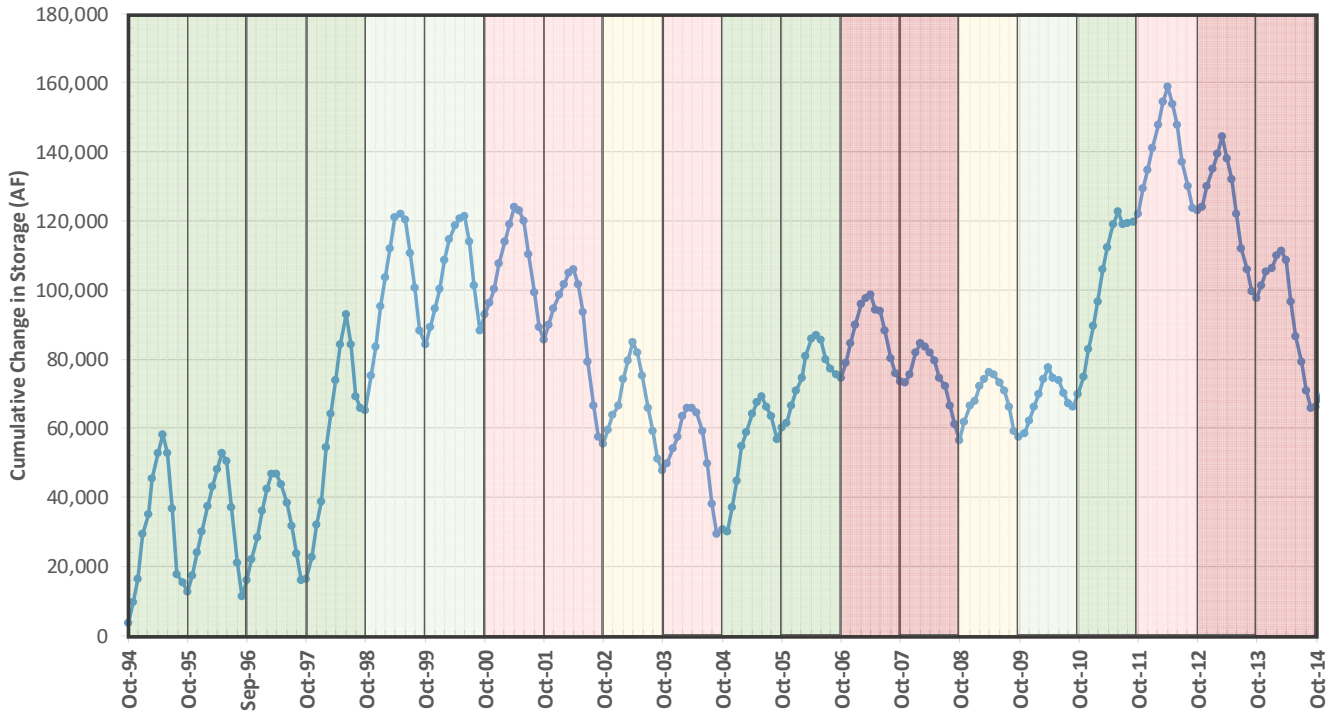
1. DWR Water Year Type is from DWR's Water Year Hydrologic Classification Indices for the San Joaquin Valley <http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST>.

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Annual Change in Storage vs. DWR Water Year Type

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-9



Legend

DWR Water Year Type

= Wet

= Above Normal

= Below Normal

= Dry

= Critical

Abbreviations

AF = acre-feet

Sources

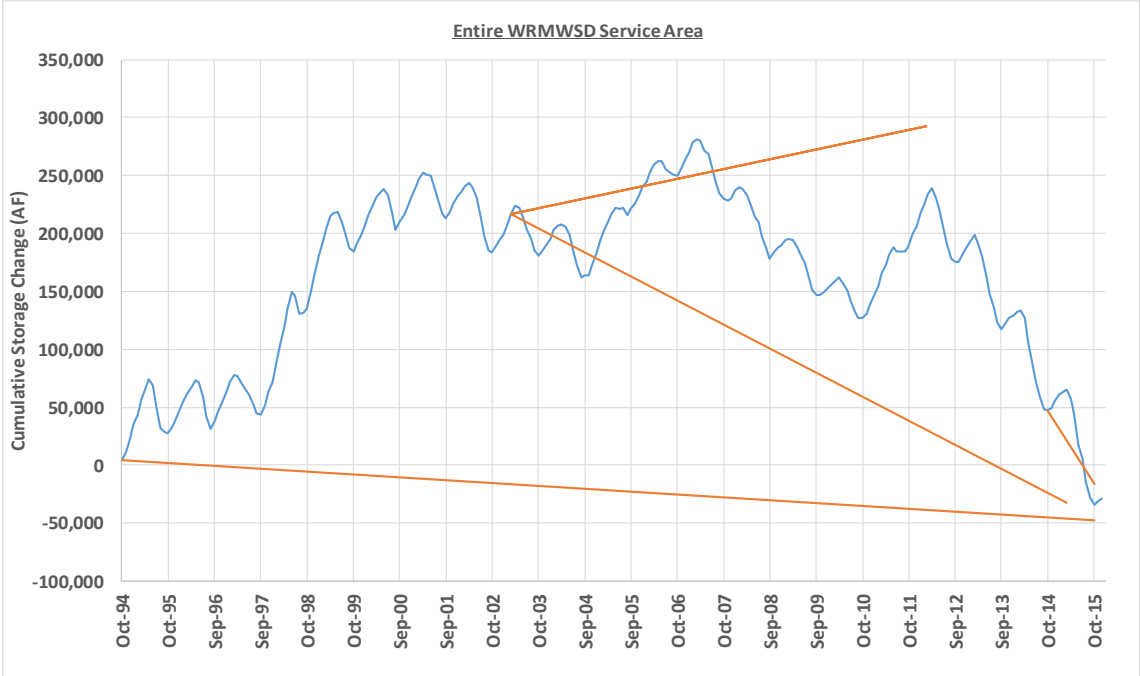
1. DWR Water Year Type is from DWR's Water Year Hydrologic Classification Indices for the San Joaquin Valley <http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST>.

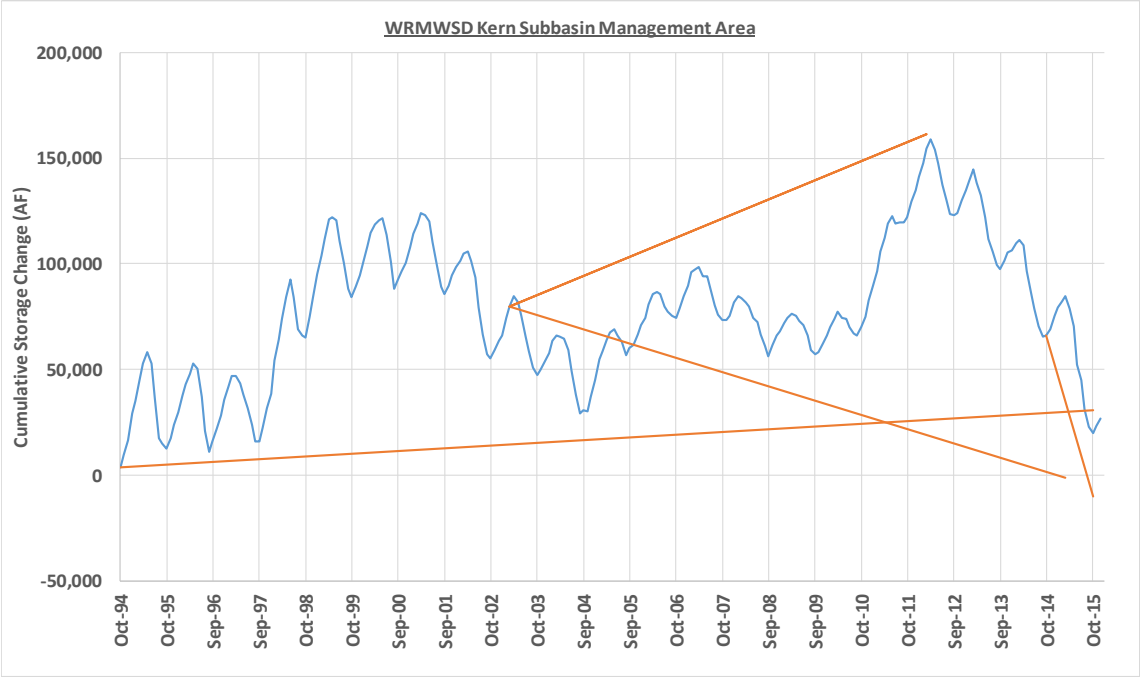
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Cumulative Change in Storage vs. DWR Water Year Type

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-10





Legend

= Raster-Based Estimated Change In Storage (AF)

= Water Budget Spreadsheet Model-Calculated Change In Storage (AF)

Abbreviations

AF = acre-feet

Notes

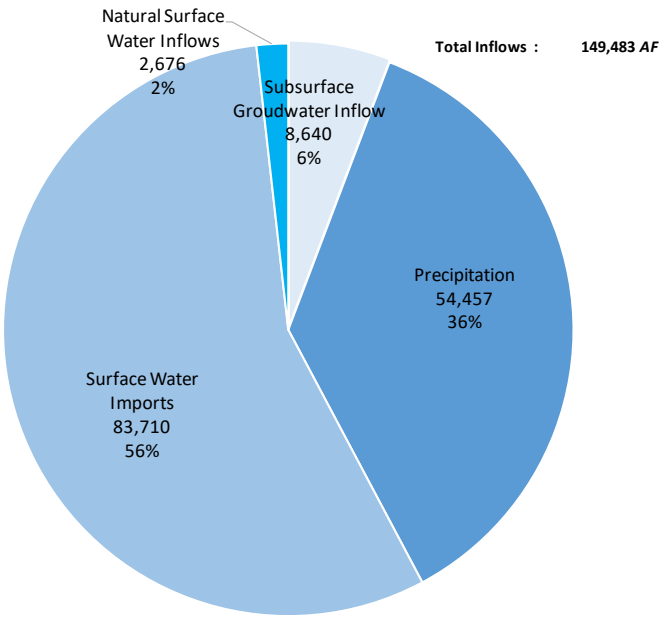
1. Calibration of the water budget spreadsheet model was performed for the District's entire service area, including the portion within the White Wolf Subbasin.

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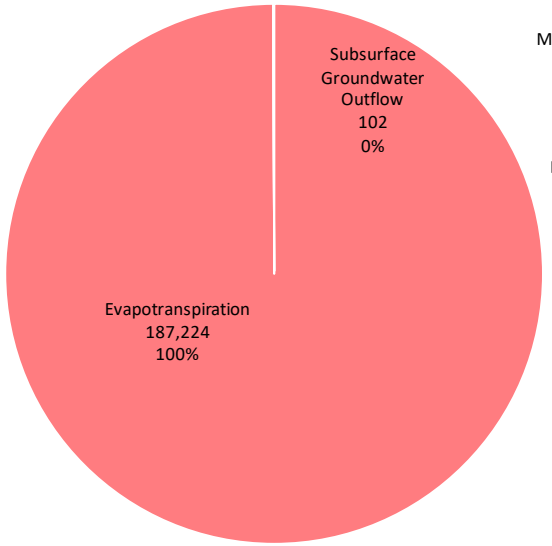
Comparison of Modeled & Water Level-Based Estimated Change in Storage

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-11



Total Inflows : 149,483 *AF*



Total Outflows: 187,327 *AF*

M&I Consumptive Use
0
0%

Surface Water Exports + Losses
0
0%

Natural Surface Water Outflow
0
0%

Legend

Inflows

= Subsurface GW Inflows

= Surface Water Imports

= Precipitation

= Natural Surface Water Inflows

Outflows

= Subsurface GW Outflows

= Evapotranspiration

Abbreviations

AFY = acre-feet per year
GW = groundwater
M&I = municipal & industrial
WY = Water Year

Notes

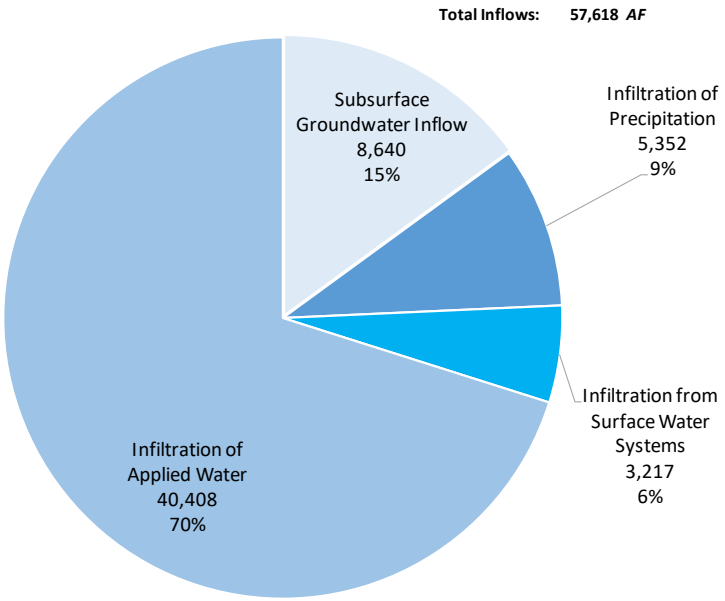
1. All values reported in acre-feet per year (AFY).

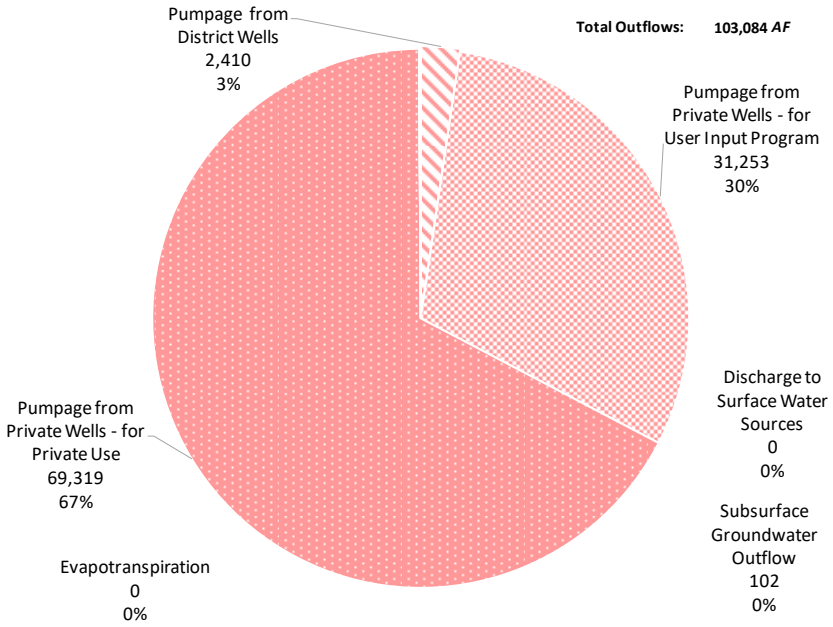
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Summary of Total Inflows & Outflows, WY 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-12





Legend

Groundwater Inflows

- = Subsurface GW Inflow
- = Infiltration of Applied Water
- = Infiltration of Precipitation
- = Infiltration from Surface Water Systems
- = Recharge from Spreading Basins

Groundwater Outflows

- = Groundwater Extraction
- = Subsurface GW Outflow

Change in Groundwater Storage

- = Gain in GW Storage
- = Reduction in GW Storage

Abbreviations

AF = acre-feet
GW = groundwater
WY = Water Year

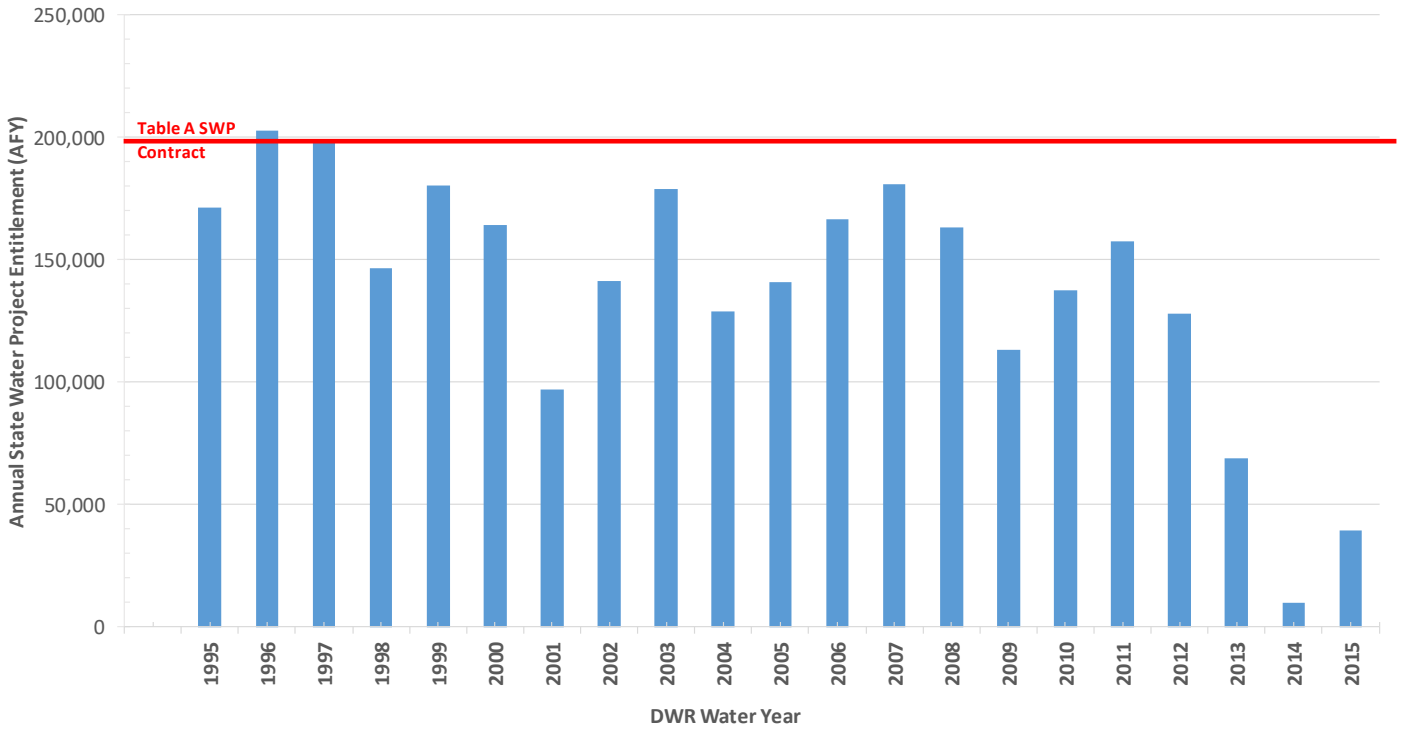
Notes

1. All values reported in acre-feet (AF).
2. "Groundwater Extraction" includes all District and private groundwater pumping.

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Summary of Groundwater Inflows & Outflows, WY 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01
Figure WB-13



Legend

= SWP Annual Entitlement

= SWP Table A Contract

Abbreviations

AFY = acre-feet per year

SWP = State Water Project

Notes

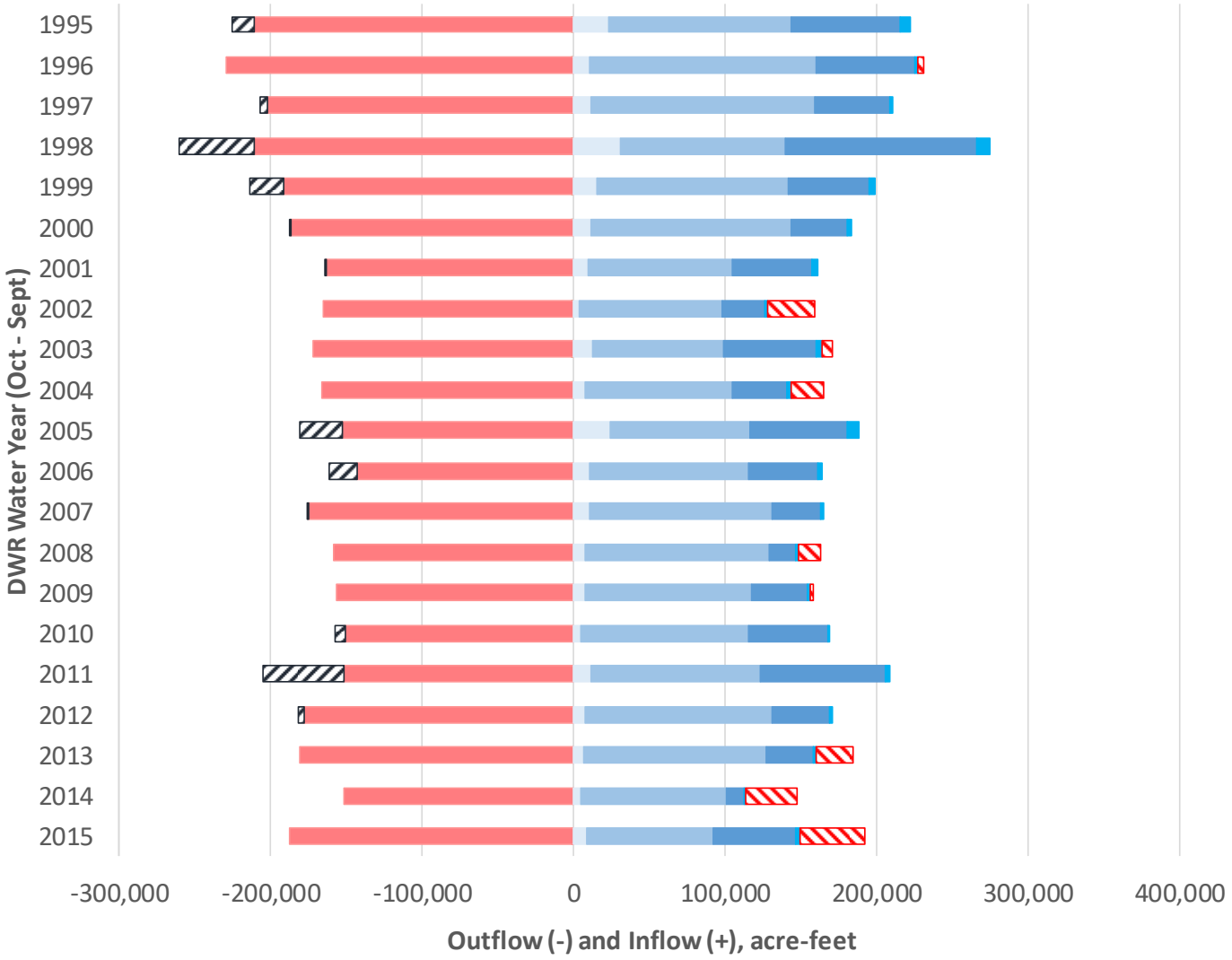
1. WRMWSD's Table A SWP Contract is 197,088 AFY

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Annual State Water Project Entitlement vs. Table A Contract

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-14



Legend

Inflows

= Subsurface GW Inflow

= Surface Water Imports

= Precipitation

= Natural Surface Water Inflows

Outflows

= Subsurface Outflows

= Evapotranspiration

Change in Groundwater Storage

= Gain in GW Storage

= Reduction in GW Storage

Abbreviations

DWR = California Department of Water Resources

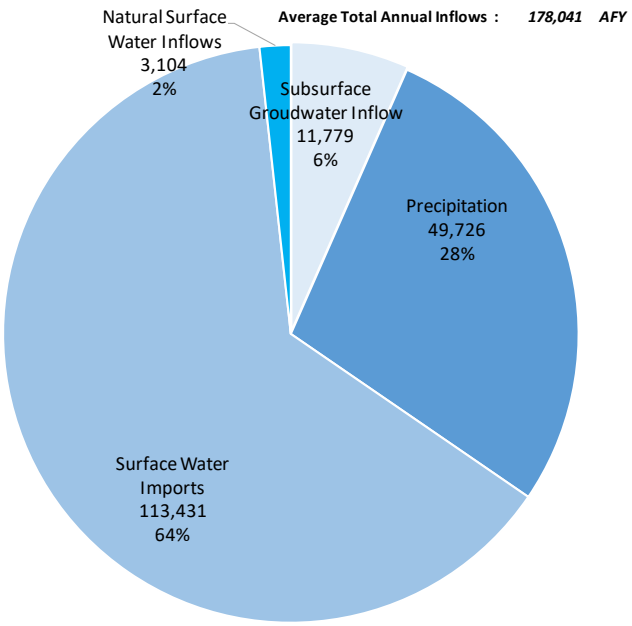
GW = groundwater

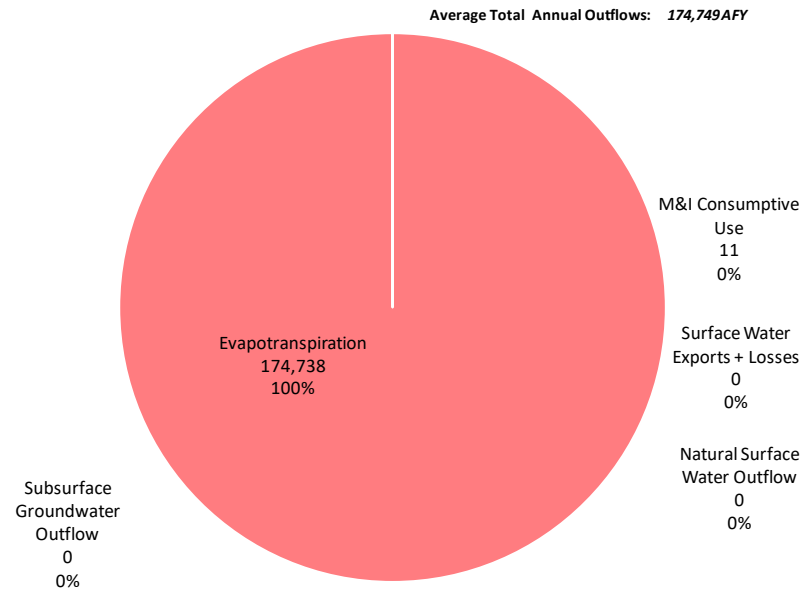
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Annual Inflows & Outflows

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-15





Legend

Inflows

- = Subsurface GW Inflows
- = Surface Water Imports
- = Precipitation
- = Natural Surface Water Inflows

Outflows

- = Subsurface GW Outflows
- = Evapotranspiration

Abbreviations

AFY = acre-feet per year
GW = groundwater
M&I = municipal & industrial
WY = Water Year

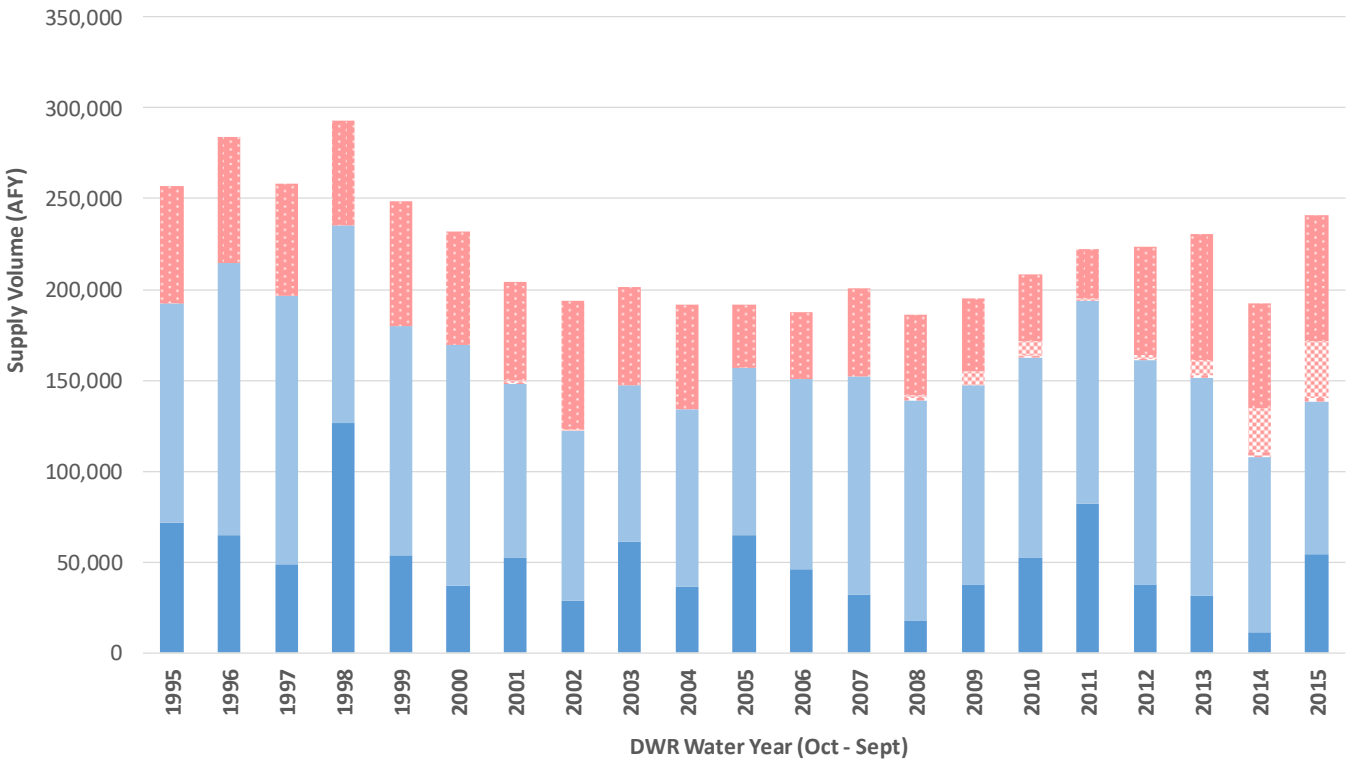
Notes

1. All values reported in acre-feet per year (AFY).

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Summary of Total Inflows & Outflows, WY 1995 - 2014

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01
Figure WB-16



Legend

= Precipitation

= Surface Water Imports

= District Pumpage

= Private Pumpage - User Input Program

= Private Pumpage - Private Use

Abbreviations

AFY = acre-feet per year

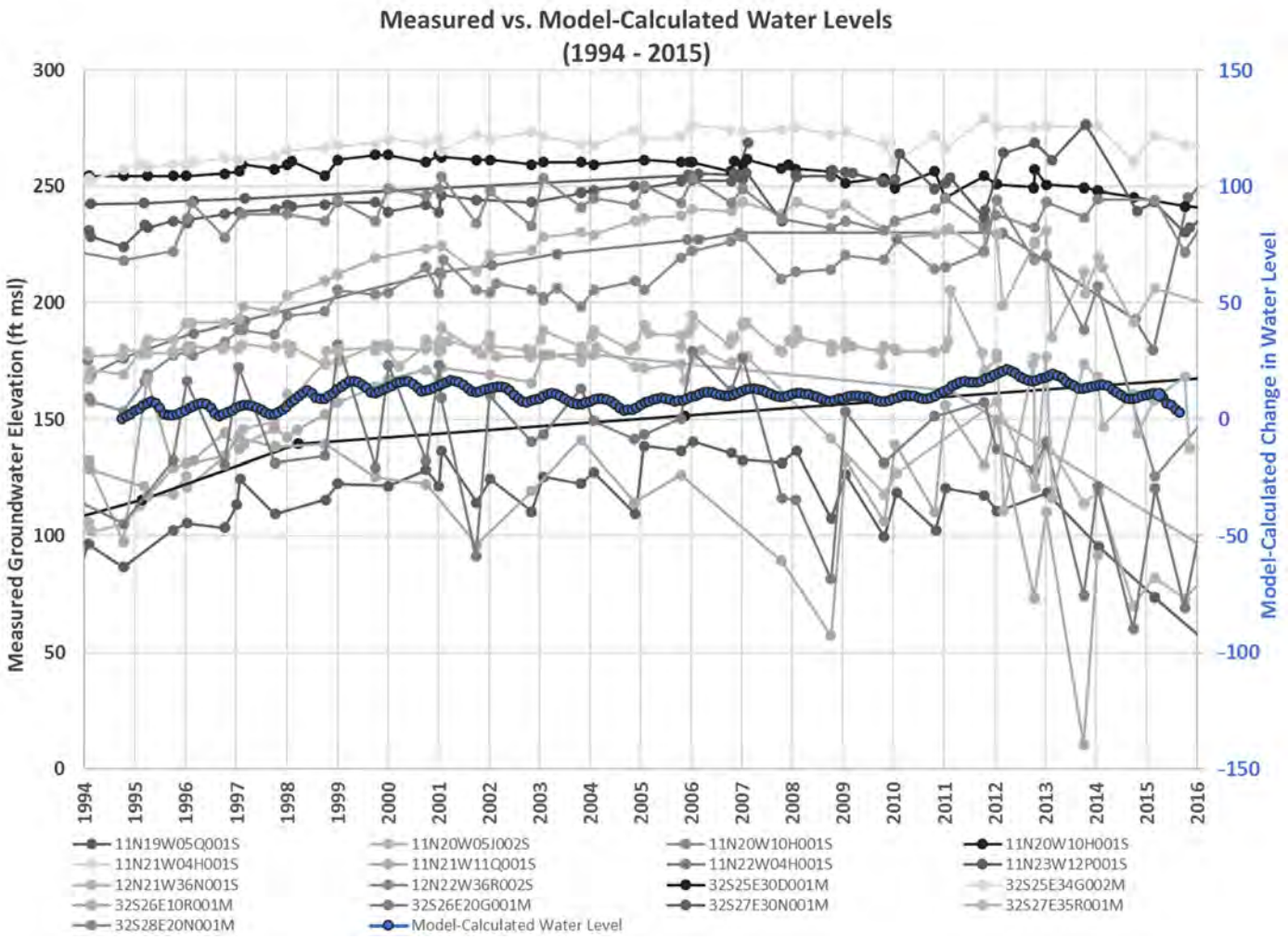
WY = Water Year

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Water Supply Portfolio and Annual Precipitation, WY 1995 - 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-17



Legend

= Measured Water Level (ft msl)

= Water Budget Spreadsheet Model-Calculated Change In Water Level (ft)

Abbreviations

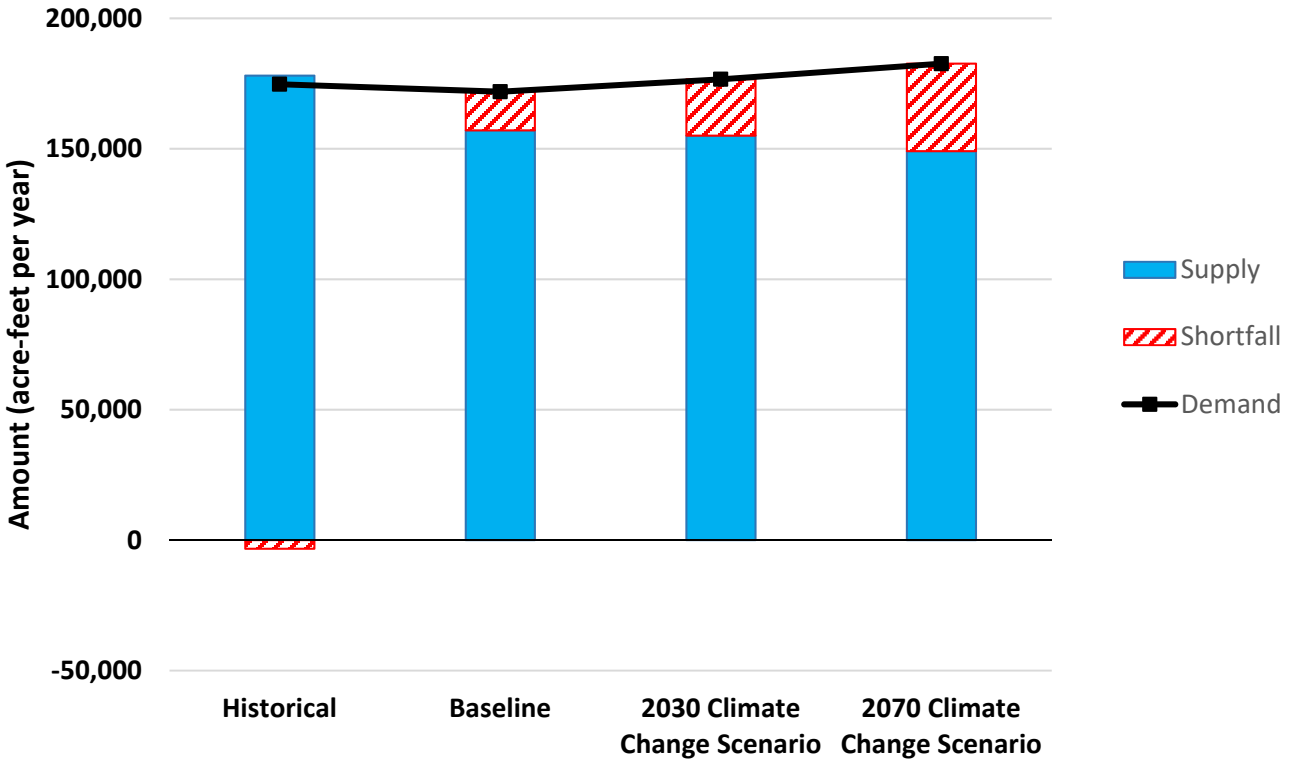
ft	= feet
ft msl	= feet above mean sea level
WY	= Water Year

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Observed vs. Modeled Change in Water Levels, WY 1995 - 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure WB-18



Projected Water Budget Supplies, Demands, and Shortfall Before Project & Management Action Implementation
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01
Figure WB-19

10. MANAGEMENT AREAS

☑ 23 CCR § 354.20(a)

The information presented in the Basin Setting sections of this GSP (i.e., **Section 7** ***Hydrogeologic Conceptual Model,*** **Section 8** ***Current and Historical Groundwater Conditions*** and **Section 9** ***Water Budget Information***) is specific to and describes conditions within the Wheeler Ridge-Maricopa Management Area. As discussed in **Section 5.1.6** ***Lands Outside of District Covered by MA Plan***, information regarding the undistricted lands (i.e., "White Lands") covered by this MA Plan is presented in **Appendix B**.

10.1. Description and Justification

☑ 23 CCR § 354.20(b)(1)
☑ 23 CCR § 354.20(c)

As discussed previously in **Section 5.1.1** ***Area Covered by the Plan***, the Kern Subbasin is overlain by a large number of entities with water or land use management authority. A subset of these entities formed the Kern Groundwater Authority GSA. WRMWSD is a member of the KGA GSA but is locally responsible for SGMA compliance within a specific portion of the KGA GSA -- the Wheeler Ridge-Maricopa Management Area. This Management Area includes all of WRMWSD's service area within the Kern Subbasin except for small portions on the far western side (see **Figure HCM-1**).

The reason for creation of the Wheeler Ridge-Maricopa Management Area is to ensure that WRMWSD maintains maximum flexibility and control over sustainable groundwater management within the portion of its service area where land and water use is predominantly agricultural, and where there is a strong nexus between WRMWSD management decisions and groundwater conditions.

10.2. Minimum Thresholds and Measurable Objectives

☑ 23 CCR § 354.20(b)(2)
☑ 23 CCR § 354.20(b)(4)

The Sustainable Management Criteria developed for the Wheeler Ridge-Maricopa Management Area, including the rationale for their selection, are described in detail in **Section 14** ***Minimum Thresholds*** and **Section 15** ***Measurable Objectives and Interim Milestones***.

10.3. Monitoring

☑ 23 CCR § 354.20(b)(3)

Monitoring networks for each applicable Sustainability Indicator, including a discussion of the level of monitoring an analysis appropriate for the Wheeler Ridge-Maricopa Management Area, are described in detail in **Section 16** ***Monitoring Network***.

SUSTAINABLE MANAGEMENT CRITERIA

11. INTRODUCTION TO SUSTAINABLE MANAGEMENT CRITERIA

☑ **23 CCR § 354.22**

The Sustainable Groundwater Management Act (SGMA) legislation defines "Sustainability Goal" as "the existence and implementation of one or more groundwater sustainability plans that achieve sustainable groundwater management by identifying and causing the implementation of measures targeted to ensure that the applicable basin is operated within its sustainable yield" (California Water Code [CWC] § 10721(u)). SGMA requires Groundwater Sustainability Plans (GSPs) to develop and implement plans to meet the Sustainability Goal (CWC § 10727(a)) and defines terms related to achievement of the Sustainability Goal, including:

- Interim Milestone - a target value representing measurable groundwater conditions, in increments of five years, set by an Agency as part of a plan (23 CCR § 351(q));
- Measurable Objective - specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted plan to achieve the sustainability goal for the basin (23 CCR § 351(s)); and
- Minimum Threshold - a numeric value for each sustainability indicator used to define undesirable results (23 CCR § 351(t)).

Collectively, the Sustainability Goal, Interim Milestones, Measurable Objectives, and Minimum Thresholds are referred to herein as Sustainable Management Criteria (SMCs).

The GSP Emergency Regulations specify how Groundwater Sustainability Agencies (GSAs) must establish SMCs for each applicable Sustainability Indicator. **Sections 12**, **13**, **14**, and **15** of this GSP describe the **Sustainability Goal**, **Undesirable Results**, **Minimum Thresholds**, and **Measurable Objectives and Interim Milestones**, respectively, developed as part of this MA Plan.

12. SUSTAINABILITY GOAL

☑ 23 CCR § 354.24

SGMA requires that a Sustainability Goal be defined for the basin (CWC § 10727(a)). The sustainability goal for the Wheeler Ridge-Maricopa Management Area is to maintain an economically-viable groundwater resource for the beneficial use of the Management Area's landowners and water users by utilizing the area's groundwater resources within the local sustainable yield. Long-term groundwater sustainability, i.e., the absence of undesirable results within 20 years of the applicable statutory deadline, will be achieved and maintained through the implementation of projects and management actions as described herein to both increase water supplies and reduce demands within the Management Area.

The local sustainability goal, above, is consistent with and in addition to the basin-wide sustainability goal being adopted by all GSAs in the Kern Subbasin, shown below.

"The sustainability goal of the Kern County Subbasin is to:

- Achieve sustainable groundwater management in the Kern County Subbasin through the implementation of projects and management actions at the member agency level of each GSA.
- Maintain its groundwater use within the sustainable yield of the basin.
- Operate within the established sustainable management criteria, which are based on the collective technical information presented in the GSPs in the Subbasin.
- Implement projects and management actions that include a variety of water supply development and demand management actions.
- Collectively bring the Subbasin into sustainability and to maintain sustainability over the implementation and planning horizon.

Further, the Subbasin sustainability goal includes a commitment to monitor and report groundwater conditions, as required by SGMA, and to continue coordination among the KGA member agencies and all other GSA's in the Subbasin to identify the potential for, or presence of, undesirable results and actions to prevent undesirable results. The coordination process established in the development of this GSP and memorialized in the Coordination Agreement and Appendices thereto will ensure that the Subbasin is managed as a shared groundwater resource and that the districts within the Subbasin work collaboratively towards achieving and maintaining sustainable groundwater use."

13. UNDESIRABLE RESULTS

☑ 23 CCR § 354.26(a)

This section describes the Undesirable Results defined for the Wheeler Ridge-Maricopa Management Area[66]. Pursuant to the GSP Emergency Regulations, which state that Undesirable Results are to be defined consistently throughout the basin (23 CCR § 354.20), definitions of Undesirable Results have been developed through a coordinated effort of the Kern Subbasin GSAs and are described in the KGA Umbrella GSP.

As discussed below for each Sustainability Indicator, the Undesirable Results definitions for the Basin refer to and rely on Minimum Thresholds established at the local management area level. Specifically, Undesirable Results for the Basin occur when Minimum Thresholds for a certain percentage (by acreage) of management areas are exceeded. Each management area determines what the local Minimum Thresholds values are and what combination of local exceedances constitutes a local Undesirable Result. If a local Undesirable Result manifests in a management area, that area counts towards the basin-wide Undesirable Results definition.

In the following sections, the Undesirable Results statements adopted by the Kern Groundwater Authority (KGA) GSA and other Basin GSAs for each Sustainability Indicator are presented, along with a description of the local Wheeler Ridge-Maricopa Management Area definition of Undesirable Results (i.e., what combination of Minimum Threshold exceedances, if any, constitutes a local Undesirable Result).

13.1. Undesirable Results for Chronic Lowering of Groundwater Levels

The basin-wide definition of Undesirable Results for Chronic Lowering of Groundwater Levels is as follows:

> "The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.
>
> This is determined when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas which represent at least 15% of the sub-basin or greater than 30% of the subbasin (as measured by each Management Area). Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans."

The above basin-wide definition requires local definition within each management area of the Minimum Thresholds and combination of exceedances that constitute a significant and unreasonable impact to the reasonable and beneficial use of, and access to, groundwater by overlying users. As such, it is necessary to consider local conditions and beneficial uses and users within each management area.

[66] In this document, the term "Wheeler Ridge-Maricopa Management Area" is used in its entirety the first time the area is being referenced in each paragraph; subsequent references to this area in each paragraph use the term "Management Area".

13.1.1. Potential Causes of Undesirable Results

☑ 23 CCR § 354.26(b)(1)

Potential causes of Undesirable Results due to Chronic Lowering of Groundwater Levels in the Wheeler Ridge-Maricopa Management Area include increased pumping and/or reduced recharge. Because the primary use of groundwater from the principal aquifer in the Management Area is for agricultural purposes, increased pumping from the principal aquifer could occur if new land is put into agricultural production or if water use per acre on existing irrigated land increases. Pumping from the principal aquifer for potable domestic use is relatively small and unlikely to substantially increase. Reduced recharge could occur due to increased agricultural irrigation efficiency, reduced surface water imports, reduced groundwater inflows, or due to climate change that results in decreased precipitation and increased evapotranspiration (ET), as discussed in **Section 9.4 *Projected Water Budget***.

13.1.2. Criteria Used to Define Undesirable Results

☑ 23 CCR § 354.26(b)(2)
☑ 23 CCR § 354.26(c)

Per Section 354.26(b)(2) of the GSP Emergency Regulations, the description of Undesirable Results must include a quantitative description of the number of Minimum Threshold exceedances that constitute an Undesirable Result. As discussed further below in **Section 14 *Minimum Thresholds*** and in **Section 16 *Monitoring Network***, within the Wheeler Ridge-Maricopa Management Area Minimum Thresholds for groundwater levels are set at 15 Representative Monitoring Sites by considering groundwater levels and trends, well depths (i.e., beneficial users), and proximity to critical infrastructure. In a similar manner to how Undesirable Results are defined at the basin level, at the local Management Area level it is considered an Undesirable Result for Chronic Lowering of Groundwater Levels if Minimum Thresholds are exceeded in 40% or more of the Representative Monitoring Sites (i.e., 6 or more out of 14 sites) over four consecutive seasonal measurements (i.e., two measurements at the seasonal high condition and two measurements at the seasonal low condition).

13.1.3. Potential Effects of Undesirable Results

☑ 23 CCR § 354.26(b)(3)

The primary potential effects of Undesirable Results caused by Chronic Lowering of Groundwater Levels on beneficial uses and users of groundwater in the Wheeler Ridge-Maricopa Management Area include groundwater well dewatering, increased pumping lift, and potential land subsidence. Well dewatering is detrimental to wells as it can lead to increased maintenance costs (i.e., well rehabilitation/redevelopment, pump lowering) and reduced well lifespan due to corrosion of well casing and screen. Increased pumping lift results in more energy use per unit volume of groundwater pumped and greater pumping costs and can cause increased wear and tear on well pumps/motors. Land subsidence can affect critical infrastructure as discussed further below in **Section 13.5 *Undesirable Results for Land Subsidence***.

13.2. Undesirable Results for Reduction of Groundwater Storage

The basin-wide definition of Undesirable Results for Reduction of Groundwater Storage is as follows*:*

> "The point at which significant and unreasonable impacts, as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended drought period. (10-years?)
>
> This is determined when the volume of storage (above the groundwater level minimum thresholds) is depleted to an elevation lower than the groundwater level minimum threshold in at least three (3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the subbasin (as measured by the acreage of each Management Area).
>
> Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans."

The above basin-wide definition ties the Undesirable Result for Reduction of Groundwater Storage directly to the Minimum Thresholds for Chronic Lowering of Groundwater Levels which, as stated above, are defined locally within each management area of the Kern Subbasin.

13.2.1. Potential Causes of Undesirable Results

☑ **23 CCR § 354.26(b)(1)**

Reduction of Groundwater Storage is generally correlated to Chronic Lowering of Groundwater Levels. Therefore, the potential causes of Undesirable Results due to Reduction in Groundwater Storage are generally the same as the potential causes listed above for Undesirable Results due to Chronic Lowering of Groundwater Levels (i.e., increased groundwater pumping and reduced recharge).

13.2.2. Criteria Used to Define Undesirable Results

☑ **23 CCR § 354.26(b)(2)**
☑ **23 CCR § 354.26(c)**

The criteria used to define Undesirable Results for Reduction of Groundwater Storage in the basin-wide definition above are the Minimum Thresholds established at a local management area level for Chronic Lowering of Groundwater Levels. Furthermore, Minimum Thresholds set related to Subsidence protect against excessive loss of aquifer storage (and resulting reduction of Groundwater Storage). Extending this definition to the local Wheeler Ridge-Maricopa Management Area level, it would be considered an Undesirable Result if groundwater storage were to be reduced by an amount that would cause the groundwater levels in 40% or more of Representative Monitoring Sites to exceed their Minimum Thresholds for Chronic Lowering of Groundwater Levels over four consecutive seasonal measurements. As discussed below in **Section 14 *Minimum Thresholds***, due to the great depth of fresh water and wells able to access it, there is significant usable groundwater storage within the Management Area even below the elevation of the Minimum Thresholds. As such, on a local level it is not necessary to define unique SMCs for Reduction of Groundwater Storage; the criteria set for Chronic Lowering of Groundwater Levels are "protective" and a reasonable proxy.

13.2.3. Potential Effects of Undesirable Results

☑ 23 CCR § 354.26(b)(3)

The primary potential effect of Undesirable Results caused by Reduction of Groundwater Storage on beneficial uses and users of groundwater in the Wheeler Ridge-Maricopa Management Area is reduced groundwater supply reliability. The effect of reduced groundwater supply reliability would be most significant during periods of reduced surface water supply availability due to, for example, natural drought conditions, regulatory restrictions, natural disasters, or other causes. However, as discussed below in **Section 14 *Minimum Thresholds***, there is significant groundwater storage within the Management Area, and so these effects are unlikely to occur.

13.3. Undesirable Results for Seawater Intrusion

☑ 23 CCR § 354.26(d)

The GSP Emergency Regulations state that "An Agency that is able to demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin shall not be required to establish criteria for undesirable results related to those sustainability indicators" (23 CCR § 354.26(d)). Because the Kern Subbasin is not located near any saline water bodies, seawater intrusion is not present and not likely to occur. Therefore, the Seawater Intrusion Sustainability Indicator is not applicable to the Kern Subbasin and no Undesirable Results for this Sustainability Indicator are defined.

13.4. Undesirable Results for Degraded Water Quality

The basin-wide definition of Undesirable Results for Degraded Water Quality is as follows:

> "The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.
>
> This is determined when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent management areas which represent at least 15% of the subbasin or greater than 30% of the designated monitoring points within the basin. Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans."

As with Chronic Lowering of Groundwater Levels, the above basin-wide definition allows for local definition, within each Management Area of the Kern Subbasin, of the Minimum Thresholds that constitute a significant and unreasonable impact to the reasonable and beneficial use of, and access to, groundwater by overlying users. Key to the basin-wide definition is the phrase "as caused by water management actions". This phrase rightfully distinguishes between water quality impacts that are due to human actions and those that are the result of natural conditions. Because impacts due to natural conditions are not caused by (and in some cases, cannot be remedied by) human action, those impacts are not considered to be Undesirable Results subject to SGMA compliance.

13.4.1. Potential Causes of Undesirable Results

☑ 23 CCR § 354.26(b)(1)

Potential causes of Undesirable Results due to Degraded Water Quality within the Wheeler Ridge-Maricopa Management Area include the addition of constituents of concern (COCs) to groundwater in the principal aquifer through processes that are causatively related to water management or land use activities. These potential processes include:

- Deep percolation of precipitation, seepage from various natural and man-made channels, and recharge from reservoirs and spreading basins;
- Irrigation system backflow into wells and flow through well gravel pack and screens from one formation to another[67];
- Deep percolation of excess applied irrigation water and other water applied for cultural practices (e.g., for soil leaching). Potential COCs include salinity (i.e., Total Dissolved Solids [TDS]), nitrate, and agricultural chemicals;
- Lateral migration from adjacent areas with poorer quality groundwater (e.g., the area to the west of the Management Area). Potential COCs include salinity and other natural constituents (e.g., chloride and sulfate);
- Leaching from internal sources such as fine-grained, clay-rich interbeds. Potential COCs include arsenic and other constituents associated with fine-grained depositional environments (Smith et al., 2018);
- Upwards vertical flow from deeper zones below the bottom of the basin. Potential COCs include salinity, petroleum hydrocarbons, and other naturally-occurring constituents.

In the case of deep percolation of excess applied irrigation and leaching water, such activities are regulated separately under the Central Valley Regional Water Quality Control Board's (CVRWQCB's) Irrigated Lands Regulatory Program (ILRP) and CV-SALTS. For the last three items listed above, the underlying cause has to do with hydraulic gradients and heads (groundwater levels), and thus the causes are the same as those associated with the Undesirable Effects of Chronic Lowering of Groundwater Levels, discussed above. As discussed in **Section 8.5 *Groundwater Quality*** and shown by the groundwater level and quality graphs included in **Appendix F**, there is no discernable and consistent relationship between groundwater levels and groundwater quality that is consistent across the Wheeler Ridge-Maricopa Management Area. Additional data collection and analysis will be needed to evaluate this potential relationship further.

13.4.2. Criteria Used to Define Undesirable Results

☑ 23 CCR § 354.26(b)(2)

The basin-wide definition of Undesirable Results provides for local definition of the combination of Minimum Threshold exceedances that constitute and Undesirable Result in a Management Area. As described in **Section 8.5 *Groundwater Quality***, agricultural use is the dominant beneficial use within the

[67] Kern County's existing well destruction programs are designed to help minimize cross-connection between aquifer zones and prevent groundwater quality impairments that can result from cross-contamination of aquifer zones

Wheeler Ridge-Maricopa Management Area, and groundwater quality is generally suitable for agricultural uses, with the exception of groundwater on the western side of the District which has poorer quality (i.e., higher TDS and sulfate) due to natural geologic conditions. Water quality issues related to deep percolation of agricultural chemicals such as nitrate are regulated separately under the ILRP and CV-SALTS. Therefore, based on the existing and potential beneficial uses and users of groundwater within the Management Area, Undesirable Results for Degraded Water Quality are not defined on a local level. It should be noted, however, that monitoring for water quality will be conducted at a set of Representative Monitoring Site locations, as discussed further in **Section 16.1.4** ***Monitoring Network for Degraded Water Quality***.

13.4.3. Potential Effects of Undesirable Results

☑ **23 CCR § 354.26(b)(3)**

Per **Section** 354.26(b)(3) of the GSP Emergency Regulations, potential effects of Undesirable Results must be identified. As discussed above, because the dominant beneficial use is agricultural, and water quality is generally suitable for agricultural uses within the Wheeler Ridge-Maricopa Management Area, Undesirable Results are not defined for this Sustainability Indicator.

The above notwithstanding, more generally the potential effects of Undesirable Results caused by Degraded Water Quality on beneficial uses and users of groundwater may include: increased costs to treat groundwater to drinking water standards if it is to be used as a potable supply source; increased costs to blend relatively poor-quality groundwater with higher quality sources for agricultural and non-agricultural uses; limitations on viable crop types or crop yield depending on crop sensitivity and tolerance to COCs in groundwater used for irrigation; and potential reduction in "usable storage" volume of groundwater in the basin if large areas of aquifer are impacted to the point that they cannot be used to support beneficial uses and users.

As discussed in **Section 5.2.1** ***Existing Monitoring and Management Programs***, the District conducts groundwater quality sampling and monitoring for its own agricultural water management program, as does the State Water Resources Control Board (SWRCB) through its Groundwater Ambient Monitoring and Assessment (GAMA) program. These groundwater quality monitoring programs are expected to continue during the SMGA implementation horizon and will be incorporated into future SGMA reporting and analysis.

13.5. Undesirable Results for Land Subsidence

The basin-wide definition of Undesirable Results for Land Subsidence is as follows:

> "The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure.
>
> This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan."

Critical infrastructure is defined in the adopted Undesirable Results definition document as:

> "facilities which are utilized to provide public services such as water, utilities, and or transportation service for a region"

Unlike the Undesirable Results definitions for Chronic Lowering of Groundwater Levels, Reduction in Groundwater Storage, and Degraded Water Quality, the above basin-wide definition for Undesirable Results for Land Subsidence does not look towards a local definition of Minimum Thresholds on a management area level, but instead refers to a basin-wide coordinated GSP subsidence monitoring plan and affected water, utilities, and transportation service "for a region". Thus, the definition is focused on regional impacts, rather than local impacts.

13.5.1. Potential Causes of Undesirable Results

☑ **23 CCR § 354.26(b)(1)**

Land subsidence can be caused by several mechanisms, but the mechanism most relevant to sustainable groundwater management is the depressurization of aquifers and aquitards due to lowering of groundwater levels, which can lead to compaction of compressible strata and lowering of the ground surface. Therefore, the potential causes of Undesirable Results due to Land Subsidence are generally the same as the potential causes listed above for Undesirable Results due to Chronic Lowering of Groundwater Levels.

13.5.2. Criteria Used to Define Undesirable Results

☑ **23 CCR § 354.26(b)(2)**

The basin-wide definition of Undesirable Results refers to significant and unreasonable impacts to critical infrastructure which, as noted above, is defined with a regional emphasis. Within the Wheeler Ridge-Maricopa Management Area, the only critical infrastructure is the California Aqueduct. The California Aqueduct is the backbone of the State Water Project and is vital to the movement of water from northern California to the south. As such, the aqueduct is subject to ongoing subsidence monitoring by the DWR, which is anticipated to continue during the SGMA implementation period.

Recent monitoring has shown some land subsidence impacts to the section of the Aqueduct within the Wheeler Ridge-Maricopa Management Area. Recognizing the importance of the California Aqueduct to regional and statewide water infrastructure, it is considered an Undesirable Result for land subsidence to continue indefinitely in the vicinity of the Aqueduct. That being said, it is also recognized that due to the inherent time lag of the aquitard depressurization process, there may still be some "built-in" subsidence potential that has yet to manifest. It is therefore unrealistic to define the Undesirable Result as "any further land subsidence", as such an outcome would almost certainly be unavoidable, and therefore would prevent achievement of the Sustainability Goal. Therefore, the Undesirable Result for land subsidence is defined based on exceedance of a Minimum Threshold rate of subsidence which is based on historical observations of subsidence along the California Aqueduct.

Given the variability in subsidence throughout the Wheeler Ridge-Maricopa Management Area, it is appropriate to incorporate a fraction of monitoring sites in the definition of Undesirable Results, similar to how the Undesirable Results definition for Chronic Lowering of Groundwater Levels states that it occurs when Minimum Thresholds for that indicator are exceeded in 40% of Representative Monitoring Sites. For Land Subsidence, it is considered an Undesirable Result if the Minimum Threshold rate is exceeded in 40%

or more (i.e., 16 out of 40) of the DWR survey benchmark locations[68] between Mileposts 256.14 (Check No. 31) and 278.13 (Teerink Pumping Plant). The Minimum Threshold rate is described in **Section 14.5 *Minimum Threshold for Land Subsidence***

13.5.3. Potential Effects of Undesirable Results

☑ **23 CCR § 354.26(b)(3)**

Potential effects of Undesirable Results caused by land subsidence on beneficial uses and users of groundwater and overlying land uses within the Wheeler Ridge-Maricopa Management Area would include damage to gravity-driven water conveyance infrastructure (i.e., the California Aqueduct) which could impair its ability to move water to points further south. Land subsidence could also affect non-critical infrastructure such as local water conveyance systems (e.g., the District's pressure pipeline distribution system) and groundwater well casings, but those land uses are not considered critical infrastructure per the basin-wide definition which emphasizes regional impacts.

13.6. Undesirable Results for Depletions of Interconnected Surface Water

No basin-wide definition of Undesirable Results for Depletions of Interconnected Surface Water has been developed by the Kern Subbasin GSAs. Based on available data and information, depletion of interconnected surface water has not been observed within the Wheeler Ridge-Maricopa Management Area.

13.6.1. Potential Causes of Undesirable Results

☑ **23 CCR § 354.26(b)(1)**

Depletion of Interconnected Surface Water is generally correlated to Chronic Lowering of Groundwater Levels in an interconnected groundwater aquifer system. Therefore, the potential causes of Undesirable Results due to Depletion of Interconnected Surface Water are generally the same as the potential causes listed above for Undesirable Results due to Chronic Lowering of Groundwater Levels (i.e., increased groundwater pumping and reduced recharge). However, as discussed above, the degree of hydraulic connection between the principal aquifer and surface water within the Wheeler Ridge-Maricopa Management Area is unknown but suspected to be small based on available water level information. Therefore, there does not appear to be any active potential causes for Undesirable Results due to Depletion of Interconnected Surface Water.

13.6.2. Criteria Used to Define Undesirable Results

☑ **23 CCR § 354.26(b)(2)**

As described in **Section 8.7 *Interconnected Surface Water Systems***, there are no major surface water systems that are believed to be interconnected to the underlying groundwater table within the Wheeler Ridge-Maricopa Management Area. Because there is little to no interconnected surface water, no

[68] The DWR surveyed benchmark locations at which the Undesirable Results are defined are those within Pools 32 through 35 presented in Table 6-7 of DWR (2017).

Undesirable Result for Depletion of Interconnected Surface Water is defined within the Management Area.

13.6.3. Potential Effects of Undesirable Results

☑ 23 CCR § 354.26(b)(3)

Potential effects of Undesirable Results of Depletion of Interconnected Surface Water may include reduced surface water flows to support downstream or in-stream uses. As discussed above, there is little to no interconnected surface water within the Wheeler Ridge-Maricopa Management Area, and therefore no effects from Undesirable Results for this indicator have occurred or are expected to occur within the Management Area.

13.7. Undesirable Results Summary

Table SMC-1 below provides a summary of the local definitions of Undesirable Results for each Sustainability Indicator.

Table SMC-1. Summary of Undesirable Results Definitions within the Wheeler Ridge-Maricopa Management Area

Sustainability Indicator	Undesirable Results Definition within the Wheeler Ridge-Maricopa Management Area
Chronic Lowering of Groundwater Levels	Minimum Threshold exceedance in at least 40% (i.e., 6 or more out of 14) of Representative Monitoring Sites over four consecutive seasonal (bi-annual) measurements
Reduction of Groundwater Storage	No local Undesirable Results definition; Chronic Lowering of Groundwater Levels used as a proxy.
Seawater Intrusion	No local Undesirable Results definition; Sustainability Indicator not applicable within the Kern Subbasin
Degraded Water Quality	No local Undesirable Results definition
Land Subsidence	Subsidence at rates exceeding the Minimum Threshold rate throughout the SGMA implementation period in at least 40% (16 of 40) of subsidence monitoring locations
Depletion of Interconnected Surface Water	No local Undesirable Results definition; Sustainability Indicator not applicable within the Wheeler Ridge-Maricopa Management Area

14. MINIMUM THRESHOLDS

☑ 23 CCR § 354.28(a)

Minimum Thresholds are the numeric criteria for each Sustainability Indicator that, if exceeded, may cause Undesirable Results. This section describes the Minimum Thresholds that have been developed to avoid Undesirable Results for each applicable Sustainability Indicator in the Wheeler Ridge-Maricopa Management Area. These Minimum Thresholds have been developed in coordination with other KGA members and GSAs within the "south of Kern River" portion of the Kern Subbasin (e.g., Arvin-Edison Water Storage District and the Kern River GSA).

As shown in **Table SMC-2**, Minimum Thresholds within the Wheeler Ridge-Maricopa Management Area are defined at different spatial scales and locations, or not at all, depending on the Sustainability Indicator. Where appropriate, the Minimum Thresholds for the Sustainability Indicators have been set using groundwater levels as a proxy, based on demonstration "that there is a significant correlation between groundwater levels and the other metrics" (California Department of Water Resources [DWR] Sustainable Management Criteria Best Management Criteria [BMP] document; DWR, 2018).

Table SMC-2. Spatial Scale of Minimum Threshold Definition

Sustainability Indicator	Spatial Scale of Minimum Threshold Definition	Notes
Chronic Lowering of Groundwater Levels	Sustainability Criteria Zones	There are three Sustainability Criteria Zones defined; Groundwater levels will be measured at 14 Representative Monitoring Sites (i.e., wells)
Reduction of Groundwater Storage	No Minimum Threshold defined	Chronic Lowering of Groundwater Levels will be used as a proxy
Seawater Intrusion	No Minimum Threshold defined	Sustainability Indicator not applicable within the Kern Subbasin
Degraded Water Quality	No Minimum Thresholds defined	Monitoring for groundwater quality at selected locations will continue as part of District agricultural water management and as part of compliance with other regulatory programs
Land Subsidence	Representative Monitoring Sites	Surface elevations will be monitored at a network of benchmarks along the California Aqueduct by DWR and others

Depletion of Interconnected Surface Water	No Minimum Thresholds defined	Sustainability Indicator not applicable within the Wheeler-Ridge Maricopa Management Area

14.1. Minimum Threshold for Chronic Lowering of Groundwater Levels

☑ **23 CCR § 354.28(c)(1)**

Chronic Lowering of Groundwater Levels is arguably the most fundamental Sustainability Indicator, as it influences several other key Sustainability Indicators, including Reduction of Groundwater Storage, Land Subsidence, and in certain ways, Degraded Water Quality. Groundwater levels are also the most readily available and measurable metrics of groundwater conditions, which allows for a systematic, data-driven approach to development of Minimum Thresholds to be applied. There are no state, federal, or local standards that relate to this Sustainability Indicator.

14.1.1. Minimum Threshold Development

☑ **23 CCR § 354.28(c)(1)(A)**
☑ **23 CCR § 354.28(c)(1)(B)**

Consistent with the GSP Emergency Regulations (23 CCR § 354.28(c)), the definition of Minimum Thresholds for Chronic Lowering of Groundwater Levels in the Wheeler Ridge-Maricopa Management Area is based on consideration of trends in historical groundwater levels, water year types, projected water use in the management area, and the relationship to other Sustainability Indicators. Specifically, the information and criteria relied on to establish the Minimum Thresholds for Chronic Lowering of Groundwater Levels includes:

- Historical water level data from selected wells with long-term representative water level records[69];
- The proximity to critical infrastructure (i.e., for consideration of potential land subsidence impacts); and
- Well construction information (i.e., for consideration of impacts to beneficial users).

This information was used to develop initial Minimum Threshold estimates using a quantitative algorithm that accounted for trends, historical lows, and water level variability (discussed below) and then these initial estimates were mapped and generalized spatially to create three "Sustainability Criteria Zones" within the Wheeler Ridge-Maricopa Management Area. This approach allowed for the most complete and representative historical water level information to inform the Minimum Thresholds, while also allowing

[69] The representativeness of the wells with long-term hydrograph records is illustrated on **Figure SMC-1**, which shows the Fall 2015 groundwater level at each well compared to the average Fall 2015 groundwater elevation by Public Land Survey System (PLSS) section for all sections "associated with" (i.e., closest to) each long-term hydrograph location. The figure shows that the percent difference in water level in the local area around each well is small in most cases, indicating that the well is representative of that local area.

for potentially different wells (i.e., other than those with the best historical records) to be used as Representative Monitoring Sites.

Minimum Threshold Algorithm

☑ 23 CCR § 354.28(b)(1)

The initial Minimum Threshold estimates for Chronic Lowering of Groundwater Levels were developed for each long-term hydrograph well location through development and application of an algorithm that considers the above information, as follows:

- Historical low water levels over a relevant time period are used as a starting point for Minimum Thresholds based on the fact that significant and unreasonable impacts to beneficial uses and users of groundwater due to groundwater levels are not known to have occurred since the time when water levels were at their historical low. The relevant time period for historical low determination is defined as Water Year (WY) 1966 - 2018 for the following reasons:
    - The assumed upper-end usable lifespan of groundwater wells is approximately 50 years, and therefore most wells would likely not have experienced conditions prior to about 50 years ago;
    - The WRMWSD started surface water importation in 1971, and AEWSD (which overlaps WRMWSD in the eastern portion of the management area) began importing water in 1966. These actions represented a significant change to water management in this part of the Kern Subbasin; and
    - The relevant time period includes conditions observed up to "present" (Fall 2018).
- Variability in groundwater levels is accounted for by calculating a Variability Correction Factor as the product of the observed water level range over a relevant time period and a "Range Fraction". This Variability Correction Factor is applied to the historical low (as discussed below) and acknowledges the fact that different locations within the Wheeler Ridge-Maricopa Management Area have experienced different amounts of water level variability.
    - The time period for water level range determination is defined as WY 1995 – 2015 for the following reasons:
        - The 21-year length of this period is roughly the same as the 20-yr SGMA implementation period, and therefore the SGMA implementation period is expected to include a similar range of variability as the groundwater level range period;
        - The period includes a mix of wet and dry years and so variability in groundwater levels during this time should be reflective of variable climate;
        - The period is climatically close to the long-term average for precipitation and Kern River Flow (Todd Groundwater, 2016); and
        - This period is the same as the historical and current water budget period of interest defined by KGA and its member agencies, and therefore water budget and model results are available for this period.

- The Range Fraction is set at 25% as a conservative allowance for water level fluctuation within a well.

- Recent trends in groundwater levels and projected water use are accounted for by extending the trend for a certain amount of time (the "Trend Extension Period") to determine a Trend Continuation Factor. This factor is also applied to historical low water levels (as discussed below) in order to avoid rapid disruption to land uses and allow time for implementation of any Projects and/or Management Actions needed to eliminate declining trends.
  - The time period for water level trend calculation is defined as WY 2009 – 2018 for the following reasons:
    - This period reflects the effects of changes to SWP/CVP deliveries resulting from Delta-related federal District Court rulings; and
    - The period includes the recent significant drought, and therefore allows the Trend Continuation Factor to incorporate the possibility of another long-term drought in the future (e.g., potentially exacerbated by climate change), consistent with the basin-level Undesirable Results definition for Reduction in Groundwater Storage.
  - The Trend Extension Period was set to ten years for the following reasons:
    - This length of time is considered reasonable and necessary to implement the various Projects & Management Actions that may be required to reverse declining groundwater level trends, in consideration of the potential regulatory, environmental, logistical, engineering, socioeconomic and other challenges that the various Projects & Management Actions may entail, as well as the time that such measures would likely take to manifest in observed groundwater level conditions; and
    - This length of time is half the duration of the SGMA implementation period, suggesting that by the halfway point, the Wheeler Ridge-Maricopa Management Area should be on a trajectory towards achieving the Sustainability Goal.

- Using the above values (i.e., the Historical Low, the Variability Correction Factor, and the Trend Continuation Factor), the initial Minimum Threshold estimates for Chronic Lowering of Groundwater Levels at each long-term hydrograph location are calculations as the lower of: (a) the historic low groundwater level minus the Variability Correction Factor), and (b) the recent (Fall 2015) groundwater level minus the greater of either the Variability Correction Factor or the Trend Continuation Factor. In mathematical terms, the algorithm for defining the initial Minimum Threshold estimates for Chronic Lowering of Groundwater Levels at each long-term hydrograph location is as follows:

$$MT = min\begin{cases} HL - VCF \\ Recent - max\begin{cases} VCF \\ TCF \end{cases} \end{cases}$$

$$VCF = Range * 25\%$$

$$TCF = Trend * 10\ yrs$$

where:

MT is the initial Minimum Threshold estimate (ft msl);

HL is the historical low groundwater level over the WY 1965 – 2018 period (ft msl),

VCF is the Variability Correction Factor (ft);

TCF is the Trend Continuation Factor (ft);

Recent is the Fall 2015 groundwater level (ft msl);

Range is the water level range over the WY 1995 – 2015 period; and

Trend is the groundwater level trend over the 2009 – 2015 period (ft/yr).

Adjustment in Areas Proximal to Critical Infrastructure

☑ **23 CCR § 354.28(b)(2)**
☑ **23 CCR § 354.28(b)(4)**

In areas proximal to critical infrastructure that may be particularly sensitive to significant and unreasonable effects from land subsidence (discussed further below), an adjustment to the initial Minimum Threshold estimates was applied in the algorithm to keep the values at historical low groundwater levels. Specifically, for long-term hydrograph locations that were within one mile of critical infrastructure, the initial Minimum Threshold estimates were set to their historical low groundwater levels, as this theoretically prevents any further subsidence from occurring. Results from the initial Minimum Threshold estimation exercise described above are shown on **Figure SMC-2**. Also shown on this figure are the proposed Sustainability Criteria Zones defined within the Wheeler Ridge-Maricopa Management Area which are discussed below.

Consideration of Adjacent Basins

☑ **23 CCR § 354.28(b)(3)**

Minimum Thresholds have been developed in consideration of and in coordination with neighboring water agencies within the Kern Subbasin (see **Section 5.5.5 *Interagency Coordination***) and in neighboring basins (see **Section 5.5.6 *Interbasin Coordination*).** Through its membership in the White Wolf GSA (along with AEWSD and TCWD), WRMWSD has and will continue to consider the effects of Sustainability Criteria in the Wheeler Ridge-Maricopa Management Area on the adjacent White Wolf Basin's ability to achieve its sustainability goal.

Spatial Generalization into Sustainability Criteria Zones

Once the initial Minimum Threshold estimates for the long-term hydrograph locations were calculated using the algorithm described above, they were plotted on a map and examined for spatial patterns that could be used to generalize the values into zones. The purpose of this step was to allow flexibility in the selection of Representative Monitoring Sites for this Sustainability Indicator, recognizing that not all of the wells with long-term hydrograph data are available for use in the monitoring network. It was determined that the Wheeler Ridge-Maricopa Management Area could be divided into three zones, referred to as the Western, Northeastern, and Southeastern zones, as shown on **Figure SMC-2**. The Minimum Threshold Values for each Sustainability Criteria Zone is shown on **Figure SMC-3**.

As part of the delineation of Sustainability Criteria Zones within the Wheeler Ridge-Maricopa Management Area, an analysis was performed regarding potential well impacts associated with various Minimum Threshold values. Using available well construction information for domestic, production (agricultural), and public supply wells, an assessment was made of the number of wells that could be dewatered at different generalized Minimum Threshold levels. Through this analysis which was performed iteratively with different Minimum Threshold levels, the proposed Minimum Thresholds would potentially result in seven wells being dewatered, the impacts would not be unreasonable and would be prevented and/or mitigated through an Impacted Well Mitigation Program (see **Section 18.6.1 *Impacted Well Mitigation Program***), to be developed as part of GSP Implementation. Results from this well impact analysis of Minimum Thresholds are shown on **Figure SMC-4** and **Figure SMC-5** for the Sustainability Criteria Zones and the PLSS sections, respectively.

The final Minimum Thresholds for Chronic Lowering of Groundwater Levels in each Sustainability Criteria Zone and at each Representative Monitoring Site are shown in **Table SMC-3** and on **Figure SMC-3**.

14.2. Minimum Threshold for Reduction of Groundwater Storage

☑ **23 CCR § 354.28(c)(2)**

As discussed above, the Undesirable Results definition for Reduction of Groundwater Storage at the basin level refers to a decrease in storage that would cause water levels to decline below Minimum Thresholds established in each management area for Chronic Lowering of Groundwater Levels. It is logical to tie these two Sustainability Indicators together, as the amount of groundwater in storage is directly, if not linearly, related to groundwater levels. Because of the close relationship between these two Sustainability Indicators, and because the Minimum Thresholds for Chronic Lowering of Groundwater Levels (discussed above) are protective of the beneficial uses and users of groundwater, it is not necessary to set a unique Minimum Threshold for Reduction of Groundwater Storage. Rather, Minimum Thresholds for Chronic Lowering of Groundwater Levels will be used as a proxy for the Reduction of Groundwater Storage Sustainability Indicator. There are no state, federal, or local standards that relate to this Sustainability Indicator.

14.2.1. Use of Groundwater Levels as Proxy

☑ **23 CCR § 354.28(d)**

Pursuant to the GSP Emergency Regulations (23 CCR § 354.28(d)) and as further described in the DWR Sustainable Management Criteria BMP, Minimum Thresholds for Reduction of Groundwater Storage may be set by using groundwater levels as a proxy if it is demonstrated that a correlation exists between the two metrics. One approach to using groundwater levels as a proxy, described in the DWR Sustainable Management Criteria BMP, is to demonstrate that Minimum Thresholds for Chronic Lowering of Groundwater Levels are sufficiently protective to ensure prevention of significant and unreasonable occurrences of the Sustainability Indicator in question.

To demonstrate that the Minimum Thresholds for Chronic Lowering of Groundwater Levels are sufficiently protective, a calculation was performed to determine the volume of groundwater that would be removed from the primary aquifer if groundwater levels were to decline from current (Fall 2015) levels to their respective Minimum Thresholds for Chronic Lowering of Groundwater Level. This volume is then compared to the volume of usable storage, and it is shown that there is more usable storage is greater,

and therefore, the Minimum Thresholds for Chronic Lowering of Groundwater Levels are protective for the Reduction of Groundwater Storage Sustainability Indicator.

Usable Storage

To support the use of Minimum Thresholds for Chronic Lowering of Groundwater Levels as a proxy for Reduction of Groundwater Storage, it is informative to define an actual volume of "usable storage" above the median bottom depth of wells. This volume is calculated based on the following data and assumptions:

- Area of Wheeler Ridge-Maricopa Management Area (92,343 acres)
- Storage coefficient (0.08)[70]
- Average depth to groundwater in Fall 2015 (approximately 303 ft)
- Depth corresponding to the 50% cumulative bottom depth of wells (approximately 1,100 ft)

The volume of usable storage is approximately 5.9 million AF. This volume corresponds to the volume that would be pumped in roughly 100 years of pumping at the average rate pumped from WY 1995 through 2015 (i.e., 59,152 AFY).

Storage Reduction at Minimum Threshold Levels

The volume of groundwater that would be removed from storage if groundwater levels were to decline to Minimum Threshold levels volume is calculated for each PLSS section by subtracting the Minimum Threshold from the associated Sustainability Criteria Zone from the "current" (Fall 2015) gridded groundwater elevation data, multiplying the difference by the storage coefficient, and then summing the values for each PLSS section to arrive at a total volume for the entire Wheeler Ridge-Maricopa Management Area. This calculation is shown in the equation below:

$$MT_Stor = \sum_{k=1}^{n} (GWL_i - MT_GWL_i) * A_k * S_k$$

where:

MT_Stor is the Minimum Threshold for Reduction of Groundwater Storage (AF);

GWL is the current groundwater elevation (ft msl);

MT_GWL is the Minimum Threshold for Chronic Lowering of Groundwater Levels within the Sustainability Criteria Zone (subscript *i*) (ft msl);

A is the area (acres); and

S is the storage coefficient (dimensionless). The subscript *k* refers to each PLSS section (a total of *n* sections within the Wheeler Ridge-Maricopa Management Area).

The resulting volume is approximately 1.08 million AF which is much less than the 5.9 million AF of "usable storage". Therefore, the Minimum Thresholds for Chronic Lowering of Groundwater Levels are sufficiently protective to ensure prevention of significant and unreasonable occurrences of Reduction of Groundwater

[70] There is uncertainty in the value for the storage coefficient used in the above calculations, as discussed in Section **7.1.4** ***Principal Aquifers and Aquitards***. However, the value of 0.08 is considered conservative.

Storage. Therefore, no Minimum Threshold for Reduction of Groundwater Storage is set within the Wheeler Ridge-Maricopa Management Area.

14.3. Minimum Threshold for Seawater Intrusion

☑ 23 CCR § 354.28(c)(3)
☑ 23 CCR § 354.28(e)

The GSP Emergency Regulations state that "An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators" (23 CCR § 354.28(e)). Because the Kern Subbasin is not located near any saline water bodies, seawater intrusion is not present and not likely to occur. Therefore, the Seawater Intrusion Sustainability Indicator is not applicable to the Kern Subbasin and no SMCs for this Sustainability Indicator are defined in the Wheeler Ridge-Maricopa Management Area.

14.4. Minimum Threshold for Degraded Water Quality

☑ 23 CCR § 354.28(c)(4)

The GSP Emergency Regulations state that "An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators" (23 CCR § 354.28(e)). As discussed above, based on the existing beneficial uses and users of groundwater within the Wheeler Ridge-Maricopa Management Area, there are not Undesirable Results for Degraded Water Quality occurring and the Minimum Thresholds for Chronic Lowering of Groundwater Level are anticipated to be protective in terms of preventing migration of poor-quality water. Therefore, no unique Minimum Thresholds are set for this Sustainability Indicator. It should be noted, however, that monitoring for water quality will be conducted at a set of Representative Monitoring Site locations, as discussed further in **Section 16.1.4 *Monitoring Network for Degraded Water Quality***.

14.5. Minimum Threshold for Land Subsidence

☑ 23 CCR § 354.28(c)(5)

Minimum Thresholds for Land Subsidence are defined herein as levels of land subsidence that, if they occurred, would result in significant and unreasonable impacts to critical infrastructure and surface land uses. There are no state, federal, or local standards that relate to this Sustainability Indicator.

Within the Wheeler Ridge-Maricopa Management Area, the critical infrastructure that has the potential to be significantly and unreasonably impacted by land subsidence includes the California Aqueduct. While certain other land uses exist within the Management Area that are potentially affected by land subsidence (see **Section 13.5 *Undesirable Results for Land Subsidence***), the Aqueduct is considered the most critical to avoid Undesirable Results from land subsidence in the Management Area because it is associated with the regional water supply system as well as the central mission of WRMWSD which is the importation and delivery of surface water.

14.5.1. Minimum Threshold Development

☑ 23 CCR § 354.28(b)(1)
☑ 23 CCR § 354.28(b)(4)

Historical and recent rates of subsidence measured within the Wheeler Ridge-Maricopa Management Area in proximity to the sensitive land uses listed above are discussed in **Section 8.6 *Land Subsidence***. The Minimum Threshold rate for Land Subsidence is defined herein based on the maximum rate of subsidence observed through ground-based surveys between 1975 and 2019 at survey benchmarks along the California Aqueduct. The Minimum Threshold amount of subsidence is defined as the amount that would occur if the Minimum Threshold rate were extended forward until the end of the SGMA implementation timeline (i.e., to 2040).[71] Specifically, the Minimum Threshold for Land Subsidence is calculated as follows:

$$MT_Sub = Max_rate_Aqueduct * t_impl$$

where:

MT_Sub is the Minimum Threshold for Land Subsidence as a cumulative amount (in);

$Max_rate_Aqueduct$ is the maximum average rate of subsidence between 1975and 2019 observed at any survey benchmark along the California Aqueduct between Mileposts 256.14 (Check No. 31) and 278.13 (Teerink Pumping Plant), equal to 0.50 inches per year[72]; and

t_impl is time from 2019 until the end of the SGMA GSP implementation timeframe (2040), equal to 22 years.

The rationale for this Minimum Threshold rate of subsidence is that such subsidence has been historically managed by DWR through maintenance and improvements to its facilities. Within the Wheeler Ridge-Maricopa Management Area, as of 2013 there are no reaches of the Aqueduct that have less than the minimum recommended freeboard (2.5 ft); the minimum freeboard is approximately 3.9 ft in one location around milepost 256.56, and along most other portions of these reaches the freeboard is between 6 and 8 feet (DWR, 2017).

14.5.2. Final Minimum Thresholds

☑ 23 CCR § 354.28(b)(2)
☑ 23 CCR § 354.28(b)(6)

Per the above calculation, the resulting Minimum Threshold rate of subsidence is 0.5 in/yr, and the Minimum Threshold cumulative amount of subsidence is 10.93 inches, relative to elevations measured in 2018. The Minimum Threshold applies to the 40 DWR survey benchmark locations between Mileposts 256.56 (Check No. 31) and 278.13 (Teerink Pumping Plant) that are included on the profiles included in

[71] Satellite-based land subsidence measurements (i.e., InSAR data) indicate recent subsidence of 1 to 4 inches between May 2015 and September 2016, with localized amounts of between 4 and 8 inches (see **Figure GWC-15**). However, this data collected method, while useful for spatial understanding of subsidence patterns, is considered less accurate at any given location than ground-based survey methods, and for purposes of subsidence monitoring near critical infrastructure, ground-based survey methods will be used. Therefore, the ground-based survey data collected by DWR along the California Aqueduct are used herein to define Minimum Thresholds for Land Subsidence in the vicinity of critical infrastructure.

[72] The maximum rate of subsidence between 1975 and 2019 of 0.50 inches per year was observed at Mileposts 257.63 and 275.00.

the DWR (2017) report plates included in Appendix I. The final Minimum Thresholds for Land Subsidence are shown in **Table SMC-4**. Additional information about the Representative Monitoring Sites for this Sustainability Indicator is provided in **Section 16 *Monitoring Network***.

It should be noted that the Minimum Thresholds for Chronic Lowering of Groundwater Levels include consideration of land subsidence by limiting the Minimum Thresholds to the historical low groundwater levels in those Representative Monitoring Sites that are within one mile of critical infrastructure (see **Section 14.1**

Minimum Threshold for Chronic Lowering of Groundwater Levels). While groundwater level measurements are not being used as a proxy for land subsidence measurements in these areas (i.e., the land subsidence monitoring network will consist of survey benchmark locations maintained and measured by DWR), these Minimum Thresholds for Chronic Lowering of Groundwater Levels are set conservatively to avoid further land subsidence.

14.6. Minimum Threshold for Depletion of Interconnected Surface Water

☑ **23 CCR § 354.28(c)(6)**
☑ **23 CCR § 354.28(e)**

The GSP Emergency Regulations state that "An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in 23 CCR § 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators" (23 CCR § 354.28(e)). As discussed above, based on available data and information, Depletion of Interconnected Surface Water has not been observed within the Wheeler Ridge-Maricopa Management Area, and depths to groundwater are so deep as the preclude the possibility of occurrence of interconnected surface water. Therefore, there are no Undesirable Results and no Minimum Thresholds defined for this Sustainability Indicator.

15. MEASURABLE OBJECTIVES AND INTERIM MILESTONES

☑ 23 CCR § 354.30(a)
☑ 23 CCR § 354.30(b)

This section discusses the development of Measurable Objectives and Interim Milestones for all relevant Sustainability Indicators in the Arvin-Edison Management Area.

15.1. Measurable Objective and Interim Milestones for Chronic Lowering of Groundwater Levels

15.1.1. Measurable Objective for Chronic Lowering of Groundwater Levels

☑ 23 CCR § 354.30(c)

Initial estimates for Measurable Objectives for Chronic Lowering of Groundwater Levels were developed based on the groundwater levels that were observed in the 16 long-term hydrograph locations in or around Fall 2015. As with the Minimum Thresholds, the initial Measurable Objective estimates were then adjusted and generalized into values for each Sustainability Criteria Zone. The adjustments and generalizations generally entail decreasing the Measurable Objective for the zone relative to the Fall 2015 levels. The downward adjustments were made in recognition of the fact that in most cases groundwater levels in 2015 were not near their historical low, and therefore an ample Margin of Operational Flexibility could be achieved even with levels lower than they were in 2015. Also, considering the potential for reduced surface water imports in the future and potentially increased groundwater use, it was considered appropriate to set the Measurable Objectives to allow for some decrease from 2015 levels. Measurable Objectives for Chronic Lowering of Groundwater Levels for each Sustainability Criteria Zone and at each Representative Monitoring Site are shown in are shown on **Table SMC-3** and **Figure SMC-6**.

15.1.2. Interim Milestones for Chronic Lowering of Groundwater Levels

☑ 23 CCR § 354.30(e)

Interim Milestones for Chronic Lowering of Groundwater Levels are defined herein based on a trajectory for groundwater levels informed by the current (Fall 2018) levels, the Minimum Thresholds, and the Measurable Objectives. This trajectory allows for and assumes a continuation of current groundwater level trends for the first 5-year period, a deviation from that trend over the second 5-year period, a recovery to the 5-year Interim Milestone in the third 5-year period, and recovery towards the Measurable

Objectives over the fourth (last) 5-year period. Specifically, the trajectory for groundwater levels prescribed in the Interim Milestones is as follows:

Table SMC-5. Interim Milestone Trajectory for Chronic Lowering of Groundwater Levels

Calendar Year	Interim Milestone for Chronic Lowering of Groundwater Levels	Basis for Interim Milestone
2020	Not applicable	Not applicable
2025	$IM\text{-}5_{GWL}$	$½ * (GWL_{Fall2018} + MT_GWL)$
2030	$IM\text{-}10_{GWL}$	$½ * (IM\text{-}5_{GWL} + MT_GWL)$
2035	$IM\text{-}15_{GWL}$	$½ * (IM\text{-}10_{GWL} + MO_GWL)$
2040	Not applicable (Measurable Objective)	Not applicable (Measurable Objective)

where:

$IM\text{-}5_{GWL}$, $IM\text{-}10_{GWL}$, and $IM\text{-}15_{GWL}$ are the Interim Milestones for Chronic Lowering of Groundwater Levels after 5 years, 10 years and 15 years, respectively;

$GWL_{Fall2018}$ is the groundwater elevation measured in Fall 2018;

MT_GWL is the Minimum Threshold for Chronic Lowering of Groundwater Levels (defined previously); and

MO_GWL is the Measurable Objective for Chronic Lowering of Groundwater Levels (defined previously;)

Interim Milestones and Measurable Objectives for Chronic Lowering of Groundwater Levels are presented in **Table SMC-3**, and are displayed relative to historical water levels at each Representative Monitoring Site on **Figure SMC-7**.

15.2. Measurable Objective for Reduction of Groundwater Storage

☑ 23 CCR § 354.30(c)
☑ 23 CCR § 354.30(d)

As discussed above, the Undesirable Results definition for Reduction of Groundwater Storage at the basin level refers to a decrease in storage that would cause water levels to decline below Minimum Thresholds established in each management area for Chronic Lowering of Groundwater Levels. It is logical to tie these two Sustainability Indicators together, as the amount of groundwater in storage is directly, if not linearly, related to groundwater levels. Because of the close relationship between these two Sustainability Indicators, the Measurable Objective for Chronic Lowering of Groundwater Levels serves as a proxy for Reduction of Groundwater Storage, and it is not necessary to set a unique Measurable Objective for Reduction of Groundwater Storage. As stated above, the Measurable Objectives for Chronic Lowering of Groundwater Levels provide an adequate Margin of Operational Flexibility.

15.3. Measurable Objective for Seawater Intrusion

The GSP Emergency Regulations state that "An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in 23 CCR § 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators" (23 CCR § 354.28(e)). Because the Kern Subbasin is not located near any saline water bodies, and seawater intrusion is not present and not likely to occur, the Seawater Intrusion Sustainability Indicator is not applicable to the Kern Subbasin, and therefore no SMCs for this Sustainability Indicator are defined.

15.4. Measurable Objective for Degraded Water Qualtiy

☑ **23 CCR § 354.30(c)**

As discussed above, based on the existing beneficial uses and users of groundwater within the Wheeler Ridge-Maricopa Management Area, there are not Undesirable Results for Degraded Water Quality occurring and the Minimum Thresholds for Chronic Lowering of Groundwater Level are anticipated to be protective. Therefore, no unique Minimum Thresholds or Measurable Objectives are set for this Sustainability Indicator.

15.5. Measurable Objectives and Interim Milestones for Land Subsidence

☑ **23 CCR § 354.30(c)**
☑ **23 CCR § 354.30(e)**

The Measurable Objective for Land Subsidence is defined as half of the amount of land subsidence that would be observed if the Minimum Threshold subsidence rates (0.5 in/yr) were to continue from 2018 through 2030 and then cease, which amounts to approximately half of the Minimum Threshold amount. This corresponds to a total amount of subsidence by 2040 of no more than 5.96 inches in no more than 40% of the Representative Monitoring Sites. While ideally there would be no further land subsidence along the Aqueduct, as stated above, due to the inherent time lag of the aquitard depressurization process, there may still be some "built-in" subsidence potential that has yet to manifest. Therefore, it is not considered reasonable to expect an immediate and complete cessation to the historic subsidence rates. Rather, it is considered a reasonable and potentially achievable goal to reduce the historical rate by half over the SGMA implementation period (i.e., by 2040). Interim Milestones for land subsidence are specified as follows:

Table SMC-6. Interim Milestone Trajectory for Land Subsidence

Calendar Year	Interim Milestone for Land Subsidence	Basis for Interim Milestone
2020	Not applicable	Not applicable
2025	$IM\text{-}5_{Subs}$	$GS_Elev_{2018} - 7 * MT_Rate$
2030	$IM\text{-}10_{Subs}$	$GS_Elev_{2018} - 12 * MT_Rate$
2035	$IM\text{-}15_{Subs}$	$GS_Elev_{2018} - 12 * MT_Rate$
2040	Not applicable (Measurable Objective)	$GS_Elev_{2018} - 12 * MT_Rate$

where:

$IM\text{-}5_{Subs}$, $IM\text{-}10_{Subs}$, and $IM\text{-}15_{Subs}$ are the Interim Milestones for Land Subsidence after 5 years, 10 years and 15 years, respectively;

GE_Elev_{2018} is the measured ground surface elevations in 2018; and

MT_Rate is the Minimum Threshold rate for Land Subsidence (0.5 in/yr; defined previously).

Interim Milestones and Measurable Objectives for Land Subsidence are presented in **Table SMC-4**.

15.6. Measurable Objective for Depletions of Interconnected Surface Water

As discussed above, based on available data and information, Depletion of Interconnected Surface Water has not been observed within the Wheeler Ridge-Maricopa Management Area. Therefore, there are no SMCs defined for this Sustainability Indicator.

TABLE SMC-3

Summary of Minimum Thresholds, Interim Milestones, and Measurable Objectives for Chronic Lowering of Groundwater Levels

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

Representative Monitoring Site ID	Sustainability Criteria Zone	Minimum Threshold (ft msl)	Interim Milestones (ft msl)			Measurable Objective (ft msl)	Margin of Operational Flexibility (ft)
			2025	2030	2035		
11N22W06H001S	Western	100	184	142	171	200	100
32S25E29Q001M	Western	100	195	147	174	200	100
32S26E20G001M	Northeastern	-50	33	-8	-4	0	50
32S26E24K001M	Northeastern	-50	33	-8	-4	0	50
32S27E30N001M	Northeastern	-50	93	21	11	0	50
32S27E35R001M	Northeastern	-50	49	-1	0	0	50
32S26E34P001M	Northeastern	-50	68	9	4	0	50
32S26E36P002M	Northeastern	-50	63	6	3	0	50
32S28E16P001M	Northeastern	-50	111	30	15	0	50
11N22W01D001S	Southeastern	0	93	47	61	75	75
11N21W16E001S	Southeastern	0	3	2	38	75	75
12N21W35Q001S	Southeastern	0	100	50	62	75	75
12N21W34Q001S	Southeastern	0	62	31	53	75	75
11N21W09C001S	Southeastern	0	80	40	58	75	75

Abbreviations:

ft = feet

ft msl = feet above mean sea level

TABLE SMC-4
Summary of Minimum Thresholds, Interim Milestones, and Measurable Objectives for Land Subsidence
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

Survey Benchmark Location (milepost)	Annual Subsidence Rate (in/yr)									2018 Elevation (ft NGVD1929)	Sustainable Management Criteria					
											Interim Milestones			Measurable Objective (ft NGVD1929)	Minimum Threshold (ft NGVD1929)	Margin of Operational Flexibility (ft)
	1975-1978	1978-1981	1981-1986	1986-1993	1993-2000	2000-2006	2006-2013	2016-2019	Weighted Average (1975-2019; excluding 1981-1986)		2025	2030	2035			
256.56	-1.1	-0.7	0.7	-0.3	-0.2	-0.6	-0.1	-0.54	-0.41	502.53	502.24	502.04	502.04	502.04	501.62	0.41
257.00	-0.2	-0.2	1	0	0	-0.4	0	-0.34	-0.13	504.06	503.77	503.56	503.56	503.56	503.15	0.41
257.48	-0.5	-0.4	0.9	-0.1	-0.2	-0.5	-0.1	-0.03	-0.24	503.08	502.79	502.59	502.59	502.59	502.17	0.41
257.63	-0.5	-0.7	0.7	-0.3	-0.3	-0.7	-0.3	-1.26	-0.50	502.66	502.37	502.16	502.16	502.16	501.75	0.41
258.00	-0.4	-0.2	1	-0.2	-0.2	-0.6	-0.2	-0.52	-0.31	502.97	502.68	502.47	502.47	502.47	502.06	0.41
258.50	-0.8	-0.6	0.8	-0.2	-0.2	-0.6	-0.1	-0.42	-0.35	502.42	502.13	501.92	501.92	501.92	501.51	0.41
259.00	-0.4	-0.1	1.1	-0.2	-0.1	-0.5	-0.1	-0.26	-0.22	503.12	502.83	502.63	502.63	502.63	502.21	0.41
259.50	-0.5	-0.4	1	-0.2	-0.2	-0.6	-0.2	-0.56	-0.34	502.75	502.46	502.25	502.25	502.25	501.84	0.41
260.50	-0.5	0	1	-0.3	-0.2	-0.6	-0.2	-0.54	-0.32	502.28	501.99	501.79	501.79	501.79	501.37	0.41
261.00	-0.5	-0.1	1.2	-0.2	-0.2	-0.5	-0.2	-0.64	-0.30	502.30	502.01	501.80	501.80	501.80	501.39	0.41
261.72	-0.6	0	1.1	-0.3	-0.1	-0.5	-0.1	-0.50	-0.27	502.02	501.73	501.52	501.52	501.52	501.11	0.41
262.00	-0.4	0	1.2	-0.2	-0.2	-0.5	-0.1	-0.58	-0.26	503.29	503.00	502.80	502.80	502.80	502.38	0.41
262.50	-0.3	0.1	1.2	0	0	-0.4	0	-0.50	-0.12	503.68	503.39	503.18	503.18	503.18	502.77	0.41
263.00	-0.3	0.1	1.2	0	0	-0.4	0	-0.46	-0.12	503.74	503.45	503.24	503.24	503.24	502.83	0.41
263.50	-0.3	0	1.2	0	0	-0.4	0	-0.51	-0.13	503.51	503.22	503.01	503.01	503.01	502.60	0.41
264.00	-0.7	-0.1	1	0	0	-0.5	-0.1	-0.72	-0.23	502.83	502.54	502.33	502.33	502.33	501.91	0.41
264.50	-0.5	0	1	0.1	0	-0.4	-0.1	-0.39	-0.14	502.69	502.40	502.20	502.20	502.20	501.78	0.41
265.00	-0.5	0.1	1.1	0.1	0	-0.4	-0.1	-0.41	-0.13	502.70	502.41	502.21	502.21	502.21	501.79	0.41
265.50	-0.4	0.1	1.2	0	0	-0.4	-0.1	-0.39	-0.14	502.50	502.21	502.00	502.00	502.00	501.59	0.41
266.00	-0.4	0.2	1.3	-0.1	0	-0.4	-0.1	-0.34	-0.15	502.45	502.16	501.96	501.96	501.96	501.54	0.41
266.50	-0.4	0.3	1.3	-0.1	0	-0.4	-0.1	-0.37	-0.14	502.23	501.94	501.74	501.74	501.74	501.32	0.41
266.91	-0.5	0.4	1.3	-0.1	0	-0.4	-0.1	-0.20	-0.13	502.25	501.96	501.75	501.75	501.75	501.34	0.41
268.00	-0.6	0.5	1.3	-0.1	0	-0.4	-0.1	-0.10	-0.12	501.63	501.34	501.13	501.13	501.13	500.72	0.41
268.50	-0.6	0.5	1.3	-0.1	0	-0.4	-0.2	0.07	-0.13	501.42	501.13	500.92	500.92	500.92	500.51	0.41
269.30	-0.6	0.6	1.3	-0.1	0	-0.4	-0.2	0.38	-0.09	500.84	500.55	500.34	500.34	500.34	499.93	0.41
270.00	-0.7	0.6	1.4	-0.2	0	-0.4	-0.2	0.56	-0.11	500.35	500.07	499.86	499.86	499.86	499.44	0.41
270.50	-0.9	0.5	1.3	-0.3	0	-0.4	-0.3	0.21	-0.20	500.13	499.84	499.63	499.63	499.63	499.21	0.41
271.50	-1.3	0.3	1.2	-0.4	0	-0.4	-0.3	0.26	-0.26	499.54	499.25	499.04	499.04	499.04	498.63	0.41
272.00	-1.2	0.2	1.2	-0.4	0	-0.4	-0.2	-0.03	-0.27	499.58	499.29	499.08	499.08	499.08	498.67	0.41
273.00	-1	0.4	1.3	-0.3	0	-0.5	-0.2	0.01	-0.23	499.75	499.46	499.26	499.26	499.26	498.84	0.41
273.75	0	0.4	1.3	-0.4	-0.1	-0.5	-0.2	-0.38	-0.24	499.50	499.21	499.00	499.00	499.00	498.59	0.41
274.04	0	0.1	1.2	-0.4	-0.1	-0.6	-0.5	-0.52	-0.36	498.68	498.40	498.19	498.19	498.19	497.77	0.41
274.50	-1.2	-0.5	1	-0.5	-0.2	-0.5	-0.4	-0.31	-0.47	498.36	498.07	497.87	497.87	497.87	497.45	0.41
275.00	-1.3	-0.3	1.1	-0.4	-0.2	-0.6	-0.4	-0.83	-0.50	498.11	497.82	497.62	497.62	497.62	497.20	0.41
275.50	-1.2	-0.4	1.1	-0.5	-0.2	-0.5	-0.3	-0.31	-0.44	498.15	497.86	497.66	497.66	497.66	497.24	0.41
276.00	-0.9	-0.1	1.2	-0.3	-0.2	-0.5	-0.2	-0.73	-0.36	498.81	498.52	498.31	498.31	498.31	497.90	0.41
276.50	-0.6	0.2	1.3	-0.2	-0.1	-0.4	-0.2	-0.34	-0.23	499.73	499.45	499.24	499.24	499.24	498.82	0.41
277.13	-1	-0.6	1.4	-0.4	-0.2	-0.5	-0.3	-0.26	-0.41	498.21	497.92	497.71	497.71	497.71	497.30	0.41
277.50	-0.8	-0.1	1.3	-0.3	-0.2	-0.5	-0.2	-0.28	-0.32	498.61	498.32	498.11	498.11	498.11	497.70	0.41
278.00	-0.3	0.4	1.4	-0.2	-0.1	-0.5	-0.2	-0.30	-0.20	499.80	499.51	499.30	499.30	499.30	498.89	0.41
Average	-0.62	0.01	1.15	-0.20	-0.09	-0.48	-0.18	-0.33	-0.25							
Minimum	0.0	0.6	1.4	0.1	0.0	-0.4	0.0	0.56	-0.09							
Maximum	-1.3	-0.7	0.7	-0.5	-0.3	-0.7	-0.5	-1.26	**-0.50**							

Abbreviations

ft msl = feet above mean sea level
in/yr = inches per year
NGVD1929 - National Geodetic Vertical Datum of 1929

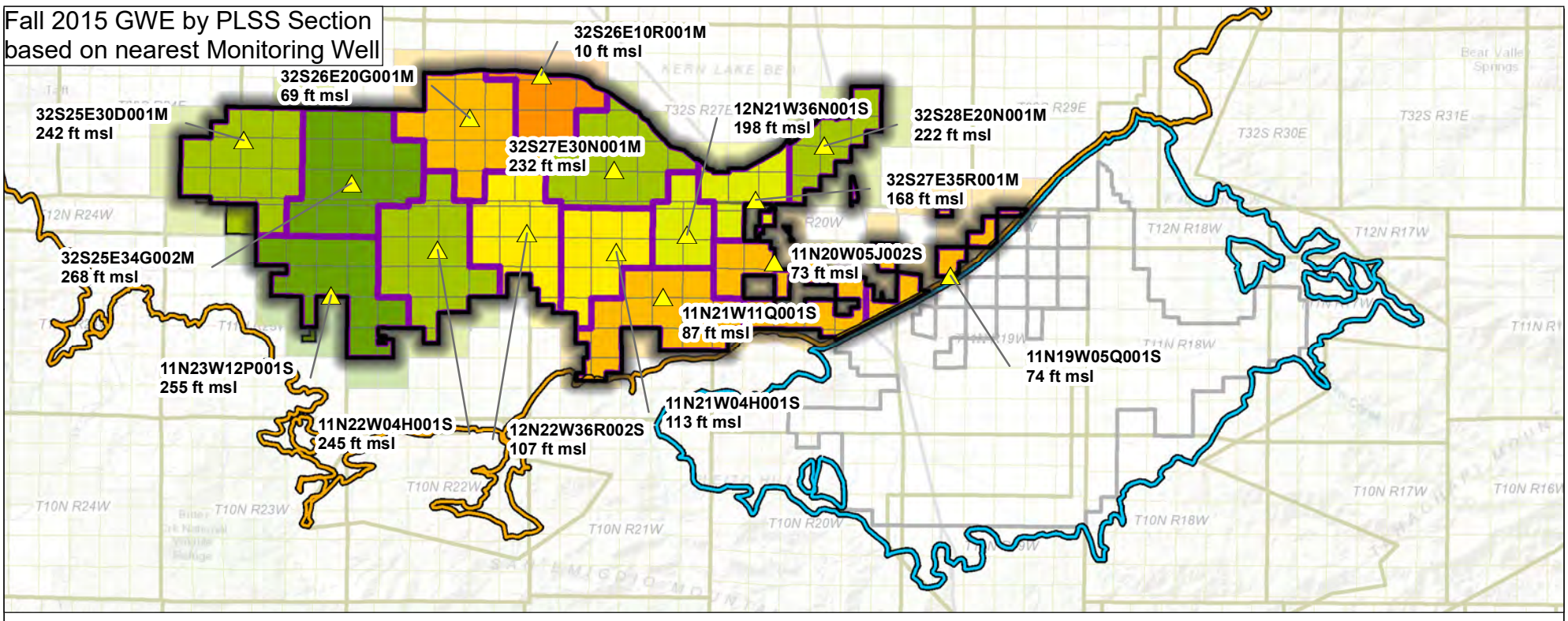
Notes:

1. Subsidence rate information for 1975-2013 is from DWR (2017), and for 2016-2019 is from data provided by DWR on 22 July 2019.
2. Minimum Threshold rate for land subsidence (-0.50 in/yr) is the maximum average long-term rate of subsidence at the survey benchmark locations for the period 1975-2019, excluding 1981-1986.
3. Data from 1981-1986 are note used in subsidence rate averages (per DWR, 2017).

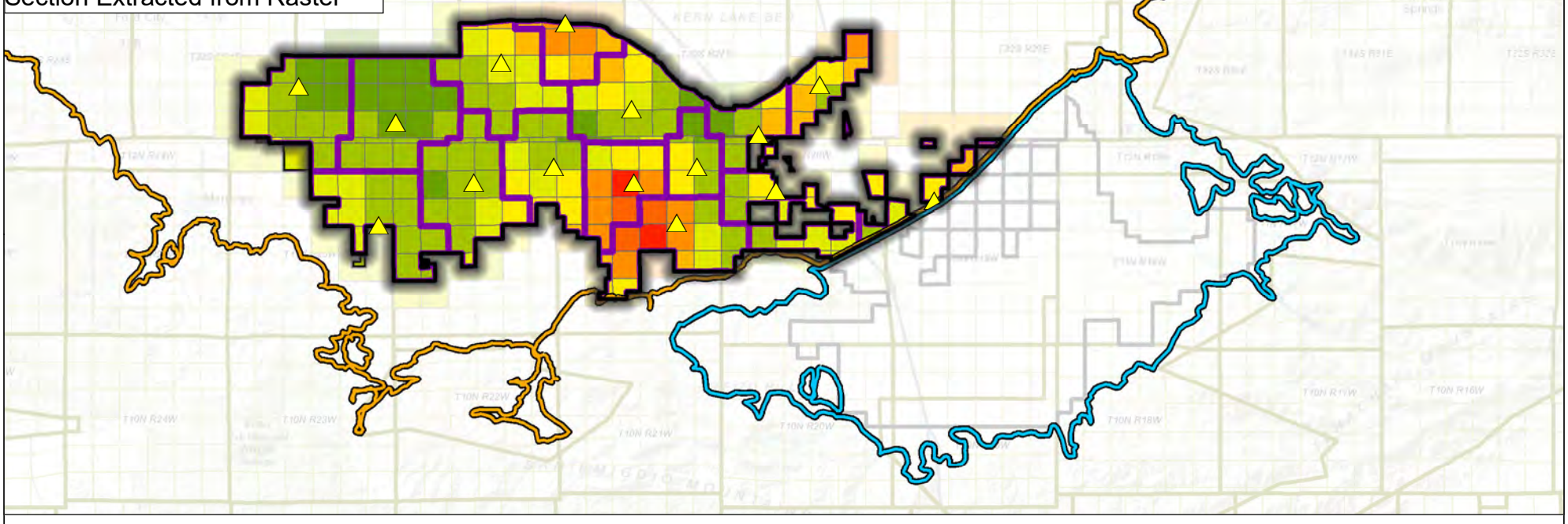
Sources:

California Department of Water Resources (DWR), 2017, California Aqueduct Subsidence Study, San Luis Field Division, San Joaquin Field Division, 206 pp.

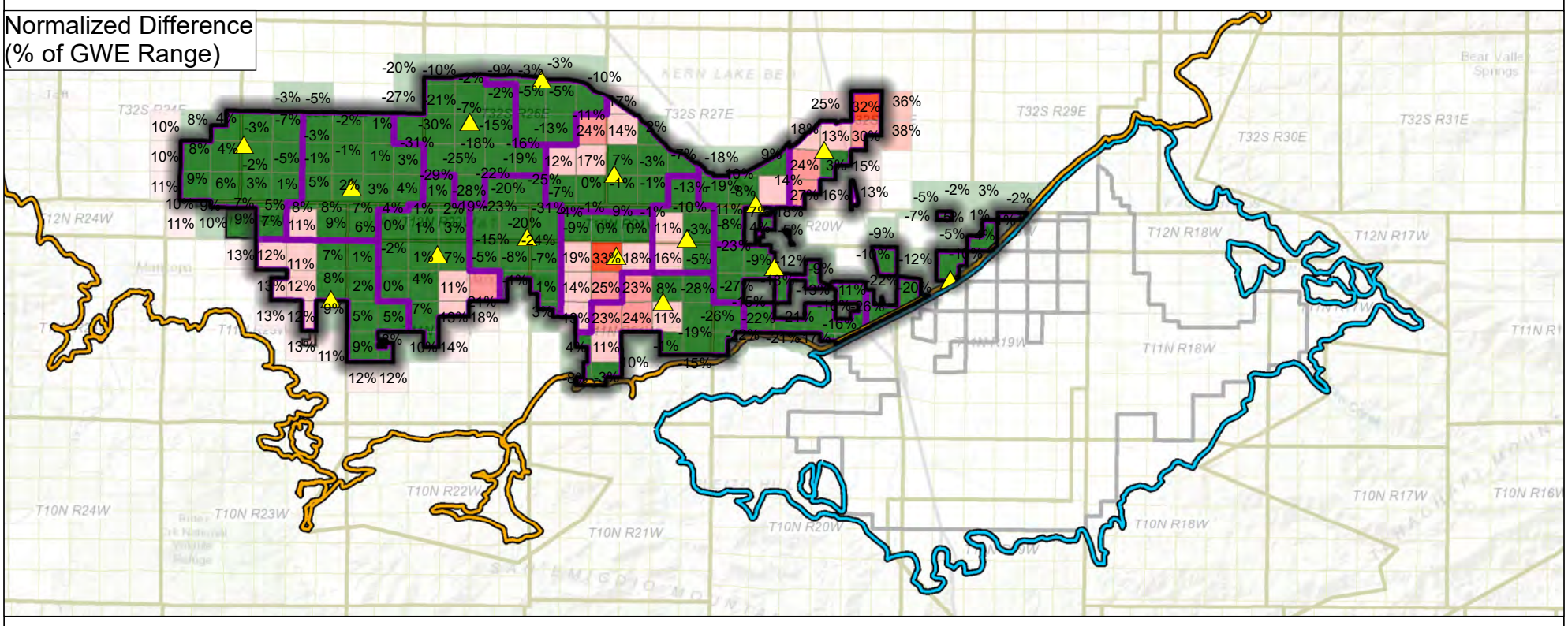
Fall 2015 GWE by PLSS Section based on nearest Monitoring Well



Fall 2015 Average GWE by PLSS Section Extracted from Raster



Normalized Difference (% of GWE Range)



Legend

- WRMWSD Service Area
- Long-Term Hydrograph Well
- Representative Coverage Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Normalized Difference (RML - Actual)

- < 10%
- 10% to 20%
- 20% to 30%
- > 30%

Fall 2015 Groundwater Elevation (ft msl)

- < - 50
- -50 to 0
- 0 to 50
- 50 to 100
- 100 to 150
- 150 to 200
- 200 to 250
- 250 to 300
- 300 to 350
- > 350

Notes

1. All locations are approximate.
2. "Normalized Difference" is defined herein as the difference between the Fall 2015 GWE at the RML and the average Fall 2015 GWE within each section, divided by the total range of Fall 2015 GWE within the WRMWSD Kern Management Area.
2. Negative normalized differences (i.e. where the GWE at RML is less than the average Fall 2015 GWE within the section), are represented in green as these sections have an RML that is considered "overprotective" of local water level conditions.

Abbreviations

GWE	= Groundwater Elevation
DWR	= California Department of Water Resources
ft msl	= feet above mean sea level
PLSS	= Public Land Survey System
RML	= Representative Monitoring Location
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.

N

0 5 10

(Scale in Miles)

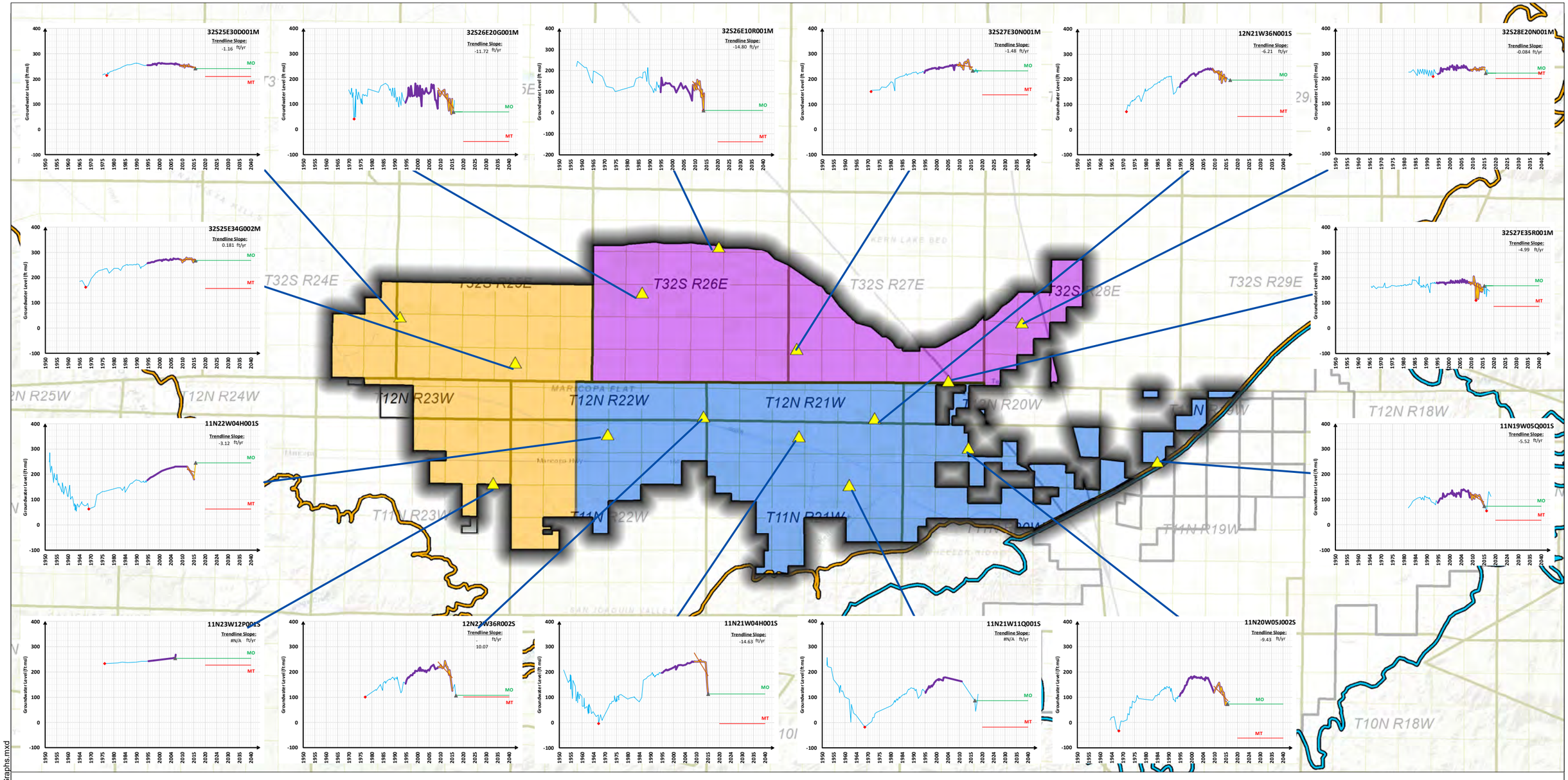
Representativeness of Long-Term Hydrograph Locations

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure SMC-1

eki environment & water

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Legend

- WRMWSD Service Area
- Long-Term Hydrograph Well

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Sustainability Criteria Zones

- Northeastern Zone
- Southeastern Zone
- Western Zone

- Hydrograph
- Range Period (10/94 - 9/15)
- Trend Period (1/09 - 11/15)
- Initial Measurable Objective (MO) Estimate
- Initial Minimum Threshold (MT) Estimate
- Historical Low
- Fall 2015
- Linear Regression (Trend Period)

Abbreviations

DWR	= California Department of Water Resources
ft bgs	= feet below ground surface
ft msl	= feet above mean sea level
MO	= Measurable Objective
MT	= Minimum Threshold
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Water levels that showed a rate of change between consecutive measurements greater than 50 ft in 60 days, or a significant change without a reasonable hydrological explanation, were removed from the hydrographs.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Groundwater elevation data provided by WRMWSD on 8 December 2017.

N

0 3 6

(Scale in Miles)

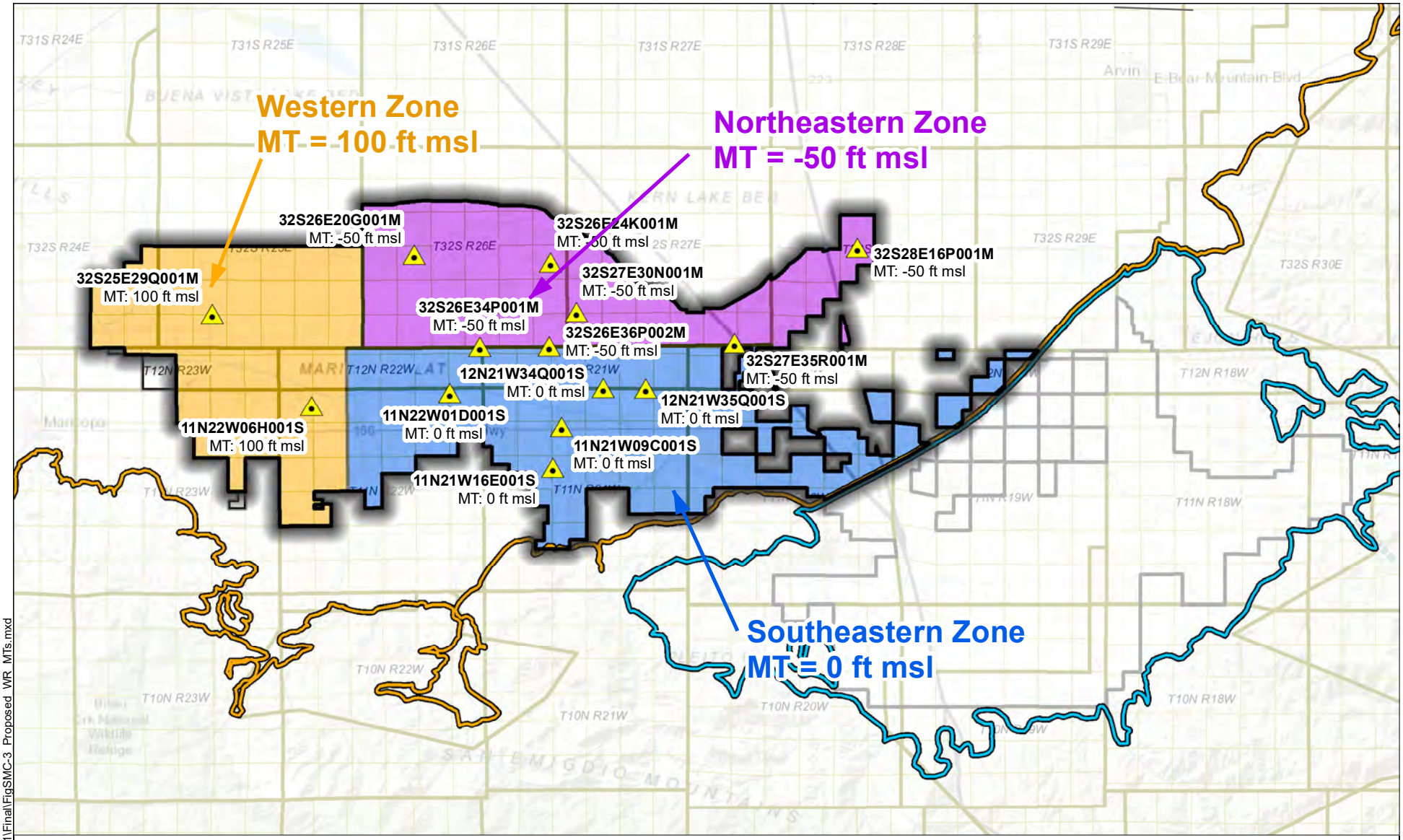
Water Level Sustainability Criteria - Hydrograph Analysis

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure SMC-2

eki environment & water

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Legend

- Representative Monitoring Site
- WRMWSD Service Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Sustainability Criteria Zones

- Northeastern Zone
- Southeastern Zone
- Western Zone

Abbreviations

DWR	= California Department of Water Resources
ft msl	= feet above mean sea level
MT	= Minimum Threshold
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 December 2019.

N

0 5 10

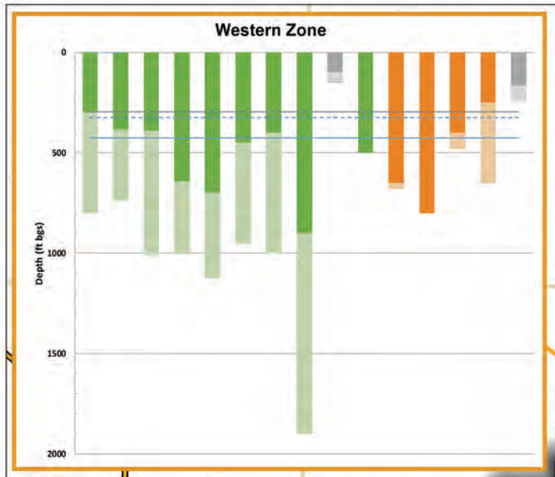
(Scale in Miles)

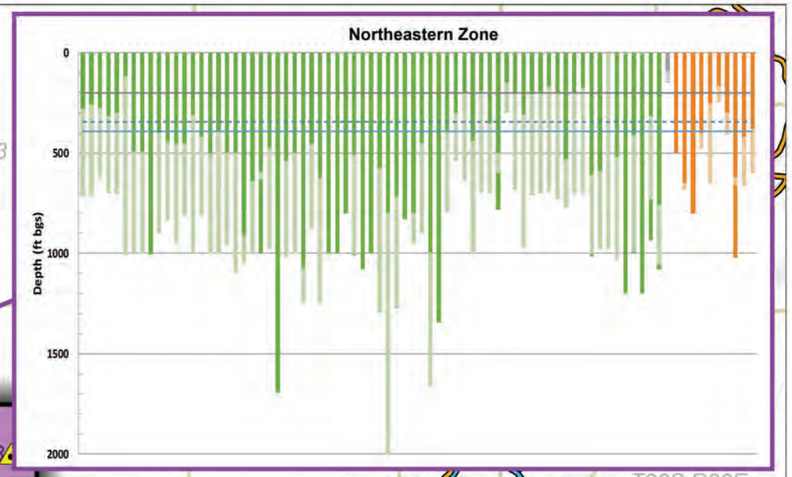
Proposed Water Level Minimum Thresholds

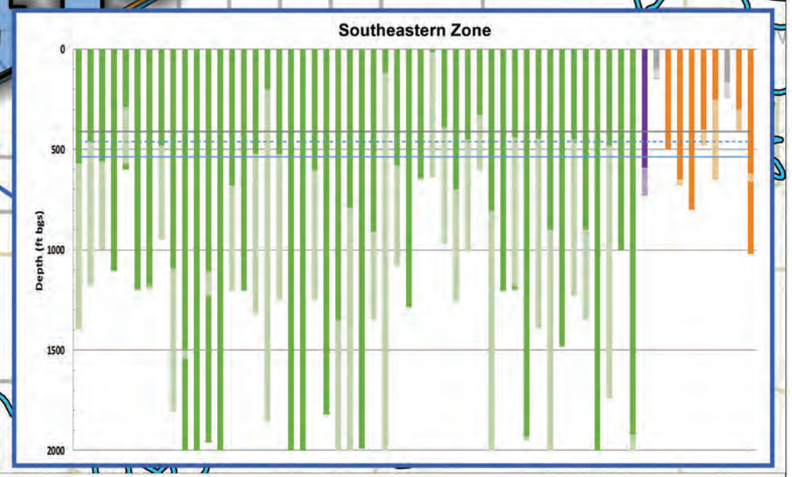
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01
Figure SMC-3

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigSMC-3 Proposed WR MTs.mxd







T31S R25E
T31S R26E
T31S R27E
T32S R26E
T32S R27E
T32S R30E
T12N R24W
T12N R23W
T12N R22W
T12N R21W
T12N R20W
T12N R18W
T11N R23W
T11N R22W
T11N R21W
T10N R23W
T10N R22W
T10N R21W
T10N R20W

Zone	Water Level	# of Wells Dewatered	% of Wells Dewatered
Western	MO	0	0%
	MT	1	7%
Northeastern	MO	3	4%
	MT	3	4%
Southeastern	MO	1	2%
	MT	3	5%

Legend
- WRMWSD Service Area
- Representative Monitoring Site

Groundwater Subbasin
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Sustainability Criteria Zones
- Northeastern Zone
- Southeastern Zone
- Western Zone

- Production Well
- Public Supply Well
- Domestic Well
- Well Screen Interval
- Fall 2015 Water Level
- Measurable Objective
- Minimum Threshold

Abbreviations

DWR	= California Department of Water Resources
ft bgs	= feet below ground surface
KGA	= Kerm Groundwater Authority
MO	= Measurable Objective
MT	= Minimum Threshold
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. MTs and MOs are defined as elevations, and are displayed on the bar graphs as their average depth (ft bgs) within all representative sections.
3. A "dewatered well" is considered to be a well whose total depth is less than the MT specified for the given sustainability criteria zone.
4. Wells displayed in grey were already dewatered relative to Fall 2015 groundwater conditions and are thus not included in the count of dewatered wells.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 December 2019.
2. Well info obtained from KGA on 21 November 2018.

N

0 3 6
(Scale in Miles)

Preliminary Well Impact Analysis by Sustainability Criteria Zone

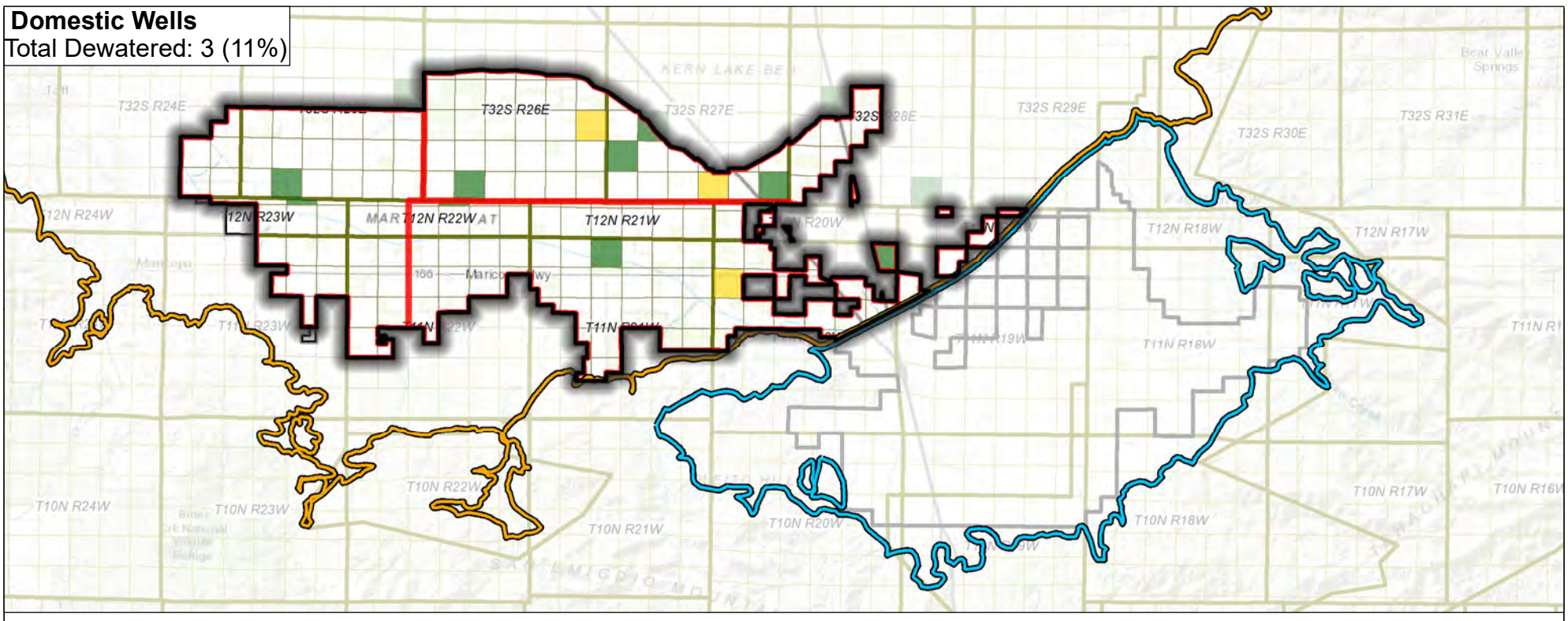
Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure SMC-4

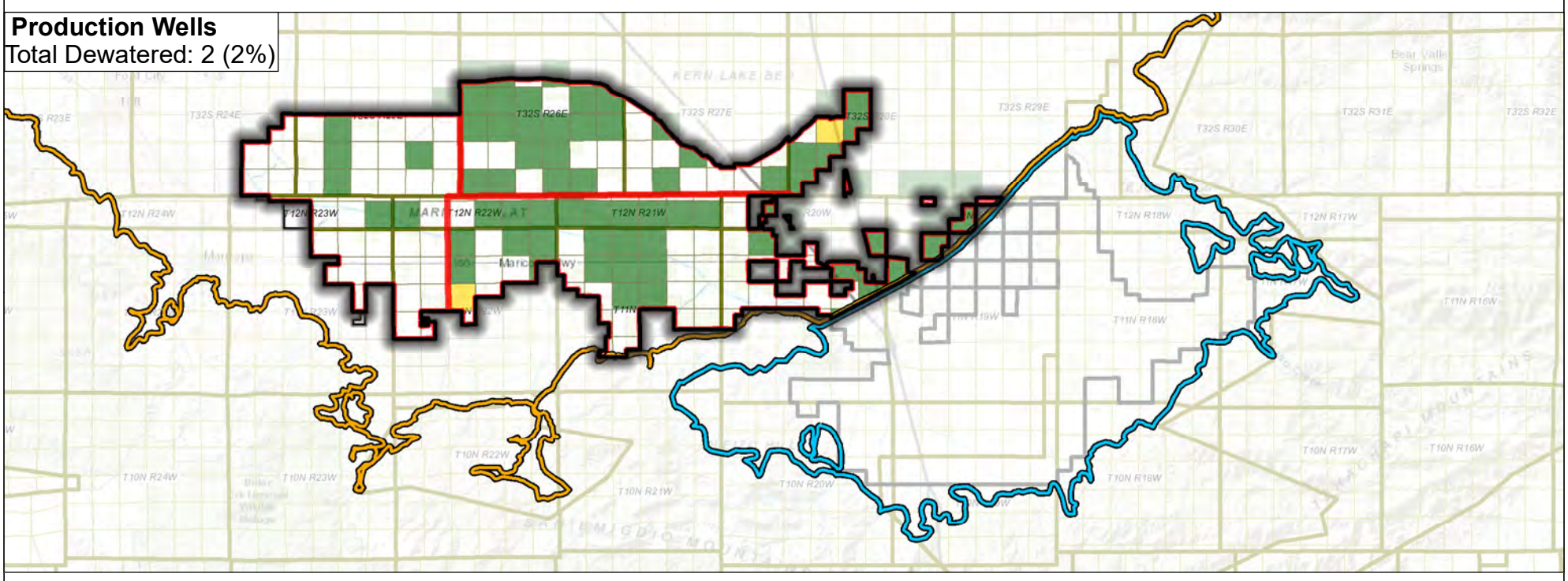
eki environment & water

Path: X:\B70103\Maps\for GSP\20191111\Final\FigSMC-4_SMC_Dewatered_Graphs.mxd

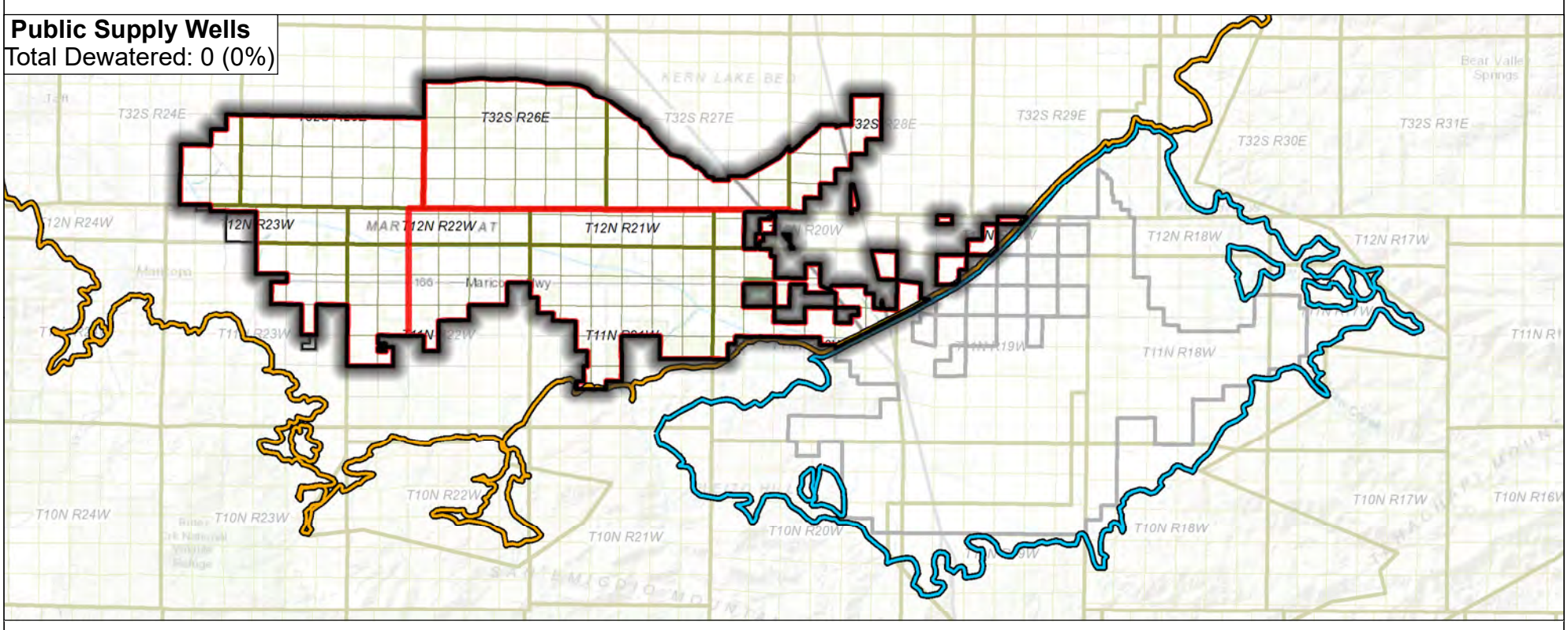
Domestic Wells
Total Dewatered: 3 (11%)



Production Wells
Total Dewatered: 2 (2%)



Public Supply Wells
Total Dewatered: 0 (0%)



Legend

- WRMWSD Service Area
- Sustainability Criteria Zones

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Count of Wells Dewatered at Minimum Threshold

- N/A
- 0
- 1
- 2
- 3

Notes

1. All locations are approximate.
2. A "dewatered well" is considered to be a well whose total depth is less than the MT specified for the given sustainability criteria zone.
3. Wells that were already dewatered relative to Fall 2015 groundwater conditions are not included in the count of dewatered wells.

Abbreviations

DWR	= California Department of Water Resources
MT	= Minimum Threshold
N/A	= Not Applicable
PLSS	= Public Land Survey System
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Sources

1. Well count and depth statistics from Well Completion Report Map Application, obtained on 19 October 2018, website: https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37
2. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.

N

0 5 10

(Scale in Miles)

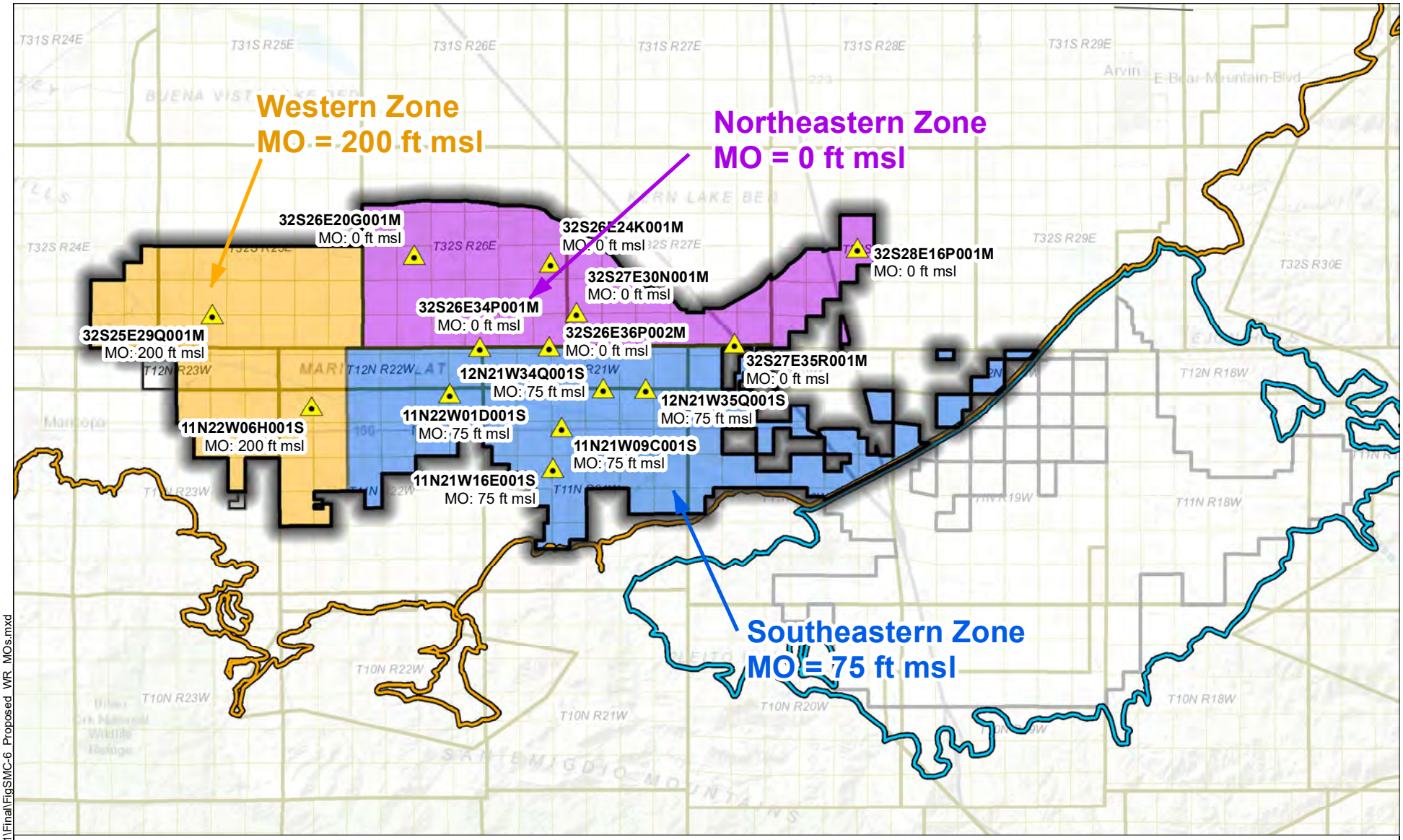
Preliminary Well Impact Analysis by PLSS Section

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure SMC-5

eki environment & water

Path: X:\B70103\Mapsfor_GSP\2019\11\Final\FigSMC-5_SMC_Dewatered_PLSS.mxd



Legend

- Representative Monitoring Site
- WRMWSD Service Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Sustainability Criteria Zones

- Northeastern Zone
- Southeastern Zone
- Western Zone

Abbreviations

DWR	= California Department of Water Resources
ft msl	= feet above mean sea level
MO	= Measurable Objective
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 December 2019.

N

0 5 10

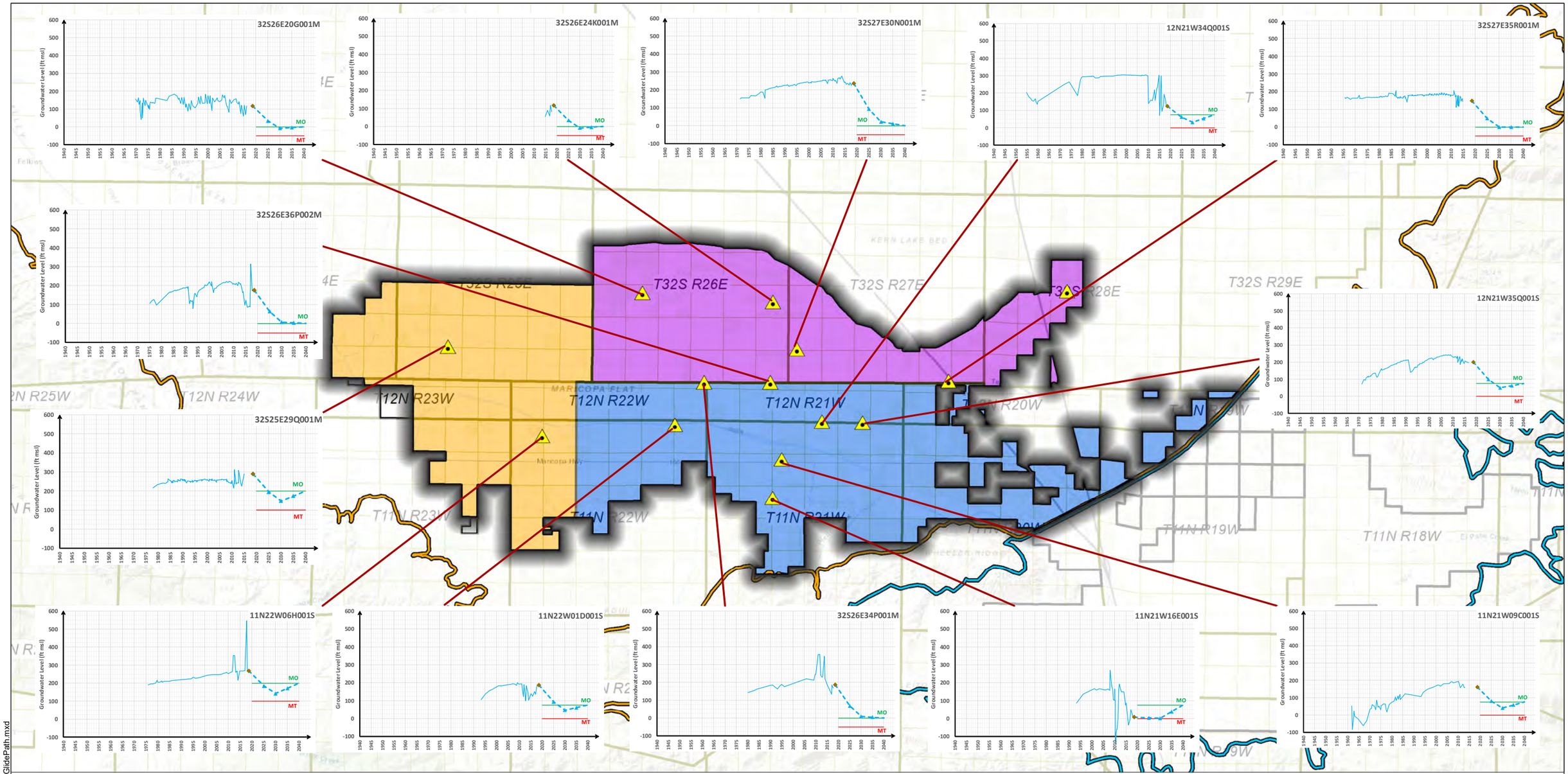
(Scale in Miles)

Proposed Water Level Measurable Objectives

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01
Figure SMC-6

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigSMC-6 Proposed WR MOs.mxd



Legend

- Representative Monitoring Site
- WRMWSD Service Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Sustainability Criteria Zones

- Northeastern Zone
- Southeastern Zone
- Western Zone

- Hydrograph
- Measurable Objective (MO)
- Minimum Threshold (MT)
- Interim Milestone (IM)
- Glide Path
- Fall 2018

Abbreviations

DWR	= California Department of Water Resources
ft	= feet
IM	= Interim Milestone
MO	= Measurable Objective
MT	= Minimum Threshold
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Representative Monitoring Well 32S28E16P001M does not have a historical water level record and is thus not displayed on the map

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 December 2019.
2. Groundwater elevation data provided by WRMWSD on 26 September 2018.

N

0 3 6

(Scale in Miles)

Water Level Sustainability Criteria - Interim Milestones

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure SMC-7

eki environment & water

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MONITORING NETWORK

16. MONITORING NETWORK

☑ 23 CCR § 354.32

This section describes the monitoring network designed for the Wheeler Ridge-Maricopa Management Area, subsequently referred to as the "SGMA Monitoring Network". Pursuant to the GSP Emergency Regulations, the SGMA Monitoring Network objective is to collect sufficient data for the correct assessment of the Sustainability Indicators relevant to the Management Area (see **Section 13** ***Undesirable Results***), and the impacts to the beneficial users of groundwater. Per 23 CCR § 354.32(e), the SGMA Monitoring Network incorporates elements from the existing monitoring programs occurring within the Management Area (see **Section 5.2.1** ***Existing Monitoring and Management Programs***) and includes additional components to comply with the GSP Emergency Regulations. All monitoring will be performed in accordance with the protocols agreed upon for the Basin, as described the KGA Umbrella GSP.

16.1. Description of Monitoring Network

☑ 23 CCR § 354.34(a)
☑ 23 CCR § 354.34(b)
☑ 23 CCR § 354.34(d)
☑ 23 CCR § 354.34(f)

The objective of the Wheeler Ridge-Maricopa Management Area SGMA Monitoring Network is to collect data with sufficient temporal frequency and spatial density necessary to evaluate Plan implementation as it relates to:

- Monitoring short-term, seasonal, and long-term trends in groundwater and related surface water conditions (see **Section 8** ***Current and Historical Groundwater Conditions***);
- Demonstrating progress toward achieving measurable objectives described in the Plan (see **Section 15** ***Measurable Objectives and Interim Milestones****);*
- Monitoring impacts to the beneficial uses and users of groundwater (see **Section 5.5.1** ***Beneficial Uses and Users of Groundwater***);
- Monitoring changes in groundwater conditions relative to Measurable Objectives (see **Section 15** ***Measurable Objectives and Interim Milestones***) and Minimum Thresholds (see **Section 14** ***Minimum Thresholds***); and
- Quantifying annual changes in water budget components (see **Section 9** ***Water Budget Information****)*.

The Representative Monitoring Network consists of a series of Representative Monitoring Sites that: (1) were selected from the existing monitoring programs that are active within the Wheeler Ridge-Maricopa Management Area (see **Section 5.2.1** ***Existing Monitoring and Management Programs***), (2) have been demonstrated to be representative of groundwater conditions within the Management Area (see **Figure**

SMC-1, for example), and (3) where Sustainability Criteria (Minimum Thresholds, Measurable Objectives, and Interim Milestones) have been defined for at least one of the relevant Sustainability Indicators to the Basin (see **Section 13 *Undesirable Results***):

- Chronic Lowering of Groundwater Levels;
- Reduction of Groundwater Storage;
- Degraded Water Quality[73]; and
- Land Subsidence[74].

Per 23 CCR § 354.32(e), the selection of Representative Monitoring Sites was informed by the existing local monitoring programs (see **Section 5.2.1 *Existing Monitoring and Management Programs***) and leverages historical data wherever possible to help assess and quantify Basin response to Plan implementation relative to historical groundwater conditions (see **Section 8 *Current and Historical Groundwater Conditions***). Pursuant to 23 CCR § 354.32(f), the spatial distribution, spatial density, and temporal frequency of measurements collected from Representative Monitoring Sites is determined for each Sustainability Indicator based on considerations of:

- Amount of current and projected groundwater use;
- Aquifer characteristics, including any vertical and/or lateral barriers to groundwater flow;
- Potential impacts to beneficial uses and users of groundwater, land uses, and property interests affected by groundwater production, and other adjacent basins (and GSAs within the Basin); and
- Availability of historical data to evaluate long-term trends in groundwater conditions associated with the above factors.

Per 23 CCR § 354.32(g), other factors considered in the selection of Representative Monitoring Sites include:

- Availability of existing technical information about the Representative Monitoring Site (e.g., well location, construction information, condition, status, etc.);
- Quality and reliability of historical data at the Representative Monitoring Site;
- "Representativeness" to local groundwater conditions and nearby well populations (per 23 CCR § 354.36); and
- Projected availability of long-term access to the Representative Monitoring Site.

Table MN-1 summarizes the site type, site count, measured constituent(s), measurement frequency, and spatial density of the Monitoring Network for each of the relevant Sustainability Indicators mentioned

[73] No Sustainability Criteria are defined for Degraded Water Quality within the Wheeler Ridge-Maricopa Management Area. Representative Monitoring Sites for Degraded Water Quality are included in the SGMA Monitoring Network for use in collecting supplemental data to allow for continued evaluation of groundwater quality trends within the Management Area (see **Section 16.1.4**).

[74] WRMWSD will leverage DWR's existing regional subsidence monitoring program along the California Aqueduct for use in evaluating land subsidence conditions within the Management Area (see **Section 16.1.5**).

above. Further details about the SGMA Monitoring Network for each Sustainability Indicator can be found in **Sections 16.1.1** through **16.1.6**.

Table MN-1. Summary of SGMA Monitoring Network

Sustainability Indicator	Site Type	Site Count	Measured Constituent(s)	Measurement Frequency	Spatial Density (# sites / 100 mi^2)
Chronic Lowering of Groundwater Levels	Well	14	Water Level	Semiannually	10.4
Reduction of Groundwater Storage	Well	15	Water Level	Semiannually	10.4
Degraded Water Quality[75]	Well	9	see list in **Section 16.1.4**	Annually	6.7
Land Subsidence (2)	Stationary GPS	40	Ground Surface Elevation	Annually, or per DWR schedule	27.7

Note:

(1) Spatial density of monitoring sites is calculated based on only the area of the Wheeler Ridge-Maricopa Management Area that is not overlapped by AEWSD (86,112 acres), as WRMWSD and AEWSD have agreed that AEWSD will cover the overlap lands for SGMA monitoring purposes.

(2) The land subsidence monitoring network described herein is supplemental to the basin-wide subsidence monitoring network being implemented, as discussed in the KGA Umbrella GSP and Appendices thereto.

Pursuant to 23 CCR § 354.32(i), in all cases the SGMA Monitoring Network will adhere to the monitoring protocols specified for the Basin as described in **Section 16.2** and in the KGA Umbrella GSP.

16.1.1. Monitoring Network for Chronic Lowering of Groundwater Levels

☑ 23 CCR § 354.34(c)(1)

The SGMA Monitoring Network for Chronic Lowering of Groundwater Levels consists of 14 wells distributed across the Wheeler Ridge-Maricopa Management Area (spatial density of 10.4 wells / 100 mi^2.) for which water level Sustainability Criteria have been defined within this MA Plan (see **Section 14.1** ***Minimum Threshold for Chronic Lowering of Groundwater*** Levels and **Section 15.1** ***Measurable Objective and Interim Milestones for Chronic Lowering of Groundwater Levels***). As described in **Section 14.1**

Minimum Threshold for Chronic Lowering of Groundwater Levels, a series of 15 wells with long-term groundwater level records were initially selected to analyze historical and current groundwater conditions

[75] *Ibid [73].*

across the Management Area and to inform the development of Sustainability Criteria for Chronic Lowering of Groundwater Levels (see **Sections 14.1** and **15.1**). These wells were included in the selection of Representative Monitoring Sites wherever possible; however, in WRMWSD's recent stakeholder outreach efforts, it became clear that there were several instances in which the "long-term hydrograph" wells would not be available for continued monitoring. In these cases, alternative Representative Monitoring Sites were identified in areas proximate to the long-term hydrograph well locations such that the SGMA Monitoring Network achieves a comparable spatial density, distribution, and "representativeness" to local groundwater conditions. Specific details regarding each of the Representative Monitoring Sites are listed in **Table MN-2.** The site locations and their spatial distribution are displayed on **Figure MN-1**. These Representative Monitoring Sites were selected based on the following considerations:

- **Current and projected groundwater use** – The Monitoring Network includes ten wells located within or immediately adjacent to WRMWSD's surface water service area and four wells located in the "groundwater only" portion of the Management Area.
- **Aquifer characteristics** – All 14 wells included in the Monitoring Network screen the Tulare Formation, which is the only principal aquifer defined within this portion of the Basin.
- **Potential impacts to beneficial uses and users of groundwater, land uses or property interests, and adjacent Basins (or GSAs) –** The Monitoring Network includes three wells situated within one mile of the California Aqueduct (11N22W06H001S, 11N22W01D001S, and 11N21W09C001S), which is defined as "critical infrastructure" to the Management Area (see **Section 13.5 *Undesirable Results for Land Subsidence***). The Monitoring Network also includes one well situated within half a mile of San Emigdio Creek (11N21W16E001S), which will be used to monitor hydraulic gradients between the creek and underlying principal aquifer[76]. Finally, the Monitoring Network includes three wells near the WRMWSD-KDWD boundary (32S26E20G001M, 32S26E24K001M, and 32S29E16P001M) and two wells near the WRMWSD-AEWSD boundary (32S28E16P001M and 32S27E35R001M), which will be used to assess hydraulic gradients between the Management Area, the KDWD portion of the Kern River GSA, and AEWSD.
- **Availability of historical data –** Eight of the 14 Representative Monitoring Sites have associated water level records spanning back through at least 1971, the year that WRMWSD began importing surface water and coincident to the general period of historical low groundwater elevations within the Wheeler Ridge-Maricopa Management Area (see **Section 8 *Current and Historical Groundwater Conditions***). Thirteen out of 14 Representative Monitoring Sites have associated water level records spanning back through at least October 1994, coincident with the start of the historical water budget period (see **Section 9.3.2 *Historical Water Budget***).
- **Availability of site-specific technical information –** As shown in **Table MN-2**, each of the 14 Representative Monitoring Sites have known geographic coordinates, ground surface elevations, and reference point elevations. Nine of the 14 sites contain known well depths, and 11 of the 14 sites contain known well screen intervals. Four of the 14 wells are presumed to still be active and

[76] There are no interconnected surface water features presumed to occur within the Management Area as the water table is encountered well below the ground surface (i.e., depth to water greater than 100 ft. bgs) throughout WRMWSD (see **Section 8.7 *Interconnected Surface Water Systems***).

in use for irrigation or production purposes, while the other 10 are inactive wells which will be used for dedicated monitoring purposes only. All 14 wells are confirmed to be in suitable condition for recording water level measurements. For the sites where well construction information is incomplete or currently unavailable, WRMWSD has developed a plan to fill these data gaps in accordance with 23 CCR § 354.38 (see **Section 16.4 *Assessment and Improvement of Monitoring Network***).

- **Quality and reliability of historical data –** Twelve of the 14 Representative Monitoring Sites contain at least 35 water level records, and 13 of 14 have at least one record in the last five years (i.e., since January 2014). Nine of the 14 sites are included in WRMWSD's voluntary CASGEM network, and most sites have been monitored biannually for at least the past 10 years as part of WRMWSD's routine water level monitoring program.
- **"Representativeness" to local groundwater conditions –** As described above, Representative Monitoring Sites were selected from the list of "long-term hydrograph" wells demonstrated to be representative of local groundwater conditions (see Figure SMC-1) wherever possible; however, there were several cases where the long-term hydrograph wells would not be available for continued monitoring going forward. In these cases, alternative Representative Monitoring Sites were identified in areas proximate to the long-term hydrograph well locations such that the SGMA Monitoring Network achieves a comparable spatial density, distribution, and "representativeness" to local groundwater conditions.
- **Long-term access –** For each of the 14 Representative Monitoring Sites, a preliminary agreement has been reached with associated landowners/well owners allowing WRMWSD long-term access to the site to conduct monitoring for SGMA compliance purposes. A copy of the long-term access agreement can be found in **Appendix H**.

All Representative Monitoring Sites will be monitored semiannually in accordance with the monitoring protocol described in **Section 16.2 *Monitoring Protocols for Data Collection and Monitoring***. All data will be reported to DWR per the requirements specified under **Section 16.5 *Reporting Monitoring Data to the Department***.

16.1.2. Monitoring Network for Reduction of Groundwater Storage

☑ **23 CCR § 354.34(c)(2)**

As described in **Section 13.2.2 *Criteria Used to Define Undesirable Results*** and in **Section 14.2.1 *Use of Groundwater Levels as Proxy***, the criteria used to define Undesirable Results for Reduction of Groundwater Storage are the Minimum Thresholds established at a local management area level for Chronic Lowering of Groundwater Levels. As such, the SGMA Monitoring Network for Reduction of Groundwater Storage will be comprised of the same Representative Monitoring Sites described in **Section 16.1.1 *Monitoring Network for Chronic Lowering of Groundwater Levels***. The information collected from this SGMA Monitoring Network will be sufficient to estimate the change in annual groundwater in storage.

16.1.3. Monitoring Network for Seawater Intrusion

☑ 23 CCR § 354.34(c)(3)
☑ 23 CCR § 354.34(j)

As described in **Section 13.3 *Undesirable Results for Seawater Intrusion***, seawater intrusion is not present and not likely to occur within the Kern Subbasin. Therefore, the Seawater Intrusion Sustainability Indicator is not applicable to the basin and no Undesirable Results for this Sustainability Indicator are defined for the basin. As such, per the stipulations defined under 23 CCR § 354.32(j), a monitoring network has not been defined for the Seawater Intrusion Sustainability Indicator as it is demonstrated to not be applicable to the Basin.

16.1.4. Monitoring Network for Degraded Water Quality

☑ 23 CCR § 354.34(c)(4)

As described in **Section 14.4 *Minimum Threshold for Degraded Water Quality***, based on the existing beneficial uses and users of groundwater within the Wheeler Ridge-Maricopa Management Area, Undesirable Results for Degraded Water Quality are not likely to occur and no unique Minimum Thresholds are currently defined for this Sustainability Indicator. However, WRMWSD has historically conducted routine monitoring of groundwater quality conditions (see **Section 5.2.1 *Existing Monitoring and Management Programs***), and has elected to develop a SGMA Monitoring Network for Degraded Water Quality to facilitate continued monitoring and evaluation of groundwater quality trends within the Wheeler Ridge-Maricopa Management Area throughout Plan implementation.

The SGMA Monitoring Network for Degraded Water Quality includes nine Representative Monitoring Sites selected from WRMWSD's existing water quality sampling program. Specific details regarding each of the Representative Monitoring Sites are listed in **Table MN-2.** The site locations are displayed on **Figure MN-2**. These Representative Monitoring Sites were selected based on the following considerations:

- **Current and projected groundwater use** – The Monitoring Network includes five wells located within WRMWSD's surface water service area and four wells located in the "groundwater only" portion of the Management Area.
- **Aquifer characteristics** – All nine wells included in the Monitoring Network screen the Tulare Formation, which is the only principal aquifer defined within this portion of the Basin.
- **Potential impacts to beneficial uses and users of groundwater, land uses or property interests, and adjacent Basins (or GSAs) –** The Monitoring Network is spread generally evenly across the Management Area and includes Representative Monitoring Sites in the areas of groundwater quality concern identified in **Section 8.5 *Groundwater Quality***.
- **Availability of historical data –** All nine Representative Monitoring Sites have been sampled for groundwater quality constituents (including the constituents of concern [COCs] identified in **Section 8.5 *Groundwater Quality***) at least three times, and six of nine at least 15 times. Eight of the nine sites have been sampled at least once since the year 2000, and seven sites have sampling records extending back through at least 1981.
- **Availability of site-specific technical information –** As shown in **Table MN-2**, each of the nine Representative Monitoring Sites have known geographic coordinates, ground surface elevations,

and reference point elevations. Three of the nine sites contain known well depths, and five of the nine sites contain known well screen intervals. Four of the nine wells are presumed to still be active and in use for irrigation purposes, while the other five will be used for dedicated for monitoring purposes only. All nine wells are confirmed to be in suitable condition for collecting water quality samples. For the sites where well construction information is incomplete or currently unavailable, WRMWSD has developed a plan to fill these data gaps in accordance with 23 CCR § 354.38 (see **Section 16.4 *Assessment and Improvement of Monitoring Network***).

- **Quality and reliability of historical data –** Each of the nine Representative Monitoring Sites contains at least three water quality sampling records, and eight of nine contain at least one record since 2000, and four of nine contain at least one record in the last five years (i.e., since January 2014). Most sites have been monitored regularly for at least the past ten years as part of WRMWSD's routine water quality sampling program.
- **"Representativeness" to local groundwater conditions –** As described above, the nine sites are spread generally evenly across the Management Area, including some wells in the areas of groundwater quality concern identified in **Section 8.5 *Groundwater Quality***.
- **Long-term access –** For each of the nine Representative Monitoring Sites, a preliminary agreement has been reached with associated landowners/well owners allowing WRMWSD long-term access to the site to conduct monitoring for SGMA compliance purposes. A copy of the long-term access agreement can be found in **Appendix H**.

All Representative Monitoring Sites will be sampled annually in accordance with the monitoring protocol described in **Section 16.2 *Monitoring Protocols for Data Collection and Monitoring***. Representative Monitoring Sites will be sampled for the COCs identified in **Section 8.5 *Groundwater Quality***, namely:

- Total Dissolved Solids
- Nitrate
- Arsenic
- Boron
- Iron
- Manganese
- Sulfate
- Chloride
- Uranium

In addition, Representative Monitoring Sites will be monitored for other relevant groundwater quality constituents[77] which may include constituents within some or all of the following categories:

- Descriptive parameters (temperature, pH, etc.)

[77] As identified in Stanford University's "A Guide to Water Quality Requirements under the Sustainable Groundwater Management Act" (Moran & Belin, 2019).

- Major ions
- Heavy metals
- Organic substances
- Pesticides
- Microbes

All data will be reported to DWR per the requirements specified under **Section 16.5 *Reporting Monitoring Data to the Department***.

16.1.5. Monitoring Network for Land Subsidence

☑ **23 CCR § 354.34(c)(5)**

As described in **Section 14.5 *Minimum Threshold for Land Subsidence,*** the California Aqueduct is considered the most critical infrastructure to avoid Undesirable Results from Land Subsidence in the Management Area. As such, WRMWSD intends to utilize DWR's existing land subsidence monitoring program along the California Aqueduct for its local SGMA Monitoring Network for Land Subsidence (see **Appendix I**).

DWR maintains 40 ground surface elevation survey benchmark locations within the Wheeler Ridge-Maricopa Management Area, between Mileposts 256.56 (Check No. 31) and 278.13 (Teerink Pumping Plant) of the California Aqueduct. These benchmarks have been surveyed intermittently since 1967, including the most recent surveys completed in 2019[78]. WRMWSD will coordinate with DWR to obtain access to future survey data collected between Pools 32 – 35 (i.e., Mileposts 256.56 – 278.13) from this regional monitoring program, and will use these publicly-available data to evaluate changes in ground surface elevation along the local reaches of the California Aqueduct within the Management Area, and to assess Plan Implementation relative to the Sustainability Criteria for Land Subsidence defined under **Section 14.5 *Minimum Threshold for Land Subsidence*** and **Section 15.5 *Measurable Objectives and Interim Milestones for Land Subsidence*** of this MA Plan.

16.1.6. Monitoring Network for Depletions of Interconnected Surface Water

☑ **23 CCR § 354.34(c)(6)**
☑ **23 CCR § 354.34(j)**

As described in **Section 13.6 *Undesirable Results for Depletions of Interconnected Surface Water***, no basin-wide definition of Undesirable Results for Depletions of Interconnected Surface Water has been developed and, based on available data and information, depletion of interconnected surface water has not been observed within the Wheeler Ridge-Maricopa Management Area. As such, per the stipulations

[78] DWR survey information along the California Aqueduct through 2013 are presented in DWR (2017), several plates of which are included as **Appendix I**. Additional benchmark survey data provided by DWR on 22 July 2019 is also included in **Appendix I**.

defined under 23 CCR § 354.32(j), a monitoring network has not been defined for the Depletion of Interconnected Surface Water Sustainability Indicator as it is demonstrated to not be applicable.

16.2. Monitoring Protocols for Data Collection and Monitoring

☑ **23 CCR § 352.2**

Pursuant to 23 CCR § 354.32(i), in all cases the Wheeler Ridge-Maricopa Management Area SGMA Monitoring Network will adhere to the monitoring protocols specified for the Basin as described in the KGA Umbrella GSP and Appendices thereto.

16.3. Representative Monitoring

☑ **23 CCR § 354.36**

As described in **Section 16.1 *Description of Monitoring Network***, WRMWSD has defined a SGMA Monitoring Network for each relevant Sustainability Indicator in the Management Area that will be used for SGMA reporting purposes to evaluate Plan implementation with respect to meeting the Sustainability Goal defined for the Basin through compliance with the Minimum Thresholds and Measurable Objectives described in the Plan. The rationale for selecting Representative Monitoring Sites are described for each Sustainability Indicator in **Sections 16.1.1** - **16.1.6** of this MA Plan.

As described in **Section 16.1.2 *Monitoring Network for Reduction of Groundwater Storage***, the Monitoring Network for Chronic Lowering of Groundwater Levels will be used as a proxy to monitor Reduction in Groundwater Storage. As described in **Section 14.2 *Minimum Threshold for Reduction of Groundwater Storage***, groundwater levels are considered sufficiently protective of Reduction in Groundwater Storage, and thus no Sustainability Criteria have been defined for this Sustainability Indicator. There are no other Sustainability Indicators for which groundwater levels will be used as a proxy for representative monitoring.

16.4. Assessment and Improvement of Monitoring Network

☑ **23 CCR § 354.38**

As described above and in the Basin-wide Monitoring Protocols (see KGA Umbrella GSP and Appendices thereto), the Wheeler Ridge-Maricopa SGMA Monitoring Network for the Kern Subbasin will be reevaluated in each five-year GSP update, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the Sustainability Goal for the Basin.

In all cases, the SGMA Monitoring Network developed for each Sustainability Indicator includes a sufficient density and spatial distribution of monitoring sites to meet the monitoring objectives outlined in **Section 16.1 *Description of Monitoring Network***. In most cases, the existing Representative Monitoring Sites selected for each Sustainability Indicator conform to the best management practices for monitoring networks outlined in DWR's BMP 2 – *Monitoring Networks and Identification of Data Gaps.* As identified in **Sections 16.1.1** - **16.1.6**, there are a few notable exceptions:

Regarding the Monitoring Network for Chronic Lowering of Groundwater Levels

- Five of the 14 sites are missing well depth information (wells 32S26E24K001M, 11N22W01D001S, 11N22W06H001S, 12N21W35G001S, and 32S28E16P001M));
- Three of the 14 sites are missing perforation interval information (wells 32S26E24K001M, 12N21W35G001S, and 11N22W06H001S); and
- Four of the 14 wells are presumed to still be active and in use for irrigation or production purposes (wells 11N21W16E001S, 32S27E35R001M, 32S26E34P001M, and 32S25E29Q001M).

Regarding the Monitoring Network for Degraded Water Quality

- Six of the nine sites are missing well depth information (wells 32S28E16P001M, 32S26E17H001M, 11N21W12N002S, 11N22W09A001S, 12N21W31P001S, and 32S26E14J001M);
- Four of the nine sites are missing perforation interval information (wells 11N21W12N002S, 11N22W09A001S, 12N21W31P001S, and 32S26E14J001M); and
- Four of the nine wells are presumed to still be active and in use for irrigation or municipal and industrial purposes (wells 32S25E29Q001M, 11N21W12N002S, 12N21W31P001S, and 32S26E14J001M).

For the Representative Monitoring Sites currently missing well information and well screen information, WRMWSD has developed a plan to fill these data gaps by conducting video-logging on the identified wells (see **Section 18 *WRMWSD Plan Implementation***). In the event these data gaps cannot be readily filled, WRMWSD will identify alternative sites or develop plans to construct new Representative Monitoring Sites for Chronic Lowering of Groundwater Levels and Degraded Water Quality as deemed necessary by the District.

For the Representative Monitoring Sites still under active use, WRMWSD will work to convert these sites to dedicated monitoring sites or will otherwise identify or develop alternative sites by the GSP implementation deadline (i.e., by January 2040).

16.5. Reporting Monitoring Data to the Department

☑ 23 CCR § 354.40

Data collected from the SGMA Monitoring Network will be uploaded to the Data Management System maintained for the Kern Subbasin and reported to the DWR in accordance with the Monitoring Protocols developed for the Basin as described in the KGA Umbrella GSP and Appendices thereto. Additional data collected as part of WRMWSD's other regular monitoring programs (see **Section 5.2.1 *Existing Monitoring and Management Programs***) may be used in conjunction with data collected from the SGMA Monitoring Network to meet compliance with GSP Emergency Regulations regarding Annual Reporting (23 CCR § 356.2) or as otherwise deemed necessary by the District.

TABLE MN-2
Summary of Representative Monitoring Sites
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

Monitoring Site ID	Representative Monitoring Well (RMW) ID	Monitoring Site Type	Type of Measurement Taken	Frequency of Measurement	Sustainability Indicator(s) *(1,2)*						CASGEM Details			Monitoring Site Location						
					Groundwater Level	Groundwater Storage	Seawater Intrusion	Groundwater Quality	Land Subsidence	Interconnected Surface Water	Station ID	Well ID	CASGEM Well Type	Latitude (° NAD 83)	Longitude (° NAD 83)	APN	Landowner / Well Owner	Contact Name/#	Description of Site Location	Long-term Access Agreement in Place?
32S26E20G001M	RMW-094	Well	Groundwater Level	Semiannually	x	x					351303N1192078W001	23790	Voluntary	35.13376	-119.20768	295-040-25	MOC	Michael Blaine	1.5 mi N/o t/o 5G85	Verbal Agreement
32S26E24K001M	RMW-231	Well	Groundwater Level	Semiannually	x	x					-	-	-	35.13044	-119.13660	295-030-39	MFC	Alex Shafer	Bonanza 701	Verbal Agreement
11N22W01D001S	RMW-232	Well	Groundwater Level	Semiannually	x	x					-	-	-	35.07496	-119.18920		WHEELER RDG MARICOPA WTR DIST	Sheridan Nicholas		Executed Agreement
11N22W06H001S	RMW-233	Well	Groundwater Level	Semiannually	x	x					350686N1192609W001	30197	Voluntary	35.06924	-119.26117		SUN PAC	Jose Marin		Verbal Agreement
11N21W16E001S	RMW-234	Well	Groundwater Level	Semiannually	x	x					-	-	-	35.04283	-119.13554	239-041-07	WHEELER RDG MARICOPA WTR DIST	Sheridan Nicholas		Executed Agreement
32S27E30N001M	RMW-095	Well	Groundwater Level	Semiannually	x	x					351092N1191270W001	21426	Voluntary	35.10948	-119.12320	295-130-02	C & A FARMS LLC	Michael Blaine	Located near t/o 7G46 N/o center pivots	Verbal Agreement
32S27E35R001M	RMW-097	Well	Groundwater Level	Semiannually	x	x					350961N1190435W001	21811	Voluntary	35.09602	-119.04069	295-120-55	DIAMOND FARMING	Carl Voss	Located at ISO Copus Rd and I-5; consistently high WL	Verbal Agreement
12N21W35Q001S	RMW-258	Well	Groundwater Level	Semiannually	x	x					-	-	-	35.07685	-119.08714	295-220-10	WEST COAST GRAPE FARMS	Frank Canela	Located near t/o 8G18	Verbal Agreement
12N21W34Q001S	RMW-235	Well	Groundwater Level	Semiannually	x	x					350772N1191087W001	33971	Voluntary	35.07710	-119.10918	295-270-11	ALMOND BLOSSOM RANCH LLC	Jon Goni	Located at t/o 8G15	Verbal Agreement
11N21W09C001S	RMW-236	Well	Groundwater Level	Semiannually	x	x					350592N1191328W001	12159	Voluntary	35.06010	-119.13088	239-320-26	MILLWOOD RANCH CO LTD	Jose Marin	No completion report; located between t/o 7P8 and 7P39; could be infl. by San Emigdio Ck; typ 30'	Verbal Agreement
32S26E34P001M	RMW-237	Well	Groundwater Level	Semiannually	x	x					-	-	-	35.09430	-119.17355	295-050-57	P & N PTP	Peter Dulcich	Located near t/o 7G26 on Copus Rd; could be composite based on screen, but WLs look right	Verbal Agreement
32S26E36P002M	RMW-238	Well	Groundwater Level	Semiannually	x	x					350947N1191370W001	21294	Voluntary	35.09466	-119.13748	259-050-58	P & N L P	Peter Dulcich	Located near t/o 7G32	Verbal Agreement
32S25E29Q001M	RMW-239	Well	Groundwater Level & Groundwater Quality	Semiannually	x	x		x			351083N1193140W001	23744	Voluntary	35.10876	-119.31313	220-170-10	MOC	Michael Blaine	Behind locked fence; located at t/o 4G27	Verbal Agreement
32S28E16P001M	RMW-240	Well	Groundwater Level & Groundwater Quality	Semiannually	x	x		x			351397N1189767W001	21937	Voluntary	35.13668	-118.97678	445-030-16	BIDART	Leonard Bidart		Executed Agreement
32S26E17H001M	RMW-241	Well	Groundwater Quality	Annually				x			351450N1191992W001	37161	Voluntary	35.14836	-119.20019	295-040-36	HALL	Paula Hall		Verbal Agreement
11N21W12N002S	RMW-242	Well	Groundwater Quality	Annually				x			350489N1190806W001	12300	Voluntary	35.05004	-119.08134					Verbal Agreement
11N22W09A001S	RMW-243	Well	Groundwater Quality	Annually				x			-	-	-	35.06164	-119.22530					Verbal Agreement
12N21W31P001S	RMW-244	Well	Groundwater Quality	Annually				x			-	-	-	35.07771	-119.16659					Verbal Agreement
12N21W34N001S	RMW-245	Well	Groundwater Quality	Annually				x			350772N1191178W001	15237	Voluntary	35.07743	-119.11721					Verbal Agreement
32S26E14J001M	RMW-246	Well	Groundwater Quality	Annually				x			351450N1191459W001	36997	Voluntary	35.14505	-119.14618					Verbal Agreement
32S27E36R001M	RMW-247	Well	Groundwater Quality	Annually				x			350953N1190215W001	21813	Voluntary	35.09582	-119.02226					Verbal Agreement

TABLE MN-2
Summary of Representative Monitoring Sites
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

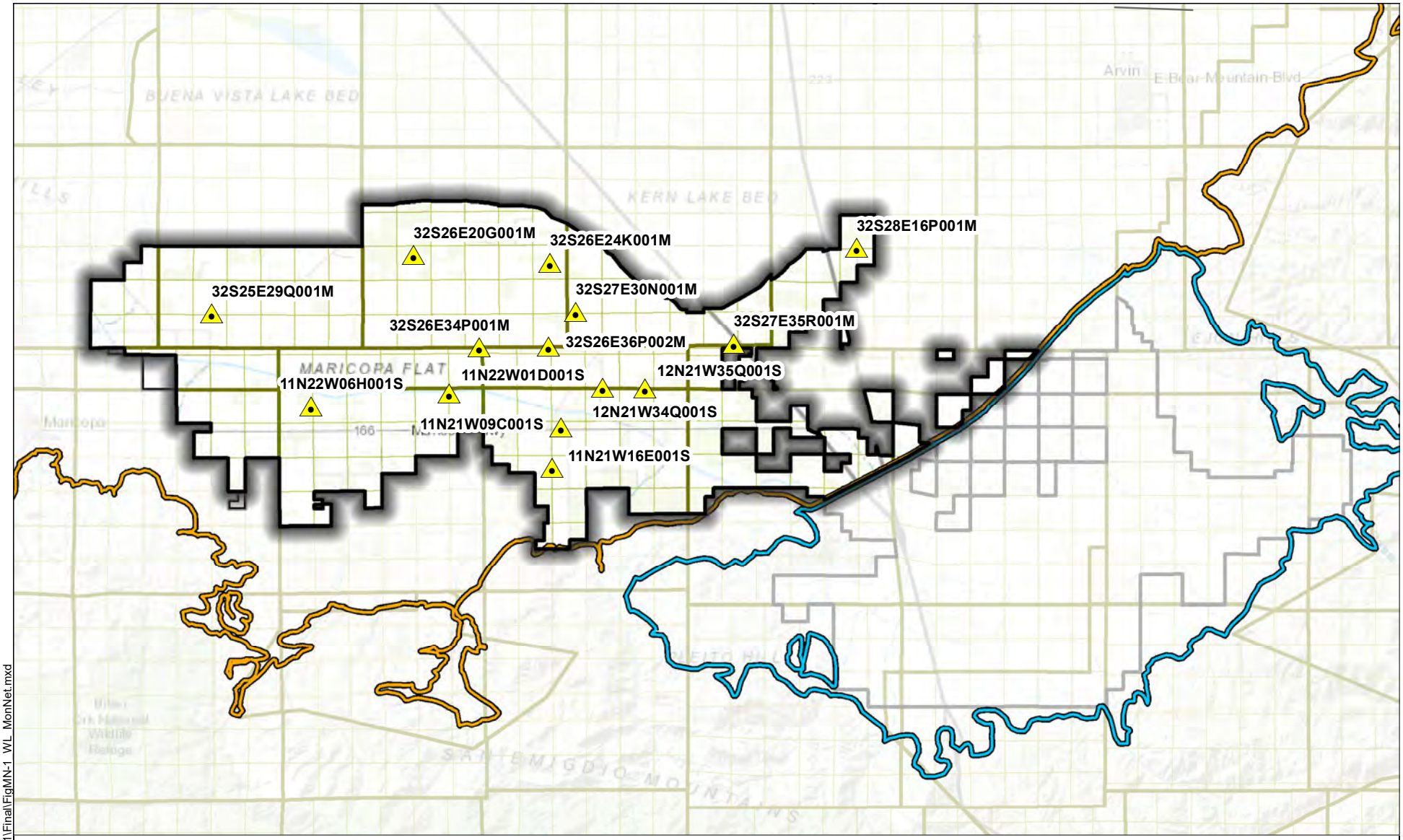
Monitoring Site ID	Reference Point			Status_Code	Well Type	Well Status	Well Completion Type	Well Construction Details										DWR Well Completion Report No.	Principal Aquifer(s) Monitored *(3)*
	Ground Surface Elevation (ft amsl)	Reference Point Elevation (ft amsl)	Reference Point Description					Year Drilled	Total Completed Depth (ft bgs)	Borehole Depth (ft bgs)	Top of Perforations Depth (ft bgs)	Bottom of Perforations Depth (ft bgs)	Casing Diameter (in)	Pump Type	Nameplate - Horsepower	Well Capacity (gpm)	Well Discharge (in)		
32S26E20G001M	335.42	335.42	*Data Gap - will be filled as part of GSP implementation*	OY	Irrigation	Inactive	Single	1969	1201		295	1201	*Data Gap - will be filled as part of GSP implementation*						Principal Aquifer (KRF)
32S26E24K001M	317.00	317.00			Unknown	Unknown	Single												Principal Aquifer (KRF)
11N22W01D001S	501.00	500.00		IWRM	Monitoring	Inactive	Single				820	1858							Principal Aquifer (KRF)
11N22W06H001S	542.51	544.51		OB	Monitoring	Inactive	Single												Principal Aquifer (KRF)
11N21W16E001S	644.00	644.00		AWRM	Production	Active	Single	1992	1500		619	2280							Principal Aquifer (KRF)
32S27E30N001M	352.39	352.39		OB	Monitoring	Inactive	Single	1953	1002		252	1002							Principal Aquifer (KRF)
32S27E35R001M	346.41	348.41		OB	Monitoring	Active	Single	1958	1314		647	1314							Principal Aquifer (KRF)
12N21W35Q001S	415.00	417.00		OB	Monitoring	Active	Single	1937											Principal Aquifer (KRF)
12N21W34Q001S	439.46	439.96		OB	Monitoring	Inactive	Single	1950	800		400	800							Principal Aquifer (KRF)
11N21W09C001S	545.51	546.01		OY	Irrigation	Inactive	Single		2100		800	2100							Principal Aquifer (KRF)
32S26E34P001M	427.00	425.00		AA	Irrigation	Active	Single	1951	700		350	700							Principal Aquifer (KRF)
32S26E36P002M	402.43	402.43		OY	Irrigation	Inactive	Single	1958	1802		552	1802							Principal Aquifer (KRF)
32S25E29Q001M	422.51	424.51		AA	Irrigation	Active	Single	1977	1002		642	1002							Principal Aquifer (KRF)
32S28E16P001M	316.23	316.23		OY	Irrigation	Inactive	Single				350	700							Principal Aquifer (KRF)
32S26E17H001M	312.40	312.40		OY	Irrigation	Inactive	Single				444	836							Principal Aquifer (KRF)
11N21W12N002S	530.54	530.54		Unknown	Irrigation	Active	Single												Principal Aquifer (KRF)
11N22W09A001S	565.00	565.00		Unknown	Unknown	Unknown	Single												Principal Aquifer (KRF)
12N21W31P001S	487.00	489.00		Unknown	Irrigation	Active	Single												Principal Aquifer (KRF)
12N21W34N001S	447.46	448.96		Unknown	Unknown	Unknown	Single	1964	2050		647	2002							Principal Aquifer (KRF)
32S26E14J001M	306.35	306.35		Unknown	Irrigation	Active	Single												Principal Aquifer (KRF)
32S27E36R001M	354.44	356.44		Unknown	Unknown	Unknown	Single		1800		600	1800							Principal Aquifer (KRF)

Abbreviations

amsl = above mean sea level
bgs = below ground surface
CASGEM = California Statewide Groundwater Elevation Monirtoring
DWR = California Department of Water Resources
ft = feet
gpm = gallons per minute
in = inches
KRF = Kern River Formation
N/A = not applicable
NAD = North American Datum
t/o = turnout

Notes

(1) Seawater intrusion is not considered to be a sustainability indicator of concern to the Wheeler Ridge-Maricopa Management Area and is thus not monitored for SGMA compliance
(2) Depletion of Interconnected Surface Water is not considered to be a sustainability indicator of concern to the Wheeler Ridge-Maricopa Management Area and is thus not monitored for SGMA compliance
(3) Only one Principal Aquifer is defined for the Wheeler Ridge-Maricopa Management Area - the "Kern River Formation Principal Aquifer"



Legend

- WRMWSD Service Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Representative Monitoring Sites

Abbreviations

DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 December 2019.
2. Well type data received from WRMWSD on 20 November 2017.

N

0 5 10

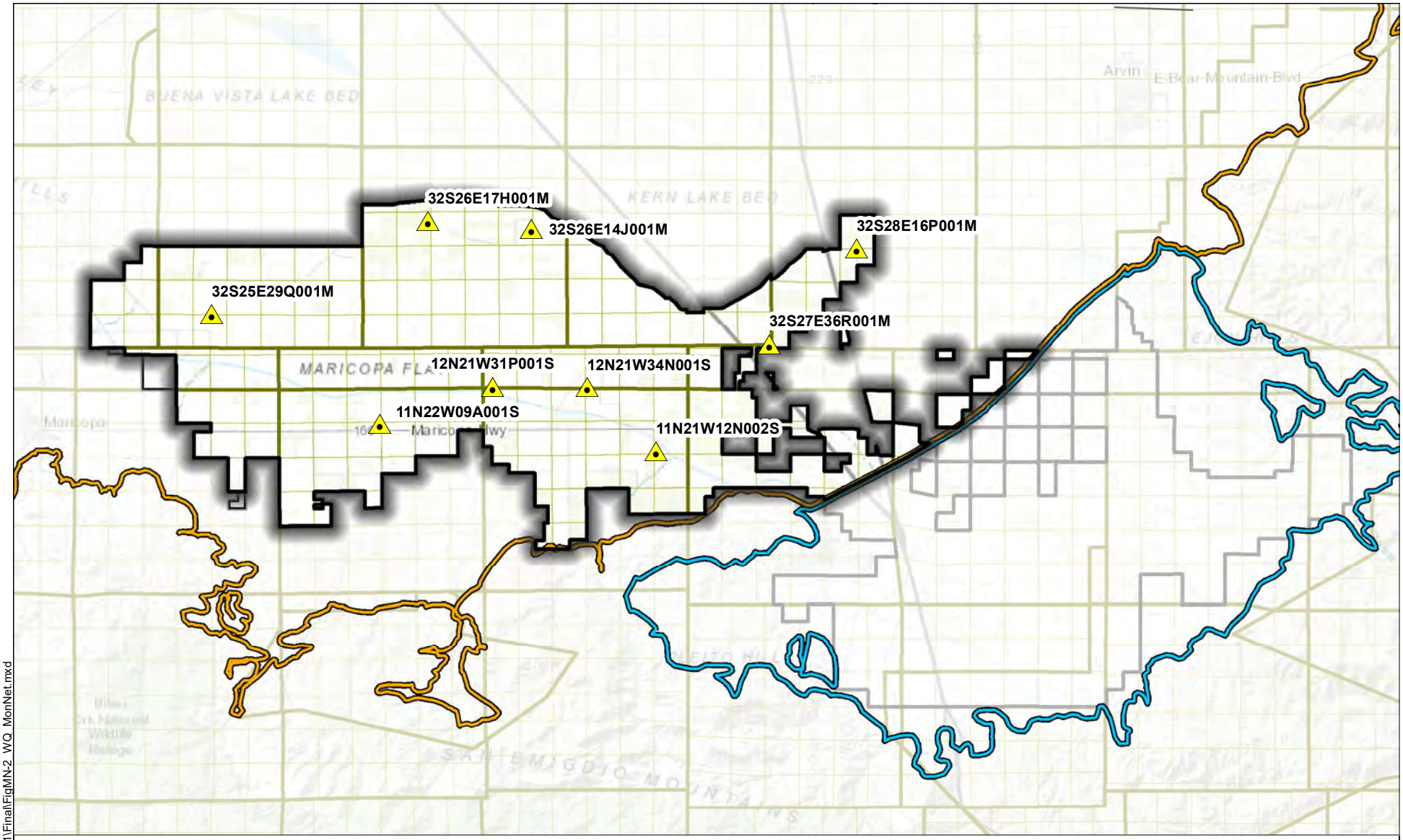
(Scale in Miles)

SGMA Water Level Monitoring Network

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01
Figure MN-1

eki environment & water

Path: X:\B70103\Maps\for GSP\2019\11\Final\FigMN-1 WL MonNet.mxd



Legend

- WRMWSD Service Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Representative Monitoring Site

Abbreviations

DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 22 November 2019.
2. Well type data received from WRMWSD on 20 November 2017.

N

0 5 10

(Scale in Miles)

SGMA Water Quality Monitoring Network

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01
Figure MN-2

eki environment & water

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PROJECTS AND MANAGEMENT ACTIONS

17. PROJECTS AND MANAGEMENT ACTIONS

☑ **23 CCR § 354.42**

Pursuant to the GSP Emergency Regulations, this section presents the Projects and Management Actions (P/MAs) proposed to support achievement of the sustainability goal within the Wheeler Ridge-Maricopa Management Area[79]. The P/MAs were developed using a portfolio approach whereby individual P/MAs were identified and grouped into categories based on their expected benefits. Implementation of P/MAs within those benefit categories is estimated to occur along a "glide path" that will result in closing of the currently identified "deficit" under the 2030 Climate Change Scenario by the January 2040 GSP implementation deadline (see **Section 9.4.3 *Projected Water Budget Results***), as well as in response to observed groundwater conditions relative to the associated Sustainability Indicators. The proposed P/MAs thus represent a path to achieve the sustainability goal for the Management Area, as further demonstrated by results from the basin-wide numerical groundwater flow model that show groundwater levels exceeding Measurable Objectives when P/MAs are implemented. This approach allows for flexible implementation of P/MAs as needed to address future conditions throughout the 50-year GSP planning and implementation horizon (i.e., out to 2070). The P/MAs presented herein were developed with consideration of costs and benefits and preliminary feasibility analysis; however, each P/MA will require significant further evaluation (i.e., engineering, economic, legal, etc.) prior to implementation. In addition to the P/MAs presented herein, WRMWSD will continue to conduct data gap filling activities as part of Plan Implementation that may include, but are limited to, validating the status of existing wells, refining the water budget parameters based on additional data and modeling, collecting additional data related to aquifer conditions and properties, and conducting additional data compilation and analysis of groundwater conditions information (see **Section 18 *WRMWSD Plan Implementation***).

This section first presents the goals and objectives of the P/MAs, including the relevant Sustainability Indicators, the spatial "focus areas" within the Wheeler Ridge-Maricopa Management Area, the categories of expected benefits and the implementation glide path. Next, a list of specific P/MAs grouped by benefit category and type is presented, information which is also provided in. Following this list is a discussion of how the P/MAs address overdraft conditions or other Undesirable Results (i.e., water quality); a description of the various potentially applicable permitting and regulatory requirements; a discussion of the P/MA status and implementation timeline; a discussion of how the expected benefits will be evaluated; a description of sources of outside water that are relied upon; a discussion of the legal authority required to implement the P/MAs; a summary of estimated costs and how the Wheeler Ridge-Maricopa Water Storage District (WRMWSD) plans to meet those costs; and a discussion of how recharge and extraction will be managed to avoid depletion of groundwater levels and storage.

[79] In this document, the term "Wheeler Ridge-Maricopa Management Area" is used in its entirety the first time the area is being referenced in each paragraph; subsequent references to this area in each paragraph use the term "Management Area".

17.1. Goals and Objectives of Projects and Management Actions

17.1.1. Relevant Sustainability Indicators

Per the GSP Emergency Regulations, GSPs must include P/MAs to address any existing or potential future Undesirable Results for the identified relevant Sustainability Indicators. As discussed in **Section 13 *Undesirable Results***, the relevant Sustainability Indicators in the Wheeler Ridge-Maricopa Management Area for which Undesirable Results and Sustainable Management Criteria (SMCs) have been defined include: (1) Chronic Lowering of Groundwater Levels, (2) Reduction of Groundwater Storage, and (3) Land Subsidence. Because groundwater levels and storage area directly correlated, P/MAs that address groundwater levels also address groundwater storage, and the two Sustainability Indicators are considered together in this discussion of P/MAs. Each of these relevant Sustainability Indicators is further associated with specific areas within the Management Area. Therefore, the goal of the P/MAs discussed herein is to address significant and unreasonable effects related to the relevant Sustainability Indicators in the relevant areas.

17.1.2. Focus Areas

As discussed in **Section 8.2 *Groundwater Elevations and Flow Direction*,** groundwater levels in 2015 were lowest in the southern central portion and the far northernmost portion of the Wheeler Ridge-Maricopa Management Area, and the patterns likely reflect, in part, the distribution of groundwater pumping (the latter of these two areas is outside of the Surface Water Service Area [SWSA] and therefore relies exclusively on groundwater) (see **Figure GWC-1**, **Figure GWC-2**, and **Figure GWC-5**). For that reason, the proposed P/MAs that address groundwater levels and storage are focused on those areas. Land Subsidence is also closely tied to groundwater levels but is only relevant where there is critical infrastructure (defined with an emphasis on regional infrastructure, as discussed in **Section 13.5 *Undesirable Results for Land Subsidence*** above). The area most relevant to the Land Subsidence Sustainability Indicator is along the California Aqueduct, which is also within the SWSA. Groundwater quality is generally suitable for agricultural uses within the Management Area, except for the far western portion of the Management Area where naturally-occurring salinity affects groundwater quality, and therefore no SMCs are defined, and no P/MAs are proposed to address effects related to this Sustainability Indicator.

17.1.3. Benefit Categories

☑ 23 CCR § 354.44(b)(5)

The primary water management "tools" (i.e., authorities) by which Groundwater Sustainability Agencies (GSAs) can address conditions that may lead to Undesirable Results associated with water quantity (i.e., Chronic Lowering of Groundwater Levels and Reduction of Groundwater Storage) pertain to management of inflows (supplies) and outflows (demands). Therefore, the primary categories of expected benefits for these water quantity-related P/MAs are:

- Water supply augmentation, including
    - Wet year supplies
    - Other (i.e. all year) new supplies; and
- Water demand reduction.

All of the P/MAs have a water quantity-related benefit relating to at least one of those two primary categories. In addition, some P/MAs also have secondary benefits, including:

- Water quality improvement; and
- Water management flexibility/efficiency.

17.1.4. Implementation Glide Path

☑ 23 CCR § 354.44(d)

As stated above, the goals and objectives of the P/MAs presented herein are to address any existing or potential Undesirable Results by the GSP implementation deadline for the Kern County Subbasin (Kern Subbasin) (i.e., by January 2040). As such, P/MAs will be implemented incrementally on an as-needed basis to achieve this goal. While the exact schedule and timetable for implementation of individual P/MAs is not known at this time, a general implementation schedule, also known as a "glide path", has been developed and is summarized in **Table PMA-2**. This preliminary "glide path" aims to address a certain percentage of the projected deficit during each five-year period through 2040, which in turn will affect conditions of the relevant Sustainability Indicators based on the assumption that those conditions are directly related to the balance of supplies and demands within the Wheeler Ridge-Maricopa Management Area. The "glide path" also includes a preliminary estimate of the supply augmentation and/or demand reduction measures necessary to address the projected deficit specified under the 2070 Climate Change Scenario by the end of the 50-year GSP planning and implementation horizon (i.e., January 2070).

Table PMA-2. General Project and Management Actions Implementation Schedule ("Glide Path")

		P/MA Implementation Schedule				
		By 2025	**By 2030**	**By 2035**	**By 2040**	**By 2070**
Projected Deficit [1] (AFY)		21,400				33,300
Target Deficit Reduction (%)		15%	45%	75%	100%	100%
Target Deficit Reduction (AFY)		3,200	9,600	16,100	21,400	33,300
P/MA Benefits, by Type (AFY)						
Water Supply Augmentation	Wet Year Supplies	896	2,688	4,508	5,992	5,992
	Other New Supplies	1,024	3,072	5,152	6,848	12,798
Demand Reduction		1,280	3,840	6,440	8,560	14,510
Total P/MA Benefits		**3,200**	**9,600**	**16,100**	**21,400**	**33,300**

Abbreviations:
AFY = acre-feet per year
P/MA = Project and Management Actions

Notes:
1. Projected Deficit to be addressed by implementation of P/MAs up to 2040 is the net water supply shortfall based on the 2030 Climate Change Scenario. Projected Deficit to be addressed by future P/MA implementation beyond 2040 (i.e., up to 2070) is the net water supply shortfall based on the 2070 Climate Change Scenario.
2. In the 2025 through 2040 periods, 60% of the target deficit reduction is met by Water Supply Augmentation P/MAs and the remaining 40% may be met by Demand Reduction P/MAs as necessary. In the period from 2040 through 2070, 50% of the additional target deficit reduction is met with Water Supply Augmentation P/MAs, and the remaining 50% with Demand Reduction P/MAs as necessary.

17.2. List of Projects and Management Actions

☑ 23 CCR § 354.44(b)(1)

This section provides a list of the P/MAs identified by WRMWSD, divided into the two primary benefit categories discussed above, both of which address the Chronic Lowering of Groundwater and Reduction of Groundwater Storage Sustainability Indicators. Within these two categories, the P/MAs are further classified into five types based on the mechanism by which the primary benefit is achieved. Details of the P/MAs are provided in **Table PMA-1**.

17.2.1. Water Supply Augmentation Projects

The Projects listed below have supply augmentation as their primary expected benefit, and include Projects to Enhance Recharge/Banking, Projects to Increase Water Management Flexibility, and Projects to Develop New Supplies.

Projects to Enhance Recharge/Banking

1. On-Farm Recharge[80]
2. In-District District Banking Facilities
3. Increase Out-of-District Banking Operations

Projects to Increase Water Management Flexibility

4. Expand District Distribution System

Projects to Develop New Supplies

5. Purchase Additional Supplies
6. Desalination Facilities
7. "Thru Delta" Facility

17.2.2. Water Demand Reduction Management Actions

The Management Actions listed below have water demand reduction as their primary expected benefit and include Management Actions / Policies to Raise Funds to Support Sustainable Groundwater Management Act (SGMA) Compliance and Management Actions / Policies to Reduce Groundwater Pumping.

Management Actions to Raise Funds to Support SGMA Compliance

8. Acreage Assessment

Management Actions / Policies to Reduce Groundwater Pumping

9. Groundwater Allocation and Market
10. Voluntary Pumping Limitations
11. Mandatory Pumping Limitations
12. Land Retirement

17.3. Circumstances for Implementation

☑ 23 CCR § 354.42(b)(1)(A)

Using the portfolio approach, P/MAs will be selected for implementation based on further consideration of the magnitude of expected benefit, the relative cost and ease of implementation, and other factors.

[80] As discussed in Section **7.3.4 Recharge and Discharge Areas**, much of the District, especially the southern portion, has surface conditions deemed suitable for recharge (see **Figure HCM-19**).

Some P/MAs will be implemented immediately upon adoption of the GSP. Others will be implemented when grant funds are obtained or upon completion of feasibility studies, economic evaluations, and/or other necessary planning studies. A key precursor to implementing some of the P/MAs will be renegotiation and modification to the contracts between the District and landowners to allow for certain funding and assessment provisions, and to allow greater flexibility in the types of water supplies that the District can purchase. Renegotiation of the contracts will be pursued by the District's Board immediately upon adoption of the GSP.

As discussed above, an overall P/MA implementation schedule, or "glide path" has been developed that serves as a framework to guide the level of benefits that are planned to be achieved over the GSP implementation period (i.e., until 2040), and further through the SGMA planning and implementation horizon (i.e., through 2070). Accelerated implementation of P/MAs (i.e., at expected benefit accrual rates faster than those shown in **Table PMA-2** above) will be triggered if Minimum Thresholds for Chronic Lowering of Groundwater Levels are exceeded in more than 20% of (i.e., at least 3 out of 14) of Representative Monitoring Sites.

17.4. Public Notice Process

☑ 23 CCR § 354.42(b)(1)(B)

Public notice requirements vary for the different P/MAs listed above. Some projects that involve infrastructure improvements only may not require specific public noticing (other than that related to construction), whereas certain other management actions that involve, for example, imposition of fees by WRMWSD, may require public noticing pursuant to Proposition 218 or Proposition 26. In general, P/MAs being considered for implementation will be discussed during regular WRMWSD Board Meetings which are open to the public. Additional stakeholder outreach efforts will be conducted prior to and during P/MA implementation, as required by law.

17.5. Addressing Overdraft Conditions

☑ 23 CCR § 354.44(b)(2)

As discussed in **Section 9.2.4 *Overdraft Conditions***, the Wheeler Ridge-Maricopa Management Area as a whole does not have a net water budget deficit over the historical period based on the Management Area-specific spreadsheet water budget model.[81] However, groundwater levels in some areas, both inside and outside of the SWSA, have shown decreasing trends in recent years, suggesting a local imbalance of supplies versus pumping over this period (which includes a significant drought period). Furthermore, the projected water budget indicates that under the 2030 Climate Change Scenario, imported water supplies to the Management Area may be reduced, resulting in a net deficit of approximately -21,400 AFY. The P/MAs presented herein are expected to result in benefits (discussed below) that will address the projected deficit so as to avoid Undesirable Results and achieve sustainability.

[81] Prior to the start of water importation into the WRMWSD area in 1971, groundwater levels were in a state of chronic decline.

17.6. Permitting and Regulatory Process

☑ 23 CCR § 354.44(b)(3)

Permitting and regulatory requirements vary for the different P/MAs depending on whether they are infrastructure projects, recharge projects, demand reduction management actions, and so forth. The various types of permitting and regulatory requirements (not all applicable to every P/MA) include the following:

- Federal
  - National Environmental Policy Act (NEPA) documentation, if federal grant funds are used;
  - National Pollution Discharge Elimination System (NPDES) stormwater program permit (administered by the California State Water Resources Control Board [SWRCB]);
- State
  - California Environmental Quality Act (CEQA) documentation, including one or more of the following: Initial Study (IS), Categorical Exemption (CE), Negative Declaration (ND), Mitigated Negative Declaration (MND), Environmental Impact Report (EIR);
  - California State Water Resources Control Board permits and regulations regarding recycled water use, waste discharge, and stormwater capture for recharge;
- Regional
  - San Joaquin Valley Air Pollution Control District (SJVAPCD) permit and regulations;
- County/Local
  - Encroachment permits – Kern County, Caltrans, and others;
  - Kern County grading permit.

Specific currently-identified permitting and regulatory requirements for each P/MA are listed in **Table PMA-1**. Upon implementation of any P/MA, the regulatory and permitting requirements of the P/MA will be re-examined.

17.7. Status and Implementation Timetable

☑ 23 CCR § 354.44(b)(4)

With a few exceptions, the current status of P/MAs listed in **Table PMA-1** is "not yet initiated". As discussed above in **Section 17.3 *Circumstances for Implementation***, P/MAs related to water quantity will be initiated in a manner and sequence that achieves the "glide path" level of expected benefits shown in **Table PMA-2**, with accelerated implementation if Minimum Thresholds for Chronic Lowering of Groundwater Levels are exceeded in more than 20% (i.e., at least 3 out of 14) of Representative Monitoring Sites. **Table PMA-1** presents preliminary estimates of the time required to complete/implement each P/MA and a timetable for accrual of expected benefits. These estimates will be refined, as necessary, upon further evaluation of the P/MAs.

17.8. Expected Benefits

☑ 23 CCR § 354.44(b)(5)

The different categories of expected benefits are presented above in **Section 17.1.3 *Benefit Categories***, and the specific expected benefits of each P/MA are presented in **Table PMA-1**. Below is a discussion of how the expected benefits will be evaluated.

17.8.1. Evaluation of Benefits

Each of the P/MAs has expected benefits related to water quantity. Once a P/MA is implemented, it is important for there to be a way to evaluate, ideally to quantify, the benefits resulting from that P/MA. The way in which P/MA benefits are evaluated/quantified depends on the P/MA type. For those P/MAs that involve direct supply augmentation, the benefit is quantified directly through measurement of those flows and corresponding response in water levels. For P/MAs that involve indirect supply augmentation through, for example, increased delivery flexibility, quantification of the benefit will require a comparison of the observed water supply condition (e.g., total imported water) For P/MAs that involve water demand reduction the benefit will be evaluated by comparison of the observed water demand condition (e.g., irrigated acreage) against a hypothetical condition where the P/MA was not in place. Because it is not possible to determine with certainty what the condition without the P/MA would be like, quantification of the benefits is inherently uncertain.

As discussed above, although the P/MAs described herein are laid out along a general timetable defined by incremental elimination of water budget deficits (i.e., the "glide path"), the goals and objectives of P/MA implementation are not necessarily to achieve a certain water budget outcome, but rather to ensure that Undesirable Results for relevant Sustainability Indicators are avoided by the end of the SGMA implementation period (i.e., by 2040). For this reason, ultimately the success of the collective implementation of P/MAs will be determined by whether the Sustainability Goal is achieved.

17.8.2. Evaluation Relative to Water Level Sustainability Criteria

As mentioned in **Section 9 *Water Budget Information***, as part of its involvement in the KGA GSA, WRMWSD is participating in the development of a numerical groundwater water flow model for the Kern Subbasin based on DWR's California Central Valley Groundwater-Surface Water Simulation beta fine-grid model (C2VSim-FG). As part of this process, all Basin GSAs were asked to input their proposed P/MAs into the Baseline and 2030 Climate Change C2VSim-FG projected model scenarios to assess water level responses to GSP implementation relative to proposed Water Level Sustainability Criteria defined for each GSA/Management Area (see **Sections 14.1** and **15.1**). As demonstrated in **Figure PMA-1**, for each of the fifteen water level Representative Monitoring Sites within the Wheeler Ridge-Maricopa Management Area, groundwater elevations are expected to meet their Minimum Thresholds under P/MA implementation in both the Baseline and 2030 Climate Change Scenarios. In all cases, water levels are also maintained at or above the Measurable Objectives upon full P/MA implementation. The results of this Basin-wide projected modeling exercise thus further support the notion that the proposed P/MA implementation strategy is expected to result in sustainable management of groundwater levels within the Wheeler Ridge-Maricopa Management Area.

17.9. Source and Reliability of Water from Outside WRMWSD

☑ 23 CCR § 354.44(b)(6)

Several of the P/MAs discussed below and shown in **Table PMA-1** rely on additional water supplies from outside of the WRMWSD area. Specifically, certain P/MAs rely on the availability of water during wet years to conduct managed recharge, banking inside and outside of the District, and offset groundwater pumping. As discussed in **Section 9.4 *Projected Water Budget***, the volume of SWP supplies is anticipated to decrease under the 2030 Climate Change Scenario relative to the historical water budget period (Water Year [WY] 1995 – 2014) and the Baseline Scenario, and that decrease is the main cause of the projected deficit. However, the District understands that additional wet year supplies may be available, if sufficient infrastructure is developed to take it in (within or outside of the District). Furthermore, the District is an active participant in the various surface water transfer, exchange and purchase markets in the Central Valley and will continue those efforts.

The District is also participating in efforts to develop several new surface water supplies that would provide a more regular (i.e., year to year) source of supply, to be conveyed through the California Aqueduct. These potential additional sources of supply include the following:

- Sites Reservoir Project; and
- Water Fix and Eco Restore (formerly known as the Bay Delta Conservation Plan, referred to in **Table PMA-1** as the "Thru Delta" Facility).

17.10. Legal Authority Required

☑ 23 CCR § 354.44(b)(7)

WRMWSD is a Participating Member of the KGA GSA, which is organized as a joint powers authority. WRMWSD, as a water storage district, possesses the legal authority to implement the supply augmentation P/MAs discussed herein. As a GSA, per California Water Code (CWC) § 10725 through 10726.8, the KGA GSA possesses the legal authority outlined in necessary to implement the demand management P/MAs described herein and will either act upon WRMWSD's behalf to enforce these P/MAs as necessary or will delegate authority to WRMWSD itself to enforce the GSP within the Wheeler Ridge-Maricopa Management Area. As mentioned above, the District will pursue renegotiation of landowner contracts as one of the initial steps of GSP implementation.

17.11. Estimated Costs and Plans to Meet Them

☑ 23 CCR § 354.44(b)(8)

Estimated costs for each P/MA are presented in **Table PMA-1**. Given the uncertainty in the scope and timing of these P/MAs, in some cases the costs are presented as ranges, and in all cases are considered approximate subject to refinement. These costs include "one-time" costs and ongoing costs. The one-time costs may include capital costs associated with construction, feasibility studies, permitting, environmental (CEQA) compliance, or any other costs required to initiate a given P/MA. The ongoing costs are associated with operations and maintenance (O&M) of facilities, costs for purchased water supplies, and/or costs to otherwise continue implementing a given P/MA. It should be noted that depending on the source and

nature of funding for the P/MAs, the one-time costs may or may not be incurred entirely at the beginning of the P/MA; in some instances, loans or other financing options may allow for spreading out of "one-time" costs over time.

Potential sources of funding for the various P/MAs are also presented in **Table PMA-1**, and include the following:

- WRMWSD funds, generally supported by fees charged to landowners within WRMWSD, including potentially the following:
    - General fund
    - SGMA compliance subaccount
- Partnering agencies for certain P/MAs
- Grant funding from sources including DWR and others
- Other

Upon implementation of any given P/MA, the available funding sources for that P/MA will be re-examined.

17.12. Management of Recharge and Groundwater Extractions

☑ 23 CCR § 354.44(b)(9)

As stated previously in **Section 9 *Water Budget Information***, under historical conditions (WY 1995 – 2014), the Wheeler-Ridge Maricopa Management Area is in a state of approximate water supply/demand balance (i.e., with a moderate net surplus of approximately 3,300 AFY, based on the Management Area-specific spreadsheet water budget model). Under the Baseline and 2030 (and 2070) Climate Change Scenarios, however, a net water supply deficit is projected to occur. That projected deficit is due, in large part, to a projected reduction in imported water supplies. However, as discussed above, one of the primary means by which the deficit will be addressed is through the implementation of P/MAs that obtain additional outside sources of water, in particular during normal to wet years. Most of the supply augmentation projects discussed herein and shown on **Table PMA-1** take advantage of additional wet year supplies that are assumed to be available once demands increase. These P/MAs include various direct recharge projects and projects that increase storage capacity and delivery flexibility.

In addition to these supply augmentation projects, the portfolio also includes policy-based management actions aimed at demand reduction. Some of these management actions aim to reduce overall water demand, and others are more specifically focused on reducing groundwater pumping. These management actions will rely initially on financial incentives (e.g., tiered pricing and/or fees) to drive voluntary demand reduction, but also include setting of mandatory groundwater pumping allocations, if necessary. A groundwater allocation program would likely include mechanisms to allow for trading or exchange of pumping allocations, subject to constraints dictated by groundwater conditions observed within the Monitoring Network and policies developed by the WRMWSD Board. Through this combination of increased recharge during wet years and as-needed demand reduction, WRMWSD's P/MA efforts will ensure that chronic lowering of groundwater levels and storage during drought will be offset by increases in groundwater levels and storage during other periods.

Table PMA-1
Details of Projects and Management Actions
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

P/MA Number	P/MA Name	Summary Description	Relevant Sustainability Indicators Affected			Circumstances for Implementation	Public Noticing Process	Permitting and Regulatory Process Requirements	Status	Timetable / Circumstances for Initiation
			Groundwater Levels & Storage	Groundwater Quality	Land Subsidence					
Projects to Enhance Recharge / Banking										
1	**On-Farm Recharge**	Study and implement on-farm recharge where viable.	•	•		To be implemented upon adoption of WRMWSD GSP Chapter	Regular District Board meetings	CEQA	Not yet initiated	2020
2	**In-District Banking Facilities**	Program to promote private and/or District-owned banking facilities within the District.	•	•		To be implemented upon adoption of WRMWSD GSP Chapter	Regular District Board meetings	CEQA	Not yet initiated	2020
3	**Increase Out-of-District Banking Operations**	Increase size/participation in out-of-District banking facilities (i.e., Kern Water Bank and Pioneer Project). Increased banking of wet year supplies outside of the District would support deliveries of imported water into the District in normal/dry years.	•	•		To be implemented upon adoption of WRMWSD GSP Chapter	Regular District Board meetings	CEQA	Not yet initiated	2020
Projects to Increase Water Management Flexibility										
4	**Expand District Distribution System**	Project to expand District distribution system into area currently using only private groundwater.	•	•	•	upon modification of water service contracts	Regular District Board meetings	CEQA	Not yet initiated	TBD
Projects to Develop New Supplies										
5	**Purchase Additional Supplies**	Continue purchase of additional supplies, as available, for banking outside of the District or direct delivery within the District.	•	•	•	Ongoing	Regular District Board meetings	CEQA	Ongoing	Ongoing
6	**Desalination Facilities**	Desalination facilities to allow for use of additional poor quality groundwater for agricultural use, easing demand on principal aquifer.	•	•	•	Localized pumping lowering GW levels near MT	Regular District Board meetings	CEQA	Not yet initiated	TBD
7	**"Thru Delta" Facility**	Particpation of some sort of "Thru Delta" Facility to increase access to contracted (SWP) supplies.	•	•	•	State-led effort underway	Prop 218	CEQA	State-led effort underway	Underway
Management Actions to Raise Funds to Support SGMA Compliance										
8	**Acreage Assessment**	Set policy to implement an acreage assessment to fund purchase of additional supplies, purchase of land for fallowing, and other investments to support SGMA compliance.	•		•	To be implemented upon adoption of WRMWSD GSP Chapter	Prop 218	CEQA	Not yet initiated	2020

Table PMA-1
Details of Projects and Management Actions
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

P/MA Number	P/MA Name	Timetable for Completion	Timetable for Accrual of Expected Benefits	Expected Benefits				Source(s) of Water, if applicable	Legal Authority Required	Estimated Costs		
				Primary		Secondary						
				Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency			One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
Projects to Enhance Recharge												
1	**On-Farm Recharge**	TBD; depending on grower interest	First wet year after construction	approx. 2,000 AFY (10,000 AF every five years)		•	•	Additional wet-year imported water supplies	None	CEQA Costs <$50K	Costs tied to water purchases plus pumping costs (~ $50/AF)	WRMWSD
2	**In-District Banking Facilities**	construction duration: TBD	First wet year after construction	approx. 2,000 AFY (10,000 AF every five years)	approx. 2.75 AFY per acre of land converted to basins	•	•	Additional wet-year imported water supplies	None	Approx. $40K per acre for land purchase and recharge basin construction	Costs tied to water purchases plus pumping costs (~ $50/AF)	WRMWSD
3	**Increase Out-of-District Banking Operations**	construction duration: TBD	First wet year after construction	TBD; depends on recharge basin area		•	•	Additional wet-year supplies	None	Approx. $40K per acre for land purchase and recharge basin construction	Costs tied to water purchases plus pumping costs (~ $50/AF)	WRMWSD
Projects to Increase Water Management Flexibility												
4	**Expand District Distribution System**	construction duration: TBD	First wet year after construction	approx. 2,000 AFY		•	•	Additional wet-year imported water supplies	District authority as a Water Storage District	approx. $18M for 2,000 acre SWSA expansion	Costs tied to water purchases plus pumping costs (~ $50/AF)	WRMWSD; grants
Projects to Develop New Supplies												
5	**Purchase Additional Supplies**	Ongoing	Immediately	Increase purchases by 5,000 AFY		•		Additional imported water supplies	District authority as a Water Storage District	NA	District has been an active purchaser of additional supplies for some time. Average costs are approx. $500/AF.	WRMWSD
6	**Desalination Facilities**	construction duration: 1-3 years	Immediately upon completion of construction	No net supply augmentation, but minimizes local GW pumping impacts		•		poor-quality (currently unused) groundwater	None	NA	Annual costs approximately $600/AF	WRMWSD; grants
7	**"Thru Delta" Facility**	2035	1 year after completion	up to 25,000 AFY		•		State Water Project	None	NA; as this Project would be bonded through SWP, costs would occur on annual bills	TBD; estimates of Cal WaterFix Project were >$600/AF	WRMWSD
Management Actions / Policies to Reduce Overall Water Demand												
8	**Acreage Assessment**	upon modification of water service contracts	1-3 years after completion		•			NA	District authority as a Water Storage District	approx. $50,000 to set up program	This management action would be used to fund other P/MA	WRMWSD; grants

Table PMA-1
Details of Projects and Management Actions
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

P/MA Number	P/MA Name	Summary Description	Relevant Sustainability Indicators Affected			Circumstances for Implementation	Public Noticing Process	Permitting and Regulatory Process Requirements	Status	Timetable / Circumstances for Initiation
			Groundwater Levels & Storage	Groundwater Quality	Land Subsidence					
Management Actions / Policies to Reduce Groundwater Pumping										
9	**Groundwater Allocation and Market**	Develop a groundwater pumping allocation methodology, including a market system for trading and/or transfering of allocations.	•		•	To be implemented upon adoption of WRMWSD GSP Chapter	Regular District Board meetings	CEQA	Not yet initiated	2020
10	**Voluntary Pumping Limitations**	Set non-binding pumping limitations in conjunction with a fee for pumping above limits.	•		•	To be implemented upon adoption of WRMWSD GSP Chapter	Prop 218	CEQA	Not yet initiated	2020
11	**Mandatory Pumping Limitations**	Set binding pumping limitations in conjunction with a fee for pumping above limits.	•		•	if other PMAs are insufficient	Prop 218	CEQA	Not yet initiated	2030
12	**Land Retirement**	Purchase and permanently fallow previously irrigated acreage within District to reduce overall water demand and groundwater extractions.	•		•	if other PMAs are insufficient	Prop 218	CEQA	Not yet initiated	2035

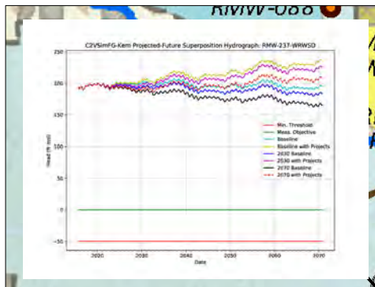
Table PMA-1
Details of Projects and Management Actions
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

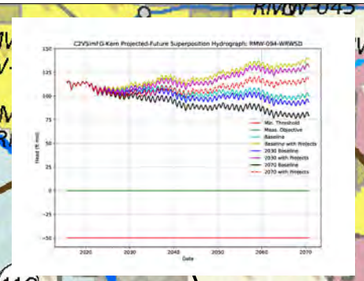
P/MA Number	P/MA Name	Timetable for Completion	Timetable for Accrual of Expected Benefits	Expected Benefits				Source(s) of Water, if applicable	Legal Authority Required	Estimated Costs		
				Primary		Secondary						
				Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency			One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
Management Actions / Policies to Reduce Groundwater Pumping												
9	**Groundwater Allocation and Market**	upon modification of water service contracts	1 year after completion				•	NA	District authority as a GSA (KGA Member)	approx. $50,000 to set up program	Minimal	WRMWSD; grants
10	**Voluntary Pumping Limitations**	upon modification of water service contracts	1-3 years after completion		up to 21,000 AFY			NA	District authority as a Water Storage District	approx. $100,000 to set up program	approx. $100,000/yr for monitoring costs; this management action would be used to fund other P/MAs	WRMWSD; grants
11	**Mandatory Pumping Limitations**	2030	1-3 years after completion		up to 21,000 AFY			NA	District authority as a GSA (KGA Member)	Minimal additional cost beyond Voluntary Pumping Limitations P/MA	Minimal additional cost beyond Voluntary Pumping Limitations P/MA	WRMWSD; grants
12	**Land Retirement**	TBD; depending on landowner interest	1 year after completion		up to 21,000 AFY			NA	District authority as a GSA (KGA Member)	approx. $40,000 per acre for land purchase (incl. interest); 30 yrs of water savings at 2.75 AFY/ac gives net cost of ~$500 per AF	$250/yr per acre for maintenance	WRMWSD; grants

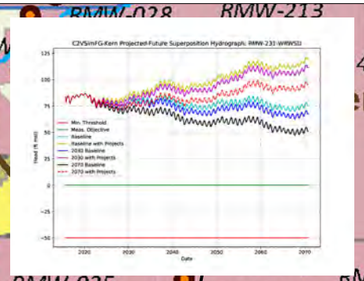
Abbreviations:

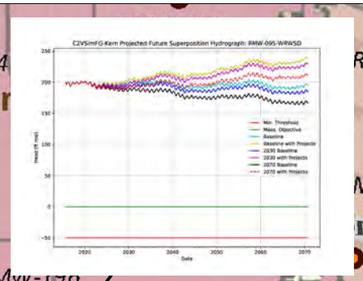
AFY = acre-feet per year
CEQA = Califronia Environmental Quality Act
GSA = Groundwater Sustainability Agency
GSP = Groundwater Sustainability Plan
KGA = Kern Groundwater Authority
NA = Not Applicable
P/MA = Project/Management Action
SGMA = Sustainable Groundwater Management Act
TBD = to be determined
WRMWSD = Wheeler Ridge-Maricopa Water Storage District
SWP = State Water Project
GW = groundwater

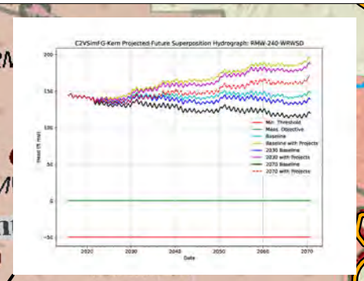
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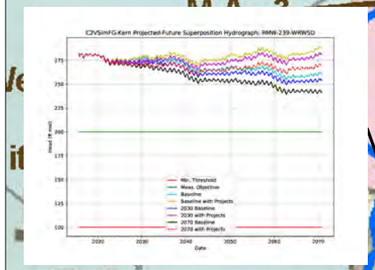


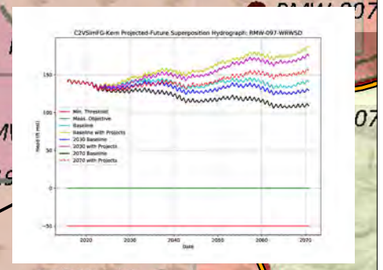


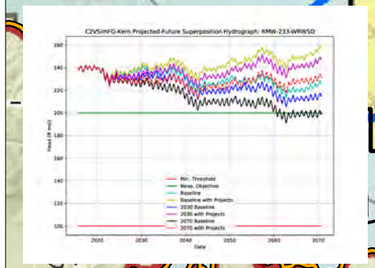




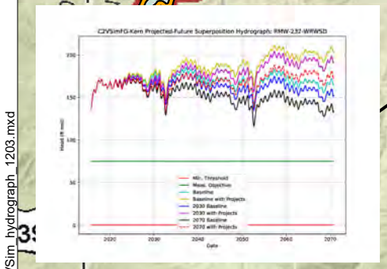


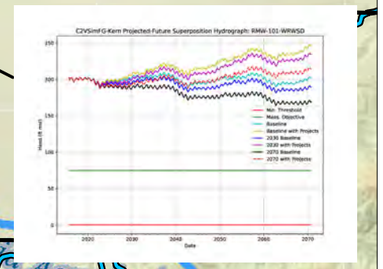


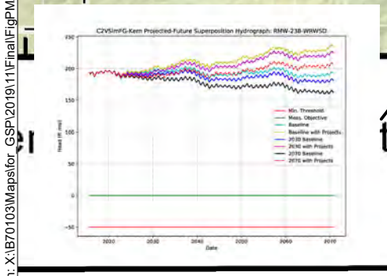


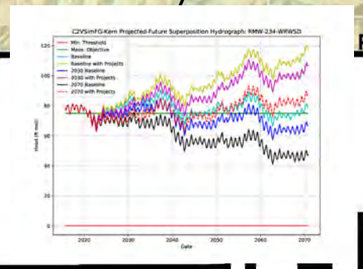


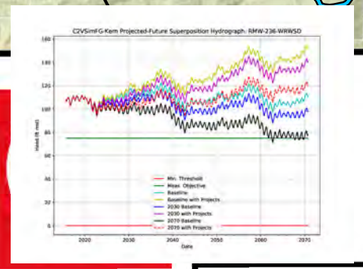


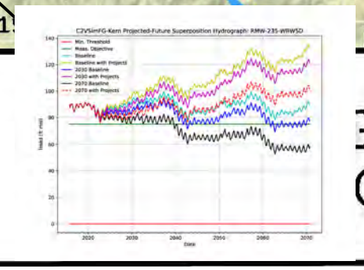












Henry Miller W.D.

Wheeler Ridge-Maricopa W.S.D.

Taft

Santiago Creek

California Aqueduct

RMW-088 RMW-045 RMW-028 RMW-213 RMW-035 RMW-195 RMW-196 RMW-219 RMW-005 RMW-006 RMW-037 RMW-038 RMW-114 RMW-116 RMW-115 RMW-117 RMW-042 RMW-118 RMW-192 RMW-040 RMW-218 RMW-041 RMW-200 RMW-094 RMW-231 RMW-239 RMW-237 RMW-095 RMW-240 RMW-012 RMW-013 RMW-097 RMW-014 RMW-101 RMW-233 RMW-235 RMW-015 RMW-232 RMW-234 RMW-236 RMW-016 RMW-103

119 223 99 5

R23W R21W R1

Legend

- WRMWSD Service Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Minimum Threshold
- Measurable Obejective
- Baseline
- Baseline with Projects
- 2030 Baseline
- 2030 with Projects
- 2070 Baseline
- 2070 with Projects

Abbreviations

C2VSim-FG	=	California Central Valley Groundwater-Surface Water Simulation Model, beta fine-grid version
DWR	=	California Department of Water Resources
ft	=	feet
P/MA	=	Project / Management Action
RMW	=	Representative Monitoring Well
SGMA	=	Sustainable Groundwater Management Act
WRMWSD	=	Wheeler Ridge-Maricopa Water Stroage District

Notes

1. All locations are approximate.

Sources

1. Model-projected hydrographs were provided by Todd Groundwater on 1 December 2019.
2. Basemap of RMW locations were provided by GEI on 27 November 2019.

N

0 4 8

(Scale in Miles)

C2VSim-FG Projected Hydrographs with and without P/MA Implementation

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
B70103.01

Figure PMA-1

eki environment & water

Path: X:\B70103\Maps\for_GSP\2019\11\Final\FigPMA-1_C2VSim_hydrograph_1203.mxd

PLAN IMPLEMENTATION

18. WRMWSD PLAN IMPLEMENTATION

☑ 23 CCR § 351(y)

Per the GSP Emergency Regulations, "plan implementation" refers to "an [Groundwater Sustainability] Agency's exercise of the powers and authorities described in the Act, which commences after an Agency adopts and submits a Plan or Alternative to the Department and begins exercising such powers and authorities" (23 CCR § 351(y)). This section describes the activities that will be performed by Wheeler Ridge-Maricopa Water Storage District (WRMWSD or District) as part of GSP implementation within the Wheeler Ridge-Maricopa Management Area, with a focus on the first five years. This section does not address any actions by other entities with potential management authority in the Management Area – i.e., the Kern Groundwater Authority (KGA) Groundwater Sustainability Agency (GSA).

Key GSP implementation activities to be undertaken by the District over the next five years include:

- Monitoring and data collection;
- Data gap filling;
- Projects & Management Action (P/MA) implementation, including policy development to support GSP implementation;
- Technical and non-technical coordination with other water management entities within the Kern County Subbasin (Kern Subbasin);
- Continued outreach and engagement with stakeholders;
- Annual reporting;
- Enforcement and response actions, as necessary; and
- Evaluation and updates, as necessary, of the District's MA Plan as part of the required periodic evaluations (i.e., "five-year updates").

Each of these activities is discussed in more detail below.

18.1. Monitoring and Data Collection

As discussed in **Section 16 *Monitoring Network***, successful sustainable groundwater management relies on a foundation of data to support decision making. As such, collection of data within the Wheeler Ridge-Maricopa Management Area will be a key part of GSP implementation. These data collection efforts include data on applicable sustainability indicators to be collected from the networks of Representative Monitoring Sites (RMS), as well as other data and information required for management and reporting under the Sustainable Groundwater Management Act (SGMA), as described below.

Monitoring of Applicable Sustainability Indicators

Section 16 *Monitoring Network* discusses the monitoring networks (i.e., Representative Monitoring Sites) and protocols that will be used for the applicable sustainability indicators within the Wheeler Ridge-Maricopa Management Area, including Chronic Lowering of Groundwater Levels, Reduction of Groundwater Storage (using groundwater levels as a proxy), and Land Subsidence. Those protocols will be followed in the defined networks as part of GSP implementation. Data collected will be incorporated into the District's own Data Management System (DMS) for subsequent inclusion in the basin-wide DMS. These data will be used to support coordination efforts within the KGA GSA and the Kern Subbasin (e.g., as part of Annual Reports; see **Section 18.5 *Annual Reporting***).

Monitoring results will be evaluated against applicable Sustainable Management Criteria (SMCs; i.e., Undesirable Results, Minimum Thresholds, and Measurable Objectives) to support local management efforts. In addition, although no SMCs are defined at this time for Degraded Water Quality, a network of water quality monitoring sites and sampling protocols have been established within the Wheeler Ridge-Maricopa Management Area. Those data collection activities will also be conducted to support improved local understanding and groundwater management decisions. If it is determined in the future that SMCs are warranted for this Sustainability Indicator, the MA Plan will be amended as such.

The District anticipates that within the first five years of GSP implementation (i.e., in the 2020 – 2025 timeframe), the following efforts related to monitoring will be performed:

- Refinement of the local DMS to comply with the basin-wide DMS;
- Refinement of the Monitoring Network, including potentially adding, replacing or drilling new wells and/or video-logging to collect missing screen/depth info of Representative Monitoring Sites with data existing data gaps (see **Section 16.4 *Assessment and Improvement of Monitoring Network***);
- Semi-annual monitoring for water levels at the RMS, with the potential for more frequent (i.e., monthly) monitoring and/or monitoring of additional well sites;
- Annual monitoring for water quality at the RMS, with the potential for monitoring of additional well sites; and
- Compilation and review of publicly available subsidence data.

Collection of Other Required Information

Besides the data on Sustainability Indicators described above, collection and reporting of other types of information is required under SGMA (see further discussion below in **Section 18.5 *Annual Reporting***). These other types of information include:

- Groundwater extraction information; and
- Surface water supply data

Groundwater extraction information will be quantified for inclusion in the Annual Reports through methods described in the Coordination Agreement and Appendices thereto.

Surface water supply data will be based on metered diversions at each of the turnouts off the California Aqueduct. All surface water delivered into the Wheeler Ridge-Maricopa Management Area will have a

source/type (e.g., State Water Project [SWP], Kern River, Central Valley Project [CVP], or other) assigned to it to facilitate basin-wide accounting of these supply sources.[82]

Data Gap Filling

The District will prioritize and begin to fill the key data gaps identified in this MA Plan related to the hydrogeologic conceptual model, groundwater conditions, and water budgets, among other things. Such efforts will include, but not be limited to, validating the status of existing wells, refining the water budget parameters based on additional data and modeling, collecting additional data related to aquifer conditions and properties, and conducting additional data compilation and analysis of groundwater conditions information using sources identified in **Appendix E** and other public datasets as they become available (e.g., California Department of Fish and Wildlife's new "Critical Species Lookbook" dataset[83]).

18.2. Project and Management Action Implementation

A main part of GSP implementation will be the implementation of P/MAs to address and prevent potential Undesirable Results. As described in **Section 17 *Projects and Management Actions***, a portfolio of P/MAs has been developed with the goal of addressing the relevant Sustainability Indicators in the specific areas of concern within the Wheeler Ridge-Maricopa Management Area, and each P/MA in the portfolio has certain expected benefits. **Table PMA-1** provides the required details about each P/MA, including the circumstances under which they will be implemented.

For many of the P/MAs shown in **Table PMA-1**, initial steps in implementation will include performing various studies or analyses to refine the concepts into actionable projects and/or policies[84]. Studies and work efforts may include, but are not limited to, the following:

- White papers exploring policy options;
- California Environmental Quality Act (CEQA) studies and documentation;
- Engineering feasibility studies and preliminary design reports;
- Financial and/or economic analysis such as Proposition 218 studies; and
- Legal analyses.

Once the necessary initial studies are completed, P/MAs will undergo, as necessary, final engineering design (in the case of infrastructure projects) and final drafting (in the case of policy-based actions). At that point, construction of projects and/or adoption of policies will occur, followed by ongoing operations and maintenance (O&M), as necessary. It is anticipated that each implemented P/MA will have its own set of monitoring or data collection components to allow for P/MA assessment and, if necessary, modification.

[82] The District's sole contractual source for imported water supplies is for SWP supplies through the Kern County Water Agency (KCWA). However, the District also obtains water through various exchanges, transfers and sales of water from other sources from time to time.
[83] https://groundwaterresourcehub.org/sgma-tools/the-critical-species-lookbook/
[84] Studies conducted in support of P/MA implementation will be based on the best available data and science.

The District anticipates that within the first five years of GSP implementation (i.e., in the 2020 – 2025 timeframe), the following efforts related to P/MA implementation will be performed:

- Initiate study, permitting (i.e., CEQA), and implementation of on-farm recharge (P/MA #1);
- Initiate program to promote private and/or District-owned banking facilities within the District (P/MA #2);
- Explore options to increase size/participation in out-of-District banking facilities (P/MA #3);
- Initiate feasibility and engineering studies to expand the District's distribution system to areas currently using only private groundwater (P/MA #4);
- Actively participate in the local, regional and state-wide water market(s) to secure additional short- and long-term surface water supplies through exchanges, trades, and sales (P/MA #5);
- Actively participate in the efforts supporting the "Thru-Delta" facility (P/MA #7);
- Initiate re-negotiation of the District's landowner contracts to provide, among other things, greater flexibility to the District in terms of water purchase and delivery (in support of P/MA #4 and others) and revenue to support other P/MAs (P/MA #8);
- Initiate study of potential groundwater allocation and market system (P/MA #9); and/or
- Develop policies to implement voluntary pumping limitations (P/MA #10).

18.3. Intrabasin Coordination

Just as this MA Plan has been developed as part of a coordinated GSP process in the Kern Subbasin, coordination amongst all water management entities involved in SGMA in the Kern Subbasin will continue during GSP implementation. This coordination will include both technical and non-technical matters, as discussed below.

18.3.1. Technical Coordination

Continued technical coordination will be critical to ensure that all entities in the Kern Subbasin as a whole approach local groundwater management using a robust shared framework of data, information, and technical assumptions. WRMWSD will coordinate with other water management entities on technical matters including, but not limited to, the following:

- DMS development and maintenance;
- Groundwater model refinement and updates;
- Water budget refinement and collection of supporting data; and
- Basin-wide monitoring and reporting efforts.

18.3.2. Non-Technical Coordination

Non-technical coordination will involve matters related to policy, advocacy, governance, and the like. The District will continue to actively participate in coordination meetings with and amongst fellow KGA members and the other Kern Subbasin GSAs. The WRMWSD Board has also adopted a resolution to become an exclusive GSA for the Wheeler Ridge-Maricopa Management Area and plans to finalize this in early 2020. This GSA formation effort will be conducted in coordination with all other GSAs in the Kern

Subbasin to ensure continued GSA coverage of the Subbasin. Other non-technical coordination activities will be pursued, as necessary.

18.4. Stakeholder Engagement

The District's Stakeholder Communication and Engagement Plan (SCEP; **Appendix C**) is a key part of the MA Plan, and will continue to be refined, updated and executed during GSP implementation. Anticipated stakeholder engagement activities include, but are not limited to:

- Regular SGMA updates during District Board meetings;
- Hosting stakeholder workshops, as needed;
- Posting of relevant announcements and information on the District website; and
- Conducting informational discussions and meetings, as necessary, with interested stakeholders.

Any GSP implementation actions that relate to establishment of allocations of groundwater pumping or "native yield" on a landowner level will be conducted through a robust stakeholder engagement process.

18.5. Annual Reporting

☑ 23 CCR § 356.2(b)(1)(2)(3)

Per the GSP Emergency Regulations, an annual report on basin conditions and GSP implementation status is required to be submitted to the Department of Water Resources (DWR) by April 1 of each year following GSP adoption. These annual reports will be prepared on the basin-level but will require input from each local entity, including from WRMWSD. Activities required at the District level and the Basin level are described below.

18.5.1. District-Level Activities

In support of the annual reporting requirements, the District will provide to the basin-level entity preparing the reports all monitoring data from the RMS in its designated monitoring networks, as well as the other required information discussed in above. The District will also provide review and comment on the draft reports to ensure that local information is properly incorporated into the basin-level reports.

18.5.2. Basin-Level Activities

An entity will be designated at the basin level to compile and consolidate all of the local information into annual reports that meet the requirements of the GSP Emergency Regulations (23 CCR § 356.2).

18.6. Enforcement and Response Actions

Part of successful management involves the ability to adapt and respond to unforeseen or uncertain circumstances. To the extent possible, methods to address foreseeable problems should be developed before those problems arise. It is anticipated that there may need to be actions taken to enforce compliance with the GSP and any policies adopted thereunder. Such actions, if necessary, will be taken in accordance with applicable laws and authorities.

18.6.1. Impacted Well Mitigation Program

In other cases, a response action may be needed that is driven not by a non-compliance concern (e.g., an Undesirable Result), but rather by a physical, social or economic condition that falls outside of the six Sustainability Indicators defined under SGMA. One such condition that may arise is that of wells being impacted by low groundwater levels. Impacts could include dewatering of pumps or dewatering of well screens to the point of significant reduction in production. To address this potential occurrence, an Impacted Well Mitigation Program will be developed whereby a potential remedy will be provided to owners of wells that are demonstrably impacted by groundwater conditions, as defined within the policy. Funding for such a program may be sourced from the WRMWSD general fund or from a dedicated fund supported by a fee on owners of commercial (i.e., agricultural or industrial) supply wells. The program may be modeled after similar programs developed elsewhere in the basin or around the state (e.g., the Kern Water Bank's program]), and may include remedies such as lowering of pumps, deepening of wells, drilling new wells, and support for access to alternative water sources. The program will be developed in coordination with and in consideration of the interests of local stakeholders within the MA Plan area.

18.7. Periodic Evaluations of GSP

☑ **23 CCR § 356.4**

The District will conduct a periodic evaluation of its MA Plan, at least every five years, and will modify the MA Plan as necessary to ensure that the Sustainability Goal defined for the Kern Subbasin (see **Section 12 *Sustainability Goal***) is achieved within the Wheeler Ridge-Maricopa Management Area. The GSP elements that will be covered in the periodic evaluation are described below. It is anticipated that the 2025 plan will require substantial revision, especially on matters related to the water budget, P/MAs and sustainability criteria.

18.7.1. Sustainability Evaluation

This section will evaluate the current groundwater conditions for each applicable sustainability indicator within the Wheeler Ridge-Maricopa Management Area, including progress toward achieving Interim Milestones and Measurable Objectives.

18.7.2. Plan Implementation Progress

This section will evaluate the current implementation status of P/MAs, along with an updated project implementation schedules and any new projects that are not included in this MA Plan.

18.7.3. Reconsideration of GSP Elements

Per 23 CCR § 356.4 (c), elements of the MA Plan, including the Basin Setting, Management Areas, Undesirable Results, Minimum Thresholds, and Measurable Objective, will be reviewed and revised if necessary.

18.7.4. Monitoring Network Description

This section will provide a description of the Monitoring Network, including identification of data gaps, assessment of monitoring network function with an analysis of data collected to date, identification of actions that are necessary to improve the monitoring network, and development of plans or programs to fill data gaps.

18.7.5. New Information

This section will provide a description of significant new information that has been made available since the adoption or amendment of the MA Plan, or the last five-year assessment, including data obtained to fill identified data gaps. As discussed in **Section 18.7.3 *Reconsideration of GSP Elements***, if evaluation of the Basin Setting, Measurable Objective, Minimum Threshold, or Undesirable Results definition warrant changes to any aspect of the MA Plan, these new information would also be included.

18.7.6. Regulations or Ordinances

WRMWSD possesses the legal authority to implement regulations or ordinances related to the MA Plan. This section will provide a description of relevant actions taken by WRMWSD, including a summary of related regulations or ordinances.

18.7.7. Legal or Enforcement Actions

This section will summarize legal or enforcement actions taken by WRMWSD or the KGA GSA in relation to the MA Plan, along with how such actions support sustainability in the Wheeler Ridge-Maricopa Management Area.

18.7.8. Plan Amendments

This section will provide a description of proposed or complete amendments to the MA Plan.

18.7.9. Coordination

This section will describe coordination activities relevant to the Wheeler Ridge-Maricopa Management Area.

19. PLAN IMPLEMENTATION COSTS

☑ 23 CCR § 354.6(e)

Per the GSP Emergency Regulations (23 CCR § 354.6(e) and 354.44(b)(8)), this section provides estimates of the costs to WRMWSD to implement this MA Plan and potential sources of funding to meet those costs.[85]

19.1. Estimated Costs

Costs to the District to implement this MA Plan can be divided into several groups, as follows:

- Costs of local groundwater management activities;
- District's proportional share of costs for basin-wide groundwater management activities; and
- Costs to implement P/MAs, including capital/one-time costs and ongoing costs.

Table PI-1 provides an estimate of the costs for each of the above groups. Costs to implement P/MAs are shown in **Table PI-1** for each main P/MA category; estimated costs for individual P/MAs are provided in **Table PMA-1**.

19.2. Sources of Funding to Meet Costs

As shown in **Table PI-1**, costs for GSP implementation are estimated to be significant – i.e., ranging from approximately $3.8 million to $7.5 million per year on average over the next 20 years. To meet these costs, the District will need to establish new funding sources or increase existing funding sources. SGMA grants GSAs certain financial authorities (California Water Code [CWC] § 10725.4 and 10730 through 10731), including to raise revenue through use of fees, assessments, pump taxes, and other methods to pay for the costs incurred by the GSA for SGMA compliance. The District will likely meet the estimated costs through a combination of the following:

- District revenue from assessments/fees;
- Special assessments/fees for specific projects;
- Grant funding or other financing options; and/or
- Penalties levied on prohibited activities.

20. PLAN IMPLEMENTATION SCHEDULE

This section discusses a general estimated schedule for GSP implementation. The GSP Emergency Regulations do not specifically require that a schedule for GSP implementation over the 20-year implementation period (i.e., 2020 through 2040) be provided, and any such schedule would be subject to

[85] Implementation of this MA Plan is likely to result in additional costs to landowners and stakeholders within the Wheeler Ridge-Maricopa Management Area; however, this section does not attempt to quantify those potential costs, but rather focuses on the costs, and funding sources to meet those costs, for the District.

considerable uncertainty. However, the following factors and constraints inherent to the GSP process guide the schedule for GSP implementation:

- The GSP Emergency Regulations require achievement of the Sustainability Goal (i.e., avoidance of Undesirable Results) within 20 years of GSP adoption, which in the case of the Kern Subbasin means by 2040.
- The P/MA implementation glide path discussed in **Section 17.1.4 *Implementation Glide Path*** above spells out the general schedule for when expected benefits from P/MAs will accrue between 2020 and 2040.
- Annual reports are due on April 1 of the following year.
- Periodic evaluations are required at least every five years, meaning this MA Plan will be updated no later than 31 January 2025.

REFERENCES AND TECHNICAL STUDIES

☑ 23 CCR § 354.4(b)

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APPENDICES

Appendix A	GSP Submittal Checklist
Appendix B	Parcels Outside of WRMWSD Covered by MA Plan
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Appendix A

GSP Chapter Submittal Checklist

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
§ 354.			**Introduction to Plan Contents**					
			This Article describes the required contents of Plans submitted to the Department for evaluation, including administrative information, a description of the basin setting, sustainable management criteria, description of the monitoring network, and projects and management actions.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
SubArticle 1.			**Administrative Information**					
§ 354.2.			**Introduction to Administrative Information**					
			This Subarticle describes information in the Plan relating to administrative and other general information about the Agency that has adopted the Plan and the area covered by the Plan.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.4.			**General Information**					
			Each Plan shall include the following general information:					
(a)			An executive summary written in plain language that provides an overview of the Plan and description of groundwater conditions in the basin.	15:28	ES			
(b)			A list of references and technical studies relied upon by the Agency in developing the Plan. Each Agency shall provide to the Department electronic copies of reports and other documents and materials cited as references that are not generally available to the public.	250:252	References			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10733.2 and 10733.4, Water Code.					
§ 354.6.			**Agency Information**					
			When submitting an adopted Plan to the Department, the Agency shall include a copy of the information provided pursuant to Water Code Section 10723.8, with any updates, if necessary, along with the following information:					
(a)			The name and mailing address of the Agency.	31	3.1			
(b)			The organization and management structure of the Agency, identifying persons with management authority for implementation of the Plan.	31:32	3.2			
(c)			The name and contact information, including the phone number, mailing address and electronic mail address, of the plan manager.	32	3.3			
(d)			The legal authority of the Agency, with specific reference to citations setting forth the duties, powers, and responsibilities of the Agency, demonstrating that the Agency has the legal authority to implement the Plan.	32	3.4			
(e)			An estimate of the cost of implementing the Plan and a general description of how the Agency plans to meet those costs.	32, 248	3.5, 19			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.8, 10727.2, and 10733.2, Water Code.					
§ 354.8.			**Description of Plan Area**					
			Each Plan shall include a description of the geographic areas covered, including the following information:					
(a)			One or more maps of the basin that depict the following, as applicable:					
	(1)		The area covered by the Plan, delineating areas managed by the Agency as an exclusive Agency and any areas for which the Agency is not an exclusive Agency, and the name and location of any adjacent basins.	35:36, 52	5.1.1	PA-1		
	(2)		Adjudicated areas, other Agencies within the basin, and areas covered by an Alternative.	36, 52:54	5.1.2	PA-1:PA-3		

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(3)		Jurisdictional boundaries of federal or state land (including the identity of the agency with jurisdiction over that land), tribal land, cities, counties, agencies with water management responsibilities, and areas covered by relevant general plans.	36, 53	5.1.3	PA-2		
	(4)		Existing land use designations and the identification of water use sector and water source type.	37, 55, 58	5.1.4	PA-4, PA-7		
	(5)		The density of wells per square mile, by dasymetric or similar mapping techniques, showing the general distribution of agricultural, industrial, and domestic water supply wells in the basin, including de minimis extractors, and the location and extent of communities dependent upon groundwater, utilizing data provided by the Department, as specified in Section 353.2, or the best available information.	37:38, 57	5.1.5	PA-6		
(b)			A written description of the Plan area, including a summary of the jurisdictional areas and other features depicted on the map.	35:38, 56, 272:273	5.1, Appendix B	PA-5		
(c)			Identification of existing water resource monitoring and management programs, and description of any such programs the Agency plans to incorporate in its monitoring network or in development of its Plan. The Agency may coordinate with existing water resource monitoring and management programs to incorporate and adopt that program as part of the Plan.	38:42	5.2.1			
(d)			A description of how existing water resource monitoring or management programs may limit operational flexibility in the basin, and how the Plan has been developed to adapt to those limits.	42	5.2.2			
(e)			A description of conjunctive use programs in the basin.	42	5.2.3			
(f)			A plain language description of the land use elements or topic categories of applicable general plans that includes the following:					
	(1)		A summary of general plans and other land use plans governing the basin.	43:45	5.3			
	(2)		A general description of how implementation of existing land use plans may change water demands within the basin or affect the ability of the Agency to achieve sustainable groundwater management over the planning and implementation horizon, and how the Plan addresses those potential effects	43:45	5.3			
	(3)		A general description of how implementation of the Plan may affect the water supply assumptions of relevant land use plans over the planning and implementation horizon.	43:45	5.3			
	(4)		A summary of the process for permitting new or replacement wells in the basin, including adopted standards in local well ordinances, zoning codes, and policies contained in adopted land use plans.	45	5.3.2			
	(5)		To the extent known, the Agency may include information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management.	N/A				Not applicable - no land use plans outside the basin are anticipated to affect WRMWSD's ability to achieve sustainability
(g)			A description of any of the additional Plan elements included in Water Code Section 10727.4 that the Agency determines to be appropriate.	45:47	5.4			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10720.3, 10727.2, 10727.4, 10733, and 10733.2, Water Code.					
§ 354.10.			**Notice and Communication**					
			Each Plan shall include a summary of information relating to notification and communication by the Agency with other agencies and interested parties including the following:					

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
(a)			A description of the beneficial uses and users of groundwater in the basin, including the land uses and property interests potentially affected by the use of groundwater in the basin, the types of parties representing those interests, and the nature of consultation with those parties.	47, 275:306	5.5.1, Appendix C			
(b)			A list of public meetings at which the Plan was discussed or considered by the Agency.	47:48, 275:306	5.5.2, Appendix C			
(c)			Comments regarding the Plan received by the Agency and a summary of any responses by the Agency.	48:49, 308:334	5.5.3, Appendix D		PA-1	
(d)			A communication section of the Plan that includes the following:					
	(1)		An explanation of the Agency's decision-making process.	49:50, 275:306	5.5.4, Appendix C			
	(2)		Identification of opportunities for public engagement and a discussion of how public input and response will be used.	49:50, 275:306	5.5.4, Appendix C			
	(3)		A description of how the Agency encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin.	49:50, 275:306	5.5.4, Appendix C			
	(4)		The method the Agency shall follow to inform the public about progress implementing the Plan, including the status of projects and actions.	49:50, 275:306	5.5.4, Appendix C			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.8, 10728.4, and 10733.2, Water Code					
SubArticle 2.			**Basin Setting**					
§ 354.12.			**Introduction to Basin Setting**					
			This Subarticle describes the information about the physical setting and characteristics of the basin and current conditions of the basin that shall be part of each Plan, including the identification of data gaps and levels of uncertainty, which comprise the basin setting that serves as the basis for defining and assessing reasonable sustainable management criteria and projects and management actions. Information provided pursuant to this Subarticle shall be prepared by or under the direction of a professional geologist or professional engineer.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.14.			**Hydrogeologic Conceptual Model**					
(a)			Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.	60:96	7	HCM-1:HCM-11	HCM-1:HCM-2	
(b)			The hydrogeologic conceptual model shall be summarized in a written description that includes the following:					
	(1)		The regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.	60:61	7.1.1			
	(2)		Lateral basin boundaries, including major geologic features that significantly affect groundwater flow.	61	7.1.2			
	(3)		The definable bottom of the basin.	61:64	7.1.3			
	(4)		Principal aquifers and aquitards, including the following information:					
		(A)	Formation names, if defined.	64:69	7.1.4			
		(B)	Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.	64:69	7.1.4			

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
		(C)	Structural properties of the basin that restrict groundwater flow within the principal aquifers, including information regarding stratigraphic changes, truncation of units, or other features.	64:69	7.1.4			
		(D)	General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.	64:69	7.1.4			
		(E)	Identification of the primary use or uses of each aquifer, such as domestic, irrigation, or municipal water supply.	64:69	7.1.4			
	(5)		Identification of data gaps and uncertainty within the hydrogeologic conceptual model	69	7.1.5			
(c)			The hydrogeologic conceptual model shall be represented graphically by at least two scaled cross-sections that display the information required by this section and are sufficient to depict major stratigraphic and structural features in the basin.	69:71 , 86:90	7.2	HCM-12:HCM-14		
(d)			Physical characteristics of the basin shall be represented on one or more maps that depict the following:					
	(1)		Topographic information derived from the U.S. Geological Survey or another reliable source.	71, 91	7.3.1	HCM-15		
	(2)		Surficial geology derived from a qualified map including the locations of cross-sections required by this Section.	71:72, 86	7.3.2	HCM-12		
	(3)		Soil characteristics as described by the appropriate Natural Resources Conservation Service soil survey or other applicable studies.	72, 92:93	7.3.3	HCM-16:HCM-17		
	(4)		Delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.	72:73, 94:95	7.3.4	HCM-18:HCM-19		
	(5)		Surface water bodies that are significant to the management of the basin.	73:74, 96	7.3.5	HCM-20		
	(6)		The source and point of delivery for imported water supplies.	56, 74, 115	7.3.6	PA-5, GWC-3		
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10727.2, 10733, and 10733.2, Water Code.					
§ 354.16.			**Groundwater Conditions**					
			Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:					
(a)			Groundwater elevation data demonstrating flow directions, lateral and vertical gradients, and regional pumping patterns, including:					
	(1)		Groundwater elevation contour maps depicting the groundwater table or potentiometric surface associated with the current seasonal high and seasonal low for each principal aquifer within the basin.	99:103, 113:114, 116	8.2	GWC-1:GWC-2, GWC-4	GWC-1	
	(2)		Hydrographs depicting long-term groundwater elevations, historical highs and lows, and hydraulic gradients between principal aquifers.	99:103, 117:120	8.2	GWC-5:GWC-8		
(b)			A graph depicting estimates of the change in groundwater in storage, based on data, demonstrating the annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions, including the annual groundwater use and water year type.	103:105, 121:122	8.3	GWC-9:GWC-10	GWC-2	
(c)			Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.	105	8.4			

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
(d)			Groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes.	105:109, 123:127, 336:374, 376:385	8.5, Appendix E, Appendix F	GWC-11:GWC-15	GWC-3	
(e)			The extent, cumulative total, and annual rate of land subsidence, including maps depicting total subsidence, utilizing data available from the Department, as specified in Section 353.2, or the best available information.	110:111, 128:129	8.6	GWC-16:GWC-17		
(f)			Identification of interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems, utilizing data available from the Department, as specified in Section 353.2, or the best available information.	111	8.7			
(g)			Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or the best available information.	111:112, 130	8.8	GWC-18		
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.2, 10727.4, and 10733.2, Water Code.					
§ 354.18.			**Water Budget**					
(a)			Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form.	131:176, 387:482	9, Appendix G			
(b)			The water budget shall quantify the following, either through direct measurements or estimates based on data:					
	(1)		Total surface water entering and leaving a basin by water source type.	137:139, 151, 160:161	9.2.1	WB-3:WB-4	WB-2	
	(2)		Inflow to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.	139, 152, 162:163	9.2.2	WB-5:WB-6	WB-3	
	(3)		Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow.	139, 152, 162:163	9.2.2	WB-5:WB-6	WB-3	
	(4)		The change in the annual volume of groundwater in storage between seasonal high conditions.	139:140, 153:155, 164:165	9.2.3	WB-7:WB-8	WB-4:WB-6	
	(5)		If overdraft conditions occur, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.	140:141, 153:155	9.2.4		WB-4:WB-6	
	(6)		The water year type associated with the annual supply, demand, and change in groundwater stored.	141:142, 154, 166:167	9.2.5	WB-9:WB-10	WB-5	
	(7)		An estimate of sustainable yield for the basin.	142:143	9.2.6			
(c)			Each Plan shall quantify the current, historical, and projected water budget for the basin as follows:					
	(1)		Current water budget information shall quantify current inflows and outflows for the basin using the most recent hydrology, water supply, water demand, and land use information.	144, 152, 155, 169:170	9.3.1	WB-12:WB-13	WB-3, WB-6	

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(2)		Historical water budget information shall be used to evaluate availability or reliability of past surface water supply deliveries and aquifer response to water supply and demand trends relative to water year type. The historical water budget shall include the following:					
		(A)	A quantitative evaluation of the availability or reliability of historical surface water supply deliveries as a function of the historical planned versus actual annual surface water deliveries, by surface water source and water year type, and based on the most recent ten years of surface water supply information.	133, 144:146, 171, 175	9.3.2	WB-14, WB-18	WB-1	
		(B)	A quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the tools and methods used to estimate and project future water budget information and future aquifer response to proposed sustainable groundwater management practices over the planning and implementation horizon.	144:146, 168, 172:175	9.3.2	WB-11, WB-15:WB-18		
		(C)	A description of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability of the Agency to operate the basin within sustainable yield. Basin hydrology may be characterized and evaluated using water year type.	144:146, 154, 166:167	9.3.2	WB-9:WB-10	WB-5	
	(3)		Projected water budgets shall be used to estimate future baseline conditions of supply, demand, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components. The projected water budget shall utilize the following methodologies and assumptions to estimate future baseline conditions concerning hydrology, water demand and surface water supply availability or reliability over the planning and implementation horizon:					
		(A)	Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology. The projected hydrology information shall also be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.	140:150, 156:157, 176	9.4	WB-19	WB-7:WB-8	
		(B)	Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand. The projected water demand information shall also be applied as the baseline condition used to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate.	140:150, 156:157, 176	9.4	WB-19	WB-7:WB-8	
		(C)	Projected surface water supply shall utilize the most recent water supply information as the baseline condition for estimating future surface water supply. The projected surface water supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply identified in Section 354.18(c)(2)(A), and the projected changes in local land use planning, population growth, and climate.	140:150, 156:157, 175	9.4	WB-18	WB-7:WB-8	
(d)			The Agency shall utilize the following information provided, as available, by the Department pursuant to Section 353.2, or other data of comparable quality, to develop the water budget:					
	(1)		Historical water budget information for mean annual temperature, mean annual precipitation, water year type, and land use.	135:136	9.1.2			

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(2)		Current water budget information for temperature, water year type, evapotranspiration, and land use.	135:136	9.1.2			
	(3)		Projected water budget information for population, population growth, climate change, and sea level rise.	135:136, 147:149	9.1.2, 9.4.2			
(e)			Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, climate change, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow. If a numerical groundwater and surface water model is not used to quantify and evaluate the projected water budget conditions and the potential impacts to beneficial uses and users of groundwater, the Plan shall identify and describe an equally effective method, tool, or analytical model to evaluate projected water budget conditions.	134:136	9.1			
(f)			The Department shall provide the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) and the Integrated Water Flow Model (IWFM) for use by Agencies in developing the water budget. Each Agency may choose to use a different groundwater and surface water model, pursuant to Section 352.4.	131	9			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10721, 10723.2, 10727.2, 10727.6, 10729, and 10733.2, Water Code.					
§ 354.20.			**Management Areas**					
(a)			Each Agency may define one or more management areas within a basin if the Agency has determined that creation of management areas will facilitate implementation of the Plan. Management areas may define different minimum thresholds and be operated to different measurable objectives than the basin at large, provided that undesirable results are defined consistently throughout the basin.	177	10			
(b)			A basin that includes one or more management areas shall describe the following in the Plan:					
	(1)		The reason for the creation of each management area.	177	10.1			
	(2)		The minimum thresholds and measurable objectives established for each management area, and an explanation of the rationale for selecting those values, if different from the basin at large.	177	10.2			
	(3)		The level of monitoring and analysis appropriate for each management area.	177	10.3			
	(4)		An explanation of how the management area can operate under different minimum thresholds and measurable objectives without causing undesirable results outside the management area, if applicable.	177	10.2			
(c)			If a Plan includes one or more management areas, the Plan shall include descriptions, maps, and other information required by this Subarticle sufficient to describe conditions in those areas.	177	10.1			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10733.2 and 10733.4, Water Code.					
SubArticle 3.			**Sustainable Management Criteria**					
§ 354.22.			**Introduction to Sustainable Management Criteria**					
			This Subarticle describes criteria by which an Agency defines conditions in its Plan that constitute sustainable groundwater management for the basin, including the process by which the Agency shall characterize undesirable results, and establish minimum thresholds and measurable objectives for each applicable sustainability indicator.					

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.24.			**Sustainability Goal**					
			Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline. The Plan shall include a description of the sustainability goal, including information from the basin setting used to establish the sustainability goal, a discussion of the measures that will be implemented to ensure that the basin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved within 20 years of Plan implementation and is likely to be maintained through the planning and implementation horizon.	30, 179	2, 12			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10721, 10727, 10727.2, 10733.2, and 10733.8, Water Code.					
§ 354.26.			**Undesirable Results**					
(a)			Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.	180:188, 205:206, 208:209	13	SMC-1:SMC-2, SMC-4:SMC-5	SMC-1	
(b)			The description of undesirable results shall include the following:					
	(1)		The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.	180:188	13			
	(2)		The criteria used to define when and where the effects of the groundwater conditions cause undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.	180:188	13			
	(3)		Potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results.	180:188	13			
(c)			The Agency may need to evaluate multiple minimum thresholds to determine whether an undesirable result is occurring in the basin. The determination that undesirable results are occurring may depend upon measurements from multiple monitoring sites, rather than a single monitoring site.	180:188	13			
(d)			An Agency that is able to demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin shall not be required to establish criteria for undesirable results related to those sustainability indicators.	180:188	13			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10721, 10723.2, 10727.2, 10733.2, and 10733.8, Water Code.					
§ 354.28.			**Minimum Thresholds**					
(a)			Each Agency in its Plan shall establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site established pursuant to Section 354.36. The numeric value used to define minimum thresholds shall represent a point in the basin that, if exceeded, may cause undesirable results as described in Section 354.26.	189:198, 189:190, 203:204, 207	14	SMC-3	SMC-2:SMC-4	
(b)			The description of minimum thresholds shall include the following:					

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(1)		The information and criteria relied upon to establish and justify the minimum thresholds for each sustainability indicator. The justification for the minimum threshold shall be supported by information provided in the basin setting, and other data or models as appropriate, and qualified by uncertainty in the understanding of the basin setting.	189:198	14			
	(2)		The relationship between the minimum thresholds for each sustainability indicator, including an explanation of how the Agency has determined that basin conditions at each minimum threshold will avoid undesirable results for each of the sustainability indicators.	189:198	14			
	(3)		How minimum thresholds have been selected to avoid causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals.	189:198	14			
	(4)		How minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests.	189:198	14			
	(5)		How state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the Agency shall explain the nature of and basis for the difference.	189:198	14			
	(6)		How each minimum threshold will be quantitatively measured, consistent with the monitoring network requirements described in Subarticle 4.	189:198	14			
(c)			Minimum thresholds for each sustainability indicator shall be defined as follows:					
	(1)		Chronic Lowering of Groundwater Levels. The minimum threshold for chronic lowering of groundwater levels shall be the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results. Minimum thresholds for chronic lowering of groundwater levels shall be supported by the following:					
		(A)	The rate of groundwater elevation decline based on historical trends, water year type, and projected water use in the basin.	190:194, 206	14.1	SMC-2		
		(B)	Potential effects on other sustainability indicators.	190:194	14.1			
	(2)		Reduction of Groundwater Storage. The minimum threshold for reduction of groundwater storage shall be a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results. Minimum thresholds for reduction of groundwater storage shall be supported by the sustainable yield of the basin, calculated based on historical trends, water year type, and projected water use in the basin.	194:195	14.2			
	(3)		Seawater Intrusion. The minimum threshold for seawater intrusion shall be defined by a chloride concentration isocontour for each principal aquifer where seawater intrusion may lead to undesirable results. Minimum thresholds for seawater intrusion shall be supported by the following:					
		(A)	Maps and cross-sections of the chloride concentration isocontour that defines the minimum threshold and measurable objective for each principal aquifer.	196	14.3			
		(B)	A description of how the seawater intrusion minimum threshold considers the effects of current and projected sea levels.	196	14.3			

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(4)		Degraded Water Quality. The minimum threshold for degraded water quality shall be the degradation of water quality, including the migration of contaminant plumes that impair water supplies or other indicator of water quality as determined by the Agency that may lead to undesirable results. The minimum threshold shall be based on the number of supply wells, a volume of water, or a location of an isocontour that exceeds concentrations of constituents determined by the Agency to be of concern for the basin. In setting minimum thresholds for degraded water quality, the Agency shall consider local, state, and federal water quality standards applicable to the basin.	196	14.4			
	(5)		Land Subsidence. The minimum threshold for land subsidence shall be the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results. Minimum thresholds for land subsidence shall be supported by the following:					
		(A)	Identification of land uses and property interests that have been affected or are likely to be affected by land subsidence in the basin, including an explanation of how the Agency has determined and considered those uses and interests, and the Agency's rationale for establishing minimum thresholds in light of those effects.	197	14.5			
		(B)	Maps and graphs showing the extent and rate of land subsidence in the basin that defines the minimum threshold and measurable objectives.	197, 208, 489:517	14.5	Appendix I	SMC-4, Appendix I	
	(6)		Depletions of Interconnected Surface Water. The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results. The minimum threshold established for depletions of interconnected surface water shall be supported by the following:					
		(A)	The location, quantity, and timing of depletions of interconnected surface water.	198	14.6			
		(B)	A description of the groundwater and surface water model used to quantify surface water depletion. If a numerical groundwater and surface water model is not used to quantify surface water depletion, the Plan shall identify and describe an equally effective method, tool, or analytical model to accomplish the requirements of this Paragraph.	198	14.6			
(d)			An Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence.	194:196	14.2.1			
(e)			An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators.	196, 198	14.3,14.6			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.2, 10733, 10733.2, and 10733.8, Water Code.					
§ 354.30.			**Measurable Objectives**					
(a)			Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.	199:200, 202:204, 210:211	15	SMC-6:SMC-7	SMC-3:SMC-6	

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
(b)			Measurable objectives shall be established for each sustainability indicator, based on quantitative values using the same metrics and monitoring sites as are used to define the minimum thresholds.	199	15			
(c)			Measurable objectives shall provide a reasonable margin of operational flexibility under adverse conditions which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty.	199	15			
(d)			An Agency may establish a representative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence.	200	15.2			
(e)			Each Plan shall describe a reasonable path to achieve the sustainability goal for the basin within 20 years of Plan implementation, including a description of interim milestones for each relevant sustainability indicator, using the same metric as the measurable objective, in increments of five years. The description shall explain how the Plan is likely to maintain sustainable groundwater management over the planning and implementation horizon.	199	15			
(f)			Each Plan may include measurable objectives and interim milestones for additional Plan elements described in Water Code Section 10727.4 where the Agency determines such measures are appropriate for sustainable groundwater management in the basin.	N/A				Not applicable - no additional Plan elements were incorporated into Sustainability Criteria.
(g)			An Agency may establish measurable objectives that exceed the reasonable margin of operational flexibility for the purpose of improving overall conditions in the basin, but failure to achieve those objectives shall not be grounds for a finding of inadequacy of the Plan.	N/A				Not applicable - all measurable objectives tied to reasonable margin of operational flexibility.
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10727.2, 10727.4, and 10733.2, Water Code.					
SubArticle 4.			**Monitoring Networks**					
§ 354.32.			**Introduction to Monitoring Networks**					
			This Subarticle describes the monitoring network that shall be developed for each basin, including monitoring objectives, monitoring protocols, and data reporting requirements. The monitoring network shall promote the collection of data of sufficient quality, frequency, and distribution to characterize groundwater and related surface water conditions in the basin and evaluate changing conditions that occur through implementation of the Plan.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.34.			**Monitoring Network**					
(a)			Each Agency shall develop a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation.	212:219, 222, 224:225	16.1	MN-1:MN-2	MN-1:MN-2	
(b)			Each Plan shall include a description of the monitoring network objectives for the basin, including an explanation of how the network will be developed and implemented to monitor groundwater and related surface conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial density to evaluate the affects and effectiveness of Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:					

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(1)		Demonstrate progress toward achieving measurable objectives described in the Plan.	212:219	16.1			
	(2)		Monitor impacts to the beneficial uses or users of groundwater.	212:219	16.1			
	(3)		Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds.	212:219	16.1			
	(4)		Quantify annual changes in water budget components.	212:219	16.1			
(c)			Each monitoring network shall be designed to accomplish the following for each sustainability indicator:					
	(1)		Chronic Lowering of Groundwater Levels. Demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features by the following methods:					
		(A)	A sufficient density of monitoring wells to collect representative measurements through depth-discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer.	214, 224:225	16.1.1	MN-1	MN-1:MN-2	
		(B)	Static groundwater elevation measurements shall be collected at least two times per year, to represent seasonal low and seasonal high groundwater conditions.	214	16.1.1			
	(2)		Reduction of Groundwater Storage. Provide an estimate of the change in annual groundwater in storage.	216, 224:225	16.1.2	MN-1	MN-1:MN-2	
	(3)		Seawater Intrusion. Monitor seawater intrusion using chloride concentrations, or other measurements convertible to chloride concentrations, so that the current and projected rate and extent of seawater intrusion for each applicable principal aquifer may be calculated.	217	16.1.3			
	(4)		Degraded Water Quality. Collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues.	217, 222, 224:225	16.1.4	MN-2	MN-1:MN-2	
	(5)		Land Subsidence. Identify the rate and extent of land subsidence, which may be measured by extensometers, surveying, remote sensing technology, or other appropriate method.	214, 219, 489:517	16.1.5		MN-1, SMC-4, Appendix I	
	(6)		Depletions of Interconnected Surface Water. Monitor surface water and groundwater, where interconnected surface water conditions exist, to characterize the spatial and temporal exchanges between surface water and groundwater, and to calibrate and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. The monitoring network shall be able to characterize the following:					
		(A)	Flow conditions including surface water discharge, surface water head, and baseflow contribution.	219	16.1.6			
		(B)	Identifying the approximate date and location where ephemeral or intermittent flowing streams and rivers cease to flow, if applicable.	219	16.1.6			
		(C)	Temporal change in conditions due to variations in stream discharge and regional groundwater extraction.	219	16.1.6			
		(D)	Other factors that may be necessary to identify adverse impacts on beneficial uses of the surface water.	219	16.1.6			
(d)			The monitoring network shall be designed to ensure adequate coverage of sustainability indicators. If management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the basin setting and sustainable management criteria specific to that area.	212:219, 222, 224:225	16.1	MN-1:MN-2	MN-1:MN-2, SMC-3:SMC-4	

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
(e)			A Plan may utilize site information and monitoring data from existing sources as part of the monitoring network.	212:219, 222, 224:225	16.1	MN-1:MN-2	MN-2	
(f)			The Agency shall determine the density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends based upon the following factors:					
	(1)		Amount of current and projected groundwater use.	212:219	16.1			
	(2)		Aquifer characteristics, including confined or unconfined aquifer conditions, or other physical characteristics that affect groundwater flow.	212:219	16.1			
	(3)		Impacts to beneficial uses and users of groundwater and land uses and property interests affected by groundwater production, and adjacent basins that could affect the ability of that basin to meet the sustainability goal.	212:219	16.1			
	(4)		Whether the Agency has adequate long-term existing monitoring results or other technical information to demonstrate an understanding of aquifer response.	212:219	16.1			
(g)			Each Plan shall describe the following information about the monitoring network:					
	(1)		Scientific rationale for the monitoring site selection process.	212:219, 222	16.1		MN-1:MN-2	
	(2)		Consistency with data and reporting standards described in Section 352.4. If a site is not consistent with those standards, the Plan shall explain the necessity of the site to the monitoring network, and how any variation from the standards will not affect the usefulness of the results obtained.	212:219, 222	16.1		MN-2	
	(3)		For each sustainability indicator, the quantitative values for the minimum threshold, measurable objective, and interim milestones that will be measured at each monitoring site or representative monitoring sites established pursuant to Section 354.36.	200, 202:204, 207, 210:211, 222:223	16.1	SMC-3, SMC-6, SMC-7	SMC-3:SMC-6	
(h)			The location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used.	212:219, 222, 224:225	16.1	MN-1:MN-2	MN-2	
(i)			The monitoring protocols developed by each Agency shall include a description of technical standards, data collection methods, and other procedures or protocols pursuant to Water Code Section 10727.2(f) for monitoring sites or other data collection facilities to ensure that the monitoring network utilizes comparable data and methodologies.	220	16.2			
(j)			An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish a monitoring network related to those sustainability indicators.	217, 219	16.1.3, 16.1.6			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.2, 10727.4, 10728, 10733, 10733.2, and 10733.8, Water Code					
§ 354.36.			**Representative Monitoring**					
			Each Agency may designate a subset of monitoring sites as representative of conditions in the basin or an area of the basin, as follows:					
(a)			Representative monitoring sites may be designated by the Agency as the point at which sustainability indicators are monitored, and for which quantitative values for minimum thresholds, measurable objectives, and interim milestones are defined.	220	16.3			

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
(b)			(b) Groundwater elevations may be used as a proxy for monitoring other sustainability indicators if the Agency demonstrates the following:					
	(1)		Significant correlation exists between groundwater elevations and the sustainability indicators for which groundwater elevation measurements serve as a proxy.	220	16.3			
	(2)		Measurable objectives established for groundwater elevation shall include a reasonable margin of operational flexibility taking into consideration the basin setting to avoid undesirable results for the sustainability indicators for which groundwater elevation measurements serve as a proxy.	220	16.3			
(c)			The designation of a representative monitoring site shall be supported by adequate evidence demonstrating that the site reflects general conditions in the area.	220	16.3			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10727.2 and 10733.2, Water Code					
§ 354.38.			**Assessment and Improvement of Monitoring Network**					
(a)			Each Agency shall review the monitoring network and include an evaluation in the Plan and each five-year assessment, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin.	220	16.4			
(b)			Each Agency shall identify data gaps wherever the basin does not contain a sufficient number of monitoring sites, does not monitor sites at a sufficient frequency, or utilizes monitoring sites that are unreliable, including those that do not satisfy minimum standards of the monitoring network adopted by the Agency.	212:219	16.1			
(c)			If the monitoring network contains data gaps, the Plan shall include a description of the following:					
	(1)		The location and reason for data gaps in the monitoring network.	212:219	16.1			
	(2)		Local issues and circumstances that limit or prevent monitoring.	212:219	16.1			
(d)			Each Agency shall describe steps that will be taken to fill data gaps before the next five-year assessment, including the location and purpose of newly added or installed monitoring sites.	212:219	16.1			
(e)			Each Agency shall adjust the monitoring frequency and density of monitoring sites to provide an adequate level of detail about site-specific surface water and groundwater conditions and to assess the effectiveness of management actions under circumstances that include the following:					
	(1)		Minimum threshold exceedances.	212:219	16.1			
	(2)		Highly variable spatial or temporal conditions.	212:219	16.1			
	(3)		Adverse impacts to beneficial uses and users of groundwater.	212:219	16.1			
	(4)		The potential to adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of sustainability goals in an adjacent basin.	212:219	16.1			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10723.2, 10727.2, 10728.2, 10733, 10733.2, and 10733.8, Water Code					
§ 354.40.			**Reporting Monitoring Data to the Department**					
			Monitoring data shall be stored in the data management system developed pursuant to Section 352.6. A copy of the monitoring data shall be included in the Annual Report and submitted electronically on forms provided by the Department.					
			Note: Authority cited: Section 10733.2, Water Code.					

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
			Reference: Sections 10728, 10728.2, 10733.2, and 10733.8, Water Code.					
SubArticle 5.			**Projects and Management Actions**					
§ 354.42.			**Introduction to Projects and Management Actions**					
			This Subarticle describes the criteria for projects and management actions to be included in a Plan to meet the sustainability goal for the basin in a manner that can be maintained over the planning and implementation horizon.					
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Section 10733.2, Water Code.					
§ 354.44.			**Projects and Management Actions**					
(a)			Each Plan shall include a description of the projects and management actions the Agency has determined will achieve the sustainability goal for the basin, including projects and management actions to respond to changing conditions in the basin.	226:240	17	PMA-1	PMA-1	
(b)			Each Plan shall include a description of the projects and management actions that include the following:					
	(1)		A list of projects and management actions proposed in the Plan with a description of the measurable objective that is expected to benefit from the project or management action. The list shall include projects and management actions that may be utilized to meet interim milestones, the exceedance of minimum thresholds, or where undesirable results have occurred or are imminent. The Plan shall include the following:					
		(A)	A description of the circumstances under which projects or management actions shall be implemented, the criteria that would trigger implementation and termination of projects or management actions, and the process by which the Agency shall determine that conditions requiring the implementation of particular projects or management actions have occurred.	230	17.3			
		(B)	The process by which the Agency shall provide notice to the public and other agencies that the implementation of projects or management actions is being considered or has been implemented, including a description of the actions to be taken.	231	17.4			
	(2)		If overdraft conditions are identified through the analysis required by Section 354.18, the Plan shall describe projects or management actions, including a quantification of demand reduction or other methods, for the mitigation of overdraft.	231	17.5			
	(3)		A summary of the permitting and regulatory process required for each project and management action.	232	17.6			
	(4)		The status of each project and management action, including a time-table for expected initiation and completion, and the accrual of expected benefits.	232	17.7			
	(5)		An explanation of the benefits that are expected to be realized from the project or management action, and how those benefits will be evaluated.	233	17.8			
	(6)		An explanation of how the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.	234	17.9			
	(7)		A description of the legal authority required for each project and management action, and the basis for that authority within the Agency.	234	17.10			
	(8)		A description of the estimated cost for each project and management action and a description of how the Agency plans to meet those costs.	234	17.11			

Article 5.			Plan Contents for Kern County Basin	GSP Document References				
				Page Numbers of Plan	Or Section Numbers	Or Figure Numbers	Or Table Numbers	Notes
	(9)		A description of the management of groundwater extractions and recharge to ensure that chronic lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater levels or storage during other periods.	235	17.12			
(c)			Projects and management actions shall be supported by best available information and best available science.	226:240	17			
(d)			An Agency shall take into account the level of uncertainty associated with the basin setting when developing projects or management actions.	226:240	17			
			Note: Authority cited: Section 10733.2, Water Code.					
			Reference: Sections 10727.2, 10727.4, and 10733.2, Water Code.					

Appendix B

Parcels Outside of WRMWSD Covered by GSP

Table B-1

Parcels Outside of Wheeler Ridge-Maricopa Management Area Covered by GSP

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

Property Owner Name	APN	Acreage	Land Use	Well Information
Sun Pacific	239-102-130	241.42	Unirrigated	No wells, per DWR well completion report database
Sun Pacific	239-102-189	160.9	Unirrigated	No wells, per DWR well completion report database
Maricopa Orchards	239-150-11	640	Unirrigated	No wells, per DWR well completion report database

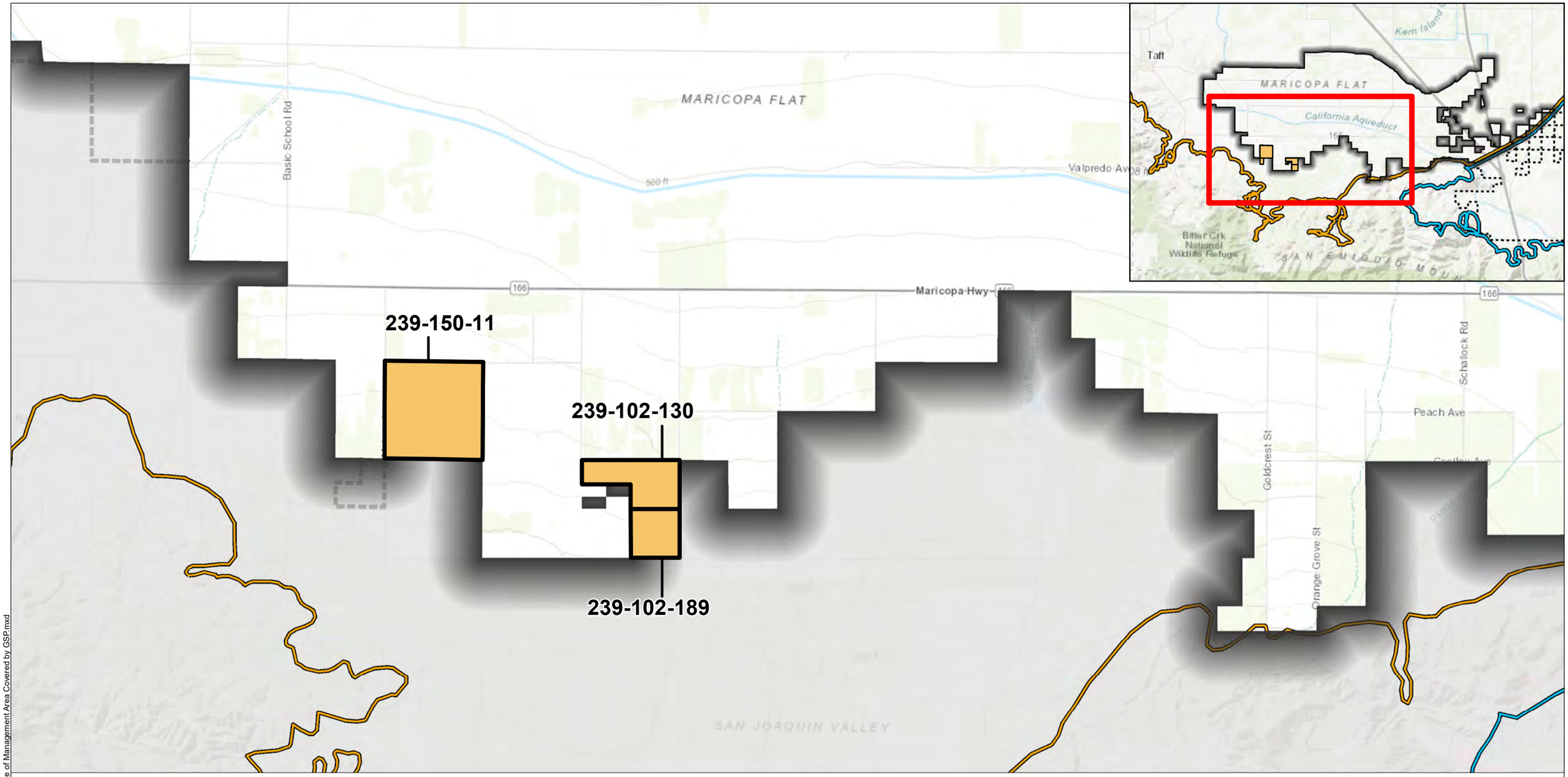
TOTAL
1042.32

Abbreviations:

APN = Assessor's Parcel Number

DWR = California Department of Water Resources

GSP = Groundwater Sustainability Plan



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Parcels Outside of Management Area Covered by GSP (label shows APN)

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Abbreviations

APN	= Assessor's Parcel Number
DWR	= California Department of Water Resources
GSP	= Groundwater Sustainability Plan
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 December 2019.
2. Parcel boundaries are from Kern County Assessor, obtained in June 2018.
3. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
4. WRMWSD Management Area boundary was received by WRMWSD staff on 3 July 2018 and excludes overlap area with West Kern Water District Groundwater Sustainability Agency.

N

0 1 2

(Scale in Miles)

Parcels Outside of Wheeler Ridge-Maricopa Management Area Covered by GSP

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure B-1

eki environment & water

Path: X:\B70103\Mapsfor_GSP\2019\08\FigB-1_Parcels_Outside_of_Management_Area_Covered_by_GSP.mxd

Appendix C

Summary of Stakeholder Communications and Engagement

Stakeholder Communication and Engagement Plan

Wheeler Ridge-Maricopa Management Area of the Kern County Subbasin

FINAL

August 8 2018

Prepared by eki environment & water

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Glossary / Abbreviations

ACSD	Arvin Community Services District
AEWSD	Arvin-Edison Water Storage District
CASGEM	California Statewide Groundwater Elevation Monitoring
CC	Coordination Committee
CCR	California Code of Regulations
CWC	California Water Code
CWD	Cawelo Water District
C&E	Communications and Engagement
DAC	Disadvantaged Communities
DWR	California Department of Water Resources
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	Hydrogeologic Conceptual Model
JPA	Joint Powers Agreement
KCWA	Kern County Water Agency
KGA	Kern Groundwater Authority
KTWD	Kern-Tulare Water District
KWBA	Kern Water Bank Authority
NKWSD	North Kern Water Storage District
RRBWSD	Rosedale-Rio Bravo Water Storage District
SCEP	Stakeholder Communication and Engagement Plan
SGMA	Sustainable Groundwater Management Act
SSJMUD	Southern San Joaquin Municipal Utility District
SWID	Shafter-Wasco Irrigation District
SWSD	Semitropic Water Storage District
TCWD	Tejon-Castac Water District
WDWA	Westside District Water Authority
WKWD	West Kern Water District
WRMWSD	Wheeler Ridge-Maricopa Water Storage District

1. INTRODUCTION

> *§ 354.10. Each Plan shall include a summary of information relating to notification and communication by the Agency with other agencies and interested parties including the following:*
> *(a) A description of the beneficial uses and users of groundwater in the basin, including the land uses and property interests potentially affected by the use of groundwater in the basin, the types of parties representing those interests, and the nature of consultation with those parties.*
> *(b) A list of public meetings at which the Plan was discussed or considered by the Agency.*
> *(c) Comments regarding the Plan received by the Agency and a summary of any responses by the Agency.*
> *(d) A communication section of the Plan that includes the following:*
> *(1) An explanation of the Agency's decision-making process.*
> *(2) Identification of opportunities for public engagement and a discussion of how public input and response will be used.*
> *(3) A description of how the Agency encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin.*
> *(4) The method the Agency shall follow to inform the public about progress implementing the Plan, including the status of projects and actions.*

The Wheeler Ridge-Maricopa Water Storage District (WRMWSD or District) has developed this Stakeholder Communication and Engagement Plan (SCEP) to describe its approach to communication and engagement throughout the Groundwater Sustainability Plan (GSP) Chapter development process. This SCEP was prepared in accordance with California Water Code (CWC), the GSP Regulations (Title 23 of the California Code of Regulations [CCR] §354.10 [see above]), and the California Department of Water Resources (DWR) *Guidance Document for Groundwater Sustainability Plan Stakeholder Communication and Engagement* (DWR, 2018), as well as additional reference documents recommended by DWR for guidance.

Communication and engagement efforts carried out as described in this SCEP will help to ensure that local beneficial uses and users of groundwater are adequately considered in the GSP Chapter development process as required by GSP Regulations (23-CCR §354.10). Specifically, in this SCEP:

- **Section 2** describes the District and Groundwater Sustainability Agency (GSA) decision-making process (23-CCR §354.10(d)(1));
- **Section 3** identifies stakeholders;
- **Section 4** describes how the District intends to build upon its current understanding of stakeholders in the Management Area (23-CCR §354.10(d)(3) and CWC §10723.4);
- **Section 5** describes the key messages for communication and engagement efforts, and anticipated questions as well as possible responses (23-CCR §354.10(d)(4));
- **Section 6** identifies opportunities for public engagement and how public input an response will be used (23-CCR §354.10(d)(2));

- **Section 7** describes the Communications and Engagement (C&E) implementation timeline, including when this SCEP will be updated to inform the public about GSP Chapter implementation progress, including the status of projects and actions (23 CCR §354.10(d)(4));
- **Section 8** describes SCEP assessment and evaluation during the GSP Chapter development process.

2. OBJECTIVES AND DECISION-MAKING

This SCEP is designed to effectively engage a variety of relevant stakeholders in the development of a GSP Chapter that will guide the District, in coordination with the Kern Groundwater Authority (KGA) GSA, to demonstrate sustainability by 31 January 2040 and maintain sustainability through the Sustainable Groundwater Management Act (SGMA)'s 50-year planning timeline.

2.1. GSA and Management Area Description and Boundary

The WRMWSD is a public agency whose jurisdiction encompasses about 147,000 acres of land in Kern County, California, at the southern end of the San Joaquin Valley. The WRMWSD is one of the member agencies of the KGA GSA. The KGA GSA overlies a portion of the Kern County Subbasin (Basin; DWR 5-022.18) of the San Joaquin Valley Basin.

The Wheeler Ridge-Maricopa Management Area (Management Area) comprises approximately 91,000 acres of the KGA GSA, as shown in Figure 1. The remainder of the WRMWSD service area is located outside of the Management Area and within the White Wolf Subbasin. The Basin is a high priority basin that has been designated as being in critical groundwater overdraft condition and has a GSP submission deadline of 31 January 2020.

2.2. WRMWSD Structure and Decision-Making Process

Key GSP Chapter development and implementation decisions are made by the WRMWSD Board of Directors (District Board). The WRMWSD staff help to guide the GSP Chapter development technical consultant team and provide feedback on draft work products.

2.2.1. WRMWSD Board Structure and Meetings

The District is governed by an elected nine-member Board of Directors. District Board meetings are held on the second Wednesday of the month (unless otherwise noticed) and are open to the public. District Board meeting agendas and packets are posted to the WRMWSD website (https://wrmwsd.com) at least 72 hours before each Board meeting.

An ad-hoc committee of the District Board has been formed that will support more detailed engagement with the GSP Chapter development process. The ad-hoc committee will meet on an as-needed basis.

2.2.2. KGA Board Structure and Meetings

Per the Joint Powers Agreement (JPA) executed on 22 March 2017, the KGA GSA Board is composed of one representative from each of the general member agencies (Arvin Community Services District [ACSD], Arvin-Edison Water Storage District [AEWSD], Cawelo Water District [CWD], Kern County Water Agency [KCWA], Kern-Tulare Water District [KTWD], Kern Water Bank Authority [KWBA], North Kern Water Storage District [NKWSD], Rosedale-Rio Bravo Water Storage District [RRBWSD], Semitropic Water Storage District [SWSD], Shafter-Wasco Irrigation District [SWID], Southern San Joaquin Municipal Utility District [SSJMUD], Tejon-Castac Water District [TCWD], West Kern Water District [WKWD], Westside District Water Authority [WDWA], and WRMWSD plus one representative from the County as well as the City of Shafter).

The KGA GSA Board meetings are held on the fourth Wednesday of every month and are open to the public. The KGA GSA Board meeting agendas and packets are posted to the KGA website (www.kerngwa.com\board-of-directors.html).

The KGA GSA Board is supported by a Coordination Committee (CC) that is composed of one to two (1-2) representatives from each voting party of the KGA GSA and encompasses residential, agricultural, environmental, rural, domestic well, and municipal interests[1]. The specific role of the KGA's CC is to make recommendations to the KGA GSA Board regarding technical and other matters (e.g., stakeholder outreach) related to GSP development.

The CC meetings are held the first Monday of each month, and they are open to the public. Meeting agendas and packets are posted to the KGA website (www.kerngwa.com/committees.html).

2.3. Desired Outcome

The WRMWSD aims to develop a GSP Chapter that sets its Management Area on a path to maintain sustainability through SGMA's 50-year planning timeline.

[1] Kern Groundwater Authority Communication & Engagement Plan (http://www.kerngwa.com/assets/kga-communication---engagement-plan---may-2018.pdf)

2.4. Communication Objectives to Support the GSP Chapter

The WRMWSD SCEP efforts aim to support development of a GSP Chapter that meets the needs of beneficial uses and users of groundwater in the Management Area and reflects and incorporates stakeholder input as appropriate. The WRMWSD aims to be knowledgeable about and anticipate stakeholder interests and concerns.

2.5. Challenges for the Plan Area

The WRMWSD is aware of and plans to address the following challenges:

- Several large landowners in the District overlie both the Basin and the White Wolf Subbasin (White Wolf Basin; DWR 5-022.18). The WRMWSD will need to coordinate with entities and landowners in the White Wolf Basin to ensure that communication and engagement efforts conducted by the District and the KGA GSA align with communication and engagement efforts in the White Wolf Basin. Should substantially different groundwater management decisions be made in each basin, WRMWSD will communicate with stakeholders near and straddling the basin boundary to help them understand how GSP implementation in each basin will impact them.

- Irrigated agriculture is the primary land use in the District. It is anticipated that there will be concerns regarding how SGMA compliance could impact that land and water use. The District will be open and transparent in decisions that will have a substantial impact on beneficial users of groundwater, and will engage stakeholders early in the decision-making process to consider their interests and concerns.

3. STAKEHOLDER IDENTIFICATION

The KGA GSA identified current beneficial uses and users of groundwater in the Basin in its formation Notice submitted on 30 May 2017 in accordance with the interests listed in CWC §10723.2. The following are the identified beneficial uses and users of groundwater within the Management Area. Representatives of specific organizations on this list form the basis of the District's list of interested parties, as required by CWC §10723.2.

3.1. Holders of overlying groundwater rights

3.1.1. Agricultural Users

The primary land use in the Management Area is irrigated agriculture. The WRMWSD provides water service to agricultural water users within its service area.

3.1.2. Domestic Well Owners

There are several known domestic wells scattered throughout the Management Area, but the full extent and distribution of active domestic wells within the Management Area is currently unknown.

3.2. Municipal Well Operators

There are currently no identified municipal well operators within the Management Area.

3.3. Public Water Systems

The WRMWSD provides untreated water for irrigation and industrial purposes. However, there are some small public water systems that provide treated groundwater for domestic uses[2], including:

1. Andrews Ag – Non-community water system that serves a residential population of two (2) and a transient population of 50.
2. Opal Fry and Son – Community water system that serves a residential population of 40.
3. Wheeler Farms Headquarters – Non-Transient Non-Community water system that serves a non-transient population of 25.

While publicly available data have been examined to identify Public Water Systems in the Management Area[3], WRMWSD acknowledges that these datasets are known to be incomplete.

3.4. Local Land Use Planning Agencies

The Management Area is comprised of unincorporated County land, for which the Kern County Planning and Community Development is responsible for land use planning. The County will be involved in the

[2] The State Water Resources Control Board Safe Drinking Water Information System (https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystems.jsp?PointOfContactType=none&number=&name=&county=Kern).

[3] Including the California Environmental Health Tracking Program Water System Map Viewer (http://www.cehtp.org/page/water/water_system_map_viewer).

development and implementation of the KGA GSP (which includes the District's GSP Chapter) through its participation in the KGA GSA.

3.5. Environmental Users of Groundwater

There is minimal interaction between groundwater and surface water in the Management Area, except in the area of known perched groundwater along the northern boundary. While this perched groundwater appears to support localized wetlands areas, as mapped by DWR[4], this system is disconnected from and not part of the principal aquifer. In most of the Management Area, the groundwater table is encountered more than 200 feet below ground surface and thus there is no groundwater contribution to streamflow or other surface water features.

Wind Wolves Preserve is a nature preserve that is adjacent to the Management Area.

3.6. Surface Water Users

Surface water features in the Basin include ephemeral streams draining the San Emigdio Mountains, several small lakes and ponds, the California Aqueduct, and a network of irrigation canals and ditches.

The US Bureau of Land Management holds appropriative water rights, Wildlands Conservancy holds diversion water rights, and CalMat Co. holds both appropriative and diversion water rights on San Emigdio Creek[5]. There are also several entities with diversion rights from springs near the boundary of the Basin. These include inactive rights held by Dole Dried Fruit & Nut Company and active federal claims held by USDA – Los Padres National Forest.

3.7. The Federal Government

Two parcels located south of the Rim Ditch within the Management Area, Southeast ¼ of Section 20 and South ½ of Section 22 within Township 32 South, Range 26 East, are identified as federal lands owned by the US Bureau of Land Management.

3.8. California Native American Tribes

There are no identified California Native American tribal lands within the Management Area.

3.9. Disadvantaged Communities

There were no Disadvantaged Community Places identified within the Management Area (U.S. Census, 2015). A portion of US Census Tracts 33.04, 33.06, and 62.02, which overlie almost the entire Management Area, was identified as a Disadvantaged Community Census Tract based on an average household income less than 80% of the State median (U.S. Census, 2015). Census Tract 33.06 includes a Severely Disadvantaged Community Census Block Group (Block Group 1 of Census Tract 33.05) in the southern portion of the Management Area.

[4] DWR NC Dataset Viewer (https://gis.water.ca.gov/app/NCDatasetViewer/).
[5] According to the SWRCB Electronic Water Rights Information Management System (eWRIMS), accessed 26 July 2018.

As described in the KGA GSA Community & Engagement Plan to engage residents of disadvantage communities/areas, the KGA GSA is coordinating with Self-Help Enterprises (SHE) to identify convenient times and locations for public outreach meetings and to distribute meeting notices.

3.10. Groundwater Monitoring Entities

The WRMWSD submitted a notice to become a monitoring entity for its service area under the California Statewide Groundwater Elevation Monitoring (CASGEM) Program in 2011. The current status for this application process is under review and pending development of the CASGEM monitoring network. However, AEWSD is a Monitoring Entity in the Basin and overlaps with the Management Area. AEWSD is a member of the KGA GSA and will be involved in coordinating GSP Chapter development

Additionally, Kern River Fan Group (comprised of Kern Delta Water District, Henry Miller Water District, and Buena Vista Water Storage District) is a Monitoring Entity just north of the Management Area. Henry Miller Water District and Buena Vista Water Storage District have formed their own GSAs, and Kern Delta Water District is part of the Kern River GSA. Monitoring coordination will be included in a coordination agreement as required by the GSP Regulations (23-CCR §357.4).

4. STAKEHOLDER SURVEY AND MAPPING

The WRMWSD intends to update its list of stakeholders based on new information as appropriate. To learn more about its stakeholders, WRMWSD has coordinated with the KGA GSA to distribute a stakeholder survey (Appendix A) by:

- Posting the survey on WRMWSD website (https://wrmwsd.com/);
- Having copies of the survey available at WRMWSD Board meetings and stakeholder workshops;
- Sending the survey in water bill mailings or special mailings; and
- Coordinating with the community organizations (e.g., Kern County Farmers Bureau, Self-Help Enterprises, etc.) to distribute the survey to diverse members of the population that may not be otherwise be reached.

Based on current knowledge of stakeholders, WRMWSD has completed a "Lay of the Land" exercise in **Table 1**, identifying specific stakeholder organizations/individuals, stakeholder type, key interests and issues, the sections of the GSP Chapter likely to be relevant to this stakeholder, and the level of engagement (e.g., inform, consult, involve) expected with each stakeholder organization/individual.

Given that WRMWSD will gain more knowledge of the interests, issues, and challenges of stakeholders over the course of GSP Chapter development, **Table 1** will be updated as part of GSP Chapter development. Should WRMWSD need to learn more about specific stakeholders, individual meetings will be arranged to find out more about their issues, interests, and challenges.

In addition to the more detailed stakeholder survey, WRMWSD intends to maintain a simple form or an e-mail request link on its webpage for individuals to enroll in WRMWSD interested parties list and provide their contact information.

5. MESSAGES

The WRMWSD aims to convey consistent high-level messaging to stakeholders throughout GSP Chapter development and implementation. The following are the key messages that will form the foundation for communication and engagement efforts:

1. WRMWSD aims to engage with diverse stakeholders to best represent their interests in the GSP Chapter development process;
2. Key GSP Chapter development decisions will be made in an open and transparent fashion during public District Board meetings; and
3. Technical GSP Chapter development progress will be communicated in an accessible manner to support stakeholder understanding and input.

Additionally, the GSA has developed **Table 2** to document anticipated questions as well as possible responses. **Table 2** will be updated, as needed, to add additional, frequently received questions as well as to build upon responses based on GSP Chapter development progress.

Table 2 Likely Questions and Responses

Likely Questions	Responses
How can I participate in the GSP Chapter development and implementation process?	District Board meetings are open to the public and held at 8:30 AM on the second Wednesday of the month unless otherwise noticed in the District Headquarters, 12109 Highway166, Bakersfield CA 93313. Stakeholder workshops will be held throughout the GSP Chapter development process, and will be publicized on WRMWSD website (https://wrmwsd.com/).
Will I have to fallow my land?	We are currently in the initial phases of GSP Chapter development. Projects and management actions to achieve sustainability will be discussed later in the process, with opportunity for stakeholder input.
What types of management actions or projects are going to occur in my area?	We are currently in the initial phases of GSP Chapter development. Projects and management actions to achieve sustainability will be discussed later in the process, with opportunity for stakeholder input.
Are pump meters going to be required? Who will pay for meters?	We are currently in the initial phases of GSP Chapter development. Projects and management actions to achieve sustainability will be discussed later in the process, with opportunity for stakeholder input.
Who is paying for GSP Chapter development and implementation?	Agencies in the Basin have obtained state funding to support specific efforts related to GSP development (https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Sustainable-Groundwater). The WRMWSD will pay for GSP Chapter development and will contribute to the development of a GSP Umbrella by the KGA GSA. The actual cost to the landowner has yet to be determined.

6. VENUES FOR ENGAGING

The WRMWSD intends to provide a variety of opportunities for engagement with stakeholders. Stakeholder input received will inform and be incorporated into corresponding sections of the GSP Chapter as appropriate.

6.1. District Board Meetings

As described in Section 2.2.1, District Board meetings are open to the public and are a consistent venue for public engagement.

The WRMWSD understands that Basin-wide public outreach meetings will direct residents to the member agency in whose management area they reside, and welcomes residents within its Management Area, including the overlying DAC areas, to attend its public board meetings.

6.2. Stakeholder Workshops

Stakeholder workshops will be held to communicate progress on GSP technical components to stakeholders and to receive input on upcoming decisions and work efforts. At least two stakeholder workshops and one public hearing will be held during GSP Chapter development:

- **Stakeholder Workshop #1** – held 24 May 2018 – SGMA Overview, draft results of Basin Setting Information, Preliminary Undesirable Results, and Key Policy Decisions
- **Stakeholder Workshop #2** – to be held in Winter 2018/2019 – Draft Sustainable Management Criteria and Discussion of Projects and Management Actions.
- **Public Hearing** – Review of the draft GSP Chapter.

The WRMWSD will publicize all stakeholder workshops on its website (https://wrmwsd.com/) and to its list of interested parties and will coordinate with community organizations (e.g., Kern County Farmers Bureau, Self-Help Enterprises, etc.) to send out emails and mailings as appropriate.

The KGA GSA is holding a series of stakeholder workshops focused on Basin-wide GSP development. The WRMWSD will coordinate with the KGA GSA as appropriate about their respective stakeholder workshops.

Additional stakeholder workshops may be held during GSP Chapter implementation. The timing and content of these stakeholder workshops will be determined when the GSP Implementation Plan is developed shortly before GSP Chapter submission.

6.3. Website Communication

The WRMWSD will update its website with WRMWSD Board meeting materials as described in Section 2.2.1, and will additionally update the website with key GSP Chapter updates.

6.4. Stakeholder Surveys

The WRMWSD intends to learn about stakeholder interests using surveys that will be distributed as discussed in Section 4. This stakeholder survey is included as Appendix A.

7. IMPLEMENTATION TIMELINE

The GSA's C&E implementation timeline aligns with a four phase GSP Chapter development timeline, as described in **Table 3** below.

Table 3 GSP Development and C&E Efforts by Phase

Phase	Timeframe	Overall GSP Efforts (led by technical consultant team)	C&E Efforts (led by the WRMWSD staff)
GSP Foundation	May 2018 – September 2018	• Select and design a Data Management System (DMS) • Conduct data gaps assessment • Evaluate numerical groundwater model options	• Develop SCEP • Distribute Stakeholder Survey • Update Stakeholder Constituency Table
Basin Characterization and Analysis	May 2018 – October 2018	• Implement plan for filling data gaps • Develop Hydrogeologic Conceptual Model (HCM) and definition of groundwater conditions • Develop water budget • Assess existing monitoring programs	• Conduct Stakeholder Workshop #1 • Update Stakeholder Constituency Table
Sustainability Planning	August 2018 – December 2018	• Evaluate potential management areas • Develop sustainable management criteria • Identify projects and management actions • Create GSP implementation plan • Finalize monitoring network and protocols	• Conduct Stakeholder Workshop #2 • Update Stakeholder Constituency Table • Update SCEP to reflect plan for C&E efforts during GSP Implementation
GSP Preparation and Submittal	December 2018 – January 2020	• Compile complete draft GSP • Revise draft GSP (if necessary) per stakeholder feedback • Finalize GSP and submit to DWR	• Distribute draft GSP • Hold Public Hearing on draft GSP • Assess C&E progress and plan for C&E related to GSP Implementation • Update Stakeholder Constituency Table

The WRMWSD will update this SCEP while creating a GSP Chapter implementation plan. This update will focus on informing the public about GSP implementation progress, including the status of projects and actions (23-CCR §354.10(d)(4)).

8. EVALUATION AND ASSESSMENT

The WRMWSD intends to assess its SCEP during GSP Chapter development, as shown in **Table 3**. The WRMWSD staff will present brief summaries of SCEP implementation progress at District Board meetings and will lead a discussion about lessons learned and what can be improved as part of GSP implementation. The following questions will guide SCEP evaluation:

- What worked well?
    - What allowed us insight into stakeholder concerns?
    - What types of materials best communicated GSP development to stakeholders?
- What didn't work as planned?
    - Could materials (e.g., presentation slides, website pages) have been improved to better communicate GSP development progress?
    - Are certain stakeholder groups less represented in the GSP development process than they should be?
- What do we plan on doing differently during the next phase based on what we have learned?
- How much of our communication and engagement budget have we spent relative to work completed? Do we have enough remaining budget to complete our SCEP?

REFERENCES AND TECHNICAL STUDIES

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SDWIS. Safe Drinking Water Information System. Water System Details for Wheeler Farms Headquarters, accessed 14 May 2018. https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=1417&tinwsys_st_code=CA&wsnumber=CA1502017.

U.S. Census, 2015. US Census American Community Survey, 2010-2014.

Table 1
Stakeholder Constituency – "Lay of the Land" Exercise

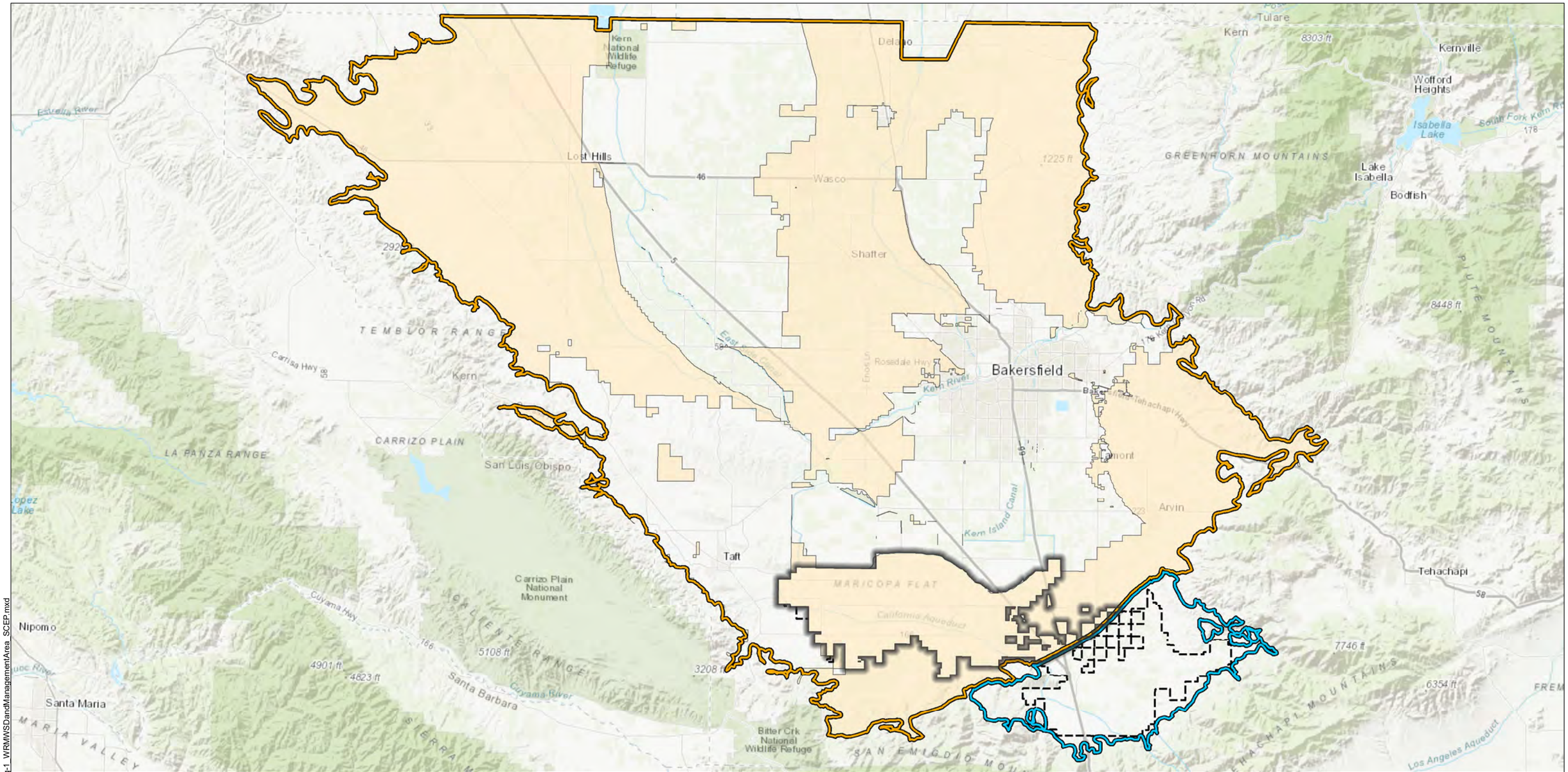
Organization/ Individual	Type of Stakeholder (a)	Anticipated Key Interests	Anticipated Key Issues (b)	Relevant GSP Sections	Level of Engagement and Rationale (c)
Agricultural Water Users	Agricultural Users	Preserving access to high quality groundwater for irrigation	• Potential curtailment of pumping • GSP development and implementation costs	• Sustainable Management Criteria • Projects and Management Actions	Collaborate to ensure sustainable management of groundwater
Domestic Well Users	Domestic Well Owners	Preserving access to high quality groundwater for domestic users	• Water quality degradation • Declining water levels • Potential curtailment of pumping • GSP development and implementation costs	• Sustainable Management Criteria • Projects and Management Actions	Inform and involve to avoid negative impact to these users
Kern County Planning and Community Development	Local Land Use Planning Agency	Managing County-wide land use	*Need to identify*	• Plan Area • Projects and Management Actions	Consult and involve to ensure land use policies are supporting GSPs
Active oil field operators	Industrial Users	Continue to operate oil fields	• Definition of vertical extent of the groundwater basin based on salinity	• Basin Setting • Sustainable Management Criteria • Projects and Management Actions	Inform and involve to avoid negative impact to these users
Andrews Ag	Public Water System	*Need to identify*	*Need to identify*	*Need to identify*	*Need to identify*
Opal Fry and Son	Public Water System	*Need to identify*	*Need to identify*	*Need to identify*	*Need to identify*
Wheeler Farms Headquarter	Public Water System	*Need to identify*	*Need to identify*	*Need to identify*	*Need to identify*
Arvin-Edison Water Storage District	Agricultural Users, Groundwater Monitoring Entity	Preserve access to high quality groundwater for irrigation	• Potential curtailment of pumping • GSP development and implementation costs • Operation of recharge basins	• Basin Setting • Sustainable Management Criteria • Projects and Management Actions	Collaborate to ensure sustainable management of groundwater
Wheeler Ridge-Maricopa Water Storage District	Agricultural Users, Groundwater Monitoring Entity	Preserve access to high quality groundwater for irrigation	• Potential curtailment of pumping • GSP development and implementation costs	• Basin Setting • Sustainable Management Criteria • Projects and Management Actions	Collaborate to ensure sustainable management of groundwater

Table 1
Stakeholder Constituency – "Lay of the Land" Exercise

Organization/ Individual	Type of Stakeholder (a)	Anticipated Key Interests	Anticipated Key Issues (b)	Relevant GSP Sections	Level of Engagement and Rationale (c)
Wind Wolves Preserve	Environmental Users	Preserve ecosystem	• Analyzing potential groundwater dependence of ecosystems	• Basin Setting • Sustainable Management Criteria • Projects and Management Actions	Inform and involve to sustain ecosystem
The US Bureau of Land Management	Surface Water Users	*Need to identify*	*Need to identify*	*Need to identify*	*Need to identify*
CalMat Co.	Surface Water Users	*Need to identify*	*Need to identify*	*Need to identify*	*Need to identify*
Wildlands Conservancy	Surface Water Users	*Need to identify*	*Need to identify*	*Need to identify*	*Need to identify*
U.S. Bureau of Land Management	The Federal Government	*Need to identify*	*Need to identify*	*Need to identify*	*Need to identify*

Abbreviations:
CWC = California Water Code
DWR = California Department of Water Resources
GSA = Groundwater Sustainability Agency
GSP = Groundwater Sustainability Plan
SGMA = Sustainable Groundwater Management Act

Notes:
(a) Type of stakeholder based on CWC §10723.2 (e.g., agricultural groundwater users, municipal well operators, etc.).
(b) Any documented issues (media coverage, statements, reports, etc.), specific issues such as past events, or issues that have been otherwise communicated to or are anticipated by the GSA.
(c) Level of engagement based on the International Association of Public Participation Spectrum of Public Participation, as referenced in DWR's Guidance Document for Groundwater Sustainability Plan Stakeholder Communication and Engagement (DWR, 2018).



Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- KGA GSA

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Abbreviations

DWR = California Department of Water Resources
KGA GSA = Kern Groundwater Authority Groundwater Sustainability Agency
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 9 August 2018.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
3. WRMWSD Management Area boundary was received by WRMWSD staff on 3 July 2018 and excludes overlap area with West Kern Water District Groundwater Sustainability Agency.
4. KGA GSA boundary was extracted from the SGMA portal on12 October 2017.

N

0 8 16

(Scale in Miles)

WRMWSD Management Area and KGA GSA

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
August 2018
B70103.01

Figure 1

Path: \\ekiconsult.com\go\Gis\B70103\Maps\for_GSP\20180810\Fig-1 WRMWSDandManagementArea_SCEP.mxd

APPENDIX A – STAKEHOLDER SURVEY

Stakeholder Survey

KERN GROUNDWATER AUTHORITY

Date: _____

Stakeholder Type (check all that apply):

☐	Agricultural User	☐	Domestic Well Owner/User	☐	Municipal Well Operator
☐	Public Water Systems	☐	Local Land Use Planning Agency	☐	Environmental User
☐	Surface Water User	☐	Native American Tribe	☐	Disadvantaged/Rural Community Resident
☐	City Resident	☐	Food Processor	☐	Industrial User/Oil Producer
☐	Entity monitoring and reporting groundwater elevations in all or part of the groundwater basin				

Note: Please complete your name and contact information if you'd like to be added to the GSA's email and mailing list for future updates and information regarding Sustainable Groundwater Management Act (SGMA) and the Kern Groundwater Authority.

Name: _____

Address: _____

City: _____ State: _____ Zip: _____

Email: _____ Telephone: _____

1. Are you familiar with Sustainable Groundwater Management Act (SGMA) regulations? ☐ Yes ☐ No

2. Are you currently working on or discussing groundwater management in this region? ☐ Yes ☐ No

3. Do you own or manage/operate land in this region? ☐ Yes ☐ No

4. Where are you getting your water supply?
   ☐ City or Community Water System ☐ Surface ☐ Groundwater
   ☐ Both Groundwater & Surface Water ☐ Unknown

5. Agriculture & Domestic Well Users: What is your well(s) depth? _____

6. Agriculture & Domestic Well Users: Has your well(s) ever gone dry? ☐ Yes ☐ No
   If yes, when (month/year)? _____

7. If you are an Agricultural User, do you: ☐ Irrigate ☐ Dry Farm ☐ Graze Livestock
   ☐ Other: _____

8. How reliable is your current groundwater supply? _____

   _____

   _____

9. If you grow crops, do you use irrigation for frost protection? ☐ Yes ☐ No

10. Do you manage water resources? ☐ Yes ☐ No
    If yes, what is your role? _____

11. What is your primary interest in land or water resources management? _____

12. Do you have concerns about groundwater management? ☐ Yes ☐ No

If so, what are they? _____

13. Do you have requests or recommendations regarding groundwater management? ☐ Yes ☐ No

If so, what are they? _____

14. Any other information the Kern Groundwater Authority should be aware of or take into consideration while developing the Groundwater Sustainability Plan (GSP)?

Please return completed surveys to the Kern Groundwater Authority by emailing tbarton@ppeng.com, faxing to (661) 479-7172, or mail to Kern Groundwater Authority 93301.

Stakeholder Surveys may also be completed online by visiting www.kerngwa.com.

KERN GROUNDWATER AUTHORITY

Encuesta de Partes Interesadas

Fecha: _____

Tipo de Interesado (marque todas que apliquen):

☐	Usuario agrícola	☐	Propietario / usuario de pozo doméstico	☐	Operador municipal de pozos
☐	Sistema de agua público	☐	Agencia local de planificación del uso de la tierra	☐	Usuario ambiental
☐	Usuario de agua superficial	☐	Tribu native americana	☐	Residente de comunidad desventajada/ rural
☐	Residente de la ciudad	☐	Procesador de alimentos	☐	Usuario industrial/Productor de petróleo
☐	Entidad que monitorea y reporta elevaciones de aguas subterráneas en toda o parte de la cuenca de agua subterránea				

Nota: Por favor complete su nombre y la información de contacto si desea ser agregado a la lista de correo electrónico de la GSA y lista de correo para futuras actualizaciones e información sobre la Ley del Manejo Sostenible del Agua Subterránea (SGMA) y la Autoridad de Aguas Subterráneas de Kern (KGA GSA).

Nombre: _____

Dirección Postal: _____

Ciudad: _____ Estado: _____ Código postal: _____

Correo Electrónico: _____ Teléfono: _____

1. ¿Está usted familiarizado con las regulaciones de la ley de Manejo Sostenible del Agua Subterránea (SGMA)? ☐ Sí ☐ No

2. ¿Está usted actualmente involucrado en actividades o discusiones Sobre el manejo de aguas subterráneas en esta regíon? ☐ Sí ☐ No

3. ¿Usted es propietario o administra/opera tierra en esta región? ☐ Sí ☐ No

4. ¿De dónde recibe su suministro de agua?
   ☐ Sistema de agua de la ciudad o la comunidad ☐ Superficie ☐ Agua subterránea
   ☐ Agua subterránea y superficial ☐ No sé

5. Usuarios de pozos Agrícolas Y Domésticos: ¿Cuál es la profundidad de su pozo(s)? _____

6. Usuarios de poza Agrícolas Y Doméesticos: ¿Alguna vez se ha secado su pozo(s)? ☐ Sí ☐ No
   ¿Si la respuesta es sí, cuándo (mes/año)? _____

7. Si eres un usuario agrícola, qual haces: ☐ Irrigar ☐ Granja seca ☐ Pastoreo
   ☐ Otro: _____

8. ¿Qué tan seguro es su suministro de agua subterránea, corrientemente ?_____

   _____

   _____

9. Si cultiva, ¿utiliza el riego para la protección contra las heladas? ☐ Sí ☐ No

10. ¿Usted administra recursos de agua? ☐ Sí ☐ No
    Si la respuesta es sí, ¿cuál es su papel? _____

11. ¿Cuál es su interés principal en el manejo de recursos de agua o tierra? _____

12. ¿Tiene preocupaciones acerca el manejo de las aguas subterráneas? ☐ Sí ☐ No

Si la respuesta es sí, ¿cuáles son? _____

13. ¿Tiene used alguna recomendación sobre el manejo de agua subterráneas? ☐ Sí ☐ No

Si la respuesta es sí, ¿cuáles son? _____

14. ¿Tiene used alguna otra información pertinente que debería tener en cuenta el Kern Groundwater Authority GSA para desarroler el Plan de Sostenibilidad de Aguas Subterránease (GSP)?

Por favor regrese la encuesta terminada al Kern Groundwater Authority GSA enviando un corre electrónico a tbarton@ppeng.com , manduando un fax al (661) 478-7172, o por correo a Kern Groundwater Authority GSA, 1800 30th Street, Suite 280, Bakersfield, CA 93301.

Esta Encuesta de Partes Interesadas también se puede completer visitando la página www.kerngwa.com.

Meetings at which WRMWSD SGMA/GSP Topics Were Discussed

WRMWSD Board Meetings

- 14 February 2018
- 24 May 2018
- 12 September 2018
- 14 November 2018
- 11 March 2019
- 10 April 2019
- 14 May 2019
- 10 July 2019

GSP Stakeholder Workshops

- 12 June 2019

Basin-wide Stakeholder Open House

- 14 May 2019

KERN
GROUNDWATER AUTHORITY

May 31, 2019

Landowner

Re: Sustainable Groundwater Management Act Compliance and Coverage

Dear Landowner,

The Sustainable Groundwater Management Act (SGMA) went into effect on January 1, 2015 and requires the formation of Groundwater Sustainability Agencies (GSA) to sustainably manage all groundwater basins in California including the Kern Sub-Basin. SGMA authorizes public agencies with land use or water management authority to become a GSA and manage groundwater. If no agency or group of agencies elects to be a GSA for the entire basin, SGMA designates the county as the default GSA to manage groundwater sustainably for the unmanaged lands in the basin. If the county declines to act as the GSA, SGMA requires the unmanaged lands report groundwater pumping directly to the State Water Resources Control Board and pay applicable fees.

The Kern Groundwater Authority (KGA) was formed on April 26, 2017 by several public agencies, which included the County of Kern, through a joint power agreement (JPA). Pursuant to the JPA and SGMA requirements, each member district of the KGA is responsible for the management of the groundwater within its respective jurisdiction and the County was responsible for managing groundwater in the areas not otherwise included in the jurisdiction of a member district ("undistricted lands").

On December 11, 2018, Kern County Board of Supervisors voted to withdraw from the KGA and stated that it would no longer manage groundwater in the undistricted lands of the Kern Sub-Basin. The County sent a notice of withdrawal to the KGA dated December 12, 2018. However, the County did not provide written notice to the affected landowners regarding its withdrawal from the KGA or of its decision to not provide SGMA coverage to those landowners not within the jurisdiction of a member district.

In response to the County's withdrawal, the KGA and its members have been working diligently to provide a means for those undistricted lands to have SGMA coverage. Accordingly, the KGA and its member districts are allowing landowners in these areas the opportunity to sign up to be managed by neighboring KGA member districts. Landowners who do not sign up with KGA member districts will be removed from the KGA GSA boundary and will be designated as unmanaged by the State Water Board.

You are receiving this letter because your property, or a portion thereof, has been identified as unmanaged land due to the County's action to withdraw from the KGA and by its decision to no longer provide SGMA management. This letter provides you notice that the opportunity to obtain coverage through the KGA will be closed on July 1, 2019. If you would like to avoid being designated as unmanaged by the State Water Board (see attachment 1 [State Water Board unmanaged notice]), please contact the KGA member closest to your property (see attachment 2 [Kern Basin Map]) and execute the necessary management documents by July 1, 2019. If you have questions regarding this notice, please contact Patty Poire at 661-479-7171.

Respectfully,
Kern Groundwater Authority

1800 30th Street, Suite 280, Bakersfield, CA 93301 • Tel: (661) 616-5900 • Fax: (661) 616-5890 • www.kerngwa.com

State Water Resources Control Board

DATE

Mailing ID #: «Mailing_ID»

«OWNER_FIRST» «OWNER_LAST»
«CO» «CARE_OF»
«ADDRESS» «UNIT» «UNIT_NUMBER»
«CITY», «STATE» «ZIP»«Dash»«ZIP4»

NOTICE OF GROUNDWATER EXTRACTION REPORTING UNDER THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT (SGMA).

AVISO DE ENVIAR REPORTE(S) SOBRE EXTRACCIÓN DE AGUA SUBTERRÁNEA REQUERIDO POR LA LEY DE GESTIÓN SUSTENTABLE DEL AGUA SUBTERRÁNEA (SGMA)

This letter requires your immediate attention. This letter provides notice that you may be required to file one or more groundwater extraction reports with the State Water Resources Control Board (Board) pursuant to the Sustainable Groundwater Management Act (SGMA). Failure to file a required report may result in penalties of up to $500 per day.

Para obtener más información en español (formularios u otra información), nos puede llamar al (916) 322-6508 o enviar un mensaje a: groundwater_management@waterboards.ca.gov.

Why you are receiving this notice

This Notice is being sent to persons who may own property or operate a public water supply system in an unmanaged area where groundwater was extracted on or after DATE through DATE. An unmanaged area is an area within a high- or medium-priority groundwater basin that is outside the jurisdiction of any groundwater sustainability agency (GSA) and not subject to an alternative or other exemption from SGMA requirements.

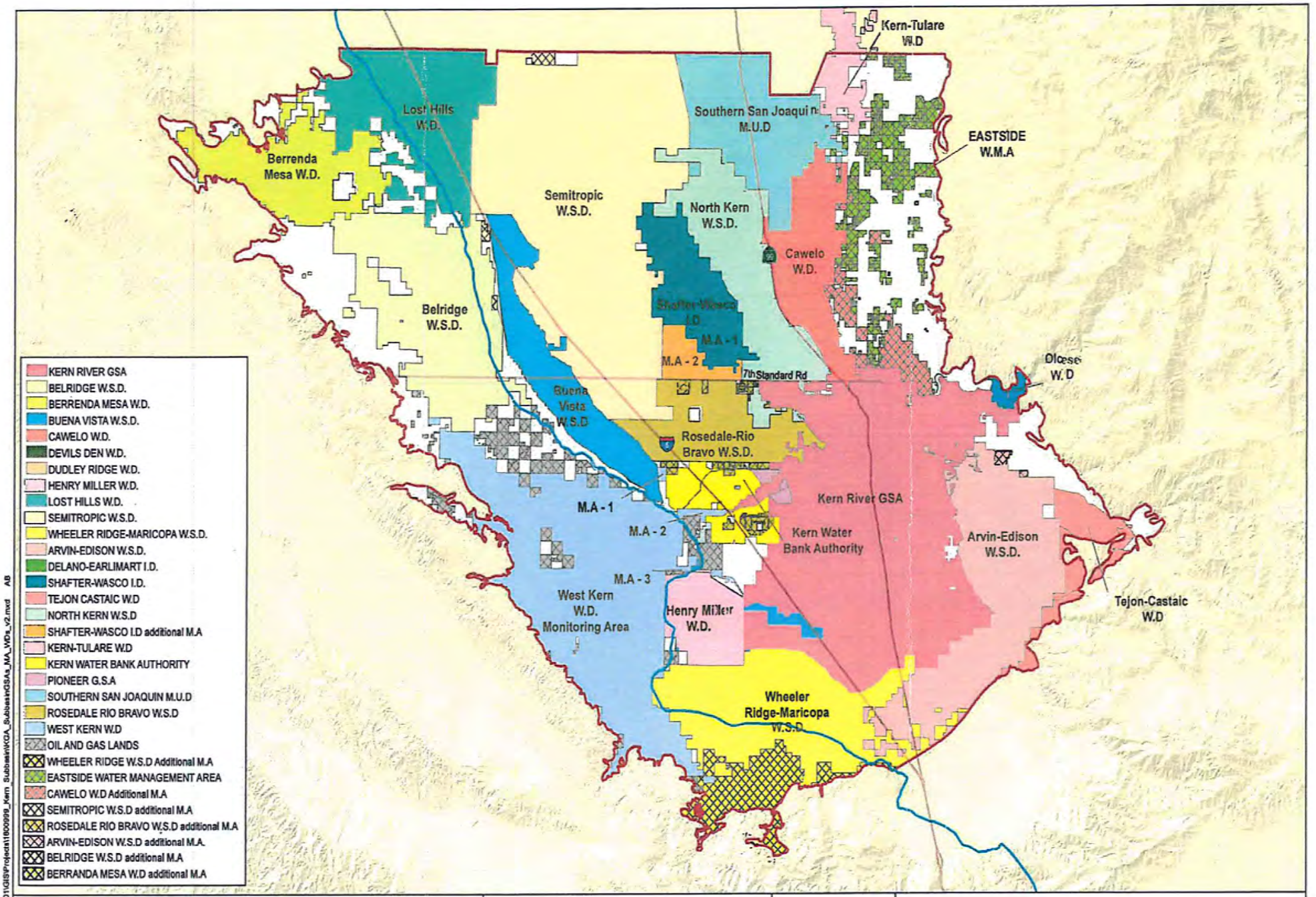
Data indicate that you own or are responsible for the parcel(s) or public water supply system(s) listed at the end of this notice. The Board has identified this parcel(s) or water supply system(s) as located within an unmanaged area. If you extract groundwater from an unmanaged area and you are not a small domestic user, SGMA requires that you file an annual groundwater extraction report for extractions made during the previous water year.

If you have questions regarding this notice or need assistance completing the online groundwater extraction report, please contact Board staff by email at groundwater_management@waterboards.ca.gov or by phone at 916-322-6508.

Enclosures: Groundwater Extraction Report Quick Guide

The following Assessor's Parcel Numbers (APN) prompted this letter:

«APN_1»
«APN_2»
«APN_3»
«APN_4»
«APN_4»
«APN_5»
«APN_6»
«APN_7»
«APN_8»
«APN_9»
«APN_10»
«APN_11»
«APN_12»
«APN_13»
«APN_14»
«APN_15»
«APN_16»
«APN_17»
«APN_18»
«APN_19»
«APN_20»



Kern Goundwater Authority

Kern County, California

GEI Consultants

Kern SGMA Basin

May 2019

FIGURE 1

04-Apr-2019 I:\Sac1s+fs01\GIS\Projects\16000999_Kern_Subbasin\KGA_SubbasinGSAs_MA_WDs_v2.mxd AB

Appendix D

Detailed Responses to Selected Comments Received Regarding the MA Plan

Appendix D

Detailed Responses to Selected Comments Received on the Public Draft Wheeler Ridge-Maricopa Management Area Plan

Summary of Comments in Chevron email (11/19/2019) to WRMWSD, and Responses from WRMWSD

Chevron Comment Number	Chevron Comment	Response from WRMWSD
1	An aquifer may not be suitable for beneficial use if: a) is not currently serving as a source of drinking water, b) it has commercially producible minerals or hydrocarbons, or c) it is not expected to supply a public water system and d) is either economically or technologically infeasible for treatment or recovery now or in the future for domestic, agricultural, or industrial use. The purpose of this plan is not to exempt aquifers, nor is it to define the maximum depth or water quality concentration at which groundwater is economically recoverable or treatable now or in the future. However, by applying the criteria of 40 CFR §144.3 and 40 CFR §146.4, active oil and gas aquifers and exempted aquifers are not a part of the groundwater basin for beneficial use. As described above, the following, whichever is shallowest, are the lateral and vertical boundaries of the groundwater Subbasin: a) depth to producible minerals or hydrocarbons or primacy productive limits, b) depth to exempted aquifers, c) depth that makes recovery of water for domestic, commercial, or industrial purposes no longer economically or technologically feasible, or	• ***Section 7.1.3 was modified to clarify that in areas where pools in oil fields in the MA Plan area are at shallower depths than the base of fresh water, the bottom of the basin is defined as the shallower depth of fresh water from the DOGGR oil field data.***

Chevron Comment Number	Chevron Comment	Response from WRMWSD
	d) the depth at which groundwater cannot now or in the future serve as a source of drinking water. For example, water bearing zones below the depth to producible hydrocarbons are not within the groundwater basin; likewise, water bearing zones below an exempted aquifer are not within the groundwater basin.	

Summary of Comments in the California Department of Fish and Wildlife (CDFW) Comment Letter (11/25/2019) to KGA and Semitropic WSD, and Responses from WRMWSD

CDFW Comment Number	CDFW Comment	Response from WRMWSD
1	The Plan Area narrative does not identify Department-owned lands.	• There are no state-owned lands within the Wheeler Ridge-Maricopa Management Area. • See KGA response to this comment for further information.
2	The GSP identifies an 'environmental' category of beneficial user but does not specify how impacts to environmental beneficial uses and users of groundwater were considered throughout the GSP.	• The process used to assess the potential occurrence of "environmental" uses/users of groundwater in the Management Area is based on depth to groundwater based on available data from wells in the principal aquifer, as described in **Section 8.2**, **8.7** and **8.8**. This process was informed by the TNC (2019) guidance for evaluation of GDEs. • See KGA response to this comment for further information.
3	The GSP identifies the potential for interconnected surface waters but dismisses further evaluation of interconnectivity and abdicates oversight of shallow groundwater-surface water communication.	• The process used to assess the potential occurrence of interconnected surface water in the Management Area is based on depth to groundwater (similar to the process used for evaluation of GDEs, which was done consistent with TNC (2019) guidance; see below) based on available data from wells in the principal aquifer, as described in **Section 8.2** and **8.7**. • See KGA response to this comment for further information.
4	The GDE identification section, pursuant to 23 CCR§ 354.16 (g), identifies ecosystems that may depend on groundwater. A report completed by the California Department of Water Resources (CDWR) (1997) shows that a large area of Kern County has 0 to 10 feet to depth to free water below the surface (see CDWR Figures 2, 3 and 5). Based	• The process used to assess the potential occurrence of GDEs in the Management Area is based on depth to groundwater based on available data from wells in the principal aquifer, as described in **Section 8.2** and **8.8**.

CDFW Comment Number	CDFW Comment	Response from WRMWSD
	on the presence of shallow groundwater, the Department supports the further investigation of GDEs and recommends including additional references for a more robust GDE evaluation. The Department recognizes that Natural Communities Commonly Associated with Groundwater (NCCAG) (Klausmeyer et al. 2018) provided by CDWR is a good starting reference for GDEs. There are additional resources available for evaluating GDE locations and habitat types, as well as information for State and Federal listed species. These recommended references include, but not limited to the following tools and other resources: the California Department of Fish and Wildlife (CDFW) Vegetation Classification and Mapping Program (VegCAMP) (CDFW 2019A); the CDFW California Natural Diversity Database (CNDDB) (2019B); the California Native Plant Society (CNPS) Manual of California Vegetation (CNPS 2019A); the CNPS California Protected Areas Database (CNPS 2019B); the United States Fish and Wildlife Service (USFWS) National Wetlands Inventory (2018); the USFWS online mapping tool for listed species critical habitat (2019); the United States Forest Service CALVEG ecological grouping classification and assessment system (2019); and other publications by Klausmeyer et al. (2019), Rohde et al. (2018), The Nature Conservancy (TNC) (2014, 2019), and Witham et al. (2014).	• ***Section 8.8 was modified to include mention the use of the TNC (2019) guidance and criteria therein.*** • The criteria used to remove NCCAG from the list of potential GDEs is a depth to water greater than 30 feet, which is based on guidance from The Nature Conservancy (2019). • See KGA response to this comment for further information.
5	The identification of undesirable results and selection of minimum thresholds are based on an extended 10-year drought period and exclude Sustainable Management Criteria for surface water depletions.	• Because interconnected surface waters are determined to not occur within the MA Plan area, based on depth to groundwater data from the principal aquifer, sustainable management criteria for Depletion of Interconnected Surface Waters are deemed not applicable/necessary. • See KGA response to this comment for further information.

Summary of Comments in the Leadership Counsel for Justice and Accountability (LCJA) Comment Letter (11/26/2019) to KGA, and Responses from WRMWSD

Page Number in LCJA Letter	LCJA Comment	Response from WRMWSD

6	The GSP was not crafted in a way that adequately considered the input of disadvantaged communities, either at the GSA level or the member agency level.	• WRMWSD conducted substantial stakeholder outreach and engagement during the Wheeler Ridge-Maricopa Management Area Plan (MA Plan) development process. This outreach is described in in **Section 5.5** of the MA Plan, as well as the Stakeholder Communication and Engagement Plan (SCEP) included as **Appendix C**. WRMWSD outreach efforts included:
		  • letters sent to all landowners and all interested parties;
		  • distribution and compilation of a Stakeholder Survey (direct mail in WRMWSD billing statements);
		  • Outreach to certain well owners to discuss domestic well status and location and regarding development of a monitoring network;
		  • Letters to "white land" owners;
		  • Multiple public stakeholder workshops,
		• The above outreach efforts are in addition to those performed by the KGA. ***A list of meetings during which GSP and SGMA were discussed is included in Appendix C of the MA Plan, which was updated to reflect additional recent meetings***.
		• See KGA response to this comment for further information.

12	The KGA GSA did not ensure that minimum thresholds created by member agencies considered the interests of all beneficial user groups,	• WRMWSD <u>did</u> evaluate potential impacts of Minimum Thresholds on dewatering of wells, including an assessment of how many wells could potentially be

Page Number in LCJA Letter	LCJA Comment	Response from WRMWSD
	or prioritize the security of drinking water in the subbasin, in developing minimum thresholds.	dewatered (see **Section 14.1.1** and **Figures SMC-4** and **SMC-5**). • ***Section 18.1.6 of the MA Plan includes discussion of development of an Impacted Well Mitigation Program (also referred to as a Well Dewatering Mitigation Program) to address potential impacts arising from low groundwater levels, and has been updated to include more information on the types of mitigation that may be included in the program.*** • See KGA response to this comment for further information.
14-15	As in the case of groundwater levels, it is clear that the GSA has not considered the potential impact on drinking water users, in particular disadvantaged communities who are less able to afford solutions to treat contaminated drinking water.	• WRMWSD did conduct an extensive analysis of water quality based on the available data (see **Section 8.5** and **Figures GWC-11 through GWC-13**, and **Appendix F**). • Constituents in groundwater within the Wheeler Ridge-Maricopa Management Area are either naturally occurring or related to land use practices which are regulated under separate programs such as the Irrigated Lands Regulatory Program [ILRP], Waste Discharge Requirements [WDRs], etc. WRMWSD is involved with those efforts as part of the Kern River Watershed Coalition Authority (see **Section 8.5.1** of the MA Plan). • All monitoring sites will be sampled for the constituents identified in the Groundwater Quality Concerns section (**Section 8.5.1**), as well as other relevant groundwater quality parameters (see **Section 16.1.4**). Collection of additional data during plan implementation will be used to refine SMC definitions, as discussed in **Section 13.4**.

Page Number in LCJA Letter	LCJA Comment	Response from WRMWSD
		• See KGA response to this comment for further information.
18	The groundwater quality monitoring network does not adequately capture impacts on drinking water users.	• As described in **Section 16.1.4**, the water quality monitoring in this MA Plan includes nine locations throughout the MA and is considered representative. • See KGA response to this comment for further information.
20	The GSA has allowed member agencies like the Arvin-Edison WSD to use a "glidepath" approach that increases surface water and groundwater recharge before demand reduction measures are implemented.[67]	• Demand reduction and supply augmentation Projects and Management Actions (P/MAs) are to be implemented concurrently and in a balanced approach under the "glide path" laid out in the Wheeler Ridge-Maricopa MA Plan (see **Section ES.10**; **Section 9.4.5**; **Section 17.1.4**; and **Table PMA-2**). • See KGA response to this comment for further information.

Summary of Comments in the Wonderful Orchards/Wonderful Citrus (WOWC) Comment Letter (11/27/2019) to KGA and Responses from WRMWSD

Page Number in WOWC Letter	WOWC Comment	Response from WRMWSD
1	**Quantification of Native Yield** It is imperative that the final GSP properly address the quantification of native yield. The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource. For example, a district or pumper located adjacent to the foothills does not necessarily have a superior claim to native yield over someone located in the center of the basin just because they are geographically closer to the source of mountain front recharge. Similarly, a district or pumper located in a cone of depression does not necessarily have a superior claim to native yield just because groundwater is flowing toward them. Surface water entering the groundwater via seepage in natural channels, including the Kern River and small streams, may be attributable to the native yield depending upon the circumstances of that seepage. A thorough technical and legal analysis is necessary to determine appropriate sources contributing to the native yield and to quantify these supplies.	• "Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). • ***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that the "native yield" is for planning purposes only and not a determination of actual legal ground water rights.*** • Implementation of P/MAs, including actions to further refine issues related to allocations of groundwater, is described in **Section 18.2**. • See KGA response to this comment for further information.
2	**Allocation of Native Yield** In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield. Currently, the GSP references native yield in terms of acre-feet per gross acre for water budget purposes. Appendix J of the GSP indicates the subbasin native yield is approximately 0.144 acre-feet per	• ***Section 18.4 which describes Stakeholder Engagement as part of MA Plan implementation, has been modified to include a statement that any actions to establish landowner-level allocations of native yield will be***

Page Number in WOWC Letter	WOWC Comment	Response from WRMWSD
	acre. It is our understanding that subsequent to the release of the draft GSP, all MAPs and other GSPs in the basin agreed to utilize the same number for their water budgets. If referencing native yield this way is necessary, the GSP should clarify that it is for initial water budget purposes ONLY, is non-precedent setting, and is not a determination of individual landowner allocations or groundwater rights. Alternatively, in the 2020 plans subbasin native yield could be described as a total volume of water and not associated with a given gross or net area. In addition, GSAs should initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations of native yield that are coordinated across the subbasin. The allocation methodology should be consistent with various legal considerations drawn from applicable case law and be generally consistent with groundwater rights, recognizing that GSAs do not have statutory authority to make a final determination of water rights. An equal-per-gross acre approach to allocations is not likely to be consistent with established water rights doctrine, which must recognize many equitable considerations in addition to acreage owned, to determine a legally defensible allocation. Further information regarding allocation methodology can be found in Groundwater Pumping Allocations Under California's Sustainable Groundwater Management Act – Environmental Defense Fund and New Current Water & Land, July 2018.	***conducted through a robust stakeholder engagement process.*** • See KGA response to this comment for further information.
2	**Groundwater Markets** Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent	• The MA Plan includes in its portfolio of P/MAs a management action to evaluate and potentially implement a groundwater marketing and trading system (see **Section 17.2.2**). • As described in **Section 18.2**, implementation of P/MAs, including the potential establishment of a market-based

Page Number in WOWC Letter	WOWC Comment	Response from WRMWSD
	undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next.	system, will include performance of any appropriate further studies and analysis, including engineering, economic/financial, and/or legal, as appropriate. • See KGA response to this comment for further information.
2	**Pumping Restrictions** Wonderful understands that there are instances where it may be necessary to restrict pumping in order to achieve basin-wide sustainability. If this becomes a necessity, the GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity. As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled).	• Demand reduction Management Actions are included in the MA Plan as one element in a portfolio of P/MAs (see **Section 17**). • The P/MA implementation timetable is based on a phased/incremental "glide path" approach (see **Section 17.1.4**). • P/MA implementation will entail, in many cases, performing studies and/or analysis to refine concepts into actionable projects or policies (see **Section 18.2**). ***Section 18.2 was modified to clarify that such studies will be based on using the best available data and science.*** • See KGA response to this comment for further information.
3	**Groundwater Recharge and Banking** GSAs must develop clear policies and conditions that protect existing investment in groundwater banking and banked inventory, and without interference with existing rules and regulations. GSAs must also find a way to incentivize additional investment, such as on-farm recharge, and allow flexibility for recharged or banked water to be freely transferable (subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results). Where possible, GSPs should also identify management areas that may	• As described in **Section 18.2**, implementation of P/MAs, including projects to enhance recharge and projects to manage and/or capture floodwater, will include performance of any appropriate further studies and analysis, including engineering, economic/financial, and/or legal, as appropriate. • See KGA response to this comment for further information.

Page Number in WOWC Letter	WOWC Comment	Response from WRMWSD
	benefit from additional recharge and banking. We also recommend that GSAs work to develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	
3	**Measurement and Data Management** Finally, GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	• ***Section 8.1 has been added to the MA Plan to describe data sources used in MA Plan development and how this local DMS will be coordinated with the basin-wide DMS.*** • ***Appendix E has been added to the MA Plan to list additional water quality data sources that will be evaluated during MA Plan implementation.*** • The Plan implementation section includes an action to refine the local DMS to comply with (coordinate with) the basin-wide DMS (see **Sections 18.1** and **18.3**). • See KGA response to this comment for further information.

Summary of Comments in the Farmland Reserves (FR) Comment Letter (11/27/2019) and Responses from WRMWSD

Comment Number	FR Comment	Response from WRMWSD
1	**Allocation of Groundwater Rights.** Though not specifically addressed, we are concerned that the overlying right to extract groundwater will be allocated among all District landowners based on gross acreage. While this is a simple approach to what can be a complex issue, it ignores accepted principles of law intended to more fairly allocate this right among those who have historically used groundwater for irrigation purposes-and made substantial investments based on that use. We wish to at least see identification of this issue in the Chapter and an acknowledgment that it will not be decided now. If the District determines that the issue is broader, then we leave it to the District to address it at the Umbrella GSP level. Any implication that the District has decided to allocate the overlying groundwater rights based simply on gross acreage could invite some to pursue premature legal action to challenge the District's conclusion, which might not be necessary depending on the success of the proposed actions in the Chapter. While this issue certainly affects our interests, we are equally concerned about avoiding unnecessary legal challenges made by others and the instability that would bring to the sub-basin.	• "Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). • ***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that the "native yield" is for planning purposes only and not a determination of actual legal ground water rights.*** • Implementation of P/MAs, including actions to further refine issues related to allocations of groundwater, is described in **Section 18.2**. • See KGA response to this comment for further information.
2	**Native Yield.** The Chapter identifies a coordinated estimated native yield of 0.15-.0.30 acre feet per acre across the KGA. We understand and acknowledge that some number needed to be identified for Water Budget and planning purposes and support the use of these numbers for such purposes. However, these numbers should not be seen as establishing a precedent or used to establish some legal right. Therefore, a statement emphasizing the above points should be made - the planning purpose nature of these numbers and not establishing legal precedent. Additionally, in coordinating with other members of the KGA under the Umbrella GSP, the District should push for a consistent native yield and related methodology across the sub-basin. We understand that this can be a politically charged process, but we are confident the District	• "Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). • ***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that the "native yield" is for planning purposes only and not a determination of actual legal ground water rights.*** • Implementation of P/MAs, including actions to further refine issues related to allocations of groundwater, is described in **Section 18.2**. • See KGA response to this comment for further information.

Comment Number	FR Comment	Response from WRMWSD
	can provide support for a consistent approach, which will enable a more stable sub-basin.	
3	**Groundwater Market.** This issue might be premature at this point. However, the Chapter could address the possibility of a market for the exchange or transfer of groundwater credits. If a market system were contemplated, we would encourage such a system to be as flexible as possible (within the requirements of SGMA, the Chapter and the Umbrella GSP) to facilitate the needs of farmers with lands in different areas of the sub-basin and those with the ability to store surface water underground. Again, this might be premature at this time, but a mention of the District's position to support a flexible groundwater market could help move the discussion forward once the Umbrella GSP is submitted to the Department of Water Resources and agencies begin the implementation process.	• The MA Plan includes in its portfolio of P/MAs a management action to evaluate and potentially implement a groundwater marketing and trading system (see **Section 17.2.2**). • As described in **Section 18.2**, implementation of P/MAs, including the potential establishment of a market-based system, will include performance of any appropriate further studies and analysis, including engineering, economic/financial, and/or legal, as appropriate. • See KGA response to this comment for further information.

Summary of Comments in the Hancock Financial Services (HFS) Comment Letter (11/27/2019) to KGA and Responses from WRMWSD

Page Number in HFS Letter	HFS Comment	Response from WRMWSD
1	**Allocation of Native Yield** The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water, for example xxx,xxx acre-feet and not associated with a given gross or net area. In the event that allocations of any sort are distilled to a landowner or property level, HFS encourages the GSAs in the basin to initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations that are coordinated across the basin. The allocation methodology should be consistent with various legal considerations drawn from applicable case law and attempt to be consistent with groundwater rights, recognizing that GSAs do not have statutory authority to make a final determination of water rights. An equal-per-gross acre approach to allocations is not likely to be consistent with established water rights doctrine, which must recognize many equitable considerations, in addition to acreage owned, to determine a legally defensible allocation. Further information regarding allocation methodology can be found in Groundwater Pumping Allocations Under California's Sustainable Groundwater Management Act – EDF and NCWL, dated July, 2018	• "Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). • ***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that the "native yield" is for planning purposes only and not a determination of actual legal ground water rights.*** • Implementation of P/MAs, including actions to further refine issues related to allocations of groundwater, is described in **Section 18.2**. • ***Section 18.4 which describes Stakeholder Engagement as part of MA Plan implementation, has been modified to include a statement that any actions to establish landowner-level allocations of native yield will be conducted through a robust stakeholder engagement process.*** • See KGA response to this comment for further information.
1	**Groundwater Recharge and Banking** GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge	• As described in **Section 18.2**, implementation of P/MAs, including projects increase in-District and out-of-District banking operations, will include performance of any appropriate further studies and analysis, including engineering, economic/financial, and/or legal, as appropriate.

Page Number in HFS Letter	HFS Comment	Response from WRMWSD
	by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	• See KGA response to this comment for further information.
3	**Refinement and Validation of Consumptive Use Calculations Based on ET Measurement** HFS supports use of efficient and accurate systems to determine groundwater use. GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration. These methodologies should be developed in consultation with the vendor providing ET data to ensure it is applicable and useful in creating the best available data set. Additionally, GSAs and/or MAs should establish criteria and procedures to address apparent inaccuracies in the ET calculations. An obvious use of the procedure would be in instances where the grower can demonstrate that applied water, plus precipitation, is less than the calculated ET. In these instances, and subject to any requirements established by the GSA, the grower's use of groundwater should be reduced to the applied water total as the ET calculation should not be greater than applied water.	• The comment is noted. • See KGA response to this comment for further information.

Summary of Comments in the Westchester Group Investment Management (WGIM) Comment Letter (11/27/2019) to KGA and Responses from WRMWSD

Page Number in WGIM Letter	WGIM Comment	Response from WRMWSD
1	**Allocation of Native Yield** The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water and not associated with a given gross or net area. In the event that allocations are to be made at a landowner or property level, WGIM encourages the KGA and other GSAs in the basin to initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations that are coordinated across the basin. The allocation methodology should be consistent with various legal considerations drawn from applicable case law and attempt to be consistent with groundwater rights, recognizing that GSAs and Management Areas (MAs) do not have statutory authority to make a final determination of water rights. An equal-per-gross acre approach to allocations is not likely to be consistent with established water rights doctrine, which must recognize many equitable considerations, in addition to acreage owned, to determine a legally defensible allocation. Further information regarding allocation methodology can be found in Groundwater Pumping Allocations Under California's Sustainable Groundwater Management Act – EDF and NCWL, dated July, 2018.	• "Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). • ***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that the "native yield" is for planning purposes only and not a determination of actual legal ground water rights.*** • Implementation of P/MAs, including actions to further refine issues related to allocations of groundwater, is described in **Section 18.2**. • ***Section 18.4 which describes Stakeholder Engagement as part of MA Plan implementation, has been modified to include a statement that any actions to establish landowner-level allocations of native yield will be conducted through a robust stakeholder engagement process.*** • See KGA response to this comment for further information.
1	**Pumping Restrictions** We understand that there are instances where it may be necessary to restrict pumping in order to achieve basin-wide sustainability. If this becomes a necessity, the GSAs and MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible without creating undesirable results, pumping should be ramped down gradually over the	• Demand reduction Management Actions are included in the MA Plan as one element in a portfolio of P/MAs (see **Section 17**). • The P/MA implementation timetable is based on a phased/incremental "glide path" approach (see **Section 17.1.4**).

Page Number in WGIM Letter	WGIM Comment	Response from WRMWSD
	implementation period to avoid a sudden disruption in economic activity. As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated and consistent across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled).	• P/MA implementation will entail, in many cases, performing studies and/or analysis to refine concepts into actionable projects or policies (see **Section 18.2**). ***Section 18.2 was modified to clarify that such studies will be based on using the best available data and science.*** • See KGA response to this comment for further information.
2	**Groundwater Recharge and Banking** GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked water inventory, and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	• As described in **Section 18.2**, implementation of P/MAs, including projects to increase in-District and out-of-District banking operations, will include performance of any appropriate further studies and analysis, including engineering, economic/financial, and/or legal, as appropriate.
2	**Measurement and Data Management** GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions.	• The comment is noted. • ***Section 8.1 has been added to the MA Plan to describe data sources used in MA Plan development and how this local DMS will be coordinated with the basin-wide DMS.*** • ***Appendix E has been added to the MA Plan to list additional water quality data sources that will be evaluated during MA Plan implementation.***

Page Number in WGIM Letter	WGIM Comment	Response from WRMWSD
	Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	• The Plan implementation section includes an action to refine the local DMS to comply with (coordinate with) the basin-wide DMS (see **Sections 18.1** and **18.3**). • See KGA response to this comment for further information.
3	**Refinement and Validation of Consumptive Use Calculations Based on ET Measurement** WGIM supports use of efficient and accurate systems to determine groundwater use. GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration. These methodologies should be developed in consultation with the vendor providing ET data to ensure it is applicable and useful in creating the best available data set. Additionally, GSAs and/or MAs should establish criteria and procedures to address apparent inaccuracies in the ET calculations. An obvious use of the procedure would be in instances where the grower can demonstrate that applied water, plus precipitation, is less than the calculated ET. In these instances, and subject to any requirements established by the GSA, the grower's use of groundwater should be reduced to the applied water total as the ET calculation should not be greater than applied water.	• The comment is noted. • See KGA response to this comment for further information.

Summary of Comments in The Nature Conservancy (TNC) Comment Letter (11/27/2019) to KGA, and Responses from WRMWSD

Page Number in TNC Comment Letter	TNC Comment	Response from WRMWSD
9	**Notice and Communication** Please describe the other beneficial uses and users of groundwater in the Subbasin identified by the Water Code including: GDEs; managed wetlands; Protected Lands, including preserves, wildlife refuges, conservation areas, recreational areas and other protected lands; and Public Trust Uses, including wildlife, aquatic habitat, fisheries, recreation and navigation. Please identify any environmental uses and users of groundwater in the plan area, and take particular note of the species with protected status.	• See KGA response to this comment for further information.
10	**Plan Area Setting** Please provide a description of any current and planned instream flow requirements or regulatory requirements for protection of species of concern in the Kern River, Poso Creek and Caliente Creek. If there are no requirements in place or planned, then please state that in the GSP.	• See KGA response to this comment for further information.
10	**Existing Plans in the Plan Area** We suggest adding a discussion of General Plan goals and policies related to the protection and management of GDEs and aquatic resources that could be affected by groundwater withdrawals. Please include a description of any land use or environmental plans relevant to wetlands, aquatic resources and other GDEs and ISWs and their relationship to the GSP. Please include a discussion of how implementation of the GSP may affect and be coordinated with General Plan policies and procedures regarding the protection of wetlands around the Kern Wildlife Refuge, aquatic resources and other GDEs and ISWs.	• **Section 5.3** of the MA Plan includes information about land use plans (i.e., General Plans), including a summary of goals, policies and implementation measures related to land and water use. • See KGA response to this comment for further information.

Page Number in TNC Comment Letter	TNC Comment	Response from WRMWSD
	Please identify all relevant HCPs and NCCPs within the Subbasin and address how GSP implementation will coordinate with the goals of these HCPs or NCCPs.	
10	**Existing and Ongoing Water Resource Programs** Please provide a description of resource management plans, monitoring activities and responsibilities by State, Federal and local agencies and jurisdictions related to aquatic resources and GDEs that could be affected by groundwater withdrawals, and list them in Table 2-1. Please review and discuss the potential groundwater reliance of critical species in the Subbasin. Please include a discussion regarding the management of critical habitat for these aquatic species and its relationship to the GSP. Please include a discussion of any monitoring programs related to GDEs and sensitive habitats.	• See KGA response to this comment for further information.
11	**Well Permitting Process, Well Construction Policies** Please discuss that future well permitting and well construction must be coordinated with the GSP to assure achievement of the Plan's sustainability goals. Please state how the well permitting process incorporates protection of GDEs and ISWs within the Subbasin. Please include a discussion of the need for well permitting programs to comply with this requirement.	• **Sections 5.3.2** and **5.4** of the MA Plan includes discussion of the Kern County Well Permitting Process. • See KGA response to this comment for further information.
11	**Hydrogeologic Conceptual Model – Bottom of the Subbasin** Please characterize groundwater well extractions from the deepest wells in relation to defining the basin bottom.	• **Section 7.1.3** of the MA Plan describes the definition of the bottom of the basin, which includes consideration of the deepest groundwater wells.

Page Number in TNC Comment Letter	TNC Comment	Response from WRMWSD
	If the bottom boundary of the Subbasin has not been clearly defined in certain management areas, please identify this as a data gap and elaborate in the monitoring section how and where additional observations can be made to reconcile this data gap.	• See KGA response to this comment for further information.
12	**Hydrogeologic Conceptual Model – Principal Aquifers and Aquitards** Please provide additional description of the shallow aquifers within the Subbasin including characteristics of interconnections with surface water and GDEs, vertical groundwater gradients, connections with underlying production aquifers, and the resulting potential interaction of groundwater pumping with ISWs and GDEs. Please state whether localized perched aquifers are present in the Subbasin. Describe any data gaps. The function and significance of the Shallow Aquifers that provide groundwater to ISWs and GDEs should be summarized in Table 2-3. Please describe whether the existence of Aquifer Exemptions has any bearing or implications related to environmental beneficial uses of groundwater.	• **Section 7.1.4** of the MA Plan mentions the occurrence of the "A"-Clay which may result in localized perched groundwater in some areas. • **Section 7.3.2** of the MA Plan mentions that these perched zones are often poor quality and do not yield significant or economic amounts of water to wells, springs, or surface water systems, and are therefore not considered part of the principal aquifer. • See KGA response to this comment for further information.
12	**Hydrogeologic Conceptual Model – Data Gaps and Uncertainty** If data are not present to produce the information requested in the comment above, please clearly identify this as a data gap. Please elaborate in the monitoring section how and where additional observations are to be conducted in order to address this data gap.	• See KGA response to this comment for further information.
	Hydrogeologic Conceptual Model – Cross-Sections Please include near-surface cross sections or insets that depict the conceptual understanding of shallow groundwater and ISW interactions at different locations, including perched and regional aquifers and GDEs.	• See KGA response to this comment for further information.
13	**Hydrogeologic Conceptual Model - Elevation and Flow Directions** Please provide any available stratigraphic data, hydrograph data, pumping test data or other information to substantiate these claims. If the data are not available, please identify this as a data gap.	• See KGA response to this comment for further information.

Page Number in TNC Comment Letter	TNC Comment	Response from WRMWSD
14	**Interconnected Surface Water Systems** Please provide additional data or analysis to substantiate the nature of the hydrologic relationship between the shallow aquifer and production aquifers and ISWs. If data are not available to verify that such a connection does not exist, acknowledge where ISWs may exist and identify appropriate sustainable management criteria, monitoring networks and management actions for sustainable ISW management or to address data gaps. Data could include groundwater level data from shallow or nested monitoring wells, comparison of stream stages to groundwater levels, modeling information or additional gaging data. Please elaborate how and where additional observations (shallow monitoring wells, stream gauges, and nested / clustered wells) along surface water features can be used to address data gaps in the Monitoring Network section of the GSP to improve identification of ISWs rather than prematurely disregarding them in the GSP.	• The process used to assess the potential occurrence of interconnected surface water in the Management Area is based on depth to groundwater (similar to the process used for evaluation of GDEs, which was done consistent with TNC (2019) guidance; see below) based on available data from wells in the principal aquifer, as described in **Section 8.2** and **8.7**. • See KGA response to this comment for further information.
14	**Groundwater-Dependent Ecosystems** Please identify any data gaps related to identifying and mapping GDEs. If there are data gaps, please describe in detail in the monitoring plan how the data gaps will be addressed. Please support this statement with specific groundwater level data that indicate a gap in the saturated zone between the production aquifers and shallow groundwater, and define the extent of the NCCAG dataset polygons that are excluded from consideration as GDEs on this basis. Please identify any data gaps related to identifying and mapping GDEs. If there are data gaps, please describe in detail in the monitoring plan how the data gap will be resolved. Please revise the GDE analysis in the GSP by conducting more substantial, data-based evaluation focusing on GDE identification in	• The process used to assess the potential occurrence of GDEs in the Management Area is based on depth to groundwater based on available data from wells in the principal aquifer, as described in **Section 8.2** and **8.8**. Specific data regarding depths to groundwater water in the principal aquifer in Spring 2015 were provided. • ***Section 8.8 was modified to include mention of the use of TNC (2019) guidance and criteria therein.*** • The criteria used to remove NCCAG from the list of potential GDEs is a depth to water greater than 30 feet, which is based on guidance from The Nature Conservancy (2019). • See KGA response to this comment for further information.

Page Number in TNC Comment Letter	TNC Comment	Response from WRMWSD
	the GSP, clearly identify which NCCAG polygons are excluded, which polygons are determined to be GDEs and which polygons are uncertain at this time and will be verified as data gaps are address. Confirmation of GDEs should be performed based on depth to groundwater in the shallow zone, and additional information provided as to whether the shallow zone may be affected by groundwater withdrawal from the production aquifers. Please refer to Appendix D of this letter for best practices for using groundwater data to verify a connection to groundwater. Therefore, we recommend using depth to groundwater contour maps derived from subtracting groundwater levels from a DEM, as described above, to identify whether a potential connection to groundwater exists for the wetlands mapped in Attachment H of the GSP. Please refer to Attachments D and E of this letter for best practices for using local groundwater data to 1) verify whether polygons in the NC Dataset are supported by groundwater in an aquifer, and 2) verify whether ecosystem decline or recovery is correlated with groundwater levels. We recommend the inclusion of a discussion regarding the nature and characteristics of GDEs. Please provide information on the historical or current groundwater conditions near the GDEs or the ecological conditions present. We recommend an ecological inventory (see Appendix III, Worksheet 2 of the GDE Guidance) for all potential GDEs that includes vegetation or habitat types and rank the GDEs as having a high, moderate or low value. Explain how each rank was characterized.	

Page Number in TNC Comment Letter	TNC Comment	Response from WRMWSD
	Please identify whether any endangered or threatened freshwater species of animals and plants, or areas with critical habitat were found in or near any of the GDEs. Some organisms rely on uplands and wetlands during different stages of their lifecycle.	
17	**Water Budget** Please provide a breakdown of ET for native and riparian vegetation (such as wetlands, riparian vegetation, phreatophytes and other communities). Please evaluate the spatial relationship of native vegetation ET to NCCAG polygons to determine the groundwater use by this beneficial user for inclusion in the water budget. Identify any data gaps and outline the actions needed to address them.	• ET information used in the water budget analysis is from the ITRC-METRIC study and includes all lands, including non-irrigated lands. • See KGA response to this comment for further information.
17	**Sustainability Goal** Please clarify the sustainability goal and expand its description to ensure that all beneficial uses and users of groundwater are identified as being protected from undesirable results, and in particular, include GDEs, ISWs and related critical habitats. Since GDEs and ISWs may be present in the Subbasin (please see comments under Checklist Items 16-20) they should be recognized as beneficial users of groundwater and should be specifically included in the Sustainability Goal. In addition, a statement about any intention to address pre-SGMA impacts should be included. Please include ISWs in the Sustainability Goal until/unless sufficient data is available and provided to verify the status of ISWs. Given that there are potential GDEs in the Subbasin and that they may be affected by water quality, they should be included in the Sustainability Goal and addressed in the Water Quality section.	• The sustainability goal for the MA Plan area is stated in **Section 2** and **Section 12**, and does include mention of beneficial uses including environmental. • See KGA response to this comment for further information.
18	**Minimum Thresholds and Measurable Objectives** For each of these applicable sustainable management criteria, please include a discussion of GDEs (see comments under checklist items 16-	• Because GDEs are determined to not occur within the MA Plan area, based on depth to groundwater data from the principal aquifer, sustainable management

Page Number in TNC Comment Letter	TNC Comment	Response from WRMWSD
	20) and whether the minimum thresholds, measurable objectives and interim milestones will help achieve the sustainability goal as it pertains to the environment. Please modify Section 3.2.2 to specifically address impacts from degraded water quality to the plant and wildlife communities within GDEs.	criteria for Depletion of Interconnected Surface Waters are deemed not applicable/necessary. • See KGA response to this comment for further information.
19	**Undesirable Results** Please add "possible adverse impacts to potential GDEs and ISWs" to the list of potential undesirable results. Please review these spatial patterns and, where possible, correlate them with water level trends. Any indications of adverse trends and any data gaps should be identified. For each identifiable GDE unit with supporting hydrological datasets, please include the following: For identifiable GDE units without supporting hydrological datasets please describe data gaps and / or insufficiencies. Compile and synthesize biological data for each GDE unit by: Describe possible effects on potential ISWs, GDEs, land uses, and property interests, including:	• Because GDEs and ISW are determined to not occur within the MA Plan area, based on depth to groundwater data from the principal aquifer, sustainable management criteria for Depletion of Interconnected Surface Waters are deemed not applicable/necessary. • See KGA response to this comment for further information.
20	**Monitoring Network** Please modify the description of the monitoring network to provide methodologies, data and other information to address the data gaps associated with GDEs and ISWs. This modification should include 1) locating new wells that are appropriately screened to detect changes in groundwater levels in the uppermost water table and the connectivity of GDEs and ISWs with the upper unconfined or shallow zone aquifer; and 2) identifying or installing additional stream gauges in areas where there is potential for ISWs and GDEs. Please expand on	• See KGA response to this comment for further information.

Page Number in TNC Comment Letter	TNC Comment	Response from WRMWSD
	the discussion of how the new well and stream data will be used to improve ISW mapping and inform an adequate analysis, and how the data will be used to verify possible GDEs. Please address data gaps along the Kern River and tributary creeks identified earlier in the GSP in this section of the GSP to improve ISW mapping in companion or future GSPs (e.g., through shallow monitoring wells, stream gauges, and nested/clustered wells).	
21	**Projects and Management Actions** For the projects already identified, please consider stating how ISWs and GDEs will benefit or be protected, or what other environmental benefits will accrue. Please consider additional management actions and projects targeted for protecting ISWs and GDEs. Please describe how the projects and management actions will be evaluated to assess whether adverse impacts to GDEs may occur and/or will be mitigated or prevented.	• Because GDEs and ISW are determined to not occur within the MA Plan area, based on depth to groundwater data from the principal aquifer, P/MAs to benefit and protect GDEs and ISW are deemed not applicable/necessary. • See KGA response to this comment for further information.

Appendix E

Potential Additional Water Quality Data Sources

Summary of Water Quality Data Sources

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   1.1. Regulated Site Portal 2
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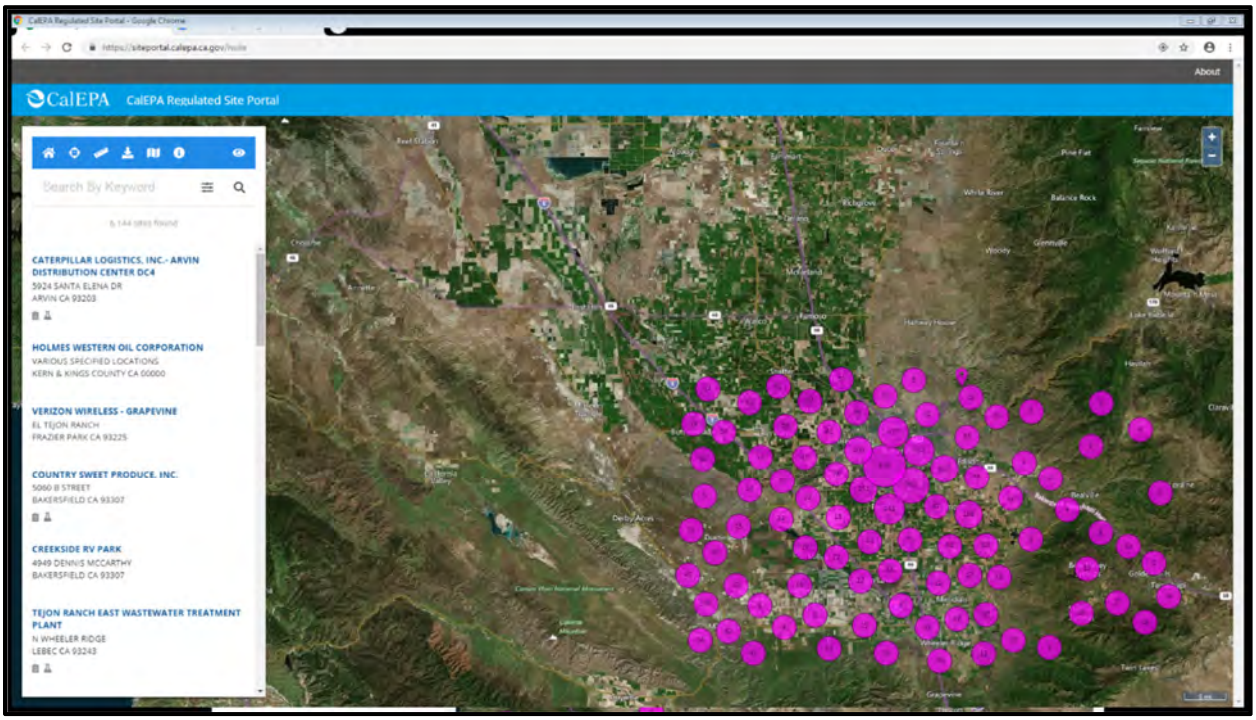
1. California EPA – Information on Hazardous Waste in Groundwater

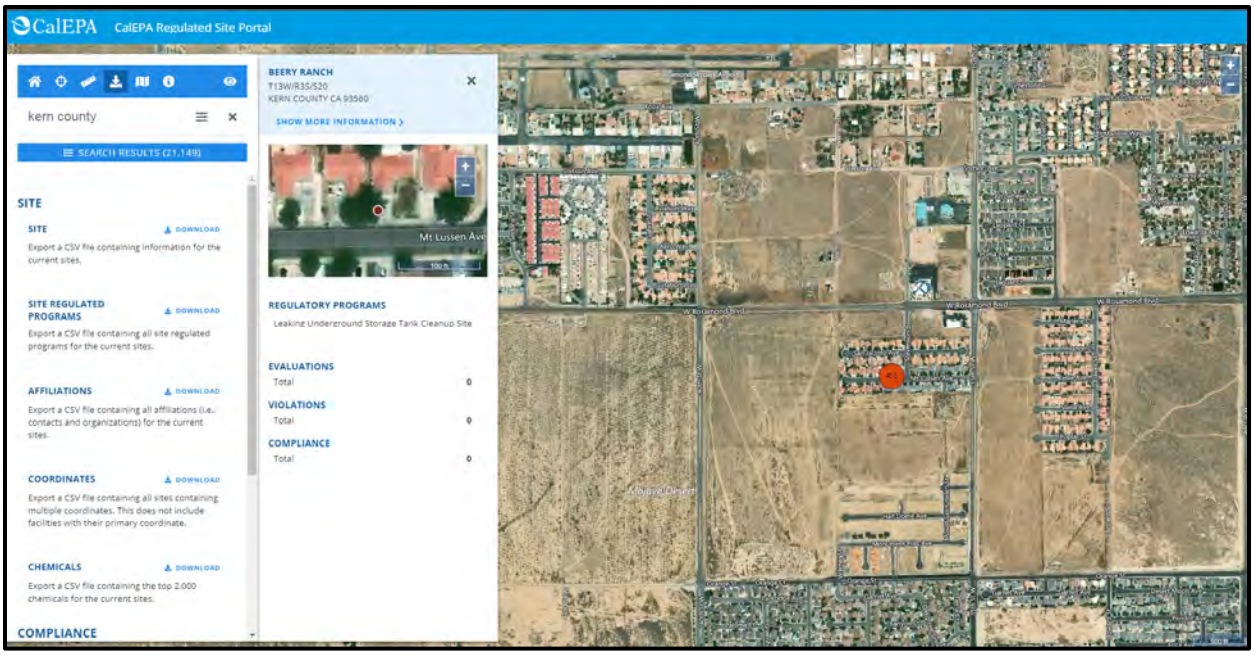
1.1. Regulated Site Portal

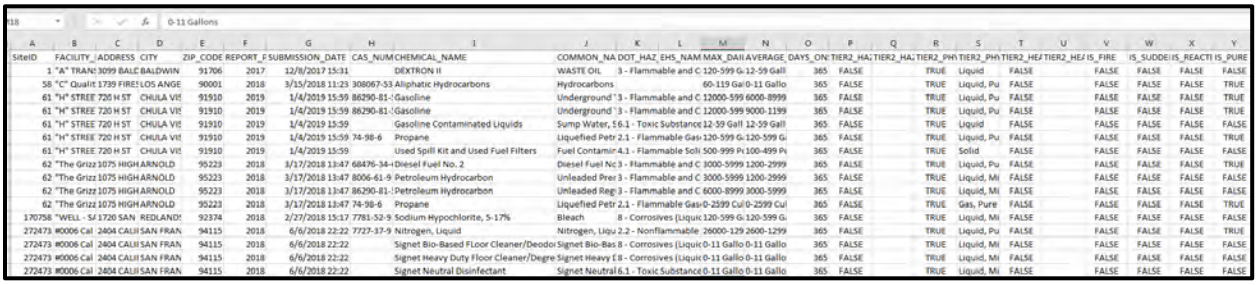
https://siteportal.calepa.ca.gov/nsite

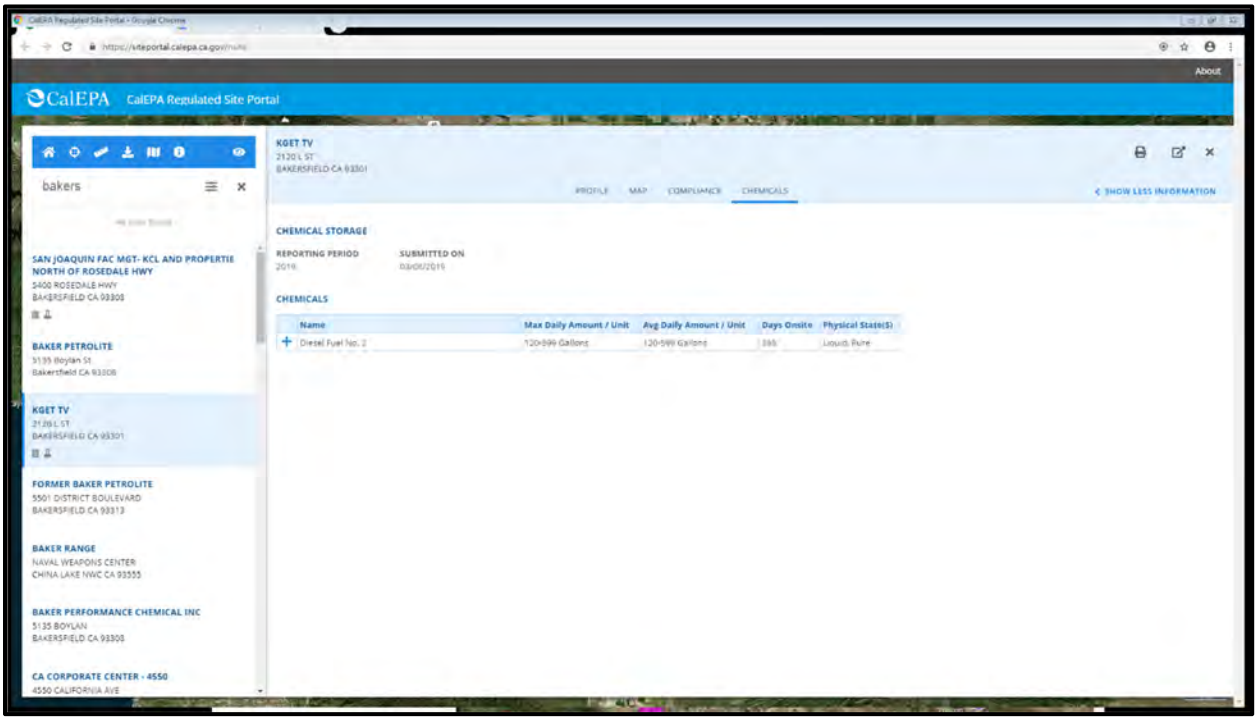
- Lists many environmentally regulated sites and facilities, including: hazardous waste and materials, hazardous waste facilities and sites, and storm water management sites.
- Data sources include California Occupational Safety and Health Administration (Cal/OSHA), California Environmental Reporting System (CERS), California Integrated Water Quality System (CIWQS), US EPA's Emission Inventory System (EIS), the California Department of Toxic Substances Control's (DTSC) EnviroStor site, the State Water Resources Control Board's (SWRCB) GeoTracker site, the SWRCB's Stormwater Multiple Application and Report Tracking System (SMARTS), the Solid Waste Information System (SWIS), and the federal Toxic Release Inventory (TRI) database.
- Contains downloadable data (e.g., quantity of chemical release), and other regulatory documents.
- No available spatial or temporal concentration data.

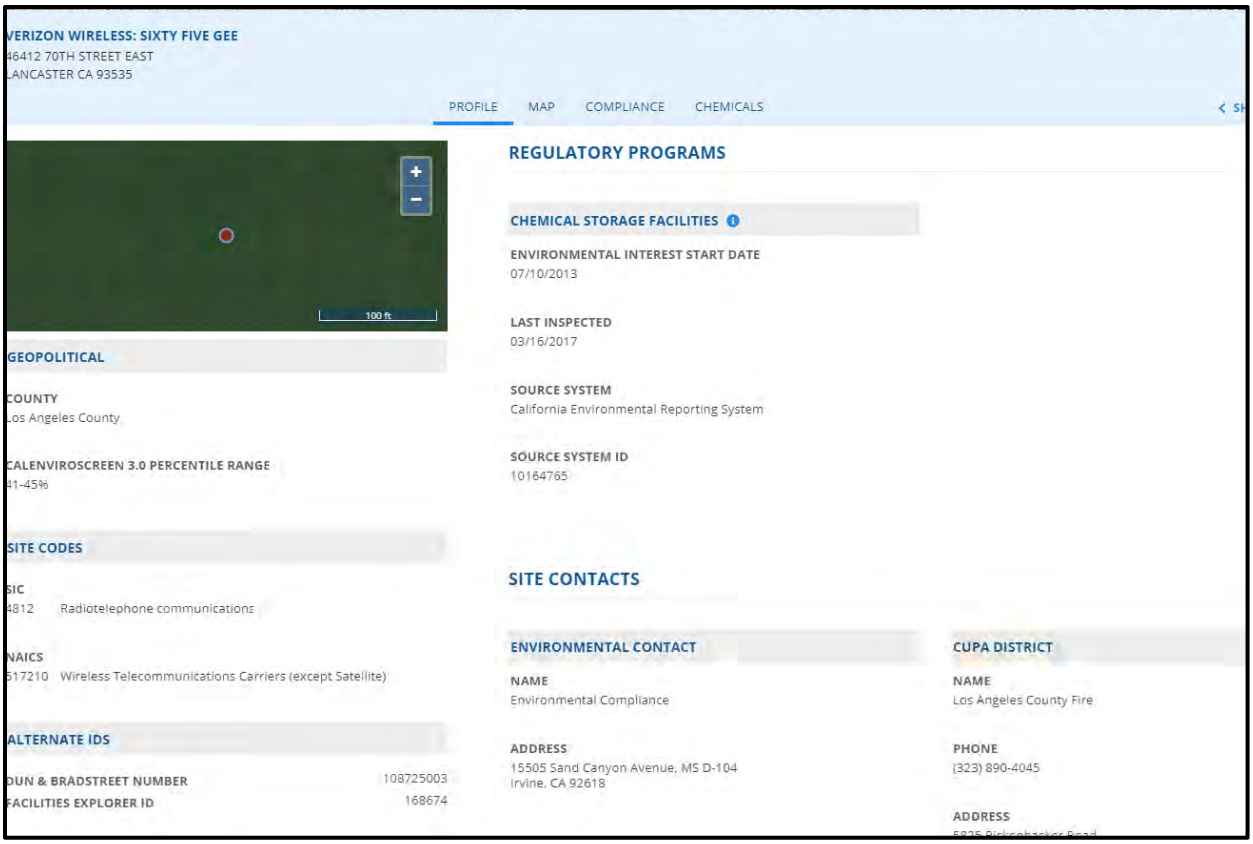
Screenshots of website and selected downloadable data:




CalEPA
CalEPA Regulated Site Portal
kern county
SEARCH RESULTS (21,149)
SITE
SITE
DOWNLOAD
Export a CSV file containing information for the current sites.
SITE REGULATED PROGRAMS
DOWNLOAD
Export a CSV file containing all site regulated programs for the current sites.
AFFILIATIONS
DOWNLOAD
Export a CSV file containing all affiliations (i.e., contacts and organizations) for the current sites.
COORDINATES
DOWNLOAD
Export a CSV file containing all sites containing multiple coordinates. This does not include facilities with their primary coordinate.
CHEMICALS
DOWNLOAD
Export a CSV file containing the top 2,000 chemicals for the current sites.
COMPLIANCE
BEERY RANCH
T13W/R35/S20
KERN COUNTY CA 93560
SHOW MORE INFORMATION
Mt Lussen Ave
REGULATORY PROGRAMS
Leaking Underground Storage Tank Cleanup Site
EVALUATIONS
Total 0
VIOLATIONS
Total 0
COMPLIANCE
Total 0
Mojave Desert


0-11 Gallons
SiteID FACILITY_ ADDRESS CITY ZIP_CODE REPORT_F SUBMISSION_DATE CAS_NUM CHEMICAL_NAME COMMON_NA DOT_HAZ EHS_NAM MAX_DAIL AVERAGE_ DAYS_ON TIER2_HA TIER2_HA TIER2_PH TIER2_PH TIER2_HEA TIER2_HEA IS_FIRE IS_SUDDE IS_REACTI IS_PURE
1 "A" TRAN 3099 BALE BALDWIN 91706 2017 12/8/2017 15:31 DEXTRON II WASTE OIL 3 - Flammable and C 120-599 G 12-59 Gall 365 FALSE TRUE Liquid FALSE FALSE FALSE FALSE FALSE
58 "C" Qualit 1739 FIRE LOS ANGE 90001 2018 3/15/2018 11:23 308067-53 Aliphatic Hydrocarbons Hydrocarbons 60-119 Gal 0-11 Gallo 365 FALSE TRUE Liquid, Pu FALSE FALSE FALSE FALSE TRUE
61 "H" STREE 720 H ST CHULA VIS 91910 2019 1/4/2019 15:59 86290-81-5 Gasoline Underground 3 - Flammable and C 12000-599 6000-8999 365 FALSE TRUE Liquid, Pu FALSE FALSE FALSE FALSE TRUE
61 "H" STREE 720 H ST CHULA VIS 91910 2019 1/4/2019 15:59 86290-81-5 Gasoline Underground 3 - Flammable and C 12000-599 9000-1199 365 FALSE TRUE Liquid, Pu FALSE FALSE FALSE FALSE TRUE
61 "H" STREE 720 H ST CHULA VIS 91910 2019 1/4/2019 15:59 Gasoline Contaminated Liquids Sump Water, 5 6.1 - Toxic Substance 12-59 Gall 12-59 Gall 365 FALSE TRUE Liquid FALSE FALSE FALSE FALSE FALSE
61 "H" STREE 720 H ST CHULA VIS 91910 2019 1/4/2019 15:59 74-98-6 Propane Liquefied Petr 2.1 - Flammable Gas 120-599 G 120-599 G 365 FALSE TRUE Liquid, Pu FALSE FALSE FALSE FALSE TRUE
61 "H" STREE 720 H ST CHULA VIS 91910 2019 1/4/2019 15:59 Used Spill Kit and Used Fuel Filters Fuel Contamir 4.1 - Flammable Soli 500-999 Pi 100-499 Pi 365 FALSE TRUE Solid FALSE FALSE FALSE FALSE FALSE
62 "The Grizz 1075 HIGH ARNOLD 95223 2018 3/17/2018 13:47 68476-34-7 Diesel Fuel No. 2 Diesel Fuel No 3 - Flammable and C 3000-5999 1200-2999 365 FALSE TRUE Liquid, Pu FALSE FALSE FALSE FALSE TRUE
62 "The Grizz 1075 HIGH ARNOLD 95223 2018 3/17/2018 13:47 8006-61-9 Petroleum Hydrocarbon Unleaded Pren 3 - Flammable and C 3000-5999 1200-2999 365 FALSE TRUE Liquid, Mi FALSE FALSE FALSE FALSE FALSE
62 "The Grizz 1075 HIGH ARNOLD 95223 2018 3/17/2018 13:47 86290-81-5 Petroleum Hydrocarbon Unleaded Reg 3 - Flammable and C 6000-8999 3000-5999 365 FALSE TRUE Liquid, Mi FALSE FALSE FALSE FALSE FALSE
62 "The Grizz 1075 HIGH ARNOLD 95223 2018 3/17/2018 13:47 74-98-6 Propane Liquefied Petr 2.1 - Flammable Gas 0-2599 Cul 0-2599 Cul 365 FALSE TRUE Gas, Pure FALSE FALSE FALSE FALSE TRUE
170758 "WELL - SJ 1720 SAN REDLAND 92374 2018 2/27/2018 15:17 7781-52-9 Sodium Hypochlorite, 5-17% Bleach 8 - Corrosives (Liquic 120-599 G 120-599 G 365 FALSE TRUE Liquid, Mi FALSE FALSE FALSE FALSE FALSE
272473 #0006 Cal 2404 CALIF SAN FRAN 94115 2018 6/6/2018 22:22 7727-37-9 Nitrogen, Liquid Nitrogen, Liqu 2.2 - Nonflammable 26000-129 2600-1299 365 FALSE TRUE Liquid, Pu FALSE FALSE FALSE FALSE TRUE
272473 #0006 Cal 2404 CALIF SAN FRAN 94115 2018 6/6/2018 22:22 Signet Bio-Based Floor Cleaner/Deodor Signet Bio-Bas 8 - Corrosives (Liquic 0-11 Gallo 0-11 Gallo 365 FALSE TRUE Liquid, Mi FALSE FALSE FALSE FALSE FALSE
272473 #0006 Cal 2404 CALIF SAN FRAN 94115 2018 6/6/2018 22:22 Signet Heavy Duty Floor Cleaner/Degre Signet Heavy 8 - Corrosives (Liquic 0-11 Gallo 0-11 Gallo 365 FALSE TRUE Liquid, Mi FALSE FALSE FALSE FALSE FALSE
272473 #0006 Cal 2404 CALIF SAN FRAN 94115 2018 6/6/2018 22:22 Signet Neutral Disinfectant Signet Neutral 6.1 - Toxic Substance 0-11 Gallo 0-11 Gallo 365 FALSE TRUE Liquid, Mi FALSE FALSE FALSE FALSE FALSE


CalEPA
CalEPA Regulated Site Portal
About
bakers
SAN JOAQUIN FAC MGT- KCL AND PROPERTIE
NORTH OF ROSEDALE HWY
5400 ROSEDALE HWY
BAKERSFIELD CA 93308
BAKER PETROLITE
5135 Boylan St
Bakersfield CA 93308
KGET TV
2120 L ST
BAKERSFIELD CA 93301
FORMER BAKER PETROLITE
5501 DISTRICT BOULEVARD
BAKERSFIELD CA 93313
BAKER RANGE
NAVAL WEAPONS CENTER
CHINA LAKE NWC CA 93555
BAKER PERFORMANCE CHEMICAL INC
5135 BOYLAN
BAKERSFIELD CA 93308
CA CORPORATE CENTER - 4550
4550 CALIFORNIA AVE
KGET TV
2120 L ST
BAKERSFIELD CA 93301
PROFILE MAP COMPLIANCE CHEMICALS
< SHOW LESS INFORMATION
CHEMICAL STORAGE
REPORTING PERIOD
2019
SUBMITTED ON
03/01/2019
CHEMICALS
Name Max Daily Amount / Unit Avg Daily Amount / Unit Days Onsite Physical State(s)
Diesel Fuel No. 2 120-599 Gallons 120-599 Gallons 365 Liquid, Pure

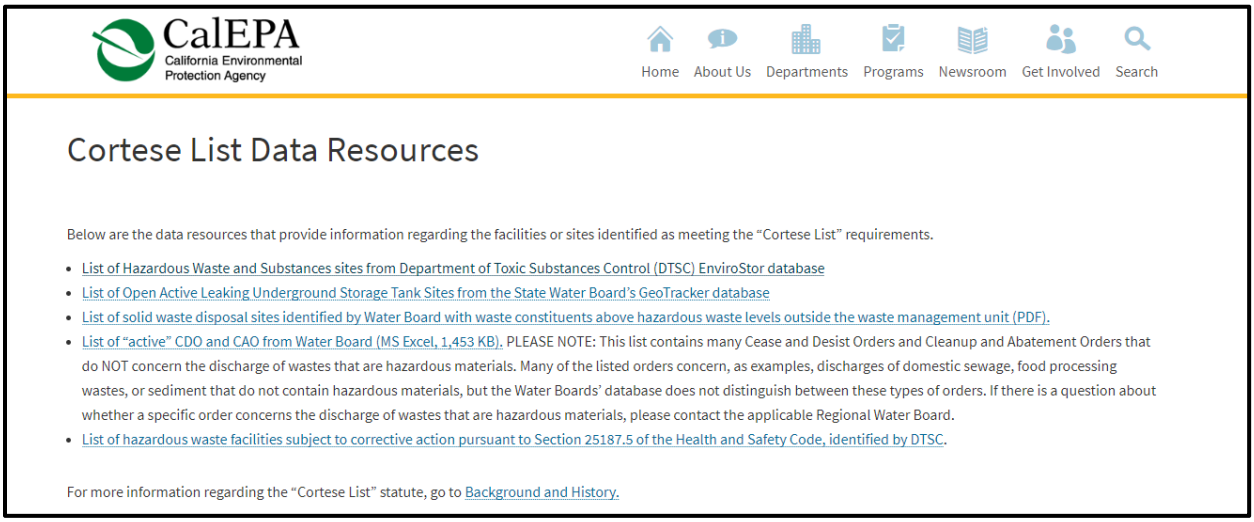

VERIZON WIRELESS: SIXTY FIVE GEE
46412 70TH STREET EAST
LANCASTER CA 93535
PROFILE
MAP
COMPLIANCE
CHEMICALS
100 ft
GEOPOLITICAL
COUNTY
Los Angeles County
CALENVIROSCREEN 3.0 PERCENTILE RANGE
41-45%
SITE CODES
SIC
4812 Radiotelephone communications
NAICS
517210 Wireless Telecommunications Carriers (except Satellite)
ALTERNATE IDS
DUN & BRADSTREET NUMBER 108725003
FACILITIES EXPLORER ID 168674
REGULATORY PROGRAMS
CHEMICAL STORAGE FACILITIES
ENVIRONMENTAL INTEREST START DATE
07/10/2013
LAST INSPECTED
03/16/2017
SOURCE SYSTEM
California Environmental Reporting System
SOURCE SYSTEM ID
10164765
SITE CONTACTS
ENVIRONMENTAL CONTACT
NAME
Environmental Compliance
ADDRESS
15505 Sand Canyon Avenue, MS D-104
Irvine, CA 92618
CUPA DISTRICT
NAME
Los Angeles County Fire
PHONE
(323) 890-4045
ADDRESS

1.2. Cortese List

https://calepa.ca.gov/sitecleanup/corteselist/

- A list released by CalEPA annually, including hazardous waste and substance sites (DSTC), leaking USTs, solid waste disposal sites, "active" CDO and CAO sites.
- Data sources from DTSC, SWRCB, and local enforcement agencies.
- No available spatial or temporal concentration data.

Screenshot of website:

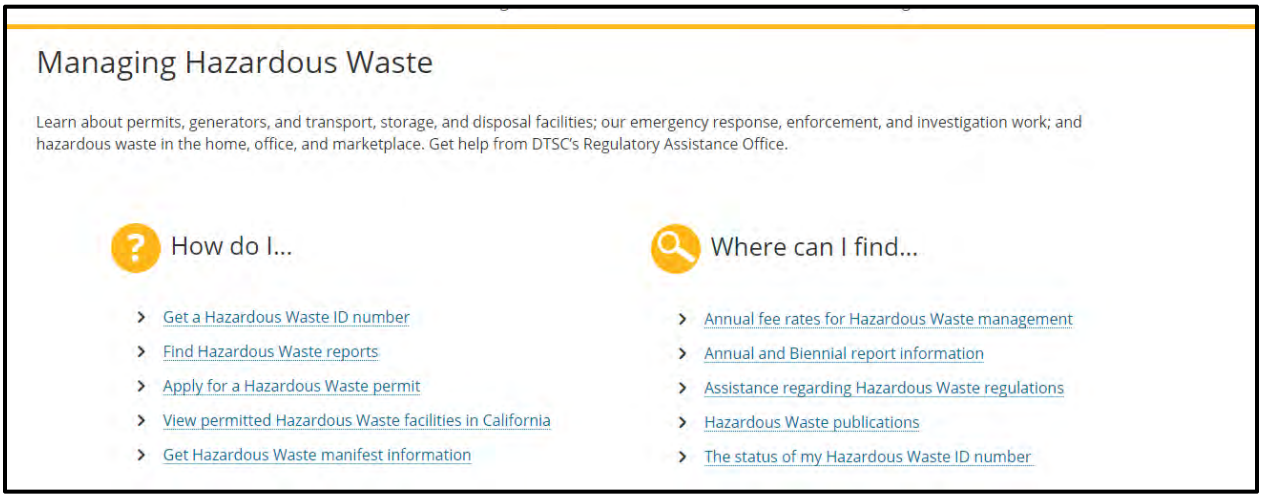


1.3. Managing Hazardous Waste website

https://dtsc.ca.gov/managing-hazardous-waste/

- Hazardous waste sites updates/status/current regulation.

Screenshot of website:

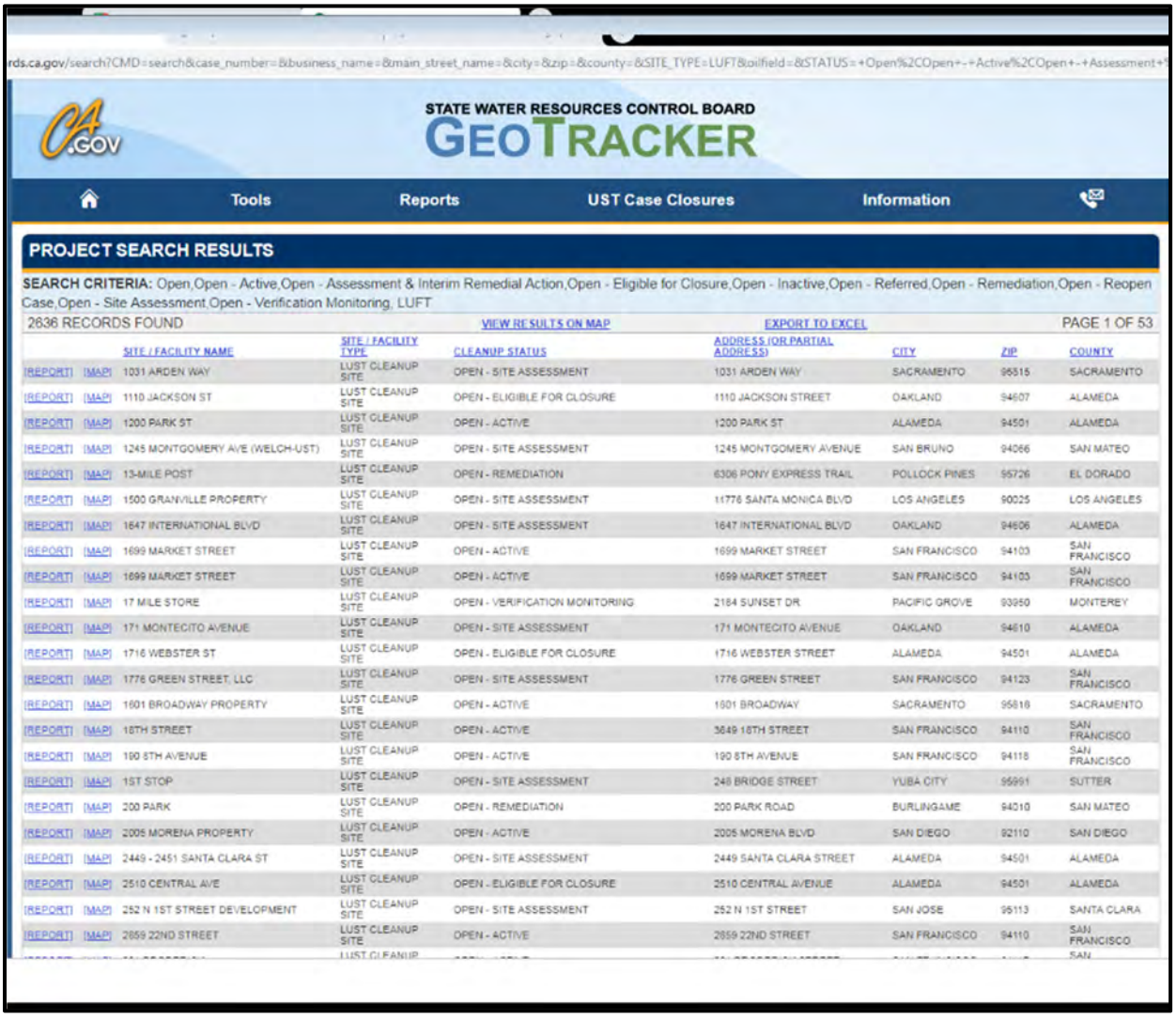


1.4. GeoTracker

https://geotracker.waterboards.ca.gov/map/?global_id=T10000006808

- Lists relevant information about the hazardous sites, including location, substance of spill, clean up timeline, monitoring reports, site investigation reports, regulatory correspondence, etc.
- Chemical data available for each county (as txt file, can be opened with Access or Excel). https://geotracker.waterboards.ca.gov/data_download_by_county
- Temporal and spatial chemical concentration data.

Screenshots of website and selected downloadable data:



rds.ca.gov/search?CMD=search&case_number=&business_name=&main_street_name=&city=&zip=&county=&SITE_TYPE=LUFT&oilfield=&STATUS=+Open%2COpen+-+Active%2COpen+-+Assessment+

STATE WATER RESOURCES CONTROL BOARD

GEOTRACKER

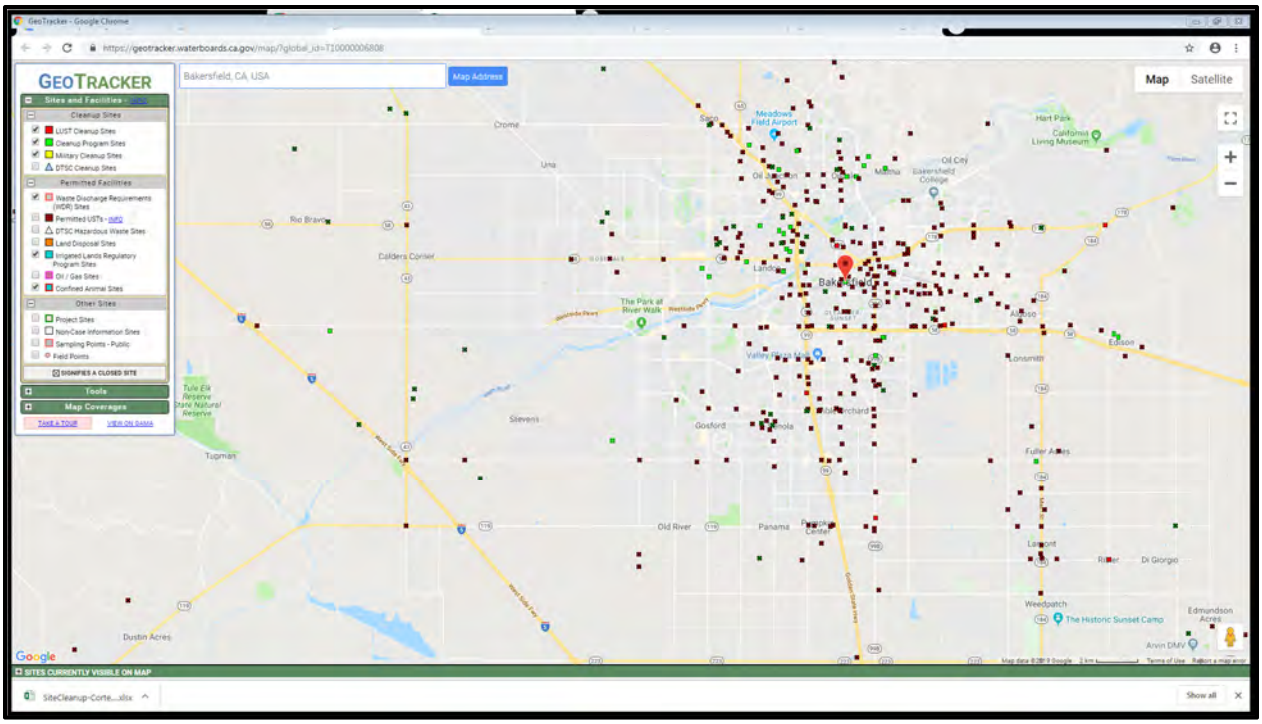
Tools | Reports | UST Case Closures | Information

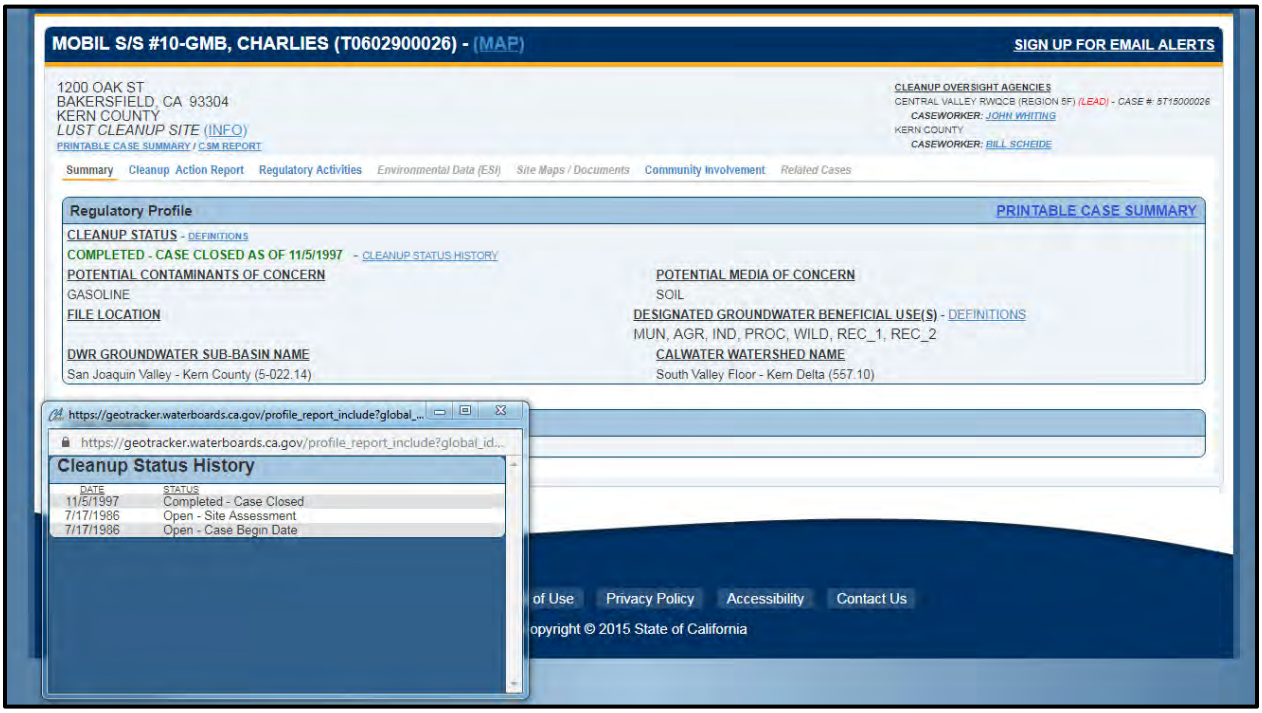
PROJECT SEARCH RESULTS

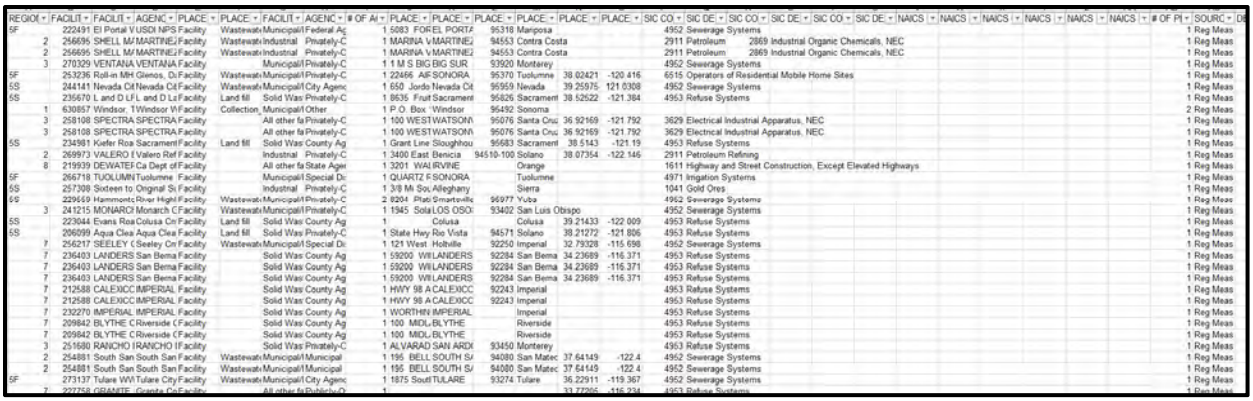
SEARCH CRITERIA: Open,Open - Active,Open - Assessment & Interim Remedial Action,Open - Eligible for Closure,Open - Inactive,Open - Referred,Open - Remediation,Open - Reopen Case,Open - Site Assessment,Open - Verification Monitoring, LUFT

2636 RECORDS FOUND | VIEW RESULTS ON MAP | EXPORT TO EXCEL | PAGE 1 OF 53

		SITE / FACILITY NAME	SITE / FACILITY TYPE	CLEANUP STATUS	ADDRESS (OR PARTIAL ADDRESS)	CITY	ZIP	COUNTY
[REPORT]	[MAP]	1031 ARDEN WAY	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	1031 ARDEN WAY	SACRAMENTO	95815	SACRAMENTO
[REPORT]	[MAP]	1110 JACKSON ST	LUST CLEANUP SITE	OPEN - ELIGIBLE FOR CLOSURE	1110 JACKSON STREET	OAKLAND	94607	ALAMEDA
[REPORT]	[MAP]	1200 PARK ST	LUST CLEANUP SITE	OPEN - ACTIVE	1200 PARK ST	ALAMEDA	94501	ALAMEDA
[REPORT]	[MAP]	1245 MONTGOMERY AVE (WELCH-UST)	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	1245 MONTGOMERY AVENUE	SAN BRUNO	94066	SAN MATEO
[REPORT]	[MAP]	13-MILE POST	LUST CLEANUP SITE	OPEN - REMEDIATION	6306 PONY EXPRESS TRAIL	POLLOCK PINES	95726	EL DORADO
[REPORT]	[MAP]	1500 GRANVILLE PROPERTY	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	11776 SANTA MONICA BLVD	LOS ANGELES	90025	LOS ANGELES
[REPORT]	[MAP]	1647 INTERNATIONAL BLVD	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	1647 INTERNATIONAL BLVD	OAKLAND	94606	ALAMEDA
[REPORT]	[MAP]	1699 MARKET STREET	LUST CLEANUP SITE	OPEN - ACTIVE	1699 MARKET STREET	SAN FRANCISCO	94103	SAN FRANCISCO
[REPORT]	[MAP]	1699 MARKET STREET	LUST CLEANUP SITE	OPEN - ACTIVE	1699 MARKET STREET	SAN FRANCISCO	94103	SAN FRANCISCO
[REPORT]	[MAP]	17 MILE STORE	LUST CLEANUP SITE	OPEN - VERIFICATION MONITORING	2184 SUNSET DR	PACIFIC GROVE	93950	MONTEREY
[REPORT]	[MAP]	171 MONTECITO AVENUE	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	171 MONTECITO AVENUE	OAKLAND	94610	ALAMEDA
[REPORT]	[MAP]	1716 WEBSTER ST	LUST CLEANUP SITE	OPEN - ELIGIBLE FOR CLOSURE	1716 WEBSTER STREET	ALAMEDA	94501	ALAMEDA
[REPORT]	[MAP]	1776 GREEN STREET, LLC	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	1776 GREEN STREET	SAN FRANCISCO	94123	SAN FRANCISCO
[REPORT]	[MAP]	1801 BROADWAY PROPERTY	LUST CLEANUP SITE	OPEN - ACTIVE	1801 BROADWAY	SACRAMENTO	95818	SACRAMENTO
[REPORT]	[MAP]	18TH STREET	LUST CLEANUP SITE	OPEN - ACTIVE	3649 18TH STREET	SAN FRANCISCO	94110	SAN FRANCISCO
[REPORT]	[MAP]	190 8TH AVENUE	LUST CLEANUP SITE	OPEN - ACTIVE	190 8TH AVENUE	SAN FRANCISCO	94118	SAN FRANCISCO
[REPORT]	[MAP]	1ST STOP	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	248 BRIDGE STREET	YUBA CITY	95991	SUTTER
[REPORT]	[MAP]	200 PARK	LUST CLEANUP SITE	OPEN - REMEDIATION	200 PARK ROAD	BURLINGAME	94010	SAN MATEO
[REPORT]	[MAP]	2005 MORENA PROPERTY	LUST CLEANUP SITE	OPEN - ACTIVE	2005 MORENA BLVD	SAN DIEGO	92110	SAN DIEGO
[REPORT]	[MAP]	2449 - 2451 SANTA CLARA ST	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	2449 SANTA CLARA STREET	ALAMEDA	94501	ALAMEDA
[REPORT]	[MAP]	2510 CENTRAL AVE	LUST CLEANUP SITE	OPEN - ELIGIBLE FOR CLOSURE	2510 CENTRAL AVENUE	ALAMEDA	94501	ALAMEDA
[REPORT]	[MAP]	252 N 1ST STREET DEVELOPMENT	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	252 N 1ST STREET	SAN JOSE	95113	SANTA CLARA
[REPORT]	[MAP]	2859 22ND STREET	LUST CLEANUP SITE	OPEN - ACTIVE	2859 22ND STREET	SAN FRANCISCO	94110	SAN FRANCISCO


GeoTracker - Google Chrome
https://geotracker.waterboards.ca.gov/map/?global_id=T10000006808
GEOTRACKER
Bakersfield, CA, USA
Map Address
Map
Satellite
Sites and Facilities
Cleanup Sites
LUST Cleanup Sites
Cleanup Program Sites
Military Cleanup Sites
DTSC Cleanup Sites
Permitted Facilities
Waste Discharge Requirements (WDR) Sites
Permitted USTs - INFO
DTSC Hazardous Waste Sites
Land Disposal Sites
Irrigated Lands Regulatory Program Sites
Oil / Gas Sites
Confined Animal Sites
Other Sites
Project Sites
Non-Case Information Sites
Sampling Points - Public
Field Points
SIGNIFIES A CLOSED SITE
Tools
Map Coverages
TAKE A TOUR
VIEW ON DATA4
Crome
Meadows Field Airport
Hart Park
Oil City
Bakersfield College
Rio Bravo
Calders Corner
The Park at River Walk
Lamont
Edison
Lonsmith
Tule Elk Reserve
Stevens
Gosford
Tupman
Old River
Panama
Di Giorgio
Weedpatch
The Historic Sunset Camp
Edmundson Acres
Dustin Acres
Arvin DMV
Google
SITES CURRENTLY VISIBLE ON MAP
SiteCleanup-Corte....xlsx
Show all


MOBIL S/S #10-GMB, CHARLIES (T0602900026) - (MAP)
SIGN UP FOR EMAIL ALERTS
1200 OAK ST
BAKERSFIELD, CA 93304
KERN COUNTY
LUST CLEANUP SITE (INFO)
PRINTABLE CASE SUMMARY / CSM REPORT
CLEANUP OVERSIGHT AGENCIES
CENTRAL VALLEY RWQCB (REGION 5F) (LEAD) - CASE #: 5T15000026
CASEWORKER: JOHN WHITING
KERN COUNTY
CASEWORKER: BILL SCHEIDE
Summary
Cleanup Action Report
Regulatory Activities
Environmental Data (ESI)
Site Maps / Documents
Community Involvement
Related Cases
Regulatory Profile
PRINTABLE CASE SUMMARY
CLEANUP STATUS - DEFINITIONS
COMPLETED - CASE CLOSED AS OF 11/5/1997 - CLEANUP STATUS HISTORY
POTENTIAL CONTAMINANTS OF CONCERN
GASOLINE
POTENTIAL MEDIA OF CONCERN
SOIL
FILE LOCATION
DESIGNATED GROUNDWATER BENEFICIAL USE(S) - DEFINITIONS
MUN, AGR, IND, PROC, WILD, REC_1, REC_2
DWR GROUNDWATER SUB-BASIN NAME
San Joaquin Valley - Kern County (5-022.14)
CALWATER WATERSHED NAME
South Valley Floor - Kern Delta (557.10)
https://geotracker.waterboards.ca.gov/profile_report_include?global_...
https://geotracker.waterboards.ca.gov/profile_report_include?global_id...
Cleanup Status History
DATE
STATUS
11/5/1997
Completed - Case Closed
7/17/1986
Open - Site Assessment
7/17/1986
Open - Case Begin Date
of Use
Privacy Policy
Accessibility
Contact Us
opyright © 2015 State of California



REGIOI	FACILIT	FACILIT	AGENC	PLACE	PLACE	FACILIT	AGENC	# OF AI	PLACE	PLACE	PLACE	PLACE	PLACE	PLACE	SIC CO	SIC DE	SIC CO	SIC DE	SIC CO	SIC DE	NAICS	NAICS	NAICS	NAICS	NAICS	NAICS	# OF PI	SOURC	DE
5F	222491	El Portal V	USDI NPS	Facility	Wastewat	Municipal/I	Federal Ag	1	5083	FOREL	PORTA	95318	Mariposa			4952	Sewerage Systems											1	Reg Meas	
	2	266695	SHELL M	MARTINEZ	Facility	Wastewat	Industrial	Privately-C	1	MARINA	V	MARTINEZ	94553	Contra Costa			2911	Petroleum	2869	Industrial Organic Chemicals, NEC									1	Reg Meas	
	2	266695	SHELL M	MARTINEZ	Facility	Wastewat	Industrial	Privately-C	1	MARINA	V	MARTINEZ	94553	Contra Costa			2911	Petroleum	2869	Industrial Organic Chemicals, NEC									1	Reg Meas	
	3	270329	VENTANA	VENTANA	Facility		Municipal/I	Privately-C	1	1	M S	BIG	BIG SUR		93920	Monterey			4952	Sewerage Systems								1	Reg Meas	
5F		253236	Roll-in MH	Glenns, D	Facility	Wastewat	Municipal/I	Privately-C	1	22466	AR	SONORA			95370	Tuolumne	38.02421	-120.416	6515	Operators of Residential Mobile Home Sites									1	Reg Meas	
5S		244141	Nevada Cit	Nevada Cit	Facility	Wastewat	Municipal/I	City Agenc	1	650	Jordo	Nevada Cit			95959	Nevada	39.25975	121.0308	4952	Sewerage Systems									1	Reg Meas	
5S		235670	L and D LF	L and D La	Facility		Land fill	Solid Was	Privately-C	1	8635	Fruit	Sacrament		95826	Sacrament	38.52522	-121.384	4953	Refuse Systems									1	Reg Meas	
	1	630857	Windsor, T	Windsor W	Facility		Collection,	Municipal/I	Other	1	P O Box	Windsor			95492	Sonoma													2	Reg Meas	
	3	258108	SPECTRA	SPECTRA	Facility			All other fa	Privately-C	1	100	WEST	WATSON		95076	Santa Cru	36.92169	-121.792	3629	Electrical Industrial Apparatus, NEC									1	Reg Meas	
	3	258108	SPECTRA	SPECTRA	Facility			All other fa	Privately-C	1	100	WEST	WATSON		95076	Santa Cru	36.92169	-121.792	3629	Electrical Industrial Apparatus, NEC									1	Reg Meas	
5S		234981	Kiefer Roa	Sacrament	Facility		Land fill	Solid Was	County Ag	1	Grant Line	Sloughhou			95683	Sacrament	38.5143	-121.19	4953	Refuse Systems									1	Reg Meas	
	2	269973	VALERO E	Valero Ref	Facility			Industrial	Privately-C	1	3400	East	Benicia	94510-100	Solano		38.07354	-122.146	2911	Petroleum Refining									1	Reg Meas	
	8	219939	DEWATEF	Ca Dept of	Facility			All other fa	State Ager	1	3201	WALI	IRVINE			Orange			1611	Highway and Street Construction, Except Elevated Highways									1	Reg Meas	
5F		266718	TUOLUMN	Tuolumne	Facility			Municipal/I	Special Dis	1	QUARTZ	F	SONORA			Tuolumne			4971	Irrigation Systems									1	Reg Meas	
5S		257308	Sixteen to	Original Si	Facility			Industrial	Privately-C	1	3/8 Mi	So	Allegheny			Sierra			1041	Gold Ores									1	Reg Meas	
5S		229669	Hammonc	River High	Facility		Wastewat	Municipal/I	Privately-C	2	8204	Plat	Smartville		96977	Yuba			4952	Sewerage Systems									1	Reg Meas	
	3	241215	MONARCI	Monarch C	Facility		Wastewat	Municipal/I	Privately-C	1	1945	Sola	LOS OSO		93402	San Luis Obispo			4952	Sewerage Systems									1	Reg Meas	
5S		223044	Evans Roa	Colusa Cn	Facility		Land fill	Solid Was	County Ag	1		Colusa				Colusa	39.21433	-122.009	4953	Refuse Systems									1	Reg Meas	
5S		206099	Aqua Clea	Aqua Clea	Facility		Land fill	Solid Was	Privately-C	1	State Hwy	Rio Vista			94571	Solano	38.21272	-121.806	4953	Refuse Systems									1	Reg Meas	
	7	256217	SEELEY C	Seeley Cn	Facility		Wastewat	Municipal/I	Special Dis	1	121 West	Holtville			92250	Imperial	32.79328	-115.698	4952	Sewerage Systems									1	Reg Meas	
	7	236403	LANDERS	San Berna	Facility			Solid Was	County Ag	1	59200	WILLA	LANDERS		92284	San Berna	34.23689	-116.371	4953	Refuse Systems									1	Reg Meas	
	7	236403	LANDERS	San Berna	Facility			Solid Was	County Ag	1	59200	WILLA	LANDERS		92284	San Berna	34.23689	-116.371	4953	Refuse Systems									1	Reg Meas	
	7	236403	LANDERS	San Berna	Facility			Solid Was	County Ag	1	59200	WILLA	LANDERS		92284	San Berna	34.23689	-116.371	4953	Refuse Systems									1	Reg Meas	
	7	212588	CALEXICC	IMPERIAL	Facility			Solid Was	County Ag	1	HWY 98	A	CALEXICC		92243	Imperial			4953	Refuse Systems									1	Reg Meas	
	7	212588	CALEXICC	IMPERIAL	Facility			Solid Was	County Ag	1	HWY 98	A	CALEXICC		92243	Imperial			4953	Refuse Systems									1	Reg Meas	
	7	232270	IMPERIAL	IMPERIAL	Facility			Solid Was	County Ag	1	WORTHIN		IMPERIAL			Imperial			4953	Refuse Systems									1	Reg Meas	
	7	209842	BLYTHE C	Riverside C	Facility			Solid Was	County Ag	1	100	MIDL	BLYTHE			Riverside			4953	Refuse Systems									1	Reg Meas	
	7	209842	BLYTHE C	Riverside C	Facility			Solid Was	County Ag	1	100	MIDL	BLYTHE			Riverside			4953	Refuse Systems									1	Reg Meas	
	3	251680	RANCHO I	RANCHO I	Facility			Solid Was	Privately-C	1	ALVARAD		SAN ARDO		93450	Monterey			4953	Refuse Systems									1	Reg Meas	
	2	254881	South San	South San	Facility		Wastewat	Municipal/I	Municipal	1	195	BELL	SOUTH SA		94080	San Mateo	37.64149	-122.4	4952	Sewerage Systems									1	Reg Meas	
	2	254881	South San	South San	Facility		Wastewat	Municipal/I	Municipal	1	195	BELL	SOUTH SA		94080	San Mateo	37.64149	-122.4	4952	Sewerage Systems									1	Reg Meas	
5F		273137	Tulare WV	Tulare City	Facility		Wastewat	Municipal/I	City Agenc	1	1875	South	TULARE		93274	Tulare	36.22911	-119.367	4952	Sewerage Systems									1	Reg Meas	
	7	227758	GRANITE	Granite Ce	Facility			All other fa	Publicly-O	1							33.77395	-116.234	4953	Refuse Systems									1	Reg Meas	

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Tools **Reports** **UST Case Closures** **Information**

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Note: To download GEO_REPORTs and other documents, please go to the Site Maps / Documents tab for a case and right-click to save each individual document to your local machine

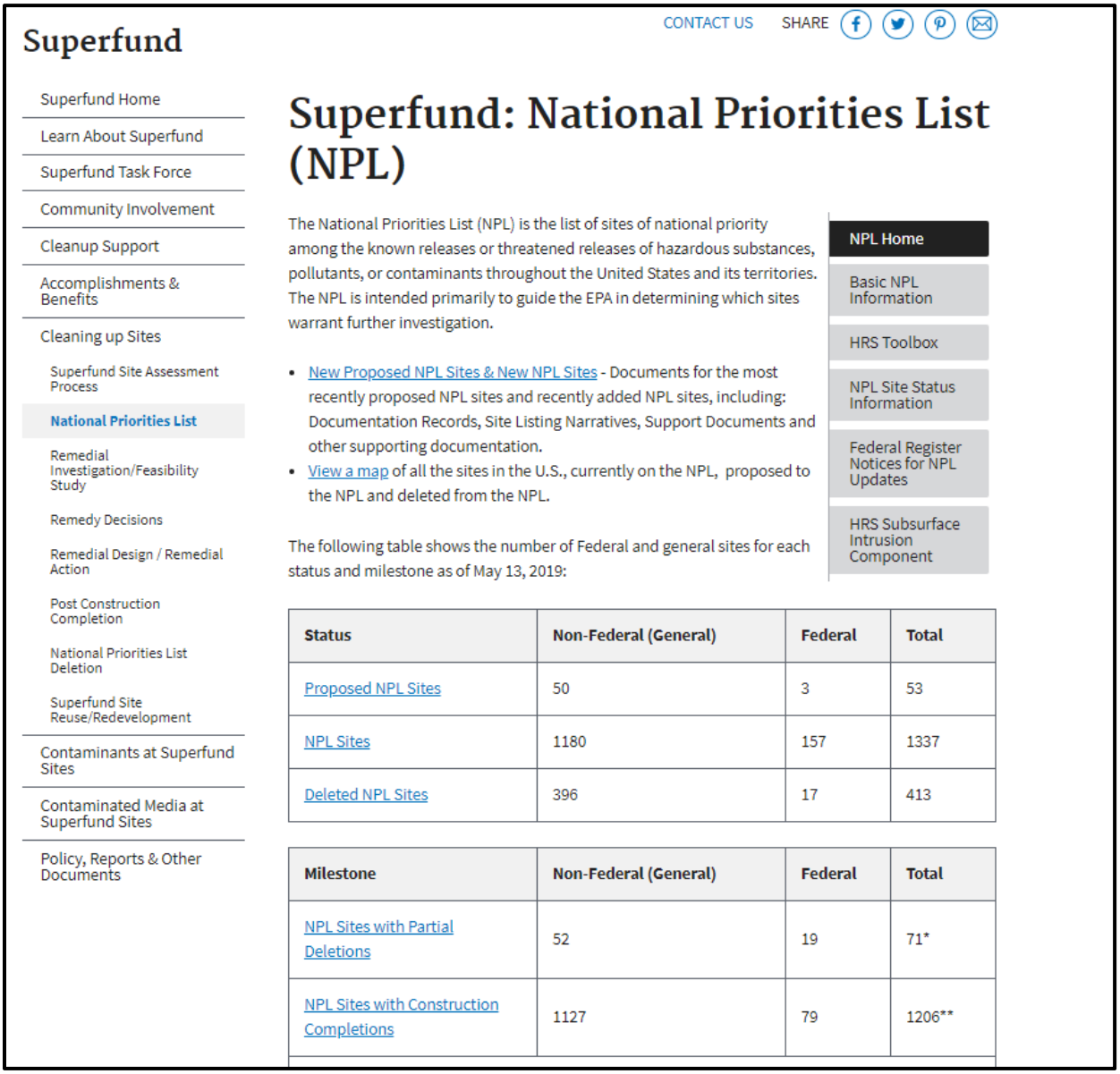
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Kern	GAGW10000018	NCL-2-02	11/21/2014	930	BTSC	NCL-2-02	W	94042-1	TAIC	94042-2	SW8260B	220753	########	N	BZ	0	ND	0.25	2	UG/L	1	
Kern	GAGW10000018	NCL-2-02	11/21/2014	930	BTSC	NCL-2-02	W	94042-1	TAIC	94042-2	SW8260B	220753	########	N	XYLO	0	ND	0.25	2	UG/L	1	
Kern	GAGW10000018	NCL-2-02	11/21/2014	930	BTSC	NCL-2-02	W	94042-1	TAIC	94042-2	CALCRAI	165284	########	N	RA226228	0.691	=	0.377	5	PCI/L	1	
Kern	GAGW10000018	NCL-28E4	9/12/2014	1000	BTSC	NCL-28E4	W	88029-1	TAIC	88029-2	A2320B	205687	########	N	HCO3	0	ND	4.8	4.8	MG/L	1	
Kern	GAGW10000018	NCL-2-02	5/10/2016	908	BTST	Monitorin	W	NA	BCLB	1613127-0	SW6010B	BZE1558	########	N	CR	1.6	=	1.1	10	UG/L	1	J,DX
Kern	GAGW10000018	NCL-2-02	5/10/2016	908	BTST	Monitorin	W	NA	BCLB	1613127-0	SW8260B	BZE1009	########	N	CTCL	0	ND	0.18	0.5	UG/L	1	U
Kern	GAGW10000018	NCL-28E4	5/10/2016	1034	BTST	Monitorin	W	NA	BCLB	1613128-0	SW8260B	BZE1009	########	N	DCBZ14	0	ND	0.062	0.5	UG/L	1	U
Kern	GAGW10000018	NCL-28E4	5/10/2016	1034	BTST	Monitorin	W	NA	BCLB	1613128-0	SW6010B	BZE1558	########	N	PB	0	ND	8	100	UG/L	2	U,DG
Kern	GAGW10000018	NCL-2-02	5/1/2015	1147	BTSC	North Col	W	1085511	TAIC	108551-1_	SW6010B	253062	5/6/2015	N	LI	0	ND	0.03	0.05	MG/L	1	
Kern	GAGW10000018	NCL-28E4	5/1/2015	1247	BTSC	North Col	W	1085511	TAIC	108551-2_	E300_28	252543	5/2/2015	N	BR	2.3	=	0.25	0.5	MG/L	1	
Kern	GAGW10000018	NCL-28E2	12/12/2018	1022	GMCE	2.80E+03	W	NA	BCLB	1838776-0	SW6010B	B032793	########	L	CD	0	ND	2.2	20	UG/L	2	U,DG

2. USEPA Superfund: National Priorities List (NPL)

https://www.epa.gov/superfund/superfund-national-priorities-list-npl

- USEPA lList all current, proposed or deleted sites of national priority resulting from known or threatened releases of hazardous substances, pollutants or contaminants.
- No downloadable data.
- Graphical display and lists all current and proposed NPL sites, sortable by state, regions, etc.
- Site descriptions include summary reports.

Screenshots of website:



Superfund

CONTACT US SHARE

- Superfund Home
- Learn About Superfund
- Superfund Task Force
- Community Involvement
- Cleanup Support
- Accomplishments & Benefits
- Cleaning up Sites
  - Superfund Site Assessment Process
  - National Priorities List
  - Remedial Investigation/Feasibility Study
  - Remedy Decisions
  - Remedial Design / Remedial Action
  - Post Construction Completion
  - National Priorities List Deletion
  - Superfund Site Reuse/Redevelopment
- Contaminants at Superfund Sites
- Contaminated Media at Superfund Sites
- Policy, Reports & Other Documents

Superfund: National Priorities List (NPL)

The National Priorities List (NPL) is the list of sites of national priority among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and its territories. The NPL is intended primarily to guide the EPA in determining which sites warrant further investigation.

- New Proposed NPL Sites & New NPL Sites - Documents for the most recently proposed NPL sites and recently added NPL sites, including: Documentation Records, Site Listing Narratives, Support Documents and other supporting documentation.
- View a map of all the sites in the U.S., currently on the NPL, proposed to the NPL and deleted from the NPL.

NPL Home
Basic NPL Information
HRS Toolbox
NPL Site Status Information
Federal Register Notices for NPL Updates
HRS Subsurface Intrusion Component

The following table shows the number of Federal and general sites for each status and milestone as of May 13, 2019:

Status	Non-Federal (General)	Federal	Total
Proposed NPL Sites	50	3	53
NPL Sites	1180	157	1337
Deleted NPL Sites	396	17	413

Milestone	Non-Federal (General)	Federal	Total
NPL Sites with Partial Deletions	52	19	71*
NPL Sites with Construction Completions	1127	79	1206**



California (98 sites)

Site Name	City	Site EPA ID	Listing Date	Site Score	Federal Facility Indicator	Additional Information	Site Location
Advanced Micro Devices, Inc.	Sunnyvale	CAD048634059	06/10/1986	37.93	No	• Site Listing Narrative • Site Progress Profile • Federal Register Notice (PDF) (34 pp, 369 K)	Site Location

Superfund Site:

CONTACT US

- Superfund Home
- **This Site's Home Page**
- Site Contacts
- Cleanup Activities
- Health & Environment
- Stay Updated, Get Involved
- Redevelopment
- Site Documents & Data
- View Site on Map

ADVANCED MICRO DEVICES, INC. SUNNYVALE, CA

Announcements and Key Topics

EPA continues indoor air sampling for TCE vapors in homes and school buildings near the Site and is overseeing the installation of more than 20 mitigation systems in residences and classrooms affected by vapor intrusion.

Background

The former Advanced Micro Devices, Inc. 901/902 Thompson Place Superfund Site (Site) covers 6 acres in Sunnyvale, California. AMD designed and fabricated semiconductor devices at two adjoined low-rise buildings at ...
Continue reading background »

Site Contacts

Community Involvement Coordinator
Alejandro Diaz
(415) 972-3242

Remedial Project Manager
Melanie Morash
(415) 972-3050

Site Location

Street Address:
901 THOMPSON PL
SUNNYVALE, CA 94086

Sign up for this Superfund site's mailing list

3. California EPA – Information on Drinking Water Quality

3.1. Water Quality Analysis Database Files

https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/EDTlibrary.html

- Electronic Data Transfer (EDT) Library, a link to Schedules for Upcoming Water Quality Monitoring, files for the Division of Drinking Water's (DDW's) water quality analyses database, and county small water system water quality data files.
- Statewide current and historical chemical data from water suppliers.
- Downloadable data, including temporal data.
- Chemical data from April 1947 to current; data format: dbf, can be opened in Access; supporting database files are needed to interpret the data.

Screenshots of website and downloadable data:

Drinking water analyses reported directly from laboratories - Last Update May 1, 2019.

- **CHEMICAL.ZIP** contains chemical data from January 1, 2013 through this month
- **CHEMHIST.ZIP** contains chemical data from January 1, 2007 through December 31, 2012
- **CHEMARCH.ZIP** contains chemical data from January 1, 2000 through December 31, 2006
- **CHEMXARC.ZIP** contains chemical data from April 1974 through December 31, 1999

Supporting database files - Last Update May 1, 2019.

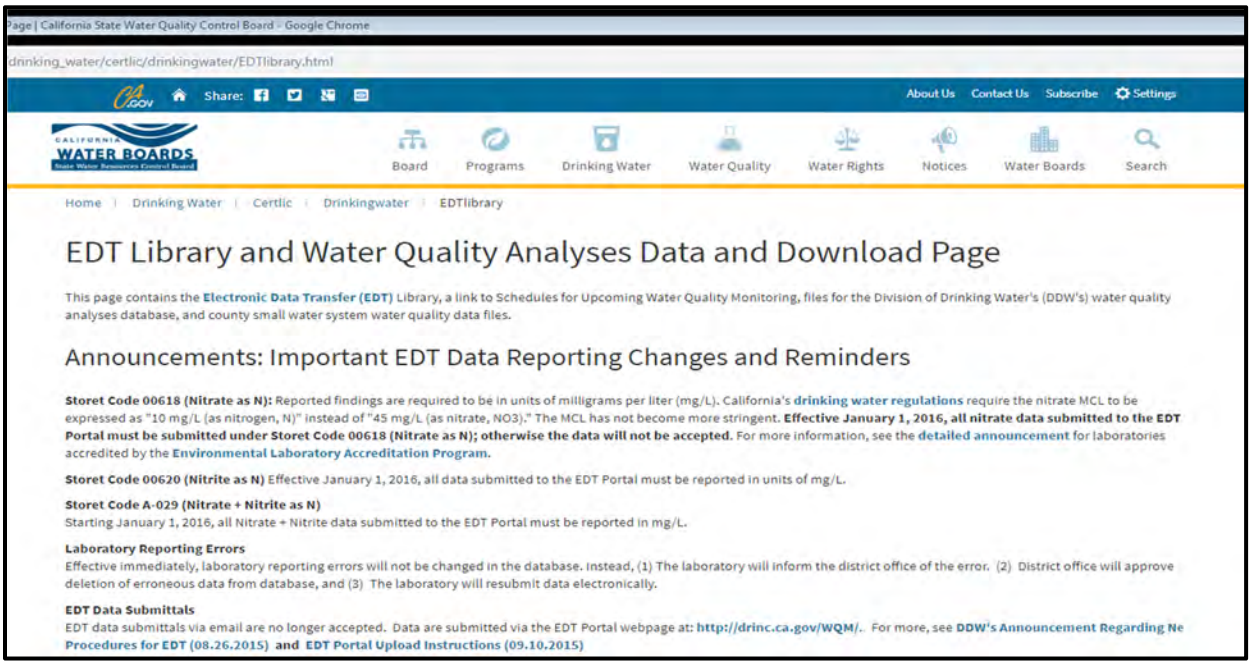
- Drinking Water Source identification number (PS Code), name and type **(SITELOC.DBF)**
- Water Systems identification number, name, and address **(WATSYS.DBF)**
- Laboratories reporting water quality analyses **(LAB.DBF)**
- Chemical (Storet) Reported **(STORET.DBF) (Pre 2016 STORET - .zip version)**
- Word file **WQM Documentation.doc** provides additional description and explanation of the individual files available for downloading - Last Update June 1, 2017

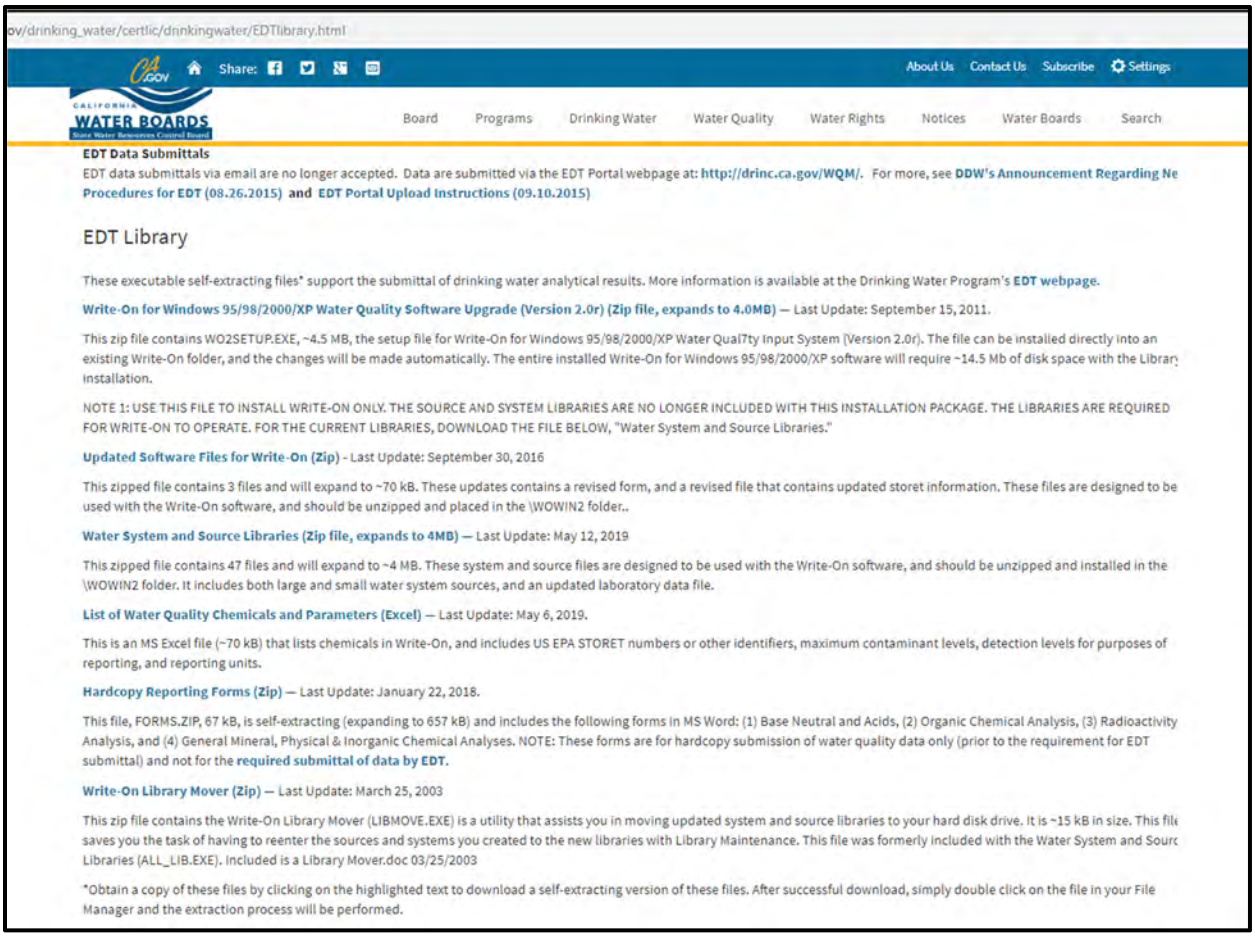
chemhist

PRIM_STA_C	SAMP_DATE	SAMP_TIME	LAB_NUM	ANADATE	INDATE	METHOD	INBY	SPECIAL	STORE_NUM	XMOD	FINDING
0103039-002	7/26/2010	1257	1120	7/26/2010	8/6/2010		#	S	71850		62
0103039-004	1/18/2007	1200	4470	1/31/2007	2/26/2007		A	S	01501		1.63
0103039-004	1/18/2007	1200	4470	1/31/2007	2/26/2007		A	S	01502		0.98
0103039-004	12/6/2007	1155	4790	12/12/2007	1/11/2008		#	S	A-031	<	4
0103039-004	1/29/2008	1140	1675	1/29/2008	2/7/2008		A	S	71850	<	0
0103039-004	5/28/2008	1200	1675	5/28/2008	6/9/2008		A	S	71850	<	0
0103039-004	6/5/2008	1255	1675	6/5/2008	6/11/2008		A	S	00081		1
0103039-004	6/5/2008	1255	1675	6/5/2008	6/11/2008		A	S	00086		1
0103039-004	6/5/2008	1255	1675	6/5/2008	6/11/2008		A	S	82079		0.06
0103039-004	6/5/2008	1255	4790	6/13/2008	7/10/2008		#	S	A-031	<	4
0103040-007	2/7/2007	1330	4470	2/27/2007	3/21/2007		A	S	01501		4.06
0103040-007	2/7/2007	1330	4470	2/27/2007	3/21/2007		A	S	01502		1.21
0103040-007	2/7/2007	1330	4470	2/27/2007	3/21/2007		A	S	11501	<	0
0103040-007	2/7/2007	1330	4470	2/27/2007	3/21/2007		A	S	11502		0.5

chemical

PRIM_STA_C	SAMP_DATE	SAMP_TIME	LAB_NUM	ANADATE	INDATE	METHOD	INBY	SPECIAL	STORE_NUM	XMOD	FINDING
0103039-004	11/22/2017	0848	4790	11/22/2017	11/30/2017	SM 212	#	S	00081	<	3
0103039-004	11/22/2017	0848	4790	11/22/2017	11/30/2017	SM 215	#	S	00086	<	1
0103039-004	11/22/2017	0848	4790	11/29/2017	11/30/2017	SM 251	#	S	00095		550
0103039-004	11/22/2017	0848	4790	11/29/2017	11/30/2017	SM4500	#	S	00403		8.1
0103039-004	11/22/2017	0848	4790	11/22/2017	11/30/2017	300.0	#	S	00618		5.7
0103040-007	8/21/2013	1442	1675	8/21/2013	9/9/2013		A	S	71850		15
0103040-007	8/4/2014	1238	1644	8/4/2014	8/26/2014		A	S	71850		14
0103040-007	7/15/2015	1306	1675	7/15/2015	8/6/2015		A	S	71850		14
0103040-007	7/15/2015	1307	1644	7/18/2015	7/27/2015		A	S	01032	<	1
0103040-007	7/12/2016	1315	1675	7/12/2016	7/22/2016	E300.0	A	S	00618		3.7
0103040-007	8/15/2016	1235	2416	8/21/2016	9/2/2016	E552.2	A	S	77288		0
0103040-007	8/15/2016	1235	2416	8/21/2016	9/2/2016	E552.2	A	S	82721		2.11
0103040-007	8/15/2016	1235	2416	8/21/2016	9/2/2016	E552.2	A	S	82723		0
0103040-007	8/15/2016	1235	2416	8/21/2016	9/2/2016	E552.2	A	S	A-041		0
0103040-007	8/15/2016	1235	2416	8/21/2016	9/2/2016	E552.2	A	S	A-042		0
0103040-007	8/15/2016	1235	2416	8/21/2016	9/2/2016	E552.2	A	S	A-049		2.11
0103040-007	8/15/2016	1237	2416	8/21/2016	9/2/2016	E524.2	A	S	32101		0.67
0103040-007	8/15/2016	1237	2416	8/21/2016	9/2/2016	E524.2	A	S	32104		2.29





EDT Information

EDT Data Submittal - FAQ
EDT - Main Page

Information about Chemicals and Contaminants

Chemicals and Contaminants in Drinking Water

Schedules of Upcoming Monitoring

Monitoring Schedules

More Information

Drinking Water Statutes and Regulations
Division of Drinking Water

Additional Information for Laboratories

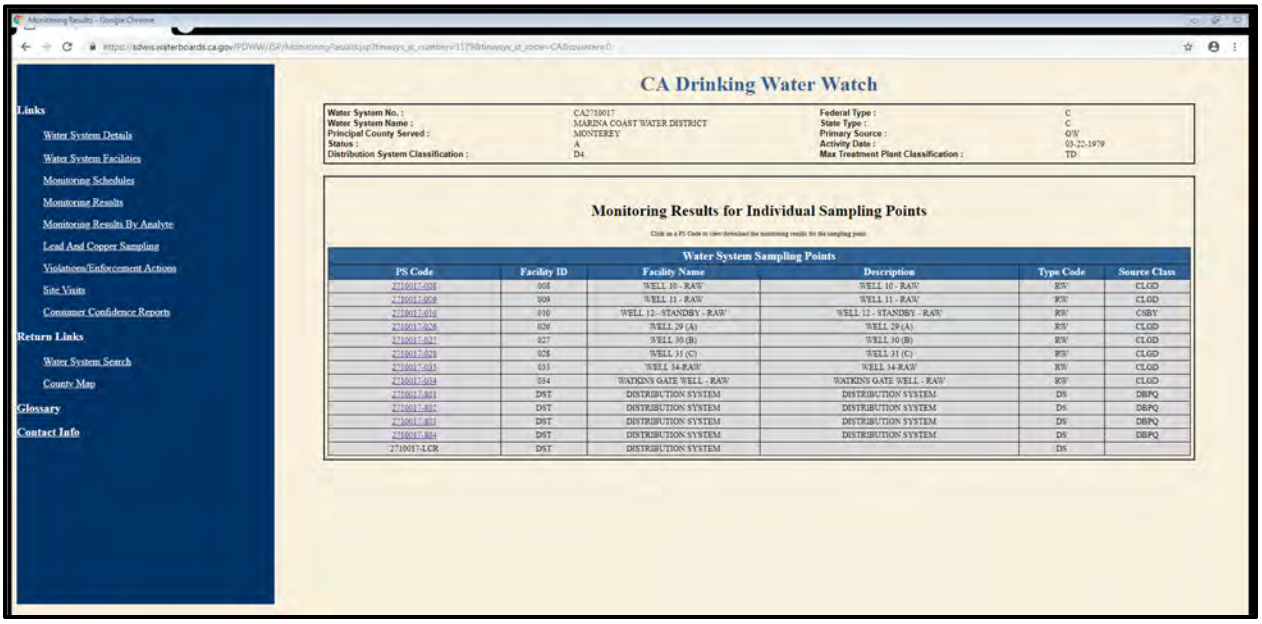
Additional Information for Laboratories

3.2. Drinking Water Watch

https://sdwis.waterboards.ca.gov/PDWW/

- This website provides a variety of chemical data (including many uncommon chemicals) for wells and distribution systems. Includes historical data (at least dated back in the 1980s).
- Data are available in the pdf form (convertible to Excel).
- With well locations and temporal changes in chemical concentrations, a trendline analysis is feasible.

Screenshots of website and downloadable data:

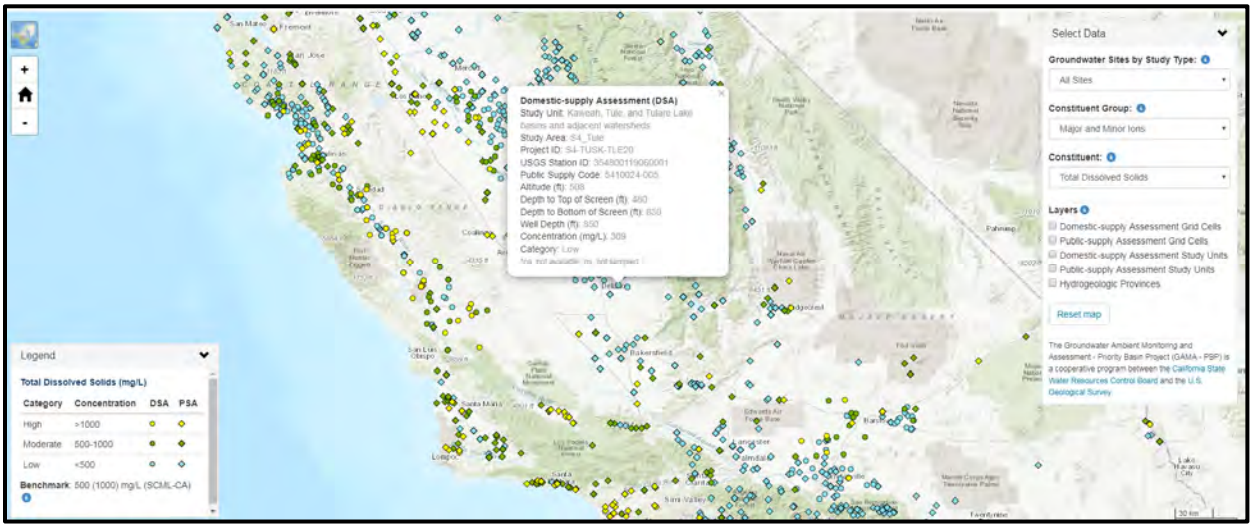


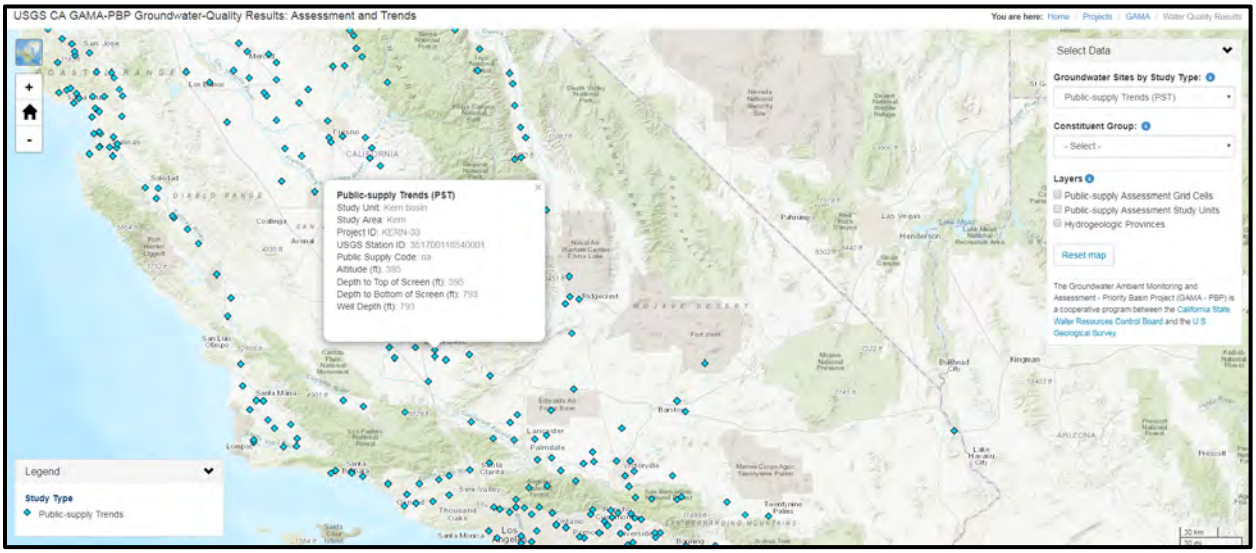
3.3. GAMA-PBP Groundwater-Quality Results: Assessment and Trends

https://ca.water.usgs.gov/projects/gama/water-quality-results/

- From USGS California Water Science Center, Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project (PBP)
- Map viewer showing concentrations and trends of many constituents, such as metal ions, nutrients, TDS, pesticides, VOCs, age-dating tracers, radioactivity, etc.
- Concentrations are provided and categorized as different ranges, with color code. No date is associated with the measurements.
- No downloadable data.

Screenshots of website:






USGS CA GAMA-PBP Groundwater-Quality Results: Assessment and Trends
You are here: Home / Projects / GAMA / Water Quality Results
Domestic-supply Trends (DST)
Study Unit: Monterey Bay and Salinas Valley basins and adjacent watersheds
Study Area: S2_Highlands
Project ID: S-MS-H24
USGS Station ID: 353830120215001
Public Supply Code: na
Altitude (ft): 1112
Depth to Top of Screen (ft): 300
Depth to Bottom of Screen (ft): 500
Well Depth (ft): 500
Select Data
Groundwater Sites by Study Type:
Domestic-supply Trends (DST)
Constituent Group:
- Select -
Layers
Domestic-supply Assessment Grid Cells
Domestic-supply Assessment Study Units
Hydrogeologic Provinces
Reset map
The Groundwater Ambient Monitoring and Assessment - Priority Basin Project (GAMA - PBP) is a cooperative program between the California State Water Resources Control Board and the U.S. Geological Survey.
Legend
Study Type
Domestic-supply Trends
DOI Privacy Policy | Legal | Accessibility | Site Map | Contact USGS

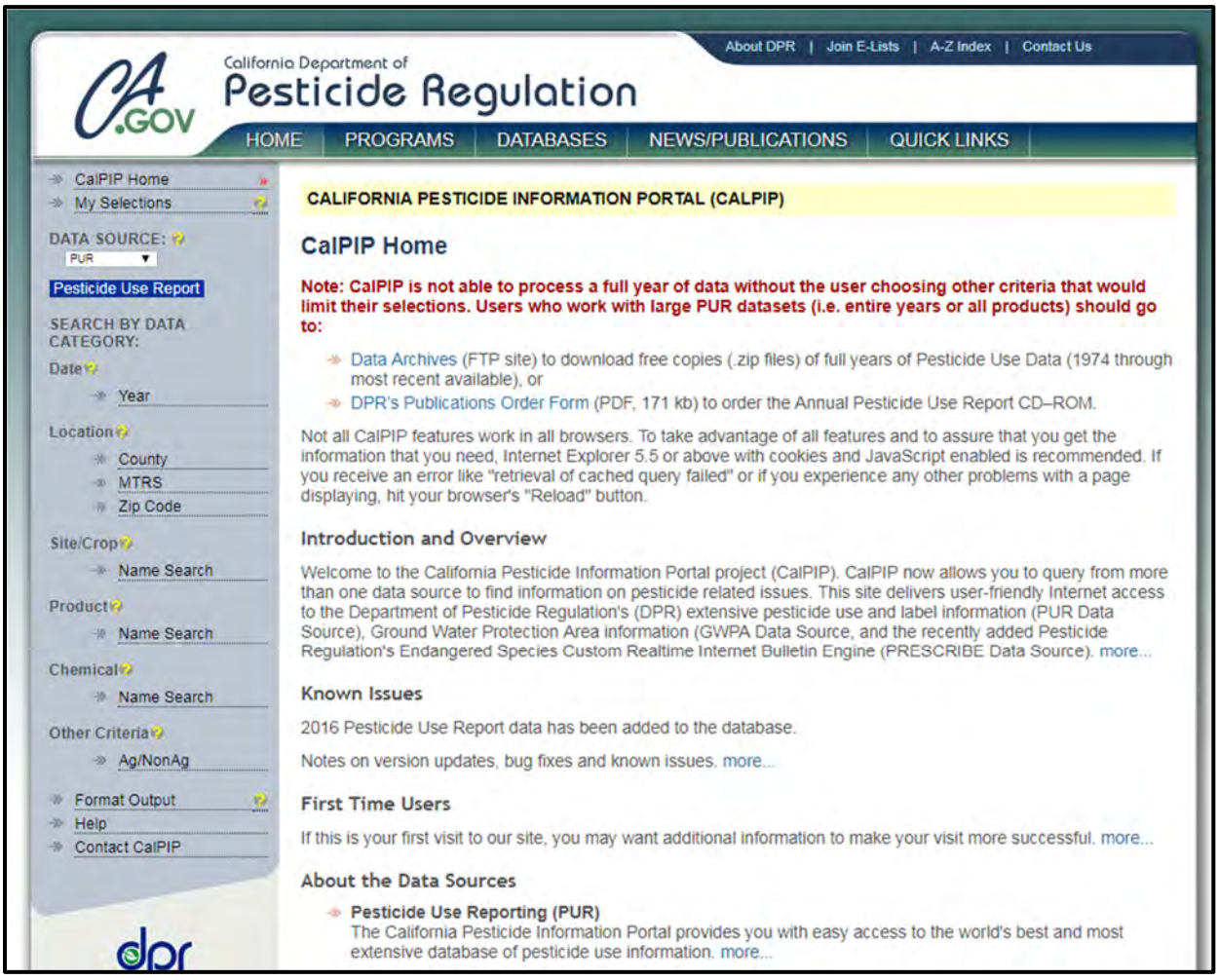
4. Information on Pesticide Use pertaining to groundwater quality

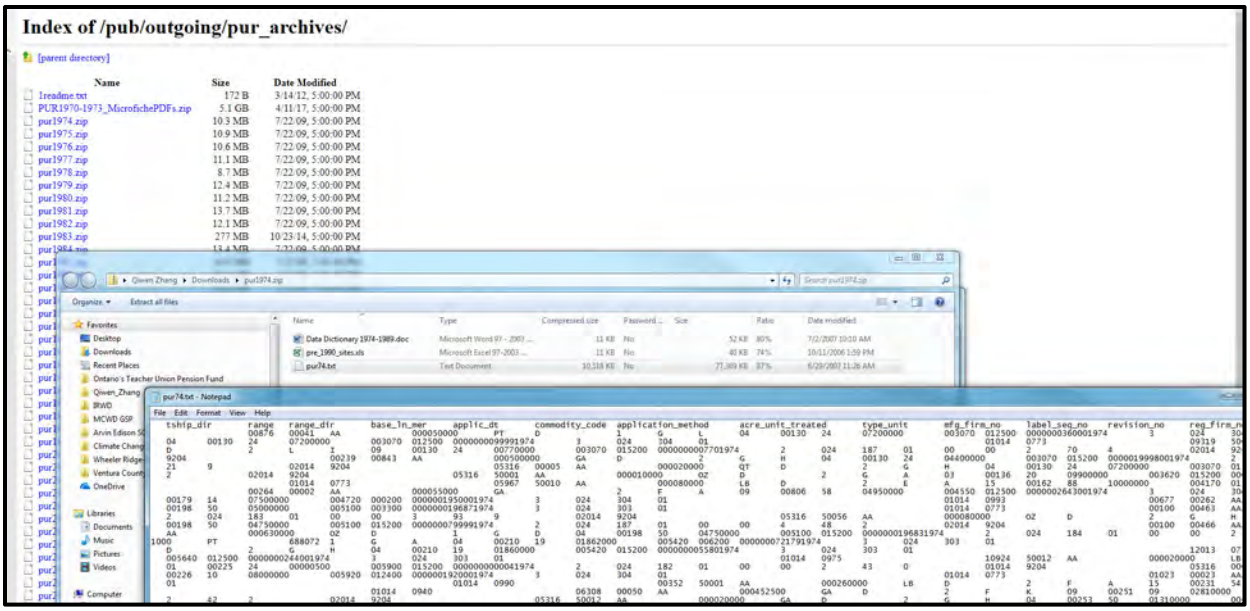
4.1. California Pesticide Information Portal (CalPIP)

https://calpip.cdpr.ca.gov/main.cfm

- From Department of Pesticide Regulation (DPR).
- Pesticide use reporting (PUR) data, and Groundwater Protection Areas (GWPAs).
- Downloadable data in text files, shapefiles, maps, and KML files.
- Data can be sorted by locations, chemicals, years, counties.
- Trendline analysis can be done on usage of pesticides, but not on groundwater elevation or chemical concentrations.
- Data archives are available for download. ftp://transfer.cdpr.ca.gov/pub/outgoing/pur_archives/
    - List the locations and quantities of pesticide uses for that year.
- Pesticide use reporting (PUR) https://www.cdpr.ca.gov/docs/pur/purmain.htm
    - Choose location of interests and generate a report.

Screenshots of website and selected downloadable data:




Index of /pub/outgoing/pur_archives/
[parent directory]
Name
Size
Date Modified
1readme.txt 172 B 3/14/12, 5:00:00 PM
PUR1970-1973_MicrofichePDFs.zip 5.1 GB 4/11/17, 5:00:00 PM
pur1974.zip 10.3 MB 7/22/09, 5:00:00 PM
pur1975.zip 10.9 MB 7/22/09, 5:00:00 PM
pur1976.zip 10.6 MB 7/22/09, 5:00:00 PM
pur1977.zip 11.1 MB 7/22/09, 5:00:00 PM
pur1978.zip 8.7 MB 7/22/09, 5:00:00 PM
pur1979.zip 12.4 MB 7/22/09, 5:00:00 PM
pur1980.zip 11.2 MB 7/22/09, 5:00:00 PM
pur1981.zip 13.7 MB 7/22/09, 5:00:00 PM
pur1982.zip 12.1 MB 7/22/09, 5:00:00 PM
pur1983.zip 277 MB 10/23/14, 5:00:00 PM
Data Dictionary 1974-1989.doc
pre_1990_sites.xls
pur74.txt
pur74.txt - Notepad


About DPR | Join E-Lists | A-Z Index | Contact Us
California Department of
Pesticide Regulation
Google Custom Search
HOME
PROGRAMS
DATABASES
NEWS/PUBLICATIONS
QUICK LINKS
Pesticide Use Reporting - 2016 Summary Data
Back to Pesticide Use Reporting Menu
Text files for all 2016 Annual Report tables and figures are available for download.
Pounds of active ingredient by county, PDF (42 kb)
Top Five Lists
The top five sites by pounds, PDF (331 kb) in total pesticide use in each county in 2016 and the top five pesticides used on each of these sites.
The top five pesticides by pounds, PDF (335 kb) used in each county in 2016 and the top five sites of use for each of these pesticides.
The top five sites by acres treated, PDF (478 kb) in each county in 2016. This table lists the top five sites and corresponding top five pesticides ranked by cumulative acres treated.
The top five pesticides by acres treated, PDF (337 kb) in each county in 2016. This table lists the top five pesticides and corresponding top five sites ranked by cumulative acres treated.
Top 100 Lists
The top 100 sites by pounds, PDF (161 kb) in total statewide pesticide use in 2016.
The top 100 pesticides by pounds, PDF (260 kb) used statewide (all sites combined) in 2016.
The top 100 sites by acres treated, PDF (244 kb) in 2016. This table ranks the top 100 sites and corresponding statewide pesticide use by cumulative acres treated.
The top 100 pesticides by acres treated, PDF (162 kb) in 2016. This table ranks the top 100 pesticides by cumulative acres treated.
2016 Statewide Report
Summary of Pesticide Use Report Data
Indexed by commodity, PDF (9.2 mb)
Indexed by chemical, PDF (9 mb)
2016 County Summary Reports:
Indexed by Commodity
Click arrow to select a county report.
Indexed by Chemical
Kern
Please send your questions and comments to PUR.inquiry@cdpr.ca.gov.

Department of Pesticide Regulation
2016 Annual Pesticide Use Report Indexed by Chemical
Kern County

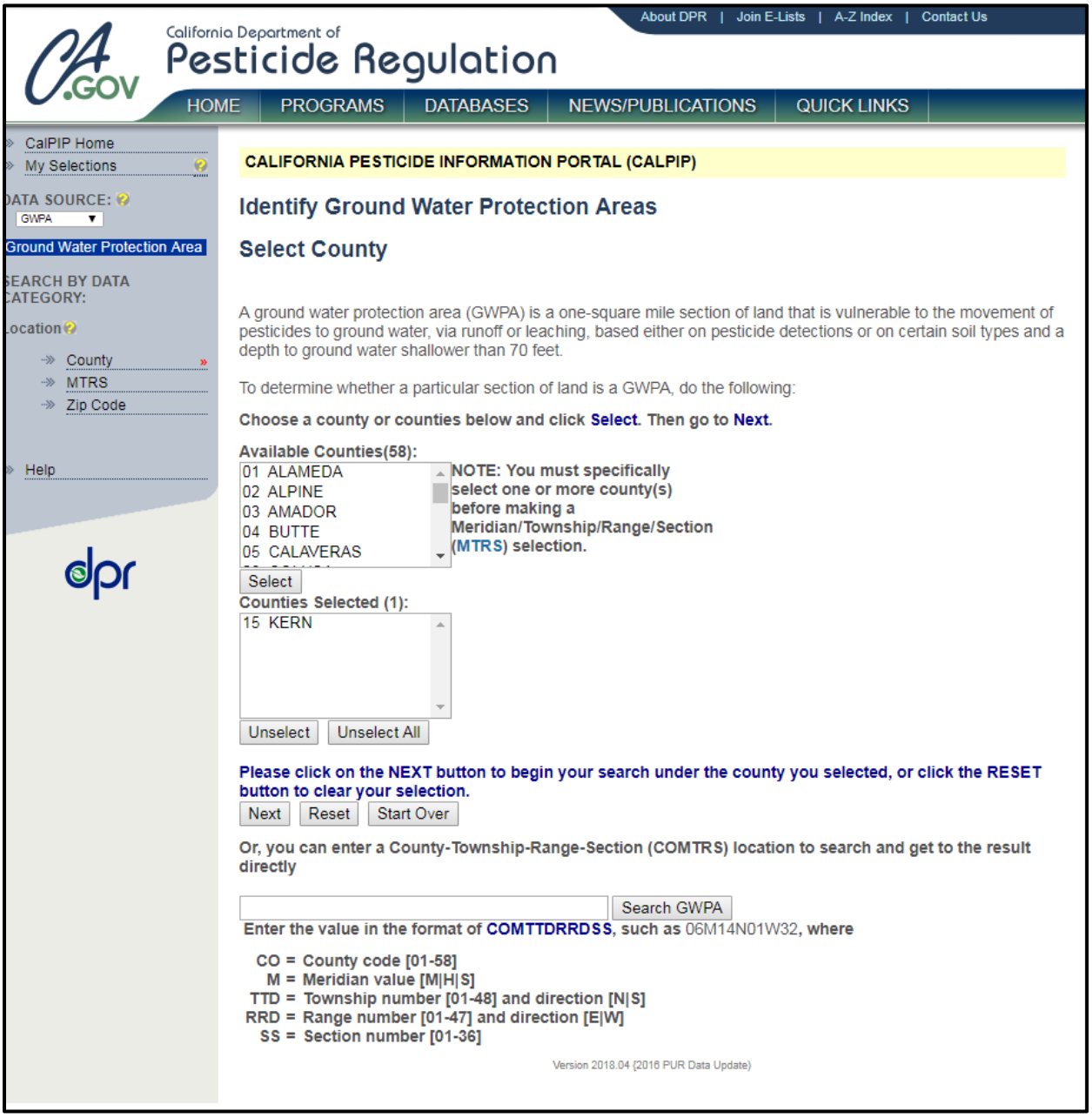
Text files of data are available at <ftp://transfer.cdpr.ca.gov/pub/outgoing/pur/data/>
Units: A = Acres, S = square feet, C = cubic feet, K = thousand cubic feet, P = pounds, T = tons, U = miscellaneous unit

Chemical Commodity	Pounds Applied	Agricultural Applications	Amount Treated	Unit Type
ABAMECTIN				
Almond	2,492.30	1,416	137,693.08	A
Apple	< 0.01	1	1.00	A
Bean, Dried	9.05	7	483.78	A
Cantaloupe	1.74	3	157.50	A
Cherry	64.40	75	2,872.13	A
Cotton	77.33	118	7,731.22	A
Eggplant	0.21	1	12.00	A
Garlic	0.69	1	34.50	A
Grape	100.36	188	7,881.72	A
Grape, Wine	35.00	28	1,836.19	A
Grapefruit	5.39	21	341.20	A
Lemon	44.83	52	2,014.82	A
Lettuce, Leaf	2.28	5	110.50	A
Melon	0.69	2	101.00	A
N-Grnhs Plants In Containers	0.11		61.25	A
N-Outdr Plants In Containers	1.09	12	96.00	A
Onion, Dry	20.93	26	1,116.00	A
Orange	770.45	501	20,775.57	A
Pepper, Fruiting	19.52	35	1,594.50	A
Pepper, Spice	40.28	22	2,106.00	A
Pistachio	3.32	6	431.63	A
Structural Pest Control	0.86			
Tangelo	2.23	5	94.40	A
Tangerine	335.10	294	17,506.75	A
Tomato, Processing	8.66	3	450.00	A
Uncultivated Ag	0.30	1	20.00	A
Walnut	10.49	16	541.94	A
Watermelon	15.68	30	1,435.05	A
Chemical Total	4,063.29	2,869		

4.1.1. Locations of Ground Water Protection Areas (GWPA)

https://www.cdpr.ca.gov/docs/emon/grndwtr/gwpa_locations.htm

- GWPA maps and county lists.
- Downloadable maps, shapefiles, KML files.
- Contains locations of regulated sites, but no data.
- Choose a township and check whether it contains GW Protection Areas. https://calpip.cdpr.ca.gov/county.cfm?ds=GWPA
- Ground Water Protection Area Lists https://www.cdpr.ca.gov/docs/emon/grndwtr/gwpa_lists.htm



Choose a Township (COMTR) or townships under the county(s) specified and click **Select**. Then choose a Section (COMTRS) or sections under the township(s) specified and click **Select**. Then go to **Submit**.

Available COMTR Township and Range under selected county(s) (257):

15 M24S18E
15 M24S34E
15 M24S36E
15 M25S17E
15 M25S18E

Select

Available COMTRS Sections within selected Township-Range (1):

15 M24S34E 31

Select

Township(s) Selected (1):

15 M24S34E

Unselect | Unselect All

Section(s) Selected (1):

15 M24S34E 31

Unselect | Unselect All

Please click on the SUBMIT button to receive GWPA information about the township and section you selected in the county(s) chosen, or click the RESET button to clear your selection.

Reset | Start Over | Submit

Version 2018.04 (2016 PUR Data Update)

Back to Ground Water Protection Area Lists

Kern County Ground Water Protection Areas
Effective May 27, 2004
County_Meridian_Township_Range_Section (COMTRS)

COMTRS	Condition
15M25S24E01	Runoff
15M25S24E11	Runoff
15M25S24E12	Runoff
15M25S25E02	Leaching
15M25S25E03	Leaching
15M25S25E05	Runoff
15M25S25E06	Runoff
15M25S25E07	Runoff
15M25S25E08	Runoff
15M25S25E17	Runoff
15M28S23E24	Runoff
15M28S23E25	Runoff
15M28S24E30	Runoff
15M28S24E31	Runoff
15M28S25E14	Leaching
15M31S27E16	Leaching

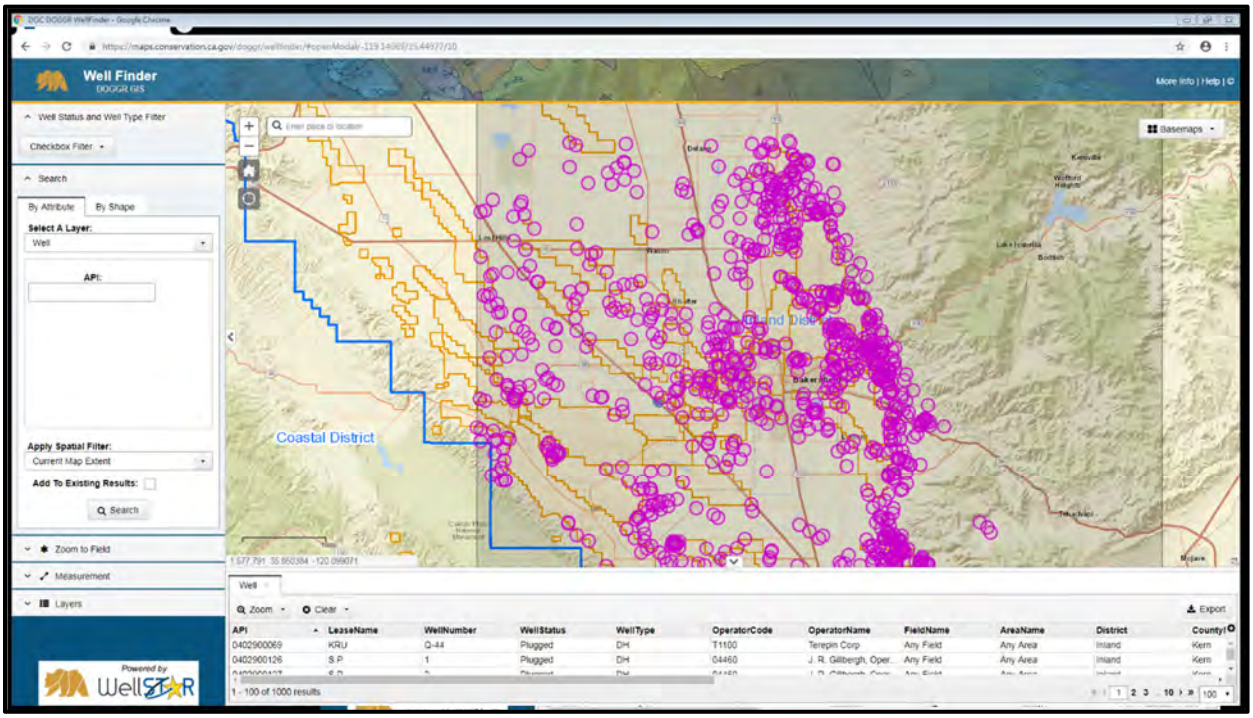
5. Information on Groundwater Quality in Areas of Oil and Gas Production

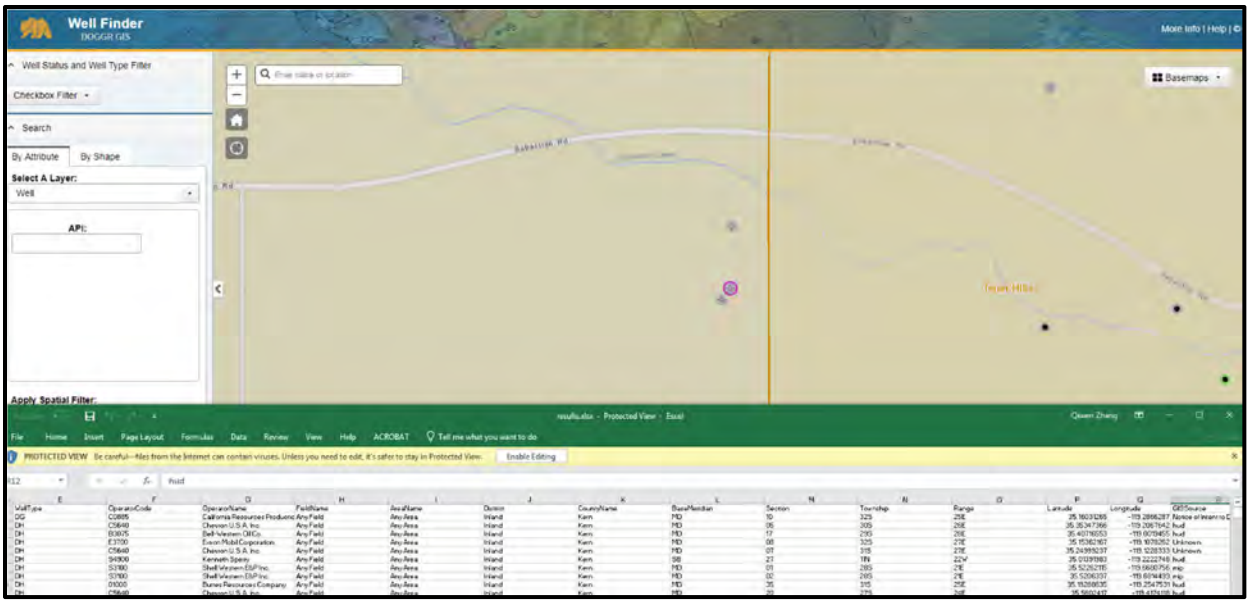
5.1. WellFinder

https://maps.conservation.ca.gov/doggr/wellfinder/#openModal/-118.94276/37.11133/6

- From California Division of Oil, Gas, and Geothermal Resources (DOGGR).
- Oil and gas well locations, information and records; Information about other oil and gas facilities.
- Data from DOGGR through third party reporting.
- Well locations as Excel; well data and reports as pdf or tif files.

Screenshots of website and selected downloadable data:



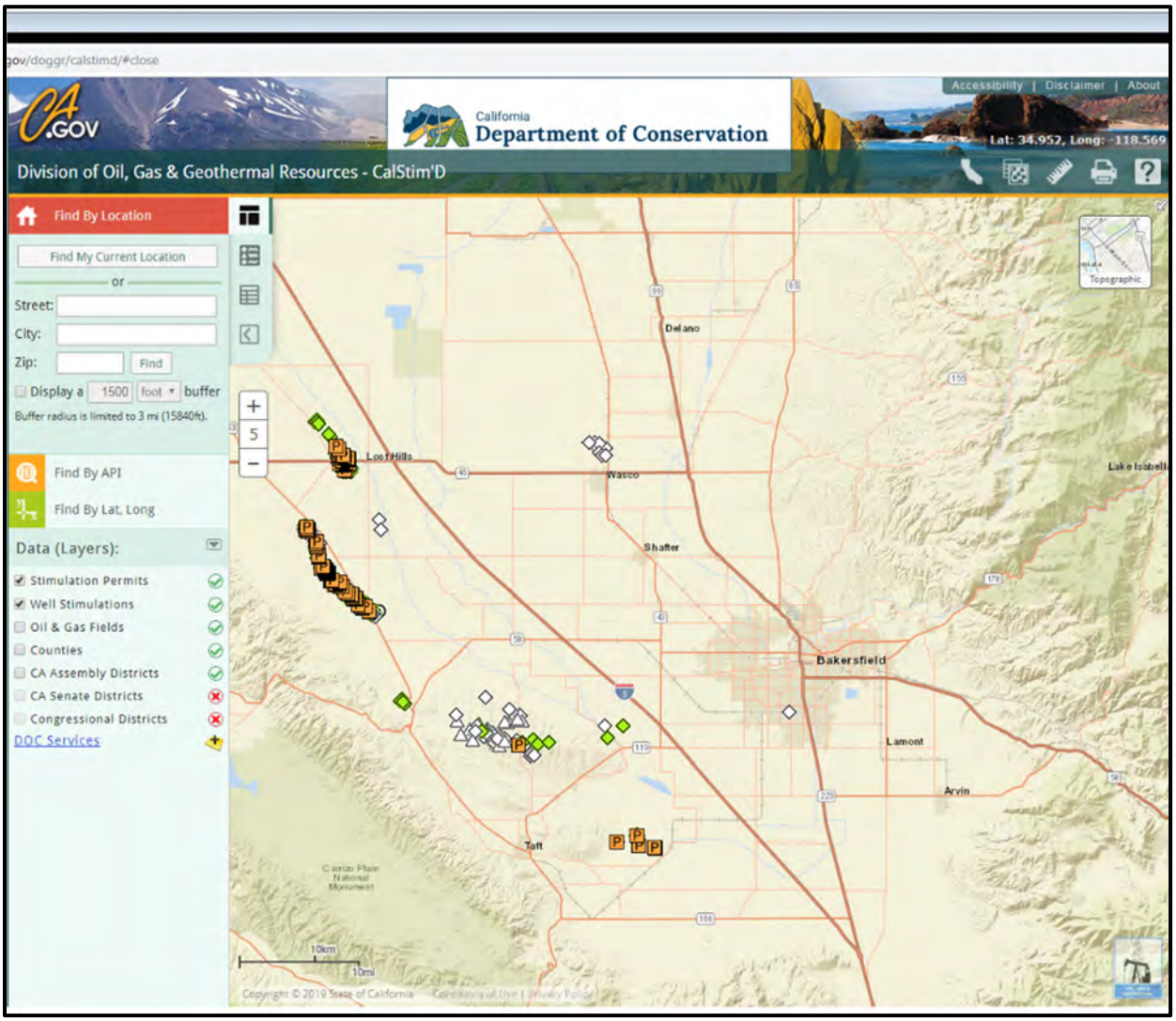

Well Finder
DOGGR GIS
More Info | Help |
Well Status and Well Type Filter
Checkbox Filter
Search
By Attribute
By Shape
Select A Layer:
Well
API:
Apply Spatial Filter:
Basemaps
PROTECTED VIEW
Enable Editing

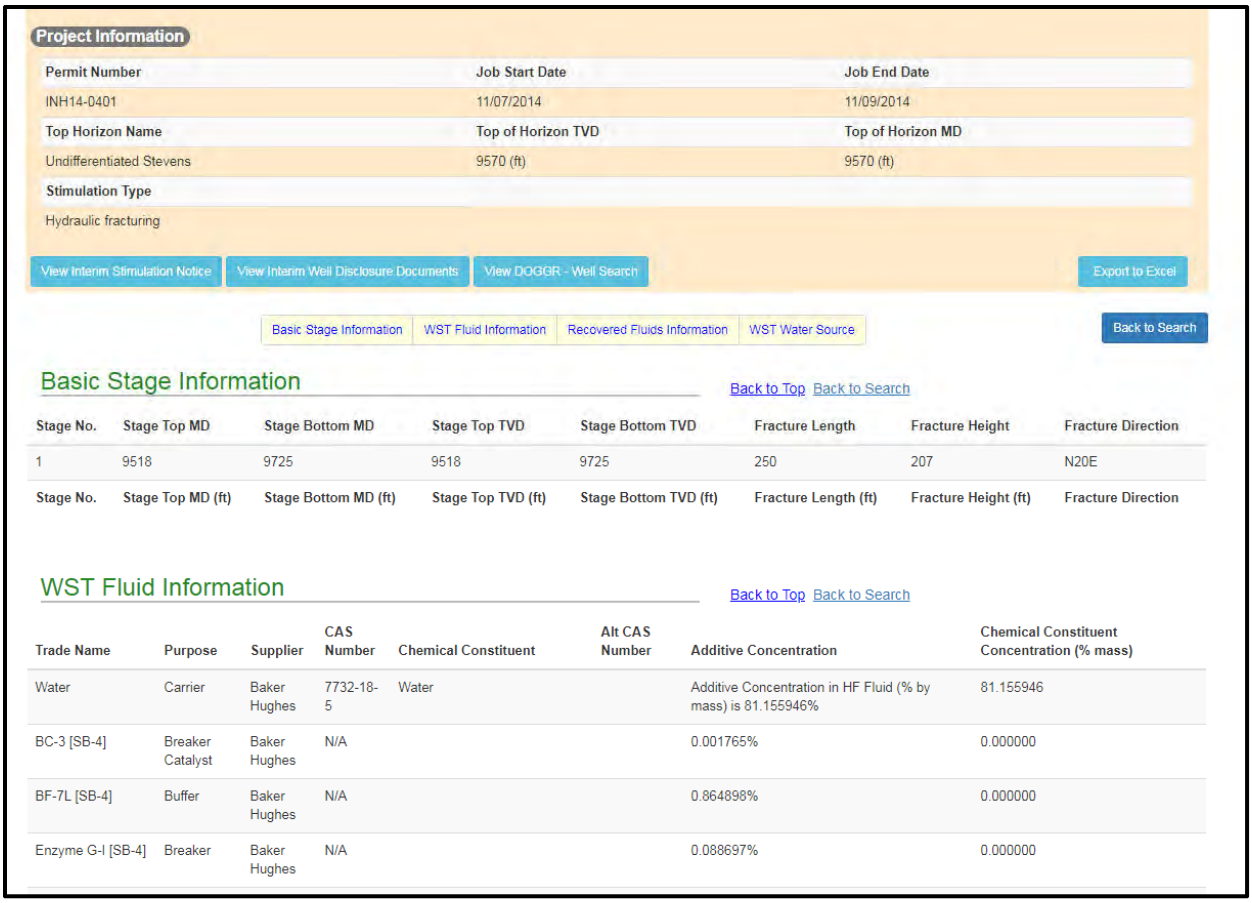
5.2. CalStim'D – Well Stimulation Permits and Sites

https://maps.conservation.ca.gov/doggr/calstimd/#close

- Data from DOGGR.
- Map viewer of well stimulation sites.
- No downloadable data.
- Searched by permits or American Petroleum Institute (API) number.
- Well Stimulation Treatment (WST) Disclosure; includes WST disclosures from Jan. 1, 2014 to present.

Screenshots of website:





Project Information

Permit Number	Job Start Date	Job End Date
INH14-0401	11/07/2014	11/09/2014
Top Horizon Name	**Top of Horizon TVD**	**Top of Horizon MD**
Undifferentiated Stevens	9570 (ft)	9570 (ft)
Stimulation Type		
Hydraulic fracturing		

View Interim Stimulation Notice | View Interim Well Disclosure Documents | View DOGGR - Well Search | Export to Excel

Basic Stage Information | WST Fluid Information | Recovered Fluids Information | WST Water Source | Back to Search

Basic Stage Information

Back to Top Back to Search

Stage No.	Stage Top MD	Stage Bottom MD	Stage Top TVD	Stage Bottom TVD	Fracture Length	Fracture Height	Fracture Direction
1	9518	9725	9518	9725	250	207	N20E
Stage No.	**Stage Top MD (ft)**	**Stage Bottom MD (ft)**	**Stage Top TVD (ft)**	**Stage Bottom TVD (ft)**	**Fracture Length (ft)**	**Fracture Height (ft)**	**Fracture Direction**

WST Fluid Information

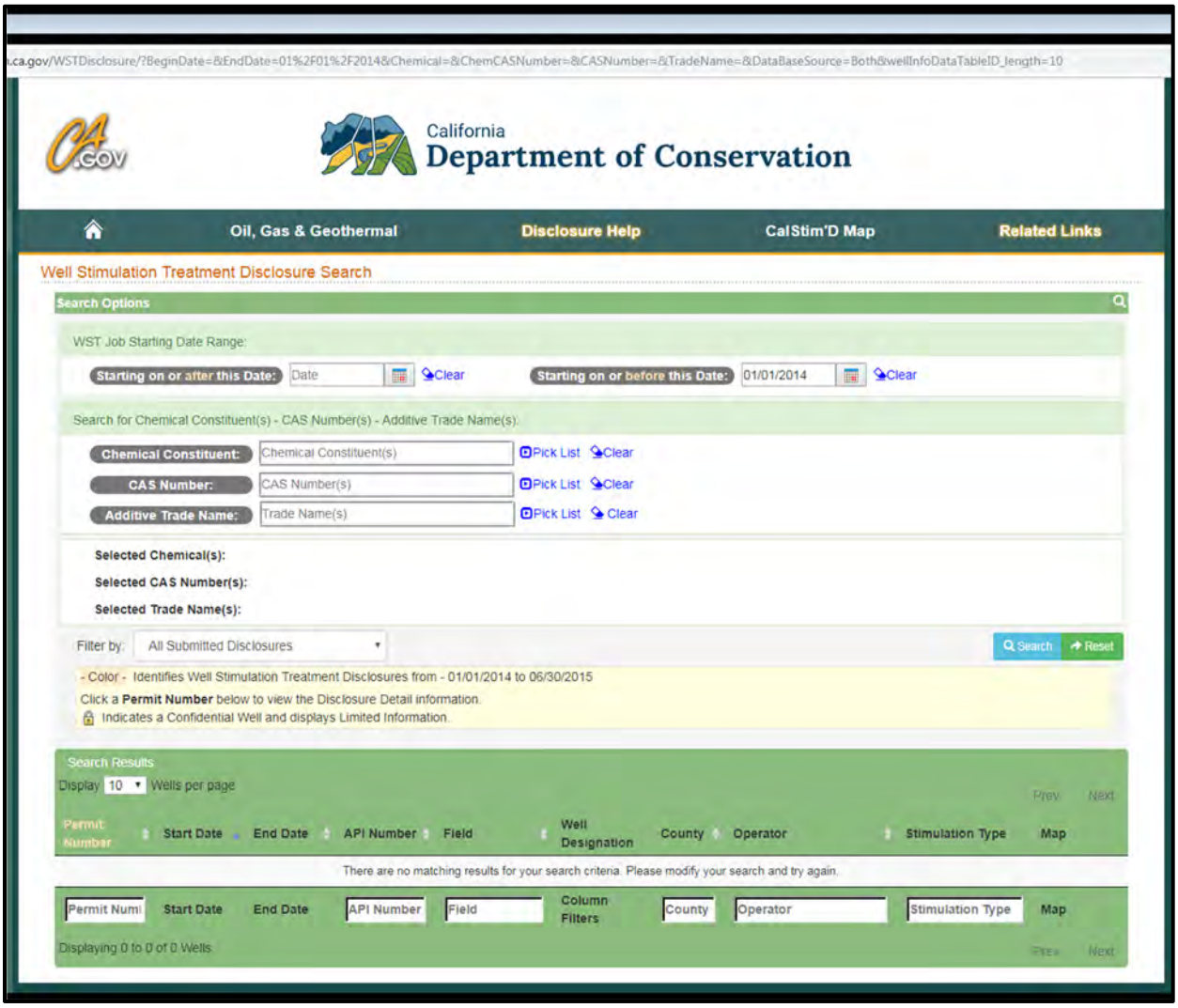
Back to Top Back to Search

Trade Name	Purpose	Supplier	CAS Number	Chemical Constituent	Alt CAS Number	Additive Concentration	Chemical Constituent Concentration (% mass)
Water	Carrier	Baker Hughes	7732-18-5	Water		Additive Concentration in HF Fluid (% by mass) is 81.155946%	81.155946
BC-3 [SB-4]	Breaker Catalyst	Baker Hughes	N/A			0.001765%	0.000000
BF-7L [SB-4]	Buffer	Baker Hughes	N/A			0.864898%	0.000000
Enzyme G-I [SB-4]	Breaker	Baker Hughes	N/A			0.088697%	0.000000

5.2.1. Well Stimulation Treatment Disclosure Search

https://secure.conservation.ca.gov/WSTDisclosure/?BeginDate=&EndDate=01%2F01%2F2014&Chemical=&ChemCASNumber=&CASNumber=&TradeName=&DataBaseSource=Both&wellInfoDataTableID_length=10

- Well stimulation sites and permits can be searched by date or chemical constituent.
- No downloadable data.



Chemical Constituent(s)

Please select up to **10** Chemical Constituent(s) to find (click to select - dblclick on row to select and close)

Page 1 of 22 View 1 - 18 of 396

	Chemical Constituent (use text boxes below to search list)	CAS Number
☐	1, 2, 3 - Propanetriol	56-81-5
☐	1,2,3-Trimethylbenzene	526-73-8
☐	1,2,4 Trimethylbenzene (impurity)	95-63-6
☐	1,2,4,5-Tetrabromobenzene	636-28-2
☑	1,2,4-Trimethylbenzene	95-63-6
☐	1,2-benzisothiazolin-3-one	2634-33-5
☐	1,2-Diiodobenzene	615-42-9
☐	1,3,5-Tribromobenzene	626-39-1
☐	1,3,5-Trimethylbenzene	108-67-8
☐	1,4-Dibromobenzene	106-37-6
☐	1-bromo-3,5-dichlorobenzene	19752-55-7
☐	1-Bromo-4-iodobenzene	589-87-7
☐	1-Butoxy-2-Propanol	5131-66-8
☐	1-Chloro-4-Iodobenzene	637-87-6
☐	1-Eicosene	3452-07-1
☐	1-Hexadecene	629-73-2
☐	1-Iodonaphthalene	90-14-2
☐	1-Methoxy-2-Propanol	107-98-2

Page 1 of 22 View 1 - 18 of 396

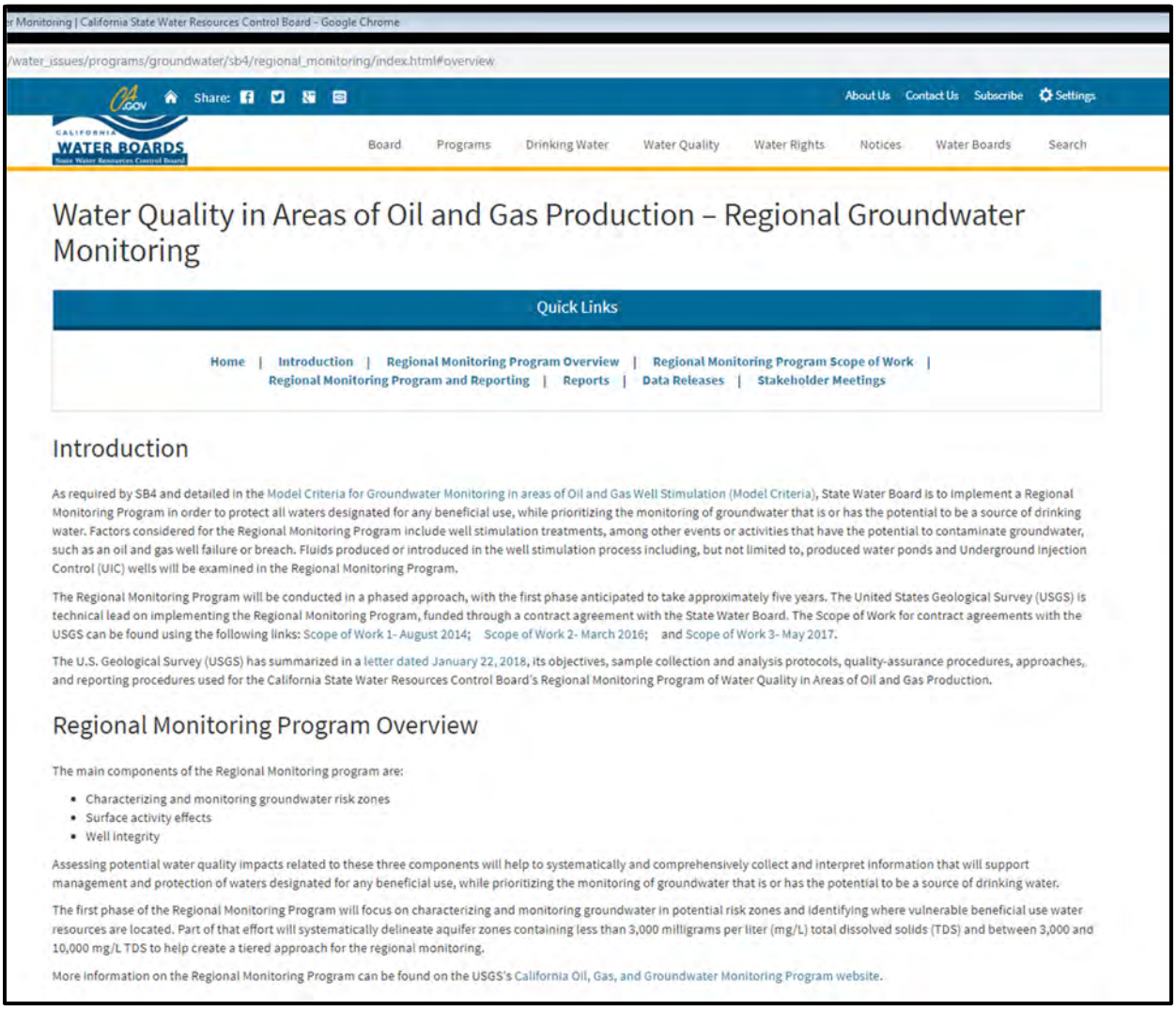
Select All Highlighted Chemical(s) | Excel Download | Close

5.3. Water Quality in Areas of Oil and Gas Production – Regional Groundwater Monitoring Program

https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/regional_monitoring/index.html#overview

- Salinity mapping.
- Produced water characterization.
- Groundwater potential risk zone analysis.
- Data from USGS, DOGGR, and other state and regional boards.
- Chemical data are available to download. Trendline analysis is feasible.
- Data releases: https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/regional_monitoring/index.html#datareleases

Screenshots of website and selected downloadable data:



Reports



The data collected during the exploratory sampling is summarized in the following report: "USGS Open-File Report 2016-1181: Data from Exploratory Sampling of Groundwater in Selected Oil and Gas Areas of Coastal Los Angeles County and Kern and Kings Counties in Southern San Joaquin Valley, 2014–15: California Oil, Gas, and Groundwater Project"



The U.S. Geological Survey sampled water wells in the Los Angeles Basin and southern San Joaquin Valley, California, and oil wells in the San Joaquin Valley for analysis of multiple chemical, isotopic, and groundwater-age tracers. This report summarizes that work to evaluate the utility of using tracers for assessing oil and gas production activities on groundwater quality in California. The report is available at the following: "Preliminary results from exploratory sampling of wells for the California oil, gas, and groundwater program, 2014–15, Open-File Report 2016-1100."



The U.S. Geological Survey compiled data that characterizes the intensity of petroleum resource development and proximity to groundwater resources. This report is available at the following: "Prioritization of oil and gas fields for regional groundwater monitoring based on a preliminary assessment of petroleum resource development and proximity to California's groundwater resources, Scientific Investigations Report 2018-5065."



The U.S. Geological Survey compiled a report to document the preliminary groundwater salinity mapping of 31 oil fields and adjacent aquifers. The data is summarized into 8 sub-regions across major oil-producing areas of central and southern California. This report is available at the following: "Preliminary groundwater salinity mapping near selected oil fields using historical water-sample data, central and southern California. Scientific Investigations Report 2018-5082."

Data Releases

Data collected from collected produced water samples from four petroleum wells in the southern San Joaquin Valley. This digital dataset contains the site information, analyzing laboratories and methods, and water chemistry and quality control results for these samples. The report is available at the following: Produced water chemistry data for samples from four petroleum wells, Southern San Joaquin Valley, California (2014)

Supporting data for the "Produced water chemistry data for samples from four petroleum wells, Southern San Joaquin Valley, California, 2014" (9/6/2016)

Data from the Fruitvale produced water ponds is available at the following link: Historical produced water chemistry data compiled for the Fruitvale Oilfield, Kern County, California (3/20/2018)

Supporting data for the "Produced water chemistry data for the Lost Hills, Fruitvale, and North and South Belridge study areas, Southern San Joaquin Valley, California" (6/7/2018)

Data Analyzed for the Preliminary Prioritization of California Oil and Gas Fields for Regional Groundwater Monitoring (7/23/2018)

Supporting data for the "Water and petroleum well data used for preliminary regional groundwater salinity mapping near selected oil fields in central and southern California" (7/24/2018)

"Groundwater and surface water chemistry results for samples collected near the Lost Hills and North and South Belridge oil fields, Kern County, California" (9/17/2018)

"Geochemical and geophysical data for wells in the Fruitvale and Rosedale Ranch oil and gas fields, Kern County, California, USA" (9/27/2018)

"Water chemistry data for samples collected at groundwater sites near the Fruitvale oil field, September 2016–February 2017, Kern County, California" (9/20/2018)

"Geochemical, geological, and geophysical data for wells in the Poso Creek oil and gas field, Kern County, California" (12/13/2018)

"Geophysical and geochemical data for salinity mapping in the Midway-Sunset oil field area" (12/19/2018)

"Historical produced water chemistry data compiled for the Lost Hills and North and South Belridge Oilfields, Kern County, California" (1/29/2019)

NEW - "Geochemical and geophysical data for selected wells in and surrounding the South Cuyama oil and gas field" (4/9/2019)

NEW - "Geological, geochemical, and geophysical data from the Lost Hills and Belridge oil fields: U.S. Geological Survey data release" (4/23/2019)

Water chemistry data for samples collected at gr…

View

An investigation was done by the U.S. Geological Survey, in cooperation with the California State Water Resources Control Board's Program of Regional Groundwater Monitoring of Water Quality in Areas of Oil and Gas Production, to assess the effects of oil and gas production activities on nearby groundwater resources. During November 2016–September 2017, 30 samples were collected at groundwater wells and 1 sample was collected at a surface-water site. This dataset contains site information and water chemistry results for samples collected near the Lost Hills and North and South Belridge oil fields, Kern County, California. Samples were analyzed for water-quality indicators, major and minor ions, nutrients, trace elements, volatile organic compounds, naturally occurring radioactive material, geochemical and age-dating tracers, dissolved organic carbon, low molecular weight organic acids, dissolved standard and hydrocarbon gases, and dissolved noble and atmospheric gases. Quality-control samples including replicates; source-solution, equipment, and field blanks; laboratory spikes; and split samples for interlab comparisons were collected and summarized in this data release.

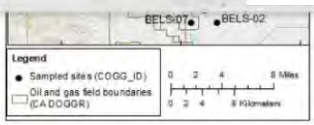
Contacts

Point of Contact :	Tracy Davis
Originator :	Tracy Davis, Jessica A. Teunis, Anthony J Mccarlson, Neil O Seitz, Joshua C Johnson
Metadata Contact :	Tracy Davis
Publisher :	U.S. Geological Survey
Distributor :	U.S. Geological Survey - ScienceBase
SDC Data Owner :	California Water Science Center
USGS Mission Area :	Water Resources

Attached Files

Click on title to download individual files attached to this item or download all files listed below as a compressed file.

LOST_BELS_sampled_sites.xlsx		16.29 KB
LOST_BELS_samples.xlsx		427.91 KB
LOST_BELS_ENV_results.xlsx		513.21 KB
LOST_BELS_QC_results.xlsx		42.3 KB
COGG_Data_Dictionary.xlsx		34.99 KB
CSV_LOST_BELS.zip		27.34 KB
LOST_BELS_metadata.xml *Original FGDC Metadata*	View	48.18 KB
SupplementalMetadata.txt		20.3 KB
LOST_BELS_map.jpg		125.44 KB



Map »



Spatial Services

ScienceBase WMS :

https://www.sciencebase.gov/catal(

Communities

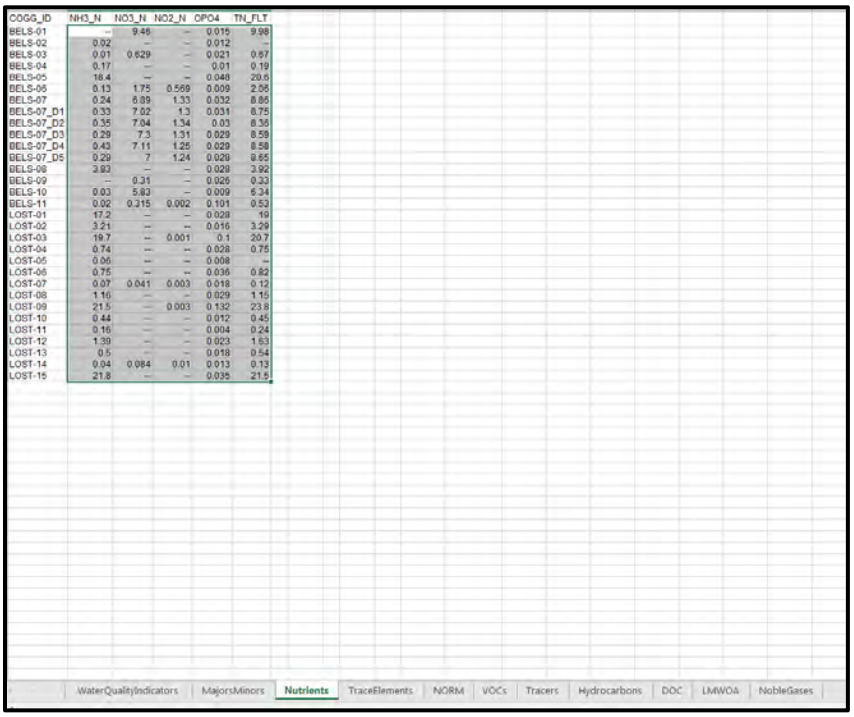
- California Oil, Gas, and Groundwater
- USGS California Water Science Center
- USGS Data Release Products

Associated Items

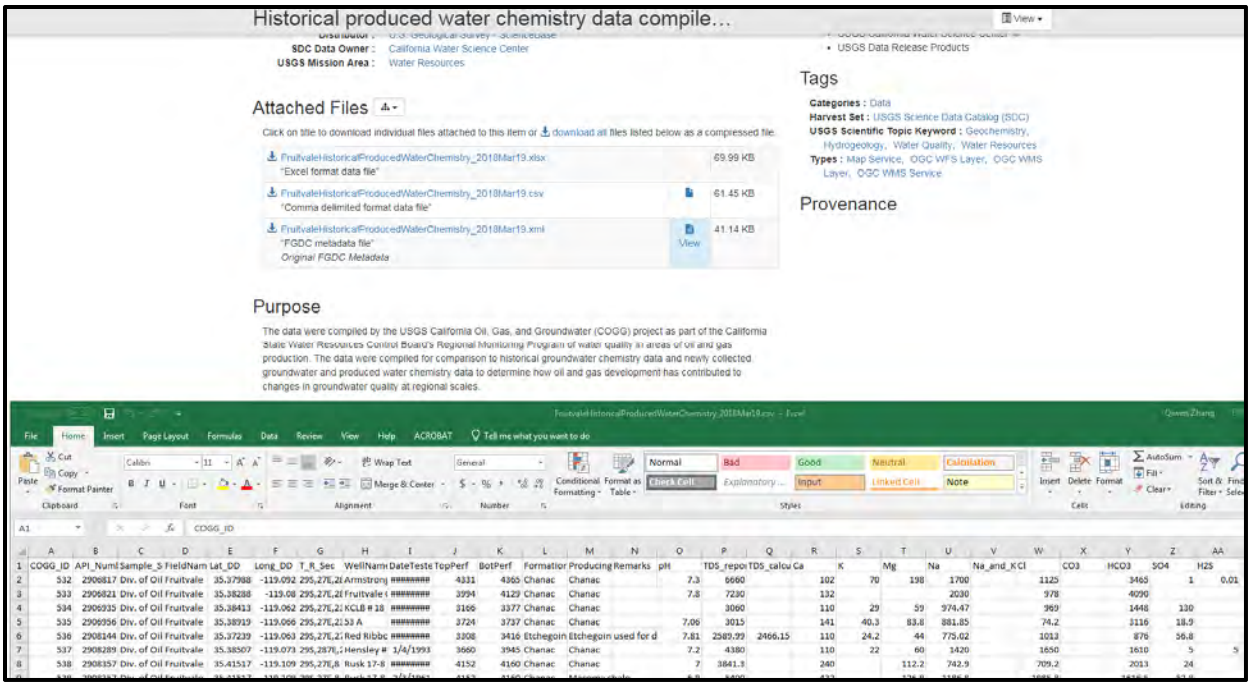
- *copied into* Water chemistry data for samples collected at groundwater and surface-water sites near the Lost Hills and Belridge oil fields, November 2016–September 2017 (ver. 2.0, May 2019), Kern County, California (COPY)

View Associated Items

Tags



COGG_ID	NH3_N	NO3_N	NO2_N	OPO4	TN_FLT
BELS-01	--	9.46	--	0.015	9.98
BELS-02	0.02	--	--	0.012	--
BELS-03	0.01	0.629	--	0.021	0.67
BELS-04	0.17	--	--	0.01	0.19
BELS-05	18.4	--	--	0.048	20.6
BELS-06	0.13	1.75	0.569	0.009	2.06
BELS-07	0.24	6.89	1.33	0.032	8.86
BELS-07_D1	0.33	7.02	1.3	0.031	8.75
BELS-07_D2	0.35	7.04	1.34	0.03	8.56
BELS-07_D3	0.29	7.3	1.31	0.029	8.59
BELS-07_D4	0.43	7.11	1.25	0.029	8.58
BELS-07_D5	0.29	7	1.24	0.028	8.65
BELS-08	3.83	--	--	0.028	3.92
BELS-09	--	0.31	--	0.026	0.33
BELS-10	0.03	5.83	--	0.009	6.34
BELS-11	0.02	0.215	0.002	0.101	0.52
LOST-01	17.2	--	--	0.028	19
LOST-02	3.21	--	--	0.016	3.29
LOST-03	19.7	--	0.001	0.1	20.7
LOST-04	0.74	--	--	0.028	0.75
LOST-05	0.06	--	--	0.008	--
LOST-06	0.75	--	--	0.036	0.82
LOST-07	0.07	0.041	0.003	0.018	0.12
LOST-08	1.16	--	--	0.029	1.15
LOST-09	21.5	--	0.003	0.132	23.8
LOST-10	0.44	--	--	0.012	0.45
LOST-11	0.16	--	--	0.004	0.24
LOST-12	1.39	--	--	0.023	1.63
LOST-13	0.5	--	--	0.018	0.54
LOST-14	0.04	0.084	0.01	0.013	0.13
LOST-15	21.8	--	--	0.035	21.5





COGG_ID	API_Num	Sample_S	FieldNam	Lat_DD	Long_DD	T_R_Sec	WellNam	DateTeste	TopPerf	BotPerf	Formatior	Producing	Remarks	pH	TDS_repor	TDS_calcu	Ca	K	Mg	Na	Na_and_KCl	CO3	HCO3	SO4	H2S
532	2906817	Div. of Oil	Fruitvale	35.37988	-119.092	29S_27E_2	Armstrong	########	4331	4365	Chanac	Chanac		7.3	6660		102	70	198	1700		1125		3465	1	0.01
533	2906821	Div. of Oil	Fruitvale	35.38288	-119.08	29S_27E_2	Fruitvale (	########	3994	4129	Chanac	Chanac		7.8	7230		132			2030		978		4090		
534	2906935	Div. of Oil	Fruitvale	35.38413	-119.062	29S_27E_2	KCLB # 18	########	3166	3377	Chanac	Chanac			3060		110	29	59	974.47		969		1448	130	
535	2906956	Div. of Oil	Fruitvale	35.38919	-119.066	29S_27E_2	53 A	########	3724	3737	Chanac	Chanac		7.06	3015		141	40.3	83.8	881.85		74.2		3116	18.9	
536	2908144	Div. of Oil	Fruitvale	35.37239	-119.063	29S_27E_2	Red Ribbc	########	3308	3416	Etchegoin	Etchegoin	used for d	7.81	2589.99	2466.15	110	24.2	44	775.02		1013		876	36.8	
537	2908289	Div. of Oil	Fruitvale	35.38507	-119.073	29S_28E_1	Hensley #	1/4/1993	3660	3945	Chanac	Chanac		7.2	4380		110	22	60	1420		1650		1610	5	5
538	2908357	Div. of Oil	Fruitvale	35.41517	-119.109	29S_27E_8	Rusk 17-8	########	4152	4160	Chanac	Chanac		7	3841.3		240		112.2	742.9		709.2		2013	24	

Table 1. Identification, sampling, and construction information for wells included in exploratory sampling of groundwater in coastal Los Angeles County and Kern and Kings Counties of the southern San Joaquin Valley, September 2014 to January 2015, California Oil, Gas, and Groundwater Project.

[Wells that were screened at multiple intervals were listed as top and bottom of first screen listed first seperated by a comma for the top and bottom for any proceeding intervals. **Abbreviations:** MW, monitoring well; WPW, water production well; ft, feet; LSD, land-surface datum; NAVD 88, North American Vertical Datum of 1988; na, not available]

Local Identifier	USGS site identification number	State identification number	Date sampled (mm/dd/yyyy)	Altitude of LSD (ft above NAVD 88)	Well Type	Use of Well	Well depth (ft below LSD)	Screen intervals (ft below LSD)
Coastal Los Angeles County								
LA_1	335100118120404	004S013W01N006S	09/18/14	44	MW	monitor water supply	300	280–300
LA_2	335100118120401	004S013W01N003S	09/18/14	44	MW	monitor water supply	1,090	970–990
LA_3	334737118101905	004S012W30J005S	09/19/14	20	MW	monitor water supply	435	415–435
LA_4	334737118101901	004S012W30J001S	09/19/14	20	MW	monitor water supply	1,495	1,435–1,455
LA_5	334445118125301	005S013W11P001S	09/21/14	13	MW	monitor water supply	1,110	1,090–1,110
LA_6	334445118125302	005S013W11P002S	09/21/14	13	MW	monitor water supply	355	335–355
LA_7	340027118071901	002S012W10Q005S	09/22/14	192	MW	monitor water supply	980	900–960
LA_8	335716118135101	002S013W34F002S	09/22/14	122	MW	monitor water supply	1,760	1,740–1,760
LA_9	340027118071903	002S012W10Q007S	09/22/14	192	MW	monitor water supply	520	500–520
LA_10	334944118203301	004S014W15E001S	09/23/14	81	MW	monitor water supply	1,235	1,195–1,235
LA_11	340040118100904	002S012W07J004S	09/23/14	164	MW	monitor water supply	590	570–590
LA_12	334944118203304	004S014W15E004S	09/23/14	81	MW	monitor water supply	550	530–550
LA_13	340040118100901	002S012W07J001S	09/23/14	164	MW	monitor water supply	1,390	1,330–1,390
LA_14	335235118175901	003S014W25K007S	09/24/14	28	MW	monitor water supply	1,375	1,275–1,295; 1,315–1,335
LA_15	335235118175903	003S014W25K009S	09/24/14	28	MW	monitor water supply	630	610–630
LA_16	335236118232105	003S014W30L006S	09/24/14	136	MW	monitor water supply	660	640–660
LA_17	335235118175904	003S014W25K010S	09/24/14	28	MW	monitor water supply	360	340–360
LA_18	335236118232101	003S014W30L002S	09/24/14	136	MW	monitor water supply	1,990	1,950–1,990
LA_19	334837118085701	004S012W21M008S	09/25/14	37	MW	monitor water supply	1,530	1,490–1,510
LA_20	334815118184701	004S014W26A002S	09/25/14	77	MW	monitor water supply	1,340	1,240–1,260
LA_21	334837118085704	004S012W21M011S	09/25/14	37	MW	monitor water supply	500	480–500
LA_22	334815118184702	004S014W26A003S	09/25/14	77	MW	monitor water supply	720	700–720
LA_23	334815118184704	004S014W26A005S	09/25/14	77	MW	monitor water supply	420	400–420
LA_24	335126118155801	004S013W05F001S	09/26/14	22	MW	monitor water supply	1,800	1,600–1,620
LA_25	335126118155803	004S013W05F003S	09/26/14	22	MW	monitor water supply	1,100	1,080–1,100
LA_26	335555118204001	003S014W04R001S	09/28/14	72	MW	monitor water supply	1,940	1,900–1,940
LA_27	335555118204003	003S014W04R003S	09/28/14	72	MW	monitor water supply	1,275	1,255–1,275

1-wells | 2-analytes | 3-field | 4a-voc-det | 4b-voc-nd | 5a-svoc-det | 5b-svoc-nd | 6-doc | 7-trace | 8-nutrients | 9-major | 10-iron | 11-isorad | 12-ng | 13-HC | A1-methods | A2a-blanks

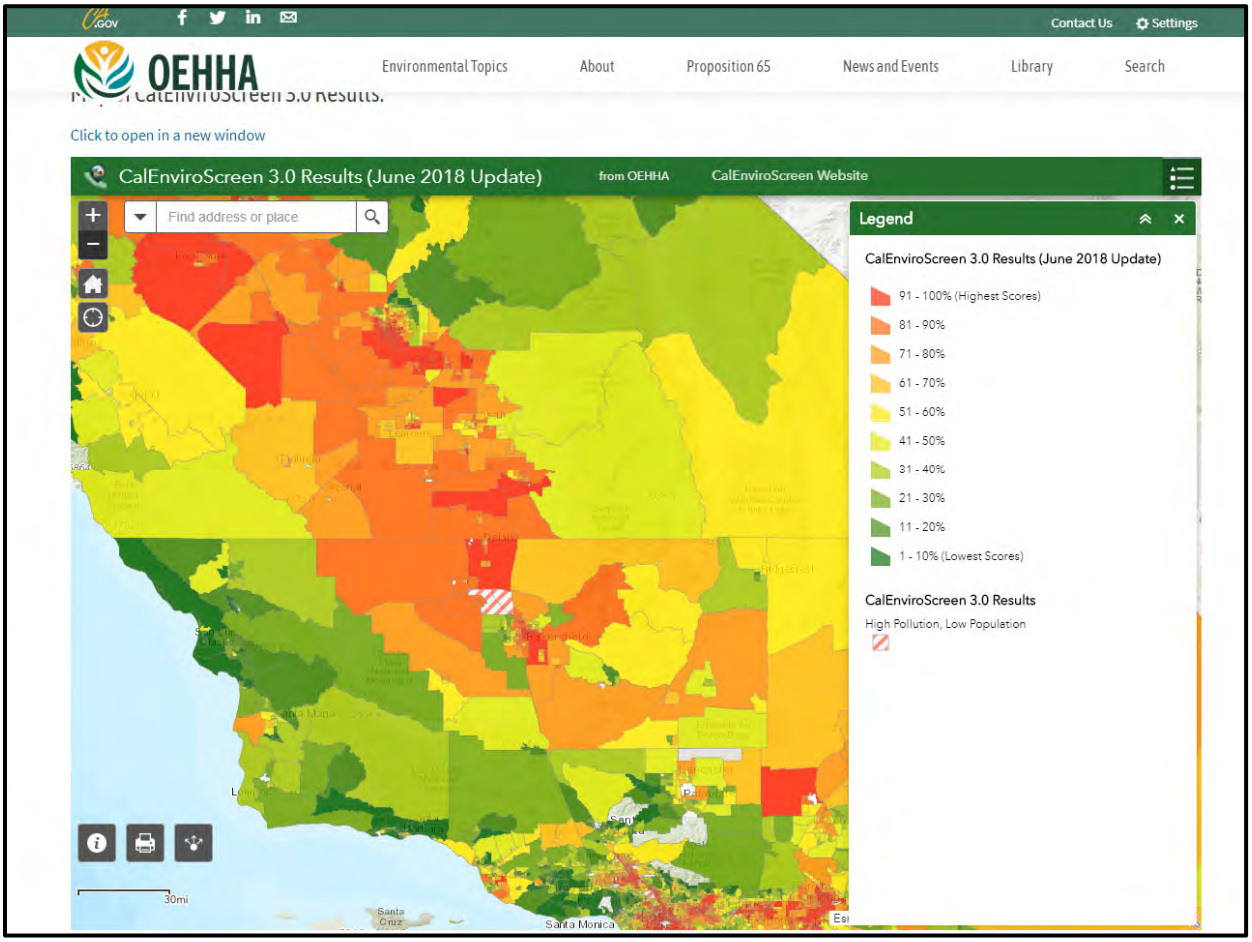
6. Information on Vulnerability Assessment Tools Pertaining to Groundwater

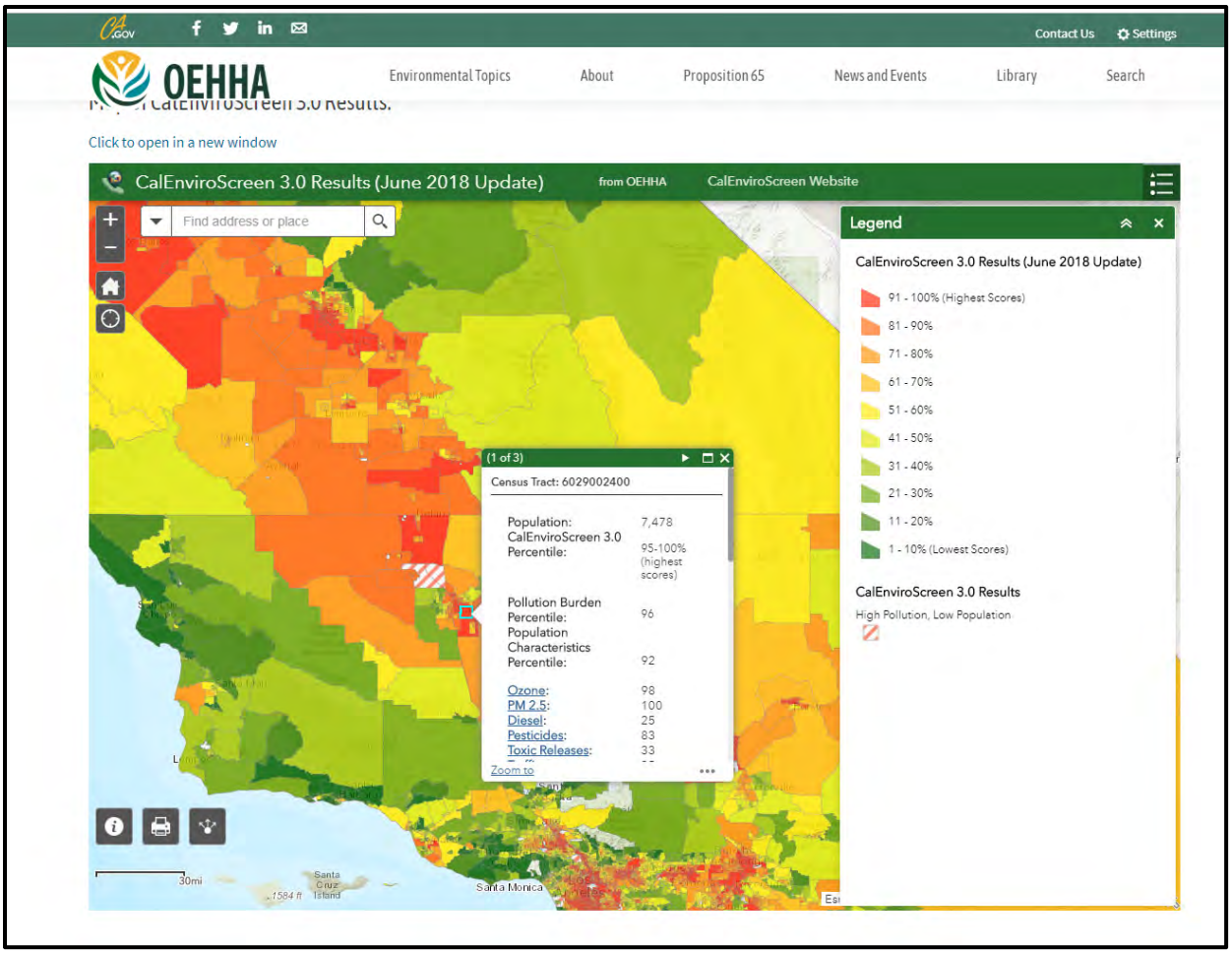
6.1. CalEnviroScreen 3.0 Maps

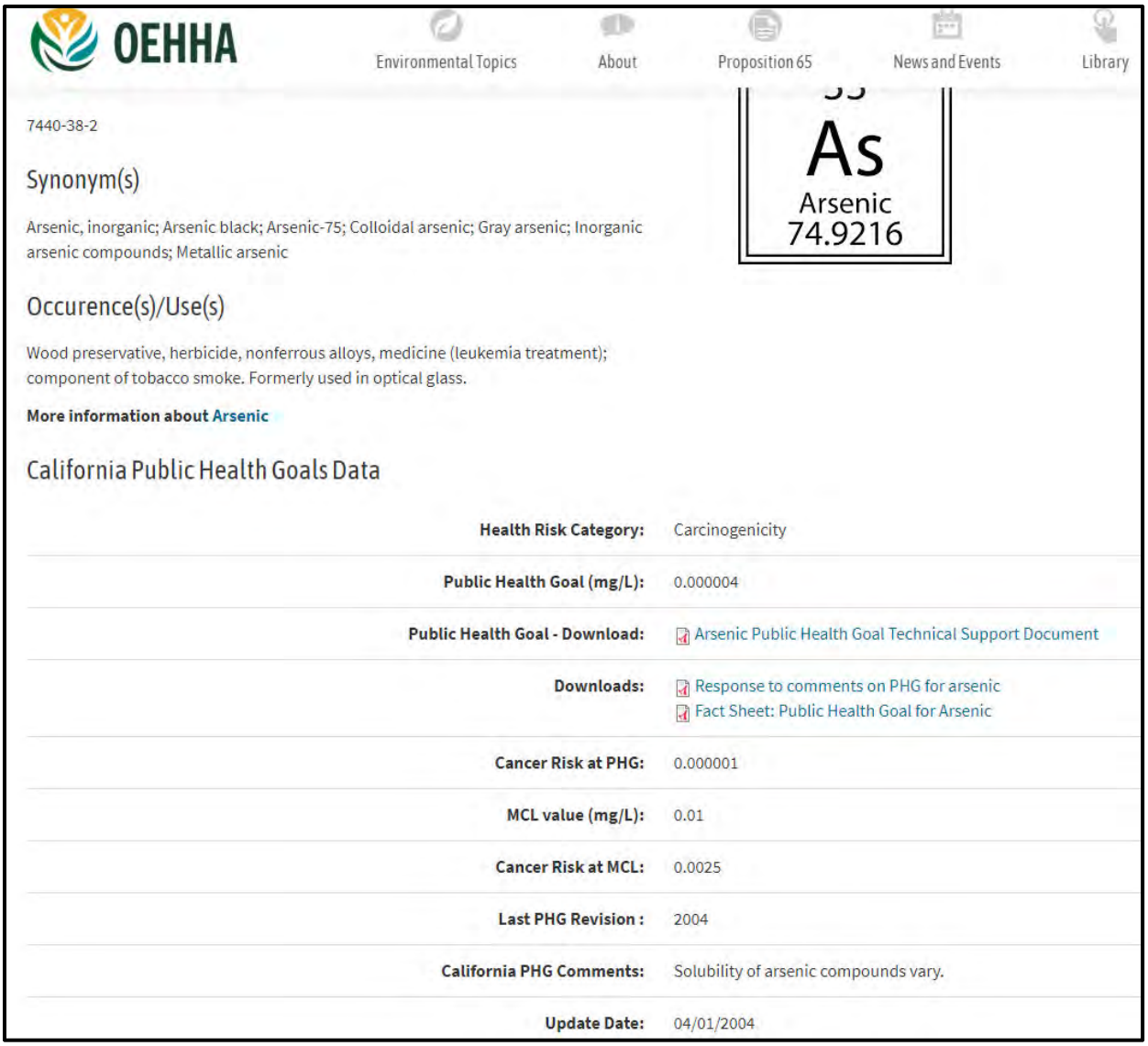
https://oehha.ca.gov/calenviroscreen/maps-data

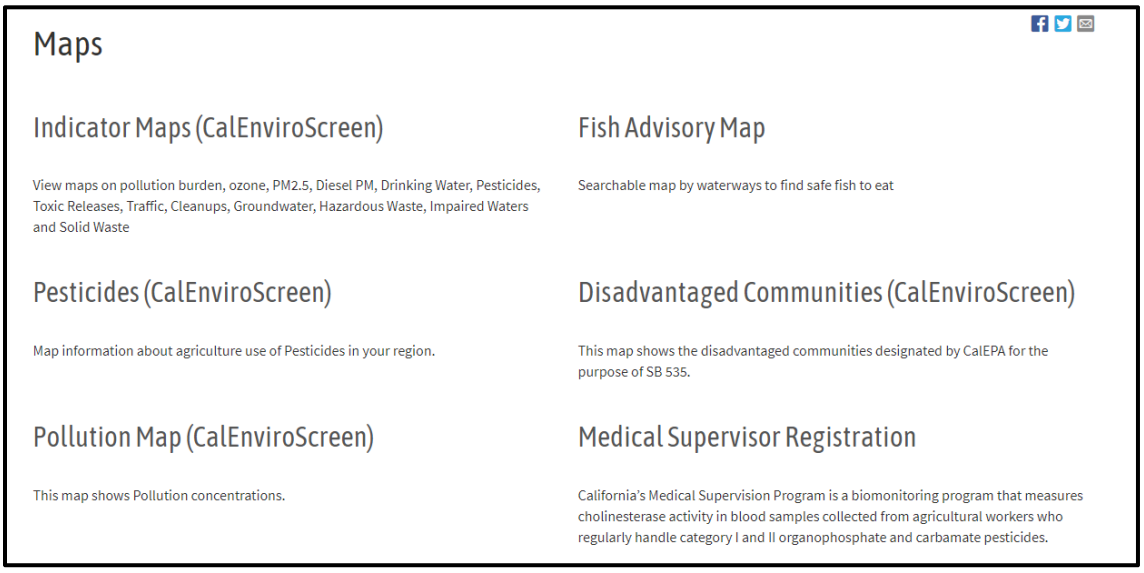
- Scores for pollution burden, including groundwater threats, drinking water contamination, clean ups, pesticides, and other indicators of pollution burden, and population characteristics by census tract.
- From various sources.
- Downloadable data in various formats (no chemical concentration measurements or groundwater elevations).
- Screening tool to help identify communities burdened by or susceptible to multiple sources of pollution.
- Maps – Cal EnviroScreen, Pesticides, Pollution Map, Disadvantaged Communities, etc. https://oehha.ca.gov/library/maps
    - Most results are expressed as scores; applicable for regulatory purposes.
- Chemicals databases – toxicity reports https://oehha.ca.gov/node/11208

Screenshots of website:



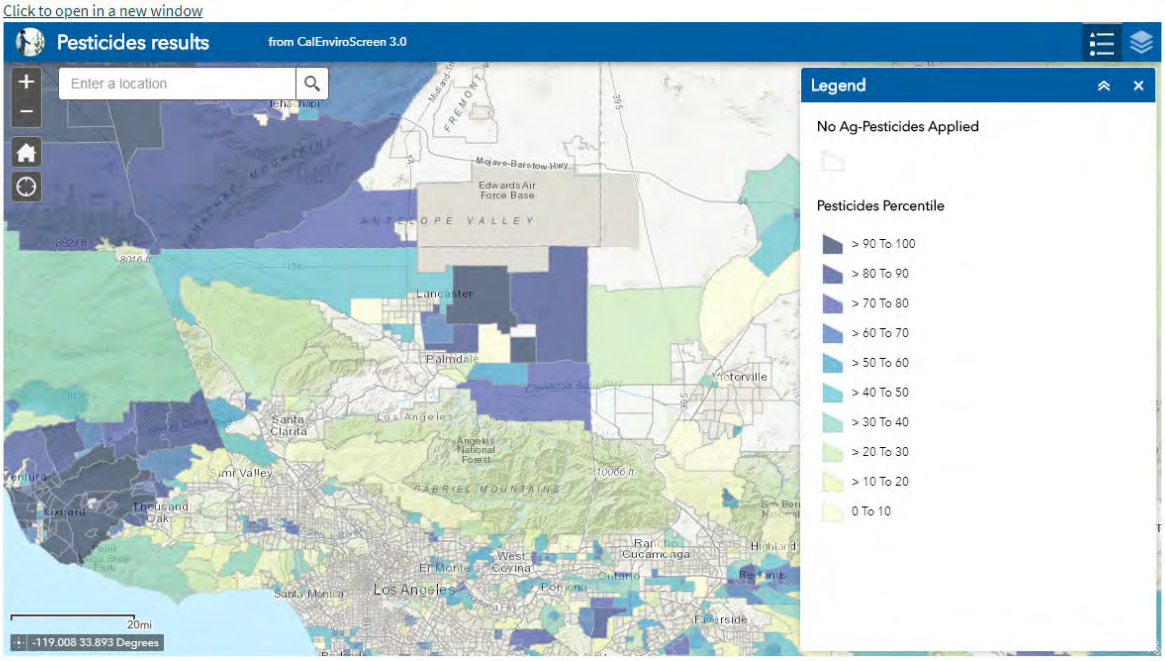

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CalEnviroScreen 3.0 Results (June 2018 Update)
from OEHHA
CalEnviroScreen Website
Find address or place
Legend
CalEnviroScreen 3.0 Results (June 2018 Update)
91 - 100% (Highest Scores)
81 - 90%
71 - 80%
61 - 70%
51 - 60%
41 - 50%
31 - 40%
21 - 30%
11 - 20%
1 - 10% (Lowest Scores)
CalEnviroScreen 3.0 Results
High Pollution, Low Population
(1 of 3)
Census Tract: 6029002400
Population: 7,478
CalEnviroScreen 3.0 Percentile: 95-100% (highest scores)
Pollution Burden Percentile: 96
Population Characteristics Percentile: 92
Ozone: 98
PM 2.5: 100
Diesel: 25
Pesticides: 83
Toxic Releases: 33
Zoom to
30mi
Santa Cruz Island
Santa Monica


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Environmental Topics
About
Proposition 65
News and Events
Library
7440-38-2
As
Arsenic
74.9216
Synonym(s)
Arsenic, inorganic; Arsenic black; Arsenic-75; Colloidal arsenic; Gray arsenic; Inorganic arsenic compounds; Metallic arsenic
Occurence(s)/Use(s)
Wood preservative, herbicide, nonferrous alloys, medicine (leukemia treatment); component of tobacco smoke. Formerly used in optical glass.
More information about Arsenic
California Public Health Goals Data
Health Risk Category: Carcinogenicity
Public Health Goal (mg/L): 0.000004
Public Health Goal - Download: Arsenic Public Health Goal Technical Support Document
Downloads: Response to comments on PHG for arsenic
Fact Sheet: Public Health Goal for Arsenic
Cancer Risk at PHG: 0.000001
MCL value (mg/L): 0.01
Cancer Risk at MCL: 0.0025
Last PHG Revision : 2004
California PHG Comments: Solubility of arsenic compounds vary.
Update Date: 04/01/2004


Maps
Indicator Maps (CalEnviroScreen)
View maps on pollution burden, ozone, PM2.5, Diesel PM, Drinking Water, Pesticides, Toxic Releases, Traffic, Cleanups, Groundwater, Hazardous Waste, Impaired Waters and Solid Waste
Fish Advisory Map
Searchable map by waterways to find safe fish to eat
Pesticides (CalEnviroScreen)
Map information about agriculture use of Pesticides in your region.
Disadvantaged Communities (CalEnviroScreen)
This map shows the disadvantaged communities designated by CalEPA for the purpose of SB 535.
Pollution Map (CalEnviroScreen)
This map shows Pollution concentrations.
Medical Supervisor Registration
California's Medical Supervision Program is a biomonitoring program that measures cholinesterase activity in blood samples collected from agricultural workers who regularly handle category I and II organophosphate and carbamate pesticides.

CalEnviroScreen 3.0 Pesticides Map

Click to open in a new window



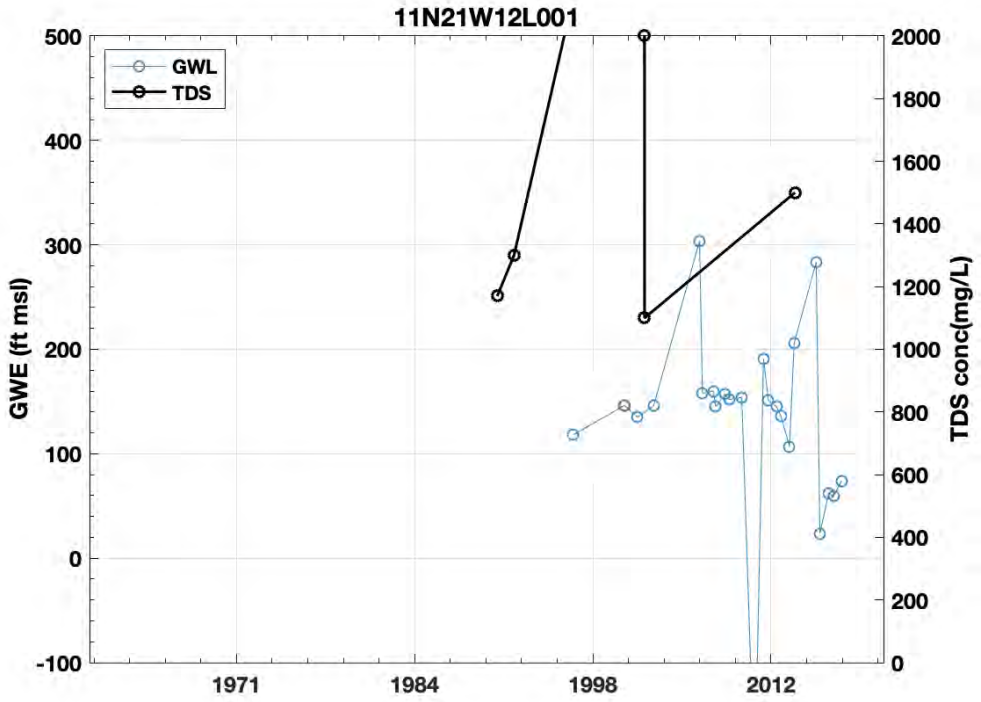
Appendix F

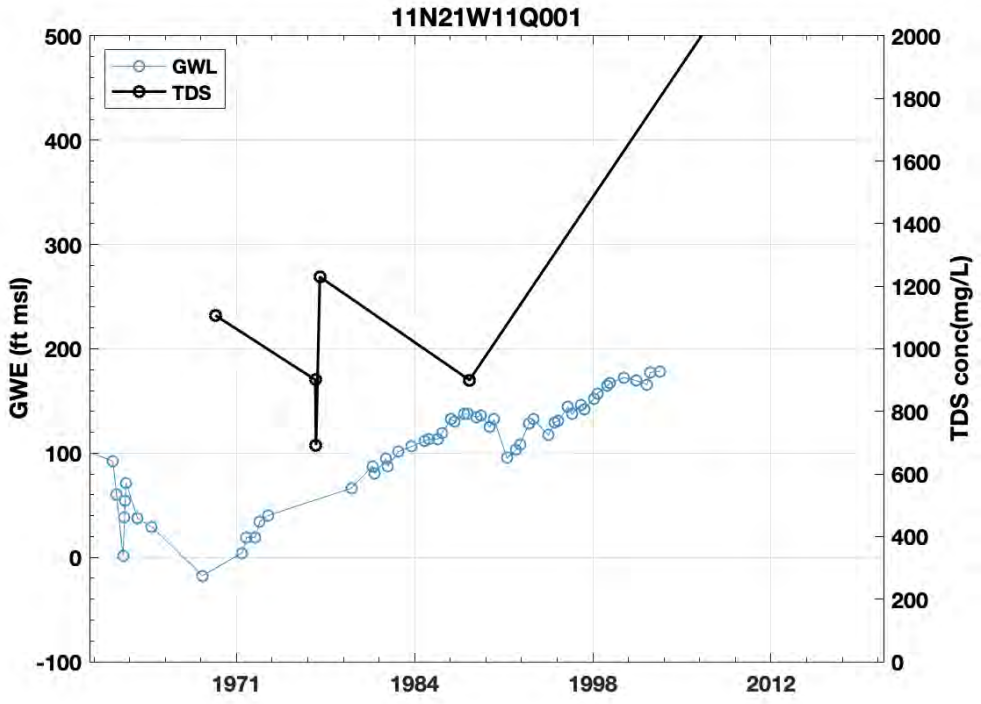
Analysis of Temporal Characteristics of Available Groundwater Quality Data

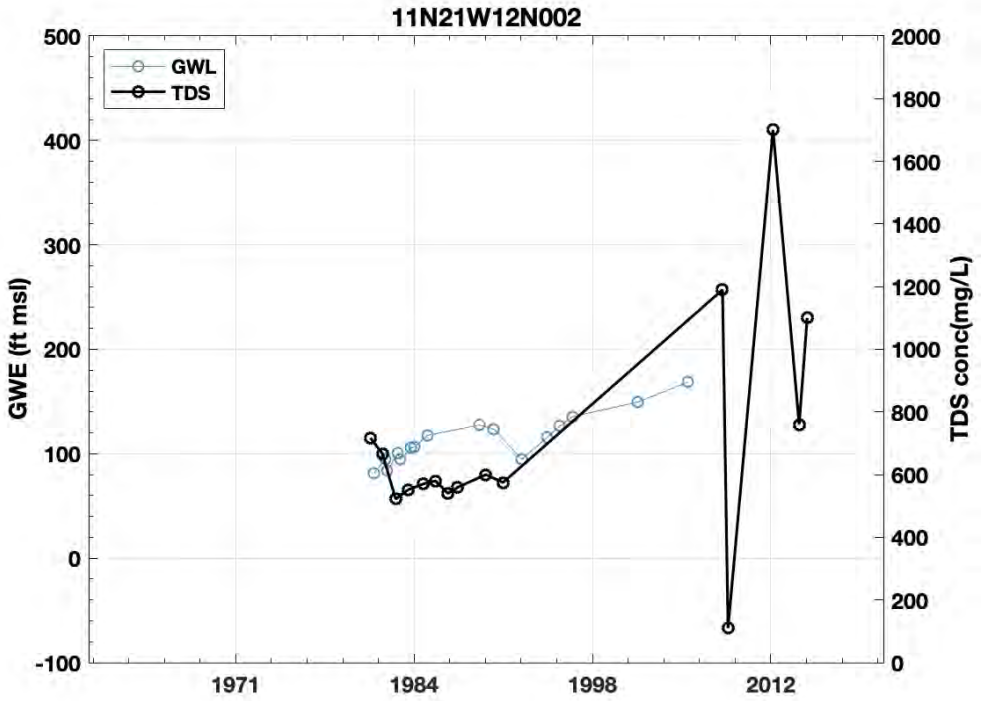
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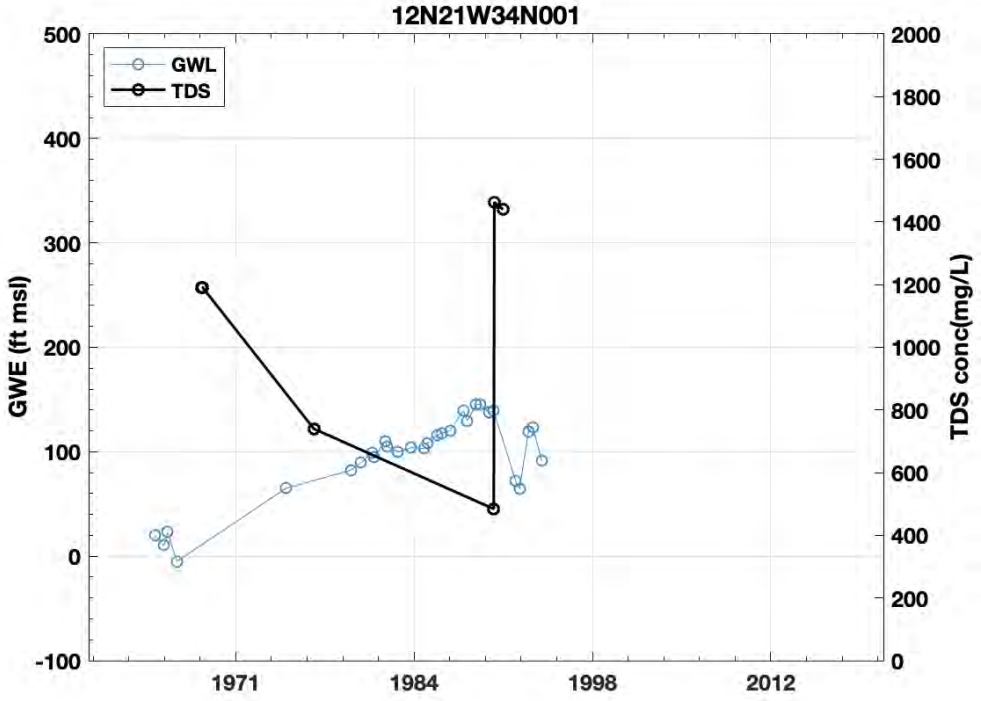
Analysis of Temporal Characteristics of Available Groundwater Quality Data - Total Dissolved Solids vs. Groundwater Elevation

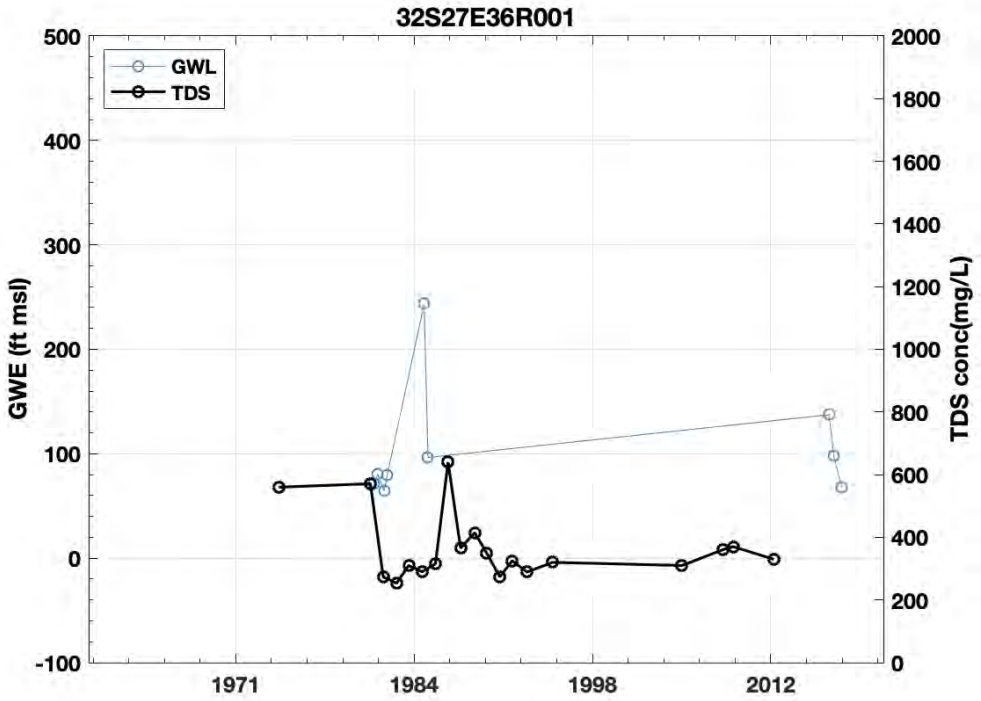
TDS


11N21W12L001
GWL
TDS
GWE (ft msl)
TDS conc(mg/L)
500
400
300
200
100
0
-100
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1971
1984
1998
2012


11N21W11Q001
GWL
TDS
GWE (ft msl)
TDS conc(mg/L)
500
400
300
200
100
0
-100
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1971
1984
1998
2012


11N21W12N002
GWL
TDS
GWE (ft msl)
TDS conc(mg/L)
500
400
300
200
100
0
-100
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1971
1984
1998
2012

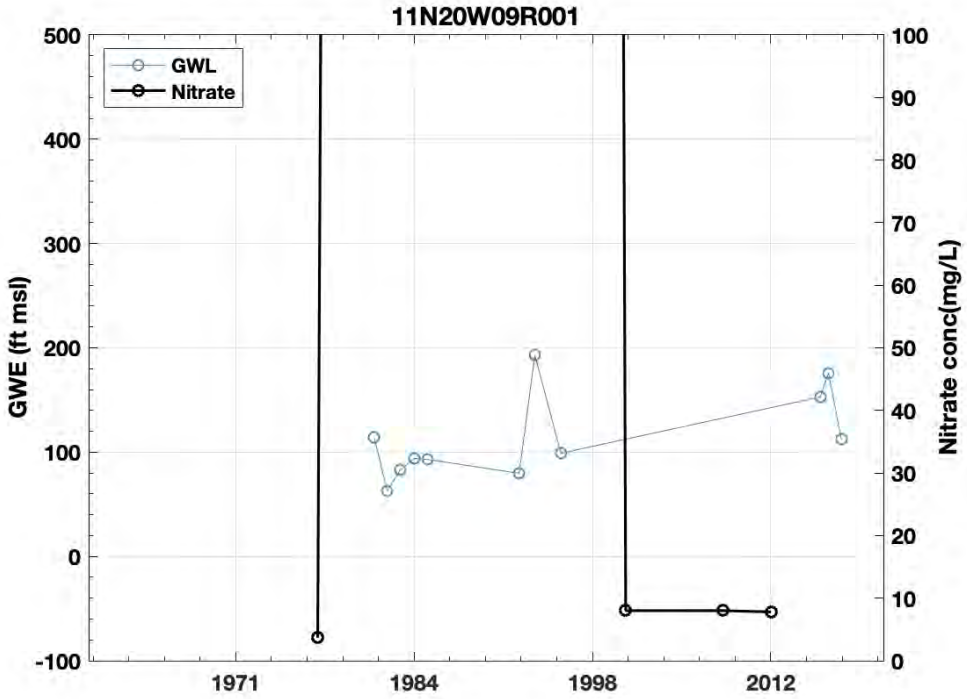

12N21W34N001
GWL
TDS
GWE (ft msl)
TDS conc(mg/L)
500
400
300
200
100
0
-100
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1971
1984
1998
2012

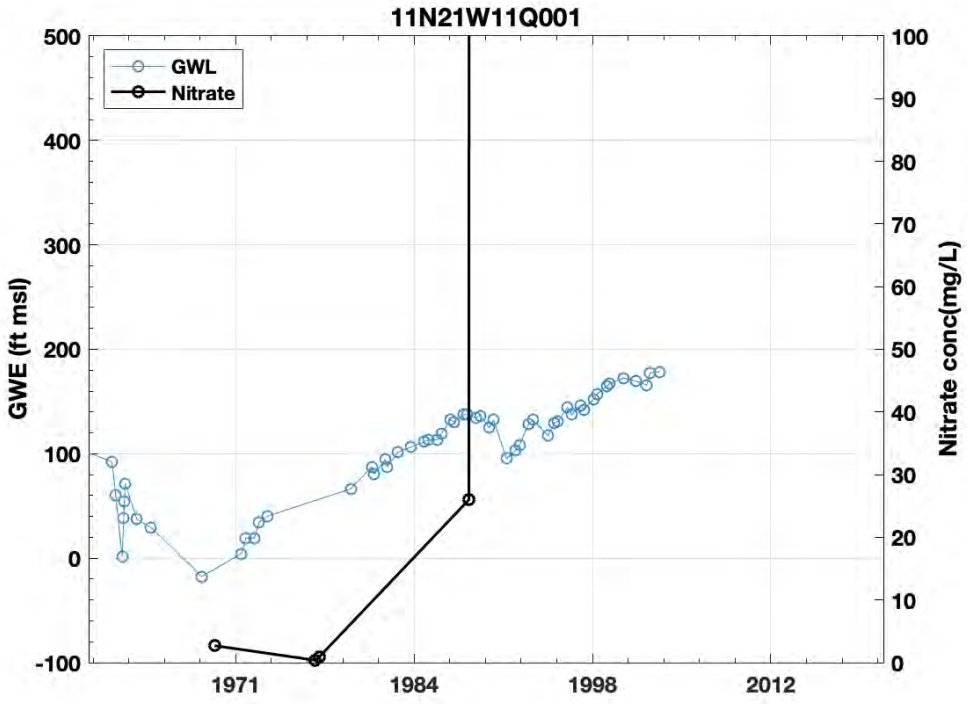

32S27E36R001
GWL
TDS
GWE (ft msl)
TDS conc(mg/L)
500
400
300
200
100
0
-100
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1971
1984
1998
2012

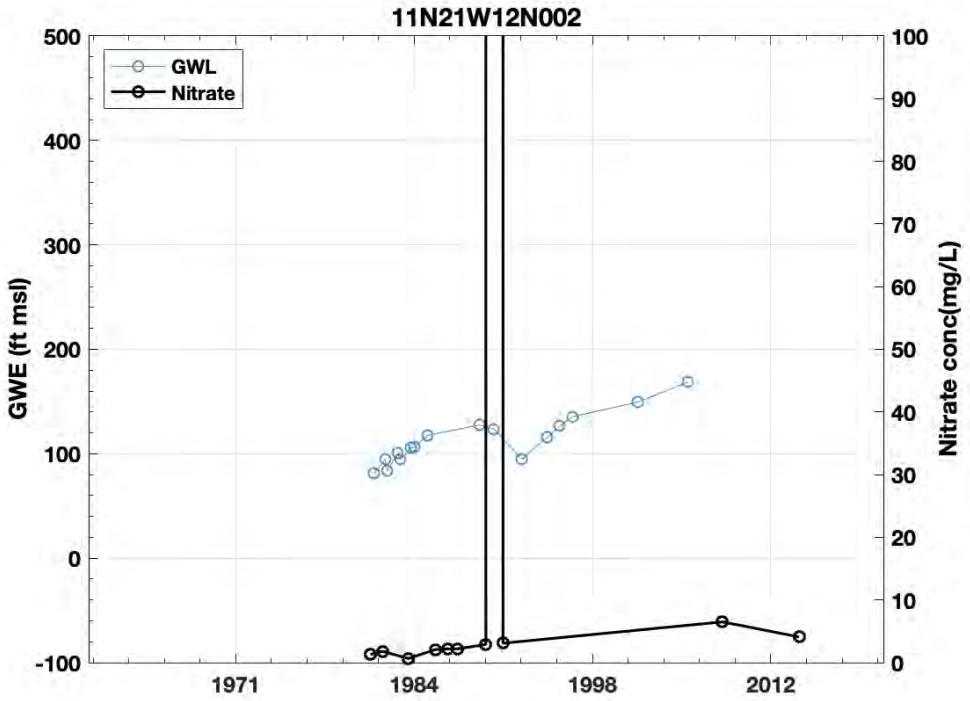
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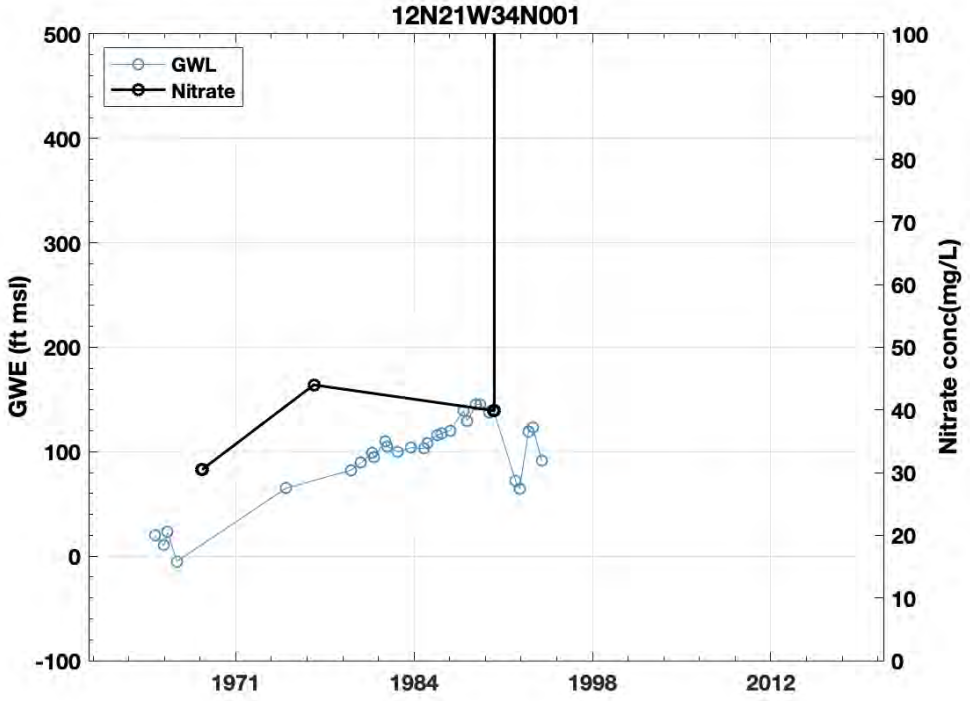
Analysis of Temporal Characteristics of Available Groundwater Quality Data - Nitrate (as NO3) vs. Groundwater Elevation

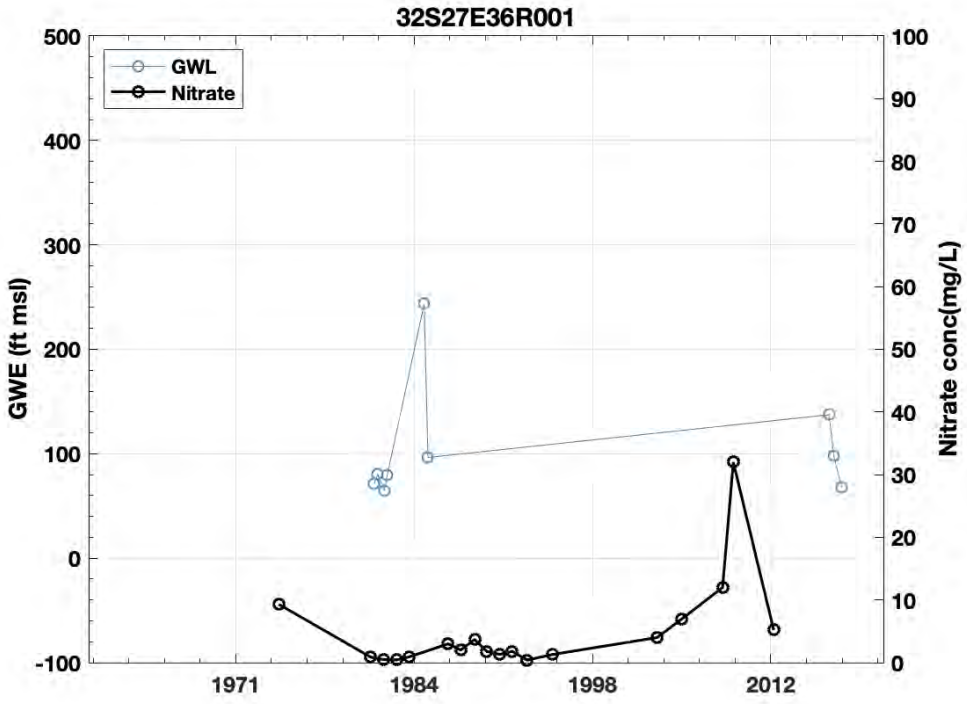
Nitrate


11N20W09R001
GWL
Nitrate
GWE (ft msl)
Nitrate conc(mg/L)
500
400
300
200
100
0
-100
100
90
80
70
60
50
40
30
20
10
0
1971
1984
1998
2012


11N21W11Q001
GWL
Nitrate
GWE (ft msl)
Nitrate conc(mg/L)
500
400
300
200
100
0
-100
100
90
80
70
60
50
40
30
20
10
0
1971
1984
1998
2012


11N21W12N002
GWL
Nitrate
GWE (ft msl)
Nitrate conc(mg/L)
500
400
300
200
100
0
-100
100
90
80
70
60
50
40
30
20
10
0
1971
1984
1998
2012

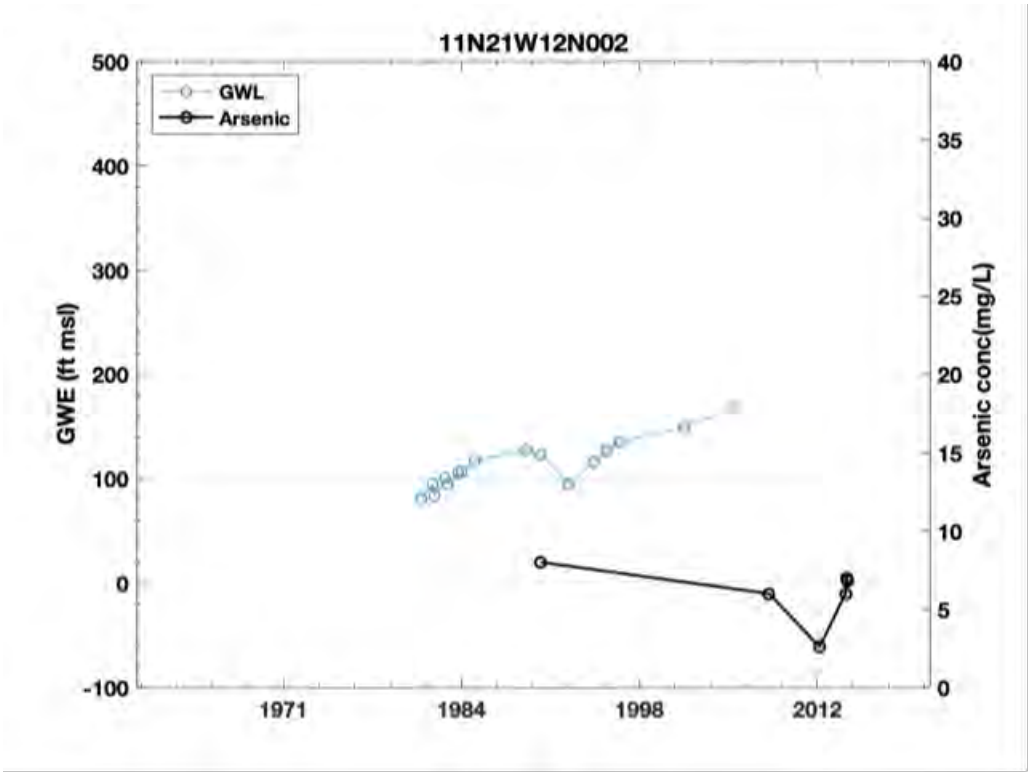

12N21W34N001
GWL
Nitrate
GWE (ft msl)
Nitrate conc(mg/L)
500
400
300
200
100
0
-100
100
90
80
70
60
50
40
30
20
10
0
1971
1984
1998
2012


32S27E36R001
GWL
Nitrate
GWE (ft msl)
Nitrate conc(mg/L)
500
400
300
200
100
0
-100
100
90
80
70
60
50
40
30
20
10
0
1971
1984
1998
2012

Appendix F -3

Analysis of Temporal Characteristics of Available Groundwater Quality Data - Total Recoverable Arsenic vs. Groundwater Elevation

Arsenic


11N21W12N002
GWL
Arsenic
GWE (ft msl)
Arsenic conc(mg/L)
500
400
300
200
100
0
-100
40
35
30
25
20
15
10
5
0
1971
1984
1998
2012

Appendix G

Methods and Data Used in the Water Budget Spreadsheet Model Approach

Appendix G-1

Water Budget Model Overview

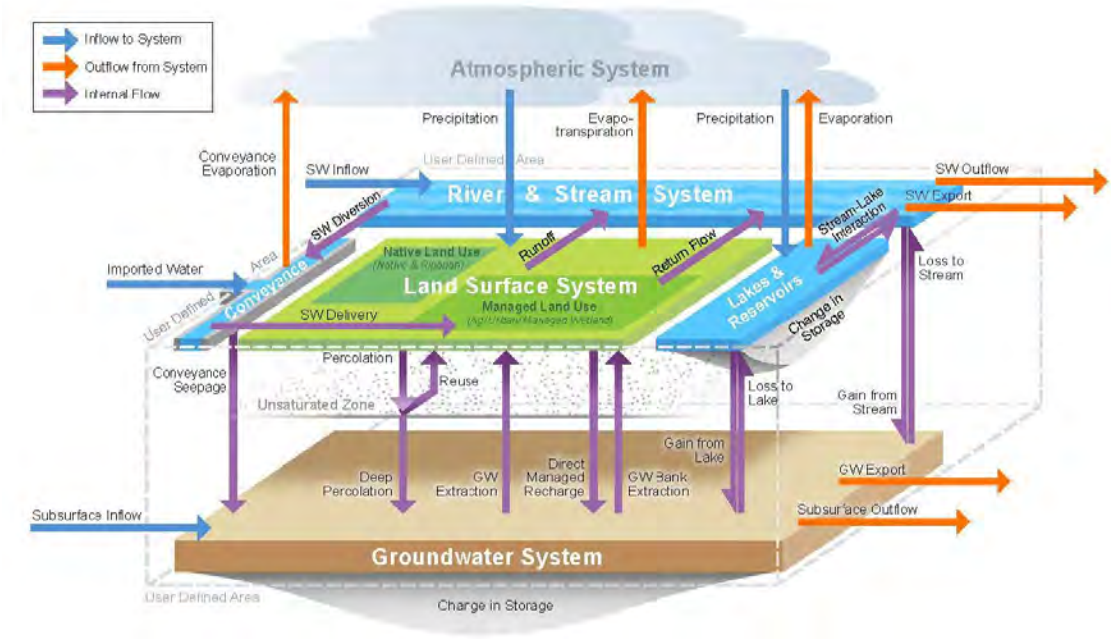
APPENDIX G-1
WATER BUDGET MODEL OVERVIEW

A water budget is an accounting of all water inflows to and outflows from a given spatial domain, and enforces the principle of mass balance through use of a change in water storage term. A water budget is expressed by the following simple equation:

Inflows - Outflows = Change in Storage

The above fundamental equation holds true for any defined domain (e.g., parcel, watershed, basin, etc.) and length of time (e.g., day, month, year, etc.) and, when properly constructed using process- and/or physics-based components, serves as a powerful tool for understanding water flow through a system.

Figure G-1-1: DWR Water Budget Schematic (Fig. 7 from DWR's SGMA BMP #4, pg. 30)



Description of Water Budget Framework

A water budget "framework" has been developed to inform the development of a water budget model for the District's service area that is consistent with the requirements of the Sustainable Groundwater Management Act (SGMA) and aligns with the historical, current, and future water budget periods as specified by the Kern Groundwater Authority GSA (KGA GSA) and further described below. The conceptual water budget model is depicted on **Figures WB-1 and WB-2** of the Wheeler Ridge-Maricopa Water Storage District (WRMWSD) Kern Subbasin Management Area Plan, and is further described below.

Water Budget Subdomains

The water budget is divided into five internal subdomains, each influenced by a number of flow components and within which mass-balance is enforced (i.e., the sum of inflow components is balanced by the sum of outflow components and/or a change in storage component). **Figure WB-1** shows the water budget domain, and the following internal subdomains:

a. Artificial channels
b. Agricultural lands
c. Urban lands
d. Natural channels, and
e. Groundwater system

In addition to the five internal subdomains, several external subdomains are incorporated into the spreadsheet model. These include the watersheds that contribute streamflow to streams entering the District, and the atmosphere which is a source of precipitation and sink for evapotranspiration. The spreadsheet model does not explicitly account for the vadose (unsaturated) zone between the land surface and the (saturated) groundwater system, but instead incorporates temporal lag factors to account for the movement of water through this zone. An implicit assumption in this approach, therefore, is that the vadose zone does not experience any change in storage over time.

Water Budget Flow Components

Within and between each subdomain are 31 water budget flow components that route water through WRMWSD. **Figure WB-2** shows a conceptual diagram of the individual water budget flow components between subdomains as well as flow components that are external to the overall water budget domain (i.e., serve only as an inflow or outflow to the entire system, rather than a flow between subdomains). The 31 conceptual water budget flow components are listed in **Table G-1-1**, along with an overview of their estimation methods**.** The general relationship between water budget subdomains, associated flow components, and mass balance relationships is further depicted in **Table G-1-2**.

Certain components are based on "raw" data which are directly measured and based on historical records. These "raw" components are considered to have a relatively high degree of certainty. Other components are estimated using a variety of analytical methods (e.g., Darcy's Law to calculate subsurface flows across the domain's external boundaries) and are thus subject to greater uncertainty based on the parameters used in their estimation. Some components (i.e., groundwater pumping for agricultural use) constitute major proportions of the overall water budget and have thus been given significant attention. Others are relatively minor in magnitude (e.g., seepage from artificial channels) and are, to some degree, less significant to the overall water budget and less well defined.

While the various subdomains and linkages shown on **Figures WB-1** and **WB-2** and in **Table G-1-1** and **Table G-1-2** indicate a highly complex system, the use of such a component-based bottom-up approach allows each component to be considered separately which can benefit model development and application. For example, if new data or methods become available for a certain component, they can be easily plugged into the appropriate component without disturbing the rest of the model.

Water Budget Time Periods

As mentioned above, the water budget spreadsheet model was developed to estimate the magnitude of water budget flow components and the resulting change in groundwater storage to the local aquifer system underlying WRMWSD for three distinct time-periods as defined by the KGA GSA:

- **Historical –** DWR Water Years 1995 – 2014 (i.e., October 1994 – September 2014);
- **Current –** DWR Water Year 2015 (i.e., October 2014 – September 2015); and
- **Future –** 50-year projection of DWR Water Years 2016 – 2065 (see **Appendix G-6**).

Water Budget Spreadsheet Model Functionality

The water budget spreadsheet model was developed using Microsoft Excel. The complete model consists of one Excel (.xlsx) workbook with several individual spreadsheet tabs which can generally be grouped into four categories:

- "Master" Models
- "User Input Parameters" and Model Calibration
- Presentation and Reporting
- "Backend" Data and Calculations

"Master" Models

The final calculations for all historical and current (1994 - 2015) water budget components occur within the following three "master" tabs of the spreadsheet:

- **"Kern_monthly_WB"**
- **"WWB_monthly_WB"**
- **"Combined_monthly_WB"**

These tabs contain the fully populated monthly historical and current water budgets for (1) the District's SGMA management area within the Kern Subbasin[1], (2) the District's SGMA management area within the White Wolf Subbasin, and (3) District's entire SGMA management area, respectively.

Results of the historical and current water budget efforts for the Kern Subbasin were subsequently used to inform the development of three projected (i.e. future) water budget scenarios for the WRMWSD Kern Subbasin Management Area, which are described in greater detail in **Appendix G-6**. The projected water budget "master" spreadsheet models include:

- **"Kern_PROJECTED_baseline"**
- **"Kern_PROJECTED_2030"**
- **"Kern_PROJECTED_2070"**

All master spreadsheets are denoted in green within the Excel workbook. Each column of the master spreadsheets represents an individual water budget flow component or associated calculation. Flow components are grouped by Water Budget Domain/Subdomain, and main flow components are listed by number (1 through 31) near the top of each master tab. Each row of the master spreadsheets (apart from the header rows) represents a single month in the model period, as defined in columns E-F. All values are listed in acre-feet (AF). Monthly values are subsequently summarized by water year at the bottom of each master spreadsheet. The master spreadsheets have been fully populated with data via linkages with the "backend" data and calculation spreadsheets (described in further detail below) and/or through calculations made directly within the master spreadsheet, and in all cases should not be directly edited

[1] This area includes the District's overlap lands with Arvin-Edison Water Storage District (AEWSD) within the Kern Subbasin. Select water budget components are reported for the overlap and non-overlap areas in **Tables WB-1 – WB-5** of the Management Area Plan. WRMWSD is actively coordinating with AEWSD regarding management responsibilities of the overlap lands under SGMA implementation, and associated water budget models will be updated accordingly going forward.

unless intending to override the existing data with updated inputs. Raw data inputs are denoted in blue shaded cells, whereas unshaded cells are calculated inputs.

"User Input Parameters" and Model Calibration

As further described in **Appendix G-5**, various "User Input Parameters" are included to assist in calibration of the historical and current water budgets. These are listed above the header rows of the master tabs, including:

- Irrigation Efficiency Coefficients (for micro-drip, micro-sprinkler, sprinkler, center-pivot sprinkler, and gravity-based irrigation types; see **Appendix G-4**)
- Deep Percolation Lag Period (i.e., approximate time delay for deep percolation to reach groundwater table; see **Appendix G-4**)
- White Wolf Fault Hydraulic Conductivity and Thickness (to estimate transmissivity along the fault; see **Appendix G-3**)
- Kern Subbasin Groundwater to Streamflow Inflow Ratio (to estimate groundwater inflows to the Kern Management Area as a residual to the groundwater subdomain; see **Appendix G-3**)
- Leachate Water Electrical Conductivity (to estimate leaching demands; see **Appendix G-4**)
- Additional Operational Demands (to estimate additional applied water demands [in terms of AFY/irrigated acre] from cultural practices and other operation requirements, e.g. dust abatement, frost control, etc.; see **Appendix G-4)**
- Ineffective Precipitation Deep Percolation Coefficient (to estimate deep percolation from ineffective precipitation; see **Appendix G-4**)
- Kern & White Wolf Watershed Consumptive Use Fractions (to estimate residual streamflows into the District; see **Appendix G-2**)
- Kern & White Wolf Watershed Precipitation Thresholds for Runoff (to estimate residual streamflows into the District, see **Appendix G-2**)
- Municipal & Industrial Consumptive Use Fraction
- Artificial Canals Seepage Rate
- Natural Channels Seepage Fraction (see **Appendix G-2**)

Many of these "User Input Parameters" have been adjusted within the model to reflect best available information and/or calibrated to optimize model response, but can be adjusted manually to reflect updated information or to test model response. Adjustments to the User Input Parameters are made within the **"Calibration"** tab of the model, and the listed values within the master tabs will update automatically.

As further described in **Appendix G-5**, The **"Calibration"** tab is the active module used to qualitatively calibrate the water budget by aligning the historical change in storage calculated in the master model tabs to change in storage values estimated via historical water level records collected within the model domain. This is principally done via adjustment of select "User Input Parameters" specified above, and subsequent

assessment of the resulting fit of the model-calculated change in storage to analogous estimates made from water level records collected at two "bookend" periods in time within the model period. The water level-calculated change in storage estimates used for this analysis are listed in the **"WL_storage_change"** spreadsheet of the Excel workbook. All calibration-related spreadsheets are denoted in yellow.

Presentation and Reporting

Live tables and figures that have been developed for inclusion in the Kern Management Area Plan, as well as several associated presentation & reporting related tabs, can be found in the blue shaded tabs within the water budget Excel workbook. These include:

- Exhibits used in the Kern Management Area Plan, including:
  - **"Table WB-1_Kern"** – Annual Surface Water Inflows and Outflows by Source Type
  - **"Table WB-2_Kern"** – Annual Inflows to and Outflows from the Groundwater System, and Change in Storage
  - **"Table WB-3_Kern" –** Annual and Cumulative Change in Groundwater Storage between Seasonal Highs
  - **"Table WB-4_Kern" –** Annual Change in Groundwater Storage vs. DWR Water Year Type
  - **"Table WB-5_Kern" –** Annual Total Inflows, Outflows, and Change in Groundwater Storage
  - **"Table WB-6_Kern" –** Summary of Projected Water Budget Results (with/without) Project & Management Action Implementation
  - **"Table_G-1-1_WB_Components"** – Summary of Analytical Water Budget Components
  - **"WB_graphs_Kern"** – includes all graphs used to develop Figures WB-1 through WB-20 of Kern Management Area Plan
  - **"Fig_WB-18" –** Figure WB-18 of Kern Management Area Plan
  - **"Fig_G-4-2" –** Agricultural Subdomain Water Budget Schematic
- Spreadsheets supporting development of Management Area Plan exhibits, including:
  - **"horiz_bar_chart"** – used to summarize water budget components for reporting in Tables WB-1 through WB-5
  - **"horiz_bar_chart_proj" –** used to summarize projected water budget components for reporting in Table WB-6
  - **"change_storage_figs" –** used to develop Figures WB-10 through WB-14, GWC-8
  - **"SW_cum_import_71_15" –** used to help develop Figure WB-4
  - **"data_as_values_for_combined_hyd" –** used to help develop Figure WB-18

"Backend" Data and Calculations

All other tabs within the Excel workbook contain various input data and calculations used to support water budget calculations in the master water balance tabs and should not be edited. Uncolored tabs correspond to various raw input data that are directly linked to the historical and current master model tabs. These include:

- **"Monthly_SW_deliveries" –** records of monthly surface water deliveries to WRMWSD customers in the Kern and White Wolf portions of the District (1999 – 2015)
- **"Monthly_GW_Pumping" –** records of monthly District and annual Private User Input groundwater pumping into the California Aqueduct (2001 – 2015)

- **"M_I_deliveries" –** records of annual WRMWSD deliveries to Municipal and Industrial (M&I) customers (1994 – 2015)
- **"Monthly_precip_WR" –** monthly precip rates [in] at WRMWSD and NOAA climate stations (1994 – 2015)
- **"C2VSim_FG_Boundary_Params" –** average transmissivity and depths of C2VSim-FG Layers 1 and 2 extracted along WRMWSD boundary lines, for use in approximating groundwater flux (see **Appendix G-3**)
- **"raster_based_gradients" –** average groundwater elevations along boundary gradient lines extracted from historical groundwater elevation raster data (see **Appendix G-3**)
- **"S1b. SWP Historic"** – record of annual historical SWP contract versus total imports, maintained by WRMWSD

Raw input data inputs to the water budget model also include spreadsheets imported directly from the R processing software, which was used predominantly to process land use and ITRC-METRIC data for integration into the Agricultural Lands subdomain (see **Appendix G-4**). These are denoted as light grey tabs in the Excel workbook, and include:

- **"monthly_ITRC_CROPS_R" –** WRMWSD monthly ITRC data by irrigation type, 2001 - 2015
- **"monthly_ITRC_CROPS_pre2k_R" –** WRMWSD monthly ITRC data by irrigation type, 1993 - 2000
- **"monthly_ITRC_channels_R" –** monthly ITRC data along California Aqueduct and 850 Canal, 1993 - 2015
- **"monthly_ITRC_Basin_unadj_R" –** monthly ITRC within WRMWSD by Basin, un-adjusted for non-coverage areas (see **Appendix G-4**), 1993 - 2015

Dark grey tabs represent spreadsheets involving a calculation or series of calculations for incorporation into the historical & current master model tabs. These include:

- **"climate_parser_master_WR**" – used to estimate precipitation on District lands and within surrounding watersheds (see **Appendix G-2**)
- **"GW_Fluxes" –** used to estimate subsurface fluxes across District boundaries (see **Appendix G-3**)
- Various tabs used to calculate components within the Agricultural Lands subdomain (see **Appendix G-4**), including:
    - **"Monthly _adjusted_ET_by_zone" –** parses monthly ITRC data into different land use subdomains and estimates ET for the in-District areas outside ITRC coverage
    - **"Monthly_acreages" –** parses seasonal crop data into different land use subdomains
    - **"Monthly_irr_eff" –** calculates monthly irrigation efficiency coefficients based on seasonal irrigation types
    - **"leaching_master" –** calculates monthly leaching volumes based on seasonal crop types
    - **"operational demands" –** calculates monthly operational demands based on irrigated acreage
    - **"effective_precip" –** calculates monthly effective precipitation using raw precipitation, ET data
    - **"2012_AgDomain" –** estimates monthly ET for calendar year 2012, where ITRC-METRIC data was unavailable
    - **"pre2k_operations"** – estimates monthly surface water deliveries, District groundwater pumping rates based on annual data from FAA Table IV records for 1994 - 2000

- **"native yield" –** used for KGA "native yield" discussions (no impact on water budget functionality)

Purple shaded tabs correspond to raw data inputs and calculations used to delineate select water budget components in the overlap and non-overlap areas of the Kern and White Wolf portions of the District. These tabs do not effect the water budget functionality, and are used for reporting purposes in **Tables WB-1 – WB-5** of the Management Area Plan only. They include:

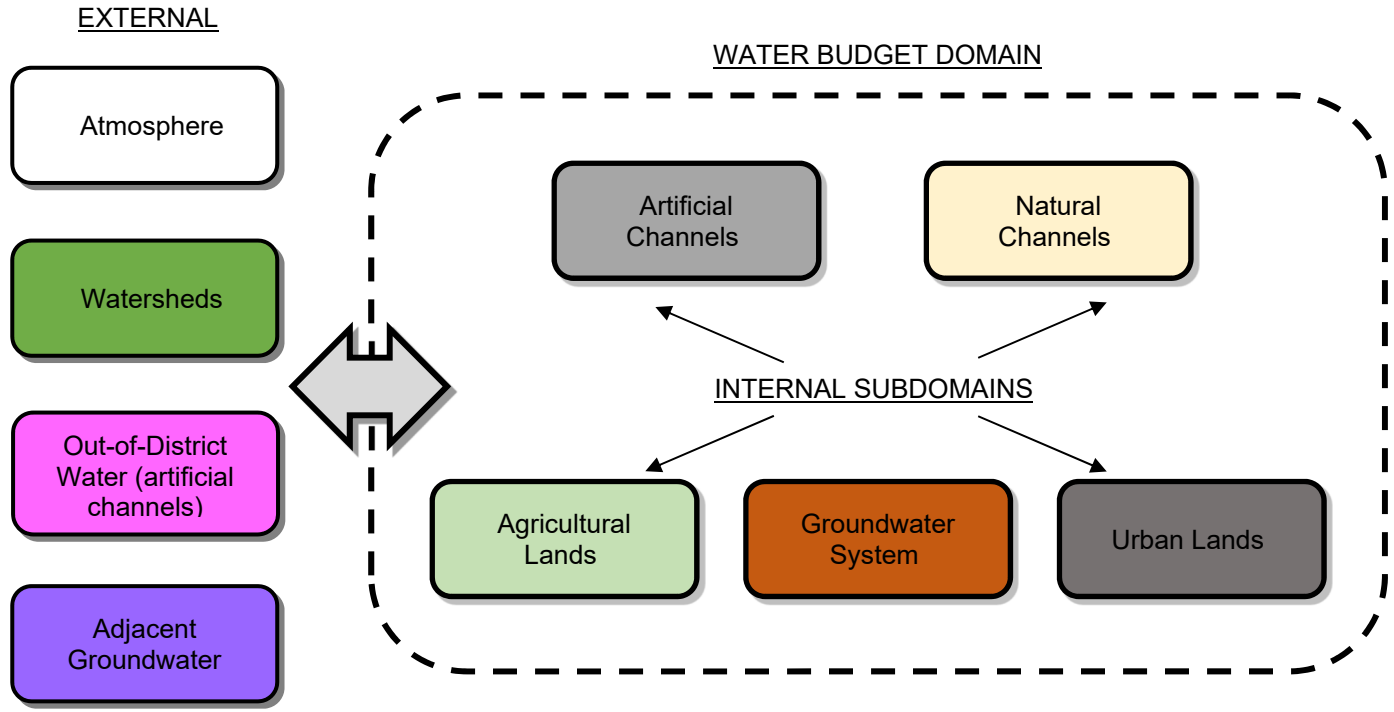
- "**ET_total_v_non-overlap"** – compares monthly ITRC ET signal for the full District and the non-overlap area only
- "**WRMWSD_Overlap_Deliveries_AE**" – monthly WRMWSD surface water delivery records to the WRMWSD-AEWSD overlap area
- **"Monthly_ET_by_zone_WR_no_overla" –** parses monthly ITRC data on the non-overlap area into different land use subdomains
- **"Monthly_acreages_WR_no_overlap" –** parses seasonal crop data in the non-overlap area into different land use subdomains
- **"2012_AgDomain_WR_no_ove" –** estimates monthly ET in the non-overlap area for calendar year 2012, where ITRC-METRIC data was unavailable
- **"MONTHLY_ITRC_Basin_WR_no_ove" –** monthly ITRC within non-overlap area by Basin, un-adjusted for non-coverage areas (see **Appendix G-4**), 1993 - 2015
- **"MONTHLY_ITRC_CROPS_no_overlap" –** WRMWSD monthly ITRC data in non-overlap area by irrigation type, 2001 - 2015
- **"MONTHLY_ITRC_CROPS_pre2k_no_ove" –** WRMWSD monthly ITRC data in non-overlap area by irrigation type, 1993 - 2000
- **"leaching_master_WR_no_overlap" –** calculates monthly leaching volumes in non-overlap area based on seasonal crop types
- **"operational_demands_WR_no_over" –** calculates monthly operational demands in non-overlap area based on irrigated acreage

Finally, brown shaded tabs correspond to raw data inputs and calculations used to inform development of three projected model scenarios (see **Appendix G-6**). These include:

- KGA climate change factors and surface water delivery assumptions for projected water budget scenarios, including:
  - **"SWP Baseline" –** Projected State Water Project supply change factors under "baseline" scenario
  - **"SWP 2030" –** Projected State Water Project supply change factors under "2030 Climate Change" scenario
  - **"SWP 2070" –** Projected State Water Project supply change factors under "2070 Climate Change" scenario
  - **"Precipitation 2030 SR 21" –** Projected precipitation change factors under "2030 Climate Change" scenario
  - **"Precipitation 2070 SR 21" –** Projected precipitation change factors under "2070 Climate Change" scenario
  - **"ET 2030 SR 21" –** Projected evapotranspiration change factors under "2030 Climate Change" scenario

- **“ET 2070 SR 21” –** Projected precipitation change factors under “2070 Climate Change” scenario

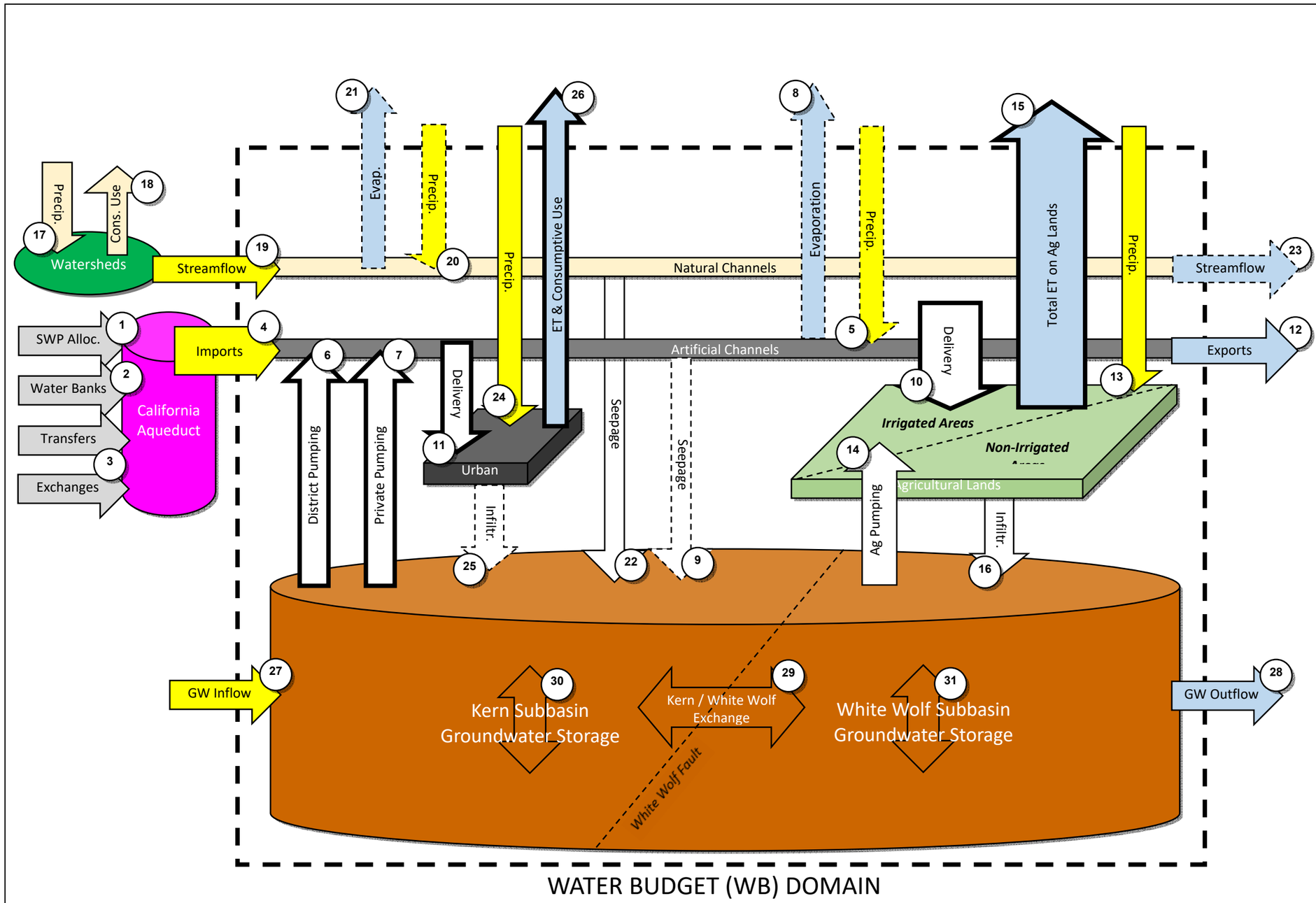
- **“Kern_PROJECTED_analog” –** Kern master water budget under 50-yr analog period (no adjustments to supplies, climate assumptions) – not used as a unique projected scenario, only to assist in calculations for baseline/2030/2070 projected scenarios
- **“P&MA_scenarios” –** used to input P&MA supply augmentation and demand reduction targets for 2030 and 2070 climate change scenarios to assess impacts on projected change in storage under full SGMA implementation



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Water Budget Domains and Subdomains

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01
Figure WB-1



Legend

- "Raw"
- Likely Negligible
- External
- Inflow to WB Domain
- Internal
- Outflow from WB Domain
- Currently Not Estimated in WB

Abbreviations:

Ag	=	agricultural
Cons.	=	consumptive
Evap.	=	evaporation
ET	=	evapotranspiration
GW	=	groundwater
Infiltr.	=	infiltration
M&I	=	municipal & industrial
Perc.	=	percolation
Precip.	=	precipitation
WB	=	water budget

Notes:

1. Components 4-28 are further parsed into their respective contributions to the Kern and White Wolf Subbasins within the water budget.

Water Budget Flow Components

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

eki environment & water

Figure WB-2

TABLE G-1-1
Conceptual Water Budget Flow Components
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

#	Water Balance Component	Component's Role in Overall Water Budget Domain	"Raw" Component	Likely Negligible	Water Budget Subdomain							Component Estimation Method in Water Budget Model
					CA Aqueduct (External)	Watersheds (External)	Artificial Channels & Pipelines	Natural Channels	Agricultural Lands	Urban Lands	Groundwater System	
1	State Water Project Allocation	External	Yes		In							Not currently quantified in water budget (contribution reflected in total imports)
2	Out-of-District Water Banks	External	Yes		In/Out							Not currently quantified in water budget (contribution reflected in total imports)
3	Out-of-District Transfers/Exchanges	External	Yes		In/Out							Not currently quantified in water budget (contribution reflected in total imports)
4	Total Surface Water Imports	Inflow					In					Calculated as Residual of Total Deliveries [10 + 11] - GW Inputs [6 + 7] - Atmospheric Exchange [5 - 8]
5	Rainfall onto Artificial Channels	Inflow		Yes			In					Precip Rate * CA Aqueduct area
6	District Groundwater Pumping Inputs to Artificial Channels	Internal Linkage	Yes				In				Out	From "WRM_Wells_Production_2001-2016_ver_2017-07-18e.xls"
7	Private Groundwater Pumping Inputs to Artificial Channels	Internal Linkage	Yes				In				Out	From "AFUSRINPUT" column of WLEDGER records, or from FAA (Table IV) Sheets; monthly distribution estimated from District GW Pump-in records
8	Evaporation from Artificial Channels	Outflow		Yes			Out					Observed ITRC-METRIC ET along CA Aqueduct * CA Aqueduct area
9	Seepage from Artificial Channels	Internal Linkage		Yes			Out				In	Seepage Rate * CA Aqueduct area
10	District Deliveries to Agricultural Lands	Internal Linkage	Yes				Out		In			Total Deliveries from "WLEDGER" monthly records - M&I Deliveries [11]
11	District Deliveries to Municipal & Industrial Customers	Internal Linkage	Yes				Out			In		Annual M&I deliveries from FAA Table IV records; assumed constant monthly distribution
12	Surface Water Exports / Unused Water	Outflow					Out					No export data provided; assumed negligible
13	Rainfall on Agricultural Lands	Inflow							In			Precip Rate * Ag. Lands area
14	Agricultural Groundwater Pumping	Internal Linkage							In		Out	Calculated as the residual of the Ag. Lands subdomain (see Appendix G-4)
15	Total Evapotranspiration from Agricultural Lands	Outflow	Yes (see Note 4)						Out			Observed ITRC-METRIC ET on Ag. Lands + Evap of Ineffective Precip (see Appendix G-4)
16	Infiltration from Agricultural Lands	Internal Linkage							Out		In	Total Applied Water - Total ET on Ag. Lands [15] + Deep Perc. of Ineffective Precip (see Appendix G-4)
17	Rainfall onto Surrounding Watersheds	External				In						Precip. Rate * Surrounding Watershed area (see Appendix G-2)
18	Consumptive Use from Surrounding Watersheds	External				Out						Rainfall onto Surrounding Watersheds [17] * CU Fraction
19	Streamflow into District	Inflow						In				Rainfall onto Surrounding Watersheds [17] - CU from Surrounding Watersheds [18]
20	Rainfall onto Natural Channels	Inflow		Yes				In				Assumed negligible due to small stream area, and included in estimate of Rainfall on Ag. Lands [13]
21	Evaporation from Natural Channels	Outflow		Yes				Out				Assumed negligible due to small stream area, and included in estimate of Evap. from Ag. Lands [15]
22	Seepage from Natural Channels	Internal Linkage						Out			In	Streamflow Into District [19] * Natural Channels Seepage Fraction

TABLE G-1-1
Conceptual Water Budget Flow Components
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

#	Water Balance Component	Component's Role in Overall Water Budget Domain	"Raw" Component	Likely Neglig-ible	Water Budget Subdomain							Component Estimation Method in Water Budget Model
					CA Aqueduct (External)	Watersheds (External)	Artificial Channels & Pipelines	Natural Channels	Agricultural Lands	Urban Lands	Groundwater System	
23	Streamflow Out of District	Outflow		Yes				Out				Streamflow Into District [19] - Seepage [22] + Atmospheric Exchange [20 - 21]
24	Rainfall onto Urban Areas	Inflow								In		Precip Rate * Urban Lands area
25	Infiltration from Urban Areas	Internal Linkage								Out	In	M&I Deliveries [11] + Rainfall onto Urban Areas [24] - ET & CU from Urban Areas [26]
26	Evapotranspiration & Consumptive Use from Urban Areas	Outflow	Yes							Out		ET directly observed from ITRC-METRIC data (see Appendix D); CU = M&I Deliveries * M&I CU Fraction
27	Subsurface Groundwater Inflows	Inflow									In	Estimated by applying Darcy's Law to groundwater head gradients derived from interpolated groundwater elevation maps, or via calibration (see Appendix G-3)
28	Subsurface Groundwater Outflows	Outflow									Out	Estimated by applying Darcy's Law to groundwater head gradients derived from interpolated groundwater elevation maps, or via calibration (see Appendix G-3)
29	Kern/White Wolf Groundwater Exchange	Internal Linkage									In/Out	Estimated by applying Darcy's Law to groundwater head gradients derived from interpolated groundwater elevation maps (see Appendix G-3)
30	Kern Basin Reduction in Groundwater Storage	Accumulation Term									In/Out	Calculated as Residual of Groundwater Basin subdomain within the Kern monthly budget
31	White Wolf Basin Reduction in Groundwater Storage	Accumulation Term									In/Out	Calculated as Residual of Groundwater Basin subdomain within the White Wolf monthly budget

Abbreviations:

Ag. = agricultural
AFY = acre-feet per year
CU = consumptive use
ET = evapotranspiration
Evap. = evaporation
GW = groundwater
M&I = municipal and industrial
Precip. = precipitation
WB = water budget

Notes:

1. Water budget subdomains outlined in dashed line are considered part of the overall water budget domain.
2. "Raw" components are those that generally are best quantified based on actual data.
3. The Artificial Channels Subdomain includes the CA Aqueduct, 850 Canal, and the District's delivery pipeline network
4. "Evapotranspiration" includes all estimated crop and vegetative evapotranspirative demands as well as evaporation of excess rainfall and from open water bodies within the District.

TABLE G-1-2
Summary of Water Budget Domains, Flow Components, and Mass Balance Equations
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

		EXTERNAL DOMAINS		*MAJOR LAND USE SUBDOMAINS*					*MINOR LAND USE SUBDOMAINS*		*SUBSURFACE SUBDOMAINS*	
	FROM / TO	**Outside of Water Budget Domain**	**Atmosphere**	**Irrigated Ag Lands (SW and GW)**	**Irrigated Ag Lands (GW only)**	**Non-Irrigated Ag Lands (dry farming)**	**Native Lands**	**Urban Lands (GW only)**	**Natural Channels**	**Artifical Channels**	**Deep (Production) Aquifer**	**Groundwater Bank "Account"**
EXTERNAL	**Outside of Water Budget Domain**								Streamflow to Adjacent Lowlands	Exports	GW Outflows to Adjacent Areas	
	Atmosphere			Applied Water ET; Eff. Precip ET; Evap. of Ineff. Precip.	Applied Water ET; Eff. Precip ET; Evap. of Ineff. Precip.	Eff. Precip ET; Evap. of Ineff. Precip.	Eff. Precip. ET; Evap. of Ineff. Precip.	Applied Water ET; Eff. Precip ET; Evap. of Ineff. Precip.	Evaporation	Evaporation		
MAJOR LAND USES	**Irrigated Ag Lands (SW and GW)**		*Precipitation*					WW Effluent Discharges	Ag Diversions	Ag Deliveries	GW Pumping for Ag Use (Applied Water)	
	Irrigated Ag Lands (GW only)		*Precipitation*								GW Pumping for Ag Use (Applied Water)	
	Non-Irrigated Ag Lands (dry farming)		*Precipitation*									
	Native Lands		*Precipitation*								Seepage to Native Lands (GDEs)	
	Urban Lands	Imports (incl. from other banks)	*Precipitation*						M&I Diversions		GW Pumping for M&I Use (Applied Water)	
MINOR LAND USES	**Natural Channels**	*Streamflow from Adjacent Uplands*	*Precipitation*					WW Effluent Discharges			Seepage to Natural Channels (GDEs)	
	Artifical Channels	Imports (incl. from other banks)	*Precipitation*	Applied Water Runoff / Tailwater	Applied Water Runoff / Tailwater						GW ("Pump-In")	Recovery Pumping / "Withdrawals"
SUBSURFACE	**Deep (Production) Aquifer**	*GW Inflows from Adjacent Areas*		Applied Water Perc.; Perc. of Ineff. Precip.	Applied Water Perc.; Perc. of Ineff. Precip.	Perc. of Ineff. Precip.	Perc. of Ineff. Precip.	Applied Water Perc.; Perc. of Ineff. Precip.	Streamflow Percolation	Artifical Channel Seepage Losses		Banking Loss ("Leave Behind")
	Groundwater Bank "Account"										Banking "Deposits"	

	INFLOWS	= *precipitation (total) + Streamflows from Adjacent Uplands + GW Inflows from Adjacent Areas* + Imports
	OUTFLOWS	= ET (consumptive use) + Streamflows to Adjacent Lowlands + GW Outflows to Adjacent Areas + Exports
	INTERNAL FLUXES	
	Domains that can have a non-zero balance	

(terms in italics are natural; these could be considered to make up the "native yield" supplies)

Mass Balance Equations

Subdomains that Must "Balance" (i.e., Inflows = Outflows); external fluxes shown in blue (inflow) or pink (outflow) text; internal fluxes shown in black text

Irrigated Ag Lands (SW and GW)	**Inflows** (Precipitation + [District] Ag Deliveries + [Private] GW Pumping for Ag Use) **= Outflows** (Applied Water ET + Effective Precip. ET + Evap. Of Ineff. Precip. + Applied Water Runoff + Applied Water Perc. + Perc. Of Ineff. Precip.)
Irrigated Ag Lands (GW only)	**Inflows** (Precipitation + [Private] GW Pumping for Ag Use) **= Outflows** (Applied Water ET + Effective Precip. ET + Evap. Of Ineff. Precip. + Applied Water Runoff + Applied Water Perc. + Perc. Of Ineff. Precip.)
Non-Irrigated Ag Lands (dry farming)	**Inflows** (Precipitation) **= Outflows** (Effective Precip. ET + Evap. Of Ineff. Precip. + Perc. Of Ineff. Precip.)
Native Lands	**Inflows** (Precipitation) **= Outflows** (Effective Precip. ET + Evap. Of Ineff. Precip. + Perc. Of Ineff. Precip.)
Urban Lands (GW only)	**Inflows** (Precipitation + [District & Dom.] GW Pumping for M&I Use + [M&I] Imports) **= Outflows** (Applied Water ET + Effective Precip. ET + Evap. Of Ineff. Precip. + WW Effluent Discharges + Applied Water Perc. + Perc. Of Ineff. Precip.)
Natural Channels	**Inflows** (Precipitation + Streamflow from Adjacent Uplands) **= Outflows** (Evaporation + Perc. Of Streamflow + Ag Diversions + M&I Diversions + Streamflow to Adjacent Lowlands)
Artifical Channels	**Inflows** (Precipitation + [District] Imports) **= Outflows** (Evaporation + Exports + [District] Ag Deliveries)

Subdomains that are not required to "Balance" (i.e., can have a change in storage); external fluxes shown in blue (inflow) or pink (outflow) text; internal fluxes shown in black text

Deep (Production) Aquifer	**Inflows** (GW Inflows from Adjacent Areas + Applied Water Perc. + Perc. Of Ineff. Precip. + Streamflow Perc. + Artificial Channel Seepage Losses + Banking "Leave Behind") - **Outflows** (GW Outflows to Adjacent Areas + GW Pumping for Ag Use + GW Pumping for M&I Use + Seepage to Native Lands (GDEs) + Seepage to Channels (GDEs) + GW Pumping to Artificial Channels ("Pump-in") + GW Bank "Deposits") = **Change in Storage**
Groundwater Bank "Account"	**Inflows** (Banking "Deposits") - **Outflows** (Banking "Leave Behind" + Recovery Pumping "Withdrawals") = **Change in Storage** ("Bank Balance")
Outside of Water Budget Domain	*tracking the mass balance of external domains is not applicable to the water budget*
Atmosphere	*tracking the mass balance of external domains is not applicable to the water budget*

Precipitation (total) gets divided into: Effective Precip. ET + Evap. of Ineff. Precip. + Perc. of Ineff. Precip.
Applied Water gets divided into: Applied Water ET + Applied Water Perc.

Appendix G-2

Description of Precipitation and Contributing Streamflow Estimates

APPENDIX G-2
DESCRIPTION OF PRECIPITATION AND CONTRIBUTING STREAMFLOW ESTIMATES

This appendix documents the process used to derive estimates of precipitation on Wheeler Ridge-Maricopa Water Storage District (WRMWSD or District) lands and the surrounding watersheds contributing to streamflow within the District.

Selection of Climate Stations

Precipitation on District lands and to surrounding watersheds is estimated from the six local climate stations maintained by and located within the District, and two additional climate stations located outside of the District maintained by the National Oceanic and Atmospheric Administration (NOAA). Each of these stations report measurements of monthly precipitation (inches per month [in/mo]) during the water budget period of interest (1993 – 2015), although data availability varies by station and includes sporadic missing monthly values which were filled with estimated values, as described below.

The six local climate stations maintained by the District include:

- **Greenlee's Pasture** (*January 1971 – December 2017)*
- **District Headquarters** (*January 1978 – December 2017)*
- **WRM-2 Pumping Plant** (*January 1978 – December 2017)*
- **5P-P2 Pumping Plant** (*January 1978 – December 2017)*
- **PA-2 Pumping Plant** (*January 1978 – December 2017)*
- **Spillway Basin** (*January 1978 – December 2017)*

The additional climate stations maintained by NOAA employed for this analysis include:

- **Tejon Rancho, CA [NOAA Coop. ID #48839]** (*January 1895 – December 2017)*[1]
- **Lebec, CA [NOAA Coop. ID #44863]** (*July 1948 – December 2017)*[2]

NOAA stations were incorporated into this analysis because there is significant topographic difference (i.e., nearly 8,000-foot elevation difference) between the District lands and the peaks of the surrounding watersheds in the San Emigdio and Tehachapi mountains to the southwest and southeast, respectively, that contribute to streamflow within the District. This elevation difference results in an orographic effect whereby precipitation in the surrounding watersheds is significantly greater than precipitation measured at the six local climate stations within the District. In order to account for this precipitation difference, data from the two additional NOAA climate stations were used. NOAA climate stations were selected based on the following criteria:

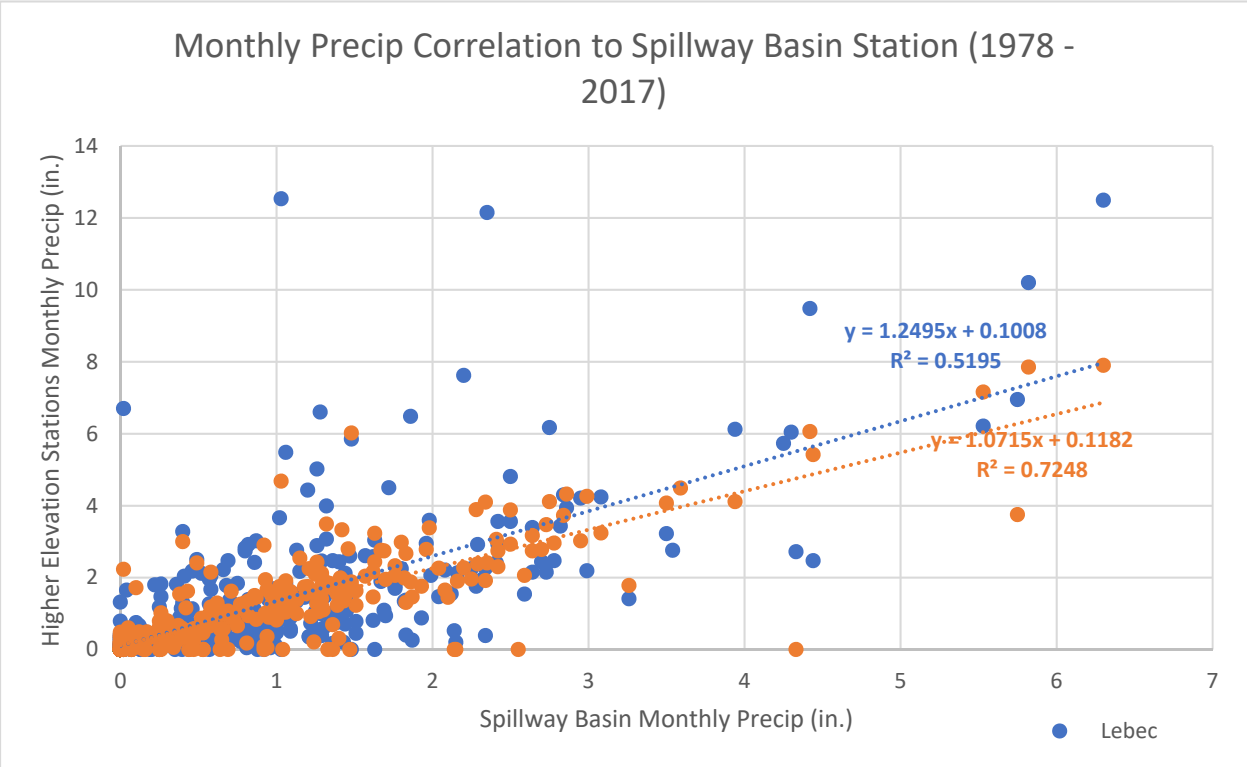
1) Data availability & continuity within the time-period of interest (1993 – 2015);
2) Location within the District's surrounding watersheds; and
3) Ground surface elevation (relative to the elevation range within surrounding watersheds).

[1] Data retrieved from NOAA's National Climatic Data Center (NCDC) online portal (https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND:USC00048839/detail)
[2] Data retrieved from NOAA's National Climatic Data Center (NCDC) online portal (https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND:USC00044863/detail)

Interpolation of Missing Monthly Precipitation Data

NOAA stations employed in this analysis contained several missing monthly values within the period of interest. For these months, precipitation was estimated based on a linear correlation model developed with a District-operated climate station. The District-operated climate station that most directly aligned with both the Tejon Rancho and Lebec stations was the Spillway Basin (elevation ~840 feet above mean sea level [ft msl]). As shown on **Figure G-2-1** below, over the entire period of record (1978-2017), monthly precipitation records collected from the Spillway Basin station showed an **85% correlation** ($R^2 = 0.72$) with data collected from the Tejon Rancho station (elevation ~1,370 ft. msl), and a **72% correlation** ($R^2 = 0.52$) with data collected from the Lebec station (elevation ~3,600 ft. msl).

Figure G-2-1. Long-term Correlation between Spillway Basin Station and NOAA Stations



As such, monthly precipitation values for months with missing precipitation data within the Tejon Rancho and Lebec records were estimated using the linear regression models derived for each station with respect to the Spillway Basin station.

Spatial Representation of Precipitation Data

Precipitation is a spatially variable phenomenon and can usually only be directly observed at discrete points within a domain (i.e., at climate station locations). Additionally, precipitation is affected by surrounding topography, and the orographic effect must be considered when deriving rainfall estimates over watershed areas with significant elevation range. As mentioned previously, the nearly 8,000 ft difference in elevation between District lands and the peaks of the surrounding watersheds in the San Emigdio and Tehachapi mountains results in an orographic effect. As such, it is practical to employ

precipitation data from higher-elevation climate stations to estimate precipitation within these surrounding watersheds contributing to streamflow into the District.

Table G-2-1 presents the approximate elevation of each climate station used in this analysis, as derived from the U.S. Geological Survey National Elevation Dataset (NED):

Table G-2-1. Climate Stations and Corresponding Ground Surface Elevations

Climate Station	Operator	Ground Surface Elevation (ft msl)
Greenlee's Pasture	WRMWSD	400
District Headquarters	WRMWSD	490
WRM-2 Pumping Plant	WRMWSD	500
5P-P2 Pumping Plant	WRMWSD	590
Spillway Basin	WRMWSD	840
PA-2 Pumping Plant	WRMWSD	940
Tejon Rancho	NOAA	1,370
Lebec	NOAA	3,590

Based on the distribution of locations and elevations from the eight climate stations employed for this analysis, a two-fold approach was employed to represent precipitation on District lands and from surrounding watersheds:

1) **Theisen polygons** were used to delineate the representative area for each of the six District-operated climate stations within the District.

2) **Elevation cutoffs** were used to delineate the representative area for the higher-elevation NOAA climate stations.

This analysis is based on the following assumptions:

- The six District-operated climate stations are located within the floor of the Central Valley at relatively similar elevations; thus, precipitation within the District is best represented spatially using the closest climate station to each point within the District.

- The two NOAA climate stations are located within surrounding watersheds to the District or near the southern boundary of the White Wolf portion of the District, and at significantly higher elevations than the District climate stations (see **Table G-2-1** above); thus, precipitation on the surrounding watersheds (and the southern-most portion of the District) is best represented by the NOAA climate station at the nearest elevation to each point within the surrounding watershed area.

Figure G-2-2 (attached) shows the location and coverage area represented by each climate station within the District and its surrounding watersheds. The following elevation cutoffs were used to determine which NOAA station (if any) would be employed in these areas:

- Elevations less than 1,155 ft msl are represented by the District climate station network (i.e., delineated by the Theisen polygon lines);
- Elevations between 1,115 ft msl and 2,480 ft msl are represented by the Tejon Rancho climate station; and
- Elevations greater than or equal to 2,480 ft msl are represented by the Lebec climate station.

Calculation of Rainfall and Contributing Streamflow

Following the spatial delineation process described above, total areas represented by each climate station were calculated for in-District lands (in both the Kern and White Wolf Subbasins), as well as for the surrounding watershed area.

The volume of monthly rainfall (acre-feet per month; [AF/mo]) on the District and on surrounding watersheds is then estimated as follows:

$$Rainfall = \sum \frac{p_{station}}{12} * A_{station} \quad (1)$$

where $p_{station}$ = monthly precipitation [in/mo] and $A_{station}$ = total area represented by the station [acres].

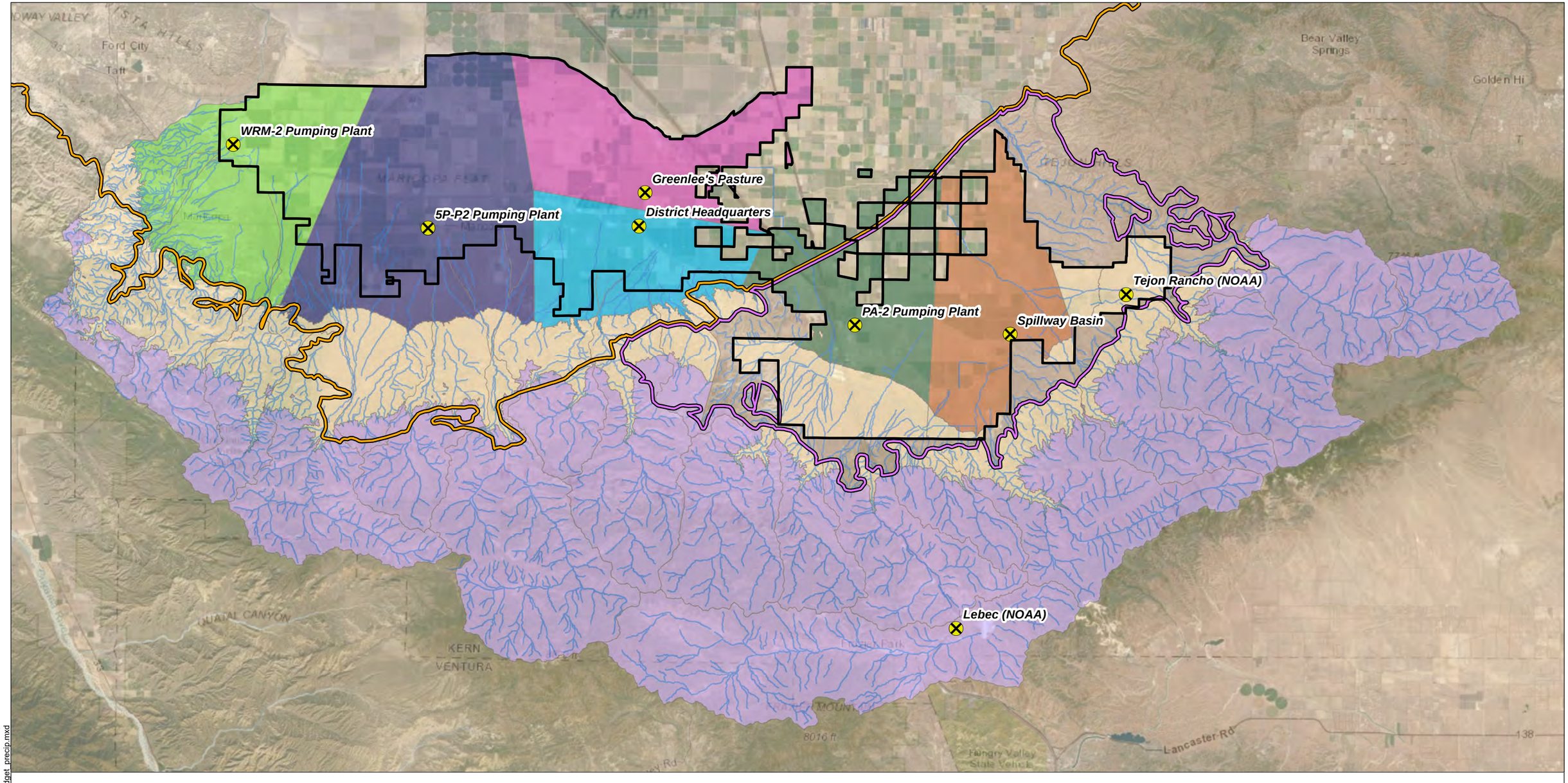
Contributing streamflow into the District is then calculated from the Rainfall on Watersheds using a linear equation with two parameters: a "Precipitation Threshold for Runoff Initiation" and a "Watershed Consumptive Use Fraction". These parameters are defined in the "User Input Parameters" of the water budget model (see Appendix G-1). Contributing streamflow into the District is calculated as:

$$Streamflow\ into\ District = max\left(0, Rainfall\ on\ Watersheds - \frac{p_{threshold}}{12} * A_{watershed}\right) * (1 - CU_{watershed}) \quad (2)$$

where $p_{threshold}$ = Precipitation Threshold for Runoff Initiation [in], $CU_{watershed}$ = Watershed Consumptive Use Fraction [dimensionless], and $A_{watershed}$ = total area of surrounding watersheds [acres].

Ultimately, based on water budget calibration, Watershed Consumptive Use Fractions of **98%** and **95%** and Precipitation Thresholds of **0.5** inches were used to estimate contributing streamflow into the Kern Subbasin and White Wolf Subbasin portions of the District, respectively. This resulted in contributing streamflow estimates of **3,104 AFY** and **8,416 AFY** for the Kern and White Wolf portions of the District, respectively, over the historical water budget period (DWR WY 1995 – 2014). These estimates align very closely with the United States Geological Survey's Basin Characterization Model[3] (USGS-BCM) estimates for the same contributing watersheds (3,480 AFY and 9,730 AFY for the Kern and White Wolf areas) over 1981 – 2010. See **Appendix G-5** for further details regarding the water budget calibration process.

[3] Flint, L.E. and Flint, A.L., 2014, California Basin Characterization Model: A Dataset of Historical and Future Hydrologic Response to Climate Change, (ver. 1.1, May 2017): U.S. Geological Survey Data Release, https://doi.org/10.5066/F76T0JPB.



Legend

- WRMWSD Service Area

Groundwater Subbasin

- White Wolf
- Kern County
- Stream/River
- Climate Stations included in WB Analysis

Representative Climate Station

- 5P-P2 Pumping Plant
- District Headquarters
- Greenlee's Pasture
- PA-2 Pumping Plant
- Spillway Basin
- WRM-2 Pumping Plant
- Tejon Rancho (NOAA)
- Lebec (NOAA)

Abbreviations

DWR	= California Department of Water Resources
ft msl	= feet above mean sea level
WB	= Water Budget
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 10 December 2019.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
3. WRMWSD boundary is from DWR's water agencies shapefile and updated based on input from WRMWSD staff on 12 April 2017.
4. Watershed boundaries obtained from the National Hydrography Dataset.

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0 5 10

(Scale in Miles)

Climate Station Locations and Representative Areas

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.00

Figure G-2-2

eki environment & water

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Appendix G-3

Description of Subsurface Cross Boundary Flow Estimates

APPENDIX G-3
DESCRIPTION OF SUBSURFACE CROSS-BOUNDARY FLOW ESTIMATES

This appendix documents the process used to estimate subsurface cross-boundary flows as a means of quantifying groundwater inflows and outflows to the aquifer system underlying Wheeler Ridge-Maricopa Water Storage District (WRMWSD or District) lands. As shown in **Figure G-3-1**, cross-boundary groundwater fluxes were calculated for three segments along the District perimeter:

- **White Wolf Fault Boundary (Exchange with AEWSD) –** to represent groundwater flux across the fault into Arvin Edison Water Storage District (AEWSD) lands in the Kern Subbasin;
- **White Wolf Fault Boundary (Internal Exchange)** – to represent groundwater flux across the fault into WRMWSD's lands in the Kern Subbasin; and
- **Kern Boundaries (Net Exchange)** – to represent net groundwater fluxes to/from the Kern Subbasin portion of the WRMWSD service area (i.e. the "Kern Management Area") resulting from (1) subsurface recharge from surrounding watersheds to the south of the Kern Management Area, and (2) groundwater exchange between WRMWSD and Kern Delta Water District (KDWD) lands and the Buena Vista Lake Bed area.

As further described below, estimates of subsurface cross-boundary flows across the White Wolf Fault were calculated using Darcy's Law, while estimates of net groundwater inflows to the Kern Management Area were calculated as a residual to the groundwater subdomain during the water budget calibration process (see **Appendix G-5** for more details).

Estimation of Groundwater Fluxes Across the White Wolf Fault

Monthly groundwater fluxes across the two segments of the White Wolf fault described above were calculated using Darcy's Law, which states that:

$$Q = T * i * L \quad (1)$$

where Q = groundwater flowrate [feet cubed per day; ft^3/d], T = aquifer transmissivity [feet squared per day; ft^2/d], i = hydraulic gradient [dimensionless], and L = length of boundary perimeter used to calculate groundwater flux [feet; ft].

Methods used to derive values for *T, I,* and *L* along each boundary segment are further documented below.

Estimation of Aquifer Transmissivity

Aquifer transmissivity (*T)* is calculated as the product of aquifer hydraulic conductivity (K) [feet per day; ft/d] and aquifer thickness (b) [ft]:

$$T = K * b \quad (2)$$

There is significant uncertainty associated with each of these parameters across the White Wolf fault segments described above. As such, initial estimates for each parameter were chosen based on associated values reported in historical hydrogeological studies, numerical models, and water budgets conducted within the region, including:

- Dibblee and Oakeshott, 1953. Dibblee, T.W. Jr. and G.B. Oakeshott, *White Wolf fault in relation to geology of the southeastern margin of San Joaquin Valley, California*, GSA Bulletin, vol. 64, p. 1502-1503, 1953.
- Wood and Dale, 1964. Wood P.R. and R. H. Dale, *Geology and Ground-Water Features of the Edison-Maricopa Area, Kern County, California*, USGS Water Supply Paper 1656, 1964.
- Croft, M.G., 1972, *Subsurface geology of the late Tertiary and Quaternary water-bearing deposits of the southern part of the San Joaquin Valley, California*, USGS Water Supply Paper 1999-H, 29 pp.
- Bookman-Edmonston Engineering, 1995. *Ground Water Studies, Wheeler Ridge-Maricopa Water Storage District*, 66 pp.
- Hagan, Karin, 2001, *The effects of the White Wolf fault on groundwater hydrology in the southern San Joaquin Valley, California*: CSU Bakersfield, M.S. theses, 96 pp.
- Bookman-Edmonston Engineering, 2007. *Groundwater Storage and Recovery Pilot Project in the White Wolf Basin. Wheeler Ridge-Maricopa Water Storage District*, 47 pp.
- Brush et al., 2013. Brush, C.F., Dogrul, E.C., and T.N. Kadir, *Development and Calibration of the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), Version 3.02-CG*, 2013.
- EKI, 2016. *White Wolf Basin Technical Report*, 77 pp.

Final aquifer hydraulic conductivity and depth values were subsequently determined through water budget calibration. See **Table G-3-1** below for initial and final (calibrated) estimates of *K* and *b* along the Kern Northern Boundary and White Wolf Fault.

Table G-3-1. Aquifer Hydraulic Conductivity and Depth Estimates

Boundary Segment	Initial *K* [ft/d]	Calibrated *K* [ft/d]	Initial *b* [ft]	Calibrated *b* [ft]
White Wolf Fault (to AEWSD)	1	3	1,000	1,000
White Wolf Fault (to WRMWSD)	1	3	1,000	1,000

Estimation of Aquifer Gradients and Perimeter Length

As mentioned previously, cross-boundary groundwater fluxes across the White Wolf fault were separated into two segments:

- White Wolf Fault Boundary (Exchange with AEWSD)
- White Wolf Fault Boundary (Internal Exchange)

To calculate boundary lengths (*L)* and hydraulic gradients (*i)*, a GIS-based methodology was employed that uses interpolated groundwater elevation rasters, polylines representing the District boundaries, and the "Zonal Statistics" toolbox to estimate average hydraulic heads across each boundary.

Groundwater elevation rasters for various seasons within the period of interest were generated through Kriging interpolation of water level data contained in the District's "WL" Access database. Based on data availability and quality, water levels from wells within the District and in the nearby area north of the District boundary were interpolated to produce groundwater elevation rasters for the following seasons:

- Spring 2003
- Fall 2005
- Spring 2006
- Fall 2006
- Spring 2009
- Fall 2009
- Spring 2011
- Fall 2011
- Spring 2013
- Fall 2013
- Spring 2014
- Fall 2014
- Spring 2015
- Fall 2015

A simplified set of "gradient line" polylines were then drawn in GIS that generally traced both sides of the two White Wolf Fault boundary segments described above (four polylines in total, see **Figure G-3-1**). The distance between polylines for each pair was 10,000 feet, and lengths were set consistently for each polyline in a pair to deduce the approximate boundary length (*L*) for the two boundary segments listed above.

Subsequently, for a given season and year, an average groundwater elevation (in feet above mean sea level [ft msl]) was deduced for each polyline on either side of the District boundary segment using the Zonal Statistics raster processing toolbox. Finally, the dimensionless hydraulic gradient (*i)* across the boundary segment for each season and year was calculated as follows:

$$i = \frac{GWE_2 - GWE_1}{10{,}000\ ft} \qquad (3)$$

where GWE_1 and GWE_2 are the average groundwater elevations along the two polylines for each boundary segment.

Estimation of Monthly Groundwater Flux in the Water Budget Model

After deducing aquifer transmissivity (*T*), boundary length (*L*) and gradient parameters for a given season and year, groundwater flux was calculated using Darcy's Law (see equation 1). Fluxes were converted from ft^3/d to acre-feet per month (AF/mo) to provide a representative "monthly" flux estimate associated with that season and year.

To populate the water budget model with a monthly groundwater flux for the entire period of interest (1994 – 2015), the "monthly" groundwater fluxes calculated for the season and year closest to the month in question within the model were used. Groundwater elevation rasters created for "Spring" seasons represent water level measurements collected in between January 15 – April 15; therefore, March 1 is used as the representative date for "Spring" groundwater flux calculations. Groundwater elevation rasters created for "Fall" seasons represent water level measurements collected in between August 15 – November 15; therefore, October 1 is used as the representative date for "Fall" groundwater flux calculations.

As an example, groundwater fluxes reported in the water budget for the month of May 2015 were represented by the calculated fluxes from the "Spring 2015" raster, whereas groundwater fluxes reported for the month of August 2015 were represented by the calculated fluxes from the "Fall 2015" raster. This allows the water budget to provide a continuous (monthly) estimate of cross-boundary groundwater fluxes that is most representative of current conditions as estimated from actual groundwater elevation data included in the District's records.

Estimation of Net Groundwater Fluxes to the Kern Management Area

Use of raster-based gradients and Darcy's law to estimate groundwater fluxes, as described above, is well suited for approximating fluxes across the White Wolf Fault, as this hydrogeologic barrier to flow is considerably well-defined and groundwater flow moves in a generally consistent southeast-to-northwest direction perpendicular to the fault line (see White Wolf Fault studies mentioned above for further details). This allows for reasonably straight-forward estimation of groundwater gradients across the fault, as the "gradient lines" can be drawn parallel to the fault line and consistent with the general direction of groundwater flow in the area.

As evident in **Figure G-3-1** and in the local groundwater elevation surfaces derived for earlier dates within the historical water budget timeframe, groundwater flow directions are much more variable along the District perimeter within the Kern Subbasin, with certain sections indicating an inflow gradient, others an outflow gradient, and still others indicating a gradient that is nearly parallel to the boundary line. Another complicating factor is that very little groundwater elevation data exists for the regions to the south and west of the WRMWSD boundary, making it challenging to accurately estimate average groundwater elevations immediately outside the District. Consequently, the average groundwater gradient across each major boundary of the WRMWSD Kern Management Area is much harder to define. Furthermore, the WRMWSD Kern Management Area boundary is highly complex in geometry, making the use of generalized "gradient lines" to approximate fluxes across each boundary segment less applicable to this particular scenario.

Given the constraints mentioned above, an approach was used that approximates net groundwater fluxes to/from the Kern Management Area as a residual in the groundwater subdomain deduced via calibration of the water budget model. After constraining all other groundwater inflow and outflow variables within the model (e.g., infiltration, pumping, etc.), a monthly groundwater flux rate was calculated that resulted in the closest fit to change in groundwater storage calibration targets developed via comparison of observed water levels between "bookend" dates within the water budget timeframe (see **Appendix G-5**).

Ultimately, it was found that the modeled change in groundwater storage achieved a closest fit to all calibration targets when net monthly groundwater fluxes to the Management Area were tied to the

estimated streamflow signal into Management Area. Specifically, it was determined that setting a "**Groundwater to Streamflow Inflow**" ratio of **3:1** within the Kern Management Area resulted in the best overall calibration of the water budget model (see **Appendix G-5**) and produced net groundwater inflow volumes on the order of **9,300 AFY** on average through the historical water budget period (DWR WY 1995 – 2014). This net inflow estimate is conservative relative to how the C2VSim-FG Kern Subbasin numerical model (developed by KGA and other Basin GSAs, see **Section 9** of the Management Area Plan) quantifies net groundwater inflows to the Management Area (31,200 AFY) over the same historical period.

This observed correlation between groundwater inflows and streamflow behavior could be in part due to the fact that the southern border of WRMWSD abuts several alluvial fans receiving recharge from various ephemeral creeks draining into the Kern Subbasin from the San Emigdio mountains to the south. Given the variable gradients observed along the northern and western boundaries of the Management Area, this subsurface recharge mechanism from the south may be the dominant groundwater flow component along the WRMWSD Kern Subbasin boundaries and would thus result in a net groundwater inflow to the Management Area. Further quantification of subsurface inflows across the southern boundary would necessitate the collection of additional groundwater elevation data to the south of the District, where very little historical data currently exist. See **Appendix G-5** for further details regarding the water budget model calibration process and results.

Kern (Net Exchange)

White Wolf - to AEWSD (North)

White Wolf - to AEWSD (South)

White Wolf - Internal (North)

White Wolf - Internal (South)

BUENA VISTA LAKE BED

KERN LAKE BED

MARICOPA FLAT

WHEELER RIDGE

SAN JOAQUIN VALLEY

PLEITO HILLS

SAN EMIGDIO MOUNTAIN

BEAR VALLEY

TEHACHA

Arvin

Taft

Ford City

Maricopa

Buena Vista Aquatic Recreation Area

Taft-Kern County Airport

Broad Creek

Cienaga Creek

Buttonwillow Creek

Lost Hills Creek

Pleito Creek

Salt Creek

El Paso Creek

Pastoria Creek

Bitter Creek National Wildlife Refuge

Bitter Creek

Maricopa Hwy

Taft Hwy

Legend

Gradient Line

- White Wolf - Internal (North)
- White Wolf - Internal (South)
- White Wolf - to AEWSD (North)
- White Wolf - to AEWSD (South)
- Kern (Net Exchange)
- Spring 2015 GWEL (50 ft interval)
- WRMWSD Service Area

Spring 2015 GWEL (ft msl)

- <0
- 0 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- >250

Spring 2015 GWEL (ft msl)

High : 320

Low : -60

Groundwater Subbasin

- Kern County
- White Wolf

Abbreviations

DWR	= California Department of Water Resources
ft msl	= feet above mean sea level
GWEL	= Groundwater Elevation
WRMWSD	= Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Gradient line pairs placed 10,000 feet apart along each boundary with substantial subsurface flow.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 10 December 2019.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2018 Update.
3. Groundwater elevation data provided by District staff.

N

0 3 6

(Scale in Miles)

Groundwater Gradient Calculations - Spring 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
December 2019
B70103.01

Figure G-3-1

eki environment & water

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Appendix G-4

Description of the Agricultural Lands Water Budget Subdomain

APPENDIX G-4
DESCRIPTION OF THE AGRICULUTRAL LANDS WATER BUDGET SUBDOMAIN

This appendix describes the process for calculating water budget components within the Agricultural Lands subdomain of the Wheeler Ridge-Maricopa Water Storage District (WRMWSD or "District") Long-term Water Budget (currently populated for 2001–2015). This analysis was based on the following data sources:

- **Satellite Evapotranspiration (ET) Data** from the Irrigation Training & Research Center (ITRC)[1] "Mapping Evapotranspiration at High Resolution with Internalized Calibration" (ITRC-METRIC) Study, funded by the Kern Groundwater Authority (KGA)[2]
    - *monthly resolution, January 1993 – December 2015* [3]

- **WRMWSD Land Use Surveys** from the District's "CROPS.shp" shapefile
    - *seasonal (spring and fall) resolution*, *Spring 2001 – Spring 2017*

- **WRMWSD Surface Water Delivery Records** from the District's "WRM_DataMDB" Access databases (i.e., "WLEDGER" tables)
    - *monthly resolution, January 1999 – December 2016*

- **Precipitation Records** from the six local climate stations maintained by and located within the District, and two additional climate stations located outside of the District maintained by the National Oceanic and Atmospheric Administration (NOAA)[4]
    - *monthly resolution, January 1971 – December 2017 (data availability varies by station)*

Description of ITRC-METRIC ET Dataset

The ITRC-METRIC ET Dataset uses satellite-based remote sensing of radiant energy and the METRIC energy balance theory to quantify actual water flux to the atmosphere from the land surface (including ET and evaporation from bare soil and open water). This approach differs from other commonly-used methods that estimate ET based on land use (i.e., cropping) patterns and reference ET data and/or crop water use coefficients. There are several advantages of the ITRC-METRIC approach over conventional crop coefficient methods:

- ITRC-METRIC provides the ability to measure actual ET over large areas without any previous knowledge of land use or climate variables, whereas crop coefficients will estimate ET based on known cropping acreages and assumed crop water use properties.

[1] The Irrigation Training & Research Center is part of the California Polytechnic State University, San Luis Obispo.
[2] Howes, D., 2018, *1993-2015 ITRC-METRIC ETc for Kern County*, prepared for the Kern Groundwater Authority on behalf of the Cal Poly Irrigation Training & Research Center. (see **Attachment G-4-1**)
[3] There is no ITRC satellite ET data for calendar year 2012, as the Landsat satellite system employed in the METRIC analysis was out of order during this period. See **Attachment G-4-1** for further details.
[4] See **Appendix G-2** for a detailed description of how climate stations are used to estimate precipitation on District lands and surrounding watersheds.

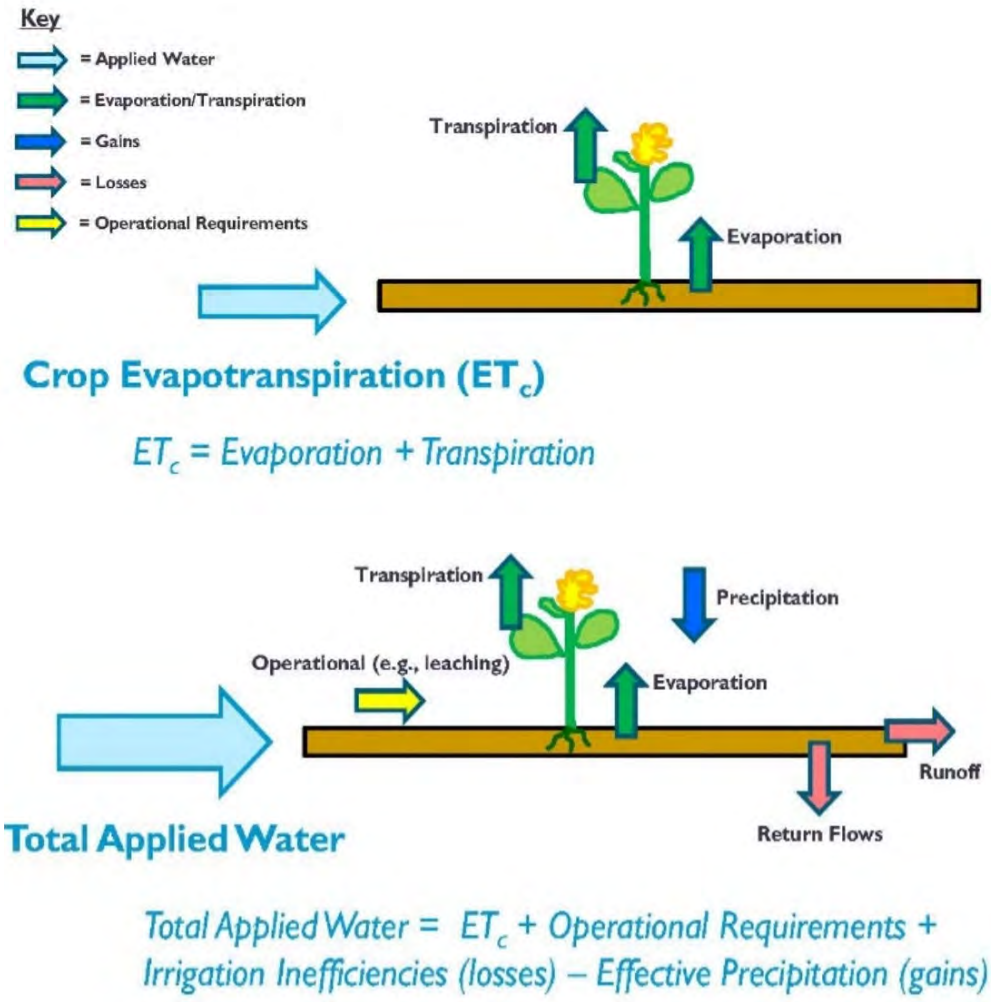
- ITRC-METRIC provides semi-continuous (i.e., rasterized) ET data at a high spatial resolution (satellite image pixel size of 30 x 30 meters) for an area of study, whereas crop coefficient-based ET estimates are limited to the resolution of the land use dataset being employed.
- ITRC-METRIC allows for ET measurement at a relatively frequent temporal resolution (e.g., approximately every 10 days), whereas crop coefficient methods are typically only available on a seasonal, or at best monthly, basis.

Due to these advantages, ET data developed using the ITRC-METRIC method will intrinsically reflect spatial and temporal variabilities in ET due to factors that cannot be fully accounted for using conventional crop coefficient methods. For example, the ITRC-METRIC ET rasters (image files) will reflect impacts on ET due to crop stresses from drought conditions, ET for crops at various stages of growth, ET for land parcels with multiple growing seasons (i.e., double cropping) and/or interbedded crops, and evaporation from surface water features (such as canals, reservoirs, spreading basins, etc.).

However, the ITRC-METRIC dataset has a significant limitation for water-budgeting purposes in that it does not provide an estimate of ***total applied water***, only ***actual (observed) ET***. *Total applied water* is a term used by water resource engineers to estimate how much water is actually being applied to the land. This differs from ET in that it includes not only water applied to satisfy crop water demand, but also unintentional over-irrigation due to irrigation inefficiency and water intentionally applied for other operational requirements or cultural practices (e.g., leaching, dust abatement, field preparation, frost control). During the main growing season from spring through fall, when precipitation is minimal and ET is greatest, total applied water is nearly always greater than evapotranspiration for any irrigated land, as no irrigation method is 100 percent efficient[5]. Calculation of total applied water must also consider water added to the land surface via precipitation, as this will reduce the irrigation demand for a given area. **Figure G-4-1** illustrates the difference between actual (crop) ET (ET_c) and total applied water.

[5] Irrigation efficiency is defined as the fraction of total applied water that is used by the crop to satisfy its vegetative water demand.

Figure G-4-1. Crop Evapotranspiration (ET or ETc) vs. Total Applied Water



Land Surface Processes within the Water Budget

From a holistic water budgeting perspective, total applied water that does not go towards satisfying crop ET will be subject to four main processes once it is applied to the land surface:

1) Evaporation to the atmosphere
2) Land surface runoff
3) Infiltration and accumulation in the root zone
4) Deep percolation below the root zone to the groundwater table (i.e., return flows)

Although this water budget model allows for temporary carry-over storage of excess effective precipitation in the root zone for subsequent uptake by crops (see below), it is assumed that there is no net long-term accumulation of water within the root zone. Accurate simulation of soil moisture changes would require detailed spatial information on soil properties and root zone depth, as well as data for precipitation, irrigation, and ET on the timescale of hours to days. As the current water budget is designed to reflect monthly changes on a District scale, this level of detail is beyond the current scope of the effort. Furthermore, assuming quasi-steady state conditions within the root zone mimics the approach of the

MODFLOW Farm Process package, which has proven that "simulated inflows into the root zone converged to outflows after time intervals of several days"[6]. Therefore, the assumption of steady-state soil moisture within the root zone is justified.

Similarly, as this water budget was developed on a District scale, and given the generally low topographic slope and lack of significant permanent streams along District boundaries, we have assumed that land surface runoff of applied water is negligible for the purposes of this water budget. Though runoff may occur between parcels within the District service area, there is no continuous receiving water body (i.e., "Natural Channels" such as streams) that could transport surface water runoff outside of the District in any significant volume. Therefore, we have assumed that all land surface runoff occurring between parcels within the District will either (1) evaporate or (2) infiltrate into the subsurface before leaving District boundaries.

Under the above assumptions, excess water applied to the ground surface on District lands will predominantly either (1) evaporate from the wetted bare soil or (2) percolate below the root zone into the deeper subsurface (eventually recharging groundwater) before leaving District boundaries. Considering that landowners within WRMWSD generally employ highly efficient irrigation techniques (such as micro-drip irrigation) and follow irrigation schedules designed to minimize evaporation of excess irrigation water, it is further assumed that evaporation of excess irrigation water is considered to be a negligible flux component of the ITRC-METRIC ET signal, and thus all "inefficient irrigation" of these lands will infiltrate through the root zone and eventually make its way down into the underlying principal aquifer.

Building the Agricultural Lands Subdomain Water Budget

As mentioned above, deep percolation is the only major component of total applied water not measured by the ITRC-METRIC dataset within the agricultural lands subdomain. Deep percolation is likely to result from three main applications of excess water to the ground surface:

1) Intentional operational and/or cultural processes, such as soil leaching and dust abatement
2) Irrigation inefficiencies
3) Excess (i.e. "ineffective") precipitation

Excess water from operational processes and irrigation inefficiencies are only relevant to the irrigated portion of the District, whereas precipitation in excess of crop water demands must be considered across the entire District area. Therefore, for purposes of this water budget, we have separated the irrigated portion of the District from the non-irrigated portion of the District (i.e., including agricultural and native vegetation lands as well as urban lands) before estimating deep percolation and total applied water.

[6] Dogrul, E. C., Schmid, W., Hanson, R., Kadir, T., & Chung, F. 2011. Integrated Water Flow Model and Modflow-Farm Process: A Comparison of Theory, Approaches, and Features of Two Integrated Hydrologic Models. prepared by California Department of Water Resources, Bay-Delta Office in conjunction with the U.S. Geological Survey.

Determining Irrigated vs. Non-Irrigated and Urban Lands

As mentioned above, historical land use data for parcels within the WRMWSD service area were provided by the District for Spring and Fall, 1994 – 2015 in a shapefile entitled "CROPS.shp"[7]. Land use for each parcel was classified on a biannual "seasonal" (i.e., Spring/Fall) basis using crop categories defined in the District's "BAL_XREF" and "CROP_XREF" spreadsheets within the "WRMData_MDB" access database. For the Fall seasons, parcels without crop category information were assumed to have the same crop as was indicated in the Spring season of that same water year (per direction from the District's GIS technician). Parcels were then classified into Irrigated, Non-Irrigated, and Urban categories for each season as follows:

- **"Non-Irrigated"** – land parcels marked as:
  - "NV" – Native Vegetation
  - "DEF" – Idle Lands
  - "FAL" – Fallowed Lands
  - "EUC" – Eucalyptus (not irrigated)
  - "WHD" – Wheat (dry farmed)
  - N/A (i.e., Spring parcels with blank entries)
- **"Urban"** – land parcels marked as "OTH" – Other Lands[8]
- "**Irrigated"** – all other land parcels included in the CROPS.shp

This analysis was performed in R software to facilitate data processing and reproducibility of results.

Determining Irrigation Methods and Irrigation Efficiency Coefficients

As mentioned above, the contribution of "unintentional overwatering" resulting from irrigation inefficiency must be accounted for in estimating total applied water and deep percolation within the agricultural lands subdomain. As such, a representative irrigation efficiency coefficient must be associated with each irrigation type listed in the land use records.

In addition to providing seasonal crop categories, the WRMWSD "CROPS.shp" shapefile also included information on parcel-specific irrigation methods for the years 2011, 2012, and 2013. Irrigation methods listed in this shapefile included:

- "MD" – Micro-Drip
- "MS" – Micro-Sprinkler
- "SP" – Sprinkler
- "CP" – Center-Pivot Sprinkler
- "Fur" – Furrow (Gravity)
- "NON" – Not Irrigated

[7] Before the year 2001, the "CROPS.shp" shapefile only contained cropping information for Spring/Fall 1995 and 1997. These were used to infer general land use categories (e.g. "irrigated", "non-irrigated", "urban") for all years before 2001, where Spring/Fall 1995 crops were used to infer land use for Spring/Fall 1994 – 1996, and Spring/Fall 1997 were used to infer land use for Spring/Fall 1997 – 2000.

[8] "OTH" parcels were classified as "urban lands" based on observations from Google Earth, in which most cases "OTH" parcels were recognized as built structures or paved surfaces.

For parcels marked as "irrigated" based on the reclassification procedure described above, irrigation methods were assigned as follows:

- For years 1994— 2011, Irrigation Method = "IRR_METH_11" (2011 irrigation data)
- For year 2012, Irrigation Method = "IRR_METH_12" (2012 irrigation data)
- For years 2013—2015, Irrigation Method = "IR_METH_13" (2013 irrigation data)

This analysis was performed in R software to facilitate data processing and reproducibility of results.

From here, an area-weighted average irrigation efficiency coefficient was calculated for each season in the record within each basin, which was then later incorporated into the calculation of deep percolation on irrigated lands. Irrigation efficiencies were initially estimated for each irrigation method based on representative values reported by the Food and Agricultural Organization of the United Nations (FAO)[9] and other commonly used resources, as follows:

- Micro-Drip (MD) – **85%**
- Micro-Sprinkler (MS) – **80%**
- Sprinkler (S) – **75%**
- Center-Pivot Sprinkler (CS) – **70%**
- Furrow (Gravity) (F) – **65%**

These values were included as "User Input Parameters" in the budget to facilitate easy adjustment, but were ultimately left unchanged during the calibration process. Parcels marked "NON" (Not Irrigated) in 2011 – 2013 almost always fell into the "Not Irrigated" category based on the crop category classification as described above. However, for years where irrigation methods were not explicitly reported in the data, various parcels may have been irrigated for that year (based on the crop type information) and attributed a "NON" irrigation type if they were not irrigated during 2011 – 2013. For these parcels, the irrigation efficiency coefficient of "NON" was determined as the long-term (2011-2016), acreage-weighted average irrigation efficiency coefficient across the District for all known irrigation types. This weighted average was calculated as **83%** based on the given data, reflecting a dominance of micro-drip irrigation systems within the District.

The resulting irrigation efficiency coefficient (e_{irr}^{i}) for agricultural lands in any month *i* in the water budget period is then calculated as:

$$e_{irr}^{i} = \frac{\sum(0.85*Acreage_{MD}^{i}+0.80*Acreage_{MS}^{i}+0.75*Acreage_{S}^{i}+0.70*Acreage_{CS}^{i}0.65*Acreage_{F}^{i}+0.83*Acreage_{NON}^{i})}{Acreage_{Irrigated\ Lands}^{i}} \quad (1)$$

where $Acreage_{x}^{i}$ = acreage of irrigated lands supplied by *x* irrigation type for month *i*, and where *x* = micro-drip (MD), micro-sprinkler (MS), sprinkler (S), center-pivot sprinkler (CS), furrow (F), and NON (unknown type) irrigation types.

[9] Brouwer, C., Prins, K., & Heibloem, M., 1989, Annex I – Irrigation efficiencies. *Irrigation Water Management Training Manual No. 4 – Irrigation Scheduling*, prepared by the Food & Agricultural Organization of the United Nations.

Linking Reclassified Land Use Information to ITRC-METRIC ET Data

Monthly ITRC-METRIC data was processed using a GIS model (i.e., automated procedure) that sums observed ET values for each parcel based on its geometry as mapped in the District's "CROPS.shp" shapefile. The GIS model employs a Spatial Analyst tool known as "Zonal Statistics" to sum the ET values from each 30 x 30 meter raster pixel within a parcel to determine the total ET value (in inches per month; [in/mo]) for each parcel included "CROPS.shp." This is then multiplied by the raster resolution (900 m^2) and converted into acre-feet per month (AF/mo) to provide a volumetric estimate of ET (in AF/mo) for each parcel on a given month. This process was iterated for the entire set of monthly ITRC-METRIC ET rasters (265 in total) resulting in monthly ET values for each for the entire period of record of the ITRC-METRIC dataset (1993 – 2011, 2013 – 2015). These values were then joined to the reclassified crop information using a unique parcel-based key incorporated into both datasets. Because the crop classification data is reported biannually, whereas the ITRC data is collected monthly, the following time periods were employed to link reclassified land use data to the ITRC-METRIC dataset:

- **"Spring"** – March through August of the calendar year
- **"Fall"** – September through February of the following calendar year

As an example, under this scenario an ITRC raster developed for July 2003 would be linked to the "Spring 2003" land use dataset, whereas an ITRC raster developed for February 2003 would be linked to the "Fall 2002" dataset.

The result of this process is an aggregated monthly dataset containing parcel-based information on:

- Basin location (i.e., Kern Basin or White Wolf Basin)
- Acreage
- Crop type
- Irrigation type (irrigated, not irrigated, urban)
- Irrigation method (if irrigated)
- Monthly ET

A complicating factor in this process is that the ITRC rasters do not cover the entire District area, leaving approximately 1,012 acres of land (~0.6%) without associated ET data. To account for this gap in coverage, a value for "unused acreage" by parcel was developed based on the difference in acreages of the original and joined datasets. ET was then estimated for the area of each parcel outside of ITRC coverage (if any) by applying the average per-acre ITRC ET rate for each of the three irrigation types (irrigated, not irrigated urban) from the covered area. This ensured that the entirety of the District contained an ET estimate for each month.

Determining Additional Irrigation Demands

As mentioned above, ITRC-METRIC data provides a reasonable estimate of actual ET occurring within the District but should not be considered to represent total applied water on District lands. In addition to accounting for irrigation inefficiencies, estimates of total applied water must also consider the additional irrigation demands associated with crop leaching and other operational water requirements, as well as account for any contributions of effective precipitation in meeting the ET demand measured by ITRC-

METRIC. The following subsections detail how additional irrigation demands are estimated within the analytical water budget model.

Crop Leaching Requirements

As mentioned above, soil leaching is a common practice that can significantly increase the volume of applied water required for long-term operations beyond the ET demands estimated by ITRC-METRIC data. As no specific information on leaching practices (i.e., amounts, locations, timing) was available from the District, a conventional approach outlined by the FAO was used to determine leaching requirements based on crop-specific salinity thresholds and estimates of leaching water salinity[10]. For a given crop, the "leaching fraction" (i.e. the incremental portion of irrigation water in excess of crop ET demands required to maintain the soil salinity at ideal conditions for crop yield) is defined as follows:

$$LF = \frac{EC_w}{5(EC_e) - EC_w} \quad (2)$$

where *LF* = leaching fraction [dimensionless], EC_w = electrical conductivity of the irrigation water [deciSiemens per meter; dS/m], and EC_e = crop salinity threshold [dS/m].

From here, the volumetric "leaching requirement" can be calculated as the incremental volume of water needed to satisfy the leaching demand:

$$LR = \frac{ET_c * LF}{1 - LF} \quad (3)$$

where *LR* = leaching requirement [AF] and ET_c = crop evapotranspiration [AF].

For the purposes of this analysis, leaching demands are calculated for the entire irrigated lands portion of the agricultural lands subdomain for each month. To achieve this, an area-weighted crop-salinity threshold is calculated for the irrigated lands area for each basin based on the relative acreages of each crop category included in "CROPS.shp." (see **Attachment G-4-2** for the list of indicative crop salinity thresholds used in this methodology). A leaching fraction (*LF*) is then calculated per equation (2) above within the water budget based on the area-weighted crop salinity threshold and an assumed electrical conductivity of irrigation water (EC_w). The EC_w is implemented as a user-adjustable input parameter within the water budget spreadsheet, and was ultimately set at 500 microsiemens per centimeter (µS/cm) in line with the general water quality profile of WRMWSD's imported surface water supplies. Crop evapotranspiration (ET_c) is estimated from the monthly ITRC-METRIC ET data for irrigated lands, and a monthly leaching requirement (*LR*) is calculated using equation (3) above.

Other Operational Demands

As mentioned above, in addition to soil leaching, other operational practices that require additional applied water are commonly employed for purposes such as pre-irrigation requirements, harvesting, pest control, frost control, crop uniformity, germination, and dust control. As no specific information on specific operational water uses (i.e., amounts, locations, timing) was available from the District, these additional "operational demands" are estimated from *JMLord, Inc.'s* historical agricultural demand

[10] Tanji, K.K., & Kielen, N.C., 2002, Annex I – Crop salt tolerance data. *Agricultural drainage water management in arid and semi-arid areas*, prepared by the Food & Agricultural Organization of the United Nations.

reports[11] provided for the District's neighbor, Arvin-Edison Water Storage District (AEWSD), who is known to have a similar land use profile and distribution to WRMWSD.

Based on the *JMLord, Inc.* reports, it was determined that on a District scale, agricultural water users were historically applying an additional **0.16 AFY/acre** to their lands on average (over Water Years 1994 – 2015) to meet additional operational demands beyond leaching. This value was employed for the "Additional Operational Demands" User Input Parameter within the analytical water budget model to estimate operational water demands within the District for any given month:

$$OD^i = \frac{0.16}{12} * Acreage^i_{Irrigated\ Lands} \quad (4)$$

where OD^i = operational demands for month *i* [AF] and $Acreage^i_{Irrigated\ Lands}$ = irrigated acreage for month *i*.

Processing Precipitation Data

As mentioned above, estimates of total applied water should also take into account any contribution of effective precipitation in meeting ET demands on District lands. The residual "ineffective precipitation" (i.e., the portion of precipitation which is not considered available to meet ET demands) may also contribute to groundwater recharge to a certain degree and should thus be quantified and routed to appropriate subdomains within the analytical water budget to ensure mass balance is fully conserved within the model.

Calculating Effective Precipitation

Effective precipitation as defined as "the part of rainfall that can be used to meet the evapotranspiration of growing crops. It does not include surface runoff or percolation below the crop root zone." (USDA-SCS, 1970)[12]. Since limited data exists to quantify historical rates of effective precipitation within the District, we have chosen to employ an empirical equation developed by the United States Department of Agricultural Soil Conservation Service (USDA-SCS)[13] which factors in measurements of monthly rainfall, evapotranspiration (i.e. crop consumptive use), and estimated depth of application (or "usable soil water storage" depths) to approximate effective rainfall (in inches) for any given month[14]. The resulting equation for estimating monthly effective precipitation [in] is:

$$p_e = f * (0.70917 * p_t^{0.82416} - 0.1156) * 10^{0.02426 * ET_c} \quad (5)$$

where p_e = effective precipitation [in], p_t = total precipitation [in], ET_c = crop evapotranspiration [in], and f = correction factor for irrigation application depths different from 3 inches, where:

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[11] JMLord, Inc., 1998 – 2015. *Arvin-Edison Storage District – Assessment of Reasonable Water Requirements.* Internal Reports.

[12] United States Department of Agriculture – Soil Conservation Service (USDA-SCS), 1970. *Irrigation Water Requirements*. USDA-SCSC Technical Release No. 21. 88 pp

[13] *Ibid [17].*

[14] "SCS scientists analyzed 50 years of rainfall records at 22 locations throughout the United States to develop a technique to predict [monthly] effective precipitation (USDA 1970). A daily soil moisture balance incorporating crop [ET], rainfall, and irrigation was used to determine the ET effectiveness." (USDA-SCS, 1993).

$$f = (0.531747 + 0.295164 * D - 0.057697 * D^2 + 0.003804 * D^3) \quad (6)$$

where *D* = net depth of application during irrigation [in].

Effective precipitation (p_e) was calculated for each month for both irrigated and non-irrigated lands, where *D* was set to the default value of 3 inches for irrigated lands and set to zero inches for non-irrigated lands. These normalized values were subsequently converted into volumetric effective precipitation rates (in AF per month) using the acreages of irrigated and non-irrigated lands for the given month. For example:

$$P_{e\,Irrigated\ Lands}^{\ i} = \frac{p_{e\,Irrigated\ Lands}^{i}}{12} * Acreage_{Irrigated\ Lands}^{i} \quad (7)$$

where $P_{e\,Irrigated\ Lands}^{\ i}$ = effective precipitation on irrigated lands for month *i* [AF]. A similar calculation was used for the non-irrigated lands.

Effective Precipitation Carryover Term

While a soil moisture balance is not explicitly modeled in this analytical water budget, it is recognized that excess effective precipitation in the rainy winter months of the year may be retained temporarily in the root zone and can help contribute to meeting ET demands in the early growing season, thus reducing the irrigation demand during these months. To account for this phenomenon, we have included an effective precipitation "carryover" term to allow for any residual effective precipitation in excess of ITRC-METRIC ET signal to remain available for meeting ET demands in the following month(s) throughout the model period. This effective precipitation carryover term is defined as:

$$P_{e\,Carryover}^{\ i} = \max(0,\ P_e^i - ET^i) \quad (8)$$

where $P_{e\,Carryover}^{\ i}$ = carryover of excess effective precipitation from month *i* [AF], P_e^i = effective precipitation for month *i* [AF], and ET^i = ITRC-METRIC measured ET for month *i* [AF].

This effective precipitation carryover term is subsequently added to the effective precipitation value calculated for the following month:

$$P_e^{i+1} = +P_{e\,initial}^{\ i+1} + P_{e\,Carryover}^{\ i} \quad (9)$$

where P_e^{i+1} = adjusted effective precipitation for month *i + 1* [AF], $P_{e\,initial}^{\ i+1}$ = initial effective precipitation for month *i +1* (calculated from equations 5 – 7) [AF], and $P_{e\,Carryover}^{\ i}$ = effective precipitation carryover term from month *i* [AF] (calculated from equation 8).

Parsing Ineffective Precipitation

As mentioned above, "ineffective precipitation" is defined as the portion of total (direct) precipitation that is not considered available to meet ET demands:

$$P_{ineff}^{i} = P_t^i - P_{e\,initial}^{\ i} \quad (10)$$

where P_{ineff}^{i} = ineffective precipitation for month *i* [AF], P_{t}^{i} = total precipitation for month *i* [AF], and P_{e}^{i} = initial effective precipitation for month *i* [AF] (calculated from equations 5 – 7).

Ineffective precipitation can either (1) runoff as a surface outflow from the water budget domain; (2) evaporate from the land surface before infiltrating into the root zone; or (3) percolate from the root zone into the vadose zone, where it eventually becomes groundwater recharge. As mentioned above, (1) surface runoff outside of the District is considered negligible in this water budget, leaving (2) evaporation and (3) deep percolation as the only pathways for parsing ineffective precipitation. Very little historical data or reference information exists for quantifying the proportions of evaporation versus deep percolation for ineffective precipitation, so we have chosen to define an **"ineffective precipitation deep percolation coefficient"** (f_{DP}) user input parameter to apportion these flux components within the model. Here, the portion of ineffective precipitation contributing to deep percolation for a given month (P_{DP}^{i}) is defined as:

$$P_{DP}^{i} = P_{ineff}^{i} * f_{DP} \tag{11}$$

where P_{ineff}^{i} = ineffective precipitation for month *i* [AF], and f_{DP} = ineffective precipitation deep percolation coefficient [-].

Consequently, the portion of ineffective precipitation that will evaporate from the land surface for a given month (P_{evap}^{i}) is defined as:

$$P_{evap}^{i} = P_{ineff}^{i} * (1 - f_{DP}) \tag{12}$$

Notably, P_{evap}^{i} is included as a unique evaporative flux component from the water budget domain in addition to ITRC-METERIC derived ET, as opposed to assuming that evaporation of ineffective precipitation was included in the ITRC-METRIC signal. Though the ITRC-METRIC method is considered a generally reliable estimator of actual ET over large spatial domains, it faces certain limitations, particularly in the winter months where usable LANDSAT satellite imagery may not be available due to the presence of clouds, etc., and/or satellite imagery may not adequately capture the evaporation occurring from wetted soils immediately following a precipitation event[15]. With this constraint in mind, and under the observation that ITRC-METRIC measured ET in the winter months (i.e., November – February) was usually significantly lower than pan evaporation measured at the District's nearby (5P-P2 Pumping Plant, District Headquarters, and PA-2 Pumping Plant) climate stations for the same months, it was determined that an additional "evaporation of ineffective precipitation" term (P_{evap}^{i}) was warranted for estimating evaporation of ineffective rainfall during the winter months when it is likely to be underestimated by the ITRC-METRIC method. Inclusion of P_{evap}^{i} also results in a more reasonably conservative estimate of groundwater recharge from ineffective precipitation (P_{DP}^{i}) during the wet season.

The ineffective precipitation deep percolation coefficient (f_{DP}) user input parameter was ultimately determined via calibration of the water budget model, as described further in **Appendix G-5**. A constant

[15] *Ibid [2].* See full ITRC-METRIC report for further details.

value of f_{DP} = 0.5 (i.e., 50% deep percolation of ineffective precipitation) was used for the WRMWSD analytical water budget model.

Calculating the Total Irrigation Demand and Agricultural Groundwater Pumping

Following the above methodologies to calculate the monthly ET demand, irrigation efficiency, leaching and other operational demands, and contributions of effective precipitation, the total irrigation demand within the District can be determined. After accounting for the volume of District surface water deliveries to irrigated lands from the District's "WLEDGER" tables, the volume of groundwater pumping for irrigation (otherwise termed "agricultural groundwater pumping") can also be estimated for any given month during the water budget period.

For any given month (*i)*, the unadjusted irrigation demand is defined as the ET demand on irrigated lands minus any contributions of effective precipitation:

$$I^i_{demand} = \max(0, ET^i_{Irrigated\ Lands} - P_{e}{}^{i}_{Irrigated\ Lands}) \quad (13)$$

where I^i_{demand} = unadjusted irrigation demand [AF], $ET^i_{Irrigated\ Lands}$= ITRC-METRIC ET on irrigated lands [AF], and $P_{e}{}^{i}_{Irrigated\ Lands}$ = effective precipitation on irrigated lands [AF] (equation 9) for month *i*.

The adjusted irrigation demand is then computed as follows:

$$I^i_{demand,adj} = I^i_{demand} * (1 + (1 - e^i_{irr})) + LR^i + OD^i \quad (14)$$

where e^i_{irr} = irrigation efficiency coefficient (equation 1), LR^i = leaching requirement (equation 3), and OD^i = operational demands (equation 4) for month *i.*

As seen in equations (13) and (14), if the unadjusted irrigation demand (I_{demand}) is less than zero (i.e., if there is effective precipitation in excess of the measured ET on irrigated lands) than I_{demand} is set to zero and the adjusted irrigation demand only includes the leaching requirements & operational demands for that given month.

From here, we can calculate agricultural groundwater pumping ($GW^i_{pumping}$) for month *i* as the residual of the surface water deliveries to irrigated lands and the adjusted irrigation demand:

$$GW^i_{pumping} = \max(0, I^i_{demand,adj} - SW^i_{deliveries}) \quad (15)$$

where $SW^i_{deliveries}$= surface water deliveries[16] [AF] for month *i*.

If surface water deliveries to irrigated lands are greater than the adjusted irrigation demand, then there is no additional need for irrigation water and agricultural groundwater pumping is thus set to zero.

[16] The term "surface water deliveries" is used here to refer to deliveries by the District to its customers within the Surface Water Service Area through the District's conveyance system. These deliveries may in fact include some groundwater recovered from storage by the District's recovery wells.

Calculating Instantaneous and Time-Averaged Deep Percolation

Using the above methodology, total applied water (*TAW)* [AF], is intrinsically calculated within the water budget as follows:

$$TAW^i = SW^i_{deliveries} + GW^i_{pumping} \quad (16)$$

For the irrigated lands, *TAW* includes groundwater pumping and surface water deliveries after accounting for effective precipitation on the irrigated portion of the District (see equation 13). The *TAW* term therefore inherently reflects all assumptions about irrigation efficiency, leaching, operational requirements, and effective precipitation, as these values are included in the calculation of groundwater pumping within the irrigated portion of the District. TAW reduces to zero for non-irrigated lands, while for urban lands TAW will only include surface water deliveries to municipal & industrial (M&I) customers, and/or any M&I groundwater pumpage.

From here, the total instantaneous deep percolation on irrigated lands ($DP^i_{inst_{Irrigated\ Lands}}$) [AF] for month *i* is calculated as:

$$DP^i_{inst_{Irrigated\ Lands}} = TAW^i - ET^i_{Irrigated\ Lands} + P^i_{DP_{Irrigated\ Lands}} \quad (17)$$

where $ET^i_{Irrigated\ Lands}$ = ITRC-METRIC ET on irrigated lands [AF] and $P^i_{DP_{Irrigated\ Lands}}$= portion of ineffective precipitation contributing to deep percolation on irrigated lands (equation 11) [AF].

For the irrigated lands, this term will reflect all deep percolation resulting from inefficient precipitation, irrigation inefficiency, leaching demands and any other operational water uses.

For the non-irrigated lands, TAW is, by definition, zero and the total instantaneous deep percolation on non-irrigated lands ($DP^i_{inst_{Non-Irrigated\ Lands}}$) can be re-written as:

$$DP^i_{inst_{Non-Irrigated\ Lands}} = P^i_{e_{Non-Irrigated\ Lands}} - ET^i_{Non-Irrigated\ Lands} + P^i_{DP_{Non-Irrigated\ Lands}} \quad (18)$$

Note that in equation 18 deep percolation includes a contribution from effective precipitation on non-irrigated lands ($P^i_{e\ Non-Irrigated\ Lands}$). This term is included in equation 18 as a mass-balance closure term, since it is not intrinsically considered in the calculation of TAW as it is for the irrigated lands subdomain. By definition of P^i_e in equation 9, this term should include all carryover effective precipitation from previous months where $P^i_{e\ Non-Irrigated\ Lands} > ET^i_{Non-Irrigated\ Lands}$ so as to prevent any effective precipitation from percolating below the root zone, thus reducing equation (18) to only include $P^i_{DP\ Non-Irrigated\ Lands}$. However, it has been noted that the ITRC-METRIC measured $ET_{Non-Irrigated\ Lands}$ routinely exceeds $P_{e_{Non-Irrigated\ Lands}}$ estimates during the dry season, thus resulting in a negative $DP^i_{inst_{Non-Irrigated\ Lands}}$ during the summer months. Whether or not this high ET signal in the non-irrigated portions of the District is an artifact of the ITRC-METRIC method or is in fact a

real signal, for the purposes of this water budget a negative $DP^{i}_{inst\,Non-Irrigated\ Lands}$ value results in a net reduction of groundwater storage from the non-irrigated subdomain for the given month.[17]

Though the instantaneous deep percolation value serves as a closure term within the irrigated and non-irrigated lands water budget subdomains, in reality, because the groundwater table can occur several hundred feet below the ground surface, it may take a considerable time for deep percolation to travel through the thick vadose zone before it actually reaches the groundwater table and adds to groundwater storage. For the purposes of this water budget, this "lag effect" is represented by including a "Deep Percolation Lag Period" as a user input parameter within the water budget. This allows the user to specify an estimated time (in months) that it would take for any deep percolation water to travel through the vadose zone and reach the groundwater table. The resulting "time-averaged" deep percolation, DP_{avg} [AF], is thus calculated as a moving average as follows:

$$DP_{avg} = \frac{\sum_{i-N}^{i} DP^{i}_{inst}}{N+1} \qquad (19)$$

where *N* = the deep percolation lag period [months].

This value represents the estimated volume of "deep percolation" that actually reaches the groundwater table on a given month. For the WRMWSD water budget, a final deep percolation lag period of **11 months** was selected, so the amount of deep percolation recharging the groundwater basin for a given month would equal the time-averaged deep percolation (DP_{avg}) percolation for the past 11 months up to the present. Use of this time-averaged deep percolation (i.e., use of a moving average) results in a smoothed-out time series of recharge. This method was also applied to the recharge from stream flows into the District, seepage from man-made channels (negligible), and return flows from urban water use.

[17] It should be noted that the excess non-irrigated demand likely does not come from groundwater storage depletion, but is rather made up by a combination of local runoff from adjacent irrigated lands, contributions from streamflows, and/or seepage from natural and artificial water systems. Functionally, it is justified to attribute this demand to groundwater storage depletion, because if it were to come from surface water it would then reduce the amount of surface water available for delivery to agricultural lands which would increase the demand for pumping, and so the same result is achieved.

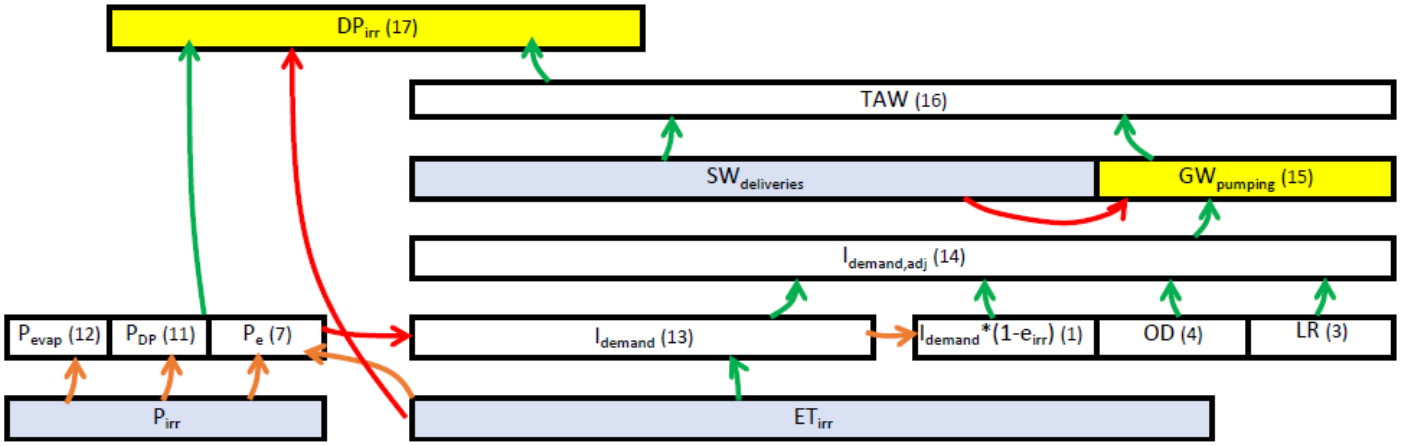
Conclusions

The result of the above processing steps is a water budget for the agricultural lands subdomain that:

- Incorporates direct measurements of ET from the land surface using ITRC-METRIC data as well as estimates of direct precipitation from local climate stations;
- Links monthly ITRC-ET data to seasonal, parcel-based land use details;
- Parses ET into buckets of (1) irrigated lands, (2) non-irrigated lands, and (3) urban lands;
- Calculates estimates of agricultural pumping and deep percolation on irrigated lands due to ineffective precipitation, irrigation inefficiencies, leaching, and operational demands;
- Calculates estimates of deep percolation on non-irrigated lands due to ineffective precipitation;
- Factors in a user-defined lag period to represent the time lag effect of vadose-zone flow on groundwater recharge due to deep percolation; and
- Accounts for evaporation of ineffective precipitation in the winter months where ITRC-METRIC ET data may not fully capture evaporation after rain events due to gaps in imaging frequency and/or less-reliable interpolations between imaging dates.

The attached **Figure G-4-2** provides a schematic of the irrigated agricultural lands subdomain equations and their interrelationships as described above.

For Irrigated Lands:



Legend

= Raw Data

= Quantity of Interest

= Calculated by Sum

= Calculated by Difference

= Calculated using Multiplication by a Calibration Factor or other constant

(#) = Corresponding equation in Appendix G-4-2

Abbreviations

ft = feet

ft msl = feet above mean sea level

eki environment & water

Irrigated Agricultural Lands Equations & Interrelationships

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

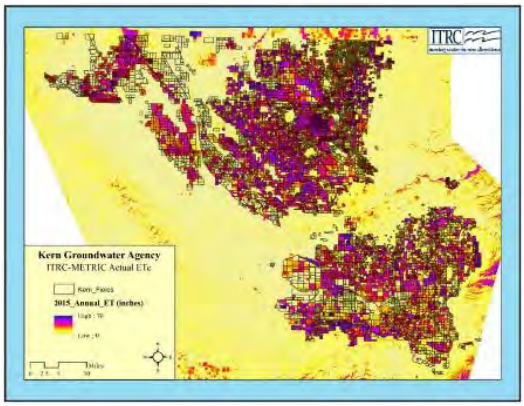
Figure G-4-2

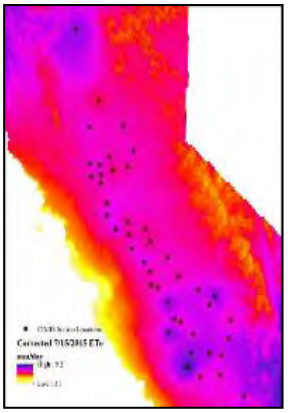
Attachment G-4-1

2015 ITRC-METRIC ET Study Report (GEI)

Kern Groundwater Authority

1993-2016 ITRC-METRIC ETc for Kern County



Prepared by
Daniel J. Howes, Ph.D., P.E.
Project Manager
Irrigation Training and Research Center
California Polytechnic State Univ.
Office: 805-756-2347, Mobile: 858-354-0504
djhowes@calpoly.edu

Prepared for
Kern Groundwater Authority
c/o Eric Averett, General Manager
Rosedale-Rio Bravo WSD
P.O. Box 20820, Bakersfield, CA 93390-0820
Phone: 661-589-6045
eaverett@rrbwsd.com

June 2018

ITRC
moving water in new directions

IRRIGATION TRAINING & RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Office Phone: (805) 756-2434 FAX: (805) 756-2433
www.itrc.org

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Kern Groundwater Authority
1993-2016 ITRC-METRIC

Introduction

The Irrigation Training & Research Center (ITRC) at California Polytechnic State University, San Luis Obispo was contracted by the Kern Groundwater Authority (KGA) to compute actual evapotranspiration (ETc) from the Southern San Joaquin Valley within and near the Kern Groundwater Basin. The area of interest is shown in Figure 1 with a "natural color" image in the background.

ITRC uses a modified Mapping of EvapoTranspiration with Internal Calibration (METRIC™) procedure to compute actual evapotranspiration using LandSAT Thematic Mapper (LandSAT) data. The original METRIC procedure was developed by Dr. Richard Allen (University of Idaho). ITRC has made a number of modifications to the original procedures including using a grass reference evapotranspiration instead of alfalfa, a semi-automated calibration procedure, spatially interpolated ETo, modifications to the aerodynamic resistance and albedo computations for certain crops, improved open water evaporation algorithm, etc.



Figure 1. Aerial image of the area of interest within which actual evapotranspiration was provided to KGA

This report will describe the general process and some results of the modeling over the timeframe. The monthly and annual results of ITRC-METRIC for this project have been transmitted to KGA (care of Eric Averett, General Manager, Rosedale-Rio Bravo WSD).

ITRC- METRIC Procedures

This *Procedures* section will discuss the information that was gathered and used to compute the actual crop evapotranspiration (ET) in the Delta. The ITRC-METRIC process is based on a surface energy balance and includes corrections for aerodynamic resistance. It depends upon both accurate and frequent LandSAT satellite thermal images and understanding of the cropping systems within a region. The METRIC programs have gradually evolved from research in the US and other countries with the objective of being able to directly estimate actual ET over large areas with limited data availability (such as crop type, irrigation method, irrigation practices, etc.). The image processing is relatively fast; however, the collection of significant background data (besides the satellite images) that are necessary to start the processing in a new area can be somewhat time-consuming. Proper use of METRIC also requires expert input/interpretation by those who run the program.

LandSAT 5, 7, and 8 image pixel resolution is 30 meters by 30 meters for all but the thermal band. The thermal band pixel resolution is 120 meters by 120 meters for LandSAT 5, 60 meters by 60 meters for LandSAT 7, and 100 meters by 100 meters for LandSAT 8. For this project, the thermal band was sharpened to 30 meter by 30 meter resolution using the nominal cubic spline that is provided in the raw images by USGS. ITRC has a more advanced thermal sharpening process, but that was not used because of time and budget constraints for this project. Inputs into the ITRC-METRIC model included:

- LandSAT imagery
- Digital elevation maps
- NASS CropScape data
- Corrected weather station data (hourly and daily)
- Corrected spatial grass reference evapotranspiration (ETo) maps (daily)
- Spreadsheet calculated values
- Tabulated constants

A critical benefit of using ITRC-METRIC to determine actual evapotranspiration is that land use/crop type information is not needed. Therefore, inaccuracies of determining land use are not part of the uncertainty in ETc output. General land use information (row crop, orchard, etc.) is used to correct for aerodynamic influences on ETc. The information provided through the NASS CropScape is of sufficient accuracy for this piece of the process.

Satellite Images

LandSAT 5, LandSAT 7, and LandSAT 8 images available from the United States Geological Survey (USGS) on sixteen-day intervals were used for the METRIC process. Table 1 shows the time frame of available images from each satellite.

Table 1. Time frame of available images for LandSAT 5, 7, and 8

LandSAT 5	LandSAT 7**	LandSAT 8
November 1982 – October 2011	June 1999 – Present	April 2013 – Present

***After May 2003, LandSAT 7 began producing images with missing data, or "bandgaps" because of a defective sensor/mirror. LandSAT 7 is only used as a backup if other LandSAT data is missing. Bandgaps are filled using interpolation techniques in GIS as described in the METRIC Application Manual Version 2.0.7 (Allen et al. 2010)*

The area of interest is covered by the LandSAT image path 42, rows 35 and 36**.** Each path identifies a path, or single trip the LandSAT takes, and the rows are different portions of that path. The rows along the same path are taken on the same day and the center of the row image is taken at approximately the same time of the day (approximately 11 a.m. Pacific Standard Time).

The METRIC modeling process relies on surface temperature data from the LandSAT thermal band. Actual ETc cannot be computed for the regions covered by clouds or fog. Figure 2 compares a non-clouded image with a cloud-covered LandSAT image. The best quality (minimal clouds and fog) LandSAT images were selected for processing. Every LandSAT image available throughout the study period was evaluated manually.

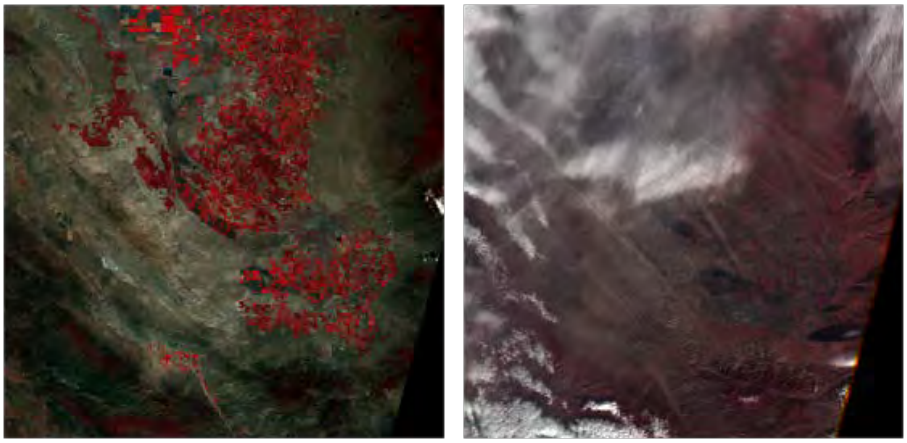


Figure 2. Cloud free LandSAT image (left) and LandSAT image with clouds (right)

All relatively cloud-free available images were used for the modeling process. Table 2 lists the images processed from late 1992 through early 2016. A total of 234 images were used to cover the study period.

If a cloud-free image was not available during a month, the image with the fewest clouds was selected or LandSAT 7 imagery was used. If an image with clouds had to be used, the clouds were masked out of the results and replaced with interpolated results from images processed before and after the image date. For the cloud masking interpolation, the two previous and three subsequent processed images were used to estimate the actual crop coefficient for the cloudy region.

Some months (generally during winter) had no usable images because of significant cloud cover. Available images, before and after the month with no data, were selected to be used to interpolate the missing image.

For those cases when three or more consecutive months did not have usable images, the closest available image was used in combination with a correction factor, to get an average estimated Kc map for the missing month. Those correction factors were established based on data from years with usable winter images. Because this process was used only for winter months, which have low ET, the overall accuracy should not be influenced significantly. However, users should understand that the uncertainty of the data for these months is greater than if LandSAT images were available. The months when this process was used can be seen in Table 3.

Table 2. Chosen image dates for 1993-2016 Kern County METRIC process

1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
10/1/1992	2/25/1994	4/1/1995	4/3/1996	3/5/1997	3/8/1998	1/22/1999	2/2/2000*	1/3/2001*	2/7/2002*	3/6/2003
12/20/1992	3/13/1994	5/3/1995	5/21/1996	4/6/1997	4/9/1998	2/23/1999	3/21/2000*	2/4/2001*	3/3/2002	4/7/2003
3/10/1993	6/1/1994	6/3/1995	6/22/1996	5/8/1997	5/27/1998	3/27/1999	4/30/2000	3/24/200*	4/12/2002*	6/10/2003
4/27/1993	6/17/1994	7/6/1995	7/8/1996	6/9/1997	6/28/1998	5/14/1999	5/24/2000	4/17/2001	5/14/2002*	7/12/2003
5/29/1993	7/3/1994	7/22/1995	7/24/1996	7/11/1997	7/14/1998	6/15/1999	6/17/2000	5/11/2001*	6/15/2002	8/13/2003
6/30/1993	8/4/1994	8/7/1995	8/9/1996	7/27/1997	7/30/1998	7/17/1999	7/3/2000	6/20/2001	7/9/2002	8/29/2003
7/16/1993	9/5/1994	9/8/1995	9/10/1996	8/28/1997	8/31/1998	7/25/1999*	7/19/2000	7/14/2001*	7/25/2002	9/14/2003
8/1/1993	9/21/1993	10/10/1995	9/26/1996	9/29/1997	9/16/1998	8/2/1999	8/12/2000*	7/30/2001*	8/18/2002*	10/16/2003
8/17/1993	10/23/1993	11/11/1995	11/29/1996	10/15/1997	10/18/1998	9/3/1999	9/29/2000*	8/23/2001	9/19/2002*	11/25/2003*
9/2/1993					11/19/1998	10/5/1999	10/7/2000	9/16/2001*	10/21/2002*	
10/20/1993					12/5/1998	11/22/1999	11/16/2000*	10/18/2016*	12/8/2002*	
11/5/1993						12/24/1999	12/26/2000	11/3/2001*		
								12/13/2001		

2004	2005	2006	2007	2008	2009	2010	2011	2014	2015
3/16/2004*	1/30/2005*	1/25/2006	1/12/2007	2/16/2008	1/17/2009	2/13/2010*	2/8/2011	12/14/2013**	1/2/2015**
4/9/2004	4/12/2005	2/10/2006	2/21/2007*	3/19/2008	2/2/2009	4/26/2010	3/4/2011*	12/30/2013**	2/27/2015*
5/11/2004	5/14/2005	4/7/2006*	3/17/2007	4/20/2008	3/30/2009*	5/12/2010	4/29/2011	1/15/2014**	3/7/2015**
6/12/2004	6/15/2005	5/7/2006*	4/10/2007*	5/30/2008*	4/23/2009	6/29/2010	5/7/2011*	2/24/2014*	4/16/2015*
7/14/2004	7/1/2005	5/17/2006	5/20/2007	6/23/2008	5/25/2009	7/15/2010	6/16/2011	4/13/2014*	5/10/2015**
7/30/2004	7/17/2005	6/18/2006	6/21/2007	7/25/2008	6/26/2009	7/31/2010	7/2/2011	4/29/2014*	6/11/2015**
8/31/2004	8/18/2005	7/20/2006	7/7/2007	8/10/2008	7/12/2019	8/16/2010	8/3/2011	5/23/2014**	7/13/2015**
9/16/2004	9/19/2005	8/5/2006	8/8/2007	8/26/2008	7/28/2009	9/17/2010	9/4/2011	6/24/2014**	7/29/2015**
10/2/2004	10/5/2005	8/21/2006	8/24/2007	9/27/2008	8/29/2009	10/3/2010	10/22/2011	7/10/2014**	8/14/2015**
	11/14/2005*	9/22/2006	9/25/2007	10/13/2008	9/30/2009	11/12/2010*	11/15/2011*	8/27/2014**	9/23/2015 *
		10/8/2006	10/19/2007*	11/14/2008	10/24/2009*	12/6/2010	12/1/2011*	9/12/2014**	10/09/2015*
		11/9/2006	11/4/2007*		11/17/2009		1/18/2012*	10/14/2014**	11/18/2015**
		12/19/2006*			12/3/2009		2/3/2012*	11/7/2014*	2/6/2016**

Note: * indicates LandSAT 7, ** indicates LandSAT 8, and no asterisk indicates LandSAT 5 images

Table 3. Months with data estimated by the factor process

1994	1995	1996	1997	1998	2003	2004
November December	January February March December	January February March December	January February November December	January February	December	January February

Weather Data

ITRC-METRIC utilizes daily spatially varied grass reference ETo for interpolation between image dates. SpatialCIMIS is a product provided by the California Irrigation Management Information System (CIMIS) maintained by the California Department of Water Resources (DWR). Spatially varied ETo is developed by interpolating ETo between CIMIS weather stations, which measure and compute the ETo on an hourly basis. However, the collected data could have errors. Therefore, ITRC quality controls the hourly weather data at each weather station in the Central Valley (Redding to south of Bakersfield) and corrects the daily Spatial CIMIS data.

ITRC-METRIC also relies on hourly weather data from a station within the area of interest for processing the instantaneous images (prior to interpolation). The Shafter and Famoso CIMIS stations were utilized as the "primary" weather stations. These stations were selected because of their centralized locations within the primary area of interest. Shafter was used from 1992-1997 and Famoso was used from 1998-2015. The same quality control procedure was used at all weather stations, as will be described.

Hourly weather data for the project time frame was collected from CIMIS weather stations located throughout the project area. Forty-nine weather stations were used for the METRIC modeling process. Figure 3 shows the majority of weather stations used in this project. Not all stations were available during the entire analysis period. Each station is listed in Table 4 showing the approximate range of time that the station was utilized. A station may have become active or inactive within this timeframe.

The weather component data collected from the weather stations included:

1. Solar radiation (W/m^2)
2. Vapor pressure (kPa)
3. Air temperature (ºC)
4. Wind speed (m/s)
5. Precipitation (mm)
6. Relative humidity (%)
7. Dew point temperature (ºC)
8. PM ETo (mm)



Figure 3. Locations of the CIMIS weather stations used in this evaluation

Table 4. Weather stations used for the METRIC modeling process

1993-2004 CIMIS Station	2005-2015 CIMIS Station
Arvin-Edison	Alpaugh
Auburn	Arvin-Edison
Belridge	Auburn
Blackwells Corner	Belridge
Brentwood	Blackwells Corner
Browns Valley	Brentwood
Bryte	Browns Valley
Colusa	Bryte
Davis	Colusa
Dixon	Davis
Durham	Delano
Esparto	Denair II
Fair Oaks	Dixon
Famoso	Durham
Firebaugh-Telles	Esparto
FivePoints	Fair Oaks
FresnoState	Famoso*
Gerber	Firebaugh
Gerber South	Five Points
Hastings Tract East	Five Points SW
Kesterson	Fresno State
Kettleman	Gerber
Lindcove	Gerber South
Los Banos	Hastings Tract East
Madera	Kesterson
Manteca	Kettleman
Merced	Lindcove
Modesto	Lodi West
Orange Cove	Los Banos
Panoche	Madera
Parlier	Madera II
Shafter*	Manteca
Shasta College	Merced
Stratford	Modesto
Twitchell Island	Oakdale
Verona	Orange Cove
Westlands	Panoche
Winters	Parlier
Woodland	Patterson
	Porterville
	Shafter
	Shasta College
	Stratford
	Tracy
	Twitchell Island
	Verona
	Westlands
	Winters
	Woodland

* “Primary” stations

All collected **hourly** weather data from the stations went through a quality control check and correction procedure. A detailed procedure on the quality control conducted can be found in FAO Irrigation and Drainage Paper No. 56[1] along with correction procedures. The main variable needing correction to accurately compute the hourly ETo is solar radiation. However, relative humidity was also examined using the procedures described in Allen et al. (1998). Figure 4 contains a graph of the corrected solar radiation for the Famoso CIMIS station for 2010-2014. This weather parameter is often in error if a pyranometer becomes covered with dust or debris, or if it loses calibration. This can be identified by comparing the daily incoming solar radiation with the maximum potential solar radiation (computed based on elevation, latitude, and time of year). If the measured value does not approach or become equal to the maximum potential over a time frame of several weeks, this could indicate an error in the measurement. Day-to-day variability is expected, but during a clear day, the measured should approach the potential. High values of solar radiation can be caused by incorrect sensor calibration.

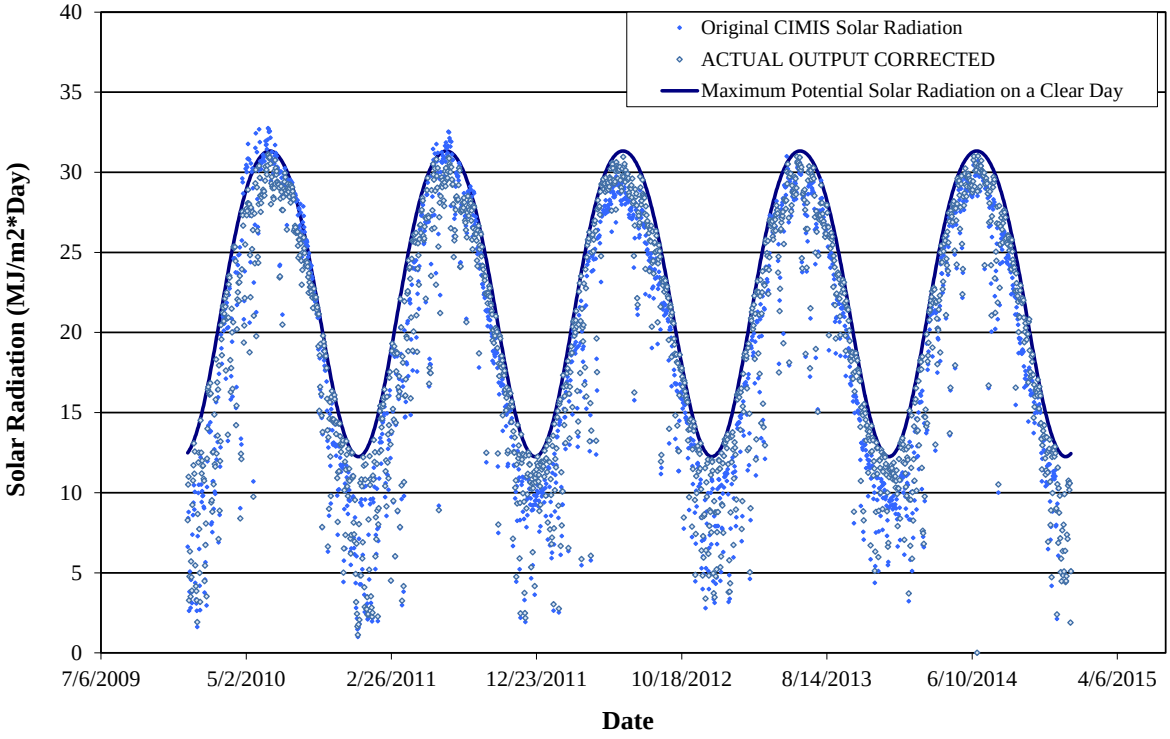


Figure 4. Example of solar adjustments made on Famoso CIMIS Station for 2010-2014. The same analysis was conducted for all weather stations in the Central Valley.

For missing data, or if an error was flagged on the CIMIS station signifying missing, incomplete, or odd data results, data were examined for general consistency. Missing data and data believed to be in error were corrected. The correction procedure used in this analysis replaced the missing or flawed data with the averages from nearby weather stations. Once all hourly data was corrected, the data was input into REF-ET™ (Dr. Richard Allen, University of Idaho) to compute the corrected hourly ASCE Standardized ETo that was used in this study.

[1] Allen, R.G.; Pereira, L.S.; Raes, D. & Smith, M. (1998). Crop evapotranspiration – Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper, No. 56, FAO, Rome

ETo and individual weather data are used within the ITRC-METRIC process to compute inputs into the software. METRIC computes the instantaneous ETc for every pixel within the LandSAT image at the instant the image is taken. Knowing the ETo at that instant from the local weather station, a **crop coefficient (Kc)** can be computed (Kc = ETc/ETo). It has been shown that this instantaneous actual Kc at the time of image acquisition (approximately 11 a.m.) is a very good representation of the Kc for that entire day. These instantaneous Kc results are interpolated using a cubic spline procedure between image dates. The interpolated pixel Kc for each day is then multiplied by the daily corrected spatial ETo discussed in the next section.

Corrected Spatial ETo

Spatial CIMIS ETo is a relatively new resource available through the DWR. A specialized algorithm uses weather station data, elevations and other inputs to interpolate ETo between stations. However, Spatial CIMIS ETo rasters rely on CIMIS weather data that could have errors. In order to improve accuracy, ITRC incorporated the corrected CIMIS weather data into the Spatial CIMIS ETo raster images using a model we developed for ArcGIS 10.1.

The basic correction procedure first included adding the locations of all 49 stations into GIS. The uncorrected Spatial ETo at the weather station location was extracted for each day over the time frame investigated. The difference between the corrected daily ETo for each station and the uncorrected Spatial ETo was computed. These differences were used to generate a difference raster using Inverse Distance Weighting (IDW) interpolation. The difference raster was combined with the uncorrected Spatial ETo to generate the corrected Spatial ETo image.

Figure 5 shows a comparison of the uncorrected Spatial CIMIS ETo and the corrected Spatial ETo for July 15, 2015. The corrected Spatial ETo represents the combination of our corrected ETo data blended with the original Spatial CIMIS ETo.

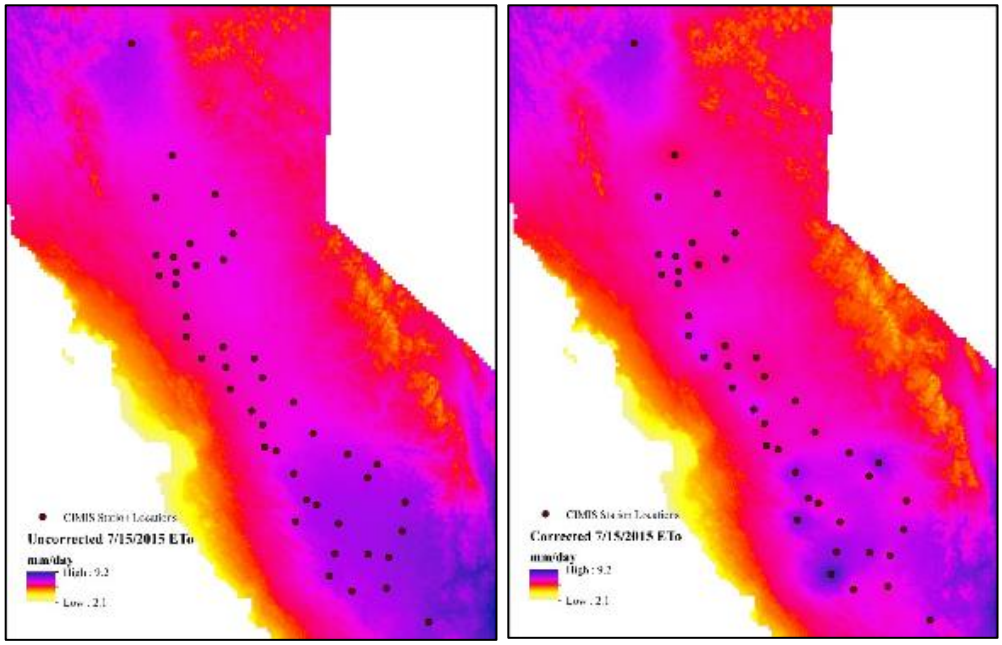


Figure 5. Example of uncorrected Spatial CIMIS ETo compared to corrected Spatial ETo for July 15, 2015

Calibration near Primary Weather Station

The METRIC process requires calibration of the hot and cold pixel for each image processed. The calibration should be conducted near a primary weather station within the image. Therefore, a primary weather station was selected for each image path. The stations selected (Shafter (1993-1997) and Famoso (1998-2015)) were chosen on the basis of the stations' history of reliable, relatively error-free data. Other reasons for choosing primary stations included:

- The location within intensive agricultural areas.
- Relatively representative of weather throughout the agricultural regions in the path.

Shafter was used as a primary station for the years 1993 through 1997. Famoso was used as a primary station for the remainder of the study period.

For the semi-automated calibration process, an area of interest (AOI) is created around the primary weather station. This AOI is generally within a 5 to 10 mile radius of the primary station and urban areas, or large non-agricultural areas are avoided. Figure 6 shows the calibration AOI for the Famoso CIMIS station.



Figure 6. Famoso CIMIS station calibration area of interest (AOI)

Elevation Data

A Digital Elevation Model (DEM) obtained from the USGS was used to adjust the model outputs based on the surface elevation throughout the area of interest. The DEM used had a resolution of 10m (1/3 arc second) which was then re-projected into a 30m × 30m pixel size to match the resolution of the LandSAT images.

Land Use Map

As previously mentioned, accurate land use/crop types are not necessary for ITRC-METRIC. General information on whether land is natural vegetation, row/field crops, orchards, or vineyards is used to adjust for aerodynamic resistance of the canopy, and is also a function of leaf area index. NASS CropScape provides sufficient accuracy for this information.

Land Use Data 2007 to Present

For years 2007 to present, only the land use data from the NASS annual rasters were used. While this information is sufficient for METRIC, there are issues with consistency within fields. Land use surveys were conducted by the California DWR on a field-by-field basis for all of the counties located in the Central Valley. DWR land use survey shapefiles were downloaded for each county, some of which may have last been surveyed in the 1990s. The shapefiles contain field boundaries or in some cases boundaries of the same crop that cover multiple fields. All non-agricultural areas in the DWR land use surveys were removed from the shapefile. Using the zonal statistics tool in ArcGIS, the NASS land use was summarized for each DWR agricultural field boundary in the Central Valley. The crop that made up the majority of the field area was assumed to cover the entire field area.

The final corrected land use maps went through a quality control check to ensure that a single land use value was uniform across an entire field. Figure 7 shows an example of the original uncorrected NASS land use compared to the land use used in this analysis, which is much more consistent. The inconsistent "pixelated" areas in the corrected land use were identified as non-cropped areas in the DWR land use survey. Therefore, these non-ag areas use the original NASS data.

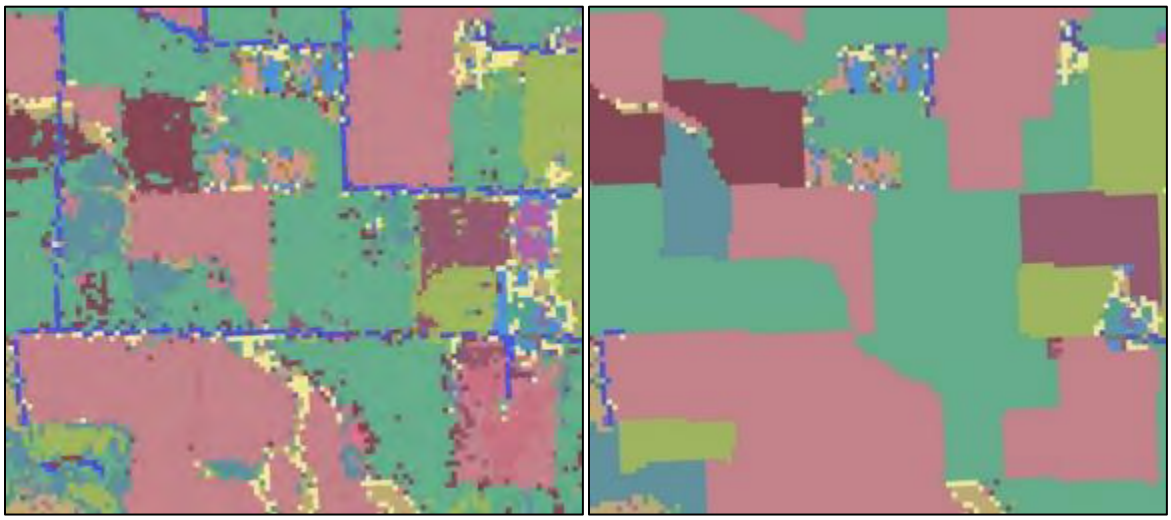


Figure 7. Example original NASS land use (left) compared to corrected land use based on the majority crop type within each agricultural field (right). Each color identifies a different land use type (i.e., almonds, alfalfa, developed, etc.)

Land Use Data 1997 to 2006

The earliest NASS land use raster available for California is from 2007. The County of Kern Agriculture and Measurement Standards provides land use shapefiles only for agricultural fields in the county from 1997 to present. The shapefiles did not provide land use data outside of the agricultural fields. Therefore, information from the last available NASS land use raster (2007) was used to fill in the missing background. The following process was used to combine the two sources to create land use maps for 1997 through 2006:

1. The crop data for each individual field from the Kern County data was converted to a specific value to match the crop identification value used by NASS. For example, a field containing alfalfa in the Kern County data was converted to the NASS crop value of 16.
2. The Kern County shapefile, with the added NASS crop value, was then converted to a raster image to represent the crop value.
3. The DWR survey shapefile was used to quality control the 2007 NASS land use raster so that the raster values within the field boundaries were all uniform.
4. The new Kern County raster was then mosaicked with the corrected 2007 NASS raster. The land use values from the Kern County raster had top priority over the 2007 NASS values and therefore were utilized in the final land use raster. Then 2007 NASS values were used in the non-agricultural areas as well as the background portion of the image.

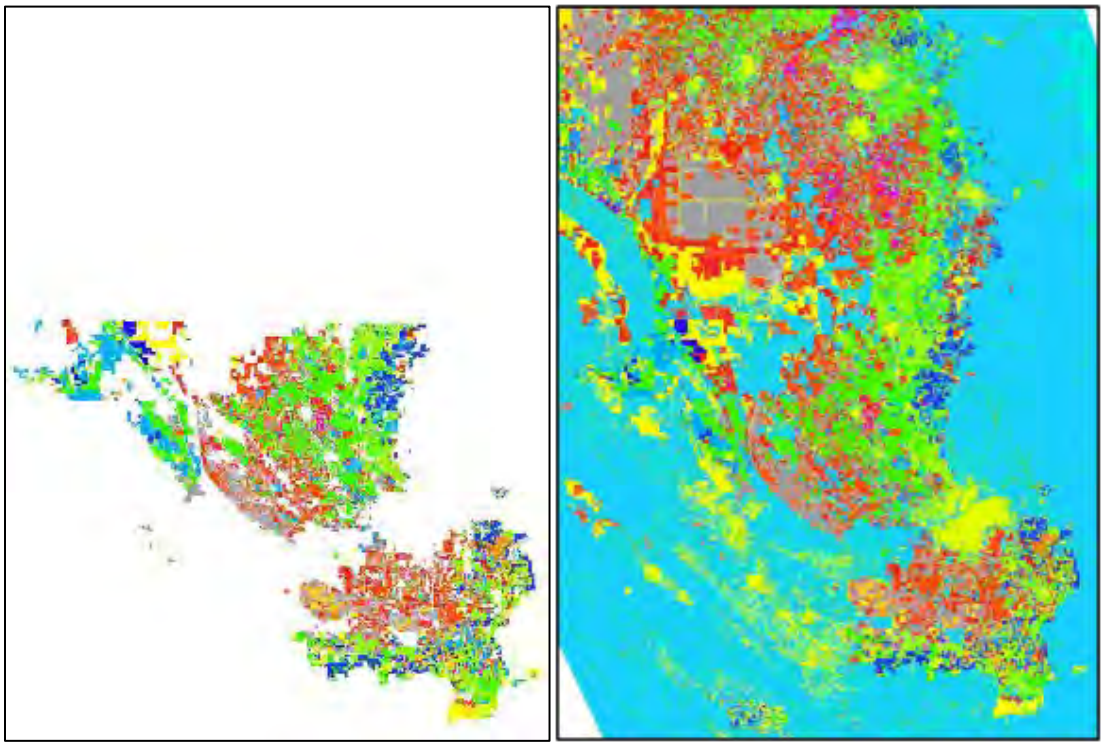


Figure 8. County of Kern agricultural land use fields (left). Combined County of Kern and NASS land use image (right)

Land Use Data 1993-1996

No land use data was available prior to 1997. Therefore, the final quality controlled 1997 land map was used for 1993 through 1996.

Interpolation between Image Dates

The selected images were processed, resulting in instantaneous actual crop coefficients (Actual Kc) on those dates for each pixel. The crop coefficient has been shown to remain constant during the majority of the daylight hours. Therefore, the instantaneous actual Kc was used as a surrogate for the daily actual Kc. In order to estimate the actual ETc between dates that images are available, actual Kc's are interpolated between image dates. A modified cubic spline approach is used to examine images within the month to be computed, prior to that month, and after that month. For example, to interpolate the ETc in the month of July, the July image(s) would be used along with May and June, and August and September. Cubic spline interpolation provides a smooth, non-linear interpolation between image dates. The interpolation takes place for every pixel in the image and the results are temporary Kc images for every day in the month. The daily pixel actual Kc values are then multiplied by the daily corrected Spatial ETo previously discussed to compute the daily actual ETc for each pixel. These daily ETc images are summed together for each month. Finally, the corrected Spatial ETo is summed for each month and the monthly ETc is divided by the ETo to generate the final monthly Kc image.

Monthly actual Kc and actual ETc results for Kern County for the period 1993-2016 have been provided to the Kern Groundwater Authority in GIS raster (image) format.

Accuracy of ITRC-METRIC ETc Estimates

Uncertainty is the quantification of accuracy in measurements and estimates. The most accurate method to estimate ETc is using a weighing lysimeter (correctly) but this is not feasible except in research situations. There are various methods that can be used to estimate ETc, each with different levels of uncertainty:

1. Traditional crop coefficient models (not used here but common in groundwater modeling) have uncertainty due to the assumptions that ETc is constant within a field and between fields in a region. Additionally, errors in land use determination (acreage of each crop), planting and harvest dates (or budbreak and dormancy for permanent crops), and crop management (irrigation, pruning, etc.) all impact the ETc uncertainty. Errors in weather data collection to determine grass reference ETo also impact the uncertainty. As a reference, uncertainties with crop coefficient methods are in the range of 20-25%.
2. Sensor-based measurements such as eddy covariance and surface renewal only measure a small footprint in a field and have potential for sensor errors due to improper calibration, loss of calibration over time, or sensor fouling. Additionally, the sensors must be adjusted, installed correctly, and some (e.g., surface renewal) depend on assumptions that may not hold. Data management and technical support make these infeasible when examining ETc over many fields.
3. NDVI-based ETc estimates have some advantages over (1) and (2) in that they provide spatial variation over a field and field to field. But these still rely on accurate crop surveys. Additionally, this method does not account for crop stress, unless that stress is so severe that it impacts the vegetative index. As with (1) above, the ETo errors translate to ETc uncertainty.
4. ITRC-METRIC ETc overcomes many of the issues with other methods, which is why it was developed. This method does not rely on accurate crop surveys. It also accounts for crop stress before it impacts the vegetation. Spatial variation in ETc throughout a field and between fields is accounted for. ETo continues to be an important part of ITRC-METRIC, which is why quality control of the data is important. In order to limit errors in ETo, ITRC conducts an extensive quality control of the weather station data and utilize spatially varied ETo to account for different climates within a region. As with other methods, it is imperative that the person doing the processing understands agronomic aspects

within the region being evaluated. Errors in processing will generate errors in ETc estimation. All ITRC-METRIC images are reviewed by project managers with many years of experience in farming, irrigation, and crop water use estimation to ensure that the outputs are correct. This overcomes potential errors in LandSAT sensor data since each image is calibrated independently.

ITRC-METRIC uncertainty is estimated to be +/-7 to 10% in this study. On a large scale (GSA or county-wide ETc volumes) the error is on the lower end of this range. On a field scale, it may be on the upper end currently. We have continued to make improvements to our methodology and feel that in the future field-scale ETc will be on the lower end of the range provided. Additionally, the launch of LandSAT 9 (planned for December 2020) will improve the temporal resolution, providing images every 16 days, offset by 8 days from LandSAT 8 (potential for images on an 8 day interval). There are no other ETc computational methods available with uncertainties on both a large scale and field scale within these ranges.

Summary of Results

The annual results have been summarized for the Kern County Valley floor and the field boundaries (majority) within the Valley floor of Kern County. Figure 9 shows the boundaries used for the data extraction for the summaries discussed in this section. Average annual ITRC-METRIC ETc was extracted using the Zonal Statistics tool in ArcGIS. The average ETc from the extracted area was multiplied by the area within the boundaries (overall boundary or each field boundary for the fields) to compute volumes. Over the 23-year period, the field boundaries and overall boundary were the same.

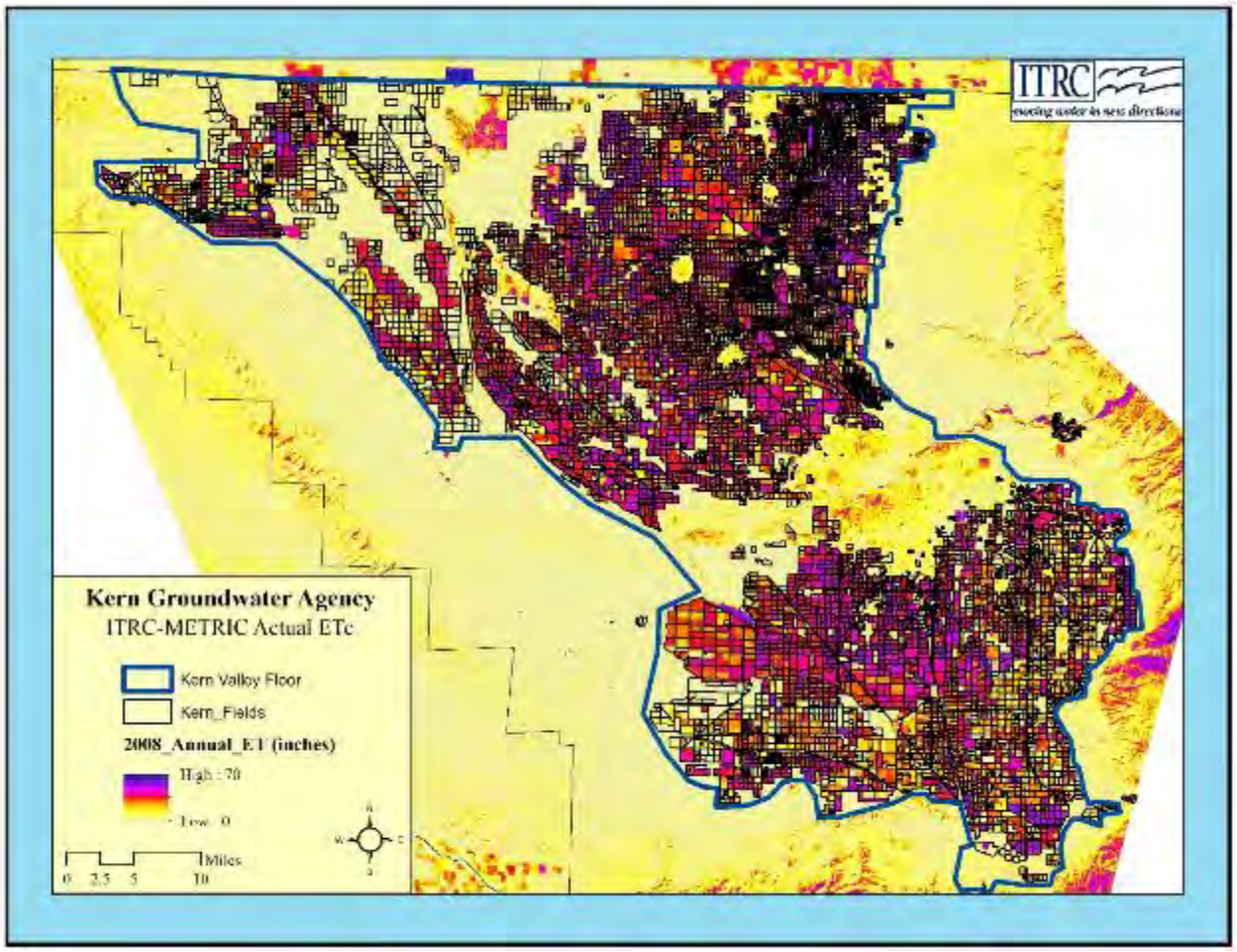


Figure 9. 2008 ETc image with Valley floor and field boundaries used for the summary analysis

The volume of actual ETc for the overall area and only within fields is shown in Figure 10. For reference, the grass reference evapotranspiration (ETo) and precipitation from the Shafter CIMIS station (1992-1997) and Famoso CIMIS (1998-2015) are also shown. ETo provides an idea of the weather conditions that drive evapotranspiration. Hotter, drier years have a higher ETo.

Figure 11 shows the volume of ETc for all water districts in Kern County and Kern Groundwater Authority members. The acreage of all districts is greater than the "Valley Floor Area" because of district boundaries covering areas outside of the valley floor (e.g., West Kern W.D.). Some districts with

substantial overlap of other districts were removed from the evaluation to limit double counting. However, some minor overlap may cause the estimates to be slightly higher than the actual volume of ETc.

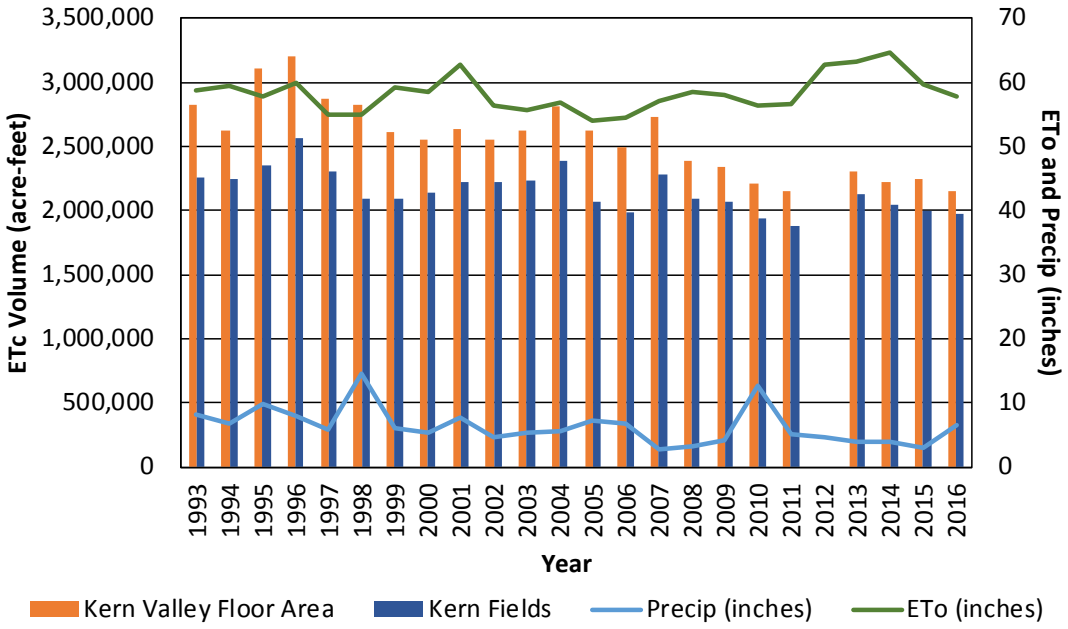


Figure 10. Annual volume of ETc for the Kern County Valley floor and within fields in Kern County. Grass reference ETo and precipitation depths are shown for each year as a reference.

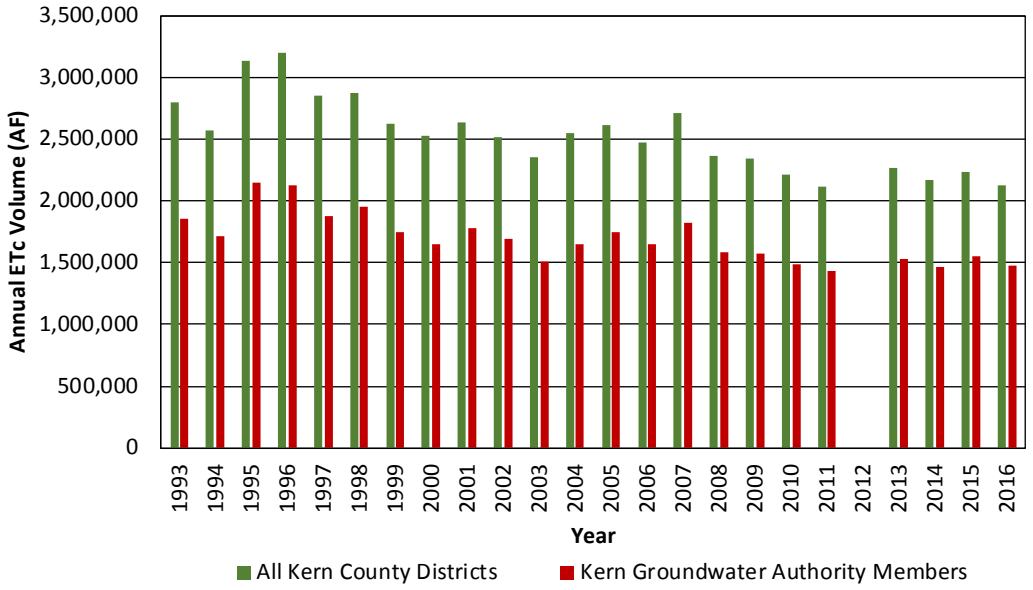


Figure 11. Annual volume of ETc for irrigation/water districts in Kern County and just Kern Groundwater Authority member districts

Evaluation of ETc Variation

In general, there is an overall decline in ETc volume from the Valley floor starting over the 23 years that the ET analysis covers. The field ETc decline is not as significant but does trend downward. The difference between the Valley floor and field ETc is due to ET and evaporation occurring outside of field boundaries. Year to year variability in ETc volume might be explained by weather differences between years. To examine this, the data was normalized to exclude weather variation by examining the annual crop coefficient (Kc), computed as the actual ETc divided by ETo (ETo is computed based on weather data, not including precipitation). Annual Kc values are shown in Figure 12 for the study period (bar graphs) for the entire Kern valley floor area (includes urban, streets, undeveloped areas, etc.) and within fields only (only agricultural fields in the same area).

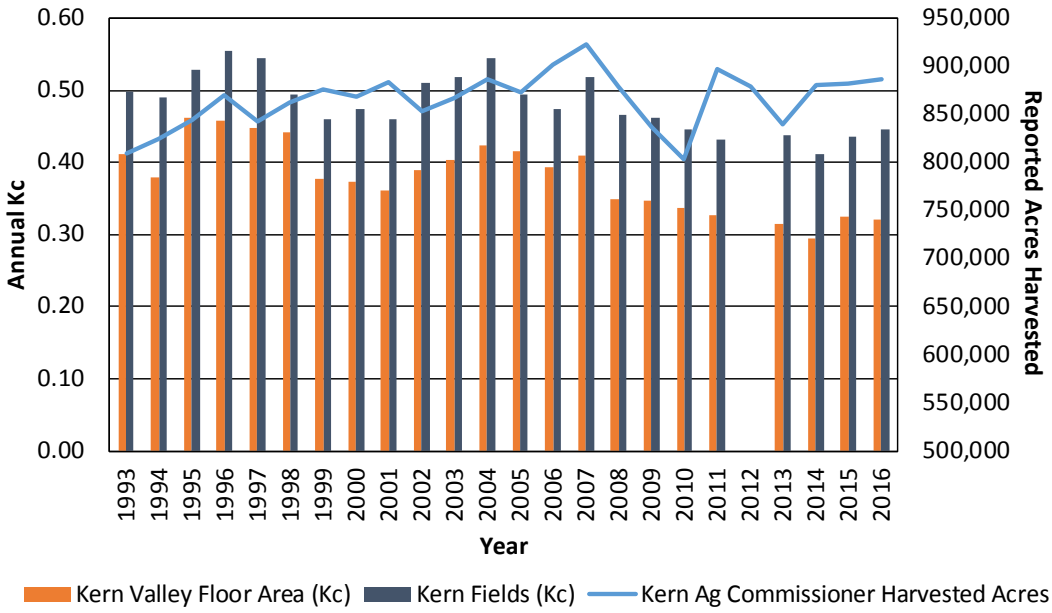


Figure 12. Annual crop coefficient (Kc) for the Kern County Valley floor and within fields in Kern County. Reported Ag Commissioner total harvested acres per year on the right axis of the graph.

As expected, the Kc is higher when only looking within field boundaries compared to the entire Valley floor of Kern County. Areas outside of the fields are in large part reliant on precipitation or are a mix of landscape and residential areas. Urban areas and open water are also included. As with the volume, there seems to be a general decline in overall Kc over the 23 years.

In the mid-2000s the Kc increases. Figure 12 also includes the Kern County Ag Commissioners total harvested acres over the 23 year period for reference and to possibly explain some of the variation. Interestingly, the Ag Commissioners' total harvested acreage increases from 1993 to 2016. While there are some general trends indicating that the annual Kc increases as the acreage increases, the trends do not follow as closely as one might expect. This could be due to the types of crops harvested over the period or the age of permanent crops being grown. It is important to restate that crop types are not used to determine ETc using ITRC-METRIC. They are only shown here as a reference to potentially explain the variation in ETc.

To delve further into the theory that crop type shifts may explain ETc variation, crop acreages of the major crops in Kern County (Kern County Agricultural Commissioner Reports) are shown in Figure 13. The higher ETc and Kc values in the mid-2000s are likely due to the increase in alfalfa acreage during this period in combination with the higher almond acreage. However, the higher ETc and Kc values in the mid-1990s are more challenging to explain. Obviously there is more cotton acreage and likely more double cropping of different row crops (although cotton is not commonly double cropped). Other crops in the cotton rotations likely include double cropping, such as corn and grain hay, which are not shown.

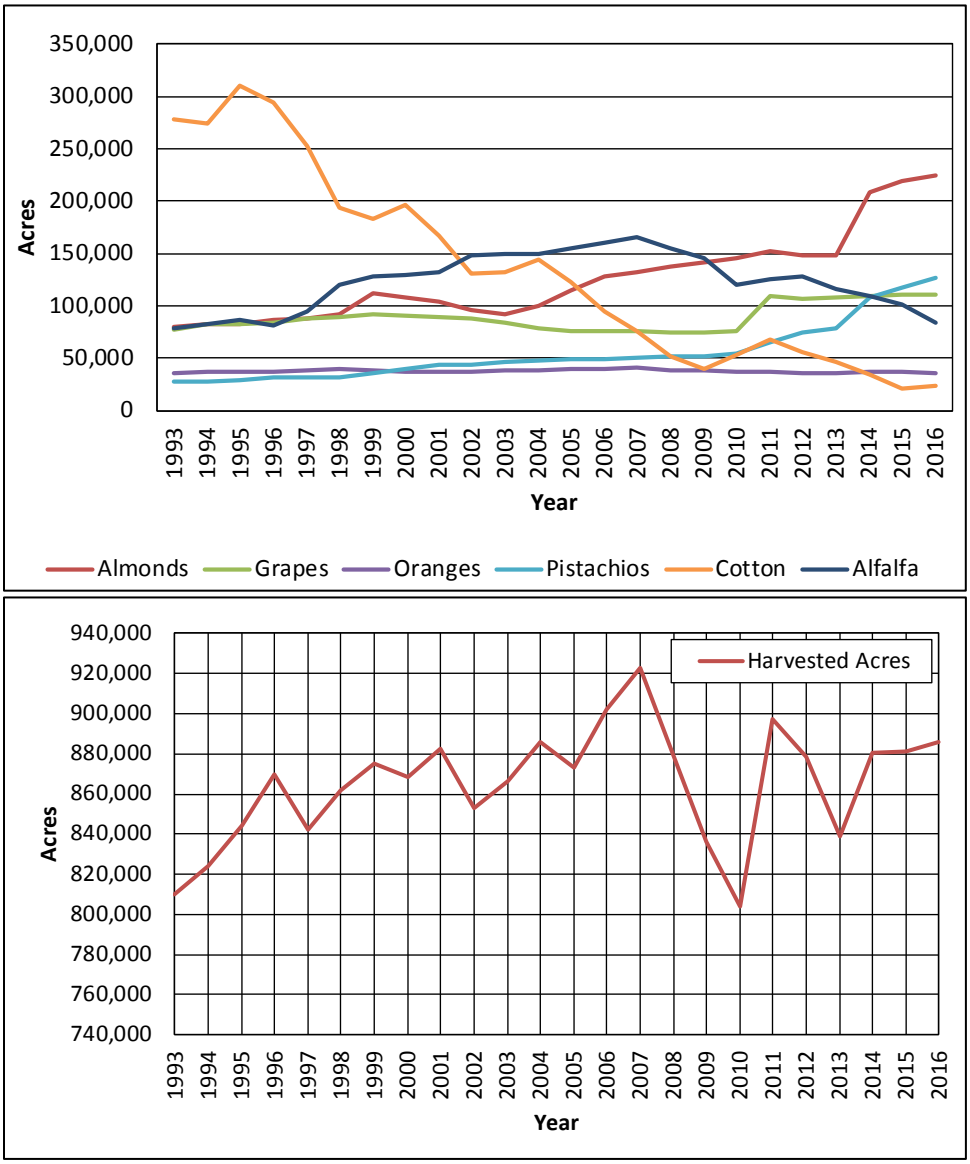


Figure 13. Crop acreage for major crops in Kern County from 1993-2016 (top) and total harvested acres (bottom) from Ag Commissioner Reports

As previously discussed, the Kern County Ag Commissioner reports showed an overall increase in harvested acreage from 1993 to 2015. The Ag Commissioner reports showed the 1993 total harvested acres at approximately 809,700 compared to the 2015 harvested acreage of 881,000. Year-to-year variations are shown in Figure 12.

There are also some unexplainable anomalies in the Ag Commissioner data, such as the increase in almond acreage from 2013 to 2014. Figure 13 shows that total acres (bearing and non-bearing) for almonds increased by over 50,000 acres from 2013-2014. The bearing acreage showed the most significant increase from 2013 to 2014 even though only 1,600 acres of non-bearing trees were reported for 2013. The bottom line is that over 50,000 acres of bearing almonds showed up in 2014 without explanation. This could be due to an error in the Ag Commissioner's reporting or a shifting methodology of accounting for certain crops.

The annual Kc by field in Kern County from ITRC-METRIC was plotted from lowest to highest Kc for four selected years (Figure 14). The fields with the lowest Kc would be fallow or young orchards/vineyards. Notice that there are more fields with Kc values below 0.2 in 2008 and 2015 than in 1993 or 1996. Of these, 1996 has the fewest low Kc fields while 2015 has the most. Different fields have different Kc values each of these years. The key point is that the lower Kc values in 2014 and 2015 (Figure 12) are likely driven down by increased fallowing or young orchards. Additionally, Figure 14 indicates that the overall field acreage was probably lower in 2015 than in 1993. While field acreage is not the same as harvested acreage because it does not account for double-cropping, it is unlikely that double cropping accounts for the full difference in reported acreage.

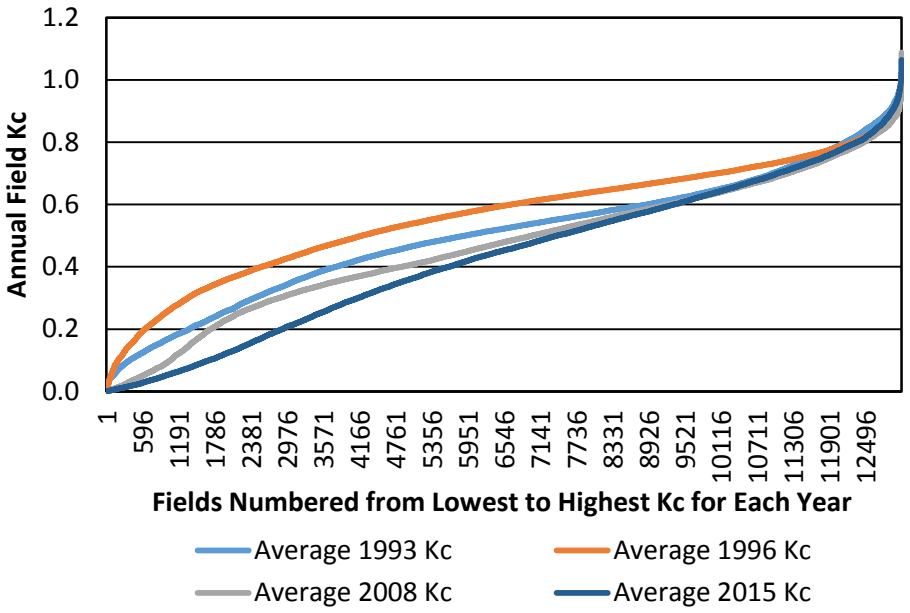


Figure 14. Annual Kc by field sorted from lowest to highest for four different years

Visually, significantly more non-cropped fields can be seen in 2015 than in 1993 (Figure 15). Portions of Kern County (red circles which include portions of Lost Hills Water District, Buena Vista WSD, and Henry Miller WD) show much lower ET in 2015 than 1993. These areas were fallowed or not cropped during the drought. In other areas, new permanent crop plantings may be the cause of lower ET. Additionally, the Kern Lake and areas south of Bakersfield have much lower ET values indicating new permanent crops or fallowing.

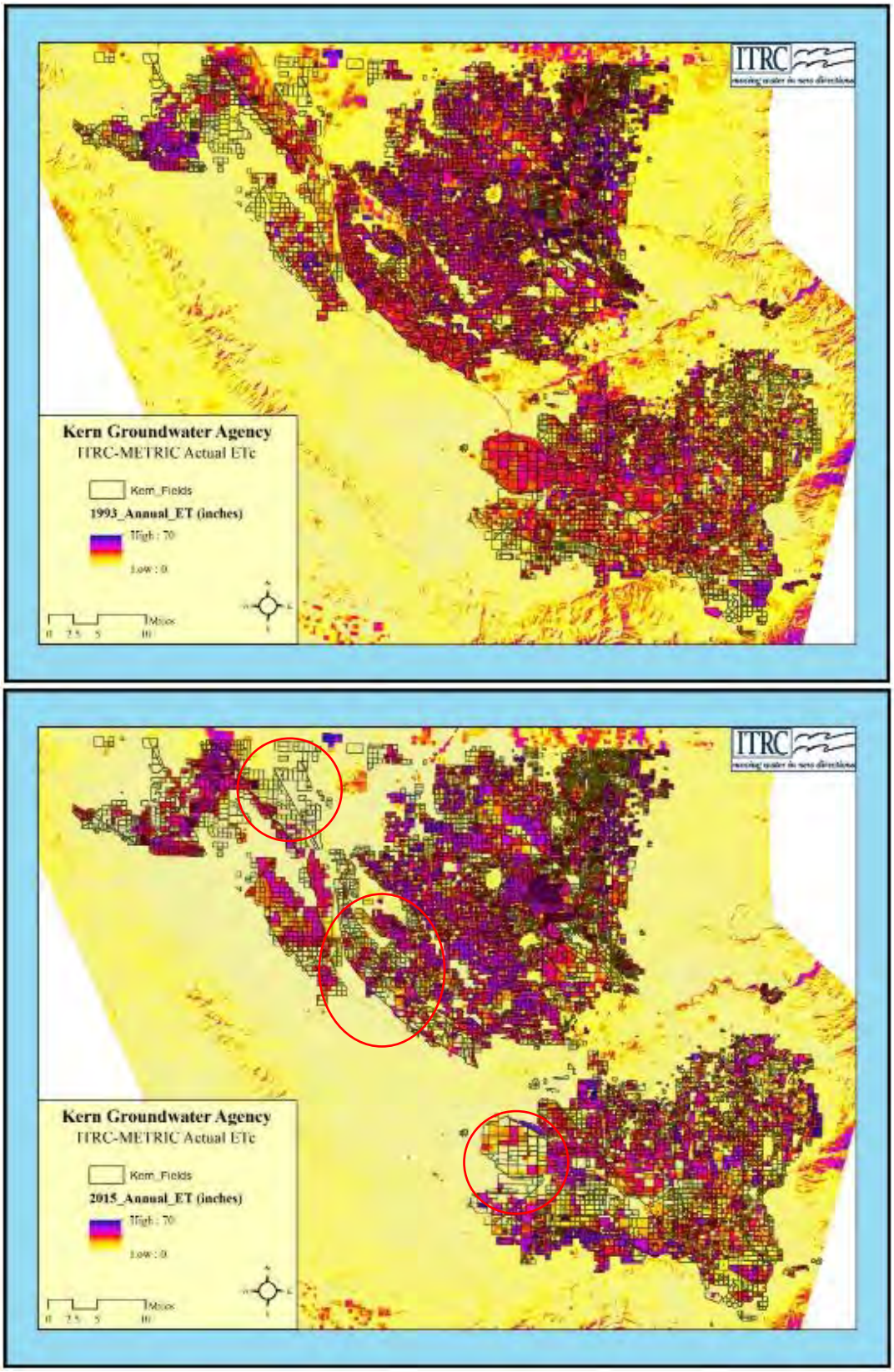


Figure 15. Annual ITRC METRIC ET in 1993 (top) and 2015 (bottom) with field boundaries

Conclusion

Over the 1993-2016 period, the volume of evapotranspiration from fields within the valley floor of Kern County ranged from approximately 2-2.5 million acre-feet. Evapotranspiration varies year to year in the valley floor portion of Kern County. This is caused by several factors including weather, crop mix, water availability, precipitation, and land fallowing. It was beyond the scope of this study to investigate exactly why evapotranspiration varied. However, the previous figures indicate that there seems to be increased fallowing or young orchards and vineyards planted in more recent years, resulting in lower evapotranspiration in this period. This acreage reduction does not coincide with Kern County Ag Commissioner's reported harvest acreage changes over the period.

The monthly and annual evapotranspiration and Kc imagery in GIS format has been transmitted to Kern Groundwater Authority.

Future Work

Net To/From Groundwater (NTFGW)

ITRC has developed a process to examine net groundwater use without the need to monitor groundwater pumping. This process is called the Net To and From Groundwater (NTFGW) and can be conducted at various scales from the farm/field, GSA, and Basin. This method incorporates surface water diversions, turnout deliveries (for farm/field scale), surface outflows, and precipitation with the monthly ETc to determine net groundwater use. Basically, if precipitation and surface water deliveries exceed ETc, the excess water would be stored in the root zone or moves to the groundwater (net to groundwater). If ETc exceed surface supplies, there is a net extraction from the groundwater to make up the difference. Results are provided spatially at the 30 meter pixel resolution. NTFGW is being used for two purposes:

1. Using historical data, to assist in calibration/verification of groundwater models. Equally important, the results provide a directly computed future ETc with net zero extraction.
2. For future management and regulation of groundwater use within the GSA. Monthly results will be provided to each GSA participant in near real-time (approximately 15 days after surface delivery information is provided to ITRC). Some GSAs are planning on providing this to farmers via a web mapping portal.

The benefits of NTFGW include:

- No groundwater metering program with meters at each well is needed. DWR has approved the method as a best-available science alternative.
- No estimates on irrigation efficiency are needed. Irrigation efficiency estimates have a high level of uncertainty, vary from field to field, and will change over time. NTFGW simplifies the evaluation of sustainable yield because inherently sustainable yield is a net value of how much groundwater can be consumed in a GSA. There is no need to estimate leaching requirements or other non-consumptive uses of groundwater. Comparing net values eliminates many uncertainties.
- It offers the ability to track net canal seepage and net recharge basin recharge by basin.
- It offers the ability to continuously track banked or over-drafted groundwater on a farm, district, and GSA level.
- It is cost-effective: the anticipated cost will be $30,000-$50,000 per year per district/GSA. Actual cost will depend on the district/GSA size and the level of evaluation.

ITRC-METRIC ETc

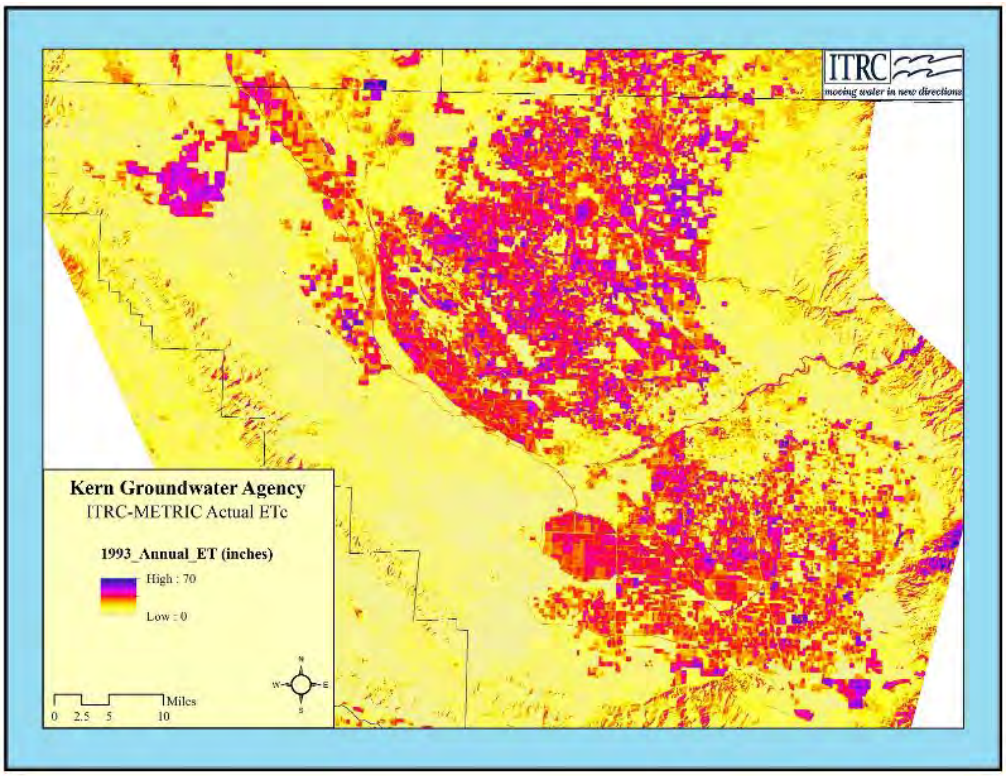
There are several options moving forward. ITRC-METRIC ETc will be an important tool. Over the past several years there have been lessons learned which will impact the process in the future:

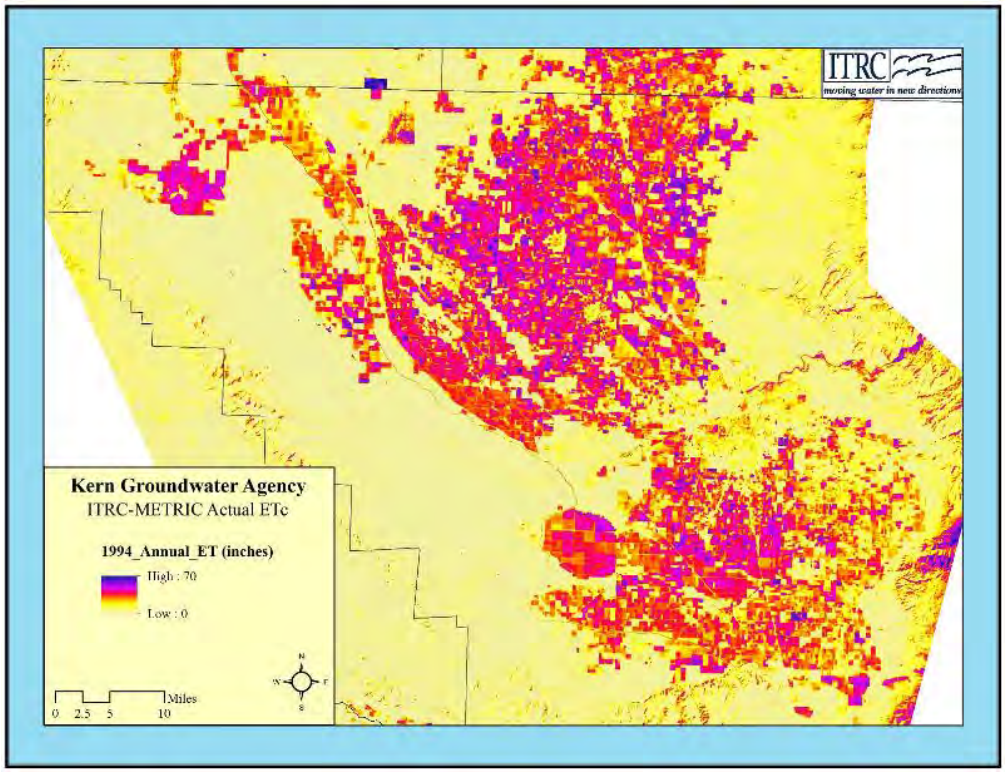
1. Thermal sharpening has not been extensively used because it is time-consuming. However, ITRC is working on expediting this process. Currently, the thermal sharpening process increases the overall processing cost by a factor of 50%. It is expected that this cost will be reduced in the future. On a larger scale it is not important because the overall ETc is not increased or decreased. On a field level, it may be more important.
2. In the past we used at least 1 image per month to compute ETc. ITRC now uses all available good-quality images (mostly cloud/fog free, some cloud coverage is okay). Again, on a large scale (over a district for example) it is not as critical, but for individual fields, especially for row and field crops, it is critical to have images at least on a 16-day interval to capture harvests appropriately.

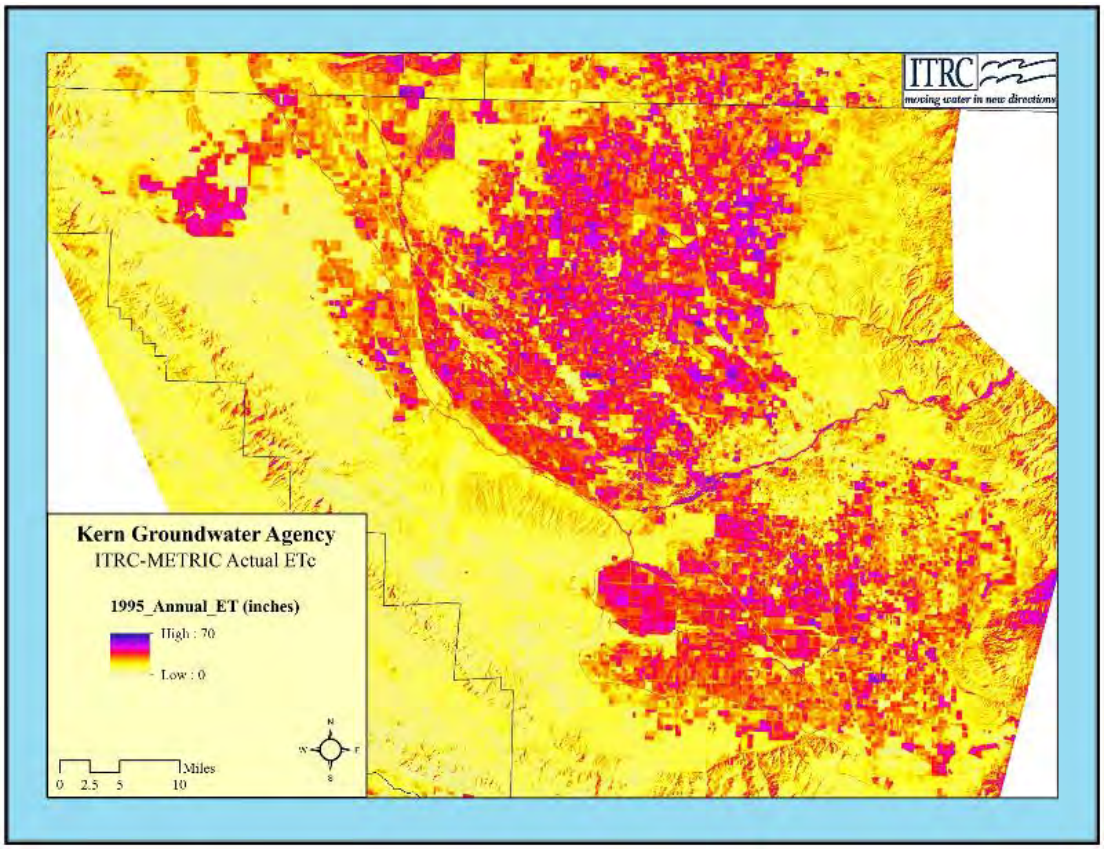
Future implementation of continuous ETc will be important for groundwater management in the Kern subbasin. The historical data generated as part of this project is being implemented in the groundwater modeling efforts in the subbasin. The next steps are towards monitoring sustainable use of the groundwater into the future. ITRC believes that NTFGW is the best methodology to monitor groundwater use since net groundwater use is more important than gross groundwater pumping. Pilot projects using NTFGW compared to groundwater pumping have been successfully implemented in a subbasin just north of Kern. ITRC would be pleased to share these results with interested parties.

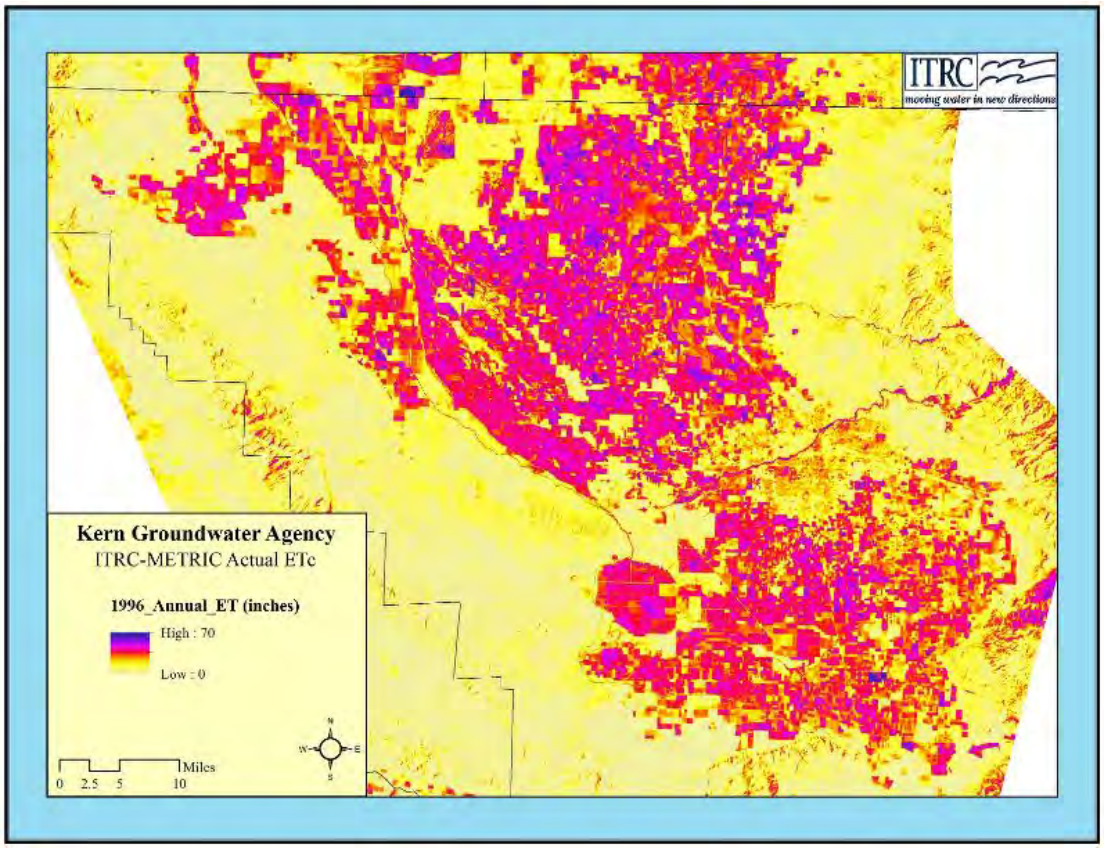
Attachment A

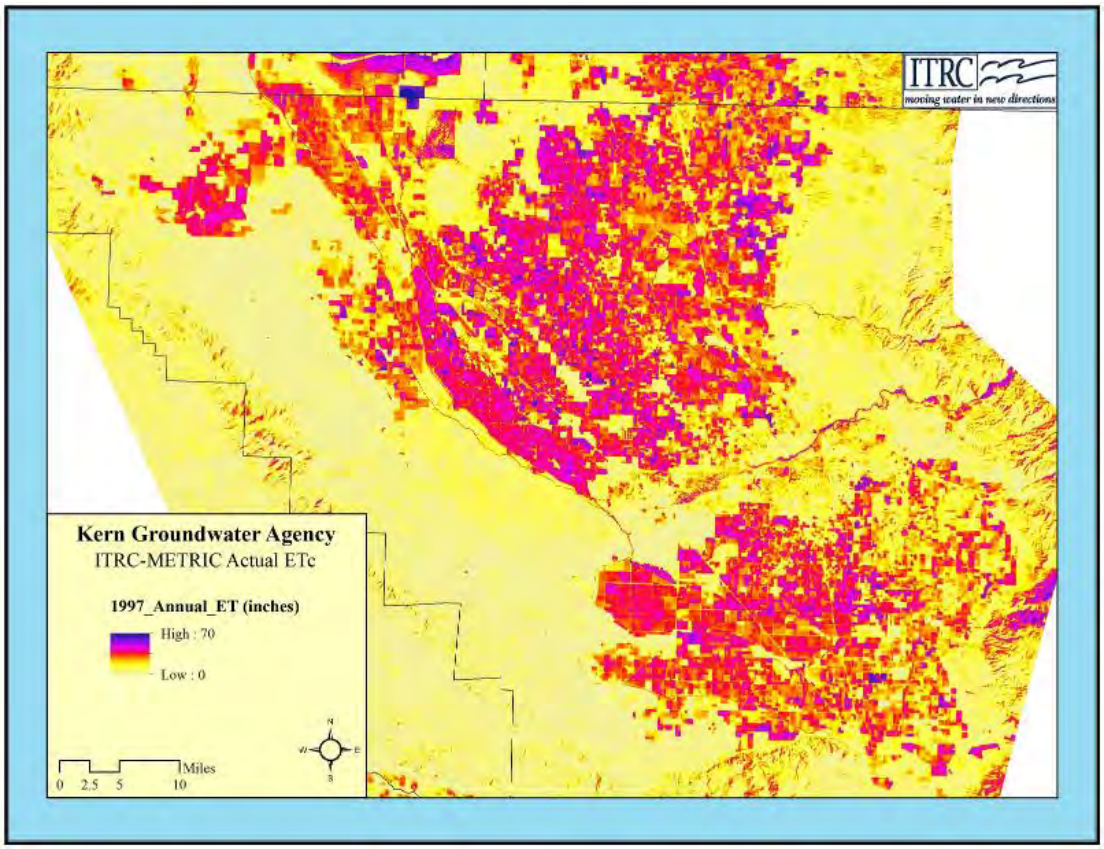
Annual ITRC-METRIC ETc

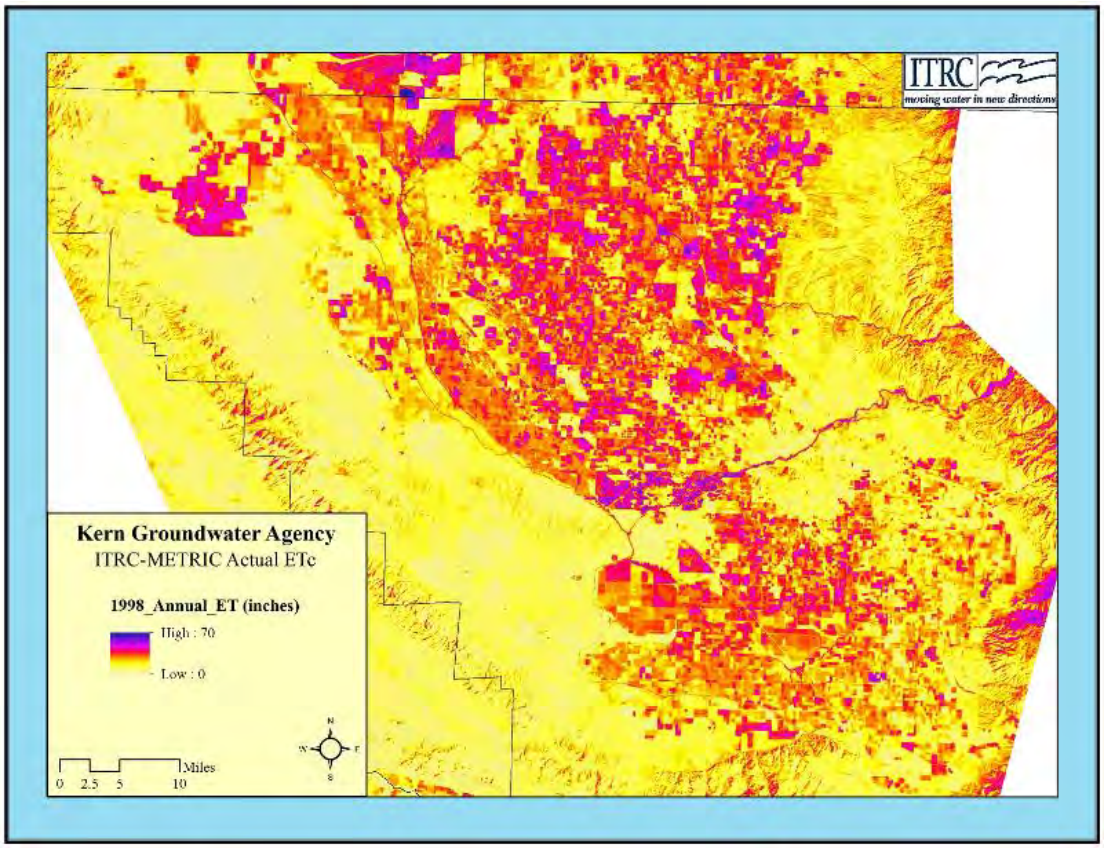


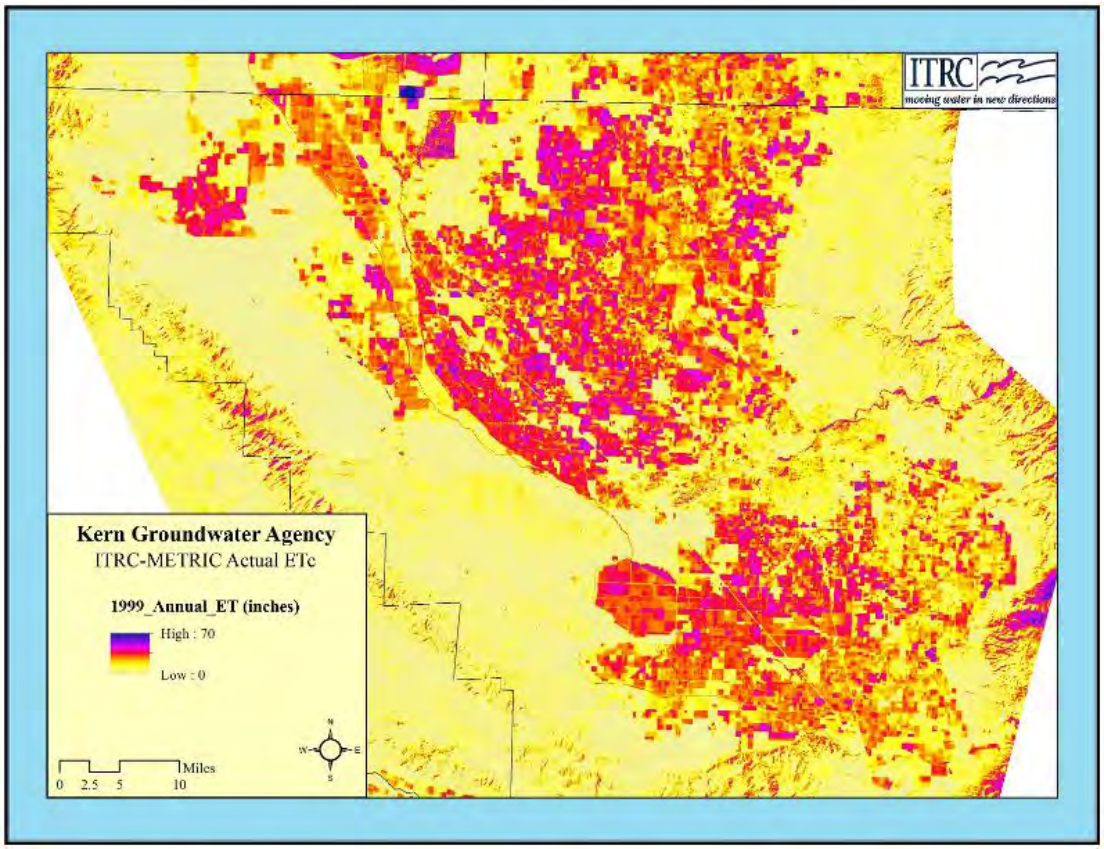


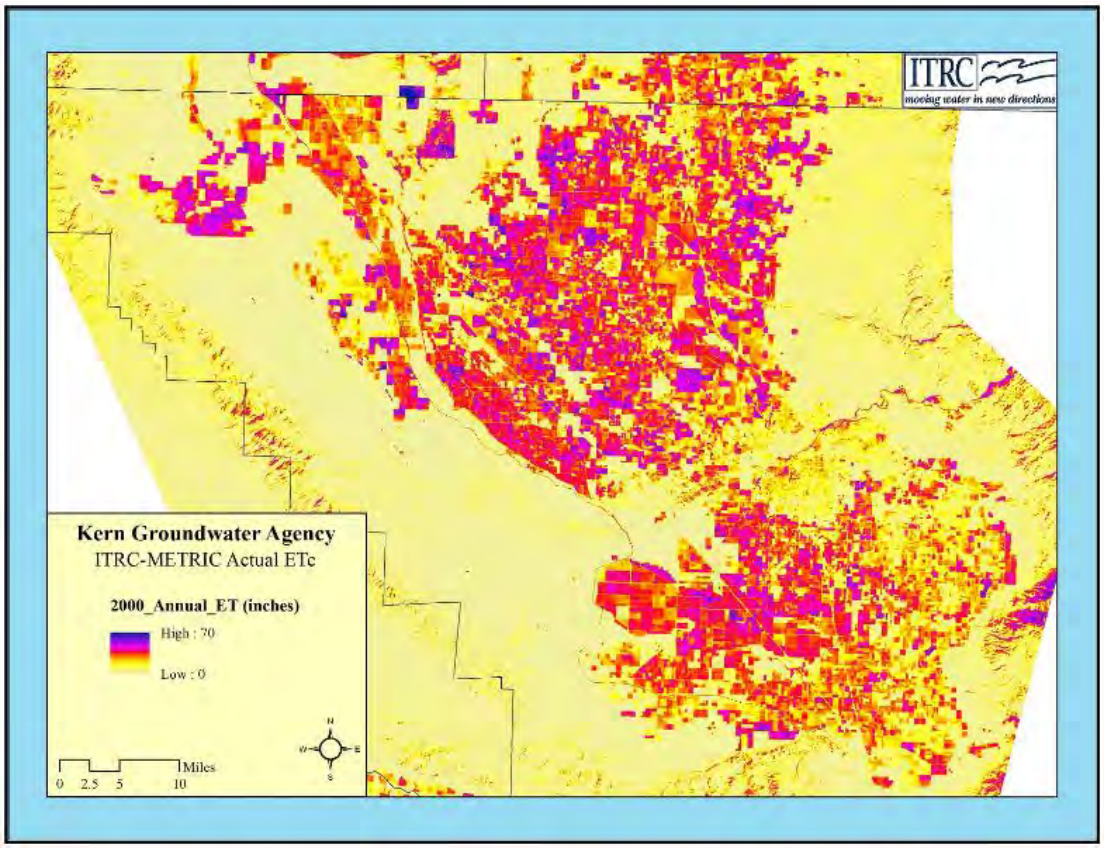

ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
1995_Annual_ET (inches)
High : 70
Low : 0
Miles
0 2.5 5 10

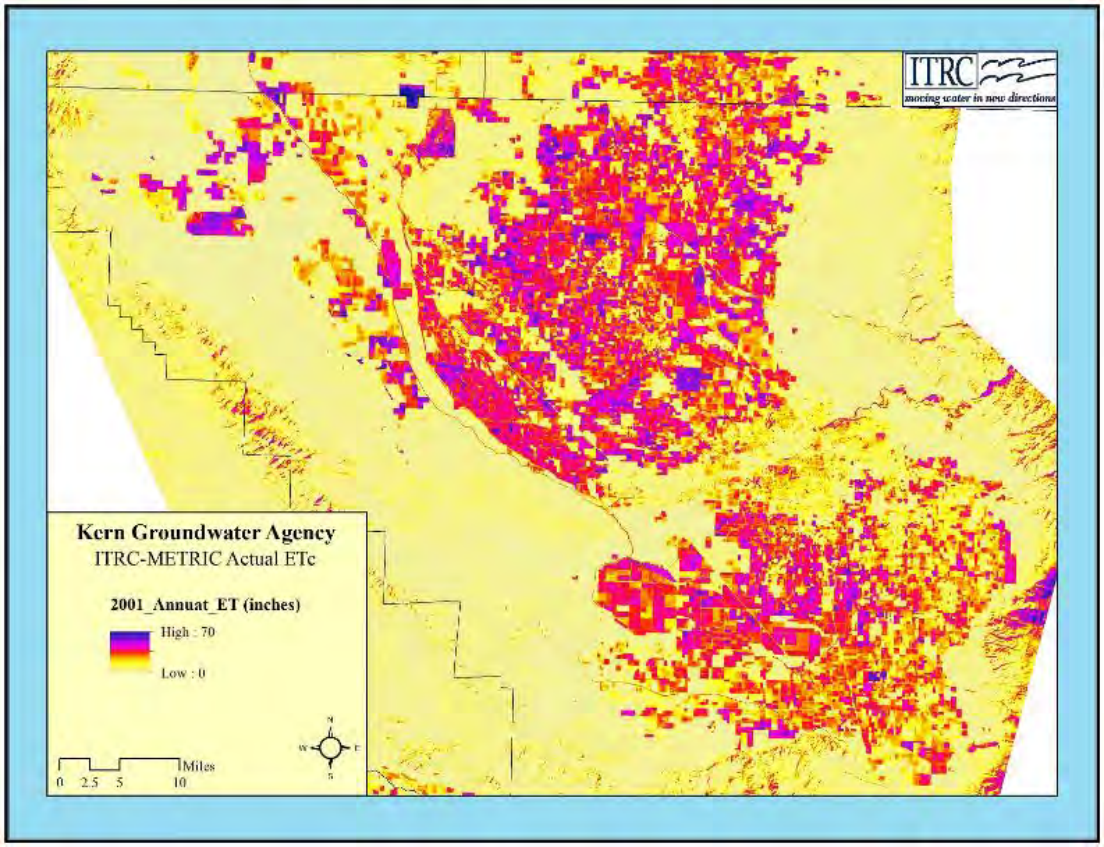

ITRC
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1996_Annual_ET (inches)
High : 70
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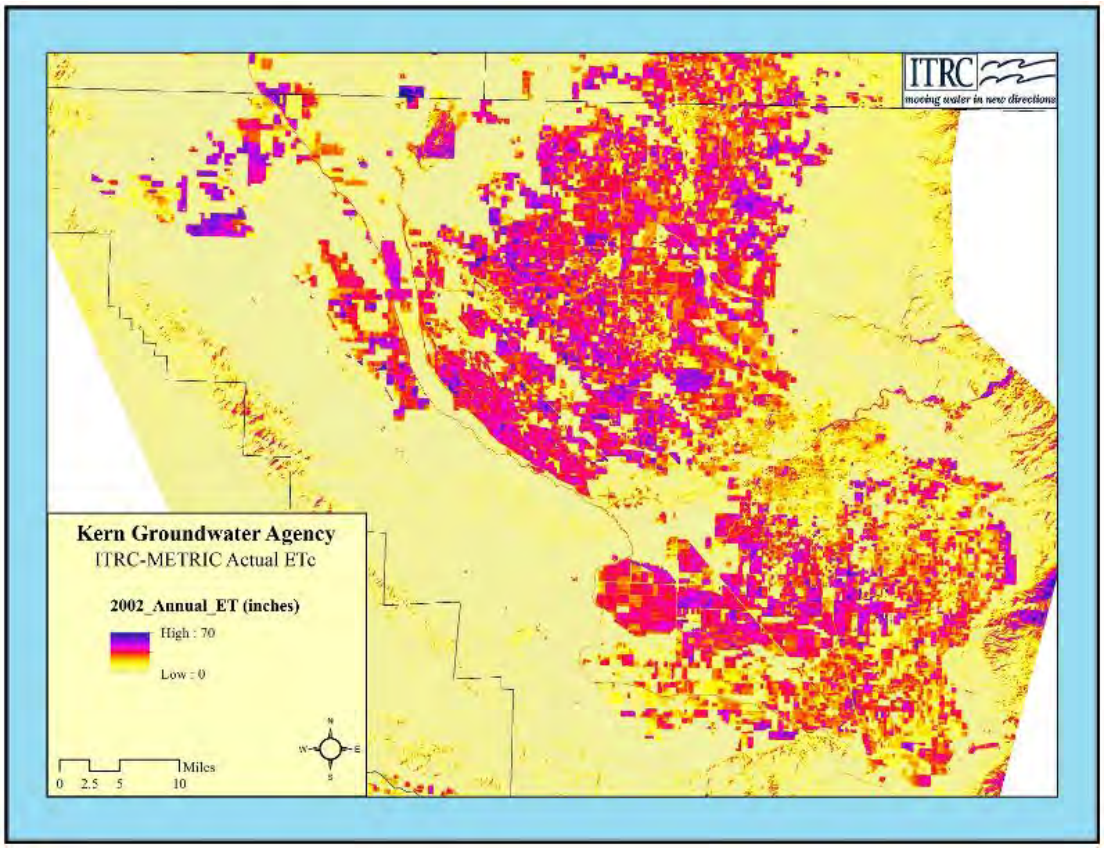

ITRC
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ITRC-METRIC Actual ETc
1997_Annual_ET (inches)
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Miles
0 2.5 5 10

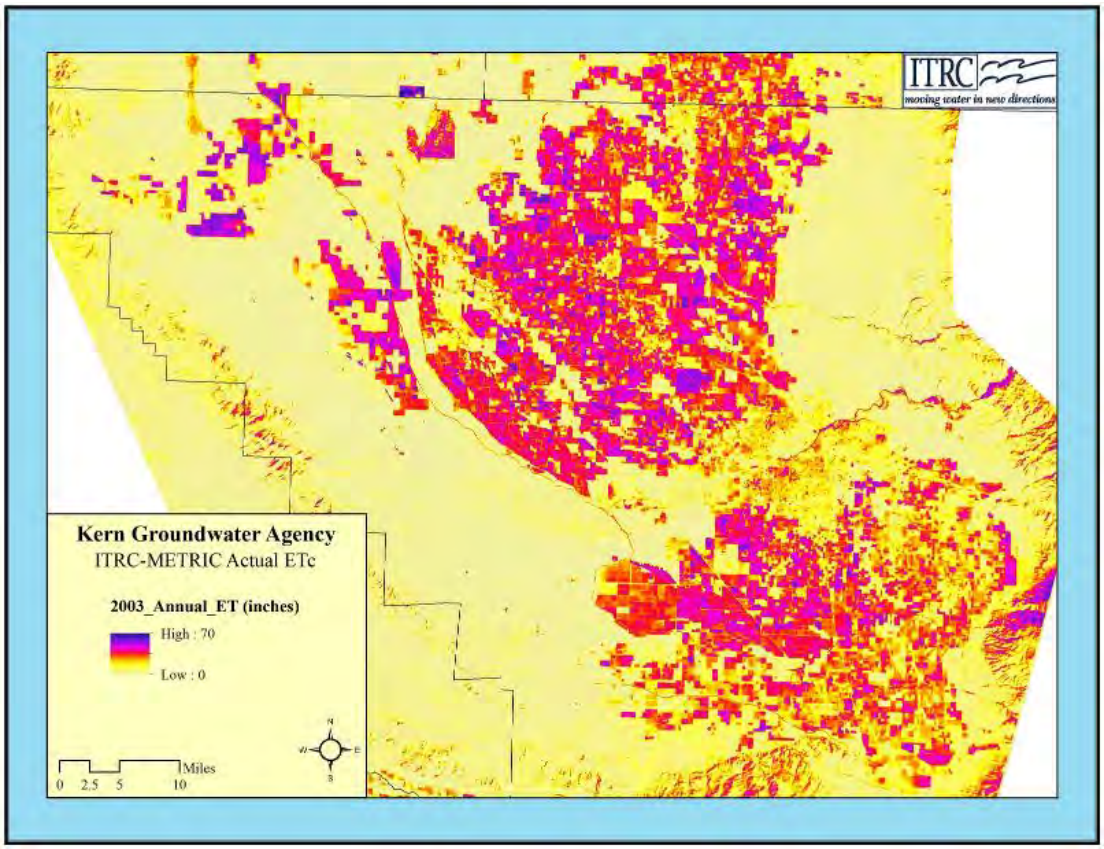

ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
1998_Annual_ET (inches)
High : 70
Low : 0
Miles
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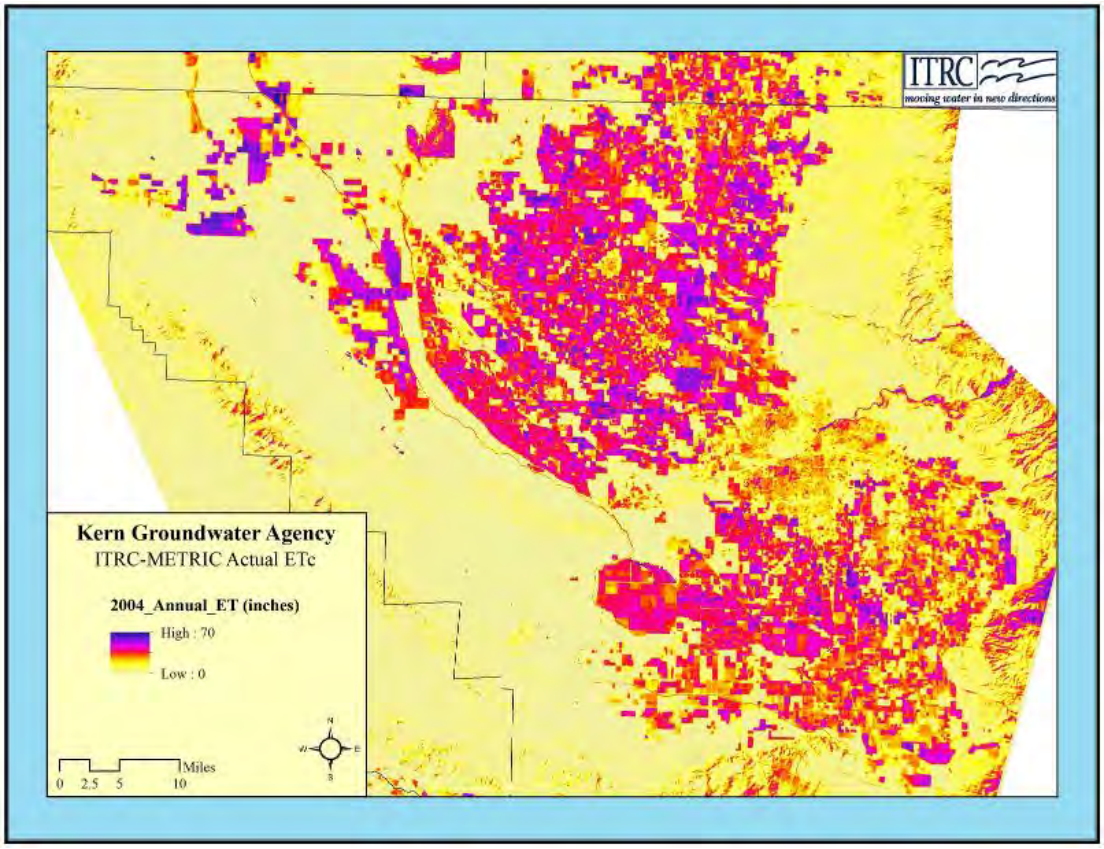

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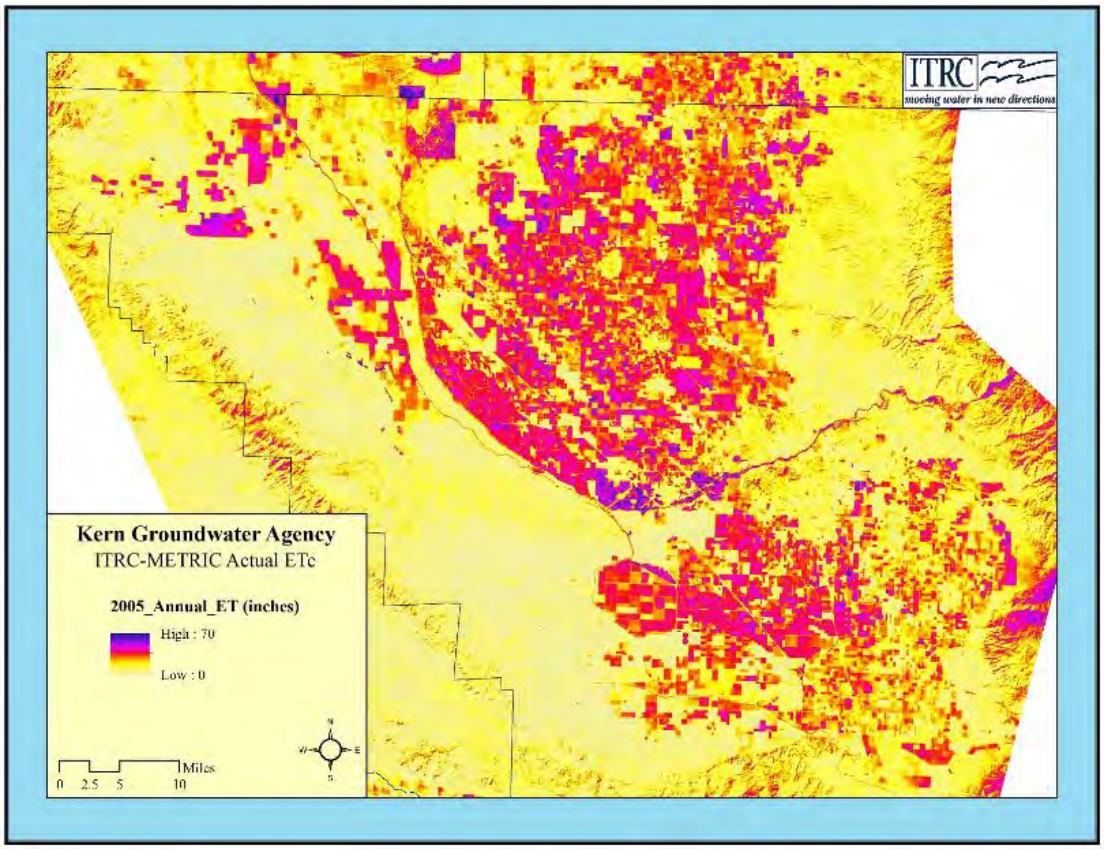

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Kern Groundwater Agency
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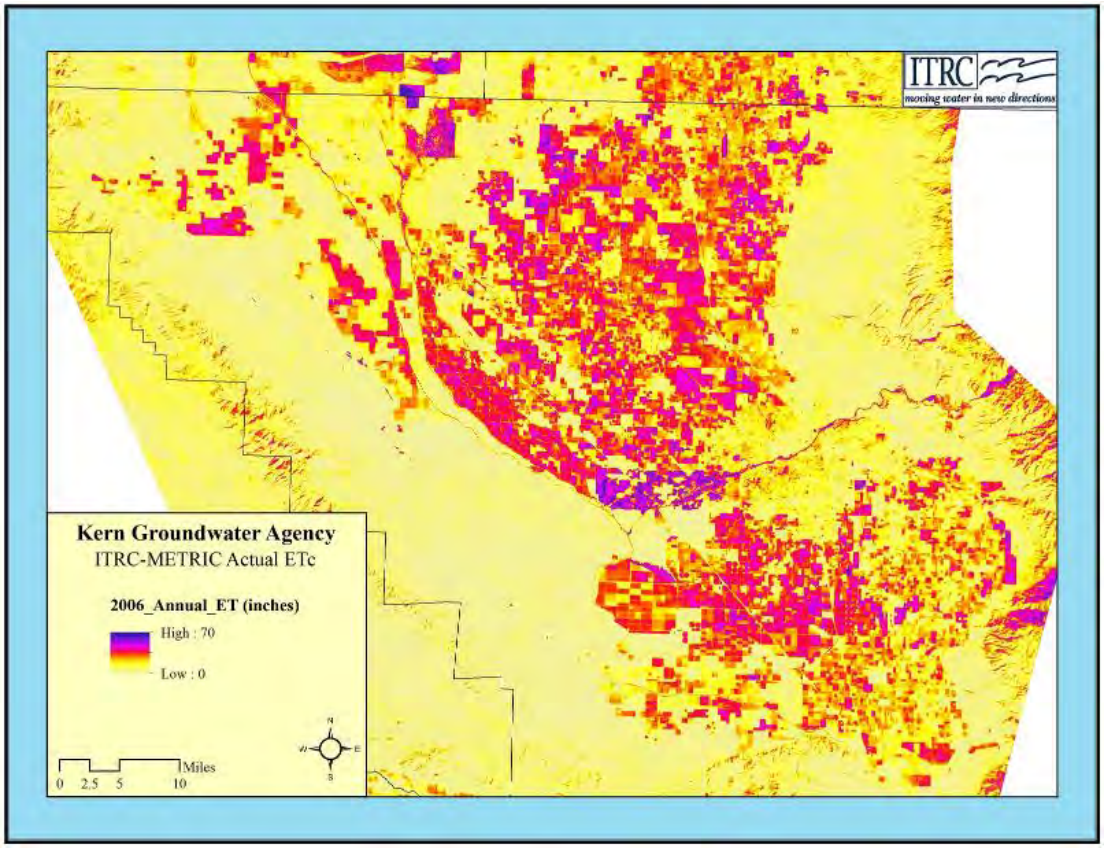

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moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2001_Annuat_ET (inches)
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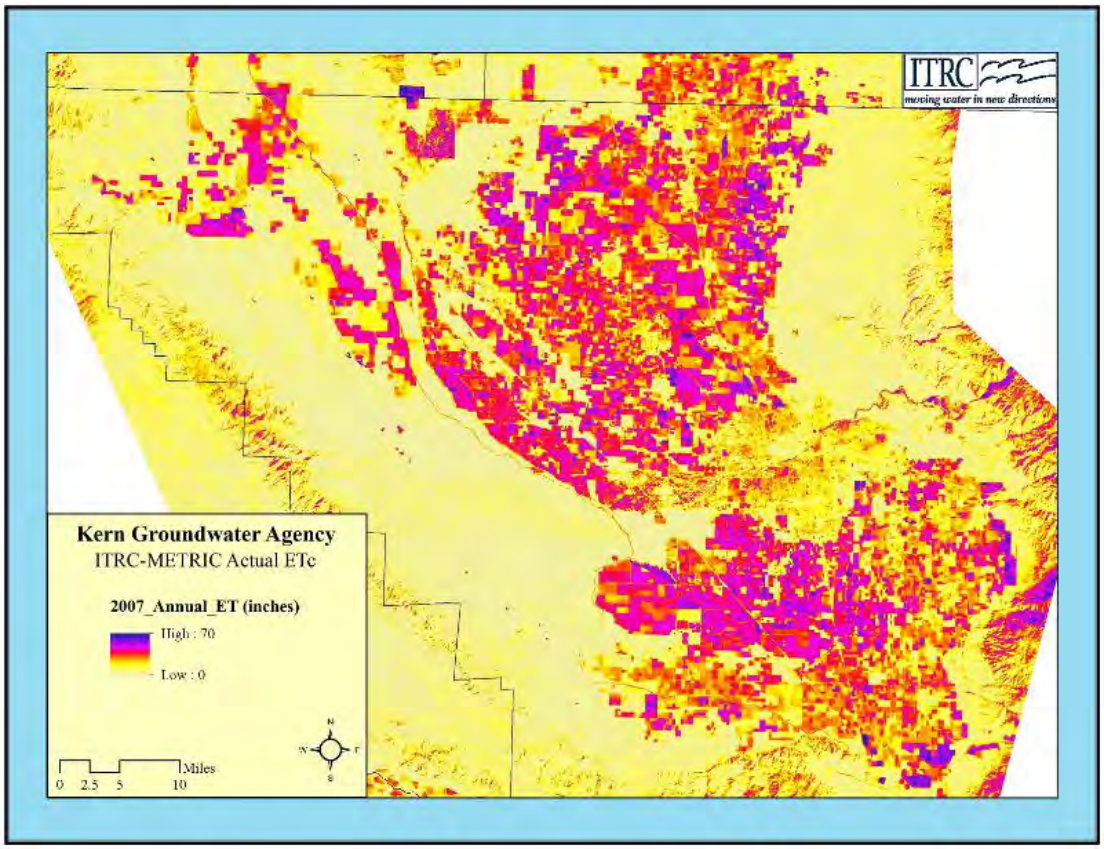

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moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2002_Annual_ET (inches)
High : 70
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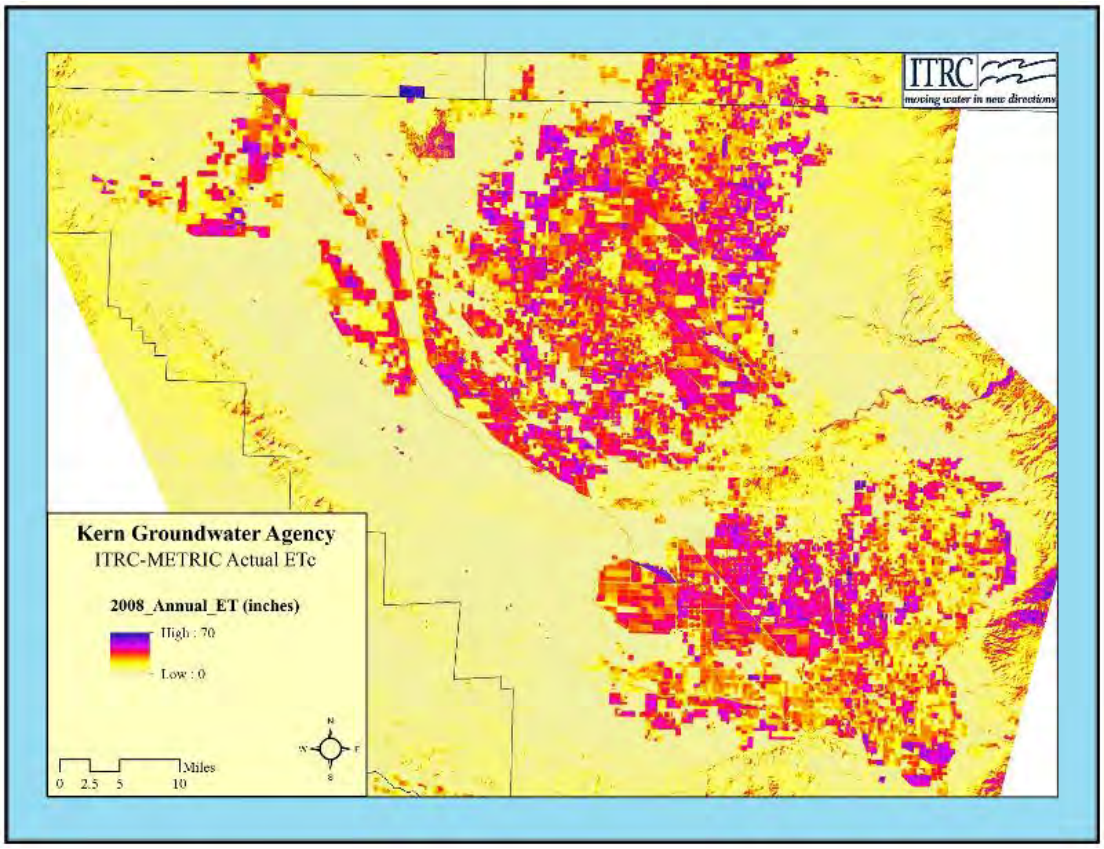

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Kern Groundwater Agency
ITRC-METRIC Actual ETc
2003_Annual_ET (inches)
High : 70
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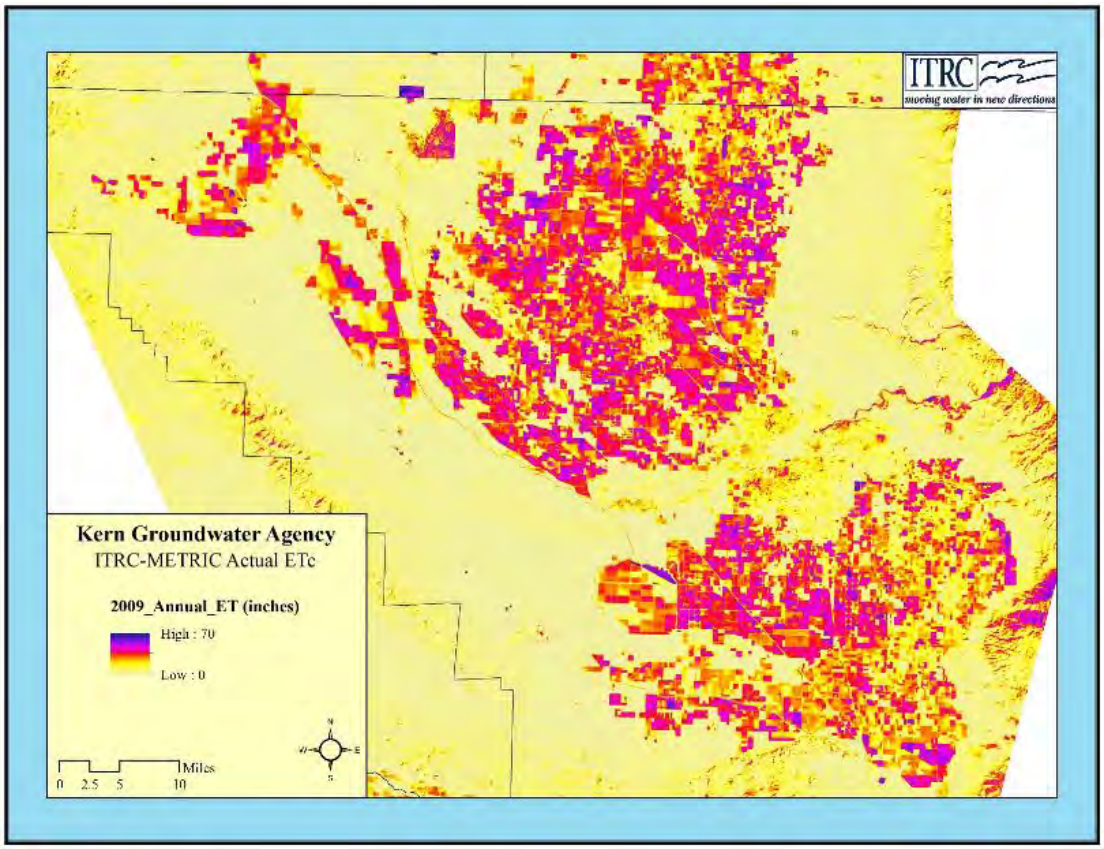

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moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2004_Annual_ET (inches)
High : 70
Low : 0
Miles
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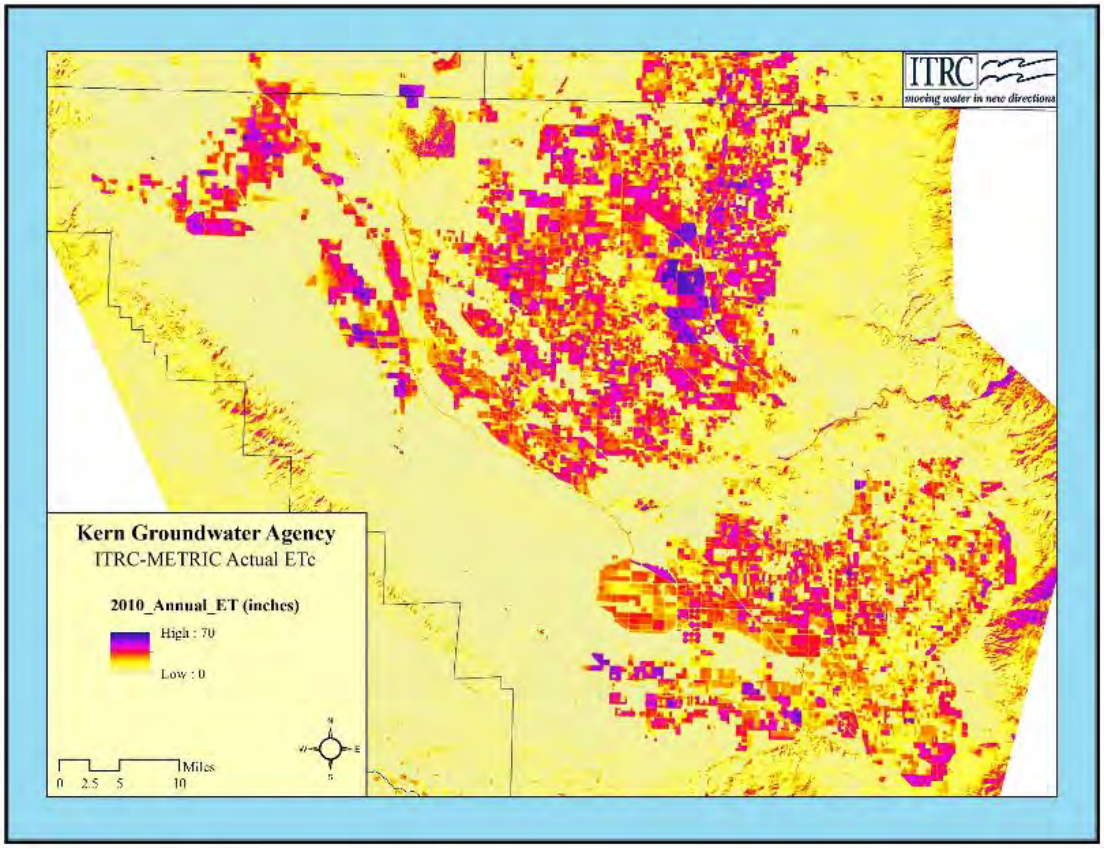

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Kern Groundwater Agency
ITRC-METRIC Actual ETc
2005_Annual_ET (inches)
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Low : 0
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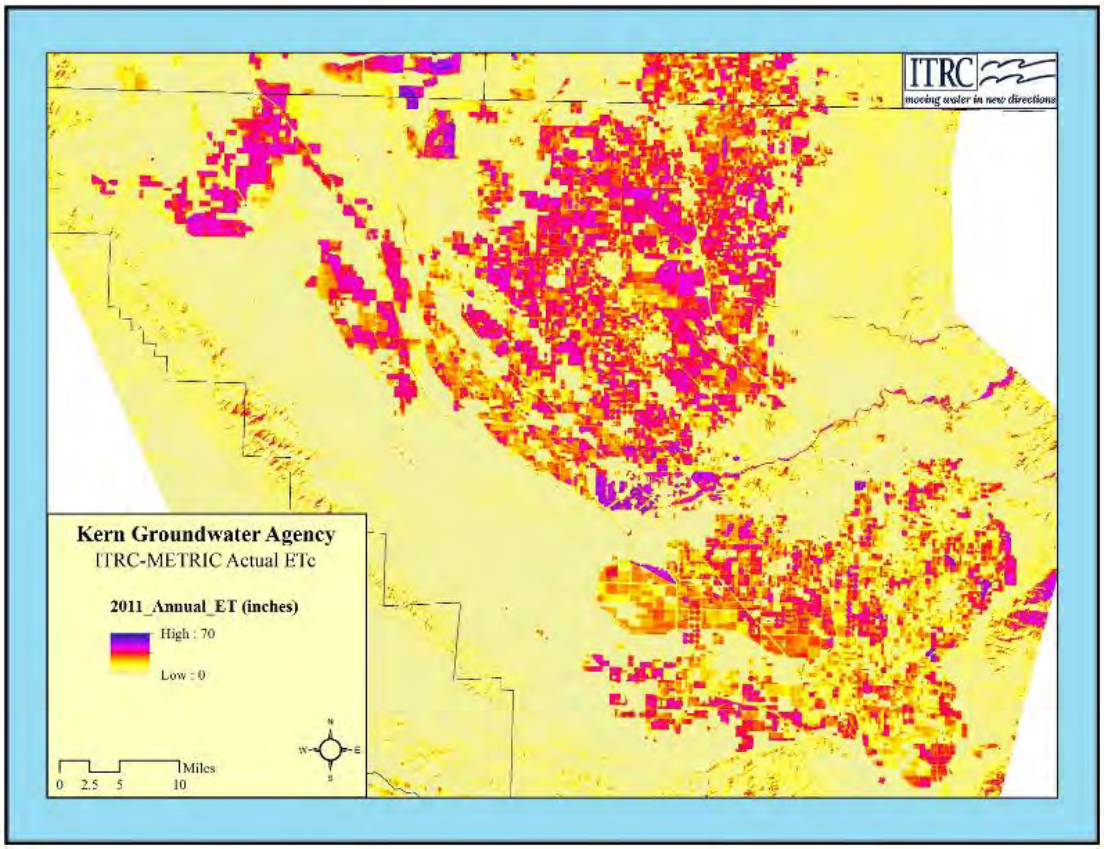

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Kern Groundwater Agency
ITRC-METRIC Actual ETc
2006_Annual_ET (inches)
High : 70
Low : 0
Miles
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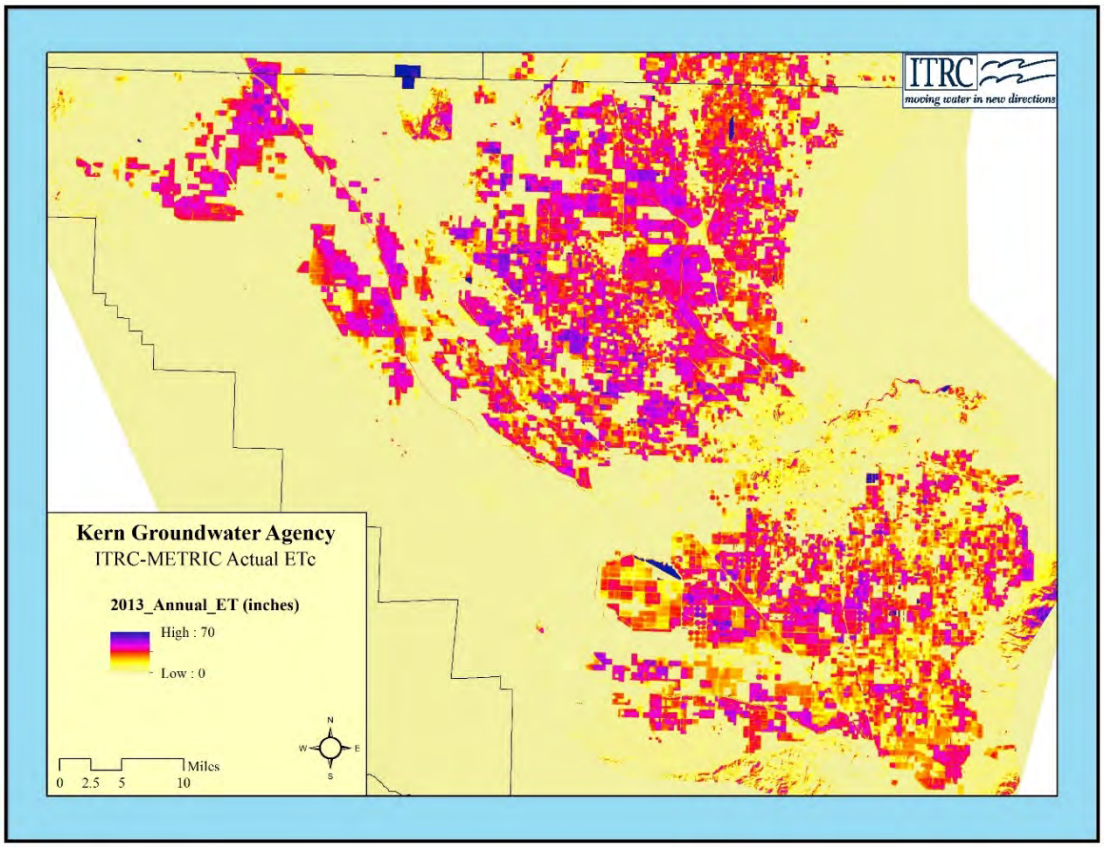

ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2007_Annual_ET (inches)
High : 70
Low : 0
Miles
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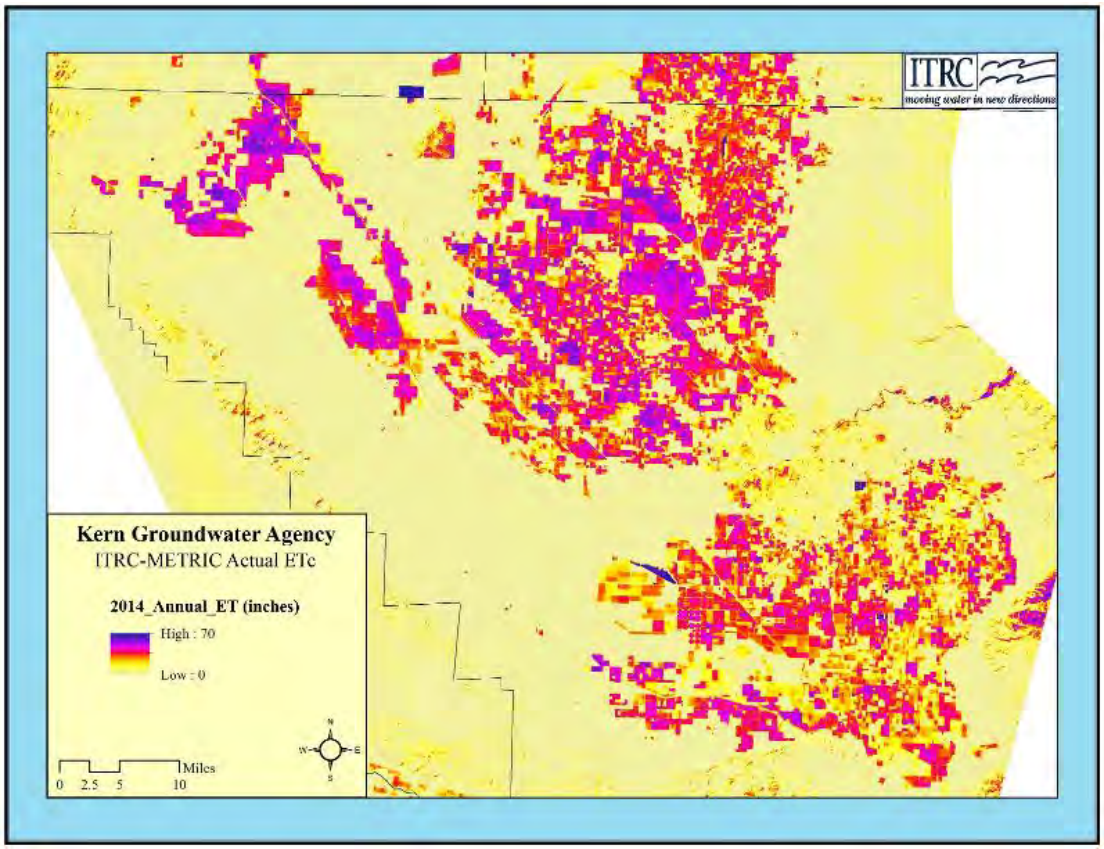

ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2008_Annual_ET (inches)
High : 70
Low : 0
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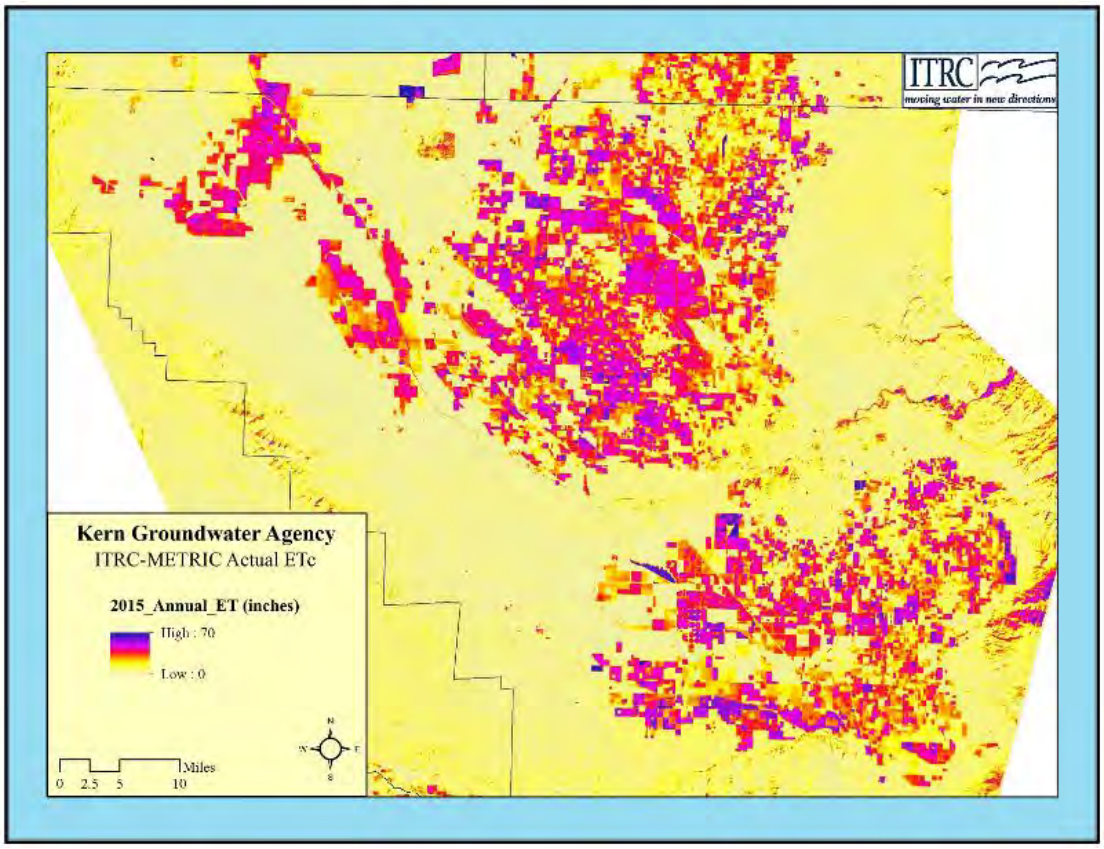

ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2009_Annual_ET (inches)
High : 70
Low : 0
Miles
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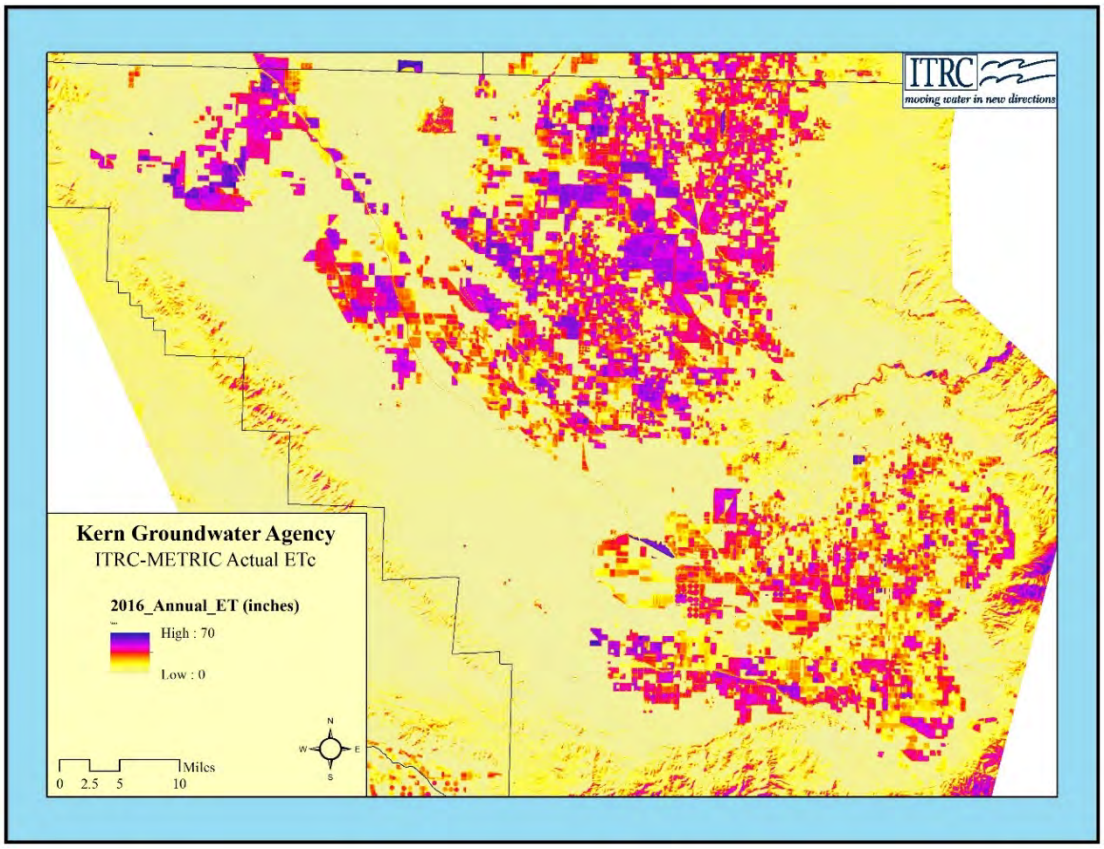

ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2010_Annual_ET (inches)
High : 70
Low : 0
Miles
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ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2011_Annual_ET (inches)
High : 70
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ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2013_Annual_ET (inches)
High : 70
Low : 0
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ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2014_Annual_ET (inches)
High : 70
Low : 0
Miles
0 2.5 5 10


ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2015_Annual_ET (inches)
High : 70
Low : 0
Miles
0 2.5 5 10


ITRC
moving water in new directions
Kern Groundwater Agency
ITRC-METRIC Actual ETc
2016_Annual_ET (inches)
High : 70
Low : 0
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0 2.5 5 10
Miles

Attachment G-4-2

List of Crop Salinity Thresholds Used for Leaching Estimate (JMLord)

Crop Salinity Thresholds for Various Crops

Crop	Salinity Threshold (dS/m)	Crop	Salinity Threshold (dS/m)	Crop	Salinity Threshold (dS/m)
Alfalfa	2	Garlic	1.2	Pecans	1.5
Almonds	1.5	Garlic (Early)	1.2	Peppers	1.5
Almonds, Young	1.5	Grain Hay	6	Peppers (Late)	1.5
Apples	1.5	Grapefruit	1.7	Persimmons	1.5
Apricots	1.6	Grapefruit, Young	1.7	Pistachios	2.5
Apricots, Young	1.6	Grapes	1.5	Pistachios, Young	2.5
Artichokes	1	Irrigated Pasture	4	Pistachios Standard	2.5
Barley	8	Jojoba	1.7	Plums	1.5
Beans (Blackeye)	1.3	Kiwi	1.5	Plums, Young	1.5
Beans (Dry)	1	Lettuce (Fall)	1.3	Potatoes	1.7
Beans (Green)	1	Lettuce (Spring)	1.3	Pumpkins	2.2
Berries	1.5	Melons	2.2	Radishes	1.2
Broccoli (Fall)	2.8	Melons(Early)	2.2	Rice	3
Broccoli (Spring)	1.8	Melons, cucumbers, squash	2.2	Safflower	5.3
Bushberries	1.5	Milo (Sorghum)	6.8	Safflower (Early)	5.3
Bushberries, Young	1.5	Misc. Deciduous	1.7	Safflower (Late)	5.3
Cabbage (Fall)	1.8	Misc. Field	6	Silage (Early)	6.8
Cabbage (Spring)	1.8	Misc. Hay & Grain	6	Silage (Late)	6.8
Cactus	4	Misc. Subtropical Fruits	1.7	Small Grains	6
Cantaloupes	2.2	Misc. Subtropical Fruits,Young	1.7	Sod	4
Carrots (Fall)	1	Misc. Trees	1.7	Spinach	1.2
Carrots (Spring)	1	Misc. Truck/Berry	1.5	Squash	2.5
Cauliflower (Fall)	1.8	Misc. Veg.	1.2	Strawberries	1
Cauliflower (Spring)	1.8	Mixed Hay & Grain	6	Sudan Grass	2.8
Celery	2.2	Native Pasture	6	Sugar Beets	7
Cherries	1.5	Nectarines	1.7	Sunflowers	5.3
Cherries, Young	1.5	Nursery Roses	0	Sweet Corn (Early)	1.7
Christmas	1.5	Oats	6	Sweet Corn (Late)	1.7
Citrus (All)	1.7	Onions & Garlic	1.2	Sweet Potatoes	1.5
Cole Crops (Fall)	2.3	Onions (Early)	1.2	Tomatoes	2.5
Cole Crops (Spring)	2.3	Onions (Late)	1.2	Tomatoes (Late)	2.5
Corn – Fall	1.7	Oranges	1.7	Turf Farm	4
Corn - Spring	1.7	Oranges, Young	1.7	Turnip	1
Cotton	7.7	Parsnips	1	Vineyards	1.5
Eucalyptus	8	Peaches	1.7	Vineyards, Young	1.5
Eggplant	1.1	Peaches & Nectarines	1.7	Walnuts	1.7
Figs	2.7	Peaches &Nectarines, Young	1.7	Watermelon	2.2
Flowers & Nursery	2.5	Pears	1.5	Wheat	6

Appendix G-5

Water Budget Model Calibration

APPENDIX G-5
WATER BUDGET MODEL CALIBRATION

This appendix documents the processes used to calibrate the Wheeler Ridge-Maricopa Water Storage District (WRMWSD) long-term water budget spreadsheet model and reports the final water budget calibration results.

Calibration Process

As described in **Appendix G-1**, the water budget model is a spreadsheet-based tool that quantifies 31 individual hydrologic flow "components" and then uses mass balance principles to link components and calculate a residual change in storage from the groundwater system at a monthly timestep.

Included in the water budget spreadsheet model are various "User Input Parameters" that can be adjusted to improve model performance. Values for these adjustable parameters were initially set to reasonable values based on review of previous relevant studies and local information, where possible (see **Appendices G-1** through **G-4**), and were subsequently adjusted to minimize the difference between model-calculated change in storage and the change in storage derived from rasterized groundwater elevation monitoring data.

Development of Groundwater Storage Change Rasters

The change in groundwater storage was estimated within the District's SGMA jurisdictional area[1] between various time periods using local groundwater elevation data provided by the District[2] along with data downloaded from the DWR's "CASGEM" portal. Local groundwater level data within and proximate to the District boundaries were interpolated using kriging[3] to create continuous groundwater elevation surfaces (rasters) for several "bookend" years of interest within the water budget period[4]. Interpolated water level surfaces were subsequently compared between bookend years to calculate the change in storage, as follows:

$$GW\ Storage\ Change_{t1 \rightarrow t2} = (GWEL_{t2} - GWEL_{t1}) * Specific\ Yield$$

[1] WRMWSD's "SGMA jurisdictional area" includes the portions of the District within the Kern Groundwater Authority Groundwater Sustainability Agency (KGA GSA) area within the Kern Subbasin and all portions of the District within the White Wolf Subbasin.

[2] Local groundwater level data also included records from Arvin-Edison Water Storage District (AEWSD) for wells located in the AEWSD-WRMWSD "overlap area".

[3] Data were interpolated using kriging, a geostatistical method commonly used to interpolate groundwater elevation data, in the software package Surfer. The output of this interpolation process is a raster file with 100-ft by 100-ft pixels, which can be subtracted from or multiplied by other raster files covering the same area, and for which total volume can be calculated.

[4] The interpolated surfaces vary significantly depending on which well data sets are used. Based on significant analysis, we have more confidence in the change in storage estimates generated from surfaces constructed using groundwater elevation data from paired and/or "nearby" wells within a 1-mile buffer radius between each other between datasets (i.e., when groundwater elevation data from each season and year were only selected if the same well or a "nearby" well also had a measurement for the other season and year used for the storage change analysis). Use of the full dataset would allow for greater data density in each bookend year, but, because of historically variable groundwater monitoring patterns, the groundwater storage change estimates are then impacted by changes in monitoring locations.

where *GWEL* is the groundwater elevation and the subscripts *t1* and *t2* refer to the beginning and ending bookend years, respectively. For the purposes of this analysis, a uniform specific yield value of **0.08** was used to calculate groundwater storage change from the rasterized water level data, in line with the representative average specific yield value of the unconfined aquifer (i.e., Layer 1) within the District used in DWR's California Central Valley Groundwater-Surface Water Simulation model, "fine-grid" Beta version (C2VSim-FG)[5].

Using this approach, groundwater storage change was calculated within the District's SGMA jurisdictional area for the following four periods, each of which representing unique timescales and/or climatic conditions within the historical/current water budget time period:

- Fall 1994 – Fall 2015 (entire KGA water budget period)
- Spring 2003 – Spring 2012: (representative long-term "wet" period)
- Spring 2003 – Spring 2015: (representative long-term "dry" period)
- Fall 2014 – Fall 2015: (representative short-term "dry" period)

Water Budget Calibration to Change in Storage Rasters

User input parameters specified within the water budget spreadsheet model (see **Appendix G-1**) were subsequently adjusted within reasonable limits to improve the fit between the water budget-calculated change in storage and the water level-based change in storage estimates for each of the four time periods mentioned above[6].

First, a sensitivity analysis was conducted to determine the most "critical" user input parameters (i.e., those that have the greatest effect on the water budget) for adjustment during model calibration. The most "critical" input parameters identified were those related to subsurface inflows and outflows, streamflow, and contributing precipitation to the District, including:

- **Kern Groundwater to Streamflow Inflow Ratio**, which controls the residual groundwater inflow term into the Kern Management Area (see **Appendix G-3**);
- **Hydraulic conductivity of the aquifer near the White Wolf Fault,** which controls the rate of groundwater flux across the fault (see **Appendix G-3**);
- **Watershed Consumptive Use Fraction and Watershed Precipitation Threshold for Runoff**. These parameters determine the amount of precipitation on contributing watersheds that runs off and becomes streamflow recharge within the District service area (see **Appendix G-2**);
- **Ineffective Precipitation Deep Percolation Coefficient**. This parameter controls how much ineffective precipitation is expected to percolate back into the groundwater subdomain, with the remainder assumed to evaporate from the wetted land surface (see **Appendix G-4**).

[5] C2VSim-FG beta is the latest release of C2VSim from DWR and is currently being used for SGMA planning and GSP development within the Kern Subbasin. Note, this model is currently uncalibrated. C2VSim input files downloaded 13 June 2018 from: https://data.cnra.ca.gov/dataset/c2vsimfg-beta-model

[6] March 1st was chosen as the representative date for which to compare "Spring" water level data to within the water budget model spreadsheet.

The above parameters were used as the primary calibration parameters to achieve an acceptable fit with the storage change estimated using the water level change method. Calibration was conducted by systematically adjusting the values of these key parameters to try to minimize the difference (in terms of root-mean-squared error [RMSE]) between the "observed" (i.e., based on water level records) change in storage for a given time period and the water budget model-calculated change in storage. Other user input parameters are less sensitive and were therefore left at their initial values in the final calibration.

Calibration Results

Table G-5-1 below reports the final calibrated values of each "User Input Parameter" included in the water budget model spreadsheet. Parameters listed in **bold** are those whose values were adjusted during the calibration process; all other parameters were held at their initial values during calibration.

Table G-5-1. Final Calibrated Values of User Input Parameters

User Input Parameter	Calibrated Value
Kern Groundwater to Streamflow Inflow Ratio (-) [1]	**3**
White Wolf Fault Hydraulic Conductivity (ft/day) [1]	**3**
Kern Watershed Consumptive Use Fraction (-)	**0.98**
Kern Watershed Precipitation Threshold for Runoff (in)	**0.5**
White Wolf Watershed Consumptive Use Fraction (-)	**0.95**
White Wolf Watershed Precipitation Threshold for Runoff (in)	**0.5**
Ineffective Precipitation Deep Percolation Coefficient	**0.5**
Irrigation Efficiency Coefficients (-)	Variable, ranging from 0.65 for furrow to 0.85 for micro-drip
Deep Percolation Lag Period (months)	11
Leaching Water EC (uS/cm)	500
Artificial Channel Seepage Rate (ft/day)	0.01
Additional Operational Demands (AFY/irrigated acre)	0.16
M&I Consumptive Use Fraction (-)	1
Natural Channels Seepage Fraction (-)	1

Abbreviations:

AFY = acre-feet per year; EC = electrical conductivity; ft/day = feet per day; in = inches; M&I = municipal and industrial; uS/cm = microSiemens per centimeter;

Notes:

1. The hydraulic conductivity values for the Wolf Fault were adjusted as calibration parameters for the groundwater inflow/outflow components. Other factors affecting this component (i.e., vertical saturated thickness of the inflow/outflow boundary) are assumed to be fixed for the purposes of calibration.

Table G-5-2 and **Figure G-5-1** (attached) present the results of the water budget model calibration in terms of the water budget spreadsheet model-calculated change in storage compared to the change in storage estimated using the water level change method for all four calibration periods mentioned above.

Table G-5-2. Water Budget Calibration Results to Raster-Based Storage Change Estimates

Time Period[1]	Rationale for Selection of Time Period Employed for Model Calibration	Average Annual Groundwater Storage Change Calculated from Water Level Rasters (AFY)[2,3]	Average Annual Groundwater Storage Change Calculated from Water Budget Model (AFY)[2,3]	Difference (Relative to Water Level Raster Method) (AFY)
Fall 1994 – Fall 2015	Entire KGA Water Budget Period	-2,500	-1,300	1,200
Spring 2003 – Spring 2012	A representative long-term "wet" period	8,500	1,900	-6,600
Spring 2003 – Spring 2015	A representative long-term "dry" period	-20,700	-12,100	8,600
Fall 2014 – Fall 2015	A representative short-term "dry" period	-63,700	-76,900	-13,100

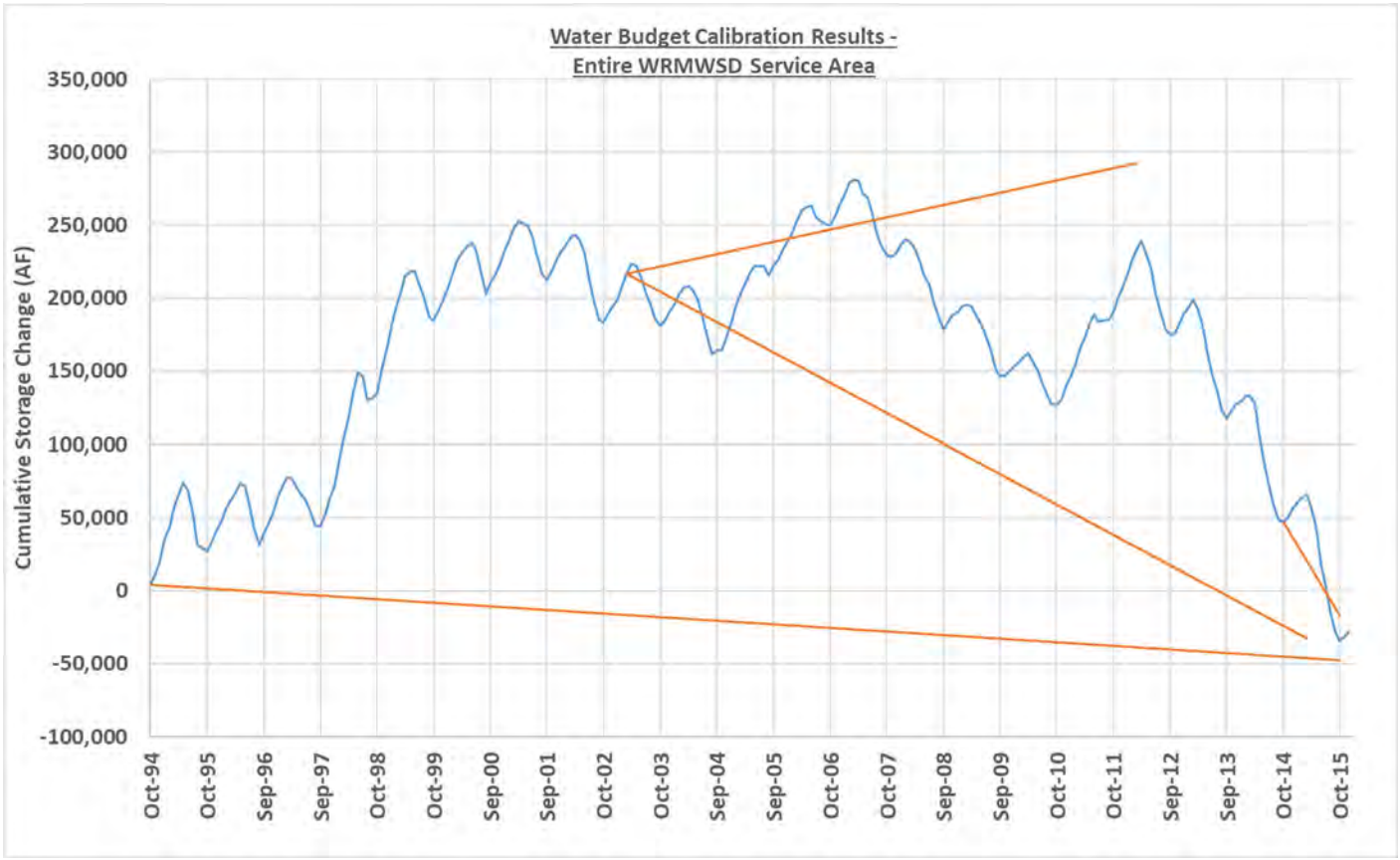
Notes:

1. March 1st was chosen as the representative date for which to compare "Spring" water level data to within the water budget model spreadsheet.
2. Results shown are rounded to the nearest 100 AFY.
3. Storage change estimates are calculated assuming of a uniform storage coefficient of 0.08.

Table G-5-2 and **Figure G-5-1** demonstrate the successful calibration of the water budget spreadsheet model to change in storage estimates deduced from the water level change method. Adjustment of the "critical" user input parameters resulted in a model calibration with a RMSE between "observed" and model-calculated annual change in storage of **8,500 AFY** when considering all four calibration targets, and **6,300 AFY** when only considering the three long-term calibration targets (i.e., Fall 1994 – 2015, Spring 2003 – 2012, and Spring 2003 – 2015). For context, the residuals in calculated vs. "observed" change in storage estimates for the three long-term periods (approximately -13,100 to 8,600 AFY) represent **0.67% to 7.36%** of the total annual average inflows into the District, thus demonstrating the spreadsheet model's accuracy in simulating long-term changes in groundwater storage relative to the total magnitude of the water budget domain.

Figure G-5-2 (attached) demonstrates the water budget-calculated change in water levels relative to a set of long-term hydrographs compiled from the District's local groundwater elevation records. This figure

further demonstrates the general agreement between observed and model-calculated changes in water levels, both in terms of magnitude and directionality, throughout the 22-year water budget timeframe.



Legend

= Raster-Based Estimated Change In Storage (AF)

= Water Budget Spreadsheet Model-Calculated Change In Storage (AF)

Abbreviations

AF = acre-feet

Notes

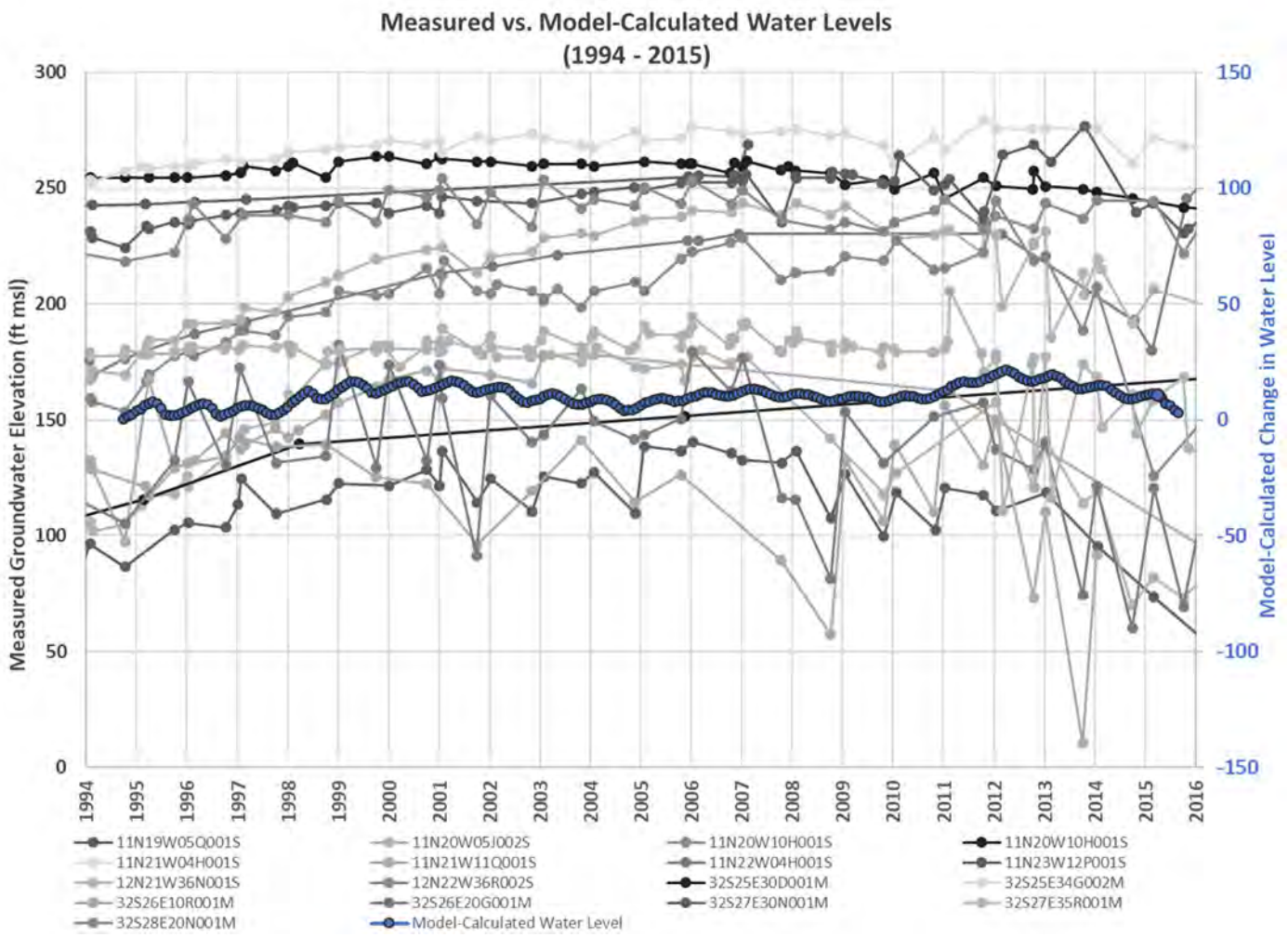
1. Calibration of the water budget spreadsheet model was performed for the District's entire service area, including the portion within the White Wolf Subbasin.

eki environment & water

Comparison of Modeled & Water Level-Based Estimated Change in Storage

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure G-5-1



Legend

= Measured Water Level

= Water Budget Spreadsheet Model-Calculated Change In Water Level (ft)

Abbreviations

ft = feet

ft msl = feet above mean sea level

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Observed vs. Modeled Change in Water Levels, WY 1995 - 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
December 2019
EKI B70103.01

Figure G-5-2

Appendix G-6

Overview of Projected Water Budget Models

APPENDIX G-6
OVERVIEW OF PROJECTED WATER BUDGET MODELS

As described in **Appendix G-1**, results from the historical and current (California Department of Water Resources [DWR] Water Years 1994 – 2015) analytical water budget were subsequently used to inform development of three projected (i.e. future) water budget scenarios for the Wheeler Ridge-Maricopa Water District (WRMWSD) Kern Subbasin Management Area. These scenarios are consistent with the Kern Subbasin-wide projected water budget modelling effort that WRMWSD is participating in as a member of the KGA. A basic description of the projected water budget model assumptions and framework is provided below.

Description of Projected Water Budget Timeline

As described in **Section 9.4.1.** of the WRMWSD Management Area Plan, per 23-CCR § 354.18(e)(2)(A), the projected water budgets must use 50 years of historical precipitation, evapotranspiration, and streamflow information as the basis for evaluating future conditions under baseline and climate-modified scenarios. The process by which a 50-year period of precipitation, evapotranspiration and streamflow information was developed is based on the process adopted by all GSAs within the Basin, as described in the KGA Umbrella GSP and the Coordination Agreement. That process is briefly summarized here.

To develop the required 50 years-worth of hydrologic input information, first an "analog period" was created from the 20 years-worth of historical information (DWR Water Years 1995-2014) by combining the years in a specific way that, on average, maintained the long-term average hydrologic conditions. This approach, which was used for both the spreadsheet water budget model approach and the basin-wide C2VSim-FG modeling approach, allowed for the creation of a complete 50-year period to inform the projected water budget analysis, even when certain component datasets were not available for that length of time. The sequence of actual years that were combined to create the 50-year analog period is as follows:

Analog Years 1-12:	Based on actual years 2003-2014
Analog Years 13-32:	Based on actual years 1995-2014
Analog Years: 33-50:	Based on actual years 1995-2012

The above mapping of actual years to analog years within the required 50-year projected water budget period applies to precipitation and ET datasets. It also applies to datasets of imported surface water with some additional modifications as described in the following section.

Description of Projected Water Budget Scenarios

As described in **Section 9.4.2.** of the WRMWSD Management Area Plan, using the 50-year analog period, three projected water budget scenarios were developed for this analysis:

- **Baseline Scenario –** uses "the most recent water supply information as the baseline condition for estimating future water supply", per 23-CCR § 354.18(e)(2)(C);
- **2030 Climate Change Scenario –** uses 2030 climate change factors developed by DWR and the Friant Water Authority to estimate future water supplies, changes to precipitation and evapotranspiration; and

- **2070 Climate Change Scenario –** uses 2070 climate change factors developed by DWR and the Friant Water Authority to estimate future water supplies, changes to precipitation and evapotranspiration.

Development of the three scenarios was done consistent with the agreed-upon process being used basin-wide. Further details of the scenario development are contained within **Section 9.4.2.** of the WRMWSD Management Area Plan, in the KGA Umbrella GSP, and in the Coordination Agreement.

Description of Projected Water Budget Model Framework

A projected water budget was developed for each of the three scenarios described above under the same framework and methodologies used to develop the historical and current water budget model. Given the scope of this effort was limited to completion of water budget requirements for the WRMWSD Management Area Plan, projected scenarios were only developed for the portion of WRMWSD contained within the Kern Subbasin.

Building the 50-year Analog Period

As described above, a 50-year "analog" period was first created using partial repeats of the 20-year historical WRMWSD water budget model (DWR Water Years 1995 – 2014) for the development of projected water budget scenarios. This was accomplished in the "master" projected water budget tabs of the spreadsheet model (see **Appendix G-1**) by creating a 50-year monthly sequence (i.e., 600 months) where, for any given month, each water budget component within the spreadsheet model directly referenced the analogous "analog" month of the historical Kern budget.

Applying Change Factors

After the 50-year "analog period" was replicated in the projected water budget "master" tabs, monthly change factors were applied to selected water budget components to incorporate projected changes to surface water supply availability, as well as precipitation and evapotranspiration intensity under each of the (3) projected water budget scenarios. These monthly change factors were provided directly from the KGA and are being used for the Basin-wide C2VSim-FG projected water budget effort[1]. In summary, the following change factors were applied to the WRMWSD projected water budget model:

- Changes to State Water Project (SWP) imports, based on data from DWR's CalSim water resources planning model and the 2008/2009 Long-Term Operations Criteria and Plan (OCAP) Biological Opinion[2];
- Changes to precipitation and evapotranspiration, based on DWR's "gridded change factors for precipitation and reference evapotranspiration" for 2030 and 2070 climate change projections[3].

[1] For more information see **Section 9.4.2.** of the WRMWSD Management Area Plan, the KGA Umbrella GSP, and in the Coordination Agreement

[2] CalSim deliveries data from: https://data.cnra.ca.gov/dataset/sgma-climate-change-resources; SWP operational data from: https://water.ca.gov/Programs/State-Water-Project/Operations-and-Maintenance/Monthly-and-Annual-Operations-Reports; new operations regulations pursuant to the 2008-2009 OCAP BOs used as basis for calculation of SWP impacts by KGA's consultant.

[3] https://data.cnra.ca.gov/dataset/sgma-climate-change-resources/resource/f86f75e8-0de6-4232-968d-83521116496e

Change factors were provided by KGA as a monthly multiplier to each analog month within the projected water budget period. These change factors were applied to their respective water budget components within the WRMWSD projected water budget models to evaluate the projected impacts to groundwater storage underlying the District given the estimated changes to surface water supply availability and climate under each projected scenario.

Modeling Projects & Management Actions

After developing the projected water budget scenarios through the methodologies described above, the approximate groundwater storage deficits resulting from each projected scenario (see **Table WB-6**) were used to inform the development of Projects and Management Actions (P&MA) for the WRMWSD Kern Subbasin Management Area. These proposed P&MAs were subsequently simulated under the 2030 and 2070 projected water budgets to assess how proposed P&MA implementation would address the groundwater storage change deficits identified from the model (see **Table WB-7**).

P&MAs were incorporated in the model as either (1) increases in surface water deliveries to the irrigated portion of the District, to simulate supply augmentation benefits, or (2) reductions in evapotranspiration from irrigated lands, to simulate demand reduction benefits. Both surface water supply augmentation and demand reduction P&MAs were applied uniformly for each year of the projected water budget model scenarios, so as to simulate the projected impacts of "full P&MA implementation" under each scenario. For each year, additional surface water supplies were delivered on a monthly basis according to WRMWSD's average historical monthly delivery patterns, whereas reductions in evapotranspiration were performed in line with the average historical breakdown of monthly ET within the irrigated portion of the District.

Appendix H

WRMWSD Long-Term Monitoring Access Agreement

MONITORING WELL ACCESS AGREEMENT

This Monitoring Well Access Agreement ("Agreement") is made and entered into by and between the Wheeler Ridge-Maricopa Water Storage District (hereafter "District") and _____ (hereafter "Landowner"), both of whom shall be referred to individually as a "Party" to this Agreement and collectively as the "Parties" to this Agreement.

RECITALS

WHEREAS, the District is a member of the Kern Groundwater Authority ("KGA") which has adopted or will adopt a Groundwater Sustainability Plan ("GSP") to comply with the Sustainable Groundwater Management Act ("SGMA"); and

WHEREAS, the District has developed and is responsible for implementing a chapter of the KGA GSP; and

WHEREAS, SGMA requires the long-term monitoring of static groundwater levels and water quality; and

WHEREAS, to comply with this requirement, the District may need access rights from Landowners within its service area to monitor groundwater elevations and water quality; and

WHEREAS, Landowner's Land (as described and depicted in Exhibit A) contains one or more groundwater wells ("Monitoring Well(s)") in the District GSP chapter area for which the District is required to monitor for groundwater elevation and water quality monitoring activities; and

WHEREAS, Landowner has agreed to grant the District limited access onto Landowner's Land, subject to the terms and conditions as set forth in this Agreement.

NOW, THEREFORE, the Parties have entered into this Agreement to allow the District to access to Landowner's Land under the following terms and conditions:

TERMS AND CONDITIONS

1. Incorporation of Recitals. The foregoing recitals are incorporated herein as terms and conditions of this Agreement.

2. Right of Entry. Landowner grants to the District and its employees, agents, consultants, and contractors a non-exclusive year-round license to enter onto Landowner's Land (as described and depicted in Exhibit A) to obtain groundwater elevation and water quality data from Landowner's Monitoring Well(s). Unless otherwise agreed to by the Parties in a written amendment to this Agreement, the Parties agree that the District's access to Landowner's Land shall be limited to wells described in Exhibit A's "Monitoring Well Locations" and in compliance with any conditions listed under "Access Instructions."

3. Access and Control. Except as otherwise provided in this Agreement, Landowner retains the exclusive right of access to and control over the Landowner's Land. Nothing contained in

this Agreement shall be construed as affording the public a right of access to any portion of the Landowner's Land or precluding Landowner's right to grant access to third parties across the Landowner's Land, provided that such access is not inconsistent with this Agreement.

4. Duration of Right. The Parties agree that this Agreement shall remain in effect until either of the following occurs: (a) Termination of the Agreement by either Party, or (b) Change in Ownership of Landowner's Land.

a. Termination by a Party. The Parties agree that this Agreement may be terminated at any time, with or without cause, by either Party upon sixty (60) days written notice to the other Party.

b. Landowner's Land: Change in Ownership. The Parties agree that this agreement shall terminate upon any change in ownership of Landowner's Land. Thereafter, the District acknowledges that it will need to enter into a new access agreement with the new owner(s) of Landowner's Land.

5. No Easement. The Parties agree that this Agreement does not grant the District a possessory right, easement, or other land interest with respect to Landowner's Land.

6. Costs. The Parties agree that all groundwater elevation and water quality monitoring performed by the District under this Agreement shall be funded by the District. The Landowner shall continue to be responsible for County well inspection fees. District agrees to provide a small concrete pad, a welded water-tight cover, and a locking cap at the Monitoring Well site if the wellhead is not already provided with a water-tight cover or pump head. The District also agrees to repair any defects in the integrity of the well collar, cap, lock, and pad above the ground surface, excepting damage caused by the sole negligence or intentional misconduct of the landowner, so long as this Agreement is in effect.

7. No Storage. The right of entry does not include permission to store soil, groundwater, or measurement apparatus on the Landowner's Land.District shall remove its materials and tools from the Landowner's Land at the end of each working day.

8. Maintenance of Landowner's Land. The Parties acknowledge that this Agreement grants the District a non-exclusive year-round license to access Landowner's Land for the limited purpose of obtaining groundwater elevation and water quality data from Landowner's Monitoring Well(s). Accordingly, except as provided in section 5 of this Agreement below ("Damage/Restoration"), the Parties agree that the District (including its employees, agents, consultants, and contractors) is under no obligation to maintain or otherwise repair the Landowner's Land.

9. Damage/Restoration. The District (including its employees, agents, consultants, and contractors) shall take all reasonable precautions to avoid damaging Landowner's Land. If any

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damage is caused to Landowner's Land by the District in the course of performance of this Agreement, the District shall notify the Landowner immediately. In addition, the District will, at its sole cost and expense and with the Landowner's consent, take all action reasonably necessary to repair the damage and restore Landowner's Land to the condition that existed immediately prior to the damage caused by the District. It is understood and agreed that the District shall not be responsible for maintenance of the Monitoring Well(s) below the ground surface. The Parties agree that the District shall not be liable in the event that groundwater contamination or unauthorized waste disposal is eventually attributed to the well(s), or in the event that destruction of the well(s) (e.g., by grouting) is ultimately required.

10. Schedule or Notice of Access. The District may develop a schedule of dates/times it will access Landowner's Land for the purposes of well monitoring. Upon reasonable notice, the Landowner shall endeavor to refrain from pumping from the Monitoring Well(s) for at least 48 hours prior to the scheduled access date. If the District does not provide a schedule, it shall undertake reasonable efforts to notify the Landowner at least twenty-four (24) hours in advance of accessing Landowner's Land pursuant the access rights granted under this Agreement.

11. Indemnity. The District agrees to defend, indemnify, and hold harmless Landowner for any costs, claims, damages, losses or other liabilities arising out of the District's (including any employees, agents, consultants, and contractors) actions on Landowner's Land under this Agreement, with the exception that the District shall not be responsible for defending, indemnifying, or holding harmless Landowner with regard to costs, claims, damages, losses, or other liabilities arising out of the sole negligence or intentional misconduct of Landowner.

12. Insurance. Prior to entering onto Landowner's Land, District shall provide to Landowner a certificate that the District or District's consultant a certificate evidencing general liability insurance in the amount of at least $1,000,000 Dollars aggregate limit.

13. Written Notices. Written notices between the Parties shall be sent via U.S. mail to the addresses listed below:

[District Name]	[Landowner's Name]
[Address]	[Address]
[City,] CA [zip code]	[City,] CA [zip code]

14. Entire Agreement. This Agreement contains the entire understanding of the Parties and supersedes all prior agreements and understandings among the Parties related to the subject matter of this Agreement.

15. Amendment. Amendments to this Agreement shall become effective upon execution of a written amendment signed by both Parties.

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16. Severability. If any provision of this Agreement is held to be unenforceable for any reason, it shall be adjusted, rather than voided, if possible, to achieve the intent of the Parties, and the balance of the Agreement shall remain in full force and effect.

17. Governing Law. This Agreement shall be interpreted and enforced pursuant to the laws of the state of California.

18. Effective Date. This Agreement shall become effective as of the latest date of execution below.

19. Confidentiality. By executing this Agreement, the Landowner authorizes the District to release the location and construction details of Landowner's Monitoring Well(s) together with any and all groundwater elevation and water quality data obtained pursuant to this Agreement to the Kern Groundwater Authority, the State of California, and their agents. It is understood and agreed that data obtained from Landowner's Monitoring Well(s) pursuant to this Agreement may be published from time to time in the District's GSP chapter, in GSP updates, or in other forms, written and electronic, that will be available to the general public.

[District]	[Landowner]
By_____	By_____
[Name, title]	[Name, title]
Date: _____	Date: _____

EXHIBIT A

Parcel (Referenced in the attached Agreement as "Landowner's Land")
Landowner Name, Contact Name APN(s): XXX-XXX-XX

Monitoring Well Locations

[Insert directions to where (on Landowner's Land) the monitoring well(s) subject to this Agreement are located.]

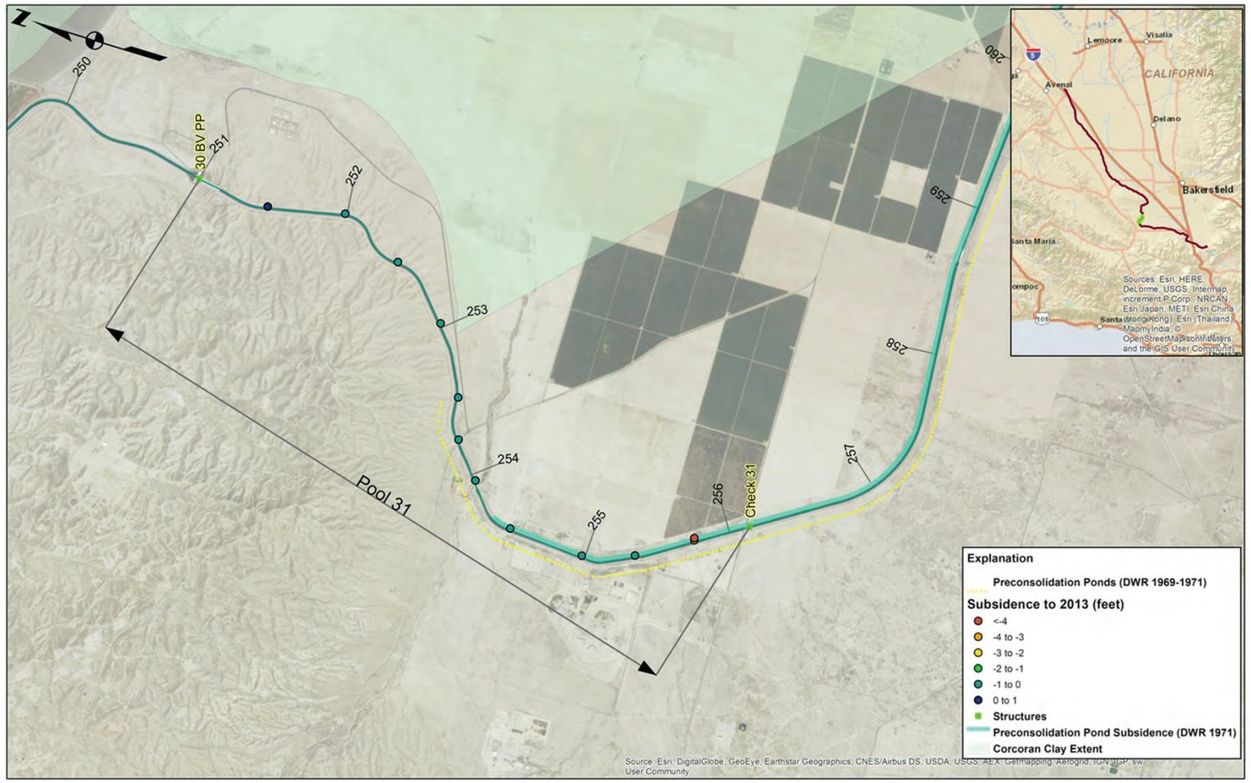
Access Instructions

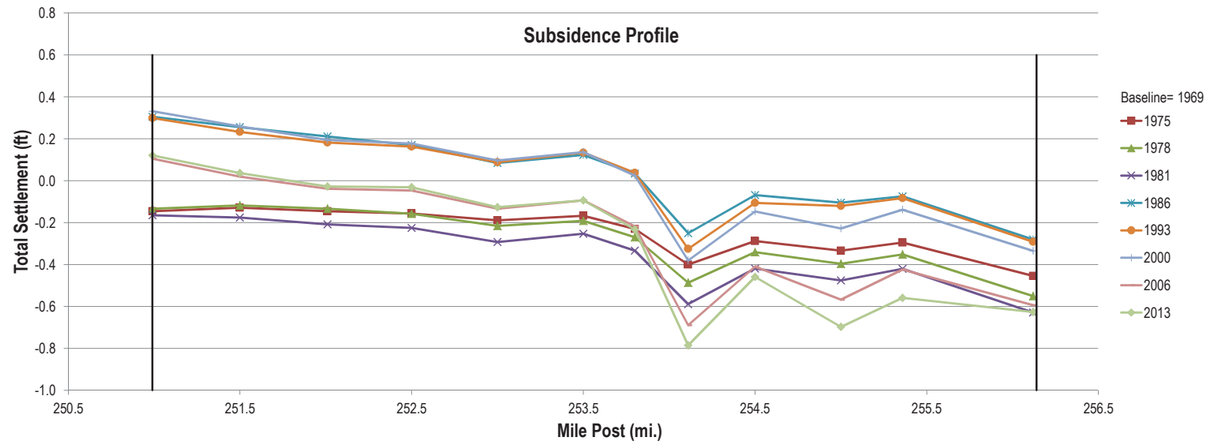
[Insert Landowner's Land access instructions here. Examples include parking restrictions, gate codes, animals to be aware of etc.]

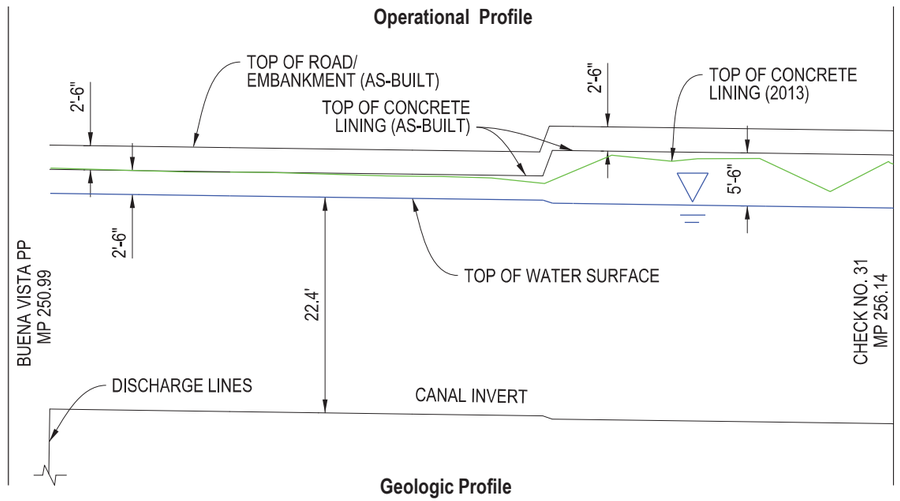
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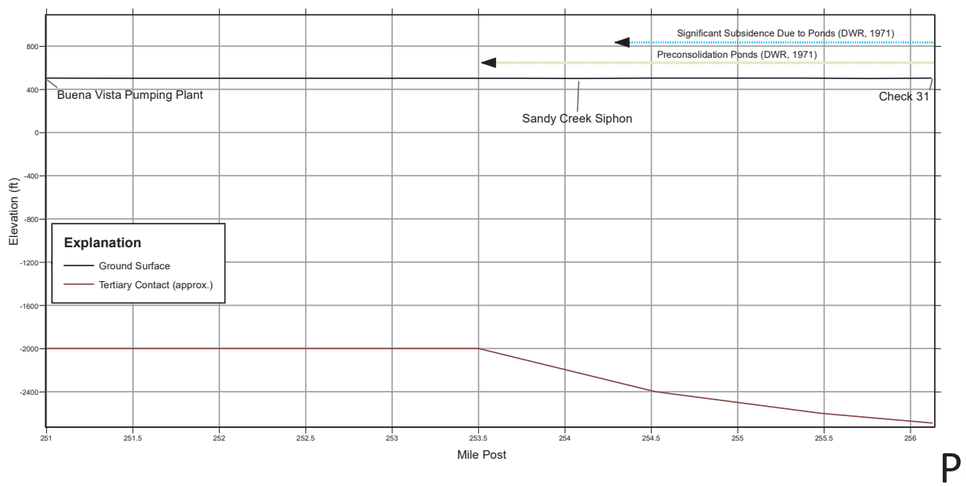
Appendix I

DWR California Aqueduct Subsidence Study (June 2017), Plates 20 – 24
DWR California Aqueduct Benchmark Survey Data, 2016-2019









STRUCTURE	SIDE OF EMBANKMENT	MP
BUENA VISTA PUMPING PLANT		250.99
PIPELINE CROSSING (4)		251.16
CULVERT CROSSING		251.35
PHONE LINE CROSSING		251.43
CULVERT CROSSING		251.54
SUMP PUMP	R	251.66
CULVERT CROSSING		251.73
CULVERT CROSSING		251.84
PIPELINE CROSSING		252.01
CULVERT CROSSING		252.03
CULVERT CROSSING		252.36
SUMP PUMP	R	252.63
CULVERT CROSSING		252.95
PIPELINE CROSSING		253.19
CULVERT CROSSING		253.26
CULVERT CROSSING		253.49

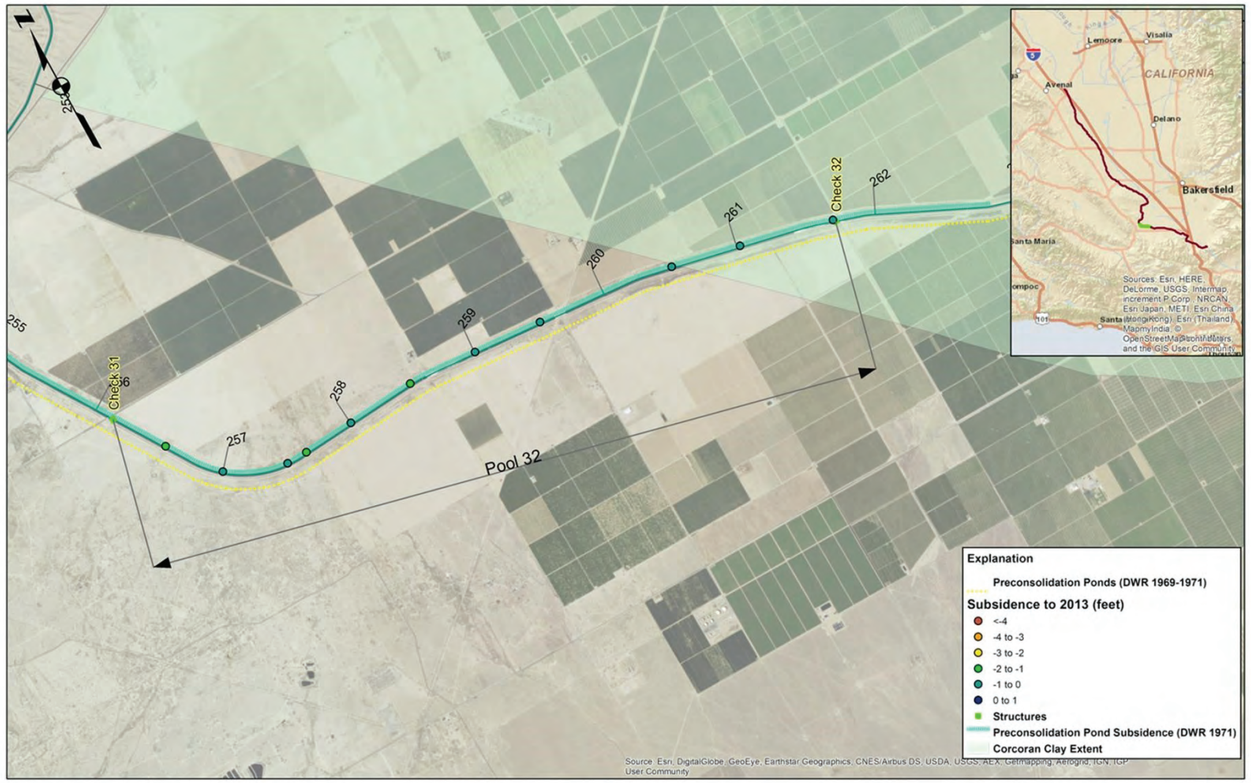
STRUCTURE	SIDE OF EMBANKMENT	MP
SUMP PUMP	R	253.6
PIPELINE CROSSING		253.8
GARDNER FIELD ROAD BRIDGE		253.8
BRIDGE		254.11
SANDY CREEK SIPHON		254.11
PIPELINE CROSSING		254.12
TURNOUT	R	254.47
POWERLINE CROSSING		254.83
PIPELINE CROSSING		254.85
PHONE LINE CROSSING		255.34
PIPELINE CROSSING		255.36
POWERLINE CROSSING		255.55
OVERCHUTE CROSSING		255.78
TURNOUT	L	256.11
CADET ROAD BRIDGE		256.13
STILLING WELL	L	256.14
CHECK NUMBER 31		256.14

PLATE 20

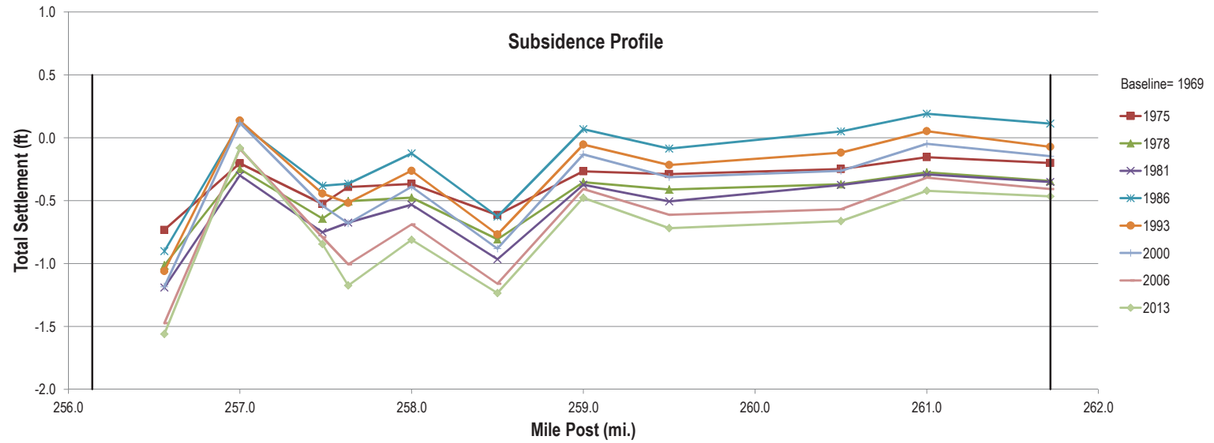
DEPARTMENT OF WATER RESOURCES
STATE WATER PROJECT
CALIFORNIA AQUEDUCT SUBSIDENCE STUDY

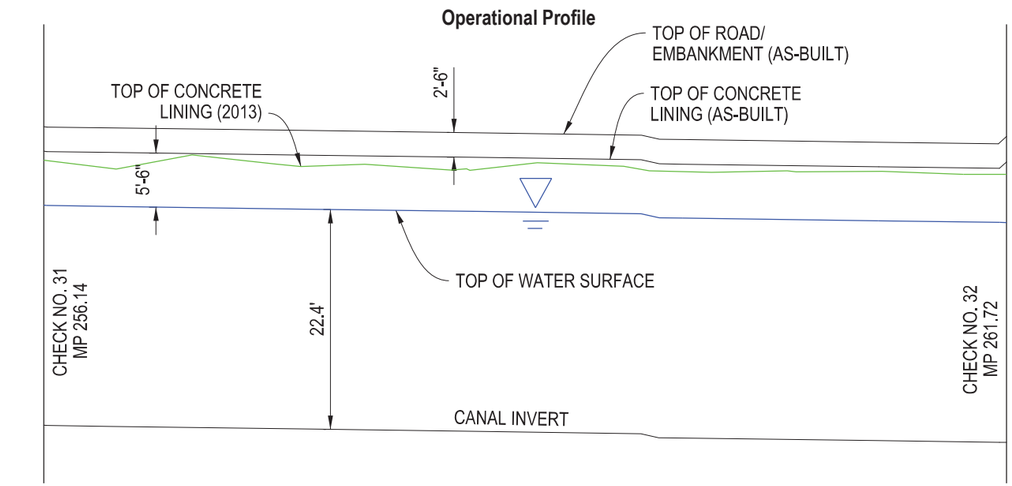
SUBSIDENCE, OPERATION, & GEOLOGIC PROFILES

POOL 31: MP 250.99 – 256.14



STRUCTURE	SIDE OF EMBANKMENT	MP
CHECK NUMBER 31		256.14
STILLING WELL	L	256.21
POWERLINE CROSSING		256.36
OVERCHUTE CROSSING		256.56
OVERCHUTE CROSSING		257.48
PIPELINE CROSSING		257.63
OVERCHUTE CROSSING		258.59
TURNOUT	L	258.61
PHONE LINE CROSSING		259.45
PIPELINE CROSSING		259.64
BRIDGE (2)		259.65
SUNSET RAIL ROAD SIPHON		259.65
PIPELINE CROSSING (2)		260.01
POWERLINE CROSSING		260.11
TURNOUT	L	260.44
PIPELINE CROSSING (3)		260.45
POWERLINE CROSSING (2)		260.66
PIPELINE CROSSING		261.47
STILLING WELL	L	261.68
PIPELINE CROSSING		261.72
SANTIAGO CREEK SIPHON		261.72
BRIDGE (2)		261.72
CHECK NUMBER 32		261.72





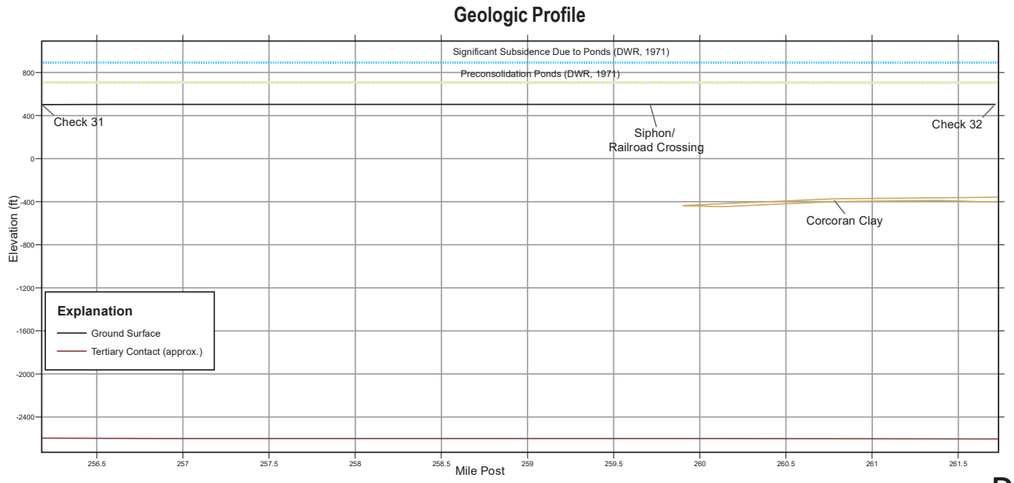
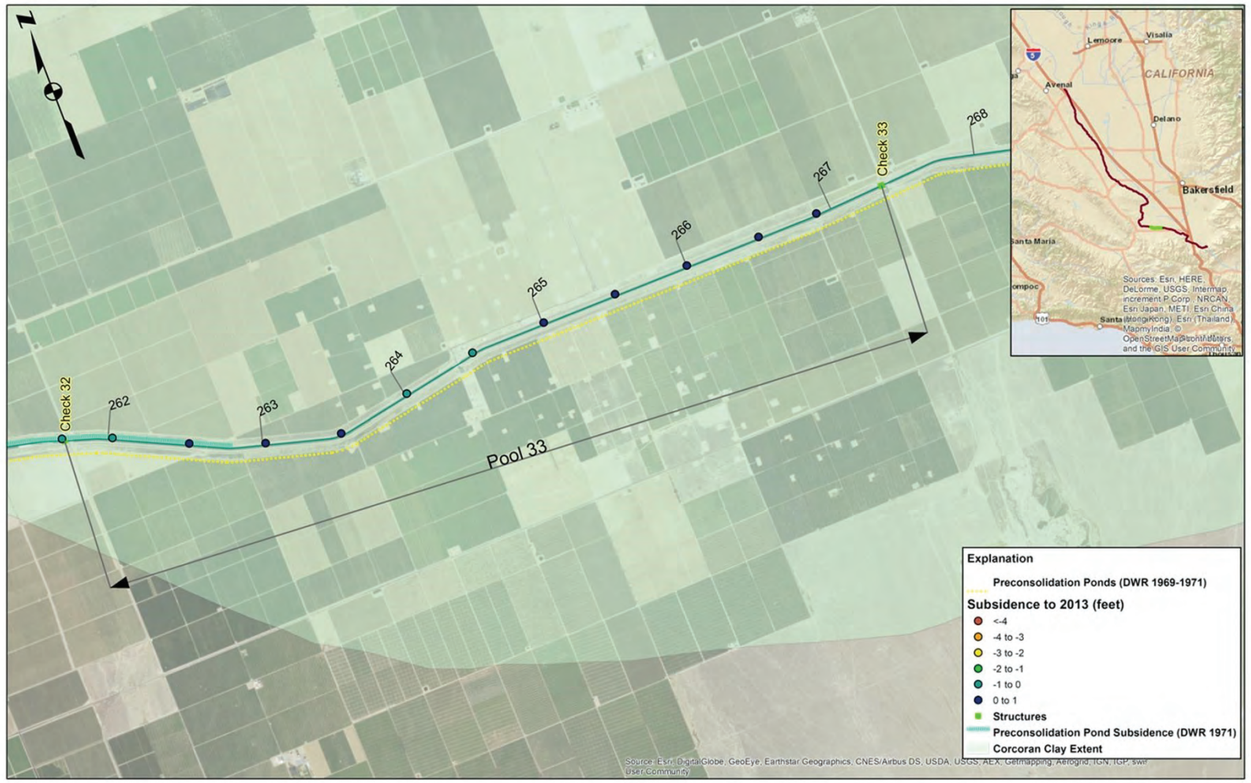


PLATE 21

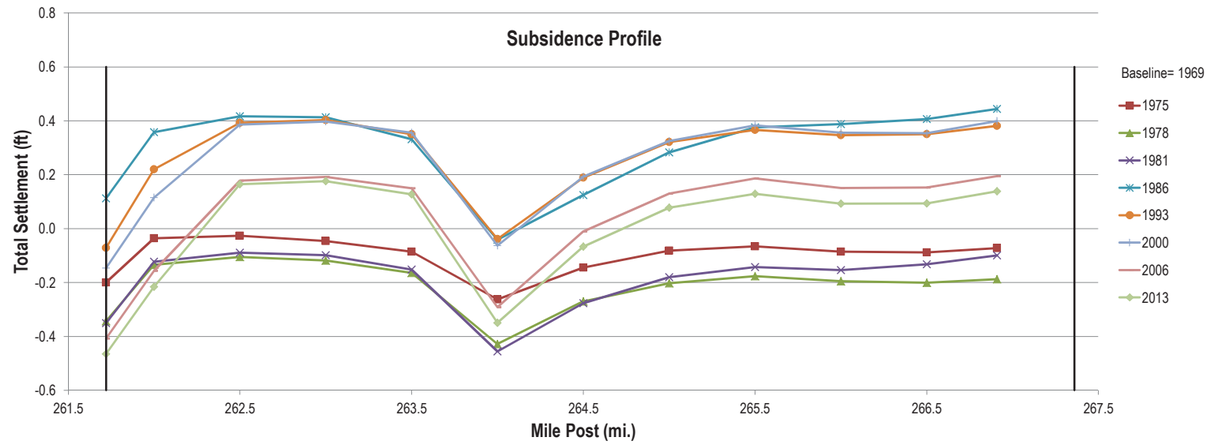
DEPARTMENT OF WATER RESOURCES
STATE WATER PROJECT
CALIFORNIA AQUEDUCT SUBSIDENCE STUDY

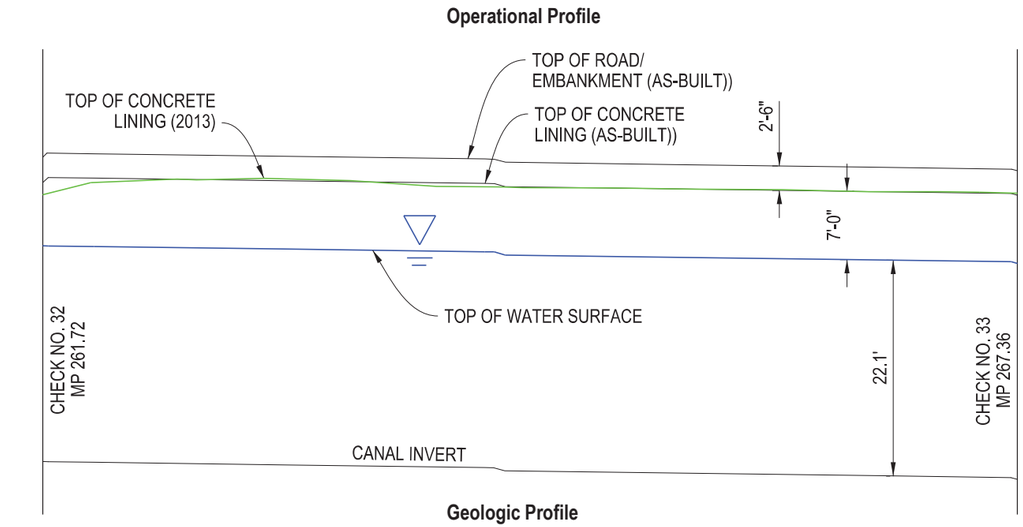
SUBSIDENCE, OPERATION, & GEOLOGIC PROFILES

POOL 32: MP 256.14 – 261.72



STRUCTURE	SIDE OF EMBANKMENT	MP
CHECK NUMBER 32		261.72
POWERLINE CROSSING		261.74
STILLING WELL	L	261.8
PHONE LINE CROSSING		262.5
PIPELINE CROSSING		262.61
BRIDGE		262.61
POWERLINE CROSSING		263.6
BRIDGE		264.37
POWERLINE CROSSING		264.37
LOS LOBOS SIPHON/BRIDGE		264.37
PIPELINE CROSSING		264.38
TURNOUT	L	264.42
POWERLINE CROSSING		264.9
POWERLINE CROSSING		265.12
TURNOUT	R	266.91
PIPELINE CROSSING		267.14
POWERLINE CROSSING		267.14
SAN EMIGDIO CREEK SIPHON		267.36
STILLING WELL	L	267.36
CHECK NUMBER 33		267.36





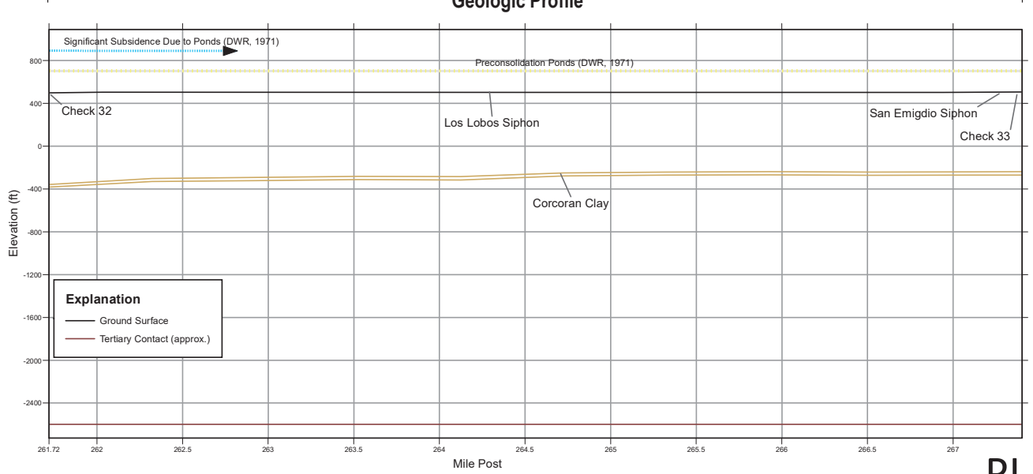
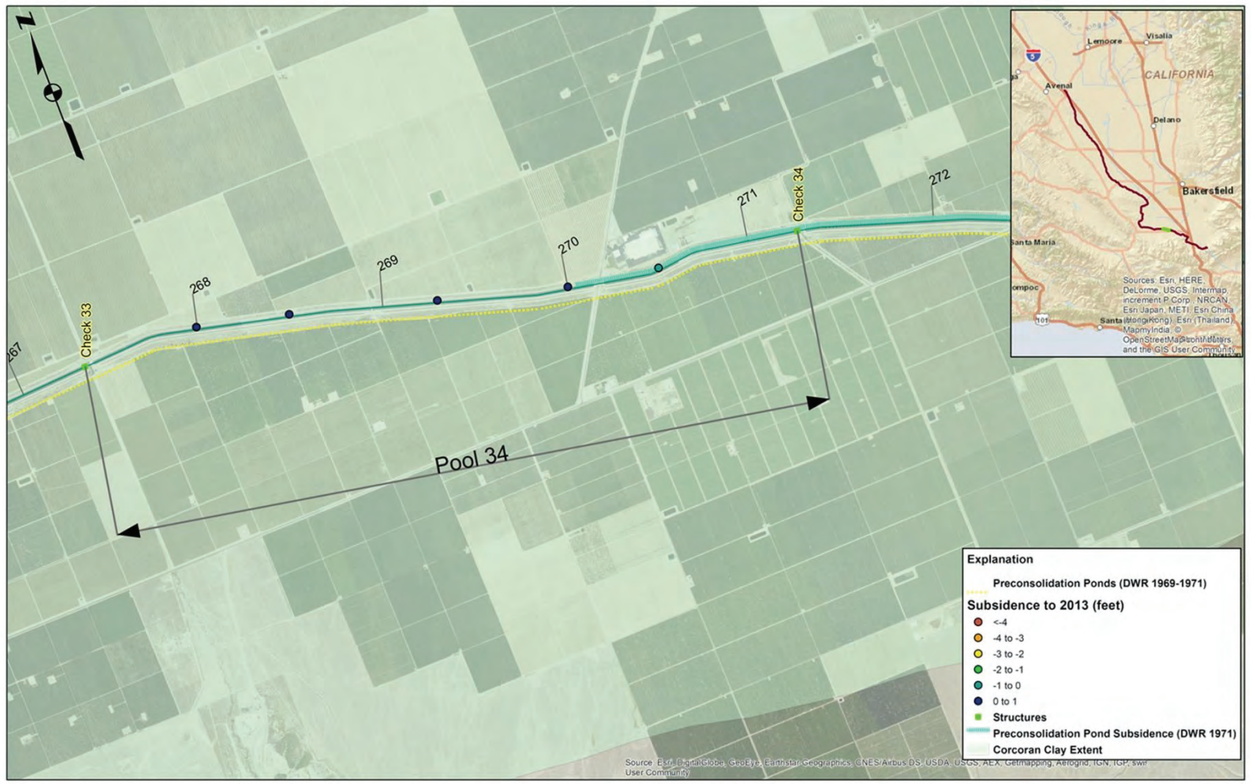


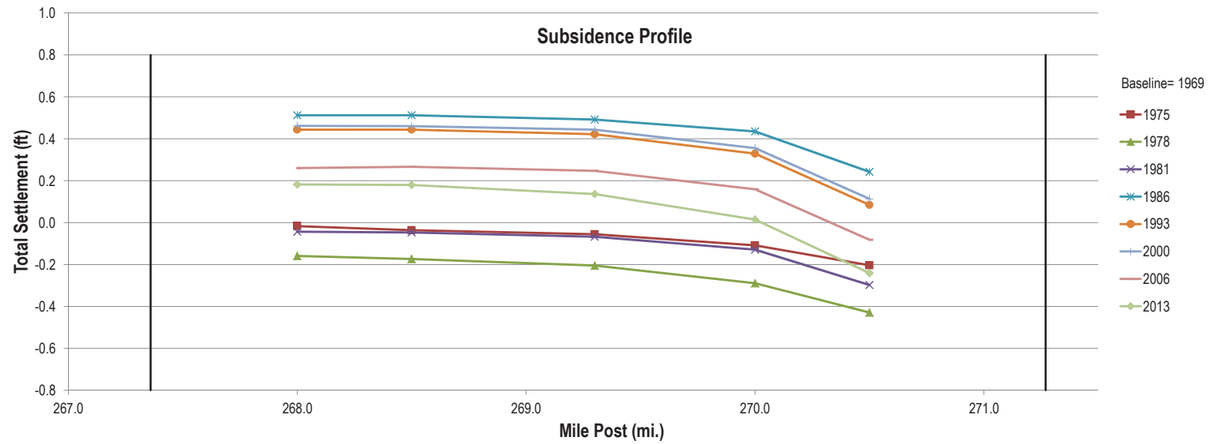
PLATE 22

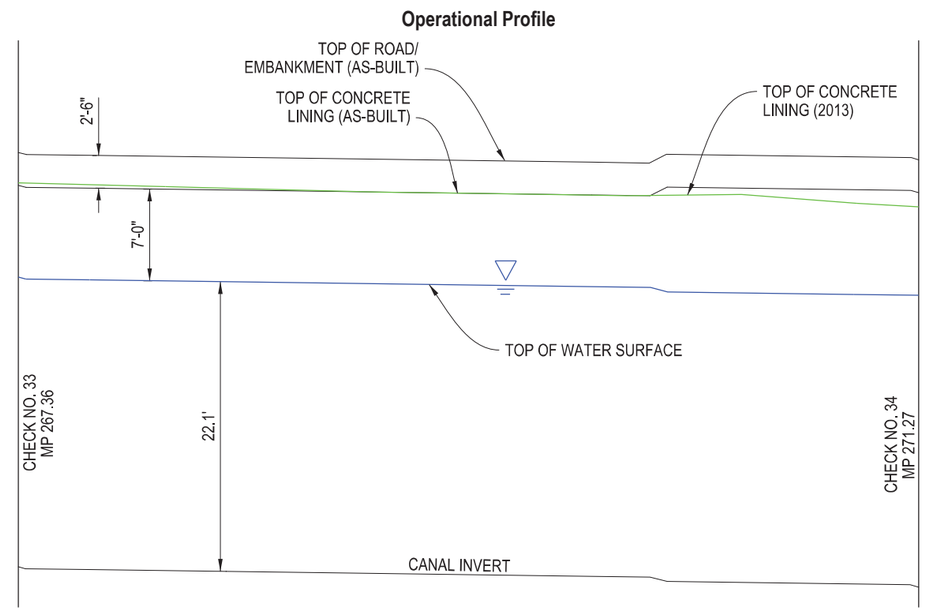
DEPARTMENT OF WATER RESOURCES
STATE WATER PROJECT
CALIFORNIA AQUEDUCT SUBSIDENCE STUDY

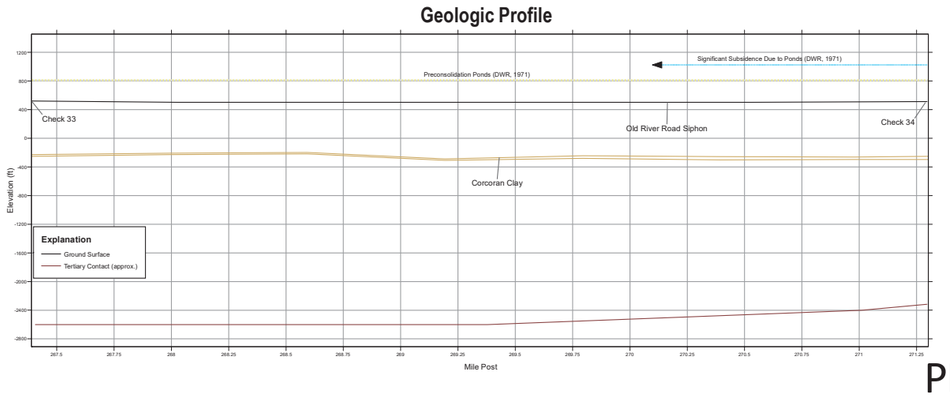
SUBSIDENCE, OPERATION, & GEOLOGIC PROFILES

POOL 33: MP 261.72 – 267.36









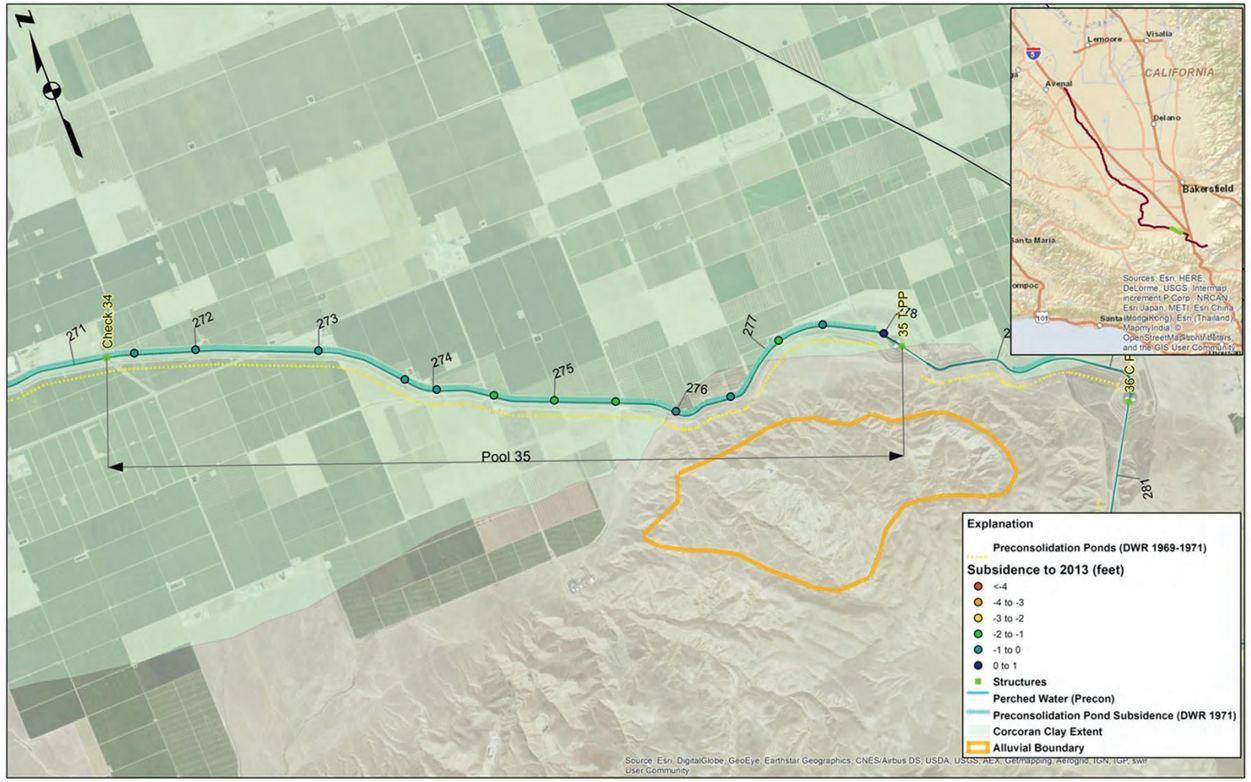
STRUCTURE	SIDE OF EMBANKMENT	MP
CHECK NUMBER 33		267.36
BRIDGE (2)		267.39
PHONE LINE CROSSING		267.44
STILLING WELL	L	267.47
POWERLINE CROSSING		267.58
PIPELINE CROSSING (3)		267.6
PIPELINE CROSSING (2)		268.54
BRIDGE		268.94
PHONE LINE CROSSING		268.95
PIPELINE CROSSING		269.3
PIPELINE CROSSING		269.66
OLD RIVER ROAD SIPHON		270.14
BRIDGE (2)		270.16
POWERLINE CROSSING		270.17
PIPELINE CROSSING		270.18
TURNOUT	L	270.24
STILLING WELL	L	271.26
PLEITITO CREEK SIPHON		271.27
CHECK NUMBER 34		271.27

PLATE 23

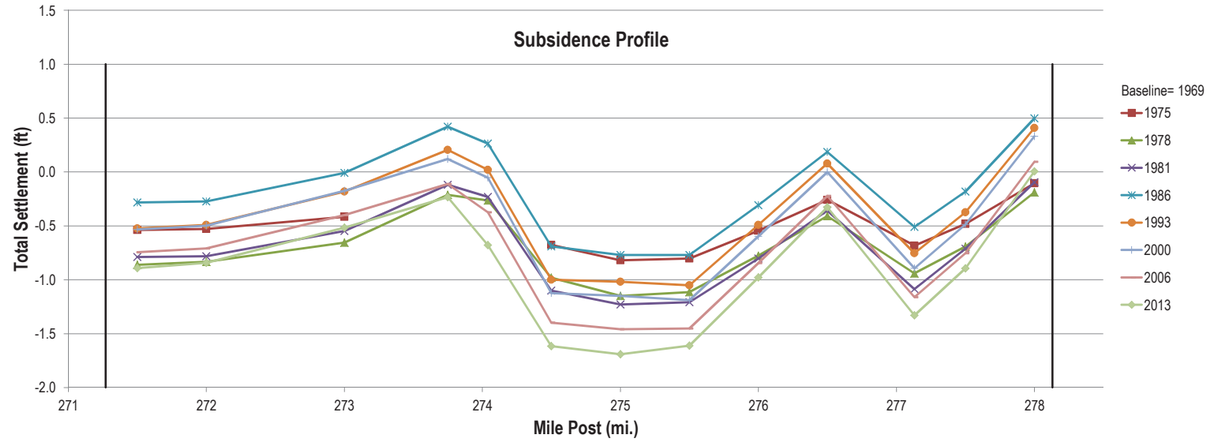
DEPARTMENT OF WATER RESOURCES
STATE WATER PROJECT
CALIFORNIA AQUEDUCT SUBSIDENCE STUDY

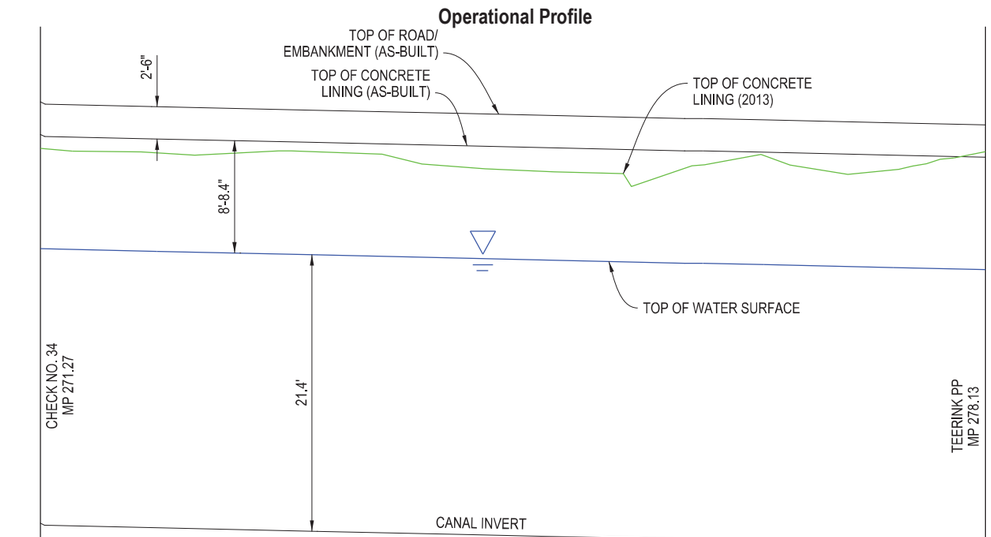
SUBSIDENCE, OPERATION, & GEOLOGIC PROFILES

POOL 34: MP 267.36 – 271.27



STRUCTURE	SIDE OF EMBANKMENT	MP
CHECK NUMBER 34		271.27
BRIDGE		271.3
STILLING WELL	L	271.37
PIPELINE CROSSING		271.85
TURNOUT	L	272.39
PIPELINE CROSSING (4)		272.4
HIGHWAY 166 BRIDGE		272.53
POWERLINE CROSSING		272.59
PIPELINE CROSSING (2)		273.09
PIPELINE CROSSING (2)		273.48
PIPELINE CROSSING		273.75
POWERLINE CROSSING		273.85
OVERCHUTE CROSSING		274.04
KELLY STATION ROAD BRIDGE		274.45
PIPELINE CROSSING		274.45
OVERCHUTE CROSSING		275.56
TURNOUT	L	276.09
OVERCHUTE CROSSING		276.5
PIPELINE CROSSING		276.71
PHONE LINE CROSSING		276.73
SAND TRAP		276.84
OVERCHUTE CROSSING		277.13
TURNOUT	L	277.31
TEERINK PUMPING PLANT		278.13





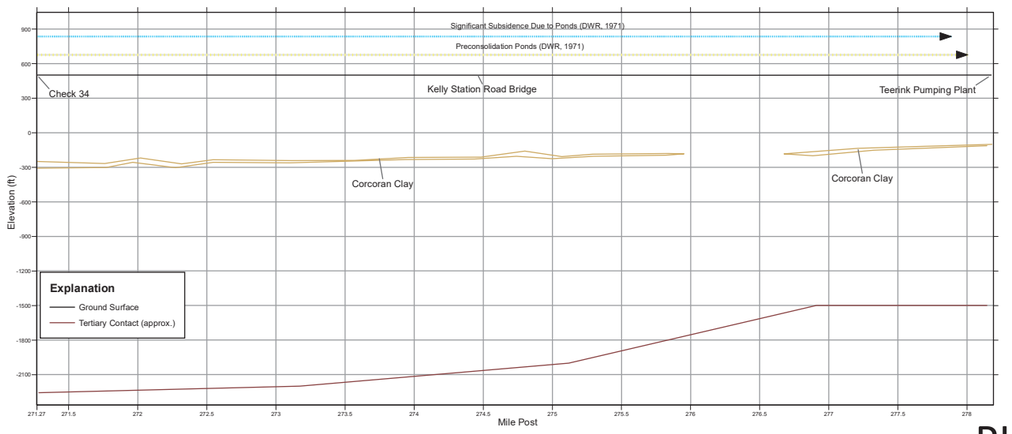


PLATE 24

DEPARTMENT OF WATER RESOURCES
STATE WATER PROJECT
CALIFORNIA AQUEDUCT SUBSIDENCE STUDY

SUBSIDENCE, OPERATION, & GEOLOGIC PROFILES

POOL 35: MP 271.27 – 278.13

STATE OF CALIFORNIA **DEPARTMENT OF WATER RESOURCES** **THE RESOURCES AGENCY**

California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
FEATURE M.P. 176.39 (I-5) TO Check 22 M.P. 184.82**												
MI. 179.2B=176.88B	10/67	96.067	96.093	.026	96.091	.024	96.087	.020	96.085	.018	(-.006)	(-.002)
MI. 179.8B=177.40B	10/67	96.041	96.074	.032	96.064	.023	96.098	.056	96.061	.020	(-.002)	(-.036)
MI. 179.8A=177.40A	10/67	97.769	97.805	.035	97.792	.022	97.814	.044	97.779	.010	(-.013)	(-.035)
MI. 180.3B=177.96B	10/67	96.008	96.101	.093	96.090	.082	96.096	.088	96.083	.075	(-.007)	(-.013)
MI. 180.9B=178.53B	10/67	95.963	96.034	.071	96.030	.067	96.036	.073	96.027	.064	(-.002)	(-.008)
MILE#180.9A=178.53A	10/67	98.550	98.581	.031	98.589	.038	98.582	.032	98.587	.037	(-.001)	(.005)
MI. 180.9B1=178.56B	10/67	95.967	95.979	.011	95.978	.011	95.970	.002	95.985	.018	(.007)	(.016)
MILE#180.9A1=178.56A	10/67	98.116	98.124	.008	98.119	.002	98.135	.019			( )	( )
MI. 181.9B=179.50B	12/93	95.959	95.947	-.013	95.942	-.017	95.930	-.029	95.938	-.021	(-.004)	(.008)
MI. 181.9A=179.50A	12/93	97.272	97.257	-.016	97.250	-.023	97.266	-.007	97.243	-.029	(-.007)	(-.023)
MI. 182.3B=179.98B	10/67	95.859	95.878	.019	95.879	.020	95.872	.013	95.874	.015	(-.005)	(.002)
MI. 182.3A=179.98A	10/67	97.482	97.487	.005	97.490	.008	97.497	.014	97.472	-.010	(-.018)	(-.025)
MI. 183.0B=180.64B	10/67	95.819	95.863	.043	95.862	.043	95.872	.052	95.887	.068	(.025)	(.016)
MILE 183.0A=180.64A	10/67	98.511	98.527	.016	98.523	.012	98.524	.013	98.535	.024	(.012)	(.011)
SECCOR 21/22/27/28	10/67	100.565	100.603	.038	100.584	.019	100.592	.026	100.550	-.015	(-.034)	(-.041)
MI. 183.5B=181.14B	10/67	95.815	95.846	.031	95.839	.023	95.834	.019	95.849	.034	(.011)	(.016)
MI. 183.5A=181.14A	10/67	98.326	98.356	.030	98.354	.028	98.362	.036			( )	( )
MI. 184.1B=181.76B	10/67	95.733	95.789	.055	95.774	.040	95.768	.034	95.784	.051	(.011)	(.017)
MI. 184.8B=182.39B	10/67	95.693	95.729	.035	95.721	.028	95.705	.011	95.697	.004	(-.023)	(-.007)
MI. 184.8A=182.39A	10/67	97.489									( )	( )
MI. 183.0 T.O.	7/00	94.944	94.896	-.049	94.881	-.064	94.886	-.058	94.860	-.084	(-.020)	(-.026)
183.19B	10/67	96.427	96.456	.028	96.458	.030	96.448	.020	96.459	.032	(.002)	(.011)
MI 185.5A=183.19A	10/67	97.134							97.127	-.007	( )	( )
183.74B	10/67	96.411	96.460	.048	96.448	.036	96.444	.032	96.452	.041	(.004)	(.008)
184.29B	10/67	96.305	96.418	.112	96.407	.102	96.392	.087	96.404	.099	(-.003)	(.012)
186.7A=184.29A	10/67	96.508	96.516	.008	96.528	.020	96.511	.003	96.521	.013	(-.007)	(.010)
H 1445	3/89	94.211	94.185	-.026	94.177	-.034	94.168	-.043	94.192	-.019	(.015)	(.024)
DR3=184.78	7/00	94.897	94.851	-.047	94.846	-.052	94.836	-.062	94.839	-.058	(-.007)	(.004)
184.82B	10/67	96.379	96.379	-.001	96.401	.022	96.383	.004	96.390	.011	(-.011)	(.007)
Index numbers			**16.1**		**17.1**		**18.1**		**19.1**			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

The vertical datum is based on the National Geodetic Vertical Datum of 1929(NGVD 1929), This is the same datum used to construct the state water project.

Units are in meters.

File Name x:\access\CaAqueduct\Kettleman-Edmonston\Ca Aq 2019 Kettleman-Edmonston+LatLong

California Aqueduct Kettleman City To Edmonston PP Elevation

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MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
CK 22 U/S RECORDER	8/86	97.515	97.484	-.031	97.462	-.053	97.466	-.049	97.474	-.041	(.013)	(.008)
MILE 187.1A=184.82A	10/67	96.692	96.707	.015	96.718	.026	96.708	.016	96.711	.019	(-.007)	(.004)
GPS CK 22	3/89	96.751	96.712	-.039	96.714	-.036	96.706	-.045	96.703	-.048	(-.011)	(-.002)
CK 22 D/S RECORDER	8/86	96.666	96.616	-.050	96.632	-.034	96.612	-.054	96.616	-.050	(-.016)	(.004)
FEATURE COASTAL M.P. 0.00 TO M.P. 14.8**												
MI.CA 0.0A=184.62A	10/67	95.096	95.129	.032							( )	( )
0.0 D/S RECORDER	12/93	95.955	95.866	-.090	95.858	-.098					( )	( )
MI. 0.0B OLD	10/67	94.895	95.003	.108	95.005	.110					( )	( )
0.0B	12/93	95.745	95.650	-.096	95.663	-.083					( )	( )
0.6B	12/93	95.694	95.604	-.091	95.614	-.081					( )	( )
LPPP U/S RECORDER	1/86	96.431	95.840	-.591	95.844	-.587					( )	( )
MI. 1.1A	11/68	96.671	96.733	.062	96.747	.076					( )	( )
MI. 1.1C	11/68	102.238	102.274	.036	102.298	.060					( )	( )
MI. 1.2A	11/68	111.797	111.901	.104	111.923	.126					( )	( )
MI. 1.2B	11/68	111.609	111.708	.098	111.721	.111					( )	( )
LPHD D/S RECORDER	1/86	112.150	112.141	-.010	112.141	-.010					( )	( )
MI. 2.2A	11/68	112.651	112.765	.114	112.780	.129					( )	( )
MI. 2.2B	11/68	111.366	111.554	.187	111.576	.209					( )	( )
MI. 3.0A	11/68	112.689	112.831	.142	112.840	.151					( )	( )
MI. 3.0B	11/68	111.156	111.386	.230	111.394	.238					( )	( )
3.54 HILTI	10/83	112.329	112.366	.037	112.373	.044					( )	( )
3.54 BOLT	10/83	111.529	111.575	.045							( )	( )
MI. 3.9B	11/68	110.957	111.032	.074	111.040	.082					( )	( )
MI. 4.2B	11/68	110.861	110.935	.074	110.937	.076					( )	( )
MI. 4.2A	7/00	112.412									( )	( )
MI. 4.2A RESET 2010	02/13	112.406									( )	( )
BHPP U/S RECORDER	1/86	111.965									( )	( )
MI. 4.2C	11/68	115.818	115.876	.057	115.883	.064					( )	( )
MI. 4.9A	11/68	157.155	157.360	.205	157.363	.208					( )	( )
MI. 4.9B	11/68	156.997	157.195	.198	157.196	.199					( )	( )
Index numbers			16.1		17.1		18.1		19.1			

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BHPP D/S RECORDER	1/86	157.562									( )	( )
MI. 4.9C	11/68	160.667	160.810	.143	160.817	.150					( )	( )
MI. 5.6B	11/68	156.788	156.925	.137	156.933	.145					( )	( )
MI. 5.6C	11/68	154.803	154.915	.112	154.921	.118					( )	( )
Mile 6.3B	11/68	156.629	156.773	.144	156.789	.160					( )	( )
MI. 6.3C	11/68	157.249	157.384	.135	157.392	.143					( )	( )
MI. 7.0A	11/68	157.825	157.976	.151	157.988	.163					( )	( )
MI. 7.0B	11/68	156.505	156.671	.166	156.676	.171					( )	( )
CK 3 U/S RECORDER	1/86	157.032	157.032	-.001							( )	( )
MI. 7.0C	11/68	154.310	154.477	.166	154.483	.172					( )	( )
MI. 7.2A	11/68	156.738	156.927	.188	156.932	.193					( )	( )
MI. 7.2B	11/68	156.408	156.622	.214	156.623	.215					( )	( )
CK 3 D/S RECORDER	1/86	157.050	157.048	-.003							( )	( )
MI. 7.2C	11/68	156.067	156.261	.194	156.265	.198					( )	( )
7.26B STAMPED 7.2B	11/68	156.392	156.593	.201	156.606	.214					( )	( )
7.26A STAMPED 7.2A	11/68	157.595	157.788	.193	157.826	.231					( )	( )
MI. 8.0B	11/68	156.209	156.411	.201	156.405	.195					( )	( )
MI. 8.0C	11/68	156.226	156.411	.184							( )	( )
MI. 8.8B	11/68	156.034	156.251	.216	156.249	.214					( )	( )
CK 4 U/S RECORDER	1/86	156.453	156.440	-.014							( )	( )
MI. 9.3A	11/68	156.114	156.199	.084	156.208	.093					( )	( )
MI. 9.3B	11/68	155.836	155.923	.087	155.937	.101					( )	( )
CK 4 D/S RECORDER	1/86	156.315	156.289	-.026							( )	( )
MI. 9.3C	11/68	154.620	154.811	.191	154.813	.193					( )	( )
BM CD 10	11/68	155.222	155.239	.017	155.257	.035					( )	( )
F 947	10/83	154.898	154.912	.013	154.939	.040					( )	( )
MI. 9.4A	11/68	156.435	156.490	.055	156.501	.066					( )	( )
MI. 9.4B	11/68	155.838	155.907	.068	155.908	.069					( )	( )
MI. 9.9B	11/68	155.709	155.787	.077	155.781	.071					( )	( )
MI. 9.9C	11/68	156.543	156.597	.053	156.590	.046					( )	( )
Index numbers			**16.1**		**17.1**		**18.1**		**19.1**			

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HPGN 06-GH	7/00	156.551	156.488	-.063	156.494	-.057					( )	( )
MI. 10.4A	11/68	157.167	157.240	.073	157.232	.065					( )	( )
MI. 10.4B	11/68	155.618	155.703	.084	155.703	.084					( )	( )
MI. 10.4C	11/68	155.668	155.727	.058	155.725	.056					( )	( )
MI. 11.3B	11/68	155.415	155.560	.144	155.554	.138					( )	( )
CK 5 U/S RECORDER	1/86	155.689	155.659	-.031	155.674	-.016					( )	( )
MI. 11.3C	11/68	155.695	155.820	.125	155.799	.104					( )	( )
MI. 12.2A	11/68	155.456	155.510	.054	155.503	.047					( )	( )
MI. 12.2B	11/68	155.237	155.275	.037	155.277	.039					( )	( )
CK 5 D/S RECORDER	1/86	155.669	155.655	-.015	155.666	-.004					( )	( )
MI. 12.5A	11/68	156.318									( )	( )
MI. 12.5B	11/68	155.096	155.162	.065	155.184	.087					( )	( )
MI. 12.5C	11/68	155.403	155.487	.084	155.495	.092					( )	( )
MI. 12.9A	10/67	156.502	156.515	.012	156.521	.018					( )	( )
MI. 12.9B	10/67	155.023	155.046	.022	155.052	.028					( )	( )
13.41 BOLT	12/93	155.492	155.410	-.082	155.419	-.073					( )	( )
MI. 13.9A	11/68	156.368									( )	( )
MI. 13.9B	11/68	154.780	154.818	.038	154.835	.055					( )	( )
MI. 13.9C	11/68	154.971	155.072	.100	155.087	.115					( )	( )
14.42 BOLT	10/83	155.229	155.274	.045	155.270	.041					( )	( )
MI. 14.8A	7/00	155.554	155.499	-.056	155.500	-.055					( )	( )
MI. 14.8B	11/68	154.590	154.629	.038	154.638	.047					( )	( )
U/S WELL	1/86	155.647	155.633	-.014	155.647	-.001					( )	( )
FEATURE COASTAL Hilltie**												
X 558	10/67	162.004	162.079	.075	162.079	.075			162.007	.003	(-.071)	( )
Y 558	10/67	201.384	201.426	.042	201.442	.058			201.363	-.021	(-.078)	( )
C 963X	10/67	245.390	245.433	.042	245.443	.053					( )	( )
D 963X	10/67	246.447									( )	( )
FEATURE Check 22 MP 184.82 to Check 23 MP 197.05**												

Index numbers 16.1 17.1 18.1 19.1

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MI. 188.0B=185.70B	10/67	95.795	95.822	.026	95.830	.034	95.802	.007	95.799	.004	(-.030)	(-.002)
MI. 188.0A=185.70A	10/67	97.194	97.243	.049	97.220	.025	97.208	.013	97.185	-.009	(-.034)	(-.022)
MI. 188.6B=186.30B	10/67	95.732	95.770	.038	95.774	.041	95.756	.023	95.756	.024	(-.017)	(.001)
MI. 189.2B=186.88B	10/67	95.660	95.684	.023	95.700	.040	95.682	.022	95.674	.014	(-.025)	(-.007)
MI. 189.2A=186.88A	10/67	97.032	97.060	.028	97.052	.020	97.038	.005	97.056	.024	(.004)	(.019)
MI. 189.9B=187.60B	10/67	95.620	95.670	.049	95.674	.053	95.656	.035	95.658	.038	(-.016)	(.002)
MI. 189.9A=187.60A	10/67	96.934	96.981	.047	96.970	.035	96.943	.008	96.939	.005	(-.031)	(-.004)
MI. 190.8B=188.47B	10/67	95.604	95.641	.037	95.644	.040	95.618	.014	95.624	.020	(-.020)	(.006)
MI. 191.6B=189.33B	10/67	95.494	95.548	.053	95.574	.079	95.541	.046	95.558	.064	(-.015)	(.018)
MI. 191.6A=189.33A	10/67	97.782	97.807	.025	97.831	.049	97.794	.011	97.799	.017	(-.031)	(.006)
Q 1451	3/89	92.629	92.570	-.059	92.578	-.051	92.551	-.078	92.562	-.067	(-.016)	(.011)
DOPP STA 10908	12/81	97.358	97.346	-.013	97.363	.004	97.325	-.034	97.342	-.016	(-.020)	(.017)
MI. 192.4B=190.09B	10/67	95.463	95.520	.057	95.491	.028	95.479	.016	95.485	.022	(-.005)	(.007)
MI. 192.4A=190.09A	10/67	96.850	96.900	.050	96.879	.029	96.861	.011	96.870	.020	(-.008)	(.010)
MI. 193.1B=190.82B	10/67	95.461	95.500	.038	95.500	.038	95.478	.017	95.481	.020	(-.019)	(.003)
V 1097	10/67	96.170	96.158	-.013	96.144	-.026	96.137	-.034	96.136	-.034	(-.008)	(-.001)
LH 2=191.18	12/93	96.288	96.171	-.118	96.161	-.128	96.157	-.132	96.150	-.138	(-.010)	(-.007)
MI. 193.9B=191.55B	10/67	95.390	95.374	-.016	95.368	-.022	95.367	-.023	95.356	-.034	(-.012)	(-.011)
MI. 193.9A=191.55A	10/67	96.971	96.967	-.005	96.950	-.022	96.926	-.046			( )	( )
MI. 194.7B=192.41B	10/67	95.313	95.289	-.025	95.281	-.032	95.264	-.049	95.271	-.042	(-.010)	(.007)
MI. 194.7A=192.41A	10/67	97.122	97.070	-.052	97.083	-.040	97.074	-.049	97.054	-.068	(-.028)	(-.019)
MI. 195.6B=193.26B	10/67	95.272	95.144	-.129	95.145	-.127	95.125	-.148	95.116	-.156	(-.029)	(-.008)
MI. 195.6A=193.26A	10/67	96.950	96.809	-.142	96.824	-.127	96.791	-.160			( )	( )
MI. 196.1B=193.85B	10/67	95.245	95.070	-.176	95.055	-.191	95.044	-.202	95.044	-.201	(-.011)	(.001)
194.22A	12/93	95.902	95.640	-.262	95.637	-.265	95.619	-.283	95.621	-.281	(-.016)	(.002)
MI. 196.7B=194.41B	10/67	95.193	94.864	-.329	94.860	-.334	94.840	-.353	94.837	-.356	(-.022)	(-.002)
MI. 196.7A=194.41A	10/67	96.920	96.560	-.361	96.534	-.386	96.525	-.395	96.521	-.399	(-.013)	(-.004)
MI. 197.2B=194.93B	10/67	95.142	94.611	-.531	94.596	-.546	94.561	-.581	94.560	-.582	(-.035)	(-.001)
MILE 197.2A=194.93A	10/67	98.352	97.793	-.560	97.784	-.569	97.749	-.603	97.742	-.610	(-.041)	(-.007)
T 1203	11/69	99.179	98.800	-.380	98.816	-.364	98.775	-.404	98.767	-.412	(-.049)	(-.008)
Index numbers			**16.1**		**17.1**		**18.1**		**19.1**			

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K 1445	3/89	93.723	93.388	-.335	93.364	-.359	93.350	-.373	93.330	-.393	(-.034)	(-.020)
198.1B=195.76B	10/67	95.092									( )	( )
195.76 B	10/67	95.717	95.016	-.701	94.991	-.726	94.965	-.752	94.948	-.769	(-.043)	(-.017)
MI. 198.9B=196.57B	10/67	95.038									( )	( )
196.57 B	10/67	95.861	95.012	-.849	95.004	-.857	94.970	-.891	94.975	-.886	(-.029)	(.005)
MI. 198.9A=196.57A	10/67	96.948	96.075	-.873	96.054	-.894	96.030	-.918	96.036	-.912	(-.017)	(.007)
X 1097	1/86	96.242	95.693	-.549	95.662	-.580	95.636	-.606	95.617	-.625	(-.044)	(-.019)
197.05B	10/67	95.960	94.964	-.997	94.932	-1.029	94.915	-1.046	94.888	-1.072	(-.043)	(-.026)
CK 23 U/S RECORDER	1/86	96.115	95.552	-.563	95.535	-.581	95.508	-.607	95.494	-.621	(-.040)	(-.014)
MI. 199.3A=197.05A	10/67	95.978	95.023	-.955	94.997	-.981	94.978	-1.000	94.959	-1.019	(-.037)	(-.019)
GPS CK 23	3/89	95.558	95.010	-.549	94.977	-.582	94.967	-.592	94.962	-.596	(-.014)	(-.004)
CK 23 D/S RECORDER	1/86	95.430	94.881	-.550	94.843	-.588	94.824	-.607	94.795	-.635	(-.047)	(-.028)
FEATURE Check 23 MP 197.05 to Check 24 MP 207.93**												
MI. 200.1B=197.84B	10/67	94.964	93.879	-1.086	93.845	-1.120	93.831	-1.134	93.797	-1.167	(-.047)	(-.034)
MI. 200.1A=197.84A	10/67	96.882			95.739	-1.144	95.705	-1.178			( )	( )
MI. 201.0B=198.75B	10/67	94.939	94.020	-.919	93.989	-.950	93.958	-.981	93.933	-1.006	(-.055)	(-.024)
MILE 201.0A=198.75A	10/67	97.143	96.178	-.966	96.155	-.989	96.133	-1.010	96.107	-1.036	(-.047)	(-.026)
MILE 201.8B=199.55B	10/67	94.864	93.778	-1.087	93.737	-1.128	93.710	-1.155	93.674	-1.190	(-.063)	(-.035)
MI. 201.8C=199.55C	10/67	91.948	90.930	-1.018	90.897	-1.051	90.865	-1.083	90.840	-1.108	(-.056)	(-.025)
R 1451	3/89	91.120	90.469	-.652	90.419	-.702	90.390	-.731	90.363	-.757	(-.055)	(-.026)
MILE 202.6B=200.34B	10/67	94.786	93.743	-1.043	93.695	-1.092	93.678	-1.109	93.637	-1.149	(-.058)	(-.040)
MI. 203.4B=201.14B	10/67	94.804	93.829	-.975	93.812	-.993	93.777	-1.028	93.753	-1.051	(-.058)	(-.023)
MILE 203.4A=201.14A	10/67	96.591	95.626	-.965	95.578	-1.013	95.544	-1.048			( )	( )
MILE 204.0B=201.69B	10/67	94.742	93.841	-.901	93.792	-.951	93.747	-.996	93.734	-1.008	(-.058)	(-.013)
MI. 204.5B=202.22B	10/67	94.738	93.966	-.772	93.931	-.808	93.883	-.855	93.866	-.872	(-.064)	(-.017)
MILE 204.5A=202.22A	10/67	96.693	95.924	-.769	95.883	-.810	95.837	-.856			( )	( )
MI. 205.3B=203.00B	10/67	94.691	94.096	-.596	94.055	-.636	94.023	-.668	94.006	-.685	(-.049)	(-.017)
MILE 205.3A=203.00A	10/67	97.714	97.053	-.662	97.035	-.680	97.008	-.706	96.988	-.726	(-.046)	(-.020)
MI. 205.6=203.28B	10/67	94.670	94.209	-.462	94.181	-.490	94.175	-.496	94.155	-.515	(-.025)	(-.019)
MILE 205.6A=203.28A	10/67	96.642	96.166	-.477	96.137	-.505	96.118	-.524			( )	( )
Index numbers			**16.1**		**17.1**		**18.1**		**19.1**			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

The vertical datum is based on the National Geodetic Vertical Datum of 1929(NGVD 1929), This is the same datum used to construct the state water project.

California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MI. 206.2B=203.92B	10/67	94.628	94.254	-.374	94.218	-.410	94.203	-.426	94.205	-.423	(-.013)	(.002)
MILE 206.2A=203.92A	10/67	96.335	95.942	-.393	95.904	-.431	95.899	-.436			( )	( )
MI. 207.0B=204.70B	10/67	94.591	94.042	-.549	94.004	-.587	93.980	-.611	93.984	-.607	(-.020)	(.004)
MILE 207.0A=204.70A	10/67	96.363	95.799	-.564	95.753	-.611	95.726	-.638			( )	( )
MI. 207.5B=205.19A	10/67	94.518	93.870	-.648	93.820	-.698	93.811	-.707	93.779	-.739	(-.041)	(-.032)
MI. 207.5A=205.19A	10/67	97.689									( )	( )
205.19A RESET 05	2006	97.182	96.923	-.260	96.866	-.317	96.884	-.299	96.856	-.326	(-.010)	(-.028)
205.19AA 2004	2006	97.807	97.549	-.258	97.496	-.311	97.486	-.322	97.475	-.332	(-.021)	(-.011)
E 873	10/67	97.021									( )	( )
DWR 153 A	10/67	96.715	95.990	-.725	95.978	-.737	95.923	-.793	95.897	-.818	(-.081)	(-.025)
J 1445	3/89	95.225	94.713	-.513	94.670	-.556	94.647	-.579	94.642	-.583	(-.028)	(-.005)
MI. 208.4B=206.06B	10/67	94.451	93.626	-.825	93.599	-.852	93.566	-.885	93.560	-.891	(-.038)	(-.005)
MILE 208.4A=206.06A	10/67	96.790	95.918	-.873	95.879	-.912	95.860	-.931	95.839	-.951	(-.040)	(-.020)
MI. 208.4B=206.09B	10/67	94.434	93.616	-.819	93.573	-.861	93.541	-.894	93.536	-.898	(-.037)	(-.004)
MILE 208.4AA=206.09A	10/67	96.288	95.432	-.856			95.369	-.919	95.367	-.921	( )	(-.001)
MILE 208.9B=206.63B	10/67	94.436	93.345	-1.092	93.284	-1.153	93.247	-1.190	93.225	-1.211	(-.059)	(-.022)
206.63BB 2005	2006	94.447	94.131	-.316	94.078	-.369	94.029	-.418	94.007	-.440	(-.070)	(-.022)
MI. 209.5B=207.18B	10/67	94.399	93.244	-1.156	93.205	-1.195	93.168	-1.232	93.147	-1.252	(-.057)	(-.020)
207.18BB 2005	2006	94.305	94.021	-.284	93.980	-.325	93.937	-.368	93.925	-.380	(-.055)	(-.011)
MIEE 209.5A=207.18A	10/67	96.190	95.019	-1.171			94.922	-1.269	94.903	-1.287	( )	(-.018)
MILE 210.2B=207.94B	10/67	94.299	93.118	-1.182	93.093	-1.207	93.054	-1.246	93.053	-1.246	(-.040)	(-.001)
207.94BB 2005	2006	94.144	93.882	-.263	93.859	-.286	93.822	-.323	93.812	-.332	(-.047)	(-.010)
CK 24 U/S RECORDER	1/86	95.294	94.646	-.648	94.614	-.680	94.577	-.718	94.585	-.709	(-.029)	(.008)
MI. 210.2A=207.94A	10/67	95.201	94.086	-1.116	94.062	-1.140	94.035	-1.167	94.033	-1.168	(-.028)	(-.001)
GPS CK 24	3/89	94.748	94.093	-.656	94.066	-.683	94.016	-.733	94.008	-.740	(-.058)	(-.008)
CK 24 D/S RECORDER	1/86	94.628	93.985	-.644	93.939	-.689	93.910	-.719	93.904	-.724	(-.035)	(-.005)
FEATURE Check 24 MP 207.94 to Check 25 MP 217.78**												
MI. 210.4B=208.11B	10/67	94.322	93.283	-1.040	93.244	-1.079	93.213	-1.110	93.204	-1.118	(-.040)	(-.009)
MILE 210.4A=208.11A	10/67	95.968	94.937	-1.032	94.887	-1.082	94.853	-1.116	94.852	-1.116	(-.034)	(-.001)
MILE 211.0B=208.73B	10/67	94.301	93.338	-.963	93.301	-1.001	93.275	-1.027	93.250	-1.051	(-.050)	(-.025)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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Units are in meters.

File Name x:\access\CaAqueduct\Kettleman-Edmonston\Ca Aq 2019 Kettleman-Edmonston+LatLong

California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MI. 211.0C=208.73C	10/67	92.661	91.684	-.978	91.642	-1.019	91.620	-1.042	91.610	-1.051	(-.032)	(-.010)
MI. 211.7B=209.36B	10/67	94.238	93.237	-1.001	93.191	-1.048	93.182	-1.057	93.161	-1.077	(-.029)	(-.020)
MILE 211.7A=209.36A	10/67	95.936	94.943	-.994	94.905	-1.032	94.861	-1.076	94.850	-1.086	(-.055)	(-.011)
Q 1262	1/75	94.686	93.949	-.738	93.898	-.788	93.877	-.810	93.852	-.834	(-.046)	(-.025)
MI. 212.6B=210.30B	10/67	94.203	93.252	-.951	93.216	-.987	93.197	-1.007	93.174	-1.029	(-.041)	(-.022)
MILE 212.6A=210.30A	10/67	96.599	95.617	-.983	95.571	-1.029	95.549	-1.051	95.531	-1.068	(-.039)	(-.017)
MI. 212.9B=210.61B	10/67	94.408	93.605	-.804	93.556	-.853	93.533	-.876	93.529	-.879	(-.026)	(-.004)
MILE 212.9A=210.61A	10/67	95.923	95.068	-.856	95.037	-.886	94.999	-.924	94.983	-.940	(-.053)	(-.016)
MILE 213.6B=211.34B	10/67	94.360	93.707	-.653	93.665	-.695	93.651	-.709	93.648	-.712	(-.017)	(-.003)
MI. 214.4B=212.10B	10/67	94.292	93.634	-.659	93.609	-.683	93.586	-.707	93.597	-.695	(-.012)	(.011)
MILE 214.4A=212.10A	10/67	95.784	95.109	-.676	95.120	-.665	95.044	-.741	95.046	-.738	(-.073)	(.003)
MILE 215.0B=212.75B	10/67	94.248	93.556	-.693	93.535	-.714	93.523	-.725	93.520	-.728	(-.014)	(-.003)
MI. 215.7B=213.39B	10/67	94.238	93.510	-.728	93.484	-.754	93.473	-.766	93.463	-.775	(-.021)	(-.010)
MILE 215.7A=213.39A	10/67	96.045	95.324	-.722	95.306	-.740	95.272	-.773	95.271	-.774	(-.034)	(-.001)
MI. 216.3B=213.96B	10/67	94.177	93.545	-.633	93.529	-.648	93.513	-.665	93.515	-.662	(-.014)	(.002)
MILE 216.3A=213.96A	10/67	96.476	95.908	-.569	95.882	-.594	95.882	-.594	95.881	-.595	(-.001)	(-.001)
MI. 216.3C=213.96C	11/69	91.761	91.171	-.590	91.168	-.593	91.144	-.617	91.137	-.624	(-.031)	(-.007)
L 1445	3/89	91.770	91.454	-.316	91.451	-.319	91.433	-.337	91.434	-.336	(-.017)	(.001)
MI. 216.6B=214.34B	10/67	94.178	93.647	-.531	93.651	-.527	93.635	-.543	93.622	-.556	(-.029)	(-.013)
MILE 216.6A=214.34A	10/67	95.998	95.456	-.543	95.476	-.523	95.449	-.550	95.419	-.579	(-.056)	(-.029)
MILE 217.3B=214.97B	10/67	94.126	93.693	-.434	93.690	-.437	93.668	-.459	93.655	-.471	(-.034)	(-.013)
MI. 217.9B=215.64B	10/67	94.088	93.639	-.449	93.655	-.433	93.630	-.458	93.622	-.466	(-.032)	(-.008)
MILE 217.9A=215.64A	10/67	95.851	95.385	-.466	95.392	-.459	95.359	-.492	95.356	-.495	(-.036)	(-.003)
Y 1097	10/67	94.803	94.442	-.361	94.451	-.352	94.430	-.373	94.427	-.376	(-.023)	(-.002)
MILE 218.7B=216.40B	10/67	94.073	93.762	-.311	93.769	-.304	93.757	-.316	93.749	-.324	(-.020)	(-.008)
R 1209	11/69	94.711	94.441	-.270	94.440	-.272	94.427	-.284	94.415	-.296	(-.024)	(-.011)
MI. 219.5B=217.16B	10/67	93.987	93.658	-.329	93.658	-.329	93.642	-.345	93.642	-.345	(-.016)	(.000)
MILE 219.5A=217.16A	10/67	95.861	95.539	-.323	95.534	-.328	95.524	-.338	95.516	-.345	(-.017)	(-.007)
MI. 220.1B=217.78B	10/67	93.979	93.655	-.325	93.666	-.314	93.644	-.335	93.644	-.335	(-.021)	(.001)
CK 25 U/S RECORDER	1/86	95.082	94.803	-.279	94.813	-.269	94.793	-.289	94.793	-.289	(-.019)	(.001)
Index numbers			**16.1**		**17.1**		**18.1**		**19.1**			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MI. 220.1A=217.78A	10/67	94.811	94.474	-.338	94.481	-.331	94.458	-.354	94.462	-.349	(-.019)	(.005)
GPS CK 25	3/89	94.713	94.485	-.228	94.493	-.220	94.469	-.244	94.471	-.242	(-.022)	(.002)
CK 25 D/S RECORDER	1/86	94.944	94.666	-.279	94.689	-.255	94.664	-.281	94.664	-.280	(-.025)	(.001)
FEATURE Check 25 MP 217.78 to Check 26 MP 224.91**												
MILE 218.31B	11/69	93.930	93.637	-.293	93.648	-.282	93.626	-.305	93.621	-.309	(-.027)	(-.005)
MILE 218.31A	11/69	97.675	97.386	-.289	97.398	-.277	97.376	-.299	97.377	-.298	(-.021)	(.001)
DOP STA 10923	12/93	95.423	95.206	-.217	95.221	-.203	95.198	-.225	95.192	-.231	(-.029)	(-.006)
MILE 218.48B	11/69	93.913	93.661	-.252	93.667	-.246	93.651	-.262	93.643	-.270	(-.023)	(-.008)
MILE 218.48A	11/69	95.553	95.281	-.272	95.293	-.260	95.280	-.273	95.283	-.270	(-.010)	(.004)
MILE 219.38B	11/69	93.899	93.695	-.204	93.708	-.192	93.683	-.216	93.693	-.206	(-.014)	(.010)
Q 1209	11/69	94.593	94.393	-.200	94.408	-.186	94.388	-.206	94.387	-.206	(-.020)	(-.001)
S 1451	3/89	94.564	94.352	-.212	94.363	-.201	94.348	-.216	94.343	-.221	(-.019)	(-.004)
MILE 220.27B	11/69	93.612	92.920	-.692	92.921	-.691	92.909	-.703	92.905	-.707	(-.016)	(-.004)
MILE 220.27A	11/69	94.364	93.794	-.570	93.795	-.570	93.781	-.584	93.766	-.598	(-.028)	(-.014)
MILE 220.27C	11/69	93.288	93.032	-.256	93.033	-.255	93.036	-.252	93.031	-.257	(-.001)	(-.004)
MILE 221.06B	11/69	93.648	93.484	-.164	93.498	-.150	93.505	-.143	93.493	-.155	(-.005)	(-.012)
MILE 221.06C	11/69	92.036	91.852	-.185	91.865	-.171	91.858	-.179	91.856	-.180	(-.009)	(-.002)
MILE 221.81B	11/69	93.549	93.364	-.185	93.377	-.172	93.372	-.178	93.373	-.176	(-.004)	(.002)
MILE 221.81C	11/69	92.128	91.931	-.197	91.947	-.182	91.953	-.176	91.938	-.190	(-.008)	(-.014)
MILE 222.58B	11/69	93.503	93.142	-.361	93.166	-.338	93.153	-.350	93.143	-.360	(-.022)	(-.010)
MILE 222.58A	11/69	95.126	94.738	-.389	94.744	-.383	94.721	-.406	94.720	-.406	(-.023)	(-.001)
MILE 222.89B	11/69	93.514	92.982	-.532	92.989	-.525	92.981	-.533	92.976	-.538	(-.013)	(-.005)
M 1445	3/89	95.769	95.476	-.293	95.487	-.283	95.476	-.294	95.465	-.304	(-.022)	(-.010)
MILE 222.89A	11/69	97.766	97.304	-.462	97.316	-.451	97.298	-.469	97.286	-.480	(-.029)	(-.011)
MILE 223.19B	11/69	93.495	93.327	-.168	93.340	-.156	93.331	-.165	93.328	-.167	(-.011)	(-.002)
Z 1097	1/75	95.795	95.739	-.056	95.739	-.056	95.725	-.070	95.731	-.064	(-.008)	(.006)
MILE 223.19A	11/69	95.076	94.905	-.171	94.923	-.153	94.910	-.166	94.922	-.154	(-.001)	(.013)
N 1445	3/89	93.979	93.806	-.173	93.817	-.163	93.801	-.179	93.812	-.167	(-.005)	(.011)
MILE 224.05B	11/69	93.375	93.078	-.297	93.084	-.291	93.061	-.314	93.059	-.316	(-.025)	(-.002)
MILE 224.05A	11/69	95.501	95.281	-.220	95.291	-.211	95.278	-.224	95.273	-.228	(-.017)	(-.005)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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File Name x:\access\CaAqueduct\Kettleman-Edmonston\Ca Aq 2019 Kettleman-Edmonston+LatLong

California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
A 1098	10/67	95.177	94.936	-.241	94.949	-.229	94.933	-.245	94.929	-.248	(-.019)	(-.004)
MILE 224.05C	11/69	92.508	92.225	-.283	92.238	-.270	92.222	-.286	92.217	-.291	(-.020)	(-.005)
MILE 224.17B	11/69	93.389	93.062	-.328	93.071	-.319	93.050	-.340	93.075	-.314	(.005)	(.026)
MILE 224.17A	10/67	95.453	94.999	-.454	95.003	-.450	94.972	-.481	94.959	-.494	(-.043)	(-.013)
MILE 224.73B	10/67	93.415	93.119	-.296	93.125	-.291	93.114	-.302	93.103	-.312	(-.022)	(-.011)
MILE 224.91B	11/69	93.336	92.871	-.465	92.852	-.484	92.848	-.489	92.846	-.490	(-.005)	(-.001)
CK 26 U/S RECORDER	1/86	95.004	94.487	-.517	94.484	-.520	94.463	-.541	94.468	-.536	(-.016)	(.005)
MILE 224.91A	10/67	94.183	93.876	-.307	93.876	-.307	93.865	-.318	93.854	-.329	(-.022)	(-.011)
CK 26 D/S RECORDER	1/86	94.539	94.321	-.219	94.317	-.222	94.305	-.234	94.298	-.241	(-.019)	(-.007)
FEATURE Check 26 MP 224.91 to Check 27 MP 231.73**												
MILE 225.05B	11/69	93.330	93.139	-.191	93.129	-.201	93.124	-.206	93.109	-.221	(-.020)	(-.015)
MILE 225.05A	11/69	94.951	94.751	-.200	94.750	-.201	94.732	-.219	94.726	-.225	(-.023)	(-.005)
MILE 225.89A	11/69	94.909	94.657	-.252	94.651	-.258	94.654	-.255	94.634	-.275	(-.017)	(-.020)
MILE 225.89B	11/69	93.267	93.025	-.242	93.013	-.254	93.010	-.257	92.986	-.281	(-.026)	(-.023)
MILE 226.79B	11/69	93.194	93.051	-.144	93.048	-.147	93.055	-.139	93.043	-.151	(-.004)	(-.011)
MILE 226.79A	11/69	94.856	94.714	-.142	94.716	-.140	94.723	-.133	94.700	-.156	(-.016)	(-.022)
MILE 227.64B	11/69	93.177	93.074	-.104	93.083	-.095	93.066	-.112	93.070	-.107	(-.013)	(.004)
MILE 227.64A	11/69	94.801	94.708	-.094	94.719	-.082	94.704	-.097	94.700	-.101	(-.019)	(-.004)
MILE 228.06B	11/69	93.131	93.012	-.120	93.019	-.112	92.991	-.141	93.008	-.123	(-.011)	(.017)
MILE 228.06C	11/69	90.575	90.456	-.120	90.455	-.121	90.433	-.142	90.446	-.129	(-.008)	(.013)
MILE 228.67B	11/69	93.101	92.986	-.115	92.986	-.115	92.963	-.138	92.956	-.145	(-.029)	(-.007)
MILE 228.67A	11/69	95.145	95.031	-.114	95.038	-.108	95.012	-.133	94.976	-.169	(-.061)	(-.035)
MILE 229.06B	11/69	93.062	92.866	-.197	92.866	-.197	92.858	-.204	92.834	-.228	(-.031)	(-.023)
MILE 229.06C	11/69	90.166	89.988	-.179	89.986	-.180	89.966	-.200	89.948	-.218	(-.038)	(-.018)
MILE 229.71B	11/69	93.024	92.774	-.251	92.758	-.266	92.753	-.272	92.753	-.271	(-.005)	(.001)
MILE 229.71A	11/69	97.126	96.863	-.264	96.857	-.270	96.841	-.285	96.847	-.279	(-.010)	(.006)
MILE 230.44B	11/69	92.964	92.807	-.157	92.809	-.156	92.796	-.168	92.795	-.169	(-.013)	(-.001)
MILE 230.44A	11/69	94.608	94.449	-.160	94.461	-.148	94.437	-.172	94.436	-.172	(-.024)	(.000)
MILE 231.06B	11/69	92.914	92.776	-.138	92.779	-.135	92.767	-.147	92.768	-.146	(-.011)	(.001)
MILE 231.60B	11/69	92.894	92.745	-.150	92.748	-.147	92.729	-.166	92.738	-.156	(-.010)	(.010)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

The vertical datum is based on the National Geodetic Vertical Datum of 1929(NGVD 1929), This is the same datum used to construct the state water project.

Units are in meters.

File Name x:\access\CaAqueduct\Kettleman-Edmonston\Ca Aq 2019 Kettleman-Edmonston+LatLong

California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MILE 231.60A	11/69	94.526	94.392	-.134	94.382	-.144	94.351	-.176	94.365	-.161	(-.017)	(.014)
CK 27 U/S RECORDER	1/86	94.572	94.204	-.368	94.206	-.367	94.175	-.398	94.189	-.383	(-.017)	(.014)
MILE 231.73A	11/69	93.686	93.522	-.165	93.522	-.165	93.499	-.188	93.510	-.176	(-.011)	(.011)
CK 27 D/S RECORDER	1/86	94.127	93.888	-.239	93.897	-.230	93.875	-.252	93.882	-.245	(-.014)	(.008)
FEATURE Check 27 MP 231.73 to Check 28 MP 238.10**												
MILE 232.24B	11/69	92.837	92.647	-.191	92.659	-.179	92.615	-.222	92.637	-.200	(-.022)	(.022)
MILE 232.24A	11/69	97.721	97.542	-.180	97.539	-.183	97.520	-.201	97.532	-.189	(-.007)	(.012)
DMA DQP 10927	12/81	97.110	97.009	-.101	97.023	-.087	96.998	-.112	96.999	-.111	(-.024)	(.001)
MILE 232.96B	11/69	92.775	92.618	-.157	92.635	-.141	92.607	-.169	92.620	-.155	(-.014)	(.014)
MILE 232.96A	11/69	94.397	94.275	-.123	94.258	-.139	94.233	-.165	94.240	-.157	(-.018)	(.007)
MILE 233.56B	11/69	92.748	92.594	-.154	92.604	-.145	92.580	-.169	92.592	-.156	(-.011)	(.013)
MILE 234.10B	11/69	92.696	92.565	-.132	92.564	-.132	92.544	-.153	92.553	-.143	(-.011)	(.010)
MILE 234.10A	11/69	94.314	94.171	-.143	94.188	-.126	94.166	-.148	94.163	-.151	(-.025)	(-.002)
MILE 234.19B	7/00	92.697	92.560	-.137	92.565	-.132	92.549	-.148	92.562	-.135	(-.002)	(.013)
MILE 234.71B	11/69	92.688	92.472	-.216	92.474	-.215	92.442	-.246	92.459	-.229	(-.014)	(.017)
MILE 235.06B	11/69	92.649	92.483	-.166	92.493	-.156	92.451	-.198	92.462	-.187	(-.031)	(.011)
MILE 235.06A	11/69	94.268	94.105	-.163	94.109	-.159	94.074	-.195	94.085	-.183	(-.024)	(.011)
MILE 235.56B	11/69	92.626	92.450	-.177	92.461	-.166	92.417	-.210	92.431	-.195	(-.029)	(.014)
S 1209	11/69	93.328	93.150	-.179	93.187	-.142	93.129	-.200	93.158	-.170	(-.028)	(.029)
MILE 236.27B	11/69	92.581	92.459	-.123	92.479	-.103	92.440	-.142	92.460	-.121	(-.019)	(.020)
MILE 236.27A	11/69	94.184	94.060	-.124	94.067	-.117	94.031	-.153	94.054	-.130	(-.013)	(.023)
MILE 236.47A	11/69	94.823	94.670	-.153	94.680	-.143	94.637	-.186	94.655	-.168	(-.025)	(.019)
MILE 236.56B	11/69	92.534	92.389	-.145	92.378	-.157	92.343	-.192	92.363	-.171	(-.014)	(.020)
MILE 237.00B	11/69	91.713	91.576	-.137	91.575	-.138	91.539	-.174	91.557	-.156	(-.017)	(.019)
MILE 237.50B	11/69	91.668	91.576	-.093	91.577	-.092	91.543	-.126	91.555	-.113	(-.021)	(.013)
MILE 238.00B	11/69	91.641	91.515	-.127	91.522	-.120	91.480	-.162	91.486	-.155	(-.035)	(.007)
MILE 238.00C	11/69	90.706	90.535	-.172	90.544	-.163	90.504	-.203	90.521	-.185	(-.022)	(.017)
MILE 238.06B	11/69	91.679	91.557	-.123	91.572	-.108	91.531	-.148	91.544	-.135	(-.028)	(.013)
MILE 238.06A	11/69	92.451	92.302	-.149	92.318	-.133	92.277	-.174	92.296	-.155	(-.021)	(.020)
MILE 238.10B	11/69	91.630	91.455	-.176	91.463	-.167	91.425	-.206	91.440	-.190	(-.023)	(.016)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
CK 28 U/S RECORDER	1/86	93.091	92.852	-.239	92.862	-.229	92.823	-.268	92.829	-.262	(-.033)	(.006)
MILE 238.10A	11/69	92.528	92.391	-.138	92.389	-.139	92.352	-.177	92.369	-.159	(-.020)	(.017)
CK 28 D/S RECORDER	1/86	93.042	92.794	-.249	92.779	-.263	92.747	-.296	92.758	-.284	(-.021)	(.011)
FEATURE Check 28 MP 238.10 to Check 29 MP 244.53**												
MILE 238.50B	11/69	91.878	91.697	-.182	91.675	-.204	91.652	-.227	91.663	-.215	(-.011)	(.011)
MILE 239.00B	11/69	91.851	91.750	-.102	91.747	-.105	91.703	-.148	91.718	-.133	(-.028)	(.016)
MILE 239.50B	11/69	91.822	91.714	-.109	91.720	-.103	91.687	-.136	91.699	-.123	(-.020)	(.013)
MILE 239.50C	11/69	91.612	91.484	-.128	91.480	-.132	91.442	-.170	91.459	-.153	(-.020)	(.017)
MILE 239.83B	11/69	91.812	91.710	-.102	91.704	-.108	91.665	-.147	91.681	-.131	(-.023)	(.016)
MILE 239.83A	11/69	93.127	93.041	-.087	93.039	-.088	92.997	-.130	93.018	-.109	(-.020)	(.022)
MILE 240.07B	11/69	91.795	91.712	-.084	91.703	-.093	91.658	-.138	91.680	-.115	(-.022)	(.023)
MILE 240.07A	11/69	92.402	92.325	-.077	92.325	-.077	92.281	-.121	92.300	-.102	(-.025)	(.019)
MILE 240.13B	11/69	91.764	91.664	-.100	91.670	-.094	91.624	-.140	91.653	-.111	(-.016)	(.029)
MILE 240.13A	11/69	94.184	94.101	-.084	94.100	-.084	94.048	-.136	94.076	-.108	(-.024)	(.028)
MILE 240.13AA	12/93	93.574	93.439	-.135	93.441	-.133	93.389	-.185	93.414	-.160	(-.026)	(.025)
MILE 240.13C	1/78	93.637	93.613	-.025	93.600	-.038	93.552	-.086	93.573	-.064	(-.027)	(.021)
MILE 240.50B	11/69	91.737	91.625	-.112	91.615	-.122	91.566	-.171	91.590	-.147	(-.025)	(.025)
MILE 240.50C	11/69	91.655	91.447	-.209	91.442	-.213	91.391	-.264	91.417	-.238	(-.025)	(.026)
MILE 241.06B	11/69	91.749	91.575	-.174	91.567	-.182	91.531	-.218	91.562	-.187	(-.005)	(.031)
MILE 241.06A	11/69	94.230	94.059	-.172	94.056	-.175					( )	( )
MILE 241.50B	11/69	91.688	91.550	-.139	91.529	-.159	91.487	-.201	91.508	-.180	(-.021)	(.021)
MILE 242.00B	11/69	91.648	91.488	-.160	91.484	-.164	91.440	-.209	91.455	-.193	(-.029)	(.016)
MILE 242.00C	11/69	91.873	91.695	-.179	91.673	-.201	91.645	-.228	91.668	-.205	(-.004)	(.023)
MILE 242.34B	11/69	91.613	91.396	-.218	91.388	-.225	91.339	-.275	91.376	-.237	(-.011)	(.038)
MILE 242.34A	11/69	93.550	93.369	-.182	93.370	-.180	93.320	-.230	93.348	-.202	(-.022)	(.028)
MILE 242.50B	11/69	91.617	91.475	-.142	91.475	-.142	91.439	-.179	91.446	-.171	(-.029)	(.007)
MILE 242.84B	11/69	91.580	91.357	-.224	91.355	-.225	91.308	-.272	91.331	-.249	(-.023)	(.023)
MILE 242.84A	11/69	92.346	92.133	-.213	92.126	-.221	92.087	-.260	92.106	-.240	(-.020)	(.019)
MILE 243.00B	11/69	91.589	91.472	-.117	91.460	-.129	91.410	-.180	91.443	-.146	(-.017)	(.034)
MILE 243.00A	11/69	93.445	93.330	-.115	93.312	-.133	93.275	-.170	93.291	-.154	(-.020)	(.016)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
P 548	11/69	93.210	93.118	-.092	93.102	-.108	93.062	-.148	93.087	-.123	(-.014)	(.026)
MILE 243.09B	11/69	91.586	91.479	-.108	91.470	-.117	91.427	-.159	91.449	-.137	(-.020)	(.022)
MILE 243.09A	11/69	92.353	92.227	-.126	92.228	-.125	92.184	-.169	92.209	-.144	(-.019)	(.026)
MILE 243.50B	11/69	91.543	91.426	-.118	91.433	-.111	91.384	-.160	91.412	-.131	(-.020)	(.029)
MILE 244.00B	11/69	91.526	91.457	-.069	91.464	-.063	91.423	-.103	91.443	-.083	(-.020)	(.020)
MILE 244.53B	11/69	91.524	91.476	-.049	91.475	-.049	91.432	-.093	91.462	-.062	(-.013)	(.031)
CK 29 U/S RECORDER	8/86	92.723	92.536	-.188	92.533	-.191	92.497	-.227	92.518	-.205	(-.014)	(.022)
MILE 244.53A	11/69	92.439	92.352	-.087	92.347	-.092	92.305	-.134	92.323	-.116	(-.024)	(.018)
CK 29 D/S RECORDER	8/86	92.673	92.485	-.189	92.487	-.186	92.447	-.227	92.477	-.196	(-.010)	(.031)
FEATURE Check 29 MP 244.53 to BUENA VISTA MP 250.99**												
MILE 244.65B	11/69	91.478	91.452	-.026	91.456	-.022	91.412	-.066	91.434	-.044	(-.022)	(.022)
MILE 244.65A	11/69	93.197	93.139	-.058	93.136	-.061	93.091	-.106	93.105	-.092	(-.031)	(.014)
MILE 245.09B	11/69	91.475			91.501	.026	91.444	-.031	91.452	-.023	(-.049)	(.008)
MILE 245.09A	11/69	93.433	93.367	-.067	93.385	-.049	93.332	-.102	93.352	-.081	(-.032)	(.020)
MILE 245.50B	11/69	91.407	91.383	-.024			91.344	-.063	91.372	-.035	( )	(.028)
MILE 246.00B	11/69	91.367	91.257	-.111	91.241	-.127	91.203	-.165	91.228	-.139	(-.013)	(.025)
MILE 246.50B	11/69	91.370	91.271	-.100	91.287	-.084	91.232	-.139	91.257	-.113	(-.029)	(.026)
MILE 246.50A	11/69	93.446	93.265	-.182	93.269	-.177	93.217	-.230	93.234	-.212	(-.035)	(.017)
MILE 247.00B	11/69	91.305	91.099	-.207	91.117	-.189	91.055	-.251	91.081	-.224	(-.035)	(.026)
MILE 247.00C	11/69	90.830			90.660	-.171	90.612	-.218	90.640	-.190	(-.019)	(.028)
MILE 247.50B	11/69	91.292	91.147	-.145	91.155	-.138	91.093	-.200	91.114	-.178	(-.040)	(.022)
MILE 248.00B	11/69	91.261	91.151	-.110	91.169	-.093	91.099	-.162	91.126	-.135	(-.042)	(.028)
MILE 248.13B	11/69	91.255	91.142	-.113	91.167	-.088	91.099	-.156	91.127	-.128	(-.040)	(.028)
MILE 248.13A	11/69	93.543	93.404	-.139	93.408	-.136	93.350	-.194	93.363	-.180	(-.044)	(.013)
MILE 248.50B	11/69	91.244	91.226	-.019	91.234	-.010	91.163	-.082	91.198	-.046	(-.036)	(.035)
MILE 248.50C	11/69	91.054	90.979	-.076	90.994	-.061	90.932	-.123	90.964	-.090	(-.029)	(.032)
MILE 248.97B	11/69	91.190									( )	( )
MILE 248.97B RESET 20	3/16				91.192		91.119		91.146		(-.046)	(.028)
MILE 248.97A	11/69	93.191	93.117	-.075	93.129	-.063	93.073	-.118	93.103	-.088	(-.026)	(.030)
MILE 249.50B	12/81	90.886	90.902	.016	90.912	.026	90.855	-.031	90.869	-.017	(-.043)	(.014)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MILE 249.65B	11/69	90.881	90.854	-.028	90.851	-.031	90.818	-.064	90.835	-.046	(-.016)	(.017)
MILE 249.65A	11/69	92.124	92.096	-.028	92.102	-.022	92.066	-.058	92.071	-.053	(-.031)	(.005)
MILE 249.85B	11/69	90.939	90.921	-.018	90.928	-.011	90.876	-.063	90.891	-.048	(-.036)	(.016)
MILE 249.85A	11/69	91.790	91.762	-.029	91.787	-.004	91.724	-.067	91.734	-.056	(-.053)	(.010)
MILE 250.00B	11/69	90.867	90.861	-.007	90.873	.005	90.813	-.055	90.819	-.048	(-.053)	(.007)
MILE 250.50B	11/69	90.856	90.838	-.018	90.853	-.003	90.794	-.063	90.799	-.057	(-.053)	(.006)
MILE 250.99B	11/69	92.431	92.392	-.039	92.397	-.034	92.354	-.078	92.362	-.069	(-.035)	(.008)
A 1	12/93	94.520	94.401	-.119	94.419	-.102	94.371	-.149	94.375	-.145	(-.043)	(.004)
M 1210	11/69	92.399	92.435	.035	92.433	.034	92.372	-.028	92.399	.000	(-.034)	(.028)
BVPP U/S RECORDER	8/86	93.159									( )	( )
N 1210	11/69	92.468	92.427	-.041	92.455	-.014	92.400	-.068	92.409	-.059	(-.045)	(.009)
FEATURE BUENA VISTA MP 250.99 to Check 31 MP 256.14**												
BV-D	1/86	102.678									( )	( )
BM (UNSTAMPED)	12/81	114.723									( )	( )
TBMX=C-4	8/86	128.510									( )	( )
TBMX-1=C-5	8/86	138.328									( )	( )
2022 RESET 1968	11/69	150.227									( )	( )
MILE 251.14A	11/69	154.861	154.785	-.077	154.785	-.077	154.752	-.109	154.757	-.104	(-.027)	(.006)
GPS BVOW	1/86	154.920	154.778	-.143	154.784	-.136	154.739	-.182	154.747	-.173	(-.037)	(.009)
MILE 251.14B	11/69	153.356	153.296	-.061	153.284	-.073	153.252	-.105	153.263	-.093	(-.020)	(.012)
BVOW D/S RECORDER	8/86	155.094	154.955	-.139	154.963	-.132	154.915	-.180	154.923	-.171	(-.039)	(.009)
MILE 251.50B	11/69	153.377	153.328	-.050	153.320	-.058	153.286	-.092	153.284	-.093	(-.035)	(-.001)
MILE 252.01B	11/69	153.317	153.244	-.074	153.241	-.077	153.207	-.111	153.213	-.104	(-.028)	(.007)
MILE 252.01A	11/69	153.464	153.389	-.076	153.399	-.066	153.351	-.114	153.365	-.099	(-.033)	(.015)
MILE 252.50B	11/69	153.302	153.235	-.067	153.255	-.048	153.196	-.107	153.203	-.099	(-.051)	(.008)
MILE 253.00B	11/69	153.256	153.163	-.094	153.191	-.066	153.118	-.139	153.135	-.121	(-.055)	(.018)
MILE 253.19B	11/69	153.248	153.132	-.117	153.129	-.120	153.090	-.159	153.100	-.148	(-.028)	(.011)
MILE 253.19A	11/69	153.360	153.215	-.146	153.231	-.130	153.183	-.178	153.196	-.164	(-.034)	(.014)
MILE 253.50B	11/69	153.195	153.105	-.091	153.120	-.076	153.067	-.129	153.078	-.117	(-.041)	(.012)
MILE 253.80B	11/69	153.188	153.054	-.135	153.070	-.119	153.017	-.172	153.023	-.165	(-.046)	(.007)
Index numbers			16.1		17.1		18.1		19.1			

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California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

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MILE 253.80A	11/69	155.548	155.401	-.148	155.418	-.131	155.369	-.180	155.373	-.175	(-.044)	(.005)
X 542	11/69	165.780	165.638	-.143	165.670	-.111	165.597	-.184	165.609	-.171	(-.060)	(.013)
E1/4 COR 22/23	11/69	165.619	165.492	-.128	165.486	-.134	165.439	-.181	165.449	-.170	(-.036)	(.011)
MILE 254.11B	11/69	153.178	152.865	-.314	152.883	-.296	152.825	-.353	152.823	-.355	(-.059)	(-.001)
GARDNER	2006	155.250	155.185	-.065	155.192	-.058	155.145	-.105	155.146	-.104	(-.046)	(.001)
MILE 254.11A	11/69	154.727	154.418	-.310	154.418	-.310	154.357	-.371	154.379	-.348	(-.038)	(.023)
MILE 254.50B	11/69	153.979	153.780	-.200	153.788	-.192	153.742	-.238	153.745	-.234	(-.042)	(.004)
MILE 254.85B	11/69	153.921	153.580	-.341	153.595	-.327	153.536	-.386	153.539	-.382	(-.055)	(.004)
L 1210	11/69	154.307	153.961	-.346	153.974	-.334	153.919	-.388	153.926	-.381	(-.047)	(.007)
MILE 255.00B	11/69	153.936	153.654	-.283	153.682	-.255	153.611	-.326	153.615	-.321	(-.066)	(.005)
MILE 255.36B	11/69	153.905	153.667	-.239	153.668	-.238	153.607	-.299	153.622	-.283	(-.045)	(.016)
MILE 255.36A	11/69	154.021	153.770	-.251	153.763	-.258	153.719	-.303	153.713	-.308	(-.049)	(-.005)
MILE 255.77B	11/69	153.861	152.610	-1.251	152.615	-1.247	152.569	-1.292	152.562	-1.299	(-.052)	(-.006)
K 1210	11/69	157.487	156.041	-1.447	156.057	-1.431	156.020	-1.468	156.003	-1.484	(-.054)	(-.017)
MILE 256.11B	1/78	153.649	153.571	-.078	153.579	-.070	153.535	-.114	153.538	-.111	(-.040)	(.004)
CK 31 U/S RECORDER	8/86	154.941	154.761	-.181	154.769	-.173	154.729	-.213	154.725	-.216	(-.043)	(-.004)
MILE 256.11A	11/69	154.559	154.287	-.273	154.267	-.293	154.247	-.313	154.241	-.318	(-.025)	(-.005)
MILE 256.12B	11/69	153.782	153.519	-.264	153.526	-.257	153.487	-.296	153.487	-.295	(-.038)	(.001)
MILE 256.12A	11/69	156.217	155.932	-.286	155.944	-.274	155.898	-.320	155.899	-.318	(-.044)	(.002)
MILE 256.14B	1/78	153.601	153.478	-.124	153.495	-.107	153.450	-.151	153.457	-.144	(-.037)	(.007)
GPS CK 31	1/86	154.487	154.316	-.171	154.324	-.163	154.287	-.200	154.284	-.203	(-.040)	(-.002)
CK 31 D/S RECORDER	8/86	155.039	154.858	-.182	154.882	-.157	154.838	-.202	154.843	-.196	(-.038)	(.006)
FEATURE Check 31 MP 256.14 to Check 32 MP 261.72**												
MILE 256.56B	11/69	153.761	153.201	-.561	153.242	-.520	153.174	-.588	153.160	-.601	(-.081)	(-.013)
J 1210	11/69	157.505	157.037	-.469	157.049	-.457	157.024	-.482	157.003	-.502	(-.046)	(-.020)
MILE 257.00B	11/69	153.746	153.650	-.097	153.681	-.066	153.639	-.108	153.624	-.122	(-.056)	(-.014)
MILE 257.48B	11/69	153.698	153.353	-.346	153.386	-.313	153.342	-.357	153.351	-.347	(-.034)	(.010)
H 1210	11/69	157.256	156.864	-.393	156.888	-.369	156.827	-.430	156.816	-.440	(-.071)	(-.010)
MILE 257.63B	11/69	153.721	153.269	-.453	153.292	-.430	153.212	-.510	153.173	-.548	(-.118)	(-.038)
MILE 257.63A	11/69	153.795	153.319	-.476	153.355	-.441	153.274	-.522	153.260	-.535	(-.094)	(-.013)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

The vertical datum is based on the National Geodetic Vertical Datum of 1929(NGVD 1929), This is the same datum used to construct the state water project.

Units are in meters.

File Name x:\access\CaAqueduct\Kettleman-Edmonston\Ca Aq 2019 Kettleman-Edmonston+LatLong

California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MILE 258.00B	11/69	153.680	153.341	-.340	153.368	-.313	153.307	-.374	153.301	-.379	(-.066)	(-.006)
MILE 258.50B	11/69	153.630	153.167	-.464	153.178	-.453	153.139	-.492	153.135	-.495	(-.042)	(-.004)
MILE 258.59B	11/69	153.631	153.198	-.434	153.210	-.422	153.173	-.459	153.157	-.474	(-.052)	(-.015)
G 1210	11/69	157.222	156.786	-.437	156.778	-.445	156.729	-.494	156.739	-.483	(-.038)	(.011)
MILE 258.61B	12/81	153.345	153.160	-.186	153.172	-.174	153.121	-.225	153.122	-.223	(-.049)	(.002)
MILE 258.61A	12/93	154.174	153.917	-.258	153.908	-.267	153.885	-.290	153.874	-.300	(-.034)	(-.010)
MILE 259.00B	11/69	153.622	153.379	-.244	153.394	-.229	153.354	-.269	153.359	-.263	(-.034)	(.006)
MILE 259.50B	11/69	153.586	153.267	-.320	153.302	-.285	153.240	-.347	153.224	-.362	(-.077)	(-.016)
MILE 259.65B	11/69	153.530	153.140	-.391	153.150	-.381	153.115	-.416	153.104	-.426	(-.045)	(-.010)
MILE 259.65A	11/69	154.188	153.907	-.281	153.916	-.273	153.881	-.308	153.848	-.340	(-.067)	(-.032)
MILE 260.01B	11/69	153.380	153.094	-.287	153.089	-.292	153.065	-.316	153.036	-.344	(-.052)	(-.028)
MILE 260.01A	11/69	153.535	153.218	-.317	153.218	-.317	153.187	-.349	153.162	-.373	(-.055)	(-.024)
MILE 260.44A	11/69	154.170	153.902	-.268	153.901	-.269	153.867	-.304	153.848	-.322	(-.052)	(-.018)
MILE 260.45B	11/69	153.352	153.152	-.201	153.148	-.205	153.112	-.241	153.103	-.249	(-.044)	(-.008)
MILE 260.45A	11/69	153.442	153.146	-.297	153.139	-.304	153.109	-.334	153.093	-.349	(-.046)	(-.016)
MILE 260.50B	11/69	153.398	153.126	-.273	153.110	-.288	153.098	-.301	153.085	-.313	(-.024)	(-.012)
MILE 261.00B	11/69	153.339	153.135	-.205	153.117	-.223	153.102	-.238	153.086	-.253	(-.030)	(-.015)
MILE 261.47B	11/69	153.279	153.045	-.234	153.050	-.230	153.015	-.264	153.015	-.264	(-.035)	(.000)
MILE 261.47A	11/69	153.407	153.155	-.253	153.168	-.240	153.141	-.267	153.133	-.274	(-.034)	(-.007)
CK 32 U/S RECORDER	8/86	154.442	154.190	-.253	154.200	-.243	154.168	-.275	154.167	-.275	(-.032)	(.000)
MILE 261.72B	11/69	153.263	153.058	-.206	153.063	-.201	153.018	-.246	153.020	-.243	(-.042)	(.003)
F 1210	11/69	154.054	153.889	-.166	153.900	-.155	153.858	-.197	153.852	-.202	(-.047)	(-.005)
GPS CK 32	1/86	154.104	153.900	-.205	153.911	-.193	153.863	-.242	153.853	-.251	(-.058)	(-.009)
MILE 261.72A	11/69	154.395	154.198	-.198	154.222	-.174	154.172	-.224	154.153	-.242	(-.069)	(-.018)
CK 32 D/S RECORDER	8/86	154.907	154.700	-.208	154.725	-.183	154.682	-.226	154.666	-.241	(-.058)	(-.016)
FEATURE Check 32 MP 261.72 to Check 33 MP 267.39**												
MILE 262.00B	11/69	153.572	153.440	-.133	153.452	-.121	153.406	-.167	153.396	-.176	(-.055)	(-.010)
MILE 262.50B	11/69	153.567	153.549	-.019	153.566	-.002	153.524	-.044	153.511	-.056	(-.054)	(-.012)
MILE 262.61B	11/69	153.559	153.531	-.029	153.518	-.042	153.496	-.064	153.482	-.077	(-.035)	(-.013)
MILE 262.61A	11/69	155.774	155.733	-.042	155.716	-.059	155.698	-.077	155.686	-.088	(-.029)	(-.011)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

The vertical datum is based on the National Geodetic Vertical Datum of 1929(NGVD 1929), This is the same datum used to construct the state water project.

California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MILE 263.00B	11/69	153.583	153.566	-.018	153.550	-.034	153.542	-.042	153.531	-.052	(-.018)	(-.010)
MILE 263.50B	11/69	153.531	153.494	-.038	153.492	-.040	153.471	-.061	153.455	-.076	(-.036)	(-.015)
MILE 264.00B	11/69	153.492	153.309	-.184	153.328	-.165	153.263	-.230	153.254	-.238	(-.073)	(-.008)
MILE 264.37B	1/78	153.315	153.280	-.035	153.278	-.037	153.253	-.062	153.242	-.073	(-.035)	(-.011)
LOS LOBOS SIPHON	1/78	160.513	160.436	-.077	160.461	-.052	160.394	-.119	160.388	-.125	(-.072)	(-.005)
HPGN STA 06.CLI	6/00	160.376	160.195	-.182	160.195	-.182	160.152	-.225	160.133	-.243	(-.061)	(-.018)
MILE 264.37A	11/69	154.160	154.008	-.153	154.032	-.129	153.983	-.178	153.967	-.193	(-.064)	(-.015)
MILE 264.42A	11/69	154.140	153.930	-.210	153.965	-.176	153.897	-.244	153.892	-.248	(-.072)	(-.004)
MILE 264.50B	11/69	153.366	153.246	-.121	153.283	-.084	153.223	-.144	153.216	-.150	(-.066)	(-.006)
MILE 265.00B	11/69	153.315	153.239	-.077	153.267	-.049	153.226	-.090	153.208	-.107	(-.058)	(-.017)
MILE 265.00C	1/78	151.289	151.275	-.014	151.305	.016	151.257	-.032	151.249	-.040	(-.055)	(-.007)
K 1053	11/69	150.653									( )	( )
MILE 265.50B	11/69	153.256	153.193	-.064	153.193	-.064	153.163	-.094	153.163	-.093	(-.029)	(.001)
MILE 265.50C	1/78	152.028	152.011	-.018	152.019	-.010	151.989	-.040	151.986	-.042	(-.032)	(-.002)
MILE 266.00B	11/69	153.258	153.176	-.083	153.170	-.089	153.150	-.109	153.150	-.108	(-.019)	(.001)
MILE 266.50B	11/69	153.189	153.103	-.087	153.082	-.108	153.083	-.107	153.075	-.114	(-.006)	(-.007)
MILE 266.50C	1/78	151.892	151.869	-.023	151.855	-.037	151.847	-.045	151.845	-.047	(-.009)	(-.001)
MILE 266.91B	11/69	153.183	153.097	-.087	153.088	-.096	153.088	-.096	153.082	-.101	(-.005)	(-.005)
MILE 267.14B	11/69	153.154	153.073	-.082	153.063	-.091	153.069	-.085	153.064	-.090	(.001)	(-.005)
MILE 267.14A	11/69	153.680	153.606	-.075	153.587	-.094	153.590	-.091	153.583	-.097	(-.004)	(-.006)
CK 33 U/S RECORDER	8/86	154.500	154.269	-.232	154.255	-.246	154.259	-.242	154.248	-.252	(-.006)	(-.011)
MILE 267.36A	11/69	153.958	153.850	-.109	153.819	-.139	153.825	-.133	153.837	-.121	(.018)	(.012)
GPS CK 33	1/86	154.081	153.841	-.240	153.823	-.258	153.818	-.263	153.828	-.253	(.006)	(.010)
MILE 267.39A	11/69	153.862	153.749	-.113	153.748	-.115	153.724	-.138	153.734	-.128	(-.013)	(.010)
CK 33 D/S RECORDER	8/86	154.421	154.186	-.236	154.175	-.246	154.171	-.251	154.159	-.262	(-.016)	(-.011)
FEATURE Check 33 MP 267.39 to Check 34 MP 271.27**												
MILE 267.60A	11/69	153.301	153.166	-.135	153.158	-.143	153.142	-.159	153.153	-.148	(-.005)	(.011)
MILE 268.00B	11/69	153.024	152.917	-.107	152.916	-.109	152.898	-.126	152.909	-.115	(-.006)	(.011)
MILE 268.50B	11/69	152.955	152.832	-.123	152.825	-.131	152.834	-.121	152.837	-.118	(.012)	(.003)
MILE 268.54A	11/69	153.383	153.244	-.139	153.226	-.158	153.223	-.160	153.245	-.138	(.020)	(.022)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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Units are in meters.

File Name x:\access\CaAqueduct\Kettleman-Edmonston\Ca Aq 2019 Kettleman-Edmonston+LatLong

California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MILE 268.94B	11/69	152.909	152.743	-.166	152.718	-.191	152.725	-.185	152.758	-.151	(.041)	(.034)
MILE 268.94A	1/78	154.677	154.565	-.112	154.542	-.135	154.546	-.131	154.577	-.100	(.036)	(.032)
MILE 269.30B	11/69	152.885	152.677	-.209	152.678	-.208	152.658	-.227	152.706	-.179	(.029)	(.048)
MILE 269.30A	11/69	153.341	153.129	-.212	153.134	-.208	153.119	-.222	153.153	-.188	(.019)	(.034)
MILE 269.66B	11/69	152.872	152.605	-.267	152.632	-.241	152.600	-.272	152.639	-.233	(.008)	(.039)
MILE 269.66A	11/69	153.320	153.042	-.278	153.061	-.260	153.032	-.288	153.079	-.241	(.019)	(.047)
MILE 270.00B	11/69	152.867	152.536	-.331	152.558	-.310	152.510	-.357	152.579	-.288	(.022)	(.069)
OLD RIVER SIPHONBR	1/78	159.063	158.733	-.330	158.748	-.315	158.690	-.372	158.762	-.301	(.015)	(.072)
MILE 270.16A	11/69	153.800	153.380	-.420	153.395	-.406	153.321	-.479	153.412	-.388	(.018)	(.091)
MILE 270.24A	11/69	153.792	153.349	-.443	153.362	-.431	153.297	-.495	153.372	-.420	(.011)	(.075)
MILE 270.50B	11/69	152.975	152.506	-.470	152.517	-.459	152.440	-.535	152.522	-.453	(.006)	(.082)
MILE 271.00B	1/75	152.793	152.370	-.423	152.380	-.414	152.318	-.475	152.386	-.407	(.007)	(.068)
CK 34 U/S RECORDER	8/86	153.901	153.376	-.526	153.396	-.506	153.328	-.574	153.402	-.499	(.006)	(.075)
E 1210	11/69	153.548	152.832	-.717	152.817	-.732	152.771	-.777	152.834	-.714	(.018)	(.063)
MILE 271.30A	11/69	153.505	152.855	-.651	152.864	-.642	152.837	-.668	152.878	-.627	(.014)	(.041)
CK 34 D/S RECORDER	8/86	153.824	153.340	-.485	153.349	-.476	153.316	-.509	153.356	-.468	(.008)	(.041)
FEATURE Check 34 MP 271.27 to WRidgePP MP 278.13**												
MILE 271.50B	11/69	152.818	152.282	-.537	152.281	-.538	152.262	-.557	152.302	-.516	(.022)	(.041)
MILE 271.85A	11/69	152.839	152.318	-.522	152.320	-.520	152.275	-.565	152.318	-.521	(-.001)	(.044)
MILE 272.00B	11/69	152.784	152.302	-.483	152.299	-.486	152.274	-.511	152.300	-.484	(.002)	(.027)
MILE 272.39B	12/81	152.472	152.244	-.229	152.246	-.227	152.208	-.265	152.244	-.228	(-.001)	(.037)
MILE 272.39A	11/69	153.491	152.966	-.526	152.961	-.531	152.931	-.561	152.955	-.536	(-.005)	(.025)
MILE 272.53A RESET 20	04/13	154.900	154.615	-.286	154.618	-.283	154.581	-.320	154.610	-.290	(-.007)	(.030)
MILE 273.00B	11/69	152.709	152.352	-.358	152.354	-.356	152.327	-.383	152.353	-.356	(.000)	(.027)
MILE 273.09B	11/69	152.707	152.367	-.341	152.355	-.353	152.328	-.380	152.354	-.353	(.000)	(.027)
MILE 273.09A	11/69	153.179	152.835	-.345	152.832	-.348	152.807	-.373	152.823	-.356	(-.008)	(.017)
MILE 273.48A	11/69	152.769			151.591	-1.179	151.586	-1.184	151.568	-1.201	(-.022)	(-.017)
MILE 273.75B	11/69	152.543	152.298	-.246	152.293	-.251	152.249	-.295	152.269	-.274	(-.023)	(.021)
MILE 273.75A	11/69	153.023	152.739	-.285	152.730	-.294	152.688	-.335	152.713	-.310	(-.016)	(.025)
MILE 274.04B	11/69	152.449	152.057	-.393	152.046	-.404	152.001	-.449	152.017	-.432	(-.028)	(.017)
Index numbers			**16.1**		**17.1**		**18.1**		**19.1**			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
D 1210	11/69	156.295	155.753	-.542	155.746	-.549	155.711	-.584	155.729	-.566	(-.016)	(.019)
MILE 274.45A	11/69	154.693	154.120	-.574	154.115	-.579	154.089	-.605	154.101	-.592	(-.013)	(.013)
MILE 274.50B	11/69	152.623	151.937	-.686	151.933	-.691	151.903	-.721	151.913	-.710	(-.019)	(.011)
MILE 275.00B	11/69	152.570	151.884	-.686	151.863	-.708	151.827	-.744	151.821	-.749	(-.041)	(-.005)
MILE 275.50B	11/69	152.507	151.866	-.642	151.870	-.638	151.839	-.669	151.842	-.665	(-.027)	(.004)
MILE 275.56B	11/69	152.517	151.556	-.962	151.536	-.982	151.497	-1.021	151.507	-1.010	(-.028)	(.011)
MILE 275.56A	11/69	155.987	154.959	-1.029	154.954	-1.034	154.926	-1.062	154.933	-1.054	(-.020)	(.007)
MILE 276.00B	11/69	152.499	152.079	-.421	152.070	-.430	152.039	-.460	152.023	-.476	(-.046)	(-.016)
MILE 276.09B	11/69	152.484	152.098	-.387	152.085	-.400	152.066	-.419	152.063	-.421	(-.022)	(-.002)
MILE 276.09A	11/69	153.244	152.866	-.379	152.868	-.377	152.831	-.413	152.832	-.412	(-.035)	(.001)
MILE 276.50B	11/69	152.569	152.348	-.221	152.348	-.221	152.321	-.249	152.322	-.247	(-.025)	(.002)
MILE 276.50A	11/69	155.221							154.975	-.246	( )	( )
MILE 276.71B	11/69	152.448	152.093	-.356	152.106	-.343	152.063	-.386	152.066	-.382	(-.039)	(.004)
MILE 276.71A	11/69	152.760	152.400	-.361	152.405	-.356	152.372	-.388	152.364	-.396	(-.040)	(-.007)
MILE 277.13B	11/69	152.404	151.873	-.532	151.883	-.522	151.855	-.550	151.853	-.551	(-.029)	(-.001)
MILE 277.13A	11/69	155.054	154.506	-.549	154.509	-.546	154.469	-.586	154.472	-.582	(-.036)	(.004)
MILE 277.50B	11/69	152.387	151.998	-.390	152.002	-.386	151.977	-.411	151.977	-.410	(-.024)	(.001)
MILE 277.60B	11/69	152.409	152.076	-.334	152.086	-.323	152.060	-.350	152.060	-.349	(-.025)	(.001)
MILE 277.70B	11/69	152.406	152.140	-.267	152.142	-.265	152.125	-.282	152.121	-.285	(-.020)	(-.003)
MILE 277.80B	11/69	152.462	152.242	-.221	152.250	-.213	152.227	-.236	152.228	-.234	(-.021)	(.002)
MILE 277.90B	11/69	152.445	152.280	-.166	152.291	-.155	152.268	-.178	152.266	-.179	(-.024)	(-.001)
MILE 278.00B	11/69	152.448	152.358	-.091	152.357	-.092	152.340	-.109	152.335	-.113	(-.021)	(-.004)
MILE 278.10B	12/81	153.374	153.308	-.066	153.316	-.058	153.299	-.075	153.290	-.084	(-.025)	(-.008)
WRPP U/S RECORDER	8/86	154.502									( )	( )
C 1210	11/69	153.756	153.639	-.118	153.646	-.111	153.644	-.113	153.639	-.117	(-.006)	(-.004)
B 1210	11/69	153.763	153.656	-.108	153.672	-.092	153.638	-.126	153.645	-.118	(-.026)	(.008)
WR 1R	1/78	153.432	153.391	-.042	153.395	-.038	153.366	-.067	153.376	-.056	(-.018)	(.011)
FEATURE WRidgePP MP 278.13 to WGapPP MP 280.36**												
1046A	1/78	210.699									( )	( )
A 1210	11/69	223.736	223.512	-.225	223.510	-.227	223.507	-.230	223.494	-.242	(-.015)	(-.012)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

The vertical datum is based on the National Geodetic Vertical Datum of 1929(NGVD 1929), This is the same datum used to construct the state water project.

Units are in meters.

File Name x:\access\CaAqueduct\Kettleman-Edmonston\Ca Aq 2019 Kettleman-Edmonston+LatLong

California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
GPS WROW	8/86	225.882	225.597	-.286	225.599	-.284	225.592	-.290	225.581	-.301	(-.017)	(-.011)
MILE 278.40B	1/75	222.815	222.658	-.157	222.662	-.154	222.644	-.172	222.644	-.171	(-.017)	(.001)
MILE 278.47A	1/78	225.798									( )	( )
WROW D/S RECORDE	8/86	227.956	227.677	-.280							( )	( )
MILE 278.80B	1/78	222.835	222.769	-.067	222.769	-.067	222.757	-.079	222.754	-.081	(-.014)	(-.002)
278.80A	1/78	225.461	225.394	-.068	225.395	-.067	225.383	-.079	225.382	-.079	(-.012)	(.000)
MI. 278.93B	1/78	222.822	222.750	-.072	222.753	-.069	222.743	-.079	222.730	-.091	(-.023)	(-.012)
MILE 278.93A	1/78	225.492	225.423	-.070	225.430	-.063	225.414	-.078	225.398	-.094	(-.031)	(-.016)
MILE 279.05B	1/78	222.785	222.691	-.095	222.695	-.091	222.680	-.106	222.671	-.114	(-.023)	(-.008)
MI. 279.05A	11/69	225.079	224.921	-.159	224.924	-.156	224.909	-.171	224.894	-.185	(-.029)	(-.014)
MI. 279.45B	11/69	222.836	222.627	-.210	222.642	-.195	222.622	-.215	222.614	-.222	(-.027)	(-.007)
279.45A	1/78	225.661	225.560	-.102	225.574	-.088	225.556	-.106	225.545	-.116	(-.029)	(-.011)
Z 1209	1/78	226.363	226.251	-.112	226.254	-.109	226.246	-.117	226.213	-.150	(-.040)	(-.032)
MI. 280.06B	11/69	222.813	222.689	-.125	222.700	-.113	222.682	-.131	222.665	-.148	(-.035)	(-.017)
280.06A RESET 1973	1/75	223.653	223.561	-.093	223.567	-.087	223.555	-.099	223.561	-.092	(-.005)	(.007)
280.36B	12/81	223.077	222.995	-.083	223.006	-.072	222.985	-.093	222.982	-.095	(-.023)	(-.002)
WGPP U/S RECORDER	8/86	223.814									( )	( )
Y 1209	11/69	223.094	222.939	-.156	222.977	-.118	222.943	-.151	222.928	-.166	(-.048)	(-.014)
X 1209	11/69	222.931	222.789	-.143	222.792	-.140	222.778	-.154	222.773	-.158	(-.018)	(-.004)
WG 1R	1/78	223.066	222.980	-.086	223.009	-.057	223.006	-.060	222.989	-.077	(-.019)	(-.016)
FEATURE WGapPP MP 280.36 to Check 37 283.98**												
WG B	7/00	236.621	236.435	-.187	236.453	-.169	236.435	-.187	236.431	-.190	(-.021)	(-.003)
UNIT #9	1/78	272.662									( )	( )
3014 A	1/78	282.072									( )	( )
WG F	1/78	294.599	294.515	-.084	294.520	-.079	294.512	-.087	294.502	-.097	(-.017)	(-.010)
WG O	7/00	380.898	380.721	-.178	380.723	-.176	380.707	-.192	380.721	-.177	(-.002)	(.014)
GPS WGOW	1/86	383.570	383.326	-.245	383.325	-.246	383.319	-.252	383.323	-.247	(-.002)	(.004)
MILE 280.74A	1/78	381.483	381.429	-.055	381.415	-.069	381.416	-.068	381.412	-.071	(-.003)	(-.004)
MILE 280.88B	12/93	380.181	379.986	-.195	379.977	-.204	379.978	-.203	379.980	-.200	(.004)	(.002)
WGOW D/S RECORDE	8/86	381.542	381.295	-.247	381.287	-.255	381.280	-.262	381.291	-.251	(.005)	(.011)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MILE 281.16C	1/78	380.987	380.909	-.078	380.918	-.069	380.912	-.075	380.919	-.068	(.001)	(.007)
281.16BB	12/93	380.187	379.988	-.200	379.988	-.200	379.979	-.209	379.977	-.210	(-.011)	(-.002)
MILE 281.16B	1/78	380.030	379.962	-.068	379.959	-.071	379.953	-.077	379.961	-.069	(.002)	(.008)
MILE 281.16A	1/75	382.308	382.219	-.089	382.212	-.096	382.207	-.101	382.219	-.089	(.007)	(.012)
MILE 281.41B	1/75	380.024	379.917	-.107	379.920	-.104	379.910	-.114	379.920	-.104	(.000)	(.010)
MI. 281.41A	1/75	382.638	382.550	-.088	382.541	-.097	382.527	-.111	382.538	-.100	(-.002)	(.012)
MILE 281.78B	1/75	379.988	379.842	-.147	379.841	-.147	379.830	-.159	379.846	-.142	(.005)	(.017)
MILE 281.78A	1/75	382.649	382.489	-.161	382.525	-.125	382.495	-.154	382.497	-.152	(-.027)	(.002)
MILE 282.00B	1/78	379.957	379.711	-.247	379.719	-.239	379.698	-.260	379.709	-.248	(-.010)	(.012)
MI. 282.00A	11/69	382.708	382.386	-.322	382.397	-.312	382.382	-.327	382.383	-.325	(-.014)	(.001)
MI. 282.05B	11/69	380.073	379.890	-.183	379.896	-.177	379.879	-.194	379.891	-.182	(-.005)	(.012)
W 1209	11/69	382.111	381.964	-.147	381.975	-.136	381.958	-.153	381.970	-.141	(-.005)	(.012)
MILE 282 44B	12/81	379.928	379.828	-.100	379.837	-.091	379.823	-.105	379.835	-.093	(-.002)	(.012)
MI. 282.44A	11/69	382.657	382.418	-.239	382.434	-.223	382.424	-.233	382.426	-.231	(-.008)	(.002)
MILE 283.19B	12/81	379.954	379.900	-.054	379.904	-.050	379.886	-.068	379.904	-.050	(.000)	(.018)
MILE 283.19A	1/78	382.572	382.531	-.042	382.527	-.046	382.513	-.060	382.523	-.049	(-.003)	(.011)
V 1209	11/69	382.999	382.909	-.091	382.897	-.103	382.902	-.098	382.897	-.102	(.000)	(-.005)
MILE 283.95B	1/78	379.872	379.826	-.047	379.817	-.056	379.800	-.073	379.820	-.052	(.003)	(.020)
CK 37 U/S RECORDER	8/86	381.483	381.246	-.238	381.250	-.233	381.230	-.253	381.238	-.245	(-.012)	(.008)
MI. 283.95A	11/69	380.643	380.540	-.103	380.530	-.113	380.515	-.128	380.530	-.113	(.000)	(.015)
MILE 283.98A	11/69	380.848	380.736	-.113	380.742	-.106	380.722	-.127	380.732	-.116	(-.010)	(.011)
CK 37 D/S RECORDER	8/86	381.423	381.168	-.255	381.175	-.248	381.160	-.263	381.172	-.251	(-.002)	(.012)
FEATURE Check 37 283.98 to Check 38 MP 287.12**												
MILE 284.80B	1/75	379.769	379.697	-.072	379.700	-.070	379.683	-.087	379.696	-.073	(-.003)	(.014)
MILE 284.80A	1/75	382.539	382.472	-.067	382.467	-.072	382.457	-.082	382.463	-.076	(-.003)	(.007)
CALTRANS HSGT 8126	12/93	381.302	381.067	-.236	381.063	-.240	381.052	-.251	381.064	-.238	(.002)	(.012)
U 1209	11/69	381.955	381.851	-.104	381.852	-.103	381.839	-.116	381.842	-.113	(-.010)	(.003)
MILE 285.00A	1/78	380.455	380.402	-.053	380.394	-.061	380.382	-.073	380.389	-.066	(-.005)	(.007)
MILE 285.70B	1/78	379.661	379.619	-.042	379.613	-.048	379.602	-.059	379.605	-.056	(-.007)	(.004)
MILE 285.70C	1/78	380.476	380.432	-.044	380.419	-.057	380.418	-.058	380.426	-.050	(.007)	(.008)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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Units are in meters.

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California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MILE 285.99B	1/75	379.077	379.027	-.050			379.000	-.077	379.005	-.072	( )	(.005)
MILE 285.99A	1/75	379.238	379.183	-.055	379.171	-.067	379.161	-.077	379.175	-.063	(.005)	(.014)
MILE 287.06B	1/75	379.737	379.719	-.019	379.727	-.011	379.692	-.046	379.706	-.031	(-.020)	(.014)
CK 38 U/S RECORDER	8/86	380.304	380.125	-.179	380.122	-.182	380.096	-.208	380.111	-.193	(-.011)	(.015)
MILE 287.09B	1/75	378.994	378.976	-.019	378.980	-.014	378.948	-.047	378.960	-.034	(-.020)	(.012)
MILE 287.09A	11/69	379.743	379.695	-.048	379.700	-.043	379.672	-.071	379.690	-.053	(-.010)	(.018)
MILE 287.12A	1/75	379.853	379.834	-.019	379.837	-.017	379.810	-.043	379.829	-.024	(-.007)	(.019)
S 1052	11/69	383.688									( )	( )
DOPP STA.10941	12/93	379.272	379.079	-.193	379.075	-.197	379.056	-.216	379.072	-.200	(-.002)	(.017)
CK 38 D/S RECORDER	8/86	380.302	380.102	-.201	380.099	-.204	380.082	-.221	380.090	-.212	(-.009)	(.008)
FEATURE Check 38 287.12 to Check 39 MP 290.21**												
MILE 287.06B	1/78	379.618	379.719	.100	379.727	.108	379.692	.073	379.706	.088	(-.020)	(.014)
MILE 287.60B	1/75	378.926	378.919	-.007	378.918	-.008	378.894	-.032	378.904	-.022	(-.014)	(.010)
287.60C	1/75	375.974	375.981	.007	375.964	-.010	375.939	-.035	375.955	-.019	(-.009)	(.016)
W 1052	11/69	373.749	373.727	-.023	373.726	-.024	373.706	-.043	373.717	-.032	(-.009)	(.011)
MILE 288.27B	1/75	378.897	378.903	.006	378.891	-.006	378.879	-.018	378.891	-.006	(.000)	(.012)
MILE 288.27C	1/75	377.512	377.520	.007	377.507	-.005	377.489	-.024	377.508	-.004	(.001)	(.019)
MILE 288.99B	1/75	378.816	378.826	.010	378.814	-.002	378.803	-.013	378.815	-.001	(.001)	(.012)
MILE 288.99A	1/75	381.786	381.802	.016	381.775	-.012	381.758	-.029	381.776	-.010	(.002)	(.019)
U 1052	11/69	374.630	374.652	.022	374.631	.001	374.614	-.017	374.632	.002	(.001)	(.019)
MILE 289.94B	1/75	378.752	378.783	.031	378.759	.007	378.743	-.010	378.760	.008	(.001)	(.017)
MILE 289.94A	1/75	381.556	381.582	.026	381.549	-.007	381.539	-.017	381.557	.001	(.009)	(.019)
CK 39 U/S RECORDER	8/86	380.173	379.996	-.178	379.977	-.197	379.964	-.209	379.977	-.196	(.000)	(.013)
MILE 290.21B	1/75	378.724	378.767	.043	378.738	.014	378.725	.001	378.734	.010	(-.004)	(.009)
MILE 290.21A	1/75	379.467	379.472	.005	379.473	.006	379.454	-.013	379.471	.004	(-.002)	(.017)
CK 39 D/S RECORDER	8/86	380.125	379.953	-.172	379.930	-.195	379.910	-.215	379.916	-.209	(-.014)	(.006)
FEATURE Check 39 290.21 to AD Edmonstom MP 293.45**												
MILE 290.34B	1/75	378.724	378.709	-.015	378.687	-.037	378.672	-.052	378.685	-.039	(-.002)	(.013)
MILE 290.34A	1/75	381.306	381.321	.015	381.302	-.004	381.284	-.022	381.289	-.017	(-.013)	(.005)
Index numbers			16.1		17.1		18.1		19.1			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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California Aqueduct Kettleman City To Edmonston PP Elevation

Elevations are in Meters

MARK NAME	DATE	INITIAL	2016 GPS	Diff. Vs Init	2017 GPS	Diff. Vs Init	2018 GPS	Diff. Vs Init	2019 GPS	Diff. Vs Init	2019vs2017	2019vs2018
MILE 290.58B	1/75	378.685	378.706	.021	378.685	.000	378.665	-.020	378.683	-.002	(-.002)	(.018)
MILE 290.58A	1/75	381.349	381.379	.030	381.350	.001	381.330	-.019	381.349	.000	(-.001)	(.019)
290.58AA(UNSTAMPED	6/71	383.750	383.802	.052	383.766	.016	383.746	-.004	383.750	.000	(-.016)	(.005)
MILE 291.19B	1/75	378.634	378.694	.060	378.660	.026	378.632	-.002	378.646	.012	(-.014)	(.014)
MILE 291.19A	1/75	381.312	381.380	.067	381.334	.022	381.306	-.007	381.308	-.004	(-.026)	(.002)
MILE 291.26B	1/75	378.664	378.724	.060	378.688	.024	378.664	.000	378.676	.012	(-.012)	(.012)
MILE 291.26A	1/75	379.390	379.442	.052	379.419	.029	379.390	.000	379.406	.016	(-.012)	(.017)
HSGT 8206	12/93	377.486	377.333	-.153	377.324	-.162	377.288	-.198	377.301	-.185	(-.023)	(.013)
MILE 292.11B	1/75	378.596	378.650	.053	378.634	.038	378.602	.005	378.613	.017	(-.021)	(.012)
MILE 292.11A	1/75	380.340	380.391	.051	380.386	.046	380.345	.005	380.352	.012	(-.034)	(.007)
MILE 292.11AA	12/81	380.352	380.400	.048	380.381	.029	380.344	-.008	380.354	.002	(-.027)	(.010)
Y 1219	6/71	378.436	378.541	.105	378.521	.085	378.474	.038	378.487	.051	(-.034)	(.014)
B 1059	6/71	353.154									( )	( )
MILE 293.07B	6/71	378.430	378.538	.107	378.524	.093	378.468	.037	378.484	.054	(-.040)	(.016)
MILE 293.07C	6/71	378.968	379.056	.087	379.034	.065	378.983	.014	378.994	.026	(-.039)	(.012)
MILE 293.39B TPP	1/78	379.774									( )	( )
MILE 293.39B TPP RES	7/00	380.251	380.134	-.117	380.117	-.134	380.068	-.183	380.075	-.176	(-.042)	(.007)
EPP 1L	6/71	379.938	380.008	.070	380.015	.077	379.983	.045	379.971	.034	(-.043)	(-.012)
EPP 1R	6/71	379.342	379.423	.081	379.394	.052	379.373	.031	379.380	.038	(-.014)	(.007)
EP U/S RECORDER Hilt	8/86	380.152									( )	( )
ESB 1246.5	6/71	379.922									( )	( )
WSB 1246.5	6/71	379.925									( )	( )
FEATURE PASTORIA CREEK Hilltie**												
R 1052	11/69	380.959	381.009	.050	381.016	.057	380.989	.029	380.988	.029	(-.028)	(.000)
Q 1052	11/69	437.389	437.468	.079	437.450	.060	437.424	.034	437.440	.051	(-.010)	(.017)
P 1052	11/69	439.933	440.004	.071	439.998	.065	439.981	.048	439.978	.045	(-.019)	(-.002)
FEATURE EDMONSTON Hilltie**												
Z 1219	6/71	425.778	425.632	-.147	425.628	-.151	425.592	-.187	425.585	-.193	(-.043)	(-.007)
SW 2	6/71	425.477									( )	( )
Index numbers			**16.1**		**17.1**		**18.1**		**19.1**			

Control Bench Marks C 926 Elevation = 88.6879 Meters Fixed(Dos Amigos). Y 1159 Elevation 264.9335(mean of 2017-2019) Held for Kettleman City to Edmonston based on C 926.

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California Aqueduct Kettleman City To Edmonston PP Elevation

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D 1059	6/71	451.332	451.161	-.171	451.159	-.173	451.158	-.174	451.159	-.173	(.000)	(.001)
E 1220	6/71	490.925	490.787	-.139	490.766	-.159	490.733	-.192	490.742	-.183	(-.024)	(.010)
HSGT 8187	12/93	551.638	551.514	-.125	551.470	-.169	551.458	-.180	551.466	-.172	(-.004)	(.008)
F 1220	6/71	552.062									( )	( )
F 1059	6/71	607.820	607.696	-.125	607.683	-.138	607.658	-.163			( )	( )
DL 1A	6/71	619.895			619.756	-.139	619.718	-.178			( )	( )
DL 2A	12/93	645.876			645.716	-.161	645.672	-.205			( )	( )
H 1059	6/71	790.198			790.089	-.109	790.041	-.157			( )	( )
G 1220	6/71	874.621	874.536	-.085	874.536	-.085	874.536	-.085			( )	( )

Index numbers 16.1 17.1 18.1 19.1

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Appendix J

Board Resolution

BEFORE THE BOARD OF DIRECTORS OF
WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT

IN THE MATTER OF: **RESOLUTION NO. 2019-18**

RESOLUTION APPROVING MANAGEMENT AREA PLAN FOR WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT MANAGEMENT AREA

WHEREAS, the Kern Groundwater Authority (the "Authority") is duly formed and existing under and pursuant to that certain Second Amended and Restated Agreement Joint Powers Agreement (the "JPA"), for the purposes of carrying out the Sustainable Groundwater Management Act (Water Code § 10720 *et seq.*) (SGMA), including the development, adoption and implementation of a Groundwater Sustainability Plan (GSP) for lands within the boundaries of the Authority's members and elsewhere within the Tulare Lake Groundwater Basin;

WHEREAS, the District is a member of the Authority;

WHEREAS, pursuant to Section 7.01 of the JPA, the District has exercised its option under the JPA to develop a chapter governing SGMA implementation within the boundaries of the District for inclusion in the Authority's GSP, which is titled *Groundwater Sustainability Plan-* Wheeler Ridge-Maricopa *Water Storage District Management Area* (the "WRMWSD Chapter"); and,

WHEREAS, the District has conducted public outreach, solicited public input on, and, as appropriate, has responded and/or will respond to public comments on, the WRMWSD Chapter as required under SGMA; and

WHEREAS, following such outreach, solicitation and response, the District's Board of Directors reviewed and evaluated the WRMWSD Chapter.

NOW, THEREFORE, THE BOARD OF DIRECTORS OF THE WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT does hereby resolve, declare and order as follows:

1) Each of the matters set forth above is true and correct and the Board so finds and determines.

2) The Board finds that the WRMWSD Chapter is consistent with the requirements of SGMA, and pursuant to Section 2.03(b) of the JPA approves the Chapter for inclusion in the Authority's GSP.

3) The Board hereby authorizes District staff to undertake such actions as are necessary and appropriate to transmit the WRMWSD Chapter to the Authority and to present the WRMWSD Chapter to the Authority's Board of Directors for consideration of inclusion in the Authority's GSP.

ALL THE FOREGOING being on motion of Director Reiter, seconded by Director Marin, and authorized by the following vote, to wit:

AYES: Atkinson, Blaine, Fry, Marin, Mettler, Reiter, Richardson.

NOES: None.

ABSTAIN: None.

ABSENT: Valpredo.

I HEREBY CERTIFY that the foregoing resolution is the resolution of said District as duly passed and adopted by said Board of Directors on the 11th day of December 2019.

WITNESS my hand and seal of said Board of Directors this 11th day of December 2019.

(District Seal)

Mark Valpredo
Vice-President of the Board of Directors

KERN

GROUNDWATER AUTHORITY





Groundwater Sustainability Plan

Kern County, CA



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Kern Groundwater Authority

Groundwater Sustainability Plan

Kern County, CA

January 2020

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7. North Kern Water Storage District & Shafter-Wasco Irrigation District
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11. Southern San Joaquin Municipal Utility District
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13. West Kern Water District
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List of Abbreviations

µmhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter
AB	Assembly Bill
AF	Acre-Feet
Al/Fe-	Aluminum- and Iron-Bearing
AOI	Area of Interest
BGS	Below Ground Surface
BMP	Best Management Practices
BMSL	Below Mean Sea Level
BVARA	Buena Vista Aquatic Recreation Area
C&E	Communications and Engagement Plan
CASGEM	California Statewide Groundwater Elevation Monitoring Program
CDFW	California Department of Fish and Wildlife
CGPS	Continuous Global Positioning System
CIWQS	California Integrated Water Quality System
Cr3	Trivalent Chromium
Cr6+	Hexavalent Chromium
CUP	Conditional Use Permit
CVP	Central Valley Project
CVPIA	Central Valley Improvement Act of 1992
CVRWQCB	Central Valley Regional Water Quality Control Board
CWC	California Water Code
DBCP	Dibromochloropropane
DDW	Division of Drinking Water
DOGGR	Division of Oil, Gas, and Geothermal Resources
DTSC	Department of Toxic Substances
DTW	Depth to Water
DWR	California Department of Water Resources
ESA	European Space Agency
GAMA	Groundwater Ambient Monitoring and Assessment Program
GDE	Groundwater Dependent Ecosystems
GPM	Gallons per Minute
GPS	Global Positioning System
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWE	Groundwater Elevation
HCM	Hydrogeologic Conceptual Model
HMWD	Henry Miller Water District
HR2W	Human Right to Water
ID4	Improvement District 4

ILRP	Irrigated Lands Regulatory Program
InSAR	Inferometric Synthetic-Aperture Radar
IRWM	Integrated Regional Water Management Plan
JPA	Joint Powers Agreement
JPL	Jet Propulsion Laboratory
KCWA	Kern County Water Agency
KDWD	Kern Delta Water District
Kern Fan	Kern Alluvial Fan
KGA	Kern Groundwater Authority
KGET	Kern Golden Empire Television
KRGSA	Kern River Groundwater Sustainability Agency
KRWCA	Kern River Watershed Coalition Authority
LANDSAT	Land Remote-Sensing Satellite
LSCE	Luhdorff & Scalmanini Consulting Engineers
LUST	Leaking Underground Storage Tank
MA	Management Area
Mc	Fanglomerate
MCL	Maximum Contaminant Level
mg/l	Milligrams Per Liter
MGSA	McFarland Groundwater Sustainability Agency
MIT	Mechanical Integrity Test
msl	Mean Sea Level
NASA	National Aeronautics and Space Administration
NCCAG	Natural Communities Commonly Associated with Groundwater
NHD	National Hydrography Dataset
NHI	Nitrate Hazard Index
NKWSD	North Kern Water Storage District
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PPB	Parts per Billion
PPT	Parts per Trillion
RPE	Reference Point Elevation
RWQCB	Regional Water Quality Control Board
SAGBI	Soil Agricultural Groundwater Banking Index
SB	Senate Bill
SDWIS	State Drinking Water Information System
SGMA	Sustainable Groundwater Management Act
SMCL	Secondary Maximum Contaminant Level
SOPAC	Scripps Orbit and Permanent Array Center
SpC	Specific Conductance
SSJMUD	Southern San Joaquin Municipal Utility District
SSURGO	Soil Survey Geographical Database

Subbasin	Kern County Subbasin
SWP	State Water Project
SWRCB	State Water Resources Control Board
TCP	1,2,3-trichloropropane
TDS	Total Dissolved Solids
TNC	The Nature Conservancy
UAVSAR	Unmanned Aerial Vehicle Synthetic Aperture Radar
UIC	Underground Injection Control
UNAVCO	Unmanned Aerial Vehicle Synthetic Aperture Radar
USDA	United States Department of Agriculture
USDW	Underground Source of Drinking Water
USGS	United States Geological Survey
UST	Underground Storage Tank
WDR	Waste Discharge Requirements

Executive Summary

The Kern Groundwater Authority (KGA) Groundwater Sustainability Agency (GSA) covers approximately 1.2 million acres of the Kern County Subbasin's (Subbasin) approximate 1.8 million acres, as defined by the California Department of Water Resources (DWR) Bulletin 118 (see Figure E-1). DWR has identified the Kern Subbasin as a "critically overdraft basin". The Kern Groundwater Authority includes 16 member entities made up of water districts/agencies, groundwater banking projects, and organized nondistricted lands. The 16 member entities also constitute the KGA Board, with one representative from each member entity. Its boundary stretches along the northwest, northeast, and southern parts of the Subbasin. The KGA was formed for the purpose of:

- Coordinating groundwater management programs and activities;
- Identifying and addressing issues pertaining to sustainable groundwater management;
- Establishing a framework for local groundwater management; and
- Coordinating with other GSAs in the Subbasin.

The KGA provides, through a Joint Powers Agreement, each member the sole right and responsibility to implement SGMA within its respective boundaries and/or management areas, in a manner determined by the member. However, the implementation actions can not interfere with the surrounding members or GSAs in their ability to comply with SGMA. The KGA, as such, provides the critical mechanism for coordination of SGMA related activities between its members as well as with the other GSAs in the Subbasin.

The Subbasin includes 11 organized GSAs. Of these, six GSAs have elected to be included in the Groundwater Sustainability Plan (GSP) of the KGA and two are included in the Kern River Groundwater Sustainability Agency GSP. Three additional district-specific GSPs have been prepared in the Subbasin by Buena Vista Water Storage District, Henry Miller Water District, and Olcese Groundwater Sustainability Agency. The five GSAs submitting GSPs have coordinated throughout the development of the GSPs in the Subbasin as indicated in the executed Coordination Agreement and will continue through the implementation of the GSPs.

Kern County produces a wide variety of crops on approximately 900,000 acres, making it a major contributor to California's agricultural economy. One important honor that Kern County is known for is its agricultural industry ranking. Kern County is currently ranked the #1 agricultural producing county in the United States and has been for the last three years with gross value of all agricultural commodities produced in 2017 estimated at $7.25 billion. The top five commodities are grapes, almonds, citrus, milk, and pistachios, which make up more than $4.5 billion (63 percent) of the total value. With this, Kern County agriculture is the largest employer in the region with 1 in every 5 jobs related to agriculture. The communities, economy, and local governments are and have been reliant on Kern County agriculture and are dedicated to preserving the viability of agriculture into the future.

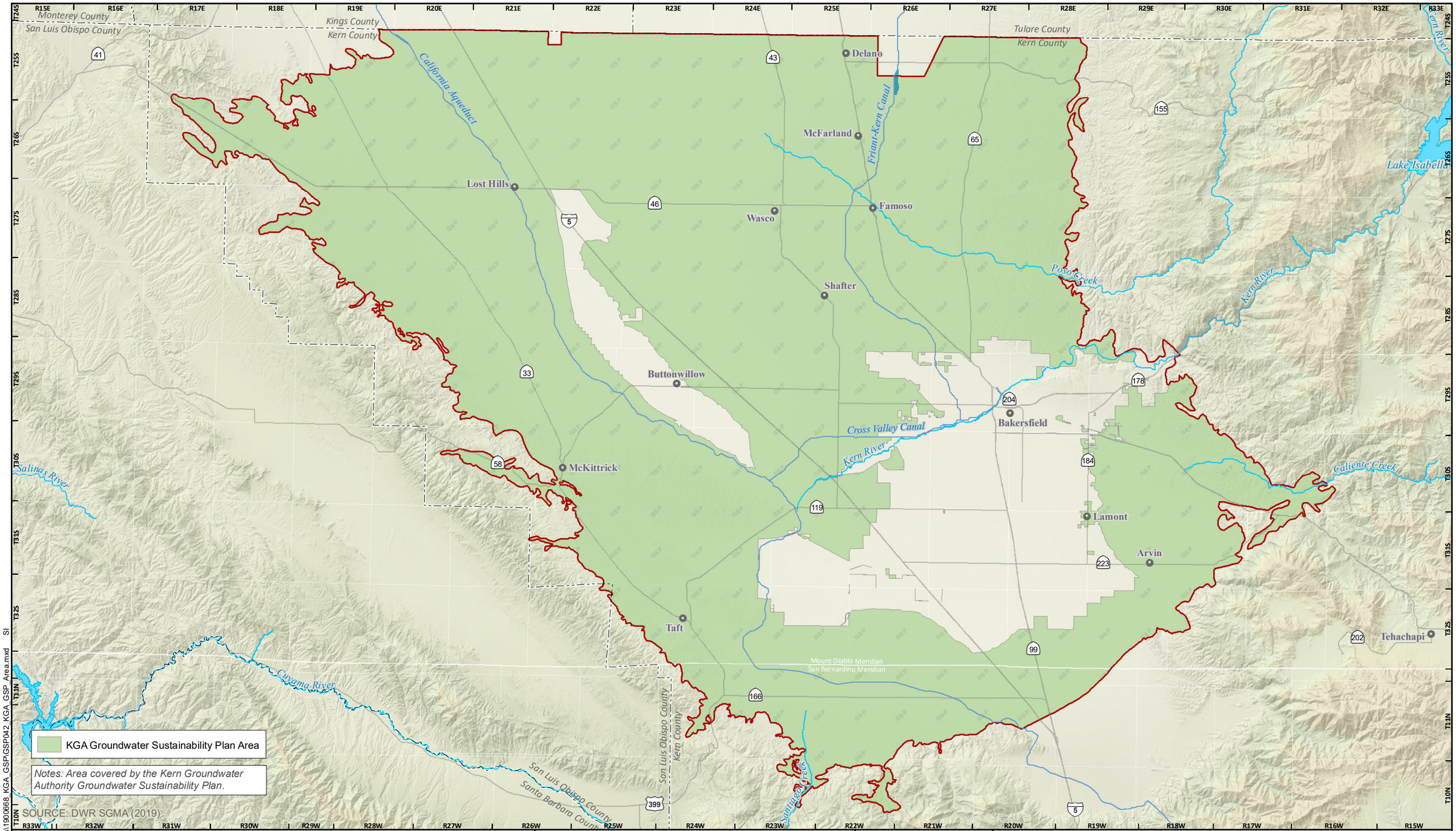
As stated, all the GSAs in the Subbasin have coordinated and collaborated on the development of water modeling budgets (historical, baseline and projected) in the Subbasin. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions, as described in this GSP. Subbasin-wide water budget results from the numerical model-based water budget show the Subbasin, as a whole, has an overdraft of 324,326 acre-feet per year over the baseline conditions of which the KGA is approximately 256,281 of the deficit.

In response to this level of overdraft the KGA members, in coordination with the other GSAs in the Subbasin, have developed Subbasin-wide Sustainable Management Criteria. This includes required Measurable Objectives and Minimum Thresholds for the Sustainability Indicators relevant to the specific management areas of the Subbasin to protect against the occurrence of Undesirable Results that would cause unreasonable impacts the beneficial users and uses of groundwater in the Subbasin.

The KGA members have sources of water supplies such as local streams (Caliente, Poso Creek), Kern River, State Water Project and Central Valley Project sources. Each member addresses their own individual water supply sources in greater detail in their individual management area plans along with how the beneficial users in their jurisdiction will participate in achieving sustainability.

The KGA members have also identified more than 150 projects and management actions ranging from expansion of local and regional conveyance and recharge facilities to take advantage of surplus supplies; new conveyance and recharge projects; and participation in the California WaterFix or other thru-Delta improvement projects. Management actions range from implementing district level fee structures to incentive reduced groundwater pumping; participation in local, regional, and state-wide water markets; and setting allocation for groundwater use by landowner, based on the sustainable yield of management areas.

The coordinated modeling effort shows that implementation and completion of the identified projects and management actions during the implementation period of 2020 to 2040, as stated in the individual management area plans and GSPs from the other GSAs in the Subbasin, would result in an average surplus of 85,578 acre-feet per year over the projected baseline condition simulation.



Kern Groundwater Authority
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

KERN GROUNDWATER AUTHORITY GROUNDWATER SUSTAINABILITY PLAN AREA

JANUARY 2020

FIGURE ES-1

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1 Introduction

The Kern County Subbasin is located at the southern end of the San Joaquin Valley and is known for its rich soil and Mediterranean-like climate, which has made Kern County one of the top producing agriculture regions in the nation. The Kern County Subbasin (Subbasin) is bounded by the Kern County Line and the Tule Groundwater Subbasin on the north; the granitic bedrock of the Sierra Nevada foothills on the east; the Tehachapi mountains on the southeast; and by the marine sediments of the San Emigdio Mountains and Coast Ranges on the southwest and west (DWR, 2006).

California is the nation's largest agricultural producer and is the nation's sole exporter of many agricultural commodities, supplying nearly 99 percent of the almonds, artichokes, and garlic. Recent study by the University of California (November 2019) highlighted the contribution of agriculture to California's economy. Agricultural production, agricultural support, agricultural distribution, and agricultural processing employ nearly 1.2 million people and generated approximately $264 billion in sales in 2018. The San Joaquin Valley is the major contributor to California agricultural economy as can be shown in Table 1-1.

Table 1-1: San Joaquin Valley Contribution to California's Agricultural Economy (2018)

	Agricultural Production	Agricultural Support	Agricultural Distribution	Agricultural Processing
San Joaquin Valley				
Jobs	131,700	116,900	33,700	62,900
Earnings ($ billion)	$6.5	$4.2	$1.9	$4.0
Sales ($ billion)	$24.0	$7.7	$6.4	$31.7
California				
Jobs	325,200	320,000	304,00	245,000
Earnings ($ billion)	$16.2	$18.0	$17.8	$16.0
Sales ($ billion)	$61.0	$32.0	$57.4	$113.0

Sources: California's Working Landscapes, University of California, November 2019

In Kern County a wide variety of crops are produced on approximately 900,000 acres, making it a major contributor to California's agricultural economy. One important honor that Kern County is known for is its agricultural industry ranking. Kern County currently is ranked the #1 agricultural producing county in the United States and has been for the last three years with gross value of all agricultural commodities produced in 2017 estimated at $7.25 billion (Kern County Department of Agriculture and Measurement Standards, 2018). The top five commodities are grapes, almonds, citrus, milk, and pistachios, which make up more than $4.5 billion (63 percent) of the total value. With this, Kern County agriculture is the largest employer in the region with 1 in every 5 jobs related to agriculture. The communities, economy, and local governments are and have been reliant on Kern County agriculture and are dedicated to preserving the viability of agriculture into the future.

Bulletin 118 published by California Department of Water Resources (DWR) in January 1980 states that "The Kern County Water Agency, which covers the Kern County Basin, presently receives about half of its maximum annual entitlement from the State Water Project. If no new lands were to go into production, and the full entitlement from the State Water Project were delivered today, there would be no overdraft in Kern County as a whole." Harvested acres in Kern County have remained relatively steady at an average of 858,000 acres a year with only a 10 percent annual fluctuation from that average between 1980 and 2017.

Since the operation of the State Water Project (SWP) in 1968 until 2007, SWP contractors received on average 86 percent of their entitlement. However, in May 2007, Federal Judge Oliver Wagner overturned a federal scientific study that aimed to protect Delta Smelt in the Sacramento-San Joaquin Delta (Delta) resulting in curtailing Delta export pumping operations to protect the continued existence of the fish. In addition, the State of California experienced a historic extended drought from 2012 to 2016. As a result, SWP contractors received on an average only 48 percent of their entitlement from 2008 to 2016.

Despite the reduction in SWP deliveries, the groundwater overdraft in the entire Subbasin declined from 600,000 acre-feet per year in 1980 (Bulletin 118-80) to a current estimate of 324,300 acre-feet in 2015 (Todd, 2019). This decrease in amount of overdraft per year was achieved through change in crop patterns; increase in agriculture efficiency; and increase in conjunctive use and banking projects throughout the Subbasin.

The current baseline condition estimates that the Subbasin has an average annual overdraft of 324,326 acre-feet per year (Todd, 2019 projected water model). However, with the proposed projects and management actions slated for development and implementation in the Subbasin, it is forecasted that the Subbasin will achieve sustainability by 2040 with an estimated 42,144 acre-feet of annual surplus (see Attachment H). The projects and management actions are described in this Groundwater Sustainability Plan (GSP) and the individual management area plans, attached to this GSP, and the 4 other GSPs prepared within the Subbasin. Collectively, the projects and management actions currently proposed provide a reasonable approach for sustainable management of the groundwater Subbasin and can be adaptively managed to meet future challenges as necessary.

1.1 Sustainable Groundwater Management Act

During the height of the last drought in 2014, the State Legislature passed the Sustainable Groundwater Management Act (SGMA), which consists of a three-bill package of Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley) and SB 1319 (Pavley). SGMA as it is called, provides for the local control of groundwater resources while requiring the sustainable management of that groundwater resource. One of the first requirements under the SGMA law was to form/establish a local governance body called a Groundwater Sustainability Agency (GSA) with the local authority to develop, adopt, and implement a GSP. GSPs must document monitoring conditions and establish management criteria to avoid undesirable results and identify potential actions which either maintain and/or achieve sustainable groundwater management by 2040 or 20 years from the date of the adoption of the GSP. The KGA, through a

Joint Powers Agreement, is a recognized GSA in the Subbasin for the purpose of developing a GSP.

Sustainable management of groundwater is defined under SGMA as the "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results" (California Water Code (CWC) Section 10721(v)). The undesirable results under SGMA include the significant and unreasonable lowering of groundwater levels; loss of groundwater storage and supply; degradation of water quality; land subsidence; surface water depletion; and sea water intrusion.

Further, under the SGMA law, water basins throughout California were determined or classified to be of "high" or "medium" priority by DWR. The Subbasin was determined or classified to be a "high" priority basin, which triggers the requirement of submittal of its GSP by January 31, 2020.

1.2 Purpose of the Groundwater Sustainability Plan

The purpose of this GSP is to comply with SGMA and serve as a comprehensive foundation for groundwater management within areas of the Subbasin covered by the Kern Groundwater Authority (KGA) by providing information on the current groundwater conditions; establishing the sustainability goals to be achieved through the implementation of management actions and projects; and demonstrating how sustainability will be achieved through the 20-year implementation period.

In the Subbasin, there are four other established GSAs who are submitting GSPs: the Kern River Groundwater Sustainability Agency (KRGSA), Buena Vista Water Storage District (BVGSA), Henry Miller Water District (HMGSA), and Olcese Groundwater Sustainability Agency (Olcese GSA).

Throughout the development process for this GSP, the KGA has considered and coordinated with the other four GSAs in the Subbasin to comply with the requirement of developing and utilizing consistent data and methodologies throughout the Subbasin, especially the development of a basin-wide basin setting. Additionally, the GSAs within the Subbasin coordinated the respective elements of their GSPs necessary for achieving the sustainability goals for the Subbasin.

1.3 Sustainability Goal

Under Section 354.24 of the GSP emergency regulations, each agency shall establish in its GSP a sustainability goal for the basin that culminates in the absence of undesirable results within 20-years of the applicable statutory deadline. This GSP and the GSPs of the other GSAs in the Subbasin have collaborated on the development of the following sustainability goal for the Kern County Subbasin.

The sustainability goal of the Kern County Subbasin is to:

- *Achieve sustainable groundwater management in the Kern County Subbasin through the implementation of projects and management actions at the member agency level of each GSA.*
- *Maintain its groundwater use within the sustainable yield of the basin as demonstrated by monitoring and reporting groundwater conditions.*
- *Operate within the established sustainable management criteria, which are based on the collective technical information presented in the GSPs in the Subbasin.*
- *Collectively bring the Subbasin into sustainability and to maintain sustainability over the implementation and planning horizon.*

1.4 Agency Information

In complying with Section 354.6 of the GSP emergency regulations, the following section provides agency information, legal authority, and estimated cost of plan implementation for the KGA and its members in the Subbasin.

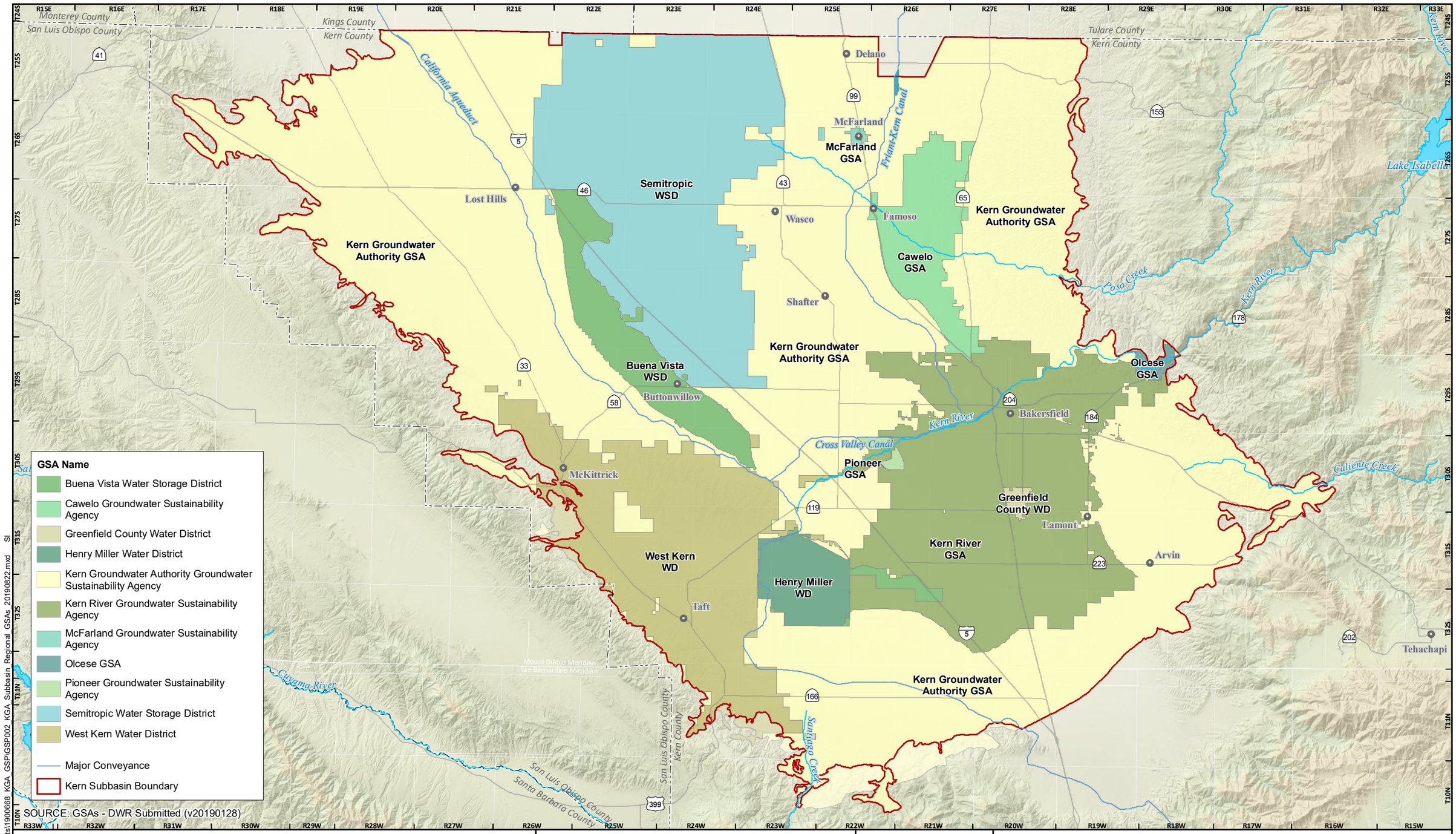
Agency's Name:	Kern Groundwater Authority
Agency's Address:	1800 30th Street, Suite 280
Agency's Phone Number:	(661) 479-7171
Agency's Website:	http://www.kerngwa.com/index.html
Contact Person:	Patty Poire
Contact Person's Title:	Planning Manager, KGA

1.4.1 Organization and Management Structure of the KGA GSA

The Subbasin includes 11 organized GSAs, as shown in Figure 1-1. Of these, several GSAs have elected to be included in the GSP of either the KGA or the KRGSA. Table 1-2 indicates if the GSA have elected to prepare an independent GSP or if they are part of either the KGA or KRGSA. In total, 11 GSAs in the Subbasin are developing five GSPs.

Table 1-2: Groundwater Sustainability Agencies in Kern County Subbasin

GSA Name	Independent GSP	GSP Name
Buena Vista Water Storage District	Yes	BVGSA GSP
Henry Miller Water District	Yes	HMWD GSA GSP
Cawelo Groundwater Sustainability Agency	No	KGA GSP
Kern Groundwater Authority	Yes	KGA GSP
McFarland Groundwater Sustainability Agency	No	KGA GSP
Pioneer Groundwater Sustainability Agency	No	KGA GSP
Semitropic Water Storage District	No	KGA GSP
West Kern Water District	No	KGA GSP
Greenfield County Water District	No	KRGSA GSP
Kern River Groundwater Sustainability Agency	Yes	KRGSA GSP
Olcese GSA	Yes	OGSA GSP



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

GROUNDWATER SUSTAINABILITY AGENCIES WITHIN KERN COUNTY SUBBASIN

AUGUST 2019

FIGURE 1-1

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The KGA, as a Subbasin coordination group, was created prior to the enactment of SGMA with the intent of establishing a framework for the coordinated management of the groundwater basin underlying the San Joaquin Valley portion of Kern County, including the preservation and maintenance of local control over groundwater resources and to provide future certainty for basin users. With the passage of SGMA, the KGA elected to form a GSA under a Joint Powers Agreement (JPA) (Attachment A), thereby assuming responsibility for development of a comprehensive GSP for an area which includes agricultural lands, urban and industrial development as well as oil fields.

The KGA GSA covers approximately 1.2 million acres of the Subbasin's approximate 1.8 million acres and includes 16 member agencies (Table 1-3 and Figure 1-2). The 16 member agencies also constitute the KGA Board, with one representative from each agency. Its boundary stretches along the northwest, northeast, and southern parts of the Subbasin. The KGA also includes a single associate member, the Eastside Water Management Authority, who consistent with SGMA, is a non-voting member of the GSA and represents lands outside of a KGA member agency boundary.

Table 1-3: Kern Groundwater Authority Member Agencies

Member Agencies	
Arvin Community Serviced District	Rosedale-Rio Bravo Water Storage District
Arvin-Edison Water Storage District	Semitropic Water Storage District[1]
Cawelo Water District[1]	Shafter-Wasco Irrigation District
City of Shafter	Southern San Joaquin Municipal Utility District
Kern County Water Agency - Pioneer Project[1]	Tejon-Castac Water District
Kern-Tulare Water District	West Kern Water District[1]
Kern Water Bank Authority	Westside District Water Authority
North Kern Water Storage District	Wheeler Ridge-Maricopa Water Storage District
Associate Members	
Eastside Water Management Authority	

1 – Groundwater Sustainability Agency

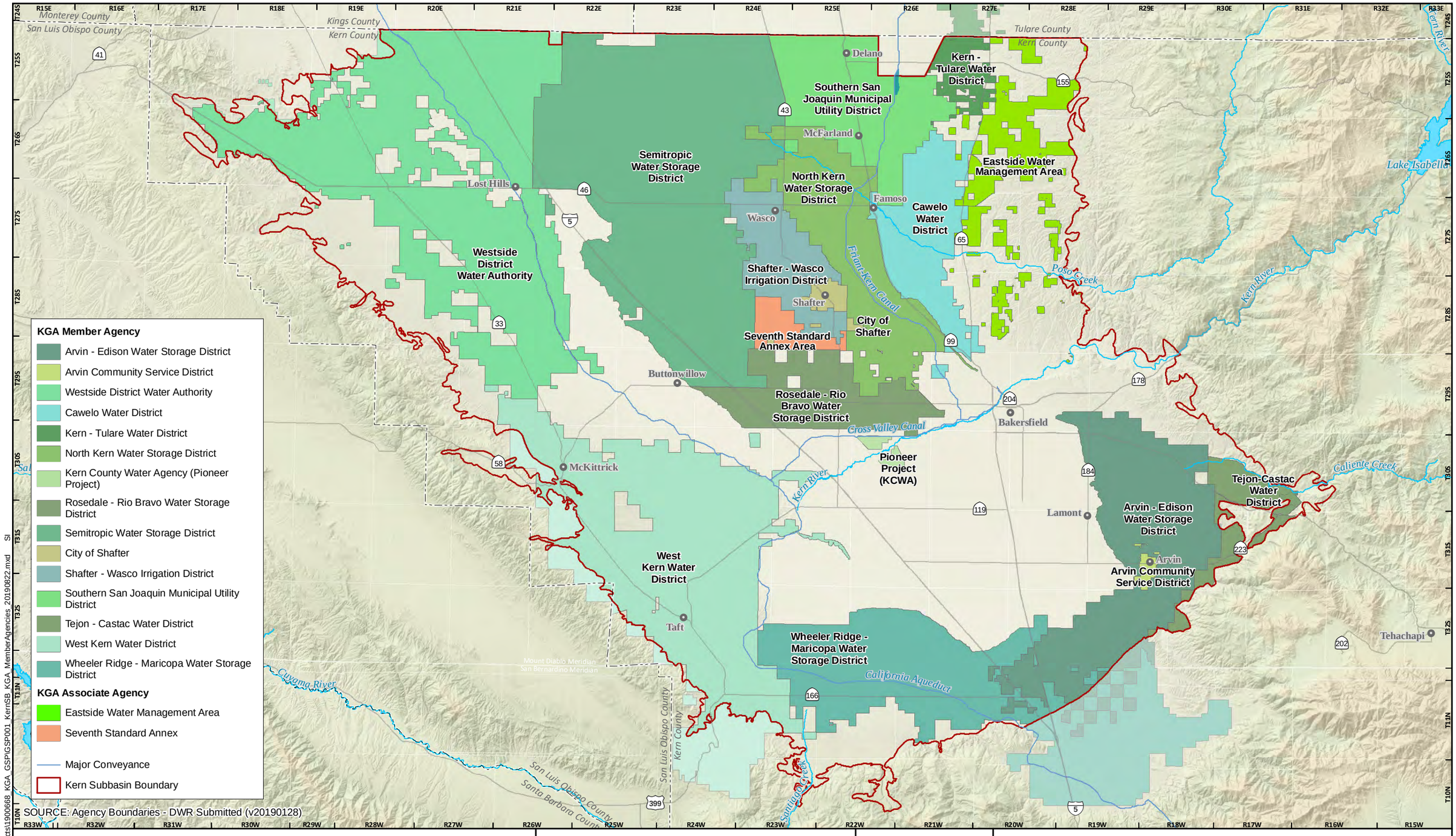
At the inception of the KGA, Kern County was a member of the KGA to represent lands within the Subbasin and outside of the jurisdiction of a local agency participating in a GSA in the Subbasin – non-districted lands. However, in December 2018, Kern County supervisors elected to withdrawal from the KGA and from that action, approximately 440,950 acres of non-districted lands became not covered by a GSA (Figure 1-3). At the December 19, 2018 KGA Board meeting, the direction provided by the Board was to reach out to the non-districted landowners and extend coverage; however, those non-districted landowners who are not wanting to participate will be eventually removed from the KGA GSA boundary and will then be required to report directly to the State Water Resources Control Board (State Water Board). The KGA reached out to those landowners via a mass mail-out to advise of the County's decision and extended the opportunity to participate in SGMA through the member agencies of the KGA. The coverage to the non-districted lands was handled by the landowners entering into agreements

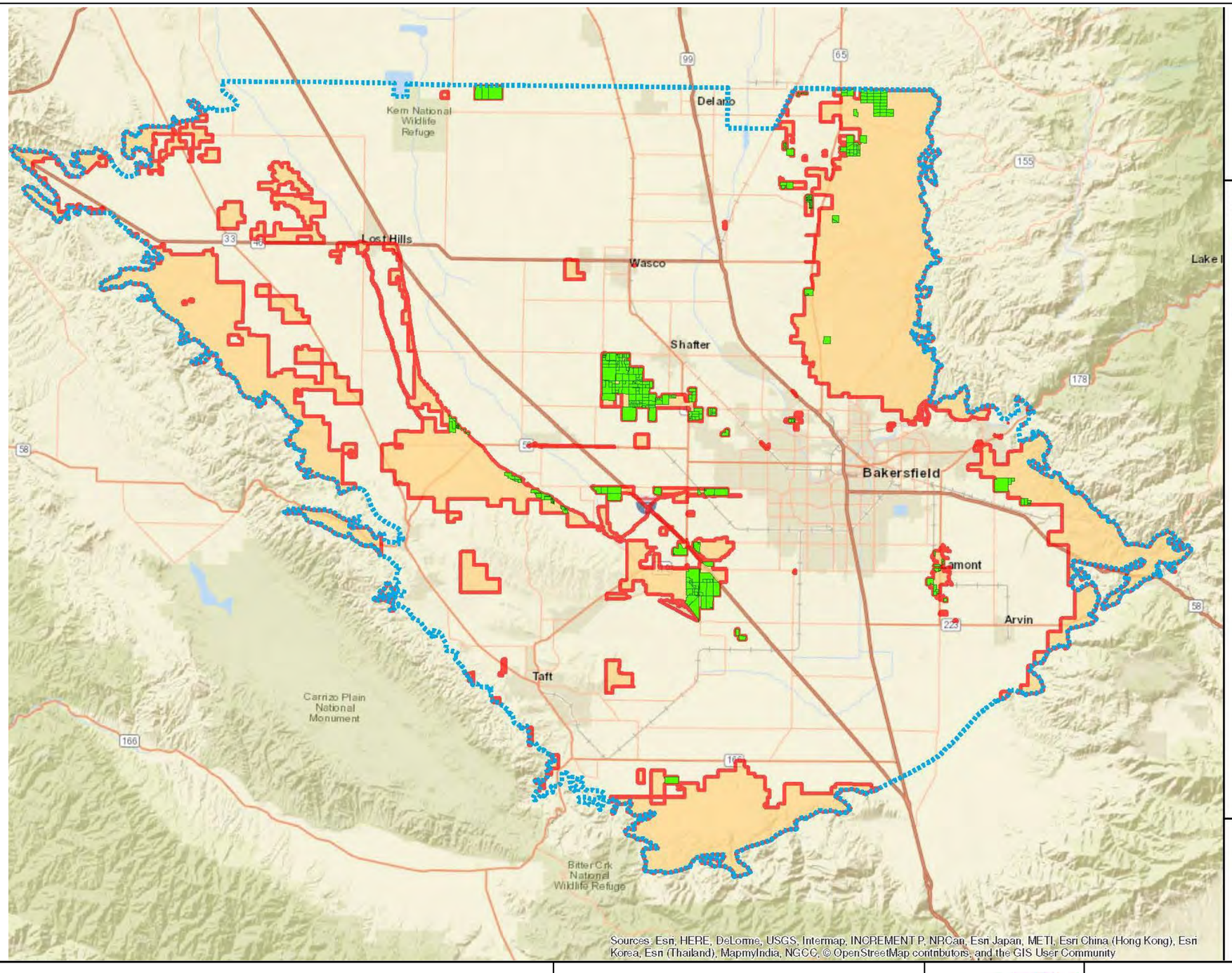
with the KGA member agencies, including associate members, for SGMA coverage under the KGA members' respective management area plans. Assistance from Kern County Water Agency made this coverage possible by lending its jurisdiction under SGMA to the KGA members' who have agreements with those non-districted landowners. Through the efforts by the member agencies of the KGA, approximately 242,180 acres of the non-districted lands will be covered and will be compliant with SGMA. The remaining 198,770 acres not covered are typically grazing lands or lands associated with oil production where minimal or no groundwater usage exists (Figure 1-4). The decision to extend SGMA coverage and to revise the KGA GSA boundary to remove non-districted lands not participating with KGA member agencies has been presented and discussed openly at public KGA board meetings since the initial discussion at the December 2018 board meeting.

For those non-districted lands not covered by a member of the KGA, the five Subbasin GSAs have coordinated to cover all those non-districted lands in the water modeling effort for the historic, baseline, and future projections. Today, the future projection water modeling results demonstrate that the entire Kern Subbasin (including the non-districted lands) will be sustainable with implementation of proposed projects and management actions activities by 2040. Also, the Kern Subbasin GSAs have agreed to continue to coordinate on the monitoring of those non-districted lands going forward and to include the monitoring data in the annual reporting requirements of the Subbasin, thus covering the entire basin in the GSP.

To facilitate the implementation of the KGA GSP, KGA's jurisdictional area is divided into management areas formed by the portion of the Subbasin that underlies the boundaries of each member agency and any associated non-districted lands. Each member agency of KGA has developed its own management area plan to support the development of this KGA Umbrella GSP and collectively are used as reference for details regarding the variances between management areas throughout this report. Southern San Joaquin Municipal Utility District entered into an agreement with McFarland Groundwater Sustainability Agency to include them as part of its management area plan. As Southern San Joaquin Municipal Utility District became a member agency of KGA GSA, the McFarland GSA is also included in the KGA GSP even though they are not a member agency.

KGA includes two disadvantages communities (DAC) as full voting member agencies from the beginning of the formation of the exclusive GSA, the Arvin Community Services District and the City of Shafter. Sustainable management for the Arvin Community Services District is covered in the management area plan developed by Arvin-Edison Water Storage District. The City of Shafter is covered in North Kern Water Storage District & Shafter-Wasco Irrigation management area plan. Both DACs have been actively engaged with the KGA and their respective management area plans development.


KGA Member Agency
Arvin - Edison Water Storage District
Arvin Community Service District
Westside District Water Authority
Cawelo Water District
Kern - Tulare Water District
North Kern Water Storage District
Kern County Water Agency (Pioneer Project)
Rosedale - Rio Bravo Water Storage District
Semitropic Water Storage District
City of Shafter
Shafter - Wasco Irrigation District
Southern San Joaquin Municipal Utility District
Tejon - Castac Water District
West Kern Water District
Wheeler Ridge - Maricopa Water Storage District
KGA Associate Agency
Eastside Water Management Area
Seventh Standard Annex
Major Conveyance
Kern Subbasin Boundary
SOURCE: Agency Boundaries - DWR Submitted (v20190128)
Semitropic Water Storage District
Southern San Joaquin Municipal Utility District
Kern - Tulare Water District
Eastside Water Management Area
North Kern Water Storage District
Cawelo Water District
Westside District Water Authority
Shafter - Wasco Irrigation District
City of Shafter
Seventh Standard Annex Area
Rosedale - Rio Bravo Water Storage District
Pioneer Project (KCWA)
West Kern Water District
Arvin - Edison Water Storage District
Tejon-Castac Water District
Arvin Community Service District
Wheeler Ridge - Maricopa Water Storage District
Lost Hills
Wasco
McFarland
Famoso
Delano
Shafter
Buttonwillow
McKittrick
Taft
Lamont
Arvin
Bakersfield
Tehachapi
Lake Isabella
Kern River
Friant-Kern Canal
Cross Valley Canal
California Aqueduct
Poso Creek
Caliente Creek
Cuyama River
Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Mount Diablo Meridian
San Bernardino Meridian
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Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
KERN GROUNDWATER AUTHORITY
MEMBER AGENCIES
AUGUST 2019
FIGURE 1-2
22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP001_KernSB_KGA_MemberAgencies_20190822.mxd SI



Kern Groundwater Authority

Kern County White Area
Irrigated Parcels Review

Legend

- SJV Kern County GW Subbasin (DWR B118, 2017)
- Irrigated Parcels in Kern Co. White Area (Review of ET, Aerial, and Parcel Land Use)
- Kern County White Area

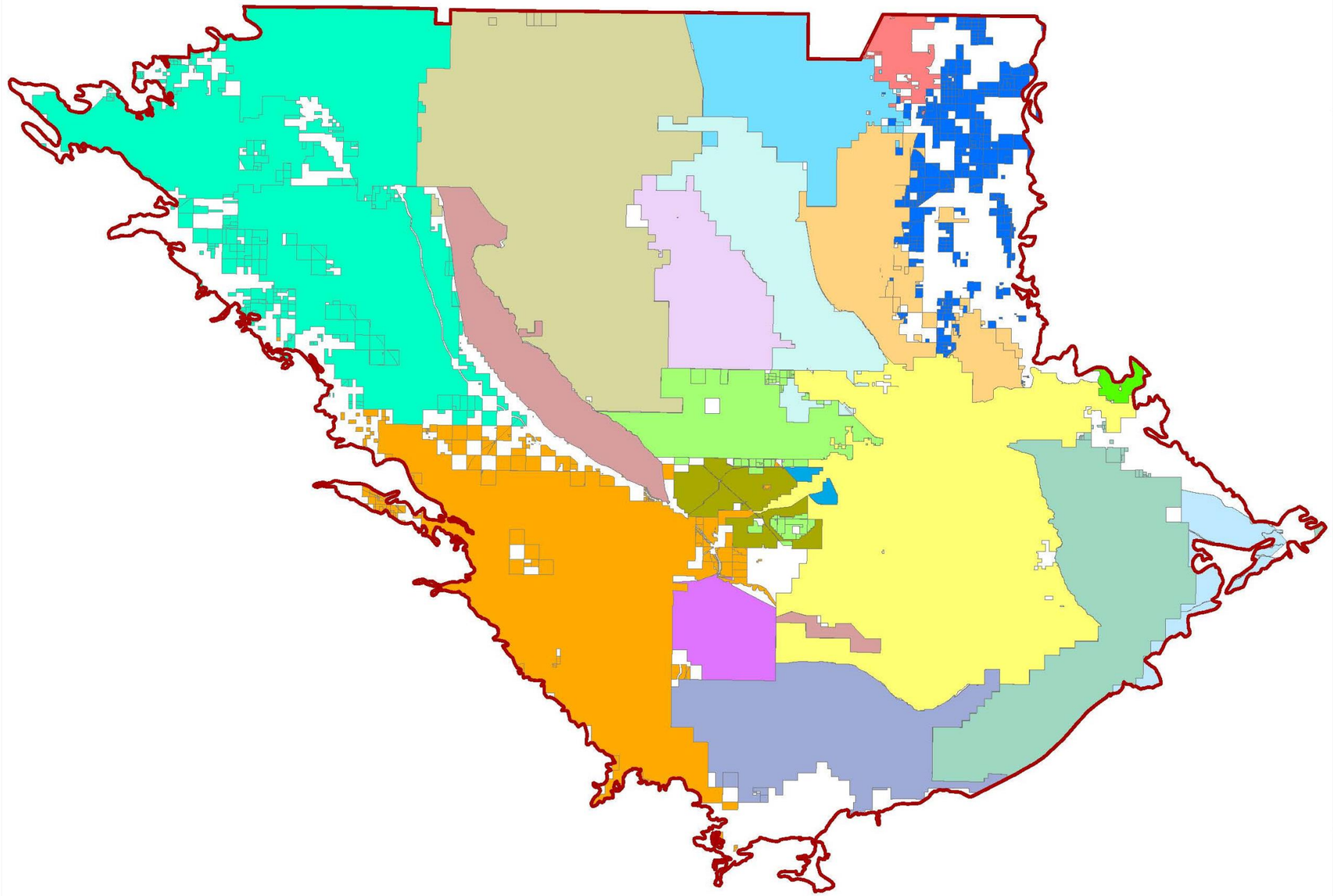
**Approximate area of irrigated parcels is 25,086 acres as calculated in GIS*

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CONSULTING GROUP
An Employee Owned Company

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	Kern Groundwater Authority	GEI Consultants	Kern County Subbasin Non-Districted Lands
	Kern County, California		December 2020 Figure 1-3



Kern Groundwater Authority

GSA Management Areas Review

- SJV Kern County GW Subbasin (DWR B118, 2019)
- Kern Water Bank
- Cawelo GSA
- Kern River GSA
- Arvin-Edison WSD
- EWMA Member
- Kern-Tulare WD
- North Kern WSD
- Buena Vista W.S.D.
- Henry Miller W.D.
- Olcese Groundwater Sustainability Agency
- Pioneer Groundwater Sustainability Agency
- Semitropic WSD
- Rosedale-Rio Bravo WSD
- Shafter-Wasco ID (Includes Annexation)
- Southern San Joaquin MUD
- Tejon Castac WD
- Wheeler-Ridge Maricopa WSD

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	Kern Groundwater Authority	GEI Consultants	Kern County Subbasin Lands Covered and Uncovered by SGMA
	Kern County, California		January 2020 Figure 1-4

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The KGA has been working proactively to coordinate with all GSAs and its associated GSP within the Subbasin to ensure that all GSPs developed within the Subbasin meet the requirements of the Kern County Subbasin Coordination Agreement. All the GSAs in the Subbasin have collaborated in the development and adoption of a Coordination Agreement, as required under SGMA, for the coordinated management and implementation of the five GSPs prepared in the Subbasin. Attachment B provides a copy of the Kern Subbasin Coordination Agreement. Table 1-4 provides the additional information of the five GSPs in the Subbasin.

Table 1-4: GSAs preparing GSPs within the Kern County Subbasin

GSA	Contact Person Title	Mailing Address	Phone Number	Website
Buena Vista Water Storage District	Tim Ashlock General Manager	PO Box 756 Buttonwillow, CA 93206	661-324-1101	www.bvh2o.com
Henry Miller Water District	Walter Bricker Manager	PO Box 9759 Bakersfield, CA 93389	661-327-3551	wbricker@jgbosswell.com
Kern Groundwater Authority	Patty Poire Planning Manager	1800 30th Street Ste #280 Bakersfield, CA 93301	661-479-7171	www.kerngwa.com
Kern River Groundwater Sustainability Agency	Art Chianello Water Resources Manager	1600 Truxtun Avenue Bakersfield, CA 93301	661-326-3767	www.kernrivergsa.org
Olcese GSA	Brian Grant	P.O. Box 60679 Bakersfield, CA 93386-0679	661- 872-5050	www.olcesewaterdistrict.org

1.4.2 Legal Authority of the GSA

The KGA was granted the legal authority of a GSA by complying with CWC Section 10723.8 (see Attachment A). The KGA held the required public hearings regarding the establishment of a GSA as stated in CWC Section 10723(b) and passed a resolution to form the KGA GSA (Attachment C). The authority granted to the KGA is to develop, adopt, and implement a GSP that would be available to those lands within the boundaries of the KGA members. KGA provided the required notification of intent to prepare a GSP to DWR on December 20, 2017 (Attachment D). Under CWC Section 10723.2, the KGA within its boundaries shall consider the interests of all beneficial uses and users of groundwater, as well as those responsible for implementing GSPs.

The KGA was formed for the purpose of:

- Coordinating groundwater management programs and activities;
- Identifying and addressing issues pertaining to sustainable groundwater management; and
- Establishing a framework for local groundwater management.

The intent of the members under this JPA is to provide each member the sole right and responsibility to implement SGMA within its respective boundaries and/or management areas, in

a manner determined by the member. Members expressly intend that the KGA will not have the authority to limit or interfere with the respective members rights and authorities over their own internal matters, including, but not limited to, a member's surface water supplies, groundwater supplies, facilities, operations, water management, and water supply matters.

1.4.3 GSP Implementation Costs & Funding

The KGA has developed the costs in Table 1-5 for its own administrative and coordination efforts as it serves as the coordination entity for the KGA member agencies. These costs will be funded through cost share agreement with the KGA member agencies.

The cost of implementing SGMA at the member agency level can be found in the management area plans attached to this GSP.

Table 1-5: Estimated Costs for GSP Implementation

Item	Description	Estimated Cost
Annual Administration	Administrative activities for ongoing coordination among Member Agencies and other GSA in the Subbasin and coordination with DWR.	$659,700
Sustainability Management and Coordination	KGA coordination with Member Agencies for coordinated implementation of sustainability management practices	$230,000
Coordinated Monitoring Activities	Basin-wide coordinated monitoring activities, such as, subsidence and evapotranspiration monitoring.	$200,000
Annual Report	Data collection and consolidation from Member Agencies to facilitate annual reporting to DWR	$350,000
5-Year GSP Update and Report	Data collection, consolidation and report generation of KGA 5-year update	$500,000

1.5 GSP Organization

The KGA Umbrella GSP provides SGMA coverage for all the Subbasin lands covered in the management areas of its member agencies. The members of the KGA have prepared management area plans that provide details for all GSP required elements, including the technical detail for setting sustainable management criteria specific for their respective management area. The KGA Umbrella GSP provides an overview and summary, a roll-up concept, of the GSP elements developed in the management area plans. There is a total of 15 management area plans attached to this GSP. This GSP is organized as follows:

2. Introduction
3. Plan Area and Basin Setting
4. Sustainable Management Criteria
5. Projects and Management Actions
6. Plan Implementation

7. References
8. Attachments
9. Management Area Plan Attachments
    1. Arvin Edison Water Storage District
    2. Cawelo Water District
    3. Eastside Water Management Authority
    4. Kern County Water Agency – Pioneer Project
    5. Kern Tulare Water District
    6. Kern Water Bank Authority
    7. North Kern Water Storage District & Shafter-Wasco Irrigation District
    8. Rosedale-Rio Bravo Water Storage District
    9. Semitropic Water Storage District
    10. Shafter Wasco Irrigation District – 7th Standard Annexation Management Area
    11. Southern San Joaquin Municipal Utility District
    12. Tejon-Castac Water District
    13. West Kern Water District
    14. Westside District Water Authority
    15. Wheeler Ridge-Maricopa Water Storage District

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2 Plan Area and Basin Setting

2.1 Description of Plan Area

KGA's jurisdictional boundary is entirely within the Subbasin, as defined in DWR Bulletin 118, South of the Tulare Lake Hydrologic Region of the San Joaquin Valley Groundwater Basin. The following section describes the area covered by the KGA GSP.

2.1.1 Summary of Jurisdictional Areas and other Features

The Subbasin is located within the southernmost portion of the Tulare Lake Hydrologic Region of the San Joaquin River Basin and is bounded by the Sierra Nevada on the east; by the Tehachapi Mountains, San Emigdio Mountains, and White Wolf Subbasin on the South; and the Coast Range (Temblor Range) on the west. As shown in Figure 2-1, KGA's jurisdictional boundary represents 1,617 square miles or approximately 58 percent of the Subbasin. There are no Adjudicated Areas within the Kern County Subbasin.

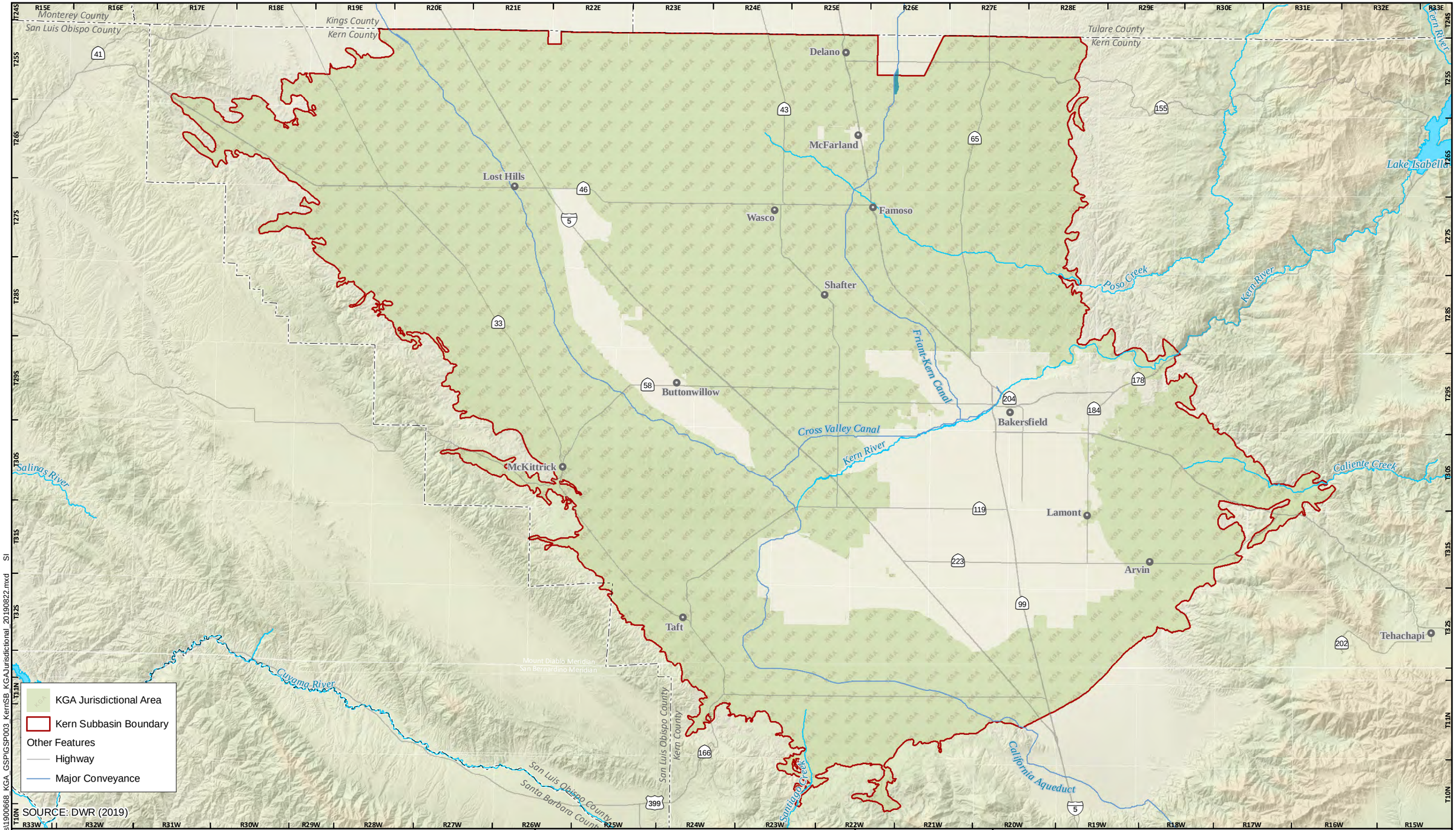
Hydrologic systems in the Subbasin include numerous rivers, lakes, and canals, many of which are located in the KGA boundaries or are used to supply water to the entire Subbasin. The prominent natural surface water body in the Subbasin is the Kern River, which originates in the Sierra Nevada to the northeast of the Subbasin. Canals and conveyance systems within the Subbasin supply water for beneficial uses throughout the Subbasin. A detailed description of these hydrologic systems is included in Section 2.2 of the basin setting of this Umbrella GSP.

There are several incorporated cities within KGA's jurisdictional boundary as shown in Figure 2-1. There are a number of de minimis domestic water users and multi-parcel water systems located within the KGA jurisdictional area, which will be covered under the management area GSPs.

2.1.2 Plan Area Setting

Land use designations within the KGA jurisdictional boundary are predominantly agricultural (Figure 2-2). Most urban and incorporated land use areas are in the eastern portion of the Subbasin while the agricultural lands dominate the northern, western, and southern portions. For lands covered by a water district, source of water is a combination of surface water and groundwater, as shown in Figure 2-3. Generally, all other lands not covered by a district are dependent on groundwater.

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Kern Groundwater Authority
Basin Setting

Kern County, California

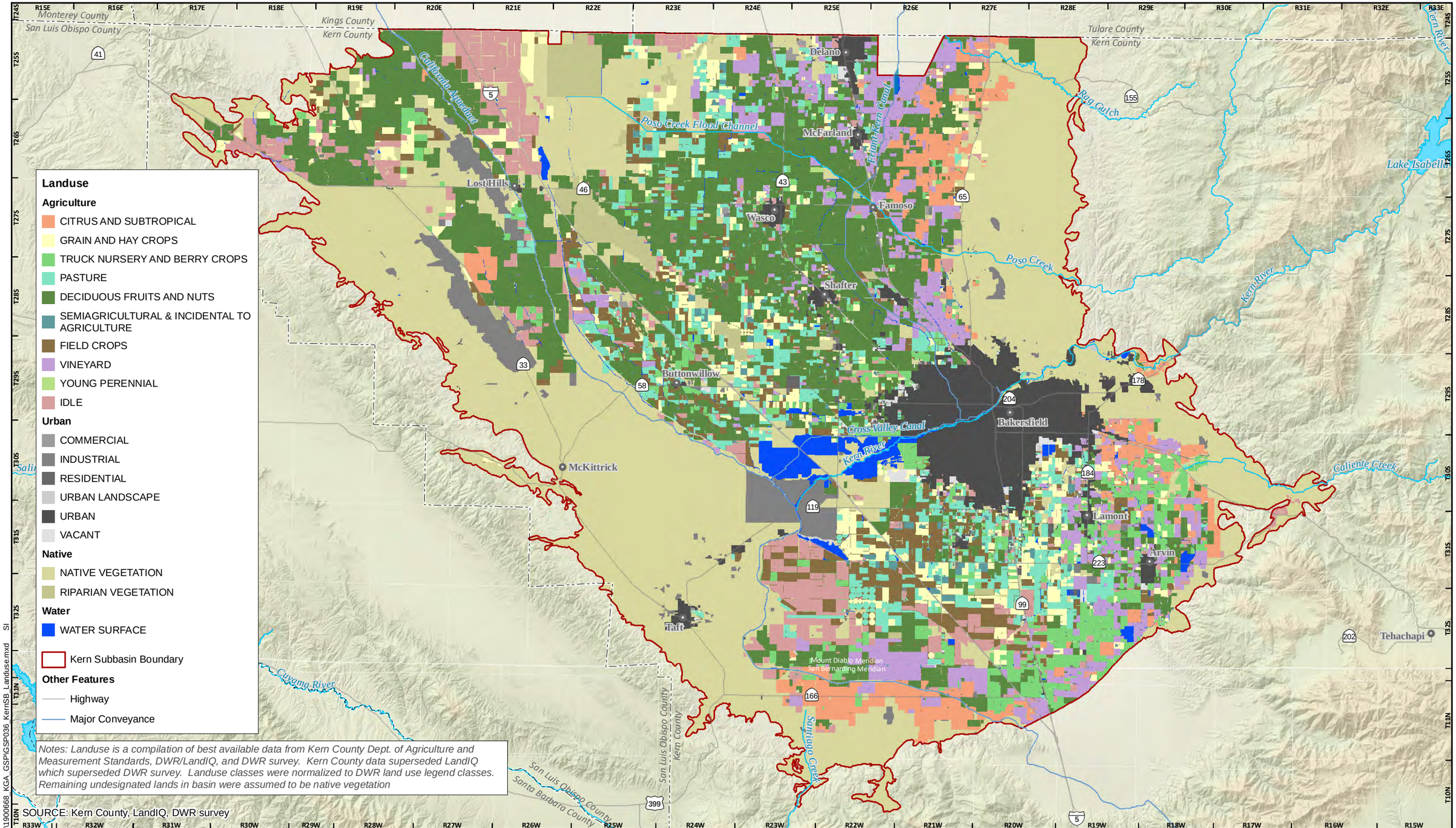
GEI Consultants

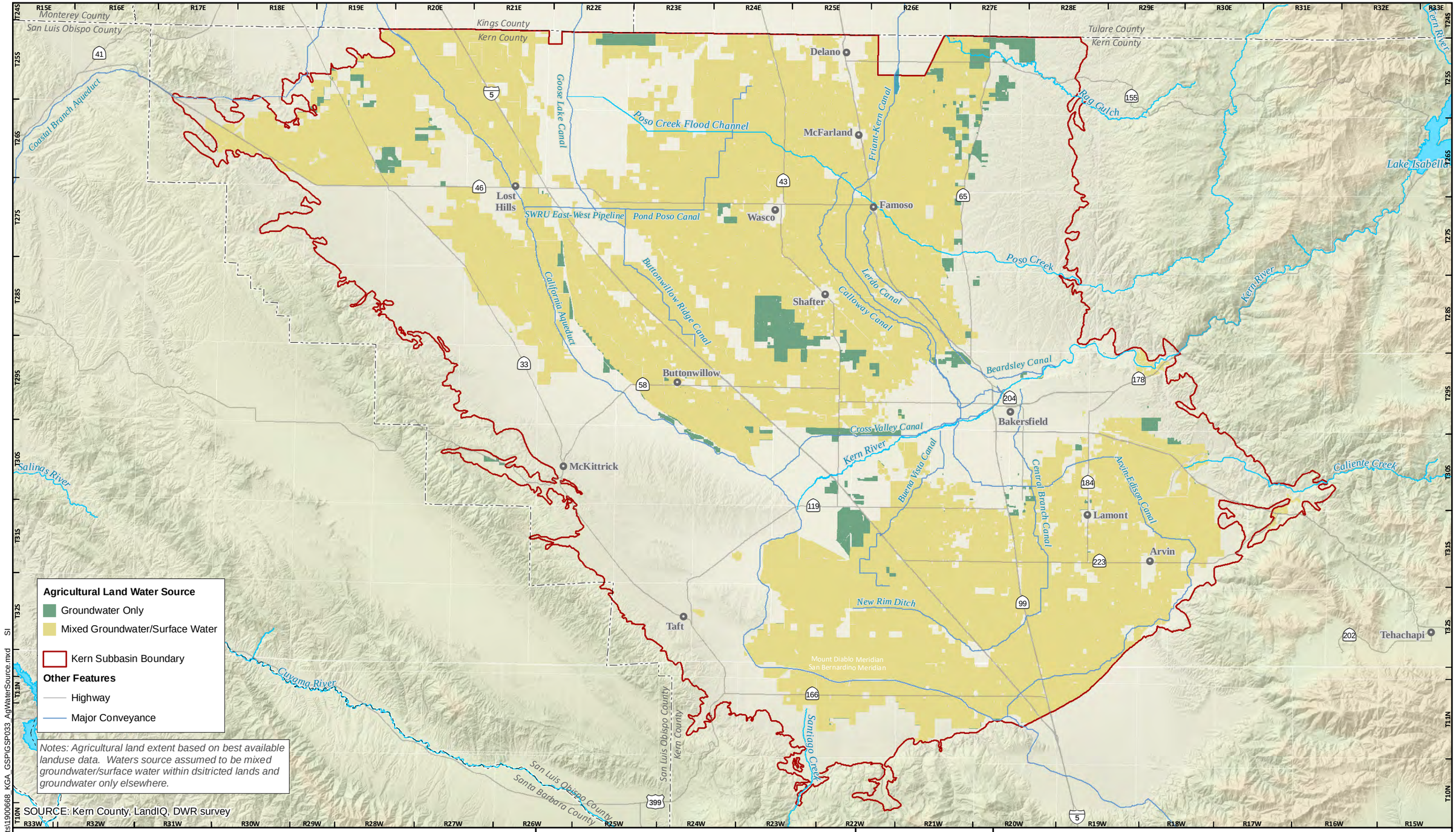
JURISDICTIONAL AREA OF KERN GROUNDWATER AUTHORITY

AUGUST 2019

FIGURE 2-1

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Landuse
Agriculture
CITRUS AND SUBTROPICAL
GRAIN AND HAY CROPS
TRUCK NURSERY AND BERRY CROPS
PASTURE
DECIDUOUS FRUITS AND NUTS
SEMIAGRICULTURAL & INCIDENTAL TO AGRICULTURE
FIELD CROPS
VINEYARD
YOUNG PERENNIAL
IDLE
Urban
COMMERCIAL
INDUSTRIAL
RESIDENTIAL
URBAN LANDSCAPE
URBAN
VACANT
Native
NATIVE VEGETATION
RIPARIAN VEGETATION
Water
WATER SURFACE
Kern Subbasin Boundary
Other Features
Highway
Major Conveyance
Notes: Landuse is a compilation of best available data from Kern County Dept. of Agriculture and Measurement Standards, DWR/LandIQ, and DWR survey. Kern County data superseded LandIQ which superseded DWR survey. Landuse classes were normalized to DWR land use legend classes. Remaining undesignated lands in basin were assumed to be native vegetation
SOURCE: Kern County, LandIQ, DWR survey
Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
Delano
McFarland
Wasco
Famoso
Shafter
Lost Hills
Buttonwillow
McKittrick
Taft
Bakersfield
Lamont
Arvin
Tehachapi
Lake Isabella
California Aqueduct
Poso Creek Flood Channel
Friant-Kern Canal
Poso Creek
Kern River
Cross Valley Canal
Caliente Creek
Cuyama River
Santiago Creek
Mount Diablo Meridian
San Bernardino Meridian
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Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
LANDUSE WITHIN KERN COUNTY SUBBASIN
JULY 2019
FIGURE 2-2
23-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP036_KernSB_Landuse.mxd SI


Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
Delano
McFarland
Famoso
Lost Hills
Wasco
Shafter
Buttonwillow
McKittrick
Taft
Bakersfield
Lamont
Arvin
Tehachapi
Goose Lake Canal
Poso Creek Flood Channel
Friant-Kern Canal
Rag Gulch
Lake Isabella
SWRU East-West Pipeline
Pond Poso Canal
Buttonwillow Ridge Canal
California Aqueduct
Lerdo Canal
Calloway Canal
Poso Creek
Kern River
Beardsley Canal
Cross Valley Canal
Kern River
Buena Vista Canal
Central Branch Canal
Arvin-Edison Canal
Caliente Creek
New Rim Ditch
Mount Diablo Meridian
San Bernardino Meridian
Santiago Creek
Cuyama River
Salinas River
Coastal Branch Aqueduct
San Luis Obispo County
Santa Barbara County
San Luis Obispo County
Kern County
Agricultural Land Water Source
Groundwater Only
Mixed Groundwater/Surface Water
Kern Subbasin Boundary
Other Features
Highway
Major Conveyance
Notes: Agricultural land extent based on best available landuse data. Waters source assumed to be mixed groundwater/surface water within dsitricted lands and groundwater only elsewhere.
SOURCE: Kern County, LandIQ, DWR survey
0 3.5 7 14 21
Miles
N
S
E
W
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
AGRICULTURAL LAND WATER SOURCE
WITHIN KERN COUNTY SUBBASIN
JULY 2019
FIGURE 2-3
Z:\Projects\1900668_KGA_GSP\GSP\033_AgWaterSource.mxd SI
23-Aug-2019

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Well densities for production, domestic, and public supply wells within the Subbasin are presented on Figures 2-4 through 2-6, respectively. This dataset is based on well statistics provided by DWR (2019) from the Online System for Well Completion Reports and is intended to be for qualitative informational purposes. Production wells include those described in completion reports as irrigation, municipal, public, or industrial wells. In summary, higher well densities can be found in the central portion of the Subbasin whereas moderate to lower densities are found in the north-east and south-east regions. The western region ranges in areas of low densities to no wells at all. For further information on well types and densities for each management area within the Subbasin, refer to the individual management area plans.

Under the KGA jurisdictional boundary, there are state, small multi-parcel water systems, and domestic water users that are groundwater dependent. In addition, there are incorporated cities within the KGA jurisdictional boundary as shown in Figure 2-7.

2.1.3 Existing Plans in the Plan Area

In general, the goals, policies, and implementation measures established by existing plans (e.g. the Kern County General Plan) are complementary to sustainable groundwater management of the local management areas relative to future land use development and conservation. The plan encourages development of the County's groundwater supply to ensure that existing users have access to high quality water, and states that future growth should be accommodated only while ensuring that adequate high-quality water supplies are available to existing and future users. Below is a list of all existing general plans within the Subbasin. The agencies that developed and adopted the general plans below have retained their jurisdiction over land use and zoning as well as the elements included into their respective general plans. The KGA nor its members have any jurisdiction over the development of general plans within the Subbasin, however, as general plans are being updated in the future, the KGA and its members will actively participate in the coordination of general plan update with the GSP implementation. The descriptions of plans associated with specific management areas are described in greater detail in the management area plans.

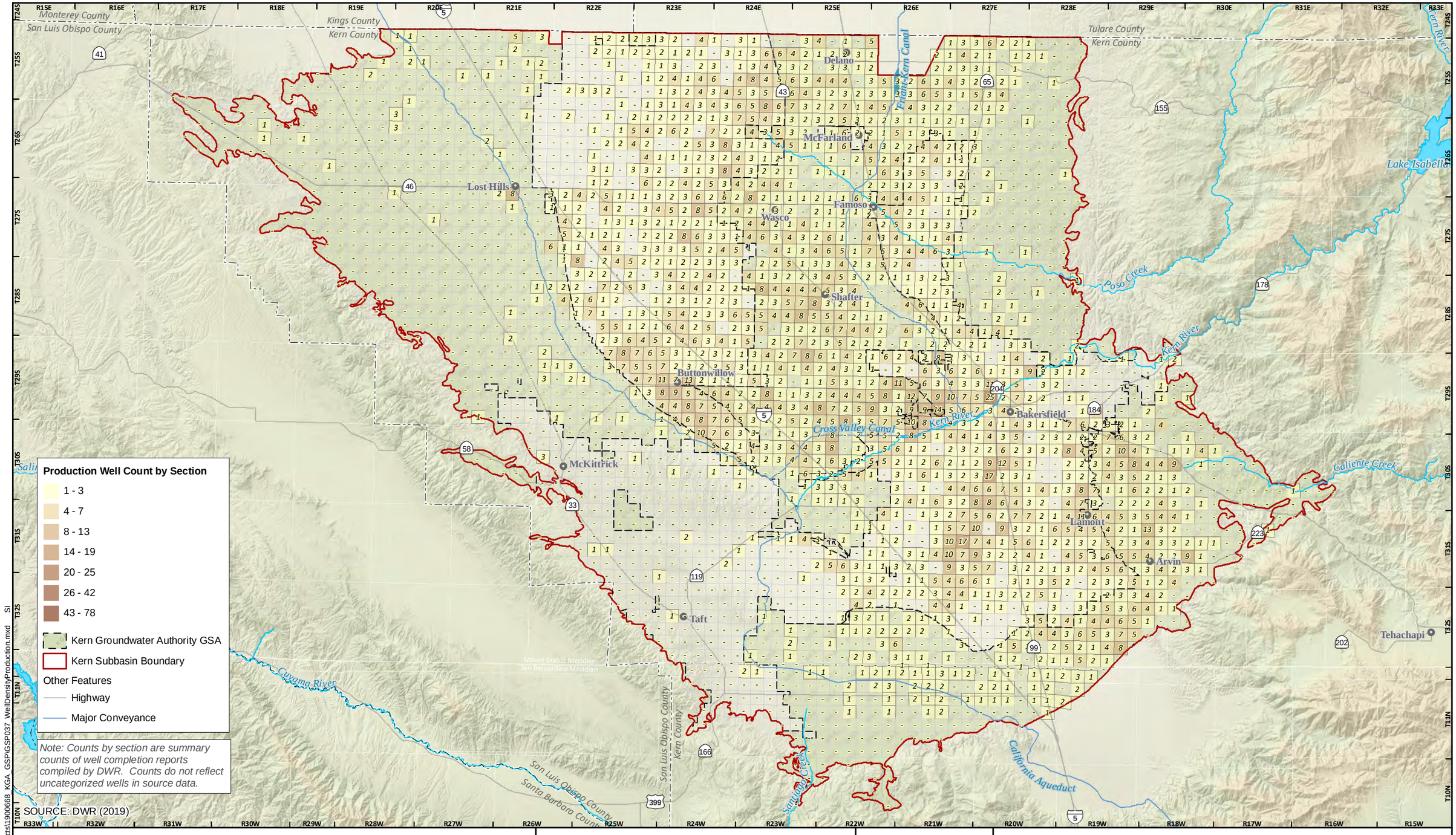
- **Kern County General Plan –** This plan was adopted in 2004 and is being updated through the year 2040. Its overall goal is to ensure the county can accommodate anticipated growth and development while maintaining a safe and healthful environment and a prosperous economy by preserving valuable natural resources and assuring the provision of adequate public services (Kern County, 2009).
- **Metropolitan Bakersfield General Plan –** The current plan was first adopted in 2002. This plan aims to achieve goals related to new development, protecting natural resources from environmental damage, as well as preserving agricultural land (City of Bakersfield, 2016) The Metropolitan Bakersfield General Plan is mostly located within the Kern River GSA. There also exists a Metropolitan Habitat Conservation Plan that is mostly located within the Kern River GSA jurisdiction.

- **City of Arvin General Plan –** This plan aims to promote the protection, stewardship, and use of the city's natural resources and to prevent wastefulness, unsustainable usage, and neglect (City of Arvin, 2012).
- **City of Shafter General Plan –** This plan's goals include, but is not limited to, recognizing and retaining commercial agriculture as a desirable land use and as a major segment of the community's identity and economic base (City of Shafter, 2005).
- **City of Wasco General Plan –** This plan was adopted in 2002 and contains objectives, policies and standards specific to the protection of groundwater resources as well as soils and air quality within the City of Wasco and its planning area.
- **City of Delano General Plan –** This plan was adopted in 2005 and aims to protect natural resources, including groundwater, soils, and air quality.
- **City of McFarland General Plan –** This plan was adopted in 1991; however, current versions of the plan do not specifically address groundwater.
- **City of Taft General Plan –** This plan was adopted in 2010; however, the adopted version does not specifically address groundwater.
- **City of Maricopa General Plan –** This plan was adopted in pieces with the last piece adopted in July 2017; however, there is no water element section in the General Plan that specifically addresses groundwater

Successful implementation of this GSP will help to ensure that the Subbasin's groundwater supply is managed in a sustainable manner. Implementation of existing policies are expected to be compatible with management areas strategies in the Subbasin to achieve groundwater sustainability. It is anticipated that implementation of this GSP, while consistent with existing plans and policies to protect water resources, will alter the water supply assumptions and potentially land use plans over the planning horizon. Given that the existing plans are being updated concurrently with the development of this GSP, it is anticipated that future plans would take into account this GSP and utilize consistent water supply assumptions over the 2040 planning horizon.

Land use plans vary between each management area, as they implement policies which best fit their communities. Management area plans provide specific information regarding land use plans and effects of those plans in the individual management areas.

The implementation of land use plans outside of the Subbasin could potentially affect the ability of the KGA to achieve sustainable groundwater management, especially to the north of the Subbasin. However, at this stage, coordination with neighboring Subbasin's has been limited. Future activities of the KGA include increased coordination with neighboring groundwater Subbasins, which will be documented in future updates to this GSP.



Kern Groundwater Authority
Basin Setting

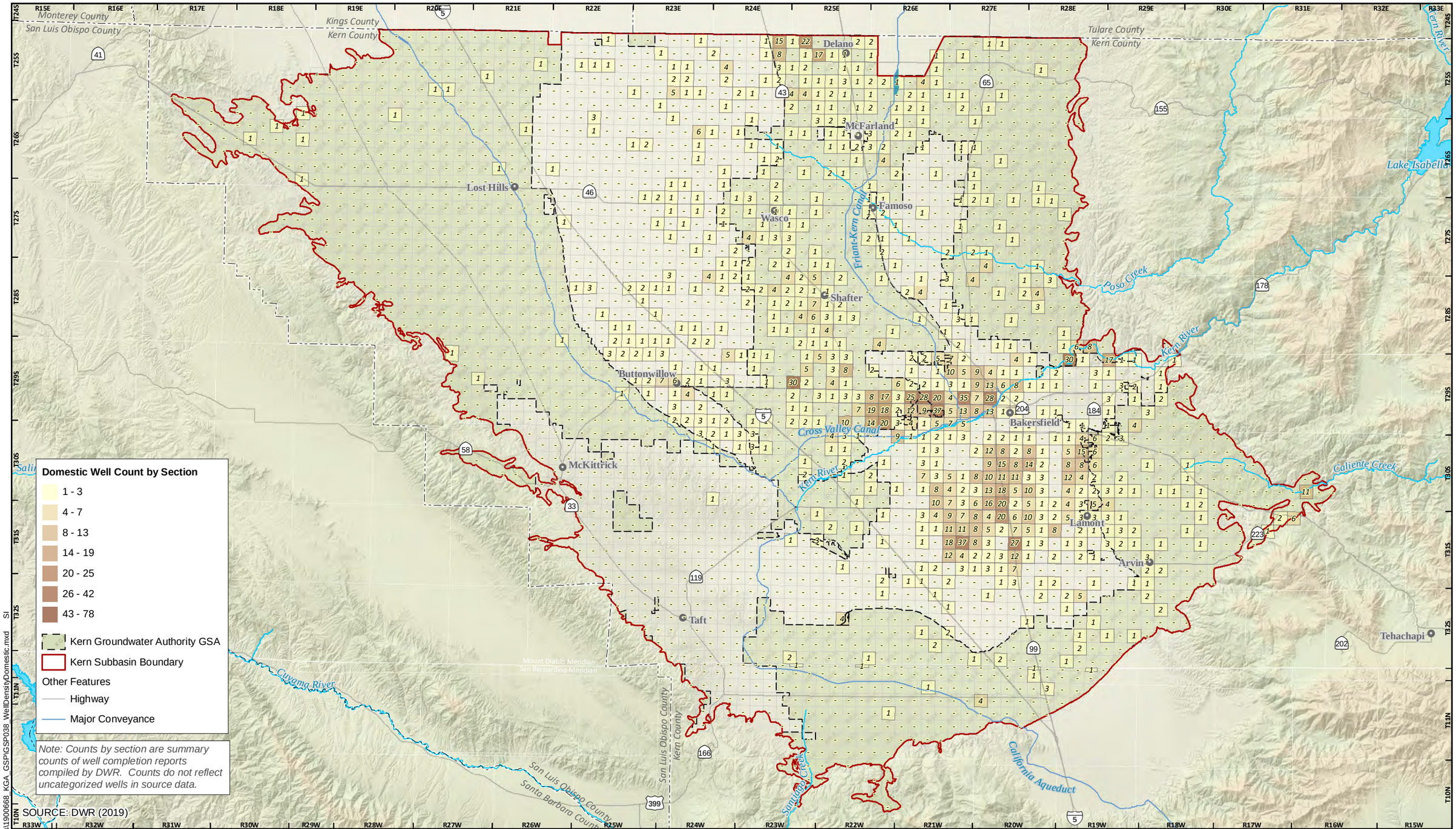
Kern County, California

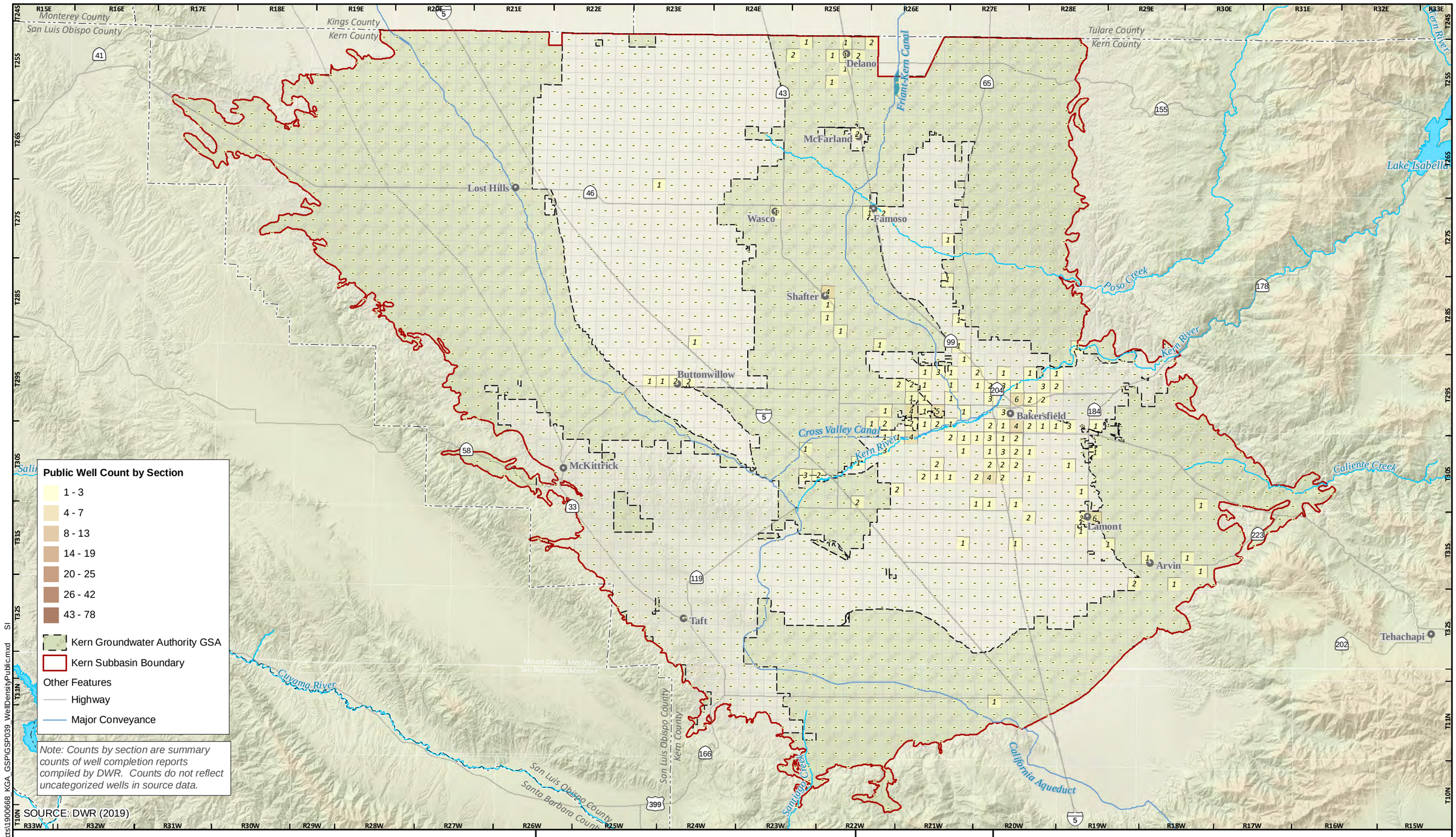
GEI Consultants

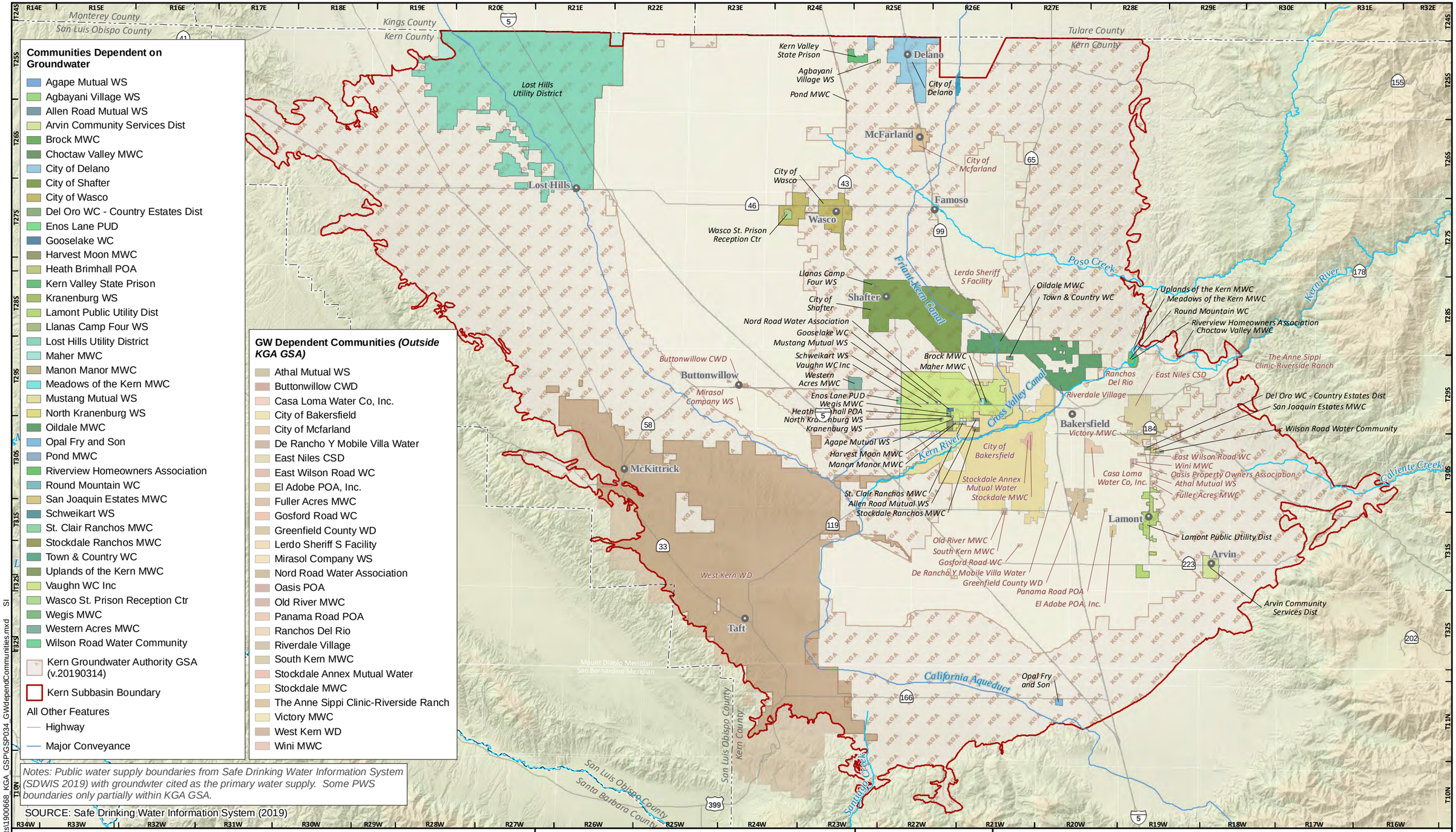
DENSITY OF WELLS PER SQUARE MILE (PRODUCTION)

JULY 2019

FIGURE 2-4


Domestic Well Count by Section
1 - 3
4 - 7
8 - 13
14 - 19
20 - 25
26 - 42
43 - 78
Kern Groundwater Authority GSA
Kern Subbasin Boundary
Other Features
Highway
Major Conveyance
Note: Counts by section are summary counts of well completion reports compiled by DWR. Counts do not reflect uncategorized wells in source data.
SOURCE: DWR (2019)
Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
Delano
McFarland
Lost Hills
Wasco
Famoso
Shafter
Buttonwillow
McKittrick
Bakersfield
Lamont
Arvin
Taft
Tehachapi
Lake Isabella
Kern River
Friant-Kern Canal
Poso Creek
Kern River
Cross Valley Canal
Caliente Creek
Cuyama River
San Luis Obispo County
Santa Barbara County
San Luis Obispo County
Kern County
Santiago Creek
California Aqueduct
Mount Diablo Meridian
San Bernardino Meridian
0 3.5 7 14 21
Miles
N
W
E
S
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
DENSITY OF WELLS PER SQUARE MILE
(DOMESTIC)
JULY 2019
FIGURE 2-5
23-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP038_WellDensityDomestic.mxd SI


Public Well Count by Section
1 - 3
4 - 7
8 - 13
14 - 19
20 - 25
26 - 42
43 - 78
Kern Groundwater Authority GSA
Kern Subbasin Boundary
Other Features
Highway
Major Conveyance
Note: Counts by section are summary counts of well completion reports compiled by DWR. Counts do not reflect uncategorized wells in source data.
SOURCE: DWR (2019)
Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
Delano
McFarland
Lost Hills
Wasco
Famoso
Shafter
Buttonwillow
McKittrick
Bakersfield
Lamont
Arvin
Taft
Tehachapi
Lake Isabella
Friant-Kern Canal
Cross Valley Canal
Kern River
Poso Creek
Caliente Creek
California Aqueduct
Cuyama River
San Luis Obispo County
Santa Barbara County
San Luis Obispo County
Kern County
Mount Diablo Meridian
San Bernardino Meridian
0 3.5 7 14 21
Miles
N
S
E
W
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
DENSITY OF WELLS PER SQUARE MILE
(PUBLIC)
JULY 2019
FIGURE 2-6
23-Aug-2019 Z:\Projects\19006668_KGA_GSP\GSP039_WellDensityPublic.mxd SI


Communities Dependent on Groundwater
Agape Mutual WS
Agbayani Village WS
Allen Road Mutual WS
Arvin Community Services Dist
Brock MWC
Choctaw Valley MWC
City of Delano
City of Shafter
City of Wasco
Del Oro WC - Country Estates Dist
Enos Lane PUD
Gooselake WC
Harvest Moon MWC
Heath Brimhall POA
Kern Valley State Prison
Kranenburg WS
Lamont Public Utility Dist
Llanas Camp Four WS
Lost Hills Utility District
Maher MWC
Manon Manor MWC
Meadows of the Kern MWC
Mustang Mutual WS
North Kranenburg WS
Oildale MWC
Opal Fry and Son
Pond MWC
Riverview Homeowners Association
Round Mountain WC
San Joaquin Estates MWC
Schweikart WS
St. Clair Ranchos MWC
Stockdale Ranchos MWC
Town & Country WC
Uplands of the Kern MWC
Vaughn WC Inc
Wasco St. Prison Reception Ctr
Wegis MWC
Western Acres MWC
Wilson Road Water Community
Kern Groundwater Authority GSA (v.20190314)
Kern Subbasin Boundary
All Other Features
Highway
Major Conveyance
GW Dependent Communities (Outside KGA GSA)
Athal Mutual WS
Buttonwillow CWD
Casa Loma Water Co, Inc.
City of Bakersfield
City of Mcfarland
De Rancho Y Mobile Villa Water
East Niles CSD
East Wilson Road WC
El Adobe POA, Inc.
Fuller Acres MWC
Gosford Road WC
Greenfield County WD
Lerdo Sheriff S Facility
Mirasol Company WS
Nord Road Water Association
Oasis POA
Old River MWC
Panama Road POA
Ranchos Del Rio
Riverdale Village
South Kern MWC
Stockdale Annex Mutual Water
Stockdale MWC
The Anne Sippi Clinic-Riverside Ranch
Victory MWC
West Kern WD
Wini MWC
Notes: Public water supply boundaries from Safe Drinking Water Information System (SDWIS 2019) with groundwter cited as the primary water supply. Some PWS boundaries only partially within KGA GSA.
SOURCE: Safe Drinking Water Information System (2019)
Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
Lost Hills
Delano
McFarland
Wasco
Famoso
Shafter
Buttonwillow
McKittrick
Taft
Bakersfield
Lamont
Arvin
Lost Hills Utility District
Kern Valley State Prison
Agbayani Village WS
Pond MWC
City of Delano
City of Mcfarland
City of Wasco
Wasco St. Prison Reception Ctr
Llanas Camp Four WS
City of Shafter
Nord Road Water Association
Gooselake WC
Mustang Mutual WS
Schweikart WS
Vaughn WC Inc
Western Acres MWC
Enos Lane PUD
Wegis MWC
Heath Brimhall POA
North Kranenburg WS
Kranenburg WS
Agape Mutual WS
Harvest Moon MWC
Manon Manor MWC
St. Clair Ranchos MWC
Allen Road Mutual WS
Stockdale Ranchos MWC
Stockdale Annex Mutual Water
Stockdale MWC
Old River MWC
South Kern MWC
Gosford Road WC
De Rancho Y Mobile Villa Water
Greenfield County WD
Panama Road POA
El Adobe POA, Inc.
Lerdo Sheriff S Facility
Oildale MWC
Town & Country WC
Uplands of the Kern MWC
Meadows of the Kern MWC
Round Mountain WC
Riverview Homeowners Association
Choctaw Valley MWC
Brock MWC
Maher MWC
Ranchos Del Rio
East Niles CSD
Riverdale Village
The Anne Sippi Clinic-Riverside Ranch
Del Oro WC - Country Estates Dist
San Joaquin Estates MWC
Wilson Road Water Community
East Wilson Road WC
Wini MWC
Oasis Property Owners Association
Athal Mutual WS
Fuller Acres MWC
Casa Loma Water Co, Inc.
Lamont Public Utility Dist
Arvin Community Services Dist
Opal Fry and Son
Mirasol Company WS
Buttonwillow CWD
West Kern WD
Friant-Kern Canal
Cross Valley Canal
California Aqueduct
Kern River
Poso Creek
Caliente Creek
San Luis Obispo County
Santa Barbara County
Kern County
Mount Diablo Meridian
San Bernardino Meridian
0 3.5 7 14 21
Miles
N
W
E
S
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
GROUNDWATER DEPENDENT COMMUNITIES
JULY 2019
FIGURE 2-7
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23-Aug-2019

2.1.4 Existing and Ongoing Water Resource Programs

Per Section 354.8(c) of the GSP regulations, this section identifies and describes existing water resources programs in the KGA jurisdictional area. This section provides an overview of each program being implemented within the KGA. Table 2-1 provides a matrix showing which programs are being implemented within each management area. Additional details are provided in the individual management area plans.

2.1.4.1 Management Plans

The State of California has pre-SGMA programs for the management of groundwater supply and quality. These programs are managed at various levels of government by existing public agencies, either individually or collaboratively with neighboring agencies within the same groundwater basin. The following section provides an overview of these management programs and the elements addressed in each.

Groundwater Management Plans

In 1992, the State of California passed the Groundwater Management Act (AB 3030). This legislation provided guidelines for the agencies and districts to provide planned and coordinated monitoring, operation, and administration of groundwater basins with the goal of long-term sustainability. There are several types of Groundwater Management Plans, which are described below.

Pre-SB 1938 Plans: These plans, typically adopted before 2002, could be prepared by a local agency in a Bulletin 118-desginated basin on a voluntary basis. The voluntary components of these plans include:

- The control of saline water intrusion.
- Identification and management of wellhead protection areas and recharge areas.
- Regulation of the migration of contaminated groundwater.
- The administration of a well abandonment and well destruction program.
- Mitigation of conditions of overdraft.
- Replenishment of groundwater extracted by water producers.
- Monitoring of groundwater levels and storage.
- Facilitating conjunctive use operations.
- Identification of well construction policies.
- The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.
- The development of relationships with state and federal regulatory agencies.
- The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

Table 2-1: Summary of KGA Water Resources Programs

KGA Management Area Plan	Water Management Programs									
	Groundwater Management Plans			Integrated Regional Water Management Plans	USBR Water Management Plans	Irrigated Lands Regulatory Program	Groundwater Export Ordinance	Title 22 Drinking Water Program	Urban Water Management Plans	Agricultural Water Management Plans
	Pre-SB 1938 Plans	SB 1938 Plans	AB 359 Plans							
Arvin-Edison Water Storage District		X		X	X	X		X	X	
Cawelo Water District		X		X		X			X	X
Eastside Water Management Area						X				
Kern Water Bank										
Kern-Tulare Water District		X								
North Kern Water Storage District and Shafter-Wasco Irrigation District		X		X		X	X	X		X
		X		X		X	X	X	X	X
Pioneer				X					X	
Rosedale- Rio Bravo Water Storage District			X	X		X				
Semitropic Water Storage District		X		X		X	X	X		
Shafter-Wasco Irrigation District (7th Standard Rd.)										
Southern San Joaquin Municipal Utility District		X		X		X	X	X	X	X
Tejon-Castac Water District				X						
West Kern Water District	X			X					X	
Westside District Authority				X		X				X
Wheeler Ridge-Maricopa Water Storage District		X		X		X				X

SB 1938 Plans: These plans were generally adopted during or after 2002, incorporating the elements of the Pre-SB 1938 Plans. With the passage of SB 1938, the following components were required as part of any Groundwater Management Plan:

- Basin Management Objectives: The Groundwater Management Plan shall include Basin Management Objectives relating to the monitoring and management of groundwater levels within the groundwater basin, groundwater quality degradation, inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin.
- Agency Cooperation: The local agency shall prepare a plan to involve other agencies that enables the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin.
- Mapping: The local agency shall prepare a map that details the area of the groundwater basin, as defined in DWR's Bulletin 118, and the area of the local agency, that will be subject to the Groundwater Management Plan, as well as the boundaries of other local agencies that overlie the basin in which the agency is developing a Groundwater Management Plan.
- Monitoring Protocols: The local agency shall adopt monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence (in basins for which subsidence has been identified as a potential problem), and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin.
- Located outside Bulletin 118 Groundwater Basins: Plans located outside DWR Bulletin 118 alluvial groundwater basins will incorporate the above components and shall use geologic and hydrologic principles appropriate to those areas.

AB 359 Plans: When AB 359 was enacted in 2013, it required additional technical components related to groundwater recharge areas and modification to several of the existing groundwater management plan adoption procedures in place as part of SB 1938. The additional technical components are as follows:

- The groundwater projects to which these requirements apply include projects that are part of an integrated regional water management program or plan.
- Groundwater projects require a description of how recharge areas identified in the plan substantially contribute to the replenishment of the groundwater basin and a map identifying the recharge areas, as defined, for the groundwater basin to be included in a groundwater management plan for purposes of the state funding requirements.
- Require the local agency to provide the map of the recharge areas to local planning agencies and notify the department and other interested persons when a map is submitted to those local planning agencies.

Integrated Regional Water Management Plans

In 2002, the Regional Water Management Planning Act (SB 1672) created the Integrated Regional Water Management (IRWM) Program. The IRWM Program is used as a collaborative effort to identify and implement water management solutions on a regional scale that increase regional self-reliance, reduce conflict between agencies and users, and manage water to concurrently achieve social, environmental, and economic objectives. By collaborating on projects, participants in the IRWM Program can provide these benefits and meet their water supply and quality goals. In the Kern County Subbasin, there are two IRWM Plans: the Poso Creek IRWM Plan and the Kern County IRWM Plan.

USBR Water Management Plans

The Central Valley Improvement Act of 1992 and Section 210(b) of the Reclamation Reform Act of 1982 requires certain entities to prepare and submit a Water Management Plan. Entities required are those that enter into a repayment contract or water service contract with the Bureau of Reclamation. Not all member agencies under KGA are required to have a plan under USBR. Refer to management area plans for specific details.

Irrigated Lands Regulatory Program

The Tulare Lake Basin General Order (Order R5-2013-0120) was passed by the Regional Water Quality Control Board (RWQCB) in 2006. This order requires that any irrigated land having the potential to discharge to surface water or groundwater must comply with the requirements set by the RWQCB. Compliance includes membership in a Coalition or obtaining coverage through an Individual Order from the RWQCB. Several districts in the KGA jurisdictional area are members of the Kern River Watershed Coalition Authority, which was formed in 2011.

Groundwater Export Ordinance

Kern County adopted a groundwater export ordinance in 1998, which requires a Conditional Use Permit for export of water to areas both outside the County and within watershed areas of underlying aquifers in the County. The ordinance applies only to the southeastern drainage of the Sierra Nevada and Tehachapi mountains in the South Lahontan Hydrologic Region in eastern Kern County.

Title 22 Drinking Water Program

The Division of Drinking Water regulates public drinking water systems, which include municipal and state small water systems. These systems are required to comply with the standards set forth in Title 22 of the California Code of Regulations. For single parcel/single-connection systems, Kern County Environmental Health Services provides regulation and oversight to meet the requirements of Title 22.

2.1.4.2 Conjunctive Use Programs

Conjunctive use or "the coordinated use of surface water and groundwater" has been used for many years in Kern County, for the benefit of water users, to allow for flexibility in the way water is delivered, whether climatic conditions allow for imported surface water, or if

groundwater is needed in any given year. Conjunctive use is further described by the Water Education Foundation with the following: "In its passive form, also called in-lieu conjunctive use, surface water is used in wet years and groundwater is used in dry years. In active conjunctive use, surface water is directly injected into aquifers and wells to be used as needed as part of groundwater banking" (Water Education Foundation, 2019).

In the Kern Subbasin, conjunctive use plays a vital role for all beneficial users to coordinate the use of surface water and groundwater to improve the overall reliability of water supply. Whether it be water used to irrigate crops or to service communities for drinking water purposes, all users benefit from conjunctive use programs throughout the Subbasin. Conjunctive use programs in the Subbasin have been developed to capture and transport wet year surface water for the purpose of groundwater recharge and offset use of groundwater pumping. In turn, this prepares the basin for dry periods when groundwater may be limited. Projects such as interties, pipelines, and recharge basins have been developed, financed, and implemented by districts within the Kern Subbasin to deliver, bank, and return surface water, as well as replenish aquifers to better prepare for and manage during times of dry periods when beneficial users are more reliant on groundwater. Many of these types of projects have been incorporated in other state programs, such as the IRWM program. In the Kern Subbasin, there are two IRWM regions including the Poso Creek IRWM Region and the Kern IRWM Region. Both regions have developed plans to manage water use and delivery as well as the development of water related projects. Further information on the types of conjunctive use programs in the Kern Subbasin can be found in each of these plans. Additionally, many of the projects captured in the IRWM plans are included in the management area plans as project and management actions to be implemented within the Kern Subbasin to achieve groundwater sustainability.

The majority of the KGA member agencies partake in groundwater banking and recharge programs. The purpose of these programs is to bring surface water into the Subbasin to recharge groundwater levels and better prepare for and manage water during times of dry periods or in wet periods where water is of excess. Groundwater banking refers to recharging specific amounts of water in a groundwater basin that can later be withdrawn and used by the entity that deposited the water.

KGA member agencies have banking agreements amongst each other. For example, members of the Poso Creek IRWM such as Semitropic WSD and North Kern WSD, operate long-term water banking programs that allow banking partners, including districts outside of the Poso Creek IRWM Region, to store surplus water in another district and to recover their water when needed. These districts receive surface water from the banking partners in years of ample supplies and deliver it to their landowners for irrigation use in-lieu of groundwater pumping (*Poso Creek Integrated Regional Water Management Plan, 2019 Update*). Once banked, the entity depositing the water receives a credit and groundwater which otherwise would have been pumped remains in storage. In the Poso Creek IRWM Region alone, there is approximately 25,000 acre-feet per month of recharge capacity that can be used to bank imported surface water.

In addition to banking programs within the Poso Creek IRWM Region, other prominent groundwater banking facilities in the Kern Subbasin include the Kern Water Bank and Kern

County Water Agency - Pioneer Project. These are facilities managed by the Kern Water Bank and the Kern County Water Agency, respectively. Kern Water Bank contains approximately 7,000 acres of recharge ponds, which can recharge up to 72,000 acre-feet per month. When water is available to the Kern Subbasin which cannot be absorbed, these water banking projects provide additional storage facility for otherwise potentially lost surplus surface supplies available during wet years. Most members of the KGA participate in banking and recharge programs in one way or another. For further explanation of banking and recharge programs as well as district involvement, refer to individual management area plans.

2.1.4.3 Well Permitting Process

Well permits within the Subbasin are issued by the Kern County Public Health Services Department Water Well Program and will continue under SGMA. Kern County will continue to retain jurisdiction over the water well permitting process. The Water Well Program issues permits to construct, reconstruct, and destroy water wells. All wells must be constructed in accordance with Kern County Ordinance Code, Section 14.08, and the State Department of Water Resources' Bulletin 74-81 and Bulletin 74-90, except as modified by subsequent revisions. The ordinance requires, among other things, that domestic and agricultural wells be installed a minimum distance from potential pollution and contaminant sources; water quality be tested for new and reconstructed wells; an NSF 61 approved flowmeter be installed; and the final well construction be inspected by Kern County staff.

Through a collaborated process, the Kern Subbasin GSAs, with the KGA taking the lead, worked with the Kern County Public Health Services Department to develop a supplemental well application for wells to be installed within the Kern Subbasin (Figure 2-8). This new form requires the applicant to provide additional information regarding construction of the well, proposed use, and amount of water to be pumped. If the applicant knows the water district and GSA in which the well will be located, it is indicated on the form. The application is completed and submitted to the Kern County Public Health Department where it is forwarded to the appropriate water district or GSA, through the KGA Planning Manager. The district in which the well is located is able to provide comments on the application advising the applicant of sustainability criteria that may impact the operation of the well. This process has been in place since January 2019 and demonstrates coordination between Kern County Public Health Services requirements and SGMA requirements concerning water well permitting processes.

2.1.4.4 Plan Elements from CWC Section 10727.4

Per Section 354.8(g) of the GSP regulations, each plan shall include a description of any additional GSP elements included in Water Code Section 10727.4 appropriate to the region. While management area plans provide full details for each element, this section provides a brief overview.

(a) Control of saline water intrusion.

- Because the Kern County Subbasin is located far from coastal areas, saline water intrusion is not considered to be an issue.

ENVIRONMENTAL HEALTH DIVISION
2700 M Street, Suite 300, Bakersfield, CA 93301
Phone # (661) 862-8740 Fax (661) 862-8701
Email EH@kerncounty.com

Overdrafted Basin Supplemental Well Application

FOR OFFICE USE ONLY **Corcoran Clay: ☐ Yes ☐ No** **WP** _____

Assessor's Parcel Number: _____ **Township/Range/Section:** _____

GPS Coordinates: Lat _____ **Long** _____ **Well Elevation (ft):** _____

Water District/GSA: _____ **Est Cumulative Extraction Volume (ac ft) by 12/31/19:** _____

☐ Irrigation ☐ Livestock ☐ Domestic ☐ Municipal ☐ Industrial ☐ Other _____

PROPOSED WELL DESIGN INFORMATION	
Proposed Well Depth (ft):	
Proposed Well Capacity (gal):	
Estimated Pumping Rate (gal/day):	
Proposed Pumping Schedule:	
Est Annual Extraction Volume (ac ft):	

GEOLOGIC SITING INFORMATION PROPOSED WELL	
Water Table Depth (ft):	
Seasonal Fluctuations in Water Table:	
Recharge Area (Yes/No):	
Recharge Rate (if known):	
Area to be served by well (in acres):	

EXISTING ON SITE WELL INFORMATION	Well 1	Well 2	Well 3
Type/Use of Well:			
Depth (ft):			
Diameter (in):			
Screen Interval (ft):			
Pumping Rate (gal/day):			
Est. or Annual Extraction Volume (ac ft):			
Capacity or Pump Test (gal) (if available):			

In addition to the above information, the following information ***must be shown*** on a detailed site map and include actual measurements (to scale not necessary). If in the Corcoran Clay, you may include 2 maps to satisfy the requirements below.

☐ Distance to potential sources of pollution, including but not limited to, septic systems, sewer lines, wells (all types), animal/fowl enclosures, or transmission lines; either existing or proposed.

☐ Distance from lakes, ponds, streams within 300 ft of proposed well

☐ If in Corcoran Clay, location of canals, ditches, pipelines, utility corridors, and roads within 2 miles.

Submitted By_____ Title_____ Date_____

Figure 2-8. Kern County Public Health Services – Overdrafted Basin Supplemental Well Application

(b) Wellhead protection areas and recharge areas.

- Kern County Public Health Services Department Water Well Program issues permits to construct, reconstruct, and destroy water wells (see Section 2.1.4). Recharge areas are managed by individual water districts in the Subbasin to bring in surface water to recharge the groundwater aquifers. Many districts engage in banking programs and work conjunctively to exchange water to support the sustainability of the Subbasin.

(c) Migration of contaminated water.

- The mitigation, remediation, and management of groundwater contamination plumes is regulated in the Subbasin by the Central Valley Regional Water Quality Control Board (CVRWQCB) and the County of Kern. Groundwater contamination plumes have been identified by individual districts, which actively monitor groundwater sampling and work with the CVRWQCB to address groundwater contamination issues. Contamination plumes are not found in every district under KGA, refer to management area plans for specific information.

(d) A well abandonment and well destruction program.

- Kern County Public Health Services Department Water Well Program issues permits to construct, reconstruct, and destroy water wells (see Section 2.1.4).

(e) Replenishment of groundwater extractions.

- KGA member agencies actively manage the groundwater basin within their respective boundaries through conjunctive use and other programs. For specific details pertaining to each management area refer to their management area plan.

(f) Activities implementing, opportunities for, and removing impediments to, conjunctive use or underground storage.

- KGA member agencies actively manage the groundwater basin within their respective boundaries through conjunctive use and other programs. Refer to management area plans for specific details pertaining to each management area.

(g) Well construction policies.

- Kern County Public Health Services Department Water Well Program issues permits to construct, reconstruct, and destroy water wells. To see how this process is coordinated under SGMA with the Subbasin GSAs, see Section 2.1.4.3.

(h) Measures addressing groundwater contamination cleanup, groundwater recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects.

- Oversight of groundwater contamination cleanup is provided by the CVRWQCB and the County of Kern.

- Recharge policies exist across the Subbasin that allows on-farm banking as well as banking and exchanges with other districts in the region.
- Conservation and irrigation efficiency practices have been encouraged and incorporated both at the district and grower level.
- In-lieu use, diversions to storage, water recycling, conveyance, and extraction projects on managed on a district level in the Kern Subbasin.

(i) Efficient water management practices, as defined in Section 10902, for the delivery of water and water conservation methods to improve the efficiency of water use.

- KGA Member Agencies are constantly pursuing efficiency with their water management practices through management plans as outlined in the management area plans.

(j) Efforts to develop relationships with state and federal regulatory agencies.

- Many of the member agencies under KGA hold state and federal water contracts as well as work closely with DWR on projects and management practices. Refer to management area plans for further details.

(k) Processes to review land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity.

- There are a number of water use and land use programs member agencies are involved in within the Kern Subbasin that require land use plans. Refer to management area plans for further details.

(l) Impacts on groundwater dependent ecosystems.

- This element is covered in the KGA Umbrella Chapter, Section 2.3.8, as well as the individual management area plans.

2.1.5 Notice and Communication

SGMA requires that GSAs consider the interests of all beneficial uses and users of groundwater and to encourage and include them in the GSP development process. To capture the intent of SGMA, as legislation better served under local control, KGA member agencies played a vital role in the development of this GSP. This process included communication and outreach at the local level, with each KGA member agency engaging with its beneficial users to gather vital input, data, and feedback to ensure the success of this GSP and individual management area plans.

In May of 2018, the KGA initiated the development of a Communication and Engagement Plan (C&E Plan) (Attachment E) to facilitate and assist KGA member agencies in stakeholder engagement and outreach. KGA communication and outreach consisted of stakeholder meetings and workshops; maintaining an interested parties list for KGA events; and development of a Stakeholder Survey and Agricultural Survey for the benefit of KGA member agencies. In

addition to outreach and communication through the KGA, each member agency was tasked with conducting their own communication and outreach to better capture the diverse needs of their beneficial users within their jurisdictional areas. By receiving information directly for member agencies using a local control approach, users greatly benefitted.

For more detailed information on KGA member agency communication and outreach efforts please see the member agencies' management area plans.

2.1.5.1 Description of Beneficial Uses and Users in the Subbasin

As was previously stated, as required by SGMA, GSAs must consider the interests of all beneficial uses and users of groundwater and include them in the GSP development process. For the KGA and its member agencies, beneficial users are stakeholders who have an interest or a need in groundwater use within the boundaries of the KGA. With the development of the C&E Plan the focus was to address the opportunities for engagement and to encourage participation by beneficial users. Located within the C&E Plan are lists of beneficial users as well as a stakeholder engagement timeline based on phases of the GSP development and implementation processes. The engagement timeline for the KGA are shown in the following figures; Figures 2-9, Phase 1: GSA Formation and Coordination; Figure 2-10, GSP Preparation and Submission; and Figure 2-11, GSP Review and Evaluation.

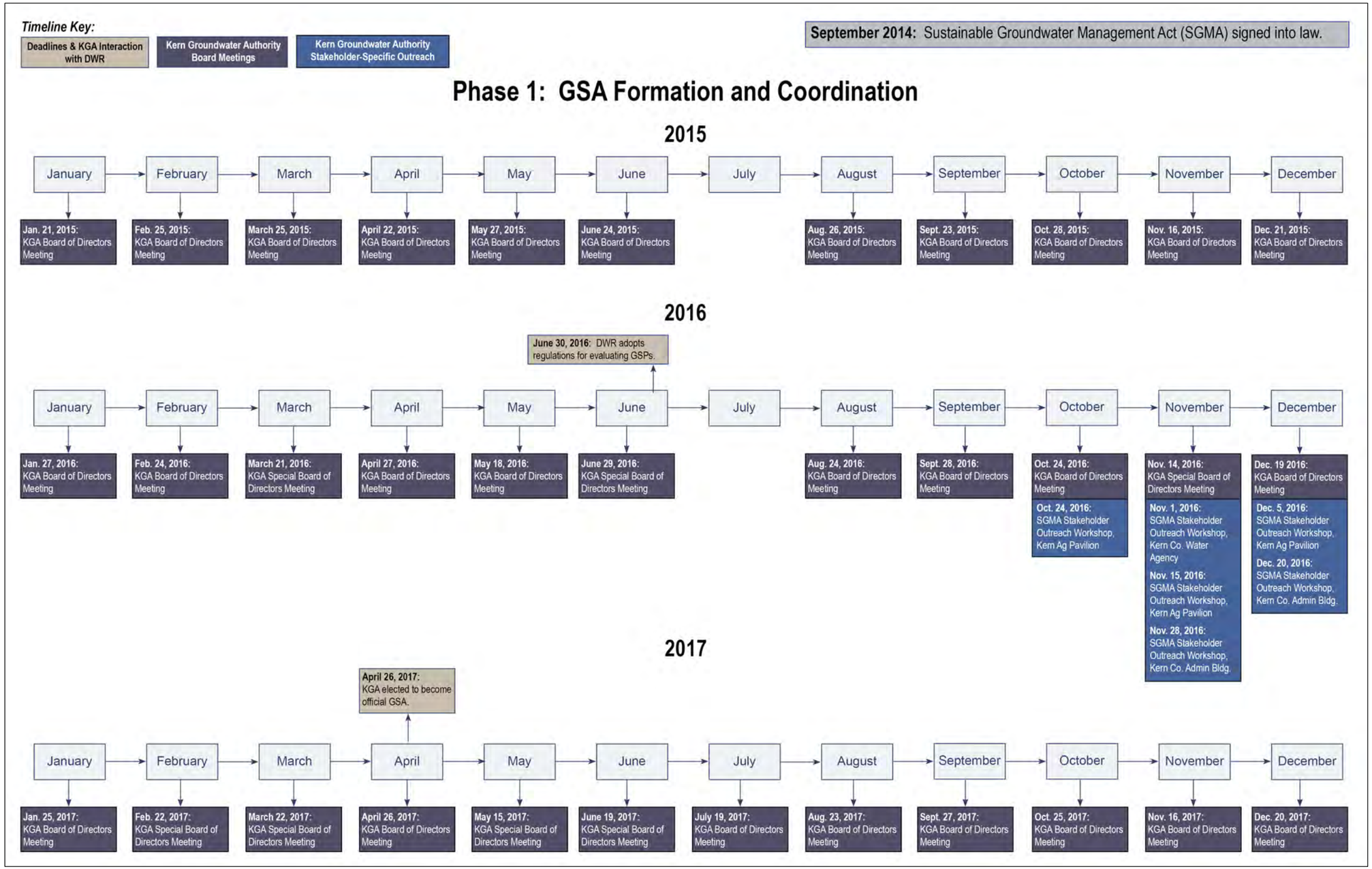
Another component of the C&E Plan was the development of the interest parties list. The interested parties list began development immediately and is constantly updated to include all interested parties who sign in/attend any of the monthly meetings held by the KGA and/or its member agencies.

The development of the Stakeholder Survey and Agricultural Survey was a vital instrument in the KGA outreach during the process of the development of the management area plans. To capture as many diverse beneficial users as possible, the Stakeholder Survey was developed in both English and Spanish and was available at workshops, stakeholder meetings, and both were accessible on the KGA website where they could be completed online. The information provided by the beneficial user assisted the KGA member agencies in the development of their projects and management actions. These surveys are located on the KGA website and can be completed online anytime during the process of the development of the management area plans. Monthly, the KGA took the information provided from those surveys and provided a summary report to the KGA Board of Directors, the KGA member agency managers, and to the public for their consideration.

2.1.5.2 Communication

Decision-Making Process

KGA was formed by a JPA that stipulates that each member agency has the sole right and responsibility to develop and implement SGMA within its respective boundaries; however, the KGA Board is the final decision-maker for the KGA and its member agencies, except for the implementation of SGMA within a management area. Implementation of SGMA is to be governed by the member agency within its jurisdiction.



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Figure 2--9. Kern Groundwater Authority's Communication & Engagement Timeline – Phase 1: GSA Formation and Coordination

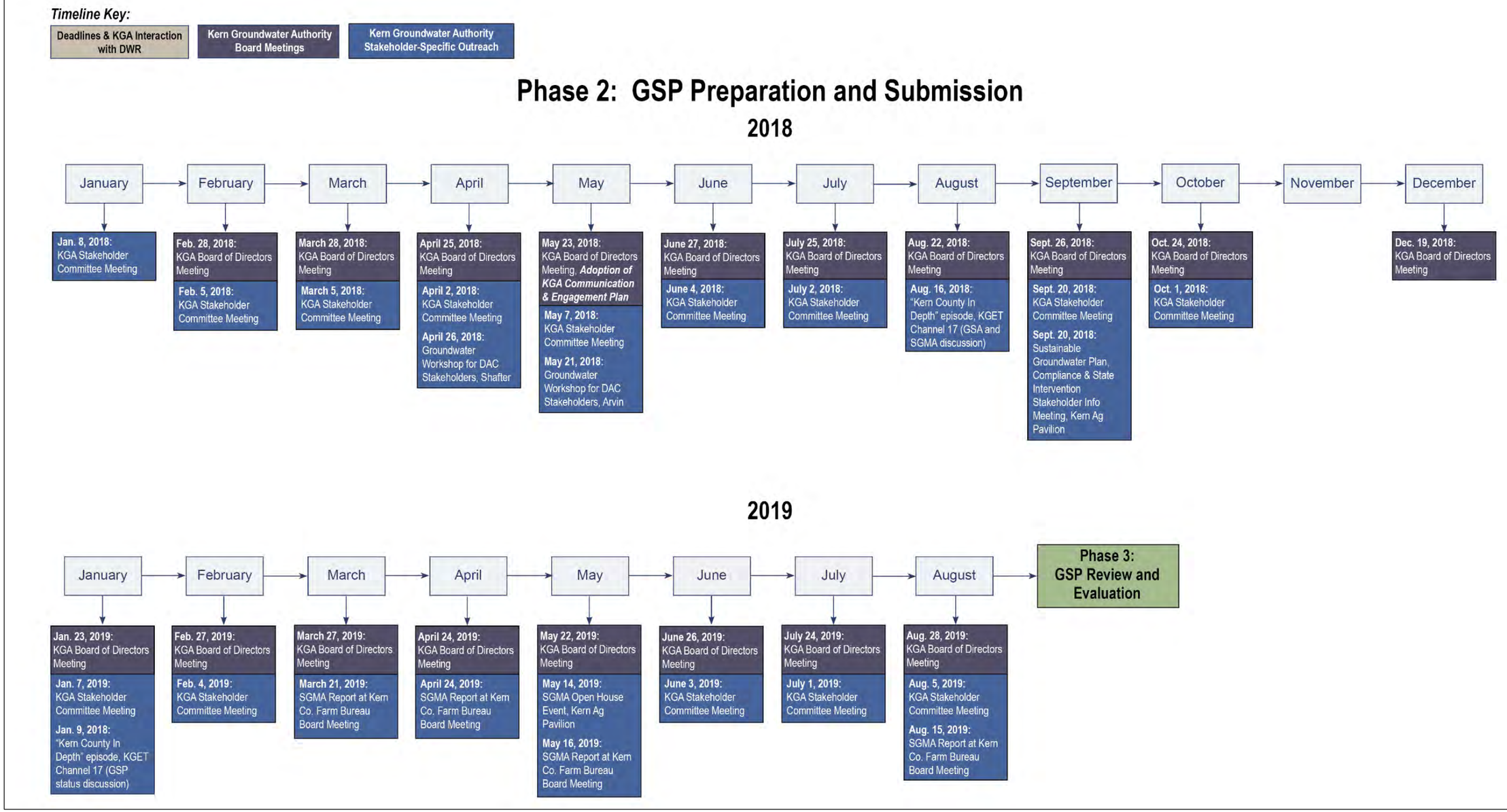


Figure **2-10**. Kern Groundwater Authority's Communication & Engagement Timeline – Phase 2: GSP Preparation and Submission, and Phase 3: GSP Review and Evaluation

Timeline Key:

Deadlines & KGA Interaction with DWR | Kern Groundwater Authority Board Meetings | Kern Groundwater Authority Stakeholder-Specific Outreach

Phase 3: GSP Review and Evaluation

2019

August

Aug. 28, 2019: KGA Board of Directors Meeting

Aug. 5, 2019: KGA Stakeholder Committee Meeting

August 2019: Management Area/ GSP Plan Presentations to KGA Member Agencies' Boards of Directors

Aug. 28, 2019: "Kern County In Depth" episode, KGET Channel 17 (Release of GSPs for public review, management actions/projects, and next steps)

September

Sept. 25, 2019: KGA Board of Directors Meeting

Sept. 4, 2019: KGA Stakeholder Committee Meeting

Sept. 13, 2019: GSP Public Review Presentation, Greater Bakersfield Chamber of Commerce

Sept. 20, 2019: GSP Public Review Presentation, California Partnership for the San Joaquin Valley

Sept. 26, 2019: GSP Public Review Open House for Stakeholders, Kern Ag Pavilion

October

Oct. 23, 2019: KGA Board of Directors Meeting

Oct. 7. 2019: KGA Stakeholder Committee Meeting

November

Nov. 20, 2019: KGA Board of Directors Meeting

Nov. 4, 2019: KGA Stakeholder Committee Meeting

Nov. 11, 2019: GSP Public Review Presentation, Kern Leaders Academy

Nov. 12, 2019: GSP Public Review Presentation, Bakersfield Hispanic Chamber of Commerce

Nov. 1, 2019: GSP Public Review Presentation, Kern County Farm Bureau

December

Dec. 18, 2019: KGA GSP Public Hearing & Board of Directors Meeting

Dec. 19, 2019: GSP Update Presentation, Central California Environmental Justice Network

2020

January

January 31, 2020: Kern Groundwater Authority GSP due to DWR

Jan. 15, 2020: KGA Board of Directors Meeting

Jan. 15, 2020: GSP Overview Presentation, CAL CPA

Jan. 16, 2020: GSP Overview Presentation, Kern County Farm Bureau

Jan. 22, 2020: GSP Overview Presentation, Kern County LAFCO Board

February

February 3, 2020: 60-day Public Review period through DWR begins

Phase 4: Implementation & Reporting begins

March

April

April 2, 2020: 60-day Public Review period through DWR ends

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Figure 2.11. Kern Groundwater Authority's Communication & Engagement Timeline – Phase 3: GSP Review and Evaluation

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The JPA is written to provide open and transparent communication to all beneficial users; thus, the KGA's decision-making process consists of several public meeting opportunities:

- The KGA Board of Directors public meetings are on the fourth Wednesday of every month and include presentations regarding the development of the GSP as well as decisions on coordinated SGMA requirements with the other GSAs in the Subbasin. Public meetings also include administrative and financial decisions. Meeting notification includes public posting of the board agenda and background materials on the KGA website and an email notification to the interested parties list a week prior to the meeting, which also includes all relevant meeting materials.
- As the Subbasin GSPs were developed, KGA and the other GSAs established coordination meetings. These meetings began in July 2018 to coordinate each of the five GSPs scheduled to be developed and submitted to DWR. These meetings are held every Friday morning and are attended by all KGA member agency managers and the other four GSA managers. These meetings included discussions to obtain an understanding and consensus on the data and methodologies used in the five GSPs. Once an understanding and consensus was reached, the data and methodology were then discussed at the Kern GSA Coordination Committee meeting, where each of the five GSAs are represented by a policy or board member and a staff manager, as well as at stakeholder public meetings.
- Stakeholder public meetings were held on the first Monday of every month where presentations were made concerning the development of this GSP as well as items that need to be coordinated under SGMA with the other GSAs. These meetings began under the name of the Coordination Committee and then changed to Stakeholder meetings in 2018. Typically, meetings were open discussions with occasional presentations for specific GSP elements. If there were no new developments on the GSP, meetings were cancelled to take into consideration beneficial users' time. All meeting dates and presentation materials are located on the KGA website with email notifications sent out to the interested parties list prior to meetings, which included all relevant meeting materials.
- Kern GSA Coordination Committee meetings were established to coordinate the data and methodologies at a policy-level. These meetings were held on the third Wednesday of every month and were attended by one policy decision-maker from each of the GSAs and staff members to assist in the discussion. These meetings were established to maintain the coordination as well as the requirement of utilizing the same data and methodologies throughout the development of the five GSPs.

Public Engagement Opportunities

As previously stated, each KGA member implemented its own outreach programs to provide opportunities for beneficial users to participate in the development of individual management area plans. The details of these outreach programs can be found in the management area plans. However, the KGA held several public workshops, stakeholder meetings (mentioned above),

Farm Bureau meetings discussions, and media outreach. These meetings are listed in the C&E Plan and are also indicated in the list below.

2.1.5.3 Informing the Public about GSP Development Progress

KGA Website

The website was established immediately upon approval as an exclusive GSA and is updated monthly with materials from all the meetings including presentation materials and board packages. There is also a Resource & Outreach tab that provides the technical reports and workshop materials.

Interested Parties List

An email distribution list of stakeholders and beneficial users was developed and is constantly updated for outreach and notices throughout the GSP planning process. The list is maintained and updated by the KGA and is included in the C&E Plan.

Media

The KGA has participated in several media segments televised by Kern Golden Empire Television (KGET) Channel 17 – Kern County in Depth segment. There have been three tapings since the establishment of SGMA, one for the formation of the GSAs, the withdrawal of Kern County impacts to SGMA and the beginning process of the GSP, and the release of the GSP and the process moving forward. These are televised for a month and are also located on KGET Channel 17 website.

2.1.5.4 Public Comments

Public comments were collected throughout GSP development process and incorporated into the development of KGA Umbrella GSP and the management area plans of the KGA members, as described above. Additionally, the KGA prepared a Public Draft Kern Groundwater Authority Groundwater Sustainability Plan in August 2019. The draft KGA GSP was made available during a noticed public comment period from August 30, 2019 to November 28, 2019. Comments received were considered and responded to either in this final version of the KGA GSP or were forwarded to the appropriate KGA member agency for their consideration. All comments received and responded to those comments are included in Attachment F.

2.2 Basin Setting

This basin setting focuses on the area encompassed within the jurisdiction of the KGA, its participating members agencies, and collaborators. Figure 2-1 presents the current extent of the KGA jurisdictional area and member agencies. Due to the proximity of adjacent GSAs, details and data from adjacent GSAs are included herein. This basin setting is intended to represent an overview of the entire Subbasin. Additional details are included in the basin setting description of other GSPs prepared in the Subbasin and in the management area plans prepared by KGA member agencies.

2.2.1 Hydrogeologic Conceptual Model

Numerous descriptions and reports of local hydrogeologic conditions are available for the Subbasin. Details from previous investigations relating to the regional geologic and structural setting of the Subbasin; geologic features affecting groundwater flow; vertical and lateral boundaries; primary aquifers and aquitards; groundwater elevations and flow direction over time; and water quality are described below. This information is the foundation for the hydrogeologic conceptual model (HCM).

This HCM has been prepared under the supervision of Matthew Mayry, Certified Hydrogeologist.

2.2.1.1 Kern County and Lateral Boundaries

The Kern County Subbasin (5-022.14) (Figure 2-12), is within the southernmost portion of the Tulare Lake Hydrologic Region of the San Joaquin River Basin (5-022). The Subbasin encompasses a surface area of 1,792,000 acres (2,800 square miles) and contains approximately 32,000 feet (6 miles) of marine and continental sediments (DWR, 2006; Page, 1986). The Subbasin has approximately 40,000,000 acre-feet (AF) of groundwater storage with another 10,000,000 AF of storage capacity, including areas where water levels have declined (DWR, 2006). A recent U.S. Geological Survey (USGS) estimate of sediment thickness is 3 miles for the San Joaquin Valley (Faunt et al., 2009). Continental sediments comprise up to approximately 3,400 feet of the material along the Kern River near the town of Tupman (western side of the valley), and the base of the fill is over 18,000 feet deep (Davis et al., 1959).

The lateral boundaries of the Subbasin, are defined by various jurisdictional and geomorphic segments, as presented by DWR (2016b). The Subbasin is bounded by the Sierra Nevada on the east; by the Tehachapi mountains, San Emigdio mountains, and White Wolf Subbasin (5-022.18) on the south; and the Coast Range (Temblor Range) on the west. To the north of Subbasin are the following Subbasins: Kettleman Plain (5-022.17), Tulare Lake (5-022.12), and Tule (5-022.13).



Figure 2-12. Kern County Subbasin and Vicinity

2.2.1.2 Regional Geologic and Structural Setting

A brief description of the evolution of valley sediments and fill is included below, as it relates to the regional aquifer system of the Tulare Lake Region of the San Joaquin Valley Basin.

During pre-Tertiary time granitic rocks were deposited in the present-day area of the Sierra Nevada and Tehachapi Mountains (eastern and southeastern flanks of the Subbasin). Plutonic and tectonic activity also formed metamorphics that occur along the margins of the Subbasin. As tectonic activity uplifted these granitic and metamorphic deposits, erosion with subsequent transport of sediment into the basin occurred. These rocks form an almost impermeable boundary for the groundwater basin, but fractures and joints permit small yields of water to wells (Page, 1986).

Near the end of the Late Cretaceous, tectonic movements elevated the Coast Ranges to the west of the Central Valley which created a marine embayment in the present-day Southern San Joaquin region. During the Tertiary, seas advanced and retreated within this southern embayment, resulting in deposits comprised of both continental and marine sediments. The most recent of which are the Pyramid Hills, Vedder Sand, Olcese Sand, Santa Margarita Formation, and San Joaquin and Etchegoin Formations.

During the late Tertiary, uplift of basement occurred near present-day Bakersfield forming what researchers have termed the Bakersfield Arch. The Arch effectively resulted in depocenters for thick sequences of sediment to accumulate to the north and south of the Kern River (Bartow, 1991; Vasconcellos, 2016; Figure 2-13) during later Tertiary and Quaternary time. Tertiary crustal uplift and shifting caused the formation of the Sierra Nevada, Temblor, and Coast Ranges (Bartow, 1991). Crustal deformation along the proto-San Andreas and present-day San Andreas led to the formation of the structural traps for oil and gas accumulation throughout the west-side.

The Quaternary Period (Pleistocene and Holocene), marked a time when the seas retreated, and continental deposits from alluvial and fluvial systems formed (Tulare and Kern River Formations (Page, 1986). Marine rocks and deposits are, in part, the source rocks for the Tulare Formation on the west and the granitic from the Sierra Nevada on the east are the source rocks for the Kern River Formation. Some of the marine deposits on the west, contain saline water, that could have migrated into adjacent and overlying continental deposits (Page, 1986). Overall, the continental rocks make up most of the regional aquifer system in the central and eastern sides of the Subbasin while brackish to freshwater deposits and eroded marine deposits of the Coast Range make up a very small portion of the water-bearing units on the western side of the Subbasin.

The Pleistocene Epoch was dominated by brackish and freshwater lakes within the Subbasin, resulting in thick deposits of clay, as found throughout the upper Tulare Formation. In particular, the Corcoran Clay has been mapped over much of the San Joaquin Valley (including Tulare Lake Region), and its equivalents have been correlated to clays beneath the Kern and Buena Vista dry lake beds in the southern part of the Subbasin, as well as the Tulare Lake sediments on the northern boundary of Kern County (Croft 1972; Page, 1986) (Figure 2-14). This clay makes up a considerable impermeable to semipermeable zone that divides shallower poor-quality water from higher quality water of the regional aquifer system.

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DWR Bulletin 118 - San Joaquin Valley Groundwater Basin - Kern County Subbasin

Qs — Alluvial and lacustrine sediments (Quaternary)

Tv — Volcanic rocks (Tertiary)

Ts — Sedimentary rocks (Tertiary) - Marine and nonmarine rocks.

TJgv — Great Valley sequence (Tertiary to Jurassic) - Melanges of sedimentary rocks

Approximate area of structural arch

Contact

Fault - Dashed where approximately located; dotted where concealed; queried where uncertain. Bar and ball on downthrown side; R on upthrown side of reverse fault; arrows indicate direction of relative movement.

Thrust fault - Dotted where concealed. Sawteeth on upper plate

Fold - Dotted where concealed. Showing approximate trace of axial plane; arrows indicate direction of plunge

Anticline

Syncline

Boundary of structural region - Dashed where approximately located

5 — Location of stratigraphic column - Number refers to column number on plate 2

SOURCE: Bartow, 1991. PP 1501. Plate 1 - Generalized Geologic Map and Cross Sections of the San Joaquin Valley Area, California

10 5 0 10

Miles

N

W E

S

Kern Groundwater Authority
Basin Setting

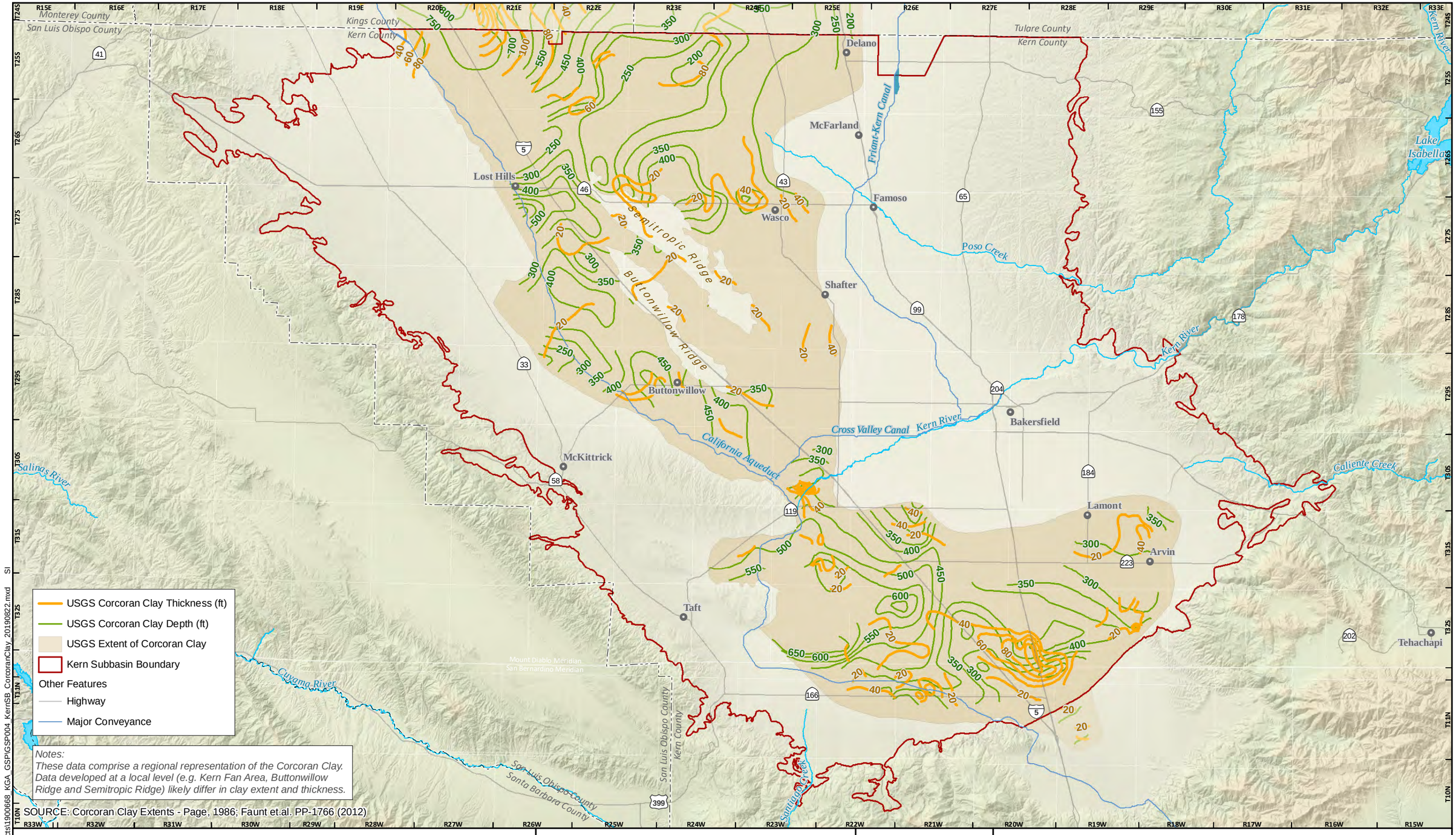
Kern County, California

GEI Consultants

GEOLOGIC MAP (BARTOW, 1991)

AUGUST 2019

FIGURE 2-13



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

APPROXIMATE THICKNESS AND EXTENT OF E-MODIFIED CORCORAN CLAY

JULY 2019

FIGURE 2-14

Since the Pleistocene Epoch, stream channels, lakes, and rivers have deposited alluvium throughout the Subbasin. Alluvial fans have formed on both sides of the valley, but most notably on the eastern side where the Sierra Nevada granitics are the main source of sediment (Poso Creek Fan, Kern River Fan, and Caliente Creek Fan). On the eastern side of the valley, these stream channels are large, laterally migrating distributary channels. Over time, shifting stream channels have created coalescing fans, forming broad sheets of inter-fingering, wedge-shaped lenses of gravel, sand, and finer detritus (Page, 1986), which make up the shallow continental water-bearing deposits of the regional aquifer system. Page (1986) identified various depositional environments for the continental sediments, including alluvial fan and deltaic conditions on the eastern side of the valley, and flood-plain, lake, and marsh conditions on the western side. Consequently, coarse-grained deposits are predominant on the eastern side while fine-grained deposits are predominant within the central and western areas of the Subbasin.

Figure 2-15 is a conceptual block diagram that generally illustrates the highlands surrounding the Subbasin with folded beds separating the west side from the east side. This diagram displays the succession of marine deposition to more recent continental deposition and alluvium with fresher water deposits.

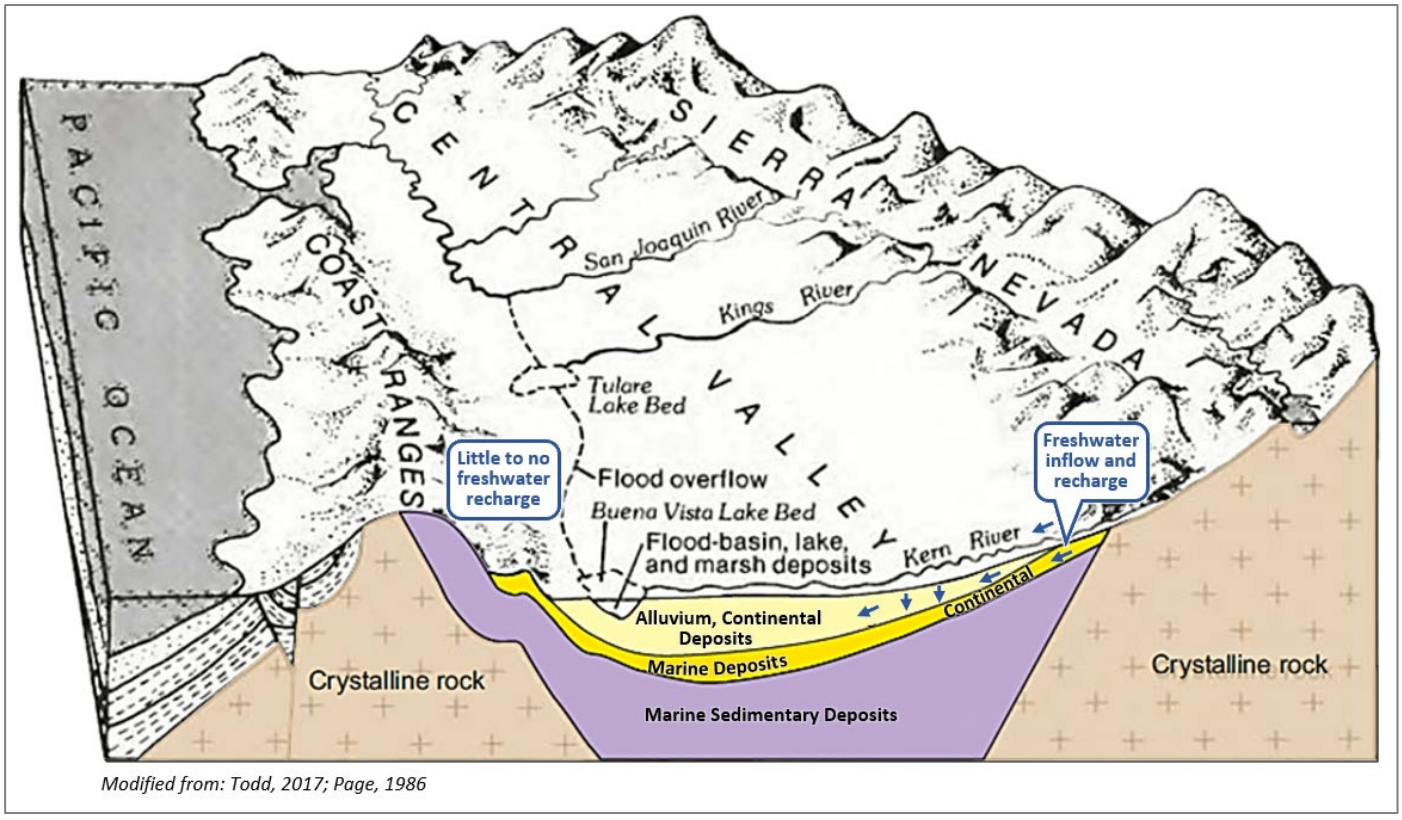


Figure 2-15. Conceptual Block Diagram Looking North from Kern River

The geologic history discussed above is related to the stratigraphy described below, and as summarized in Table 2-2. The description also includes a discussion of the portions of the formations that bear groundwater that have been utilized historically.

Table 2-2. Generalized Hydrostratigraphy of Kern County Subbasin

Age	Geologic Units of Interest	General Description		Deposition		AE	General Hydrogeologic Context
Recent	Alluvium	Discontinuous beds of sand, silt, clay and gravel, becoming finer grained toward the valley.		Continental / Alluvial	Alluvial Fans		Shallow unconfined aquifer in some areas of the subbasin.
Pleistocene	Older Alluvium						
	Tulare Formation	Interbedded gravel, sand, silt, and clay.			Marine, Debris Flows, Fluvial, Semi-arid to arid (West)/ Fluvial-Lacustrine (East)		Major freshwater aquifer of the subbasin.
	Corcoran Clay	Silt and clay. Lacustrine.					Confining/semi-confining aquitard in the west-central and central-southern subbasin.
	Tulare Formation	Kern River Formation Alluvial Fan Deposits. Interbedded gravel, sand, silt, and clay.	Interbedded gravel, sand, silt, and clay.			**AE**	Major fresh water aquifer of the subbasin.
Pliocene	San Joaquin Formation		Siltstone, clayey, diatomaceous with thin lenticular sand beds.	Transitional	Continental and brackish to restrictive marine		Fresh water production limited to deep wells.
Miocene	Etchegoin Formation **AE**	Fresh water production on east side of the valley.	Clay and silt to sand, gravel, and sandstone		Marine to partly continental	**AE**	Fresh water production limited to deep wells.
	Santa Margarita Sandstone **AE**	Chanac Formation Conglomerate with lenses of coarse sand and clays Non-Marine Clastic. Limited fresh water production on east side.	Fine to coarse white sand, gravel, and sandstone.		Shallow Marine Clastic	**AE**	Fresh water aquifer on east/northeast side of the valley
	Round Mountain Silt	Brown siltstone, diatomaceous		Marine	Marine		Aquitard on east side of the subbasin.
	Olcese Sand	Light gray sandstone with a few pebble and siltstone beds.			Marine/ nonmarine clastic wedge	**AE**	Fresh water aquifer on the east/northeast side of the subbasin.
	Freeman-Jewett Silt	Brown siltstone with interbedded ash.			Marine to shallow water	**AE**	Aquitard
Oligocene	Pyramid Hills and Vedder Sands	Interbedded sandstone and siltstone			Marine to shallow water	**AE**	Possible fresh water aquifer on the east/northeast side of the subbasin.

Data sources from: Page, 1986; Bartow, 1983 and 1991; Provost and Pritchard, 2003; Todd Engineers et al, 2007; Scheirer et al, 2007; SWSD, 2012; Tor Nilsen, 1996; and KTWD, 2016.

Aquifer Exemptions present (AE) - California Department of Conservation, https://www.conservation.ca.gov/dog/Pages/Aquifer-Exemptions-Status.aspx.

Stratigraphy

The Oligocene Pyramid Hills and Vedder Sands are interbedded sandstone and siltstone deposited in a shallow to deep marine environment and in a limited non-marine environment. They may produce fresh groundwater on the east and southeast sides of the Subbasin (Page, 1986).

The Miocene Olcese Sand and Santa Margarita Sandstone are current sources of drinking water in the northeastern portion of the Subbasin where they occur as confined aquifers (KTWD, 2016). The origin of the Miocene Olcese Sand and Santa Margarita Sandstone varies from continental to marine going from east to west across the Subbasin (Scheirer, et al, 2007a). The Miocene Olcese Sand ranges up to 600 feet in thickness and consists of unconsolidated medium- to coarse-grained sand containing a few pebble and siltstone beds. The formation is exposed in the Poso Creek area (Page, 1986) and is utilized by the Olcese Water District in the Kern River Canyon. The Santa Margarita Sandstone ranges in thickness from 200 to 600 feet and consists of coarse-grained sand (DWR 2006), and includes an upper bed of fine, silty, well sorted gray sand, and a lower bed of brownish-gray and brown fossiliferous micaceous sandy siltstone. According to Page (1986), the sandstone is a major aquifer that reportedly yields as much as 1,950 gallons per minute (gpm) to wells. Croft (1972) reported that the formation also yields water to wells in the foothills southeast of Bakersfield. The Round Mountain Silt is an aquitard that separates the Miocene Olcese Sand from the Santa Margarita Sandstone and acts as a confining unit for the Miocene Olcese Sand (KTWD, 2016). This silt unit consists mostly of a gray and brown siltstone that contains beds of diatomite and silty sand (Page, 1986), and ranges in thickness from 0 to about 200 feet.

The Mio-Pliocene Etchegoin Formation varies considerably, ranging from clay and silt to sand, gravel, and sandstone. It ranges in thickness from a few tens of feet to more than 2,000 feet. Several wells near the foothills and a few deep wells in the valley derive fresh water from the Etchegoin; however, its depth is more than 3,000 feet beneath most of the valley and is limited to deep well production (Page, 1986).

Overlying the Etchegoin Formation is the Pliocene San Joaquin Formation of marine deposition. It contains silt and silty sandstone, with a conglomerate at the base of the formation. In the deep subsurface northeast of the Kettleman Hills, the formation is considered a shoreline deposit because the material is coarser and more permeable than in the Kettleman Hills area and yields fresh water to many wells. The San Joaquin Formation is the youngest marine deposit in the Central Valley (Page, 1986), representing the end of marine deposition in this area. Overlying sediments were deposited by alluvial, fluvial, and lacustrine processes.

The Tulare Formation is Plio-Pleistocene in age, and in conjunction with the Kern River Formation (Mio-Pliocene to possibly early Pleistocene), represents west-east facies change across the Subbasin. The Tulare and Kern River formations are moderately to highly permeable and are major freshwater sources within the Subbasin (Page, 1986; SWSD, 2012).

The Tulare Formation (western-central Subbasin) contains up to 2,200 feet of interbedded, oxidized to reduced sands, gypsiferous clays, and gravels derived primarily from Coast Range

sources. The permeable deposits of the Tulare Formation are divided into upper and lower units, separated by the E-modified Corcoran Clay member (Corcoran Clay) of the formation. Groundwater beneath the Corcoran Clay is typically confined to semiconfined (Page, 1986; SWSD, 2012). In addition to its confining properties, laboratory tests indicate that the clay is highly susceptible to compaction (Faunt, et al., 2009). On the west side of the Subbasin, the Tulare Formation is also divided by upper and lower units by potential equivalents to the Corcoran Clay that are reported locally (Rector, 1983; Geomega, 2001). While the central part of the basin was deposited in a fluvial-lacustrine environment, the west side has lacustrine claystones, fan-delta deposits, debris-flow dominated alluvial-fan deposits, but also paleosols representing an arid to semiarid setting (Nilsen and Campbell, 1996). The difference in Tulare deposition illustrates fundamental differences between the west side and east side aquifer system.

The Corcoran Clay occurs laterally in the north Subbasin (~34 miles wide in extent) from Delano to Lost Hills (Figure 2-14) and narrows to the south where it is not a confining bed in the Kern Fan Area. Although the USGS data present a clay in the western part of the Kern Fan area, local data do not support the presence of an extensive confining clay in the Kern Fan area. A clay in the south part of the Subbasin has been correlated as the Corcoran Clay by many investigators including Croft (1972) and Page (1986). It extends from Buena Vista Lake Beds to just east of Arvin and DiGiorgio (~31 miles wide in extent). In the south Subbasin, the Corcoran Clay is present at depths between 250 and 650 feet (DWR, 1981). Within the central area of the Subbasin between the Kern River and Highway 46, the depth to the Corcoran Clay varies from 300 to 450 feet. Further north to the county line, the depth varies from 200 to 750 feet. The Corcoran Clay, most notably the modified E-clay (Page, 1986) is generally very fine grained; however, isolated, coarser zones are possible, particularly where the clay is less than 20 feet thick. The thickness of the clay is as much as 100 feet in a small area of the southern Subbasin but typically varies between 20 and 40 feet. In the northern Subbasin, the clay might be as thick as 60 to 80 feet in isolated areas, but the thickness typically varies between 10 and 30 feet. The Corcoran Clay does not exist under the Kern Alluvial Fan (Kern Fan), where the shallow unconfined layers are separated from deeper layers by an intermediate zone of interbedded sands and silts which retard vertical groundwater flow and create an increase in semi-confinement with depth. The Corcoran Clay is also not present in the eastern/northeastern part of the Subbasin from the cities of McFarland and Bakersfield, to Edison (Faunt et al., 2009).

The Kern River Formation includes from 500 to 2,000 feet of poorly sorted, lenticular deposits of clay, silt, sand, and gravel derived from the Sierra Nevada. The Kern River Formation crops out in the east Subbasin and reaches its maximum thickness of 2,600 feet in the subsurface west of mapped outcrops (Bartow and Pittman, 1983). The formation consists mostly of poorly sorted fluvial sandstone and conglomerate with interbeds of siltstone or mudstone that becomes finer grained northward and westward. Some of the thicker siltstone or mudstone interbeds may represent deposits of small ephemeral lakes or ponds (Bartow and Pittman, 1983). The Kern River Formation is coarsest in its easternmost exposures, generally the area south of the Kern River, where the composition includes a cobble conglomerate with boulders near the base and pebbly sandstone. (Bartow and Pittman, 1983). Two oil-producing zones occur in the lower part

of the formation where it is believed to have migrated to the Kern River Formation from older marine sediments (Bartow and Pittman, 1983).

The Kern River Formation unconformably overlies the Chanac Formation and may be contemporaneous with the Etchegoin, San Joaquin, and the Tulare formations (Bartow and Pittman, 1983 and Bartow, 1991); however, Graham and others (1988) concluded that the Kern River Formation predates the Corcoran Clay, which has a basal age of about 725,000 years. Radiometric dating of a volcanic ash layer near the top of the Kern River Formation at the Kern River oilfield may agree with the aforementioned basal age; however, others dated this ash bed at 6 million years which would place the Kern River Formation solely in the Miocene (Scheirer et al., 2007a). Nevertheless, the gradational relationship between the Kern River Formation and seemingly younger units such as the Etchegoin, San Joaquin, and Tulare formations would have to be reexamined.

Older alluvium and terrace deposits overly the Tulare and Kern River formations. These deposits also make up a portion of the regional aquifer system. They are composed of up to 250 feet of Pleistocene-age lenticular deposits of clay, silt, sand, and gravel that are loosely consolidated to cemented. These deposits are moderately to highly permeable and yield sufficient water to wells. They are often indistinguishable from the underlying Tulare and Kern River formations (DWR, 2006).

The Holocene-age younger alluvium and flood basin deposits vary in character and thickness in the Subbasin. Along the eastern and southern Subbasin margins, these younger deposits consist of up to 150 feet of interstratified and discontinuous beds of clay, silt, sand, and gravel. In the southwestern portion of the Subbasin, the deposits are finer-grained and less permeable as they grade into fine-grained flood basin deposits underlying the historic lakebeds of Buena Vista and Kern lakes in the southern portion of the Subbasin. The flood basin deposits consist of silt, silty clay, sandy clay, and clay interbedded with poorly permeable sand layers. These flood basin deposits are difficult to distinguish from underlying fine-grained older alluvium (Page, 1986; DWR, 2006).

As described above for the deposition of the Tulare and Kern River formations and Quaternary facies differ from west to east across the basin. The below diagram (Figure 2-16) illustrates the general distribution of facies fluvial-deltaic deposition dominating the east-side; alluvial, lacustrine, and marsh deposition dominating the central portions of the basin, and alluvial and debris flow deposition dominating the western side of the Subbasin during the Quaternary.

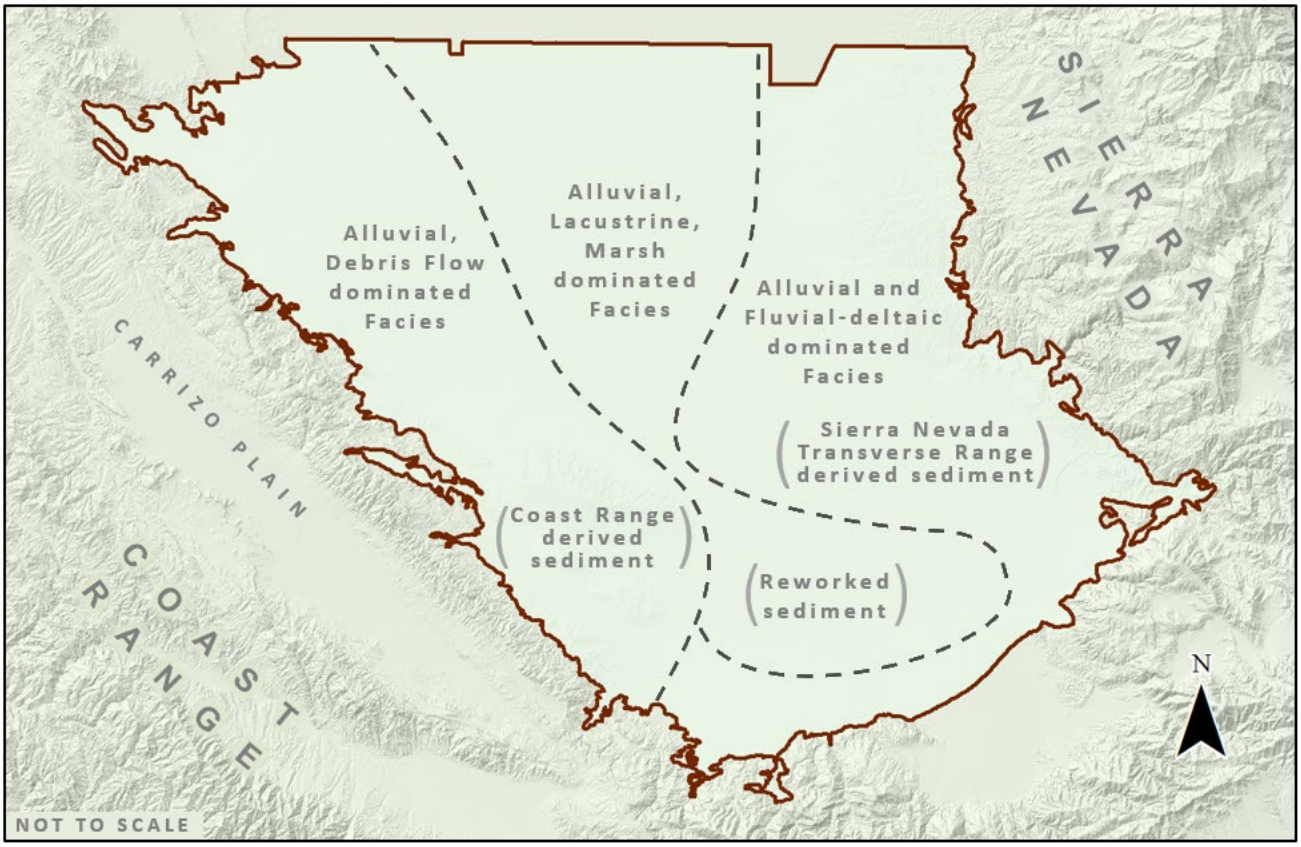


Figure 2-16: Generalized Quaternary Depositional Facies

2.2.1.3 Geologic Features that Significantly Affect Groundwater Flow

The primary structure in the Subbasin that affects groundwater flow is the large asymmetric structural trough (San Joaquin Valley Syncline) that has been the depocenter of thousands of feet of sediments since late Mesozoic time (Bartow, 1991). Groundwater naturally flows northwest along the trend of the syncline. Likewise, the Bakersfield Arch is a broad southwest-plunging arch of basement rock that separates the small Maricopa-Tejon sedimentary basin at the south end with the remainder of the sedimentary basin to the north and west (Figure 2-13, from Bartow, 1991). Groundwater recharging from the Kern River will flow north and south along the flanks of the arch away from the center of the Subbasin.

Numerous faults and folds are located in the Subbasin, as shown in local geologic maps (Figures 2-13, 2-17, and 2-18). Bartow (1991) identified portions of three types of structural regions in Subbasin, excluding the Bakersfield Arch. The northeastern third of the Subbasin, including the north half of the Arch, is located on the minimally-deformed eastern limb of the valley syncline. Normal faulting is associated with the Bakersfield Arch, occurring mostly in the older sediments (QPc; Ts) but extending into and concealed by the younger sediments (Qoa, Q; Qs), notably the Pond-Poso Creek Fault. Fault orientations vary from northwest to northeast due to alternating compressional and extensional forces.

.

DWR Bulletin 118 - San Joaquin Valley Groundwater Basin - Kern County Subbasin

DESCRIPTION OF MAP UNITS

Qs **Sand dunes (Holocene)** Windblown sand and dune sand

Qb **Flood-basin deposits (Holocene)** Clay, silt, and some sand; near Stockton consist of muck, peat, and other organic soils. In places may include part of the Modesto Formation (Pleistocene)

Qr **River deposits (Holocene)** Gravel, sand, silt, and minor amounts of clay deposited along channels, flood plains, and natural levees of main streams. In places may include part of Modesto Formation (Pleistocene)

QTl **Lacustrine and marsh deposits (Pliocene to Holocene)** Clay, silt, and some sand; in subsurface include three widespread clays: A clay (Pleistocene and Holocene?); C clay (Pleistocene); and modified E clay (Pleistocene), includes Corcoran Clay Member of Tulare and Turlock Lake Formations

QTc **Continental rocks and deposits (Miocene to Holocene)** Heterogeneous mix of generally poorly sorted clay, silt, sand, and gravel; some beds of claystone, siltstone, sandstone, and conglomerates. Include some informal units: younger alluvium (Holocene), older alluvium (Pleistocene and Holocene?) and continental deposits (Pliocene and Pleistocene); three formations of Pleistocene age: Modesto, Riverbank, and Turlock Lake; Tulare Formation (Pliocene and Pleistocene) on western side of valley, Laguna Formation (Pliocene) on eastern side, and Kern River Formation (Miocene to Pleistocene?) on southeastern part

Tvd **Volcanic rocks and deposits (Miocene and Pliocene)** Massive tuff with large fragments of vesicular basalt northwest of Tracy; tuff, and volcanic breccia at south end of valley

Tcpm **Continental rocks and deposits (Miocene and Pliocene)** Gravel, sand, silt, clay, conglomerate, sandstone, siltstone, and claystone, contain andesitic material. Principally Mehrten Formation (Miocene and Pliocene) on eastern side of valley; include continental equivalents of Etchegbin Formation (Miocene and Pliocene) on western side of valley, and Chanac Formation (Miocene) on southern part

Tcmo **Continental and marine rocks and deposits (Miocene and Pliocene)** Gravel, sand, silt, clay, silty sandstone, and siltstone. Include continental and marine equivalents of San Joaquin Formation (Pliocene) and Etchegoin Formation (Miocene and Pliocene)

Tm **Marine rocks and deposits (Eocene, Oligocene, Miocene, and Pliocene)** Sand, clay, silt, sandstone, shale, mudstone, and siltstone. On western side of valley include the San Joaquin and Etchegoin Formations, Temblor Formation (Oligocene and Miocene) and Kreyenhagen Formation (Eocene). On southeastern side include the Santa Margarita Formation of various authors, the Round Mountain Silt, the Olcese Sand, the Freeman Silt, and the Jewett Sand (including the Pyramid Hill Sand Member) (all Miocene), and the Vedder Sand (Oligocene)

Tcmo **Continental rocks and deposits (Oligocene and Miocene)** Gravel, conglomerate, sand, tuffaceous sand, clay, and sandy clay; contain rhyolitic material on eastern side of valley. Principally Valley Springs Formation (Oligocene and Miocene) on eastern side of valley; unnamed fanglomerates (Miocene), and Bena Gravel (Miocene) in the southern part

Tcme **Continental rocks and deposits (Eocene to Miocene)** Conglomerate, sandstone, consolidated fanglomerate, claystone, tuff and tuff breccia; near Fresno consist of tuffaceous sand and gravel. Near Bakersfield include the Bealville Fanglomerate (Oligocene and Miocene) and the Walker Formation (Eocene to Miocene)

Tcs **Continental rocks and deposits (Eocene)** Conglomerate and sandstone; along eastern side of valley contain anauxite. Principally Ione Formation (Eocene) on eastern side of valley

Unconformity

pTs **Marine rocks (Pre-Tertiary)** Sandstone, shale, siltstone, and some limestone, chiefly on western side of valley; in places contain abundant secondary gypsum. Include Moreno Formation (Cretaceous and Paleocene) and Panoche Formation (Cretaceous)

pTg **Granitic rocks (Pre-Tertiary)** Chiefly granitic rocks on eastern side of valley, in places consists of mafic intrusive rocks

pTm **Metamorphic rocks (Pre-Tertiary)** Metasedimentary, metavolcanic and other metamorphic rocks on eastern side of valley

CORRELATION OF MAP UNITS

Qs Qb Qr	Holocene	QUATERNARY
QTl	Pliocene to Holocene	TERTIARY AND QUATERNARY
QTc	Miocene to Holocene	
Tvd Tcpm Tcmo	Miocene and Pliocene	TERTIARY
Tm	Eocene, Oligocene, Miocene, and Pliocene	
Tcmo	Oligocene and Miocene	
Tcme	Eocene to Miocene	
Tcs	Eocene	
	Unconformity	
pTs		PRE-TERTIARY
pTg		
pTm		

Contact Approximately located

Fault Dashed where approximately located, dotted where concealed

D—D' Line of geologic section

• 34A Well and number

SOURCE: Page, 1986, PP 1401-C Plate 2 - Geologic Map of the San Joaquin Valley, California

10 5 0 10
Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

GEOLOGIC MAP (PAGE, 1986)

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FIGURE 2-17

Regional Cross Sections

Geologic Units

Qls - Pleistocene-Holocene: Selected large landslides, such as the Blackhawk Slide on the north side of San Gabriel Mountains; early to late Quaternary.

Q - Pleisto-Holocene: alluvium, lake, playa and terrace deposits; unconsolidated and semi-consolidated

Qoa - Quaternary: older alluvium, lake, playa and terrace deposits

QPc - Plio-Pleistocene: sandstone, shale and gravel deposits; mostly loosely consolidated

P - Pliocene: sandstone, siltstone, shale and conglomerate; mostly moderately consolidated

Mc/M - Miocene: sandstone, shale, conglomerate and fanglomerate; moderately to well consolidated

O - Oligocene: sandstone, shale and conglomerate; mostly well consolidated

E - Eocene: Shale, sandstone, comglomerate, minor limestone; mostly well consolidated.

TC - Undivided Tertiary: sandstone, shale, conglomerate, breccia and ancient lake deposits

m - pre-Cenozoic: Undivided pre-Cenozoic metasedimentary and metavolcanic rocks of great variety. Mostly slate, quartzite, hornfels, chert, phyllite, mylonite, schist, gneiss, and minor marble.

gb - Mesozoic: Gabbro and dark dioritic rocks; chiefly Mesozoic.

grMz - Mesozoic: Mesozoic granite, quartz monzonite, granodiorite, and quartz diorite.

Ku - Lower Cretaceous: Upper Cretaceous sandstone, shale, and conglomerate.

Kl - Lower Cretaceous; Lower Cretaceous sandstone, shale, and conglomerate.

Kern Subbasin Boundary

Other Features

Highway

Major Conveyance

Geologic Features

fault, certain

fault, approx. located

fault, concealed

thrust fault, certain

Anticline, certain

Anticline, concealed

Syncline, certain

Syncline, concealed

Fault, certain

Fault, approx. located

Fault, concealed

Thrust fault, certain

Thrust fault, approx. located

Thrust fault, concealed

Reverse fault, certain

SOURCE: California Geological Survey, 2010.

0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

GEOLOGIC INDEX MAP (CGS, 2010)

AUGUST 2019

FIGURE 2-18

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21-Aug-2019

Faults

Several faults have historical displacement or have been identified as features that affect groundwater flow. The following are: Pond-Poso Fault, Edison Fault, White Wolf Fault, Kern Front Fault, Premier Fault, New Hope Fault, and small portions of the Pond Fault (California Geological Survey, 2010a). The Edison Fault and White Wolf Faults also affect the flow groundwater (DWR, 2006).

The southeastern quarter of the Subbasin, including the south half of the Bakersfield Arch, is considered to be "highly deformed" and the "most complex tectonic history" (Bartow, 1991) due to the alternating north-south compressional and extensional forces since the Cretaceous Period. The southern boundary of the Subbasin is delineated by the northeast-trending White Wolf Fault, a reverse fault with active displacement (DMG, 1955), that may have originally been a normal fault (Bartow, 1991). The White Wolf Fault separates the Subbasin from the new White Wolf Subbasin to the south. Two northeast-trending thrust faults are located at the southwestern corner of the Subbasin, including the Wheeler Ridge and Pleito Faults. During the 1952 Bakersfield earthquake, a group of small ground fractures developed in an alignment just north and subparallel to White Wolf Fault. Numerous normal faults are located along the eastern margin of the southern Subbasin, including the Edison Fault and many unnamed fault segments that were active during the 1952 earthquake. More detailed descriptions of local faults and folds of interest are described in the chapters herein.

Folds

Several concealed folds have been delineated in the central Subbasin, the Paloma anticline, Buttonwillow and Semitropic anticlines, San Joaquin Valley syncline, and other unnamed anticlines and synclines in the Subbasin.

West-Side Fold Belt and Groundwater Flow

The west-side fold belt includes anticlines: Kettleman Hills, Lost Hills, Elk Hills, and at the east boundary of the fold-belt, Buttonwillow and Semitropic anticlines (Bartow, 1991) (Figure 2-17; Page, 1986). These structures are oriented toward the northwest, subparallel to the Coast Range and the San Andreas Fault. Page (1986) and DWR (2006), identified the anticlinal folds of the highlands, specifically Lost Hills, as restrictions to groundwater flow within the lowlands, and this condition likely applies to other anticlines in the Subbasin.

Structurally, and to a large degree, lithological, the western side differs from the central and eastern portions of the Subbasin. Western Plio-Pleistocene deposits are derived from weathering and erosion of the Coastal Range made up of marine deposits yielding clays and silts and some sands. On the other hand, the east side is made up of quartzose and feldspathic coarser sized sediments from the Sierra Nevada.

In addition to structure, the thickness of fresh water bearing deposits and the sources of groundwater recharge differ between the west side and the central and east side of the Subbasin. In general, the differences result in more restrictive localized groundwater system with poorer quality water on the west side of the Subbasin.

2.2.1.4 Kern County Subbasin Boundaries

As described above, the lateral boundaries are defined by jurisdictional and structural boundaries (DWR, 2003, 2016a, 2016b). Within the jurisdictional boundaries of the Subbasin, are effective lateral boundaries of usable groundwater or effective extents of the principal aquifers.

These boundaries will be discussed in the remainder of this section, and include the presence or absence of: a sufficient quantity of groundwater for beneficial use; water quality changes rendering groundwater unusable; and aquifer exemptions of portions of the Subbasin that either contain commercially producible hydrocarbons or minerals, are high in total dissolved solids, and/or are otherwise isolated from the rest of the Subbasin by geologic boundaries. The characteristics of the effective groundwater Subbasin, as described above, also apply to the bottom of the groundwater basin and are discussed in Section 2.2.1.5.

Criteria for the Extent of Groundwater with Beneficial Use in the Subbasin

An aquifer may not be suitable for beneficial use if:

- It is not currently serving as a source of drinking water,
- It has commercially producible minerals or hydrocarbons, or
- It is not expected to supply a public water system, and
- It is either economically or technologically infeasible for treatment or recovery now or in the future for domestic, agricultural, or industrial use.

The purpose of this GSP is not to exempt aquifers, nor is it to define the maximum depth or water quality concentration at which groundwater is economically recoverable or treatable now or in the future. However, by applying the criteria of 40 CFR §144.3 and 40 CFR §146.4, active oil and gas aquifers and exempted aquifers are not a part of the groundwater basin for beneficial use.

The groundwater Subbasin's extent, where no exemptions or commercially producible hydrocarbons exist, likely ranges between 3,000 milligrams per liter (mg/l) and 10,000 mg/l total dissolved solids (TDS) depending on the feasibility of treatment and recovery of the groundwater for beneficial use. The estimated lateral extents of the Subbasin are further presented with the bottom of the Subbasin and cross sections of this plan.

2.2.1.5 Bottom of Subbasin

As described above, the following whichever is shallowest, are the lateral and vertical boundaries of the groundwater Subbasin:

- depth to producible minerals or hydrocarbons,
- depth to and aerial extent of exempted aquifers,
- depth that makes recovery of water for domestic, commercial, or industrial purposes no longer economically or technologically feasible, or

- the depth at which groundwater cannot now or in the future serve as a source of drinking water.

For example, water bearing zones below the depth to producible hydrocarbons are not within the groundwater basin; likewise, water bearing zones below an exempted aquifer are not within the groundwater basin.

In some parts of the Subbasin the lateral and bottom boundaries of the groundwater are subject to depths to producible hydrocarbons and extent of depths to aquifer exemptions. As described above, any water bearing zone below these three criteria are outside of the groundwater Subbasin. The available depth to hydrocarbons and aquifer exemptions at the time of this GSP compilation, although possibly generalized, are incorporated into Figures 2-19 and 2-20 for comparison.

As discussed above, it is not the intent of this plan to evaluate at which depth the groundwater is economically recoverable or treatable in the future; but, for discussion purposes only, a TDS of 2,000 mg/l is presented in Figure 2-19, to consider the vertical and lateral distribution of a fresh groundwater dataset in the Subbasin. A TDS of 2,000 mg/l has been mapped throughout the region by Page (1973), historically, it was considered a limiting TDS concentration for the irrigation of most crops (Page, 1973); however, it does not define the bottom of the groundwater Subbasin (or the depth to water that is no longer economically or technologically feasible for groundwater beneficial use). Other local datasets for a TDS of 2,000 mg/l are included in management area plans.

By comparison the depth to TDS of 10,000 mg/l (Gillespie et. al. 2017) (one of the criteria for classification as an underground source of drinking water (USDW)) is presented on Figure 2-20. As discussed above, this depth may not represent the USDW if there are aquifer exemptions or producible hydrocarbons shallower in the subsurface.

In addition to the datasets mentioned above, the SWRCB Resolution Number 88-63 (SRWCB, 1988), has also listed criteria for the suitable sources of drinking water for municipal or domestic water supply. These sources are defined as waters that: have a TDS of less than 3,000 mg/l; are reasonably expected by Regional Boards to supply a public water system, including sufficient yield; are not contaminated or beyond reasonable treatment; and are not exempted by 40 CFR §146.4 (SRWCB, 1988). At this time, there is no dataset developed to present basin-wide correlations of the SRWCB 88-63 base of drinking water.

An additional informal description of the bottom of the Subbasin may be referred to by some researchers, at times, as the “current operational bottom of the Subbasin” which basically describes the depth of active groundwater well pumping; however, this description should not be used to satisfy SGMA requirements § 354.14(b)(3) of the California Code. The range of well depths and perforations generally deepen in the alluvial aquifer system from the margins of the basin toward well discharge points in the south-central and north-central Subbasin. The historical operational bottom of the depth and/or the current operational bottom of the basin are not mapped herein because the operational bottom of the Subbasin has increased with depth as groundwater elevations have decreased over the years. In general, groundwater wells extend to

depths of more than 1,000 feet (Page, 1986), and the maximum thickness of freshwater deposits is calculated at about 4,400 feet, occurring at the south end of the valley (Page, 1986). Cross sections included in this plan provide a representation of current well depths in the Subbasin.

Page (1973) Base of Freshwater

Although, not the bottom of the groundwater basin, the base of fresh groundwater (Figure 2-19) has historically been defined by Page (1973), as the depth at which specific conductance (SpC) is 3,000 micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µS/cm), and is considered to be generally equivalent to a TDS concentration of 2,000 mg/l. These values have been reported because they may be considered a limiting factor for irrigation. The conversion factor from SpC to TDS used for this determination was 0.67, which is midway between the typical range of 0.55 to 0.75 (Hem, 1985), and is dependent on the composition of groundwater.

The base of fresh groundwater is quite variable in the Subbasin ranging over 4,000 feet, as listed below:

Location			Elevation, feet msl	Depth, feet below ground
Southeast,	T31S/R28E-Section 32,	West of Arvin	> -4400	~ 4700
Northwest,	T26S/R20E-Section 34,	Lost Hills area	0	~ 400
Northeast,	T25S/R27E-Section 6,	South of Richgrove	-2800	~ 3300
East central,	T29S/R27E-Section 12,	Oildale	-2000	~ 2500
West central,	T29S/R24E-Section 16,	East of Buttonwillow	-800	~ 1100

On the east side of the Subbasin, the base of fresh groundwater trends parallel to nearby faulting. The 2,400-foot below mean sea level (bmsl) contour (and other deep contours) on Figure 2-19 represents a northwest-trending trough of fresh groundwater between Bakersfield and Wasco. This trough lies between the concealed Poso Creek fault to the northeast and the pre-Quaternary Greeley Fault on the southwest that extends from the Kern River to the Kern National Wildlife Refuge. This “graben” of deeper fresh groundwater appears to be trending with these faults.

A smaller, northwest-trending trough of fresh groundwater is located east of Delano and south of Richgrove on the west side of several northeasterly-trending faults. This trough of fresh groundwater may be more of an indicator of freshwater in the Santa Margarita and Olcese aquifers.

On the west side of the Subbasin, notably, west of Lost Hills, Buttonwillow, and Elk Hills, Page (1973), reported very little data for groundwater less than 3,000 µmhos/cm. The lack of data is a combination of evidence suggesting that there is very little fresh water (<3,000 µmhos/cm), on the west side as corroborated by other sources (Gillespie et. al., 2017; and Metzger and Landon, 2018), and a potential data gap where additional data may be useful.

NOTES:

(Approximate) Elevation of base of fresh water (Specific conductance generally less than 3,000 micomhos per centimeter) or ~2,000 mg/L TDS.

Hydrocarbon elevations from primacy productive limits represent difference between average surface elevation and minimum depth of productive limit.

Elevation to hydrocarbons and the top of exempted aquifers are generalized. Refer to the report table for details. Exemptions are subject to change as applications are approved.

Per 40 CFR §144.3, exempted aquifers are not USDWs. Based on criteria of 40 CFR §146.4, primacy productive limits are not suitable USDWs.

USDW: Underground Source of Drinking Water (Source: Code of Federal Regulations).

Datum is Mean Sea Level

Elevation Contour of Specific Conductance 3,000 micromhos per centimeter (Page-1973)

Elev — Aquifer Exemption (max Elevation)

Elev — Primacy Productive Limits (Hydrocarbon max Elevation)

Kern Subbasin Boundary

Other Features

Highway

Major Conveyance

SOURCE: Base of Fresh Groundwater (Approximately 3,000 micromhos) in the San Joaquin Valley, California (R.W. Page 1973)

0 3.5 7 14 21

Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

BASE OF FRESH WATER BY PAGE (1973) WITH NON-USDWS

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FIGURE 2-19

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP006_FreshwaterBase_Page1973_and_DOGGR_PPL_Elevs_20190822.mxd SI

NOTES:

(Approximate) Elevation of ~10,000 mg/L TDS.

Hydrocarbon elevations from primacy productive limits represent difference between average surface elevation and minimum depth of productive limit.

Elevation to hydrocarbons and the top of exempted aquifers are generalized. Refer to the report table for details. Exemptions are subject to change as applications are approved.

Per 40 CFR §144.3, exempted aquifers are not USDWs. Based on criteria of 40 CFR §146.4, primacy productive limits are not suitable USDWs.

USDW: Underground Source of Drinking Water (Source: Code of Federal Regulations).

Datum is Mean Sea Level

Elevation Contour of 10,000 mg/L TDS (Gillespie et.al. 2017)

Elev — Primacy Productive Limits (Hydrocarbon max Elevation)

Elev — Aquifer Exemption (max Elevation)

Kern Subbasin Boundary

Other Features

Highway

Major Conveyance

SOURCE: Approximately 10,000 mg/L TDS in the San Joaquin Valley, California (Gillespie et.al. 2017)

0 3.5 7 14 21

Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

ELEVATION CONTOURS OF 10,000 MG/L TDS WITH NON-USDWS

AUGUST 2019

FIGURE 2-20

Z:\Projects\1900668_KGA_GSP\GSP007_FreshwaterBase_Gillespie2017_and_DOGGR_PPL_Elevs_20190822.mxd SI

22-Aug-2019

Gillespie et. al. 10,000 mg/L TDS

The depth to groundwater with a TDS of 10,000 mg/l (Figure 2-20), is the deepest possible USDW. Gillespie et. al. (2017) and Kong (2016) developed these data based on geochemical analysis of water samples and geophysical log analysis. The depth to 10,000 mg/l TDS is generally consistent with regional trends within the Subbasin. Southeast of the City of Bakersfield, the 10,000 mg/l TDS is mapped to a depth of 6000 ft. This is consistent with the knowledge that this area of the Subbasin receives the greatest amount of fresh water recharge from the Sierras.

In the Maricopa depocenter in the south part of the Subbasin a couple miles north of Wheeler Ridge the 10,000 mg/l TDS contour may be as deep as 10,000 ft. No chemical analysis data were available to verify this geophysical log interpretation; however, the results from Page (1973), also mapped the depth to 2000 mg/l groundwater at 4600 ft (which was the deepest fresh water in the Subbasin) (Gillespie et. al., 2017). The Maricopa depocenter appears to have fresh water that extends deeper than anywhere else in the Subbasin.

Salinities in the west Subbasin are much higher, and depths to the base of USDW are more variable (Gillespie et. al., 2017). The structural complexity along the west side of the valley may be a contributing factor to the variable distribution of water salinity in this area. Gillespie et. al. (2017), cite that numerous wells contain waters between 3000 and 10,000 parts per million (ppm) in the nonmarine Tulare Formation and overlying alluvium in the western Subbasin.

Figure 2-21 below is a conceptual profile illustrating the general difference between the shallow and deep aquifer systems (fresh water continental deposits and alluvium, and saline water marine deposits), and the differences between the west and east side aquifer systems. In general, groundwater is more saline on the westside, while the freshwater column is thickened in the eastern-central part of the Subbasin.

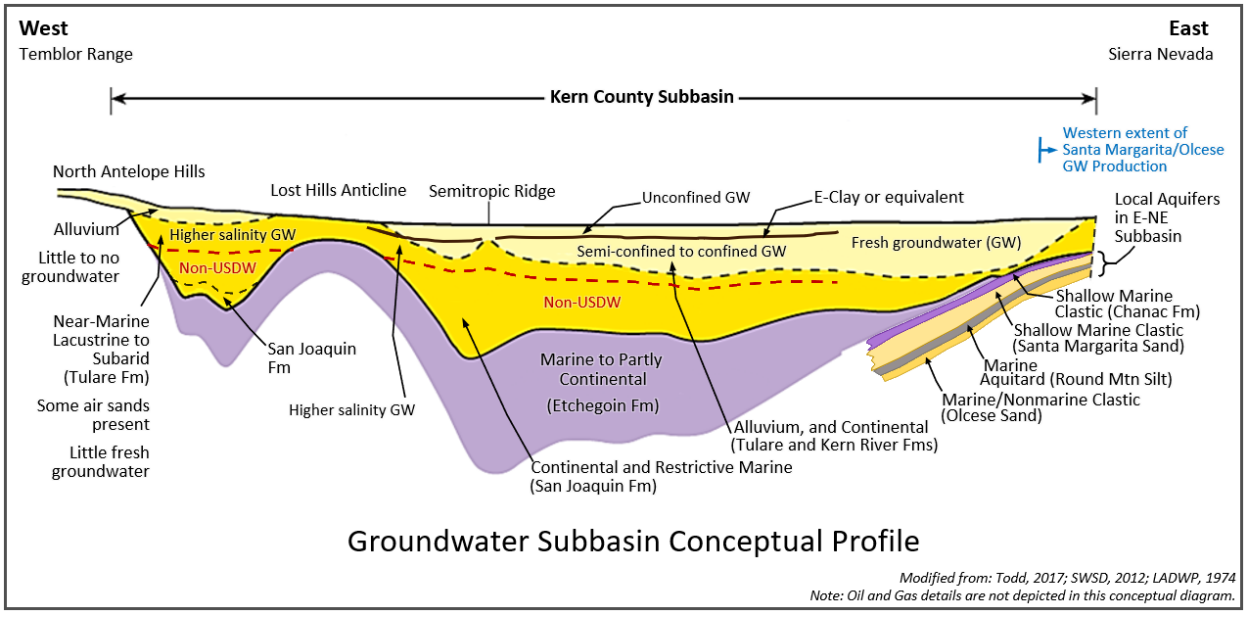


Figure 2-21. Groundwater Subbasin Conceptual Profile

2.2.1.6 Principal Aquifers and Aquitards

The groundwater aquifers of the Subbasin are geologically diverse with differing zones of confined, semiconfined, and unconfined groundwater conditions. As depicted in the below Figure 2-22, the primary aquifer system occurs in the central-northern, central, and central southern portions of the Subbasin. It consists of the Tulare formation, Kern River formation, and overlying alluvium. On the eastern side of the Subbasin are the confined Santa Margarita, Olcese, Pyramid Hills, and Vedder Sands. Groundwater wells extract water where these aquifers are not exempted and where they are feasible for groundwater supply use without hydrocarbons, On the western side of the Subbasin, very little usable groundwater occurs. In the northwest, groundwater supply production is likely limited and may occur in alluvium and/or the Tulare Formation.

In addition to the formations described above, groundwater may also be pumped from the San Joaquin and Etchegoin (Page, 1986; Bartow and Pittman, 1983) in the central portion of the Subbasin; however, little information is available to further document the groundwater characteristics or extraction within these zones.

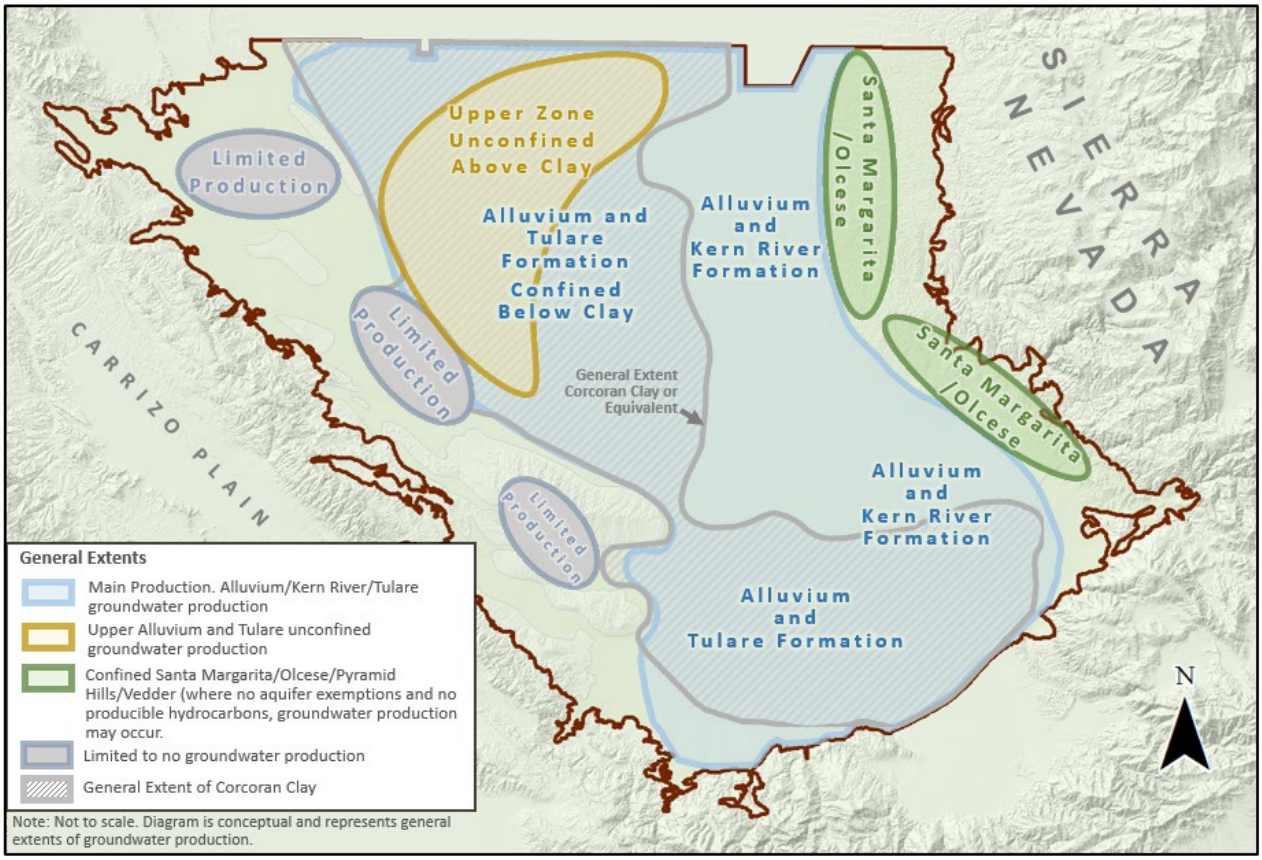


Figure 2-22. General Distribution of Groundwater Aquifer Supply Production in Kern County Subbasin

Formation Names

Table 2-2 presents the hydrostratigraphy and summary of the geologic units of interest with general details and a general summary of deposition and aquifer context.

The Subbasin groundwater system is dominated by alluvial/fluvial deposits on a basin-wide scale and produces an intricate, heterogenous grouping of aquifers. Although formations can be mapped across the Subbasin, much of the material is not distinctive in the subsurface and designation of a particular formation is difficult. Additionally, the E-modified layer of the Corcoran Clay member of the Tulare Formation is correlated across much of the Tulare Lake Hydrologic Region; however, there are still localized debates and questions on the extent and correlation of the E modified clay.

Refer to the discussion on stratigraphy in section 2.2.1.2. for a brief description of the formations and their general context in relation to the aquifer system.

Primary Aquifer System

The primary aquifer system of the Subbasin is within the Tulare and Kern River formations and overlying alluvium. It includes differing zones of confined, semiconfined, and unconfined groundwater conditions, due to the presence of clays that act as local aquitards. The Corcoran Clay and other equivalent clays occur within the Tulare Formation in the central and southern parts of the Subbasin (Page, 1983 and Page, 1986). Where extensive clays are present, some areas of the aquifer system may consist of a deeper confined zone and a shallower unconfined to semi-confined zone. Within the eastern portion of the Subbasin and in the vicinity of the Kern River Alluvial Fan, the aquifer system is made up of an unconfined to semi-confined zone. Shallow zones are also present locally in the northwestern and southern portions of the central Subbasin. The shallow zone is not a part of active groundwater extraction, but data are included in the groundwater conditions section of this report to evaluate changes over time.

Some researchers in the Subbasin define the primary aquifer system as one principal aquifer because the confining beds such as the E-modified Corcoran Clay or equivalent, are not laterally continuous across the Subbasin, or lithologically consistent allowing for continuous confinement. In addition, there are older wells in some parts of the Subbasin, that are screened across the Corcoran Clay which could allow interconnection of water between the upper and lower zones. However, for the past few decades, local county enforcement has worked to eliminate well construction practices with screens across encountered upper unconfined zones and lower confined zones.

In addition, to the aquifer zones described above, there is a shallow groundwater zone occurs above the A-Clay or other shallow clay; however, this zone has poor quality water and is not a part of the groundwater supply aquifer system.

Table 2-3 below is a summary of generalized aquifer characteristics of the primary aquifer system.

Table 2-3. Primary Aquifer System of Kern County Subbasin

Generalized Hydrostratigraphy	Relative Depth	Basin Extent	Water Quality	Corresponding Formations
Unconfined Zone	Middle to Deep	East side "main production zone"	Good	Eastside Alluvium and Kern River Formation
		Central, above the Corcoran Clay	Moderate	Central Subbasin, above the Corcoran Clay Member (E) of the Tulare Formation, or other equivalent fine-grained layers.
Confined, Semi-confined, or Lower Zone		Central "main production zone"	Good to Moderate	Confined to Semiconfined. Alluvium, Kern River Formation, and Tulare Formation

Eastern Confined Aquifers

Along the eastern margins of the Subbasin, other principal aquifers, where classified as USDWs and not exempted, include, semiconsolidated rock such as the Santa Margarita Sandstone, and Olcese Sands. These confined aquifers are hydraulically separated from the Kern River Formation aquifer system by Pliocene marine deposits. Other aquifers to the east, where classified as USDWs and not exempted, include the Pyramid Hills, Vedder Sand, and the Chanac Formation (Page, 1986; Bartow and Pittman, 1983). The extent of groundwater production in these aquifers is limited by the extent of producible hydrocarbons, aquifer exemptions, and increased salinity with depth.

West-side Aquifers

Alluvial aquifer zones on the west side of the Subbasin may contain groundwater that is higher in TDS. This groundwater occurs in the fold belt associated with folded and faulted strata. Where aquifers are classified as USDWs and not exempted per 40 CFR §144.3, groundwater may be pumped for beneficial use. The Tulare Formation makes up most of the aquifer system on the west side; however, the Tulare Formation differs in facies and origin than what is documented in the central portion of the Subbasin. West-side aquifers are described in more details in the management area plans.

Physical Properties of Each Aquifer and Aquitard

Aquifer parameters within the Subbasin are available from both well pumping tests and calibrated groundwater models. Data are summarized in Table 2-4 and Figure 2-23. Aquifer properties reported herein include hydraulic conductivity which is a volume of water that will move in a unit of time, under a unit hydraulic gradient through a unit area, and the specific yield

(unconfined systems) and storage coefficient (confined systems), which are functions of an aquifer's ability to store and release water from storage (storativity).

Table 2-4. Aquifer Parameters for Kern County Subbasin

Data Source	Calculated Horizontal Hydraulic Conductivity (feet/day)	Vertical Anisotropy Kh/Kz	Storage Coefficient	Specific Yield
Kern Pumping Tests Compilation (Todd, 2018)	7 to 250	--	0.0008 to 0.034	--
USGS - Kern Pumping Tests (Observation Wells)	20 to 1600	--	0.0004 to 0.002	--
USGS - Kern Recovery Tests	100 to 800	--	--	--
USGS - CVHM Range	0.24 to 3300	--	--	0.09 to 0.40
DWR - C2VSim Range				
Layer 1	15 to 78	275 to 500	--	0.12 to 0.40
Layer 2	< 1 to 100	20 to 4000	5.E-07 to 8.E-06	--
Layer 3	3.0 to 7.0	60 to 100	--	--
Todd Groundwater 2018 Model Range				
Layer 1	32 to 85	10 to 200	--	0.15 to 0.25
Layer 2			3.E-02	0.02 to 0.21
Layer 3	29 to 75	50 to 500	1.4E-07 to 9.4E-07	0.00004 to 0.00022
Layer 4	10 to 70	500		0.0011 to 0.0019
Todd Groundwater 2017 Model Average				
Layer 1	300 to 335	1150 to 1200	--	0.21
Layer 2	2	1050 to 1250	8.6E-06 1.4E-05	--
Layer 3	67 to 70	1000	0.00024	--
Layer 4	22 to 37	2200 to 3700	0.00058	--
USGS - Water Supply Paper 1618				
White-Poso Unit (upper 200 ft)	--	--	--	0.086 to 0.095
Kern River Unit (upper 200 ft)	--	--	--	0.125 to 0.132
Edison-Maricopa Unit (upper 200 ft)	--	--	--	0.12 to 0.14
USGS - Water Supply Paper 1618				
Clay and Fine Grained Units	--	--	--	0.03
Silt, Gravelly Clay, Sandy Clay Units	--	--	--	0.05
Fine, tight sand, tight gravel	--	--	--	0.10
Loose, well sorted sand, gravel	--	--	--	0.25

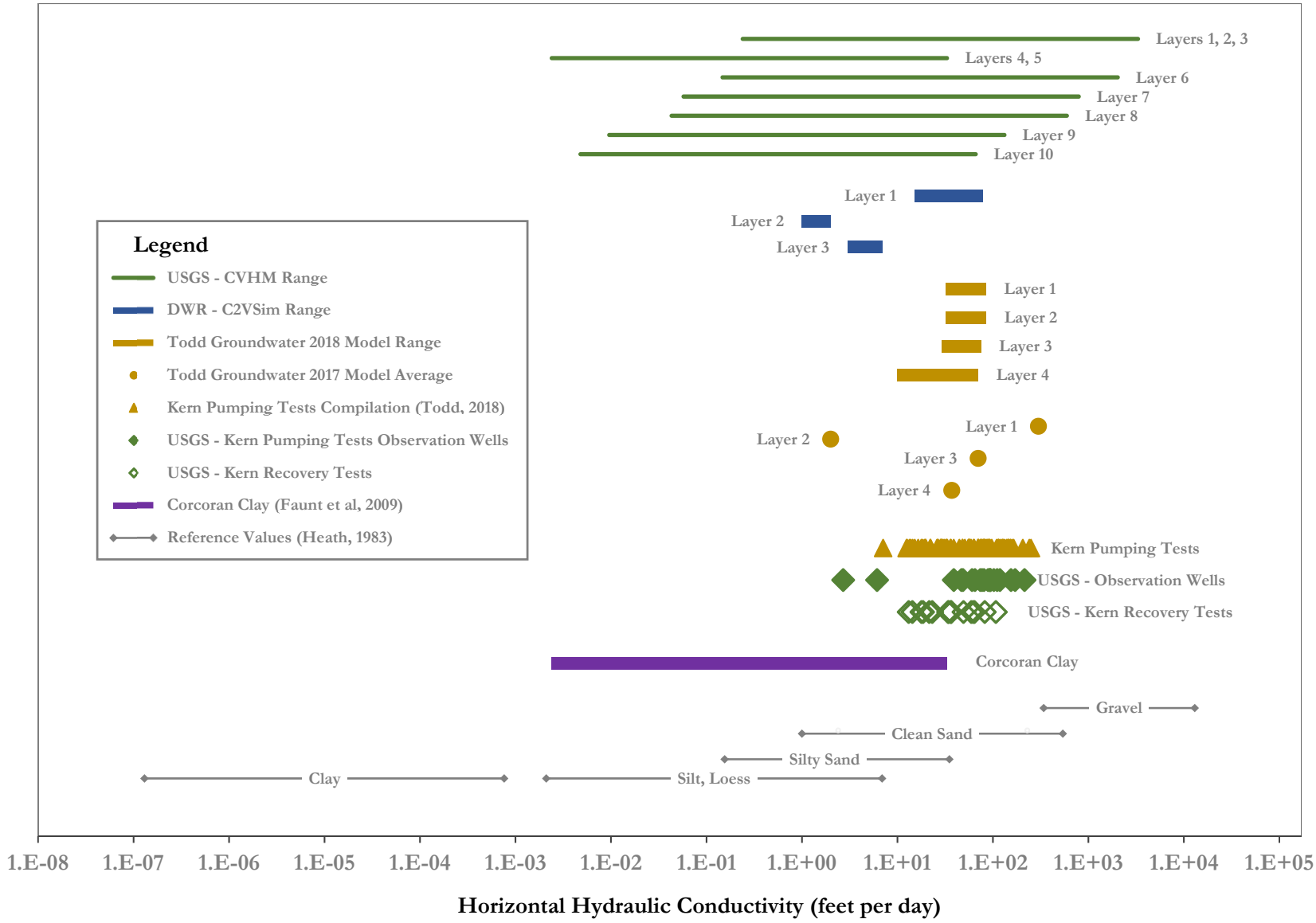


Figure 2-7.pptx

Kern Groundwater Authority Basin Setting	GEI Consultants	HYDRAULIC CONDUCTIVITY VALUES
Kern County, California		AUGUST 2019 FIGURE 2-23

Hydraulic Conductivity

Aquifer data derived from pumping tests were taken from two sources: 1) relatively short (1.5- to 5-hour) pumping tests by the USGS at irrigation wells during the late 1950s and 1960 (McClelland, 1962), and 2) from constant rate pumping tests from engineering consultants in the 2000's (Todd, 2018). The depth of these test wells varied from 98 to 1,500 feet below ground surface (bgs) (median: 650 ft bgs), and pumping rates varied from 44 to 4,480 gpm (median: 2,500 gpm). The analysis included the use of water level recovery data from pumping wells and water levels from observation wells. From these tests, the hydraulic conductivity was estimated and ranges from 3 to 250 feet per day (ft/d; median: 60 ft/d), which is consistent with published ranges for clean, medium- to coarse-grained sand (Heath, 1983), or for a fine sand to coarse gravel (Schwartz & Zhang, 2003). These values also fall within the range of the groundwater models that were partially calibrated with these data (C2VSim; CVHM; Todd, 2018; Todd, 2017) (Figure 2-23).

The Corcoran Clay of the Tulare Formation is most commonly known for its fine-grained beds; however, lithology does vary from fine (clay and silt) to coarse (sand) texture (Page, 1986; Faunt et al., 2009). These coarser-grained beds are isolated and principally occur where the Corcoran Clay is less than 20 feet thick. Faunt et al., (2009) compiled and estimated horizontal hydraulic conductivities within the range of 0.0024 to 33 ft/d, which is within the range of silt to fine/medium sand (Figure 2-23) (Heath, 1983). A range of vertical hydraulic conductivity was estimated from permeameters and field tests between 6.6×10^{-6} ft/d to 1.5×10^{-3} ft/d (Faunt et al., 2009), representing a potential vertical anisotropy range of 3.6×10^{2} to 2.2×10^{4}. As noted by Faunt et al., (2009) laboratory permeameter tests may have underestimated the hydraulic conductivity while field testing may have overestimated hydraulic conductivity due to potential for intra-borehole flow across the clay. Additionally, recent inelastic compaction of the Corcoran Clay in areas of subsidence may have further reduced vertical hydraulic conductivity (Faunt et al., 2009).

Specific Yield and Storage

Storage of an aquifer is primarily described and quantified by the storativity or the volume of water released from storage per unit surface area of the aquifer per unit decline in hydraulic head (Heath, 1983). It is important to note that while storativity applies to both confined and unconfined systems, it can be further simplified for these two systems. Storativity accounts for aquifer compression and water expansion (specific storage components), which are the primary factors for estimating storage in confined systems; thus, for confined systems, the specific storage or storage coefficient is most often reported. In contrast, for unconfined systems, the specific yield or effective porosity (gravity-driven dewatering of an aquifer) better represents storativity because aquifer compressibility and water expansion are somewhat negligible in unconfined systems. For unconfined systems, specific yield is most often reported, and is a function of porosity and specific retention.

For confined systems, the aquifer compressibility of the storage coefficient can be further defined as elastic and inelastic skeletal specific storage, where inelastic storage will be lost once compression and dewatering occur. It is estimated that in the Central Valley, the inelastic

specific storage typically is 30 to several hundred times larger than the elastic skeletal specific storage (Faunt et al., 2009; Ireland et al., 1984). Where fine-grained deposits with inelastic storage are thick in the aquifer system, water released could be a major source of water, but could also result in a permanent loss in storage capacity of fine-grained sediments.

Specific yield of unconfined zones and the storage coefficient of confined zones within the Subbasin have been estimated by laboratory testing of sample cores, calculation based on lithology type, and groundwater model calibration (Dale, 1966; Davis et al., 1959; Davis et al., 1964; Faunt et al., 2009; DWR, 2013; Todd, 2017 and 2018). A range is presented in Table 2-4 and is within the range of values published for similar grain sizes and lithology (Heath, 1983; Morris and Johnson, 1967) (generally 0.02-0.40).

General Water Quality of Principal Aquifers

As required in the regulations, this section is a general summary of water quality of the principal aquifers in the Subbasin. This section does not replace the discussion of water quality issues under Groundwater Quality Section 2.3.3.

This discussion provides a high-level description of water quality variation in the principal alluvial aquifer system of the Subbasin, both laterally (from west to east across the Subbasin) and vertically (shallow–deep within the Subbasin). For local details on water quality for specific areas of an aquifer, refer to the management area plans.

Total dissolved solids are discussed in this section only for the purpose of comparing and contrasting different portions of the aquifer system for Subbasin characterization. For details regarding water quality issues and current groundwater conditions, refer to Section 2.3.3 and individual management area plans. In general, water quality is higher in TDS in the western third of the Subbasin than in the rest of the Subbasin. Higher nitrate and other solutes concentrations are typically present in shallow perched zones and in the unconfined zone above the Corcoran Clay. Groundwater is progressively fresher and lower in TDS below the Corcoran Clay, toward the center of the basin, and in the eastern half of the Subbasin. In contrast, arsenic concentrations increase with depth and in close proximity near portions of the Corcoran Clay. Arsenic and salinity progressively increase with depth approaching the base of USDW.

Kern County Water Agency Water Supply Reports which end in 2011 presented groundwater quality maps using data pre-1997. These maps report that unconfined groundwater (typically above the E-modified Corcoran Clay) in the central portion of the Subbasin generally ranges from less than 500 to 1,500 ppm for TDS, while the west side unconfined groundwater ranges from 1,000 to 5,000 ppm for TDS. The confined aquifer zone (typically below the E-modified clay) in the central portion of the Subbasin generally ranges from less than 200 to 500 ppm for TDS, while west side confined water typically ranges from 1,000 to 4,000 ppm.

The high TDS groundwater in the west side with respect to the east side has recently been reported in a preliminary groundwater salinity mapping study conducted by the USGS (Metzger and Landon, 2018). Within the Subbasin, the study reported much higher TDS in west side water when compared with east side groundwater. Metzger and Landon suggest that higher TDS could

be related to a combination of natural conditions (west side sediments derived from marine deposits with some connate water) and anthropogenic factors such as infiltration from disposal ponds and/or agricultural drainage ponds. The researchers suggest that groundwater on the east side of the Subbasin have the lowest TDS and greatest depths to non-USDWs because they are adjacent to Sierra Nevada that is a source of low TDS (fresh water Ca-HCO_3 type) recharge, whereas, aquifer zones on the west side of the Subbasin have higher TDS values. The west side aquifer zones likely receive very little recharge from the Temblor Range which is made up of marine deposits, and west side aquifer zones such as the west side Tulare Formation likely contain connate water derived from marine deposits (Wood & Dale, 1964). This higher TDS water (Na/Ca-SO_4 type) in west side water is consistent with historical reports and is documented for more than 60 miles from north to south in the Subbasin (KCDEH, 1980; KCDEH and KCWA, 1982; Sierra Scientific Services, 2013). Additional sections of this GSP provided by west side entities, discuss further details on the west-side Subbasin aquifer system.

Primary Use of Each Principal Aquifer

The unconfined zone in the eastern portion of the Subbasin and in the Kern Fan, and the confined zone below the Corcoran Clay are the primary production zones of the Subbasin aquifer system. In addition, the upper unconfined zone is pumped for beneficial use in the north central and west central areas of the Subbasin. The primary uses of the Subbasin aquifer system include agricultural, municipal, domestic, and storage for the banking of surface water.

Summary of Beneficial Uses and Users of Groundwater

Land use in the Subbasin includes agriculture, urban/industrial/residential, and open space use. According to the 2014 SGMA legislation, beneficial users of groundwater and property interests potentially affected by the use of groundwater include:

- Agricultural Users
- Domestic Users
- Municipal Well Operators
- Public water systems
- Local Land Use Planning Agencies
- Environmental Users

According to DWR well completion reporting and the CASGEM program, groundwater wells are constructed for a variety of uses including:

- Domestic / Residential
- Irrigation
- Stock
- Municipal / Public
- Monitoring / Observation

- Industrial
- Cathodic Protection
- Other / Unknown

2.2.1.7 Data Gaps and Uncertainty

The primary data gaps in the hydrogeologic conceptual model include:

- Physical properties of the westside aquifers and eastside aquifers,
- Physical properties of the upper zone of the primary aquifer system,
- Groundwater characterization on the eastern and western flanks of the Subbasin and in the upper and shallow zones, and
- Groundwater quality of the primary aquifer zones and confined zones on the eastern and western flanks of the Subbasin, from wells screened solely in a single aquifer zone.

As improvements to monitoring networks are made, data can be used to fill data gaps in the Subbasin.

2.2.1.8 Cross Sections

A general summary of regional subsurface information is provided below in the context of cross sections developed for this plan. Where applicable, detailed discussions of the subsurface are included in some management area plans of the Subbasin.

Cross sections were developed to illustrate the subsurface conditions of the Subbasin. The locations of the cross sections discussed below are provided on Figure 2-18. Section A-A' north of the Kern River (Figure 2-24a) is northeast-trending and perpendicular to the numerous faults and folds within the valley. Section B-B' north of the Kern River (Figure 2-24b) is northwest-trending to be parallel to the axis of the valley. Geologic and hydrogeologic data were compiled from DWR well logs, DOGGR well logs, Page (1973), Gillespie et al (2017), *California Oil and Gas Fields* (DOGGR, 1998), and other regional investigations.

Cross sections spanning the southern and southeastern portions of the Subbasin were developed for management area plans and are included herein (Figures 2-24c to 2-24g). For a discussion of the subsurface across the White Wolf Fault, data including a cross section are presented in the *White Wolf Subbasin Technical Report* (EKI, 2016), that was a part of the 2016 Basin Boundary Modification Request.

A SW — NE **A'**

APPROXIMATE ELEVATION (FT MSL)

1,500 / 1,000 / 500 / 0 / -500 / -1,000 / -1,500 / -2,000 / -2,500

KCS Boundary

Belridge WSD

7th Standard Rd

SR-33

28/22-30_

California Aqueduct

Buena Vista WSD

28/22-27_

Semitropic WSD

Interstate 5

Ridge

28-23-8_

27-23-25_

27-24-20_

SWID

27-24-14_

City of Wasco

SR-43

B-B'

SR-46

NKWSD

Poso Creek

26-25-25_

SR-99

SSJMUD

Friant-Kern Canal

Cawelo WD

26-26-12

Kern-Tulare WD

25-27-32

25-27-33

SR-65

26-27-4

25-27-24

25-28-17 (Projected)

KCS Boundary

25-28-14 (Projected)

Equivalent of Corcoran Clay Rector, 1983

Tulare Formation

Alluvium

Spring 2015 GW Elevation (Upper Zone)

Corcoran C2VSim Layer

Spring 2015 GW Elevation

Kern River Formation

Anticline

Base of Tulare Angular Unconformity

South Belridge Oil Field

Anticline (to the North)

Cymric Oil Field (North Extent)

Plio-Miocene Marine Deposits

Seismic Form Lines

Buttonwillow Syncline

Buttonwillow Anticline

Semitropic Anticline

Base of ~2,000 ppm TDS Page, 1973

Base of 10,000 mg/L TDS Gillespie et. al. 2017

Rector, 1983 DOGGR, 1998

Base of Tulare

Buttonwillow Gas Field

Semitropic Oil Field

Pond-Poso Fault (50 ° to 70° dip to SW)

Fault Unknown Depth (no subsurface data available)

Bartow, 1989

Santa Margarita

Olcese Sand

Basement Complex (Granitic)

Greater than 2,000 ppm TDS

Pyramid Hills / Vedder Sand / Walker

Estimated Extent of 2,000 mg/L TDS (Hilton et. al. 1961)

Approximate Scale
0 1.8 3.7 Miles
Vertical Exaggeration = 39x

Well Perforated Intervals
Resistivity (ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model
Alluvium / Kern River Formation / Tulare Formation
Plio-Miocene Marine Deposits (Etchegoin/San Joaquin)
Oil Field Primacy Extents (Approximate) (DOGGR, 1998)

Kern Groundwater Authority
Basin Setting

Kern County, CA

GEI Consultants

CROSS SECTION A-A' NORTH OF RIVER

AUGUST 2019

FIGURE 2-24A

FENCE GEI 11X17: KERN NORTH OF RIVER DATABASE 2019.GPJ; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\16-20-19\A-A KGA.GDW; 4/17/2019 8:46:21 PM

Output Scale: Distance 1 inch = 19485 ft. H: to ft. V: 1 inch = 494 ft, 1500 to -2500 ft

B NW

SE B'

APPROXIMATE ELEVATION (FT MSL)

1,500
1,000
500
0
-500
-1,000
-1,500
-2,000
-2,500

Kern County Subbasin
Northern Boundary

Approximate Extent of Bakersfield Arch

Kern River GSA

Semitropic WSD

NKWSD

SWID

NKWSD

ID4

RRBWSD

ID4

25-23-27_

Spring 2015
GW Elevation
(Upper Zone)

-- Poso Creek

26-24-8_

26-24-21_

City Of Wasco

SR-46

A-A'
SR-43

27-25-19_

27-25-28_

28-25-3_

City Of Shafter

28-25-12_

-- 7th Standard Rd

SR-58

CV Canal
-- Kern River

Alluvium

Corcoran
C2VSim Layer

Spring 2015 GW Elevation

Alluvium

Seismic
Form Lines
PGA, 1991

Tulare
Formation

Base of 10,000 mg/L TDS
Gillespie et. al. 2017

Base of ~2,000 ppm TDS
Page, 1973

Seismic Form Lines. Apparent Dip
(Chevron Oil Company. Aug. 1966. Line T-874)

Kern River
Formation

Mio-Pliocene Marine Deposits

Rose Oil Field approximately
-7000 feet msl

Shafter North Oil Field
approximately -7100 feet msl

Seventh Standard
Oil Field
approximately
-7100 feet msl

Rosedale
Oil Field
approximately
-5100 feet msl

NOTE: Although contacts with the Top of San Joaquin Formation (Mio-Pliocene Marine Deposits) are reported in Oil and Gas records for some of this cross section, facies changes are likely occurring and can cause difficulty in correlation along the cross section.

Miles
0 1.4 2.9
Vertical Exaggeration = 31x

Well Perforated Intervals
Resistivity (0-100 ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model
Alluvium / Kern River Formation / Tulare Formation
Mio-Pliocene Marine Deposits

Kern Groundwater Authority
Basin Setting

Kern County, CA

GEI Consultants

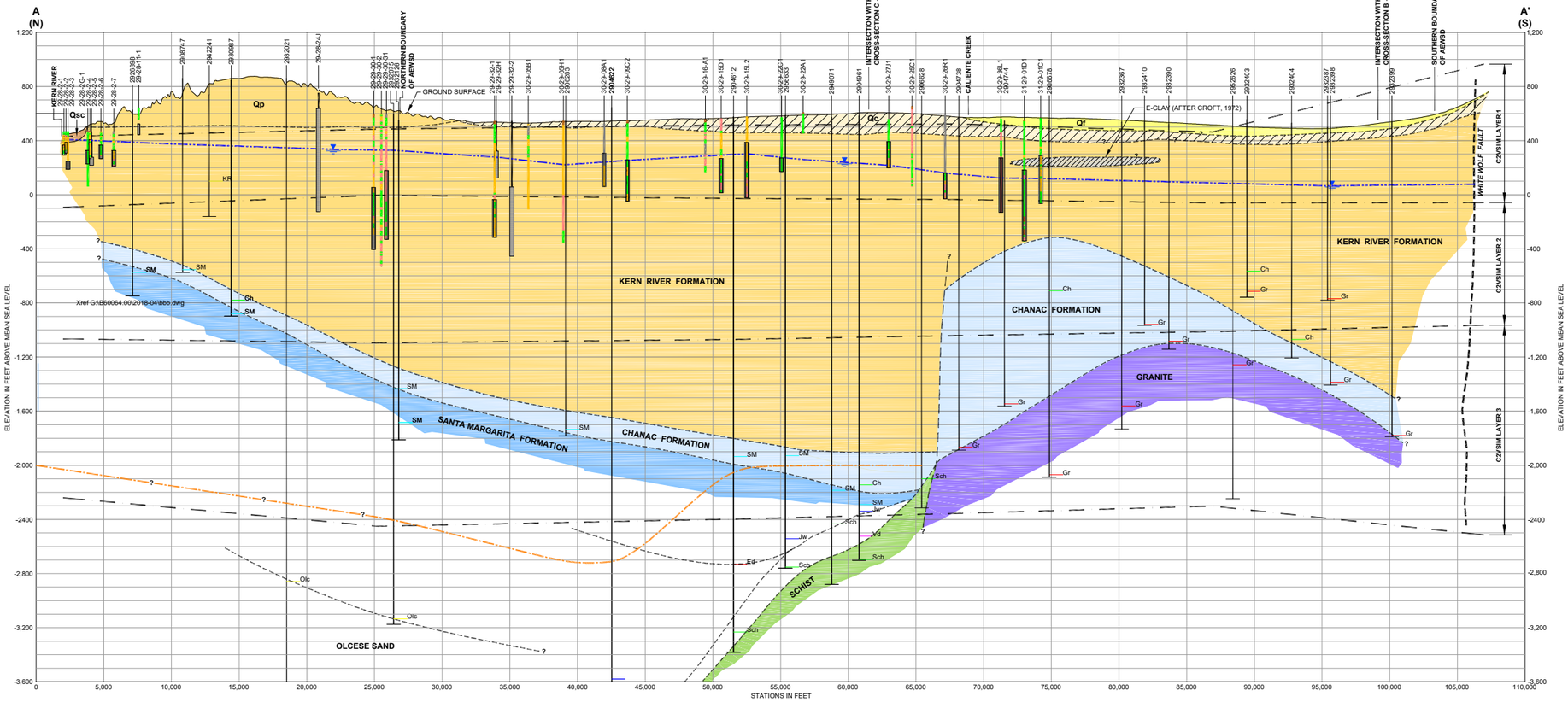
CROSS SECTION B-B' NORTH OF RIVER

AUGUST 2019

FIGURE 2-24B

FENCE GEI 11X17: KERN NORTH OF RIVER DATABASE 2019.GPJ; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\6-20-19\B-B\B-B KGA.GDW; 6/28/2019 5:23:12 PM

Output Scale: Distance 1 inch = 15310 ft. H: to ft. V: 1 inch = 494 ft, 1500 to -2500 ft



GEOLOGIC CROSS-SECTION A - A'

LEGEND:

WATER WELLS
- WELL IDENTIFICATION
- SEQUENCE
- TRACT
- SECTION
- RANGE
- TOWNSHIP
- WELL CASING
- UNKNOWN
- SOIL
- COARSE
- MEDIUM
- FINE
- GENERALIZED TEXTURE DERIVED FROM WELL LOGS
- WELL SCREEN

OIL WELLS
- OIL WELL IDENTIFICATION
- API NUMBER
- NOTED FORMATION MARKER (SEE NOTE 5)
- TOTAL DEPTH

- C2VSIM LAYER
- FORMATION CONTACT
- GROUNDWATER ELEVATION FALL 2016
- BASE OF FRESH GROUNDWATER (AFTER PAGE, 1973)

- Qsc
- Qf
- Qc
- Qp
- SURFICIAL GEOLOGIC UNITS (SEE NOTE 2)
- E-CLAY
- CHANAC FORMATION
- SANTA MARGARITA FORMATION
- SCHIST
- GRANITE
- SELECTED SUBSURFACE GEOLOGIC UNITS (SEE NOTE 3)

ABBREVIATIONS:

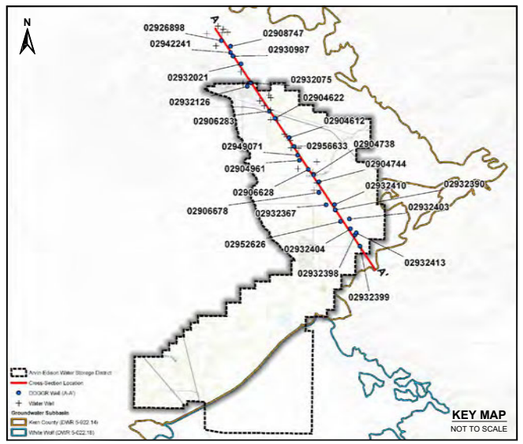
AEWSD	= ARVIN-EDISON WATER STORAGE DISTRICT
API	= AMERICAN PETROLEUM INSTITUTE
C2VSIM	= CALIFORNIA CENTRAL VALLEY GROUNDWATER-SURFACE WATER SIMULATION MODEL
CDMG	= CALIFORNIA DIVISION OF MINES AND GEOLOGY
DOGGR	= DIVISION OF OIL, GAS & GEOTHERMAL RESOURCES

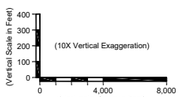
SOURCES:

1. CDMG, 1964, CALIFORNIA DIVISION OF MINES AND GEOLOGY, GEOLOGIC MAP, OLAF P. JENKINS EDITION, BAKERSFIELD SHEET.
2. CROFT, 1972. CROFT, M.G., 1972, SUBSURFACE GEOLOGY OF THE LATE TERTIARY AND QUATERNARY WATER-BEARING DEPOSITS OF THE SOUTHERN PART OF THE SAN JOAQUIN VALLEY, CALIFORNIA, USGS WATER SUPPLY PAPER 1999-H, 29 PP.
3. BARTOW, 1984. BARTOW, J.A. TERTIARY STRATIGRAPHY OF THE SOUTHEASTERN SAN JOAQUIN VALLEY, CALIFORNIA, USGS BULLETIN 1529-J, 1984.
4. DOGGR OIL WELL RECORDS.
5. PAGE R.W., 1973. BASE OF FRESH GROUNDWATER (APPROXIMATELY 3,000 MICROMHOS) IN THE SAN JOAQUIN VALLEY, CALIFORNIA. USGS HYDROLOGIC INVESTIGATIONS ATLAS HA-489.

NOTES:

1. WELL IDENTIFICATION BASED ON PUBLIC LAND SURVEY SYSTEM.
2. SURFICIAL GEOLOGY AS SHOWN ON CDMG (1964). SURFICIAL GEOLOGY MAP UNIT SYMBOLS ARE:
   - Qsc - RECENT STREAM CHANNEL DEPOSITS
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4. SEE FIGURE 8a FOR CROSS-SECTION LOCATION. WELLS SHOWN ON CROSS-SECTION ARE LOCATED WITHIN 1/2 MILE OF CROSS-SECTION LINE.
5. FORMATION MARKERS FROM DOGGR OIL WELL RECORDS INCLUDE: Ch (CHANNAC), SM (SANTA MARGARITA), Olc (OLCESE), Ed (EDISON), Jw (JEWETT), Vd (VEDDER), Sch (SCHIST) AND Gr (GRANITE).





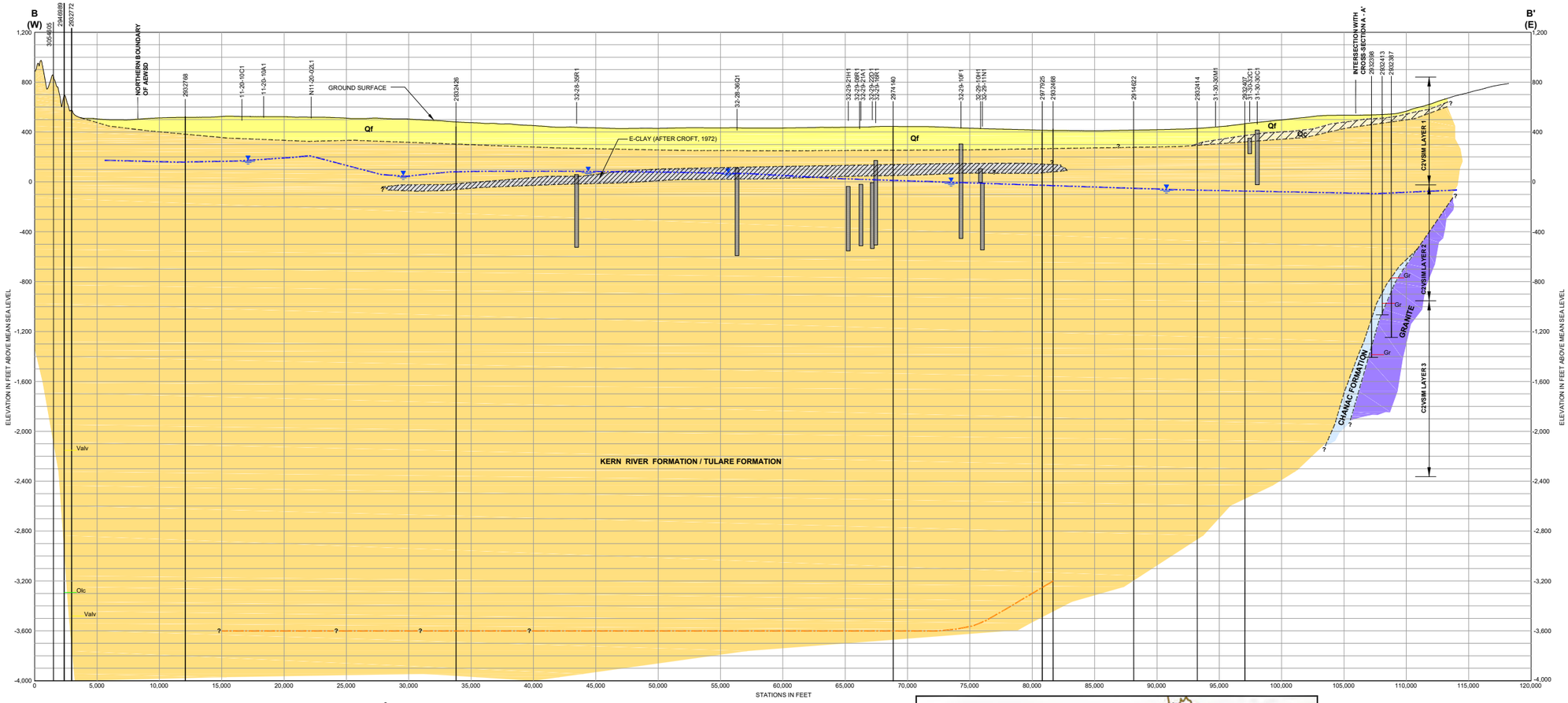
GEOLOGIC CROSS-SECTION A - A'

Arvin-Edison Water Storage District
Kern County, CA
June 2018
EKI B60064.01

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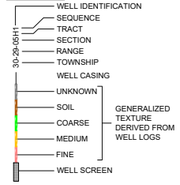
Source: EKI, 2019. Arvin-Edison Water Storage District Groundwater Sustainability Plan.

Kern Groundwater Authority Basin Setting	GEI Consultants	**GEOLOGIC CROSS SECTIONS A-A' (AEWSD)**
Kern County, California	NOVEMBER 2019	FIGURE 2-24C

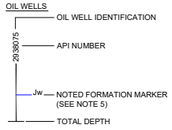


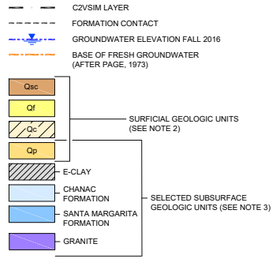
LEGEND:

WATER WELLS



OIL WELLS





GEOLOGIC CROSS-SECTION B - B'

ABBREVIATIONS:

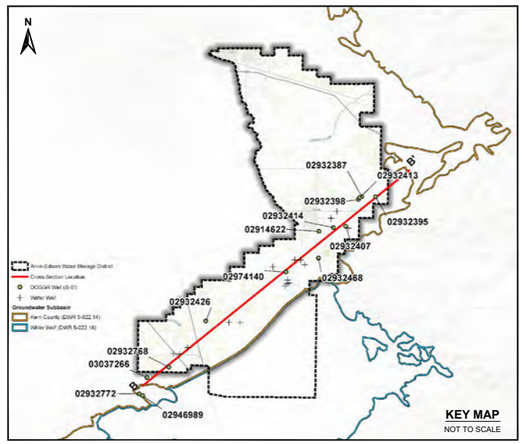
AEWSD	= ARVIN-EDISON WATER STORAGE DISTRICT
API	= AMERICAN PETROLEUM INSTITUTE
C2VSIM	= CALIFORNIA CENTRAL VALLEY GROUNDWATER-SURFACE WATER SIMULATION MODEL
CDMG	= CALIFORNIA DIVISION OF MINES AND GEOLOGY
DOGGR	= DIVISION OF OIL, GAS & GEOTHERMAL RESOURCES

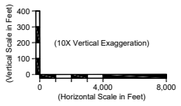
SOURCES:

1. CDMG, 1964, CALIFORNIA DIVISION OF MINES AND GEOLOGY, GEOLOGIC MAP, OLAF P. JENKINS EDITION, BAKERSFIELD SHEET.
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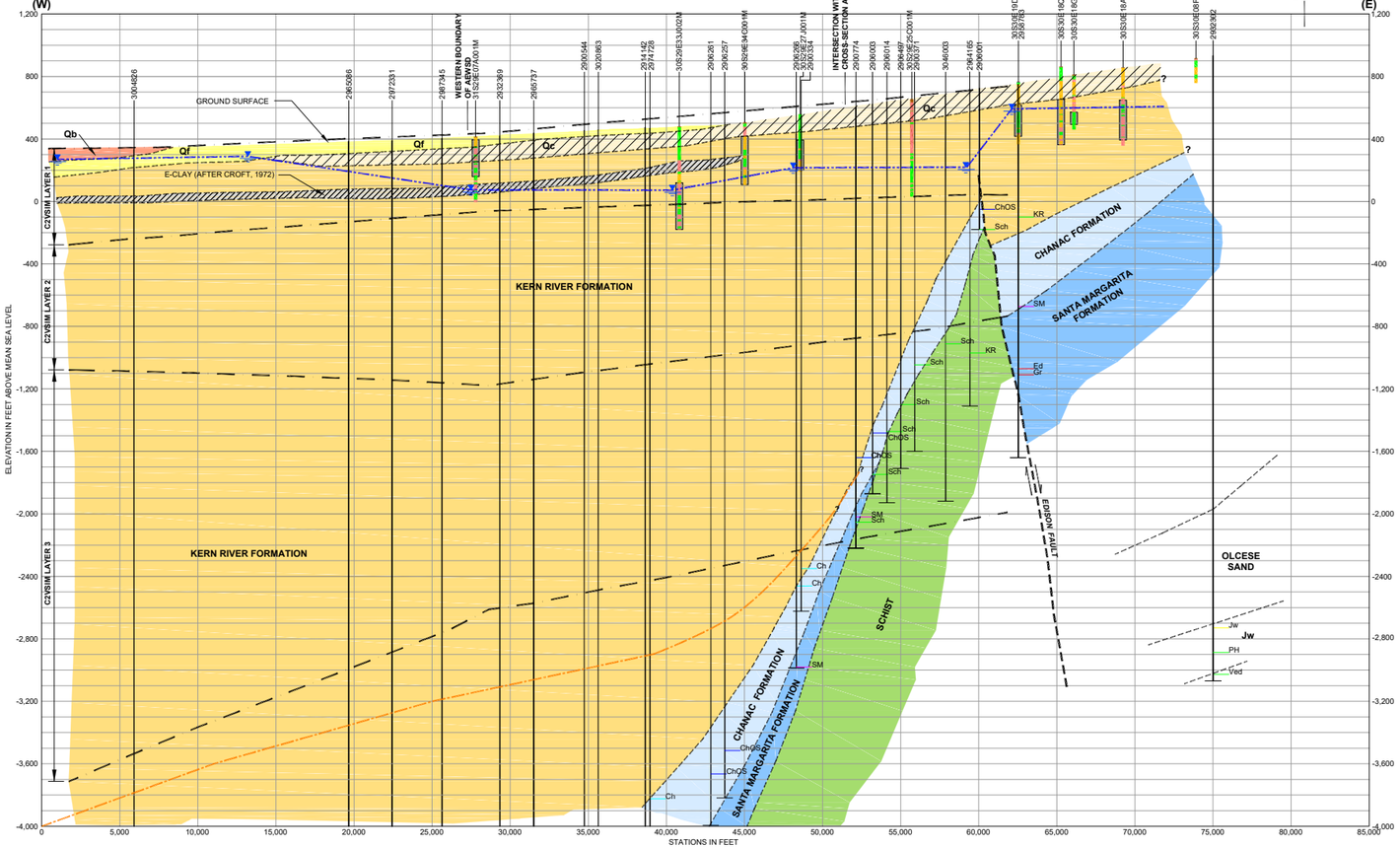
GEOLOGIC CROSS-SECTION B - B'

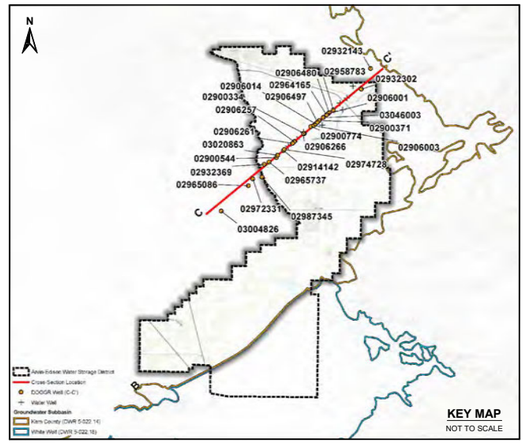
Arvin-Edison Water Storage District
Kern County, CA
June 2018
EKI B60064.01

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Source: EKI, 2019. Arvin-Edison Water Storage District Groundwater Sustainability Plan.

Kern Groundwater Authority Basin Setting	GEI Consultants	**GEOLOGIC CROSS SECTIONS B-B' (AEWSD)**
Kern County, California	NOVEMBER 2019	FIGURE 2-24D





GEOLOGIC CROSS-SECTION C - C'

LEGEND:

WATER WELLS
- WELL IDENTIFICATION
- SEQUENCE
- TRACT
- SECTION
- RANGE
- TOWNSHIP
- WELL CASING
- UNKNOWN
- SOIL
- COARSE
- MEDIUM
- FINE
- WELL SCREEN

GENERALIZED TEXTURE DERIVED FROM WELL LOGS

OIL WELLS
- OIL WELL IDENTIFICATION
- API NUMBER
- NOTED FORMATION MARKER (SEE NOTE 5)
- TOTAL DEPTH

- C2VSIM LAYER
- FORMATION CONTACT
- GROUNDWATER ELEVATION FALL 2016
- BASE OF FRESH GROUNDWATER (AFTER PAGE, 1973)

- Qsc
- Qf
- Qc
- Qp
- Qb

SURFICIAL GEOLOGIC UNITS (SEE NOTE 2)

- E-CLAY
- CHANAC FORMATION
- SANTA MARGARITA FORMATION
- SCHIST

SELCTED SUBSURFACE GEOLOGIC UNITS (SEE NOTE 3)

ABBREVIATIONS:

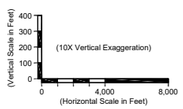
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   - Qp - PLIO-PLEISTOCENE NON-MARINE
   - Qb - RECENT BASIN DEPOSITS
3. SUBSURFACE GEOLOGIC UNITS BASED ON BARTOW (1984) & CROFT (1972) AND DOGGR OIL WELL RECORDS.
4. SEE FIGURE 8a FOR CROSS-SECTION LOCATION. WELLS SHOWN ON CROSS-SECTION ARE LOCATED WITHIN 1/2 MILE OF CROSS-SECTION LINE.
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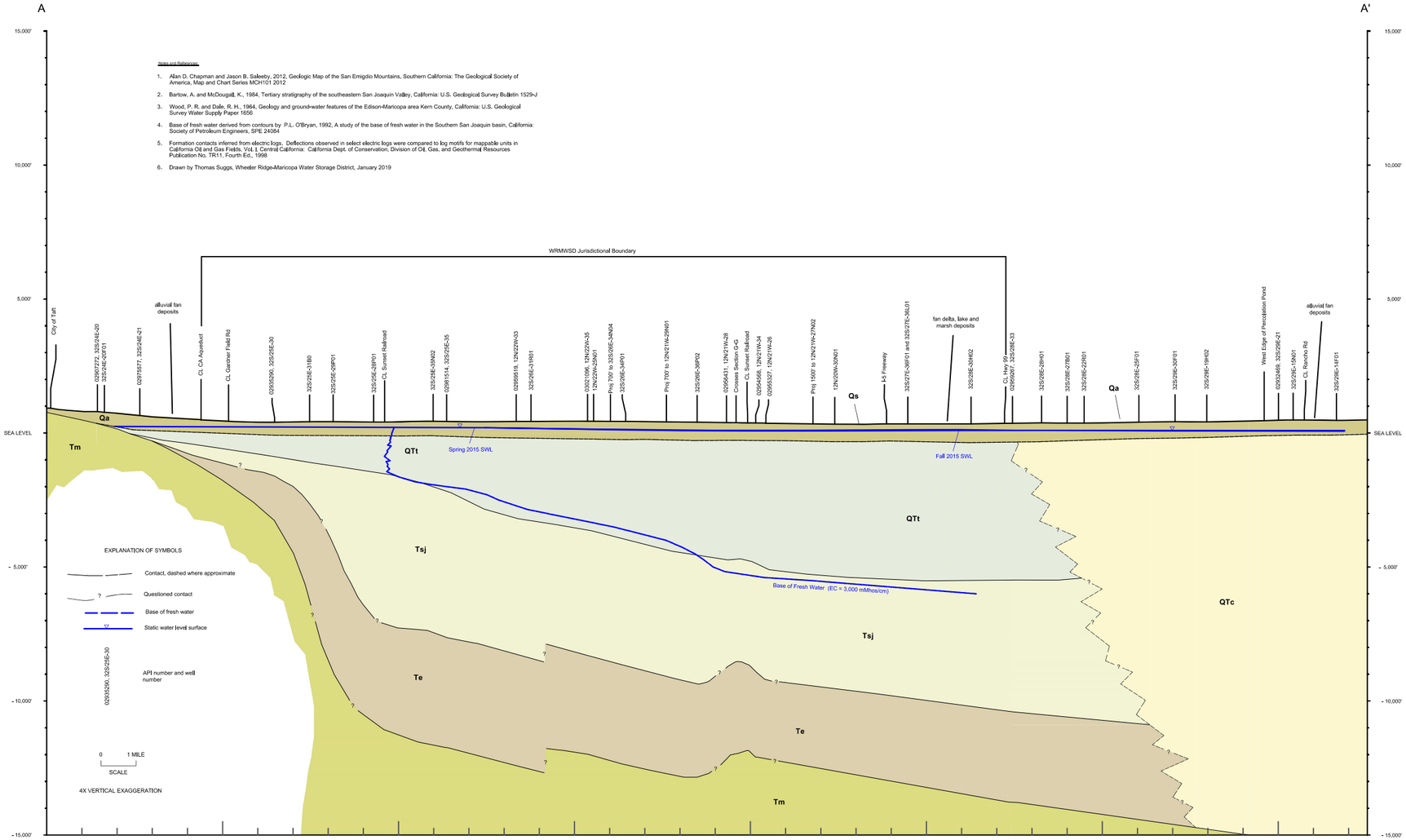
GEOLOGIC CROSS-SECTION C - C'

Arvin-Edison Water Storage District
Kern County, CA
June 2018
EKI B60064.01

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Source: EKI, 2019. Arvin-Edison Water Storage District Groundwater Sustainability Plan.

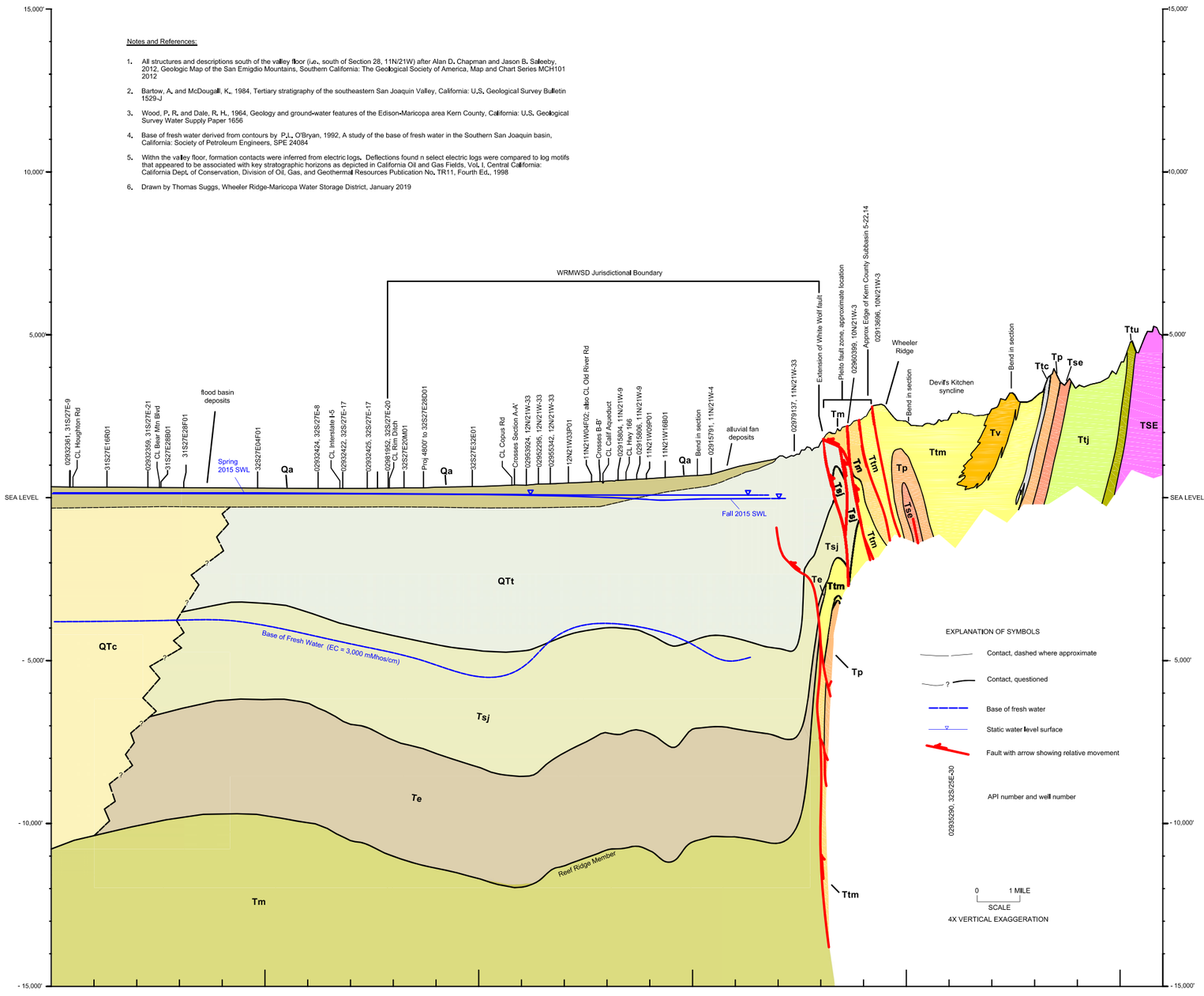
Kern Groundwater Authority Basin Setting	GEI Consultants	**GEOLOGIC CROSS SECTIONS C-C' (AEWSD)**
Kern County, California	NOVEMBER 2019	FIGURE 2-24E



GEOLOGIC CROSS SECTION A-A', SAN JOAQUIN VALLEY, CALIFORNIA

Source: 2019 Wheeler Ridge Maricopa Water Storage District Groundwater Sustainability Plan.

Kern Groundwater Authority Basin Setting	GEI Consultants	**GEOLOGIC CROSS SECTIONS A-A' (WRMWSD)**
Kern County, California		NOVEMBER 2019 — FIGURE 2-24F



GEOLOGIC CROSS SECTION G-G', SAN JOAQUIN VALLEY, CALIFORNIA

Source: 2019 Wheeler Ridge Maricopa Water Storage District Groundwater Sustainability Plan.

Kern Groundwater Authority Basin Setting	GEI Consultants	**GEOLOGIC CROSS SECTIONS G-G' (WRMWSD)**
Kern County, California	NOVEMBER 2019	FIGURE 2-24G

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A-A' North of the River

A-A' north of the river illustrates the change in hydrogeology from west to east. The westside has a thin fresh water zone due to a shallow base of fresh water. The geology on the westside is dominated by marine deposits and the overlying Tulare formation consists of alluvial fan and debris flow facies primarily from sediments derived from the Coast Range marine deposits. To the east of the California Aqueduct, the Corcoran Clay of the Tulare includes diatomaceous clay and other fine-grained deposits associated with basin center facies. Section A-A' includes seismic form lines from the PGA (1991) investigation that show general structure of bedding that are consistent with mapped Buttonwillow and Semitropic folds and the structure of the base of the Tulare. In contrast, traditionally mapped Corcoran Clay layers which are available through the USGS and DWR (C2VSIM on Section A-A'), correlate clays that do now follow the general bedding forms observed in seismic lines. Future investigation may clarify the discrepancies between these interpretations.

The upper zone groundwater elevation is plotted on section A-A' which is generally considered to pertain to wells screened above the Corcoran Clay. Section A-A' displays wells screened in the upper zone above the Corcoran Clay which is the primary groundwater production zone to the west of Interstate 5 (I-5). Some groundwater production in the upper zone occurs east of I-5 with wells screened above the mapped Corcoran Clay and other wells screened across the Corcoran Clay. The upper zone likely extends further west and east; however, additional data were not available to continue the correlation.

The main regional groundwater surface is plotted across the basin. The groundwater is generally confined where wells are below the Corcoran Clay and semiconfined where wells are outside the extent of the Clay. As described in section 2.2.1.3, Pond-Poso Fault has been documented to affect groundwater flow. High resolution water level data across the fault, however, were not available for this cross section.

The central portion of the Subbasin (just west of the Pond-Poso Fault), has a much thicker aquifer zone with a deeper base of freshwater and thicker deposits of continental sediments (Kern River formation) derived from the Sierra Nevada where freshwater recharge into the Subbasin predominates.

Further to the east, wells have been drilled deeper (greater than 2000 feet) in order to extract fresh groundwater from the Santa Margarita formation and Olcese Sand. Although these aquifers are separate from the main alluvial aquifer system of the valley by Plio-Miocene Marine Deposits, some wells are screened across the continental deposits (Kern River formation), extending through marine and into the Santa Margarita formation and Olcese Sand.

B-B' North of the River

Section B-B' from northwest to southeast trends through a portion of the Subbasin with a deep base of freshwater. Seismic form lines confirm bedding gradually rise to the south onto the Bakersfield Arch beginning from just north of the City of Shafter southward toward the City of Bakersfield and the Kern River. The alluvium and Kern River formation become thicker toward the south where the Kern River has been a major source of the sediment input into the Subbasin.

South of the River Cross Sections

Cross sections developed for management area plans in the southern portion of the Subbasin are included herein (Figures 2-24c to 2-24g). These sections present the base of fresh water where it is deepest in the central southern area of the Subbasin southwest of the City of Arvin. They also present the White Wolf Fault and Edison Fault which alter groundwater flow. In general, water wells are screened in the upper 1000 feet of the subsurface across the southern portions of the Subbasin, in the Kern River Formation and Tulare Formation. In the southeastern portion of the Subbasin, faulting and folding has created a thinner column of Kern River Formation deposits to the east of Lamont. The top of the Chanac Formation may be as shallow as 900 feet below ground surface in T31S-R29E. Consequently, data on the base of fresh water were not readily available for plotting in the southeastern portion of the Subbasin.

Cross sections across the White Wolf Fault are provided in the *White Wolf Subbasin Technical Report* (EKI, 2016). Historical sections document change in groundwater elevations (generally a 50 feet decline) across the fault from south to north. Displacement of beds across the fault increases with depth. In general, groundwater aquifer thickness is not significantly affected by displacement across the fault. Additional information is available at the Basin Boundary Modification website: https://sgma.water.ca.gov/basinmod/basinrequest/preview/34.

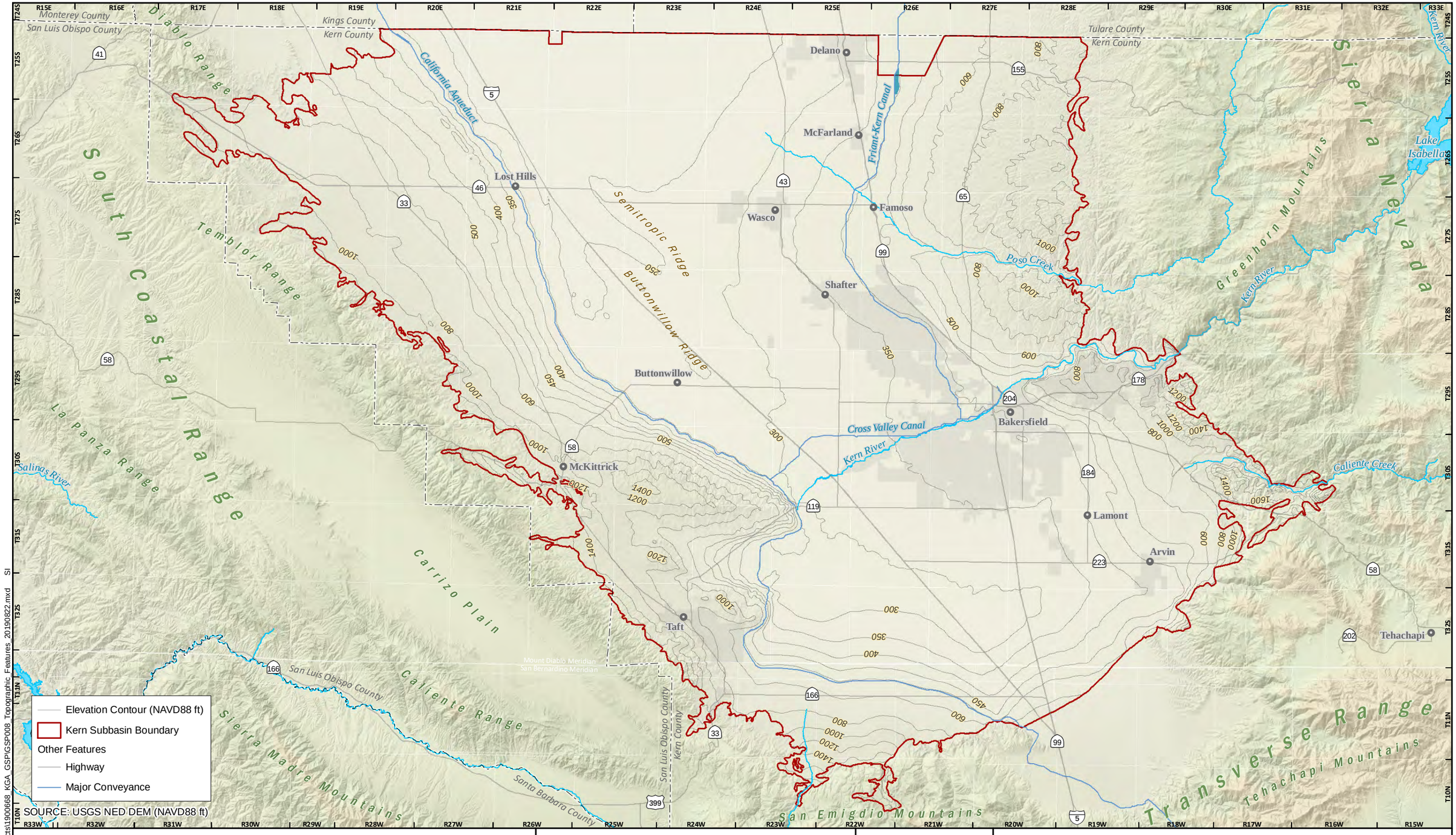
2.2.1.9 Mapped Physical Characteristics

Topographic Information

Figure 2-25 presents a basin-wide topographic map of the Subbasin. The rim elevation of the Subbasin varies from approximately 600 feet msl along the White Wolf Fault on the south to over 2,000 feet in the foothills of the adjacent San Emigdio Mountains. On the east and west sides, the rim elevations vary between 1,000 and 2,000 feet msl. As such, the topography of the Subbasin slopes toward the center of the valley on three sides, and the 400-foot contour line generally defines a long and narrow valley floor, which slopes to the northwest. The lowest land surface elevations are approximately 210 feet msl and are located along the County line between Highway 43 and Interstate 5 (18 of 24 miles). Within the Subbasin, prominent topographic features include the Elk Hills, and the Buttonwillow and Semitropic ridges.

Surficial Geology (Including Location of Geologic Sections)

The surficial geology of the Subbasin has been documented in a variety of previous investigations and is presented on Figures 2-13, 2-17, and 2-18 (Bartow, 1991; Page, 1986; and CGS, 2010b) According to the California Geological Survey (2010b), the center of the basin consists mainly of Pleistocene to recent unconsolidated and semi-consolidated alluvial (Q of Figure 2-17), lake, playa, and terrace deposits. Older Pleistocene alluvium (Qao) is present in the eastern portion of the basin on top of Pliocene-Pleistocene deposits (QPc) of sandstone, shale and gravel deposits, including the Kern River Formation. The QPc unit includes the Tulare Formation and occurs as islands, surrounded by recent alluvium, within the center of the northern Subbasin along the western side and within the alluvium. Small remnants of older continental sediments are included along the southeastern flank of the Subbasin, including undivided



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Kern Groundwater Authority
Basin Setting

Kern County, California

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TOPOGRAPHIC FEATURES

AUGUST 2019

FIGURE 2-25

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Tertiary-age sandstone, shale, conglomerate, breccia, and lake deposits (Tc) and Miocene-age sandstone, shale, conglomerate, and fanglomerate (Mc) plus smaller remnants of older marine sediments: Miocene-age sandstone, siltstone, shale, conglomerate, breccia (M). These remnant units would include the Santa Margarita Formation, Round Mountain Silt, and Olcese Sand.

Bartow (1991) provides a similar map (Figure 2-13) as the California Geological Survey map but refers to Quaternary alluvial and lacustrine sediments (Qs) on the valley floor and Tertiary sedimentary rocks (TS) along the flanks and for the islands of older rocks in the valley center. As discussed further below, the map shows the location of the Bakersfield Arch as well as three structural regions within the Subbasin.

Page's (1986) presentation of the surficial geology, as shown by Figure 2-17 better display the lakebed deposits. Recent river deposits (Qr) associated with the present-day Kern River, are shown as a long, narrow strip from the mouth of the Kern Canyon, and are comprised of gravel, sand, silt, and minor amounts of clay. The center of the valley floor is underlain by Recent flood basin (Qb) – clay, silt, and some sand; and by Pliocene to Recent lacustrine and marsh deposits (QTl) – clay, silt, and some sand with extensive subsurface clay layers (A, C, E/Corcoran). The former unit is associated with the original Kern River drainage and flood basin while the latter unit is associated with the historical Kern Lake Bed, Buena Vista Lake Bed, Goose Lake Beds, and the southern edge of the Tulare Lake Bed. The remainder of the valley is underlain by Miocene to recent continental deposits (QTc) – a heterogenous mixture of gravel, sand, silt, and clay with some layers of conglomerate, sandstone, siltstone, and claystone. Like the other maps, remnants of older continental deposits are shown along the rim of the Subbasin, primarily the southeastern side, including Oligocene to Miocene deposits (Tcmo) of gravel, conglomerate, sand, and clay; and Eocene to Miocene deposits (Tcme) of conglomerate, sandstone, fanglomerate, claystone, and breccia plus limited occurrences of undifferentiated marine deposits (Tm) of sand, clay, silt, sandstone, shale, mudstone, and siltstone of Eocene to Pliocene ages.

Soil Characteristics

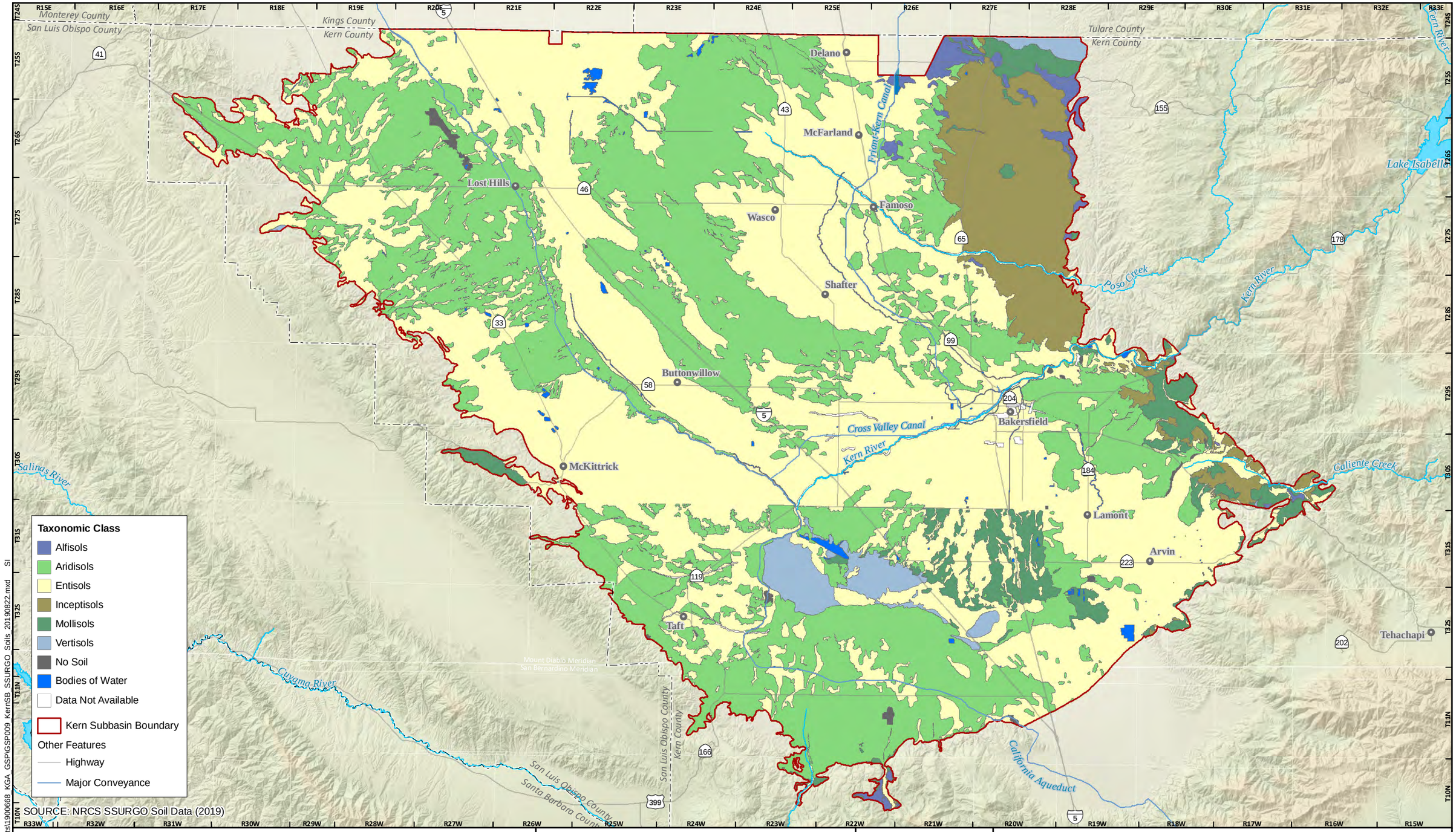
Soils within the Subbasin have two general origins that are approximately delineated by the trough of the valley, which also mirror depositional patterns as mapped in surficial geology. The eastern alluvial fans were deposited primarily by runoff from the Sierra Nevada, Tehachapi, and Transverse mountain ranges. These soils are of igneous and metamorphic origin; are typically well drained, very low in salinity, and ideal quality for agriculture. The northwestern alluvial fans originated from Coast Range sedimentary rock formed on the sea bottom. This northwest region tends to have more areas with poorly drained soils of relatively marginal quality (Provost & Pritchard, et al., 2015). The Groundwater Quality Assessment Report (Provost & Pritchard, et al., 2015) describes five areas of different soil texture in the Subbasin: the clay rim area of fine grained texture near the historical lake beds, the foothills of medium texture, the Kern Fan region derive from river deposition, northern areas with some alluvium and other sources, and Wheeler Ridge/Arvin Edison with coarse soil. These five areas contain the different soil types described below.

Soils in the center of the Subbasin are generally categorized into three types according to texture. Fine-grained soils are found in the southwest, the historical lake beds, and northwest corners of

Subbasin. Coarse grained soils within the Poso Creek fan, Kern River fan, and Caliente creek fan. And the moderate infiltration of soils along the distal edges of the fans. The lake bed areas are composed of fine-grained soils of the historical Buena Vista and Kern lakebeds, and swamp and overflow lands, which continue north along the historical drainage paralleling the Goose Slough, Goose Lake, and southern edge of the Tulare Lake depositional environment. Medium to coarse grained soils are distributed in the Poso Creek and Kern River drainage beds as well as the proximal and medial portions of the Kern Fan, and the south boundary of the Subbasin.

Figure 2-26 and 2-27 present the soil distribution within the Subbasin as defined by U.S. Dept. of Agriculture (USDA), National Resources Conservation Service, Soil Survey Geographical Database (SSURGO) as obtained from the DWR SGMA Data Viewer website (2018). Figure 2-26 shows that six soil orders are present in the Subbasin, including Aridisols and Entisols throughout most of the Subbasin, with Inceptisols along the eastern highland, and much lesser amounts of Alfisoils, Mollisols, and Vertisols. According to the online Encyclopedia Britannica (EB, 2018), Ardisols are dry soils characterized by a low humus, light-colored surface horizon with a subsurface accumulation of soluble salts, silicate clays, and possibly a cemented layer of calcium carbonate, calcium sulfate (gypsum) or silica. Entisols are characterized by the absence of soil horizons due to recent deposition or active erosion under extreme wet or dry conditions (EB, 2018). Inceptisols exhibit a weak appearance of soil horizons overlying a weathering-resistant parent material. Alfisols are characterized by well-developed soil horizons enriched with aluminum- and iron-bearing (Al/Fe-) minerals but depleted of calcium carbonate (EB, 2018). Translocated clays typically form a layer with relatively high amounts of mineral nutrients (calcium, magnesium, sodium, and potassium). Mollisols are characterized by a thick, dark surface horizon of humus, which typically originates from native grass vegetation, and mineral nutrients are present in most horizons (EB, 2018). Humus and Al/Fe-bearing minerals do not migrate to subsurface layers. Vertisols are clay-rich soils (>30 percent) with significant cracking during the dry season due to the shrink-swell response of the clay minerals during the dry and wet seasons (EB, 2018). The shrink-swell action produces significant vertical mixing of the soil.

Figure 2-27 shows the distribution of hydrogeologic soil groups, which is based largely on four categories of infiltration rates: high, moderate, slow, and very slow. Group A soils have a high infiltration rate due to well drained sands or gravelly sands. Group B soils are moderately well drained due to moderately fine to coarse textures. These soils are present on the east, west, and south sides of the valley floor. Group C soils have a low infiltration rate due to their fine texture or because of a layer that impedes downward movement of water. These soils are present along the valley floor, along the eastern highlands, and at various locations along the northwestern side of the Subbasin. Group D soils have a very slow infiltration rate due to the presence of clay and are located primarily along the northern Subbasin boundary within the valley floor. More detailed soil survey data can be found in four USDA reports on various portions of the Subbasin: *Soil Survey of Kern County, California* (USDA, 1981, 1988, 2007, and 2009), including recent online updates.



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22-Aug-2019

Kern Groundwater Authority
Basin Setting

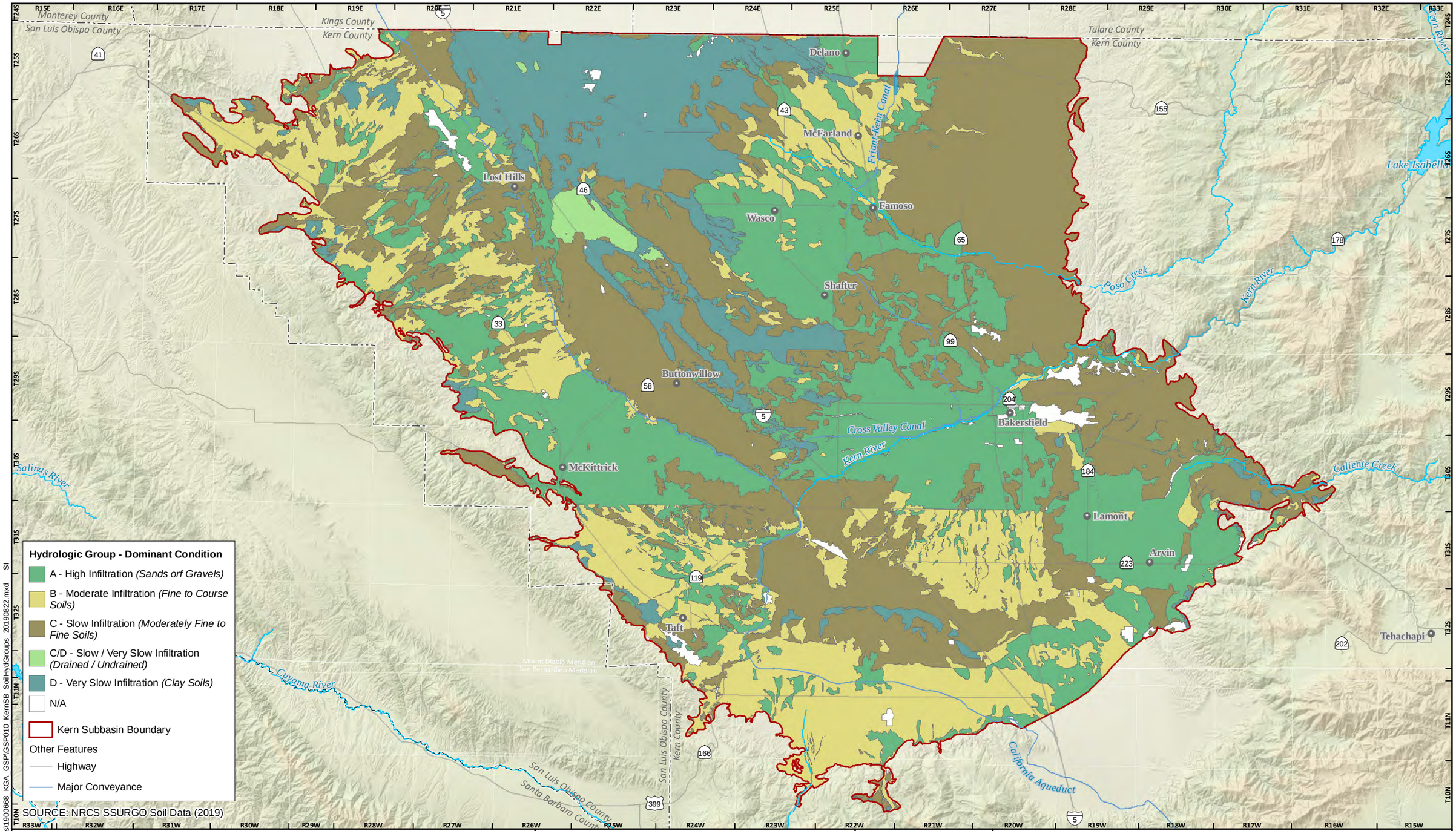
Kern County, California

GEI Consultants

SOILS OF KERN COUNTY SUBBASIN

AUGUST 2019

FIGURE 2-26



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22-Aug-2019

Kern Groundwater Authority
Basin Setting

Kern County, California

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HYDROLOGIC SOIL GROUPS

AUGUST 2019

FIGURE 2-27

Natural Recharge, Direct Recharge Areas, and Potential Recharge Areas

Direct recharge and potential recharge areas are differentiated in this section from natural recharge. Natural recharge occurs by groundwater underflow from adjacent sources, precipitation outgaining evapotranspiration in a Subbasin, or from natural surface waters flowing into the Subbasin. On the other hand, direct recharge is either planned or unplanned application of surface water by unlined conveyance, field application, managed recharge, and spreading operations. This section focuses mainly on direct recharge and potential recharge to the Subbasin, but briefly discusses natural recharge to the Subbasin. In-lieu recharge is not discussed in this section because it does not provide an actual input to the groundwater system for budgeting purposes, but only curtails or reduces the amount of groundwater that would have been pumped. In-lieu recharge is discussed in other sections of this GSP. This section may not include all localized recharge activities and facilities, but these local activities and facilities are further described within the individual management area plans.

Natural recharge to the Subbasin occurs mainly by underflow or surface recharge from the eastern and southern highlands (Sierra Nevada and Tehachapi Mountains). The surface water bodies as a source of recharge are discussed in the next section. In general, natural in-situ recharge by precipitation is absent in Subbasin, and may only occur in extreme wet years, because typically evapotranspiration outgains the amount of natural precipitation to the Subbasin (Provost and Pritchard et. al., 2015). The absence of natural recharge by in-situ precipitation in the Subbasin further illustrates the lack of recharge to the west side of the Subbasin where it is likely that very little if any freshwater underflow recharges the west side. In contrast, the east side is dominated by recharge from the Kern River and the Sierra Nevada.

Significant direct recharge to groundwater in the Subbasin occurs through managed recharge and water banking (storage) projects; as well as unmanaged recharge through natural waterways, unlined spill basins and regulating (balancing) reservoirs, percolation of applied water to crops that descend below the root zone, and unlined canals. Numerous sources of water are recharged by various projects, including local surface water (Kern River, Poso Creek, and other drainages) and imported water (State Water Project [SWP] and Central Valley Project [CVP]).

The major areas of direct recharge (facilities and drainages) are presented in Figure 2-28. Additional areas of unmanaged or managed recharge may include agricultural land where excess irrigation water percolates below the root zone, wastewater treatment spreading areas, and urban drainage spreading areas. Additional locations of natural recharge from surface water features may include springs, seeps, ephemeral/intermittent streams flowing into the Subbasin (Figure 2-29). The surface water features are described in more detail in the following section.

Since the late 1980s, large-scale groundwater recharge/banking operations have been constructed along the Kern River. Given the permeable nature of sediments within the Kern River Fan, most of the enhanced recharge projects involve surface spreading through ponds, low-lying fields, or basins. Some projects are dedicated to the replenishment of the groundwater basin, while other projects store surplus SWP and CVP water for subsequent extraction; and some banking projects do both. (Todd, 2017).

The Soil Agricultural Groundwater Banking Index (SAGBI), can further estimate groundwater recharge suitability to quantify recharge of deep percolated applied irrigation water and potential recharge from future managed recharge within the Subbasin. The California Soil Resource Lab at University of California Davis has developed an online application (https://casoilresource.lawr.ucdavis.edu/sagbi/) to present the SAGBI, which estimates groundwater recharge suitability based on five major factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. The application includes mapping coverage of the SAGBI and indicates a moderately good to excellent rating for the Poso Creek alluvial fan in the north central Subbasin, the Kern River alluvial fan in the central area, and in much of the southeastern to southwestern corners of the Subbasin. SAGBI ratings are moderately poor to very poor along the eastern margin, central western margin, as well as the center of the valley from the former Kern and Buena Vista lake beds, north along the Goose Neck Slough to the Tulare Lake Bed. While moderately good to good SAGBI is shown for much of the western margin, this area is underlain by marine sediments and is not likely to be a useful area for recharge. The SAGBI ratings generally agree with mapped soil data where higher rated SAGBI soil corresponds with moderate to high infiltration soils. Note that an abrupt east-west alignment of good versus poor SAGBI occurs in the southern central Subbasin and is likely due to the methods and results of historical soil surveys.

Groundwater discharge areas in the Subbasin are limited due to the depth of usable groundwater, typically greater than 100 feet throughout the Subbasin. Shallow, poor-quality groundwater (above the A-clay) does occur in the west central and southern areas. These shallow groundwater areas may support salt-tolerant vegetation. Effects of a shallow water table and evapotranspiration may discharge poor quality shallow groundwater from these areas to the surface. Historically, flowing wells were present throughout much of the valley floor (Mendenhall, 1916), including the Buena Vista and Kern lakes and the area to the north (>180 square mi), and from Buttonwillow north beyond the county line (>400 square mi). Over 100 flowing wells were identified in 1905 and reductions in flow were recognized in the following years. According to the USGS groundwater model (Faunt, 2009), the Kern River is a groundwater discharge area along a nominal 7-mile reach within Bakersfield, east of Highway 99; however, the City of Bakersfield measures flow at six weirs along the river across the valley and shows an overall loss of flow (seepage) from the Kern River.

Surface Water Bodies

Figure 2-29 presents the location of surface water bodies in the Subbasin according to the National Hydrography Dataset. These water bodies include the California Aqueduct (SWP) and federal Friant-Kern Canal, and other local canals that help convey Kern River water and imported surface water to beneficial users in the Subbasin. This dataset also includes the Kern River, Poso Creek, Caliente Creek, and other significant ephemeral streams, spring, and seeps, that are sources of recharge from the mountains on the east, southeast, and south sides of the Subbasin. The National Hydrography Dataset also includes wetlands delineations around the Kern Wildlife Refuge. The refuge is now sustained by imported surface water typically wheeled from the California Aqueduct and conveyed by the Goose Lake Canal to the refuge (USFS, 2005).

Major Canal
- Lined
- Unlined

Minor Canal
River, Creek or Ephemeral Stream
Area of Direct Recharge
Kern Subbasin Boundary

Other Features
Highway
Major Conveyance

SOURCE: USGS NHD, Kern County

0 3.5 7 14 21
Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

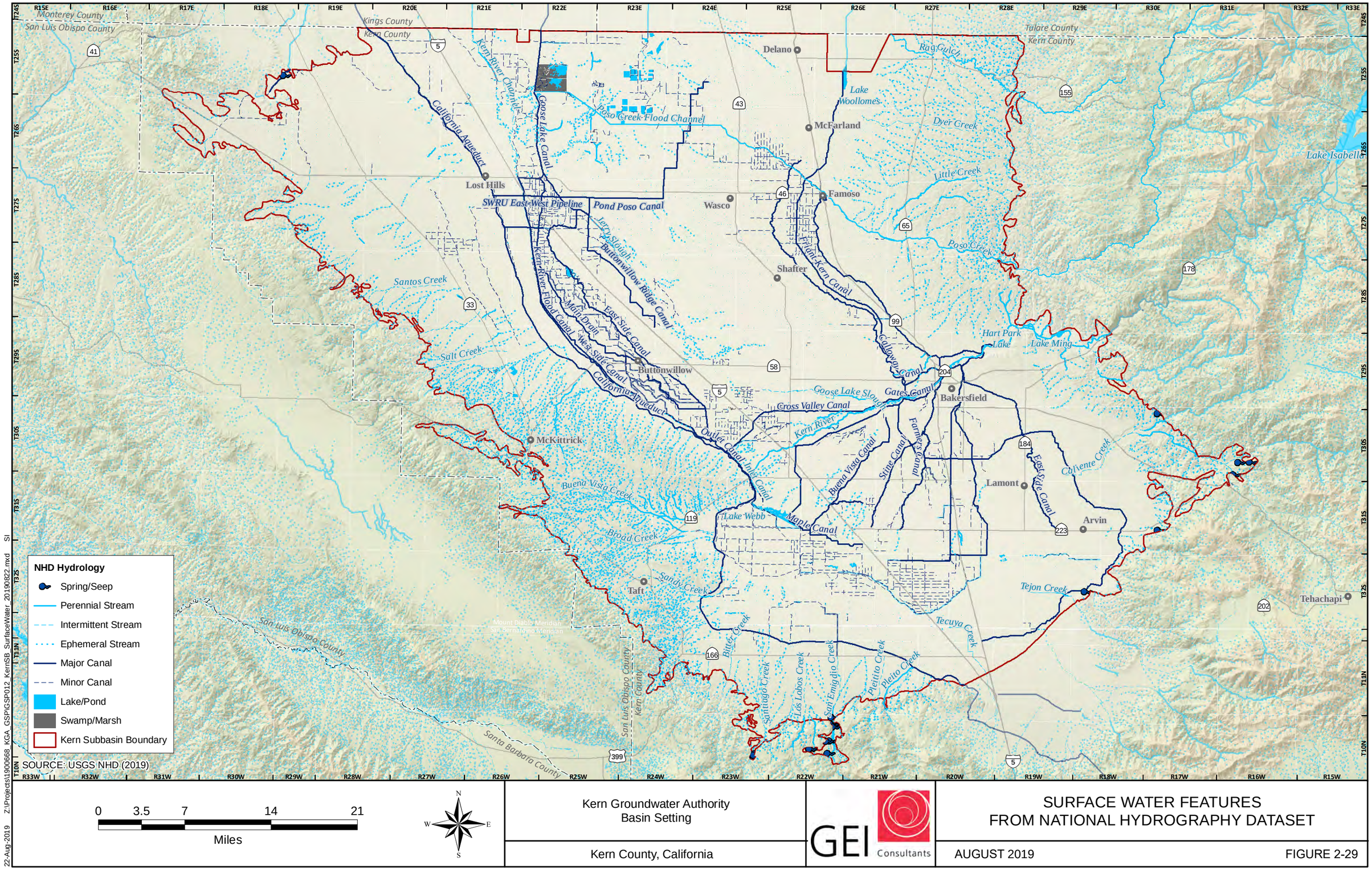
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AREAS OF DIRECT RECHARGE

AUGUST 2019

FIGURE 2-28

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Kern Groundwater Authority
Basin Setting

Kern County, California

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SURFACE WATER FEATURES FROM NATIONAL HYDROGRAPHY DATASET

AUGUST 2019

FIGURE 2-29

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22-Aug-2019

The most important source of naturally occurring surface water for the Subbasin is the Kern River, which has been regulated by the Isabella Dam and Reservoir since 1954. The dam and reservoir are operated by the U.S. Army Corps of Engineers and the distribution of water is administered by the Kern River Watermaster. The Kern River is approximately 164 miles long and is fed by rain and snowmelt from the Southern Sierra Nevada, including Mount Whitney. The last 35 to 40 miles of river crosses the Subbasin.

Local streams, many of which are ephemeral, provide additional local surface water during the wet season and during above normal and wet water years. A very small percentage of minor stream runoff is collected and used for irrigation; the majority of these irregularly occurring flows likely serve to recharge local groundwater basins (Kennedy and Jenks, 2011).

Source and Point of Delivery for Imported Water Supplies

Imported water is supplied by the Central Valley Project's (CVP) Friant-Kern Canal and California Department of Water Resources through the SWP. CVP water from the Friant Division is conveyed to users in the Subbasin through the Friant-Kern Canal, and SWP water is conveyed through the California Aqueduct together with CVP water from the Delta Division. Treated produced water is also used as an imported source of water to the groundwater Subbasin for beneficial use.

Central Valley Project – Friant Division

The CVP Friant-Kern Canal diverts water from Millerton Reservoir, created by Friant Dam on the San Joaquin River, and extends southward a distance of 152 miles through Fresno, Tulare and Kern counties to its terminus at the Kern River in Bakersfield. The capacity of Millerton Reservoir is about 520,000 AF, but 130,000 AF of this storage lies below the intake for the Friant-Kern Canal.

Water districts along the east side of the San Joaquin Valley entered into long-term water supply contracts with Reclamation, which provide for the delivery of three types of water; Class 1, Class 2, and Section 215.

Class 1 Water is the supply of water stored in or flowing through Millerton Lake which, subject to the contingencies described in the Contracts, will be available for delivery from Millerton Lake and the Friant-Kern and Madera Canals as a dependable water supply during each Contract Year.

Class 2 Water is the supply of water which can be made available subject to the contingencies described in the Contracts for delivery from Millerton Lake and the Friant-Kern and Madera Canals in addition to the supply of Class 1 Water. Because of its uncertainty as to availability and time of occurrence, such water will be undependable in character and will be furnished only if, as, and when it can be made available as determined by the Contracting Officer.

Section 215 Water is a temporary supply of water, other than Class 1 Water or Class 2 Water, made available to the Contractors in addition to water provided pursuant to water service contracts, including water made available that is not subject to acreage limitation pursuant to

Section 215 of the Reclamation Reform Act of October 12, 1982 (96 Stat. 1263), as amended. The historical allocation priorities for Section 215 Water are as follows:

- Long-term contractors
- Cross Valley contractors
- Other parties within the Friant Division service area with direct delivery capabilities
- CVP contractors outside of the Friant Division service area
- Other parties

Central Valley Project – Delta Division

In 1973, DWR completed the initial facilities of the SWP, including the main line of the California Aqueduct. Portions of the SWP were constructed for use in conjunction with the facilities of the CVP. As the state and federal projects developed, a group of water users planned the Cross-Valley Canal as a means of taking delivery of CVP water conveyed through the California Aqueduct. The Cross-Valley Canal was completed in 1975 and, in 1976, the water users entered into three-party contracts with DWR and Reclamation. Under these contracts, CVP water available to Reclamation in the Delta can be pumped by the SWP's Harvey O. Banks Pumping Plant into the California Aqueduct for delivery to the Tupman turnout where this water is diverted into the Cross-Valley Canal. This federal water, conveyance of which is subordinate to conveyance of SWP water, can then be delivered to water users in the Subbasin.

State Water Project

The Kern County Water Agency was formed in the 1960s to contract with the DWR for the importation of SWP water to Kern County. The California Aqueduct, the SWP's principal conveyance feature, transports water from the Delta along the west side of the San Joaquin Valley to the Subbasin. Individual water districts holding contracts with Kern County Water Agency have turnouts directly from the aqueduct into their service areas or receive water via the Cross-Valley Canal.

Two types of water are available from the SWP, including relatively firm Table A Water and surplus Article 21 Water. Table A Water takes its name from an exhibit to the contract between the DWR and the SWP contracting agencies that serves as the basis for allocating water among the agencies.

While the reliability of SWP water is less than was anticipated when the contracts were executed, a contract amendment, introduced in the Monterey Agreement of 1994, put agricultural and urban contractors on equal footing respecting the allocation of water supply during shortages. Prior to the amendment, agricultural contractors were burdened with a larger share of any shortages.

Article 21 Water, unlike Table A water, cannot be scheduled; rather, it must be taken at the time it is declared to be available and is analogous to Section 215 Water for the CVP-Friant contractors. The following conditions govern the availability of Article 21 Water:

- Available only when deliveries do not interfere with Table A allocations and SWP operations
- Available only when excess water is available in the Delta
- Available only when conveyance capacity is not being used for SWP purposes or scheduled SWP deliveries
- Cannot be stored within the SWP system. In other words, the contractors must be able to use the Article 21 water directly or store it in their own system

Due to these conditions, Article 21 Water is only available during the wet months of the year, typically December through March.

Produced Water

Water brought to the surface when oil is extracted is often referred to as "produced water." Produced water is groundwater that is commingled with hydrocarbons and located within the hydrocarbon bearing reservoir. Produced water is generated as oil is extracted for use. Often, produced water is returned to the original geological formation for enhanced oil recovery or disposal. Some produced water is suitable for beneficial use with treatment, though most is higher in salinity and must undergo extensive treatment and be blended with other water before use. New technology and the need to find new sources of water are driving the ability to process and treat produced water for beneficial use.

2.3 Groundwater Conditions

Annual groundwater elevation contour maps covering much of the Subbasin have historically been prepared by Kern County Water Agency in Water Supply Reports since before the 1990s until 2012. These maps provide seasonal high groundwater level conditions from spring water level data, and generally depict groundwater flow conditions over time consistent with flow directions observed in 2015. Groundwater conditions are also monitored through a number of local and joint district activities, as well as state mandated programs, such as CASGEM.

2.3.1 Groundwater Trends

Based on historical groundwater trends from USGS and the Kern County Water Agency (Page, 1986; and KCWA), groundwater flows into the Subbasin mostly from the uplands along the south and east margins of the Subbasin. Below is a generalized diagram depicting groundwater flow into the Subbasin (Figure 2-30). In the absence of pumping or significant barriers, groundwater naturally flows from high elevation points of recharge to lower elevation points with less recharge. In general, groundwater flow diverges to the north and south away from natural and managed recharge points along the Kern River. The river flows into Subbasin roughly along the axis of the Bakersfield Arch, which has a broad topographical rise that gradually dips to the north and south; thus, the rough alignment of the river effectively splits the Subbasin into northern and southern groundwater flow regimes. Groundwater to the south of the river flows toward discharge points at pumping wells within the south-central areas of the Subbasin, and groundwater to the north of the river migrates toward the northwest discharge points at pumping wells and continues north until it leaves the Subbasin as subsurface underflow.

Figure 2-30 presents the approximate location of the San Joaquin Valley (Buttonwillow) Syncline which likely affects the flow of westside groundwater from significantly impacting the main production zone of the Subbasin. In general, groundwater elevation trends near the river may be highly variable due to high volumes of managed groundwater recharge and extractions associated with groundwater banking projects. Groundwater elevation patterns further away from banking operations show more seasonal responses from pumping and recharge, and, an overall, long-term decline in groundwater level in the majority of the Subbasin.

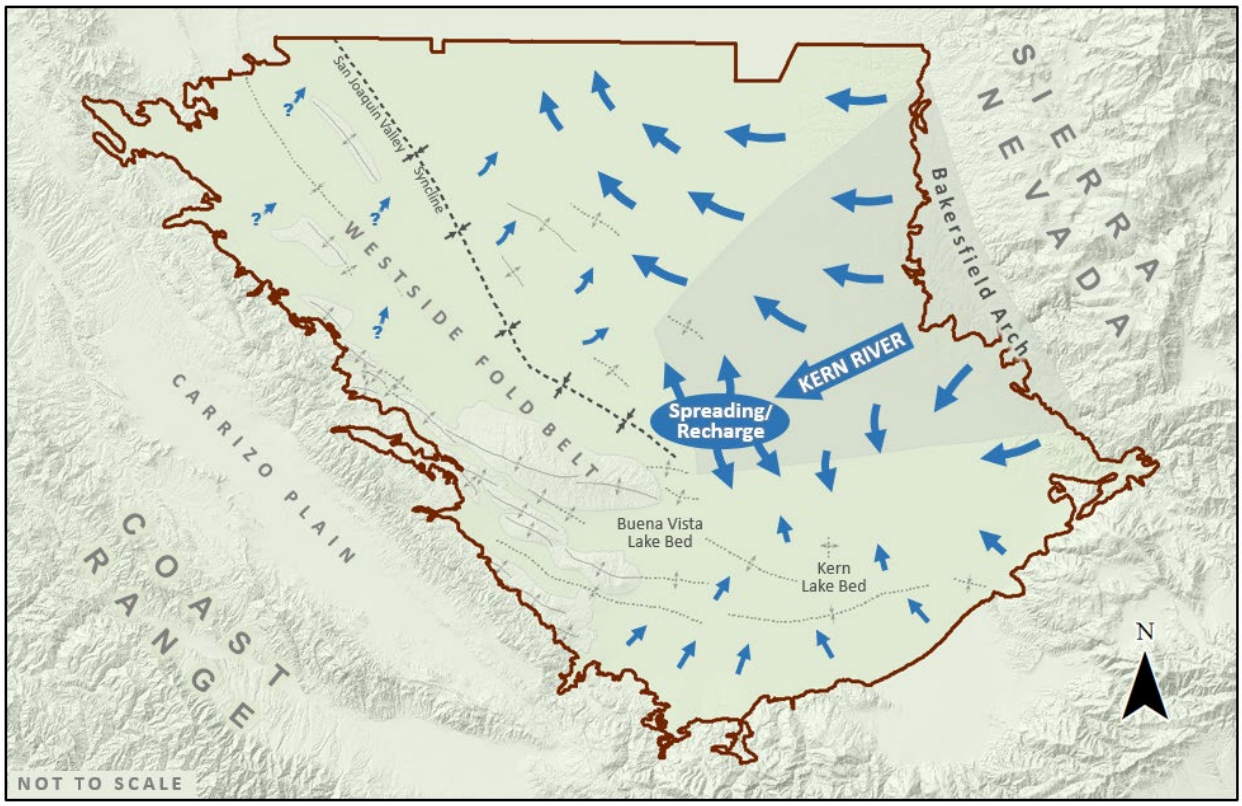


Figure 2-30. Generalized Diagram of Groundwater Flow in Kern County Subbasin

2.3.1.1 Elevation and Flow Directions

Groundwater elevation contour maps were prepared for Spring 2015 to provide relatively current groundwater flow trends across the Subbasin since the inception of SGMA. Contours were prepared for Spring 2015 (seasonal high) in the primary aquifer zone or "main production zone" which is generally confined below the E-clay or Corcoran and unconfined to semiconfined outside the extent of the E-clay (Figure 2-31). Contours for the "Upper Zone" by Schmidt and Associates (2018) are presented on Figure 2-32 for Spring 2015 data. They represent the upper unconfined to semiconfined zone (above the E-clay or equivalent) underlying the northwest-central part of the Subbasin. A Fall 2015 contour map was also developed to represent seasonal low groundwater conditions in the primary aquifer zone (Figure 2-33). At this time, there is insufficient data to contour a fall 2015 upper zone map. In addition, to production zones, depth contours developed by the Kern County Water Agency (2012) for the shallow unconfined zone (above the A-clay or equivalent) are presented on Figure 2-34.

Well Location

Generalized Production Zone Boundary
West of the boundary, groundwater production is in the Upper Zone which is above the Corcoran Clay.
East of the boundary where underlying the Corcoran Clay, the production zone is the

Spring 2015 Groundwater Surface Elevation

Kern Subbasin Boundary

Other Features

Highway

Major Conveyance

Notes:
Contours are generated at a subbasin scale to depict overall regional trends and flow directions. High resolution site-specific data may not be reflected in this dataset. Refer to chapter-level GSPs for any local modifications.

Upper Production Zone Contours Presented on Separate Figure

0 3.5 7 14 21
Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

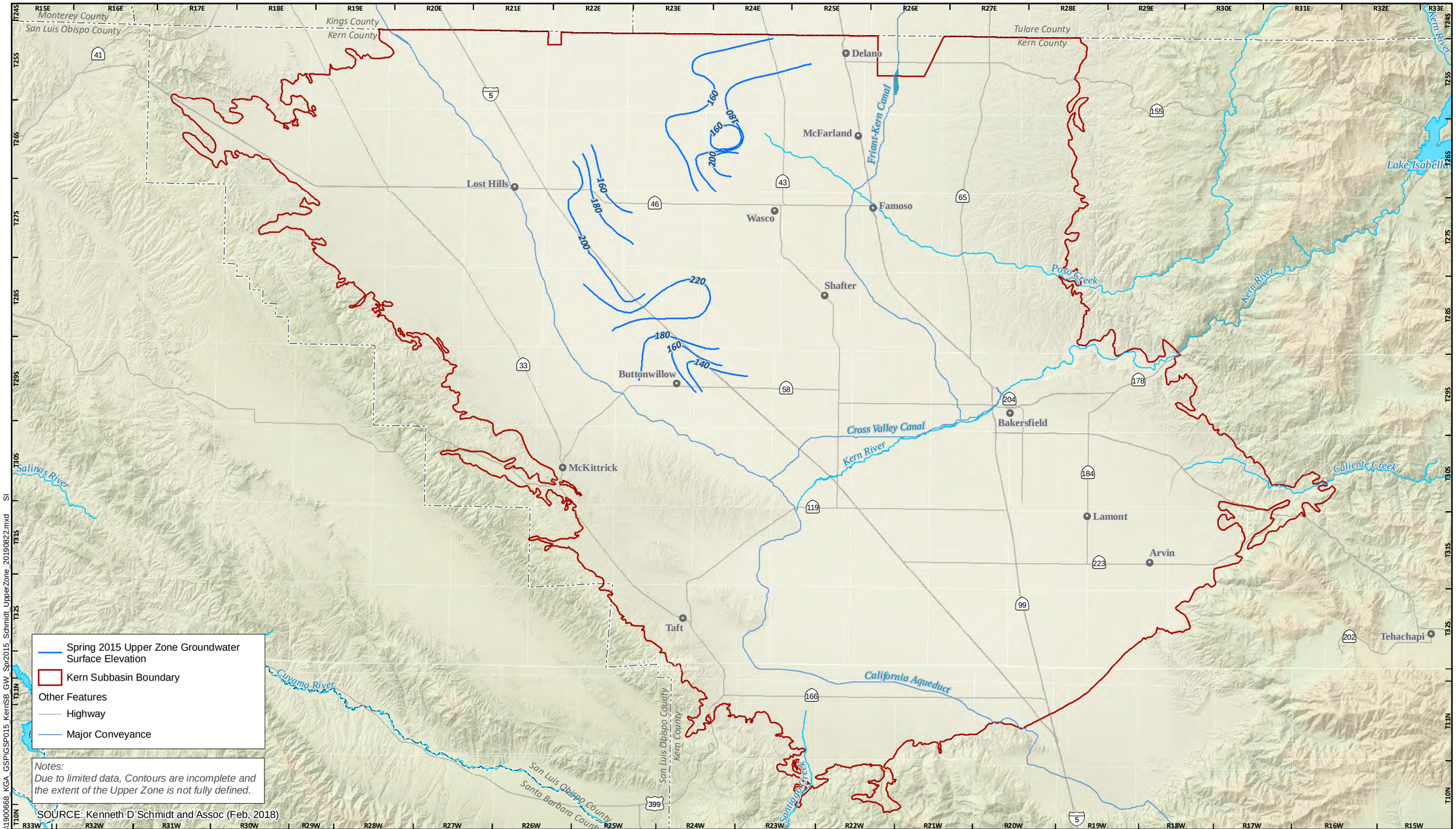
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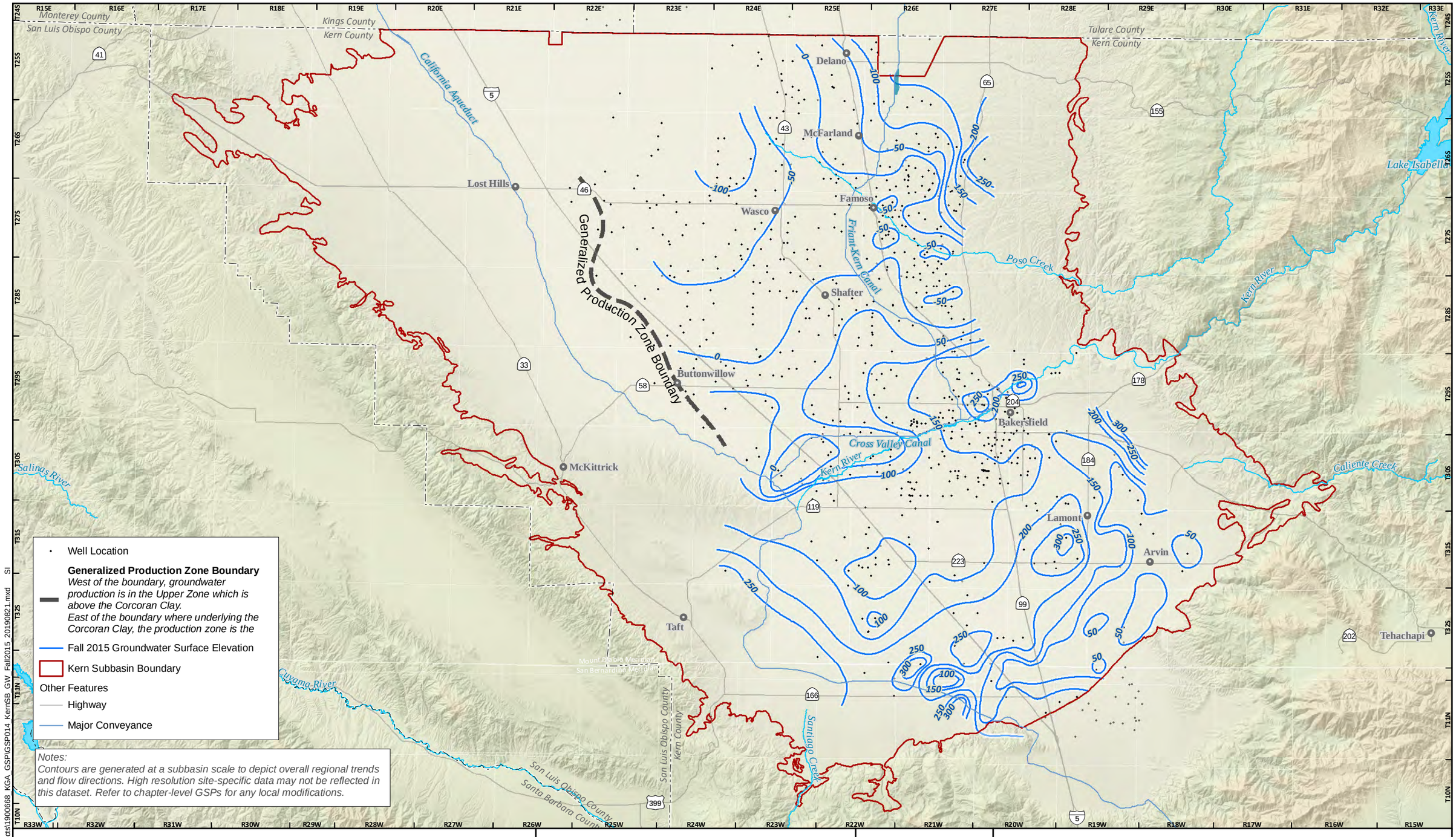
SPRING 2015 REGIONAL GROUNDWATER ELEVATIONS

AUGUST 2019

FIGURE 2-31

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Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
Delano
McFarland
Friant-Kern Canal
Lost Hills
Wasco
Famoso
Shafter
Buttonwillow
Bakersfield
Cross Valley Canal
Kern River
Poso Creek
Lake Isabella
McKittrick
Taft
Lamont
Arvin
Tehachapi
California Aqueduct
Caliente Creek
Salinas River
Cuyama River
San Luis Obispo County
Santa Barbara County
Kern County
Santiago Creek
160
180
200
220
140
Spring 2015 Upper Zone Groundwater Surface Elevation
Kern Subbasin Boundary
Other Features
Highway
Major Conveyance
Notes:
Due to limited data, Contours are incomplete and the extent of the Upper Zone is not fully defined.
SOURCE: Kenneth D Schmidt and Assoc (Feb, 2018)
0 3.5 7 14 21
Miles
N
W
E
S
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
SPRING 2015 UPPER ZONE
GROUNDWATER ELEVATIONS
AUGUST 2019
FIGURE 2-32
22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP015_KernSB_GW_Spr2015_Schmidt_UpperZone_20190822.mxd SI



Kern Groundwater Authority
Basin Setting

Kern County, California

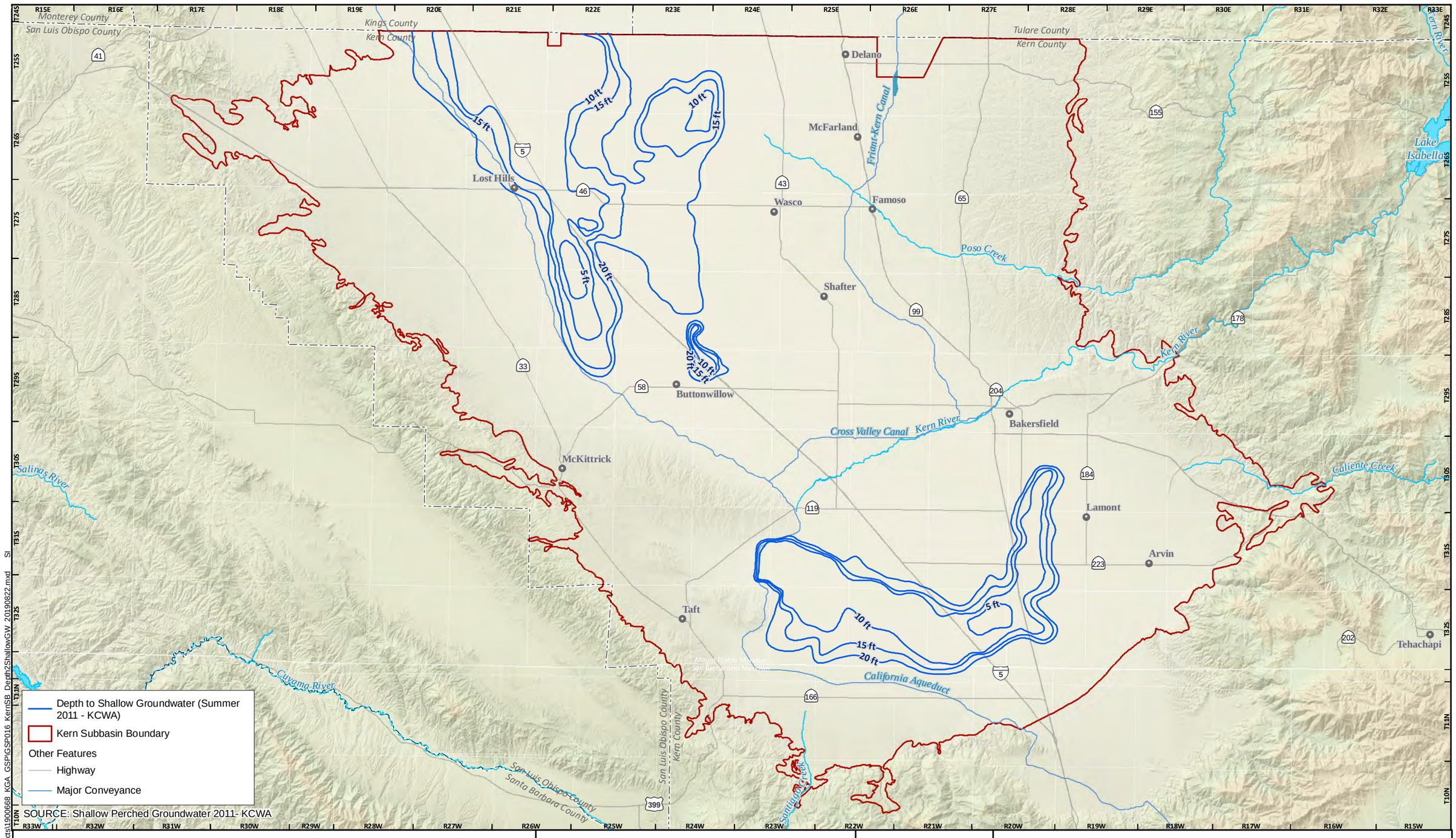
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FALL 2015 REGIONAL GROUNDWATER ELEVATIONS

AUGUST 2019

FIGURE 2-33

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21-Aug-2019



Kern Groundwater Authority
Basin Setting

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SUMMER 2011 UPPER ZONE GROUNDWATER ELEVATIONS

AUGUST 2019

FIGURE 2-34

These contours were developed from Summer 2011 and are generally representative of 2015 conditions. In general, shallow elevations are fairly constant over time.

Regional Contours

In general, groundwater flow directions reported are consistent with historical trends, with groundwater flowing from the uplands on the south, east, and west of the Subbasin toward the center of the Subbasin. Groundwater tends to diverge at the Kern River with flow to the south of the river toward pumping well discharge points, and flow to the northwest of the river toward pumping wells, and further north until it leaves the Subbasin. Based on 2015 groundwater elevations, the divergence to the North and to the South along the river is less notable due to the drought conditions which resulted in greater groundwater use with very little recharge during 2013 to 2015. Depressions in the groundwater potentiometric do occur south of the river; however, a general trend of flow toward the north and center "trough" of the Subbasin is apparent.

Groundwater elevations during Spring 2015 in the main production zone of the aquifer system ranged from less than minus 100 ft msl in the north-central part of the Subbasin to greater than 300 ft msl in the eastern and southeastern part of the Subbasin.

Groundwater elevation data for the Fall 2015 were limited in availability due to the high demand for pumping; therefore, the data range is incomplete, it may be affected by pumping, and it represents only a partial dataset; however, general groundwater flow trends are consistent with historical trends. Groundwater elevation data for the Fall 2015 in the main production zone of the aquifer system ranged from less than minus 150 ft msl (north-central Subbasin) to greater than 250 ft msl (south-southeast Subbasin). Contours in the upper unconfined zone of north-central Subbasin and shallow zone of Subbasin were not prepared for Fall 2015 due to a lack of sufficient data.

Upper Zone Contours

Groundwater elevations during Spring 2015 in the upper zone of the north central part of the Subbasin ranged from 220 ft msl to 160 ft msl. Within Townships 27S and the northern half of 28S, groundwater in the Upper Zone flows northeasterly. Within the southern half of Township 28S and 29S, groundwater flows southeasterly. Some of this flow may be affected by the Buttonwillow Syncline and Buttonwillow Ridge (anticline). As observed in Cross Section A-A' of North of the River (Figure 2-24A), beds from this groundwater aquifer system are deformed (folded).

Shallow Depth Contours

Groundwater depths in the shallow zone historically range from approximately 20 to 25 ft bgs to less than 5 ft bgs (ranging from 200 ft msl to 245 ft msl). Representative contour maps were chosen from the Kern County Water Agency's 2011 Water Supply Report (KCWA, 2012) (Figure 2-34), because more recent data from 2011 to 2015 are limited in extent; nonetheless, the recent data agree with DWR published maps of shallow perched groundwater in the San Joaquin Valley (DWR, 2009), and with the Kern County Water Agency's historical water supply reports.

Shallow groundwater is not significantly impacted by groundwater pumping in the production zone, as observed by the relatively consistent shallow groundwater depths and extents in historical water supply reports from the Kern County Water Agency and DWR across multiple water year types. The source of shallow groundwater as mapped by the Kern County Water Agency, is derived from the percolation of applied irrigation water, as well as historical natural percolation during large storm events. The extent of shallow groundwater, which is typically perched on shallow fine-grained sedimentary units and likely disconnected from the productive aquifer system, is relatively consistent with Page's (1986) extent of mapped surficial fine-grained flood deposits (Figure 2-17 and shallow clay units related to the "A" Clay of the Corcoran Clay (KCWA, 1976). During the mid to late 1980's, sufficient data were collected for the Kern County Water Agency's water supply report to show that, at times, the perched shallow groundwater units to the north of the river and to the south of the river have been joined at the northwest of the Kern River Fan, generally following the extent of flood plain deposits as mapped by Page (1986).

While shallow groundwater data is collected in certain regions of the Subbasin, the current data collection effort does not provide sufficient data to understand the interconnection between the lower production aquifer and the shallow purged groundwater system that existing in portions of the basin. This data gap will be addressed in projects and management actions identified in individual management area plans.

Horizontal Gradients

The following is a summary of general regional groundwater flow direction and general regional horizontal gradients based on the contour maps presented herein. For more detailed trends, refer to management area plans.

Groundwater in Spring 2015 for the main production zone (confined below the E-clay and semi-confined outside of the clay) in the east-northeast flows southwesterly at a gradient of 0.011 ft/ft. In the north-central area, groundwater flows northwesterly at a gradient of 0.002 ft/ft. In the central area of the Subbasin near the Kern River and banking activities, groundwater flows north to northwesterly at a gradient of 0.002 to 0.004 ft/ft. In the southeast, groundwater flows southwesterly at a gradient of 0.025 ft/ft. In the south, groundwater flows northwesterly to southeasterly at gradients of 0.004-0.012 ft/ft and 0.004 ft/ft respectively. In the southwest, groundwater flows northeasterly at a gradient of 0.001 ft/ft. Groundwater in the Bakersfield area flows away from the river from 0.005 to 0.011 ft/ft in a southeasterly to northwesterly gradient.

Groundwater in Fall 2015 for the main production zone (confined below the E-clay and semi-confined outside of the clay) in the east-northeast flows west to southwesterly at a gradient of 0.015 ft/ft. In the north-central area, groundwater flows northwesterly at a gradient of 0.002 ft/ft. In the central area of the Subbasin near the Kern River groundwater flows toward the banking activities northeasterly and southwesterly at gradients of 0.006 ft/ft and 0.003 ft/ft respectively. In the southeast, groundwater flows southwesterly at a gradient of 0.016 ft/ft. In the south, groundwater flows northwesterly to southeasterly at gradients of 0.007 ft/ft and 0.008 ft/ft respectively. In the southwest, groundwater flows northwesterly at a gradient of 0.005 ft/ft.

Groundwater in Spring 2015 for the upper unconfined zone (unconfined above the E-clay) in the north half of Township 28S and 27S flows northeasterly at a gradient of 0.002 ft/ft. In the south half of T28S and T29S, groundwater flows southeasterly at a gradient of 0.003 ft/ft. In the far north mapped area of the upper unconfined zone, groundwater flows at a gradient of 0.001 ft/ft northwesterly and 0.004 ft/ft westerly.

2.3.1.2 Hydrographs and Vertical Gradients

Hydrographs presenting change in groundwater elevation over time and vertical groundwater gradients for specific areas of the Subbasin are provided in the chapters herein for local management areas. In general, hydrographs presented in the management area plans indicate that groundwater elevations decline during below normal water years (as defined by the water year index), and groundwater elevations begin recovering during above normal water years. Additional information can be found Section 2.4, Water Budget Information.

2.3.2 Seawater Intrusion

The Subbasin is located in the Central Valley, more than 40 miles from the Pacific Ocean. Seawater intrusion will not affect the Subbasin.

2.3.3 Groundwater Quality

To characterize groundwater quality in the Subbasin, a literature review was conducted using USGS studies and other technical reports, as well as data extracted from GeoTracker and EnviroStor to identify contaminant plumes. The SWRCB's Human Right to Water portal was used to identify contaminants that are commonly violating drinking water standards and an evaluation of the groundwater water quality was conducted using data from local Water Districts and the State Drinking Water Information System (SDWIS), which collects sample results from all State regulated public water systems. This section of the report provides a brief introduction to the contaminants most commonly found in the Subbasin. A more focused evaluation of the groundwater is provided in the management area plans for each member agency that comprises the KGA.

Characterization of groundwater quality was conducted to comply with (California Code of Regulations – Title 23 – Waters; Subarticle 2 §354.16(d) – Groundwater Conditions: groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes. Constituents evaluated and the methodology used were consistent with guidance provided in:

- Assembly Bill 1249 (AB 1249) which states that "if the IRWM region has areas of nitrate, arsenic, perchlorate, or hexavalent chromium contamination, the (IRWM) Plan must include a description of location, extent, and impacts of the contamination; actions undertaken to address the contamination, and a description of any additional actions needed to address the contamination" (Water Code §10541.(e)(14)).

- Division of Drinking Water's (DDW) Human Right to Water (HR2W) portal, which identifies the contaminants that public water systems have received maximum contaminant level (MCL) violations. Commonly found contaminants were trended and occurrence data was evaluated.
- Water Quality Control Plan for Tulare Lake Basin (Basin Plan), dated May 2018, which is the State Board's implementation plan for Water Code §106.3. The amended Basin Plan requires permittees to "address the immediate needs of those drinking groundwater that exceeds the drinking water standard for nitrate."

Incorporating guidance from these sources was intended to incorporate the major constituents of concern and characterize groundwater in a manner that is consistent with current water quality focused programs. Of the regulated drinking water constituents considered, the most common water quality issues within the Subbasin are: nitrate, arsenic, boron, hexavalent chromium, dibromochloropropane (DBCP), 1,2,3-trichloropropane (TCP), total dissolved solids (TDS), sodium, and chloride. This water quality discussion is divided by constituent to explain the drinking water and agricultural standards and how these constituents impact beneficial uses in the different regions of the Subbasin. Since the predominant land use in the Subbasin is for agricultural purposes, agricultural Water Quality Goals (as established by Ayers and Westcott) are referenced for evaluation of groundwater salinity (SWRCB, 2016a). The most applicable standard, Drinking Water Standard or agricultural goals will be used as a reference point when discussing each constituent.

Maps created to show constituent prevalence were developed using data extracted from the Groundwater Ambient Monitoring and Assessment (GAMA) Groundwater Information System. Only wells from the Public Water System dataset were used because they provide more consistent results since compliance monitoring frequency is regulated by DDW. To depict the highest contaminant values, the maximum concentrations were plotted, rather than average concentrations, from each public water system spanning a 10-year timeframe (2009-2019). These maps are intended to provide a general overview of constituent prevalence and concentrations. They should not be interpreted as indicating contamination throughout the region because constituent concentrations typically vary depending on well construction and local hydrogeologic conditions. More detailed analysis of water quality trends is discussed in the individual management area plans.

2.3.3.1 Arsenic

Arsenic has a primary drinking water MCL of 10 parts per billion (ppb) and an agricultural goal of 100 ppb. Reports published by the Department of Pesticide Regulation and USGS studies and the hydrogeology of the Subbasin indicate that the major source of arsenic in this Subbasin is naturally occurring from erosion of natural deposits. Throughout the southern San Joaquin Valley, arsenic-rich minerals such as arsenopyrite, a common constituent of shales and apatite, and phosphorites are the most common sources of arsenic leaching materials in the aquifer (Burton et al, 2012). In the Subbasin, these minerals are mostly found in lake bed deposits or the Corcoran Clay. USGS reports that most of the highest arsenic detections are near the City of Delano and at the southwest extents of the Kern Fan, near the City of Bakersfield.

Since arsenic is mostly derived from natural geochemical processes, elevated concentrations are localized and appear to be associated with lake bed areas where there are thick clay deposits: Tulare Lake, Kern Lake, and Buena Vista Lake (Bulletin 118, DWR). In the Subbasin, consistently high concentrations generally concentrate in the center of the valley along the north margin of Buena Vista lake bed. Data trending indicates that its predominately found in wells constructed deeper than 1,000 feet below ground surface (bgs). Trending of the public water system wells in the Kern Fan indicates elevated arsenic is consistently found in wells constructed deeper than 650 feet bgs, and when groundwater elevations decline. A study conducted by USGS reports that arsenic is the trace element most frequently present at high concentrations in the Subbasin. Concentrations found in nearly 1,400 samples ranged from 10 to 30 ppb (Burton et al, 2012).

Severe drought conditions from 2012 through 2016 resulted in groundwater levels significantly declining throughout Kern County; subsequently, wells located in the Kern Fan are showing higher concentrations of arsenic from the deeper aquifers into the pumping zone due to the proportion of water from the deeper screened intervals increasing. Consequently, higher concentrations of arsenic have been observed in municipal wells. As groundwater levels temporarily recovered in 2017, there was a noticeable correlation to lower arsenic concentrations.

Findings from a study conducted by Negrini et. al (2008) explain that the thickest part of the coarsening-upward unit in the Kern Fan is in the same region as the wells with elevated arsenic concentrations. The study identified a large-scale sedimentary sequence (a specific geologic sequence) that was primarily prevalent in most of the wells in this study area. This sequence unit consists mostly of uniformly fine-grained silts and clays and the unit abruptly thickens basin-wide. The thickest part of this unit was found to have groundwater arsenic concentrations above 50 ppb. Depth interval containing sediments from this unit generally coincide with intervals having elevated arsenic concentrations. It was also found that at the same depth interval, arsenic is in an easily exchangeable state in the bulk sediment where oxidizing geochemical conditions dissolve the pyrite and release arsenic into the groundwater.

In addition to the lake bed areas, there is common arsenic detections associated with the Corcoran Clay. Mineral deposits transported by rivers into the San Joaquin Valley, from the Sierra Nevada and the coastal mountain ranges, became enriched with arsenic mineral deposits then adsorbed on the clay surfaces that were buried over time. When the oxygen deprived mineral deposits come into contact with oxygenated water, the result is dissolution of arsenic within the clay pore and into the groundwater. These deposits typically begin at depths greater than 180 feet bgs. Occurrence of arsenic in groundwater and any associations to the Corcoran Clay are addressed at the management area plans water quality sections.

2.3.3.2 Nitrate

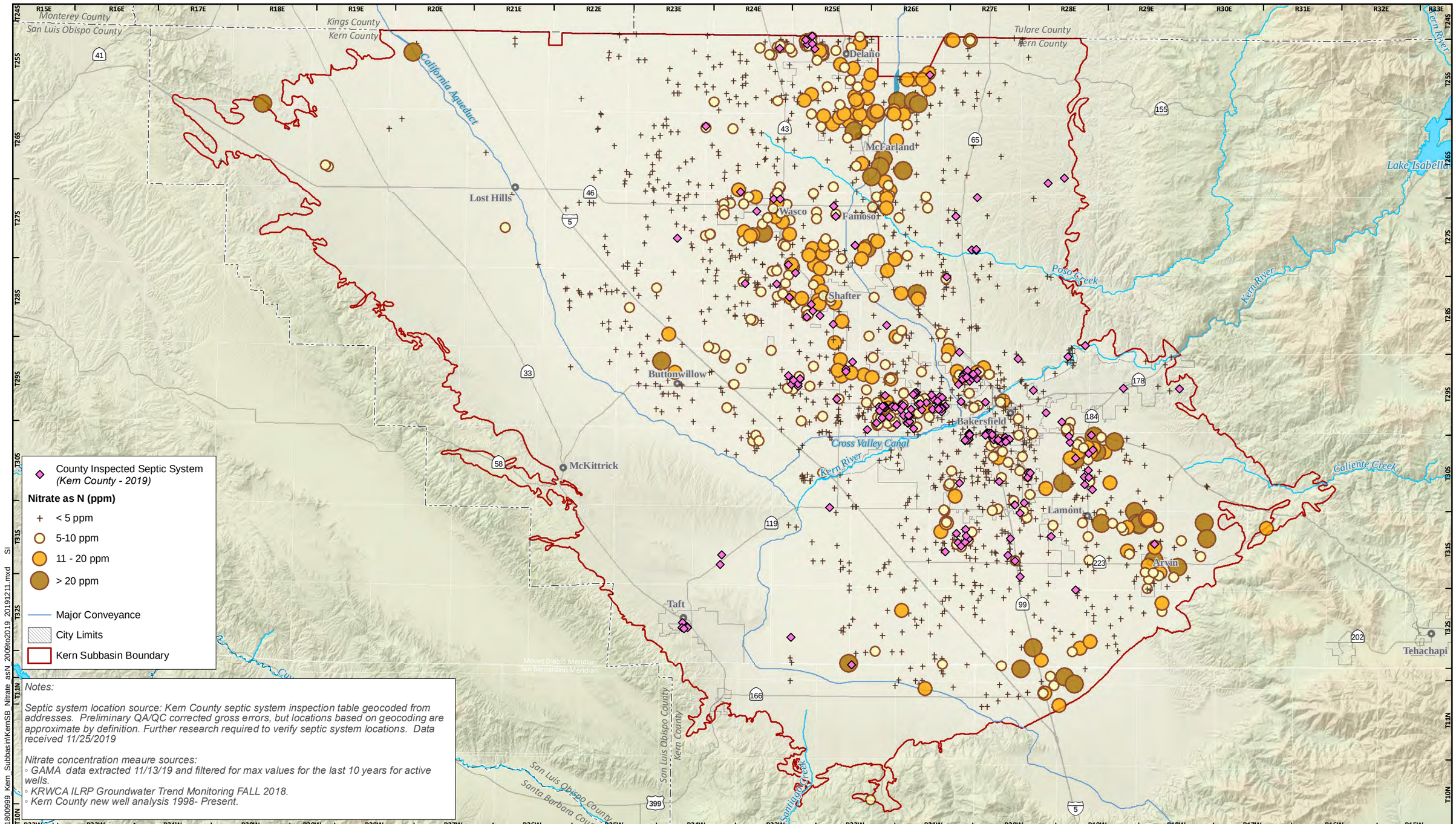
Nitrate as nitrogen has an acute drinking water MCL of 10 parts per million (ppm); there is no agricultural goal. Sources of nitrate contamination in groundwater are runoff and leaching from fertilizer use; leaching from septic systems and sewage; confined animal facilities; and very

small concentrations from erosion of natural deposits. Typically wells in the San Joaquin Valley have higher nitrate concentrations in the shallower zones. However, higher nitrate concentrations can also occur in deep wells, depending on source concentrations, lithology, and well construction. Dubrovsky et al (2010) considers background nitrate concentrations above 1 ppm to indicate human activity.

Although the agricultural industry is believed to be a primary contributor to nitrate contamination of the groundwater basins in the Central Valley, based on mass loading calculations, irrigation practices in this Subbasin have been improved to reduce nitrate leaching into groundwater. In a study conducted for the Kern River Watershed Coalition Authority (KRWCA, 2013), it is acknowledged that nitrate leaching from agricultural irrigation is not like other basins to the north because irrigation practices are more efficient here, which reduced nitrate leaching into the groundwater. This assessment is supported by a comparison of the Nitrate Hazard Index results from 1990 and 2012, which shows a significant reduction in nitrate risk to groundwater.

KRWCA is leading the Irrigated Lands Regulatory Program (ILRP) for the Subbasin and have provided results from the initial groundwater sampling that took place in fall of 2018 (KRWCA, 2019). Their groundwater trend monitoring program requires nitrate sampling of first encounter groundwater during spring and fall each year. Trends are not ascertained yet since fall of 2018 was the first year of monitoring and these are the only results that are publicly available. Of the 26 representative wells sampled (14 domestic and 12 irrigation), nitrate results ranged from 1.1 to 21 parts per million (ppm) with a median value of 9.9 ppm. Nine of the wells sampled exceed 10 ppm: of these, seven wells are domestic and two are used for irrigation. Nitrate concentrations of these wells is included in Figure 2-35, although they are not specifically labeled as first encounter groundwater wells.

In addition to studies evaluating agricultural impacts of nitrate contamination, studies investigating the correlation of other potential nitrate sources were also reviewed. Dubrovsky et al (2010) finds that domestic wells located in agricultural areas are not only influenced by irrigation practices and/or livestock as a potential nitrate source, but also from septic systems. A USGS study (Burton et al, 2012) was conducted in the Southeast San Joaquin Valley and the Kern County Subbasin. This study used statistical analysis of land uses, well construction data, water quality parameters and number of septic systems around each study well to determine that land uses fairly represent nitrate sources impacting the well. Some of the data obtained for the Burton et. al, (2012) study were from the State Water Board's GAMA Domestic Well Project, where wells were sampled in 2006 (Shelton, 2006). The Project analyzed 29 of the 181 domestic study wells in the Kaweah Subbasin study area, for stable isotopes of nitrogen and oxygen. Wells with higher nitrate concentrations (median of 5 ppm and mean of 11 ppm) were targeted for this study. Testing showed that 28 of the 29 impacted wells have nitrate characteristics consistent with a dairy manure or septic system source. Septic systems elevate groundwater nitrate concentrations since they only remove half of the nitrogen in the wastewater, leaving the remaining half to percolate to groundwater (McCalasand, 2019). One of the 29 wells showed an isotopic composition indicative of a synthetic fertilizer. While the isotopic composition of nitrate


County Inspected Septic System
(Kern County - 2019)
Nitrate as N (ppm)
< 5 ppm
5-10 ppm
11 - 20 ppm
> 20 ppm
Major Conveyance
City Limits
Kern Subbasin Boundary
Notes:
Septic system location source: Kern County septic system inspection table geocoded from addresses. Preliminary QA/QC corrected gross errors, but locations based on geocoding are approximate by definition. Further research required to verify septic system locations. Data received 11/25/2019
Nitrate concentration meaure sources:
◦ GAMA data extracted 11/13/19 and filtered for max values for the last 10 years for active wells.
◦ KRWCA ILRP Groundwater Trend Monitoring FALL 2018.
◦ Kern County new well analysis 1998- Present.
Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
California Aqueduct
Delano
McFarland
Wasco
Famoso
Lost Hills
Shafter
Buttonwillow
Bakersfield
Cross Valley Canal
Kern River
Poso Creek
Lake Isabella
Caliente Creek
McKittrick
Lamont
Arvin
Taft
Tehachapi
Mount Diablo Meridian
San Bernardino Meridian
San Luis Obispo County
Kern County
Santa Barbara County
Santiago Creek
0 3.5 7 14 21
Miles
N
W
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S
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
NITRATE CONCENTRATIONS AND SEPTIC SYSTEMS
DECEMBER 2019
FIGURE 2-35
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12-Dec-2019

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varies with land use, it is consistent between nitrate source (soil, fertilizer, manure, septic or community wastewater). Private well sampling for stable isotopes of nitrate was not conducted in the Kern County Subbasin.

Kern County Environmental Health Department (EHD) updated their program and ordinance with the development of the County's Local Agency Management Program (LAMP) to comply with the State Water Board's policy on septic systems (SWRCB, 2012). This was adopted to allow local agencies to continue use of septic systems, while protecting water quality and public health. An analysis was conducted to estimate baseline septic systems in Kern County. Four basic elements used in their analysis were parcel development status; general soil/septic systems suitability mapping; hydrologic areas; and groundwater basins. Since it was assumed that incorporated areas have municipal sewer systems that either serve or are available to these parcels, only non-sewerage unincorporated areas of the County were included in the analysis. This study revealed that approximately 30 percent of developed parcels within the Subbasin rely on septic systems. KGA is working with Kern County to document the location of these septic systems. A partial list of system recently inspected was provided and is shown in Figure 2-35.

Prior to the State's policy, EHD has been collecting water quality data on newly drilled wells to gain an understanding of groundwater quality. Initial assessment showed about eight percent of the wells tested are above the nitrate MCL; data from 1998 through 2019 are included in Figure 2-35. While there is currently a data gap, it is anticipated that continued work with Kern County and through the implementation of their LAMP that the domestic well water quality data and location of septic systems will be available to KGA. Although not all septic system location data is available at the time of this evaluation, it is noted areas with septic systems and domestic wells, generally show elevated nitrate concentrations.

Studies conducted by UC Davis, Center for Watershed Sciences have evaluated nitrate sources in the Tulare Lake Basin and documented that on a regional scale, groundwater nitrogen loading from sewer collection system leaks and septic systems is negligible compared to fertilizers. However, when looking at a local level, septic systems can be a significant source of nitrate contamination to domestic wells in peri-urban areas surrounding cities, or in areas of relatively high rural household density (Viers et. al, 2012). Findings also indicate that disadvantaged communities with water quality issues are in these same areas. Septic systems are considered low-hanging fruit (Dzurella et al, 2012), but is an important issue to address due to its impact to localized drinking water sources.

Data gaps often identified in these studies include lack of localized data such as location of septic systems, proximity of domestic wells to septic systems, and water quality of unregulated domestic wells. Reports such as Viers et al, (2012) and the initial assessment for the LAMP report have acknowledged these data gaps. To better assess nitrate sources, future monitoring programs should be geared towards better data collection methods to conduct a more comprehensive evaluation on septic system impacts to groundwater. Additionally, nitrate issues need to be evaluated on a local level rather than regional approach, especially when looking at the impacts to human health and consumption of water from unregulated domestic wells.

2.3.3.3 Boron

There is no federal or state MCL for boron. However, California does have a Notification Level of 1,000 ppb, and there is an agricultural goal of 700 ppb. The agricultural goal is set to protect various agricultural uses of water, including irrigation of various types of crops and stock watering. These levels are used as a baseline to compare against and are not intended to represent an acceptable maximum value for the Subbasin. Since most of the land use in the Subbasin is irrigated lands, the agricultural goal for boron is used as a reference point, rather than the drinking water Notification Level. The most prevalent sources of boron in drinking water are from leaching of rocks and soils, wastewater, and fertilizer/pesticides applications.

According to the USGS Scientific Investigations Report 2011-5218 (Burton et al, 2012) boron is most commonly found in the southern part of the Subbasin near the Tehachapi Mountains. Even though the USGS study for boron was limited to the southern part of the Subbasin, it was concluded that elevated concentrations of boron may be naturally occurring. Boron is potentially associated with sediments in the aquifer derived from marine deposits that are naturally high in boron from the Coast Ranges and San Emigdio Mountains. Saline waters have also been found to contain relatively high concentrations of boron, groundwater that underlies the freshwater aquifer could contribute high boron concentrations in deep wells.

2.3.3.4 Hexavalent Chromium

There is no federal MCL for hexavalent chromium. In July 2014, California adopted a primary MCL of 10 ppb, which was invalidated as of September 2017. While DDW is repeating the regulatory process for adopting a new MCL, the federal MCL of 50 ppb for total chromium applies. There is no agricultural goal for hexavalent chromium.

Hexavalent chromium can come from anthropogenic and natural sources. Anthropogenic sources include discharges of dye and paint pigments, wood preservatives, chrome-plating liquid wastes, and leaching from hazardous waste sites into the environment. Naturally occurring chromium is a metal found in ore deposits containing other elements, mostly as chrome-iron ore. Chromium is also prevalent in soil and plants: the phenomenon of releasing chromium into groundwater is believed to be similar geochemical processes to arsenic. Generally, natural chromium in the environment occurs as trivalent chromium (Cr3) then is oxidized to a hexavalent state (Cr6+). This typically occurs in oxidizing conditions such as alkaline pH range (between 8 and 14 units) or in the presence of manganese dioxide; in these conditions, naturally occurring hexavalent chromium is likely to exist.

The presence of manganese oxide minerals within ultramafic and serpentinite derived soils and/or sediments can trigger the oxidation of chromium, leading to the presence of naturally occurring hexavalent chromium in the aquifers (SWRCB, 2017; Groundwater Information Sheet 2017). While studies have not been conducted on the types of soils and sediments in the Subbasin where hexavalent chromium is present, the relatively low concentrations (typically in the range of 5 – 13 ppb) indicate the source is naturally occurring (GAMA). Additionally, GeoTracker and EnviroStor databases were searched for open contamination cleanup sites and do not identify any point source contamination in the Subbasin.

2.3.3.5 Synthetic Organic Chemicals

Synthetic organic chemicals predominately found in the Subbasin are dibromo-3-chloropropane (DBCP) and 1,2,3-trichloropropane (TCP). Both chemicals have very low drinking water MCLs. There are no agricultural goals. DBCP has a primary MCL of 0.2 ppb; sources of contamination are a banned nematicide that is still present in soils and groundwater due to runoff or leaching from former use on soybeans, cotton, vineyards, tomatoes, and tree fruit. Since its use was banned in 1977, groundwater contaminant concentrations in municipal wells have shown either steady or decreasing trends. In 2008 the Department of Public Health (transferred to State Water Board as DDW in July 2014) estimated the median half-life of DBCP in the Central Valley is 20 years. This is consistent with the public well data that has been evaluated for this Subbasin.

TCP has a primary MCL of 5 parts per trillion (ppt), which became effective in January 2018 and requires all active drinking water sources are tested at least quarterly during 2018. Since the MCL is set at the detection limit, any well with a detection is identified as exceeding the standard. According to the Water Boards Q1 Report, there is a clear correlation between the location of the of drinking water sources contaminated with TCP and agricultural activities (State Water Resources Control Board, TCP Sampling in Q1 2018).

In the past, TCP was present as an impurity in certain soil fumigants (1,3-D soil fumigants) used to kill nematodes. TCP also has some limited industrial uses. Throughout the Central Valley, most of the TCP found in groundwater was introduced through agricultural application of soil fumigants sold under the trade names of D-D and Telone. In the mid-1970s, Telone was reformulated and the name changed to Telone II. D-D was discontinued in 1984. Telone II remains on the market today but no longer contains TCP. Because TCP was an impurity in these soil fumigants, the potential groundwater contamination was not disclosed to distributors or users, by the product manufacturers. Application rates were not tracked, making it difficult to determine where groundwater contamination is likely to occur. TCP is a highly stable compound, meaning that it is resistant to degradation and has a half-life of hundreds of years (Samin et. al. 2012).

Many large public water systems (serving more than 10,000 population) began sampling their wells for TCP using a low-level analytical method around 2003, as a requirement of the Unregulated Chemical Monitoring Rule. From this data, DDW determined that the most impacted counties are Kern, Fresno, Tulare, Merced, and Los Angeles. Since a primary MCL was adopted, all water systems were required to test their wells quarterly beginning January 2018. Occurrence data from the State Water Board's DDW shows 94 of California's public water systems have 562 TCP impacted wells (DDW, June 2016). In Kern County, 18 water systems have 124 impacted wells, or approximately 52 percent of their total wells (State Water Board, June 2016).

Figure 2-36 provides a graphical representation of TCP concentrations for the public water system wells within the Subbasin (data extracted on April 29, 2019). To simplify the figure, only the maximum concentrations from January 2018 to April 2019 are shown. Results from the initial compliance monitoring indicates that increased testing requirements directly increased the prevalence of TCP impacted wells in the Subbasin.

the maximum concentrations from January 2018 to April 2019 are shown. Results from the initial compliance monitoring indicates that increased testing requirements directly increased the prevalence of TCP impacted wells in the Subbasin.

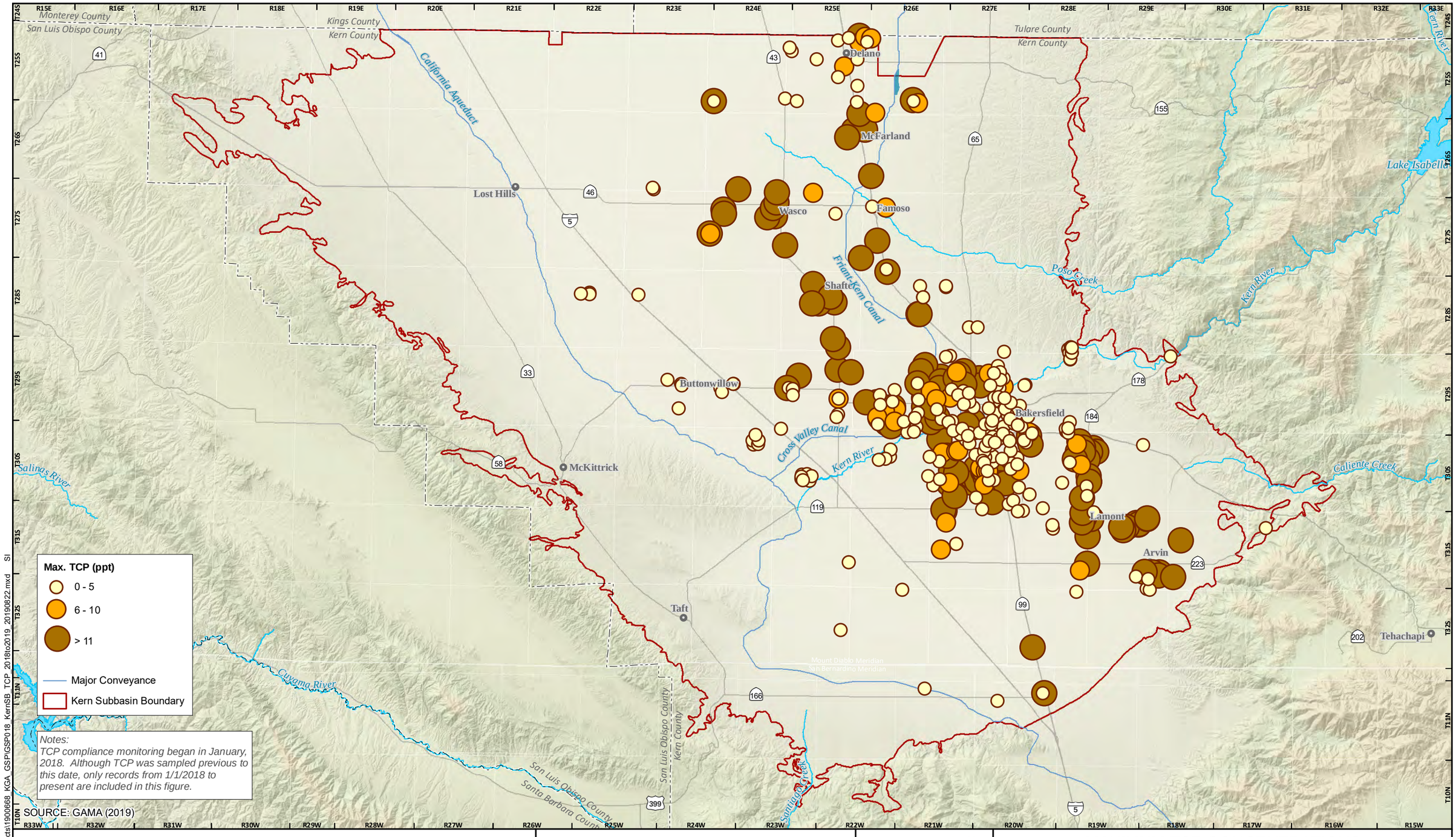
2.3.3.6 Total Dissolved Solids (TDS), Sodium and Chloride

Based on drinking water standards, the recommended secondary maximum contaminant level (SMCL) of total dissolved solids is 500 parts per million with an upper limit of 1,000 ppm and chloride is 250 ppm with an upper limit of 500 ppm. There is no drinking water standard for sodium; however, Water Quality Goals for Agriculture, published by the Food and Agriculture Organization of the United Nations in 1985, has set agricultural goals for TDS, sodium, and chloride at 450 ppm, 69 ppm, and 106 ppm, respectively. The criteria identified are protective of various agricultural uses of water, including irrigation of various types of crops and stock watering. These levels are used as a baseline to compare against and are not intended to represent an acceptable maximum value for the Subbasin. Since a majority of the land use in the Subbasin is irrigated lands, the agricultural goals for TDS, sodium, and chloride are used for this portion of the water quality evaluation.

The Burton et. al (2012) report states that in general the higher concentrations of TDS may be affected by sediments from the Tehachapi and San Emigdio Mountains and the Coast Ranges which contain marine deposits. Report findings showed positive correlations between agricultural land use and TDS levels but concluded that higher concentrations of TDS in the Subbasin may primarily be from natural sources as well as human activities. The same findings were true for chloride concentrations.

In a preliminary groundwater salinity mapping study conducted by USGS Scientific Investigations (Report 2018-5082, Metzger and Landon, 2018), groundwater salinity related to the distribution of 31 oil fields and adjacent aquifers was mapped across major oil-producing areas of central and southern California. The objective of this mapping study was to define groundwater with TDS concentrations less than 10,000 ppm using data from petroleum and groundwater wells, and to document data gaps. The study concluded that there is no hydrogeological connection between oil wells and water wells in the mapped regions. This conclusion is based on salinity mapping and well construction: the top perforation of the oil wells is deeper than the bottom perforation of water wells, except for oil fields in the north eastern part of Kern County. Well perforations in the north eastern part showed little to no vertical separation. Additionally, the study found that the west side of the San Joaquin Valley (in in Kern County) generally has the highest TDS levels at the shallowest depths.

Salinity defined in the chapters of this report are sometimes general, referring to TDS levels, or may be more specific to address the ions of concern based on predominant land uses. TDS is comprised of several dissolved minerals (calcium, phosphates, nitrates, sodium, potassium, and chloride), most of which have minimal impact on beneficial uses of the groundwater. Throughout the Subbasin, sources of salinity identified include a combination of naturally occurring marine deposits; infiltration from produced water disposal ponds; perched water subject to evaporative pumping; or agricultural drainage ponds.



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

MAXIMUM TCP CONCENTRATIONS FROM PUBLIC SUPPLY WELLS FROM JAN. 2018 – APR. 2019

JULY 2019

FIGURE 2-36

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Sodium and chloride ions contribute to TDS and in this region are more important to evaluate due to its impact to the agricultural industry. Both sodium and chloride show similar trends in the wells evaluated; therefore, some sections of the water quality evaluation collectively refer to these ions as salinity. There is slightly more focus on sodium since it is an important measurement to crop yield.

2.3.3.7 Groundwater Contaminant Sites

An evaluation of documented groundwater contaminant sites in the Subbasin were identified through the GAMA Groundwater Information System. GAMA contains information from other programs and databases, such as SWRCB – GeoTracker and Department of Toxic Substances (DTSC) – EnviroStor databases. The data included in this basin setting is in response to the emergency regulations § 354.16(d), that requests within the GSP, "a description and map of the location of known groundwater contamination sites and plumes." However, it is not the intent of this section to evaluate or confirm whether any of these sites as listed by regulatory agencies are impacting groundwater with beneficial use. Furthermore, this GSP cannot guarantee the accuracy of the data acquired from these regulatory sources. This section presents cases as were listed from the regulatory databases that may document potentially impacted groundwater sites. Programs listed below were reviewed from GAMA. There are two figures to graphically represent the distribution of sites; Figure 2-37 shows permitted facilities and Figure 2-38 shows clean-up sites.

- Waste Discharge Requirements (WDR)
- Underground Storage Tank (UST)
- Leaking Underground Storage Tank (LUST)
- Cleanup Program Sites
- DTSC Hazardous Waste Sites
- Department of Pesticide Regulation
- Underground Injection Control (UIC) Wells
- Oil and Gas Sites
- Irrigated Lands Regulatory Program Sites
- Confined Animal Site

Permitted Facilities with Waste Discharge Requirements Orders

While GeoTracker does not include water quality data for WDRs a list of sites and their general location is accessible through the State Board's California Integrated Water Quality System (CIWQS). The general location of Confined Animal Facilities is also available through this database. Figure 2-37 is a graphical representation of the known WDRs and Confined Animal Sites in the Subbasin. A total of 264 sites were identified; however, 43 sites are not included in this figure because latitude/longitude coordinates were not available to confirm that the site are within the Subbasin. The intent of mapping the location of the sites is to provide an idea of where the WDRs and Confined Animal Sites are located throughout the Subbasin.

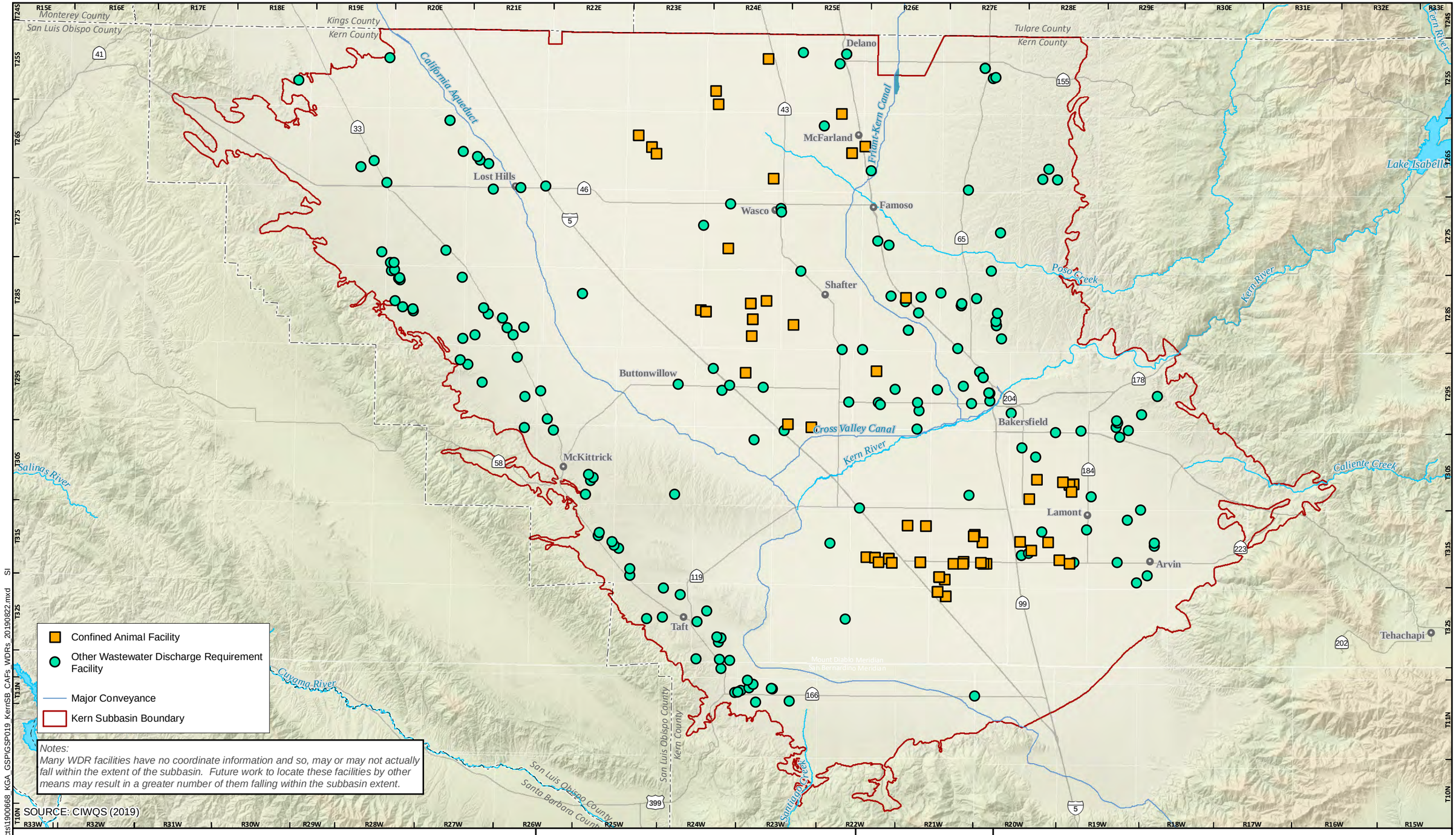
Irrigated Lands Regulatory Program (ILRP) is permitted as a third-party WDR, like the WDR permit for Confined Animal Sites. However, site specific information is not publicly available because there are too many enrolled parcels under the Order. The Kern River Watershed Coalition Authority reports on the program. Relevant reports were reviewed and incorporated into the water quality discussion.

Underground Injection Control Permitted Wells

UIC permitted wells are not included in the list of groundwater contaminant sites because the UIC program's objective is to confine injected fluid to the approved injection zone so that injected fluid does not migrate to a zone where it could degrade valuable groundwater or hydrocarbon resources. Wells permitted under the State's Class II UIC program are presented on Figure 2-39. The UIC program's objective is to confine injected fluid to the approved injection zone so that injected fluid does not migrate to a zone where it could degrade valuable groundwater or hydrocarbon resources (DOGGR, April 2019). This program requires that any injection well have at least two cemented strings of casing across any underground source of drinking water located above a proposed injection zone, an annual Mechanical Integrity Test (MIT) and an annual step-rate test to ensure that groundwater is protected.

Data acquired from the regulatory sources listed above are included in Table 2-5 (Envirostor and Geotracker Databases) only if they applied to the following criteria in the order listed below:

1. potential media of concern defined as "groundwater," "other groundwater," or "drinking groundwater,"
2. potential contaminant of concern defined, or "unknown,"
3. the site/case reported as "not closed", and had one of the following statuses:
    - active cleanup
    - active land use restrictions
    - open remediation
    - open site assessment
    - open – eligible for closure
    - inactive-action required
    - other evaluation



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22-Aug-2019

Kern Groundwater Authority
Basin Setting

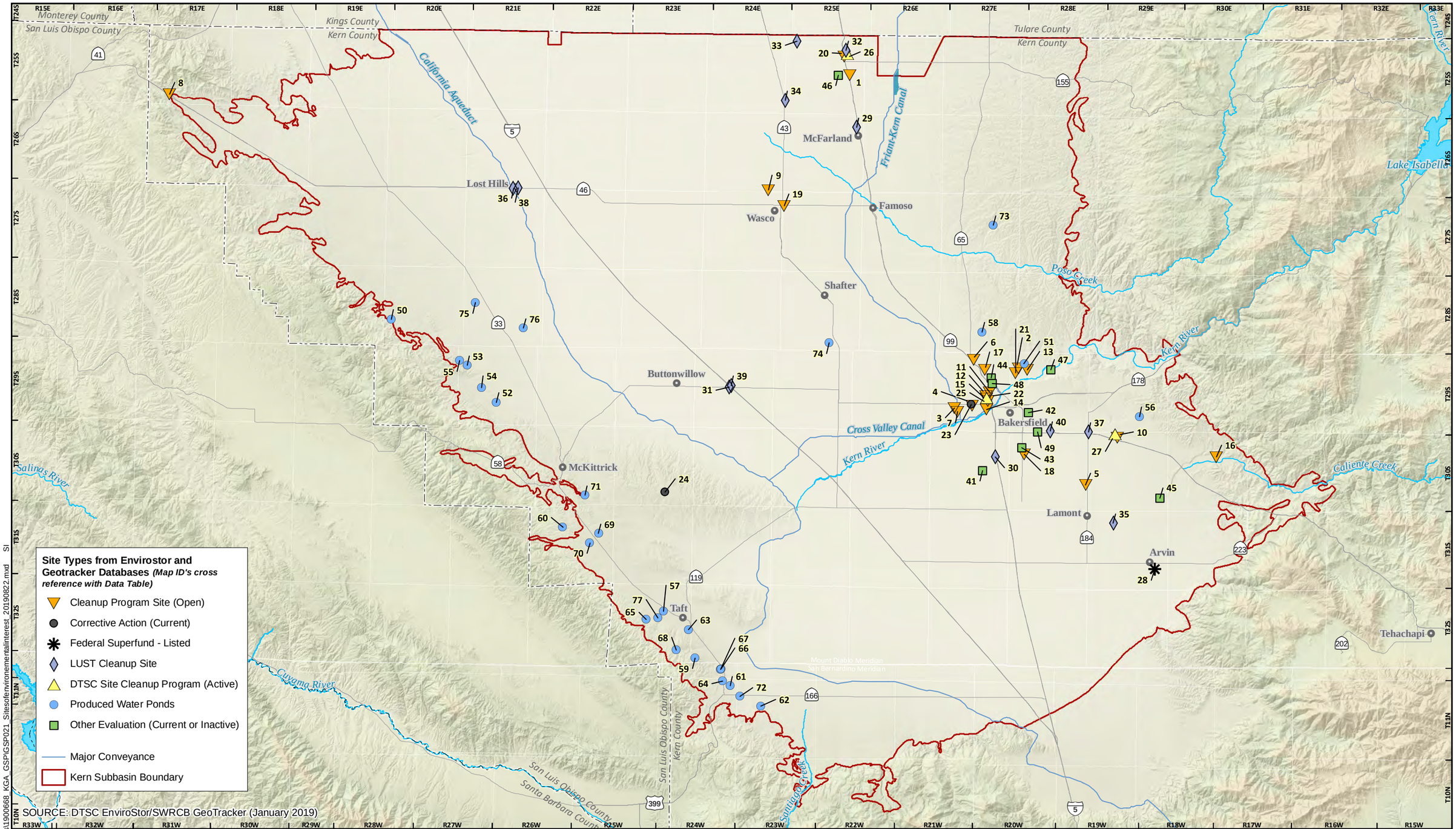
Kern County, California

GEI Consultants

PERMITTED DISCHARGE LOCATIONS

AUGUST 2019

FIGURE 2-37



Kern Groundwater Authority
Basin Setting

Kern County, California

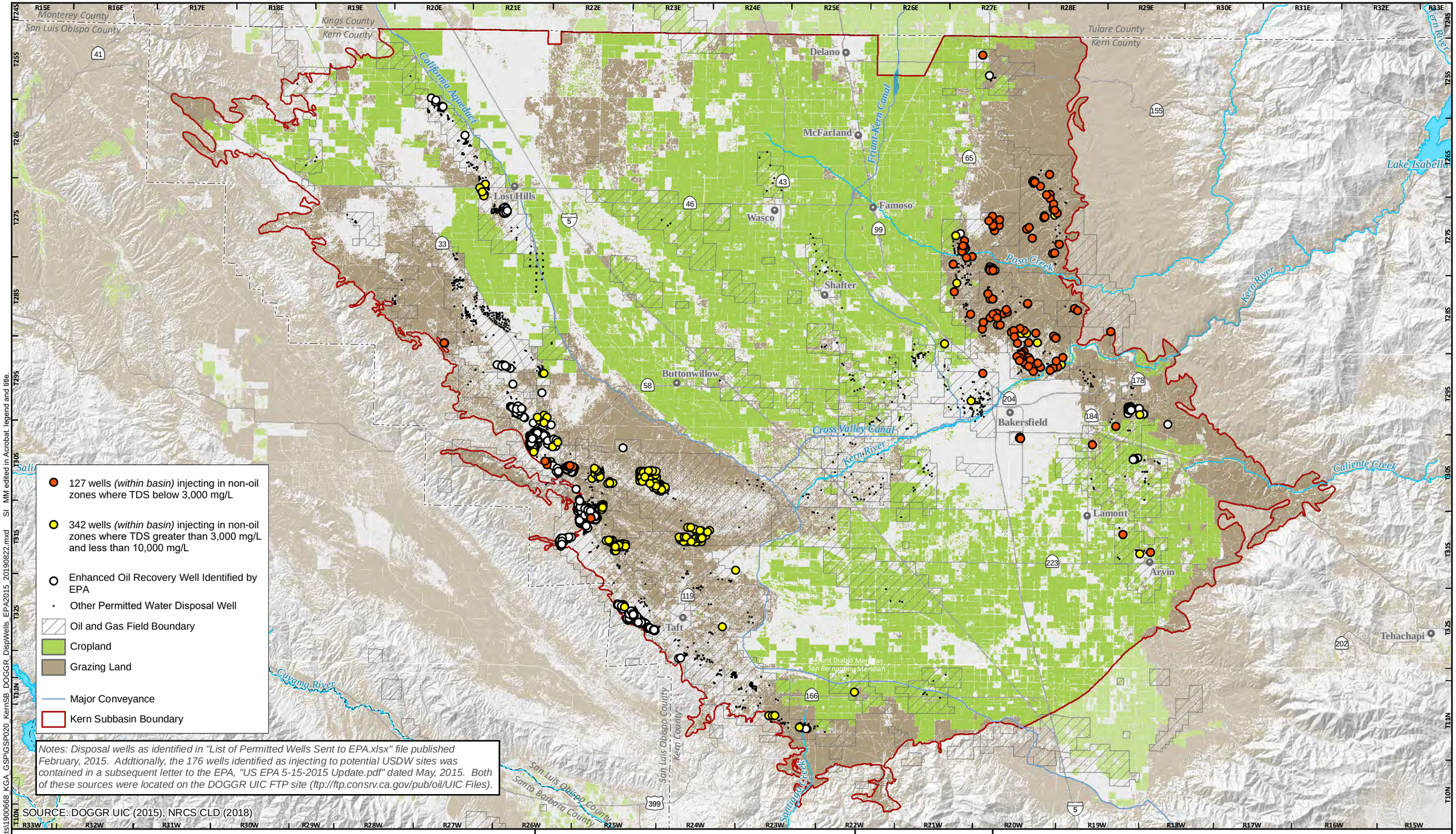
GEI Consultants

CLEAN-UP SITES LISTED IN ENVIROSTOR AND GEOTRACKER DATABASES

AUGUST 2019

FIGURE 2-38

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Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
California Aqueduct
Friant-Kern Canal
Kern River
Poso Creek
Lake Isabella
Caliente Creek
Cross Valley Canal
Cuyama River
San Luis Obispo County
Santa Barbara County
Kern County
Mount Diablo Meridian
San Bernardino Meridian
Delano
McFarland
Famoso
Wasco
Shafter
Lost Hills
Buttonwillow
Bakersfield
Lamont
Arvin
Taft
Tehachapi
127 wells (within basin) injecting in non-oil zones where TDS below 3,000 mg/L
342 wells (within basin) injecting in non-oil zones where TDS greater than 3,000 mg/L and less than 10,000 mg/L
Enhanced Oil Recovery Well Identified by EPA
Other Permitted Water Disposal Well
Oil and Gas Field Boundary
Cropland
Grazing Land
Major Conveyance
Kern Subbasin Boundary
Notes: Disposal wells as identified in "List of Permitted Wells Sent to EPA.xlsx" file published February, 2015. Addtionally, the 176 wells identified as injecting to potential USDW sites was contained in a subsequent letter to the EPA, "US EPA 5-15-2015 Update.pdf" dated May, 2015. Both of these sources were located on the DOGGR UIC FTP site (ftp://ftp.consrv.ca.gov/pub/oil/UIC Files).
SOURCE: DOGGR UIC (2015), NRCS CLD (2018)
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E
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Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
OIL AND GAS WELLS IN THE
UNDERGROUND INJECTION CONTROL PROGRAM
AUGUST 2019
FIGURE 2-39
22-Aug-2019 Z:\Projects\19006668_KGA_GSP\GSP\020_KernSB_DOGGR_DispWells_EPA2015_20190822.mxd SI_MM edited in Acrobat: legend and title.

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Table 2-5
GeoTracker and EnviroStor Sites with Potential Groundwater Media
Kern Groundwater Authority
Kern County, California
(Updated January 2019)

New Map ID	Site / Facility Name	ENVIROSTOR/ Geotracker ID	Source	Program Type	Status	Address	City	Zip	CALEnviroscreen Score	X Coord	Y Coord	Constituents of Concern
1	CROP PRODUCTION SERVICES (CPS) DELANO	SL185724257	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	930 WOOLOMES AVE	DELANO	93215-9553	---	-119.2422	35.7466	VOCs and Pesticides, NITRATE, OTHER CHLORINATED HYDROCARBONS, OTHER SOLVENT OR NON-PETROLEUM HYDROCARBON
2	CHEVRON USA (AKA: CHEVRON REFINERY & WAIT TANK YD)	SL205064267	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	2525 NORTH MANOR STREET	BAKERSFIELD	93308	---	-119.0087	35.4238	BENZENE, CRUDE OIL, LEAD, OTHER PETROLEUM
3	PG&E KERN POWER PLANT (FORMER:COFFEE RD. OVERPASS)	SLT5FP024290	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	2401 COFFEE ROAD	BAKERSFIELD	93308-5748	---	-119.094919	35.37920074	BENZENE, CRUDE OIL, OTHER PETROLEUM
4	BAKERSFIELD REFINERY	SL205314279	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	6451 ROSEDALE HIGHWAY	BAKERSFIELD	93308	---	-119.071219	35.38198244	BTEX, TPH, MTBE / TBA / OTHER FUEL OXYGENATES, OTHER SOLVENT OR NON-PETROLEUM HYDROCARBON
5	KERN OIL & REFINING	SL372524510	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	7724 E PANAMA LANE	BAKERSFIELD	93307-9210	---	-118.9169	35.2954	BTEX, TPH, MTBE / TBA / OTHER FUEL OXYGENATES, PAHs
6	BAKERSFIELD AIRPORT BUSINESS PARK (CHEVRON LAND/D)	SL0602981532	Geotracker	CLEANUP PROGRAM SITE	OPEN - VERIFICATION MONITORING	UNICORN RD. AT HWY 99/65	BAKERSFIELD	93308	---	-119.0698	35.4328	CRUDE OIL
7	SUNLAND REFINING CORPORATION	SL205224272	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	2152 COFFEE ROAD	BAKERSFIELD	93308-5746	---	-119.0911102	35.37550916	CRUDE OIL, GASOLINE, MTBE / TBA / OTHER FUEL OXYGENATES
8	CHEVRON - ANTELOPE PUMP STATION	SL0602985189	Geotracker	CLEANUP PROGRAM SITE	OPEN - ASSESSMENT & INTERIM REMEDIAL ACTION	STATE ROUTE 46	LOST HILLS	93249	---	-120.164723	35.71251	CRUDE OIL, WASTE OIL / MOTOR / HYDRAULIC / LUBRICATING
9	WASCO AIRPORT	SLT5FQ444336	Geotracker	CLEANUP PROGRAM SITE	OPEN - VERIFICATION MONITORING	PALM AVE & MCCOMBS	WASCO	93280	---	-119.3505	35.6184	DDD / DDE / DDT, OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
10	J. R. SIMPLOT - EDISON	SLT5FS324450	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	430 PEPPER DR.	EDISON	93220	---	-118.8745	35.3485	DIBROMOCHLOROPROPANE (DBCP), FERTILIZER, PESTICIDES/HERBICIDES
11	SAN JOAQUIN REFINING CO - FRUITVALE REFINERY	SL205714283	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	STANDARD STREET	BAKERSFIELD	93308	---	-119.048	35.3972	DIESEL
12	BAKERSFIELD REFINERY - AREA 3	T10000001848	Geotracker	CLEANUP PROGRAM SITE	OPEN - VERIFICATION MONITORING	3663 GIBSON STREET	BAKERSFIELD	93308	---	-119.0527654	35.39330068	DIESEL, GASOLINE
13	WEST COAST OIL REFINERY, BAKERSFIELD	SL0602978387	Geotracker	CLEANUP PROGRAM SITE	OPEN - INACTIVE	1157 CHINA GRADE LOOP	BAKERSFIELD	93308	---	-118.9975	35.4225	DIESEL, GASOLINE, LEAD
14	APEX BULK COMMODITIES	T10000011271	Geotracker	CLEANUP PROGRAM SITE	OPEN - ASSESSMENT & INTERIM REMEDIAL ACTION	2111 BRICYN LANE	BAKERSFIELD	93308	---	-119.05178	35.37789	DIESEL, OTHER PETROLEUM
15	SAN JOAQUIN DRUM	SLT5FR634417	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	3930 GILMORE AVE	BAKERSFIELD	93308-6214	---	-119.05165	35.39017952	METALS/HEAVY METALS, PESTICIDES/HERBICIDES, VOLATILE ORGANIC COMPOUNDS
16	J. R. SIMPLOT - BENA (AKA: BENA FERTILIZER)	SLT5FS304448	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	NONE	EDISON	93220	---	-118.7406	35.3276	NITRATE, OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
17	WESTERN FARM SERVICE INC-1610 NORRIS ROAD BAKERSFIELD	SL186364605	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	1610 NORRIS RD	BAKERSFIELD	93308-2234	---	-119.0541923	35.42200027	OTHER CHLORINATED HYDROCARBONS
18	GARRIOTT CROPDUSTERS	SLT5FQ134306	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	2010 S UNION AVE	BAKERSFIELD	93307-4154	---	-119.0003209	35.32892143	OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
19	SIMPLOT WASCO	SLT5FS184436	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	541 HWY 46	WASCO	93280-1433	---	-119.3289256	35.60078769	OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
20	WIP - DELANO, PCE	SL0602943992	Geotracker	CLEANUP PROGRAM SITE	OPEN - INACTIVE		DELANO	93215	---	-119.2496	35.7672	PCE
21	WITCO REFINERY (OILDALE)	SLT5FQ474339	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	1134 MANOR STREET	BAKERSFIELD	93308-3553	---	-119.0129	35.419	PETROLEUM/FUELS/OILS
22	SABRE REFINERY	SLT5FQ334326	Geotracker	CLEANUP PROGRAM SITE	OPEN - INACTIVE	W. BAKERSFIELD-ROSEDALE AREA	BAKERSFIELD	93308	---	-119.05	35.3876	TOTAL PETROLEUM HYDROCARBONS (TPH)
23	BIG WEST OF CALIFORNIA LLC	80001738	EnviroStor	CORRECTIVE ACTION (CURRENT)	REFER: RWQCB	6451 ROSEDALE HWY	BAKERSFIELD	93308	81-85%	-119.072547	35.383247	BTEX, MTBE
24	OCCIDENTAL OF ELK HILLS INC	80001254	EnviroStor	CORRECTIVE ACTION (CURRENT)	ACTIVE - LAND USE RESTRICTIONS, POST CLOSURE RCRA PERMIT	28590 HIGHWAY 119	TUPMAN	93276	76-80%	-119.484792	35.281959	Metals, Petroleum, PCBS, Radioactive isotopes, Volatile Organics
25	ASSURED TRANSPORTATION SITE	15420001	EnviroStor	DTSC SITE CLEANUP PROGRAM (ACTIVE)	ACTIVE	3228 GIBSON ST	BAKERSFIELD	93308	81-85%	-119.051671	35.3904494	Halogenated Organic Compounds, Tetrachloroethylene (PCE)
26	DELANO PCE PLUME	60001327	EnviroStor	DTSC SITE CLEANUP PROGRAM (ACTIVE)	ACTIVE	MAIN STREET AND 10TH AVENUE	DELANO	93215	66-70%	-119.2456698	35.76910534	Tetrachloroethylene (PCE)
27	J R SIMPLOT, EDISON	15070030	EnviroStor	DTSC SITE CLEANUP PROGRAM (ACTIVE)	ACTIVE - LAND USE RESTRICTIONS	430 PEPPER DRIVE	EDISON	93220	81-85%	-118.8778	35.35147831	Organochlorine pesticides (8081 OCPS), Volatile Organics (8260B VOCS)
28	BROWN AND BRYANT, INC., ARVIN FACILITY	15280011	EnviroStor	FEDERAL SUPERFUND - LISTED	ACTIVE	600 S DERBY ST	ARVIN	93203	81-85%	-118.8231039	35.20314691	DINOSEB and Volatile Organics (8260B VOCS)

Table 2-5
GeoTracker and EnviroStor Sites with Potential Groundwater Media
Kern Groundwater Authority
Kern County, California
(Updated January 2019)

New Map ID	Site / Facility Name	ENVIROSTOR/ Geotracker ID	Source	Program Type	Status	Address	City	Zip	CALEnviroscreen Score	X Coord	Y Coord	Constituents of Concern
29	FASTLANE MINI MART	T0602912732	Geotracker	LUST CLEANUP SITE	OPEN - ELIGIBLE FOR CLOSURE	201 ELMO HWY	MCFARLAND	93250	---	-119.2322588	35.68861163	Gasoline
30	HOWARDS MINI MARKET	T10000000635	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	3300 PLANZ ROAD	BAKERSFIELD	93309	---	-119.0392612	35.325438	Diesel, Gasoline
31	JEFFRIES BROS, OASIS	T10000007369	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	35750 HWY 58	BUTTONWILLOW	93206	---	-119.39992	35.39946	Benzene, Diesel, Ethylbenzene, Gasoline, MTBE / TBA / Other Fuel Oxygenates, Naphthalene, Toluene, Xylene
32	LOGRECCO PROPERTY	T0602925877	Geotracker	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	1330 HIGH STREET	DELANO	93215	---	-119.247728	35.773859	Gasoline
33	NORTH KERN STATE PRISON	T0602900672	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	2737 CECIL AVE W	DELANO	93216	---	-119.3145731	35.7831358	Gasoline
34	POND MERCANTILE	T0602900113	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	29310 POND RD.	POND	93280	---	-119.3292703	35.71777716	Gasoline
35	RIBIER MARKET	T0602900267	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	11228 EDISON RD S	LAMONT	93241	---	-118.8792731	35.25343586	gasoline
36	ROBERTSONS MARKET	T0602902377	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	21124 HWY 46(FORMERLY 62160 HWY 46)	LOST HILLS	93249	---	-119.6964148	35.6153236	Diesel, Gasoline
37	SAMCO FOOD STORE NO. 3	T10000009045	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	8101 EAST BRUNDAGE LANE	BAKERSFIELD		---	-118.91375	35.35406	Diesel, Gasoline
38	TAYLOR AUTOMATED FUELS	T0602900529	Geotracker	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	61700 HWY 46, (NW CORNER OF HWY 46 AND LOST HILLS RD)	LOST HILLS	93249	---	-119.6900572	35.61639925	Gasoline
39	TRAVEL CENTERS OF AMERICA	T10000010004	Geotracker	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	27769 LAGOON DRIVE	BUTTONWILLOW	93206	---	-119.39723	35.40124	Benzene, Diesel, Gasoline, MTBE / TBA / Other Fuel Oxygenates, Naphthalene, Toluene, Xylene
40	WHOLESALE FUELS, INC.	T10000007773	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	2200 EAST BRUNDAGE LANE	BAKERSFIELD	93307	---	-118.96564	35.35471	Benzene, Ethylbenzene, Gasoline, MTBE / TBA / Other Fuel Oxygenates, Naphthalene, Toluene, Xylene
41	BAKERSFIELD DISCOVERY PROJECT	60001630	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - ACTION REQUIRED	PACHECO ROAD AND STINE ROAD	BAKERSFIELD	93318	66-70%	-119.056751	35.310412	Tetrachloroethylene (PCE), Trichloroethylene (TCE)
42	BAKERSFIELD PLATING WORKS	15340012	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: OTHER AGENCY	527 EAST 19TH	BAKERSFIELD	93305	81-85%	-118.9954948	35.37490554	Metals (cadmium, chromium III/VI. Copper. Lead, Nickel)
43	BC CHEMICALS	15280041	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: RWQCB	1511 SOUTH UNION AVENUE	BAKERSFIELD	93307	91-95%	-119.0036166	35.33598464	Arsenic
44	CALTRANS SERVICE YARD	60001605	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - NEEDS OTHER EVALUATION (CURRENT OR INACTIVE)	1200 OLIVE DRIVE	OILDALE	93308	86-90%	-119.046228	35.413042	PCE, TCE
45	EASTLAND FLYING SERVICE	15070006	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - NEEDS OTHER EVALUATION (CURRENT OR INACTIVE)	16849 MT. VIEW ROAD	LAMONT	93241	76-80%	-118.816845	35.28164	Carbaryl, 8141A OPPS, Toxaphene
46	KERN COUNTY DUMP	15490017	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: RWQCB	SE OF XING OF STRADLEY & WOOLOMES AVES	DELANO	93215	96-100%	-119.25779	35.74616	Tetrachloroethylene, trichloroethylene, Dichlorodifluoromethane, 1,1 Dichloroethane
47	KERN COUNTY GUN CLUB	15860001	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: OTHER AGENCY	2818 CHINA GRADE LOOP	BAKERSFIELD	93308	76-80%	-118.965412	35.422405	Lead, Other Organic Solids, Polynuclear aromatic hydrocarbons
48	RAIN FOR RENT	60001771	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - NEEDS OTHER EVALUATION (CURRENT OR INACTIVE)	3404 STATE STREET	OILDALE	93308	96-100%	-119.044861	35.406524	Unknown
49	SPARKLE/BRUNDAGE CLEANERS	60002071	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	BACKLOG	1517 W. BRUNDAGE ROAD	BAKERSFIELD	93304	96-100%	-118.9824817	35.3539159	Tetrachloroethylene, trichloroethylene
50	CARNEROS CREEK, THETA	L10009422184	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	CARNEROS CREEK OIL FIELD	LOST HILLS		---	-119.85852	35.46844	Crude Oil
51	CHEVRON USA INC-KERN RIVER-SAN JOAQUIN	T10000007105	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	KERN RIVER OIL FIELD	MALTHA		---	-119.001769	35.428919	Crude Oil
52	CYMRIC OIL FIELD, BOWLES LEASE	T10000006948	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	SW OF LOKEN RD / LOST HILLS RD	MCKITTRICK	93251	---	-119.71424	35.37855	Crude Oil
53	CYMRIC OIL FIELD, LEHI-RICHARDSON LEASE	T10000007036	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	CYMRIC OIL FIELD	MCKITTRICK		---	-119.754775	35.418844	Crude Oil
54	CYMRIC OIL FIELD, OVERLAND ANDERSON LEASE	T10000007035	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NE TAFT (S20, T29S, R21E, MDB&M)	MCKITTRICK	93251	---	-119.73454	35.3944	Crude Oil
55	CYMRIC OIL FIELD, USL LEASE	T10000007037	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	CYMRIC OIL FIELD	MCKITTRICK		---	-119.765	35.42378	Crude Oil
56	EDISON OIL FIELD, RACETRACK LEASE	T10000007136	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	EDISON OIL FIELD	EDISON		---	-118.84515	35.37177	Other inorganic / salt, TDS, Crude Oil
57	J&K, MIDWAY-SUNSET OIL FIELD, JADE KERN PROJECT LEASE	T10000006764	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	KRISTIN STREET NE 1/4, SEC 15 T32S R23E MDB&M	TAFT	93268	---	-119.48427	35.14988	Crude Oil
58	KERN FRONT NO. 2	T10000007097	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	KERN FRONT OIL FIELD	SACO		---	-119.05882	35.46374	Crude Oil

Table 2-5
GeoTracker and EnviroStor Sites with Potential Groundwater Media
Kern Groundwater Authority
Kern County, California
(Updated January 2019)

New Map ID	Site / Facility Name	ENVIROSTOR/ Geotracker ID	Source	Program Type	Status	Address	City	Zip	CALEnviroscreen Score	X Coord	Y Coord	Constituents of Concern
59	MIDWAY-SUNSET OIL FIELD, BERRY & EWING LEASE	T10000007297	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.44121	35.09873	Crude Oil
60	MIDWAY-SUNSET OIL FIELD, C. E. HOUCHIN ET AL LEASE	T10000006771	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	SEC 9, T31S, R22E, MDB&M	FELLOWS	93224	---	-119.62194	35.24141	Crude Oil
61	MIDWAY-SUNSET OIL FIELD, FULTON LEASE	T10000007030	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTHEAST OF MARICOPA (S1, T11N, R24W, SBB&M)	MARIPOSA	93252	---	-119.39335	35.06877	Crude Oil
62	MIDWAY-SUNSET OIL FIELD, HAVENSTRITE LEASE	T10000006789	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.35188	35.0463	Crude Oil
63	MIDWAY-SUNSET OIL FIELD, JAMESON TRUST LEASE	T10000006947	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	7026 DARNOCH WAY	WEST HILLS	91307	---	-119.45068	35.13032	Crude Oil
64	MIDWAY-SUNSET OIL FIELD, JAMESON TRUST LEASE	L10002548641	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.40374	35.0736	Crude Oil
65	MIDWAY-SUNSET OIL FIELD, LOCKWOOD LEASE	T10000007029	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	WEST OF TAFT	TAFT	93628	---	-119.5077454	35.14047576	Crude Oil
66	MIDWAY-SUNSET OIL FIELD, MOCO 35 LEASE (PLASTIC-LINED POND 3)	T10000007039	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTH OF MARICOPA (S35, T12N, R24W, MDB&M)	MARICOPA	93252	---	-119.4057919	35.08717628	Crude Oil
67	MIDWAY-SUNSET OIL FIELD, MOCO 35 LEASE (PONDS 1&2, SAND PITS)	T10000007031	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTH OF MARICOPA (S35, T12N, R24W, MDB&M)	MARIPOSA	93252	---	-119.4065	35.08679	Crude Oil
68	MIDWAY-SUNSET OIL FIELD, NATIONAL USL LEASE	T10000007032	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	TWO MILES SOUTHWEST OF TAFT (S35, T32S, R23E, MDB&M)	TAFT	93268	---	-119.46687	35.10715	Crude Oil
69	MIDWAY-SUNSET OIL FIELD, SHALE 14 LEASE	T10000007033	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	1.5 MILES SOUTHEAST OF DERBY ACRES (S14, T31S, R22E)	DERBY ACRES	93224	---	-119.57365	35.23502	Crude Oil
70	MIDWAY-SUNSET OIL FIELD, W & S LEASE	T10000007034	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	2 MILES SOUTHEAST OF DERBY ACRES (S14, T31S, R22E)	DERBY ACRES	93224	---	-119.5852	35.22457	Crude Oil
71	MIDWAY-SUNSET OIL FIELD, WEBBER LEASE	T10000006776	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	LDD ENERGY - NE ¼ SECTION 34, T30S, R22E, MDB&M	FELLOWS	93224	---	-119.59296	35.27708	Crude Oil
72	MIDWAY-SUNSET, HOYT LEASE	T10000006779	Geotracker	PRODUCED WATER PONDS	UNDER REVIEW	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.37986	35.05688	Crude Oil
73	POSO CREEK, POSO	T10000007301	Geotracker	PRODUCED WATER PONDS	INACTIVE - UNPERMITTED	LINN OPERATING INC - NW OF BRONZE HILL RD. & WHITE CROWN DR.	MCFARLAND	93250	---	-119.0452	35.58195	Crude Oil
74	RIO BRAVO OIL FIELD, KERNCO LEASE	T10000006733	Geotracker	PRODUCED WATER PONDS	OPEN - INACTIVE	NW OF 7TH STANDARD RD / TRANSPORT LN S1/2 OF THE NE1/4 OF SECTION 34, T28S, R25E, MDB&M	SHAFTER	93263	---	-119.2656	35.44952	Crude Oil
75	S. BELRIDGE OIL FIELD, HILL LEASE	SL0602935481	Geotracker	PRODUCED WATER PONDS	INACTIVE - PERMITTED	SEC 19, T28S, R21E, MDB&M	SOUTH BELRIDGE OIL FIELD		---	-119.7453854	35.4882413	Other inorganic, Salt
76	SOUTH BELRIDGE OIL FIELD, SOUTH WASTEWATER DISPOSAL FACILITY	SL0602990565	Geotracker	PRODUCED WATER PONDS	INACTIVE - PERMITTED	SOUTH BELRIDGE OIL FIELD	SPICER CITY		---	-119.6796305	35.46115366	Other inorganic / salt
77	VAUGHN-MIDWAY-SUNSET OIL FIELD, USL 15	T10000006813	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTHWEST IF MIDOIL RD / THOMAS ST	TAFT	93268	---	-119.49199	35.14231	Crude Oil

Source: DTSC Envirostor: https://www.envirostor.dtsc.ca.gov/public/ and SWRCB Geotracker: http://geotracker.waterboards.ca.gov/

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- under review
- open-inactive
- inactive-permitted
- inactive-unpermitted

There is a total of 77 sites identified within the Subbasin. Figure 2-38 and Table 2-5, with cross referenced Map IDs, present the locations and details of known impacted groundwater or potentially impacted groundwater within the Subbasin. Table 2-5 provides the Site/Facility Name, Site Regulatory Identification and Status, associated site address and latitude/longitude, CalEnviroScreen Score (if applicable), as well as any identified constituents of concern impacting the groundwater at these sites.

2.3.4 Land Subsidence

Inelastic (irrecoverable) land subsidence (subsidence) is a sustainability indicator that often occurs in the region due to over pumping of aquifers with a high percentage of fine-grained deposits. Inelastic land subsidence has the potential to alter the land surface in ways that could increase flood risk in low lying areas; and damage well casing, canals, and other linear infrastructure. This section summarizes land subsidence data collected within the Subbasin and discusses documented impacts and potential impacts of land subsidence in or near the Subbasin.

2.3.4.1 Processes Leading to Land Subsidence

Several processes contribute to land subsidence in the Subbasin and include, in order of decreasing magnitude: aquifer compaction by overdraft; hydrocompaction (shallow or near-surface subsidence) of moisture deficient deposits above the water table that are wetted for the first time since deposition; petroleum reservoir compaction due to oil and gas withdrawal; and subsidence caused by tectonic forces (Ireland et al., 1984). Subsidence associated with oil and gas activities may be included on datasets in figures and tables of this GSP due to the regional method of data collections such as LANDSAT and InSAR. If significant impacts to critical infrastructure associated with oil and gas activities are identified by regional subsidence monitoring, they will be communicated to DOGGR to address as appropriate pursuant to Public Resources Code 3315.

Inelastic compaction or land subsidence occurs in the fine-grained beds of the aquifer system. Clays and silts, although not very permeable, are typically highly porous. In many of these fine-grained layers, pore spaces are supported by water at the time of deposition. This water is essentially groundwater storage to the Subbasin, although the majority of it is a component of inelastic storage, and therefore, it is not reusable. During over-pumping conditions, groundwater is pumped from pore spaces between grains of sand and gravel. Once the aquifer system is pumped beyond the sustainable yield, the lowered water pressure in the sand and gravel causes slow drainage of water from the clay and silt beds. The subsequent release of water and water pressure from the clay and silt beds result in compaction (the beds become thinner) as clay particles supported by water in pore spaces rearrange and collapse. Groundwater cannot re-enter the clay structure after the collapse.

This condition represents a permanent loss of the water storage volume in the clay layers. The effects of compaction are also seen as a lowering of the land surface, otherwise known as land subsidence.

2.3.4.2 Impacts due to Land Subsidence

There are various impacts of land subsidence on surface land uses and groundwater use that are documented in Kern County and adjacent study areas. Some of these references are from historical investigations while others are current. Both provide examples of potential future impacts of long-term subsidence in the study area.

Loss in Groundwater Storage and Increased Pumping Lifts

As described above, inelastic land subsidence can lead to the reduction in storage of fine-grained units. The reduction in storage ultimately leads to increased pumping lifts. Ireland et. al. (1984), explained that during compaction of fine-grained units caused by overdraft, there is a one-time release of water that is a short-term benefit to users because it results in extra water released from clay storage that is not renewable. Figure 2-40 below provides a conceptual diagram illustrates how over-pumping and subsidence leads to increased pumping lifts.

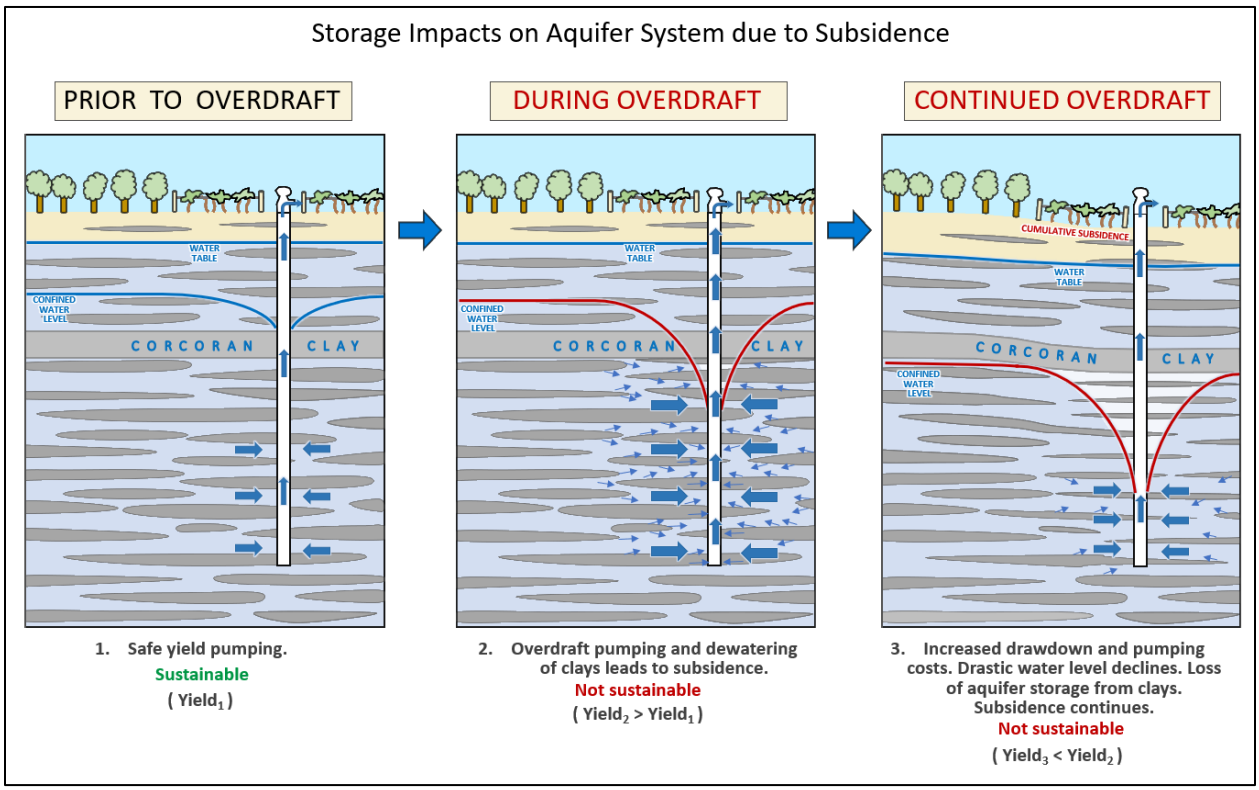


Figure 2-40. Conceptual Diagram of Impacts of Over-Pumping and Subsidence

Ireland et. al. (1984) documented the above phenomenon in the Los Banos-Kettleman City area. In the late 1960's, water levels were drawn down to historical lows with subsidence rates that exceeded 1 ft per year. Water levels subsequently recovered, and subsidence nearly ceased in the middle 1970's with the delivery of surface water. During the drought of 1976-1977, a second

cycle of overdraft and subsidence occurred. Water level declines were more rapid during the second cycle due to the loss of one-time storage from the first event. In addition, subsidence rates typical of those during the first event were observed (Ireland et al, 1984). In 1980, wet conditions and more available surface water resulted in groundwater levels recovering to pre-drought conditions and subsidence rates nearly ceased (Ireland et al, 1984).

Ojha et. al. (2019), references recent studies suggesting that subsidence between 2007 and 2015 in the Central Valley (primarily San Joaquin Valley) resulted in losses of 0.4% to 5.25% storage capacity in the aquifer system. However, this storage reduction does not substantially decrease usable or renewable storage for groundwater because the clay layers do not typically store significant amounts of recoverable, usable groundwater (LSCE, 2014). Nonetheless, it is estimated in the past, that by the mid-1970s, about one-third of the volume of water pumped from storage in areas such as Los Banos-Kettleman City, came from compaction of fine-grained beds (Poland and others, 1975; Faunt et al, 2009). Although the largest body of clay is the Corcoran Clay, a relatively insignificant volume of water has been released from storage in the Corcoran Clay (Faunt et al, 2009), likely because of its large thickness and low permeability.

Ojha et. al. (2019) suggests that loss in storage due to subsidence may impact the overall aquifer system by increasing the replenishment time of the aquifer which could pose challenges to water management in the future.

Surface Linear Infrastructure

Large-scale linear infrastructure is most susceptible to the regional subsidence caused by regional groundwater withdrawal. When subsidence rates are not equal across a region, differential compaction can occur. This differential compaction or subsidence may result in the formation of new low-lying areas for which canal designs have not taken into account. Newly formed low-lying areas are what impact large-scale linear infrastructure such as canals; often reducing freeboard and capacity. Examples of infrastructure that have been impacted by subsidence in the Southern San Joaquin Valley include the Friant-Kern Canal and California Aqueduct.

CVP

The Friant Kern Canal impacts have been well documented to the north of the Subbasin in an approximate five-mile stretch across Deer Creek (FWA, 2018). Subsidence was roughly 2 feet of the canal invert. Due to land subsidence the canal's water delivery capability has been reduced by nearly 60% to some contractor's (FWA, 2018). In contract, within the Subbasin, the Friant Kern Canal has experienced a few inches subsidence near Poso Creek (Mileposts 127 to 137).

SWP

The California Aqueduct was constructed in some areas with historical subsidence. "In an effort to prevent future subsidence from affecting the operation of the Aqueduct (and future water deliveries), extra freeboard was also added to [certain stretches] of the Aqueduct" (DWR, 2017c). During initial operation, only a few places experienced lining cracks including an area

with a concrete culver undercrossing just downstream of the Buena Vista Pumping Plant experienced settlement (DWR, 2017c).

Two segments of the Aqueduct were raised in 1989 and 1996 in Kern County (Table 2-6; DWR, 2017c). The first between MP 194.94 and 197.05 (T25S-R20E) in 1989, and the second between MP 206.10 and 207.94 (T27S-R21E). In general, this northwest portion of the basin is far from the main groundwater production in the central part of the Subbasin, so it is uncertain if groundwater supply extraction contributes to land subsidence in this area. Swanson (1998) also reported subsidence in this area along a 29-mile reach of the California Aqueduct, the cause of which was uncertain. The subsidence rates increased during dry periods and decreased during wet periods. Swanson (1998) recommended that observation wells and an extensometer be installed along this reach "to determine the cause of the subsidence because there is little ground-water pumping in the immediate area."

Table 2-6: 1989 and 1996 Canal Raise in the San Joaquin Field Division

Year	Pool	Spec	Milepost		Station		Length (miles)	Maximum Raise (inches)
			From	To	From	To		
1989	22	89-26	182.39	184.82	718+00	846+00	2.43	30
1989	22	89-26	194.94	197.05	1373+41.59	1485+00	2.11	39
1996	22	96-19	206.10	207.94	1962+84	2059+99.2	1.84	30

Fault Movement

Within the Subbasin, Pond-Poso Fault movement has been detected during dry years. Although the impact to infrastructure is unknown. Holzer (1980) observed fault movement along the Pond-Poso Fault from February 1977 to March 1979. This fault movement was observed during seasons of water level decline, and he concluded that 9 inches of offset had occurred along the Pond-Poso Fault System since the 1950's. In addition, Holzer (1980) observed that fault offset of groundwater levels was greater during dry years when the lowest seasonal water level low occurred.

Impacts to Well Casing

Although not in the Subbasin, just north of Subbasin, Wilson (1968) documented well casing failures attributed to land subsidence. Wilson reported that during 1950-1961 in a part of the Los Banos-Kettleman Hills area, wells that were screened primarily below the Corcoran Clay experienced screen failures associated with compaction or land subsidence.

Degraded Water Quality

Degradation of water quality due to land subsidence has been studied in the San Joaquin Basin to the north of the Subbasin. Smith et. al. (2018), hypothesizes that poor water quality in clays may be released to the aquifer system during over pumping and compaction of clays. Specifically, data north of the Subbasin in the San Joaquin Valley may indicate that areas with a thicker Corcoran Clay extent have seen an increase in arsenic concentrations as subsidence rates have increased due to over pumping (Smith et. al., 2018).

2.3.4.3 Land Subsidence Monitoring

Historical documentation of subsidence has relied on various types of data, including ground surveys, declining groundwater levels, and borehole extensometers. Recent subsidence studies have relied on ground surveys, borehole extensometers, continuous GPS stations, and remote sensing to collect data.

Each method has advantages and drawbacks. An extensometer measures a discrete subsurface interval, or typically the interval of the ground surface to the total depth of the extensometer. On the other hand, CGPS and InSAR monitor overall change in ground surface relative to a datum such as sea level, regardless of the depth interval. Moreover, InSAR provides information over a wide area.

Remote Sensing

Within the Central Valley, and in particular the Subbasin, researchers have utilized remote sensing techniques such as satellite-based Interferometric Synthetic Aperture Radar (InSAR) and aircraft-based L-band SAR or Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR). These surveys have been led by the National Aeronautics and Space Administration (NASA) and Jet Propulsion Laboratory (JPL), as well as other international researchers. The benefit of remote sensing is that large areas of land can be surveyed with no invasive actions or land surface access complications. DWR has commissioned studies (TRE Altamira, 2019) to evaluate the accuracy of remote sensing and identify additional processing and calibration methods for accuracy.

The following is a summary of recent remote sensing findings with respect to the TRE Altamira report:

- InSAR data with nearby UNAVCO CGPS have been processed and calibrated for northern Kern County Subbasin to the north of Visalia using the TRE Altamira-patented method SqueeSAR.
- InSAR calibration by TRE Altamira reports accuracy to 20 mm (0.07 feet) at 95% confidence interval.
- The calibration points include UNAVCO CGPS points (subsidence results as great as 8 inches over the time period of 2015 to 2018).
- Other points in the SOPAC network including Corcoran and Lemoore stations were not included in calibration; however, Ojha et al (2019) demonstrated that LEMA Lemoore and CRCN Corcoran (high subsidence areas) (at least 50 inches of subsidence between 2015 to 2018) may correlate well with InSAR.

Filling data gaps in the San Joaquin Valley with high subsidence areas lacking calibration monitoring points such as CGPS may be beneficial for future remote sensing work and calibration.

2.3.4.4 Historical Subsidence Results

Within the Subbasin, subsidence has been documented from leveling by the National Geodetic Survey at up to 12 feet from 1926 to 1970 (Ireland et al., 1984). USGS estimates that about 75 percent of the subsidence occurred in the 1950s and 1960s, corresponding to extensive groundwater development (Galloway, et al., 1999). Water levels during this period were continuing to fall to historic lows each year, for the first time, which were associated with larger amounts of subsidence (Todd, 2017).

Subsidence was also measured by USGS borehole extensometers in the west Subbasin from 1978 to 1983 (26S/23E-16H2 and 16H3) and to the south of Bakersfield from 1963 to 1978 in Extensometer 32S-28E-20Q1). These two extensometers have since been abandoned; however, a couple new extensometers have been installed in the Subbasin.

2.3.4.5 Recent Subsidence Results

Recent subsidence data is summarized in Table 2-7. In addition, time-series plots of subsidence monitoring points are included in Attachment G. Table 2-4 includes a summary of InSAR data published in a subsidence study commissioned by the California Water Foundation. Subsidence was measured at 0 to 0.5 feet from 2007 to 2011 across the Subbasin (LSCE, 2014). Subsidence was measured from 2005 to 2017 in the north and west Subbasin (based on six continuous GPS (CGPS) stations (BVPP, P544, P545, P563, P564, P565). These CGPS stations are monitored as a part of UNAVCO's Plate Boundary Observation (PBO).

Two extensometers have produced current data: 25S/22E-35B1 and 30S/25E-16L. Data for these extensometers are also included in Table 2-7.

JPL provided a progress report of InSAR subsidence monitoring in California (Farr et al., 2015), for data processed from the Japanese PALSAR for 2006 to 2010, Canadian Radarsat-2 for the period May 2014 through January 2015. From April 2014 to January 2015, subsidence was measured along the California Aqueduct from State Route 58 south to White Wolf Fault. Additional InSAR subsidence monitoring was reported by JPL (Farr et al., 2016) in 2016 for data from the European Space Agency's satellite-borne Sentinel-1A from the period May 2015 through September 2016, and NASA airborne UAVSAR for the period March 2015 through June 2016. The ESA's Sentinel-1A surveyed the entire San Joaquin and Tulare Basins, and subsidence was estimated between 4 and 8 inches in the north central portion of Subbasin as well as in the south of the Subbasin. The UAVSAR southern flight line along the California Aqueduct measured as much as 12 inches of subsidence, from April 2014 to June 2016, between east of Buena Vista Pumping Plant and Wind Gap Pumping Plant near Old River Road.

According to Luhdorff & Scalmanini Consulting Engineers (LSCE), Borchers and Carpenter (2014), subsidence is on-going and leading to significant impairment of the California Aqueduct and the Friant-Kern Canal. According to DWR (2014) the Subbasin was rated at a high risk for future subsidence due to 1) a significant number of wells (51%) with water levels at or below historic lows; 2) documented historical subsidence; and 3) documented current subsidence. Moreover, greater amounts of subsidence are occurring to the north of Subbasin in the Tulare

Subbasin. The amount of future subsidence will depend on whether future water levels decline below previous low levels and remain low for a considerable amount of time. Maintaining water levels above the previous low water levels may limit the risk of future subsidence.

2.3.4.6 Annual Rate of Subsidence

The following tabulated data includes cumulative inches of subsidence within Subbasin, and a calculated approximate annual rate for the time period for the data collection period.

Table 2-7 Land Subsidence Data

Subbasin Area	Date Range	Cumulative Subsidence (inches)	Calculated Annual Rate of Subsidence (inches/year)	Source
Historical Range in the Subbasin	1926 - 1970	12 - 96	~ 0.3 - 2.2	Ireland, 1984. Topographic Maps and Leveling Data.
North Central Subbasin	1978 - 1983	-0.04 – 1.5	-0.001 – 0.03	Extensometer 26S/23E-16H2 and -H3, USGS
South of Bakersfield	1963 – 1977	23.3	~0.14	Extensometer 32S-28E-20Q1, USGS
North and West Subbasin	2005 - 2017	0.1 – 11.7 0.2	~0 – 1.3	CGPS PBO. (BVPP, P544, P545, P563, P564, P565).
South central Subbasin	2006-2016	9.8 - 11.5	~1.1	CGPS (BKR1/BKR2, ARM1)
West Subbasin and South of Bakersfield	Jan. 2007 – Mar. 2011	6.0	~1.4	LSCE, 2014. Compiled from InSAR.
North Central Subbasin	Dec. 2013 – Mar. 2018	3.2	~0.8	SWSD Extensometer 25S22E35B001M
Central Subbasin	July 1994 - June 2018	-3 (negative value indicates uplift)	Not Presented Here.	Kern Fan Extensometer 30S/25E-16L According to AECOM (2016), data from extensometer show “little response to changes in water level changes during recharge or recovery operations.”
Southwest Subbasin along California Aqueduct	Apr. 2014 – Jan. 2015	0.5 - 5	~0.7 – 6.7	UAVSAR. InSAR Canadian Radarsat-2 (Farr et al., 2015)
North Central Subbasin	May 2015 – Sep. 2016	~1 - 12	~1.3 – 9.2	InSAR ESA Sentinel-1A (Farr et al., 2016)
Southwest Subbasin along California Aqueduct	Apr. 2014 – Jun. 2016	0 - 16	~0 – 7.4	UAVSAR (Farr et al., 2016)

2.3.4.7 Map of Subsidence Locations

Subsidence within the Subbasin measured by historical studies is plotted on Figure 2-41. Subsidence as measured by recent studies and monitoring points including the UAVSAR and InSAR datasets is plotted on Figures 2-42 and 2-43, respectively. Corresponding rates of subsidence are presented on Figures 2-44 and 2-45. CGPS data locations, which are monitored continuously by UNAVCO, are plotted with recent calculated subsidence.

2.3.4.8 Data Gaps in Subsidence Understanding

There are data gaps in land subsidence that will be considered for future data collection. These data gaps include subsidence monitoring along points of critical infrastructure such as the Friant Kern Canal and California Aqueduct.

As described herein, there are a valuable dataset of CGPS monitoring points with which to pair water level monitoring data; however, InSAR data show that many of the CGPS points are not in zones of high subsidence, nor adjacent to critical infrastructure. Therefore, CGPS points alone are useful as quality control points, but they are likely not situated in areas of high subsidence or near critical infrastructure to facilitate decision making on sustainable management criteria.

InSAR is a dataset that may be able to fill the gaps between CGPS points. Continued InSAR data collection can fill the temporal data gap in the record. Correlations between CGPS and InSAR could confirm InSAR results in high subsidence areas near Subbasin, as they have been demonstrated in low subsidence and other areas (Tre Altamira, 2019; and Ojha et al, 2019).

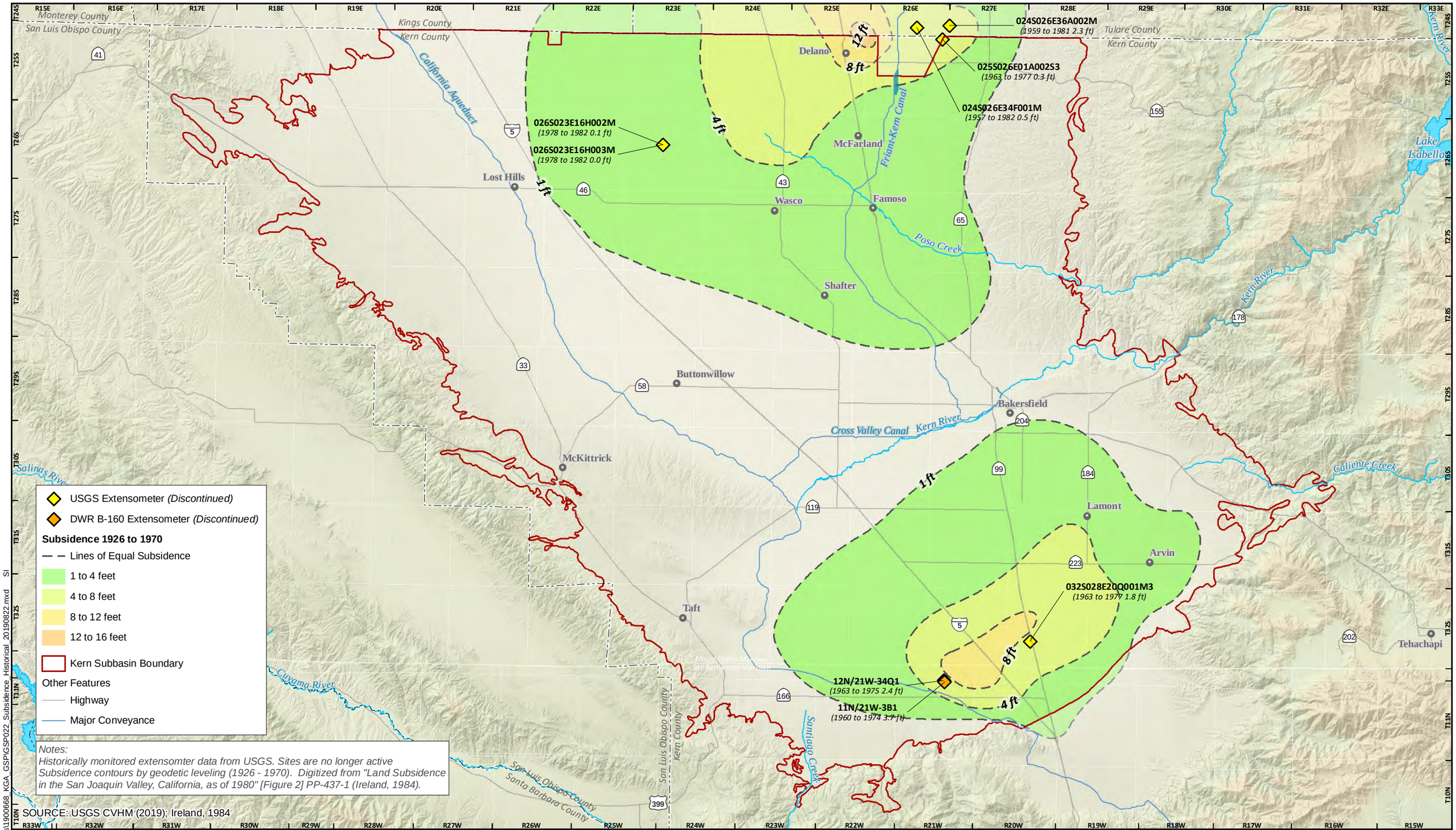
As the water level monitoring network is established in the Subbasin, collocated temporal water level data with CGPS data can be collected to evaluate the relationship between active subsidence and residual subsidence with respect to water level change over time. The understanding of residual subsidence will better inform sustainable management criteria for setting thresholds.

2.3.5 Interconnected Surface Water Systems

Interconnected surface water systems are surface waters that are hydraulically connected by a continuous saturated zone to an underlying aquifer 23-CCR § 351(o). Within the Subbasin, there are no interconnected natural surface water systems in monitored areas associated with the pumping zone of the regional aquifer system.

The following are naturally occurring surface water bodies within the Subbasin:

- Kern River: Flows within the Subbasin (located within the Olcese and Kern River GSAs) are a function of hydrologic conditions in the Kern River watershed and regulation by Isabella Dam and Reservoir; and
- Poso Creek and other minor streams: Streamflow is unregulated and is ephemeral within the Subbasin, principally occurring during “wet” months of “wet” years.



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

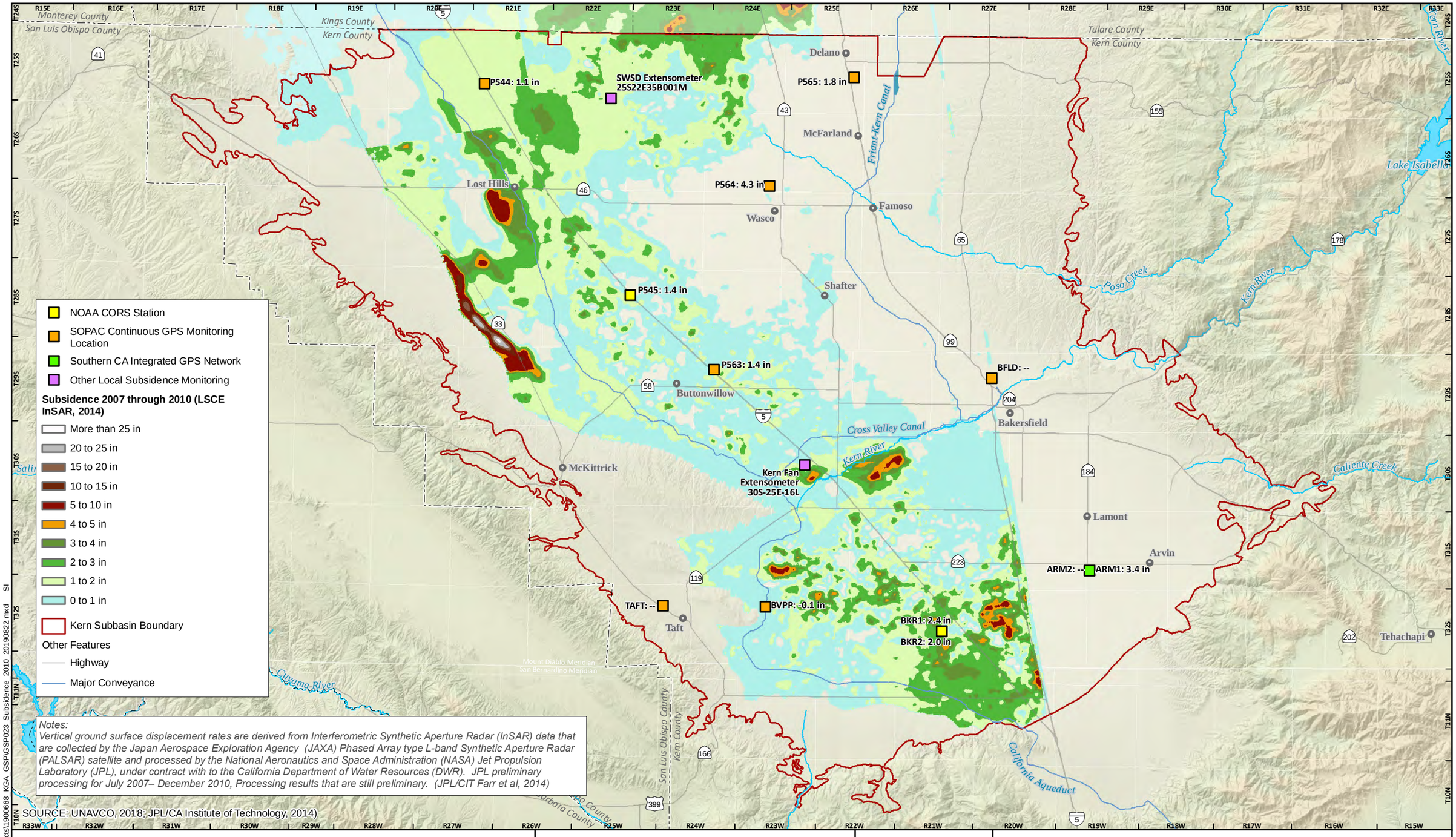
HISTORICAL SUBSIDENCE

AUGUST 2019

FIGURE 2-41

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22-Aug-2019



Kern Groundwater Authority
Basin Setting

Kern County, California

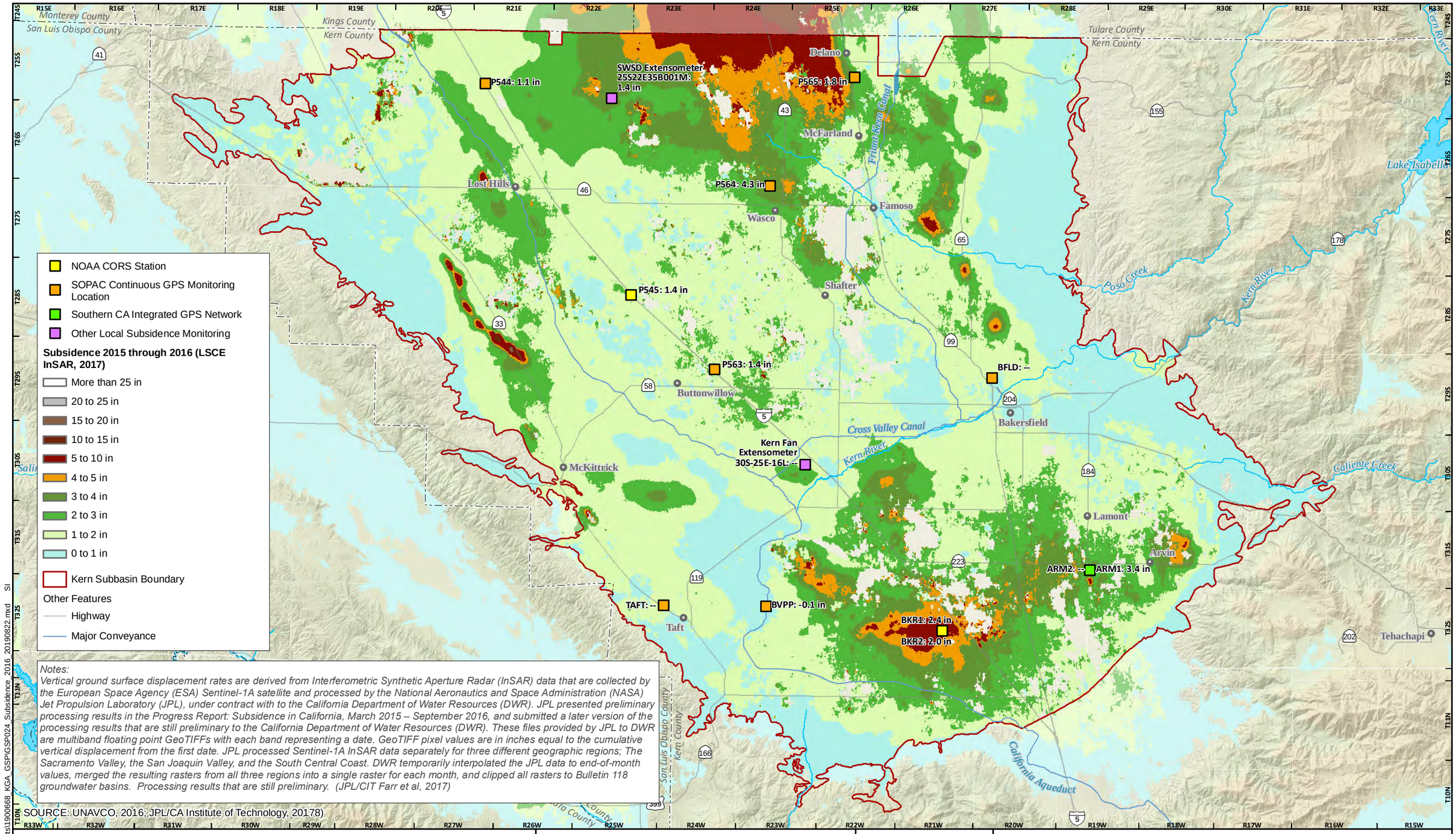
GEI Consultants

SUBSIDENCE 2007 - 2010

AUGUST 2019

FIGURE 2-42

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Notes:
Vertical ground surface displacement rates are derived from Interferometric Synthetic Aperture Radar (InSAR) data that are collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), under contract with to the California Department of Water Resources (DWR). JPL presented preliminary processing results in the Progress Report: Subsidence in California, March 2015 – September 2016, and submitted a later version of the processing results that are still preliminary to the California Department of Water Resources (DWR). These files provided by JPL to DWR are multiband floating point GeoTIFFs with each band representing a date. GeoTIFF pixel values are in inches equal to the cumulative vertical displacement from the first date. JPL processed Sentinel-1A InSAR data separately for three different geographic regions; The Sacramento Valley, the San Joaquin Valley, and the South Central Coast. DWR temporarily interpolated the JPL data to end-of-month values, merged the resulting rasters from all three regions into a single raster for each month, and clipped all rasters to Bulletin 118 groundwater basins. Processing results that are still preliminary. (JPL/CIT Farr et al, 2017)

0 3.5 7 14 21
Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

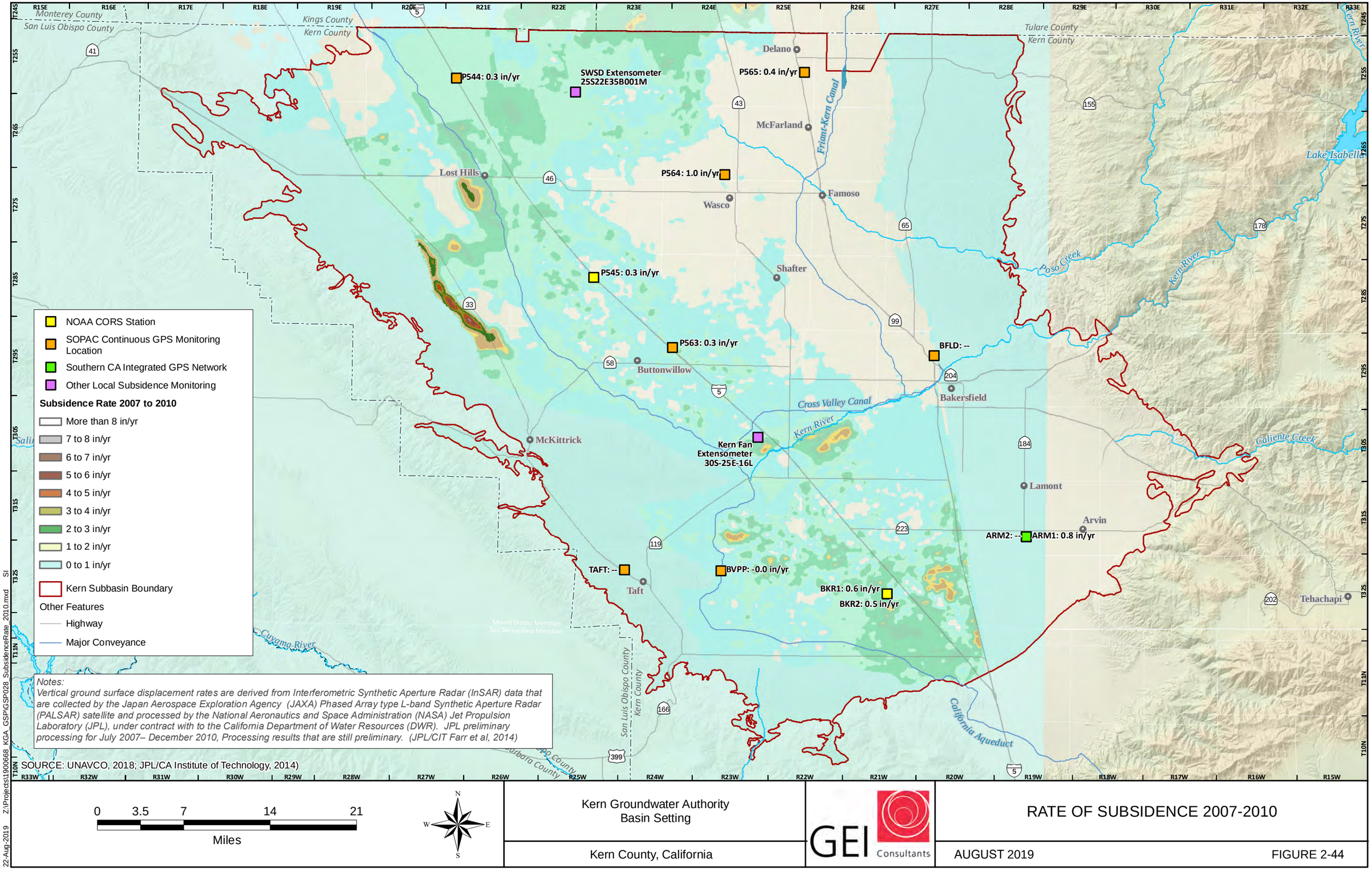
GEI Consultants

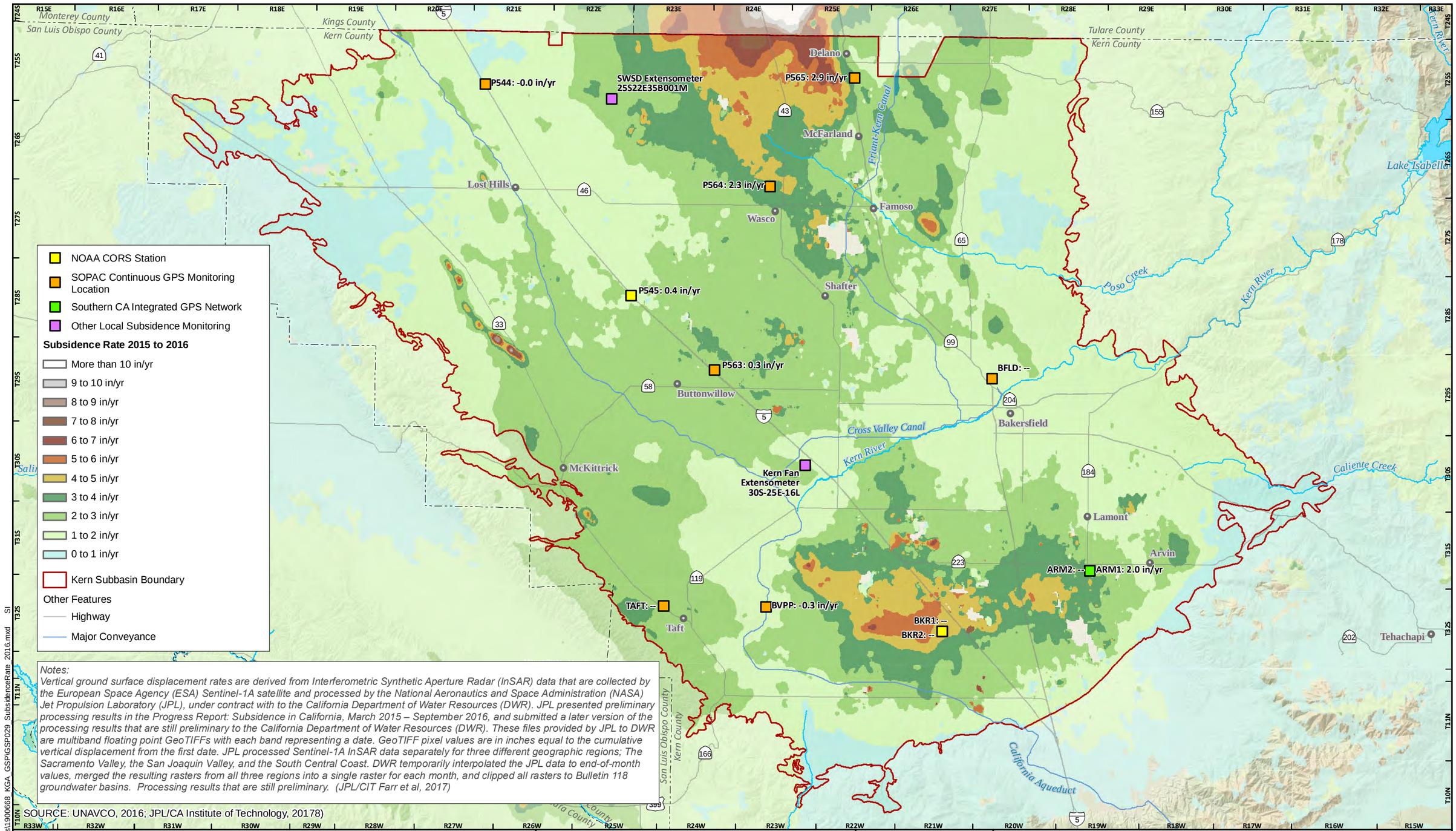
SUBSIDENCE 2015 - 2016

AUGUST 2019

FIGURE 2-43

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Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Kern County
Delano
McFarland
Friant-Kern Canal
Lost Hills
Wasco
Famoso
Shafter
Poso Creek
Kern River
Lake Isabella
Buttonwillow
Cross Valley Canal
Bakersfield
McKittrick
Kern Fan Extensometer 30S-25E-16L
Lamont
Arvin
Caliente Creek
Taft
Tehachapi
Cuyama River
San Luis Obispo County
Kern County
California Aqueduct
Mount Diablo Meridian
San Bernardino Meridian
P544: 0.3 in/yr
SWSD Extensometer 25S22E35B001M
P565: 0.4 in/yr
P564: 1.0 in/yr
P545: 0.3 in/yr
P563: 0.3 in/yr
BFLD: --
TAFT: --
BVPP: -0.0 in/yr
BKR1: 0.6 in/yr
BKR2: 0.5 in/yr
ARM2: --
ARM1: 0.8 in/yr
NOAA CORS Station
SOPAC Continuous GPS Monitoring Location
Southern CA Integrated GPS Network
Other Local Subsidence Monitoring
Subsidence Rate 2007 to 2010
More than 8 in/yr
7 to 8 in/yr
6 to 7 in/yr
5 to 6 in/yr
4 to 5 in/yr
3 to 4 in/yr
2 to 3 in/yr
1 to 2 in/yr
0 to 1 in/yr
Kern Subbasin Boundary
Other Features
Highway
Major Conveyance
Notes:
Vertical ground surface displacement rates are derived from Interferometric Synthetic Aperture Radar (InSAR) data that are collected by the Japan Aerospace Exploration Agency (JAXA) Phased Array type L-band Synthetic Aperture Radar (PALSAR) satellite and processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), under contract with to the California Department of Water Resources (DWR). JPL preliminary processing for July 2007– December 2010, Processing results that are still preliminary. (JPL/CIT Farr et al, 2014)
SOURCE: UNAVCO, 2018; JPL/CA Institute of Technology, 2014)
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Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
RATE OF SUBSIDENCE 2007-2010
AUGUST 2019
FIGURE 2-44
22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP028_SubsidenceRate_2010.mxd SI



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

RATE OF SUBSIDENCE 2015-2016

AUGUST 2019

FIGURE 2-45

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Other surface water bodies, such as the Buena Vista Aquatic Recreation Area lakes, are situated in former basins of natural surface water bodies but are now dependent on managed water deliveries.

Since the advent of groundwater pumping in the Subbasin and subsequent impoundment and regulation of flow of the Kern River, groundwater levels near the river are no longer connected with the river bed by a continuous saturated zone. Water quality data suggest that some portion of the recharge to the principal water-bearing aquifer underlying the far eastern portion of the Subbasin (the Olcese Sand Aquifer) may come from percolation of Kern River surface water via seepage through the Kern Gorge Fault and/or through the overlying shallow alluvium. However, such recharge occurs independent of groundwater production in the principal aquifer, and there is no known pumping from the shallow alluvium zone itself. Thus, there is no interconnected surface water under the influence of groundwater pumping in the principal aquifer in this area and no impacts to interconnected surface water have been observed.

The observation that there are now no interconnected surface water systems in the Subbasin is reflected in the aquifer characterization found in locally developed groundwater models. For example, groundwater levels in the Kern Delta Water District Superposition Model are indicated to be disconnected from the Kern River and other simulated streams (Todd, 2017). See the Kern River GSA GSP, which addresses in more detail the lack of interconnected surface water around the Kern River bed, as the area in around the Kern River bed is located within the jurisdiction of the Kern River GSA. The information below, as required by GSP regulations, is provided for completeness of the KGA GSP basin setting, however, for a more detailed discussion of interconnected surface water systems related to the Kern River, see the Olcese and Kern River GSAs GSPs, as the Kern River is outside of the jurisdictional area of the KGA.

2.3.5.1 Groundwater Elevation and the Kern River

Recent maps of groundwater contours developed by the Kern County Water Agency Improvement District 4 indicate there is a significant separation between the potentiometric surface near the river channel and the elevation of the river bed in areas where groundwater elevations have been mapped near the Kern River. The Hydrologic Profile from the most recent *Kern Fan Operations Report* (KCWA, 2018), illustrates prevailing groundwater conditions both spatially and temporally near the Kern River. This profile, which is transverse to the axis of the Kern River, indicates that during “wet” years, such as 1998 and 2006, groundwater elevations are highest directly below the Kern River bed while, during “dry” years, groundwater levels have declined to depths greater than 200 feet below the river bed. This prevailing pattern suggests that, during wet years, recharge to groundwater from the Kern River channel and nearby water banking operations forms a groundwater mound that gradually flows away from the river to the north and the south. Conversely, in dry years, there is an overall decrease in groundwater levels due to the lack of recharge from the Kern River and nearby water banking operations.

2.3.5.2 Hydrographs

Upstream of the Improvement District 4 monitoring coverage is a segment of the river, near Hart Park and the First Point of Measurement within Subbasin, that has available groundwater elevation data from the Kern County Water Agency for supply wells 29S/28E-02A01 and 29S/28E-10K01. These wells are located upgradient of Rocky Point Weir, and groundwater elevation data are plotted against the elevation of the adjacent river bed. In general, water levels in the wells consistently ranged from approximately 27 to 49 feet lower than the river bed between 1995 to 2016 (Figure 2-46). The Kern River is outside of the KGA jurisdictional area. For more information see the Olcese and Kern River GSA GSPs.

2.3.5.3 Stream Gaging

Stream gaging data for the Kern River are available for stations upstream of the Subbasin at Democrat Springs (USGS 11192500 and USGS 11192000), as well as at the First Point of Measurement upstream of Beardsley River Weir and Rocky Point Weir. Differences in annual flow volumes were calculated between Democrat Springs and the First Point of Measurement (factoring in diversions between these points) for water years 1990 through 2016. In general, streamflow tends to increase between Democrat Springs and the First Point of Measurement during wet years (i.e. 1993, 1998, 2005, and 2011), which in part reflects surface water inflow from tributaries along this segment of the River. In contrast, Kern River flows decrease during some dry years such as 2001, 2008, 2009, and 2013, but also exhibit gains during the periods from 2001 to 2002 and from 2013 to 2014.

The Kern River is outside of the KGA jurisdictional area. For more information see the Olcese and Kern River GSA GSPs.

2.3.5.4 Data Gaps

Although available data confirm that the Kern River is not interconnected with the underlying groundwater downstream of the First Point of Measurement, it appears that the Kern River from Democrat Springs to the First Point of Measurement may be gaining flow, with accretion from groundwater being one of the sources contributing to these gains. However, available data between these two locations (approximate 22 1/2-mile reach) are not adequate to refine the assessment of gaining and losing segments from the east boundary of the Subbasin to the First Point of Measurement (approximate 10-mile reach). In this regard, there are several mapped springs throughout the Kern River Canyon, with an absence of any mapped springs below the mouth of the canyon within the Subbasin, indicating that the majority of gains are likely within the canyon. For additional information see the Olcese and Kern River GSA GSP.

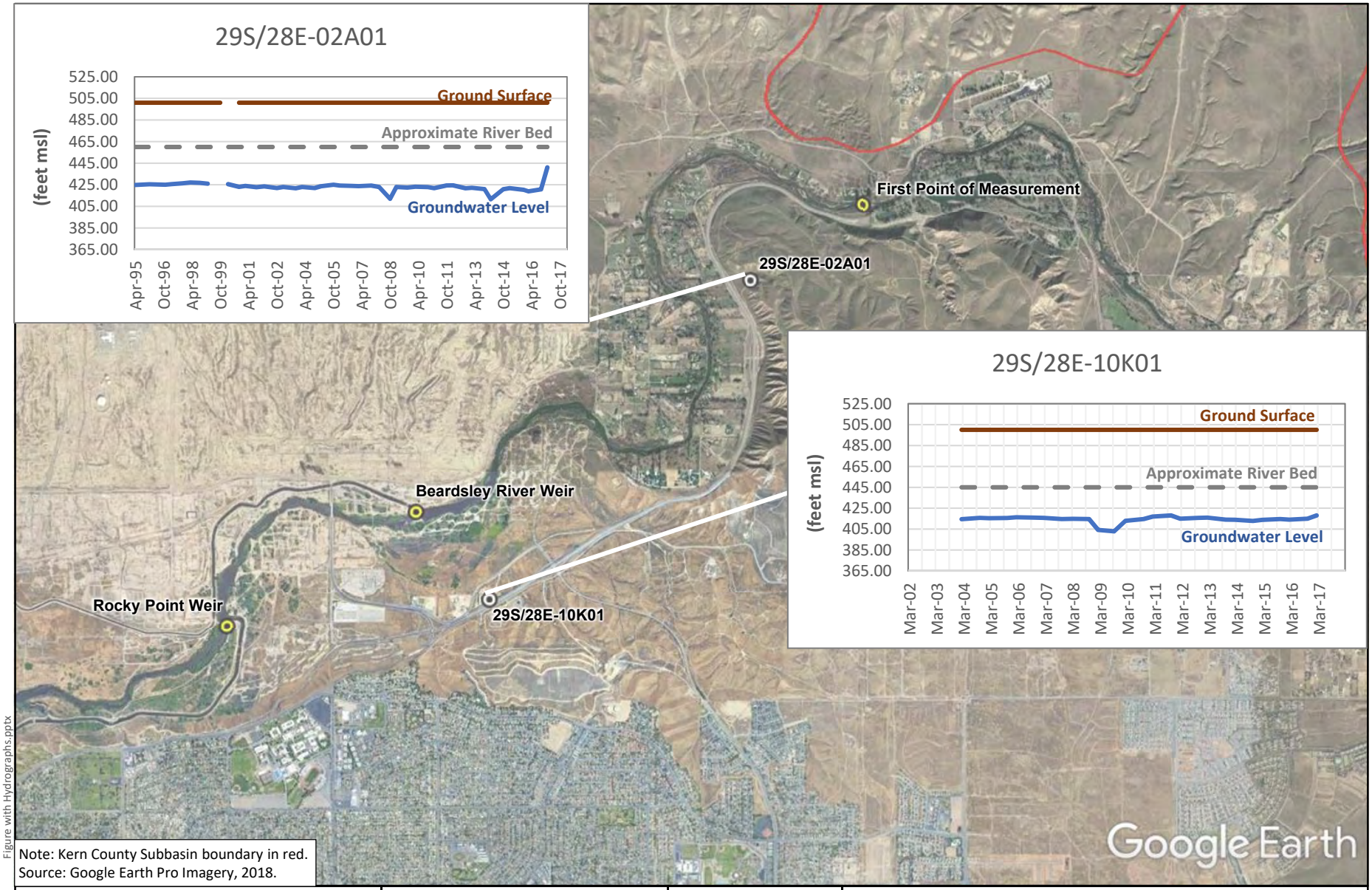


Figure with Hydrographs.pptx

Note: Kern County Subbasin boundary in red.
Source: Google Earth Pro Imagery, 2018.

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Mile
(Approximate)

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Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

SUPPLY WELL HYDROGRAPHS

AUGUST 2019

Figure 2-46

2.3.6 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are ecological communities that depend on groundwater emerging from aquifers or groundwater occurring near the ground surface (shallow water table). In the Kern Subbasin, potential GDEs are likely to be associated with wetlands and riparian areas that are supported either by shallow groundwater or by a combination of shallow groundwater and surface water. As discussed previously, shallow groundwater is present in west-central and southern portions of the Subbasin. Ephemeral wetlands covered by water seasonally are likely to be supported by irrigation deliveries and precipitation and are unlikely to be surface expressions of groundwater. For example, the Kern National Wildlife Refuge, is now sustained by imported surface water (USFS, 2005). Other features having the potential to provide habitat, such as groundwater recharge basins that are artificially flooded with surface water, also depend on diversion of surface water rather than a shallow groundwater table. The distribution of potential GDEs in the Kern Subbasin was assessed based on DWR's Natural Communities Commonly Associated with Groundwater (NCCAG) data.

The following is taken from the DWR Natural Communities dataset website for NCCAG (DWR, 2019):

> *"*The Natural Communities dataset is a compilation of 48 publicly available State and Federal agency datasets that map vegetation, wetlands, springs, and seeps in California. A working group comprised of DWR, the California Department of Fish and Wildlife (CDFW), and The Nature Conservancy (TNC) reviewed the compiled dataset and conducted a screening process to exclude vegetation and wetland types less likely to be associated with groundwater and retain types commonly associated with groundwater, based on criteria described in Klausmeyer et al., 2018. Two habitat classes are included in the Natural Communities dataset: (1) wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions; and (2) vegetation types commonly associated with the sub-surface presence of groundwater (phreatophytes)."

The data included in the Natural Communities dataset do not represent DWRs determination of a GDE. However, the Natural Communities dataset can be used by GSAs as a starting point when approaching the task of identifying GDEs within a groundwater basin."

Figure 2-47 shows CDFW lands in the Central Region. Similarly, Figure 2-48a and 2-48b shows potential location of wetlands and GDEs in the Subbasin, respectively, as identified in the National Hydrography Dataset. In addition, the surface water bodies from the National Hydrography Dataset are also discussed in relation to potential GDEs.

The below discussion presents NCCAG dataset of the Subbasin. Any further details regarding these mapped datasets are provided in the management area plans. Where data gaps exist, future monitoring and GSP updates will seek to fill these gaps, as described in the management area plans of the individual KGA members.

2.3.6.1 NCCAG Mapped Data

Figure 2-29 displays the locations of seeps and springs based on data extracted from the National Hydrography Dataset at the base of the mountains and foothills in the southeast, southwest, and northwest edges of the Subbasin.

Figure 2-48a and 2-48b displays NCCAG data in the Subbasin. NCCAG features are mapped along spring-fed streams in the southwest along the perimeter of the Subbasin: Santiago Creek to San Emigdio Creek situated in the Wind Wolves Preserve. Toward the east, Pleitito and Pleito Creeks have mapped NCCAG datasets. Potential spring-fed streams to the southeast of Sycamore Canyon Golf Course may have associated NCCAG mapped data. In the southeast corner of the Subbasin, in the highlands along the Caliente Creek drainage are mapped NCCAG features. On the eastern side of the Subbasin, NCCAG wetlands and vegetation are mapped along the Kern River and Poso Creek. On the northern boundary of the Subbasin, NCCAG wetlands and vegetation are mapped in the Kern River channel to the southwest of Kern Wildlife Refuge. Along the western edges of the Subbasin, there are mapped NCCAG features.

Groundwater potentiometric surfaces from Kern Fan Monitoring Reports (KCWA, 2016) indicate that underlying aquifers are not connected with stream channels. Some flow in the Kern River, as well as in Poso Creek and other mountain-front creeks, is likely to be sustained periodically by release of bank storage (surface water stored in stream banks), but the underlying groundwater is too deep to sustain flow in the valley floor.

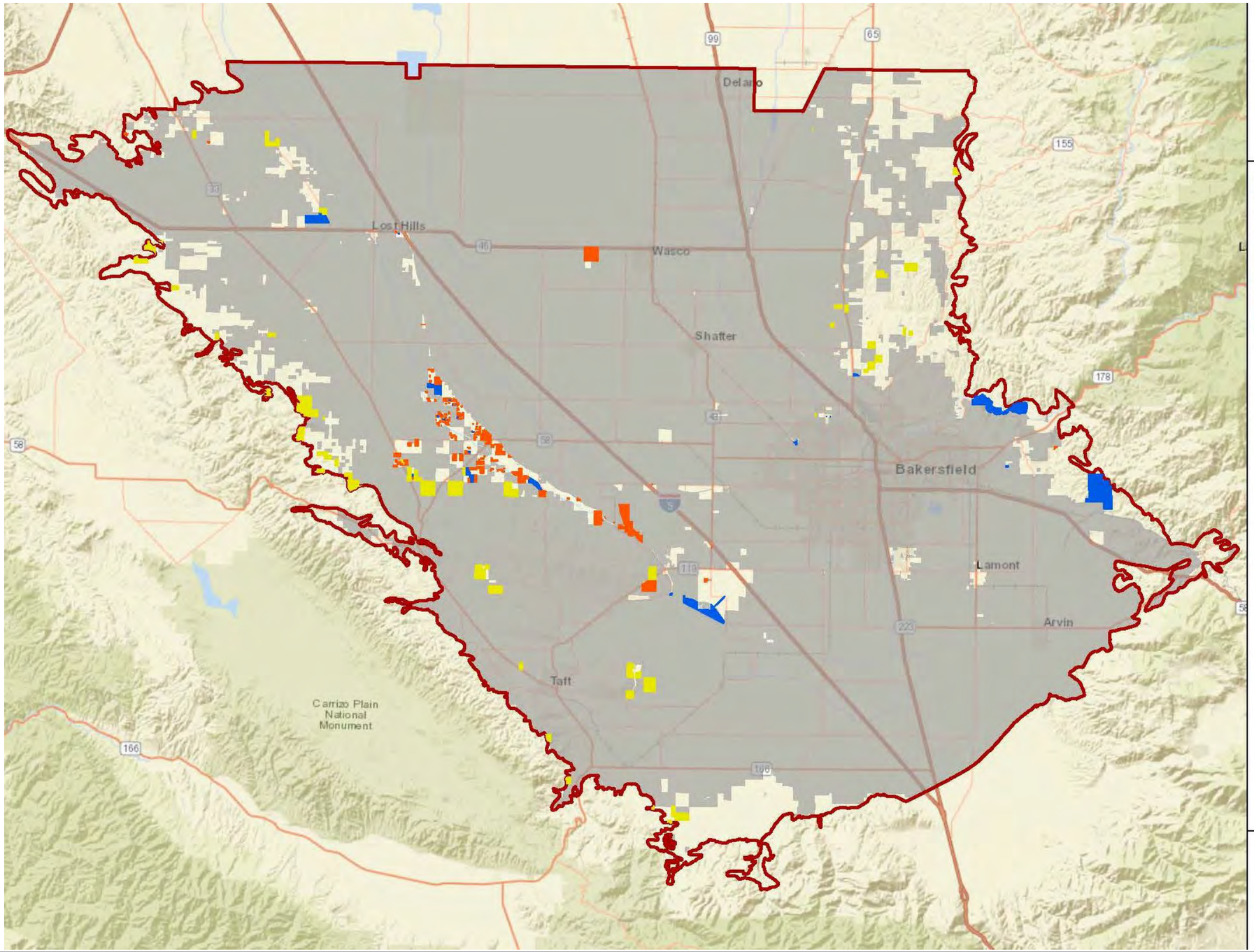
2.3.6.2 Evaluation of NCCAG Results

The conditions in the center of the Subbasin suggest that the groundwater production aquifer does not reach the shallow subsurface. The production aquifer lies at depths that prevent surface water expressions or accessibility for vegetation. The respective chapters within this GSP may present additional data regarding NCCAG mapped dataset.

Based on the NCCAG dataset along the margins of the Subbasin where spring-fed streams exist, further confirmation is needed to evaluate the presence of GDEs. Chapter-level GSPs, where necessary, provide local details regarding the current understanding of potential GDEs in the respective area.

In the west-central and southern-central Subbasin, shallow groundwater levels are present. These clays have historically been a concern regarding encroachment of poor-quality perched groundwater into crop root zones. The shallow groundwater in the west-central and southern-central Subbasin is not well suited for agricultural or domestic water supply; therefore, existing water management practices and practices that may be introduced through the implementation of SGMA are unlikely to draw on the shallow groundwater that may support potential GDEs.

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Kern Groundwater Authority

SJV Kern County GW Subbasin (DWR B118, 2019)

White Area Parcels

By Agency

- County
- Federal
- State

Areas Covered by Agencies

- District Boundary and Managment Areas (parcels)

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	Kern County Groundwater Authority	GEI Consultants	STATE AND FEDERAL LANDS IN THE KERN COUNTY SUBBASIN
	Kern County, California		December, 2019 Figure 2-47

Delano
McFarland
Lost Hills
Wasco
Shafter
Buttonwillow
Bakersfield
McKittrick
Lamont
Arvin
Taft
Tehachapi
Poso Creek
Friant-Kern Canal
Kern River
Lake Isabella
Cross Valley Canal
Caliente Creek
California Aqueduct
Tejon Creek
Pleito Creek
Santiago Creek
San Emigdio Creek
Santa Margarita Lake
Salinas River
Lopez Lake
Twitchell Reservoir
Santa Maria River
Cuyama River
99
5

Wetlands (NCCAG)
USGS Extent of Corcoran Clay
Kern Subbasin Boundary

SOURCE: Natural Communities Commonly Associated with Groundwater (NCCAG), May 2018

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Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

NCCAG WETLANDS

JANUARY 2019

Figure 2-48A

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Delano
McFarland
Lost Hills
Wasco
Shafter
Buttonwillow
Bakersfield
McKittrick
Lamont
Arvin
Taft
Tehachapi
Poso Creek
Friant-Kern Canal
Kern River
Lake Isabella
Cross Valley Canal
California Aqueduct
Caliente Creek
Tejon Creek
Santa Margarita Lake
Salinas River
Lopez Lake
Twitchell Reservoir
Santa Maria River
Cuyama River
Santiago Creek
San Emigdio Creek
Pleito Creek
99
5

Vegetation (NCCAG)
USGS Extent of Corcoran Clay
Kern Subbasin Boundary

SOURCE: Natural Communities Commonly Associated with Groundwater (NCCAG), May 2018

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Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

NCCAG VEGETATION

JANUARY 2019

Figure 2-48B

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2.4 Water Budget Information

All GSAs in the Subbasin coordinated and collaborated on the development of water modeling budgets (historical, baseline and projected). The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop a groundwater model on behalf of the Subbasin. The contract required that Todd Groundwater use the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) provided by DWR. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions, as described below. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (Attachment H). Subbasin -wide water budget results from the numerical model-based water budget are provided in Attachment H and show the Subbasin, as a whole, has a total storage deficit of 324,326 acre-feet per year (AFY) over the baseline period.

The Subbasin's dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a separate water accounting system using Subbasin specific values for supply, demand and net results. The C2VSim model results reflect Subbasin-wide conditions and does not allocate water shortages/surpluses, nor do the results allocate the "ownership" of water. As a result, the GSAs, through a coordinated effort, developed water budgets that estimate current conditions for each GSA that are generally consistent with the C2VSim model results under baseline condition. These GSA-level budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability. Table 2-8 reflects the coordinated development the GSA-level water budgets for the Kern Subbasin and is also included in the Coordination Agreement for the Kern Subbasin.

Table 2-8: Kern Subbasin GSA-Level Water Budgets

Entity	Total Water Demand (acre-feet)	Total Water Supply (acre-feet)	Net Water Budget (acre-feet)
Kern Groundwater Authority	1,939,409	1,683,128	-256,281
Henry Miller GSA	40,884	35,791	-5,093
Olcese Water District GSA	2,650	3,202	552
Kern River GSA	305,310	276,157	-29,153
Kern River GSA – App K Properties	1,308	0	-1,308
Buena Vista GSA	103,950	126,936	22,986
Non-Districted Lands*	18,013	0	-18,013
TOTALS:	**2,411,524**	**2,125,214**	**-286,310**
Todd Groundwater Model Results for Baseline Condition:			**-324,326**
Todd Groundwater Model Results for Historical Change in Groundwater Storage:			**-277,114**

*Most of the irrigated non-districted lands are now managed /covered under SGMA by GSAs.

To ensure the KGA individual water budgets reflected actual conditions, the KGA members developed a coordinated water accounting methodology. The result of that effort indicates a current baseline shortage/deficit for KGA members of -256,281 AFY[1]. This reflects the difference between a total demand for KGA members of 1,939,409 AFY, and a total supply of 1,683,128 AFY. Each KGA member agency management area plan reflects their consistent management area water budget in their individual water budget sections.

2.4.1 Model Development

SGMA regulations require that water budget analyses for GSPs be conducted on a basin-wide basis. DWR developed C2VSim to simulate water demands and supplies in the Central Valley. The C2VSim Fine Grid Beta Model (C2VSimFG-Beta) is derived from a series of Central Valley hydrologic models developed by DWR and other agencies beginning in the early 1990s. C2VSimFG Beta includes historical input data for WY1922-2015 in the Kern Subbasin. These data include monthly precipitation and annual land use for each model element and estimated monthly evapotranspiration for each modeled land use type and agricultural crop. Historical surface water data include monthly surface water inflow for each river entering the model boundary and monthly surface water diversions.

C2VSimFG Beta input files have been modified to incorporate locally-derived managed water supply and demand data to better represent the local water balance for the Subbasin. known as C2VSimFG-Kern model. This model includes revised data for the Kern County subbasins to better represent local water conditions. To comply with the SGMA water budget requirements (Section 354.18), the KGA and the other four GSAs in the Subbasin engaged in a basin-wide effort to develop a basin-wide groundwater model. The results of this effort are provided in Attachment H - TODD Groundwater C2VSimFG-Kern Report and Results, which is summarized below.

2.4.2 Data Compilation

Historical surface water diversions, water bank recharge and water bank withdrawal information were collected from Kern County water purveyors. Urban land use was restricted to developed areas, and urban populations and per-capita water demands were updated. Detailed description of data compilation methodology, assumptions and sources are provided in Attachment H: Historical and Projected Future Water Budget Development with C2VSimFG-Kern.

[1] The water supplies available to each KGA member from the Pioneer and Kern Water Bank banking programs are incorporated into the listed total available supplies. Note that both programs only store surface supplies, and do not have consumptive demands that contribute to the listed shortages. For more detail on the banking projects, please see the respective chapters.

2.4.3 Historical and Current Water Budget

C2VSimFG-Kern was used to develop historical (WY1995 to WY2014) water budget for the Kern County Subbasin and is presented in Figure 2-49. The results are summarized as follows:

- **Deep Percolation –** This is defined as precipitation and applied water that reaches the groundwater after simulated transport across the unsaturated zone. The simulated historical 20-year average resulted in a net inflow of 669,398 AFY.
- **Managed Recharge and Canal Seepage –** This is defined as combined groundwater recharge from managed aquifer recharge operations, groundwater banking, and seepage from canals and other conveyance. The simulated historical 20-year average resulted in a net inflow of 583,598 AFY.
- **Net Groundwater-Surface Water (GW/SW) Interactions –** This is defined as net volumetric exchange of surface water and groundwater between the aquifer and streams: Positive represents a net groundwater recharge, and negative represents a net groundwater discharge to the stream. The simulated historical 20-year average resulted in a net inflow of 98,606 AFY.
- **Groundwater (GW) Pumping –** This is defined as total groundwater pumping by wells. Groundwater banking recovery pumping is specified as fixed input values and agricultural and municipal pumping is calculated by C2VSimFG-Kern based on demand minus surface water diversions. The simulated historical 20-year average resulted in a net outflow of 1,590,373 AFY.
- **Small Watershed Inflow –** This is defined as runoff, small stream inflow and subsurface inflow from the small watersheds and areas surrounding the groundwater basin. The simulated historical 20-year average resulted in a net inflow of 48,760 AFY.
- **Subsurface Flow with Adjacent Groundwater (GW) Basins –** This is defined as net subsurface groundwater flow to and from the Subbasin with adjoining groundwater basins: negative is a net flow out of the Subbasin and positive is a net flow into the Subbasin. The simulated historical 20-year average resulted in a net outflow of 87,102 AFY.
- **Change in Groundwater Storage –** This is the sum of the inflow components (positive numbers) plus the outflow components (negative numbers): positive is an increase in storage typified by a rise in groundwater levels whereas a negative is a decrease in storage typified by a decline in groundwater levels. The simulated historical 20-year average resulted in a decline in groundwater storage of 277,114 AFY.

Figure 2-50 presents the average annual historical water budget for the Subbasin that includes the out-of-basin groundwater banking obligation of 85,965 AFY.

Figure 2-51 shows the simulated annual and cumulative change in groundwater storage over the 20-year historical period. It was observed that during the periods of WY1995 to WY2000, WY2005 to WY2006 and WY2010 and WY2011, the groundwater storage volume was stable to

increasing and correlates to the above average rainfall and surface water availability during these times. Similarly, during the periods WY2001 to WY2004, WY2007 to WY2009 and WY2012 to WY2015, groundwater storage volume decreased, correlated to periods of drought and low surface water availability. Figure 2-52 shows the simulated historical groundwater recharge by source that also reflects a climatic pattern with high deep percolation to groundwater and steep increases in managed aquifer recharge and canal seepage during the above average rainfall periods and lower groundwater recharge during the drought years.

As a result, groundwater pumping for agriculture shows a general increasing trend from WY1995 to WY2014; however, groundwater pumping is lower in above average rainfall years and higher during droughts as shown in Figure 2-53. This general increasing trend follows a comparable decreasing trend in surface water deliveries over the same period as shown in Figure 2-54.

2.4.3.1 Sustainable Yield

SGMA defines Sustainable Yield as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result". To determine the sustainable yield for the Kern Subbasin, the results of the C2VSimFG-Kern model were used with two methods to estimate the amount of groundwater pumping that would avoid the undesirable result of a reduction in groundwater storage over the historical base period 1995 to 2014.

- **Sustainable Yield from Groundwater Pumping** – The model results produced an average annual groundwater pumping in the Kern Subbasin of 1,590,373 AFY with a decline in groundwater storage of 277,114 AFY. Subtracting the groundwater storage decline from groundwater pumping produced a sustainable yield of approximately 1,313,000 AFY for the Kern Subbasin.
- **Sustainable Yield from Groundwater Recharge** – The model results produced an average annual groundwater recharge in the Kern Subbasin of 1,400,362 AFY. The subsurface outflow from the GSA totals 87,102 AFY. Subtracting these losses from the groundwater recharge produced a sustainable yield of approximately 1,331,000 AFY.

Using WY1995 to WY2015 as the base period, C2VSimFG-Kern results show declining groundwater levels and long-term reduction of groundwater storage. During this period, average annual inflow to the aquifer is 1,400,362 AFY, and outflow is 1,677,475 AFY. This yields an average annual deficit of 277,144 AFY. Based on these historical C2VSimFG-Kern results, the sustainable yield of the basin is approximately 1,313,000 AFY, plus or minus 10%.

2.4.3.2 Native Yield

SGMA does not require the native yield to be considered or addressed, however, in the process of working on the Sustainable Yield, water budget allocations, and the water modeling for the entire Kern Subbasin, the discussion of the native yield and how best to address it in the Kern Subbasin occurred. The C2VSimFG-Kern results does model the concept of native yield,

however, as described in section 4.2.2 of Attachment H, the Native Yield at this time is based on available data. However, there exists in this area data gaps and as such, as those data gaps are eliminated and management actions are implemented, the estimate of native yield is likely to change. With the current available data for input to the C2VSimFG-Kern, the model provides the following results:

- The volume of precipitation that recharges the groundwater in the irrigated agricultural areas is 77,780 AFY
- The volume of precipitation that recharges groundwater in the other areas is 132,981 AFY
- The volume of inflow from unallocated small watersheds that recharges the groundwater in the irrigated agricultural areas is 48,760 AFY
- The above inputs resulted in a native yield for the Kern Subbasin of 259,520 AFY which resulted in the native yield estimate of 0.144 acre-feet per acre for the total area of the Kern County Subbasin.

During the process of working through the water budget allocations for the entire Kern Subbasin with all GSAs, the native yield was one of the most critical supply source to be coordinate. Acknowledging the presence of data gaps and implementation of projects and management actions, the GSAs of the Kern Subbasin have agreed to the continued analysis and refinement of the native yield, from a technical and legal basis. This has been identified as a management action for the KGA, in coordination with all other Kern Subbasin GSAs, in 2020.

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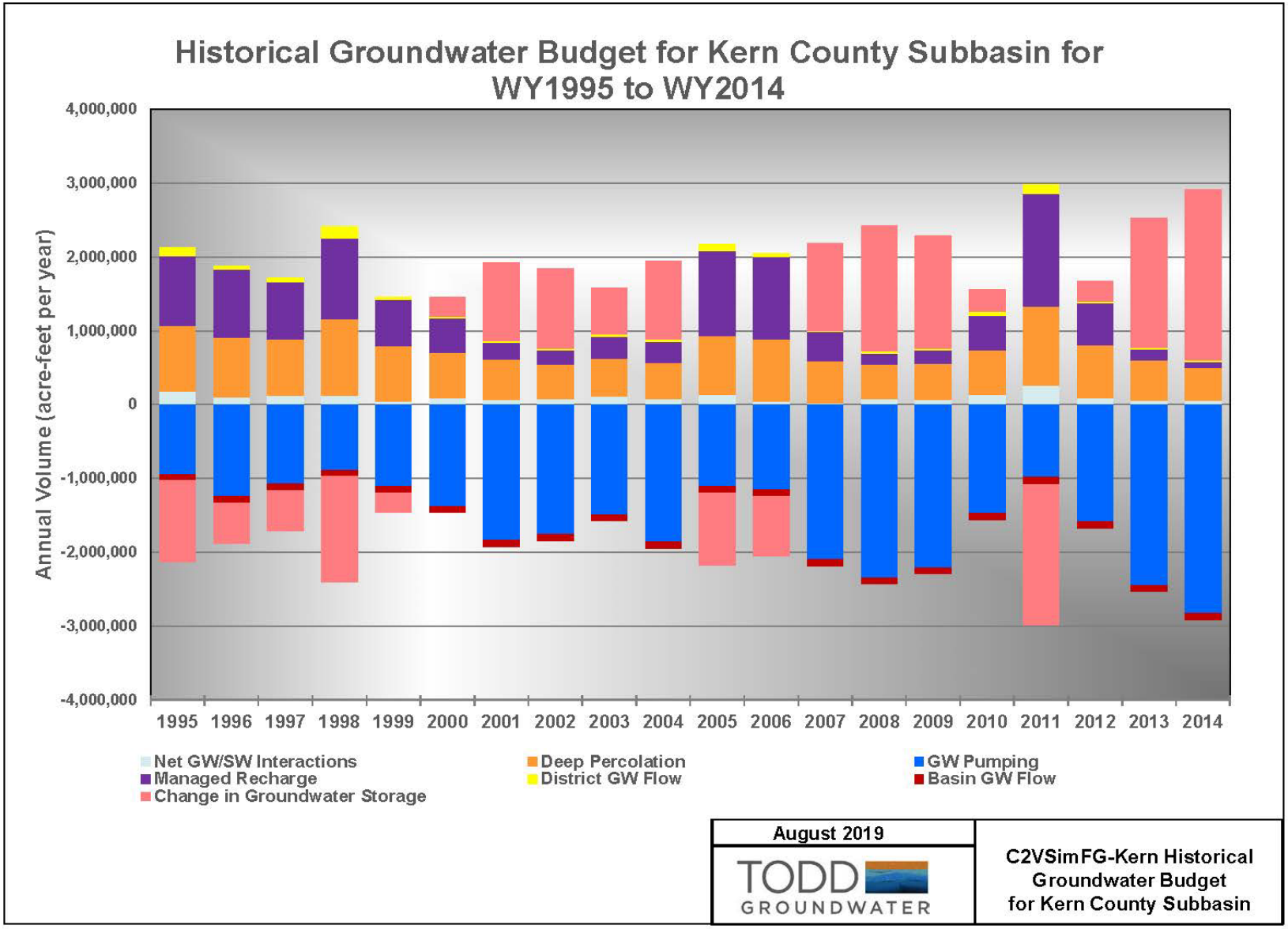


Figure 2-49. Historical Groundwater Budget for Kern County Subbasin for WY1995 to WY2014

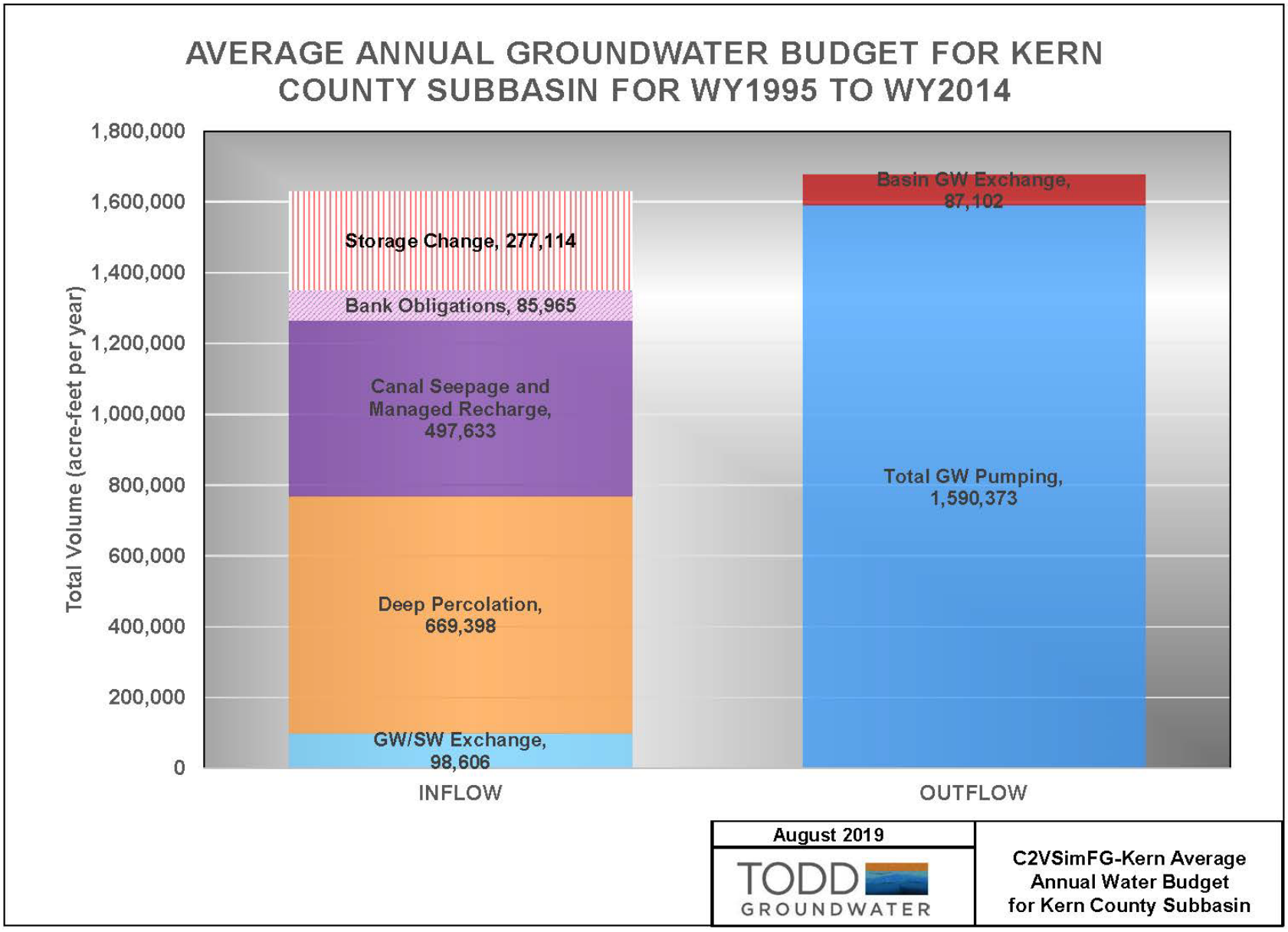


Figure 2-50. Average Annual Groundwater Budget for Kern County Subbasin for WY1995 to WY2014

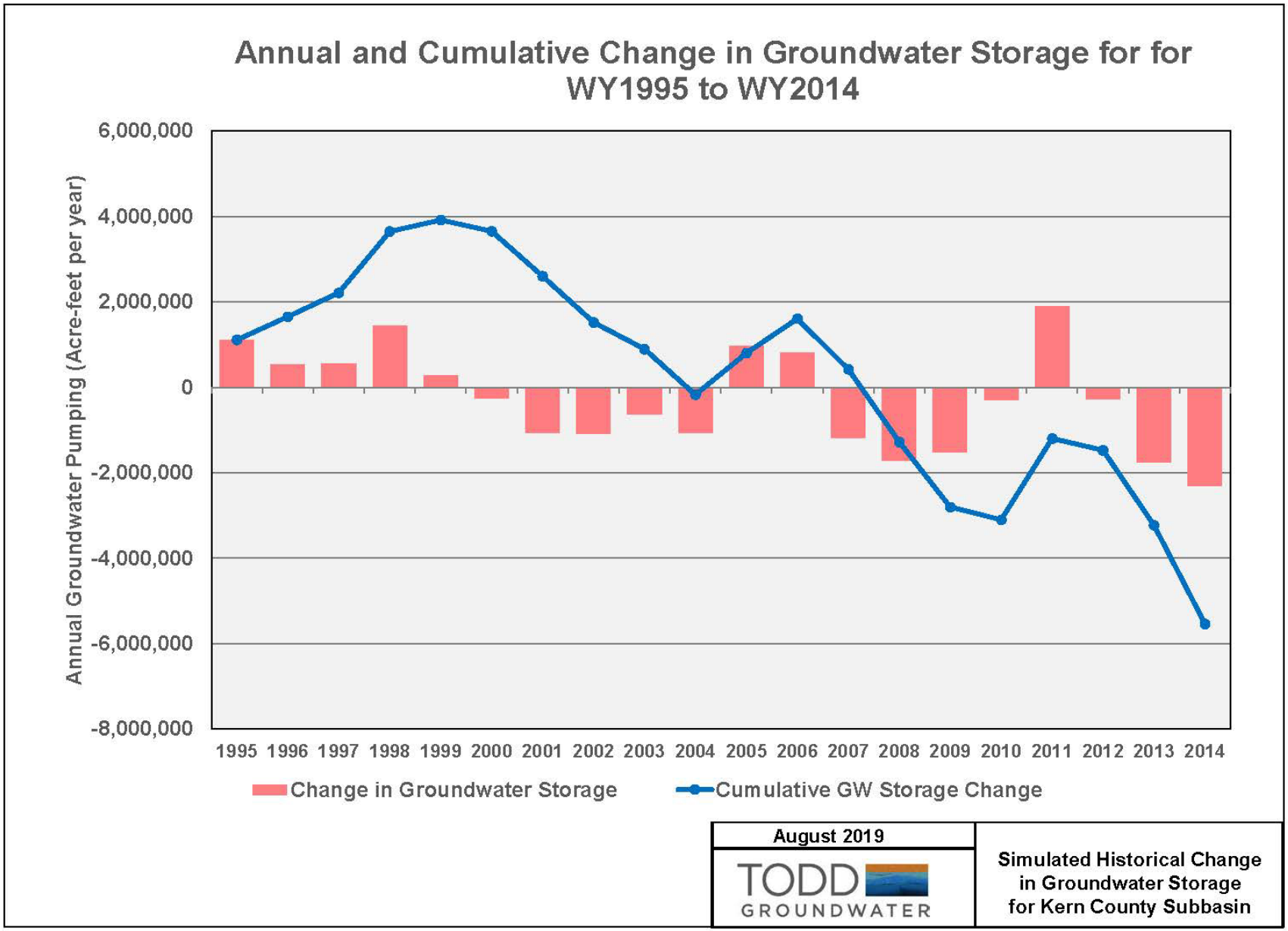


Figure 2-51. Annual and Cumulative Change in Groundwater Storage for WY1995 to WY2014

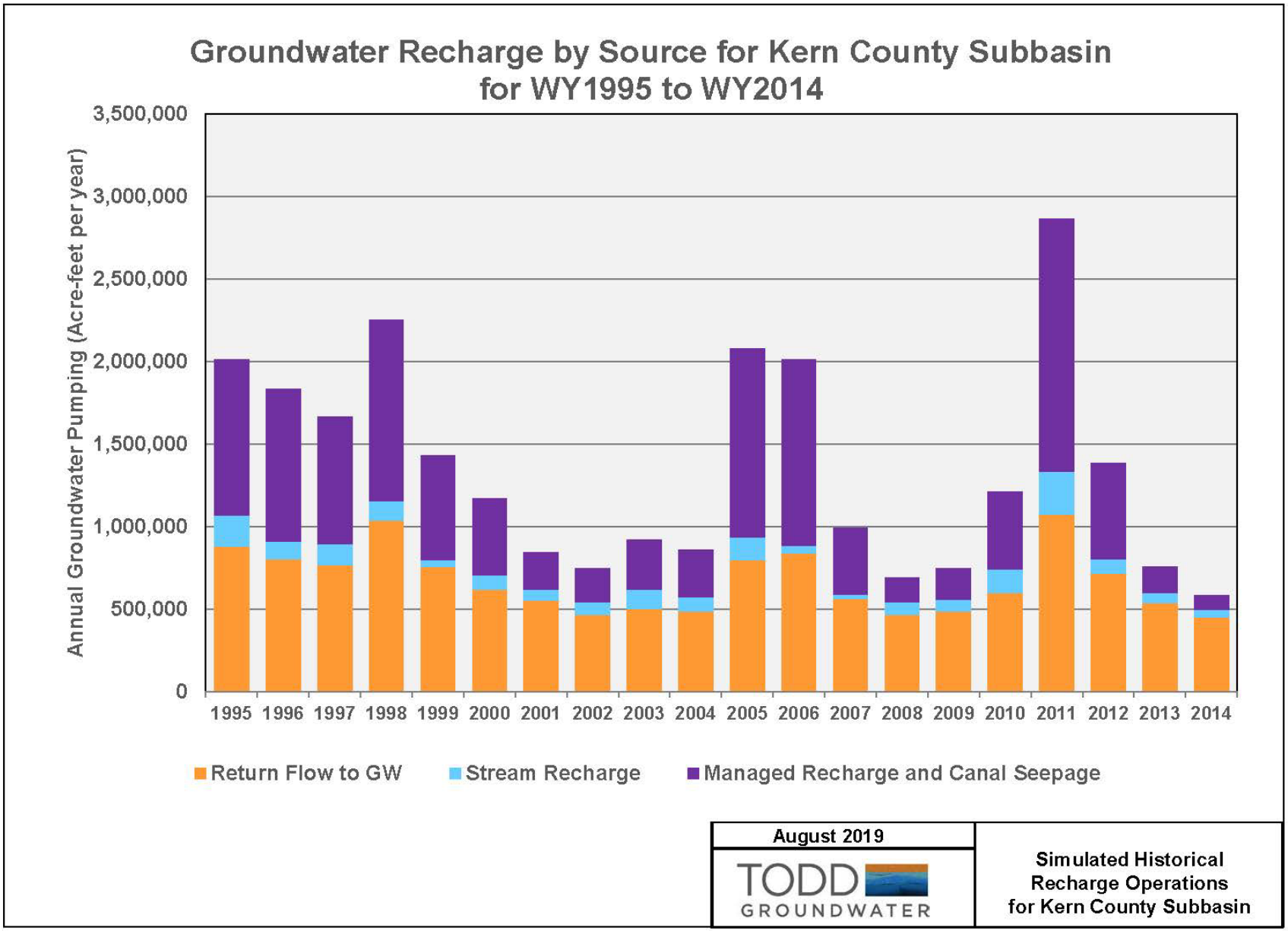


Figure 2-52. Groundwater Recharge by Source for Kern County Subbasin for WY1995 to WY2014

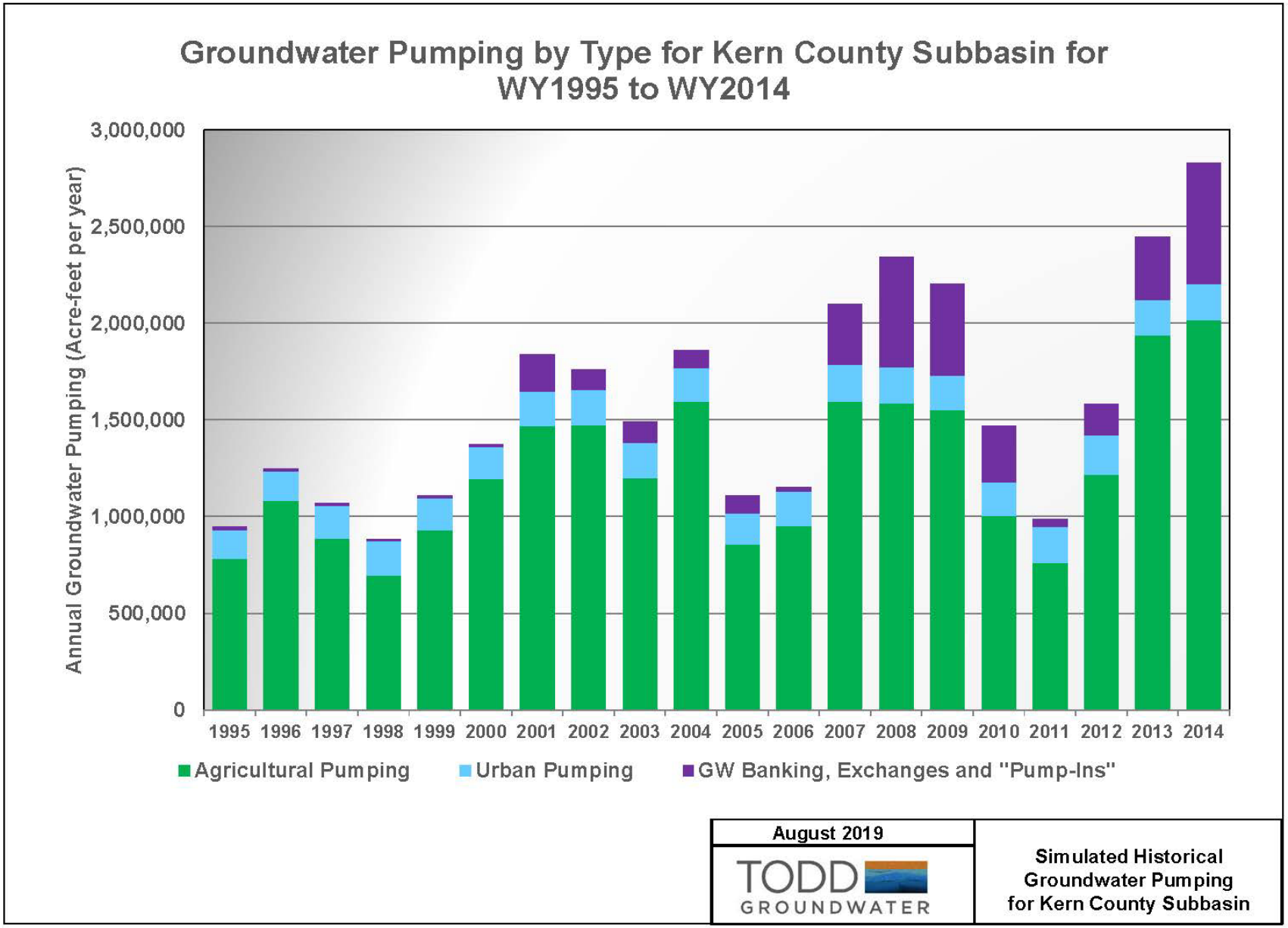


Figure 2-53. Groundwater Pumping by Type for Kern County Subbasin for WY1995 to WY2014

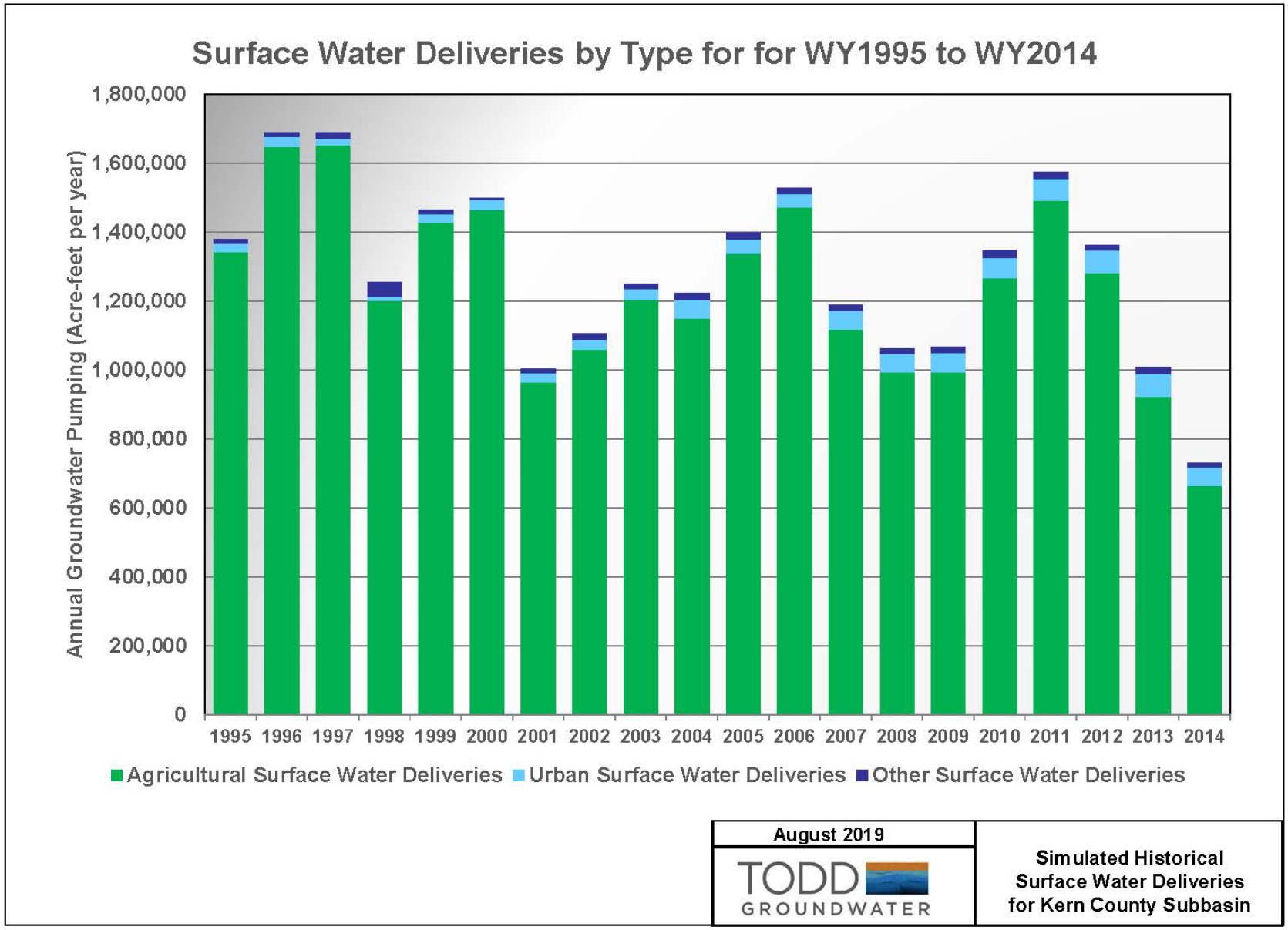


Figure 2-54. Surface Water Deliveries by Type for WY1995 to WY2014

2.4.4 Projected Future Water Budgets without SGMA Implementation

Projected future water budgets for the Subbasin were developed using the C2VSimFG-Kern for future baseline conditions and 2030 and 2070 Climate Conditions over a 50-year planning and implementation horizon. These scenario models provide a basis of comparison for evaluating proposed sustainability management actions and projects over the SGMA planning and implementation horizon.

- **Future Baseline Conditions:** Repeat historical hydrology with future water supply reliability provided by DWR.
- **2030 Climate Conditions:** Adjust historical hydrology for 2030 climatic conditions and water supply reliability provided by DWR.
- **2070 Climate Conditions:** Adjust historical hydrology for 2070 climatic conditions and water supply reliability provided by DWR.

Detailed description of assumptions, hydrology estimations, precipitation rates, surface water deliveries, sources of data and groundwater banking conditions are provided in Attachment H: Historical and Projected Future Water Budget Development with C2VSimFG-Kern.

2.4.4.1 Future Baseline Water Budget

The Baseline Scenario simulates how the Subbasin aquifer would respond if the recent hydrology were repeated with current expected surface water availability and current land use. The primary difference between historical conditions and the projected future baseline is a nearly 20% decrease in imported surface water deliveries primarily from the SWP due to the long-term Operational Criteria and Plan (OCAP) Biological Opinion and is replaced with additional groundwater pumping. As a result, total net aquifer outflows increase by about 35,600 AFY, total net aquifer inflows decrease by about 11,600 AFY with the average groundwater pumping of 1,625,000 AFY, which includes agricultural pumping, urban pumping and exported water. This results in an additional loss of groundwater storage of about 47,200 AFY over the 50-year projected future baseline. Baseline simulation results indicate that the Subbasin has an average annual overdraft of 324,326 AFY, however, with the implementation and completion of projects and management actions as stated in the individual management area plans and GSPs from the other GSAs in the Subbasin, the baseline simulation results show that the Subbasin has an average surplus of 85,578 AFY.

2.4.4.2 2030 Climate Change Water Budget

The 2030 Scenario simulates how the Subbasin aquifer would respond assuming hydrologic conditions representing a potentially drier climate (no or limited amount of snow pack) and are based on the DWR Climate Change Guidance (DWR 2018). The 2030 DWR climate change factors were applied to the Baseline Scenario Conditions. Additional adjustments were made to the imported surface water supplies from the SWP, CVP and Kern River, accounting for about an additional 2% decrease from the Baseline Conditions.

The results show a net increase in aquifer inflows of about 44,700 AFY along with an increase in aquifer net outflows of about 101,200 AFY. This is mostly attributed to the climate shift to earlier rainfall making more surface water available for managed aquifer recharge during the winter but less available for irrigation in the summer resulting in higher groundwater pumping. The net change in groundwater storage is an additional decline of about 56,600 AFY due to the climate change impacts. 2030 Climate Change simulation results indicate that the Subbasin has an average annual overdraft of 372,120 AFY with the net change in groundwater storage showing an additional decline of about 47,794 AFY, compared to the Baseline, due to the climate change impacts. However, with the implementation and completion of management actions/projects as stated in the individual management area plans and GSPs from the other GSAs in the Kern Subbasin, 2030 Climate Change simulation results indicate that the Subbasin has an average deficit of approximately 46,829 AFY.

2.4.4.3 2070 Climate Change Water Budget

The 2070 Scenario simulates how the Subbasin aquifer would respond assuming hydrologic conditions representing a potentially very dry climate and are based on the DWR Climate Change Guidance (DWR 2018). The 2070 DWR climate change factors were applied to the Baseline Scenario Conditions. Additional adjustments were made to the imported surface water supplies from the SWP, CVP and Kern River, but these accounted for an additional 6% decrease from the Baseline Conditions. The 2070 Climate Change Scenarios were run both with and without SGMA Projects.

The results show a net increase in aquifer inflows of about 66,100 AFY along with an increase in aquifer net outflows of about 231,600 AFY. This is mostly attributed to an even greater climate shift to earlier rainfall making more surface water available for managed aquifer recharge during the winter but less available for irrigation in the summer resulting in higher groundwater pumping. 2070 Climate Change simulation results indicate that the Kern County Subbasin has an average annual overdraft of 472,336 AFY with the net change in groundwater storage showing an additional decline of about 148,010 AFY due to the climate change assumptions. As indicated in the above model simulations, with the implementation and completion of management actions/projects as stated in the individual management area plans and GSPs from the other GSAs in the Kern Subbasin, the 2070 Climate Change model results unfortunately still indicate a average deficit of 45,969 AFY.

2.5 Management Areas

KGA members worked together to establish management areas within the Subbasin to implement projects and management actions as well as better capture local groundwater conditions. In order to prevent undesirable results in adjacent management areas, members have established minimum thresholds consistent with each other.

The Subbasin consists of many entities with land use or water management authority. While a majority of these entities are members of the KGA who have water management authority as explained in Section 1.4, they retain their local responsibility for compliance with SGMA. The County of Kern and municipalities located within the management areas retain their land use

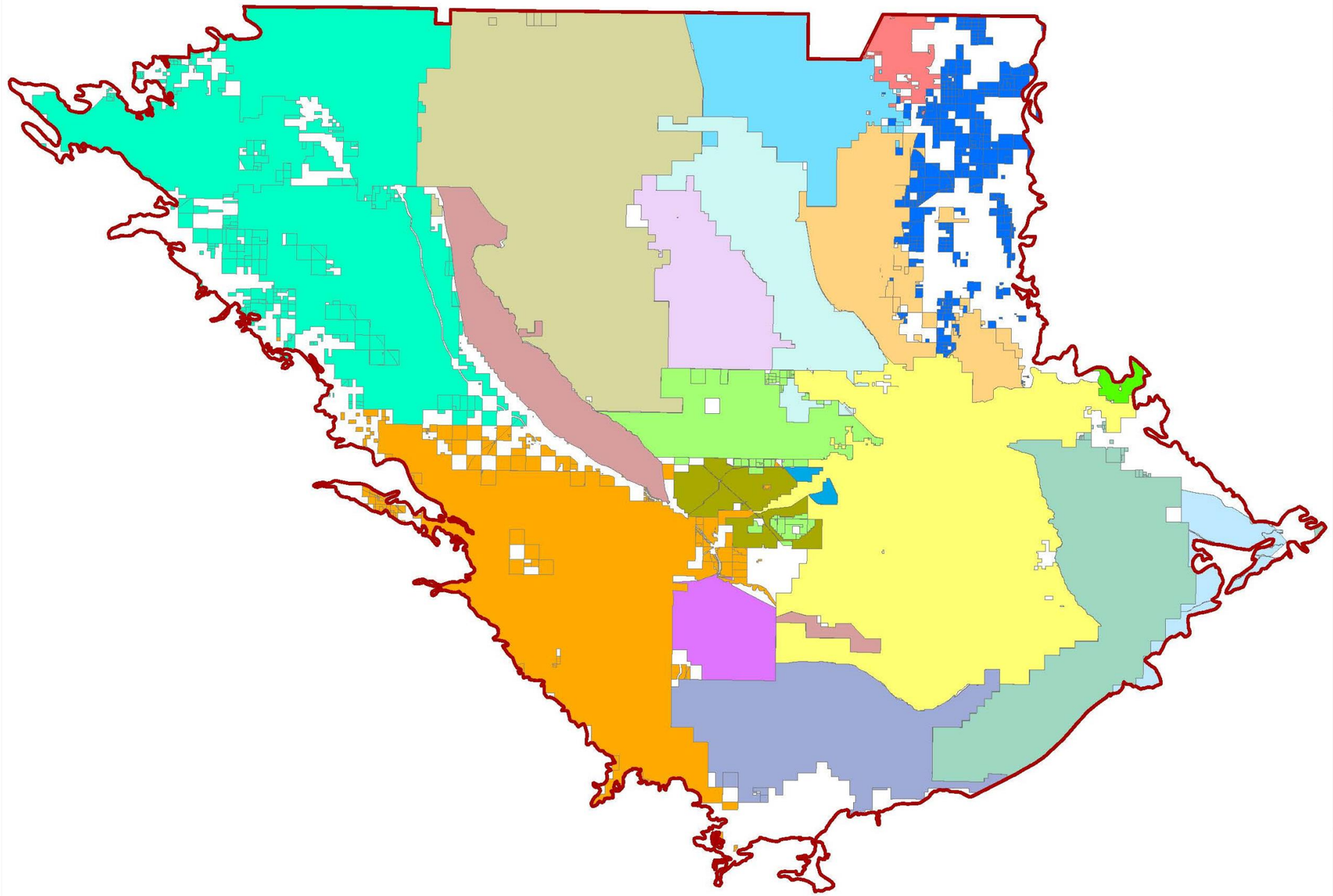
jurisdiction. Ultimately the members of the KGA have the responsibility to implement projects and management actions, as described in Section 4 of this GSP and in the individual management area plans, to achieve sustainability within their management areas. The management areas are summarized in Table 2-9 and presented on Figure 2-55. A detailed explanation of each management area under the KGA is provided in their respective management area plans. The following section provides a brief overview of how and why management areas were created as well as how each area will be managed.

Management areas were created by the districts/member agencies under the KGA to support groundwater sustainability in the Subbasin. Due to the size and variability of water supplies in the region, 25 management areas were created to better manage groundwater. While there is no one approach, majority of the management areas in the region maintain respective district boundaries. Districts and member agencies under the KGA already maintain/manage water rights, contracts, and governing agreements in their regions. By creating their own management areas, Districts/members can maintain/manage maximum flexibility and control over SGMA compliance within its service area, allowing them to implement projects and management actions applicable to their respective areas.

Management areas are designated within the Subbasin to leverage existing relationships with water users for local water accounting and management actions of imports; exports; water consumption and conservation; and groundwater pumping. While most were created from district boundaries, other management areas were developed based off groundwater and geological conditions in each respective service area, which is why some districts have multiple management areas as shown in Table 2-9. These management areas will preserve groundwater management practices and implement additional requirements set forth in this GSP. The JPA with KGA allows for each district or member agency to establish individual management areas and manage them to support the sustainability of the region.

Table 2-9. Management Areas Under the Kern Groundwater Authority

No.	Management Area Plan	MA NO.	Management Areas
1	Arvin-Edison Water Storage District (AEWSD)	AEWSD MA-1	Arvin-Edison Management Area
2	Cawelo Water District (CWD)	CWD MA-1	Cawelo Water District
3	Eastside Water Management Area (EWMA)	EWMA MA-1	Eastside Water Management Area
4	Kern Water Bank (KWB)	KWB MA-1	Kern Water Bank
5	Kern-Tulare Water District (KTWD)	KTWD MA-1	KTWD Kern County Management Area
		KTWD MA-2	KTWD Non-Service Management Area
6	North Kern Water Storage District (NKWSD) and Shafter-Wasco Irrigation District (SWID)	NKWSD MA-1	North Kern Old District Management Area
		NKWSD MA-2	Rosedale Ranch Improvement District Management Area
		SWID MA-1	SWID Management Area
7	KCWA Pioneer GSA (PGSA)	PGSA MA-1	Pioneer GSA Management Area
8	Rosedale-Rio Bravo Water Storage District (RRBWSD)	RRBWSD MA-1	Rosedale-Rio Bravo Management Area
		RRBWSD MA-2	White Lands within RRBWSD
9	Semitropic Water Storage District (SWSD)	SWSD MA-1	Management Area 1
		SWSD MA-2	Management Area 2
		SWSD MA-3	Management Area 3
10	Shafter-Wasco Irrigation District (7th Standard Rd.)	SWID MA-2	7th Standard Annex (under SWID's Jurisdiction)
11	Southern San Joaquin Municipal Utility District (SSJMUD)	SSJMUD MA-1	SSJMUD Management Area
12	Tejon-Castac Water District (TCWD)	TCWD MA-1	North of Edison Fault/Uplands Management Subarea
		TCWD MA-2	South of Edison Fault/Valley Floor Management Subarea
13	West Kern Water District (WKWD)	WKWD MA-1	North Project Management Area
		WKWD MA-2	South Project Management Area
		WKWD MA-3	Lake Management Area
		WKWD MA-4	Western Management Area
14	Westside District Authority (WDWA)	WDWA MA-1	WDWA Management Area
15	Wheeler Ridge-Maricopa Water Storage District (WRMWSD)	WRMWSD MA-1	Wheeler Ridge-Maricopa Management Area



Kern Groundwater Authority

GSA Management Areas Review

- SJV Kern County GW Subbasin (DWR B118, 2019)
- Kern Water Bank
- Cawelo GSA
- Kern River GSA
- Arvin-Edison WSD
- EWMA Member
- Kern-Tulare WD
- North Kern WSD
- Buena Vista W.S.D.
- Henry Miller W.D.
- Olcese Groundwater Sustainability Agency
- Pioneer Groundwater Sustainability Agency
- Semitropic WSD
- Rosedale-Rio Bravo WSD
- Shafter-Wasco ID (Includes Annexation)
- Southern San Joaquin MUD
- Tejon Castac WD
- Wheeler-Ridge Maricopa WSD

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Kern Groundwater Authority

Kern County, California

GEI Consultants

MANAGEMENT AREAS WITHIN KERN COUNTY SUBBASIN

January 2020

Figure 2-55

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3 Sustainable Management Criteria

3.1 Sustainability Goal

SGMA requires that a sustainability goal be defined for the basin (23-CCR § 354.22), and that the sustainability goal be defined on a basin-wide basis. As introduced in Section 1.3, the KGA, working with all GSAs and its member agencies in the Subbasin have developed the following sustainability goals for the Kern County Subbasin:

- *Achieve sustainable groundwater management in the Kern County Subbasin through the implementation of projects and management actions at the member agency level of each GSA.*
- *Maintain its groundwater use within the sustainable yield of the basin as demonstrated by monitoring and reporting groundwater conditions.*
- *Operate within the established sustainable management criteria, which are based on the collective technical information presented in the GSPs in the Subbasin.*
- *Collectively bring the Subbasin into sustainability and to maintain sustainability over the implementation and planning horizon.*

3.2 Undesirable Results

Undesirable results for each sustainability indicator have been developed through a collaborative process with all the GSAs in the Subbasin, compliant with GSP emergency regulations, which state that undesirable results are to be defined consistently throughout the basin (23-CCR § 354.20). Seawater intrusion and depletion of interconnected surface water were determined not to be present in the Subbasin; therefore, undesirable results for these sustainability indicators were not defined. Justification for these determinations is provided in Sections 3.2.4 and 3.2.5.

The undesirable results developed for this Subbasin represent a condition creating unreasonable impacts to the beneficial uses and users of groundwater over a broad area of the Subbasin. The undesirable results definition for the Subbasin allows flexibility for each management area within the Subbasin to define minimum thresholds that protect against significant and unreasonable impacts to the beneficial uses and users of groundwater within specific management areas. The minimum thresholds within a management area, which define undesirable results, have also been coordinated with other management areas and/or other GSAs to ensure that undesirable results are avoided across management areas and over broad areas of the Subbasin. Each management area plan provides details for minimum thresholds for their respective management areas and how an exceedance of those will be mitigated should they occur.

3.2.1 Criteria Used to Define Undesirable Results

Within the KGA, the criteria used to characterize an undesirable result within each management area was developed by each member of the KGA for their respective management area(s), which

is also coordinated with other management areas and/or GSAs to prevent impact to neighboring areas of the Subbasin and ensure that all areas can be sustainably managed. In all cases the undesirable result is defined as occurring when minimum thresholds within a management area are exceeded at representative monitoring sites. However, the exceedance of a minimum threshold at a single representative monitoring site does not constitute an undesirable result for the Subbasin. Each management area has defined the criteria for the number of representative monitoring sites to exceed their minimum threshold for the management area to become an undesirable result watch area and potentially an undesirable result at the basin level. For example, a management area may adopt criteria specifying that if 50% of the representative monitoring sites within the management area exceed their minimum thresholds it becomes an undesirable result watch area. The criteria used to define undesirable results for each management areas varies and is explained in each individual management area plans.

3.2.2 Undesirable Result for Chronic Lowering of Groundwater Levels

The basin-wide definition for undesirable results for chronic lowering of groundwater levels is as follows:

> *The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.*
>
> *This is determined when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area). Minimum thresholds shall be set by each of the management areas through their respective management area plans or Groundwater Sustainability Plans.*

This undesirable result definition at the Subbasin level provides flexibility at the management area level to identify the appropriate users and uses of groundwater and the levels of impacts important in that area of the Subbasin. Consistent with DWR's Draft BMP for Sustainable Management Criteria, the Subbasin recognizes that: "overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods." The Subbasin has agreed that a drought period of greater than 10-years would constitute prolonged drought and the lowering of groundwater levels or groundwater storage to below minimum thresholds resulting from a prolonged drought will not constitute an undesirable result.

Within the Subbasin, a management area will be considered an undesirable result watch area for the chronic lowering of groundwater levels when it exceeds its minimum threshold criteria, as determined by each management area. For example, one management area can be considered an undesirable result watch area when 51% of the representative monitoring sites in the management area violates their minimum threshold for groundwater levels. Similarly, another

management area can set this at 75% of their representative monitoring sites. However, if multiple undesirable result watch areas meet the criteria for a Subbasin undesirable result, as defined above, the Subbasin would be experiencing an undesirable result. To prevent the Subbasin from triggering an undesirable result as defined above, once an undesirable results watch area occurs, the Kern SGMA Coordination Committee will review and may provide direction to the effected management area(s).

Establishment of specific measurable objectives and minimum thresholds based on the above definition for this undesirable result can be found in Section 3.3 and with additional regional detail provided within each management area plan.

3.2.2.1 Potential Cause of Chronic Lowering of Groundwater Levels

Section 354.26(b)(1) of the GSP Regulations requires identification of potential causes of an undesirable result for each sustainability indicator. Potential causes of undesirable results for chronic lowering of groundwater levels vary throughout the Subbasin. Lowering groundwater levels can be attributed to increased groundwater pumping, reduced imported water supplies, reduced groundwater inflows from adjacent areas, and/or climate change that results in more frequent and extreme droughts and dry periods. For more specific information regarding the cause of chronic lowering of groundwater levels in the regions of the Subbasin, refer to the management area plans.

3.2.2.2 Potential Effects of Chronic Lowering of Groundwater Levels

Section 354.26(b)(3) of the GSP regulations requires identification of potential effects of an undesirable result for chronic lowering of groundwater levels. Potential effects of an undesirable result due to the chronic lowering of groundwater levels is the potential to affect the reasonable and beneficial use of, and access to, groundwater by overlying users. As previously mentioned, the beneficial uses and users of water varies across the Subbasin and each management area plan address the potential effects on those uses and users. Also, as previously mentioned, these plans are coordinated to avoid impacts the neighboring GSAs or management areas. As mentioned in Section 2.5 Management Areas and the reason why management areas were established, for more detailed information on how the effects or impacts to the beneficial users concerning the chronic lowering of groundwater levels in specific areas refer to the individual management area plans.

3.2.3 Undesirable Result for Reduction of Groundwater Storage

The basin-wide definition of an undesirable result for reduction of groundwater storage is as follows:

> *The point at which significant and unreasonable impacts, as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended 10-year drought period.*

This is determined when the volume of storage (above the groundwater level minimum threshold) is depleted to an elevation lower than the groundwater level minimum threshold in at least three (3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the subbasin (as measured by the acreage of each management areas). Minimum thresholds shall be set by each of the management area through their respective management area plans or Groundwater Sustainability Plans.

As with chronic lowering of groundwater levels, the above basin-wide definition allows for local determination of potentially effected uses and users and the level of impacts important to the various management areas in the Subbasin. As groundwater levels are used as proxy for groundwater storage, an undesirable result watch area for reduction of groundwater storage is defined similar to the undesirable result watch area for chronic lowering of groundwater levels.

Establishment of specific measurable objectives and minimum thresholds based on the above definition for this undesirable result can be found in Section 3.3 and with additional regional detail provided within each management area plan.

3.2.3.1 Potential Cause of Reduction of Groundwater Storage

Section 354.26(b)(1) of the GSP regulations requires identification of potential causes of undesirable results for each sustainability indicator. Potential causes of an undesirable result for reduction of groundwater storage vary throughout the Subbasin, specifically the volume of storage need to manage through a drought period. Reduction of groundwater storage can be attributed to increased groundwater pumping; reduced imported water supplies; reduced surface water and banking; reduced groundwater inflows from adjacent areas; and/or climate change that results in more frequent and extreme droughts and dry periods. Similar to the chronic lowering of groundwater levels, for more specific areas of the Subbasin and to determine the potential cause of reduction of groundwater storage, refer to the management area plan for the specific area.

3.2.3.2 Potential Effects of Reduction of Groundwater Storage

Section 354.26(b)(3) of the GSP regulations requires identification of potential effects of an undesirable result for reduction of groundwater storage. Potential effects of reduction of groundwater storage could lead the limited groundwater availability during a prolonged drought.

3.2.4 Undesirable Result for Degraded Water Quality

The basin-wide definition of an undesirable result for degraded water quality is as follows:

The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

This is determined when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the designated monitoring points within the

basin. Minimum thresholds shall be set by each of the management areas through their respective management area plans or Groundwater Sustainability Plans.

As with chronic lowering of groundwater levels, the above basin-wide definition allows for local definition, within each management area of the Subbasin, of the minimum thresholds that constitute a significant and unreasonable impact to the reasonable and beneficial use of groundwater by overlying users. Similar to reduction of groundwater storage, groundwater levels are also used as proxy for degraded water quality. An undesirable result watch area for degraded water quality is defined similar to the undesirable result watch area for chronic lowering of groundwater levels.

Establishment of specific measurable objectives and minimum thresholds based on the above definition for this undesirable result can be found in Section 3.3 and with additional regional detail provided within each management area plan.

An overview of the existing water quality conditions in the Subbasin is provided in the basin setting section of this GSP. More specific information regarding current water quality conditions can be found in each individual management area plan. Additionally, details of the water quality monitoring in the KGA can be found in Section 3.4.7.2.

3.2.4.1 Potential Cause of Degraded Water Quality

Section 354.26(b)(1) of the GSP regulations requires identification of potential causes of undesirable results for each sustainability indicator. Potential causes of an undesirable result for degraded water quality vary throughout the Subbasin. Water quality in the Subbasin has been historically sustainable with few exceptions. In the future, water quality can be degraded by significant increase in groundwater pumping or unforeseen point source contamination issues caused by natural or human activity. Each management area plan addresses the cause of degraded water quality in their management area differently since the Subbasin has dynamic differences in hydrology and water supplies and uses. For detailed causes of degraded water quality in a specific area, refer to the management area plans.

3.2.4.2 Potential Effects of Degraded Water Quality

Section 354.26(b)(3) of the GSP regulations requires identification of potential effects of an undesirable result for degraded water quality. An undesirable result for degraded water quality could affect beneficial users. This could potentially reduce the amount of usable supply delivered to groundwater users and require the need for treatment systems, which could potentially have a negative economic effect. As mentioned above for the cause of degraded water quality, the effects or impacts vary in the Subbasin and the management area plans provide more detailed information for their specific areas.

3.2.5 Undesirable Result for Land Subsidence

The basin-wide definition of an undesirable result for land subsidence is as follows:

The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure.

This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.

As with chronic lowering of groundwater levels, the above basin-wide definition allows for local definition, within each management area of the Subbasin, of the minimum thresholds that constitute a significant and unreasonable impact to the reasonable and beneficial use of groundwater by overlying users. However, as described in Section 3.3.3, the determination of minimum thresholds for land subsidence has not been completed for the Subbasin and is identified as a data gap. While it is generally acknowledged that subsidence exists in portions of the Subbasin, there are generally no significant impacts to infrastructure within the Subbasin. It is unclear whether subsidence occurring in the northern portion of the Subbasin is the results of groundwater pumping from within the Subbasin or from the Tule and Tulare Lake subbasins to the north, where subsidence has been documented to significantly impact critical water infrastructure. As detailed in the monitoring plan, the KGA along with the other GSAs in the Subbasin will develop a joint subsidence monitoring program to better understand the cause and impacts of subsidence. The intent of the KGA and the other GSAs in the Subbasin is to develop minimum thresholds for subsidence for inclusion in the 2025 GSP update. The Monitoring Network section of this GSP provides a description of the proposed basin-wide land subsidence monitoring strategy that has been adopted by the KGA and all other GSAs in the Subbasin.

Establishment of specific measurable objectives and minimum thresholds based on the above definition for this undesirable result can be found within each management area plan. Additional details on subsidence monitoring can be found in 3.4.7.4.

3.2.5.1 Potential Cause of Land Subsidence

Section 354.25(b)(1) of the GSP regulations requires identification of potential causes of an undesirable result for land subsidence. Potential causes of land subsidence vary throughout the Subbasin. While subsidence is not a widespread issue in the Subbasin, potential causes for future subsidence could be tied to significant increases in groundwater pumping, resulting in dewatering of compressible clays in the subsurface. Recent reports of damage to critical infrastructure due to land subsidence are provided in detail in the management area plans. Data gaps and challenges to setting sustainable management criteria and monitoring for undesirable results due to land subsidence are presented in Section 3.4.

3.2.5.2 Potential Effects of Land Subsidence

Section 354.26(b)(3) of the GSP regulations requires identification of potential effects of an undesirable result for land subsidence. Potential effects of land subsidence include damage to critical infrastructure including pipelines, roads, building, water conveyance systems, and flood control facilities. Damage to these systems could impact water delivery to surface water, resulting in increased groundwater use.

3.2.6 Seawater Intrusion

The Subbasin is located approximately 60 miles from the Pacific Ocean, separated by the Coastal Range and other geologic features that prevent seawater from migrating into the Subbasin. Details of the geologic structure of the Subbasin can be found in the basin setting of this GSP. Based on the separation of the Subbasin from any source of seawater, the Subbasin has not developed sustainable management criteria for this sustainability indicator.

3.2.7 Interconnected Surface Water

As defined in the California Code of Regulations (§ 351. Definitions), "Interconnected Surface Water" refers to water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted." A discussion on interconnected surface water is included in Section 2.3.5. As there are no known natural interconnected surface water systems within the KGA boundary, this sustainability indicator is not included in this GSP.

3.3 Minimum Thresholds and Measurable Objectives

The SGMA planning effort began in 2013, prior to the enactment of SGMA, as districts in the Subbasin recognized the need to begin coordination of groundwater management activities. The initial efforts focused on developing an understanding of the significant issues facing groundwater management at the Subbasin and at the district level. Particularly important to this process was understanding the unique conditions that existed in the Subbasin. These conditions include, but are not limited to:

- Not all district's or areas have equal access to groundwater resources (quantity or quality).
- Each district has variable imported or local water supplies (State Water Project, Friant Project, Kern River) each with their own management and reliability challenges.
- The ability to implement water management programs within district's varies by the authorities of the district and in some cases challenges coordination between districts.
- The beneficial uses and users of groundwater varied across the Subbasin.

Despite these unique conditions, the districts within the Subbasin understood the need to coordinate the development of groundwater management activities and common technical materials on which to develop future management activities.

The KGA was formed under a JPA in 2017 and through that process the KGA/GSA Managers Group was formalized. The KGA/GSA Managers Group includes representatives from all KGA member agencies, typically the district general managers and technical experts, as well as representatives from each of the other GSAs developing a GSP in the Subbasin; Kern River GSA, Buena Vista GSA, Henry Miller GSA and Olcese GSA. The measurable objectives and minimum thresholds within the Subbasin were developed in a collaborative process, starting with the KGA/GSA Managers Group. The Managers Group has been meeting on a weekly basis to

address coordination issues; develop and share technical information; identify and resolve potential conflicts; and, where appropriate, elevated issues to the Board of Directors of their respected GSAs and/or the Kern SGMA Coordination Committee comprised of representatives of all GSAs in the Subbasin.

Through the Managers Group, the process for developing minimum thresholds and measurable objectives for the entire subbasin was initiated. This process involved review of the SGMA requirements for thresholds and objectives, including their relationship and coordination to management areas; presentation of technical methods for establishing thresholds and objectives; and coordination between districts and GSAs through the establishment of draft and final thresholds and objectives.

The process was facilitated by the KGA/GSA Planning Manager and technical team with input and identification of issues from member agencies and GSA representatives. The general process for developing minimum thresholds and measurable objectives is outlined below:

Step 1: Regulatory and technical review of minimum threshold and measurable objectives requirements.

- **KGA/GSA Managers Group:** Provided overview of regulatory and technical requirements.
- **Member agencies and GSA representatives and technical consultants:** Sharing of technical approaches to establishing thresholds and objectives for their respective management areas.

Step 2: Defining roles and responsibilities for GSAs and management areas (district areas).

- **KGA/GSA Managers Group:** Presentations on roles and responsibilities for managing resources through proposed thresholds and objectives.
- **Member agencies and GSA representatives and technical consultants:** Identification of potential management area conflicts and opportunities for joint resource management strategies.

Step 3: Development of first draft minimum thresholds and measurable objectives for all Subbasin management areas.

- **KGA/GSA Managers Group:** Facilitate review of draft thresholds and objectives, including development of contour maps and cross-sections of thresholds and objectives.
- **Member agencies and GSA representatives and technical consultants:** Develop and execute technical approach for developing thresholds and objectives with presentation to the KGA Managers Group for review.

Step 4: Development of second draft thresholds and objectives for all Subbasin management areas.

- **KGA/GSA Managers Group:** Facilitate review of draft minimum thresholds and measurable objectives, including development of contour maps and cross-sections of thresholds and objectives.

- **Member agencies and GSA representatives and technical consultants:** Develop and execute technical approach for developing thresholds and objectives and presentation to the KGA Managers Group for review. Identify areas of potential conflicting minimum thresholds and measurable objectives in adjacent management areas and coordinate resolution with adjacent management area.

Step 5: Adoption of final minimum thresholds and measurable objectives.

- **KGA/GSA Managers Group:** Facilitate review of final thresholds and objectives and presentation of thresholds and objectives to KGA Board of Directors.
- **Member agencies and GSA representatives and technical consultants:** Resolve any outstanding conflicts and review thresholds and objectives with management area Boards of Directors and stakeholder groups
- **GSA Boards:** KGA/GSA managers presented to their specific boards for policy board approval

As demonstrated in the steps above, the KGA/GSA Managers Group facilitated the coordination and review of the Subbasin's minimum thresholds and measurable objectives. The technical work required to establish thresholds and objectives at the management area level was completed by the member agencies or GSAs. For the details of the technical processes utilized by KGA member agencies see their respective management area plans. One item to note, that during this entire process the KGA held several stakeholder/beneficial users workshops to roll-out the minimum thresholds and measurable objectives for their input at each step. Also, at the KGA Board meetings, the minimum thresholds and measurable objectives appeared as discussion items.

3.3.1 Chronic Lowering of Groundwater Levels and Reduction of Groundwater Storage

The final Subbasin minimum thresholds and measurable objectives for the chronic lowering of groundwater levels sustainability indicator at each representative monitoring site are presented in listed in Table 3-1 and the representative monitoring sites are shown in Figure 3-1. Figure 3-2 show only the minimum thresholds for the groundwater levels sustainability indicator with elevation contours between each of the representative monitoring sites. This figure provides an indication of how the thresholds values at each representative monitoring site relate to adjacent monitoring site values. Contour maps such as these were used in the review of draft thresholds to determine areas of potential conflicting thresholds between neighboring management areas, such as drastically differing threshold values, elevation gradients steeper than typically observed gradients, or elevation gradients contrary to typically observed gradients.

Figure 3-3 shows only the measurable objective values for groundwater levels sustainability indicator at each representative monitoring site, with elevation contours between monitoring site. The draft measurable objectives were reviewed in the same manner as minimum thresholds.

The chronic lowering of groundwater level minimum thresholds and measurable objective values serve as proxy for the reduction of groundwater storage in the entire Subbasin. Through the

KGA/GSA Managers Group process, it was generally agreed that the withdrawal of groundwater from the Subbasin would not create impacts to beneficial uses or users of groundwater in the Subbasin if groundwater elevations are maintained above the minimum threshold values. Further, the KGA/GSA Managers Group agreed that the measurable objective for groundwater levels should be set sufficiently higher than the minimum threshold for groundwater levels to support groundwater extractions through a 10-year drought cycle, like that experienced from 2006 to 2016, as an example. As a result, the measurable objective for chronic lowering of groundwater levels and reduction in groundwater storage are the same or the measurable objective for groundwater levels serves as a proxy for groundwater storage. The exact methodology and planned drought period used by each management area is described in the management area plans.

3.3.2 Degraded Water Quality

The minimum thresholds and measurable objectives for degraded water quality were established by each of the management areas. All the representative monitoring sites for water quality are also shown in Figure 3-4 and summarized in Table 3-1. In many instances, the minimum threshold and measurable objectives values for groundwater levels serves as a proxy for water quality. In other words, no water quality degradation, migration of contaminate plumes, or other indicators of water quality impairment would be experienced at the groundwater level minimum threshold value at that representative monitoring site.

The details, methodologies, and justification of the water quality minimum threshold and measurable objectives can be found in the management area plans.

3.3.3 Land Subsidence

Land subsidence due to groundwater withdrawal is generally correlated with declining groundwater levels. Land subsidence is currently monitored by extensometers, CGPS stations, and level surveying with benchmarks throughout the Subbasin. The development of minimum thresholds for land subsidence at the basin level is ongoing due to data gaps in monitoring and identification of undesirable results in the Subbasin. Some management areas have not set minimum thresholds for land subsidence pending development of additional data and monitoring, other management areas have established preliminary minimum thresholds.

A combination of water level monitoring and land subsidence monitoring will be used to help set sustainability criteria. As detailed in the monitoring plan section of this GSP, the existing network of subsidence monitoring will be expanded to better understand the causes and impacts of subsidence in the Subbasin. The monitoring plan also provides a plan for filling data gaps to support future establishment of minimum thresholds and measurable objectives for the land subsidence sustainability indicator.

Additional details regarding land subsidence can be found in the groundwater conditions section of this GSP and in the management area plans.

Table 3-1: Summary of Minimum Thresholds and Measureable Objectives

Monitoring Sites			Lowering of Groundwater Levels				Sustainability Indicators		
Member Agency	Zone/Management Area	Monitoring Site/Parameter	Minimum Threshold		Measureable Objective		Reduction of Groundwater Storage	Degraded Water Quality (MT Value)	Unit
			Value	Unit	Value	Unit			
Arvin-Edison Water Storage Distict	North Canal	29S29E33N001M	50	ft msl	100	ft msl	X	X	ft msl
		30S29E29A001M	50	ft msl	100	ft msl	X	X	ft msl
		31S29E05E001M	50	ft msl	100	ft msl	X	X	ft msl
		31S29E12M001M	50	ft msl	100	ft msl	X	X	ft msl
		31S30E17K001M	50	ft msl	100	ft msl	X	X	ft msl
		31S30E30J001M	50	ft msl	100	ft msl	X	X	ft msl
	Edison	30S29E11N001M	250	ft msl	300	ft msl	X	X	ft msl
		30S30E19E001M	250	ft msl	300	ft msl	X	X	ft msl
	ACSD	31S29E34A001M	-70	ft msl	30	ft msl	X	X	ft msl
		ACSD Well No. 14	-70	ft msl	30	ft msl	X	X	ft msl
	South Canal	11N20W05J001S	0	ft msl	50	ft msl	X	X	ft msl
		12N20W36K001S	0	ft msl	50	ft msl	X	X	ft msl
		32S28E23H001M	0	ft msl	50	ft msl	X	X	ft msl
		32S29E12P001M	0	ft msl	50	ft msl	X	X	ft msl
		32S29E20H001M	0	ft msl	50	ft msl	X	X	ft msl
		32S29E31N001M	0	ft msl	50	ft msl	X	X	ft msl
Cawelo Water District	Cawelo Main Modified	Well 12H	25	ft msl	103	ft msl	X	X	ft msl
		Well 24R	-43	ft msl	35	ft msl	X	X	ft msl
		Well 11M	-81	ft msl	3	ft msl	X	X	ft msl
		Well 6C	-85	ft msl	-1	ft msl	X	X	ft msl
		Well 33C	-64	ft msl	20	ft msl	X	X	ft msl
		Well 28L	26	ft msl	110	ft msl	X	X	ft msl
	SSJMUD	Well 4R	-24	ft msl	60	ft msl	X	-3	ft msl
Eastside Water Management Area	EWMA	EWMA #03	-86	ft msl	135	ft msl	X	X	ft msl
		EWMA #21	-110	ft msl	136	ft msl	X	X	ft msl
		EWMA #23	N/A	ft msl	N/A	ft msl	N/A	-71	ft msl
		EWMA #30	-228	ft msl	-71	ft msl	X	X	ft msl
		EWMA #37	132	ft msl	200	ft msl	X	X	ft msl
		EWMA #41	-41	ft msl	230	ft msl	X	X	ft msl
		EWMA #42	568	ft msl	588	ft msl	X	X	ft msl
		EWMA #06	-46	ft msl	48	ft msl	X	X	ft msl

Monitoring Sites			Lowering of Groundwater Levels				Sustainability Indicators		
Member Agency	Zone/Management Area	Monitoring Site/Parameter	Minimum Threshold		Measureable Objective		Reduction of Groundwater Storage	Degraded Water Quality (MT Value)	Unit
			Value	Unit	Value	Unit			
Kern-Tulare Water District	KTWD	Well 30D	-150	ft msl	20	ft msl	X	X	ft msl
		Well 4P1	-150	ft msl	20	ft msl	X	X	ft msl
		Well 20C1	-150	ft msl	20	ft msl	X	X	ft msl
		Well 15P1	-150	ft msl	20	ft msl	X	X	ft msl
		Well 24Q1	-150	ft msl	20	ft msl	X	X	ft msl
		Well 32M1	-150	ft msl	20	ft msl	X	X	ft msl
		Well 8L1	-150	ft msl	20	ft msl	X	X	ft msl
North Kern Water Storage District	North Kern	88-03-009	-127.02	ft msl	-52	ft msl	X	X	ft msl
		88-09-009	-141.27	ft msl	-66	ft msl	X	X	ft msl
		88-21-005	-130.72	ft msl	-56	ft msl	X	X	ft msl
		88-29-014	-132.63	ft msl	-57	ft msl	X	X	ft msl
		99-00-003	-72.22	ft msl	4	ft msl	X	X	ft msl
		99-00-081	-192.10	ft msl	-114	ft msl	X	X	ft msl
		99-22-084	-213.09	ft msl	-135	ft msl	X	X	ft msl
		Shafter Well 18	-128.70	ft msl	-54	ft msl	X	N/A	ft msl
		Proposed Site 3	-238.53	ft msl	-154	ft msl	X	X	ft msl
Kern County Water Agency - Pioneer	Pioneer MA	Well 34	-12.5	ft msl	186	ft msl	X	X	ft msl
		Well 51	-24.8	ft msl	93	ft msl	X	X	ft msl
		Well 54	-24.8	ft msl	93	ft msl	X	X	ft msl
		Well 55	-51.4	ft msl	111	ft msl	X	X	ft msl

Monitoring Sites			Lowering of Groundwater Levels				Sustainability Indicators		
Member Agency	Zone/Management Area	Monitoring Site/Parameter	Minimum Threshold		Measureable Objective		Reduction of Groundwater Storage	Degraded Water Quality (MT Value)	Unit
			Value	Unit	Value	Unit			
Rosedale-Rio Bravo Management Area	North Zone	Bushnell	-33.1	ft msl	48	ft msl	X	X	ft msl
		L.R. Stout	-2.7	ft msl	78	ft msl	X	X	ft msl
		RGB School	3.5	ft msl	85	ft msl	X	X	ft msl
	Central Zone	Cauzza	8.3	ft msl	82	ft msl	X	X	ft msl
		P. Enns Domestic	41.9	ft msl	116	ft msl	X	X	ft msl
		Section 18	16.3	ft msl	90	ft msl	X	X	ft msl
		Blacco HW New	9.2	ft msl	83	ft msl	X	X	ft msl
	South Zone	Parsons	28.3	ft msl	127	ft msl	X	X	ft msl
		West I-5	43.6	ft msl	143	ft msl	X	X	ft msl
		Virgil Bussell	49.1	ft msl	148	ft msl	X	X	ft msl
		Mayer Double	55.3	ft msl	154	ft msl	X	X	ft msl
		Enos Double	68.6	ft msl	168	ft msl	X	X	ft msl
	East Zone	Chet Reed	101.0	ft msl	209	ft msl	X	X	ft msl
		Home Place	88.4	ft msl	196	ft msl	X	X	ft msl
		Greeley Double	84.1	ft msl	192	ft msl	X	X	ft msl
		Harvest Ranch	91.0	ft msl	199	ft msl	X	X	ft msl
		Shop Double	107.1	ft msl	215	ft msl	X	X	ft msl
	South of the River Zone (East)	28J Triple	124.0	ft msl	191	ft msl	X	X	ft msl
	South of the River Zone (West)	32N Triple	131.4	ft msl	193	ft msl	X	X	ft msl
Southern San Joaquin Municipal Utility District	Tayolor Well	INAC2016	-117.1	ft msl	-42	ft msl	X	X	ft msl
	City of Delano	Well 14	-197	ft msl	-105	ft msl	X	N/A	ft msl
		Well 23	-215	ft msl	-113	ft msl	X	N/A	ft msl
		Well 30	-101	ft msl	-8	ft msl	X	N/A	ft msl
	SSJMUD Wells	8	-329	ft msl	-227	ft msl	X	X	ft msl
		14	-136	ft msl	-57	ft msl	X	X	ft msl
		23	-278	ft msl	-183	ft msl	X	X	ft msl
		42	-123	ft msl	-48	ft msl	X	X	ft msl
		53	-131	ft msl	-55	ft msl	X	X	ft msl
		59	-112	ft msl	-37	ft msl	X	X	ft msl
		62	-83	ft msl	-7	ft msl	X	X	ft msl
Shafter-Wasco Irrigation District - 7th Standard Annex	SWID - 7th Standard	KB 3	-137	ft msl	-79	ft msl	X	X	ft msl
		22866	N/A	ft msl	N/A	ft msl	N/A	X	ft msl
		33 G	N/A	ft msl	N/A	ft msl	N/A	X	ft msl
		28S/25E-31J	-137	ft msl	-79	ft msl	X	X	ft msl
		28S/24E-35C	-137	ft msl	-79	ft msl	X	X	ft msl

Monitoring Sites			Lowering of Groundwater Levels				Sustainability Indicators		
Member Agency	Zone/Management Area	Monitoring Site/Parameter	Minimum Threshold		Measureable Objective		Reduction of Groundwater Storage	Degraded Water Quality (MT Value)	Unit
			Value	Unit	Value	Unit			
Shafter-Wasco Irrigation District	SWID	Proposed-001	-215.31	ft msl	-134	ft msl	X	X	ft msl
		Proposed-002	-186.28	ft msl	-108	ft msl	X	X	ft msl
		2A	-258.9	ft msl	-171	ft msl	X	X	ft msl
		9	-221.86	ft msl	-141	ft msl	X	X	ft msl
		Well 15 Active AG	-147	ft msl	-68	ft msl	X	X	ft msl
		Well 7 Inactive	-163	ft msl	-85	ft msl	X	X	ft msl
		Shafter Well 12	-158.5	ft msl	-81	ft msl	X	N/A	ft msl
		Shafter Well 15	-146.9	ft msl	-67	ft msl	X	N/A	ft msl
		Wasco 12	-242.9	ft msl	-159	ft msl	X	N/A	ft msl
		Wasco Shafter Well 14	-144	ft msl	-67	ft msl	X	N/A	ft msl
Semitropic Water Storage District	Buttonwillow Improvement District	S-02	-200	ft msl	-127	ft msl	X	X	ft msl
		S-04	-144.1	ft msl	-76	ft msl	X	X	ft msl
		S-05	-241.6	ft msl	-161	ft msl	X	X	ft msl
		948L02	-179.6	ft msl	-101	ft msl	X	X	ft msl
		Proposed-003	-179.6	ft msl	-101	ft msl	X	X	ft msl
		Proposed-004	-267.6	ft msl	-185	ft msl	X	X	ft msl
	Groundwater Dependent Ag.	S-11	-257.9	ft msl	-195	ft msl	X	X	ft msl
		S-12	-260.5	ft msl	-194	ft msl	X	X	ft msl
		Proposed-002	-292.3	ft msl	-219	ft msl	X	X	ft msl
	Pond-Poso Improvement District	S-06	-306	ft msl	-209	ft msl	X	X	ft msl
		S-09A	-226.7	ft msl	-146	ft msl	X	X	ft msl
		S-13A	-371.2	ft msl	-269	ft msl	X	X	ft msl
		S-14B	-334.5	ft msl	-233	ft msl	X	X	ft msl
		S-15A1	-345.3	ft msl	-244	ft msl	X	X	ft msl
		Proposed-001	-217.3	ft msl	-148	ft msl	X	X	ft msl
	SWID	S-08A	-331.3	ft msl	-229	ft msl	X	X	ft msl
Tejon-Castac Water District	TCWD	RMS-1 (Caratan Well)	50	ft msl	100	ft msl	X	X	ft msl
West Kern Water District		Well 19	68	ft msl	162	ft msl	X	X	ft msl
		Well 24	-42	ft msl	106	ft msl	X	X	ft msl
		Well 29	-72	ft msl	121	ft msl	X	X	ft msl
		Well 40	37	ft msl	163	ft msl	X	X	ft msl
		Well 81	-54	ft msl	115	ft msl	X	X	ft msl
		Well 87	-8	ft msl	132	ft msl	X	X	ft msl
		Well 100	-82	ft msl	125	ft msl	X	X	ft msl
	North Project MA	Well 107	14	ft msl	70	ft msl	X	X	ft msl
		Well 108	32	ft msl	99	ft msl	X	X	ft msl

Monitoring Sites			Lowering of Groundwater Levels				Sustainability Indicators		
Member Agency	Zone/Management Area	Monitoring Site/Parameter	Minimum Threshold		Measureable Objective		Reduction of Groundwater Storage	Degraded Water Quality (MT Value)	Unit
			Value	Unit	Value	Unit			
Westside District Water Authority	Sentry Zone #1	25S21E01R001M	-115	ft msl	-62	ft msl	X	X	ft msl
	Sentry Zone #2	28S21E16	56	ft msl	112	ft msl	X	X	ft msl
		27S22E30H001M	59	ft msl	101	ft msl	X	X	ft msl
		Well 7106-63	59	ft msl	127	ft msl	X	X	ft msl
Wheeler Ridge-Maricopa Water Storage District	Western	11N22W06H001S	100	ft msl	200	ft msl	X	X	ft msl
		32S25E30D001M	100	ft msl	200	ft msl	X	X	ft msl
	Northeastern	32S26E20G001M	-50	ft msl	0	ft msl	X	X	ft msl
		32S26E24K001M	-50	ft msl	0	ft msl	X	X	ft msl
		32S27E30N001M	-50	ft msl	0	ft msl	X	X	ft msl
		32S27E35R001M	-50	ft msl	0	ft msl	X	X	ft msl
		32S26E34P001M	-50	ft msl	0	ft msl	X	X	ft msl
		32S26E36P002M	-50	ft msl	0	ft msl	X	X	ft msl
		32S28E16P001M	-50	ft msl	0	ft msl	X	X	ft msl
	Southeastern	11N22W01D001S	0	ft msl	75	ft msl	X	X	ft msl
		11N21W16E001S	0	ft msl	75	ft msl	X	X	ft msl
		12N21W34Q001S	0	ft msl	75	ft msl	X	X	ft msl
		11N21W09C001S	0	ft msl	75	ft msl	X	X	ft msl
		12N21W35Q001S	0	ft msl	75	ft msl	X	X	ft msl
		12N21W34Q001S	N/A	ft msl	N/A	ft msl	N/A	X	ft msl

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Kern Subbasin Boundary

MTMO Groundwater Level Monitoring Network

KWB Monitoring Well *(No MO/MT data)*

Kern Groundwater Authority GSA

KERN RIVER GSA

BELRIDGE W.S.D.

BERRENDA MESA W.D.

BUENA VISTA W.S.D.

CAWELO W.D.

DEVILS DEN W.D.

DUDLEY RIDGE W.D.

HENRY MILLER W.D.

LOST HILLS W.D.

SEMITROPIC W.S.D.

WHEELER RIDGE-MARICOPA W.S.D.

ARVIN-EDISON W.S.D.

DELANO-EARLIMART I.D.

SHAFTER-WASCO I.D.

KERN-TULARE W.D

SOUTHERN SAN JOAQUIN M.U.D

TEJON CASTAIC W.D

NORTH KERN W.S.D

SHAFTER-WASCO I.D additional M.A

ROSEDALE RIO BRAVO W.S.D

WEST KERN W.D

KERN WATER BANK AUTHORITY

OIL AND GAS LANDS

EASTSIDE WATER MANAGEMENT AREA

SEMITROPIC W.S.D additional M.A

ROSEDALE RIO BRAVO W.S.D additional M.A

ARVIN-EDISON W.S.D additional M.A.

BELRIDGE W.S.D additional M.A

BERRANDA MESA W.D additional M.A

0 3.5 7 14 21

Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

REGIONAL GROUNDWATER LEVEL MONITORING NETWORK

DECEMBER 2019

FIGURE 3-1

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10Jan2020

Kern Subbasin Boundary

MTMO Groundwater Level Monitoring Network

Minimum Threshold (MT) Groundwater Elevation Contour *(ft NAVD88)*

Kern Groundwater Authority GSA

KERN RIVER GSA

BELRIDGE W.S.D.

BERRENDA MESA W.D.

BUENA VISTA W.S.D.

CAWELO W.D.

DEVILS DEN W.D.

DUDLEY RIDGE W.D.

HENRY MILLER W.D.

LOST HILLS W.D.

SEMITROPIC W.S.D.

WHEELER RIDGE-MARICOPA W.S.D.

ARVIN-EDISON W.S.D.

DELANO-EARLIMART I.D.

SHAFTER-WASCO I.D.

KERN-TULARE W.D

SOUTHERN SAN JOAQUIN M.U.D

TEJON CASTAIC W.D

NORTH KERN W.S.D

SHAFTER-WASCO I.D additional M.A

ROSEDALE RIO BRAVO W.S.D

WEST KERN W.D

KERN WATER BANK AUTHORITY

OIL AND GAS LANDS

EASTSIDE WATER MANAGEMENT AREA

SEMITROPIC W.S.D additional M.A

ROSEDALE RIO BRAVO W.S.D additional M.A

ARVIN-EDISON W.S.D additional M.A.

BELRIDGE W.S.D additional M.A

BERRANDA MESA W.D additional M.A

0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

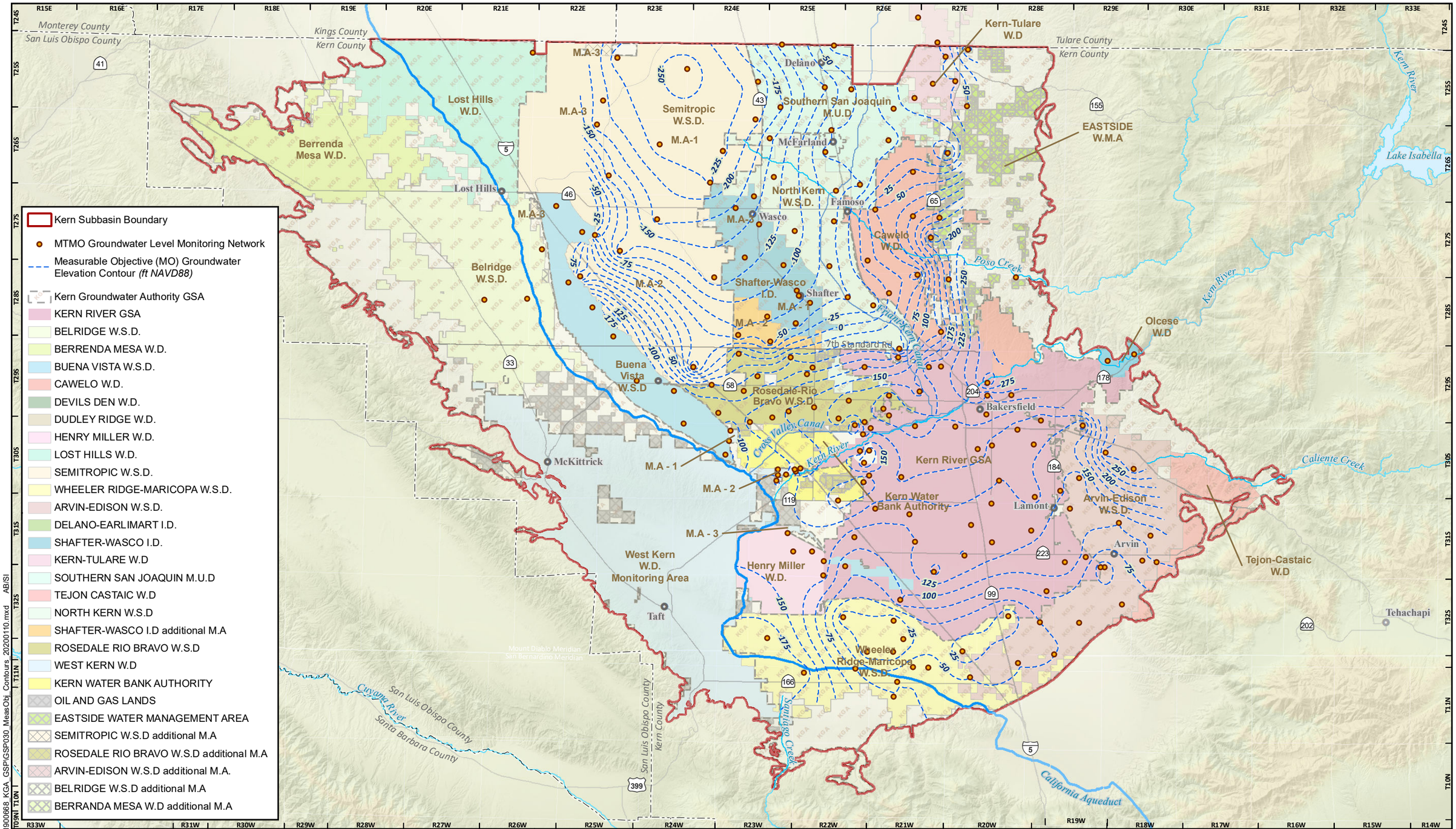
REGIONAL MINIMUM THRESHOLD
GROUNDWATER ELEVATION CONTOURS

DECEMBER 2019

FIGURE 3-2

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10Jan2020



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

REGIONAL MEASURABLE OBJECTIVE GROUNDWATER ELEVATION CONTOURS

DECEMBER 2019

FIGURE 3-3

Z:\Projects\1900668_KGA_GSP\GSP030_MeasObj_Contours_20200110.mxd AB/SI 10Jan2020



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

REGIONAL GROUNDWATER QUALITY MONITORING NETWORK

DECEMBER 2019

FIGURE 3-4

Z:\Projects\1900668_KGA_GSP\GSP040_MTMO_WQ_MonNetwork_20200110.mxd AB/SI 10Jan2020

3.3.4 Seawater Intrusion

As described above, the Subbasin is located approximately 60 miles from the Pacific Ocean, separated by the Coastal Range and other geologic features that prevent seawater from migrating into the Subbasin. Details of the geologic structure of the Subbasin can be found in the basin setting of this GSP. Based on the separation of the Subbasin from any source of seawater, the Subbasin has not developed sustainable management criteria for this sustainability indicator.

3.3.5 Depletions of Interconnected Surface Water

As described above the Subbasin, has not identified any areas of interconnected surface waters. Though many studies have been conducted in the Subbasin, including in areas such as the Kern River and Poso Creek, results do not show evidence of surface water within the Subbasin to be interconnected. As there are no known natural interconnected surface water systems within the KGA boundary or the Subbasin, this sustainability indicator is not included in this GSP. Additional information can be found in basin setting section of this GSP and in the management area plans.

3.4 Monitoring Network

The monitoring networks, protocols, and standards described within this section and in the respective management area plans meet the requirements of §352.2, and §354.32 to §354.40 of the California Code of Regulations.

3.4.1 Monitoring Network Description

Management areas within the KGA generally align with member agency boundaries and represent areas of common water management practices. Management areas are designated and managed by KGA member agencies (Table 2-9) and shown in Figure 2-61. KGA member entities are best suited to leverage existing relationships with water users for local groundwater monitoring and site access.

The monitoring network for the KGA represents the coordination of the monitoring networks and activities of the KGA member agencies within their respective management areas. Each member agency will implement its monitoring plan, as described in their management area plan. The KGA will coordinate the annual collection and reporting of monitoring data to DWR and will ensure the monitoring network and protocols are compliant with SGMA.

The monitoring network for the KGA represents the coordination of the monitoring networks and activities of the KGA/GSA Managers Group within their respective management areas. Each member agency will implement its monitoring plan, as described in their management area plan. The KGA will coordinate the annual collection and reporting of monitoring data to DWR and will ensure the monitoring network and protocols are compliant with SGMA.

Monitoring Network is capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative

information about groundwater conditions as necessary to evaluate Plan implementation. The monitoring network objectives accomplish the following:

1) Demonstrate progress toward achieving measurable objectives described in the management area and throughout the Subbasin
2) Monitor impacts to the beneficial uses and users of groundwater
3) Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds
4) Quantify annual changes in water budget components

3.4.2 Monitoring Network Objectives

The objectives of the KGA monitoring network are to:

- demonstrate progress toward achieving measurable objectives summarized in this GSP and detailed in the attached management area plans;
- monitor impacts to the beneficial uses of groundwater and stakeholders within the Subbasin; monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds; quantify annual changes in water budget components; and
- monitor changes for the following pertinent sustainability indicators in the Subbasin;
    - Groundwater Potentiometric Surfaces, or Groundwater Levels,
    - Groundwater Storage,
    - Groundwater Quality, and
    - Land Subsidence.

Seawater intrusion and depletions of interconnected surface water are not pertinent to the monitoring network as they were not considered pertinent sustainability indicators, as described in the basin setting.

3.4.3 Monitoring Data Quality Objectives

As described in DWR's *Groundwater Monitoring Protocols, Standards, and Sites BMP* (DWR, 2016c), the processes for maintaining quality control and quality assurance are iterative, and, as such, will be evaluated every 5 years for effectiveness. The monitoring networks implemented as part of this GSP include the analytical approaches to obtain acceptable data that can monitor the sustainability indicators against minimum thresholds and interim milestones. Where necessary, revisions can be made every 5 years as this GSP is updated.

The monitoring network (see Figures 3-4 and Table 3-1) will be capable of collecting sufficient data to demonstrate seasonal, short-term (1 to 5 years), and long-term (5 to 10 years) trends in groundwater and related surface conditions and yield representative information about groundwater conditions as necessary to evaluate Plan implementation. The frequency at which data will be collected for each network will be described herein.

3.4.4 Monitoring Progress Toward Measurable Objectives

As described in Section 3.2, groundwater levels in the KGA are the key sustainability indicator to monitor undesirable results. Seasonal groundwater levels in selected monitoring wells will be used to monitor progress towards identified measurable objectives. While most of the management areas have used groundwater level as a proxy to monitor other sustainability indicators, certain management areas have defined specific interim milestones for other primary sustainability indicators such as degraded water quality and groundwater storage. The details of these milestones can be found in the management area plans.

After adopting this GSP, the KGA and its member agencies will monitor the progress towards reaching interim milestones for groundwater levels. This progress will be compared with monitoring data for storage, land subsidence, and water quality as well as their respective minimum thresholds, to evaluate the effectiveness of groundwater level as proxies for these other the sustainability indicators. Where needed, interim milestones for groundwater levels or other sustainability indicators may be adjusted to maintain the objectives of the GSP.

The proposed monitoring networks will provide data used to monitor impacts of sustainable groundwater management to beneficial uses and users of groundwater. The proposed approach for monitoring impacts to beneficial uses and users of groundwater are described in Table 3-2.

Table 3-2. Monitoring Impacts to Beneficial Uses and Users

Potential impacts on beneficial uses and users of groundwater	Monitoring Network	Notes
Groundwater elevation decline may result in increased pumping costs and or dry wells.	Groundwater Level Monitoring	Groundwater levels will be compared with well screen construction and pump depth settings
Groundwater storage is reduced to less than minimum threshold affecting future supplies for use.	Groundwater Level Monitoring	Data will be incorporated into the Subbasin model to quantify and monitor storage outlooks and minimum thresholds and interim milestones.
Land subsidence due to overdraft results in infrastructure damage and loss in aquifer storage.	Groundwater Level and Land Subsidence Monitoring	Groundwater levels and land subsidence data will be evaluated against minimum thresholds and interim milestones.
Groundwater quality is degraded and is not suitable for use without additional treatment costs.	Groundwater Quality Monitoring	Data from all water quality reporting sources will be evaluated for the Subbasin to compare against minimum thresholds and objectives.

3.4.5 Coverage of Sustainability Indicators

As mentioned previously, the monitoring plan for each management area plan addresses all pertinent sustainability indicators of the Subbasin: chronic lowering of groundwater levels, reduction in groundwater storage, degraded water quality, and land subsidence. Figure 3-1 and 3-4 provides the current distribution of representative monitoring wells for water elevations and water quality, respectively, to be included in the monitoring network for the KGA by its member agencies. Based on the BMP for monitoring networks, the well density goal is to be between 4 to 10 wells per 100 square miles (DWR, 2016c). In the Subbasin, the KGA covers approximately

2,800 square miles of which, approximately 60% (or ~1,700 square miles) has active groundwater wells. Based on DWR's BMP recommended density goal, the KGA monitoring network should contain between 70 to 280 monitoring wells. The KGA's proposed monitoring network includes 194 well locations for groundwater elevation and storage and 188 well locations for water quality, nearly all of which are groundwater elevation monitoring locations.

3.4.6 Scientific Rational for Site Selection

The monitoring network for the KGA member agencies was designed using the following scientific rational for site selection:

- Aquifer representation –Per DWR's Emergency Regulations CCR § 354.34 (c) (1), monitoring wells were chosen to adequately represent each underlying aquifer within the KGA.
- Potential impacts to beneficial users of groundwater
- Availability of site-specific historical data and technical information
- Spatial and vertical representation of the underlying aquifers
- Precedence of dedicated monitoring wells over production wells
- Site accessibility

While this outlines the general procedure followed by the KGA member agencies to identify their respective monitoring networks, the detailed scientific rational for each monitoring network can be found in the respective management area plan.

3.4.7 Monitoring Protocols for Data Collection and Monitoring

3.4.7.1 Groundwater Level Monitoring Network Protocol and Standards

The existing monitoring network in the KGA includes production wells and dedicated monitoring wells. Until enough dedicated monitoring wells are installed to fill data gaps, production wells will be used to expand the spatial coverage of the existing network.

As referenced in §352.4 of the regulations, monitoring sites/wells will conform to best management practices for geographic locations, identification, and details on well construction. Table 3-3 provides the requested standards.

Table 3-3: Standards for Required Monitoring Well Information

Well Identification	Use the CASGEM well identification number. If a CASGEM well identification number has not been issued, appropriate well information shall be entered on forms made available by DWR.
Well/Site Location	Geographic locations shall be reported in GPS coordinates by latitude and longitude in decimal degree to five decimal places, to a minimum accuracy of 30 feet, relative to NAD83, or another national standard that is convertible to NAD83. Reference point elevations shall be measured and reported in feet to an accuracy of at least 0.5 feet, or the best available information, relative to NAVD88, or another national standard that is convertible to NAVD88, and the method of measurement described.
Well Type and Construction Details	A description of the well use/type, whether the well is active or inactive, and whether the well is a single, clustered, nested, or other type of well. Casing perforations, borehole depth, and total well depth shall be reported. Well completion reports will be provided, if available, from which the names of private owners have been redacted. Geophysical logs, well construction diagrams, or other relevant information will be provided, if available, including any other relevant well construction information, such as well capacity, casing diameter, or casing modifications.
Monitoring Zone	Identification of principal aquifer or aquifer zones monitored.

Requirements for well selection

- A long-term access agreement that includes year-round site access to allow for increased monitoring frequency
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact, type of information to be collected, latitude, longitude and elevation
- Monitoring location should also track all modifications to the site in a modification log

Monitoring Protocols

As referenced in §352.4 of the GSP regulations, "monitoring protocols shall be developed according to BMP. Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan and modified as necessary."

As per DWR's Monitoring Protocol BMP (DWR, 2016c) and the Subbasin's Coordination Agreement for Groundwater Elevation Data:

- Groundwater level data shall be sufficient to produce seasonal maps of potentiometric surfaces or water table surfaces throughout the basin that clearly identify changes in groundwater flow direction and gradient.
- Use the Kern Subbasin Well Data form.
- Groundwater level data shall be collected from each principal aquifer in the basin.

- Collection of data between the approved time frames only.
    - January 15th to March 30th
    - September 15th to November 15th
- A weighted water level meter will be used to measure the depth to groundwater.
- Depth to groundwater must be measured relative to an established Reference Point on the well casing. If no mark or reference point is apparent, the person performing the measurement should measure the depth to groundwater from the north side of the top of the well casing.
- The elevation of the Reference Point of the well must be surveyed to the North American Vertical Datum of 1988. The elevation must be accurate to within 0.1 foot.
- Each well's Reference Point will be cataloged to ensure identical procedures are followed for subsequent measurements.
- The data collector should remove the appropriate cap, lid or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement should follow a period of time to allow the water level to equilibrate.
- Depth to groundwater must be measured to an accuracy of 0.1 foot below the Reference Point.
- The water level meter shall be decontaminated after measuring each well.
- The data collector shall calculate the groundwater elevation as:
    - GWE = RPE – DTW
    - GWE = Groundwater Elevation
    - RPE = Reference Point Elevation
    - DTW = Depth to Water
- The data collector must ensure that all measurements are consistent units of feet, tenths of feet or hundredths of feet. Measurements and Reference Point Elevations should not be recorded in feet and inches.

Pressure Transducers

As per DWR's Monitoring Protocols BMP (DWR, 2016c), groundwater levels and/or calculated groundwater elevations may be recorded using pressure transducers equipped with data loggers installed in monitoring wells. When installing pressure transducers, care will be exercised to ensure that the data recorded by the transducers is confirmed with hand measurements.

The following general protocols will be followed when installing a pressure transducer in a monitoring well:

- The sampler will use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation.
- The sampler will note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.
- Transducers will be able to record groundwater levels with an accuracy of at least 0.1 foot. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers will be included in the evaluation.
- The sampler will note whether the pressure transducer uses a vented or non- vented cable for barometric compensation. Vented cables are preferred, but non- vented units provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.
- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that data quality objectives are being met for the GSP.
- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.

The transducer data will periodically be checked against hand measured groundwater levels to monitor electronic drift or cable movement. This will happen during routine site visits, at least annually or as necessary to maintain data integrity.

The data will be downloaded as necessary to ensure no data is lost and entered into the basin's DMS following the QA/QC program established for the GSP. Data collected with non-vented data logger cables will be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data will be deleted from the data logger to ensure that adequate data logger memory remains.

As mentioned above, for specific details regarding the monitoring network for groundwater level and change in groundwater storage for each management area, please refer to the respective individual management area plans. The data gaps and steps for improvement of the respective monitoring networks have also been identified in those management area plans.

3.4.7.2 Water Quality Monitoring Network Protocol and Standards

Groundwater Quality Monitoring Network Protocol and Standards

The existing monitoring network in the KGA includes production wells and dedicated monitoring wells. Until enough dedicated monitoring wells are installed to fill data gaps,

production wells will be used to expand the spatial coverage of the existing water quality network.

As referenced in §352.4 of the GSP emergency regulations, monitoring sites/wells will conform to best management practices for geographic locations, identification, and details on well construction.

Requirements for Well Selection

- A long-term access agreement that includes year-round site access to allow for increased monitoring frequency
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact, type of information to be collected, latitude, longitude and elevation
- Monitoring location should also track all modifications to the site in a modification log
- The use of existing water quality data within the basin should be done to the greatest extent possible
- Monitoring network should consist largely as a supplemental monitoring locations where known groundwater contamination plumes are under existing regulatory management

Monitoring Protocols

The monitoring protocols will follow, at a minimum, the sampling guidelines as provided in DWR's *Groundwater Monitoring Protocols, Standards, and Sites BMP* (2016c).

Groundwater quality sampling protocols will ensure that:

- Groundwater quality data are taken from the correct location,
- Groundwater quality data are accurate and reproducible,
- Groundwater quality data represent conditions that inform appropriate basin management and are consistent with the data quality objectives,
- All important information is recorded to normalize, if necessary, and compare data, and
- Data are handled in a way that ensures data integrity.

The following points are general guidance in addition to the techniques presented in the previously mentioned USGS *National Field Manual for the Collection of Water Quality Data.*

Standardized protocols include the following:

- Monitor groundwater quality data from each principal aquifer in the basin.
- Data should be sufficient for mapping movement of degraded water quality.
- Data should be sufficient to assess groundwater quality impacts to beneficial uses and users.

- Data should be sufficient to evaluate whether management activities are contributing to water quality degradation.
- All analyses should be performed by a laboratory certified under the State Environmental Laboratory Accreditation Program.
- Samples will be collected according to the standards listed in the Standard Methods for the Examination of Water and Wastewater, USGS National Field Manual for the Collection of Water Quality Data.
- Prior to sampling, the sampler must contact the laboratory to schedule laboratory time, obtain appropriate sampler containers, and clarify any sample holding times or sample preservation requirements.
- Each well used for groundwater quality monitoring must have a unique identifier. This identifier must appear on the well housing or the well casing to avoid confusion.
- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead. Samples are not to be taken/collected from storage tanks, at the end of long pipe runs or after any water treatment infrastructure.
- Samples will be taken/collected only after the appropriate volume of water has been purged from the casing and field parameters have stabilized.
- Sampler will clean the sampling port and/or sampling equipment. The sampling port and/or sampling equipment must be free of any contaminants.
- Groundwater elevation in the well should be measured following the protocols described in the groundwater level measuring protocols.
- Field parameters of pH, electrical conductivity and temperature should be collected for each sample. Lab pH analysis are typically unachievable due to short hold times.
- All field instruments should be calibrated daily and evaluated for drift throughout the day.
- Sample containers should be labeled prior to sample collection. The sample label must include:
    - Sample ID (well ID)
    - Sample date and time
    - Sample personnel
    - Sample location
    - Preservative used
    - Analytes and analytical method
- Samples shall be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection.
- Samples requiring preservation must be preserved as soon as practically possible.

- Samples to be analyzed for metals should be field-filtered prior to preservation. Do not collect an unfiltered sample in a preserved container.
- Samples will be chilled and maintained at 4 C to prevent degradation of the sample
- Samples will be shipped under a chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.
- Custody Seal will be used by the field technician if a third-party transportation service is used.
- A Field Sampling Log will be maintained for each sampling event and will include:
    - Sampler's identification
    - Well identification
    - Climatic conditions
    - Depth to water prior to purging
    - Type of purging and sampling device
    - Purging rate and volume
    - Relative well yield volume
    - Field parameter measurements (pH, temperature, EC, DO)
    - Type and number of samples collected
    - Date and time collected

As mentioned above, for specific details regarding the monitoring network for groundwater quality for each management area, please refer to the respective individual management area plans. The data gaps and steps for improvement of the respective monitoring networks have also been identified in those chapters.

3.4.7.3 Reduction of Groundwater Storage

The reduction of groundwater storage provides an estimate of the change in annual groundwater storage. Since the groundwater storage is not a directly measurable condition, it relies heavily on the collection of accurate groundwater level data. The changes in groundwater levels reflect changes in storage and can thus be estimated with assumptions of thickness of subsurface geologic units, porosity, and connectivity. These observations will be essential for use in calculating the water budget.

A water budget is a foundational tool used to compile water flows (supplies) and outflows (demands). It is an accounting of the total groundwater and surface water entering and leaving a basin or user-defined area. The difference between flows and outflows is a change in the amount of water stored.

Coordination of water budget data to comply with groundwater storage include:

- Surface water supply

- Total water use
- Water budget
- Sustainable yield

The change in the annual volume of groundwater storage between seasonal high conditions shall be quantify in the water budget calculations.

3.4.7.4 Land Subsidence Monitoring Network

The current regional subsidence monitoring network includes regional subsidence screening by InSAR conducted by the USGS and monitoring points at existing continuous GPS (CGPS) stations and available data from SOPAC, as described in the basin setting. These monitoring points include: P544, P545, P563, P564, P565, BFLD, ARM1/2, TAFT, and BVPP. In addition, local extensometers for Semitropic Water Storage District (25S22E35B001M) and Kern Water Bank (30S25E16L) and benchmark monuments of North Kern Water Storage District are included in the network. Data from leveling surveys of the California Aqueduct and Friant-Kern Canal are also valuable points that have some historical data, but which have not been formally incorporated into the local Subbasin network.

Subsidence monitoring is needed to understand the causes of subsidence, the potential risk of damaging critical infrastructure, and how to set minimum thresholds to avoid significant impacts to critical infrastructure in the Subbasin.

Regional coordination of monitoring is key to the design of the network in the Subbasin because regional groundwater extraction is a main driver for regional-scale subsidence, along with subsurface geologic conditions. In addition, if significant impacts to critical infrastructure due to subsidence associated with oil and gas activities identified through regional monitoring, they will be communicated to DOGGR to address as appropriate pursuant to Public Resources Code 3315.

The basis for the design of land subsidence monitoring in the Subbasin is CWC 23 CCR § 354.34. Below are excerpts of the code with pertinent requirements to the Subbasin monitoring network.

Based on 23 CCR § 354.34, the following are some of the key criteria considered for Subbasin monitoring:

- The monitoring will collect sufficient data for seasonal, short-term, and long-term trends in groundwater and related surface conditions.
- The monitoring network will focus on collecting subsidence data (rate and extent) to avoid undesirable results, which for subsidence is defined as "…the point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, affects the surface land uses or critical infrastructure…".
- The monitoring network will be based on scientific rationale.

§ 354.34. Monitoring Network

(a) Each Agency shall develop a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation.

…

(c) Each monitoring network shall be designed to accomplish the following for each sustainability indicator:

…

(5) Land Subsidence. Identify the rate and extent of land subsidence, which may be measured by extensometers, surveying, remote sensing technology, or other appropriate method.

…

(g) Each Plan shall describe the following information about the monitoring network:

(1) Scientific rationale for the monitoring site selection process.

….

(j) An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish a monitoring network related to those sustainability indicators.

Monitoring Protocols

The preliminary monitoring network is based on the following decision-making process (Figure 3-5), which represents continuous screening for land subsidence in the Subbasin by InSAR and ground truthing where necessary. Where critical infrastructure is potentially susceptible to regional subsidence and subsidence is evident, then a determination is needed as to whether groundwater extraction is causing the subsidence. If groundwater extraction is causing the subsidence, then the following actions should be taken:

1. groundwater level monitoring,
2. additional ground-truthing of subsidence, and
3. monitoring of the critical infrastructure.

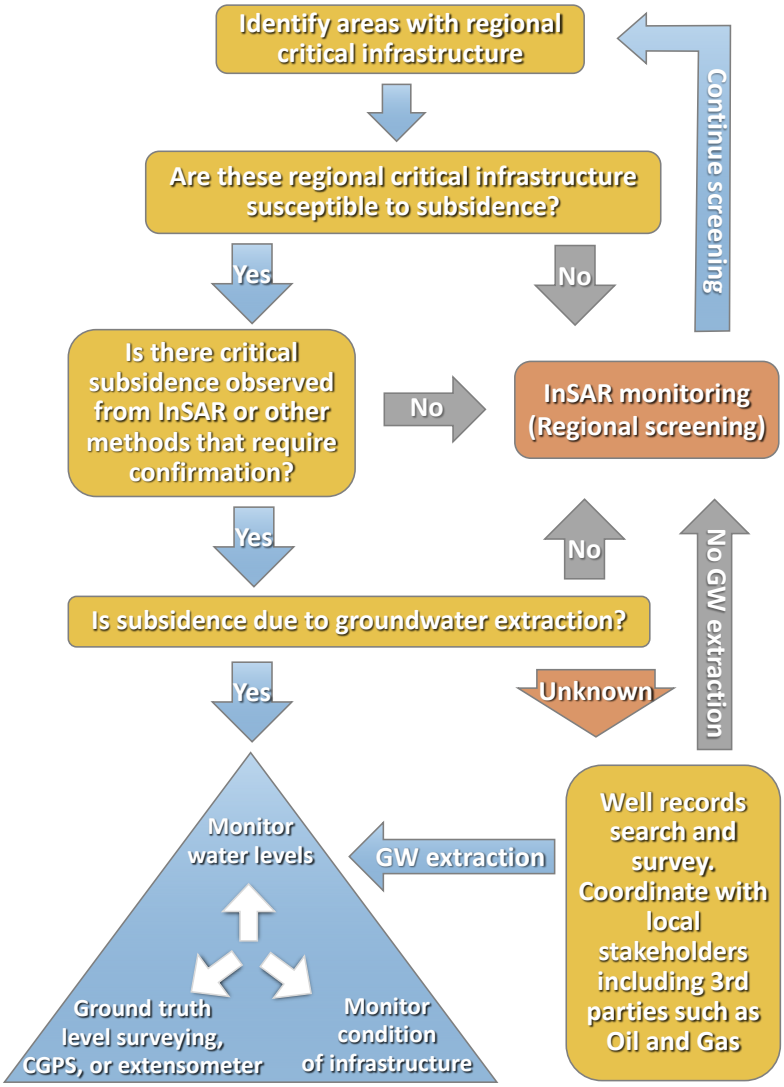
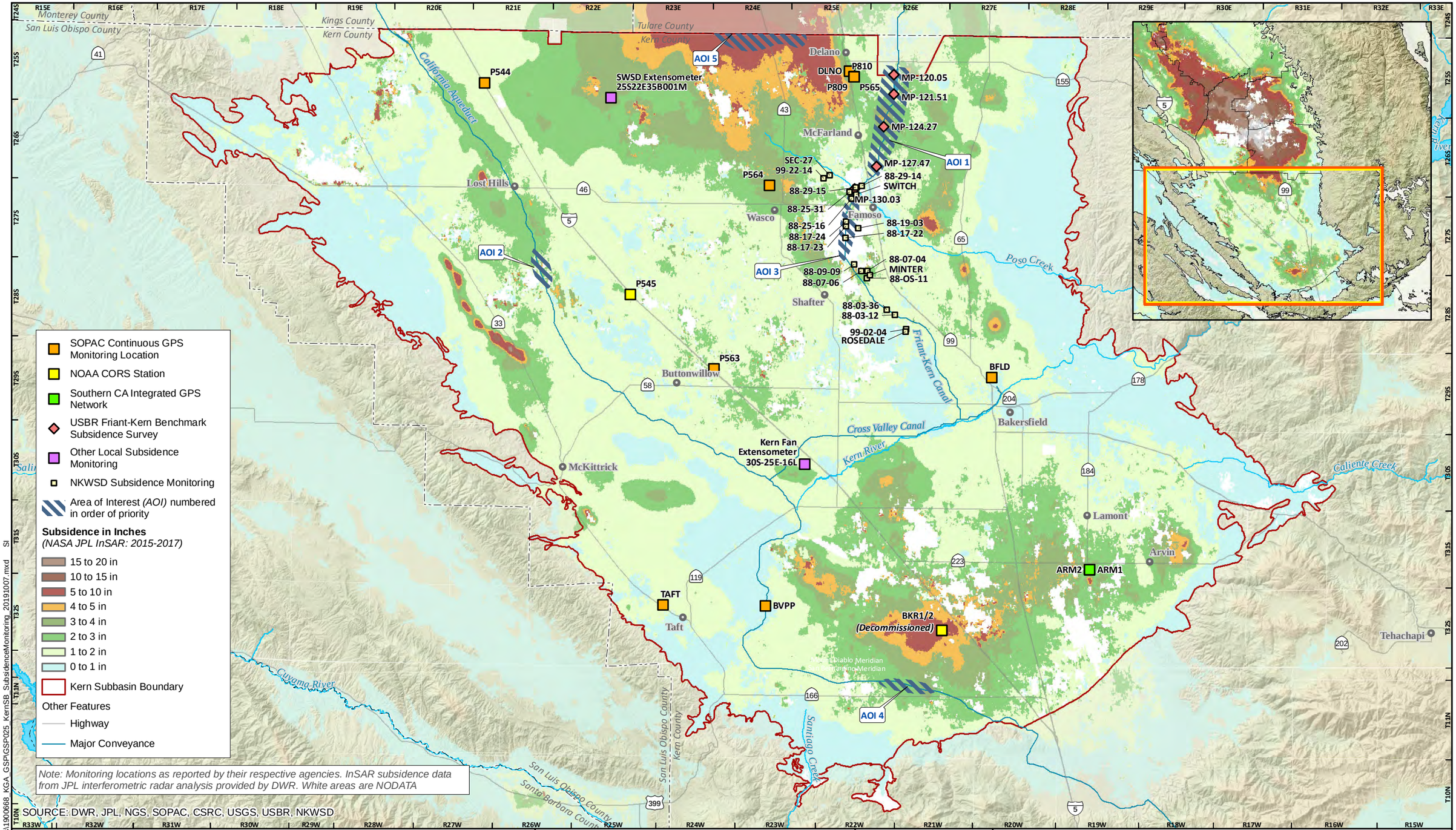


Figure 3-5. Subsidence Monitoring Design Approach

Subsidence Monitoring Network within Areas of Interest

The subsidence monitoring network areas of interest (AOI) are shown in Figure 3-6. Five AOIs were identified, in order of priority, to improve the subbasin monitoring network (AOI-1 to AOI-5). Two of these areas are located along the Friant-Kern Canal, two are along the California Aqueduct, and one area is for monitoring changes in land surface elevation along the northern boundary of the subbasin where a significant amount of subsidence has been reported in the InSAR data.

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Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

REGIONAL SUBSIDENCE MONITORING NETWORK

OCTOBER 2019

FIGURE 3-6

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Water Level Elevations

The collection of water level elevations should eb coordinated with subsidence monitoring points. If no wells within the water level monitoring network of the Subbasin are located near AOIs then monitoring wells at these locations will be identified for installation.

Five Areas of Interest

Based on the above monitoring design approach and recent InSAR and level surveying data from State Water Project, Central Valley Project, and North Kern Water Storage District as scientific rationale, four subsidence AOIs associated with critical infrastructure have been identified. In addition, a fifth AOI has been identified at the north boundary of the Subbasin. These AOIs will be covered by the monitoring network. Of these five, the stretch along CA Aqueduct MP 196 to 215 and MP 267 to 271 will be investigated to confirm if groundwater extraction is the cause of subsidence.

Where groundwater extraction is not causing subsidence in an AOI, groundwater management will not be a mitigating factor; therefore, the area will be removed from the AOI list for subsidence monitoring.

Friant-Kern Canal (AOI 1)

This high priority area is located along the Friant Kern Canal between Mileposts 120 to 130, east-northeast of the City of McFarland. The purpose of this AOI is to monitor subsidence along the Friant Kern Canal and its related infrastructure. At times, InSAR monitoring has reported up to 5 inches per year of subsidence in areas surrounding this segment of the Friant Kern Canal. At present, no significant impacts to the Friant Kern Canal have been reported along this portion of the canal's alignment. According to leveling survey data from Friant Water Authority (FWA, 2019), the Friant Kern Canal invert may have subsided from 2 ft to 3 ft below original as-built elevations between mileposts 120 to 135. Continued lowering of the canal invert can decrease freeboard from the original as-built conditions, which may contribute to reduction in emergency storage capabilities and delivery options of the Canal.

In contrast, beyond the Subbasin's northern boundary, subsidence has caused significant impacts to the Friant Kern Canal conveyance capabilities between mileposts 101 to 108.

Existing Monitoring

Currently, this area is screened by InSAR, and previous level surveying was performed by Friant Water Authority at mileposts 120 to 135. There are no other active monitoring points except for InSAR along this stretch.

New Monitoring Approach

A new CGPS station that monitors at the ground surface any subsurface subsidence, regardless of the depth interval, is recommended in this area. Monitoring at this location will assist in the KGA and its member to determine the causes of subsidence. If is it is reasonability determined that local agricultural extractions are the cause of subsidence at this location, the appropriate management area will work towards establishing appropriate measurable objectives and

minimum thresholds. This CGPS data will complement any manual level surveys that may incorporate the Friant Water Authority reported measuring points. CGPS data may also provide on-demand data as needed.

Coordination of Monitoring

Subsidence monitoring along the Friant Kern Canal benefits local stakeholders, CVP contractors, and the Friant Water Authority. It is anticipated that this monitoring can be coordinated with Friant Water Authority to share data as well as potentially share resources and cost.

Any level surveying along the canal from the United States Bureau of Reclamation Friant-Kern benchmarks will require coordination with the Friant Water Authority.

CA Aqueduct Milepost 196 to 215 (AOI 2)

This high priority area is the segment of the California Aqueduct where an embankment failure occurred at Milepost 208 in June 2011 (DWR, 2017c). This failure is partially attributed to subsidence. The cause of this subsidence is unknown and is therefore a subject of monitoring at this location. This area is along the Aqueduct between Mileposts 196 to 215 in the western central subbasin (Figure 3-5). In addition to embankment failure, other consequences of subsidence include loss in freeboard in the Aqueduct. This area has experienced at least 2 feet of subsidence since the Aqueduct was constructed.

Existing Monitoring

Currently, this area is screened by InSAR and is monitored with level surveys every three to seven years by the DWR's DOE. There are no other active monitoring points along this stretch.

New Monitoring Approach

The source of subsidence, either by groundwater extraction activities or oil activities, will be investigated by performing well records searches from DWR well completion records, the Kern County Public Health Department well permit records, and the DOGGR's databases. If necessary, a field well survey may be performed. Coordination may be needed with local stakeholders to confirm the magnitude of groundwater extracted within 1 mile of this portion of the Aqueduct's alignment and the volume of fluids extracted and injected by oil and gas activities within 1 mile of this alignment. A third potential source for subsidence in this area could be hydrocompaction, which was identified during the initial design and construction of the Aqueduct. Pre-consolidation of soil was performed during initial construction so hydrocompaction is likely not significant, however, it cannot be ruled out at this time.

If it is determined that groundwater extraction is playing a role in subsidence for this area, a monitoring point should be installed away from the footprint of the Aqueduct to avoid potential signatures of hydrocompaction if any exist. If there is question of whether some of the subsidence is related to nearby oil and gas activities, then an extensometer should be installed in the interval where groundwater production occurs. An extensometer will provide data of subsidence pertaining to intervals with groundwater production, whereas a CGPS would capture any subsidence regardless of the depth interval.

Coordination of Monitoring

Subsidence monitoring along the Aqueduct benefits local stakeholders, State Water Project (SWP) contractors, and the DWR's DOE. It is anticipated that this monitoring can be coordinated with DWR to share data as well as potentially share resources and cost.

Friant-Kern Canal Milepost 130 to 137 (AOI 3)

This medium priority area is located along the Friant Kern Canal between Mileposts 130 to 137, southwest of Famoso and Poso Creek. The purpose of this AOI is to monitor subsidence along the Friant Kern Canal infrastructure where InSAR and local stakeholders have reported subsidence in the surrounding area. As with AOI-1, no significant impacts to the Friant Kern Canal have been reported along this stretch. According to leveling survey data from the Friant Water Authority (2019), the Friant Kern Canal invert may have subsided from 2 ft to 3 ft below original as-built elevation between Mileposts 120 to 135. Continued lowering of the canal invert can decrease freeboard from the original as-built conditions, which may contribute to reduction in emergency storage capabilities and delivery options of the Canal.

Existing Monitoring

Currently, this area is screened by InSAR, and previous level surveying was performed by the Friant Water Authority at Mileposts labeled on Figure 3-5. Local districts monitor this stretch regularly. Currently there are no continuous monitoring points along this stretch.

New Monitoring Approach

A CGPS station that monitors from the ground surface, any subsurface subsidence regardless of the depth interval, is recommended because the only known cause of subsidence in this area is attributed to groundwater extraction. This CGPS data will complement manual level surveys from local district surveys. CGPS data will also provide nearly on-demand data as needed.

Where possible, this station should be tied in to benchmark surveys performed by local districts.

Coordination of Monitoring

Subsidence monitoring along the Friant Kern Canal benefits local stakeholders, CVP contractors, and the Friant Water Authority. It is anticipated that this monitoring can be coordinated with Friant Water Authority to share data as well as potentially share resources and cost.

Any level surveying along the canal from the Friant-Kern Canal benchmarks will require coordination with the Friant Water Authority.

CA Aqueduct Milepost 267 to 271 (AOI 4)

This medium priority area is located along the Aqueduct between Milepost 267 to 271 near Old River Road. InSAR data report subsidence southwest and along I-5 and southwest toward the Aqueduct along Old River Road. A former CGPS station (BKR1/2) located about 5 miles north of the Aqueduct along Old River Road also reported significant subsidence; however, this station has since been decommissioned (2016).

Existing Monitoring

Currently, this area is screened by InSAR, and is monitored by level surveying every three to seven years by the DWR's DOE. There are no other active monitoring points along this stretch.

New Monitoring Approach

Groundwater extraction is potentially the source of subsidence, so a continuous monitoring station such as a CGPS or extensometer will be installed. Other potential sources could be oil and gas extraction and hydrocompaction. A DOGGR records search may provide sufficient information to understand the extent of oil and gas extraction in this area. Although hydrocompaction may not be significant because of pre-consolidation practices during Aqueduct construction, nonetheless, in order to avoid potential signatures of hydrocompaction, a monitoring point should be installed away from the footprint of the Aqueduct. If feasible during the siting study, the site location may be selected to the north between the Aqueduct and former BKR1/2.

Where possible, this station should be tied in to benchmark surveys performed by local districts.

Coordination of Monitoring

Subsidence monitoring along the Aqueduct benefits local stakeholders, SWP contractors, and the DWR's DOE. It is anticipated that this monitoring can be coordinated with DWR to share data as well as potentially share resources and cost.

North Boundary of Subbasin (AOI 5)

This medium priority area is in the northern quarter of T25S-R24E and T25S-R25E. Currently, this AOI does not have recognized susceptible critical infrastructure. It has significant subsidence reported both historically (USGS level surveys) and recently (InSAR). A CGPS station in this area will provide a needed ground truthing point to confirm InSAR readings and will act as a useful monitoring point to gauge progress of groundwater management along the border of the subbasin in relation to neighboring subbasins to the north.

Existing Monitoring

Currently, this area is screened by InSAR. There are no other active monitoring points along this stretch.

New Monitoring Approach

Monitoring at this location will assist in the KGA and its members to determine the causes of subsidence. If is it is reasonability determined that local agricultural extractions are the cause of subsidence at this location, the appropriate management area will work towards establishing appropriate measurable objectives and minimum thresholds. If local groundwater extraction is determined to be the source of subsidence more detailed subsidence monitoring will be undertaken. a CGPS or extensometer monitoring station should be installed. Where possible, this station should be tied in to benchmark surveys performed by local districts.

Coordination of Monitoring

Subsidence monitoring along the subbasin boundary benefits local stakeholders in Kern County subbasin and adjacent subbasins. In the future, data may be shared with neighboring GSAs for coordination.

3.4.8 Assessment and Improvement of Monitoring Network

The following section describes data gaps and improvements for groundwater elevations, groundwater quality, and land subsidence. While this section provides the overall data gaps observed within the KGA, details for each management area can be found in the respective management area plan.

3.4.8.1 Groundwater Elevation and Storage

As referenced in § 352.4 of the regulations, "*If an Agency relies on wells that lack casing perforations, borehole depth, or total well depth information to monitor groundwater conditions as part of a Plan, the Agency shall describe a schedule for acquiring monitoring wells with the necessary information, or demonstrate to the Department that such information is not necessary to understand and manage groundwater in the basin."*

Well types and construction details will need to be determined to improve on the monitoring network. Downhole well surveys and desktop surveys will be utilized for existing wells to fill in the well construction details gap. New dedicated monitoring wells and converted monitoring wells from production wells will be utilized to fill in the monitoring network spatial extent and density. Plans for improvement will be developed during the next few years to be ready for proposal.

Currently, groundwater elevation and sampling measurements are not scheduled according to the 1 to 2-week period during the middle of Spring and middle of Autumn, as recommended by DWR's Monitoring Protocol BMP. Consequently, groundwater elevations and hydraulic gradients in the Subbasin are reported according to a broader range of time between Spring and Fall.

To minimize the effects of a temporal data gap in the future, it will be necessary to coordinate the collection of groundwater elevation data such that it occurs within a two-week window during the key reporting periods of mid-March and mid-October.

3.4.8.2 Groundwater Quality

New dedicated monitoring wells and converted monitoring wells from production wells will be utilized to fill in the monitoring network spatial extent and density. Plans for improvement will be developed during the next few years to be ready for proposal.

3.4.8.3 Land Subsidence

As described above, the Subbasin has agreed to a joint effort of monitoring subsidence at critical location in the Subbasin. The proposed monitoring program is to understand the causes of

subsidence, the potential risk of damaging critical infrastructure, and how to set minimum thresholds to avoid significant impacts to critical infrastructure in the Subbasin.

3.4.9 Monitoring Summary

The monitoring networks as described above will leverage existing networks for groundwater elevations and storage, groundwater quality, and land subsidence. The networks will be improved upon with data reported semiannually to meet the objectives of this plan. The networks will be evaluated as often as possible to consider improvements and adjustments, and at a minimum, every 5 years, the network reports will summarize the results against measurable objectives. The network improvement plan is provided below.

4 Projects and Management Actions

4.1 Proposed Projects and Management Actions

Projects and management actions for the KGA have been developed at the management area level. Table 4-1 (provided at the end of this section) provides a summary list of all projects and management actions being considered for implementation by each member agency, including the project title, implementation status, a brief description of the project, and benefits associated with the project. The details of each proposed project and management action can be found in each member agency's management area plan.

In addition to the projects and management actions that are proposed by the KGA members, the KGA has identified projects and management actions that it will implemented to further the coordination of groundwater management in the Subbasin. Table 4-2 list these proposed projects and management actions. These efforts will be managed by the KGA and will be cost-share through agreements with KGA members and other GSAs in the Subbasin, as appropriate.

Table 4-2: Kern Groundwater Authority Projects and Management Actions

Project Name	Project Description
Subsidence Monitoring (basin-wide)	Improve the understanding of the causes and impacts of subsidence in the Subbasin. Implementation Period: 2020 to 2025
Groundwater Modeling (basin-wide)	Improve the understanding of groundwater reactions to the implementation of projects and management actions, relationship to minimum thresholds and measurable objectives, determination of the native yield of the Subbasin, and subsurface flow within and out of the Subbasin. Implementation Period: 2020 to 2025
Study of Native Yield of the Subbasin	Studies to refine the understanding and allocation of the available native groundwater yield within the Subbasin. Implementation Period: 2020 to 2025
KGA Monitoring Network Improvement Program	The KGA will work with its member entities, and other Subbasin GSAs, to continue to improve and reach SGMA compliance for identified representative monitoring sites. The KGA will work to identify joint projects and programs to ensure efficient installation and/or rehabilitation of monitoring wells and data collection and reporting efforts. Implementation Period: 2020 to 2025.
Basin-wide Coordination	Continuation of the Kern Subbasin Managers Group to coordinate water management activities in the Subbasin, including technical analysis, project management and coordination, identification of joint management opportunities and coordination of SGMA reporting requirements to DWR. Implementation Period: 2020 to ongoing
Annual Reporting	Coordination and facilitation of annual SGMA reporting requirements. Implementation Period: 2020 to ongoing

The Subbasin includes a complex environment of various local and imported surface water supplies; variable access to groundwater supplies based on quantity and quality; water

management authorities; extent and capacity of water management infrastructure; and fiscal relationship with local landowners for participation in water management programs. Each of the member agencies within the KGA has identified projects and management actions best suited to meet the conditions of sustainability within their respective management areas within the water management and authorities of its entity. Collectively these projects and management actions are designed to maintain or achieve sustainability and the avoidance of undesirable results, first within the management area and then collaboratively throughout the Subbasin. The KGA, the KGA/GSA Managers Group and the Kern SGMA Coordination Committee will monitor the progress of project and management action implementation against reported groundwater conditions and performance to measurable objectives and interim milestones. Through this coordination effort opportunities will be explored for collaboration in implementing projects and management actions, as has been historically accomplished in the Subbasin, for joint conveyance as well as recharge and banking projects, as an example.

Table 4-1 list more than 150 projects and management actions. This includes management projects ranging from expansion of local and regional conveyance and recharge facilities to take advantage of surplus supplies; new conveyance and recharge projects; and participation in the California Water Fix or other thru-Delta improvement projects. Management actions range from implementing district level fee structures to incentive reduced groundwater pumping; participation in local, regional, and state-wide water markets; and setting allocation for groundwater use by landowner, based on the sustainable yield of the management area.

Table 4-1 also demonstrates the tremendous capacity of the entities in the Subbasin to implement projects and management actions to manage the Subbasin sustainably. As the KGA and the other Subbasin GSAs progress to 2040, the implementation of projects and management actions will be adaptively managed to ensure that the proper mix of projects or management actions are developed to avoid undesirable results. Each management area plan as developed its own adaptive management strategy, which often entails some level of groundwater pumping reductions if proposed project or management action are not realized or are not as effective as anticipated.

4.2 Projected Future Water Budgets with SGMA Implementation

Projected water budgets with implementation of the projects and management actions described in the previous section were developed using the C2VSimFG-Kern to evaluate the performance with respect to achieving groundwater sustainability. Proposed projects and management actions were simulated under Baseline conditions, 2030 Climate Conditions and 2070 Climate Conditions using the C2VSimFG-Kern. Detailed description of proposed SGMA projects, and management actions are provided in *Attachment H: Historical and Projected Future Water Budget Development with C2VSimFG-Kern*.

4.2.1 Future Baseline Water Budget with SGMA Implementation

The Baseline Scenario with Projects simulates the implementation of proposed projects and management actions applied to the Baseline Scenario. No other changes were made except for the addition of the projects to provide a direct comparison of the relative benefits of the over

400,000 AFY of proposed SGMA projects and management actions. The change in groundwater storage for projected future baseline with SGMA Projects improves by about 409,904 AFY. This change results in a net gain in groundwater in aquifer storage over the WY2041 to WY2070 sustainability period of about 85,578 AFY.

Figure 4-1 shows the comparison of the average annual water budget components for the two different Baseline Scenarios. Over this period, the average groundwater pumping of 1,354,000 AFY for the Baseline Scenario with SGMA Projects (which includes agricultural pumping, urban pumping and exported water) is over 270,000 AFY less than the Baseline Scenario.

4.2.2 2030 Climate Change Water Budget with SGMA Implementation

The 2030 Climate Scenario with SGMA Projects simulates the implementation of proposed projects and management actions applied to the 2030 climate change conditions. No other changes were made to this scenario. A comparison of the average annual water budget components for the two 2030 Climate Scenarios is presented in Figure 4-2. The change in groundwater storage for projected 2030 Climate Scenarios condition with SGMA Projects improves by about 418,949 AFY. This change results in a net deficit in groundwater in aquifer storage over the WY2041 to WY2070 sustainability period of about 46,829 AFY. Over this period, the average groundwater pumping of 1,444,300 AFY for the 2030 Climate Scenario with SGMA Projects, which includes agricultural pumping, urban pumping and exported water, is over 290,000 AFY less than the 2030 Climate Scenario without SGMA Projects.

4.2.3 2070 Climate Change Water Budget with SGMA Implementation

The 2070 Climate Scenario with SGMA Projects simulates the implementation of proposed projects and management actions applied to the 2070 climate change conditions. No other changes were made to this scenario. A comparison of the average annual water budget components for the two different 2070 Climate Scenarios is presented in Figure 4-3. The change in groundwater storage for projected 2070 Climate Scenarios condition with SGMA Projects improves by about 426,367 AFY. This change results in a net deficit in groundwater in aquifer storage over the WY2041 to WY2070 sustainability period of about 45,969 AFY. Over this period, the average groundwater pumping of 1,559,000 AFY for the 2070 Climate Scenario with SGMA Projects, which includes agricultural pumping, urban pumping and exported water, is over 307,000 AFY less than the 2070 Climate Scenario without SGMA Projects.

A comparison of the annual change in groundwater storage over the 50-year hydrologic period for the baseline conditions, 2030 and 2070 climate condition for with and without projects is presented in Figure 4-4. The time series shows that change in groundwater storage has stabilized to slightly increasing over the period from WY2041 to WY2070 for with Projects condition.

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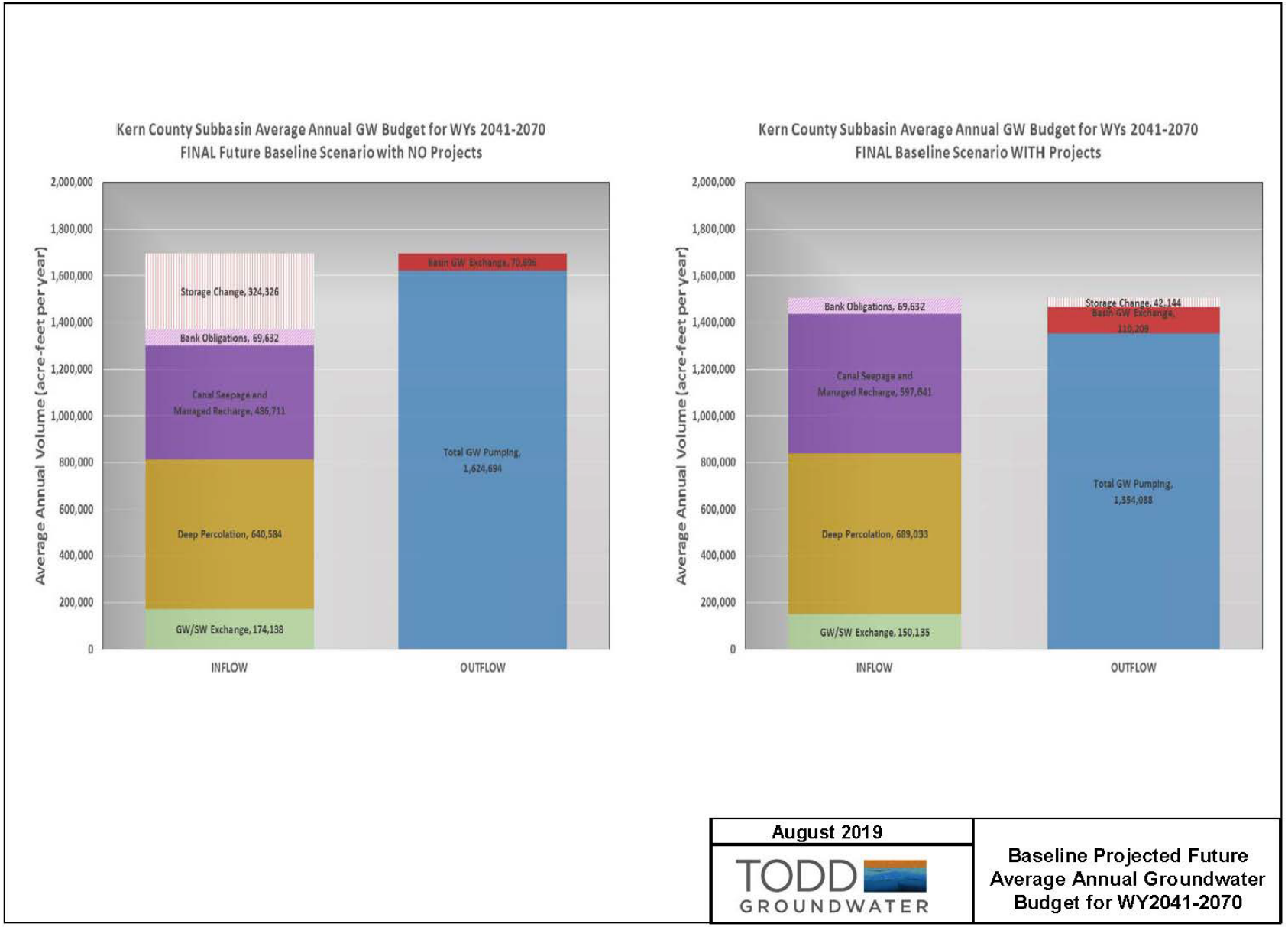


Figure 4-1. Baseline Projected Future Average Annual Groundwater Budget for WY2041-2070

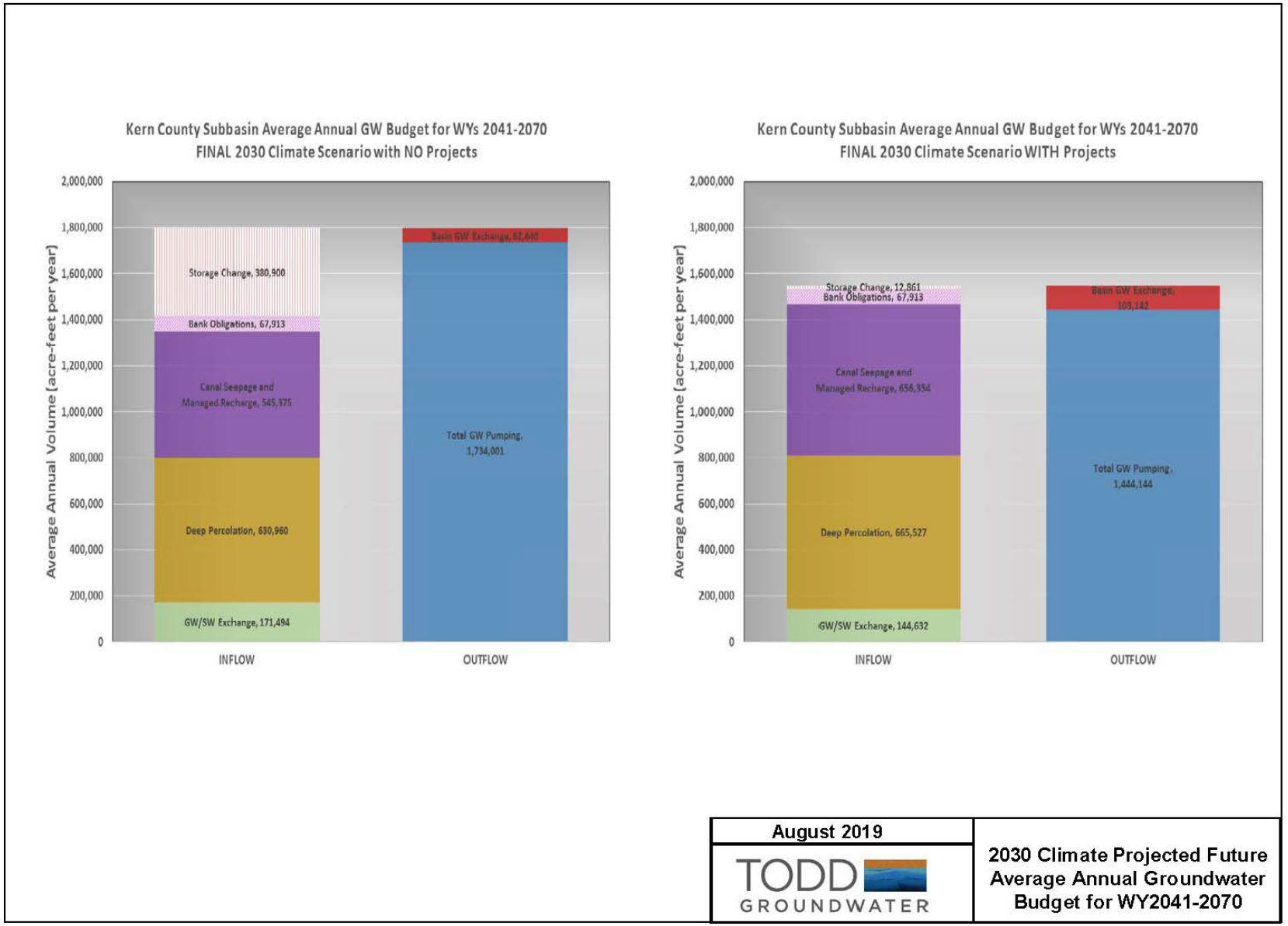


Figure 4-2. 2030 Climate Projected Future Average Annual Groundwater Budget for WY2041-2070

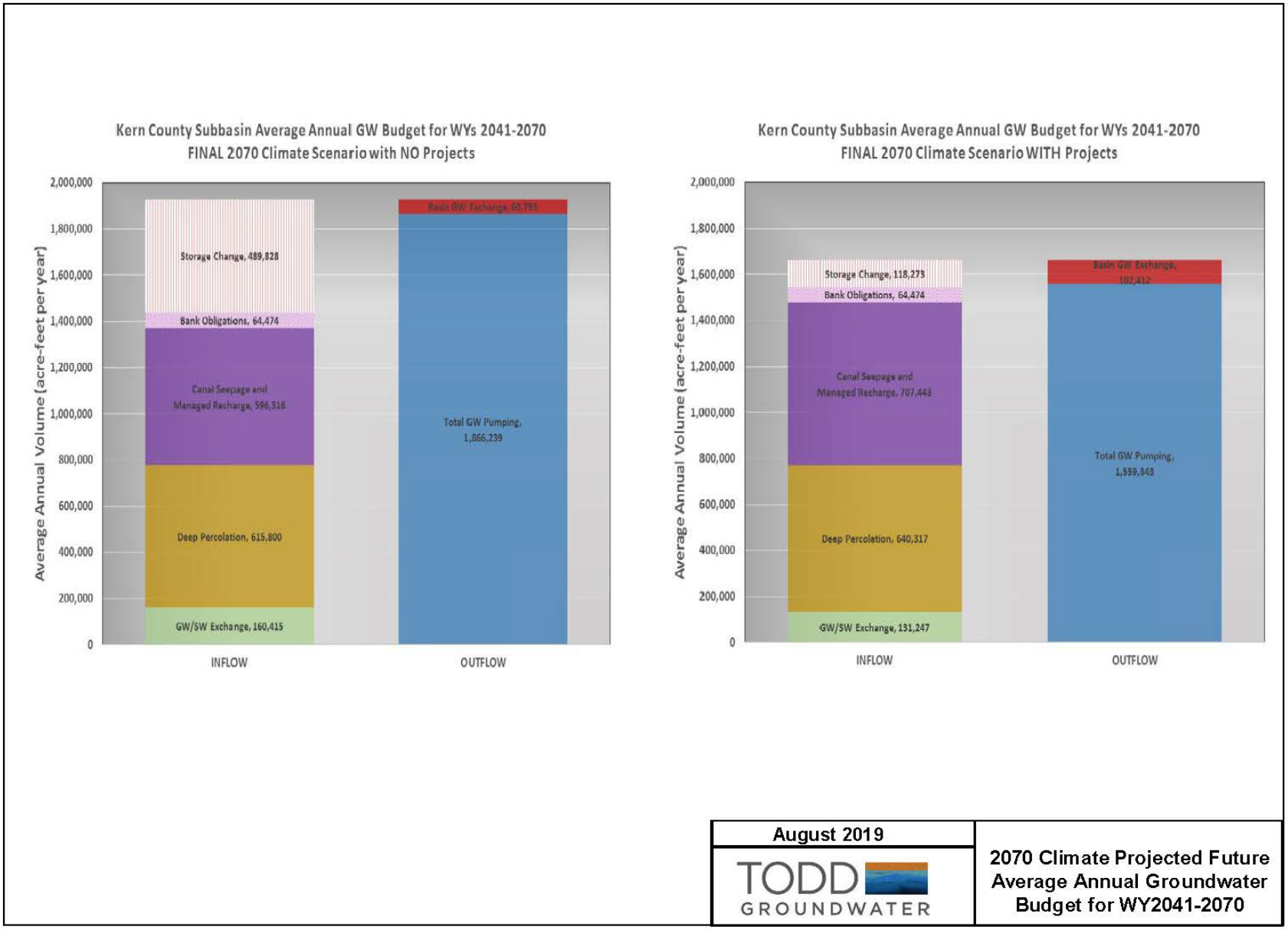


Figure 4-3. 2070 Climate Projected Future Average Annual Groundwater Budget for WY2041-2070

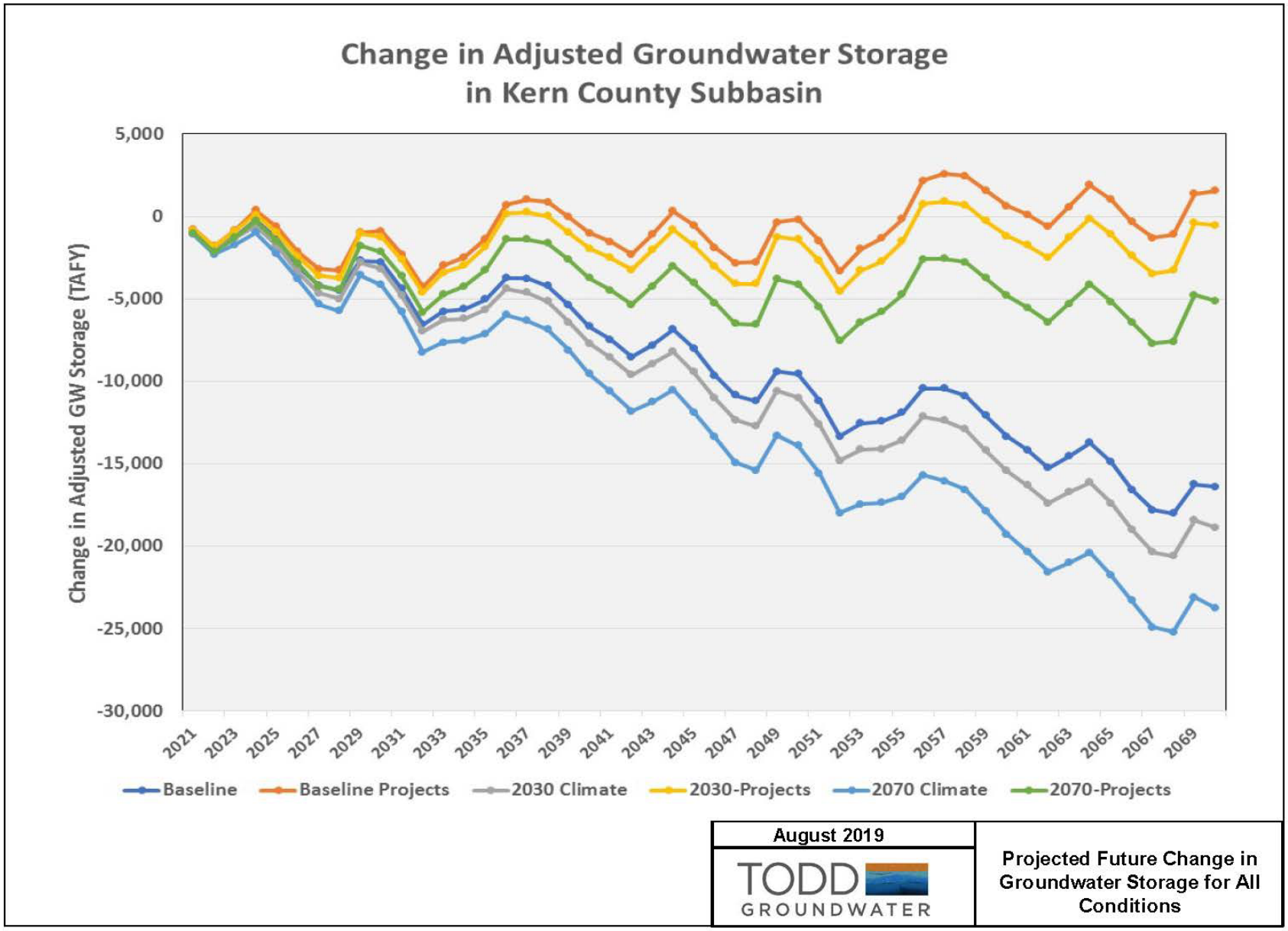


Figure 4-4. Projected Future Change in Groundwater Storage for all Conditions.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
Arvin-Edison Water Storage District				
AEWSD	AEWSD Sunset Spreading Works	Land acquisitions has been completed. To be implemented upon adoptions of AEWSD GSP Chapter and grant funding acquisition.	The Sunset Spreading Works, approximately 150 acres, is located on the boundary between AEWSDand KDWD, adjacent to KDWD's Eastside Canal. The Project will take surface water (Federal CVP,State Water Project, or local supplies) diverted through KDWD's Eastside Canal and recharge thesurface supplies as part of AEWSD's and KDWD's joint water management programs. The Project will include the construction of exterior and interior dikes for a direct recharge facility, a new turnout and pump station from the KDWD Eastside Canal, and interbasin structures.	Project enhances recharge relevant to groundwater levels, storage, and quality. Prima benefits include water supply augmentation of 2,000-3,000 AFY of recharge and a water demand reduction of 410 AFY.
AEWSD	Private and Caltrans Basin Connections	Not yet initiated. Implementation upon receipt of grant funding.	This project involves the construction of pipelines to connect several on-farm private basins and Caltrans sumps near AEWSD to utilize for groundwater recharge.	Project enhances recharge relevant to groundwater levels and storage. Primary benefits include water supply augmentation of 50-500 AFY of recharge.
AEWSD	Sycamore Creek Detention & Sedimentation Basin	Not yet initiated. Implementation upon receipt of grant funding.	The proposed basin would serve to intercept sediment from Sycamore creek flows to prevent constriction where sediment deposits downstream, reduce the peak outflow, and prevent the likelihood of a canal and spreading basin breach. Detained water could be recirculated for irrigation demands or recharged for groundwater supply augmentation.	Project enhances recharge relevant to groundwater levels, storage, and quality. Primary benefits include water supply augmentation of 200-300 AFY of stormwater capture.
AEWSD	AEWSD South Canal Flood Study / Improvements	Study to be initiated upon GSP adoption and grant funding acquisition.	The South Canal Flood Study would review and possibly revise the FEMA floodplain in this area in order to increase the height of the canal bank to provide additional operational freeboard and accordingly reduce the potential for canal spills and subsequent flooding.The additional canal storage could allow for the caputure and use of additional floodwater in-lieu of groundwater pumping.	Project enhances recharge relevant to groundwater levels and storage. Primary benefits include water supply augmentation of 100-200 AF of increased storage capacity and stormwater capture.
AEWSD	Stormwater Management and Flood Control Improvements	To be decided upon available funding. Excessive flooding or further damages may expedite intiation.	Potential construction of new sedimentation/detention basins, flood ditch erosion protection, Spillway Basin expansi lengthening the South Canal's siphon under David Road or extension of the South Canal liner through designated floodplain reaches.	Project enhances recharge relevant to groundwater levels, storage, and quality.
AEWSD	On-Farm Recharge	Underway	The program will encourage individual growers to perform on-farm recharge for individual and aggregated benefits. Water may be recharged on-farm in private basins and/or distributed through irrigation systems across irrigated acreage in excess of current crop ET.	Project enhances recharge relevant to groundwater levels and storage.
AEWSD	Caliente Creek Habitat Mitigation and Gorundwater Recharge	Not yet initiated. Implementation upon receipt of grant funding.	Restoration of agricultural lands to native vegetation to provide flood mitigation. Two alternatives are being considered, of which Alternative 1 is partial agricultural and 2 is non-agricultural.	Project provides immediate flood control benefits of local stormwwater.
AEWSD	AEWSD Intake Canal / KDWD Buena Vista Canal Intertie	Not yet initiated. Implementation to be decided.	Improvement of existing and/or construction of new interties between AEWSD Intake Canal and KDWD's Buena Vis Canal to facilitate water exchanges between the two districts and Kern County partners.	Project to increase surface storage capacity and delivery flexibility in relation to groundwater levels and storage. Primary benefits include water supply augmentation of 8,000 AFY increased transfer and exchange potential.
AEWSD	AEWSD Intake Canal / KDWD Farmer's Canal Intertie	Not yet initiated. Implementation to be decided.	Improvement of existing and/or construction of new interties between AEWSD Intake Canal and KDWD's Farmer's Canal to facilitate water exchanges between the two districts and Kern County partners.	Project to increase surface storage capacity and delivery flexibility. Primary benefits include water supply augmentation of 4,000 AFY increased transfer and exchange potential.
AEWSD	AEWSD Wasteway Basin Improvements	Project to be implemented upon FEMA grant approval.	The primary use of the existing AEWSD Wasteway Basin is to provide emergency water storage in the event of power failure. Additionally, it works as a detention facility for the City of Bakersfield stormwater. This project would include construction of a HDPE liner along the levees, installation of recirculation pumps, and basin grading. These improvements would allow the basin to serve as a location to divert and clarify sediment.	Project to increase surface storage capacity and delivery flexibility in relation to groundwater levels and storage. Primary benefits include water supply augmentation of 1,550 AFY of stormwater capture.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
AEWSD	Forrest Frick Pipeline / KDWD Eastside Canal Intertie	Not yet initiated. Implementation upon receipt of grant funding.	This project would connect the Forrest Frick Pipeline to the KDWD Eastside Canal to send AEWSD SW supplies through KDWD to serve portions of the AEWSD GWSA with temporary water contracts, utilizing existing infrastructure (turnouts, pipelines that are both District and landowner owned). With the District's new 9(d) contract, certain provisions of Reclamation law are no longer applicable and all lands within the service area can now be served with federal water supplies.	Primary benefits include water supply augmentation of 10 AFY of recharge, 3 AFY/ac of land served.
AEWSD	AEWSD North Canal Balancing Reservoir Expansion & Discharge Pipelines	To be initiated upon completion of feasibilty	The proposed project will consist of the installation of a pipeline system that will convey flows from the four (4) wells within the AEWSD Balancing Reservoir directly to the basin discharge structure and no longer through the basin low flow channels. Infiltration and evaporation losses on well discharge flows will be eliminated and power efficiency for the wells (kwh/af) will be significantly enhanced since all water pumped will be discharged into the North Canal.	Primary benefits include water supply augmentation of 16 AF of increased storage capacity and 100 AFY of recharge. In addition, water demand is expected to be reduced by 50 AFY in evaporative losses.
AEWSD	AEWSD Lateral Capacity Improvement Projects	Not yet initiated.	Increase delivery capacity of the AEWSD N-55 lateral system. Some examples of the actions considered for this project are: replacement of lateral system and landowner pipelines, renovation of storage tanks, construction of pump stations, etc.	Primary benefits include water supply augmentation of 2,000 AFY of of increased delivery capacity.
AEWSD	Conversion of Granite Quarry to Sycamore Reservoir	Study to be initiated upon GSP adoption and grant funding acquisition.	The Granite Co. quarry, located upstream of the Sycamore Spreading Basins, is approaching the end of its operational life and could be converted into a balancing / detention / spreading reservoir. Excess flows in the North Canal could be pumped into the quarry reservoir, so the detained water could be recirculated for irrigation demands in lieu of groundwater pumping and/or recharged.	Primary benefits include water supply augmentation of 3,000-6,000 AFY of recharge and an additional 2,500 AF increased storage capacity.
AEWSD	AEWSD South Canal Balancing Reservoir	Not yet intiated.	Creation of a reservoir to allow water storage for flow mismatches in the AEWSD canal system during operation or emergencies. Depending on the location, this reservoir would increase storage capacity by ~500 AF.	Primary benefits include water supply augmentation of 500 AF increased storage capacity.
AEWSD	Frick Unit In-Lieu Project	Not yet intiated. To be implemented upon grant funding.	This project would increase the ability of the District to provide surface water supplies to the Groundwater Service Area (GWSA) to help meet crop irrigation requirements. With the Project, the District will supply surface water when available through new facilities to the GWSA to meet crop irrigation requirements with the intent of reducing District wide groundwater use.	Primary benefits include water supply augmentation of 3,500 AFY of increased surface water deliveries.
AEWSD	DiGiorgio Unit In-Lieu Project	Completed Phase I. Future phases intiated upon grant funding.	The District will supply SW when available through new facilities to the GWSA to meet its water requirements with the intent of reducing District-wide GW use. However, when SW is in short supply and under agreement, the landowners could recover and return GW from their own wells to the District canal system through new pipelines once they have satisfied their own water needs.	Primary benefits include water supply augmentation of 4,250 AFY in increased surface water deliveries.
AEWSD	General In-Lieu Banking Program	Not yet initiated. To be implemented upon grant funding.	The In-Lieu Banking Program consists of suppling surface water to landowners that previously relied only on groundwater (GWSA). New infrastructure would have to be built to facilitate the implementation of this program.	Primary benefits include water supply augmentation of 2.75 AFY/ac increased surface water deliveries every 2.5 years.
AEWSD	Reclamation of Oilfield Produced Water	To be implemented upon adoptions of AEWSD GSP Chapte and agreement with partnering oil field.	Reclaiming water from oil production facilities for irrigation purposes is currently an untapped water source in AEWSD. After treatment and cooling, produced water could be pumped into AEWSD facilities to serve irrigation demands in-lieu of groundwater pumping.	The primary expected benefit is water supply augmentation.
AEWSD	Wastewater Reclamation with City of Arvin & Bakersfield	To be implemented upon adoptions of AEWSD GSP Chapte and agreement with City of Arvin and City of Bakersfield.	Reclaiming water from Cities of Arvin and Bakersfield wastewater treatment facilities for irrigation purposes is currently an untapped water source in AEWSD. After wastewater treatment, the effluent could be pumped into AEWSD facilities to serve irrigation demands in-lieu of groundwater pumping.	The primary expected benefit is water supply augmentation of 10,000 AFY.
AEWSD	Incentives for Land Conversion	To be implemented upon adoptions of AEWSD GSP Chapter.	The District would provide subsidies to incentivize groundwater users to convert land to alternative land uses (e.g. solar farms) and reduce groundwater extractions. The District may consider a subsidy structure study to determine which subsidies would result in the greatest expected annual benefit in acre-feet per year.	The primary expected benefit is water demand reduction of 2.75 AFY/ac of land converted.
AEWSD	On-farm Water Conservation	To be implemented upon stakeholder interest and acuisition of grant funding.	The NRCS is offering landowner incentive programs to assist in implementing various conservation activities, including but not limited to: irrigation system improvements, water/nutrient/pest management, and pump engine replacement. Interested landowners can call (661) 336-0967 or visit the website (www.ca.nrcs.usda.gov) for more information.	The primary expected benefit is water demand reduction of 50 - 500 AFY.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
AEWSD	Groundwater Fee Increase	Contingent on the Frick Unit In-Lieu Project, Digorgio Unit In-Lieu Project, and General In-Lieu Banking Program.	Increase GWSA costs to incentivize groundwater users to reduce groundwater extractions and take surface water when available. The District may consider modifying its fee structure study to determine the best strategy for curbing groundwater overdraft without causing inequitable economic impact.	The primary expected benefit is water demand reduction.
AEWSD	Groundwater Extraction Quantification Method	To be implemented upon adoptions of AEWSD GSP Chapter.	Application of a new policy to specify an approved method to quantify the individual and aggregated groundwater extractions for the required SGMA annual reporting. Some methods to consider (or a combination of them) are the following: (1) Irrigated Acreage determined by aerial imagery; (2) Irrigated area hybrid determined by annual crop survey alongside aerial imagery; (3) Calibrated energy records; (4) Volumetric flow measurement; (5) Remote sensing of vapotranspiration; (6) Other.	This Project is expected to improve water management flexibility and efficiency as well as data gap filling and monitoring.
AEWSD	Groundwater Allocation per Acre	To be implemented upon adoptions of AEWSD GSP Chapte and initiated as needed to meet milestones if other new supplies are not developed as anticipated.	This program would provide a finite groundwater allocation on a per acre basis. The policy would identify and forecast the demands associated with existing water rights, domestic and environmental uses. The sustainable yield and ultimate groundwater allocation would take into consideration the applicable beneficial uses and users of groundwater. Once an individual groundwater allocation is determined, the District may adopt a policy which provides a gradual “ramp-down” wherein an allocation would decrease over time to arrive at the actual roundwater allocation to allow growers time to adjust to the concept of an allocation and, for some growers, a reduction in groundwater use. The policy would detail the number of years and amount of reduction each year.	The primary expected benefit is water demand reduction.
AEWSD	Groundwater Marketing & Trading	Contingent on Management Actions; Groundwater Extraction Quanitification Method and Groundwater Allocation per Acre.	Contingent on the GW extraction quantification and allocation programs, the District would pursue a groundwater market and trading program to provide uses and beneficial users more flexibility in utilizing a groundwater allocation. The District may adopt a policy to define a groundwater trading program, acknowledging that many complexities and considerations required to successfully initiate and manage a trading program may arise. Therefore the District should discuss any other water bank/credit systems in existence. The District may adopt a groundwater trading structure and consider a variety of structures including: (1) Bilateral contracts or "coffee shop" markets; (2) Brokerage; (3) Bulletin boards; (4) Auctions and reverse auctions; (5) Electronic clearing-houses or "smart markets" ; (6) Other trade structures.	This Project is expected to improve water management flexibility and efficiency.
AEWSD	Education of Groundwater Use per Acre	To be implemented upon adoptions of AEWSD GSP Chapter.	This program would provide groundwater users an expected groundwater volume, as an education tool, prior to enforcement actions on groundwater allocations, with the goal of providing awarness of overdraft conditions. This information would be provided in an annual letter, along with average crop demand, GSA average extraction, GW overdraft, and reminders of GSA powers and authorities.	The primary expected benefit is water demand reduction of 100 AFY.
AEWSD	ACSD Emergency 1,2,3-TCP Treatment at Well No. 13	Implementation is underway.	The project involves the installation of emergency 1,2,3-TCP treatment at the well head. The work will include installation of a skid mounted treatment system with two granular activated carbon media vessels for removal of 1,2,3-TCP, connection to the existing well discharge piping, installation of below ground and above ground influent and effluent piping and appurtenances, electrical and controls, and modifications to the existing well site PLC programming.	This Project is expected to imrpove water quality.
AEWSD	ACSD Arsenic Mitigation Project - Phase II	Implementation is underway.	The purpose of the project is to bring the ACSD water system into compliance for Arsenic. All five of the ACSD active wells exceed the maximum contaminant level (MCL) of 10 ppb for Arsenic. The project was separated into two phases. Phase II involves drilling three new wells, constructing a 1.0 MG storage tank and booster pumping plant, and connecting the facilities to the existing distribution system. The original five (5) water wells will then be abandoned and destroyed in accordance with Kern County Standards.	This Project is expected to imrpove water quality.
Cawelo Water Storage District				
CWD	Voluntary Land Conversion	2020 to 2040 Implementation	The Cawelo GSA will develop a program to incentivize landowners to reduce their total crop demand by converting farmed land to groundwater recharge areas. This would reduce demands and the increased recharge capability could increase supplies. It could also reduce the potential of currently fallow land being used for future crops. This Management Action could be implemented conjunctively with Project #2: Increase GW Recharge and Banking Capacity	Range of annual benefit is 2,000 AFY with an average annual benefit at 2040 of 2,000 AFY.
CWD	Crop Conversion and Irrigation Efficiency	2020 to 2040 Implementation	The Cawelo GSA will evaluate potential programs to incentivize growers to convert from relatively high water demand crops to crops that require less water and to improve the efficiency of irrigation practices. The Cawelo GSA will partner with Federal, State and local organizations such as the California Department of Food and Agriculture, U.S. Department of Agriculture, and Natural Resources Conservation Service to provide landowners information and access to conservation programs. The programs would educate the landowners on the potential economic savings from conversion to lower water demand crops and increased irrigation efficiencies and incentivize them to seek improved economically viable agricultural operations.	Range of annual benefit is less than 2,000 AFY with an average annual benefit at 2040 of 3,8000 AFY.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
CWD	Land Acquisition	2020 to 2040 Implementation	The Cawelo GSA will evaluate and potentially implement a program to acquire land that is actively farmed to reduce irrigated acreages within the Cawelo GSA. This would directly eliminate demands and free up the associated water supplies to meet other demands. This could be a very long-term program seeking to acquire appropriate land when available or to reduce the financial burden. Another method for pot ential conservation programs will be developed that could place certain easements on land that would minimize potential future increased water demands. These programs could also be implemented by contracts or other types of agreements.	Range of annual benefi is 2,500 AFY with an average annual benefit at 2040 of 2,400 AFY.
CWD	New Water Supply Purchases	Begin program in 2020.	The Cawelo GSA would implement programs that will acquire long-term new water purchase contracts and/or establish a water purchase fund if contracts are difficult to secure because of high demand and competition and resulting high costs. The main goal would be to secure long-term new water contracts but compliance with SGMA will impact future water management practices and could make the availability of new long-term contracts scarce. If long-term contracts can't be secured then a new water fund would be established to build funding reserves for water purchases. These purchases could occur during favorable times such as hydrologically wet years when water will be more readily available at lower costs. While the Cawelo GSA would likely not need this water in wet years, these types of purchases could be in the form of banked water that the Cawelo GSA could request at a future date. Alternatively, the funds could be used to make annual water purchases and the revenue for the fund would be consistent from year to year regardless of the hydrological conditions. Therefore, during wet or average hydrologic years the water would cost less and reserves would be built up for more costly water purchases during the drier years. It is estimated that an additional 5,000 AFY to 23,000 AFY of water could be imported into the Cawelo GSA area through new long-term contracts or establishing a new water purchase fund or both.	Securing new long-term contracts or establishing a water purchase fund or both could result in an additional 5,000 AFY to 23,000 AFY of water that could be imported into the Cawelo GSA area. This additional water would increase the amount of water in the basin and decrease overdraft.
CWD	Increase Groundwater Recharge and Banking Capacity	Target 2030 Implementation	The Cawelo GSA will implement projects or programs to increase recharge capacity to capture and recharge additional wet year high flow waters to store for future use. The Cawelo GSA has limited groundwater recharge facilities and has not been able to capture and recharge all available water under wet hydrological conditions. This project would entail building additional Cawelo GSA-owned recharge facilities and/or improve the distribution system to increase the capacity to capture more water, especially during wet hydrologic events. Some facilities could be strategically located to capture storm runoff that may otherwise leave the Cawelo GSA area. It is estimated that approximately 200 to 570 acres of new recharge and banking facilities could be developed. Additionally, the Cawelo GSA will consider implementing a program to incentivize landowners to use their land for recharge. This could provide an opportunity for landowners to bank their private-owned water for future recovery and possibly allow the Cawelo GSA access to their lands for additional recharge. This program would not only increase recharge capacities during wet years but could also reduce water demand by replacing crops with recharge facilities. The privately-owned water could be purchased under Project #1, New Water Supply Purchases, described above.	There are significant regions within the Cawelo GSA with soil properties that could achieve percolation rates of up to 0.5 AF per day. Assuming an average percolation rate of 0.35 AF/day and approximately 200 to 570 acres of potential new recharge and banking land, about an average of 500 AFY to 1,500 AFY of new water could be recharged for future recovery. It is not clear what magnitude landowner-owned recharge facilities would have on importing additional waters into the Cawelo GSA are It could be anywhere between an average of 50 AFY to 500 AFY.
CWD	New Cawelo GSA Banking Partners	Begin program in 2020.	The Cawelo Water District benefits from a banking program partnership with the Zone 7 Water Agency. Located in the Livermore-Amador Valley, which is outside of the Kern County Subbasin. The District stores water for Zone 7 and keeps half of the water that it stores. For example, for every 2 AF feet of water delivered to District recharge facilities, the District is obligated to only return 1 AF. The currently banking program with Zone 7 could be modified to increase the amount of water stored for Zone 7 and/or a new banking programs and partners could be considered to fund the construction of new facilities and/or to improve existing facilities. It is estimated this could increase the annual average water supply up to 500 AFY.	The expansion of the existing banking contract with Zone 7 and/or the development of additional banking partners would be a beneficial way the Cawelo GSA could increase its groundwater supply by the portion of water each partner agrees to essentially leave in the Cawelo GSA area. Zone 7 has agreed to leave 50 percent of all that is spread. It is estimated that this program would generate about 500 AFY.
CWD	Water Treatment Facilities	Begin program in 2020.	The Cawelo GSA is currently evaluating projects to install water treatment facilities that will allow the Cawelo GSA to acquire wastewater and treat it to a level that is safe for crop irrigation. Wastewater is exempt from SGMA regulation and the treated wastewater would be considered new water. There is a substantial volume of oilfield produced water (OPW), a byproduct of oil production, available in the vicinity of the Cawelo GSA. The salinity of OPW can range from moderate to high, although even the best quality still requires some level of blending with fresh water before it can be used on crops. Reverse osmosis or distillation would generally be needed to remove enough salts to make the OPW usable for irrigation. Near the Cawelo GSA, approximately 20,000 AFY of wastewater is injected into exempt groundwater aquifers well below the base of fresh water. The Cawelo GSA is evaluating potential projects to treat anywhere from 7,500 AFY to 20,000 AFY of OPW.	The treated OPW would be a new source of about 7,500 AFY to 20,000 AFY of water for irrigation.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
CWD	Friant Pipeline Project	Construction in 2019.	The Cawelo GSA is currently developing the Friant Pipeline Project that would increase water importation capacity into the Cawelo GSA area. Currently, the amount of imported water that the Cawelo GSA can import into the area is limited by conveyance capacity, not by irrigation demand or recharge basin capacities. The Friant Pipeline Project would increase the total capacity by 100 cubic feet per second (cfs) and connect Cawelo's Famoso Recharge Basins directly to the Friant-Kern Canal. The increased capacity would allow greater access to high flow water and support banking programs with Friant Contractors. The Friant Pipeline Project would result in an additional 1,500 AFY to 2,500 AFY of water brought into the Cawelo GSA area on an average annual basis.	The Friant Pipeline Project would increase the total capacity into the Cawelo GSA by 100 cfs and increase access to CVP high flow waters and allow for banking programs with Friant Contractors. It would result in an additional 1,500 AFY to 2,500 AFY of water brought into the Cawelo GSA area on an average annual basis.
CWD	Poso Creek Flood Water Capture	Target 2030 Implementation	The CWD has appropriative rights to divert water from Poso Creek, an ephemeral stream, when there are flows into the Cawelo GSA area. Additionally, there are downstream districts that also have subsequent appropriative rights and certain adjacent landowners that exercise their riparian rights. CWD also has additional diversion rights to divert supplementary water when high flows occur. The Poso Creek Flood Water Capture Project would consist of the construction of additional facilities to take advantage of those additional rights and divert supplementary water from creek during times of high flow. In addition to making more water available to the Cawelo GSA, this capture of additional high flows could reduce potential downstream flooding impacts. Participation from downstream right holde would be needed due to potential water right impacts. The estimated net water gain is up to 150 AFY on average.	The Poso Creek Flood Water Capture Project would provide up to 150 AFY on average of additional water and could reduce potential downstream flooding impacts.
CWD	Surface Water Storage	Target 2030 Implementation	The Cawelo GSA has several existing reservoirs with a combined storage capacity of 800 AF. This project would consist of constructing a new 5,000 AF reservoir within the Cawelo GSA boundary. This would provide additional storage capacity to bring more water into the Cawelo GSA area during wet years. It is estimated that this new reser would provide approximately 500 AFY on average. This program would likely only be implemented conjunctively with other water management programs.	A new reservoir would provide approximately 500 AFY on average.
CWD	Out of Cawelo GSA Banking	Begin program in 2020.	The Cawelo GSA will evaluate groundwater banking projects that are outside the Cawelo GSA but within the Kern County Subbasin and also groundwater banking projects outside of the Kern County Subbasin. Potential banking projects outside of the Cawelo GSA are likely to have multiple participants and therefore offer a limited share of pro benefits.	This Project could yield an average annual benefit of 500 AFY to 4,000 AFY through out of Cawelo GSA banking programs.
Eastside Water Management Area				
EWMA	Project-1	Not yet initiated; Timetable TBD.	Development of oilfield produced-water supplies to potentially reduce groundwater demand.	Potential additional external source of water for the basin (annual volume TBD).
EWMA	Project-2	Not yet initiated; Timetable TBD.	Investigation of groundwater quality by compilation and analysis of (a) available water quality data, and (b) borehole geophysical data.	Improved HCM and understanding of 3-D distribution of TDS in specific aquifers or regions.
EWMA	Project-3	Not yet initiated; Timetable TBD.	Improved estimation of local (EWMA) native yield by use of additional field-collected data and analysis.	Improved HCM and understanding of groundwater recharge in specific aquifers c regions.
EWMA	Project-4	Not yet initiated; Timetable TBD.	Construction of aquifer-specific monitoring wells in locations with data gaps, to better understand hydraulic heads and gradients.	Improved ability to monitor groundwater conditions in specific aquifers or areas.
EWMA	Project-5	Not yet initiated; Timetable TBD.	Installation of pressure transducers in selected wells of the monitoring network, to collect high-resolution cost-effect data.	Improved ability to monitor groundwater conditions in EWMA.
EWMA	Project-6	Not yet initiated; Timetable TBD.	Surface runoff capture and enhanced infiltration in impoundments.	Reduced groundwater pumping (annual volume TBD) to meet sustainability goals, as needed.
EWMA	Management Action-7	Not yet initiated; Timetable TBD.	Reduction of irrigated acreage, or modification of irrigation techniques or crop types to reduce water usage.	Reduced groundwater pumping (annual volume TBD) to meet sustainability goals, as needed.
EWMA	Management Action-8	Not yet initiated; Timetable TBD.	Assess fees for groundwater use to encourage reduced pumping or curtailment.	Reduced groundwater pumping (annual volume TBD) to meet sustainability goals, as needed.
EWMA	Management Action-9	Not yet initiated; Timetable TBD.	Establish a system of transferrable water credits.	Reduced groundwater pumping (annual volume TBD) to meet sustainability goals, a needed.
EWMA	Management Action-10	Not yet initiated; Timetable TBD.	Legal and administrative review: effects of CEQA and water law on joint management of native yield.	Clarification of constraints on sustainable groundwater management in EWMA.
Kern Water Bank Authority				
KWB	Temporary Lowering of Groundwater Levels	Ongoing	KWB operations can cause a temporary lowering of groundwater levels in adjacent areas toward the end of extended droughts. In order to mitigate the potential impacts that might arise from those temporary changes, DWR has developed mitigation measures for the project, which have now been coordinated with other adjacent water banking projects and incorporated into a Joint Operations Plan. The Joint Operations Plan designates measures to prevent, eliminate or mitigate significant adverse impacts resulting from project recovery operations.	

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
KWB	Reduction of Groundwater Storage	Ongoing	KWBA cannot recover water beyond those volumes previously stored less appropriate losses. When storage accounts reach zero, recovery pumping will stop. Given due consideration to this mitigation measure, no other management actions are necessary	
KWB	Degraded Water Quality	Ongoing	Groundwater monitoring from 1994 through 2018 indicates groundwater quality is not being degraded by KWB water banking activities, and in fact the removal of salts is benefitting the aquifer. DWR developed mitigation measures to ensure that continued KWB operations do not degrade groundwater quality.	
KWB	Subsidence	Ongoing	Subsidence has not occurred in over twenty years of KWB operations. DWR has also concluded that subsidence is not likely to occur as the result of future operations. Monitoring will continue, and if subsidence begins to develop appropriate mitigation measures will be developed.	
KWB	Project	Not yet initiated.	KWBA intends to construct an additional 1,025 acres of recharge basins.	Project will allow KWBA capture more water in the future, furthering the conservation goals of SGMA.
Kern Tulare Water District				
KTWD	Action 1: Modify District Pricing Structure	ction 1 could be executed during the first 5 years of implementing the Plan (2020-2025).	The most affordable way to reduce groundwater pumping is to provide a pricing mechanism that causes groundwater to cost more than surface water. This could be accomplished by implementing a “groundwater charge” for every acre-foot pumped. Water Code §35533 provides the District the authority to collect groundwater charges. Revenue from the groundwater charge could be used to implement management actions or to reduce the cost to deliver surface water from the District.	5,580 AF/yr reduction in groundwater pumping.
KTWD	Action 2: CRC Pipeline Project - Produced Water Project	The District and CRC are in the process of acquiring permits, preparing an anti-degradation analysis and acquiring a WDR from the Regional Board. Project pipelines have been designed and plan and profile drawings have been prepared. The District is negotiating an agreement with CRC and obtaining rights-of-way. The pipeline construction is expected to be completed prior to 2025.	The District has historically accepted produced water to provide surface water to the District and is in the process of obtaining an additional source of produced water from California Resources Corporation (CRC). Produced water from CRC will be transported through 12 miles of 15-inch pipeline to the Guzman Reservoir. From the Guzman Reservoir water will be transported through 1.8 miles of 30-inch pipeline to the District’s existing Big 4 Reservoir, from which it will be blended with water from the Friant-Kern Canal and distributed in existing facilities to existing irrigated agriculture located within the District.	3,000 AF/yr of additional surface supplies (results in a reduction of 1,440 AF/yr in groundwater pumping).
KTWD	Action 3: In-District Surface Storage	The project is still in the preliminary design phase and will require additional steps before construction. The District has selected two potential reservoir sites, completed exploratory borings, and conducted a geotechnical evaluation of the two potential sites. The District has yet to acquire land and rights of way, permits, environmental documentation, or project financing. It is estimated that these facilities will be constructed between 2025 and 2030 if they are determined to be feasible and found to be necessary.	There are times when affordable water supplies are available, but the District has little to no irrigation demand and no available spreading capacity in its existing out-of-district banking programs. Construction of off-stream surface storage will allow the District to acquire water when it is available and store it to meet future irrigation demands. The District has selected two potential reservoir sites with a total capacity of 8,000 AF to capture wet year water. The sites are located to the east of the District in both the north and south portions. A location map of facilities and detailed description is not provided due to the confidential nature of the property and rights of way acquisition.	Based upon annual water supply modeling herein, the project yields only 530 AF/yr. However, a monthly analysis will need to be conducted to provide a better estimate of project yield, which could be as much as 2,000 AF/yr (assumes the reservoirs are used once every 4 years).
North Kern Water District & Shafter-Wasco Irrigation District				
NKWSD	Calloway Canal Improvements: Lining Snow Rd. to 7th Standard Rd.	Calloway Canal Lining is an ongoing project. NKWSD is in the process of acquiring adequate funding to complete the next one-mile lining of the project. The proposed project schedule includes a start date of October 2019 and completion within 36-months.	Calloway Canal Improvements is part of NKWSD’s continued effort of the recently completed 1.1-mile long canal lining. The first phase of this project consists of concrete lining approximately 2,200 LF of currently unlined portion of the Calloway Canal to increase surface water reliability and prevent seepage.. Phase two of this project includes water delivery improvements (WDI) that consist of installing magnetic flowmeters (or magmeters) at a total of 50 of the District owned production wells. Each magmeter will include a totalizer capable of measuring the volume of groundwater pumped through the wells. Further, water level sensors will also be installed in each of the 50 production wells and four additional monitoring wells to quantify the depth-to-water data. Additionally, the District proposes to implement telemetry upgrades at each of the production well sites, each of the monitoring well sites, and 14 remote Terminal Unity (RTUs-used to measure canal levels) sites. The final part of the water delivery improvements integrating these sites with NKWSD’s Supervisory Control and Data Acquisition (SCADA) setup.	Lining the canal will reduce the irrecoverable losses that result when high quality surface water seeps to poor quality groundwater, which cannot be recovered for later use without substantial treatment. Reducing these losses enhances NKWSD’s capability to deliver increased volumes of water from the Kern River to irrigators for existing demand. The integration of the telemetry system with the SCADA setup will enable the District to control well operation and access their groundwater pumping data remotely. Water conserved by lining the canal and implementing WDI is estimated at 1,576 AFY.
NKWSD	Expanded Water Banking Program	This program is an expansion of the District’s ongoing groundwater banking program. Environmental documents are being prepared to carry out the program in a timely manner.	Due to historically low groundwater levels, requirements under SGMA, and potential reductions in its historical water supplies, NKWSD is proposing a new program to increase its existing conjunctive use (or water banking) facilities a subsequently expand these facilities. Phase I of this program would primarily rely on unused capacity in existing facilities which is available from time to time (with some additional conveyance) and would seek to increase the utilization of the District’s proven recharge and recovery assets. Phase II would involve the construction of additional direct recharge and recovery facilities to further expand water banking in the District. Both the District and District landowners will receive water supply benefits from this program.	Implementation of this program would bring additional water supplies that would help offset potential losses of the District’s historical supplies, support the District’s mission of maintaining economic pumping lifts for its landowners, and maintain supplies to be used for municipal and industrial purposes by the city of Shafter. Quantitative benefits include 50,000 AFY (Phase I) and 72,000 AFY (Phase II) for a total of 122,000 AFY of water for the District.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
NKWSD	Groundwater Banking Conveyance Improvements to NKWSD Recharge and Recovery	NKWSD is in the process of acquiring adequate funding to complete this project. The proposed project schedule includes a start date of October 2019 and completion by the end of 2021.	The proposed project involves the drilling and equipping of three replacement wells and connecting two other deep wells (five total) to NKWSD's existing network to improve return capacity of recharged water for the District's neighbors. Proposed project is to construct the necessary pipelines to connect five deep wells to the District's recovery network system that improves the capacity to return water supplies multiple districts in the region during dry years.	Implementation of this project is anticipated to return previously stored water into the FKC and NKWSD's conveyance system at a rate of approximately 27 cfs. This equates to a total estimated average of 1,660 acre-feet per month, or an annual capacity of 9,961 acre-feet per year for the seasonal use of the wells (six months in a year) to improve the return capacity for the Poso Creek IRWM CVP Contractors to meet irrigation demands during a critically dry year. Two of the five wells will discharge into the District's canals and the remaining three will connect to the District's manifold pipeline, which ultimately discharges to the FKC.
NKWSD	Beneficial Reuse of Oilfield Produced Water	This is an ongoing project. NKWSD is interested in expanding the amount of oilfield produced water being brought into the district; however, no decision has been made at this time.	Since 2015, NKWSD has made beneficial reuse of oilfield produced water by blending produced water with other surface supplies for irrigation use. The California Resources Corporation (CRC) discharges 58 acre-feet per day of produced water from CRC's Kern Front Oil Field to NKWSD. The blended water is used directly for irrigation or is discharged to spreading basins in NKWSD for groundwater recharge.	Currently, this project has an important beneficial impact on water resources in the local area. One impact of the project is the annual recycling of up to 11,000 AF of oilfield produced water to the District. This flow is blended with other water sources and used for irrigation and groundwater recharge. Produced water increases the District's water supply and partially replaces groundwater that would otherwise be pumped. During the winter season, produced water is discharged to the Rosedale Spreading Basins along with any available Kern River water to recharge groundwater supplies. This has the added benefit of decreasing the rate of groundwater decline and lowering pumping costs.
NKWSD	SCADA Automation and Evapotranspiration Measurement Improvements	This is an ongoing project. The District is in the process of switching from SCADA to Wonderware Software and plans to implement upon approval from Reclamation.	The proposed project includes the installation of Supervisory Control and Data Acquisition (SCADA) Automation software along with Evapo-transpiration (ET) measurement stations. This project is divided into two components, the purpose of the first component is to remotely monitor and control the District owned and operated groundwater wells and Canal level transmitters. The second component of this project is to install evapo-transpiration (ET) stations in strategic locations within the District. The District anticipates that the crop specific ET measurements will help the District and its growers to correlate the ET and the applied water with the crop yield.	With these modernization efforts, the District can automatically record the instantaneous groundwater pumping rate, depth to groundwater, canal level, water quality parameters, and ET data.
NKWSD	Poso Creek Weir	Currently, this project is in preliminary stages. This project is part of the projects planned to meet the sustainability goal of the District by 2040. NKWSD may implement this at any time over the planning horizon to reach its sustainability goal.	NKWSD plans to construct a weir on the Poso Creek Flood channel to divert water into their facilities. The District currently has an earthen plug that works to divert water; however, the plug is not reliable and has proven to be inefficient for the District. Implementation of this project will provide a more reliable management of flows, allow water to be measured as it is diverted, and reduce the velocity and sediment loading prior to diversion. Diverted water will be used to increase groundwater banking activities in NKWSD to help prevent further lowering of groundwater levels.	Construction of a weir will provide the ability to drop out sediment prior to flood water entering the District's distribution system or direct spreading facility. By slowing the velocity and allowing sediment to drop out, higher water quality is diverted into the district.
NKWSD	Spreading Pond Facility	No Data	No Data	No Data
RRID	Expanded Recharge	Project is in the conceptual phase; however, the pre-existing conveyance pipeline allows for swift project implementation if needed.	RRID will expand their recharge to include on-farm spreading to maximize recharge capability. To ensure adequate delivery of supplies, water delivery infrastructure improvements will be included in this project. Improvements to the CRC pipeline will be made before on-farm recharge occurs.	An estimated 6,000 AFY would be added to the already 5,000 AFY provided by CRC for the purposes of beneficial reuse.
RRID	Allocation of Available NKWSD Supplies	This project is ongoing as NKWSD already allocates produced water to their facility; however, water spread in the Rosedale facility will now exclusively benefit RRID.	Oilfield produced water will be allocated to North Kern's Rosedale spreading facility for RRID's exclusive benefit.	
SWID	Diltz Intertie Lateral Piping and WMI	Design plan specifications have been completed for the proposed later improvements coinciding with the Diltz Intertie mainline design. Project is in its pre-construction phase and will be fully implemented in 2020.	The proposed project includes installing pressurized pipe laterals to connect the Diltz Intertie mainline to serve 380 acres of irrigated land. Project will consist of a 1.5-mile long, 30 cfs, 36- inch diameter, bi-directional, intertie pipeline which will allow for the efficient conveyance of surface water supplies to spreading ground facilities located in SWID.	Component 1 is expected to decrease groundwater pumping in the SWID by providing growers with pressurized surface water deliveries at a greater capacity and frequency. Decreased groundwater pumping in SWID will all for the recovery of groundwater elevations. This project will save 1,927 AFY of water following project completion.
SWID	Bell Recharge Project	Project is currently in planning phase and still requires final pipeline alignment selection to begin other project components such as easement acquisition, final design, and bidding.	Implementation of this project includes the construction of a 12 cfs conveyance improvement along SWID's existing distribution system that will allow CVP-Friant supply to be delivered from the FKC to the Bell Recharge site. Bell project will allow for delivery of surface water to the new Bell Recharge facilities form the CVP, for increased water storage.	Proposed Bell Project pipeline connection is anticipated to convey CVP wet period water into SWSD at a rate of 12 CFS with estimated annual benefits of 1,728 AFY.
SWID	Kimberlina Recharge Project	Already being implemented. To be completed by 2022.	Construction of a 285-acre recharge site for CVP surface water.	Water suuply augmentation of approximately 19,000 AFY

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Entity	Project Title	Implementation Status	Description	Benefits
SWID	Leonard Avenue Conveyance Improvement Project	Project is currently in planning phase and still requires final pipeline alignment selection to begin other project components such as easement acquisition, final design, and bidding.	This project involves the construction of 1.5 miles of pipeline to connect SWID with Semitropic Water Storage District (SWSD). Implementation of a new pipeline will provide SWID with the operational flexibility to absorb surface water when it is available for delivery to SWSD's distribution system, connecting the supply to in-lieu and direct recharge facilities in SWSD, generally during wet periods, so that water delivered can later be recovered for irrigation in peak demand months, or dry periods.	When implemented, this project will provide added capacity to absorb surplus water from the CVP during wet periods. It is estimated that this project will capture 2,880 AFY of surface supply, predominately from the CVP surface floodwater conveyed via the FKC, through SWID and into SWSD. Additional water absorbed into the groundwater basin will be split 50/50 between SWID and SWSD. The total average annual water saving to SWID is 1,440 AFY. Captured water will directly offset SWID's reliance on San Joaquin River supplies to the Bay-Delta and help conserve local groundwater supplies.
SWID	Improved Water Level Measurement of District Recharge Facility	This project is in the planning phase. Implementation of this project may begin as soon as 2020.	Proposed project includes the construction of a 400 to 500-feet deep, 8-inch diameter PVC monitoring well and the conversion of an existing older well to an 800-feet deep, 6-inch diameter monitoring well both equipped with both w level sensors and located within the District's recharge facility. Both monitoring wells will help manage and collection information on groundwater levels which can be used to document site performance as well as monitor the effects of the groundwater aquifer levels.	Implementation of this project will contribute to improving the district's drought resiliency and preserving groundwater levels by monitoring groundwater levels in the facility and improving efficiency of recharge operations.
NKWSD	Refinement of Water Budget Components	Ongoing	Improvement of monitoring and measurements to refine the accuracy of measurement or calculation of inflow a outflow components of district level water budget. Will also refine Subbasin Model and water budg	This management action is conceptual; a volume of water associated with th management action has not been calculate
NKWSD/SWID	"Surface Water First" Incentive Program	This Management Action is in the preliminary stages of consideration by the districts. It has not been formally adopte but is under consideration.	Both NKWSD and SWID have access to imported surface water to supply their respective jurisdictional areas. However, there instances in which growers have historically opted to pump groundwater, rather than receiving deliveries of surface water from the district which services their properties. When this occurs, the district must either use that water for groundwater recharge or enter into exchanges with other districts (either in the KCS or in another basin). While this may be an economic decision for the grower, it has the potential to cause local impacts to groundwater in the district over the long-term. To prevent local impacts to groundwater due to the use of groundwater over available surface water, the districts may explore a fee structure in which growers with access to surface water may be assessed for the use of groundwater when surface water is available for use. The fees collected for such activities would be applied to the expansion of existing recharge projects or the development of new recharge projects to accommodate the additional surface water that would be brought into the district to replace the additional groundwater pumped.	A reduction of groundwater extraction would result from the implementation of this incentive program. The fees collected in this incentive program have not been quantified but would also provide a source of funding for the expansion of existing recharge or the development of new recharge projects within the districts.
NKWSD/SWID	On-Farm Efficiency/Deficit Irrigation Practices Incentive Program	The provisions of the conservation laws are being complied with by both NKWSD and SWID. Ag water management plans, as required by SB 7, are being regularly updated by these districts for submittal to DWR. Plans will be updated to include the applicable requirements of AB 1668 and SB 606.	As agricultural water service providers, both NKWSD and SWID comply with all provisions of SB 7 (amending Division 6, Part 2.55 of the Water Code) passed into law in November 2009 regarding agricultural water conservation and management. Efficient management practices in the law, related to SGMA objectives, include volumetric water pricing, incentives for conjunctive use and increased groundwater recharge, and development of an overall water budget. AB 1668 and SB 606 passed in 2018 did not materially add to these objectives, save for those districts serving between 10,000 and 25,000 acres who must now prepare water management plans under the newer laws.	There are no direct benefits to be derived and quantified from compliance with the aforementioned agricultural conservation laws at the present time. The districts will continue to divert for beneficial use all local and imported water supplies to which it is entitled. Should agricultural demands for irrigation water diminish as a result of some the conservation provisions, a larger portion of diverted supplies will be devoted to groundwater recharge in the future.
NKWSD/SWID	On-Farm Recharge Activities Incentive Program	This Management Action is in the preliminary stages of consideration by the districts. It has not been formally adopte but is under consideration.	In wet years, when the districts have utilized the full capacity of their respective recharge basins and spreading grounds, it may be necessary for the districts to seek other locations for the application of available surface water for groundwater recharge. The districts will develop an incentive program to encourage landowners to take delivery of available water that is in excess of customer demand and the districts' capacity for recharge projects for application to fallow land and/or over-irrigation of crops to facilitate further groundwater recharge. Landowners will receive a groundwater credit in exchange for participation in this program, for their use within the district which has provided the water for on-farm recharge activities.	A increase of groundwater recharge would result from theimplementation of this incentive program.
NKWSD/SWID	Subsurface Recharge Feasibility Study	This Management Action is in the preliminary stages of consideration by the districts. It has not been formally adopte but is under consideration.	Both NKWSD and SWID have been approached by landowners within their respective districts about the efficacy and use of subsurface recharge methods. While subsurface recharge is being tested in neighboring districts, neither NKWSD nor SWID have taken an official position on the use of such methods. Before the implementation of any program which would supply water to landowners for use in subsurface recharge practices, the districts will conduct a feasibility study to evaluate whether or not these practices are appropriate for the hydrogeologic conditions and/or land uses within their respective jurisdictions. The scope of the feasibility study is yet to be determined, but it will include evaluation of subsurface recharge methods, the soil types located within each district, the effectiveness of subsurface recharge compared to other recharge methods, and its compatibility with existing land uses.	No benefits have been quantified for this Management Action at this time. Potential benefits gained through the use of subsurface recharge will be determined as a result of this Management Action.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
NKWSD/SWID	Land Conversion from Agricultural Use to Urban Use	The conversion of land use from agricultural to urban is an ongoing process, the pace of which is determined by external factors such as the demand for land based on each city's growth and need for additional housing and/or property to support business, industrial, or municipal use. The projected growth for each city is based upon the current General Plans and may be subject to change when the cities update their respective plans.	As described in the General Plans for the cities of Shafter and Wasco, anticipated population growth is expected to lead to changes in land use within the limits of each city and in the Sphere of Influence for each city. The conversion of land use from agricultural to urban use generally leads to an overall reduction in groundwater use due to the decreased demand, in terms of volume per unit area.	For NKWSD's jurisdiction, there is an anticipated reduction of water by 2030, based o the conversion of land use as the city of Shafter expands. In SWID's jurisdiction, the anticipated reduction of water by 2030 reflects the anticipated growth of both Shafter and Wasco.
NKWSD/SWID	Urban Water Conservation Program	The cities of Shafter and Wasco are currently evaluating their respective compliance measures for indoor use and are awaiting additional information and guidelines concerning regional outdoor and landscape compliance measures. The cities presently are complying with the 2020 mandates contained in SB 7X-7 and as embodied in their respective UWMPs. As the SWRCB establishes its compliance deadlines for both indoor and outdoor usage, anticipated to occur by 2025, the municipal KGA Members will have a clearer picture of an implementation schedule.	As referenced in the Umbrella Basin Setting (Chapter 2), urban water usage in the future is expected to comply with the conservation mandates contained in SB 606 and AB 1668, both bills signed into law in May 2018. Based on that legislation, indoor residential use is to be capped at 55 gpcd in 2019 and ramp down to 50 gpcd by 2030, and outdoor residential use is to be capped in the future based on local climate and size of landscaped areas. Standards for outdoor usage are to be defined in a SWRCB rule-making process to be completed by June 2022.	Given the early implementation stages of AB 1668 and SB 606, its benefits in terms of reduced groundwater pumping by Shafter and Wasco can only be roughly approximated. The Pacific Institute, in its 2014 report "Urban Water Conservation and Efficiency Potential in Calif." estimated that indoor usage could be reduced by 33-40 gpcd, and that outdoor/landscape usage could be reduced by 20-50 gpcd. These values are on a statewide basis and likely unrealistic in some regions; however, the report postulates that total urban water usage could be reduced by as much as 30-60%. Savings of this magnitude would represent a significant reduction in groundwater pumping by both cities. The Measurable Objectives to be partially met with additional urban conservation include groundwater level stabilization and, by proxy, groundwater storage stabilization.
SWID	Mitigation Program for Potential Impacts to Domestic Wells	Upon implementation of the law.	In coordination with other KGA members, develop a mitigation program to offer financial assistance for the replacement of domestic wells which are impacted by groundwater management to the proposed SMCs. Coordinate development of eligibility criteria for participation in mitigation program.	Since this management action is conceptual, a volume of water associated with this management action has not been calculated.
NKWSD/SWID	In-District Allocation Structure	This Management Action is in the conceptual stages, having been discussed with various stakeholder groups. However, an actual structures and fee schedules have yet to be devised for either district.	At the time of this draft of the GSP, neither NKWSD nor SWID have an established allocation structure and fee schedule for groundwater extraction. As SGMA is implemented throughout the KCS, the districts are required to manage to the Sustainable Management Criteria (SMCs). One of the ways to manage for the SMCs is to allocate the Sustainable Yield for their respective districts to the landowners within their districts. While the specifics of such an allocation structure may vary between the districts, a baseline groundwater extraction volume would be allocated to each parcel based on its size and the Sustainable Yield for the district. If a landowner were to extract more water than the baseline volume for that parcel or for the aggregate of all of their parcels within the district, they would be required to pay an extraction fee which would be applied toward projects and programs implemented by the district to reach and/or maintain sustainability.	The benefits to sustainable groundwater management have not been quantified at this time. However, the development and implementation of an allocation structure for each district would allow for the districts to utilize their Sustainable Yield as a management tool for reaching and maintaining their SMCs.
NKWSD/SWID	Voluntary Land Fallowing	At this time, this Management Action is conceptual. The districts will develop their respective fallowing programs during the SGMA implementation period.	In the event of a drought, the districts may not be able to entirely meet in-district demand by increasing the volume of imported water. The combination of decreased availability in surface water to supply to the district and decreased recharge from other sources in the subbasin has the potential to lead to violations of SMCs at the Representative Monitoring Sites, in the absence of decreased demand. To facilitate the districts' ability to maintain sustainability at their respective monitoring sites, the districts will develop and implement their own voluntary land fallowing programs for their jurisdictions.	The decrease in water demand will be dependent upon the land being fallowed and its existing land use at the time of fallowing. Agricultural demand for water is generally estimated to be 3 AF/acre. Fallowing or land retirement would reduce the demand to zero for the lands participating in the program.
NKWSD/SWID	Pumping Restrictions	At this time, this Management Action is conceptual. The districts will develop their respective processes to implement pumping restrictions within their jurisdictions.	In the event that the districts or the entire subbasin are nearing a condition where they are at risk of triggering an Undesirable Result, even with the implementation of the projects and management actions described in this Plan, it may be necessary for the districts to limit groundwater pumping. The volume of groundwater extraction permitted under this Management Action would be determined by the districts based on the Sustainable Yield for the district and the SMCs at the Representative Monitoring Sites.	Pumping restrictions based on the Sustainable Yield of the district, could decrease groundwater demand if applied to NKWSD. If applied to SWID, pumping restrictions could decrease groundwater demand.
Pioneer Groundwater Sustainability Agency				
Pioneer	Project 1: Participation in California WaterFix	Participation in California WaterFix is within the authority of KCWA as an SWP contractor and its decision to fully, partially or not participate would require coordination with its Member Units.	California WaterFix may be implemented by DWR in partnership with the Delta Conveyance Design and Construction Joint Powers Authority (JPA) to increase the amount of water that can safely be diverted from the Delta by constructing a diversion in the upper Delta and conveying it through a tunnel(s) to the existing SWP and CVP pump stations. Under current operations, the SWP and CVP are unable to consistently deliver full contract amounts of wa because of environmental and water quality concerns. Diverting a portion of Delta supplies at a point further upstream and further from the ocean would reduce water quality issues because the source water is high quality, and is less likely to cause seawater intrusion in the lower Delta. It will also help reduce diversion-specific impacts on the environment by reducing direct impacts of pumping on aquatic species, such as reversal of Delta flow and entrapme in screens on the diversion pumps (CNRA, 2018).	The new monitoring well cluster will address an identified data gap in the Pioneer GSA Area. The monitoring well cluster will also help Pioneer GSA evaluate maintenance o its sustainability goals and monitor groundwater conditions in that portion of the Pione GSA Area.

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Entity	Project Title	Implementation Status	Description	Benefits
Pioneer	Project 2: Install Monitoring Well in North Pioneer	Implementation of this project entails planning, permitting, design and currently, construction of the monitoring well cluster. KCWA and/or its consultants will secure necessary permits and plan, design and construct the wells. KCWA will monitor the wells as part of normal Pioneer Project operations.	A data gap for groundwater monitoring north of the Kern River was identified during development of this Chapter GS and a monitoring well cluster is being constructed in the northwest triangle-shaped parcel of the Pioneer Project (i.e. the area of the GSA north of Kern River). The triangle shaped parcel is in the northwest portion of the North Pioneer Area, and does not include a recharge pond. This area is in the southeast quarter of section 6, T 30S/R26E. The monitoring well cluster will allow groundwater monitoring at multiple depths using three separate boreholes.	The new monitoring well cluster will address an identified data gap in the Pioneer GSA Area. The monitoring well cluster will also help Pioneer GSA evaluate maintenance of its sustainability goals and monitor groundwater conditions in that portion of the Pione GSA Area.
Pioneer	Management Action 1: Continued Balanced Pumping and Recharge	This management action would be accomplished through continuation of existing groundwater recharge and recovery operations. Surplus water would be banked either for overdraft recovery or future use. Banked groundwater would be used to supplement water supplies in dry years or during years of shortages	Continued balanced pumping and recharge is the standard operating procedure for the Pioneer GSA. Under this management action, long-term pumping would be balanced by long-term recharge activities in the Pioneer GSA Area. Pioneer GSA would continue to closely monitor water that is pumped from the Subbasin and water that recharges the Subbasin with the goal of a balanced groundwater budget over the long term.	The Pioneer Project is operated in a manner that results in more water being recharg than recovered from the Subbasin in the Pioneer GSA Area. Therefore, continuing operation of the Pioneer Project in the same manner would provide a net positive increase of groundwater volume in the Pioneer GSA Area. Full benefits of this management action would be evaluated through accounting of water recharge volumes compared to groundwater pumping.
Pioneer	Management Action 2: Continued Participation in Basin-Wide Coordination with other GSAs	This management action would be accomplished through continued attendance at KGA coordination meetings and by arranging periodic coordination meetings with the Kern River GSA, the Henry Miller GSA, the WKWD GSA and the Buena Vista GSA. Meetings would be attended by one or more representatives of Pioneer GSA and may include the GSA manager or their designated staff. Decisions made in coordination meetings would not be binding until approved by the appropriate authority, such as the Pioneer GSA manager or by KCWA's Board of Directors.	Pioneer GSA is one of 11 GSAs in the Subbasin. Sustainable management of the Subbasin as a whole requires coordination among GSAs and their respective GSPs. During development of the GSPs in the Subbasin, GSAs have been discussing sustainability thresholds, potential projects and management actions and specific issues and concerns. The KGA is a JPA composed of member agencies that was established in 2014 to develop and implement a groundwater management plan in the Subbasin and the neighboring Tulare Lake Groundwater Basin (KGA, 2017). This management action would involve attending monthly KGA manager and coordination meetings, as well as KGA stakeholder meetings, which are held as needed. Quarterly coordination meetings would be held with the Kern River GSA, and annual coordination meetings would be held with the Henry Miller GSA, the WKWD GSA and the Buena Vista GSA.	This management action would continue existing coordination activities between GSA managers, and help to build and maintain relationships with neighboring GSAs. Through coordination activities and ongoing communication, potential conflicts among GSAs regarding groundwater management would be mitigated because GSAs would better understand the challenges facing each other and how these challenges are being addressed. It will also provide an opportunity for GSAs to inform each other of potential issues that may require intra-Subbasin coordination, and to inform neighboring GSAs of management actions and projects under way that may affect decisions of other GSAs.
Pioneer	Adaptive Management Strategy: Increase Surface Spreading Losses from 6 to 10 Percent	Coordination would be initiated by KCWA with the Pioneer Project Participants.	Under the *Pioneer Project Participation Agreement*, all surface water diverted to the Pioneer Project for spreading is assessed a 6 percent loss factor. All losses assessed are non-recoverable. This provision was set up to "prevent, eliminate or mitigate significant adverse impacts" resulting from project recovery operations. The intent of losses assessed is to assist in mitigating impacts to adjoining entities. This adaptive management strategy would explore feasibility of increasing the fixed loss rate from 6 percent to a fixed loss rate of 10 percent.	This adaptive management strategy would provide KCWA and the Pioneer Project Participants an understanding of the feasibility of increasing lossess assessed to diverted surface water. If increasing losses is deemed feasible, it would provide the Pioneer Project and the opportunity to mitigate and avoid undersirable results and support the for sustainability indicators relevant to the Pioneer GSA as follows: chronic lowering of groundwater levels (direct), reduction of groundwater storage (proxy), degraded water quality (proxy), and subsidence (proxy).
Rosedale Rio Bravo Management Area				
RRBMA	West Basin Improvements	RRBWSD purchased the properties in 20092015. Project construction was completed in 2016	The improvement of existing recharge ponds and development of an additional 50 acre project west of Bakersfield designed to recharge, store and recover water to provide a cost-effective and reliable water supply for landowners within the RRBWSD.	This project has the potential to recharge up to 5,000 AF of water in wet years. This could provide the RRBWSD with up to 1,000 AFY.
RRBMA	Stockdale East Groundwater Storage and Recovery Project	RRBWSD purchased the property in 2010. Project is 90% complete, it will be operational by 2020.	Project is a developed 200-acre project west of Bakersfield designed to recharge, store and recover water to provide a cost-effective and reliable water supply for landowners within the RRBWSD.	This project has the potential to recharge up to 25,000 AF of water in wet years. This could provide the RRBWSD with up to 4,000 AF per year on average.
RRBMA	Pilot Projects	These continued GRAT projects could be on-line as early as 2025.	In 2017 the RRBWSD developed four pilot recharge projects under which it leased properties for temporary recharge activities. Since that time the District has invested in a Groundwater Recharge Assessment Tool (GRAT) in order to identify similar projet sites in the future.	Approximately 10,000 AF was recharged during that year of implementation in these four projects. The GRAT implementation could provide RRBWSD up to 2,000 AF per year.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
RRBMA	Onyx Ranch	The project is currently undergoing a feasibility and environmental analysis. The project could be on-line as early as 2025.	The RRBWSD owns several parcels of land and the associated water rights for the Onyx Ranch and the Smith Ranch. These parcels are located along the South Fork of the Kern River in the Kern River Valley, in and around the communities of Weldon and Onyx, in an unincorporated area of northeastern Kern County. These parcels together comprise the 4,109.18-acre project site. The RRBWSD is currently conducting an analysis of a proposed change in the point of diversion and place of use of the water rights associated with these parcels so that the water can be delivered in the RRBWSD service area on the San Joaquin Valley floor and used for irrigation and groundwater recharge. The project would reduce the diversion of water on the project site and convert the irrigated fields to lower water use crops, or allow the fields to return to their native vegetative state. With the proposed project, RRBWSD would allow the water that would have been diverted on the project site to remain in the South Fork of the Kern River and flow downstream. This could result in a net increase in flows within the South Fork of the Kern River, and the Isabella Reservoir where the water would be released through the Isabella Dam and flow downstream in the lower Kern River until the water is diverted at the RRBWSD diversion point. From there, the RRBWSD would deliver the water to recharge basins and channels within and near its service area west of the City of Bakersfield (City) in unincorporated Kern County within the San Joaquin Valley.	The net increase in water supplies to the RRBWSD's service area as a result of the proposed project would help mitigate the shortages in RRBWSD's contracted State Water Project (SWP) water supply from the State of California, which has steadily reduced due to environmental constraints in the Sacramento/San Joaquin Delta. The proposed project would provide the RRBWSD with approximately 6,500 AF per year.
RRBMA	James Groundwater Storage and Recovery Project	Rosedale and Buena Vista Water Storage District jointly purchase the property in 2011. Current project status is feasibility and environmental analysis. This project could be online as early as 2025.	The James Groundwater Storage and Recovery Project is a proposed 2,078-acre project in southwest Bakersfield designed to recharge, store and recover water to provide a cost-effective and reliable water supply for landowners within the RRBWSD (and elsewhere).	This project has the potential to recharge up to 150,000 AF of water in wet years. This could provide the RRBWSD with up to 3,000 AF per year.
RRBMA	Kern Fan Groundwater Storage Project.	Project status is feasibility analysis. This project could be on-line as early as 2030.	The District has evaluated a conceptual Kern Fan Groundwater Storage Project (Kern Fan Project). This project would serve to develop a regional water bank in the Kern Fan to capture and store Article 21 water via the State Water Project (SWP) during conditions when surface water is abundant. A two-phased approach would be taken to the development of the Kern Fan Project. The first phase would be to develop a project site, including the purchase of approximately 640 acres of land in the Kern Fan area. The first phase would also include constructing conveyance facilities, recharge facilities, and recovery facilities as necessary to develop a fully functioning water banking project. The second phase of the Kern Fan project would involve acquiring an additional 640 acres of land for expansion of the water banking facilities and developing the associated recharge and recovery facilities.	This could provide the RRBWSD with up to 10,000 AFY.
RRBMA	Western Rosedale In-Lieu Service Area	Project status is shovel ready; feasibility and environmental analysis is complete. This project could be on-line as early as 2035.	The Western Rosedale Lands In-Lieu Service Area Project (the Project) includes construction and operation of up to ten miles of water conveyance pipelines, including appurtenant facilities (such as pumps and valves), and a joint service area agreement between RRBWSD and BVWSD in order to provide surface water to agricultural water users within the portion of RRBWSDs service area located westerly of Interstate 5 in close proximity to Buena Vista Water Storage Districts East Side Canal.	This could provide the RRBWSD with up to 1,000 AFY.
RRBMA	Ten Section Water Recharge Project	No implementation date is known at this time.	The owners of Ten Section located within the South of the River Monitoring Zone are currently studying the feasibility of a 200+ acre groundwater recharge, storage and recovery project.	It is estimated that approximately 2,200 AF/month could be recharged into the aquifer.
RRBMA	Water Charge Demand Reduction	This management action could be on-line as early as 2025.	The Water Charge would be expected to result in demand reduction in the RRBWSD. For market reasons it is probable that landowners will opt to fallow ground in order to trade water supplies to other District landowners, as well as fallow lands (or limit double cropping) to avoid the Water Charge all together.	With an agricultural water consumptive use demand of about 84,000 AF per year we conservatively expect a 5% demand reduction as a result of the water charge which results in about 4,000 AFY of reduced demand
RRBMA	RRBWL (White Land) Water Supplies and Demand Imbalance Reduction	This management action could be on-line as early as 2020.	White Lands (non-RRBWSD lands) within the RRBMA that are not used for groundwater banking will correct the water supply imbalance on a linear basis over the planning period of 2020-2040. Like RRBWSD lands, the white lands will start with the native yield of 0.15 AF/acre. The total annual demand for white lands in the RRBMA is about 10,300 AFY with a water supply imbalance (or deficit) of 3,618 AFY. The average agricultural demand is 2.6 AF/acre according to METRIC studies. While agricultural demands in the White Lands range from 1.4-4.9 AF/acre the initial allowable demand will be the average demand of 2.6 AF/acre. It is expected that white lands would seek to acquire water supplies for in-lieu and direct groundwater recharge via banking agreements with RRBWSD or others to offset demands.	Demand reduction will occur as follows over the 2020-2040 period; the imbalance will be reduced by 1/20 of the current imbalance each year (5%). This approach will result in about 217 AF of imbalance reduction each year and 2,170 AFY by 2030 and a total of 4,335 AFY by the 2040 sustainability planning period.
RRBMA	RRBWD 3rd Party Recharge and Storage Program	This management action could be on-line as early as 2020.	The RRBWSD will assist 3rd parties (white lands, districts, and private parties) in recharging water supplies for use in the RRBMA or other down gradient areas in the Kern Sub-basin. RRBWSD would offer existing conveyance and recharge facilities in exchange for a portion of the imported water supply and payments of yet-to-be developed costs and/or fees.	It is expected that the RRBWSD would provide this service in exchange for 20-33% of the imported water supply and that an average amount of 5000 AFY would be imported. This management action could bring an additional supply of 1,250 AFY to RRBDL lands.
Southern San Joaquin Municipal Utility District				

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
SSJMUD	In-District Spreading and Recovery Facility	SSJMUD is in the process of purchasing land and applying for construction funding. Once these steps are complete, the District will implement this project immediately.	This project will include construction of 80-acres of spreading ponds and the installation of two recovery wells within district boundaries. The proposed recharge ponds have an anticipated annual capacity of 3,240 AFY. Prior to this project, the district has not had any in-district direct recharge facilities. Implementation of this project will allow SSJMUD the opportunity to capitalize on wet period storage of CVP supplies and allow them to bypass less favorable out-of-district banking agreements to store water that would increase the District's and the subbasin's water reliability and drought resiliency.	The proposed recharge ponds have an anticipated annual capacity of 3,240 AFY. Estimated amount of water to deliver to recharge is at least 4,200 AFY. If the available surplus is delivered to an out-of-district facility, it is expected that North Kern will keep one-third of the water as part of banking agreements and SSJMUD will realize an average water benefit of 2,800 AFY. Captured water will directly offset the District's reliance on the San Joaquin River supplies to the Bay-Delta and help conserve local groundwater.
SSJMUD	SSJMUD and Semitropic Schuster Intertie	This project is in the conceptual stage of development and is included in the 2019 Poso Creek IRWM Plan Update.	The proposed project is to construct an intertie in coordination with SWSD. This pipeline will allow for SSJMUD to bank or return water to Semitropic previously delivered to Semitropic's groundwater banking program. SSJMUD could deliver wet period water from the FKC for groundwater banking to Semitropic or return water for irrigation purposes during dry years. This Project removes the need to involve a third-party in an agreement with Semitropic for banking since it establishes a direct connection to return water to SSJMUD from Semitropic, thereby increasing operational flexibility and reliability to deliver previously stored water from groundwater storage at times of drought.	Considering the frequency of surplus 'Other Water' in the Central Valley Project and the existing design limit of 50 cfs, the Project will allow for an expected average annual amount of 3,622 AF to be put into storage with 1,811 AF credited to SSJMUD for return. Given that recently the District became a member of the Poso Creek Integrated Regional Water Management Group (IRWM) in spring 2016, interties such as this pipeline were identified as the first step in the District's efforts towards banking water with their neighboring districts to add drought resiliency.
SSJMUD	SSJMUD and CWD Intertie Pipeline	This project is in the conceptual stage of development and is included in the 2019 Poso Creek IRWM Plan Update.	SSJMUD and CWD propose to construct a bidirectional intertie connecting their respective water conveyance systems. This pipeline is a regional opportunity to improve flexibility, reliability, and conjunctive use of water supplies.	The estimated annual yield of this project is approximately 50 to 500 AF, depending on the selected project size. Project size will be determined by greatest benefit yielded that is economically feasible and sustainable.
SSJMUD	SSJMUD and North Kern WSD 9-28 Intertie Pipeline	This project is in the planning stage of development, in conjunction with NKWSD, and is defined in the Poso Creek IRWM Plan.	Project proposal includes the construction of the 9-28 Intertie pipeline with NKWSD. This pipeline will allow for the return of CVP Class I, Class II, and surplus floodwater that was previously delivered to the District's groundwater banking partner (NKWSD) from the FKC for groundwater banking or irrigation purposes during wet years. The pipeline is the conveyance mechanism for return of previously stored water to the District during dry years. This project removes the need to involve a third-party in an agreement with North Kern for banking since it established a direct connection to return water to SSJMUD from NKWSD, thereby increasing operational flexibility and reliability to deliver previously stored water from groundwater storage during times of drought.	This project would allow for SSJMUD to better capture and utilize wet period supplies by increasing the District's capacity to return banked wet period water during dry periods. Considering the frequency of surplus Other Water in the Central Valley Project, the Project will allow for an expected annual amount of 10,000 AF to be put into storage with 6,667 AF credited to SSJMUD for return. The pipeline capacity to return water from North Kern to SSJMUD is 4,284 AFY, which will require roughly 1.5 years to return the water for each 10,000 AF of water banked and 6,667 AF credited.
SSJMUD	Southeast Delano Spreading Grounds	This project is in the planning stage of development. SSJMUD has already begun the process of developing a CEQA document to assess the potential impacts of the construction and operation of spreading grounds in the areas identified by the district.	SSJMUD proposes the purchasing of land holdings, with possible partnering agencies (to be identified later), in and around the eastern most portion of the District. The District is currently exploring the potential for capturing excess surface water deliveries in the FKC. Excess surface supply, or those flows beyond the quantity of water that satisfies immediate water demand, typically occur in wet years where precipitation in applicable watersheds is large enough to induce surface water available above Class I contract supplies. Potential captured flows consist of water which is currently discharged during wet year and flood conditions.	Implementation of this project has the potential for contributing water supplies to SSJMUD, the City of Delano (which qualifies as a DAC), and Poso Creek IRWM water users. Specifically, SSJMUD will use a portion of these captured flows to offset their groundwater use in dry years by moving the surplus water to this banking facility using either the Friant Kern Canal other existing infrastructure. Wet year water supplies captured in the spreading grounds and storage locations will be utilized by SSJMUD, City of Delano, and potentially other Poso Creek stakeholders, during years where other water supplies are limite
SSJMUD	City of Delano Spreading Grounds	This project is in the planning stage of development. SSJMUD has already begun the process of developing a CEQA document to assess the potential impacts of the construction and operation of spreading grounds in the areas identified by the district.	SSJMUD proposes identifying and evaluating potential land suitable for developing recharge basins, with possible purchase with private and/or public partnering agencies within the City of Delano. The purpose of this project is to capture surface water deliveries that are delivered through the FKC. Excess available surface supply, or those flows beyond the quantity of water that satisfies immediate water demand within a service area, typically occurs in wet years when precipitation in contributing watersheds is large enough to induce surface water available above Friant Class 1 contract supplies. Potential flows to capture consists of water which is currently discharged during wet years, during flood conditions and for water that needs to be delivered due to changes in timing to meet environmental water management goals for the San Joaquin River Restoration.	Implementation of this project has the potential for contributing water supplies to SSJMUD, the City of Delano (which is classified as DAC), and Poso Creek IRWM water users. Specifically, SSJMUD will use a portion of these captured flows to offset their groundwater use in dry years by moving the surplus surface water to this banking facility from the FKC or other existing infrastructure. Wet year water supplies captured in the spreading grounds and storage locations will be utilized by SSJMUD, City of Delano, and potentially other Po Creek stakeholders, during years where other water supplies are limite
SSJMUD	Pond Road Spreading Grounds	This project is in the planning stage of development. SSJMUD has already begun the process of developing a CEQA document to assess the potential impacts of the construction and operation of spreading grounds in the areas identified by the district.	SSJMUD proposes identifying and evaluating potential land holdings to be purchased, with possible private and/or public partnering agencies. The District is currently exploring the potential for capturing excess surface water deliveries in the Friant-Kern Canal. Excess surface supply, or those flows beyond the quantity of water that satisfies immediate water demand, typically occur in wet years where precipitation in applicable watersheds is large enough to induce surface water available above Class 1 contract supplies. Potential captured flows consist of water which is currently discharged during wet year and flood conditions.	Implementation of this project has the potential for contributing water supplies to SSJMUD, the City of Delano, and Poso Creek IRWM water users. Specifically, SSJMUD will use a portion of these captured flows to offset their groundwater use in dry years by moving the surplus water to this banking facility using either the California Aqueduct or other existing infrastructure. Wet year water supplies captured in the spreading grounds and storage locations will be utilized by SSJMUD, City of Delano, and potentially other Poso Creek stakeholders, during years where other water suppli are limited.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
SSJMUD	In District Spreading Grounds	This project is in the planning stage of development. SSJMUD has already begun the process of developing a CEQA document to assess the potential impacts of the construction and operation of spreading grounds in the areas identified by the district.	SSJMUD proposes identifying and evaluating potential land holdings to be purchased, with possible private and/or public partnering agencies. The District is currently exploring the potential for capturing excess surface water deliveries in the FKC. Excess surface supply, or those flows beyond the quantity of water that satisfies immediate water demand, typically occur in wet years where precipitation in applicable watersheds is large enough to induce surface water available above Class 1 contract supplies. Potential captured flows consist of water which is currently discharged during wet year and flood conditions.	Implementation of this project has the potential for contributing water supplies to SSJMUD, the City of Delano, and Poso Creek IRWM water users. Specifically, SSJMUD will use a portion of these captured flows to offset their groundwater use in dry years by moving the surplus water to this banking facility using either the California Aqueduct or other existing infrastructure. Wet year water supplies captured in the spreading grounds and storage locations will be utilized by SSJMUD, City of Delano, and potentially other Poso Creek stakeholders, during years where other water suppli are limited.
SSJMUD	Conversion of Dairy to Recharge Facility	This project is in the conceptual stage of development, with potential sites being evaluated based on data available through the RWQCB's GAMA Geotracker program, the district's recharge feasibility study, and other state and local agencies.	SSJMUD proposes identifying and evaluating potential purchase of a dairy, with possible private and/or public partnering agencies. The District is currently exploring the potential for capturing excess surface water deliveries in the FKC. Excess surface supply, or those flows beyond the quantity of water that satisfies immediate water demand typically occur in wet years where precipitation in applicable watersheds is large enough to induce surface water available above Class 1 contract supplies. Potential captured flows consist of water which is currently discharged during wet year and flood conditions.	Implementation of this project has the potential for contributing water supplies to SSJMUD, the City of Delano, and Poso Creek IRWM water users. Specifically, SSJMUD will use a portion of these captured flows to offset their groundwater use in dry years by moving the surplus water to this banking facility using either the California Aqueduct or other existing infrastructure. Wet year water supplies captured in the spreading grounds and storage locations will be utilized by SSJMUD, City of Delano, and potentially other Poso Creek stakeholders, during years where other water suppli are limited.
SSJMUD	"Surface Water First" Incentive Program	This Management Action is in the preliminary stages of consideration by the districts. It has not been formally adopte but is under consideration.	SSJMUD has access to imported surface water to supply its jurisdictional area. However, there instances in which growers have historically opted to pump groundwater, rather than receiving deliveries of surface water from the distri which services their properties. When this occurs, the district must either use that water for groundwater recharge o enter into exchanges with other districts (either in the KCS or in another basin).	An estimated reduction of 1,800 AFY of groundwater extraction would result from the implementation of this incentive program. The fees collected in this incentive program have not been quantified but would also provide a source of funding for the expansion of existing recharge or the development of new recharge projects within the districts.
SSJMUD	On-Farm Efficiency/Deficit Irrigation Practices Incentive Program	The provisions of the conservation laws are being complied with by both NKWSD and SWID. Ag water management plans, as required by SB 7, are being regularly updated by these districts for submittal to DWR. Plans will be updated to include the applicable requirements of AB 1668 and SB 606.	As an agricultural water service provider, SSJMUD complies with all provisions of SB 7 (amending Division 6, Part 2.55 of the Water Code) passed into law in November 2009 regarding agricultural water conservation and management. Efficient management practices in the law, related to SGMA objectives, include volumetric water prici incentives for conjunctive use and increased groundwater recharge, and development of an overall water budget. AB 1668 and SB 606 passed in 2018 did not materially add to these objectives, save for those districts serving between 10,000 and 25,000 acres who must now prepare water management plans under the newer laws.	There are no direct benefits to be derived and quantified from compliance with the aforementioned agricultural conservation laws at the present time. The districts will continue to divert for beneficial use all local and imported water supplies to which it is entitled. Should agricultural demands for irrigation water diminish as a result of some the conservation provisions, a larger portion of diverted supplies will be devoted to groundwater recharge in the future.
SSJMUD	On-Farm Recharge Activities Incentive Program	This Management Action is in the preliminary stages of consideration by the districts. It has not been formally adopte but is under consideration.	In wet years, when the district has utilized the full capacity of their respective recharge basins and spreading grounds, it may be necessary for the districts to seek other locations for the application of available surface water for groundwater recharge. The district will develop an incentive program to encourage landowners to take delivery of available water that is in excess of customer demand and the district's capacity for recharge projects for application to fallow land and/or over-irrigation of crops to facilitate further groundwater recharge. Landowners will receive a groundwater credit in exchange for participation in this program, for their use within the district which has provided the water for on-farm recharge activities.	An estimated increase of 1,200 AFY of groundwater recharge would result from the implementation of this incentive program.
SSJMUD	Conversion of Agricultural Land to Urban Use	The conversion of land use from agricultural to urban is an ongoing process, the pace of which is determined by externa factors such as the demand for land based on each city's growth and need for additional housing and/or property to support business, industrial, or municipal use. The projected growth for each city is based upon the current General Plans and may be subject to change when the cities update their respective plans.	As described in the General Plans for the cities of Delano and McFarland, anticipated population growth is expected lead to changes in land use within the limits of each city and in the Sphere of Influence for each city. The conversion of land use from agricultural to urban use generally leads to an overall reduction in groundwater use due to the decreased demand, in terms of volume per unit area. The City of Delano and the surrounding areas have a projected increase of 2,100 acres in urban use; the City of McFarland and its surrounding areas have a projected increase of 1,100 acres.	For SSJMUD's jurisdiction, there is an anticipated reduction of 900 AF of water by 2030, based on the conversion of land use as the cities of Delano and McFarland expand. By 2040, the projected reduction is 1750 AF.
SSJMUD	Urban Water Conservation Program	The cities of Delano and McFarland are currently evaluating their respective compliance measures for indoor use and are awaiting additional information and guidelines concerning regional outdoor and landscape compliance measures. The cities presently are complying with the 2020 mandates contained in SB 7X-7 and as embodied in their respective UWMPs. As the SWRCB establishes its compliance deadlines for both indoor and outdoor usage, anticipated to occur by 2025, the municipal KGA Members will have a clearer picture of an implementation schedule.	As referenced in the Umbrella Basin Setting (Chapter 2), urban water usage in the future is expected to comply with the conservation mandates contained in SB 606 and AB 1668, both bills signed into law in May 2018. Based on that legislation, indoor residential use is to be capped at 55 gpcd in 2019 and ramp down to 50 gpcd by 2030, and outdoor residential use is to be capped in the future based on local climate and size of landscaped areas. Standards for outdoor usage are to be defined in a SWRCB rule-making process to be completed by June 2022.	Given the early implementation stages of AB 1668 and SB 606, its benefits in terms of reduced groundwater pumping by Delano and McFarland can only be roughly approximated. The Pacific Institute, in its 2014 report "Urban Water Conservation and Efficiency Potential in Calif." estimated that indoor usage could be reduced by 33-40 gpcd, and that outdoor/landscape usage could be reduced by 20-50 gpcd. These values are on a statewide basis and likely unrealistic in some regions; however, the report postulates that total urban water usage could be reduced by as much as 30-60%. Savings of this magnitude would represent a significant reduction in groundwater pumping by both cities. The Measurable Objectives to be partially met with additional urban conservation include groundwater level stabilization and, by proxy, groundwater storage stabilization.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
SSJMUD	In-District Allocation Structure	This Management Action is in the conceptual stages, having been discussed with various stakeholder groups. However, a actual structures and fee schedules have yet to be devised fo either district.	At the time of this draft of the GSP, SSJMUD does not have an established allocation structure and fee schedule for groundwater extraction. As SGMA is implemented throughout the KCS, the districts are required to manage to the Sustainable Management Criteria (SMCs) established in Section 5 of this Chapter GSP. One of the ways to manage for the SMCs is to allocate the Sustainable Yield for their respective districts to the landowners within their districts. The allocation structure would allow for the transfer of groundwater pumping credits within each district's jurisdiction provided that it does not lead to localized impacts to at the Representative Monitoring Sites defined in Sections 4 and 5 of this Chapter GSP.	The benefits to sustainable groundwater management have not been quantified at this time. However, the development and implementation of an allocation structure for each district would allow for the districts to utilize their Sustainable Yield as a management tool for reaching and maintaining their SMCs.
SSJMUD	Voluntary Land Fallowing	At this time, this Management Action is conceptual. The district will develop its fallowing program during the SGMA implementation period.	In the event of a drought, the district may not be able to entirely meet in-district demand by increasing the volume of imported water. The combination of decreased availability in surface water to supply to the district and decreased recharge from other sources in the subbasin has the potential to lead to violations of SMCs at the Representative Monitoring Sites, in the absence of decreased demand. To facilitate the district's ability to maintain sustainability at its monitoring sites, the district will develop and implement a voluntary land fallowing program.	The decrease in water demand will be dependent upon the land being fallowed and its existing land use at the time of fallowing. Agricultural demand for water is generally estimated to be 3 AF/acre. Fallowing or land retirement would reduce the demand to zero for the lands participating in the program.
SSJMUD	Pumping Restrictions	At this time, this Management Action is conceptual. The district will develop its process to implement pumping restrictions within the plan area.	In the event that the districts or the entire subbasin are nearing a condition where they are at risk of triggering an Undesirable Result, even with the implementation of the projects and management actions described in this Plan, it may be necessary for the district to limit groundwater pumping. The volume of groundwater extraction permitted under this Management Action would be determined by the district based on the Sustainable Yield for the district and the SMCs at the Representative Monitoring Sites.	The benefits of mandatory pumping restrictions have not yet been quantified, as the guidelines for such a management action have not been established.
Shafter-Wasco Irrigation District - 7th Standard				
SWID - 7th Standard	Evaluation of Potential to Utilize SWID Kimberlina Ponds for Recharge or other Facilities	Status: Conceptual, have begun initial discussions; Initiation: 2020-2024 Completion: Ongoing Accrual of Benefits: Annual-basis	SWID operates the Kimberlina Ponds groundwater recharge facility. The Annex Area will evaluate opportunities with SWID to utilize Kimberlina Pond storage capacity for recharge. The Annex Area will evaluate opportunities to purchase non-SWID water for recharge in the Kimberlina Ponds facilities, when the Ponds have unused capacity (i. likely in nonwet and non-drought years).	Up to 4,500 AFY of imported supply, in combination with other recharge projects. Increased groundwater levels.
SWID - 7th Standard	Evaluation of Potential to Partner in Kern Fan Groundwater Storage Project	Status: Conceptual, have begun initial discussions with RRBWSD; Initiation: 2030 Completion: 2035 Accrual of Benefits: 50 years after constructio	The Kern Fan Groundwater Storage Project is under development by RRBWSD and would serve to develop a regio water bank in the Kern Fan to capture and store Article 21 water via the State Water Project (SWP) during conditions when surface water is abundant. The Annex Area could potentially become a funding partner in this project and have access to recharge and storage capacity in the Project.	Up to 4,500 AFY of imported supply, in combination with other recharge projects. Increased groundwater levels.
SWID - 7th Standard	7th Standard Annex Management Area Storage Pond Project	Status: Conceptual, have begun initial discussions with RRBWSD; Initiation: 2030 Completion: 2035 Accrual of Benefits: 50 years after construction	This project would improve water supply reliability and groundwater conditions in the Management Area. Benefits of developing a groundwater recharge facility within the Mangement Area include effective conveyance of surface water supplies when they are available, facilitation of water banking and exchange arrangements, and avoidance of direct water quality impacts. A conveyance mechanism, such as the Flat Rocks Canal would be necessary to bring such water to the Mangement Area.	Up to 1,463 AFY of recharge capacity for purchased surface water within the Management Area (assumes 320-acre basin). Increased groundwater levels.
SWID - 7th Standard	Identify Opportunities to Utilize Existing Infrastructure	Status: Conceptual, have begun initial discussions; Initiation: 2020-2024 Completion: ongoing Accrual of Benefits: annua	Several entities in the vicinity of the Annex Area have existing groundwater recharge infrastructure, which have unused capacity, particularly in nonwet years. The Annex Area will evaluate potential opportunities with these entities to utilize the unused capacity for recharge of purchased water.	Up to 4,500 AFY of imported supply, in combination with other recharge projects. Increased groundwater levels.
SWID - 7th Standard	On-Farm Groundwater Recharge	Status: Conceptual, have begun initial discussions; Initiation: 2020-2024 Completion: ongoing Accrual of Benefits: annua	In May 2019, the SWID Board adopted a new Buried Recharge policy that will allow for on-farm water banking, which will allow Annex Area landowners to purchase and recharge non-SWID water on their own properties, as well as th within the original SWID boundary.	Up to 4,500 AFY of imported supply, in combination with other recharge projects. Increased groundwater levels.
SWID - 7th Standard	Flat Rock Canal Extension	Status: Conceptual, have begun initial discussions; Initiation: 2030 Completion: 2035 Accrual of Benefits: 50 year period following construction	The Management Area will assess the feasibility of this project and seek partnership with other interest entities. This project would provide connection from the Annex Area to the Kern Water Bank Canal, Cross Valley Canal, and Goose Lake Slough. Phase 1 of this project is to distribute Kern River water to the north using gravity from Goose Lake Slough.	Improve ability to delivery surface water supplies to the District for irrigation or recharge. Benefits to neighboring entities, who would be key partners in this regional project.
SWID - 7th Standard	Develop New Interconnections Within SWID's Conveyance System (and Improve "Bottleneck" Issues)	Status: Conceptual, will require evaluation of options an benefits; Initiation: TBD Completion: TBD Accrual of Benefits: TBD	The Annex Area can work with SWID to increase the capacity and flexibility of SWID's current conveyance system, to allow access to additional supplies.	Improve operational flexibility within the SWID conveyance system to allow for increased capacity to accept surface water supplies when available.
SWID - 7th Standard	Increased Recycled Water Deliveries and Recharge	Status: In discussions for increased purchases; Initiation: In progress Completion: Anticipated 2019-2020 Accrual of Benefits: Annual	Secondary-treated municipal wastewater is from the North of the River Sanitary District is currently used for irrigation and infiltrated into groundwater within the Annex Area. The Annex Area is discussion options to increase recycled water deliveries and recharge of groundwater with secondary-treated wastewater within the Annex Area. Growth ra projected at 2% and output expected to increase to 14,000 AFY.	Up to 8,180 AFY of treated effluent (based on project increased WWTP flows), to be used for irrigation to offset groundwater demand.
SWID - 7th Standard	On-farm Water Conservation	Status: not yet initiated; Initiation: Upon stakeholder interest Completion: TBD Accrual of Benefits: 1-3 years after initiation	The NRCS is offering landowner incentive programs to assist in implementing various conservation activities, including but not limited to: irrigation system improvements, water/nutrient/pest management, and pump engine replacement. Interested landowners can call (661) 336-0967 or visit the website (www.ca.nrcs.usda.gov) for more information.	Reduce on-farm water demands.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
SWID - 7th Standard	Voluntary Rotational Land Fallowing Program	Status: not yet initiated; Initiation: Upon approval of funding mechanism Completion: Anticipated 2020-2024 Accrual of Benefits: 1 years after initiation	In order to reduce demand within the Management Area, this project would incentivize landowners to fallow their previously farmed lands voluntarily on a rotational basis. This potential project would be implemented on a voluntary rotational basis. Incentives have not yet been established, but would be anticipated to be funded by the Annex Area landowners through the same funding mechanism used for other SGMA related activities.	Up to 1,443 AFY of reduced water demand (assumed 430 acres fallowed per year).
SWID - 7th Standard	Education of Groundwater Use per Acre	Status: not yet initiated; Initiation: Upon GSP implementation Completion: Until overdraft ends/other programs initiated Accrual of Benefits: 1 year after initiation	This program would provide groundwater users an expected groundwater volume, as an education tool, prior to enforcement actions on groundwater allocations, with the goal of providing awareness of overdraft conditions. This information would be provided in an annual letter, along with average crop demand, GSA average extraction, GW overdraft, and reminders of GSA powers and authorities.	Reduce on-farm water demands.
Semitropic Water Storage District				
SWSD	Landowner Water Budgets	Under Development; Initiation expected 2020.	Establish individual water budget for landowners by landowner classes	Water demand reduction of an estimated 60,000 af total (3,000 af/yr to 2040)
SWSD	Tiered Pricing for Groundwater Pumping	Not yet started; to be implemented in 2020 after implementation of MA 1	Develop pricing structure to incentize groundwater users to manage groundwater extractions to MA1 water Budgets	Water demand reduction consistent with MA1 (Landowner Water Budgets)
SWSD	District Fallowing Program	Not yet started; to be implemented in 2020 after implementation of MA 1	Support land fallowing as a District action and by individual landowners or groups of landowners.	Water demand reduction consistent with MA1 (Landowner Water Budgets)
SWSD	Enhanced Groundwater Recharge	Status is ongoing and expected to be initiated in 2020 upon adoption of Semitropic GSP.	Development of surface and subsurface recharge projects underlying developed agricultural lands to increase groundwater recharge capacity	Water supply augmentation up to 20,000 af average annual
SWSD	Monitoring Network Improvement Plan	Not yet started; Expected to be initiated in 2020 upon adoptic of Semitropic GSP.	Assess and identify monitoring network requirements for full compliance with SGMA and development of i implementation plan for achieving full compliance	Improved groundwater monitoring in support of SGMA
SWSD	Evaluation and Assessment of GDEs within the Semitropic Area	Not yet started; Expected to be initiated in 2020 upon adoptic of Semitropic GSP.	Conduct additional analysis to verify the prescence and extent of GDE's in the Semitropic and, if present, devel appropriate monitoring protocols	
SWSD	Brackish Water Desalination	Initiated planning; expected to be initiated in 2022 upon completion of environmental and regualtory requirements.	Development of a braackish water treatment facility to treat locally sourced brackish water for District use.	Expected water supply augmentation of 1,800 af/year
SWSD	In-District Water Markets and Transfers	Not yet started; Expected to be initiated in 2022 upon adoptic of Semitropic GSP.	District will allow for the development of market for in-district transfers	Water supply augmentation TBD.
SWSD	Poso Creek MAR	Upon completion of feasibility and permitting requirements; Expected initiation in 2020	Development of floodwater capture and recharge program ffrom Poso Creek flood flows	Water supply augmentation of 1,200 af average annual
SWSD	Tulare Lake Project	Under Development since 2018; Initiated upon completion of water rights determination	Development of conveyance facilities to divert Kings River flood flows for direct use and recharge in the SWSD	Water supply augmentation of 70,000 af average annual
SWSD	Water Market Acquitions	Status is ongoing and expected to be initiated in 2020 upon adoption of Semitropic GSP.	Increased participation in state-wide water markets for spot market and long-term water transfers	Water supply augmentation of 4,000 af average annual
SWSD	Stored Water Recovery Unit	Initiated; 2025 Upon approve by SWSD BOD and identification of funding	Development of water storage to expand in-lieu service areas	Increases capacity & flexibility of conveyance for recharge
SWSD	Pond-Poso Spreading Grounds, Phase II	Inititated; Upon adotion of Semitropic SWSD; 2020.	Development of spreading facililiteis to increase groundwater recharge capacity	Increases groundwater recharge capacity
SWSD	Pond-Poso Entrance Ponds	Initiated; 2025 upon approval by SWSD BOD and identification of funding.	Development of spreading facililiteis to increase groundwater recharge capacity	Increases capacity & flexibility of conveyance for recharge
SWSD	Multi-District Conveyance (CA to Friant-Kern Canal)	Ongoing; Implementation upon approval by SWSD BOD and identification of funding.	Development of a conveyance system to deliver surface water for groundwater recharge and irrigation	Increases capacity & flexibility of conveyance for recharge
SWSD	Schuster Spreading Grounds	Not yet started; Expected initiation 2030 upon approval by SWSD BOD and identification of funding	Development of spreading facililiteis to increase groundwater recharge capacity	Increases groundwater recharge capacity
SWSD	Leonard Avenue System	Inititated 2019; Upon adotion of Semitropic SWSD.	Development of an intertie system to provide east to west surface water conveyance to for supply in groundwater dependent areas	Increases capacity & flexibility of conveyance for recharge
SWSD	Diltz Intertie	Ongoing 2018; Upon adoption of Semitropic SWSD.	Connection of an intertie to provide surface water converyance for agricultural irrigation	Increases capacity & flexibility of conveyance for recharge
SWSD	Cox Canal	Ongoing 2018; Upon adoption of Semitropic SWSD.	Developed canal for the conveyance of surface water for groundwater recharge	Increases capacity & flexibility of conveyance for recharge
SWSD	Stored Water Recovery Unit- XYZ	Ongoing 2019; Upon adoption of Semitropic SWSD.		Increases capacity & flexibility of conveyance for recharge
Tejon-Castac Water District Management Area				

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
TCWDMA	Conversion of Granite Quarry to Sycamore Reservoir	The timeframe for initiation and completion of this P/MA are not certain, but presumably would begin once the Granite Quarry facility ceases operations, which is anticipated in one to four years. Construction duration is to-be-determined.	This P/MA entails repurposing of the Granite Quarry excavation into a storage reservoir upon cessation of mining operations at the facility which is expected in the next one to four years. The P/MA is being considered and developed in conjunction with Arvin-Edison Water Storage District (AEWSD), and the source of water to fill the new reservoir would likely be surplus imported surface water, brought to the reservoir by AEWSD during wet years, with possible additional contribution from local stormflow runoff. In addition, TCWD may choose to store some of its State Water Project water supplies in the facility at times, supplies which would be wheeled through the AEWSD canal system. The facility is anticipated to serve as a storage basin for water added to it, as well as a location for recharge.	AEWSD has estimated the net benefit of this P/MA to be approximately 2,500 acre-fe (AF) of increased storage capacity (which aids in delivery flexibility for AEWSD), and between 3,000 and 6,000 acre-feet per year (AFY) of increased recharge. As a secondary benefit, recharge of imported surface water would likely have a positive effect on local groundwater quality.
TCWDMA	Recharge of Carrot Wash Water	The status of this P/MA currently underway, and the timeframe to accrual of benefits is likely on the order of one year.	Tejon Ranchcorp (TRC) recharges carrot wash water generated at a nearby carrot processing facility to a 75.5-acre parcel located just outside of the TCWD MA (Township 32S Range 30E Section 6). The site, which has been in operation since 2016, receives carrot wash water from a nearby carrot processing facility which is discharged to a se of recharge ponds. A total of over 1,000 AF has been recharged at these ponds between 2016 and early 2019. This project is anticipated to continue in the future, and results in a local recharge benefit. A production well may be installed in the future at the site to allow for recovery of recharged groundwater.	Based on the amount of water recharged since operations began in 2016, the annual benefit from this P/MA is estimated at approximately 300 AFY.
West Kern Water District				
WKWD	Project 1: Automatic Meter Reading Project	The circumstance of implementation for this project would be current conditions, once funding is secured or committed and the project approved by WKWD's Board of Directors, it could be implemented.	In 2015, WKWD began installing AMR systems for all industrial and outlying customers. To further achieve sustainability goals, WKWD would install AMR systems on the remainder of its primarily residential customer meters. The AMR system selected by WKWD for its industrial and outlying customers uploads data every 24 hours to a website where customers can access their accounts and view water use data, compare their current water use to their historical water use, and receive leak alerts.	AMR provides potential water savings through early leak detection and increased awareness of water use among customers. Upgrading meters also reduces unaccounted-for losses related to accuracy degradation in older meters. WKWD estimates that AMR will save an average 8 percent of water f each metered connection, based on savings experienced by nearby agencies. The City of Sacramento had an average 4 percent water savings based on a pilot AMR project, while the Golden Hills Community Services District realized 12 percent in average savings (WKWD, 2014). WKWD's 2015 UWMP shows residential water use ranges between 2,169 AF in 2015 to a projected high of 2,597 AF in 2040, and applying the projected 8 percent conservation, anticipated water savings from this project is estimated to be 173 to 208 AFY (WKWD, 2016). Conservation achieved by the AMR project would be measured by the reduction in water deliveries to customers with AMR meters.
WKWD	Project 2: Participation in California WaterFix	Long-term	California WaterFix is intended to address the challenges of pumping water from the Delta by diverting water upstream of the current diversion points and conveying it to existing pump stations for the SWP and the Central Val Project (CVP). Under current operation, the SWP and CVP are unable to consistently deliver state and federal water contractors their full contract supplies. California WaterFix is intended to address some of the conditions that impact the ability to export water from the Delta.	The primary benefit of this project would be the increased reliability of imported water supplies and to expand groundwater banking opportunities to meet customer demands. Additional supplies could be 1) banked in WKWD's recharge facilities, 2) used for GWE protection if monitoring shows unexpected declines in elevation, or 3) transferred to neighboring agencies to help offset groundwater pumping in the Subbasin.
WKWD	Project 3: Buena Vista Recreation Area Water Supply Management Coordination	Implementation of this project is already underway and is likely to remain an ongoing project until such time as the BVARA no longer requires water from the GSA area.	BVARA is in and adjacent to the WKWD GSA area. The 1,585-acre BVARA is home to two manmade lakes, Lake Webb and Lake Evans, boating facilities, playgrounds and volleyball courts, camp sites, and picnic areas. The lakes lie outside of the GSA area but the park facilities such as picnic areas, restrooms, and parking areas are within the GSA area. When constructed, the lakes had a combined storage capacity of over 6,800 AF. Shoreline camping and picnic areas are landscaped with grass and are irrigated during the dry season (County of Kern Parks and Recreation Department, 2019). With no outlet, water from the lakes either evaporates or percolates into the groundwater basin. Kern County pumps groundwater from wells located within the GSA area to supplement losses at the lake. Supplemental water delivered to the lakes is not metered and is not included in WKWD GSA's water balance.	Managing water supply for the BVARA would include a focused effort on monitoring pumping in that portion of the GSA area, and identifying which projects or manageme actions are needed to eliminate undesirable results in the Subbasin. Securing additional supplemental supplies would reduce the potential impacts to groundwater levels, storage, and water quality for this portion of the GSA area. Improved management of the BVARA water supply would also support ongoing use of the BVARA, a popular recreation area. The project does not have a directly measurable benefit unless implementation actions arise from these meetings.
WKWD	Management Action 1: Continued Balanced Pumping and Recharge	The circumstance of project implementation would be current conditions and would remain unless conditions indicated a different management approach was needed to achieve sustainability indicators.	Continued balanced pumping of groundwater and recharge of imported supplies has and will continue to be the operational norm for WKWD. Under this management action, recharge and recovery activity will continue to be monitored closely by WKWD to maintain balanced conditions.	This management action would allow WKWD to continue operating groundwater recharge and recovery in balance, resulting in a long-term net-zero balance in the Subbasin for the areas under WKWD's control.
WKWD	Management Action 2: Implement Water Shortage Response Plan	The circumstance of implementation for this project would be times of water shortage, supply interruption, or drought, as declared by WKWD's Board of Directors. Implementation would cease when shortages are no longer being experienced, and as approved by the WKWD's Board of Directors.	WKWD's Water Shortage Response Plan (WSRP) is incorporated into the 2015 UWMP and includes triggers for when the WSRP would be implemented. The WSRP describes management actions and use restrictions that would be implemented if water shortages were declared. Because current operation of groundwater recharge and recover the GSA area has shown a long-term increase in banked groundwater, and normal water years are projected to have a surplus of supply that can be banked, it is not expected that the WSRP would go into effect during normal or wet years. During extended dry periods, groundwater pumping would increase, and WKWD would use banked supplies to meet demands in excess of available imported and surface water supplies.	The WSRP is designed to reduce customers' overall water use by implementing restrictions on when and how water may be used. As a result, implementation of this management action would reduce overall demand, which offsets demand for imported water and groundwater. Each Response Level is designed to help achieve a specific conservation target, and would reduce overall demands between 0 and 6,900 AF (i.e. to 50 percent conservation) (Table 8-3). Conservation achieved by this management action would be measured by the reduction in metered water deliveries after this management action is implemented.

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
WKWD	Management Action 3: Continued Participation in Basin-Wide Coordination	The circumstance of implementation for this project is ongoing.	The WKWD GSA is one of 11 GSAs in the Subbasin. Coordination among these GSAs is necessary for sustainable management of the Subbasin as a whole and has been ongoing during development of their respective GSPs. Coordination during GSP development has included regular in-person meetings and calls to discuss sustainability thresholds, potential projects and management actions, and to discuss specific issues and concerns. As described in this Chapter GSP, the KGA is developing an Umbrella GSP for the Subbasin, while the other GSAs in Kern County are developing Chapter GSPs.	This management action would continue existing coordination activities among GSA managers, helping to build and maintain relationships with neighboring GSAs. Potent conflicts between GSAs regarding groundwater management would be reduced because GSAs would better understand the challenges experienced in each GSA are and how these challenges are being addressed. Coordination meetings will also prov an opportunity for GSAs to inform each other of potential issues that may require intra-Subbasin coordination to address, and to notify neighboring GSAs of management actions or projects that might affect a decision made by another GSA.
WKWD	Adaptive Management Strategy 1: Taft Recycled Water Program	This project would be implemented through an agreement between WKWD, the City of Taft, and FCTHSD.	The Taft Recycled Water Program would create up to 423 AFY of tertiary recycled water suitable for Title 22-approv applications for recycled water. This project would be implemented in partnership between WKWD, the City of Taft, and the Ford City-Taft Heights Sanitation District (FCTHSD). WKWD provides water within the WKWD GSA area, but sanitation services are provided by the City of Taft and FCTHSD, which jointly own the Taft Wastewater Treatment Facility (WWTF). The Taft WWTF currently produces undisinfected secondary effluent that is suitable for and applied to feed crops, specifically alfalfa. This effluent is not suitable for wider recycled water use, but through upgrade to tertiary treatment, it could be used more widely for non-potable applications, such as landscape irrigation, which currently use potable water to meet demands (WKWD, 2018).	The project would create up to 423 AFY of tertiary recycled water, offsetting an equal volume of potable water (WKWD, 2018). Available and unused potable water is currently banked for future use during imported and surface water supply shortages. This project would both reduce demand for groundwater pumping during dry years and allow for additional water to be banked during wet years. Tertiary recycled water would be a local supply with high supply reliability, even during drought years. The volume of water offset by this project would be measured by quantifying the amount of tertiary recycled water both produced and delivered.
WKWD	Adaptive Management Strategy 2: Shift Balance of Pumping between North and South Wellfields	Implementation would require easy-to-implement operational changes and could be implemented quickly once triggered.	In 2010, WKWD's North Wellfield (wells within the North Project Management Area) was constructed in response to falling groundwater levels at the South Wellfield (wells within the South Project Management Area). Despite a surplus of banked groundwater, local levels at the South Wellfield showed a trending decline associated with groundwater recovery activities. A single wellfield for recovery activities also limited WKWD's operational flexibility. To combat these two management challenges, the North Wellfield was constructed along with additional recharge basins. Under current operation of the two wellfields, 11,300 AFY are pumped from the South Wellfield and 12,700 AFY are pumped from the North Wellfield. The North Wellfield has an annual pumping capacity of 24,000 AFY (WKWD, 2010).	This adaptive management strategy would reduce groundwater pumping in a localized area, allowing water levels in that area to recover or to decline less sharply during times of drought. Minimizing groundwater level declines reduces the potential for localized subsidence and long-term decrease in groundwater storage capacity. It also helps to maintain well efficiency, allowing for improved wellfield longevity. Local recovery of GWEs would be determined by standard monitoring activities that are part of regular wellfield management. Local groundwater level recovery from this strategy would be measured by monitoring of groundwater levels in the vicinity of the two wellfield
WKWD	Adaptive Management Strategy 3: Implemer Permanent Demand Management Measures	As needed	According to the 2016 WSRP, Response Level 1 is ongoing, and all water use restrictions are strictly voluntai These actions only become mandatory if a Response Level 2 is declared, which requires a declaration by the WKWD's Board of Directors. This adaptive management strategy would convert the Response Level 1 actions in the WSRP from voluntary to mandatory. These water restrictions would require a 25 percent reduction in large landscape watering from 2007 levels, prohibit water waste, and reduce non-contracted industrial water use by 15 percent from 2007 levels. WKWD may choose to implement these or a different set of permanent demand management measures as appropriate at the time this adaptive management strategy is approved	Project benefits are expected to be like those achieved under Management Action 2 (Implement WSRP), though they will have long-term benefits because they are permanent measures rather than temporary ones under the WSRP. Conservation achieved by this management action would be measured by the reduction in metered water deliveries after this management action is implemented.
Westside District Water Authority				
WDWA	Collect Representative Hydrogeologic Data	The PMA No.1 will be implemented beginning with acceptance of the MNP, and directly support WDWA MT/MOs by providing foundational data to monitor and manage adaptive management projects that are designed and implemented to ameliorate the potential for significant reduction of ground water elevations and groundwater in storage	Historically, because of the brackish and naturally degraded quality of groundwater in the WDWA, growers have rel almost exclusively on surface water from the SWP for their irrigation needs. Groundwater is used primarily for blending when annual SWP deliveries are less than expected. As a result, there is currently little representative hydrogeologic data in the WDWA. This lack of data represents a significant data gap that must be addressed in order to refine the current understanding of the WDWA Conceptual Hydrogeologic Model, including key elements such as groundwater elevations, pumping and changes to groundwater in storage and the overall water budget.	The ability to generate representative data for use in updating water budget elements; Improved numerical groundwater modeling results; and Better forecasting and planning of adaptive management projects and management actions.
WDWA	Water Resource Coordination	The implementation of the disparate Water Resource Coordination Programs vary, some as described above are already in place and ongoing. Others, like a KCS-wide coordination program would likely begin with planning during the first five-year reassessment period after KCS Plan implementation. Coordination between the WDWA and its immediately adjacent GMAs would likely be structured to begin with meetings shortly after Plan approval.	The member growers in the WDWA have historically made significant investment in efficient irrigation technologies and methods that promote water conservation and sustainable management. They have also coordinated amongst themselves as individuals or via the various Water Districts to implement focused reduction demand measures, trade or purchase surplus water when deliveries from the SWP have been reduced. It is assumed that these effective ad hoc arrangements will continue after Plan implementation. In addition, the WDWA will work cooperatively and in close consultation with its members, the KGA and adjacent GMAs to coordinate water resource monitoring, testing and future water trading as part of its overall strategy for the sustainable management of all its available water resources.	More reliability and flexibility in water availability; Drought resiliency; and Sustainable water strategies for both short and long-term planning horizons.
WDWA	Conjunctive Reuse of Naturally Degraded Brackish Groundwater	Preliminary planning for a Project Engineering FS for the first phase of the project has already begun. It is expected there will be at a minimum two phases of distributed treatment facility construction.	To further enhance the sustainable and adaptive management strategies for the Westside, the WDWA is evaluating the feasibility of an innovative phased project that will integrate the treatment and conjunctive reuse of naturally degraded brackish groundwater and oilfield produced water for multiple beneficial uses.	When operational, the Project will result in multiple potential beneficial uses, including many of the "One Water" concepts enumerated in the State's California Water Action Plan.
Wheeler Ridge-Maricopa Water Storage District				

Table 4-1. Kern Groundwater Authority Member Entities List of Projects and Management Actions

Entity	Project Title	Implementation Status	Description	Benefits
WRMWSD	On-Farm Recharge	Not yet initiated; To be implemented upon adoption of WRMWSD GSP Chapter - 2020	Study and implement on-farm recharge where viable.	approx. 2,000 AFY (10,000 AF every five years)
WRMWSD	In-District Banking Facilities	Not yet initiated; To be implemented upon adoption of WRMWSD GSP Chapter - 2020	Program to promote private and/or District-owned banking facilities within the District.	approx. 2,000 AFY (10,000 AF every five years) approx. 2.75 AFY per acre of land converted to basins
WRMWSD	Increase Out-of-District Banking Operations	Not yet initiated; To be implemented upon adoption of WRMWSD GSP Chapter - 2020	Increase size/participation in out-of-District banking facilities (i.e., Kern Water Bank and Pioneer Project). Increased banking of wet year supplies outside of the District would support deliveries of imported water into the District in normal/dry years.	TBD; depends on recharge basin area
WRMWSD	Expand District Distribution System	Not yet initiated; TBD	Project to expand District distribution system into area currently using only private groundwater.	approx. 2,000 AFY
WRMWSD	Purchase Additional Supplies	Ongoing	Continue purchase of additional supplies, as available, for banking outside of the District or direct delivery within the District.	Increase purchases by 5,000 AFY
WRMWSD	Desalination Facilities	Not yet initiated; TBD	Desalination facilities to allow for use of additional poor quality groundwater for agricultural use, easing demand on principal aquifer.	No net supply augmentation, but minimizes local GW pumping impacts
WRMWSD	"Thru Delta" Facility	State-led effort underway	Particpation of some sort of "Thru Delta" Facility to increase access to contracted (SWP) supplies.	up to 25,000 AFY
WRMWSD	Acreage Assessment	Not yet initiated; To be implemented upon adoption of WRMWSD GSP Chapter - 2020	Set policy to implement an acreage assessment to fund purchase of additional supplies, purchase of land for fallowing, and other investments to support SGMA compliance.	
WRMWSD	Groundwater Allocation and Market	Not yet initiated; To be implemented upon adoption of WRMWSD GSP Chapter - 2020	Develop a groundwater pumping allocation methodology, including a market system for trading and/or transfering of allocations.	
WRMWSD	Voluntary Pumping Limitations	Not yet initiated; To be implemented upon adoption of WRMWSD GSP Chapter - 2020	Set non-binding pumping limitations in conjunction with a fee for pumping above limits.	up to 21,000 AFY
WRMWSD	Mandatory Pumping Limitations	Not yet initiated; 2030	Set binding pumping limitations in conjunction with a fee for pumping above limits.	up to 21,000 AFY
WRMWSD	Land Retirement	Not yet initiated; 2035	Purchase and permanently fallow previously irrigated acreage within District to reduce overall water demand and groundwater extractions.	up to 21,000 AFY

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Kern Groundwater Authority Groundwater Sustainability Agency
Groundwater Sustainability Plan

ATTACHMENT A

Joint Powers Agreement

KERN GROUNDWATER AUTHORITY
FOR THE TULARE LAKE BASIN PORTIONS OF KERN COUNTY
SECOND AMENDED AND RESTATED JOINT POWERS AGREEMENT

THIS SECOND AMENDED AND RESTATED AGREEMENT ("Agreement") is made and effective as of 7-22, 2019, pursuant to the Joint Exercise of Powers Act (Government Code Sections 6500, *et seq.)* by and between the public agencies listed on the attached Exhibit A.

This Agreement is made with reference to the following facts and understandings.

A. Each of the parties to this Agreement (the "Members") provides water service to landowners and/or residents and/or provides water to retail water entities within its respective service area..

B. Pursuant to Joint Powers Agreements dated May 27, 2014 (the "Original Agreement") and March 22, 2017 (the "Amended and Restated Agreement"), the Kern Groundwater Authority (the "Authority") was created to carry out the purposes of Part 2.75 of Division 6 (commencing at Section 10750 of the California Water Code) and develop, adopt and implement a groundwater management plan that would be available to those lands within the boundaries of the Authority's members and within the Tulare Lake Groundwater Basin.

C. On August 29, 2014, the California Legislature passed comprehensive groundwater legislation contained in SB 1168, SB 1319 and AB 1739. Collectively, those bills, as subsequently amended, enacted the "Sustainable Groundwater Management Act" ("SGMA"). Governor Brown signed the legislation on September 16, 20 I 4 and it became effective on January I, 2015. In adopting SGMA, the Legislature intended "[t]o provide local groundwater agencies with the authority and technical and financial assistance necessary to sustainably manage groundwater." (California Water Code Section 10720(d).)

D. SGMA anticipates that each affected groundwater basin or subbasin will be regulated separately by one or more Groundwater Sustainable Agencies (each, a "GSA"). A local agency or combination of local agencies may elect to be the GSA for a basin or sub-basin. SGMA generally provides that a combination of local agencies may form a GSA through a joint powers agreement, memorandum of understanding or other legal agreement. (California Water Code Section 10723.6)

E. Groundwater sustainability under SGMA is to be achieved through Groundwater Sustainability Plans ("GSPs"). Under SGMA, a GSP can be a single plan developed by one or more GSAs, or multiple coordinated plans within a basin or subbasin by multiple GSAs (California Water Code Section 10727).

F. The Members, individually and collectively, have the goal of cost-effective, sustainable groundwater management in the Kern County Subbasin that considers the interests and concerns of the Members and other stakeholders.

G. As used in this Agreement "Kern County Subbasin" means such basin as defined in Department of Water Resources Bulletin 118, as its boundaries may be modified from time to time through the procedures described in California Water Code Section I 0722.2.

H. The intent of the Members under this Agreement is to provide each Member with the sole right and responsibility to implement SGMA within its respective boundaries and/or Management Areas, as defined herein, in a manner determined by the Member, whether through the Authority or as a GSA. To facilitate coordination within the Kern County Subbasin, the Members desire for the Authority to have the authority to serve as a GSA for some or all of the Members within the Kern County Subbasin in a manner that allows the Members (individually or collectively) to directly implement SGMA and a GSP within their respective Management Areas as defined herein, while the Authority serves primarily a coordinating and administrative role in order to provide for sustainable groundwater management through the subbasin. The Members expressly intend that the Authority will not have the authority to limit or interfere with the respective Members' rights and authorities over their own internal matters, including, but not limited to, a Member's surface water supplies, groundwater supplies, facilities, operations, water management, and Water Supply Matters, as defined herein. Nothing in this Agreement is intended to modify or limit Members' police powers.

I. The Members expressly intend that neither SGMA, nor this Agreement, nor any GSP adopted by the Authority shall be construed as authorizing the Authority, or any dispute resolution process contained herein, to:

(i) determine or alter surface water rights or groundwater rights (California Water Code Section 10720.5 (b));

(ii) make binding determinations of the water rights of any person or entity (California Water Code Section 10726.8 (b)); or

(iii) supersede the existing land use authority of cities or counties, including the city or county general plan, within the overlying basin (California Water Code Section I 0726.8 (f)).

J. In light of the enactment of SGMA together with the goals and intent described above, the Members wish to amend and restate the Original Agreement in its entirety as provided herein.

THEREFORE, in consideration of the mutual promises, covenants and conditions herein set forth, it is agreed by and among the Members that the Amended and Restated Agreement effective as of March 22, 2017 is hereby amended and restated to read in its entirety as follows:

Article I: Definitions

As used in this Agreement, unless the context requires otherwise, the meaning of the terms hereinafter set forth shall be as follows:

(a) "Associate Members" shall mean those Members of the Authority admitted in accordance with the terms and provisions of this Agreement that are not General Members. The Board of Directors may from time to time admit Associate Members on terms and conditions consistent with SGMA and as determined by the Board. Representatives of Associate Members may not serve on the Board and/or Board Committees. Likewise, while the Board of Directors welcomes their input, the representatives of Associate Members shall be non-voting, their presence shall not be counted in determining whether a quorum is present, and they shall not be permitted in closed sessions of the Board of Directors.

(b) "Authority" shall mean the Kern Groundwater Authority, being the separate entity created pursuant to the provisions of Government Code sections 6500 *et seq.* by this Agreement.

(c) "Board of Directors" or "Board" shall mean the governing body of the Authority as established by Section 3.0I of this Agreement.

(d) "Committee" shall mean any committee established pursuant to Section 3.03 of this Agreement.

(e) "Cooperative Members" shall mean those members of the Authority admitted in accordance with the terms and provisions of this Agreement, but are not General Members or Associate Members. The Board of Directors may from time to time admit Cooperative Members on terms and conditions consistent with SGMA and as determined by the Board and/or Board Committees. Cooperative Members shall not have any obligation to fund the Authority or otherwise pay money to the Authority under Article IV of this Agreement. Cooperative Members shall have no seat or voting rights on the Authority's Board of Directors, no responsibility to draft a GSP chapter, or any other responsibility under this Agreement unless otherwise agreed to in writing.

(f) "Fiscal Year" shall mean that period of 12 months established as the Fiscal Year of the Authority pursuant to Section 4.01 of this Agreement.

(g) "General Members" shall mean those Members of the Authority more particularly identified as General Members on Exhibit A, and any parties which shall hereafter become General Members in accordance with the terms and provisions of this Agreement. A local agency as defined by SGMA may participate as a General Member on its own behalf or join with one or more agencies as a single General Member. Multiple agencies which elect to coordinate their representation as one General Member shall, for purposes of this Agreement, be treated as one General Member.

(h) "GSA" shall mean Groundwater Sustainability Agency as defined in SGMA.

(i) "GSA Notice Date" shall mean March 1, 2017.

(j) "Kern County Subbasin" means the groundwater subbasin described in Recital G of this Agreement.

(k) "GSP" shall mean Groundwater Sustainability Plan as defined in SGMA.

(l) "Management Area" shall mean the area within the boundaries of a Member or group of Members to be managed by that Member or group of Members under any GSP adopted by the Authority.

(m) "Members" shall mean the General Members, Associate Members, and Cooperative Members.

(n) "SGMA" shall mean the Sustainable Groundwater Management Act.

(o) "Special Activities" shall mean activities that are consistent with the purpose of this Agreement, but which are undertaken by fewer than all the Members in the name of the Authority pursuant to Section 3.07.

(p) "Water Supply Matters" shall mean a Member's surface water supplies, groundwater supplies, facilities, operations, water management, water supply projects and financial affairs.

Article II: Creation of Authority

Section 2.01 Creation.

The Members hereby reaffirm that, pursuant to their joint exercise of powers under the provisions of Government Code sections 6500 *et seq.*, they have created a public entity to be known as the "Kern Groundwater Authority."

Section 2.02 Term.

This Agreement is an amendment of the Amended and Restated Agreement dated March 17, 2017, and shall therefore become effective, including without limitation on General Members not executing it, upon its execution by at least 75% of the General Members and will remain in effect until terminated by agreement of a majority of then participating General Members. Notwithstanding the above, once the Authority has adopted and approved a GSP for some or all of the Kern County Subbasin, this Agreement shall not be terminated except by agreement of 75% of the General Members (as described in Section 3.05 below). Unless it is terminated, this Agreement shall remain in effect and be binding upon the Members and upon all future Members for such a period as the Authority engages in any activities under this Agreement, except as to any party which withdraws or is terminated from its participation in the Authority in accordance with this Agreement. This Agreement shall supersede the Original Agreement and the Interim Funding Agreement effective 2013. Any monies collected pursuant to the Interim Funding Agreement which have not been expended as of the date of this Agreement shall be credited towards each Member's financial commitment as identified herein.

Section 2.03 Purpose.

(a) The purposes of this Agreement are to:

(i) provide for the joint exercise of powers common to each of the Members and powers granted pursuant to SGMA (subject to the restrictions contained in this Agreement), through the Authority, to cooperatively carry out the purposes of SGMA and develop, adopt and implement a legally sufficient GSP covering those portions of the Kern County Subbasin that are within the

jurisdictional boundaries of the Members, subject to the limitations set forth herein; and

(ii) provide a mechanism for the coordination of groundwater management activities by and among the Members, in accordance with SGMA.

(b) Each of the General Members (or group of General Members) shall have the sole and absolute right, in its sole discretion, to:

(i) become a GSA individually or collectively within the General Member's boundaries or the Management Area managed in whole or in part by such General Member;

(ii) approve the portion, section or chapter of the GSP adopted by the Authority as applicable within the General Member's boundaries or the Management Area managed in whole or in part by such General Member, as provided for in Section 7.01 of this Agreement; and

(iii) implement SGMA and the GSP adopted by the Authority within the General Member's boundaries or the Management Area managed in whole or in part by such General Member.

(c) Except to the extent requested by a General Member with respect to the lands within its boundaries, the Authority shall serve primarily a coordinating and administrative role in order to provide for sustainable groundwater management of the Kern County Subbasin in a manner that does not limit any Member's rights or authority over its own water supply matters, including, but not limited to, a Member's Water Supply Matters. Subject to the provisions, limitations and restrictions contained in this Agreement, activities unrelated to coordinating and administrative tasks necessary for groundwater management and sustainability shall not be undertaken by the Authority.

(d) Notwithstanding any other provision of this Agreement, the Authority shall not seek status as a GSA or approve a GSP prior to the GSA Notice Date.

(e) Not later than the GSA Notice Date, or such later date as determined by the Board of Directors, each Member shall provide the Authority with written notice that such Member will:

(i) continue as a Member and request the Authority to act as the GSA within such Member's boundaries or for the Management Area managed in whole or in part by such Member pursuant to a separate agreement between the Authority and the Member setting forth the terms and conditions of the Authority's role as the GSA within such Member's boundaries or for the Management Area managed in whole or in part by such Member;

(ii) continue as a Member and confirm that it will implement the GSP adopted by the Authority within such Member's boundaries or for the Management Area managed in whole or in part by such Member continue as a Member;

(iii) continue as a Member but seek GSA status within its boundaries or within the Management Area managed in whole or in part by such Member in order to implement SGMA and the GSP adopted by the Authority therein; or

(iv) seek GSA status within its boundaries or within the Management Area managed in whole or in part by such Member and adopt its own GSP, in which case such Member shall be deemed to have withdrawn from the Authority pursuant to Article VI but will endeavor in good faith to develop and execute a coordination agreement with the Authority in accordance with SGMA. Such Member may still be eligible to become an Associate Member pursuant to Section 6.02 (a).

Section 2.04 Powers.

(a) Subject to the limitations and restrictions contained within this Agreement, the Authority shall have the power to take any action, for the benefit of its Members, to carry out the purposes of this Agreement, including, but not limited to, applying for loans and grants, becoming a GSA for any or all of the Kern County Subbasin except the portions thereof for which Members become the GSA, and developing, adopting and implementing a GSP, subject to the paramount right of Members to become GSAs as specified in Section 2.03. The Authority shall have the power to sue and be sued. Notwithstanding the foregoing, the Authority shall not have the power to control, limit or empower a Member's rights and authorities over its own Water Supply Matters. Likewise, unless a Member requests it, the Authority shall have no power to interfere with (i) the Member's rights, use or management of the Member's water or water supply or (ii) the rights of individual landowners within the Member's boundaries to utilize, apply, store, or otherwise use surface or groundwater. Subject to the limitations and restrictions contained in this Agreement, the Authority is authorized, in its own name, to do all acts necessary for the exercise of said powers provided that said acts are duly adopted by the then seated Board of Directors and are consistent with this Agreement. Except as provided in Section 4.05, the Authority may not levy assessments on its Members. In accordance with California Government Code Section 6509, the foregoing powers shall be subject to the restrictions upon the manner of exercising such powers pertaining to the Cawelo Water District.

(b) Notwithstanding anything to the contrary in this Agreement, the Authority shall not (i) undertake any activities within any Member's boundaries, or within a Management Area managed in whole or in part by such Member, unless the Member formally and expressly requests, consents to and agrees, in writing, to the activity proposed in accordance with Section 7.4 or (ii) acquire or seek to acquire by eminent domain any property of a Member. Nothing in this Agreement shall modify or limit the police powers of Members, if any.

Article III: Internal Organization

Section 3.01 - Governing Body.

(a) The Authority shall be governed by a Board of Directors which is hereby established and which shall be initially composed of representatives of the General Members, as shown on Exhibit A. Membership on the Authority's Board of Directors shall not include Representatives from Associate and Cooperative Members. Without amending this Agreement, the Board of Directors composition shall be altered from time to time to reflect the termination and/or admission of any new General Members.

(b) Each General Member's governing board shall select a representative from its governing body or the governing body of one of the agencies within the General Member to serve as their Board member. A General Member may designate from its governing body or the governing

body of one of the agencies within the General Member to serve as its alternative Director. The role of each alternate Director shall be to assume the duties of the Director appointed by his/her Member entity in case of the absence or unavailability of such Director, including without limitation such Director's duties as a member of any Committee established pursuant to Section 3.03. The Directors and alternates so named shall continue to serve until their respective successors are appointed.

(c) Nothing in this Agreement shall preclude a future amendment of this Agreement to reconfigure the Board of Directors into a smaller body comprised of representatives of General Members or other individuals, all as defined in such amendment.

Section 3.02 Officers.

The Board shall select a Chair from among the Board of Directors who shall be the presiding officer of the Board meetings. The Board shall select a Vice Chair from among the Board of Directors who shall serve as the presiding officer in the absence of the Chair. The Board shall also select a Secretary, who need not be a member of the Board of Directors. The terms of such Officers shall be established by the Board of Directors from time to time and as necessary.

Section 3.03 Committees.

There shall be established such Committees as the Board of Directors shall determine from time to time. Each such Committee shall be comprised of representatives of General Members, shall exist for the term specified in the action establishing the Committee, shall meet as directed by the Board of Directors, and shall make recommendations to the Board of Directors on the various activities of the Authority. The Board of Directors may delegate authority to the Committee to administer and implement the various activities of the Authority, subject at all times to the limitations on the Authority set forth in this Agreement; provided, that no power to enforce any aspect of SGMA or the GSP adopted by the Authority shall be delegated to a Committee.

Members shall be given reasonable advance notice of all Committee meetings, including without limitation ad hoc Committee meetings, all of which meetings shall be open to Members and their representatives.

Section 3.04 Seal; Bylaws.

The Board may (but need not) adopt an official seal for the Authority and adopt such bylaws as it may deem necessary to regulate the affairs of the Authority in accordance with this Agreement. The bylaws may be amended from time to time by a majority vote of the Board of Directors as it may deem necessary.

Section 3.05 Voting; Quorum.

(a) Subject to Section 3.05(c), each member of the Board of Directors shall be entitled to a vote determined as follows:

(i) Each member of the Board shall have one (I) vote on matters with respect to which such member is entitled to vote.

(ii) Voting on actions related to Special Activities shall be weighted as determined by each Special Activity agreement.

(b) Directors holding two-thirds of the voting power on the entire Board of Directors on a matter shall constitute a quorum for the transaction of Authority business. Any Board member abstaining from a vote shall be counted for purposes of determining the existence of a quorum, but shall not be deemed to be voting.

(c) A Director (including a Director serving as a member of a Committee) shall be entitled to vote on any matter or action (i) that would affect the General Member represented by such Director, (ii) relating to the general business or administration of the Authority, or (iii) that would impact any land or landowners within the boundaries of the General Member represented by such Director or the Management Area managed in whole or in part by such General Member.

(d) Examples of matters and actions on which a Director shall be entitled to vote include without limitation matters or actions relating to the implementation of SGMA within the boundaries of the General Member represented by such Director, amounts to be paid by the General Member represented by such Director to the Authority, the imposition of fees or charges within the boundaries of the General Member represented by such Director, the adoption or amendment of the Authority's GSP.

(e) In the event of a disagreement as to whether a Director is entitled to vote on a matter or action coming before the Board or a Committee, such Director shall be entitled to vote on the matter or action unless 75% of the Directors present at the meeting determine that such Director is not so entitled.

(f) Except as otherwise provided in this Agreement, any action by the Board of Directors shall require a two-thirds vote of the Directors entitled to vote thereon that are present at the meeting. Any amendment of this Agreement shall be governed by Section 8.0 I.

(g) Two-thirds of the members of a Committee entitled to vote thereon shall constitute a quorum for a matter or action before the Committee. All questions and matters of any nature whatsoever coming before any Committee shall be determined, provided a quorum is present, by the concurrence of75% of the members of such Committee entitled to vote thereon present and voting on such matter. Any Committee member entitled to vote thereon abstaining from a vote shall be counted for purposes of determining the existence of a quorum, but shall not be deemed to be voting.

(h) This Section 3.05 shall not apply to matters affecting implementation of SGMA within a particular Management Area. Such matters shall be governed by the Member or Members implementing SGMA within that Management Area, except to the extent otherwise agreed upon by such Member(s) pursuant to 2.04(b) or in a Special Activity agreement.

Section 3.06 - Meetings.

Meetings of the Board of Directors and any Committee (to the extent applicable) shall be conducted in accordance with the Ralph M. Brown Act, California Government Code Sections 54950, *et seq.*

Section 3.07 - Special Activities.

With the prior approval of the entire Board of Directors, Members may undertake Special Activities in the name of the Authority. All Members shall be given the opportunity to participate in each Special Activity of the Authority unless the Special Activity is an action described in Section

7.04. Prior to undertaking a Special Activity, the Members electing to participate in the Special Activity shall enter into an activity agreement. Such activity agreement shall provide that (i) no Special Activity undertaken pursuant to such agreement shall conflict with the terms of this Agreement and (ii) the Members to the activity agreement shall indemnify, defend and hold the Authority, and the Authority's other Members, harmless from and against any liabilities, costs or expenses of any kind arising as a result of the Special Activity described in the activity agreement. All assets, rights, benefits, debts, liabilities and obligations attributable to a Special Activity shall be assets, rights, benefits debts, liabilities and obligations solely of the Members that have entered into the activity agreement for that Special Activity, in accordance with the terms of the activity agreement, and shall not be the assets, rights, benefits, debts, liabilities and obligations of those Members that have not executed the activity agreement.
Members not electing to participate in the Special Activity shall have no rights, benefits, debts, liabilities or obligations attributable to such Special Activity.

Article IV: Financial Provisions

Section 4.01 - Fiscal Year.

The Fiscal Year of the Authority shall be from January I through December 31 of each

Section 4.02 - Funds: Accounts.

(a) The North Kern Water Storage District shall serve as the Fiscal Agent and Treasurer or the Authority unless otherwise determined by the entire Board. The Fiscal Agent shall be responsible for all money of the Authority from whatever source. The Board may compensate the fiscal agent for services rendered.

(b) All funds of the Authority shall be strictly and separately accounted for and regular reports shall be rendered of all receipts and disbursements at least quarterly during the Fiscal Year. The books and records of the Authority shall be open to inspection by the Members.

(c) The Authority shall contract with a certified public accountant to make an audit or review of the accounts and records of the Authority which shall be conducted in compliance with Section 6505 of the California Government Code. The Fiscal Agent shall have the right to reject any proposed certified public accountant. All costs associated with this Audit will be the full responsibility of the Authority.

Section 4.03 - Property: Bonds.

The Board of Directors shall from time to time designate the officers and persons, in addition to those specified in Section 4.02 above, who shall have charge of, handle, or have access to any property of the Authority. Each such officer and person shall file a bond in an amount designated by the Board of Directors.

Section 4.04 - Budget.

By a date set by the Board of Directors each Fiscal Year, the Board of Directors shall adopt a budget for the Authority for the ensuing Fiscal Year; provided, that except as provided in Section 4.05,

the Authority shall not impose assessments or other charges on Members. Notwithstanding the foregoing, by its execution of this Agreement, each Member confirms that it has authorized its Director and Alternate Director to approve actions and expenditures by the Authority over and above the approved annual budget of the Authority for a Fiscal Year that do not create a fiscal obligation greater than $5,000 on such Member without further action of such Member.

Section 4.05 - Payments To The Authority.

(a) Except as otherwise provided, all fees, costs and expenses incurred by the Authority for general administrative services, such as legal, preparation of audits, and other general administrative functions shall be funded (i) from permissible contributions from third parties and (ii) assessments on the General Members, levied from time to time by the Board of Directors to carry out the activities of the Authority generally applicable to all General Members, which shall be equal per General Member, as shown on Exhibit A.

(b) No Member shall be bound, financially or otherwise, by any obligation, contract or activity undertaken by the Authority unless and except to the extent agreed upon by the Member, except that each Member shall be obligated to fund its then current annual share of the general basic budget of the Authority, provided such budgets are otherwise approved as provided herein. Funding of other matters shall be through Special Activity agreements or as otherwise agreed to by the Members in writing.

(c) Cooperative Members shall not be assessed by the Authority and are under no obligation to fund or otherwise pay money to the Authority.

Section 4.06 - GSP Fees.

The Authority may impose reasonable fees, charges, assessments and other levies to implement its GSP and/or SGMA; provided, that the Authority shall have no authority to impose any such fees, charges, assessments or other levies on any of its Members or within a Management Area without the express consent and approval of the affected Member(s), or the Member or Member implementing the Authority's GSP and SGMA within such Management Area.

Article V: Management

Section 5.01 - Management.

In addition to, or in lieu of, hiring employees, the Authority may engage one or more General Member(s) or third party(ies) to manage any or all of the business of the Authority on terms and conditions acceptable to the Board of Directors. Any General Member or third party so engaged shall have such responsibilities as are set forth in the contract for such General Member's or third party's services.

Article VI: Relationship of Authority And Its Members

Section 6.01 - Separate Entity: Property.

In accordance with California Government Code Sections 6506 and 6507, the Authority shall be a public entity separate and apart from the parties to this Agreement. Unless, and to the extent

otherwise agreed herein, the debts, liabilities and obligations of the Authority shall not be debts, liabilities or obligations of the Member entities. The Authority shall own and hold title to all funds, property and works acquired by it during the term of this Agreement.

Section 6.02 - Admission, Withdrawal and Termination of Members.

(a) Additional qualified parties may join in this Agreement and become General Members upon the approval of the entire Board of Directors, subject to terms and conditions as may be established by the Board of Directors. Associate Members may be admitted on terms and conditions established by the entire Board of Directors. Prior to being admitted as a new Member, an entity shall execute an agreement to be bound by the terms of this Agreement and any other terms and conditions established by the Board of Directors.

(b) Notwithstanding anything herein to the contrary, any Member may withdraw from this Agreement by giving 30 days written notice of its election to do so, which notice shall be given to the Board of Directors and to each of the other parties.

(c) Upon withdrawal, the Member shall not be relieved of all obligations for assessments to pay costs or liabilities of the Authority which were incurred prior to the date of the withdrawing Member's notice of withdrawal, but shall remain responsible for all obligations for assessments to pay costs or liabilities of the Authority which were incurred prior to the date of the withdrawing Member's notice of withdrawal.

(d) Subject to any contrary provisions of SGMA, a Member may be terminated by a three-fourths vote of the Directors representing Members not subject to the termination vote if such Member is then in breach of this Agreement and the breach is identified in the vote of the Board of Directors. Upon termination, the breaching Member shall no longer be a Member of the Authority; provided, that such termination shall become effective no earlier than 90 days after such vote of the Board of Directors and shall only be effective if the breach identified in the vote of the Board of Directors has not be cured by the effective date for the termination.

(e) Upon termination, the Member shall be entitled to a reimbursement for all assessments collected within 12 months prior to the termination vote and they shall be relieved of all ongoing obligations for assessments to pay costs or liabilities of the Authority which were incurred prior to the date of the termination.

(f) Upon withdrawal or termination as a Member, the provisions of Section 2.04(b) shall remain applicable to any such withdrawing or terminated Member. The withdrawing or terminated Member will also be entitled to copies of all documents, information, and material developed by the Authority and paid for in whole or in part by the Member prior to the Member's withdrawal or termination.

(g) Upon withdrawal or termination as a Member, whether occurring before or after the GSA Notice Date and/or the date the Authority becomes a GSA as provided for in SGMA, or whether occurring before or after June 30, 2017, it is contemplated the withdrawing or terminated Member would concurrently become (or designate) a GSA for the lands within its boundaries (or a Management Area managed in whole or in part by such Member), so that such lands of the withdrawing or terminated Member would continue to be subject to a GSA and if applicable a GSP and the powers of such withdrawing Member within its boundaries would not

be limited by this Agreement. In such event the Authority and its remaining Members shall (i) not object to or interfere with the lands in the withdrawing or terminated Member's boundaries (or a Management Area managed in whole or in part by such Member) being in a GSA, as designated by such withdrawing or terminated Member, (ii) facilitate such transition to the extent reasonably necessary, and (iii) in cooperation with the withdrawing or terminated Member, withdraw from managing the Kern County Subbasin as a GSA (if it has already elected to be a GSA) for that portion of the Basin within the boundaries of the withdrawing or terminated Member and so notify the Department of Water Resources.

Section 6.03 - Disposition Of Property Upon Termination Or Determination By Board Of Directors Of Surplus.

(a) Upon termination of this Agreement or upon determination by the Board of Directors that any surplus money is on hand, such surplus money shall be returned to the Members of the Authority. The distribution of said surplus shall be proportionate to the current year percentages as shown in Exhibit A, or as modified after the inclusion of new Members.

(b) The Board of Directors shall first offer any surplus properties, works, rights and interests of the Authority for sale to the Members and the sale shall be at the Authority's actual cost unless otherwise required by law. If no such sale is consummated, then the Board of Directors shall offer the surplus properties, works, rights and interests of the Authority for sale in accordance with applicable law to any governmental agency, private entity or persons for good and adequate consideration.

Section 6.04 - Liability For Debts.

The Members do not intend hereby to be obligated either jointly or severally for the debts, liabilities or obligations of the Authority, except as may be specifically provided for in California Government Code Section 895.2 as amended or supplemented. Provided, however, if any General Member(s) of the Authority are, under such applicable law, held liable for the acts or omissions of the Authority caused by negligent or wrongful act or omission occurring in the performance of this Agreement, such parties shall be entitled to contribution from the other Members so that after said contributions each General Member shall bear an equal share of such liability, as shown on the then-current Exhibit A. This Section 6.04 does not apply to acts or omissions of a Member in implementing the GSP adopted by the Authority within such Member's boundaries or a Management Area managed in whole or in part by such Member.

Section 6.05 - SGMA-Related Expenses Incurred by Members.

Expenses incurred by a Member, or group of Members, for the implementation of the SGMA within a Management Area shall be borne solely by that Member or group of Members. Neither the Authority nor its other Members shall be liable for such expenses.

Article VII - Implementation of SGMA Section

7.01 - Development of GSP.

Any Member or group of Members may create its or their own chapter or provisions

governing SGMA implementation within their respective boundaries or a Management Area managed in whole or in part by such Member(s) for inclusion by the Authority into the Authority's GSP. Cooperative Members shall be under no obligation to prepare or otherwise contribute to the preparation of any GSP chapter(s). The Authority shall promptly review the proposed chapter or provisions for consistency with the Authority's GSP and to determine that it meets the requirements of SGMA. If the Authority determines by a vote of 75% of the Directors that a Member's proposed chapter or provisions is/are consistent with SGMA and the Authority's GSP, it shall incorporate such chapter or provisions into the Authority's GSP. Such chapter or provisions may include operating conditions and criteria for groundwater banking projects that have previously been negotiated with other Members or agencies within the Basin and/or are contained within approved environmental documents, and in reviewing a Member's chapter the Authority shall not reject or fail to approve a Member's chapter based solely upon such operating conditions and criteria. The Authority shall not adopt a GSP that will be implemented within any Member's boundaries or Management Area without the prior approval of the Member.

Section 7.02 - Authorization to Carry Out the Terms of the GSP.

The Authority is authorized to carry out any of the following powers for the benefit of its Members that are included in the GSP adopted by the Authority without any further approval of the Board of Directors, subject at all times to the limitations and restrictions contained within this Agreement:

(a) Collection and maintenance of water extraction information and other technical data.

(b) Coordination of actions within, and reporting by, a Management Area.

(c) Carrying out studies and other technical investigations.

(d) Establishment and administration of conjunctive use and land fallowing programs.

(e) Requiring permitting of water extraction facilities.

(f) Requiring installation of meters.

(g) Buy, sell, exchange, recharge, and/or store water if the benefits thereof are made available to all General Members.

(h) Fix and collect rates for replenishment and other activities as a regulatory or service fee provided for at Water Code Sections 10730 through 10731.

Section 7.03 - Actions Requiring Additional Approval.

Subject to the limitations of this Agreement, the Authority shall not do any of the following without the approval of 75% of the voting power of the Board of Directors:

(a) Restrict or otherwise limit extraction of native groundwater other than through economic incentives and disincentives.

(b) Fund capital construction projects.

Notwithstanding any other provision of this Agreement, the Authority shall not restrict or otherwise limit the extraction of water stored (whether through direct recharge or in lieu deliveries) in the Kern County Subbasin as a part of any banking or recharge project or program, or otherwise seek to regulate the operation any such project or program.

Section 7.04 - Management Areas.

Any General Member (or group of General Members) may request that the Authority directly assume the responsibility of implementing SGMA and the Authority's GSP within its Management Area by giving written notice to the Authority, which notice may be given at any time. Where the service areas of multiple General Members overlap a Management Area, the General Members within the Management Area shall unanimously join the request. The Board of Directors shall take action to accept or reject such request. If the Authority accepts such request, the Authority and the requesting General Member(s) shall develop a mutually acceptable agreement describing the respective roles and responsibilities of the Authority and the requesting General Member(s) with respect to such implementation.

Except as otherwise expressly provided, the Authority's role within a Management Area, unless otherwise unanimously requested by the General Member(s) managing such Management Area, shall be primarily coordinating and administrative. In particular, the roles and responsibilities for implementing SGMA and the GSP within a Management Area shall be the subject of a Special Activity agreement between the General Member(s) and the Authority.

Article VIII: Miscellaneous Provisions

Section 8.01 - Amendment.

This Agreement may be amended from time to time by the concurrence of 75% of the General Members. To provide non-concurring parties an opportunity to withdraw from the Authority as provided herein, an amendment shall be binding on all parties 60 days after the required concurrence has been obtained.

Section 8.02 Severability And Validity Of Agreement.

Should the participation of any party to this Agreement, or any part, term or provision of this Agreement be decided by a courts or the Legislature to be illegal, in excess of that party's authority, in conflict with any law of the State of California, or otherwise rendered unenforceable or ineffectual, the validity of the remaining portions, terms or provisions of this Agreement shall

not be affected thereby and each party hereby agrees it would have entered into this Agreement upon the remaining terms and provisions.

Section 8.03 - Assignment.

Except as otherwise provided in this Agreement, the rights and duties of the parties to this

Agreement may not be assigned or delegated without the advance written consent of the Authority (as evidenced by a majority vote of the Board of Directors), and any attempt to assign or delegate such rights or duties in contravention of this section shall be null and void. Any assignment or delegation permitted under the terms of this Agreement shall be consistent with the terms of any contracts, resolutions or indentures of the Authority then in effect, including without any Special Activity agreement to which the assigning or delegating Member is a party. This Agreement shall inure to the benefit of and be binding upon the successors and assigns of the parties hereto. This section does not prohibit a party from entering into an independent agreement with another agency regarding the financing of that party's contributions to the Authority or the disposition of proceeds which that party receives under this Agreement so long as such independent agreement does not affect, or purport to affect, the rights and duties of the Authority or the parties under this Agreement.

Section 8.04 - Execution In Parts Or Counterparts.

This Agreement may be executed in parts or counterparts, each part or counterpart being an exact duplicate of all other parts or counterparts, and all parts or counterparts shall be considered as constituting one complete original and may be attached together when executed by the parties hereto. Facsimile or electronic signatures shall be binding.

Section 8.05 - Notices.

Notices authorized or required to be given pursuant to this Agreement shall be in writing and shall be deemed to have been given when mailed, postage prepaid, or delivered during working hours to the addresses set forth for each of the parties hereto on Exhibit "A" of this Agreement, or to such other changed addresses communicated to the Authority and the Member entities in writing, and to such other entities that become Members.

Section 8.06 - Dispute Resolution.

(a) A dispute resolution group shall be established by the Board of Directors to resolve disputes and/or controversies through mediation relating to the interpretation, construction, performance, termination, breach of, or withdrawal from this Agreement (the "Dispute Resolution Group"). The Dispute Resolution Group shall meet with the parties involved no later than 30 days following notification of the dispute or controversy. Thereafter, the Dispute Resolution Group will have 90 days to endeavor to resolve the dispute.

(b) Following conclusion of the dispute resolution process as herein provided, any Member may pursue any judicial or administrative remedies otherwise available. Notwithstanding this Section 8.06, a Member may seek a preliminary injunction or other interlocutory judicial relief if necessary to avoid irreparable damages or to preserve the status quo.

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Arvin CSD

Name of Member

By: RLB

Print Name: Raul Barraza, Jr.

Title: General Manager

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Arvin-Edison Water Storage District
Name of Member



By: _____

Print Name: Edwin Camp

Title: President

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Name of Member

By: _____

Print Name: _____

Title: _____

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

City of Shafter

Name of Member

By: _____

Print Name: Chad Givens

Title: Councilmember

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Kern County Water Agency

Name of Member

By: _____

Print Name: Curtis Creel

Title: General Manager

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Kern County Water Agency on behalf of Pioneer GSA

Name of Member

By: _____

Print Name: Curtis Creel

Title: General Manager

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Kern-Tulare Water District

Name of Member

By: _____

Print Name: for Steve Dalke

Title: General Manager

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Northern WMD

Name of Member

By: _____

Print Name: Richard A. Diamond

Title: GM

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Rosedale-Rio Bravo W.S.D

Name of Member

By: _____

Print Name: ERIC L. AVERETT

Title: General Manager

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Semitropic Water Storage District

Name of Member

By: _____

Print Name: Jason Gianquinto

Title: General Manager

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Shafter-Wasco Irrigation District

Name of Member

By: _____

Print Name: Craig D. Fulwyler

Title: Board of Directors, President

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Southern San Joaquin MUD

Name of Member

By: Roland Gross

Print Name: Roland Gross

Title: GM/Secretary

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Tejon-Castac Water District

Name of Member

By: Angelica Martin

Print Name: Angelica Martin

Title: Secretary

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

WEST KERN WATER DIST

Name of Member

By: Gary J Morris

Print Name: GARY MORRIS

Title: BOARD PRESIDENT

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

WDWA

Name of Member

By: 3.7.21

Print Name: ROB GOFF

Title: BOARD MEMBER

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

WHEELER RIDGE MARICOPA W5D

Name of Member

By: _____

Print Name: SHERIDAN NICHOLAS

Title: ENGINEER. MANAGER

EXHIBIT A

GENERAL MEMBERS

Arvin Community Services District

Arvin-Edison Water Storage District

Cawelo Water District

City of Shafter

Kern County Water Agency, on behalf of the Pioneer GSA

Kern-Tulare Water District

North Kern Water Storage District

Rosedale-Rio Bravo Water Storage District

Semitropic Water Storage District

Shafter-Wasco Irrigation District

Southern San Joaquin Municipal Utility District

Tejon-Castaic Water District

West Kern Water District

Westside District Water Authority

Wheeler Ridge-Maricopa Water Storage District

EXHIBIT B

EXHIBIT B

Associate Members

Eastside Water Management Area

EXHIBIT C

Cooperative Members

Kern County Water Agency

Kern Groundwater Authority Groundwater Sustainability Agency
Groundwater Sustainability Plan

ATTACHMENT B
Coordination Agreement

Kern County Subbasin Coordination Agreement

THIS COORDINATION AGREEMENT (the "Agreement") is made effective as of JANUARY 20, 2020 by and among the Groundwater Sustainability Agencies ("GSA") within the Kern County Subbasin that are developing a Groundwater Sustainability Plan ("GSP") (each a "Party" and collectively the "Parties"), each of which is identified in Appendix 1 and is made with reference to the following facts:

WHEREAS, on September 16, 2014, Governor Jerry Brown signed into law Senate Bills 1168 and 1319 and Assembly Bill 1739, known collectively as the Sustainable Groundwater Management Act ("SGMA"); and

WHEREAS, SGMA requires all groundwater basins designated as high or medium priority by the Department of Water Resources ("DWR") to manage groundwater in a sustainable manner; and

WHEREAS, the Kern County Subbasin (Basin Number 5-22. 14, DWR Bulletin 118) ("Basin") within the San Joaquin Valley Groundwater Basin, has been designated as a high-priority basin by DWR; and

WHEREAS, the Basin includes eleven (11) GSAs that are managing the Basin through five (5) different GSPs; and

WHEREAS, SGMA allows local agencies to engage in the sustainable management of groundwater, but requires GSAs intending to develop and implement multiple GSPs within a basin to enter into a coordination agreement;

WHEREAS, the Agreement does not prevent any Party from providing comments on a GSP, or otherwise coordinating among parties with regard to specific items in a GSP outside this Agreement, on issues including but not limited to specific border conditions between GSP's and/or the timing and/or effect of projects and management actions contained within another GSP; and

WHEREAS, nothing in this Agreement represents or should be construed as the determination of any claim or assertion of a groundwater right; specifically, the coordinated water budget information or data does not amount to an allocation, or otherwise represent a determination, validation, or denial of any claimed or asserted groundwater right.

THEREFORE, in consideration of the facts recited above and of the covenants, terms and conditions set forth herein, the Parties agree as follows:

SECTION 1 – PURPOSE

The purpose of this Agreement is to comply with SGMA coordination agreement requirements and ensure that the multiple GSPs within the Basin are developed and implemented utilizing the same methodologies and assumptions as required under SGMA and Title 23 of the California Code of Regulations, and that the elements of the GSPs are appropriately coordinated to support sustainable management.

The Parties intend that this Agreement be a description of how the multiple GSPs, developed by the individual GSAs, are implemented together to satisfy the requirements of SGMA. The Parties intend this Agreement to be incorporated as part of each individual GSP developed by the Parties.

SECTION 2 – GENERAL GUIDELINES

2.1 Responsibilities of the Parties

The Parties shall work collaboratively to comply with SGMA and this Agreement. Each Party to this Agreement is a GSA and acknowledges it is bound by the terms of the Agreement. This Agreement does not otherwise affect each Party's responsibility to implement the terms of their respective GSP. Rather, this Agreement is the mechanism through which the Parties will coordinate portions of the multiple GSPs to ensure such GSP coordination complies with SGMA.

2.2 No Adjudication or Alternative Plans in the Basin

As of the date of this Agreement, there are no portions of the Basin that have been adjudicated or have submitted for DWR approval an alternative to a GSP pursuant to Water Code Section 10733.6.

SECTION 3 – GOVERNANCE

3.1 Basin Coordination Committee

The Basin Coordination Committee (BCC) will oversee the activities described in section 3.1.5 of this Agreement. The Basin Coordination Committee will consist of one representative appointed from each GSP.

3.1.1 Each Basin Coordination Committee member's compensation for service on the Basin Coordination Committee, if any, is the responsibility of the appointing Party.

3.1.2 Each Basin Coordination Committee member shall serve at the pleasure of the appointing GSP and may be removed or substituted from the Basin Coordination Committee by the appointing GSP at any time.

3.1.3 The Basin Coordination Committee will meet periodically as it deems necessary to carry out the activities described in this Agreement

3.1.4 The Basin Coordination Committee may suggest subcommittees, workgroups, or otherwise request staff of the Parties to develop technical data, supporting information and/or recommendations.

3.1.5 The purposes of the Basin Coordination Committee are to (1) recommend to their respective GSAs the appointment of a Plan Manager who will act in accordance with this Agreement, and (2) provide a forum wherein the Parties may discuss basin coordination activities, which may include the development, planning, financing, environmental review, permitting, implementation, and long-term monitoring

of the multiple GSPs in the Basin, pursuant to SMGA requirements ("Coordination Activities").

3.2 Plan Manager

The Plan Manager shall be appointed by unanimous agreement by the Parties for a term of one calendar year, and annually thereafter, and may be removed by unanimous agreement of the Parties with or without cause. The Plan Manager shall serve as the point of contact for DWR as specified in 23 CCR § 357.4, subd. (b)(1). The Plan Manager shall submit or assist with the submittal of all GSPs, plan amendments, supporting information, monitoring data and other pertinent information, Annual Reports, and periodic evaluations to DWR when required. The Plan Manager has no authority to take any action or represent the Basin Coordination Committee or a particular GSA without the specific direction and authority of the Basin Coordination Committee or the particular GSA, respectively. The Plan Manager is obligated to immediately disclose all communications he/she receives in his/her capacity as Plan Manager to the Basin Coordination Committee and the affected GSA, as appropriate under the circumstances.

SECTION 4 – EXCHANGE OF DATA AND INFORMATION

4.1 Procedure for Exchange of Information

4.1.1 The Parties may exchange information through collaboration and/or informal requests made at the Basin Coordination Committee level or through subcommittees suggested by the Basin Coordination Committee. However, to the extent it is necessary to make a written request for information to another Party, each Party shall designate a representative to respond to information requests and provide the name and contact information of the designee to the Basin Coordination Committee. Requests may be communicated in writing and transmitted in person or by mail, facsimile machine or other electronic means to the appropriate representative as named in this agreement.

4.1.2 Nothing in this Agreement shall be construed to prohibit any Party from voluntarily exchanging information with any other Party by any other mechanism separate from the Basin Coordination Committee.

4.2 Non-Disclosure of Confidential Information

Pursuant to Section 4.1 of this Agreement, a Party may provide one or more of the other Parties with confidential information. To ensure the protection of such confidential information and in consideration of the agreement to exchange said information, appropriate arrangements may be made to restrict or prevent further disclosure.

SECTION 5 – METHODOLOGIES & ASSUMPTIONS

Pursuant to California Water Code section 10727.6 and 23 CCR, § 357.4, the Parties will meet and agree upon the methodologies used in their respective GSPs with respect to utilizing the same data and methodologies for the following assumptions: 1) groundwater elevation data; 2) groundwater extraction data; 3) surface water supply; 4) total water use; 5) change in groundwater storage; 6) water

budget; and 7) sustainable yield, and that such methodologies and assumptions will continue to be used in the future development and implementation of such GSPs, except to the extent modified by the Parties in the future. Information regarding the agreed upon Basin methodologies and assumptions shall be attached as Appendix 2 to this Agreement when approved by all Parties.

SECTION 6 – MONITORING NETWORK

6.1 The Parties shall develop a monitoring network and monitoring network objectives for the Basin in accordance 23 CCR, §§ 354.32 – 354.40. Each network shall facilitate the collection of data in order to characterize groundwater and related surface water conditions in the Basin and evaluate changing conditions that occur from implementation of the individual GSPs. The individual GSPs shall include monitoring objectives, protocols, and data reporting requirements as necessary under SGMA and SGMA Regulations.

6.2 The monitoring network(s) will demonstrate short-term, seasonal, and long-term trends in groundwater and related surface water conditions. Each Party's GSP will describe the monitoring network's objectives for the Basin, including an explanation of how the network will be developed and implemented to monitor groundwater and related surface water conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial density to evaluate the affects and effectiveness of GSP implementation. The Parties shall implement the monitoring network objectives to accomplish the following: a) demonstrate progress toward achieving measurable objectives described in the GSPs; b) monitor impacts to the beneficial uses or users of groundwater; c) monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds; and d) quantify annual changes in water budget components. Information regarding the agreed upon Basin monitoring network shall be attached as Appendix 3 to this Agreement when approved by all Parties.

6.3 The Parties shall design a monitoring network that will achieve the following for the enumerated sustainability indicators:

6.3.1 Chronic Lowering of Groundwater Levels:

The network shall collect information sufficient to demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features by the following methods: a) density of monitoring wells to collect measurements through depth-discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer; and b) take static groundwater elevation measurements, at least two times a year, representing seasonal low and high conditions.

6.3.2 Change in Groundwater Storage:

The network will provide sufficient data for the GSAs to estimate the change in annual groundwater in storage.

6.3.3 Degraded Water Quality:

The network will collect sufficient spatial and temporal data from each GSA to determine groundwater quality trends for water quality indicators, as determined by the GSA, to address known water quality issues.

6.3.4 Land Subsidence:

The network will identify the location, rate and extent of land subsidence, which may be measured by extensometers, surveying, remote sensing technology, or any other appropriate method.

6.3.5 Seawater Intrusion/Depletion of Interconnected Surface Water:

The network will not be designed to monitor Seawater Intrusion and/or Depletion of Interconnected Surface Water because these issues are not applicable to the Basin.

6.4 The Parties shall determine the density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends based upon the following factors: a) the amount of current and projected groundwater use; b) aquifer characteristics, including confined or unconfined aquifer conditions or other physical characteristics that affect groundwater flow; c) impacts to beneficial uses and users of groundwater and land uses and property interests affected by groundwater production, and adjacent basins that could affect the ability of that basin to meet the sustainability goal; d) whether individual GSAs have adequate long-term existing monitoring results or other technical information to demonstrate an understanding of aquifer response.

6.5 Parties may designate a subset of monitoring sites as representative of conditions in the Basin or a portion of the Basin.

6.6 The Parties shall identify data gaps where the Basin does not contain sufficient monitoring sites, where the frequency of monitoring is insufficient, or sites are unreliable. If such gaps are identified, the Parties shall describe the reason for the gap and describe actions that may be taken to remedy such gaps.

6.7 The Parties shall share information necessary to create a Basin map displaying the location and type of each monitoring site within the Basin, and a report in tabular format, including information regarding the monitoring site type, frequency of measurement, and purpose for which the monitoring site is being used.

SECTION 7 – COORDINATED WATER BUDGET

7.1 In accordance with 23 CCR, § 357.4 subd. (b) the Parties shall prepare a coordinated water budget for the Basin as described in this sub-section, as required by 23 CCR, § 354.18. The water budget will provide an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the Basin, including historical, current, and projected water budget conditions, and the change in the volume of water stored. Information regarding the agreed upon coordinated water budget shall be attached as Appendix 4 to this Agreement when approved by all Parties.

7.2 Each Party for its respective GSP shall endeavor to provide the information required by 23 CCR, § 356.2 to the Basin Coordination Committee by March 1 for the preceding calendar year.

7.3 The Parties shall use the projected water budgets to estimate future baseline conditions of supply, demand, and aquifer response to their GSP implementation, and to identify the uncertainties of these projected water budget components. The Parties shall use the following methodologies and assumptions to estimate future baseline conditions concerning hydrology, water demand and surface water supply availability or reliability over the planning and implementation horizon for the projected water budget.

7.3.1 To the extent available, use 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology. The projected hydrology information shall also be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.

7.3.2 Projected water demand shall utilize the most recent reliable land use, population growth, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand. The projected water demand information shall also be applied as the baseline condition used to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate.

7.3.3 Projected surface water supply shall utilize the most recent reliable water supply information as the baseline condition for estimating future surface water supply. The projected surface supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply as identified in the historical water budget and the projected changes in local land use planning, population growth, and climate.

SECTION 8 – COORDINATED DATA MANAGEMENT SYSTEM

The Parties will develop and will maintain a data management system that is capable of storing and reporting information relevant to the development and/or implementation of the GSPs and monitoring network of the Basin as required by SGMA and the SGMA Regulations. Information regarding the agreed upon coordinated data management system shall be attached as Appendix 5 to this Agreement when approved by all Parties.

SECTION 9 – ADOPTION AND USE OF THE COORDINATION AGREEMENT

9.1 Cooperative Implementation of GSPs

The Parties intend that their individual GSPs will be implemented together in order to satisfy the requirements of SGMA. The collective GSPs in a coordinated manner will utilize the groundwater models, a description of the physical setting and characteristics of the separate aquifer systems within the Basin, the methodologies and assumptions as specified in Water Code section 10727.6, a description

of the undesirable results, the minimum thresholds, the measurable objectives, and monitoring protocols that together provide a description of the sustainable yield of the Basin(s) as a whole, and how it will be sustainably managed.

9.2 GSP and Coordination Agreement Submission

The Parties shall submit their respective GSPs to DWR through the Plan Manager in accordance with SGMA and SGMA Regulations. The Parties intend that this Agreement suffice to fulfill the requirements of providing an explanation of how the GSPs implemented together satisfy Water Code sections 10727.2, 10727.4 and 10727.6 for the entire Basin.

9.3 In Event Entire Basin Not Covered by GSP

In the event it appears that the entire Basin may not be covered by one or more GSPs as of January 31, 2020, each Party may take such action as deemed necessary or appropriate by such Party with respect to filing its GSP and/or other documents with DWR.

9.4 Duration of Coordination Agreement

This Coordination Agreement shall be reopened for amendment at the at the submission of the next round of GSP's covering the Kern Subbasin (no later than 5 years from January 31, 2020). Unless amended at that time, the Coordination Agreement shall be automatically renewed every 5 years. The parties may agree to unanimously amend this Coordination Agreement at any time.

SECTION 10 – Modification and Termination of the Agreement

10.1 Modification

This Agreement shall be reviewed as part of each five year assessment and may be supplemented, amended, or modified only by the written agreement of all the Parties. No supplement, amendment, or modification of this Agreement shall be binding unless it is in writing and signed by all Parties.

10.2 Withdrawal, Termination, Adding Parties

10.2.1 A Party may unilaterally withdraw from this Agreement without causing or requiring termination of this Agreement, effective upon 30 days' notice to the other Parties.

10.2.2 A new GSA or group of GSA's may be added as a Party to this Agreement if such entity or entities is submitting a GSP within the Basin.

10.2.3 This Agreement may be rescinded by unanimous written consent of all the Parties. Nothing in this Agreement shall prevent the Parties from entering into another coordination agreement.

SECTION 11 – Dispute Resolution

11.1 Procedures for Resolving Conflicts

In the event that any dispute arises among the Parties relating to the rights and obligations arising from this Agreement, the aggrieved Party or Parties shall provide written notice to the other Parties of the dispute. Within thirty (30) days after such written notice, the Parties shall attempt in good faith to resolve the dispute through informal means. If the Parties cannot agree upon a resolution of the dispute within thirty (30) days from the providing of written notice specified above, the dispute will be elevated to the BCC for consideration, along with the notice of dispute and any other relevant supporting documentation produced and shared by the disputing parties pursuant to their informal meet and confer process. The BCC may issue a recommendation concerning resolution of the dispute. If the Parties cannot agree upon a resolution of the dispute following the input of the BCC, the disputing Parties will meet and confer to determine if other alternative dispute resolution methods are agreeable, including voluntary non-binding mediation, which may include the Department of Water Resources dispute resolution process, arbitration, or appointment of a panel of technical experts prior to commencement of any legal action. The cost of alternative dispute resolution shall be paid in equal proportion among the Parties to the dispute, otherwise the Parties shall bear their own costs. Upon completion of alternative dispute resolution, if any, and if the controversy has not been resolved, any Party may exercise any and all rights to bring a legal action relating to the dispute.

11.2 Litigation

In the event a dispute or claim is not resolved by a mutually agreeable settlement through informal negotiation or voluntary mediation, the aggrieved Party may file suit in a County Superior Court with jurisdiction to provide a binding decision on the matter.

Jeff Ulrich - President — 1-10-20

Henry Miller Water District — Date
Print Name, Position

12-18-19

Kern Groundwater Authority — Date
Jason Selvidge, Vice Chair

John Vidovich — 20 January 2020

Buena Vista Water Storage District — Date
Print Name, Position

1-15-20

Kern River Groundwater Sustainability Agency — Date
Print Name, Position

Olcese Water District Groundwater Sustainability Agency — Date
Print Name, Position

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Henry Miller Water District Print Name, Position	Date
Kern Groundwater Authority Jason Selvidge, Vice Chair	Date
Buena Vista Water Storage District Print Name, Position	Date
Kern River Groundwater Sustainability Agency Print Name, Position	Date
Olcese Water District Groundwater Sustainability Agency Print Name, Position James L. Nickel, President	1/13/2020 Date

GROUNDWATER SUSTAINABILITY AGENCIES NOT SUBMITTING A GROUNDWATER SUSTAINABILITY PLAN

Greenfield County Water District

_____

Print Name, Position,

_____

MacFarland County Water District

_____

Print Name, Position,

_____

Cawelo Water District / GSA

Keith Watkins - President

Print Name, Position,

APPENDICES

APPENDIX 1

APPENDIX 1

Buena Vista Water Storage District

Henry Miller Water District

Kern Groundwater Authority Groundwater Sustainability Agency

Kern River Groundwater Sustainability Agency

Olcese Water District Groundwater Sustainability Agency

APPENDICES 2 & 4

TODD GROUNDWATER

January 7, 2020

MEMORANDUM

To: Mark Mulkay, Kern River GSA
Patty Poire, Kern Groundwater Authority GSA

From: Michael Maley, Todd Groundwater
Charles Brush, Hydrolytics LLC

Re: **SGMA Water Budget Development using C2VSimFG-Kern in support of the Kern County Subbasin Groundwater Sustainability Plans (GSPs)**

1. INTRODUCTION

In compliance with the Sustainable Groundwater Management Act (SGMA), the multiple Groundwater Sustainability Agencies (GSAs) of the Kern County Subbasin (**Figure 1**) have successfully coordinated on the development of Groundwater Sustainability Plans (GSPs). The Kern County Subbasin, the largest in the State, was designated as critically-overdrafted by the California Department of Water Resources (DWR). Water management in the Kern County Subbasin is complex. It involves more than 30 water districts/systems, contains large groundwater banking projects of State-wide importance, and provides large quantities of groundwater to support both large urban centers and one of the top agricultural-producing areas in the country. In addition, most agencies are involved in conjunctive management of local surface water, imported state and federal water, and groundwater.

Within this complex water management setting, GSAs recognized that a numerical modeling tool would be needed to meet GSP regulations for assessment of historical, current, and future projected water budgets that are developed on a Subbasin-wide basis (§357.4(b)(3)). The California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) is anticipated to be DWR's primary tool for evaluating water management in the Central Valley and is specifically referenced in the GSP regulations for application to GSP water budgets (§354.18(f)); therefore, C2VSim was selected by the GSAs for GSP compliance.

This technical memorandum describes the process and approach for selection, revisions, and application of the C2VSim to the Kern County Subbasin. The memorandum documents the development of Subbasin water budgets and presents the results. This document is being prepared as an attachment to Subbasin GSPs and as an attachment to the Kern County Subbasin GSAs' coordination agreement.

1.1 Background

During late 2016 and 2017, Subbasin GSAs held a series of meetings and workshops to evaluate potential modeling tools for GSP application. Although numerous existing models had been developed by various entities in the Subbasin over time, none of those models covered the entire Subbasin or incorporated all of the local water budget components necessary to meet GSP requirements.

During the time that the Subbasin was evaluating various modeling alternatives, DWR was in the process of updating the regional C2VSim model through water year (WY) 2015. In particular, the GSP regulations stated that DWR would provide the C2VSim model "for use by Agencies in developing the water budget." Todd Groundwater developed an approach for review, revisions, and application of the C2VSim model to the Kern County Subbasin. In March 2017, the Kern River GSA (KRGSA), on behalf of the Subbasin GSAs, entered into a contract with Todd Groundwater to conduct the proposed scope of work. The Kern Groundwater Authority (KGA), on behalf of the Subbasin GSAs, also retained Woodard & Curran to conduct a peer review of the Todd Groundwater C2VSim model revisions and application for the Kern County Subbasin.

DWR released the C2VSim Fine Grid Public Beta model (C2VSimFG-Beta) on May 18, 2018 (CNRA, 2018). An initial model review indicated that the C2VSimFG-Beta generally had good historical precipitation, streamflow, land use and crop acreage for the entire Central Valley. Historical water supply and demand data were also generally good in the Sacramento Valley and San Joaquin River hydrologic regions; however, data were considered less reliable in the Tulare Lake hydrologic region including Kern County. To address this concern, Todd Groundwater – working with all Subbasin GSAs –revised the Kern County portion of C2VSimFG-Beta for WY1985 to WY2015. This revised version of C2VSim for the Kern County Subbasin, referred to herein as the C2VSimFG-Kern model, was used to develop historical, current and projected-future water budgets in accordance with the requirements in the GSP regulations.

The Central Valley portion of Kern County contains two groundwater subbasins, the Kern County Subbasin (5-022.14) and the White Wolf Subbasin (5-22.18) based on DWR Bulletin 118 (DWR, 2016A). All of the agencies that deliver water in White Wolf Subbasin also deliver water in the Kern County Subbasin and participated in the C2VSim revision. The White Wolf Subbasin portion of C2VSimFG-Beta model was included in this update to ensure coordination of groundwater conditions between the two subbasins. These are considered separate groundwater basins under SGMA with the Kern County Subbasin listed by DWR as critically-overdrafted with a GSP deadline of January 30, 2020, whereas the White Wolf Subbasin is listed as medium priority with a GSP deadline of January 30, 2022. Therefore, only the model results for the Kern County Subbasin are evaluated and reported here.

1.2 General Approach

The current C2VSim model has a detailed finite element mesh that closely follows local hydrologic features. As a regional model, the C2VSimFG-Beta may over-generalize local conditions within the Kern County Subbasin so as to be inconsistent with local site-specific data and knowledge. To address this concern, the managed water supply and demand inputs were updated to better represent the local water balance. To do this, the more general assumptions in C2VSimFG-Beta were replaced with local data and knowledge that are regionally or locally significant over the WY1995 to WY2015 Hydrology Period. Local managed water supply input data (e.g., surface water deliveries, land use, irrigation demand, return flows, and groundwater banking) were collected and applied to C2VSim. Improvement of Kern County data focused on incorporating:

- Surface water delivery volumes, application areas and use by water district,
- Groundwater banking recharge, recovery and application of recovered water,
- Irrigation demand from recent analyses of remote sensing data of evapotranspiration in the Kern County Subbasin based (ITRC, 2017),
- Urban demand for the Subbasin focusing on Metropolitan Bakersfield, and
- Data on other water sources and demands of local significance to individual districts/GSAs.

Compiling the data needed for the model revision required a coordinated effort from the Subbasin GSAs (**Figure 1**) to provide locally derived data on managed water supply and demand that was used to revise the C2VSimFG-Beta for the Kern County Subbasin. The Subbasin GSAs also coordinated on selection of consistent study periods for the C2VSimFG-Kern water budget analyses. Based on technical considerations and a review of regional data, the following study periods were selected:

- Historical Water Budget - WY1995 through WY2014 (Section 3.2), and
- Current Water Budget - WY2015 (Section 3.2),
- Projected Water Budget - WY2021 through WY2070 using 50 years of hydrologic data based on historical data (Section 6.1).

Todd Groundwater also coordinated data collection and model revision efforts with a Technical Peer Review Team and local agencies to ensure input data were accurately represented in the model. Tabulated input data, model files and model-derived water budgets were provided to the Technical Peer Review Team for review of accuracy and appropriateness. Model input data and results were also provided to Kern County Subbasin water districts and local water purveyors for their review. Comments and data issues were reconciled and incorporated into the revised C2VSimFG-Kern model.

1.3 Acknowledgements

These regional model revisions were enhanced by the participation of the many agencies that provided local water budget input data. Todd Groundwater worked with the member agencies, and their consultants, including the Kern River GSA, Kern Groundwater Authority GSA, Henry Miller Water District GSA, Olcese Water District GSA, and Buena Vista GSA to coordinate acquisition of input data from other agencies in formats that could be easily incorporated into the C2VSim model. On-going review of interim model results by these agencies, including local zonal water budgets, groundwater hydrographs and other model results, helped ensure that the revised model reproduced local mass balance estimates across the Subbasin.

Woodard & Curran conducted an on-going peer review of model input files at the request of the GSAs in the Kern County Subbasin. Todd Groundwater worked with Woodard & Curran throughout the historical model revision process. The C2VSimFG-Kern input files for the Kern County Subbasin revised historical simulation were provided to DWR for incorporation into future C2VSim public releases.

Dr. Charles Brush of Hydrolytics LLC was added to the Todd Groundwater modeling team. As an early developer of C2VSim for DWR, he provided his experience and expertise with the C2VSim. This collaborative effort provided further assurance that the significant model revisions could be managed in an efficient manner to meet the expedited schedule for water budget development.

2. C2VSIM

C2VSim uses DWR's modeling code *Integrated Water Flow Model* (IWFM) and covers the entire California Central Valley. Kern County is located at the far southern end of the Central Valley (**Figure 2**). C2VSim simulates the full hydrologic cycle, calculating water demands and tracking water movement through surface water and groundwater systems, and is therefore well suited to support GSP development.

2.1 C2VSim Background

DWR developed C2VSim to simulate water demands and supplies in the Central Valley. C2VSim is an application of DWR's IWFM software. IWFM is an integrated hydrologic model that simulates water flows on the linked land surface, unsaturated zone, groundwater, and surface water flow systems. A key feature of IWFM is DWR's agricultural and urban water supply and demand management module that dynamically simulates the delivery of both surface water and groundwater supplies based on both water availability and calculated water demands, as affected by usage and climatic conditions.

The C2VSim is derived from a series of Central Valley hydrologic models developed by DWR and other agencies beginning in the early 1990s. Each model in this series has incorporated significant improvements over the previous version (Brush, Dogrul and Kadir, 2013). The groundwater flow system is modeled in IWFM using the finite element method and uses a highly efficient solver developed at UC Davis. The IWFM Demand Calculator (IDC) and land surface simulation process were developed with input from California irrigation management professionals. Given DWR's emphasis on water management, detailed water budgets produced by C2VSim provide strong representations of the surface water and groundwater flow systems and make it a preferred platform for developing water budgets.

2.2 C2VSImFG-Beta Model

DWR's 2018 release of C2VSimFG-Beta includes historical input data for WY1922 to WY2015. C2VSimFG-Beta includes historical precipitation, stream inflow, land use and crop acreage for the entire Central Valley. These data include monthly precipitation and annual land use for each model element and estimated monthly evapotranspiration for each modeled land use type and agricultural crop. Historical surface water data include monthly surface water inflow for each river entering the model boundary and monthly surface water diversions and deliveries.

The C2VSimFG-Beta finite element grid divides the Central Valley into 32,537 model elements (**Figure 2**). Element areas are small near streams and in developed areas and expand to larger sizes in undeveloped areas. Element sizes average 407 acres and range from 4 to 1,770 acres. Central Valley rivers and streams are represented with a network of 110 stream reaches. Surface water and groundwater inflows from uplands along the model boundary are simulated with 1,033 small watersheds. Within the Kern County Subbasin, the land surface elevation varies from 208 feet above mean sea level (msl) in the north to 3,922 feet above msl in the foothills.

The groundwater aquifer system is represented with four aquifer layers and one regional confining layer. The aquifer thickness in the Kern County Subbasin varies from 857 to 9,054 feet and the deepest aquifer location is 8,752 feet below msl. The Central Valley aquifer is simulated with the following hydrostratigraphic layers, listed from top to bottom:

- Shallow, unconfined aquifer,
- Regional confining layer,
- Active confined aquifer (contains high level of pumping),
- Inactive confined aquifer (contains limited pumping), and
- Saline confined aquifer.

C2VSimFG-Beta includes annual land use and crop acreages and monthly precipitation, evapotranspiration, stream inflows, surface water deliveries and specified groundwater pumping rates for WY1922 to WY2015. C2VSimFG-Beta uses IDC to dynamically calculate distributed monthly water demands, allocate available water supplies to meet these demands, and calculate unmetered groundwater pumping necessary to satisfy unmet demands. C2VSimFG-Beta produces detailed monthly water budgets for arbitrary sets of elements grouped into zones.

Water demands are calculated dynamically for each model element using the IWFM Demand Calculator (IDC) for agricultural, urban, native and riparian land use types. Agricultural demand is calculated based on annual crop type distribution mapping and user-specified evapotranspiration rates for 20 irrigated crop types and managed seasonal wetlands at the Kern National Wildlife Refuge. Agricultural water demand is determined based on a soil moisture balance that uses local soil properties to assess the amount of applied water (precipitation and specified surface water applications) available to meet the crop demand. If water demands in an element are not satisfied from these sources, the C2VSim model calculates the groundwater pumping needed to eliminate any deficit.

Urban demands are calculated based on population and per-capita water demands. Water demands for native, undeveloped, fallow or riparian settings are calculated from monthly evapotranspiration rates and the amount of precipitation. If water demands in an element are not satisfied, no applied water is provided to these areas, and the vegetation is assumed to be in a stressed state. Runoff of precipitation in developed and undeveloped areas within the Subbasin and surrounding small watersheds is calculated using methodology included in IWFM that is based on the Soil Conservation Service Curve Method (NRCS, 2004).

C2VSimFG-Beta was released after a preliminary model calibration. The distribution of aquifer parameters was based on a texture analysis of lithologic well logs compiled by the US Geological Survey (USGS, 2009) from Well Completion Reports submitted to DWR by well drillers. The texture analysis interpolated the percentage of coarse-grained material at each well location and depth of the C2VSimFG-Beta mesh. Aquifer parameters were then calculated for the model mesh based on the percentage of coarse-grained material and estimated properties for pure coarse- and fine-grained materials. Transmissivities were estimated using specific capacity tests, where available. Soil properties for each model element were derived from digitized soil maps published by the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS, 2018).

3. KERN COUNTY REVISIONS

C2VSimFG-Beta input files were revised to incorporate locally-derived managed water supply and demand data to better represent the local water budgets for the Kern County Subbasin. Additional revisions were made to C2VSimFG-Beta model to address issues that were identified with the physical representation of the Kern County Subbasin. The result of these Kern County specific modifications is a local version of C2VSimFG-Beta that is referred to here as C2VSimFG-Kern. The following provides a summary of the model modifications.

3.1 C2VSimFG-Kern Model

C2VSimFG-Kern input files incorporate locally-derived historical data for the Kern County and White Wolf subbasins to better represent local water conditions. These are two separate groundwater subbasins in the Kern County portion of the San Joaquin Groundwater Basin. The Kern County Subbasin is listed as critically-overdrafted by DWR with a GSP deadline of January 30, 2020, whereas the White Wolf Subbasin is listed as medium priority by DWR with a GSP deadline of January 30, 2022. C2VSimFG-Kern was not changed for areas outside of the Kern County Subbasin.

Historical surface water diversion, water bank recharge and water bank withdrawal information were collected from local GSAs, management areas, water agencies and purveyors. Urban land use was restricted to developed areas, and urban populations and per-capita water demands were updated. Model structure (elements, streams, stratigraphy, etc.) was not modified. Model parameters were not calibrated, although some model parameters were adjusted to improve model performance in specific geographic areas.

3.2 Simulation Time Period

GSP requirements indicate a need to identify an average hydrologic study period for purposes of the groundwater analyses in the basin-wide water budgets. In order to select a consistent study period, the Kern County Subbasin GSAs agreed upon an historical hydrologic study period covering WY1995 through WY2014 (October 1, 1994 through September 30, 2014). The selection of the historical hydrologic study period was based on a variety of technical criteria including:

- Covers at least 10 years consistent with GSP regulations (§354.18(c)(2)(B)),
- Contains 10 years characterized as above normal or wet years based on precipitation; also contains 10 years of below normal or dry years, including four critically dry years,
- 100 percent of the long-term average streamflow conditions on the Kern River, as indicated by an average annual Kern River Index of 100 percent (**Figure 4**),
- About 104 percent of long-term average precipitation (NOAA Bakersfield Meadows Field Airport Station),
- Widely-available high-quality data available across the Subbasin,
- Time period with current water management practices, intensive groundwater banking operations, and more recent land use patterns,
- Begins in a time of relatively stable water levels (October 1994), and
- Overlaps a time period with consistently developed basin-wide contour maps by Kern County Water Agency (KCWA).

For the historical water budget, it is desirable to define a base period when natural hydrology represents average conditions. C2VSimFG-Kern incorporates this 20-year base period of WY1995 through WY2014 with a 10-year spin-up period (WY1985 to WY1994).

Kern County water agencies provided locally-derived water budget data for WY1993 to WY2015 for this study so that data input extended beyond the historical base period. Additional water budget data prior to WY1993 were also collected where available and input into the model.

The simulation period for C2VSimFG-Kern was set to WY1986 to WY2015 (October 1, 1985 through September 30, 2015), allowing a 10-year spin-before the start of the historical base period. The C2VSimFG-Beta simulation period ran from October 1973 through September 2015 (WY1974 to WY2015). The period from October 1973 to September 1985 was not included in the simulation due to concerns about lack of comparable data from these earlier periods.

3.3 Data Compilation

Participating agencies compiled water budget input data sets (using their staff, consultants or other resources) and provided them to Todd Groundwater. Where appropriate, Todd Groundwater developed data templates that conformed to IWFM model data needs and used them to facilitate obtaining input data from local agencies. This included monthly data for the following:

- Surface water imports and diversions (inflows and outflows) by source, conveyance and application area,
- Groundwater banking and managed aquifer recharge by water district or agency,
- Groundwater recovery pumping of groundwater bank recharge for export from the basin,
- Groundwater recovery pumping of managed aquifer recharge for local use,
- Urban area population and per capita water use, and
- Crop evapotranspiration (ET) rates based an analysis of satellite data (ITRC, 2017).

In addition, groundwater banking data were compiled for the large Kern Fan banking projects. Recently developed crop ET rates derived from remote sensing data were used to develop monthly crop ET rates for agricultural crops. Urban land use was restricted to developed areas, urban populations and per-capita water demands were updated, and urban wastewater recharge operations were added.

3.4 Surface Water

Kern County surface water diversions in C2VSimFG-Beta were grouped by project or water source, and some surface water deliveries were applied to large regions rather than to individual districts. In addition, some local surface water deliveries were missing from C2VSimFG-Beta. For C2VSimFG-Kern, the 43 Kern County surface water diversions from C2VSimFG-Beta were replaced with 113 surface water diversions developed with data provided by local agencies.

The Arvin-Edison WSD, Wheeler Ridge-Maricopa WSD and Tejon-Castaic WD overlie both the Kern County and White Wolf subbasins. Surface water deliveries for these districts were apportioned to either the Kern County and White Wolf subbasins, based on data provided by Arvin-Edison WSD and Wheeler Ridge-Maricopa WSD, so that surface water deliveries to those areas could be tracked separately for the water budgets.

3.4.1 River and Stream Inflow

Inflows to the Kern River and Poso Creek at the Subbasin boundary are based on historical gauge data. Kern River inflows at the First Point gauge and downstream gauges were verified and updated based on the annual Kern River Hydrographic Reports produced by the City of Bakersfield (COB, 1985-2015). C2VSimFG-Beta contained Poso Creek inflows for WY1961 to WY1986. Poso Creek inflows for WY1987 to WY2015, based from flow records for the Coffee Canyon and Trenton stream gauges, were added to C2VSimFG-Kern based on data provided by the local agencies.

3.4.2 Surface Water Diversions

Monthly surface water diversion data for WY1995 to WY2015 were collected for 21 agencies and recharge projects in Kern County. The data from each water district or agency included monthly surface water inflow by source and monthly surface water outflow by destination.

The monthly surface water inflow and outflow data collected for this study did not have sufficient detail to track this water and create an accurate historical water budget for each canal for each month. The data did provide sufficient information to identify monthly surface water diversions from each source and deliveries to each end use. Therefore,

- All diversions from the Kern River were exported from the model and treated as imports at delivery locations,
- Diversions from Poso Creek and the Kern River Flood Channel (or Main Drain) were diverted from the appropriate stream nodes, and
- All other surface water deliveries (State Water Project (SWP), Central Valley Project (CVP), oil field recovery water, etc.) were treated as imports.

Each C2VSim surface water diversion is linked to two groups of model elements: the elements of the end use and the elements receiving the recoverable losses. A single set of elements was used for both purposes in C2VSimFG-Kern. Model elements for agricultural, urban and refuge deliveries were selected by overlaying the model grid on delivery areas maps. Model elements for recharge diversions were selected by overlaying the model grid on recharge basin maps.

Monthly water delivery data for the SWP, CVP and Kern River were also provided by the agencies. Monthly turnout-level deliveries for the SWP were also compiled from the monthly SWP Report of Operations published by DWR. Monthly CVP deliveries were compiled from the USBR Report of Operations. Monthly Kern River flow and diversions were compiled from Kern River Hydrographic Reports. Water agencies in the Kern County Subbasin trade and wheel water in real time to maximize water utilization, minimize waste and energy consumption, and meet immediate water needs. Water delivery reports from water suppliers (such as the CVP and SWP) generally identify the owner of delivered water, not where it was actually delivered.

Some surface water conveyances discharge water into stream or river channels for re-diversion downstream. A key part of the surface water system in Kern County is the Kern River. Kern River operations data were reviewed for calendar years 1970 to 2015. While **Table 1** summarizes surface water deliveries, **Table 2** summarizes Kern River diversions by turnout location as applied in C2VSimFG-Kern.

3.4.3 Surface Water Deliveries

Water flow through the Kern River and its associated canal system is very complex. Water is diverted from the Kern River into a parallel canal system at several locations, with some diverted water flowing

back to the river. Some water from the CVP and SWP are discharged into the Kern River for diversion downstream. Some water agencies are served from multiple diversion points along the Kern River. Several canals that receive water diverted from the Kern River also exchange water with other canals and receive some water from groundwater pump-in, so deliveries from many canals cannot be attributed to a single source. **Figure 5** shows the locations of the primary streams, regional surface water canals, and groundwater recharge locations in the Kern County Subbasin.

Each surface water diversion in C2VSim is allocated to a specified destination and water use. Five water use types are simulated in C2VSimFG-Kern: agricultural, urban, refuge, recharge and export. Agricultural and refuge diversions are applied to a group of model elements that corresponds to a surface water service area within a specific water agency or refuge. Urban diversions are allocated to an urban service area. Groundwater recharge diversions are allocated to the model element or elements where the receiving recharge basin is located. Three delivery fractions apportion each surface water diversion to application, loss to groundwater (recoverable loss), and loss to evaporation (non-recoverable loss). **Table 1** summarizes the annual surface water deliveries for agricultural use by water district in Kern County. **Table 3** summarizes surface water diversions for urban use, wastewater land disposal and wildlife refuge management in Kern County.

3.5 Groundwater Banking and Managed Aquifer Recharge Operations

In our preliminary discussions with the C2VSim developers at DWR, it was revealed that significant model uncertainty was related to incomplete data regarding groundwater banking and other managed aquifer recharge (MAR) operations in the Kern County Subbasin. Recognizing the importance of these groundwater banking projects for simulating groundwater conditions, the groundwater banking and MAR operations data was updated using the earliest available records.

3.5.1 Recharge and Recovery Data

A monthly time-series of recharge rates was determined for each recharge project. Recharge rates were allocated to individual recharge basins using the initial data whenever possible or were shared proportionally between basins based on historical rates. All Kern County recharge basin surface water deliveries were simulated as imports.

Recharge basin locations and recovery well locations were provided by each agency or project (**Figure 6**). The C2VSim finite element grid was overlaid onto a map of recharge basins to determine the model elements for each recharge location. Well location coordinates were added to C2VSimFG-Kern.

Monthly volumes for recharge at groundwater banking and managed aquifer recharge facilities were compiled for 16 agencies and projects (**Table 4**). This information originated from multiple sources, and included data provided by agencies, compiled from agency reports, and compiled from Kern River Hydrographic Reports. The data includes monthly recharge for years prior to 1995 for many projects. Several agencies and projects provided data for multiple recharge basins. Some groundwater wells used for recovery of banked water are also used for other purposes such as supplementing agricultural or urban surface water deliveries.

Recognizing that several of the large groundwater banking projects (especially those on the Kern Fan) pre-date the 20-year base period, and that future studies might simulate periods prior to 1985, all available historical data for groundwater banking operations was reviewed and updated. This included incorporating pre-1985 data for banking operations at

- Arvin-Edison WSD (1966-2015),
- Berrenda Mesa Project (1977-2015),
- Buena Vista WSD (1963-2015),
- City of Bakersfield 2800 Recharge Facilities (1973-2015),
- North Kern WSD (1956-2017), and
- Rosedale-Rio Bravo WSD (1980-2015).

3.5.2 Groundwater Recovery

Two types of recovery wells were added to the C2VSimFG-Kern. These include district-operated water wells that were used for out-of-district transfers or out-of-basin exports of groundwater, and wells used for recovering banked groundwater and distributing the pumped groundwater via the district's water conveyance system to provide water supply, typically for agricultural use, within the district. The locations of the specified groundwater recovery wells are shown on **Figure 6**. The specified groundwater recovery pumping input into C2VSimFG-Kern is summarized as follows:

- 229 time series for Kern County groundwater banking withdrawals were added,
- 313 simulated pumping wells and 225 pumping time series for local groundwater pumping by district-operated recovery wells were added, and
- Elemental agricultural, refuge and urban pumping was eliminated in areas where it has not historically occurred.

Recharge and withdrawal data for the Kern Fan banking projects, including the Kern Water Bank, Berrenda Mesa Project, Pioneer Project, and the City of Bakersfield 2800 Recharge Facilities were shared with the local banking authorities for verification. Banking data for district-specific groundwater banking projects were provided by these districts. A summary of the data input for groundwater recovery pumpage added to C2VSimFG-Kern is provided in **Table 5**.

3.5.3 Model Application

A separate diversion was created to deliver surface water to each recharge basin or set of geographically close jointly managed basins. A diversion time series of monthly application rates was then created for each recharge diversion from the available data. Each recharge diversion delivers water to the model elements coinciding with the receiving recharge basin(s). Recharge basins were simulated in C2VSimFG-Kern by setting the application delivery fraction to zero, the recoverable loss fraction to 94% and the evaporation loss to 6%.

Monthly groundwater recovery was generally provided by well field and destination (e.g., agriculture, urban, canal pump-in, or export). This information was used to develop a pumping time series for each well field and destination. Groundwater pumped for export from the Kern County Subbasin is summarized in **Table 6**. Recovery well locations and screen intervals were used to enter each recovery well into C2VSimFG-Kern. Recovery pumping time series were then allocated equally to all of the wells in each field.

Some well fields supply water to two different end uses, for example supplementing surface water deliveries within the district in some months and exporting water from the district in other months. This is handled in C2VSimFG-Kern by entering the well two times. Each entry is associated with a separate time series of pumping rates and delivery destination.

3.5.4 Groundwater Banking Obligations

The general operation of groundwater banking facilities is to recharge excess available surface water supplies during wet years by recharging to the groundwater and recovering this water by pumping in dry years when surface water supplies are limited. Groundwater banking programs store water in the Kern County Subbasin for use by local agencies and for export to out-of-basin entities.

For evaluating the groundwater sustainability, any water stored in the Kern County Subbasin that is contractually obligated to an out-of-basin entity does not contribute to the long-term groundwater sustainability because the owner of that water could call for its return at any time. However, this can be difficult to track because a common practice is to recover groundwater for local use to replace imported surface water that was sent to the out-of-basin entity.

C2VSimFG-Kern does not have a mechanism to track these complex contractual exchanges, so the tracking is done as a post processing step by assigning the portion of the groundwater recharge as an out-of-basin banking obligation.

The Kern County Subbasin GSAs provided the total out-of-basin banking obligation for their operations as of September 2014 for the historical assessment. As of September 2014, the out-of-basin banking obligation for the Kern County Subbasin totaled of 1,719,307 acre-feet, which, when averaged over the 20-year period, was 85,965 acre-feet per year (AFY). The 85,965 AFY is applied during post-processing of C2VSimFG-Kern historical water budget results.

3.6 Urban Water Demand

C2VSim calculates urban water demands for specified urban delivery zones, allocates specified surface water and groundwater supplies to meet these demands, and can optionally pump additional groundwater to satisfy unmet urban demands in each zone. Urban demands were represented with nine urban zones in C2VSimFG-Beta. These zones were reconfigured, and a tenth urban zone was added representing Metropolitan Bakersfield in C2VSimFG-Kern. Historical urban populations and per capita water use rates were reviewed and updated.

3.6.1 Urban Zones

C2VSimFG-Kern dynamically calculates urban water demands for urban zones using time-series data of urban populations and monthly per capita water use. The urban delivery zones of C2VSimFG-Beta were modified to better represent Kern County population centers, jurisdictional boundaries and urban water sources. Although Kern County urban water delivery systems are operated by many diverse entities, their water generally comes from two sources: surface water deliveries and agency-operated groundwater wells.

The nine Kern County urban zones in C2VSimFG-Beta for Kern County were numbered 97-105. The Urban Zone boundaries were adjusted, as shown on **Figure 7**, as follows:

- Portions of Urban Zones 97, 99, 100, and 102 in C2VSimFG-Beta were used to create Urban Zone 106 representing the Metropolitan Bakersfield area,
- Urban Zone 98 was extended southeast to near the Stockdale Highway to include unincorporated urban areas,
- The boundary of Urban Zone 99 was extended eastward to California State Route 65 to include small communities in this area, removing them from Urban Zone 100, and

- The northern boundary of Urban Zone 104 was moved north to correspond to the West Kern WD service area.

3.6.2 Urban Population and Per Capita Use

Historical annual urban populations for the urban zones were estimated using United States Census total population data from 1990, 2000 and 2010 (US Department of Commerce, 2018). Tabular historical census data and census block shapefiles were obtained from the IPUMS National Historical Geographic Information System Database (IPUMS 2018). These data were combined to produce maps of the geographic distributions of populations within Kern County. The historical populations for each Urban Zone were estimated by mapping census block centroids to the ten Urban Zones using ArcGIS. The 1990, 2000 and 2010 populations of each Urban Zone were then estimated as the sum of the populations of the associated census blocks. Populations for other years were estimated using interpolation and extrapolation. The population values by Urban Zone used for C2VSimFG-Kern are listed in **Table 7**.

3.6.3 Urban Water Use Specifications

Monthly historical urban water demands for Urban Zone 106 were calculated using water delivery data from the water purveyors in the Metropolitan Bakersfield area. Monthly historical urban water demands for the other urban zones in the Kern County Subbasin were estimated using available water use data from published urban water management plans for the communities served in those zones. The historical monthly water use in each zone was then divided by the historical population to obtain the monthly per capita urban water demand. Monthly historical per capita water demands for zones without urban water management data were estimated using the per capita water demand from zones with similar demographics.

The urban water use specifications indicate the portion of total urban water that is used indoors. In C2VSimFG-Kern, the portion used indoors becomes urban return flow, and the remainder is added to the urban root zone where it contributes to evapotranspiration and deep percolation. C2VSimFG-Beta included monthly urban water use specifications for each model subregion. The urban per capita water use was based on local water supply data and urban water management plans. **Table 8** lists the per capita water use data used for C2VSimFG-Kern.

3.6.4 Urban Wastewater

Urban wastewater for the Metropolitan Bakersfield area is treated at local wastewater treatment plants; however, wastewater disposal is primarily evaporation ponds or land disposal at locations outside of the Metropolitan Bakersfield area. C2VSimFG-Beta does not have a direct means to redirect wastewater to an outside location. Urban wastewater, based as the indoor use, is applied uniformly within the urban zone. To get around this limitation, application of wastewater for the Metropolitan Bakersfield area was turned off in C2VSimFG-Kern. The wastewater deliveries to evaporation ponds and land disposal areas from the wastewater treatment plants was assigned to the appropriate location using data provided by the plants. This conserved the water balance by not double counting wastewater, and it was applied at the appropriate locations for evaluating groundwater levels.

3.6.5 Model Application

Historical annual urban population estimates were placed in the C2VSimFG-Kern urban population input file. Historical monthly urban per capita water demand estimates for each urban zone were placed in the C2VSimFG-Kern urban per capita water use file. Urban demand was calculated by C2VSimFG-Kern and the water supply to meet these demands was met first by specified surface water and groundwater

pumping deliveries for urban use. The remaining water demand in each model element was met with groundwater pumped from the aquifer portion of that element.

3.7 Agricultural Crop Water Demand

C2VSim dynamically calculates agricultural crop water demands and allocates supplies to meet these demands for each model element. Agricultural demands are calculated for 20 crops using historical crop acreage data and crop evapotranspiration (ETc) rates. Crop water demands in each model element are first met with stored soil moisture, surface water deliveries and specified groundwater deliveries. If the agricultural demands are not satisfied, the model can optionally calculate the additional groundwater pumping required to satisfy the unmet demands and extract that water from the groundwater component of the model element.

C2VSimFG-Beta contained one set of monthly ETc rates for each model subregion that were applied to all years despite climatic variation. New monthly ETc rates for three model subregions (northeast, northwest, south) in Kern County were calculated for 1993-2015 using monthly remote sensing imagery and detailed annual crop maps. ETc for 1974-1992 were estimated from 1993-2015 values by using the values for similar water year types based on the San Joaquin Index. Satellite data were not available for 2012, so ITRC was unable to provide METRIC data for 2012. In C2VSimFG-Kern, 2013 was applied as an appropriate proxy for ETc data in 2012 because of their hydrologic similarity.

A remote sensing study of historical ETc rates across the entire Kern County Subbasin by the Irrigation and Training Research Center (ITRC, 2017) provided detailed basin-wide agricultural demands that corresponded to the WY1995 to WY2014 base period. These data were used to develop monthly ETc rates for the Kern County portion of the model.

3.7.1 ET Rates

The Irrigation Training and Research Center (ITRC) at California Polytechnic State University, San Luis Obispo, has developed a procedure to use remote sensing imagery from Landsat satellites to calculate historic ETc rates (ITRC, 2017). The Mapping of Evapotranspiration with Internal Calibration (METRIC) method was originally developed by Richard Allen of the University of Idaho. ITRC made several modifications to the original METRIC method to better match California data and conditions (named the ITRC-METRIC method). These modifications include using grass for reference evapotranspiration (ETo), incorporating a semi-automated calibration procedure and spatially interpolating ETo rates. An example of the METRIC ET data for the total annual ET in 2013 is provided in **Figure 8**.

ITRC used Landsat imagery for 1994-2015 (except 2012 when no imagery was available) and the ITRC-METRIC method to develop monthly raster maps of ETc at 30 x 30-meter resolution for the Kern County portion of the Central Valley (ITRC, 2017). The monthly ETc raster maps were used with annual DWR crop maps to calculate the average ETc by crop type for the three Kern County C2VSim subregions. ITRC-METRIC raster data were used to determine the exact areas of applied irrigation and total annual ETc. A raster pixel was assumed to be irrigated if the total annual ETc was greater than 20 inches.

The following data processing steps were used to determine monthly ETc rates for each crop and C2VSim subregion:

- Create irrigation coverages – ITRC-METRIC monthly ETc raster data were summed to calculate total annual ETc for each year for each raster location. The ArcGIS Reclassify tool was then used on each annual ETc raster to create a binary polygon coverage for each year for 1994-2015

(except 2012), setting the attribute "IRR" to 1 if total annual ETc was over 20 in/year, and to 0 if total annual ETc was equal to or less than 20 in/year.

- Create land use coverages – Annual DWR land use rasters were converted to polygon coverages with the attribute "Crop" set to the corresponding integer crop value used in C2VSimFG-Kern. The land use rasters were checked against GIS maps produced by the Kern County Agricultural Commissioner and errors in the DWR land use rasters were corrected. DWR land use maps for 1994-1997 were missing large areas of data, so the 1998 land use map was used to approximate the land use for 1994-1997.
- Create monthly zone maps – One zone shapefile was created for each month by using the ArcGIS Union tool to combine a shapefile of the three C2VSim subregions with the irrigation coverage (produced in step 1) and the land use coverage (produced in step 2). Each monthly zone polygon shapefile has three attributes: C2VSim subregion, binary irrigation indicator, and a land use crop value. The dissolve function was used to combine zones with identical parameters.
- Calculate average monthly ETc for each zone – The ArcGIS Zonal Statistics by Table tool was used to calculate the average ETc value for each zone for each month. The individual pixels in each monthly ETc raster were averaged within each zone (produced in step 3). ITRC-METRIC data for 2013 were used in place of missing data for 2012.
- Combine tables – The MS Access Append function was used to combine the monthly ETc tables into a master table of monthly ETc by crop and C2VSim subregion.
- Output data – Data from the Access database was exported in a form consistent with the C2VSimFG-Kern input files. The output was also summarized to show the average monthly ETc for the irrigated area of each crop type in each model subregion.

The monthly ETc rates for the three Kern County subregions for WY 1993-2015 were then replaced with the monthly ETc rates calculated using ITRC-METRIC data. The annual ETc rates applied to C2VSimFG-Kern by crop are listed in **Table 9**.

3.7.2 Irrigation Periods

The C2VSim Irrigation Periods file contains monthly parameters for each crop and subregion that indicate whether or not the crop is irrigated in that month. C2VSimFG-Beta irrigation periods for the three Kern County subregions were adjusted to match crop irrigation practices from ITRC-METRIC water usage. Refuge irrigation periods for the three Kern County subregions were also adjusted to match Kern NWR practices. Simulated irrigation water usage for the C2VSimFG-Kern better reflects observed irrigation practices.

3.8 Model Modifications

In general, the scope of work was to revise the managed water supply and demand for the Kern County Subbasin. During the course of this revision, several issues were identified with the hydrogeological conceptual model and simulation parameters that affected the historical water budget. The following summarizes modifications made in C2VSimFG-Kern to improve the model performance. Other issues identified regarding the hydrogeological conceptual model, model setup and simulation parameters that were not addressed in C2VSimFG-Kern but are recommended to be modified for future model updates, are listed in Section 8.5. A summary of the changes that were made in C2VSimFG-Kern are provided below.

3.8.1 Streambed Parameters

In the Kern County Subbasin, the Kern River and Poso Creek are the two largest streams. Both have multiple stream gauges along their courses including ones near where they enter the Kern County Subbasin from the Sierra Nevada. These are the only two streams that are simulated in the model using the IWFM stream module. Both are predominantly losing streams where surface water recharges groundwater, except during limited periods near the major groundwater banking operations west of Bakersfield when multi-year periods of recharge operations produce high groundwater levels.

As a part of the C2VSimFG-Kern update, the simulated recharge from the Kern River and Poso Creek were compared to changes in stream gauge measurements and estimated streambed losses to evaluate how well the model was simulating streambed seepage. For much of the Kern River, the amount of streambed seepage is estimated based on daily weir information and is documented in the annual Kern River Hydrographic Reports. The streambed parameters used in C2VSimFG-Beta were not providing a comparable volume and distribution of seepage along the Kern River streambed. In dry years, streamflow as not getting far enough downstream whereas in wet years the seepage was too low. Similarly, the Poso Creek streambed seepage showed similar issues based on comparisons to differences in stream gauge data along its course.

To address this, the Kern River and Poso Creek streambed parameters were manually modified until a reasonable approximation of the measured streambed seepage was achieved by C2VSimFG-Kern. In general, the streambed conductance was lowered whereas the stream wetted perimeter was increased. This provided the best balance in matching the measured dry, average and wet years flows in both streams.

Part of this issue is that C2VSimFG-Beta uses a simple form of the stream module in the simulation. This approach appears to work sufficiently well for the continuously flowing streams in the northern parts of the Central Valley but is not sufficient for simulating the highly variable flows that occur on the Kern River and Poso Creek. It is recommended that future revisions to C2VSimFG-Kern further evaluate issues in simulating streamflow and seepage in the Kern River and Poso Creek (see Section 8.5). This may include incorporating more advanced streamflow simulation features that are available in IWFM but that have not been utilized in C2VSimFG.

3.8.2 Small Watershed Runoff

In reviewing the small watershed contributions, it was determined that the runoff was not representing the variable nature of runoff in an arid region. Although this was not part of the originally planned model revisions, it affected the model results. Todd Groundwater revised the corresponding model parameters to be more representative of the local arid conditions in Kern County.

Runoff of precipitation from the surrounding small watersheds was calculated within C2VSimFG-Kern using methodology included in IWFM that is based on the SCS Curve Method (NRCS, 2004). The C2VSimFG-Beta results showed a steady baseflow that contributed water to the Kern County Subbasin continuously and did not show the appropriate variation in runoff expected between wet, average and dry years in the arid environment.

Two major issues were identified and revised. First, the SCS curve number was changed to allow a higher percentage of runoff in wet years to capture the flashy nature of runoff from these watersheds during differing climatic conditions. Second, IWFM uses a localized soil moisture water budget; however, soil, ET and other parameters were set that allowed for the continuous outflow from the

basins. These were changed to more appropriate values that limited baseflow from the very small watersheds while allowing baseflow from the larger watersheds. Parameters were varied to better match estimated watershed runoff from a local USGS study (Nady and Larragueta, 1983).

3.8.3 Root Zone Parameters

Areas of overly high root zone hydraulic parameters led to high volumes of deep percolation that required additional groundwater pumping to meet the overall water demand for irrigation. This issue was noted by local water district staff who recognized that the groundwater pumping and deep percolation from preliminary model results were significantly higher than what was found in practice. A review found areas of overlying hydraulic conductivity and other hydraulic parameters that caused this high percolation rate. Two types of issues were found. First, very high parameters were found in parts of the basin that were not consistent with local soil data. Second, the root zone parameters for lakebed and other heavy clay soil areas were too high. These areas were manually adjusted to be more in line with observed conditions. A more rigorous development of root zone parameters should be considered in the future as this issue demonstrates that it is a sensitive parameter.

3.8.4 Land Use Modifications

The agricultural land use and crop type distribution in the model for early period (1974-1990 and 1992-1996) from C2VSimFG-Beta used a regional distribution and did not accurately represent historical practices. This resulted in agricultural water use being distributed across the entire Kern County Subbasin including areas that did not have irrigated agriculture. To correct for this, land use and crop type data were modified to conform with irrigated agricultural areas in the early 1990s. The crop types were adjusted to be consistent with the Kern County Agricultural Commissioner reports for these years. This included capturing the appropriate crop types present in the Kern County Subbasin in the periods from 1974 through 1996. For example, there was a higher percentage of cotton produced during that period and a lower percentage of nut trees, which became one of the major crop types in the 2010s.

3.8.5 Westside Pumping Limits

Western Kern County contains large areas with poor groundwater quality. As a result, little or no agricultural or urban groundwater pumping occurs in this area. To simulate this, groundwater pumping was turned off in C2VSim-Kern in most of the area with poor groundwater quality. However, in the Westside District Water Authority Management Area, limited groundwater pumping does occur. The poor-quality water is mixed with surface water to supplement the imported water supply. To simulate this condition, the groundwater pumping rate in the Westside District Water Authority Management Area was estimated to be 10% of the surface water deliveries, and the automated groundwater pumping adjustment in C2VSimFG-Kern was turned off for these areas.

Subsequent to the completion of the historical model, GSP developers in the Westside area refined their estimate of pumping used to mix with delivered surface water to about 3,000 AFY, which is considerably lower than that used in the historical model. The Westside GSP developers included a management action to further refine the estimated groundwater use in the Westside GSP water districts. Therefore, the original assumption was left in this version of the historical model. The Westside District Water Authority Management Area GSP identifies a management action to further evaluate the groundwater pumping in their area. The results of their evaluation will be included in in future model updates.

3.8.6 Kern Wildlife Refuge pumping

C2VSimFG-Beta enabled groundwater pumping in the model elements representing the Kern National Wildlife Refuge. The Kern National Wildlife Refuge Water Management Plan (USBR, 2011) indicates that

during the simulation time period, the refuge was sustained entirely on imported surface water and occasional diversions of Poso Creek flood waters. No groundwater was pumped at the refuge during the simulation period 1985-2015. Groundwater pumping was used at some time in the past. Groundwater pumping and automated groundwater pumping adjustment were turned off for all model elements in the Kern National Wildlife Refuge.

In addition to the Kern National Wildlife Refuge, former rice fields and other areas are currently used for sustaining ponds at private duck hunting clubs in the northwestern portion of the Kern County Subbasin. Water use data for these operations were not available during the development of the historical model. This water includes a combination of surface water and groundwater, and this volume is considered to be very small relative to the overall basin water use. GSP developers included a management action to further refine the estimated water use for these facilities that will be addressed in future updates.

3.9 C2VSimFG-Beta Modifications

Minor changes were made to the C2VSimFG-Kern hydrogeological conceptual model and natural water budget components and are listed in **Table 10**. The architecture of the model including layering, discretization, boundary conditions, and aquifer properties was not revised. Aquifer parameters were adjusted in several areas to better match observed historical conditions, especially in areas with high historic recharge volumes such as the Kern Fan. Extremely high soil hydraulic conductivities in a small set of elements were reduced to more reasonable values. Stream-bed conductance values were modified in some stream reaches to better match simulated stream gains and losses to observed values. Minor adjustments to small watershed parameters were also made to match surface runoff to observed values.

Due to the number of modifications that were identified with the hydrogeological conceptual model and aquifer parameters during the C2VSimFG-Kern update, it is recommended that a more rigorous model update be conducted that will update the hydrogeological conceptual model and aquifer parameters to be consistent with that presented in the Kern County Subbasin GSPs. In addition, further calibration of C2VSimFG-Kern is recommended to update aquifer parameters in the Kern County Subbasin. Future calibration is further discussed in Section 8.5.

4. HISTORICAL AND CURRENT WATER BUDGETS FROM C2VSIMFG-KERN

C2VSimFG-Kern was used to develop historical (WY1995 to WY2014) and current (WY2015) water budgets for the Kern County Subbasin. The following summarizes the simulated water budgets from C2VSimFG-Kern. A summary of these results is provided below.

4.1 Historical and Current Water Budget

The simulated historical and current water budgets based on C2VSimFG-Kern are presented in **Tables 11A** and **11B** and are presented graphically on **Figures 9**. **Figure 10** presents the average annual historical water budget for the Kern County Subbasin. The results for the historical water budget are summarized under the following categories that are defined as:

- **Deep Percolation** – Precipitation and applied water that reaches the groundwater after simulated transport across the unsaturated zone. The simulated historical 20-year average is a net inflow of 669,398 AFY.
- **Managed Recharge and Canal Seepage**- Combined groundwater recharge from managed aquifer recharge operations, groundwater banking, and seepage from canals and other conveyance. The simulated historical 20-year average for Managed Recharge and Canal Seepage is a net inflow of 583,598 AFY. On Figure 10, this total is subdivided between out-of-basin groundwater banking obligations (85,965 AFY) and the remaining local recharge of 497,633 AFY.
- **Net Groundwater-Surface Water (GW/SW) Interactions** - Net volumetric exchange of surface water and groundwater between the aquifer and streams: Positive represents a net groundwater recharge, and negative represents a net groundwater discharge to the stream. The simulated historical 20-year average is a net inflow of 98,606 AFY.
- **Small Watershed Inflow** – Runoff, small stream inflow and subsurface inflow from the small watersheds and areas surrounding the groundwater basin. The simulated historical 20-year average is a net inflow of 48,760 AFY.
- **Groundwater (GW) Pumping** - Total groundwater pumping by wells. Groundwater banking recovery pumping is specified as fixed input values and agricultural and municipal pumping is calculated by C2VSimFG-Kern based on demand minus surface water diversions. The simulated historical 20-year average is a net outflow of 1,590,373 AFY.
- **Subsurface Flow with Adjacent Groundwater (GW) Basins** - Net subsurface groundwater flow to and from the Kern County Subbasin with adjoining groundwater basins: negative is a net flow out of the Subbasin and positive is a net flow into the Subbasin. The simulated historical 20-year average is a net outflow of 87,102 AFY.
- **Change in Groundwater Storage** - Sum of the inflow components (positive numbers) plus the outflow components (negative numbers): positive is an increase in storage typified by a rise in groundwater levels whereas a negative is a decrease in storage typified by a decline in groundwater levels. The simulated historical 20-year average is a decline in groundwater storage of 277,114 AFY.

The simulated change in groundwater storage varies over the 20-year historical period and is closely related to climatic conditions and surface water supply availability (**Figure 11**). During the periods

WY1995 to WY1999, WY2005 to WY2006 and WY2011, the groundwater storage volume was stable to increasing and correlates to the above average rainfall and surface water availability during these times. During the periods WY2000 to WY2004, WY2007 to WY2010 and Y2012 to WY2015, groundwater storage volume decreased, correlated to periods of drought and low surface water availability. The simulated historical groundwater recharge also reflects this climatic pattern with high deep percolation to groundwater and steep increases in managed aquifer recharge and canal seepage during the above average rainfall periods and lower groundwater recharge during the drought years (**Figure 12**).

Groundwater pumping for agriculture shows a general increasing trend from WY1995 to WY2014; however, groundwater pumping is lower in above average rainfall years and higher during droughts (**Figure 13)**. This general increasing trend follows a comparable decreasing trend in surface water deliveries over this same period. As shown on **Figure 14**, surface water deliveries show a general decreasing trend from WY1995 to WY2014; however, the surface water deliveries are higher in the above average rainfall years and lower during the droughts.

4.2 Sustainable Yield

Section 354.18(b)(7) of the GSP Regulations requires that an estimate of the basin's sustainable yield be provided in the GSP (or in the coordination agreement for basins with multiple GSPs). SGMA defines "sustainable yield" as:

> "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result."

SGMA does not incorporate sustainable yield estimates directly into sustainable management criteria. Sustainable yield is referenced in SGMA as part of the estimated basinwide water budget and as the outcome of avoiding undesirable results. Basinwide pumping within the sustainable yield estimate is neither a measure of, nor proof of, sustainability. Sustainability under SGMA is only demonstrated by avoiding undesirable results for the six sustainability indicators.

4.2.1 Determination of Sustainable Yield

To determine the sustainable yield for the Kern County Subbasin, the results of the C2VSimFG-Kern model were used with two methods to estimate the amount of groundwater pumping that would avoid the undesirable result of a reduction in groundwater storage over the historical base period 1995 to 2014. The results are shown in **Table 12** and are summarized below:

- **Sustainable Yield from Groundwater Pumping –** The model results produced an average annual groundwater pumping in the Kern County Subbasin of 1,590,373 AFY with a decline in groundwater storage of 277,114 AFY. Subtracting the groundwater storage decline from groundwater pumping produced a sustainable yield of approximately 1,313,000 AFY.

- **Sustainable Yield from Groundwater Recharge –** The model results produced an average annual groundwater recharge in the Kern County Subbasin of 1,400,362 AFY. The subsurface outflow from the GSA was estimated to be 87,102 AFY. Subtracting these outflow losses from the groundwater recharge produced a sustainable yield of approximately 1,313,000 AFY.

Sustainable yield estimates are part of SGMA's required basinwide water budget. In general, the sustainable yield of a basin is the amount of groundwater that can be withdrawn annually without causing undesirable results. This sustainable yield estimate can be helpful for evaluating the projects and programs needed to achieve sustainability. Although the SGMA regulations require a single value of sustainable yield calculated basinwide, it should be noted that the sustainable yield can be changed by implementation of recharge projects, variations in climate, or changes in stream flow conditions.

Using WY1995 to WY2014 as the base period, C2VSimFG-Kern results show declining groundwater levels and long-term reduction of groundwater storage. During this period, average annual inflow to the aquifer is 1,400,362 AFY, and outflow is 1,677,476 AFY (**Table 11A**). This yields an average annual deficit of 277,114 AFY. Based on these historical C2VSimFG-Kern results, the sustainable yield of the basin is approximately 1,313,000 AFY, with an estimated level of uncertainty on the order of plus or minus 10% to 20%.

4.2.2 Native Yield

Although not a SGMA requirement, the native yield is being used by Kern County GSAs for determining a portion of the groundwater allocation within the basin. The native yield is comparable to the sustainable yield except that the only recharge that is included in the calculation is the natural, unallocated portion of the groundwater recharge. For the Kern County Subbasin, this includes the groundwater recharge derived from precipitation and runoff from unallocated streams. The Kern River and Poso Creek, however, are allocated streams where specific agencies or parties have rights to specific volumes of flow.

The C2VSimFG-Kern model results over the historical base period WY1995 to WY2014 was again used for estimation of native yield. The model results were used to determine the amount of precipitation recharge over irrigated agricultural areas and the native/urban/undeveloped areas. The total and average annual volume of precipitation that percolates to groundwater during the WY1995 to WY2014 base period are listed in **Table 13**. The basinwide contribution is the relative proportion of the runoff along the basin margins from small, unallocated watersheds and inflow from the surrounding basin margin (from areas not defined as DWR groundwater basins). The results of this assessment based on the C2VSimFG-Kern results are shown in **Table 13** and are summarized below:

- The volume of precipitation that recharges the groundwater in the irrigated agricultural areas is 77,780 AFY.
- The volume of precipitation that recharges groundwater in the other areas is 132,981 AFY.
- The volume of inflow from unallocated small watersheds that recharges the groundwater in the irrigated agricultural areas is 48,760 AFY.

Totaling these inputs results in a native yield for the Kern County Subbasin of 259,520 AFY. The annual contribution per acre of approximately 0.144 acre-feet per acre is estimated by dividing the average annual contribution by the total area of the Kern County Subbasin (**Table 13**).

Similar to the sustainable yield, the native yield at this time is based on the available data. However, as data gaps are eliminated and management actions/plans are implemented, the native yield could change, and any changes to native yield will be included in future GSP amendments.

4.2.3 Application of Sustainable and Native Yield

In general, the sustainable yield of a basin is the amount of groundwater that can be withdrawn annually without causing undesirable results. The native yield is comparable to the sustainable yield except that the only recharge that is included in the calculation is the natural, unallocated portion of the groundwater recharge. The following estimates of the Kern County Subbasin sustainable and native yields are derived from the C2VSimFG-Kern historical model results for the purpose of supporting GSP assessment of the types and magnitude of projects and programs needed to achieve sustainability.

The C2VSimFG-Kern estimates of sustainable and native yield presented here are based on available data and the current level of model calibration. Therefore, these estimates are considered appropriate as guides to SGMA planning. However, the C2VSimFG-Kern sustainable and native yield estimates are initial water budget estimates that are not intended for determination of individual landowner allocations or groundwater rights. Additional technical and legal analysis, along with stakeholder involvement, is necessary to fully quantify the sustainable and native yields.

5. APPROACH FOR PROJECTED FUTURE WATER BUDGETS

Projected future Baseline water budgets for the Kern County Subbasin were developed using the C2VSimFG-Kern. These projected water budgets establish expected Baseline conditions to evaluate the impacts of GSP implementation. Three predictive scenarios were developed for the Kern County Subbasin, each representing a different expected future hydrologic condition, by adapting C2VSimFG-Kern as follows:

- Future Baseline Conditions: Repeat historical hydrology with expected future water supply,
- 2030 Climate Conditions: Adjust historical hydrology for 2030 climatic conditions and expected water supply, and
- 2070 Climate Conditions: Adjust historical hydrology for 2070 climatic conditions and expected water supply.

Projected future water budgets were developed for Baseline conditions and expected 2030 Climate Conditions and 2070 Climate Conditions over a 50-year planning and implementation horizon. These scenario models provide a basis of comparison for evaluating proposed sustainability management actions and projects over the SGMA planning and implementation horizon.

5.1 Assumptions

C2VSimFG-Kern was modified to incorporate projected future hydrology and land use using analog data from the historical C2VSimFG-Kern model. This approach meets GSP requirements using:

- A 50-year time-series of historical precipitation, evapotranspiration and stream flow information as the future Baseline hydrology conditions,
- The most recent land use, METRIC-based evapotranspiration, crop coefficient and urban population growth information as the Baseline condition for estimating future water demands,
- The most recent water supply projections as the Baseline condition for estimating future surface water supply,

- DWR Climate Change Guidance and Data Sets to incorporate estimated climate change conditions for the Kern County Subbasin,
- Specialized analysis of the Kern River watershed and estimated runoff volumes under climate change conditions,
- Specialized analysis of CVP deliveries to Kern County under climate change conditions incorporating implementation of the San Joaquin River Restoration Program, and
- Specialized analysis of SWP deliveries to Kern County under climate change conditions incorporating implementation of the OCAP Biological Opinion and recent changes in Table A and Article 21 allocations.

5.2 Projected Future SGMA Projects

Projected water budgets for the Kern County Subbasin were developed using the C2VSimFG-Kern to evaluate the performance of proposed management actions with respect to achieving groundwater sustainability. Participating agencies provided a list of projected future management actions to be implemented between WY2021 and WY2040. These projects were simulated under Baseline conditions, 2030 Climate Conditions and 2070 Climate Conditions through WY2070 using the C2VSimFG-Kern.

Proposed future projects and management actions were provided by GSAs. The types of proposed SGMA projects and management actions are summarized as follows:

- Demand Reduction is the volume of water reduced by changing the land use; these include:
    - Agricultural demand reduction projects through incentives or actions to reduce crop water use,
    - Fallowing of agricultural land and conversion of agricultural land to recharge basins, and
    - Conversion of agricultural land to urban land.
- New Supply groups together planned increases in imported water supplies; these include:
    - Increased surface water imports generally resulting from projected water purchases,
    - New water conveyance facilities including pipelines and reservoirs to increase flexibility, and
    - Expansion of surface water delivery areas to reduce groundwater usage.
- Other Supply groups together proposed projects to increase local water supplies; these include:
    - Recharging treated waste waters derived from both urban areas and oil production operations; increased recharge occurs in both existing and new locations,
    - Increased stream flow diversions; these include exercising riparian water rights and diverting flood flows,
    - Reallocation of water; generally reducing sales of surface water and banked groundwater and using this water within the agency, and
    - Brackish groundwater in areas not currently overdrafted will be treated and mixed with surface water to augment surface water supplies.

Some management actions are implemented gradually over many years, with savings increasing each year over the implementation period. Some management actions are implemented only in certain years (wet years, for example). The anticipated average-annual water supply benefit of the proposed SGMA projects and management actions steadily increases over the 20-year period from WY2021 to WY2040 to represent the implementation of the Kern County Subbasin GSPs. This increasing trend, as shown as

the average-annual water supply benefit over five-year increments on **Figure 15**, is summarized as follows:

- about 116,000 AFY over the first five-year period (WY2021-WY2025),
- about 216,000 AFY over the second five-year period (WY2026-WY2030),
- about 343,000 AFY over the third five-year period (WY2031-WY2035), and
- about 361,000 AFY over the fourth five-year period (WY2036-WY2040).

The anticipated water supply benefit of the proposed SGMA projects and management actions included in the C2VSimFG-Kern projected future simulations is 422,000 AFY over the period from WY2041 to WY2070. Benefits of implementing these projects and management actions over the 20-year implementation period are summarized in **Figure 15**.

6. PROJECTED FUTURE BASELINE DEVELOPMENT

Projected water budgets are required by GSP regulations to represent future conditions over a 50-year GSP planning and implementation horizon. A Baseline condition was developed that projects water supply, demand and operations based on current land use and expected water supply availability over 50 years. The Baseline then serves as a basis of comparison for evaluating proposed sustainability management actions and projects for achieving sustainability over the planning and implementation horizon. Each predictive scenario model simulates the 50-year planning and implementation period WY2021 to WY2070. Development of the projected future Baseline conditions is summarized below.

6.1 Projected Future Time Period Development

WY1995 to WY2014 was chosen as a historical hydrology period because detailed demand and supply data are available for this period, and most Subbasin water delivery infrastructure was fully developed by the middle of this period. The average Kern River inflow for this period is also very close to the long-term average Kern River inflow.

The projected future simulation period is based on repeating the WY1995 to WY2014 historical study period. This period is only 20 years long, so a 50-year sequence of historical hydrology was developed by repeating data from this period in the sequence as shown in **Table 14**. The development of this sequence is summarized as follows:

- Simulation period WY2021 to WY2032 used the historical period WY2003 to WY2014,
- Simulation period WY2033 to WY2052 used the historical period WY1995 to WY2014, and
- Simulation period WY2053 to WY2070 used the historical period WY1995 to WY2012.

This sequence was developed to match long-term average flows on the Kern River, and to ensure that the Baseline does not end in an extreme drought or extreme wet year. By starting the projected future simulation time sequence with WY2003, the 50-year hydrology period has approximately 100 percent of the long-term average streamflow conditions on the Kern River, as indicated by an average annual Kern River Index of 100 percent. The sequence includes the appropriate range of hydrologic conditions including extremely wet years and extended periods of drought.

C2VSimFG-Kern simulation results for the last timestep of the historical simulation (September 30, 2015) were used as initial conditions for all projected future simulations, including initial conditions for the root zone, saturated and unsaturated aquifer zones, and small watersheds. Since the historical C2VSimFG-Kern simulation period ends with WY2015, all projected future scenarios also include estimated hydrology for WY2016 to WY2020. Model input data for WY2016 to WY2020 was developed by repeating model input data for recent years based on correlation with the San Joaquin Index (DWR, 2019).

6.2 Development of Key Baseline Data Sets

Key required components for the Projected Future Baseline, as summarized in the DWR *Water Budget Best Management Practices* guidance document (DWR, 2016B) include the following:

- The projected Baseline hydrology conditions were developed using 50-years of historical precipitation and streamflow following the sequence outlined in Section 6.1.
- Surface water supplies are based on available information from DWR and others to project future water imports from the SWP, CVC - Friant-Kern Canal (FKC) and Kern River diversions. For the Kern River, recent diversion practices based on entitlements were used to develop water use consistent with the Baseline hydrology.
- WY2013 land use was used as current land use for all scenarios as drought conditions likely reduced agricultural production in WY2014 and WY2015.
- Consumptive use for agriculture and undeveloped lands was based on the recent land use and METRIC-based evapotranspiration. Following DWR guidance, METRIC data over the Baseline period was varied according to varying hydrologic conditions (e.g., water year type).
- Urban water demand was based on projections from recent urban water management plans to meet regulations for future water use. Urban demand was estimated in the model based on projected urban population growth and per capita water demand information (including recent regulatory guidance).
- Small watershed inflows used the same parameters as the historical C2VSimFG-Kern model; however, volumes varied based on changes in the precipitation and ET under the 2030 and 2070 climate change conditions.

Time-series input data were first developed for the Baseline scenario model for WY2021 to WY2070. Development of this time-series input data generally involved repeating time-series data from the historical C2VSimFG-Kern in the appropriate sequence. The following time-series data were developed for each scenario:

- Precipitation rates,
- Evapotranspiration rates,
- Surface water inflow rates,
- Surface water diversion and delivery rates, and
- Specified groundwater pumping rates.

Baseline scenario model time-series data files were then modified following DWR guidelines to produce time-series input data for the 2030 Climate Conditions and 2070 Climate Conditions scenario models. C2VSim input data were modified only in Kern County. C2VSim input data for areas outside of Kern County were not modified.

The baseline data sets were incorporated into the model files to develop the projected future water demand and supply under Baseline, 2030 Climate and 2070 Climate conditions. A summary of the development of the projected future water demand and supply is discussed below.

6.3 Projected Future Water Demand

The projected future water demand was developed using fixed WY2013 land use areas with historical evapotranspiration rates for the Baseline and modified evapotranspiration rates for the 2030 and 2070 climate scenarios and increasing urban populations.

6.3.1 Agricultural Water Demand

Evapotranspiration rates for the Baseline scenario model were developed by repeating input evapotranspiration rates from C2VSimFG-Kern in the appropriate sequence. DWR provided monthly change factors for ETo values under 2030 and 2070 central tendency climatic conditions on a 6 km x 6 km VIC grid for calendar years 1915 through 2011. The VIC grid IDs for each C2VSim subregion in the Kern County Subbasin Zone of Interest were identified and area weighted monthly ETo change factors were calculated for each subregion. Baseline scenario ETc rates for each subregion were then multiplied by the appropriate area-weighted ETo change factors to produce time-series ETc rates for the 2030 Climate Conditions and 2070 Climate Conditions scenarios. Factors for calendar years 1959-1961 were used as analogs for calendar years 2012-2014.

6.3.2 Urban Water Demand

Urban water demand calculations include an indoor component and an outdoor component. Indoor urban water demands are based on the urban population and monthly per capita water demand. Future urban populations for Kern County urban areas were estimated using California Department of Finance population projections. Future per capita urban water demands were estimated using projections from urban water management plans and California urban water conservation regulations, including SB 606 and AB 1668. Future outdoor urban water demands are based on ETc rates, which were modified as described in the Agricultural Water Demand section above.

6.3.3 Groundwater Banking Recovery

Future groundwater banking recovery rates were developed by repeating historical recovery rates in the appropriate sequence. No adjustments were made to Baseline rates or to rates for 2030 and 2070 climatic conditions.

6.4 Projected Future Water Supply

Projected future precipitation, stream inflow and surface water import time series were developed following DWR guidelines. Baseline future water supplies were developed by repeating historical values in the appropriate sequence. Surface water diversions were then adjusted to account for operational changes. Baseline water supplies were then modified to simulate 2030 and 2070 central tendency climatic conditions.

6.4.1 Precipitation Rates

Precipitation rates for the Baseline scenario model were developed by repeating input precipitation rates from C2VSimFG-Kern in the appropriate sequence. DWR provided monthly change factors for precipitation under 2030 and 2070 central tendency climatic conditions on a 6 km x 6 km VIC grid for calendar years 1915 through 2011. The VIC grid ID for each C2VSim element in the Kern County Subbasin Zone of Interest was identified and the Baseline scenario precipitation rates were multiplied by

the appropriate factors to produce time-series precipitation rates for the 2030 Climate Conditions and 2070 Climate Conditions scenarios. Factors for calendar years 1959-1961 were used as analogs for calendar years 2012-2014.

6.4.2 Surface Water Inflow Rates

Surface water inflow rates for Poso Creek and White River for the Baseline scenario model were developed by repeating input inflow rates from C2VSimFG-Kern in the appropriate sequence. DWR provided unimpaired streamflow change factor datasets for Central Valley streams, and an Excel spreadsheet tool to modify basin unimpaired streamflow using these change factors. The unimpaired streamflow change factors and spreadsheet were used to modify Baseline inflows to produce 2030 Climate Conditions and 2070 Climate Conditions scenario time series inflows for Poso Creek and White River.

Surface water inflow rates for Kern River at First Point for the Baseline scenario model were developed by repeating historical inflow rates from C2VSimFG-Kern in the appropriate sequence. Flows on the Kern River are regulated, so the unimpaired streamflow method was not appropriate for estimating future flows under 2030 and 2070 climatic conditions. Projected Kern River flows at First Point under 2030 and 2070 central tendency conditions were estimated by GEI (2018) for calendar years 1956-2010 hydrology. This analysis considered the impacts of changed runoff in each sub-watershed contributing to the Kern River to develop revised streamflow estimates for Kern River at First Point. Future scenario Kern River at First Point flows for calendar years 2011-2014 were estimated using flows for analog years with similar annual flows and monthly flow pattern. Analog years 1986, 1991, 1990 and 1961 respectively were used for 2011-2014 in the future scenarios.

6.4.3 Surface Water Deliveries

Surface water delivery rates for the Baseline scenario model were developed by first repeating input surface water delivery rates from the C2VSimFG-Kern in the appropriate sequence, and then modifying selected data sets. Surface water deliveries from in-basin sources such as Oil Field Recovery were held constant at WY2015 rates for all future scenarios.

The Kern County Subbasin is served by both the CVP and the SWP. Recent changes in CVP and SWP operations and their impacts on future surface water supplies are reflected in surface water diversion rates for the three scenarios. Future CVP deliveries will be affected by implementation of the San Joaquin River Restoration Program (SJRRP) that included the 2008 U.S. Fish & Wildlife Service biological opinion (BO) on the Long-Term Operational Criteria and Plan (OCAP) for coordination of the CVP and SWP. Future SWP deliveries will be affected by operational changes implemented between 2004 and 2008 including the OCAP BO, reduced Table A contract amounts and reduced Article 21 deliveries. DWR provided projected future deliveries from the CVP and SWP for WY1922 to WY2003, derived from CalSim-II modeling conducted for the Water Supply Investment Program (WSIP) (California Water Commission, 2016). DWR's CVP projections as provided do not fully incorporate these SJRRP operational changes. DWR's SWP delivery projections do not include the OCAP BO operational constraints, the reduced Table A amounts and reduced Article 21 water.

Future CVP delivery projections developed by the Friant Water Authority (FWUA) were used in place of DWR's CVP projections. FWUA (2018) used CalSim-II to develop projected surface water deliveries with SJRRP implementation under hydrological conditions representing the Current Baseline, 2030 and 2070 climate conditions by delivery class for WY1922 to WY2003, and estimated allocations to each CVP contractor. The 2015.c data set was used for Baseline scenario CVP deliveries, the 2030.c data set was

used for 2030 Climate Conditions scenario CVP deliveries, and the 2070.c data set was used for the 2070 Climate Conditions scenario CVP deliveries. CVP deliveries for WY2004 to WY2014 were estimated using deliveries for analog years WY1951 to WY1961; these analog years have a similar distribution of water availability.

The SWP projections provided by DWR for WY1995 to WY2003 and historical deliveries for WY2004 to WY2014 were modified to incorporate the impacts of SWP operational changes in the three scenarios. 2019 SWP Table A contract amounts were used to allocate these SWP deliveries to individual districts. In summary:

- Baseline Hydrologic Conditions
  - WY1995 to WY2003 conditions are based on 2030-Level CALSIM increased by 3.03 %,
  - WY2004 to WY2007 conditions are based on historical data adjusted for OCAP BO, and
  - WY2008 to WY2014 conditions are based on historical data with the assumption that OCAP BO adjustments are already factored into the data.
- 2030 Climate Change Hydrologic Conditions
  - WY1995 to WY2003 conditions are based on the 2030-Level CALSIM Projection,
  - WY2004 to WY2007 conditions are based on OCAP BO adjustment reduced by 3.03 %, and
  - WY2008 to WY2014 conditions are based on historical data reduced by 3.03%.
- 2070 Climate Change Hydrologic Conditions
  - WY1995 to WY2003 conditions are based on the 2070-Level CALSIM Projection,
  - WY2004 to WY2007 conditions are based on OCAP BO adjustment reduced by 8.09%, and
  - WY2008 to WY2014 conditions are based on historical data reduced by 8.09%.

Within the Kern County Subbasin, water users engage in complex real-time water trading and wheeling activities to maximize water utilization, minimize waste and energy consumption, and meet immediate water needs. It would be difficult to project future surface water deliveries in the Kern County Subbasin without the use of a surface water allocation model that simulates these water trading and wheeling activities. Therefore, for this modeling effort, monthly future scenario agricultural, urban and recharge deliveries from sources originating outside the basin were estimated by adjusting historical deliveries by the ratio of (total scenario inflows)/(total historical inflows) for each month, where total inflows are the sum of CVP deliveries, SWP deliveries and Kern River at First Point. In addition, Kern River at First Point flows above historical flows under the 2030 Climate Conditions and 2070 Climate Conditions scenarios were proportionally added to selected recharge deliveries. This method is deemed adequate for subbasin-level future scenario analyses.

Some future scenario data sets did not cover the entire period from October 1994 through September 2014. In these cases, data from an analog historical period with similar water availability was used to fill in the missing data. The analog years for each data type are summarized as:

- For CVP deliveries (CalSim-II data), WY1951 to WY1961 were used as analogs for missing WY2004 to WY2014 data; these analog years have a similar distribution of water availability.
- Projected future Kern River at First Point flows for calendar years 1986, 1991, 1990 and 1961 were used as analogs to missing calendar years 2011 through 2014; each of these analog years had a similar historical annual flow volume and monthly distribution.

- For climatic data adjustment factors, calendar years 1959-1961 were used as analogs to missing calendar years 2012-2014.

6.5 Development of Climate Change Conditions

Input data for the C2VSimFG-Kern were modified to simulate three future climatic scenarios. Historical precipitation, evapotranspiration, land use, population, surface water inflow and surface water delivery rates were replaced with projected future values for WY2016 to WY2070 for Future Baseline Conditions. The Future Baseline Conditions for WY2021 to WY2070 were then modified to simulate 2030 Climate Conditions and 2070 Climate Conditions. Water management agencies in the Kern County Subbasin provided a broad suite of proposed water management and conservation projects to increase water supplies and reduce water management demands. These projects are added to the C2VSimFG-Kern to assess the long-term impacts of these projects under the Baseline, 2030 Climate Conditions and 2070 Climate Conditions scenarios.

Projected water budgets under Future Baseline Conditions, 2030 and 2070 Climate conditions are used to evaluate the potential effects of future Baseline and extended dry conditions with respect to achieving sustainability. DWR published a *Modeling Best Management Practices* Guidance Document (DWR, 2016B) that outlines DWR recommendations for developing and running predictive scenarios. The C2VSimFG-Kern was modified following these recommendations to develop the Baseline scenario model. DWR also issued the *Guidance for Climate Change Data Use During Sustainability Plan Development* Guidance Document (DWR 2018A) that outlines how DWR recommends that climate change be addressed under SGMA. Baseline scenario data sets were modified using DWR climate change data sets for Kern County following procedures outlined in the guidance documents to develop the 2030 Climate Conditions and 2070 Climate Conditions scenario models. The adjustment factors for Baseline, 2030 Climate Change and 2070 Climate Change for SWP deliveries were developed based on consistent CalSim operations studies at current, 2030 and 2070 climate levels developed for Bay Delta Conservation Plan evaluation and provided by DWR Bay Delta Office staff. The WSIP studies provided on DWR's SGMA web site were not used due to the unavailability of a Baseline study with assumptions consistent with the 2030 and 2070 climate change studies.

6.6 Groundwater Banking Assumptions

Groundwater banking operations are simulated in the C2VSimFG-Kern with surface water diversions to recharge basins and specified pumping rates for groundwater extractions. All surface water deliveries were adjusted under the Baseline, 2030 Climate Conditions and 2070 Climate Conditions scenarios. Surface water deliveries to recharge basins were first adjusted by the same ratio as other surface water deliveries, then increased if Kern River flows were greater than historical flows. Specified pumping rates for groundwater extraction were not modified.

The out-of-basin banking obligations were assumed to follow a similar pattern where groundwater banking recharge would be affected by the limitation on surface water deliveries, but that banking recovery would remain similar to historical volumes. Therefore, the historical groundwater banking obligations were adjusted under the Baseline, 2030 Climate Conditions and 2070 Climate Conditions scenarios by the same percentage as the surface water deliveries; however, the groundwater banking recovery was assumed to remain the same. Based on the historical banking obligations and using that as a foundation going forward, no banking partner has ever requested the full amount of the water banked at any particular time even in the most recent drought years. All the banking obligation

agreements require limitations on amounts to be requested and delivered as well as "leave in" amounts that remain in the Kern County Subbasin. This historical management of banking obligations provides the Kern County Subbasin more flexibility for use of water as well as delivery of the obligations. For the projected future scenarios, the out-of-basin banking obligations were calculated as follows:

- For the Baseline scenarios, the out-of-basin banking obligations were calculated as 69,632 AFY based on surface water deliveries of about 81% of historical deliveries.
- For the 2030 Climate scenarios, the out-of-basin banking obligations were calculated as 67,913 AFY based on surface water deliveries of about 79% of historical deliveries.
- For the 2070 Climate scenarios, the out-of-basin banking obligations were calculated as 64,474 AFY based on surface water deliveries of about 75% of historical deliveries.

Tracking of banked groundwater obligations was done using the same post processing process as applied to the historical groundwater assessment by assigning the portion of the groundwater recharge as an out-of-basin banking obligation.

7. PROJECTED FUTURE C2VSIMFG-KERN SIMULATION RESULTS

The C2VSimFG-Kern was run for three scenarios that estimate hydrologic conditions of Baseline, 2030 Climate Conditions and 2070 Climate Conditions scenarios both with and without the proposed SGMA projects and management actions for a total of six projected future scenarios.

7.1 Projected Future Water Budgets

C2VSimFG-Kern calculates water budget components each month of the simulation period for each future scenario. Projected future water budgets developed based on the C2VSImFG-Kern simulation results with the proposed SGMA management actions were then compared to results for the future scenarios without the management actions to assess how these changes enhance groundwater sustainability within the Kern County Subbasin.

The average annual value of each water budget component summarizes the impacts over 50 years with current water demands. The water budget results for the six Projected Future Scenarios are presented in **Tables 16 through 21**, and include averages over three different periods, which include:

- **WY2021 to WY2040** – Implementation Period representing the 20-year period required by the SGMA regulations to implement projects and management actions to achieve sustainability.
- **WY2041 to WY2070** – Sustainability Period representing the 30-year hydrologic period following the Implementation Period to assess the long-term sustainability of the proposed projects and management actions with variable climatic conditions including periods with above average rainfall and extended droughts.
- **WY2021 to WY2070** – Simulation Period representing the entire 50-year projected future hydrologic conditions.

Changes to surface water diversions under the proposed projects and management actions included monthly increases or reductions to 37 model diversions and the addition of 7 new diversions. Ten new groundwater pumping wells were added to simulate a new groundwater pumping program. Agricultural

land use was converted to native vegetation in ten management areas, and to urban land use in three management areas. The projects and management actions included in the C2VSimFG-Kern scenarios with SGMA projects are described in the individual GSPs and management area plans. These changes were applied to a series of six C2VSimFG-Kern scenarios for Baseline, 2030 Climate Conditions and 2070 Climate Conditions both with and without SGMA projects. The results of these simulations are summarized in **Table 15** below.

Baseline simulation results indicate that the Kern County Subbasin has an average annual overdraft of 324,326 AFY. By implementing the proposed projects and management actions, the Subbasin is forecasted to achieve sustainability by 2040 with an estimated 42,144 AFY of annual surplus. With adjustments to account for limitations in the simulation (discussed in Section 7.2.1), the adjusted change in storage increases to 85,578 AFY.

Collectively, the C2VSimFG-Kern simulation results indicate that the currently proposed SGMA projects and management actions, once fully implemented, provide a reasonable approach to achieve sustainable management of the groundwater basin and can be adaptively managed to meet future challenges as necessary. A brief summary of each of the six projected future water budgets from C2VSimFG-Kern is provided below.

Table 15: Summary of Simulated Change in Groundwater Storage Results over the 2041 to 2070 Sustainability Period

C2VSimFG-Kern Model Scenario	Change in Groundwater Storage (AFY)	
	C2VSimFG-Kern Model Results	Adjusted Model Results
Historic	-277,114	-277,114
Baseline	-324,326	-324,326
Baseline with Projects	42,144	85,578
2030 Climate Change	-380,900	-372,120
2030 Climate with Projects	-12,861	46,829
2070 Climate Change	-489,828	-472,336
2070 Climate with Projects	-118,273	-45,969

7.1.1 Baseline Condition Water Budgets

The Baseline Scenarios simulate how the Kern County Subbasin aquifer would respond if the recent hydrology were repeated with current expected surface water availability and current land use. The Baseline Scenarios were run both with and without SGMA projects.

For the Baseline Scenario without SGMA Projects, the groundwater budget for WY2021 to WY2040 (**Table 16**) repeats the 20-year historical hydrologic period so it provides a direct comparison of the differences between the projected future Baseline without SGMA Projects and the historical condition. The primary difference between historical conditions and the projected future Baseline is a nearly 20% decrease in imported surface water deliveries primarily from the SWP due to the OCAP Biological

Opinion. This is replaced with additional groundwater pumping. As a result, total net aquifer outflows increase by about 20,200 AFY and total net aquifer inflows decrease by about 76,500 AFY. This is mostly because of increased groundwater pumping and decreased managed aquifer recharge due to a decline in imported SWP water. Over this period, the average groundwater pumping is 1,581,000 AFY, which includes agricultural pumping, urban pumping and exported water. This results in an additional loss of groundwater storage of about 56,300 AFY over the 50-year projected future Baseline period.

The Baseline Scenario with SGMA Projects simulates the proposed SGMA projects and management actions (Section 5.2) applied to the Baseline Scenario. No other changes were made except for the addition of the SGMA projects to provide a direct comparison of the relative benefits of about 422,000 AFY of proposed SGMA projects and management actions. The groundwater budget for the Baseline Scenario with SGMA Projects is provided in **Table 17**. Comparing the groundwater budget for WY2041 to WY2070 (**Table 17**) with the same period from the Baseline Scenario (**Table 16**) provides an evaluation of groundwater conditions after the SGMA projects and management actions have been fully implemented. As a result, total net aquifer inflows increase about 135,400 AFY due to increased managed aquifer recharge and deep percolation. The total net aquifer outflows decrease about 231,100 AFY due mostly to decreased groundwater pumping with agricultural demand reduction management actions.

The change in groundwater storage for the Baseline Scenario with SGMA Projects improves by about 366,500 AFY compared to the Baseline Scenario without SGMA Projects. This change results in a net gain in groundwater in aquifer storage over the WY2041 to WY2070 sustainability period of about 42,100 AFY. A comparison of the annual change in groundwater storage over the 50-year hydrologic period is presented in **Figure 16**. The time series shows that change in groundwater storage has stabilized to slightly increasing over the period from WY2041 to WY2070.

A comparison of the average annual water budget components for the two different Baseline Scenarios is presented in **Figure 17**. Over the WY2041 to WY2070 period, the average groundwater pumping of 1,354,000 AFY for the Baseline Scenario with SGMA Projects (which includes agricultural pumping, urban pumping and exported water) is over 270,000 AFY less than in the Baseline Scenario.

7.1.2 2030 Climate Change Water Budgets

The 2030 Scenarios simulate how the Kern County Subbasin aquifer would respond assuming hydrologic conditions representing a potentially drier climate and are based on the DWR Climate Change Guidance and Resource Guide (DWR, 2018A and 2018B). The 2030 DWR climate change factors were applied to the Baseline Scenario conditions. Additional adjustments were made to the imported surface water supplies from the SWP, CVP and Kern River, accounting for about an additional 2% decrease from the Baseline Conditions. The 2030 Climate Change Scenarios were run both with and without SGMA projects. Results for climate change budgets are illustrated in **Figures 18, 19, and 20**.

The groundwater budget for the 2030 Climate Scenario without SGMA Projects for WY2041 to WY2070 (**Table 18**) is compared the same period for the Baseline Scenario without SGMA Projects to assess the relative change due to the climate change assumptions. The results show a net increase in aquifer inflows of about 44,700 AFY, however, the aquifer net outflows increase by about 101,200 AFY. This is mostly attributed to the climate shift to earlier rainfall making more surface water available for managed aquifer recharge during the winter but less available for irrigation in the summer, resulting in higher groundwater pumping. The net change in groundwater storage is an additional decline of about 56,600 AFY due to the climate change impacts.

The 2030 Climate Scenario with SGMA Projects simulates the proposed SGMA projects and management actions (Section 5.2) applied to the 2030 climate change conditions. No other changes were made to this scenario. The groundwater budget for the 2030 Climate Scenario with SGMA Projects is provided in **Table 19**. Comparing the groundwater budget for WY2041 to WY2070 (**Table 18**) between the two 2030 Climate Scenarios, the total net aquifer inflows increase about 118,700 AFY due to increased managed aquifer recharge and deep percolation. The total net aquifer outflows decrease about 249,300 AFY due mostly to decreased groundwater pumping with agricultural demand reduction management actions.

The change in groundwater storage for the 2030 Climate Scenario with SGMA Projects improves by about 368,000 AFY. This change results in a net decline in groundwater in aquifer storage over WY2041 to WY2070 of about 12,900 AFY. A comparison of the annual change in groundwater storage over the 50-year hydrologic period is presented in **Figure 20**. The time series shows that change in groundwater storage has stabilized to slightly increasing over the period from WY2041 to WY2070, but at a level below the results for the Baseline Scenario with SGMA Projects.

A comparison of the average annual water budget components for the two 2030 Climate Scenarios is presented in **Figure 18**. Over this period, the average groundwater pumping of 1,444,000 AFY for the 2030 Climate Scenario with SGMA Projects, which includes agricultural pumping, urban pumping and exported water, is over 290,000 AFY less than in the 2030 Climate Scenario without SGMA Projects.

7.1.3 2070 Climate Change Water Budgets

The 2070 Scenarios simulate how the Kern County Subbasin aquifer would respond assuming hydrologic conditions representing a potentially very dry climate and are based on the DWR Climate Change Guidance (DWR, 2018A and 2018B). The 2070 DWR climate change factors were applied to the Baseline Scenario Conditions. Additional adjustments were made to the imported surface water supplies from the SWP, CVP and Kern River, and these accounted for an additional 6% decrease from the Baseline Conditions. The 2070 Climate Change Scenarios were run both with and without SGMA Projects.

The groundwater budget for the 2070 Climate Scenario without SGMA Projects over WY2041 to WY2070 (**Table 20**) is compared the same period for the Baseline Scenario without SGMA Projects to assess the relative change due to the climate change assumptions. The results show a net increase in aquifer inflows of about 66,100 AFY, however, the net aquifer outflows increase by about 231,600 AFY. This is mostly attributed to an even greater climate shift to earlier rainfall making more surface water available for managed aquifer recharge during the winter but less available for irrigation in the summer resulting in higher groundwater pumping. The net change in groundwater storage is an additional decline of about 165,500 AFY due to the climate change assumptions.

The 2070 Climate Scenario with SGMA Projects simulates the proposed SGMA projects and management actions (Section 5.2) applied to the 2070 climate change conditions. No other changes were made to this scenario. The groundwater budget for the 2070 Climate Scenario with SGMA Projects is provided in **Table 21**. Comparing the groundwater budget for WY2041 to WY2070 (**Table 20**) between the two 2070 Climate Scenarios, the total net aquifer inflows increase about 106,300 AFY due to increased managed aquifer recharge and deep percolation. The total net aquifer outflows decrease about 265,300 AFY due mostly to decreased groundwater pumping due to agricultural demand reduction management actions.

The change in groundwater storage for 2070 Climate Scenario with SGMA Projects improves by about 371,600 AFY. This change results in a net decline of groundwater in aquifer storage over WY2041 to WY2070 of about 118,300 AFY. A comparison of the annual change in groundwater storage over the 50-year hydrologic period is presented in **Figure 20**. The time series shows that change in groundwater storage has stabilized to slightly increasing over the period from WY2041 to WY2070, but at a level below the results for the Baseline and 2030 Scenarios with SGMA Projects.

A comparison of the average annual water budget components for the two different 2070 Climate Scenarios is presented in **Figure 19**. Over this period, the average groundwater pumping of 1,559,000 AFY for the 2070 Climate Scenario with SGMA Projects, which includes agricultural pumping, urban pumping and exported water, is over 307,000 AFY less than in the 2070 Climate Scenario without SGMA Projects.

7.2 Projected Future Sustainability Assessment

To assess the sustainability of the proposed GSP plans, the C2VSimFG-Kern model future scenario input files were modified to incorporate all the proposed SGMA projects and management actions.

7.2.1 Change in groundwater storage

Groundwater sustainability for the Kern County Subbasin was assessed using annual changes in groundwater storage. As discussed in Section 7.1, the decline in groundwater storage of the three future Baseline scenarios is significantly mitigated by the implementation of the proposed SGMA projects and management actions. An assessment of the projected future groundwater storage change for the six projected future scenarios is summarized in **Table 22**.

The Change in Groundwater Storage presented in **Table 22** provides the net difference in aquifer inflows and outflows without consideration of subsurface flow to and from adjacent groundwater basins. This provides a measure of the natural and managed water supply within the groundwater basin without being influenced either positively or negatively by the subsurface flow. For the Kern County Subbasin, the net operational flow differs from the change in groundwater storage by about 50,000 to 75,000 AFY for the scenarios without SGMA projects, indicating that most of the groundwater storage change is due to conditions within the basin.

The Adjustments to Groundwater (GW) Storage Change are made to account for limitations in either the underlying conceptual model of C2VSimFG-Kern or the setup of the projected future scenarios. The two adjustments made to the projected future water budgets include:

- **Adjustment for Excess Basin Outflows** is the difference in simulated basin outflow that is attributed to addition of SGMA projects in Kern County without comparable SGMA projects added to adjacent basins. Adjustment assumes that this difference is due to limitation of the simulation, and that this difference would remain in Kern County Subbasin when SGMA projects from adjacent basins are included in the simulation.
- **Adjustment for Excess Kern River Outflow** is the increase in simulated groundwater outflows to the Kern River relative to Baseline condition that are attributed to SGMA projects and climate change. The model is not optimized for river management. Because the Kern River is a highly managed system, the assumption is that in practice this water would be recovered for beneficial use and not allowed to flow from the basin.

These adjustments resulted in an overall improvement in the change in groundwater storage for the projected future water budgets. For the scenarios that include the SGMA Projects, the change in groundwater storage improves by 43,400 AFY (Baseline), 59,700 AFY (2030 Climate Change), and 72,300 AFY (2070 Climate Change). As a result of these adjustments, the adjusted change in groundwater storage for the three scenarios with SGMA Projects varied as follows:

- the Baseline Scenario with SGMA Projects changes from an increase of 42,100 AFY to an increase of 85,600 AFY.
- the 2030 Climate Scenario with SGMA Projects changes from a decline of 12,900 AFY to an increase of 46,800 AFY.
- the 2070 Climate Scenario with SGMA Projects changes from a decline of 118,000 AFY to a decline of 46,000 AFY.

These adjustments indicate areas of improvement for C2VSimFG-Kern. Future updates to the model will address how to better simulate these conditions directly to limit the use of post-simulation adjustments.

7.2.2 Sustainability Assessment

As defined by SGMA, the sustainable yield of a basin is the amount of groundwater that can be withdrawn annually without causing undesirable results. Although the SGMA regulations require that a single value of sustainable yield must be calculated basinwide, it should be noted that the sustainable yield can be changed with implementation of recharge projects, variations in climate, or changes in stream flow conditions. For the projected future scenarios, both the climate and the managed water supply operations are significantly affected which would lead to a change in the sustainable yield for the basin.

For the sustainability assessment, the sustainable yield was recalculated using the method described in Section 4.2, and the results are presented in **Table 23**. Without the SGMA projects and management actions, the percentage of the Average Annual Difference to the total groundwater pumping provides context to compare the significance of the level of groundwater pumping for the basin. For the scenarios without SGMA projects and management actions, the groundwater pumping exceeds the sustainable yield on the order of 25% to 34% (**Table 23**). However, with the proposed SGMA projects and management actions, the groundwater pumping is less than the sustainable yield of the Subbasin for the Baseline and 2030 climate scenarios and is within 3% of the sustainable yield for the 2070 climate scenario (**Table 23**). This assessment indicates that the proposed SGMA projects and management actions for the Kern County Subbasin are of sufficient magnitude that, if fully implemented, would lead to groundwater sustainability for the Kern County Subbasin after WY2040.

7.2.3 Minimum Thresholds and Measurable Objectives

Another requirement of SGMA is for groundwater levels not to cross their minimum thresholds to the extent that undesirable results would occur in the basin, and moreover, that proposed SGMA projects and management actions would lead to meeting the measurable objectives. The Kern County Subbasin GSAs have defined 186 representative monitoring well (RMW) locations spread across the Kern County Subbasin. A minimum threshold and measurable objective have been assigned each of the 186 locations, and the hydrographs for all 186 locations are provided in **Attachment A**. The RMW locations are shown on **Figure 21**.

The C2VSimFG-Kern results were used to assess whether the simulated groundwater levels would meet the minimum threshold and measurable objective for each monitoring well. Because C2VSimFG-Kern is

not fully calibrated, the results are presented as relative change (which does not require calibration) instead of simulated groundwater levels using the superposition method. Future change in groundwater level was determined for each of the 186 locations for each of the six projected future simulations. The change was calculated from the simulated March 2015 groundwater levels from the model. The change in groundwater level was then applied to the measured March 2015 groundwater level at the monitoring location. The result was to superimpose the simulated change in groundwater levels from the projected future C2VSimFG-Kern scenarios relative to the measured March 2015 groundwater level.

Figure 22 provides four representative examples of the simulated hydrographs using this method. Hydrographs of the simulated groundwater levels relative to the minimum thresholds and measurable objectives for all 186 locations were provided to the various GSAs and water districts for inclusion in their respective GSPs. In general, across most areas of the basin, groundwater levels fall near or below the minimum thresholds without the SGMA projects but are typically above the minimum threshold for the simulations that include the SGMA projects.

The groundwater hydrographs for some locations, especially along the eastern and western basin margins, show an unusual pattern that is likely influenced by issues with the hydrogeological conceptual model incorporated into C2VSimFG-Kern for these locations. The hydrographs for these areas are not considered to be representative of actual conditions that would physically occur. This is a limitation to the model. It is recommended that a more rigorous model update be conducted to revise the hydrogeological conceptual model to be consistent with that presented in the Kern County Subbasin GSPs. In addition, further calibration of C2VSimFG-Kern is recommended to update aquifer parameters in the Kern County Subbasin. The recommendations for revisions to the hydrogeological conceptual model and additional calibration are further discussed in Section 8.5.

8. VALIDATION OF C2VSIMFG-KERN PERFORMANCE

The C2VSimFG-Kern performs well within the central part the Kern County Subbasin. The model does not perform as well east of the Friant-Kern Canal or west of the California Aqueduct. The geologic and hydrogeologic conceptual models within the central part of the Kern County Subbasin appear to be generally realistic. The geologic and hydrogeologic conceptual models appear to be very poor in the areas where the model does not perform well.

8.1 C2VSimFG-Kern Validation

One of the concerns for the modeling is the overall calibration of C2VSimFG-Beta in Kern County. As discussed above, the assumption is that C2VSimFG-Beta was developed using reasonable care in developing the geologic framework and developing a consistent regional methodology for determining aquifer properties. An identified weakness of the C2VSimFG-Beta is the quality of data used in developing the overall water balance such as the extent of the groundwater banking operations in Kern County. The issues with the water balance are considered the primary contributing factor affecting the calibration of the C2VSimFG-Beta; the hydrogeologic conceptualization is reasonably accurate for a regional planning analysis.

To address these concerns, a validation analysis was performed for C2VSimFG-Kern by comparing simulations results to field measured groundwater level data collected during the Study Period and comparing those to a similar set of residuals from the C2VSimFG-Beta model. The statistical results of

this analysis should be comparable, if not better, for C2VSimFG-Kern compared to the C2VSimFG-Beta results.

The analysis used 42,058 groundwater levels measurements collected from 558 monitoring wells in the Kern County Subbasin. The data were collected by Kern County Water Agency, the Kern Fan Monitoring Committee, the DWR Water Data Library, and local agencies. For each location, the residual was calculated as the simulated groundwater level minus the measured groundwater level based on the well measurement data. A brief summary of the statistical measures used to evaluate the calibration results (shown on **Table 24**) is provided below:

- The residual mean is computed by dividing the sum of the residuals by the number of residual data values. The closer this value is to zero, the better the calibration especially as related to the water balance and estimating the change in aquifer storage. The residual mean of 17.3 feet for C2VSimFG-Kern is an improvement of 47% over the 32.6 feet from C2VSimFG-Beta.
- The absolute residual mean is the arithmetic average for the absolute value of the residual, so it provides a measure of the overall error in the model. The absolute residual mean of 37.4 feet for C2VSimFG-Kern is an improvement of 34% over the 56.8 feet from C2VSimFG-Beta.
- The residual standard deviation evaluates the scatter of the data. A lower standard deviation indicates a closer fit between the simulated and observed data. The standard deviation is 45.5 feet for C2VSimFG-Kern, which is an improvement of 16% over the 54.0 feet from C2VSimFG-Beta.
- The Root Mean Square (RMS) Error is the square root of the arithmetic mean of the squares of the residuals and provides another measure of the overall error in the model. The RMS Error is 50.0 feet for C2VSimFG-Kern, which is an improvement of 32% over the 73.5 feet from C2VSimFG-Beta.
- The correlation coefficient ranges from 0 to 1 and is a measure of the closeness of fit of the data to a 1 to 1 correlation. A correlation of 1 is a perfect correlation. The correlation coefficient of 0.76 for C2VSimFG-Kern is an improvement of 47% over the 0.52 from C2VSimFG-Beta.
- Another statistical measure is the ratio of the standard deviation of the mean error divided by the range of observed groundwater elevations. This ratio shows how the model error relates to the overall hydraulic gradient across the model. The ratio for C2VSimFG-Kern is 0.061 feet, which is an improvement of 34% over the 0.092 from C2VSimFG-Beta.

Considering these results in context with the overall range of measurements of 616 feet, the residual mean of 17.3 feet represents a relative percentage difference of less than 3%. For the absolute residual mean of 37.4 feet, the relative percentage difference is about 6%. Despite this improvement in model performance, the model is not considered fully calibrated. However, C2VSimFG-Kern is reasonably validated for assessing groundwater level changes on the subbasin scale for the purposes of SGMA planning.

8.2 Sensitivity Analysis

The C2VSimFG-Kern model was not formally calibrated. Some physical parameters were adjusted to improve model performance in specific areas. A sensitivity analysis was conducted on the adjusted model to understand how variations in model parameters affect model results. Eight physical parameter sets were systematically varied, and model results compared to the base model for a

selected group of groundwater hydrographs. C2VSimFG-Kern parameter sensitivities evaluated for Kern County Subbasin include:

- Horizontal hydraulic conductivity of aquifer (Kh)
- Vertical hydraulic conductivity of aquifer (Kv)
- Vertical hydraulic conductivity of Corcoran Clay aquitard (Kcorc)
- Streambed conductance of Kern River (Cstm)
- Specific storage of aquifer (Ss)
- Specific yield of aquifer (Sy)
- Soil hydraulic conductivity in root zone (Ksoil)
- Soil pore size distribution index in root zone (λ)

The Root Mean Squared Error between observed and simulated values was calculated for the original parameter set and after varying each parameter set upward and downward by a set factor. Results are presented in **Figure 23**. This sensitivity analysis shows that the hydrologic parameter values in the C2VSimFG-Kern model are generally within an acceptable range. A full model calibration would likely improve model performance.

8.3 Peer Review Process

Todd Groundwater worked with Woodard and Curran (W&C) throughout the model development process as W&C conducted an on-going peer review of model input files. W&C staff have developed several IWFM-based models and worked with DWR to develop C2VSimFG-Beta. Their reviews helped ensure that the model update used best practices when incorporating new data. The peer review process was documented in a series of meeting summaries to the KGA and KRGSA. The updated C2VSimFG-Kern input files for the Kern County Subbasin were shared with DWR for incorporation into future C2VSim public releases.

The more general assumptions in C2VSimFG-Beta were replaced with local data and knowledge that are regionally or locally significant for WY1995 to WY2015. This update employed a phased approach with regular peer reviews.

1) Phase 1 revisions address components of Regional Significance that require significant changes to the overall model input file structure. These include:
   a) Surface water delivery volumes, application areas and use by water district,
   b) Groundwater banking recharge, recovery and application of recovered water,
   c) Evapotranspiration rates and irrigation demand based on ITRC METRIC data (ITRC 2017),
   d) Urban population and per capita demand, including addition of an urban zone for Metropolitan Bakersfield, and
   e) Addition of groundwater extraction wells for groundwater banking projects.
2) Interim Review
   a) The Woodard & Curran Peer Review Team
   b) Kern County Subbasin water districts and purveyor's local data review
   c) Stakeholder input
3) Phase 2 revisions address components of Local Significance that generally require modifications of input data and parameters within the existing C2VSim model input file structure. These include:

a) Local water sources and demands of significance to individual Districts/GSAs,
b) District pumping for in-district delivery via surface water canals where significant,
c) District recharge operations utilizing canals, stream channels, and basins,
d) Wastewater disposal and land application, and
e) Review and limited adjustment of model parameters.

4) Interim Review by same reviewers listed in item 2

5) Phase 3 revisions include addressing comments and incorporating new data from the Interim Reviews

6) Interim Review by same reviewers listed in item 2

7) Tabulate model-derived water budgets for Peer-Review and GSP Use

In each update phase, historical and current water budgets for zones representing water agency service areas were produced with the revised C2VSimFG-Kern model incorporating corrected local data. These water budgets were shared with participating agencies for review, to ensure that C2VSimFG-Kern correctly represented local water balances. Where necessary, participating agencies provided additional data which was incorporated into C2VSimFG-Kern.

8.4 Internal Review Process

Todd Groundwater and Hydrolytics LLC worked collaboratively on this model revision, water budget development and the projected future scenarios. Throughout this work, efforts were applied to improve data management to develop a systematic process for generating model input files. Using this approach, internal review could be conducted with each firm reviewing the contributions from the other. The goal was to accurately represent the data provided by the Kern County agencies in the model.

Due to schedule constraints, a thorough internal review of the projected future model scenarios was not completed prior to the submission of the Public Review Draft of the model results in August 30, 2019. A thorough review of all input for the projected future scenarios was conducted in September and October 2019. During this review, several issues were identified and corrected. As a result, the results in this report vary from those provided in the August 2019 Public Review Draft. Although the numbers changed, the overall conclusions from the C2VSimFG-Kern simulations remained essentially the same.

8.5 Recommendations for Future Improvements to C2VSimFG-Kern

The C2VSimFG-Kern performs well in the Kern County Subbasin, producing simulated water budget components that generally match historical values compiled by local agencies. C2VSimFG-Kern simulated groundwater levels provide a reasonable approximation of observed groundwater levels in the central part of the Kern County Subbasin. The model is well suited for estimating the impacts of management actions on the Subbasin groundwater storage and is also well suited as a planning tool in meeting compliance of SGMA.

During the model update, several outstanding issues were identified that should be addressed in future updates to C2VSimFG-Kern. The following actions and model improvements are recommended:

- **Improve streamflow simulations of the Kern River and Poso Creek.** Flows in the Kern River channel, including local stream-groundwater interactions, are not well replicated and surface water diversions are not dynamically simulated. Some rejected recharge occurs in the Kern Fan

area in very wet years, with significant outflow of groundwater to the Kern River especially in the Kern Fan banking area (i.e., rejected recharge). This has been an ongoing issue and needs to be addressed for the projected future water budgets so that banking recharge volumes can be better matched in the model. It is recommended that future revisions to C2VSimFG-Kern further evaluate issues in simulating streamflow and seepage in the Kern River and Poso Creek (see Section 8.5). This may include incorporating more advanced streamflow simulation features that are available in IWFM but that have not been previously utilized in developing C2VSim models by DWR. Changing the stream simulation feature may require development of a local Kern County Subbasin model.

- **Improve the geologic and hydrogeologic conceptual model of the Kern County portion of the Central Valley.** A hydrogeologic conceptual model is a framework for understanding where groundwater exists, where it flows, and how groundwater interacts with surface water bodies and the land surface. A geologic conceptual model provides a framework for understanding the geologic features that control groundwater movement. Quantitative analysis of Kern County Subbasin groundwater flow is severely hampered by the lack of detailed geologic and hydrogeologic conceptual models of the areas outside the central alluvial basin. Geologic and hydrogeologic conceptual models will provide a foundation for the quantitative analysis of the groundwater flow system, and the framework for modeling the system. Key steps are:
    - Develop detailed geologic and hydrogeologic conceptual models of the Kern County Subbasin.
    - Differentiate the four Principal Aquifers that have been identified in the Kern County Subbasin based on definitions from local management area GSPs.
    - Identify the locations and characteristics of natural features that affect groundwater recharge and movement (faults, ridges, clays).
    - Understand water occurrence and movement in areas outside the central Kern County Subbasin.
    - Develop water quality maps (natural constituents and anthropogenic constituents).
    - Modify the Kern County Subbasin model to conform to the updated conceptual models.
- **Simulation of deep percolation and small watersheds.** Unreasonably high deep percolation (return flows) of the applied water in some areas has led to unreasonably elevated pumping rates to compensate. One problem is high root zone hydraulic parameter values in certain areas that were identified and corrected to better reflect local soil conditions. Because the excess pumping was returning to groundwater, the change has little effect on the basin change in storage, but the pumping and deep percolation are now more in line with local estimates. Root zone hydraulic parameters should be redeveloped throughout the subbasin to assure model values are representative of actual values.
- **Root Zone Parameters,** Areas of overly high root zone hydraulic parameters led to high volumes of deep percolation that required additional groundwater pumping to meet the overall water demand for irrigation. A review found areas of overlying high soil hydraulic conductivity and other soil parameters produced percolation rate that were too high. These areas were manually adjusted to be more in line with observed conditions. A more rigorous development of root zone parameters should be considered in the future as this issue demonstrates that it is a sensitive parameter.

- **Investigate development of a stand-alone Kern County Subbasin model.** The C2VSim model provided by DWR and updated with local data is adequate for GSP preparation. However, this model may not meet all of the groundwater modeling needs of Kern County Subbasin stakeholders. In addition, running a full Central Valley simulation model imposes longer model run times and reduces model flexibility. Stakeholders should undertake a comprehensive study to develop a list of their integrated (groundwater and surface water) modeling needs, and then decide whether further improving C2VSimFG-Kern or developing a new integrated hydrologic model is the best way to address the Subbasin modeling needs. This decision should be made before the end of 2020 to allow sufficient time to develop a new model or improve C2VSimFG-Kern in time for use in development of the 2025 GSP.
- **Adjust the finite element grid to honor water management boundaries.** The C2VSimFG-Kern model grid is a randomly generated grid that does not conform to any local features other than natural surface water channels. This limits the spatial accuracy of model inputs and the precision and flexibility of water budget outputs. Adjusting the grid to match district and agency boundaries, historical delivery areas, water management units within districts, and geologic and hydrologic features would greatly enhance model capabilities.
- **Quantify boundary flows.** Significant uncertainty exists regarding the rates and timing of groundwater flows into the Kern County Subbasin from surrounding watersheds, and groundwater flows from the Kern County Subbasin to Kings and Tulare counties to the north. Reliable estimates of boundary flows will improve model performance in boundary areas.
- **Kern County Subbasin Boundary.** The GSAs in the basin should consider when DWR updates the Bulletin 118 in 2020 to investigate the "actual" Kern County Subbasin and to remove those peripheral lands where aquifer connectivity does not exist.
- **Utilize more complex water management features of IWFM.** The Kern Update process modified information within the existing C2VSimFG-Beta model structure to improve model performance within the Kern County Subbasin. The IWFM application has several features that could be further utilized to improve model performance.
    - Adjust the agricultural crops to better match the Kern County crop mix (for example, create separate crop categories for carrots, young and mature almonds, young and mature pistachios, etc.).
    - Implement multi-cropping with semiannual or quarterly land use.
    - Some C2VSim data are organized by DWR subregions, which represent heterogeneous areas with homogeneous data. Developing Kern County Subbasin subregions and organizing model input data by these subregions may provide a better representation of local hydrologic conditions.
- **Calibrate the improved model for the Kern County Subbasin**. DWR did not fully calibrate the Kern County portion of the C2VSim model, owing to both poor historical input data and a lack of calibration data sets. The Kern Update process significantly improved the historical data in the model, developed some calibration data sets, and included limited adjustment of model parameters. The updated model performs adequately in the central part of the Kern County Subbasin and poorly in areas outside the central part of the basin. Once the above improvements are completed, the Kern County portion of the resulting model should be fully calibrated to ensure that it performs well throughout the Kern County Subbasin.

9. CONCLUSIONS

This brief summary provides an overview of the findings and conclusions of the modeling results for the Kern County Subbasin using C2VSimFG-Kern.

9.1 Findings of the C2VSimFG-Kern Application and Results

The subbasin-wide update of C2VSimFG-Kern incorporated data from many local agencies. Each participating agency provided data for their jurisdiction for use in improving the model. This included managed water supply data (e.g., surface water deliveries, land use, irrigation demand, return flows, and groundwater banking), stream and groundwater monitoring data, geologic data, and other relevant data. This information was compiled and used to improve C2VSimFG-Kern performance in the Kern County Subbasin.

The historical water budget analysis indicates that the Kern County Subbasin was in a state of overdraft equivalent to the long-term decline in groundwater storage from WY1995 to WY2014 of 277,144 AFY. Projected Future simulations indicate that the proposed SGMA projects and management actions in the Kern County GSPs are sufficient for the Kern County Subbasin to achieve sustainability under Baseline and 2030 Climate Change conditions.

C2VSimFG-Kern was used to evaluate the change in groundwater in storage for projected future conditions using a baseline condition that projects current water supply, water demand and land use over a 50-year period based on historical hydrology. The baseline was adapted following DWR climate change guidance to develop 2030 and 2070 climate change simulations. The proposed SGMA projects and management actions were compiled from all of the Kern County Subbasin GSAs and management areas. The total projects total about 421,000 AFY after implementation. This assessment indicates that the proposed SGMA projects and management actions for the Kern County Subbasin are of sufficient magnitude that, if fully implemented, would lead to groundwater sustainability for the Kern County Subbasin after WY2040.

The historical C2VSimFG-Kern performs well in the Kern County Subbasin, producing simulated water budget components and groundwater levels that generally match historical values compiled by local agencies. C2VSimFG-Kern simulated groundwater levels provide a reasonable statistical approximation of observed groundwater levels in the Kern County Subbasin that show significant improvement relative to C2VSimFG-Beta. Therefore, C2VSimFG-Kern is well suited as a planning tool to estimate the impacts of the proposed SGMA projects and management actions on groundwater conditions in the Kern County Subbasin.

The C2VSimFG-Kern model development and the water budget analysis were designed to fulfill the GSP requirement for a coordinated subbasin-wide water budget analysis, while also providing information required to fulfill other GSP requirements. The C2VSimFG-Kern was provided to DWR so the Kern County Subbasin revisions can be incorporated into their master version of the C2VSim model.

9.2 C2VSimFG-Kern Compliance with Coordination Agreement Requirements

Subbasin GSAs coordinated on the development and application of the C2VSimFG-Kern to ensure that the model was incorporating comparable data sets and the best available information; as such, the model meets numerous technical requirements for Subbasin-wide coordination, including for

Coordination Agreements in §357.4. As demonstrated throughout this memorandum, the C2VSimFG-Kern model documents the use of "the same data and methodologies" for water budget development.

Specifically, groundwater extraction data were coordinated through the use of ET METRIC data for all irrigated lands over the entire Subbasin to estimate private irrigation pumping. Monthly metered data from District, municipal, and banking pumping were incorporated as available. Surface water supply data were provided in similar units and formats using consistent templates for data collection and management in the model. Total water use and change in groundwater in storage were developed through consistent methodologies as applied in the C2VSimFG-Kern model. Calibration targets also incorporated consistent data sets for groundwater elevation data throughout the Subbasin as compiled in the DWR Water Data Library, KCWA water level database, and supplemented with local data, as needed. This memorandum documents coordination efforts in subsequent sections that demonstrates compliance with GSP requirements in §354.18, §357.4, and other portions of the regulations.

9.3 Limitations and Uncertainty of C2VSimFG-Kern

The C2VSimFG-Kern performs well in the Kern County Subbasin, producing simulated water budget components that generally match historical values compiled by local agencies. C2VSimFG-Kern simulated groundwater levels provide a reasonable approximation of observed groundwater levels in the central part of the Kern County Subbasin. The model is well suited to estimating the impacts of management actions on subbasin groundwater storage.

The C2VSimFG-Kern update was limited in scope, and some model components do not perform well. These components do not reduce model capabilities with respect to GSP development but limit the usefulness of the model for other types of studies. Flows in the Kern River channel, including local stream-groundwater interactions, are not well replicated and surface water diversions are not dynamically simulated. The Kern County Subbasin portion of the C2VSimFG-Kern is not calibrated, and although the land surface water budget components are generally accurate, groundwater conditions and stream flows are poorly simulated in much of the Subbasin. Some rejected recharge occurs in the Kern Fan area in very wet years, but this is not significant as it is a very small volume.

The C2VSimFG-Kern is a reliable and defensible tool to support planning future groundwater conditions and estimating the potential hydrological impacts of future climate conditions and management actions at the subbasin level. It is currently the best available quantitative tool for assessing projected future groundwater conditions under SGMA. DWR recommends updating and refining models used in GSPs to incorporate new data including that in annual GSP updates. Refining Kern County Subbasin hydrologic modelling tools to replicate district-level historical conditions will provide a reliable means of assessing future effects of management actions at the district level for future GSP development.

9.4 Applicability of C2VSimFG-Kern Simulation Results

Based on the model validation, C2VSimFG-Kern provides a useful planning tool to evaluate potential future trends in groundwater in the Kern County Subbasin. The model validation demonstrated the capability of C2VSimFG-Kern to reasonably simulate the groundwater elevations and trends during the period from WY1995 through WY2015 based on the comparison to measured data.

The ability to reasonably simulate historical conditions provides confidence that C2VSimFG-Kern can be used to simulate potential future conditions. The model has the capability to simulate the most beneficial application of water projects that would provide the long-term benefit to the area. For the

future case scenarios, the general practice is to evaluate model results with respect to long-term trends. Therefore, as a planning tool, it is most beneficial to run the model in relation to a base case and to evaluate the relative difference between the model scenario and the base case. The base case would assume a selected set of climatic, hydrologic and pumping conditions. Commonly, the calibration base period is assumed to repeat; however, any number of variations can be constructed.

It is important to note that in some cases the model results may vary from those measured in individual wells due to the geologic complexity of the Kern County Subbasin. However, the model is capable of evaluating the impacts of changes in pumping and water use practices in the Kern County Subbasin that are useful for SMGA planning purposes.

The conclusions and recommendations presented herein are professional opinions based on the C2VSimFG-Kern revisions and simulations as described herein. The findings and professional opinions presented in this letter are presented within the limits prescribed by the client contract, in accordance with generally accepted professional engineering, geologic and modeling practices, to support development of GSPs within the Kern County Subbasin. There is no other warranty, either expressed or implied, regarding the conclusions, recommendations, and opinions presented in this report.

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Water Year	Arvin-Edison WSD	Belridge WSD	Berrenda Mesa WSD	Buena Vista WSD	Cawelo WD	Kern River Canal Co.	Henry Miller WD	Kern Delta WD	Kern-Tulare WD	Lost Hills WD	North Kern WSD	Rosedale Rio Brave WSD	Semi-tropic WSD	Shafter-Wasco ID	So. San Joaquin MUD	Wheeler Ridge - Maricopa WSD	Olcese WD	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	144,722	106,293	90,909	162,444	78,084	14,994	43,242	183,471	27,131	103,268	198,865	0	74,487	149,252	112,888	177,348	1,493	1,668,891
1987	127,333	106,293	90,909	142,274	89,117	12,113	43,242	137,458	27,131	123,981	112,432	0	53,753	172,161	76,193	161,949	1,493	1,477,832
1988	114,321	106,293	90,909	141,152	77,106	4,203	43,242	135,078	27,131	111,872	81,580	0	47,071	164,192	71,243	154,030	1,417	1,370,840
1989	114,591	106,293	90,909	150,341	85,190	11,096	43,242	140,360	27,131	122,044	61,797	0	50,495	190,990	94,729	178,129	1,480	1,468,817
1990	70,816	106,293	90,909	124,845	67,867	14,757	43,242	114,531	27,131	88,963	51,926	0	34,381	49,992	73,000	170,693	1,480	1,130,826
1991	40,698	106,293	90,909	100,517	50,621	10,416	43,242	117,287	27,131	9,553	28,931	0	40,595	7,926	11,683	31,030	1,480	718,312
1992	52,839	106,293	90,909	108,874	54,406	9,909	43,242	118,190	27,131	52,853	34,291	0	45,851	94,467	65,310	96,514	1,480	1,002,559
1993	137,479	93,344	85,549	151,653	75,490	11,596	43,973	174,003	26,034	77,793	181,920	5,040	72,120	226,462	108,767	137,221	1,425	1,609,869
1994	171,856	110,017	93,092	125,084	62,968	13,862	53,471	132,865	28,017	87,636	117,580	2,362	47,111	110,951	83,680	151,368	1,685	1,393,606
1995	134,559	110,993	78,521	189,797	73,155	6,600	29,047	159,595	27,333	85,963	174,020	5,591	62,105	235,347	108,778	153,783	1,425	1,636,611
1996	166,288	112,412	115,132	184,597	90,229	11,591	39,539	179,052	28,749	145,349	202,199	5,722	72,231	313,420	128,865	189,454	1,987	1,986,816
1997	185,820	143,146	97,233	197,871	88,202	11,134	50,584	179,388	29,998	122,140	191,871	4,563	67,407	313,717	124,456	188,455	1,778	1,997,763
1998	120,808	79,387	85,885	152,455	69,758	4,959	30,260	124,464	24,422	80,845	153,662	4,756	53,064	240,072	89,373	148,174	849	1,463,194
1999	152,909	101,786	93,199	142,271	86,667	10,085	53,858	141,626	28,093	108,563	146,395	4,679	57,625	307,686	110,686	166,018	1,248	1,713,394
2000	158,008	111,057	87,200	135,689	87,894	12,833	44,302	152,338	29,948	119,828	133,872	3,920	61,358	315,833	119,597	179,278	1,382	1,754,337
2001	158,432	91,642	65,734	76,718	70,873	10,048	31,379	113,044	30,109	68,302	74,725	0	48,772	70,879	98,104	136,390	1,588	1,146,739
2002	158,197	107,617	63,705	78,735	75,042	9,058	31,724	116,181	25,443	67,574	62,006	0	55,121	165,448	103,849	133,652	1,702	1,255,054
2003	139,412	103,724	64,267	96,601	75,749	8,371	33,941	161,162	24,120	62,007	106,436	1,000	55,511	265,110	106,779	120,733	2,041	1,426,964
2004	155,531	118,543	68,902	86,119	78,558	9,383	39,101	138,664	25,541	67,607	99,610	1,739	58,351	174,605	106,537	138,771	1,637	1,369,199
2005	136,887	105,523	69,372	125,522	78,101	6,037	39,248	169,747	21,445	60,844	207,612	2,784	58,711	294,595	109,716	127,846	1,939	1,615,929
2006	140,411	115,146	84,869	149,851	96,249	5,317	46,538	172,882	22,525	73,422	199,626	0	68,468	332,115	120,106	150,416	2,048	1,779,988
2007	158,526	118,036	102,971	91,196	70,811	4,574	48,482	112,341	23,348	83,116	89,195	552	37,391	146,826	75,642	164,924	1,496	1,329,426
2008	157,604	114,525	86,217	70,032	62,437	4,380	18,156	145,633	22,788	74,554	86,051	0	47,623	29,675	87,776	168,211	1,700	1,177,361
2009	145,184	113,385	86,439	73,530	67,340	4,340	12,129	126,039	21,803	83,740	84,727	0	44,265	30,808	116,967	159,502	1,781	1,171,979
2010	132,462	117,589	88,556	102,109	76,351	3,604	29,694	166,787	19,272	88,191	171,744	1,543	65,238	168,870	120,394	159,162	1,756	1,513,322
2011	130,306	121,808	87,344	121,329	88,617	4,617	39,642	192,069	20,213	92,149	173,305	4,466	74,413	337,724	124,678	156,216	1,530	1,770,425
2012	148,146	130,559	87,953	96,407	89,745	3,988	41,553	195,763	21,682	91,720	81,584	1,329	35,369	227,901	81,602	168,753	1,783	1,505,837
2013	159,887	138,131	93,311	33,558	49,978	3,585	18,533	94,682	22,252	93,322	23,343	0	26,194	81,279	58,923	170,033	1,966	1,068,977
2014	144,605	123,390	82,731	410	41,223	2,645	2,246	70,367	14,067	82,546	11,290	0	8,303	5,748	14,249	152,372	1,238	757,429
2015	114,350	117,357	81,535	134	38,195	2,663	0	68,228	10,274	80,631	9,901	0	0	12,226	3,020	145,842	1,462	685,817

TABLE 2 - Summary of data input for surface water diversion from Kern River at different diversion and turnouts applied to C2VSimFG-Kern Historical Simulation

Water Year	Kern River to Beardsley Canal	Kern River to Carrier Canal at Rocky Point	Kern River to Carrier Canal at Calloway Weir	Kern River to CVC at Turnout #4	Kern River to River Canal	Kern River to Rio Vista at River Walk	Kern River to Rosedale Channel	Kern River to North Lake	Kern River to Pioneer Canal	Kern River to Berrenda Mesa WSD	Kern River to Pioneer Project	Kern River to Kern Water Bank	Kern River to Kern Water Bank Canal	Kern River to 2800 Acre Facility	Kern River to Buena Vista WSD BSA	Kern River to Aqueduct at Intertie	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	291,715	199,035	238,877	181,392	0	0	65,684	0	63,232	0	0	0	0	97,866	86,736	0	1,224,537
1987	190,539	76,888	179,876	58,811	0	0	19,893	0	756	0	0	0	0	21,592	86,736	0	635,091
1988	111,679	25,813	163,938	21,851	0	0	345	0	0	0	0	0	0	0	86,736	0	410,362
1989	98,796	28,696	168,926	23,291	0	0	0	0	0	0	0	0	0	0	86,736	0	406,445
1990	77,389	5,373	128,753	6,577	0	0	0	0	0	0	0	0	0	0	86,736	0	304,828
1991	69,736	180,189	56,331	13,944	0	0	5,869	0	0	0	0	0	0	0	86,736	0	412,805
1992	71,521	194,315	690	11,008	0	0	3,598	0	0	0	0	0	0	0	86,736	0	367,868
1993	213,099	241,104	43,555	59,099	50,897	0	54,936	0	27,803	0	0	0	0	64,852	64,488	0	819,833
1994	187,380	213,631	18,103	26,829	67	0	0	0	0	9,882	0	0	0	28,046	38,745	0	522,683
1995	256,234	248,113	65,360	144,230	136,516	0	91,721	0	40,366	23,822	45,284	0	0	60,476	103,429	11,850	1,227,401
1996	315,988	255,792	105,845	108,405	119,999	0	78,824	0	14,286	17,382	55,074	0	0	24,037	92,768	0	1,188,400
1997	288,746	280,471	123,771	130,336	123,333	0	62,841	0	23,271	14,977	45,600	0	0	27,212	134,320	52,848	1,307,726
1998	312,857	244,337	143,422	131,398	23,346	0	95,706	0	51,802	18,483	69,637	0	0	95,160	115,019	188,048	1,489,215
1999	214,847	180,856	71,974	46,274	58,082	0	33,938	0	839	6,915	21,343	0	0	17,891	77,220	0	730,179
2000	175,718	169,844	38,793	31,596	38,147	0	20,213	0	0	1,396	15,929	0	0	30,660	47,882	0	570,178
2001	130,052	188,404	23,762	14,050	4,631	0	3,177	0	2,179	0	0	0	0	0	32,686	0	398,941
2002	91,980	203,010	4,149	23,609	7,878	0	581	0	199	431	871	0	0	0	29,404	0	362,112
2003	164,112	206,448	15,893	14,088	31,451	0	12,306	0	0	1,045	0	0	0	0	38,307	0	483,650
2004	153,148	198,769	29,338	18,247	2,301	589	1,503	165	0	2,545	2,005	0	0	0	39,412	0	448,022
2005	236,776	228,885	73,215	62,146	60,019	0	141,022	1,442	1,942	39,702	102,111	21,548	23,125	77,127	72,865	0	1,141,925
2006	257,590	247,806	53,872	122,931	33,872	3,942	87,318	1,442	9,962	24,636	116,108	25,165	34,358	42,587	97,955	0	1,159,544
2007	135,525	189,169	1,049	10,483	7,752	2,746	0	0	0	13,099	17,809	7,507	0	4,568	47,914	0	437,621
2008	137,813	229,304	53,824	22,700	0	544	0	0	0	0	0	0	0	0	34,549	0	478,734
2009	139,246	238,103	31,342	28,635	115	712	109	0	0	0	0	0	0	0	18,418	0	456,680
2010	196,135	241,876	70,315	68,944	60,087	820	10,816	776	1,775	1,165	0	0	0	13,748	66,441	0	732,898
2011	298,003	266,684	75,784	160,243	90,048	1,752	101,209	787	20,479	26,223	121,857	23,951	47,187	84,876	98,416	0	1,417,499
2012	148,513	241,953	20,495	55,303	409	1,001	10,998	0	0	7,594	20,162	582	0	7,871	45,173	0	560,054
2013	45,141	153,474	706	25,758	0	247	0	0	0	3,529	0	0	0	155	0	0	229,010
2014	26,041	122,044	0	8,356	0	283	0	0	0	0	0	0	0	0	0	0	156,724
2015	16,883	104,841	0	0	0	195	0	0	0	0	0	0	0	0	0	0	121,919

TABLE 3 - Summary of data input for surface water diversions for various purposes applied to C2VSimFG-Kern Historical Simulation

Water Year	Metro Bakersfield Urban Surface Water Supply	Metro Bakersfield Wastewater Land Disposal	Kern Nat'l Wildlife Refuge SWP Supply	Kern Nat'l Wildlife Refuge Surface Water Inflows from Poso Creek	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	24,416	29,235	0	1,611	30,846
1987	25,298	30,832	0	247	31,079
1988	28,563	32,304	0	65	32,369
1989	27,818	33,785	0	136	33,921
1990	27,426	35,756	0	0	35,756
1991	20,959	36,837	0	123	36,960
1992	25,867	37,801	0	10	37,811
1993	30,261	38,774	120	852	39,746
1994	29,111	39,684	16,861	95	56,640
1995	27,248	40,709	12,097	896	53,702
1996	28,261	41,667	12,776	4,536	58,979
1997	19,216	40,832	7,964	13,811	62,607
1998	11,036	40,355	12,268	90,926	143,549
1999	26,996	39,629	14,827	1,876	56,332
2000	30,963	41,497	7,489	58	49,044
2001	28,611	41,559	13,179	0	54,738
2002	30,185	42,043	19,299	1	61,343
2003	32,206	42,962	20,945	22	63,929
2004	56,861	43,735	23,461	0	67,196
2005	43,727	44,021	23,310	9,025	76,356
2006	40,294	44,614	21,829	11,734	78,177
2007	55,334	44,643	21,607	2,440	68,690
2008	56,335	44,936	17,728	18	62,682
2009	58,834	45,416	19,494	9	64,919
2010	61,314	45,527	21,808	536	67,871
2011	64,388	46,429	26,599	7,691	80,719
2012	68,013	46,666	18,451	9	65,126
2013	66,998	45,513	23,701	0	69,214
2014	55,692	44,645	13,877	0	58,522
2015	44,981	43,256	9,203	0	52,459

TABLE 4 - Summary of data input for surface water diversion to groundwater banking and managed aquifer recharge for different facilities applied to C2VSimFG-Kern Historical Simulation

Water Year	Arvin-Edison WSD	Berrenda Mesa Project	Buena Vista WSD	Cawelo WD	Kern Delta WD	Kern River GSA	North Kern WSD	Rosedale-Rio Bravo WSD	Semi-tropic WSD	West Kern WD	City of Bakers-field	Pioneer Project	Kern Water Bank	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	63,708	0	28,948	0	0	107,936	115,498	103,384	0	25,559	164,861	0	0	609,894
1987	18,800	0	7,487	0	0	62,084	47,206	47,731	0	23,249	50,585	0	0	257,142
1988	1,434	0	227	0	0	49,926	11,171	19,026	0	24,594	18,294	0	0	124,672
1989	3,358	0	3,532	0	0	58,640	804	27,984	0	28,604	14,148	0	0	137,070
1990	4,660	0	0	0	0	35,825	0	11,530	0	22,368	9,564	0	0	83,947
1991	2,404	0	0	0	0	54,577	1,224	5,931	0	14,754	19,768	0	0	98,658
1992	3,886	0	799	0	0	48,497	10,236	11,880	0	10,368	23,482	0	0	109,148
1993	99,714	0	19,229	0	0	83,472	25,220	88,065	0	24,420	126,544	0	0	466,664
1994	28,968	0	11,485	0	0	60,217	12,333	26,016	0	29,233	67,418	0	0	235,670
1995	87,910	17,808	49,623	0	0	98,122	149,948	119,339	0	28,201	143,019	62,274	121,465	877,709
1996	69,472	23,398	18,253	0	0	102,034	103,277	116,704	0	37,351	75,468	51,330	232,355	829,642
1997	58,069	9,801	38,015	7,524	0	103,578	102,050	108,711	0	18,555	53,470	38,169	132,457	670,399
1998	97,098	9,493	63,868	9,136	0	90,233	196,469	136,250	0	23,133	149,426	57,357	236,320	1,068,783
1999	81,398	11,489	8,904	6,110	0	83,858	69,080	78,941	0	29,249	41,516	21,884	116,663	549,092
2000	95,786	1,027	238	3,446	0	74,926	163	44,501	0	23,082	51,444	22,032	36,551	353,196
2001	38,774	0	99	2,683	0	59,411	0	5,653	0	8,747	22,005	1,253	10,029	148,654
2002	4,437	0	1,065	2,596	0	63,427	0	1,404	0	19,467	11,840	0	13,439	117,675
2003	44,030	0	424	3,314	4,177	73,362	367	27,154	0	17,766	20,133	0	5,369	196,096
2004	7,160	3,172	0	5,172	1,380	65,335	3,039	9,626	0	3,513	22,480	10,768	53,070	184,715
2005	100,311	19,663	33,153	7,882	7,274	98,474	74,241	151,136	0	29,552	164,991	93,466	308,092	1,088,235
2006	90,722	28,268	22,966	4,219	1,224	95,246	138,698	174,051	0	14,385	113,166	64,388	308,877	1,056,210
2007	20,012	15,292	0	5,241	488	51,678	80,467	20,348	0	4,209	31,534	19,386	70,553	319,208
2008	4,409	0	0	5,069	0	53,118	0	0	92	0	8,787	0	0	71,475
2009	34,000	0	3,000	5,239	0	48,217	2,596	2,354	0	5,075	18,730	0	0	119,211
2010	101,606	323	19,127	6,252	11,038	97,829	18,377	76,399	0	10,419	40,113	0	8,272	389,755
2011	99,559	19,373	73,880	29,630	46,690	158,694	147,576	227,775	17,276	24,880	144,869	132,320	397,029	1,519,551
2012	27,799	20,055	0	7,162	54,573	83,460	60,613	88,019	1,865	30,166	37,046	27,293	83,991	522,042
2013	3,947	5,750	0	9,345	14,726	46,298	5,078	5,622	22	2,500	11,518	0	0	104,806
2014	3,518	0	0	2,102	0	46,654	0	0	0	0	9,176	0	0	61,450
2015	401	0	0	5,893	0	40,368	4,768	0	22	0	18,840	0	0	70,292

TABLE 5 - Summary of data input for groundwater recovery pumping for local water supply by water district applied to C2VSimFG-Kern Historical Simulation

Water Year	Arvin-Edison WSD	Berrenda Mesa Project	Buena Vista WSD	City of Bakers-field	Cawelo WD	KCWA ID4	Kern Delta WD	Kern Water Bank	Lost Hills UD	North Kern WSD	Olcese WD	Pioneer Project	Rosedale Rio Brave WSD	Semi-tropic WSD	West Kern WD	Wheeler Ridge - Maricopa WSD	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	1,955	0	0	0	0	0	0	0	274	0	101	0	0	0	12,073	0	14,403
1987	21,660	0	0	0	0	0	0	0	278	41,963	101	0	0	0	12,195	0	76,196
1988	27,486	0	960	0	0	0	0	0	281	67,609	138	0	0	0	12,316	0	108,790
1989	38,231	0	2,507	0	0	0	0	0	285	79,674	132	0	0	0	12,438	0	133,266
1990	78,769	0	2,605	0	957	0	0	0	292	73,635	132	0	0	0	12,560	0	168,949
1991	82,566	0	2,511	0	4,666	0	0	0	307	80,432	132	0	0	0	12,546	0	183,160
1992	94,444	0	4,146	0	7,124	0	0	0	306	72,926	132	0	0	0	12,533	5,419	197,029
1993	21,035	0	222	0	3,469	0	0	0	308	3,950	66	0	0	0	12,530	150	41,730
1994	67,679	0	1,732	0	7,805	0	0	0	321	37,251	123	0	0	0	12,078	2,705	129,693
1995	14,191	0	73	0	4,628	0	0	0	322	4,176	66	0	0	0	11,638	0	35,094
1996	1,095	0	175	0	2,475	0	0	0	322	4,726	143	0	0	2,373	13,642	0	24,950
1997	0	0	0	0	2,406	0	0	0	322	4,261	112	0	0	5,824	13,962	0	26,887
1998	245	0	0	0	1,008	0	0	0	307	318	232	0	0	1,499	13,404	76	17,089
1999	915	0	0	0	2,099	0	0	0	333	773	105	0	0	1,241	14,692	2,806	22,963
2000	2,119	0	855	0	6,406	0	0	0	336	15,864	81	0	0	689	17,125	0	43,475
2001	100,492	19,482	6,115	13,950	8,533	0	0	86,404	350	61,988	103	52,034	0	0	15,714	6,507	371,673
2002	86,809	3,436	4,453	13,972	10,047	0	0	24,664	360	70,804	94	9,578	0	2,082	16,247	0	242,545
2003	30,906	0	1,619	3,211	5,484	1,892	0	53,591	364	21,811	56	16,181	0	2,828	17,733	24	155,699
2004	75,399	0	3,848	7,147	8,920	3,345	0	27,736	393	49,888	120	1,985	0	2,879	20,809	41	202,510
2005	25,104	589	430	0	3,563	0	0	21,553	400	6,121	111	12,951	0	2,145	20,843	0	93,809
2006	174	0	228	0	4,202	0	0	0	416	2,645	77	0	0	156	22,108	0	30,007
2007	101,515	23,022	5,858	10,000	11,039	6,220	0	167,291	419	88,841	149	54,150	2,302	0	23,107	0	493,914
2008	141,081	27,850	6,066	13,400	12,222	9,478	9,744	246,249	423	100,465	115	77,533	7,470	0	22,340	0	674,436
2009	128,043	29,745	5,315	9,086	742	5,582	15,117	166,703	389	111,798	144	78,033	6,001	449	21,629	0	578,777
2010	37,081	15,117	841	3,896	2,078	1,886	4,466	97,576	362	20,897	112	41,021	0	375	21,334	0	247,041
2011	445	0	290	0	146	0	0	0	378	683	115	0	0	500	20,801	1,037	24,395
2012	43,589	6,362	1,835	3,960	2,058	1,319	3,148	94,381	393	103,236	107	14,257	0	0	21,107	14,579	310,330
2013	123,971	1,379	4,261	5,571	20,994	2,252	19,809	171,627	373	146,543	118	41,743	14,231	0	19,494	16,518	588,883
2014	146,319	23,891	3,269	7,997	18,120	30,884	34,160	183,235	359	133,769	472	78,603	21,604	0	33,129	16,020	731,830
2015	123,618	26,298	1,267	3,516	24,146	38,294	32,918	154,687	358	118,342	109	56,634	17,237	0	20,344	13,857	631,624

TABLE 6 - Summary of data input for groundwater pumping for basin export by water district applied to C2VSimFG-Kern Historical Simulation

Water Year	Arvin-Edison WSD to Aqueduct	DWR to Aqueduct	North Kern WSD to Friant-Kern Canal	Rosedale Rio Brave WSD to CVC	Semi-tropic WSD to Aqueduct	Wheeler Ridge - Maricopa WSD to Aqueduct	County of Kern to BVARA	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	0	0	0	0	0	0	0	2,056
1987	0	0	0	0	0	0	673	63,724
1988	0	0	0	0	0	0	6,301	96,193
1989	0	0	0	0	0	0	5,879	120,544
1990	0	0	0	0	0	0	8,836	156,097
1991	0	0	0	0	0	0	22,114	170,307
1992	0	0	0	0	0	0	25,025	184,191
1993	0	0	0	0	0	0	7,521	28,892
1994	0	0	0	0	0	0		117,295
1995	0	2,319	0	0	0	0	4,748	23,134
1996	0	0	0	0	0	0	0	10,986
1997	0	0	0	0	0	0	0	12,603
1998	0	0	0	0	0	0	0	3,378
1999	0	0	0	0	0	0	0	7,938
2000	0	0	0	0	0	0	56	26,013
2001	0	0	0	0	1,457	638	10,024	355,608
2002	0	0	0	0	21,819	0	22,402	225,938
2003	12,380	0	0	0	0	0	9,886	137,602
2004	11,573	0	0	0	8,965	0	13,643	181,308
2005	13,939	0	0	0	19,103	0	6,071	72,567
2006	0	0	0		0	0	0	7,482
2007	7,609	0	7,276	0	6,282	0	10,437	470,388
2008	42,615	0	4,612	0	92,169	0	17,351	651,673
2009	43,080	0	5,880	0	86,194	7,243	7,786	556,758
2010	56,229	0	73	0	37,995	12,404	7,019	225,345
2011	16,065	0	0	0	0	0	369	3,217
2012	10,010	0	6,803	0	0	1,340	1,889	288,831
2013	15,111	0	7,471	12,116	5,610	3,815	9,786	569,016
2014	45,195	0	12,071	28,818	95,611	18,236	21,567	698,342
2015	67,142	0	9,752	26,314	89,453	26,943	23,330	610,923

TABLE 7 - Summary of population data input by urban zone applied to C2VSimFG-Kern Historical Simulation

Water Year	Urban Zone 97	Urban Zone 98	Urban Zone 99	Urban Zone 100	Urban Zone 102	Urban Zone 103	Urban Zone 104	Urban Zone 105	Urban Zone 106	Total	Annual Growth Rate
	Population	Population	Population	Population	Population	Population	Population	Population	Population	Population	percent
1985	18,266	4,545	54,766	199	11,589	1,845	15,756	443	229,085	336,493	
1986	18,506	4,565	56,021	184	11,631	1,868	16,127	443	245,095	354,441	5.3%
1987	18,747	4,586	57,277	170	11,673	1,892	16,498	443	261,105	372,389	5.1%
1988	18,987	4,607	58,532	155	11,715	1,915	16,869	442	277,114	390,337	4.8%
1989	19,227	4,627	59,788	141	11,758	1,939	17,240	442	293,124	408,285	4.6%
1990	19,467	4,648	61,043	126	11,800	1,962	17,611	442	309,134	426,233	4.4%
1991	19,808	4,662	64,110	132	12,190	2,023	17,570	475	316,532	437,502	2.6%
1992	20,150	4,676	67,178	138	12,581	2,084	17,528	507	323,930	448,771	2.6%
1993	20,491	4,690	70,245	144	12,971	2,145	17,487	540	331,328	460,041	2.5%
1994	20,832	4,704	73,313	150	13,362	2,206	17,445	572	338,726	471,310	2.4%
1995	21,174	4,718	76,380	156	13,752	2,268	17,404	605	346,124	482,579	2.4%
1996	21,515	4,732	79,447	161	14,142	2,329	17,363	637	353,522	493,848	2.3%
1997	21,856	4,746	82,515	167	14,533	2,390	17,321	670	360,920	505,117	2.3%
1998	22,197	4,760	85,582	173	14,923	2,451	17,280	702	368,318	516,387	2.2%
1999	22,539	4,774	88,650	179	15,314	2,512	17,238	735	375,716	527,656	2.2%
2000	22,880	4,788	91,717	185	15,704	2,573	17,197	767	383,114	538,925	2.1%
2001	23,154	4,887	94,141	193	16,313	2,601	17,609	742	395,409	555,047	3.0%
2002	23,429	4,985	96,564	200	16,922	2,628	18,020	717	407,703	571,169	2.9%
2003	23,703	5,084	98,988	208	17,532	2,656	18,432	692	419,998	587,291	2.8%
2004	23,977	5,182	101,412	215	18,141	2,683	18,844	667	432,292	603,413	2.7%
2005	24,252	5,281	103,836	223	18,750	2,711	19,256	643	444,587	619,536	2.7%
2006	24,526	5,379	106,259	230	19,359	2,738	19,667	618	456,882	635,658	2.6%
2007	24,800	5,478	108,683	238	19,968	2,766	20,079	593	469,176	651,780	2.5%
2008	25,074	5,576	111,107	245	20,578	2,793	20,491	568	481,471	667,902	2.5%
2009	25,349	5,675	113,530	253	21,187	2,821	20,902	543	493,765	684,024	2.4%
2010	25,623	5,773	115,954	260	21,796	2,848	21,314	518	506,060	700,146	2.4%
2011	25,815	5,802	117,403	261	21,959	2,862	21,474	519	512,386	708,482	1.2%
2012	26,009	5,831	118,871	261	22,124	2,877	21,635	521	518,791	716,919	1.2%
2013	26,204	5,860	120,357	262	22,290	2,891	21,797	522	525,275	725,458	1.2%
2014	26,400	5,889	121,861	263	22,457	2,905	21,961	523	531,841	734,102	1.2%
2015	26,598	5,919	123,385	263	22,626	2,920	22,125	525	538,489	742,850	1.2%

TABLE 8 - Summary of data input of per-capita water use by urban zone applied to C2VSimFG-Kern Historical simulation

Water Year	Urban Zone 97	Urban Zone 98	Urban Zone 99	Urban Zone 100	Urban Zone 102	Urban Zone 103	Urban Zone 104	Urban Zone 105	Urban Zone 106
	gdpc	gdpc	gdpc	gdpc	gdpc	gdpc	gdpc	gdpc	gdpc
1985	228	196	245	159	180	159	293	159	508
1986	228	196	245	159	180	159	293	159	480
1987	228	196	245	159	180	159	293	159	450
1988	228	196	245	159	180	159	293	159	439
1989	228	196	245	159	180	159	293	159	419
1990	228	196	245	159	180	159	293	159	438
1991	228	196	245	159	180	159	293	159	409
1992	228	196	245	159	180	159	293	159	417
1993	228	196	245	159	180	159	293	159	414
1994	228	196	245	159	180	159	293	159	421
1995	228	196	245	159	180	159	293	159	381
1996	228	196	245	159	180	159	293	159	401
1997	228	196	245	159	180	159	293	159	348
1998	228	196	245	159	180	159	293	159	304
1999	228	196	248	159	159	159	237	159	388
2000	228	196	248	159	159	159	237	159	367
2001	228	196	248	159	159	159	237	159	364
2002	228	196	248	159	159	159	237	159	362
2003	228	196	248	159	159	159	237	159	358
2004	228	196	248	159	159	159	237	159	386
2005	228	196	248	159	159	159	237	159	314
2006	228	196	248	159	159	159	237	159	338
2007	228	196	248	159	159	159	237	159	375
2008	228	196	248	159	159	159	237	159	367
2009	228	196	248	159	159	159	237	159	344
2010	228	196	248	159	159	159	237	159	328
2011	228	196	248	159	159	159	237	159	351
2012	228	196	248	159	159	159	237	159	378
2013	228	196	248	159	159	159	237	159	330
2014	228	196	248	159	159	159	237	159	314
2015	228	196	248	159	159	159	237	159	261

TABLE 9 - Summary of data input for crop evapotranspiration (ET) by crop type based on METRIC satellite data applied to C2VSimFG-Kern Historical Simulation

Water Year	Grain	Cotton	Sugar Beets	Cotton	Dry Beans	Saf-flower	Other Field Crops	Alfalfa	Pasture	Tomoto-Processed	Tomato-Fresh	Curcubits	Onions & Garlic	Potatoes	Other Truck	Almonds & Pistachios	Orchards	Citrus	Vineyards	Idle	Rice	Refuge	Urban	Native
Units	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr
1985	30.0	31.6	34.6	35.4	30.8	28.0	27.9	38.9	35.8	28.8	27.3	24.9	28.7	27.6	29.3	31.6	29.7	36.5	25.0	27.4	35.8	31.6	28.1	27.5
1986	28.2	28.9	36.4	32.8	28.0	26.2	29.2	39.3	35.5	29.8	28.8	27.7	26.5	26.2	27.9	35.1	33.6	36.8	26.9	27.1	39.3	36.2	27.8	26.8
1987	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1988	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1989	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1990	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1991	30.0	31.6	34.6	35.4	30.8	28.0	27.9	38.9	35.8	28.8	27.3	24.9	28.7	27.6	29.3	31.6	29.7	36.5	25.0	27.4	35.8	31.6	28.1	27.5
1992	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1993	28.2	28.9	36.4	32.8	28.0	26.2	29.2	39.3	35.5	29.8	28.8	27.7	26.5	26.2	27.9	35.1	33.6	36.8	26.9	27.1	39.3	36.2	27.8	26.8
1994	29.5	34.0	36.9	37.0	31.9	24.0	36.5	37.6	31.4	32.4	27.3	27.4	34.1	28.7	31.6	37.2	37.5	38.7	29.1	33.3	26.6	23.9	27.0	27.3
1995	30.1	32.4	35.8	34.4	30.7	26.6	30.7	36.6	32.6	29.4	29.0	28.1	33.1	27.4	30.2	35.8	35.5	35.8	28.7	32.2	31.6	36.3	27.5	29.6
1996	35.0	37.1	39.7	39.2	38.2	32.6	35.8	42.3	38.7	36.1	32.7	28.7	35.3	30.4	33.0	39.3	40.1	39.4	32.1	32.8	34.1	36.4	30.2	31.0
1997	31.3	35.5	39.1	37.7	33.9	29.3	37.2	43.5	36.0	33.2	28.1	28.8	29.7	28.8	30.1	33.7	34.0	38.1	26.1	30.6	34.1	34.0	28.1	31.1
1998	28.2	28.9	36.4	32.8	28.0	26.2	29.2	39.3	35.5	29.8	28.8	27.7	26.5	26.2	27.9	35.1	33.6	36.8	26.9	27.1	39.3	36.2	27.8	26.8
1999	30.0	31.6	34.6	35.4	30.8	28.0	27.9	38.9	35.8	28.8	27.3	24.9	28.7	27.6	29.3	31.6	29.7	36.5	25.0	27.4	35.8	31.6	28.1	27.5
2000	31.1	34.6	36.0	33.2	29.4	28.7	33.8	44.0	38.6	32.2	32.3	27.3	30.5	29.4	29.5	37.0	34.6	41.0	28.9	27.6	41.2	31.4	32.3	33.0
2001	31.9	33.4	36.3	32.0	29.3	27.2	32.1	44.5	33.8	30.2	29.9	26.5	28.8	28.1	28.8	39.9	36.0	40.7	29.7	28.0	41.7	30.8	30.5	31.6
2002	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
2003	33.0	35.5	35.6	33.2	33.5	28.0	31.7	42.9	30.6	31.0	26.2	27.8	29.7	27.2	28.4	39.6	32.8	38.8	30.4	29.7	37.0	32.1	28.5	30.4
2004	34.5	36.6	37.3	33.5	33.3	32.8	35.6	46.4	36.1	33.1	26.4	26.1	32.4	30.3	33.1	44.2	36.7	40.0	33.1	35.5	39.0	31.5	30.1	32.4
2005	31.8	35.4	40.6	30.5	31.8	27.8	33.0	40.7	32.3	28.4	23.7	26.8	29.6	28.4	28.0	35.1	30.2	34.8	28.0	29.6	37.3	34.1	28.2	30.0
2006	30.9	33.7	33.7	31.4	31.3	24.9	31.1	41.4	33.2	25.4	26.9	29.5	26.9	31.9	28.2	33.9	28.6	35.0	27.6	27.3	39.6	39.3	27.9	29.0
2007	34.3	36.5	33.9	36.1	31.6	28.9	35.3	44.1	35.3	29.4	24.4	26.7	29.1	27.8	32.5	34.5	29.6	37.6	29.6	29.7	38.0	34.0	27.7	31.5
2008	35.2	34.1	30.6	35.3	29.7	25.1	36.0	43.8	37.2	28.0	25.1	25.7	29.7	29.1	31.3	33.2	31.5	37.9	29.6	26.9	34.2	29.9	28.3	31.4
2009	35.3	34.1	25.1	34.2	32.4	32.6	33.9	42.2	30.9	26.5	24.4	24.9	27.1	29.3	29.6	34.5	31.9	37.8	30.4	28.9	35.8	30.5	27.9	32.0
2010	31.6	28.9	25.8	30.2	28.5	23.7	29.8	38.7	26.8	23.2	23.4	26.2	25.4	26.5	27.0	37.3	31.0	35.5	32.3	28.3	33.7	30.8	27.1	30.2
2011	30.1	28.2	23.9	28.3	27.0	21.8	29.6	36.0	25.1	22.6	27.0	24.4	25.5	25.8	25.2	36.2	32.0	33.6	30.9	26.6	38.1	33.6	26.9	32.7
2012	30.2	27.3	22.5	28.7	26.3	23.0	31.0	35.8	26.1	22.6	28.1	24.3	25.8	26.1	26.1	36.6	31.7	33.9	31.2	26.0	38.4	33.8	27.5	33.0
2013	35.7	35.5	28.0	34.7	32.7	33.2	36.4	44.0	33.1	27.2	30.7	29.1	32.4	30.1	30.1	43.6	35.5	39.9	38.6	29.5	36.3	36.8	29.1	35.2
2014	33.9	33.6	25.2	32.9	28.4	28.8	36.0	40.4	28.8	25.2	28.2	28.3	28.6	28.7	29.8	42.5	33.0	37.8	34.1	28.5	36.0	35.8	29.2	34.2
2015	33.4	34.2	28.3	36.3	31.9	33.9	37.0	43.2	29.0	24.0	26.4	27.1	34.8	27.5	30.7	38.8	31.8	38.3	31.0	28.1	29.6	32.2	27.9	32.4
Average	**32.4**	**33.4**	**33.0**	**33.4**	**30.9**	**27.8**	**32.9**	**41.5**	**33.0**	**28.8**	**27.5**	**26.9**	**29.3**	**28.5**	**29.5**	**37.3**	**33.3**	**37.7**	**30.3**	**29.1**	**37.1**	**33.6**	**28.8**	**31.3**
BETA	**21.6**	**39.8**	**39.2**	**32.3**	**31.1**	**34.9**	**36.4**	**48.0**	**50.4**	**31.6**	**40.6**	**32.0**	**36.5**	**35.4**	**31.6**	**48.1**	**45.9**	**42.5**	**42.0**	**57.1**	**50.2**	**76.1**	**52.0**	**57.1**
Difference	**10.8**	**-6.4**	**-6.3**	**1.1**	**-0.2**	**-7.2**	**-3.5**	**-6.5**	**-17.4**	**-2.8**	**-13.0**	**-5.0**	**-7.2**	**-6.9**	**-2.1**	**-10.9**	**-12.6**	**-4.8**	**-11.7**	**-28.0**	**-13.1**	**-42.6**	**-23.2**	**-25.8**

TABLE 10 - Summary of C2VSimFG-Beta modifications in the Kern County Revision applied to C2VSimFG-Kern by IWFM model input file

File Name	Change to Model Input File
C2VSimFG.in	
*	Change simulation starting time to 09/30/1985_24:00
C2VSimFG_Unsat.dat	
*	Replaced initial condition values with more representative values for revised starting
C2VSimFG_SWatersheds.dat	
*	Modified parameters to improve stream discharge match to historical values
C2VSimFG_Groundwater1985.dat	
*	Added hydrologic flow barrier at White Wolf Fault
*	Set Corcoran Clay thickness to 0 ft in areas where it is not present
*	New 10/1/1985 initial condition
*	Modified hydraulic conductivity and specific storage in Layer 1 in the Kern Water Bank
*	Kern County observation wells
C2VSimFG_ElemPump.dat	
*	FRACSK and DSTSK modified for Kern County elements with limited pumping
C2VSimFG_WellSpec.dat	
*	Added Kern County groundwater water bank recovery wells
*	Added Kern County In-District and Urban wells
C2VSimFG_PumpRates.dat	
*	Added Kern County groundwater water bank recovery pumping
*	Added Kern County In-District and Urban pumping
C2VSimFG_StreamInflow.dat	
*	Exteneded Poso Creek inflow through WY2015
C2VSimFG_DiverionSpec.dat	
*	Removed all Kern County diversions and renumbered remaining diversions to 1-371
*	Added Kern County diersions 372-484
C2VSimFG_Diverions.dat	
*	Removed all Kern County diversions and renumbered remaining diversions to 1-371
*	Added Kern County diersions 372-484
*	Updated diversion data for all diversions to Kern County
C2VSimFG_BypassSpecs.dat	
*	Removed bypass #17
C2VSimFG_RootZone.dat	
*	Native return flow is sent to either nearby stream nodes as runoff or out-of-model as ET
C2VSimFG_IrrPeriod.dat	
*	Adjusted Kern County irrigation periods
C2VSimFG_ReturnFlowFrac.dat	
*	Modified Kern County Ag return flow fraction
C2VSimFG_Urban.dat	
*	Added zone 106 for Metro Bakersfield and adjusted other Kern County zone areas
*	Applied estimated September 1985 initial condition

TABLE 10 - Summary of C2VSimFG-Beta modifications in the Kern County Revision applied to C2VSimFG-Kern by IWFM model input file

File Name	Change to Model Input File
C2VSimFG_Urban_Area.dat	
*	Changed Kern County oil fields from urban to native vegetation
C2VSimFG_Urban_PerCapWaterUse.dat	
*	Updated population for Kern County Urban Zones based on 1990, 2000, 2010 Census
*	Developed demands from historical data and water management plans
C2VSimFG_Urban_Population.dat	
*	Updated population for Kern County Urban Zones based on 1990, 2000, 2010 Census
C2VSimFG_Urban_WaterUseSpecs.dat	
*	Set fractions for SRs 19-21 based on local info
C2VSimFG_NonPondedCrop.dat	
*	Return flow = 0 for Kern County
C2VSimFG_NonPondedCrop_Area.dat	
*	Revided crop distributions to match historical distribution
C2VSimFG_PondedCrop_Area.dat	
*	Modified distribution of rice to be limited to areas in northwest Kern County with
C2VSimFG_NativeVeg_Area.dat	
*	Rebalanced native veg distribution after redistribution of non-ponded crop area to

Table 11A - Historical Groundwater Budget for the Kern County Subbasin for Water Years 1995 to 2014 based on the C2VSimFG-Kern Historical Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	GW Pumping	Small Watershed Inflow	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1995	880,480	944,800	185,777	-946,782	122,287	-75,299	1,111,263
1996	801,572	926,537	106,692	-1,247,471	41,190	-84,675	543,845
1997	766,667	771,510	126,405	-1,068,169	50,548	-87,372	559,587
1998	1,034,867	1,097,180	121,413	-884,593	155,312	-87,515	1,436,665
1999	755,674	633,676	39,704	-1,109,310	32,155	-85,211	266,692
2000	617,018	462,522	91,454	-1,375,733	25,956	-83,759	-262,541
2001	551,880	222,131	66,647	-1,839,000	24,633	-81,896	-1,055,605
2002	466,463	202,687	76,147	-1,760,186	18,882	-83,943	-1,079,950
2003	502,831	297,019	118,149	-1,492,816	34,003	-85,638	-626,452
2004	488,327	284,862	83,294	-1,860,344	27,959	-89,250	-1,065,153
2005	799,614	1,147,287	132,785	-1,108,382	93,557	-89,912	974,946
2006	839,390	1,125,277	44,657	-1,149,877	40,846	-96,591	803,702
2007	560,860	403,611	26,260	-2,099,953	17,882	-91,566	-1,182,908
2008	463,721	146,763	78,841	-2,341,780	36,058	-86,260	-1,702,659
2009	485,234	186,548	73,848	-2,206,377	21,586	-85,764	-1,524,923
2010	599,434	467,683	141,715	-1,470,205	58,145	-94,664	-297,892
2011	1,073,963	1,530,123	259,404	-984,968	118,303	-94,981	1,901,842
2012	713,826	580,590	88,581	-1,583,369	19,020	-93,041	-274,395
2013	538,356	156,704	59,483	-2,447,479	19,043	-83,619	-1,757,511
2014	447,782	84,456	50,857	-2,830,674	17,832	-81,081	-2,310,831
Total	**13,387,959**	**11,671,966**	**1,972,113**	**-31,807,470**	**975,198**	**-1,742,039**	**-5,542,280**
Average	**669,398**	**583,598**	**98,606**	**-1,590,373**	**48,760**	**-87,102**	**-277,114**

Table 11B - Current Groundwater Budget for the Kern County Subbasin for Water Year 2015 based on the C2VSimFG-Kern Historical Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	GW Pumping	Subsurface Flow within GW Basin	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
2015	429,983	89,744	46,344	-2,740,237	0	-51,201	-2,225,366

NOTES:

Deep Percolation	Precipitation and applied water that reaches the groundwater after simulated transport across the unsaturated zone
Managed Recharge and Canal Seepage	Combined groundwater recharge from managed aquifer recharge operations, groundwater banking, and seepage from canals and other conveyance
Net GW/SW Interactions	Net volumetric exchange of surface water and groundwater from streams: Positive represents a net groundwater recharge, and negative represents a net groundwater discharge to the stream
GW Pumping	Total groundwater pumping by wells. Groundwater banking recovery pumping is specified input whereas agricultural and municipal pumping is calculated by C2VSim based on demand
Subsurface Flow within GW Basin	Net subsurface groundwater flow into a neighboring water district or area within the Kern County Subbasin: negative is a net flow out of the district and positive is a net flow into the district
Subsurface Flow with Adjacent GW Basins	Net subsurface groundwater flow from the Kern County Subbasin with an adjoining groundwater basin: negative is a net flow out of the Basin and positive is a net flow into the Basin
Change in Groundwater Storage	Sum of the inflow components (positive numbers) plus the outflow components (negative numbers): positive is an increase in storage typified by a rise in GW levels whereas a negative is a decrease in storage typified by a decline in GW levels

TABLE 12: Estimated sustainable yield for Kern County Subbasin for WY1995 to WY2014 Base Period based on C2VSimFG-Kern Historical Simulation

Water Year	Total Average Annual Volume	Agricultural Average Annual Volume	Agricultural Average Annual Volume per Ag Acre	Urban Average Annual Volume
Units	Acre-ft	Acre-ft	ft/acre	Acre-ft
	Sustainable Yield from Groundwater Pumping			
Groundwater Pumping	1,590,373	1,239,931	1.59	176,146
Percentage of Pumping		78%		11%
Change in Groundwater in Storage	-277,114	-216,051	-0.28	-30,692
Percentage of Pumping		-17%		-17%
Sustainable Yield	**1,313,259**	**1,023,880**	**1.31**	**145,453**
Average Annual Difference	**-277,114**	**-216,051**	**-0.28**	**-30,693**
Percent Difference	**-21%**	**-21%**	**-21%**	**-21%**
	Sutainable Yield from Basin Recharge and Outflow			
Groundwater Recharge	1,400,362	1,091,789	1.40	155,101
Subsurface Outflow	-87,102	-67,909	-0.09	-9,647
Sustainable Yield	**1,313,260**	**1,023,880**	**1.31**	**145,453**
Average Annual Difference	**-277,114**	**-216,051**	**0**	**-30,692**
Percent Difference	**0**	**0**	**0**	**0**

NOTES:

Sustainable Yield from Groundwater Pumping Approach assumes that adjusting total groundwater pumping by the change in storage provides an reasonable approximation of the Basin Sustainable

Sutainable Yield from Basin Recharge and Outflow Approach assumes that the Basin Sustainable Yield can be reasonably approximated by adding up the different recharge components and non-

TABLE 13: Estimate of potential native yield for Kern County Subbasin for WY1995 to WY2014 based on C2VSimFG-Kern Historical Simulation

	Ag Precipitation Recharge			Other Area Precipitation Recharge			Small Watershed Inflows			
Water Year	Precipitation in Agricultural Area	Precipitation to ET Demand	Precipitation to Groundwater in Agricultural Area	Precipitation in Other Areas	Precipitation to ET Demand	Precipitation to Groundwater in Other Areas	Small Watershed Subsurface Inflow	Small Watershed Runoff Percolation	Small Watershed Recharge to Groundwater	Native Yield
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1995	702,794	521,974	180,820	1,108,386	824,558	283,828	17,540	104,746	122,287	586,934
1996	381,496	351,540	29,956	526,809	422,541	104,268	17,512	23,679	41,190	175,414
1997	482,117	356,589	125,528	637,266	487,128	150,138	17,524	33,024	50,548	326,214
1998	966,485	663,632	302,853	1,492,576	1,024,918	467,658	17,840	137,472	155,312	925,823
1999	433,456	400,669	32,786	589,454	464,061	125,393	17,812	14,343	32,155	190,334
2000	384,158	357,496	26,661	476,308	398,994	77,315	17,757	8,200	25,956	129,933
2001	431,757	353,840	77,917	579,440	488,081	91,358	17,722	6,911	24,633	193,908
2002	255,111	227,877	27,234	382,463	317,069	65,394	17,679	1,203	18,882	111,510
2003	400,953	331,300	69,653	599,314	506,451	92,863	17,683	16,320	34,003	196,519
2004	301,023	275,258	25,765	422,514	339,652	82,862	17,661	10,298	27,959	136,586
2005	653,833	486,132	167,701	964,382	785,465	178,917	17,808	75,750	93,557	440,175
2006	499,756	447,319	52,437	657,647	546,950	110,697	17,783	23,063	40,846	203,981
2007	216,658	227,752	-11,095	292,814	241,483	51,331	17,725	157	17,882	58,119
2008	189,035	170,649	18,385	305,703	248,514	57,189	17,697	18,361	36,058	111,633
2009	268,010	221,348	46,663	405,160	336,116	69,044	17,674	3,913	21,586	137,293
2010	457,031	346,082	110,949	683,456	543,580	139,876	17,731	40,414	58,145	308,969
2011	649,878	441,717	208,161	1,023,701	692,781	330,919	17,932	100,370	118,303	657,382
2012	335,227	299,191	36,036	446,686	372,675	74,012	17,851	1,169	19,020	129,067
2013	214,951	203,005	11,946	303,560	246,644	56,916	17,787	1,257	19,043	87,906
2014	167,800	152,566	15,234	263,824	214,181	49,642	17,713	120	17,832	82,708
Total	**8,391,529**	**6,835,938**	**1,555,591**	**12,161,462**	**9,501,842**	**2,659,620**	**354,429**	**620,769**	**975,198**	**5,190,409**
Average	**419,576**	**341,797**	**77,780**	**608,073**	**475,092**	**132,981**	**17,721**	**31,038**	**48,760**	**259,520**
Use (ft/acre)	**0.54**	**0.44**	**0.10**	**0.59**	**0.46**	**0.13**	**0.01**	**0.02**	**0.03**	**0.144**

NOTES:

Simulation of Recharge	IWFM applies two processes to simulate the movement of water from the surface to the groundwater. The root zone simulates calculates the volume of water that will percolate below the root zone based on local soil properties. This water bases to the unsaturated zone that applies a 1-D vadose zone flow that simulates the rate that water will reach the groundwater based on subsurface properties and soil moisture content.
Percolation from Agricultural Area	Total volume of rainfall and applied water calculated to meet the total agricultural demand that percolates below the root zone in irrigated agricultural areas based on C2VSim simulation.
Percolation from Urban Area	Total volume of rainfall and applied water calculated to meet urban outdoor use that percolates below the root zone in urban areas based on C2VSim simulation.
Percolation from Native, Undeveloped or Fallow Areas	Total volume of rainfall and applied water that percolates below the root zone in native, undeveloped and fallow areas based on C2VSim simulation.
Percolation to Unsaturated Zone	Total volume of rainfall and applied water that percolates below the root zone from all areas based on C2VSim simulation.
GW Recharge from Unsaturated Zone	Volume of water going from the unsaturated zone to groundwater
GW Banking, Managed Recharge and Canal Seepage	Managed aquifer recharge and groundwater banking is simulated in C2VSim by applying a high recoverable loss factor for surface water diversions. For Kern County, these operations generally assumes that 88% to 94% of surface water deliveries physically recharge groundwater. This recharge is applied directly to the groundwater without passing through the unsaturated zone.
Net GW/SW Interactions	Net volumetric exchange between surface water in Kern River or Poso Creek and the groundwater. A positive number is surface water to groundwater, and a negative is groundwater discharge to the stream. This recharge is applied directly to the groundwater without passing through the unsaturated zone.
Total GW Recharge	Total volume to water reaching the groundwater as recharge

Table 14 - Hydrologic year correlation with relevant river indices for projected-future simulation period

Project Year	Hydrology Year	Annual Kern River Index	San Joaquin River Index
2021	**2003**	71	Below Normal
2022	**2004**	56	Dry
2023	**2005**	159	Wet
2024	**2006**	147	Wet
2025	**2007**	35	Critical
2026	**2008**	71	Critical
2027	**2009**	65	Below Normal
2028	**2010**	126	Above Normal
2029	**2011**	201	Wet
2030	**2012**	45	Dry
2031	**2013**	28	Critical
2032	**2014**	24	Critical
2033	**1995**	191	Wet
2034	**1996**	136	Wet
2035	**1997**	162	Wet
2036	**1998**	236	Wet
2037	**1999**	60	Above Normal
2038	**2000**	66	Above Normal
2039	**2001**	54	Dry
2040	**2002**	58	Dry
2041	**2003**	71	Below Normal
2042	**2004**	56	Dry
2043	**2005**	159	Wet
2044	**2006**	147	Wet
2045	**2007**	35	Critical
2046	**2008**	71	Critical
2047	**2009**	65	Below Normal
2048	**2010**	126	Above Normal
2049	**2011**	201	Wet
2050	**2012**	45	Dry
2051	**2013**	28	Critical
2052	**2014**	24	Critical
2053	**1995**	191	Wet
2054	**1996**	136	Wet
2055	**1997**	162	Wet
2056	**1998**	236	Wet
2057	**1999**	60	Above Normal
2058	**2000**	66	Above Normal
2059	**2001**	54	Dry
2060	**2002**	58	Dry
2061	**2003**	71	Below Normal
2062	**2004**	56	Dry
2063	**2005**	159	Wet
2064	**2006**	147	Wet
2065	**2007**	35	Critical
2066	**2008**	71	Critical
2067	**2009**	65	Below Normal
2068	**2010**	126	Above Normal
2069	**2011**	201	Wet
2070	**2012**	45	Dry

Table 16 - Projected Future Groundwater Budget for Kern County Subbasin under Baseline Conditions with NO SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net Stream GW/SW Interaction	Net Small Watershed Recharge	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	31,276,668	27,591,218	6,284,636	2,457,805	-80,359,227	-3,647,996	**-16,396,918**
Average	625,533	551,824	125,693	49,156	-1,607,185	-72,960	**-327,938**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	12,059,157	10,900,930	2,570,048	948,239	-31,618,403	-1,527,102	**-6,667,151**
Average	602,958	545,046	128,502	47,412	-1,580,920	-76,355	**-333,358**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	19,217,510	16,690,288	3,714,588	1,509,566	-48,740,823	-2,120,894	**-9,729,767**
Average	640,584	556,343	123,820	50,319	-1,624,694	-70,696	**-324,326**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	421,248	253,922	124,080	38,770	-1,605,058	-83,845	-850,883
2022	466,065	311,661	80,807	28,596	-1,881,001	-79,540	-1,073,415
2023	670,267	894,337	186,631	97,803	-1,082,942	-77,289	688,801
2024	782,933	971,636	250,700	67,141	-1,004,008	-81,747	986,650
2025	487,829	334,264	74,696	18,060	-1,956,094	-78,483	-1,119,730
2026	440,342	154,936	78,551	36,473	-2,258,997	-69,511	-1,618,207
2027	522,430	255,426	73,629	21,942	-1,995,091	-69,397	-1,191,063
2028	569,509	496,227	141,957	35,496	-1,490,383	-70,383	-317,575
2029	1,025,597	1,528,921	110,823	119,558	-891,968	-80,187	1,812,744
2030	692,430	587,522	63,468	19,157	-1,382,783	-79,634	-99,841
2031	550,146	164,041	109,295	19,161	-2,366,434	-73,780	-1,597,574
2032	459,496	111,528	66,581	18,134	-2,763,485	-65,268	-2,173,015
2033	742,600	875,129	188,075	126,420	-1,059,514	-71,675	801,034
2034	617,059	786,754	201,477	42,156	-1,422,316	-78,762	146,370
2035	691,055	727,363	294,732	52,652	-1,120,121	-82,586	563,094
2036	848,018	1,151,100	175,108	103,683	-890,760	-84,597	1,302,552
2037	617,636	539,499	102,463	32,114	-1,230,808	-82,549	-21,645
2038	517,060	379,550	106,226	26,241	-1,390,747	-77,398	-439,070
2039	495,144	190,829	65,868	25,370	-1,883,912	-72,405	-1,179,106
2040	442,293	186,285	74,884	19,311	-1,941,979	-68,067	-1,287,273
2041	466,980	254,002	124,912	34,980	-1,621,935	-66,834	-807,894
2042	519,154	311,722	81,095	28,467	-1,928,066	-66,378	-1,054,007
2043	723,193	894,377	183,602	100,835	-1,131,893	-66,724	703,389
2044	829,429	971,656	217,998	68,630	-1,055,212	-73,234	959,267
2045	520,072	334,263	67,722	18,136	-2,005,971	-71,742	-1,137,519
2046	465,742	154,936	78,954	36,599	-2,308,492	-64,094	-1,636,355
2047	542,433	255,426	73,991	22,117	-2,044,767	-65,020	-1,215,821
2048	587,534	496,227	142,442	35,645	-1,539,937	-66,665	-344,754
2049	1,038,285	1,528,924	111,871	121,871	-940,873	-77,190	1,782,886
2050	704,906	587,522	63,577	19,216	-1,430,758	-77,175	-132,713
2051	567,160	164,041	109,977	19,218	-2,411,967	-71,447	-1,623,019
2052	480,958	111,528	66,775	18,007	-2,776,754	-63,069	-2,162,556
2053	756,460	875,129	189,903	127,393	-1,105,182	-69,591	774,112
2054	629,422	786,754	203,667	42,236	-1,466,597	-76,937	118,546
2055	697,412	727,363	297,238	52,738	-1,163,909	-81,081	529,760
2056	955,260	1,151,202	186,248	169,221	-887,932	-83,323	1,490,676
2057	663,489	539,499	104,143	33,376	-1,272,005	-81,579	-13,077
2058	543,714	379,550	107,428	26,454	-1,432,264	-76,504	-451,623
2059	516,904	190,829	65,982	25,586	-1,924,204	-71,122	-1,196,025
2060	461,832	186,285	75,033	19,353	-1,923,734	-66,838	-1,248,069
2061	483,873	254,002	125,183	34,990	-1,662,322	-65,509	-829,782
2062	535,495	311,722	81,199	28,658	-1,968,451	-64,883	-1,076,261
2063	747,374	894,377	185,862	103,344	-1,173,248	-65,287	692,423
2064	797,596	971,656	227,478	42,092	-1,131,322	-72,135	835,365
2065	518,644	334,263	69,814	18,276	-2,046,917	-70,907	-1,176,825
2066	472,700	154,936	79,262	36,483	-2,350,004	-63,321	-1,669,944
2067	550,095	255,426	74,266	22,151	-2,087,215	-64,426	-1,249,703
2068	654,126	496,227	142,653	60,396	-1,488,744	-65,173	-200,515
2069	1,067,944	1,528,924	112,385	123,705	-984,856	-76,302	1,771,799
2070	719,324	587,522	63,930	19,394	-1,475,294	-76,404	-161,529

Table 17 - Projected Future Groundwater Budget for Kern County Subbasin under Baseline Conditions WITH SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	33,771,527	32,630,931	5,233,643	2,457,805	-69,157,708	-5,025,601	**-89,422**
Average	675,431	652,619	104,673	49,156	-1,383,154	-100,512	**-1,788**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	13,100,548	12,612,730	2,239,160	948,239	-28,535,055	-1,719,340	**-1,353,732**
Average	655,027	630,637	111,958	47,412	-1,426,753	-85,967	**-67,687**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	20,670,979	20,018,200	2,994,483	1,509,566	-40,622,653	-3,306,261	**1,264,311**
Average	689,033	667,273	99,816	50,319	-1,354,088	-110,209	**42,144**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	430,153	302,373	123,650	38,770	-1,594,606	-83,189	-782,849
2022	475,303	349,553	80,614	28,596	-1,862,120	-78,565	-1,006,617
2023	770,374	1,002,929	168,647	97,803	-1,009,264	-78,404	952,085
2024	855,058	1,086,448	198,849	67,141	-944,665	-84,319	1,178,512
2025	503,643	350,298	70,663	18,060	-1,861,303	-81,925	-1,000,565
2026	440,243	214,542	77,894	36,473	-2,187,564	-73,190	-1,491,603
2027	518,989	316,584	73,092	21,942	-1,919,158	-73,183	-1,061,733
2028	578,749	623,230	137,529	35,496	-1,407,567	-75,335	-107,901
2029	1,194,895	1,696,947	83,255	119,558	-744,743	-87,273	2,262,638
2030	750,668	608,048	58,365	19,157	-1,257,759	-87,531	90,947
2031	555,404	180,833	107,613	19,161	-2,187,295	-83,584	-1,407,869
2032	453,293	125,476	66,634	18,134	-2,567,449	-76,460	-1,980,378
2033	824,902	1,059,059	172,274	126,420	-840,738	-84,135	1,257,782
2034	653,828	917,135	178,991	42,156	-1,197,621	-93,181	501,309
2035	827,370	931,556	238,868	52,652	-872,560	-98,679	1,079,205
2036	1,116,969	1,381,739	113,563	103,683	-633,072	-102,650	1,980,231
2037	725,584	594,384	63,749	32,114	-1,023,020	-100,141	292,669
2038	511,919	433,966	84,887	26,241	-1,154,051	-95,834	-192,873
2039	489,540	224,450	65,153	25,370	-1,627,860	-92,035	-915,382
2040	423,665	213,184	74,871	19,311	-1,642,642	-89,729	-1,001,340
2041	445,485	305,376	122,807	34,980	-1,354,885	-89,185	-535,423
2042	498,858	354,364	80,832	28,467	-1,639,112	-89,772	-766,363
2043	812,155	1,090,304	140,266	100,835	-882,848	-92,437	1,168,274
2044	892,628	1,153,766	138,151	68,630	-836,920	-100,949	1,315,306
2045	524,833	355,672	49,525	18,136	-1,730,147	-100,070	-882,051
2046	454,216	218,616	78,021	36,599	-2,055,875	-92,126	-1,360,549
2047	532,454	320,562	73,425	22,117	-1,809,154	-93,438	-954,033
2048	593,653	668,774	137,874	35,645	-1,324,186	-97,255	14,505
2049	1,234,198	1,750,812	79,492	121,871	-710,054	-110,080	2,366,239
2050	768,780	619,092	54,500	19,216	-1,197,582	-110,438	153,567
2051	578,825	192,400	107,098	19,218	-2,110,155	-106,461	-1,319,074
2052	479,637	135,929	66,695	18,007	-2,470,952	-99,536	-1,870,221
2053	850,038	1,095,469	170,484	127,393	-813,603	-107,867	1,321,915
2054	682,383	948,274	168,655	42,236	-1,143,633	-117,748	580,168
2055	858,469	966,141	223,989	52,738	-849,900	-123,451	1,127,986
2056	1,291,577	1,415,721	105,108	169,221	-638,704	-126,824	2,216,098
2057	807,949	600,599	52,465	33,376	-1,027,113	-123,865	343,411
2058	541,774	439,164	78,391	26,454	-1,146,168	-119,115	-179,499
2059	503,264	229,194	64,724	25,586	-1,627,673	-114,273	-919,179
2060	435,869	217,320	75,042	19,353	-1,597,610	-111,590	-961,617
2061	449,783	308,906	122,761	34,990	-1,363,117	-110,530	-557,207
2062	501,922	357,723	80,757	28,658	-1,643,414	-110,538	-784,892
2063	820,754	1,111,099	135,039	103,344	-898,437	-113,406	1,158,393
2064	871,279	1,174,447	124,818	42,092	-868,913	-122,551	1,221,172
2065	511,277	358,753	43,942	18,276	-1,750,481	-120,972	-939,204
2066	454,845	222,078	77,969	36,483	-2,077,330	-112,479	-1,398,433
2067	531,138	323,961	73,264	22,151	-1,832,363	-113,339	-995,189
2068	672,372	689,792	138,150	60,396	-1,265,870	-116,258	178,583
2069	1,286,647	1,771,462	77,455	123,705	-733,283	-129,909	2,396,076
2070	783,917	622,428	52,784	19,394	-1,223,170	-129,799	125,553

Table 18 - Projected Future Groundwater Budget for Kern County Subbasin under 2030 Climate Conditions with NO SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	30,885,159	30,404,998	6,083,382	2,517,393	-85,792,996	-3,318,618	**-19,220,714**
Average	617,703	608,100	121,668	50,348	-1,715,860	-66,372	**-384,414**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	11,956,360	12,006,382	2,488,942	967,011	-33,772,959	-1,439,420	**-7,793,706**
Average	597,818	600,319	124,447	48,351	-1,688,648	-71,971	**-389,685**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	18,928,799	18,398,617	3,594,440	1,550,382	-52,020,037	-1,879,198	**-11,427,008**
Average	630,960	613,287	119,815	51,679	-1,734,001	-62,640	**-380,900**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	422,205	264,773	147,393	42,134	-1,686,375	-82,161	-892,031
2022	486,382	352,708	97,994	31,229	-1,966,104	-77,718	-1,075,519
2023	670,731	968,807	192,300	100,122	-1,194,263	-75,163	662,531
2024	724,438	1,015,022	177,313	64,551	-1,153,552	-78,823	748,944
2025	451,579	327,176	67,822	18,068	-2,002,002	-75,206	-1,212,569
2026	443,127	213,524	132,483	37,800	-2,325,127	-67,041	-1,565,234
2027	508,495	246,268	115,977	23,732	-2,151,549	-65,434	-1,322,507
2028	572,490	566,005	191,408	39,445	-1,651,430	-65,956	-348,038
2029	1,218,648	1,901,727	112,842	122,295	-1,104,305	-76,600	2,174,607
2030	553,673	532,639	51,185	19,641	-1,476,524	-74,857	-394,243
2031	521,194	199,452	76,829	18,143	-2,339,207	-68,717	-1,592,305
2032	453,699	143,631	46,557	17,968	-2,788,464	-60,558	-2,187,167
2033	743,629	915,198	182,822	122,210	-1,190,116	-67,058	706,686
2034	615,276	872,000	147,377	45,764	-1,543,359	-73,439	63,619
2035	736,533	843,258	281,587	55,297	-1,297,450	-77,197	542,029
2036	863,933	1,264,065	123,884	102,926	-1,044,324	-79,069	1,231,416
2037	542,139	510,531	72,919	32,384	-1,342,279	-75,848	-260,154
2038	507,189	428,732	81,591	27,413	-1,503,202	-70,781	-529,059
2039	482,914	213,280	87,387	26,084	-2,017,703	-65,709	-1,273,748
2040	438,087	227,586	101,273	19,804	-1,995,626	-62,086	-1,270,964
2041	462,417	263,946	147,623	39,151	-1,702,404	-60,765	-850,032
2042	532,326	354,460	98,221	31,228	-2,012,621	-59,960	-1,056,345
2043	717,292	967,381	179,212	103,193	-1,243,088	-59,869	664,119
2044	766,402	1,015,346	117,742	65,724	-1,204,632	-65,643	694,939
2045	477,463	326,770	51,863	18,138	-2,051,621	-63,896	-1,241,282
2046	465,642	213,337	132,843	37,870	-2,374,509	-57,074	-1,581,891
2047	526,192	246,482	116,132	23,946	-2,201,023	-56,606	-1,344,877
2048	584,963	564,936	191,656	39,636	-1,700,745	-57,895	-377,449
2049	1,218,687	1,904,385	99,805	124,949	-1,152,654	-69,447	2,125,726
2050	560,761	533,577	47,140	19,693	-1,524,426	-68,362	-431,617
2051	531,733	199,452	76,920	18,193	-2,385,216	-62,565	-1,621,483
2052	469,853	139,904	46,651	17,931	-2,807,543	-54,827	-2,188,030
2053	748,982	916,702	183,503	123,682	-1,235,658	-61,582	675,628
2054	618,472	870,588	145,806	45,880	-1,587,472	-68,329	24,946
2055	736,517	843,485	279,382	55,392	-1,341,090	-72,519	501,167
2056	954,438	1,263,249	134,078	169,164	-1,037,331	-74,710	1,408,888
2057	579,927	508,121	73,014	33,640	-1,384,414	-71,487	-261,199
2058	532,403	431,547	81,726	27,628	-1,544,662	-66,368	-537,727
2059	503,820	214,669	87,386	26,299	-2,057,978	-61,126	-1,286,930
2060	456,299	228,154	101,178	19,792	-1,984,645	-57,872	-1,237,094
2061	478,968	264,126	147,695	39,158	-1,742,970	-56,708	-869,739
2062	546,856	353,554	98,263	31,426	-2,052,889	-55,984	-1,078,775
2063	740,448	969,075	181,599	104,939	-1,284,313	-56,141	655,606
2064	735,683	1,013,851	124,774	41,649	-1,277,235	-62,203	576,518
2065	478,349	327,088	54,630	18,289	-2,092,701	-60,730	-1,275,076
2066	473,836	213,074	132,845	37,782	-2,406,519	-57,164	-1,606,144
2067	537,374	246,454	116,277	23,923	-2,231,035	-58,641	-1,365,648
2068	660,267	565,258	192,661	65,542	-1,647,974	-59,014	-223,263
2069	1,254,195	1,903,367	104,892	126,664	-1,191,285	-71,013	2,126,821
2070	578,235	536,275	48,924	19,883	-1,559,383	-70,699	-446,765

Table 19 - Projected Future Groundwater Budget for Kern County Subbasin under 2030 Climate Conditions WITH SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	32,838,979	35,447,299	4,941,607	2,517,393	-73,869,518	-4,735,936	**-2,860,202**
Average	656,780	708,946	98,832	50,348	-1,477,390	-94,719	**-57,204**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	12,873,160	13,719,306	2,153,021	967,011	-30,545,188	-1,641,666	**-2,474,378**
Average	643,658	685,965	107,651	48,351	-1,527,259	-82,083	**-123,719**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	19,965,818	21,727,994	2,788,586	1,550,382	-43,324,331	-3,094,271	**-385,823**
Average	665,527	724,266	92,953	51,679	-1,444,144	-103,142	**-12,861**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	436,607	313,191	146,335	42,134	-1,676,044	-81,420	-819,196
2022	495,680	391,450	97,863	31,229	-1,947,388	-76,701	-1,007,874
2023	777,040	1,077,709	179,601	100,122	-1,117,722	-76,444	940,302
2024	808,215	1,130,101	141,980	64,551	-1,088,738	-81,861	974,238
2025	462,701	343,315	61,517	18,068	-1,906,220	-78,953	-1,099,574
2026	439,400	273,084	131,767	37,800	-2,253,887	-70,713	-1,442,550
2027	504,308	306,757	115,891	23,732	-2,068,551	-69,760	-1,187,619
2028	576,402	692,833	189,187	39,445	-1,565,005	-71,313	-138,447
2029	1,371,389	2,070,178	67,647	122,295	-932,879	-84,094	2,614,536
2030	584,511	553,212	37,888	19,641	-1,345,295	-83,321	-233,371
2031	528,715	216,234	76,879	18,143	-2,159,236	-78,674	-1,397,939
2032	447,278	157,578	46,694	17,968	-2,586,970	-72,132	-1,989,585
2033	822,633	1,099,092	179,078	122,210	-954,120	-79,949	1,188,943
2034	642,235	1,002,883	120,224	45,764	-1,314,339	-88,379	408,386
2035	882,067	1,046,864	225,239	55,297	-1,036,291	-94,244	1,078,932
2036	1,079,981	1,496,375	67,732	102,926	-748,234	-98,400	1,900,379
2037	618,298	565,459	31,639	32,384	-1,137,009	-94,427	16,344
2038	503,029	481,733	53,082	27,413	-1,262,856	-89,986	-287,584
2039	473,864	246,867	81,296	26,084	-1,751,020	-86,330	-1,009,239
2040	418,807	254,393	101,481	19,804	-1,693,383	-84,564	-983,462
2041	444,811	315,197	147,563	39,151	-1,429,438	-83,810	-566,526
2042	514,255	397,576	97,317	31,228	-1,723,016	-83,907	-766,546
2043	816,698	1,163,940	134,478	103,193	-969,015	-86,356	1,162,938
2044	847,571	1,197,675	50,668	65,724	-949,162	-94,611	1,117,864
2045	471,125	348,281	32,446	18,138	-1,769,470	-93,309	-992,789
2046	446,314	276,979	132,424	37,870	-2,116,321	-86,037	-1,308,771
2047	507,943	310,952	116,190	23,946	-1,951,408	-86,246	-1,078,625
2048	570,746	737,315	190,434	39,636	-1,454,664	-89,846	-6,380
2049	1,365,299	2,126,760	34,358	124,949	-846,645	-103,976	2,700,745
2050	579,883	565,192	23,802	19,693	-1,287,166	-103,007	-201,604
2051	538,250	227,799	76,822	18,193	-2,083,539	-98,472	-1,320,948
2052	464,011	164,305	46,977	17,931	-2,493,990	-92,183	-1,892,949
2053	839,476	1,136,728	177,834	123,682	-921,588	-100,638	1,255,494
2054	659,537	1,032,674	98,253	45,880	-1,258,249	-110,065	468,030
2055	903,882	1,081,677	208,421	55,392	-1,002,340	-116,311	1,130,721
2056	1,216,310	1,529,332	56,914	169,164	-718,274	-120,237	2,133,209
2057	673,501	569,268	16,245	33,640	-1,122,622	-115,686	54,346
2058	522,020	489,739	44,186	27,628	-1,253,276	-110,474	-280,179
2059	481,112	252,996	77,161	26,299	-1,749,204	-105,946	-1,017,581
2060	429,670	259,054	101,488	19,792	-1,652,713	-103,828	-946,537
2061	447,419	318,905	147,790	39,158	-1,437,034	-102,731	-586,494
2062	515,397	400,090	96,110	31,426	-1,726,653	-102,439	-786,068
2063	822,203	1,186,122	125,545	104,939	-982,407	-105,263	1,151,138
2064	812,383	1,217,000	39,194	41,649	-986,296	-114,017	1,009,913
2065	461,447	351,690	27,964	18,289	-1,789,318	-112,105	-1,042,033
2066	449,867	280,211	132,607	37,782	-2,125,316	-106,826	-1,331,675
2067	511,035	314,307	116,486	23,923	-1,960,796	-107,878	-1,102,923
2068	651,081	758,626	191,836	65,542	-1,393,447	-109,878	163,759
2069	1,417,188	2,146,388	28,009	126,664	-861,456	-124,760	2,732,032
2070	585,382	571,217	19,064	19,883	-1,309,505	-123,427	-237,386

Table 20 - Projected Future Groundwater Budget for Kern County Subbasin under 2070 Climate Conditions with NO SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	30,266,907	32,824,218	5,541,096	2,495,122	-92,372,522	-3,271,463	**-24,516,680**
Average	605,338	656,484	110,822	49,902	-1,847,450	-65,429	**-490,334**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	11,792,918	12,994,527	2,263,192	960,586	-36,385,358	-1,447,672	**-9,821,843**
Average	589,646	649,726	113,160	48,029	-1,819,268	-72,384	**-491,092**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	18,473,988	19,829,691	3,277,904	1,534,536	-55,987,164	-1,823,791	**-14,694,837**
Average	615,800	660,990	109,263	51,151	-1,866,239	-60,793	**-489,828**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	408,652	250,550	140,163	38,275	-1,842,475	-83,663	-1,088,499
2022	472,102	369,832	95,673	30,903	-2,096,387	-78,608	-1,206,496
2023	673,989	1,058,910	189,890	97,206	-1,367,109	-76,560	576,325
2024	744,177	1,122,749	154,523	64,640	-1,269,966	-81,123	734,995
2025	434,940	339,216	62,383	18,095	-2,093,637	-77,242	-1,316,253
2026	469,752	316,670	142,130	42,165	-2,392,400	-68,542	-1,490,227
2027	468,805	219,342	111,136	22,713	-2,302,101	-66,245	-1,546,351
2028	565,266	622,490	194,932	37,491	-1,777,664	-66,172	-423,661
2029	1,232,895	2,021,954	94,628	120,391	-1,272,882	-75,969	2,121,016
2030	512,383	510,545	46,067	18,406	-1,606,048	-73,952	-592,602
2031	514,885	217,243	80,080	18,510	-2,404,879	-69,108	-1,643,271
2032	420,919	109,243	41,157	17,864	-2,961,316	-59,737	-2,431,871
2033	717,704	983,283	185,465	124,666	-1,366,638	-66,770	577,711
2034	636,472	1,011,310	124,135	48,403	-1,629,020	-73,691	117,609
2035	742,442	926,830	240,059	52,829	-1,506,120	-76,785	379,255
2036	840,589	1,369,821	66,325	95,355	-1,236,377	-78,889	1,056,824
2037	511,349	550,855	51,377	33,462	-1,460,435	-75,693	-389,084
2038	525,422	516,749	68,512	30,839	-1,615,455	-70,944	-544,878
2039	486,185	261,453	84,925	29,526	-2,078,540	-66,064	-1,282,515
2040	413,990	215,482	89,632	18,846	-2,105,907	-61,915	-1,429,871
2041	434,872	249,759	141,456	34,801	-1,861,023	-59,685	-1,059,819
2042	506,082	371,490	95,431	30,811	-2,143,228	-58,424	-1,197,837
2043	701,042	1,057,536	164,332	99,819	-1,415,545	-58,898	548,287
2044	765,882	1,123,035	84,872	65,709	-1,321,033	-65,596	652,868
2045	457,199	338,796	43,022	18,140	-2,143,265	-63,760	-1,349,868
2046	491,322	316,422	142,576	42,210	-2,441,728	-56,475	-1,505,673
2047	486,516	219,663	111,300	22,758	-2,350,989	-55,383	-1,566,136
2048	575,922	621,390	195,292	37,553	-1,826,869	-56,367	-453,078
2049	1,207,108	2,024,646	76,576	122,702	-1,321,171	-67,189	2,042,673
2050	516,604	511,479	41,647	18,437	-1,653,603	-66,049	-631,485
2051	524,249	217,243	80,184	18,541	-2,450,881	-61,709	-1,672,374
2052	436,390	105,521	41,256	17,846	-2,980,914	-52,973	-2,432,875
2053	721,385	984,833	185,983	125,947	-1,412,037	-60,560	545,551
2054	637,035	1,010,015	122,314	48,546	-1,673,215	-67,888	76,808
2055	739,029	926,775	240,837	53,236	-1,549,608	-71,550	338,718
2056	916,865	1,369,239	78,789	163,750	-1,223,884	-73,970	1,230,789
2057	542,683	548,446	53,332	34,610	-1,503,509	-70,686	-395,124
2058	550,193	519,512	70,081	31,051	-1,656,729	-65,944	-551,837
2059	506,313	262,783	85,481	29,722	-2,118,584	-60,956	-1,295,243
2060	434,143	216,084	89,721	18,987	-2,098,596	-57,233	-1,396,893
2061	453,048	249,994	141,478	34,761	-1,901,319	-55,229	-1,077,267
2062	522,814	370,621	95,685	30,984	-2,183,537	-54,157	-1,217,590
2063	725,002	1,059,135	169,499	100,139	-1,456,460	-54,936	542,379
2064	737,845	1,121,596	96,738	41,720	-1,390,161	-62,039	545,700
2065	456,525	339,078	47,370	18,277	-2,183,880	-60,597	-1,383,226
2066	498,361	316,005	142,585	41,907	-2,483,011	-53,520	-1,537,673
2067	496,804	219,419	111,431	22,808	-2,393,461	-52,693	-1,595,690
2068	655,939	621,712	196,418	66,128	-1,787,044	-52,309	-299,157
2069	1,243,827	2,023,476	87,110	124,017	-1,364,360	-64,030	2,050,039
2070	532,988	513,990	45,107	18,619	-1,697,522	-62,987	-649,805

Table 21 - Projected Future Groundwater Budget for Kern County Subbasin under 2070 Climate Conditions WITH SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	31,799,129	37,863,262	4,293,932	2,495,122	-79,755,674	-4,729,641	**-8,033,910**
Average	635,983	757,265	85,879	49,902	-1,595,113	-94,593	**-160,678**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	12,589,633	14,705,737	1,891,043	960,586	-32,975,395	-1,657,287	**-4,485,720**
Average	629,482	735,287	94,552	48,029	-1,648,770	-82,864	**-224,286**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	19,209,496	23,157,525	2,402,889	1,534,536	-46,780,279	-3,072,354	**-3,548,190**
Average	640,317	771,917	80,096	51,151	-1,559,343	-102,412	**-118,273**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	416,859	299,174	140,033	38,275	-1,829,917	-83,068	-1,018,646
2022	482,771	408,716	95,545	30,903	-2,075,055	-77,724	-1,134,857
2023	778,119	1,167,829	176,974	97,206	-1,283,726	-78,065	858,337
2024	824,224	1,237,834	116,452	64,640	-1,201,267	-84,296	957,582
2025	444,081	355,471	55,004	18,095	-1,995,258	-81,218	-1,203,834
2026	466,475	376,346	141,087	42,165	-2,313,156	-72,774	-1,359,861
2027	464,976	279,425	111,024	22,713	-2,213,764	-70,681	-1,406,307
2028	569,538	749,332	192,740	37,491	-1,685,558	-71,949	-208,410
2029	1,366,993	2,190,420	41,284	120,391	-1,077,423	-84,620	2,557,045
2030	534,178	531,150	29,555	18,406	-1,464,690	-82,917	-434,320
2031	519,704	234,003	79,675	18,510	-2,224,205	-79,250	-1,451,562
2032	415,122	123,188	41,020	17,864	-2,750,519	-71,829	-2,225,156
2033	783,412	1,166,531	179,799	124,666	-1,109,329	-80,416	1,064,663
2034	658,731	1,142,196	88,031	48,403	-1,395,221	-89,128	453,011
2035	863,103	1,130,070	184,994	52,829	-1,232,204	-94,328	904,464
2036	1,029,800	1,602,138	12,470	95,355	-917,373	-98,485	1,723,905
2037	570,198	605,678	8,505	33,462	-1,243,785	-94,402	-120,345
2038	523,835	569,446	34,689	30,839	-1,363,512	-90,407	-295,110
2039	479,164	294,676	72,792	29,526	-1,805,973	-86,949	-1,016,764
2040	398,352	242,115	89,372	18,846	-1,793,459	-84,780	-1,129,554
2041	414,818	301,192	141,646	34,801	-1,568,913	-83,592	-760,049
2042	491,990	414,742	93,845	30,811	-1,840,528	-83,323	-892,462
2043	790,613	1,254,107	115,429	99,819	-1,116,588	-86,323	1,057,057
2044	836,403	1,305,369	17,905	65,709	-1,045,824	-95,401	1,084,162
2045	449,154	360,429	22,817	18,140	-1,852,116	-93,998	-1,095,574
2046	471,989	380,169	142,402	42,210	-2,176,184	-86,568	-1,225,983
2047	471,984	283,737	111,550	22,758	-2,085,163	-85,737	-1,280,870
2048	554,428	793,776	194,145	37,553	-1,568,985	-88,857	-77,939
2049	1,321,092	2,246,987	3,572	122,702	-987,606	-102,881	2,603,867
2050	524,857	543,145	12,030	18,437	-1,398,511	-101,367	-401,409
2051	526,155	245,563	79,307	18,541	-2,147,741	-98,008	-1,376,184
2052	430,658	129,919	41,236	17,846	-2,649,533	-91,211	-2,121,085
2053	792,109	1,204,216	177,747	125,947	-1,064,253	-100,431	1,135,335
2054	668,348	1,172,104	66,220	48,546	-1,336,993	-110,282	507,943
2055	860,469	1,164,599	170,576	53,236	-1,194,626	-115,992	938,261
2056	1,144,616	1,635,346	2,390	163,750	-873,811	-120,178	1,952,112
2057	610,598	609,490	-6,003	34,610	-1,226,393	-115,425	-93,124
2058	546,965	577,365	26,400	31,051	-1,353,145	-110,712	-282,076
2059	486,798	300,706	68,354	29,722	-1,802,615	-106,347	-1,023,382
2060	409,456	246,809	89,277	18,987	-1,751,495	-103,792	-1,090,757
2061	418,628	304,951	141,821	34,761	-1,574,579	-102,407	-776,824
2062	495,173	417,295	92,534	30,984	-1,842,095	-101,824	-907,934
2063	793,354	1,276,196	108,214	100,139	-1,128,328	-105,241	1,044,334
2064	805,281	1,324,749	9,903	41,720	-1,082,528	-114,909	984,217
2065	440,536	363,793	19,730	18,277	-1,870,357	-113,021	-1,141,042
2066	471,618	383,251	141,837	41,907	-2,193,139	-104,993	-1,259,519
2067	473,770	286,942	111,773	22,808	-2,105,041	-103,867	-1,313,616
2068	625,100	815,113	195,615	66,128	-1,516,065	-105,894	79,999
2069	1,353,276	2,266,438	1,701	124,017	-1,005,088	-121,015	2,619,328
2070	529,258	549,028	8,916	18,619	-1,422,036	-118,758	-434,973

TABLE 22: Assessment of change in groundwater storage from C2VSimFG-Kern model results for historical and future scenarios for the Kern County Subbasin

Scenario	Model Results 2041-2070 Sustainability Period		Adjustments to GW Storage Change 2041-2070 Sustainability Period		
	Change in Groundwater Storage	Change in Net Operational Budget	Adjustment for Excess Basin Outflows	Adjustment for Excess Kern River Outflow	Adjusted Change in GW Storage
units	**AFY**	**AFY**	AFY	AFY	**AFY**
Historic	**-277,114**	**-190,012**	0	0	**-277,114**
Baseline	**-324,326**	**-253,629**	0	0	**-324,326**
Base Projects	**42,144**	**152,353**	26,327	17,108	**85,578**
2030 Climate	**-380,900**	**-318,260**	0	8,780	**-372,120**
2030 Projects	**-12,861**	**90,282**	27,056	32,634	**46,829**
2070 Climate	**-489,828**	**-429,035**	0	17,492	**-472,336**
2070 Projects	**-118,273**	**-15,861**	28,077	44,227	**-45,969**

NOTE:

"Change in *Groundwater Storage* " DOES include subsurface flow with adjacent basins

"*Operational Storage* " DOES NOT include subsurface flow with adjacent basins

"Adjustment for *Excess Basin Outflows* " is the difference in simulated basin outflow that is attributed to addition of SGMA projects in Kern County without comparable SGMA projects added to adjacent basins**.** Adjustment assumes that this difference is due to limitation of simulation, and that this difference would remain in Kern County when SGMA projects from adjacent basin are included in simulation.

"Adjustment for *Excess Kern River Outflow* " is the increase in simulated groundwater outflows to Kern River relative to Baseline condition that are attributed to SGMA Projects and Climate Change. Model is not optimized for river management. Since the Kern River is a highly managed system, the assumption is that in practice this water would be recovered for beneficial use rather than be a loss of water from the basin.

"*Adjusted Change in GW Storage* " Change in GW Storage plus modifications listed as adjustments to provide a more realistic Change in GW Storage estimate for the simulation.

TABLE 23: Evaluation of Sustainable Yield for Projected-Future scenarios based on C2VSimFG-Kern Model Results for Kern County Subbasin

Scenario	C2VSimFG-Kern Model Results 2041-2070 Sustainability Period					
	Groundwater Pumping	Change in Groundwater in Storage	GW Storage Adjustments	Sustainable Yield	Average Annual Difference of Pumping to Yield	Percent Difference of Pumping to Sustainable Yield
units	AFY	AFY	AFY	AFY	AFY	AFY
Historic	**1,590,373**	**-277,114**	**0**	**1,313,259**	**-277,114**	**-21%**
Baseline	**1,624,694**	**-324,326**	**0**	**1,300,369**	**-324,326**	**-25%**
Baseline Projects	**1,354,088**	**42,144**	**43,434**	**1,439,666**	**85,578**	**6%**
2030 Climate	**1,734,001**	**-380,900**	**8,780**	**1,361,881**	**-372,120**	**-27%**
2030 Projects	**1,444,144**	**-12,861**	**59,690**	**1,490,974**	**46,829**	**3%**
2070 Climate	**1,866,239**	**-489,828**	**17,492**	**1,393,902**	**-472,336**	**-34%**
2070 Projects	**1,559,343**	**-118,273**	**72,304**	**1,513,373**	**-45,969**	**-3%**

NOTES:

Groundwater Pumping	Total groundwater pumping by wells. Groundwater banking recovery pumping is specified input whereas agricultural and municipal pumping is calculated by C2VSim based on demand
Change in Groundwater in Storage	Sum of the inflow components (positive numbers) plus the outflow components (negative numbers): positive is an increase in storage typified by a rise in GW levels whereas a negative is a decrease in storage typified by a decline in GW levels
Adjusted Banking	Adjustment that assumes that recharge operations are affected by reductions in imported water sources, but
GW Storage Adjustments	Adjustment to GW Storage that reflect artifacts of the simulation. For Kern County, adjustments made to reflect no SGMA projects simulated north of Kern County, and that Kern River operations are not optimized to
Sutainable Yield	Sustainable yield is defined is the amount of pumping that can be sustained in the groundwater basin without the undesirable effect of a decline in groundwater storage that serves as a proxy for other undesirable effects
Average Annual Difference	The difference between the sustainable yield and the simulated groundwater pumping. A negative value is pumping in excess of the sustainable yield
Percent Difference	The percentage of the Average Annual Difference to the total groundwater pumping to provide context and a method to compare the significance of the difference in the pumping copmared to the sustainable yield.

TABLE 24: Summary of Statistical Analysis for Validation of C2VSimFG-Kern Historical Simulation

Validation Measure	C2VSimFG-Kern	C2VSimFG-Beta	Percent Change
Units	Feet	Feet	Percent
Residual Mean	17.3 ft	32.6 ft	47%
Residual Standard Deviation	45.5 ft	54.0 ft	16%
Absolute Residual Mean	37.4 ft	56.8 ft	34%
Root Mean Square (RMS) Error	50 ft	73.5 ft	32%
Scaled Absolute Residual Mean	0.061	0.092	34%
Correlation Coefficient	0.76	0.52	47%
Number of Monitor Wells	558	558	same
Number of Observations	42,075	42,075	same

Notes

Observation Point	Location in the model where measured data from well is compared to simulated model results
Residual	Difference between measured and simulated groundwater elevations at an observation point
Residual Mean	Statistical measure of fit of simulated to measured data using sum of the residuals divided by the number of residual data values
Residual Standard Deviation	Statistical evaluation of the scatter of the data by calculating standard deviation of residuals
Absolute Residual Mean	Statistical measure of fit of simulated to measured data using sum of the absolute value residuals divided by the number of residual data values
Root Mean Square (RMS) Error	Statistical measure of fit of simulated to measured data using square root of the quotient of sum of squares of residuals by the number of observations
Scaled Absolute Residual Mean	Statisical measure to provide scale of validation using ratio of the absolute residual mean divided by the range of observed groundwater elevations
Correlation Coefficient	Scaled measure of the closeness of fit of simulated to measured data from -1 to 1 correlation with 1.0 a perfect correlation
Number of Monitor Wells	Number of wells where measured groundwater level data was compared to C2VSimFG-Kern simulation results for model validation
Number of Observations	Number of groundwater level measurements that were compared to C2VSimFG-Kern simulation results for model validation

FIGURES

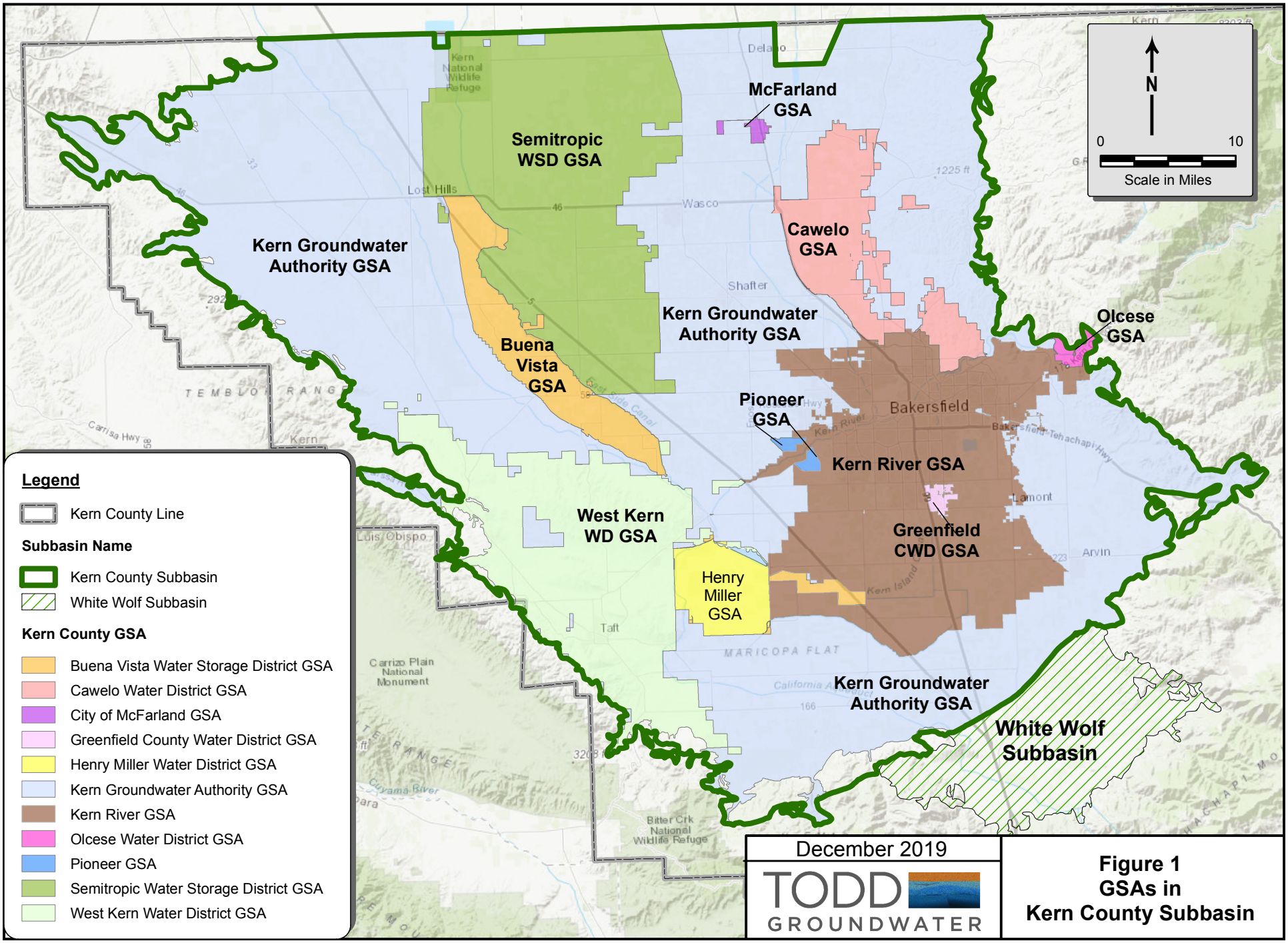
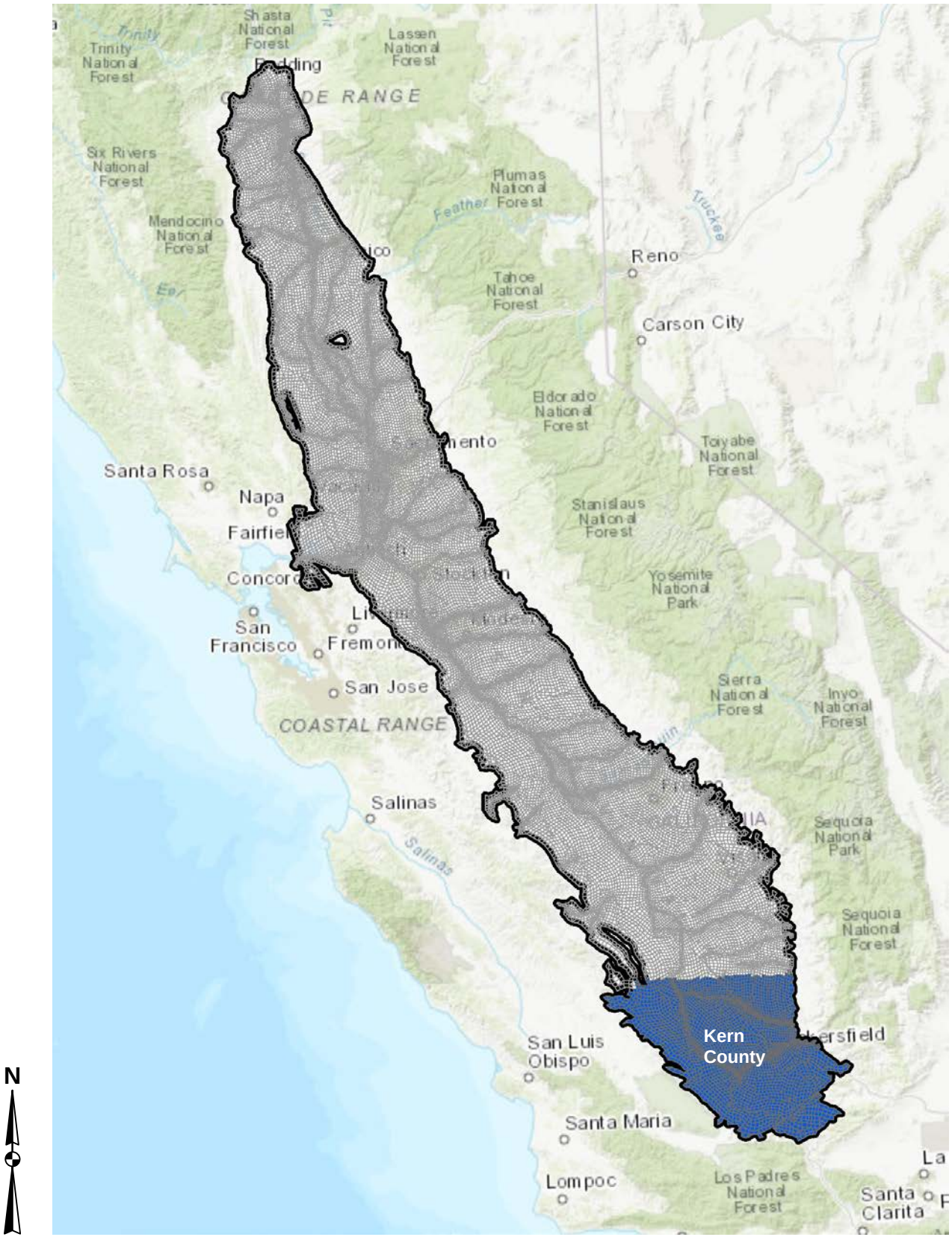
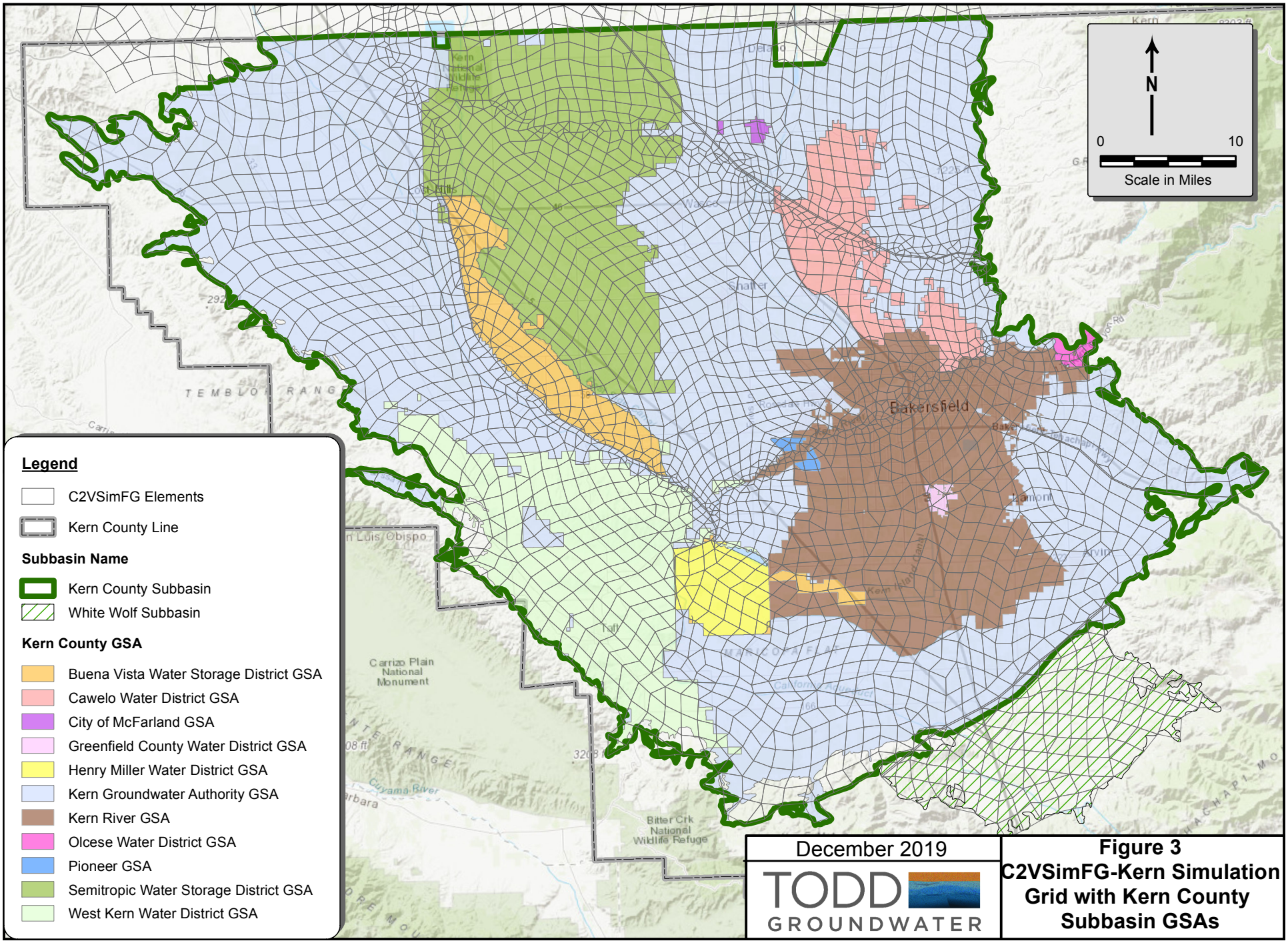


Figure 1
GSAs in
Kern County Subbasin



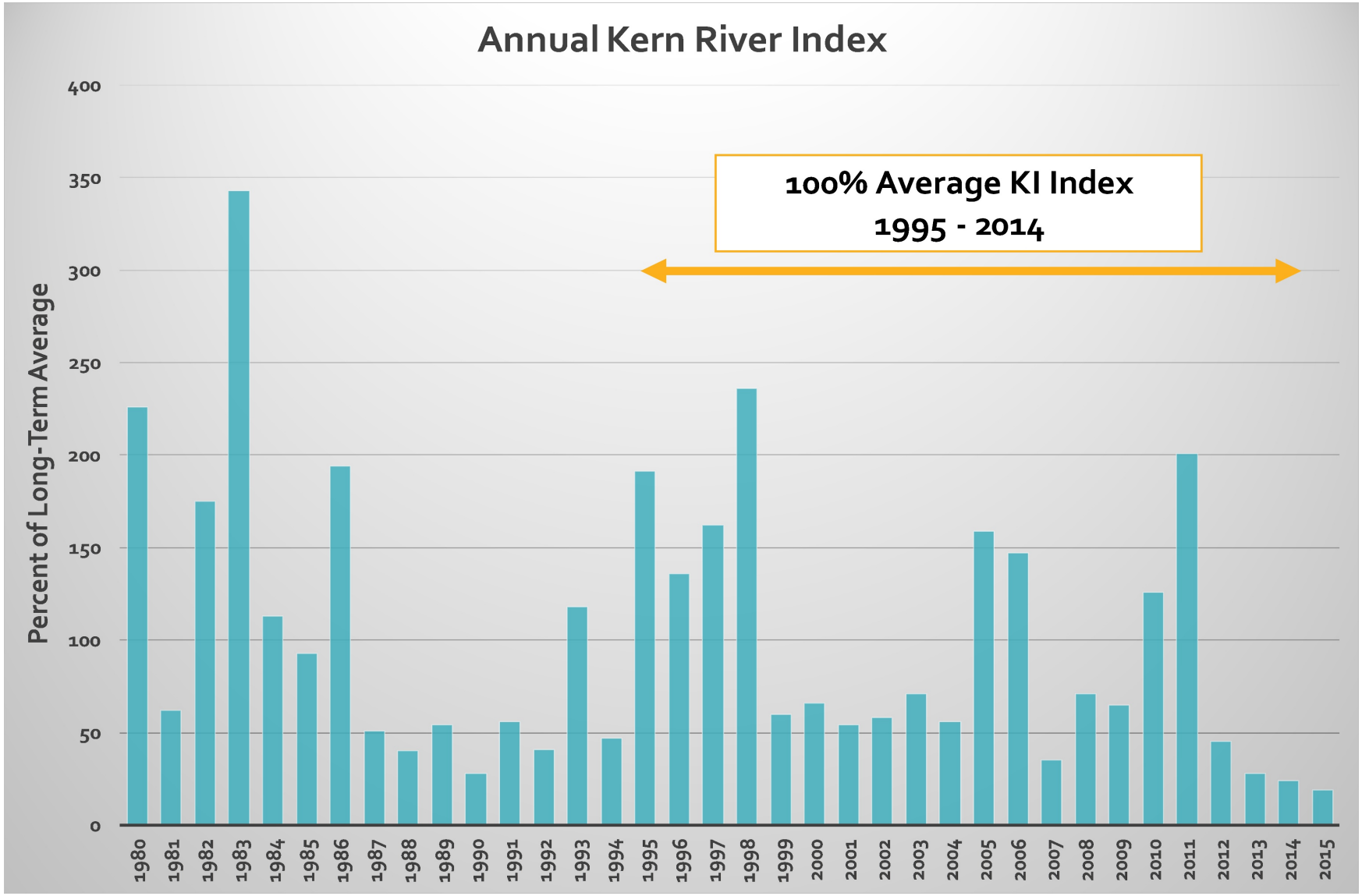
December 2019	Figure 2 C2VSimFG Simulation Grid for Central Valley Showing Kern County Subbasin
TODD GROUNDWATER	



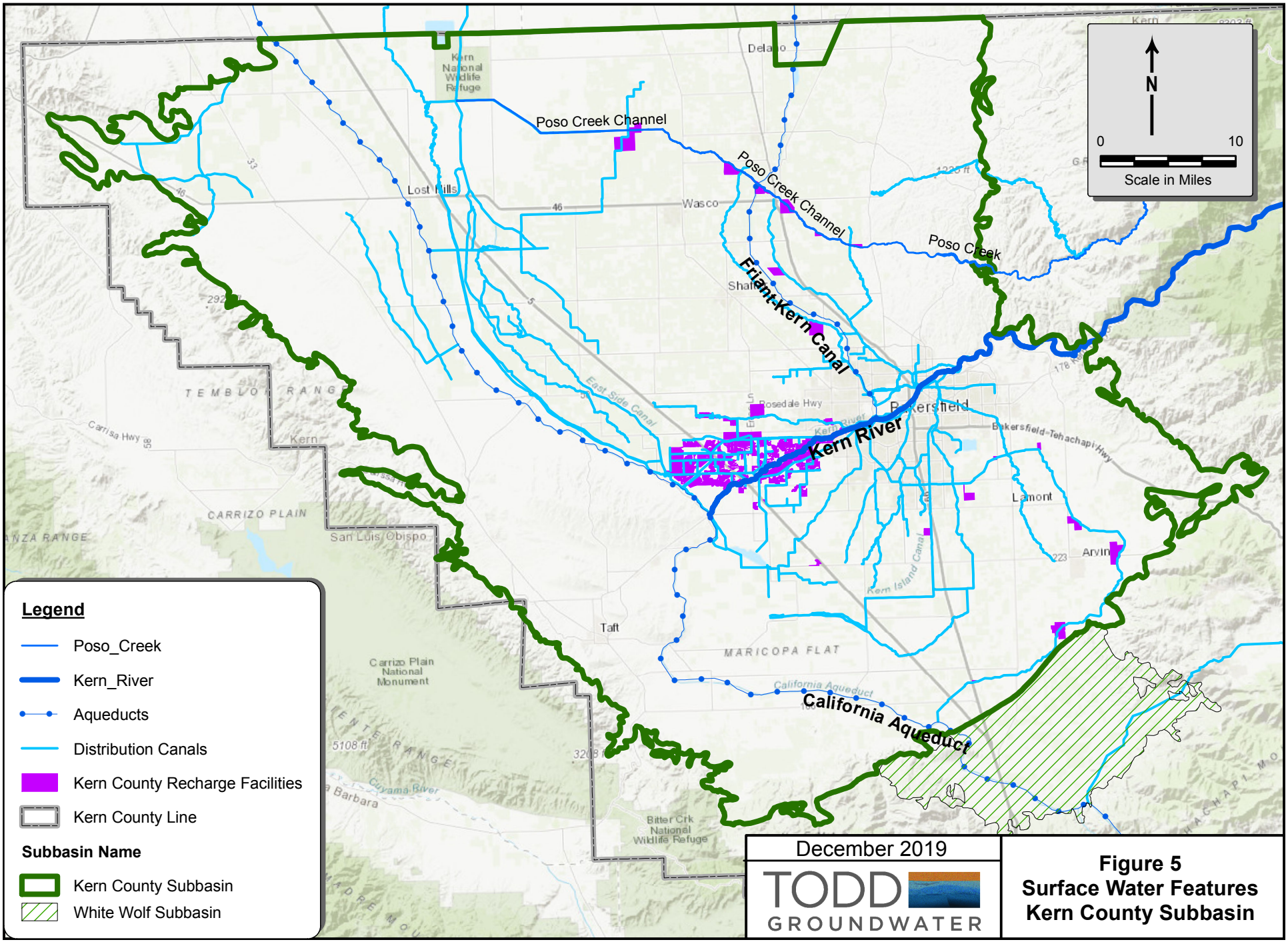
December 2019

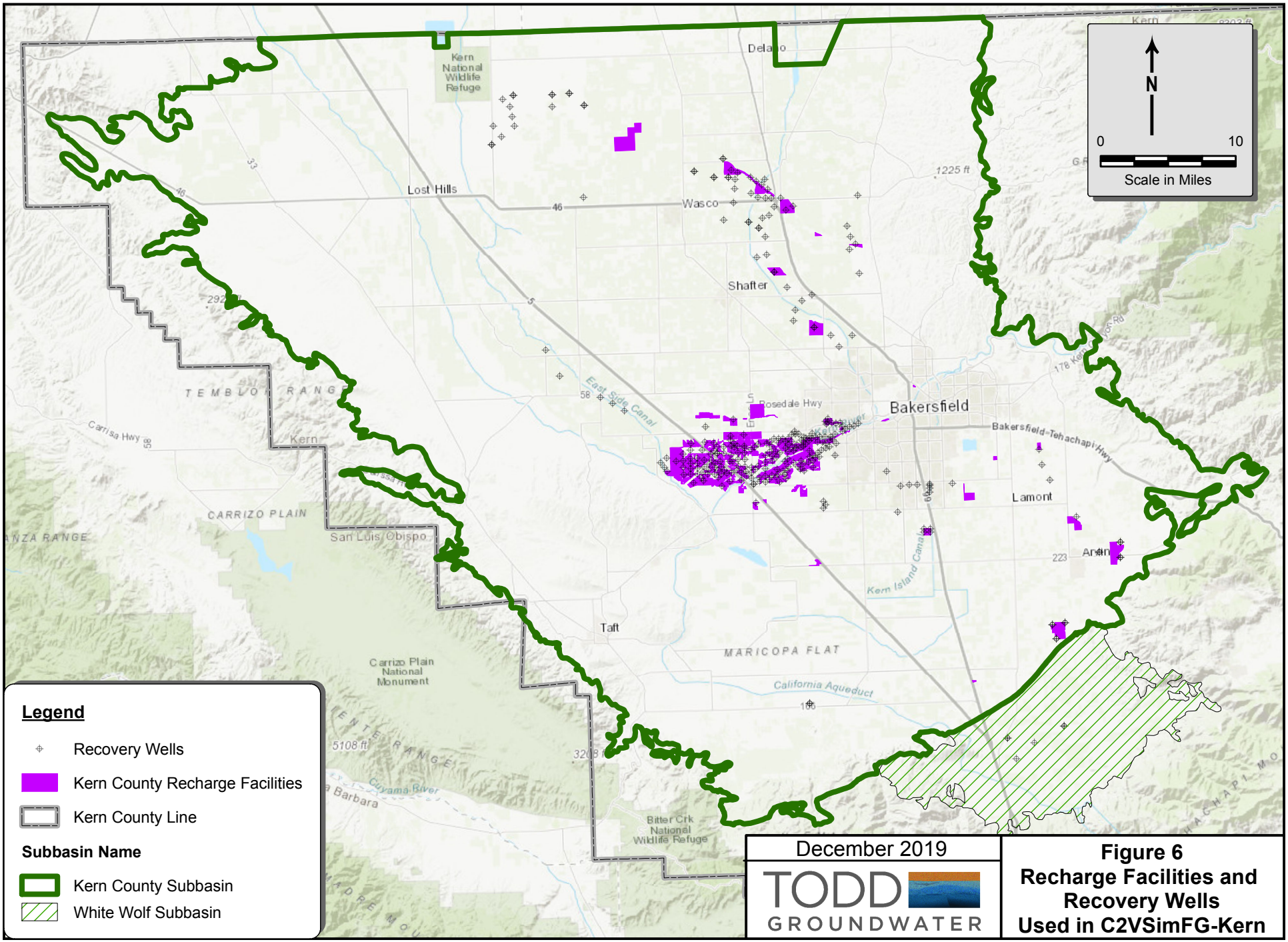
TODD GROUNDWATER

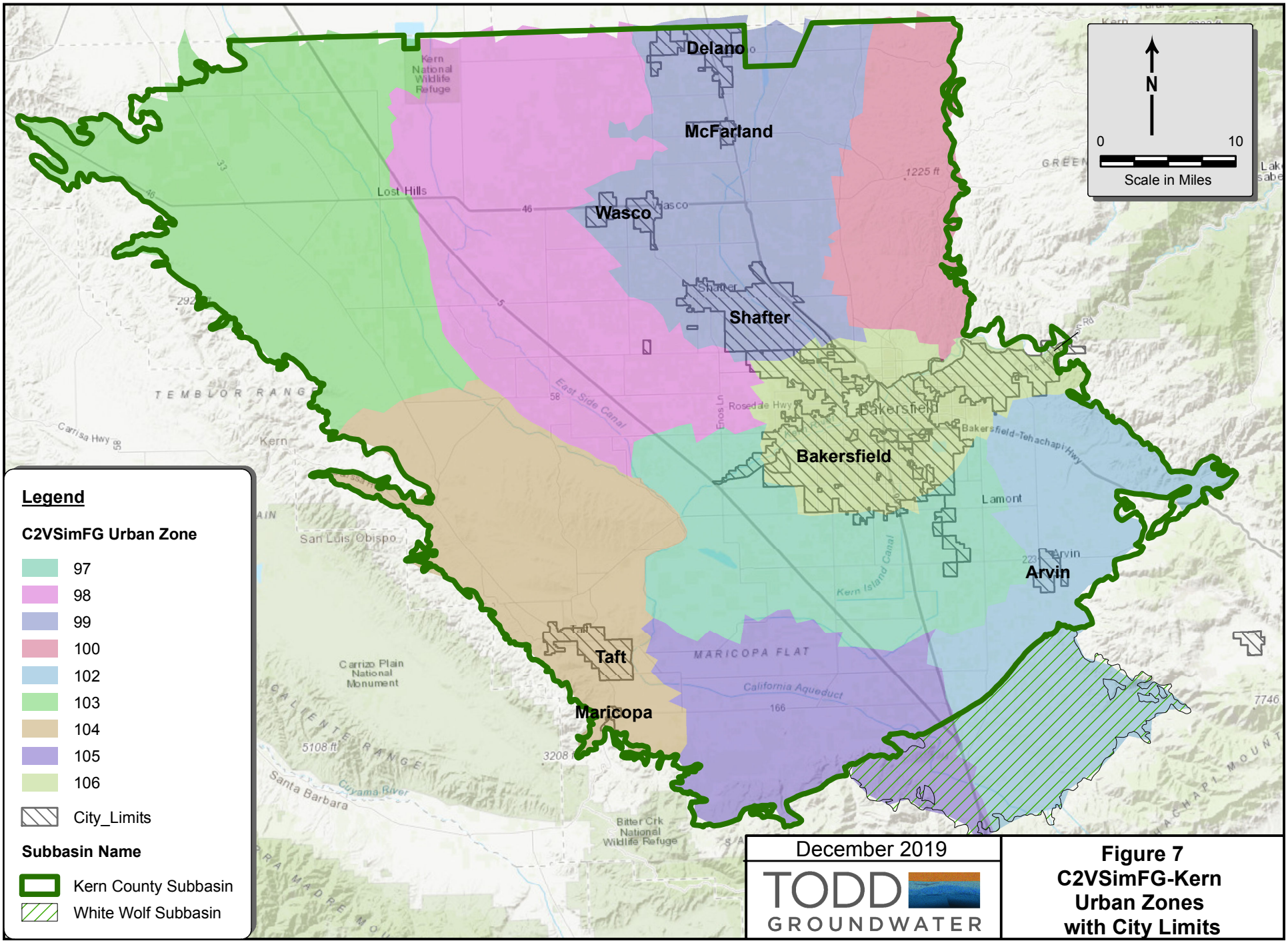
Figure 3
C2VSimFG-Kern Simulation Grid with Kern County Subbasin GSAs



December 2019	Figure 4 Annual Kern River Index used to Define 20-Year Historical Study Period
TODD GROUNDWATER	


Poso Creek Channel
Poso Creek Channel
Poso Creek
Friant-Kern Canal
Kern River
California Aqueduct
Kern National Wildlife Refuge
Lost Hills
Wasco
Delano
Shafter
Bakersfield
Rosedale Hwy
Bakersfield-Tehachapi Hwy
Lamont
Arvin
Taft
Kern
San Luis Obispo
CARRIZO PLAIN
TEMBLOR RANGE
MARICOPA FLAT
Carrizo Plain National Monument
Bitter Crk National Wildlife Refuge
East Side Canal
Kern Island Canal
Carrisa Hwy
N
0
10
Scale in Miles
Legend
Poso_Creek
Kern_River
Aqueducts
Distribution Canals
Kern County Recharge Facilities
Kern County Line
Subbasin Name
Kern County Subbasin
White Wolf Subbasin
December 2019
TODD GROUNDWATER
Figure 5
Surface Water Features
Kern County Subbasin


N
0
10
Scale in Miles
Kern National Wildlife Refuge
Delano
Lost Hills
Wasco
Shafter
Bakersfield
Lamont
Arvin
Taft
Kern
San Luis Obispo
CARRIZO PLAIN
MARICOPA FLAT
TEMBLOR RANGE
Carrizo Plain National Monument
Bitter Crk National Wildlife Refuge
East Side Canal
Kern Island Canal
California Aqueduct
Rosedale Hwy
Bakersfield-Tehachapi Hwy
Carrisa Hwy
Legend
Recovery Wells
Kern County Recharge Facilities
Kern County Line
Subbasin Name
Kern County Subbasin
White Wolf Subbasin
December 2019
TODD GROUNDWATER
Figure 6
Recharge Facilities and Recovery Wells Used in C2VSimFG-Kern


Delano
McFarland
Wasco
Shafter
Bakersfield
Lamont
Arvin
Taft
Maricopa
Lost Hills
Kern National Wildlife Refuge
Carrizo Plain National Monument
Bitter Crk National Wildlife Refuge
TEMBLOR RANGE
MARICOPA FLAT
East Side Canal
Kern Island Canal
California Aqueduct
Rosedale Hwy
Bakersfield-Tehachapi Hwy
Carrisa Hwy
San Luis Obispo
Santa Barbara
Kern
N
0
10
Scale in Miles
Legend
C2VSimFG Urban Zone
97
98
99
100
102
103
104
105
106
City_Limits
Subbasin Name
Kern County Subbasin
White Wolf Subbasin
December 2019
TODD GROUNDWATER
Figure 7
C2VSimFG-Kern
Urban Zones
with City Limits

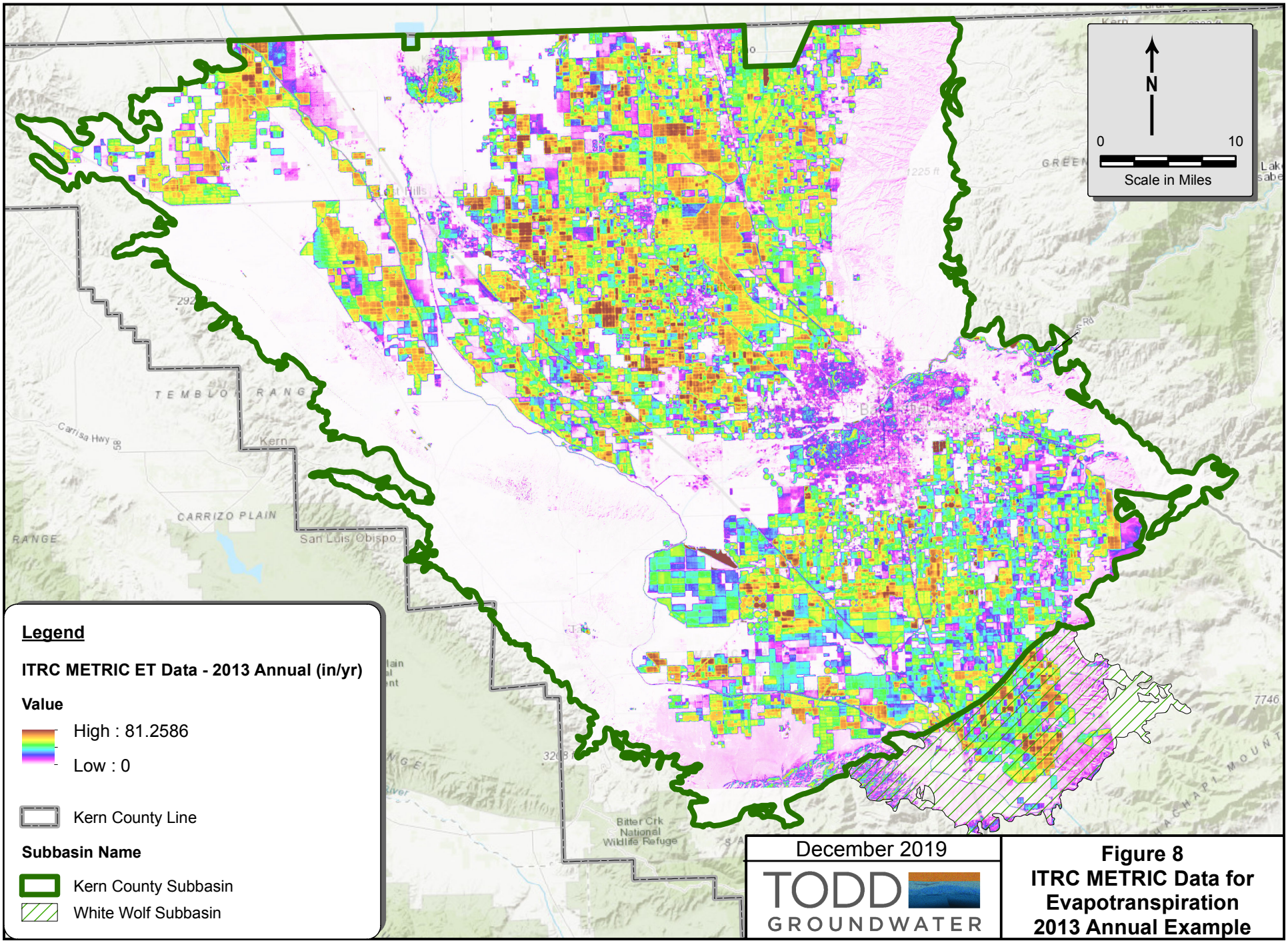
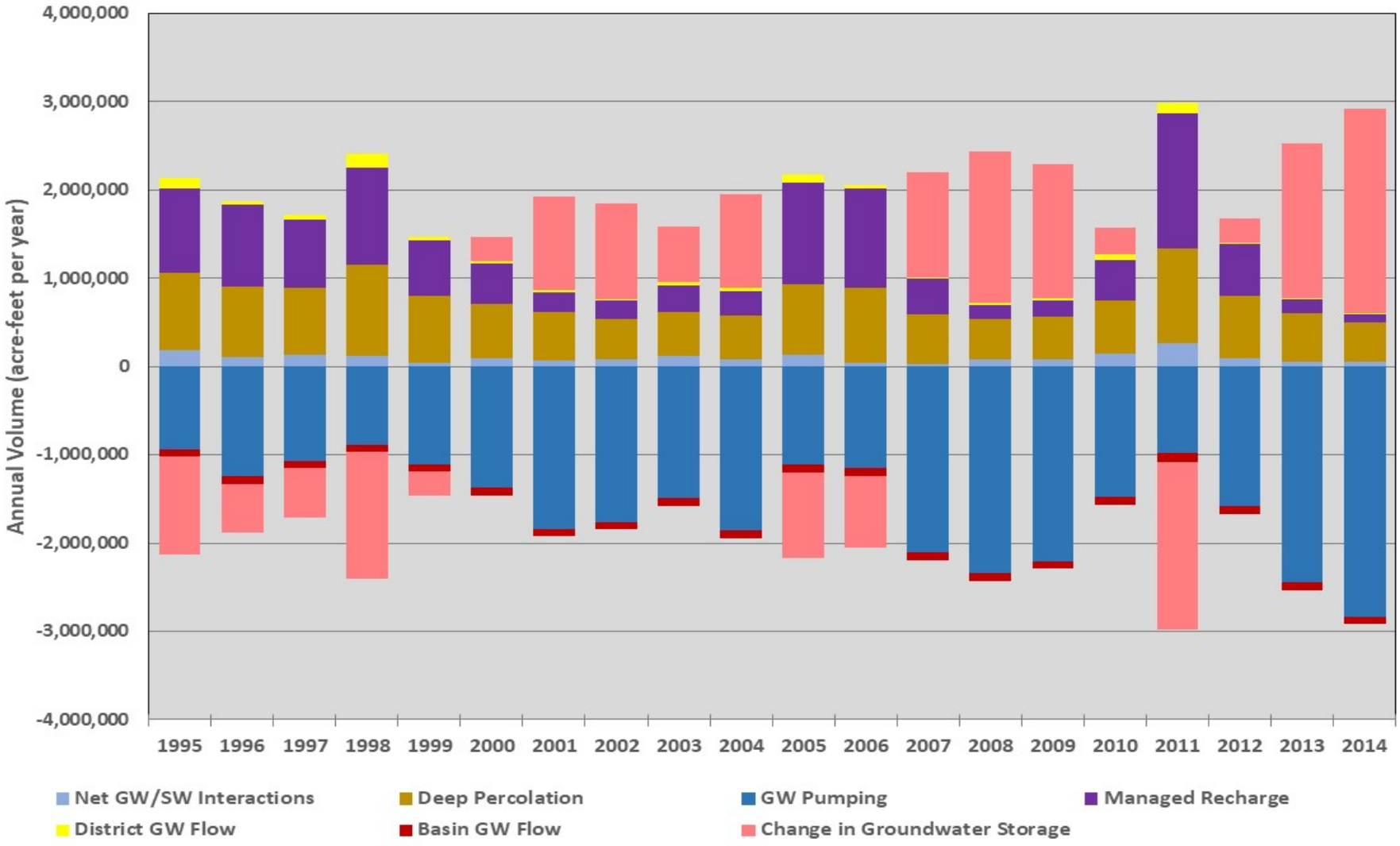
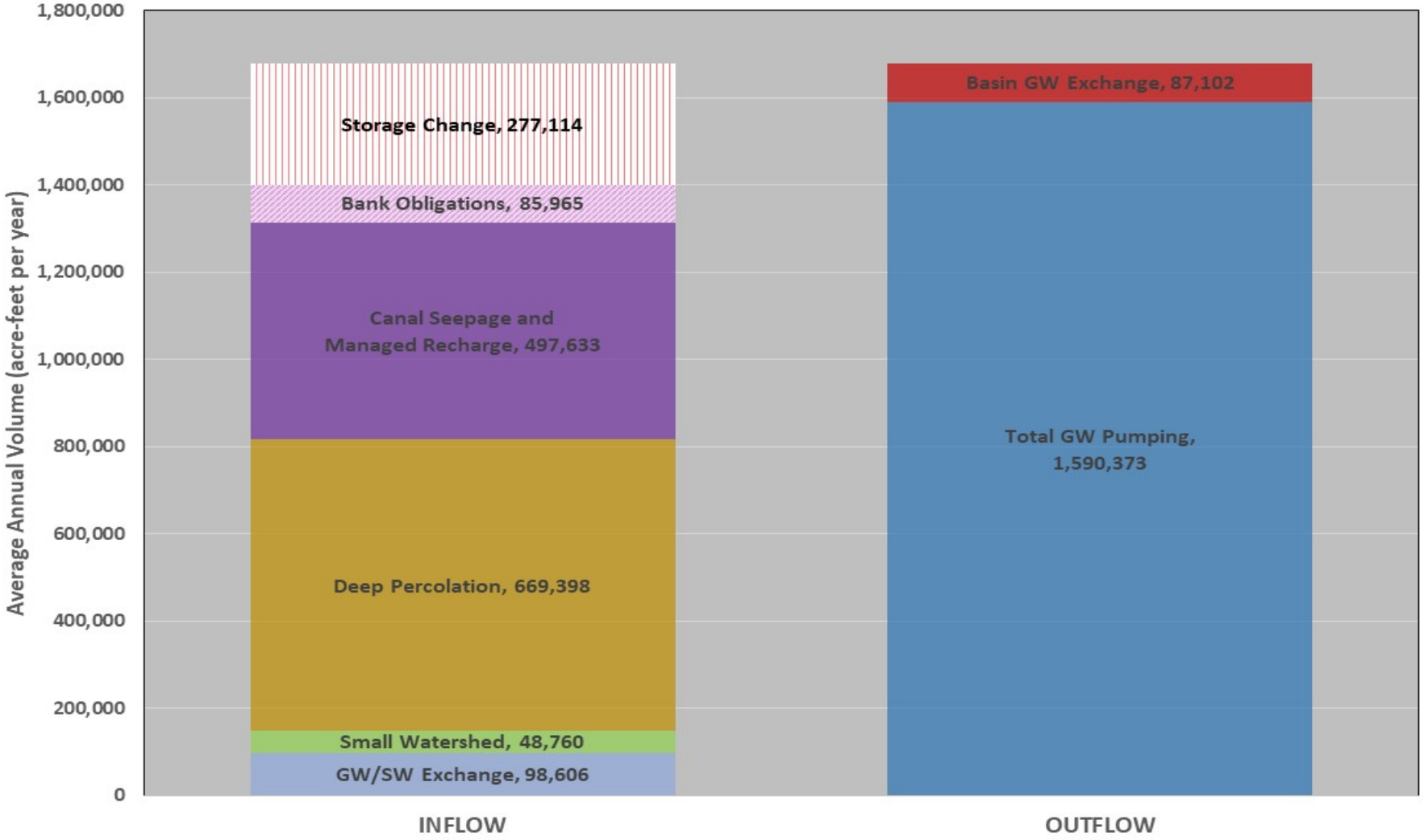


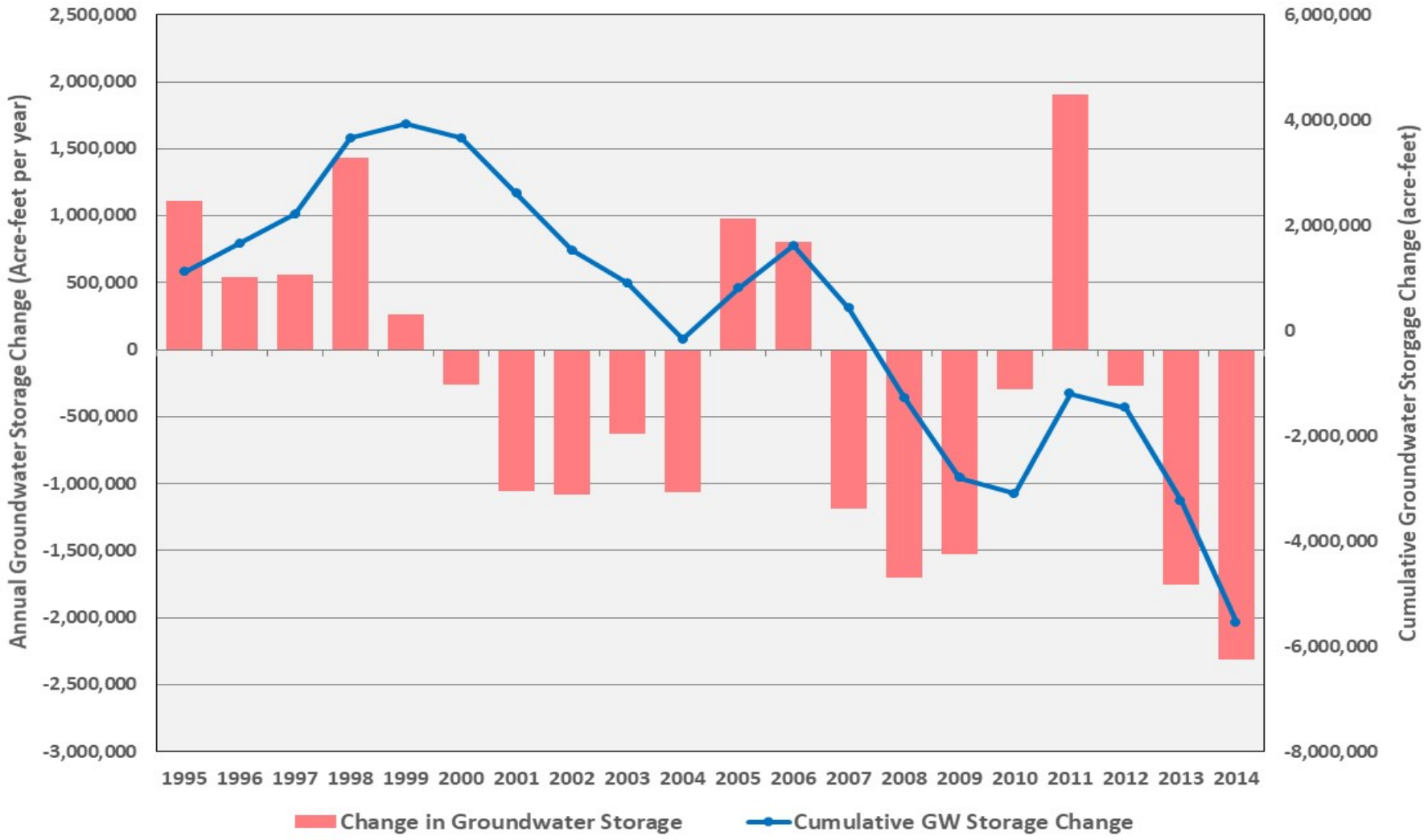
Figure 8
ITRC METRIC Data for Evapotranspiration 2013 Annual Example



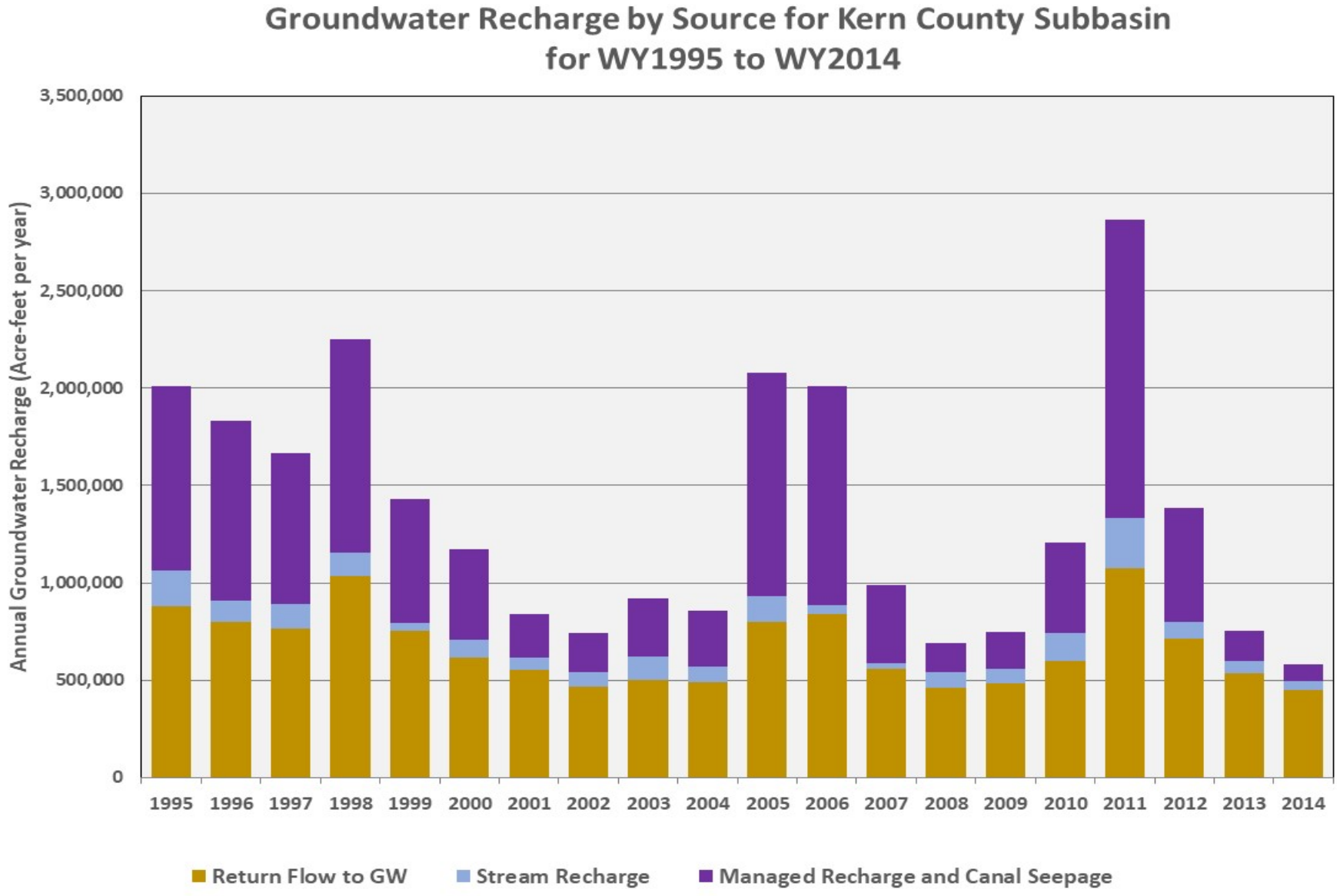
December 2019	Figure 9 C2VSimFG-Kern Historical Groundwater Budget for Kern County Subbasin
TODD GROUNDWATER	



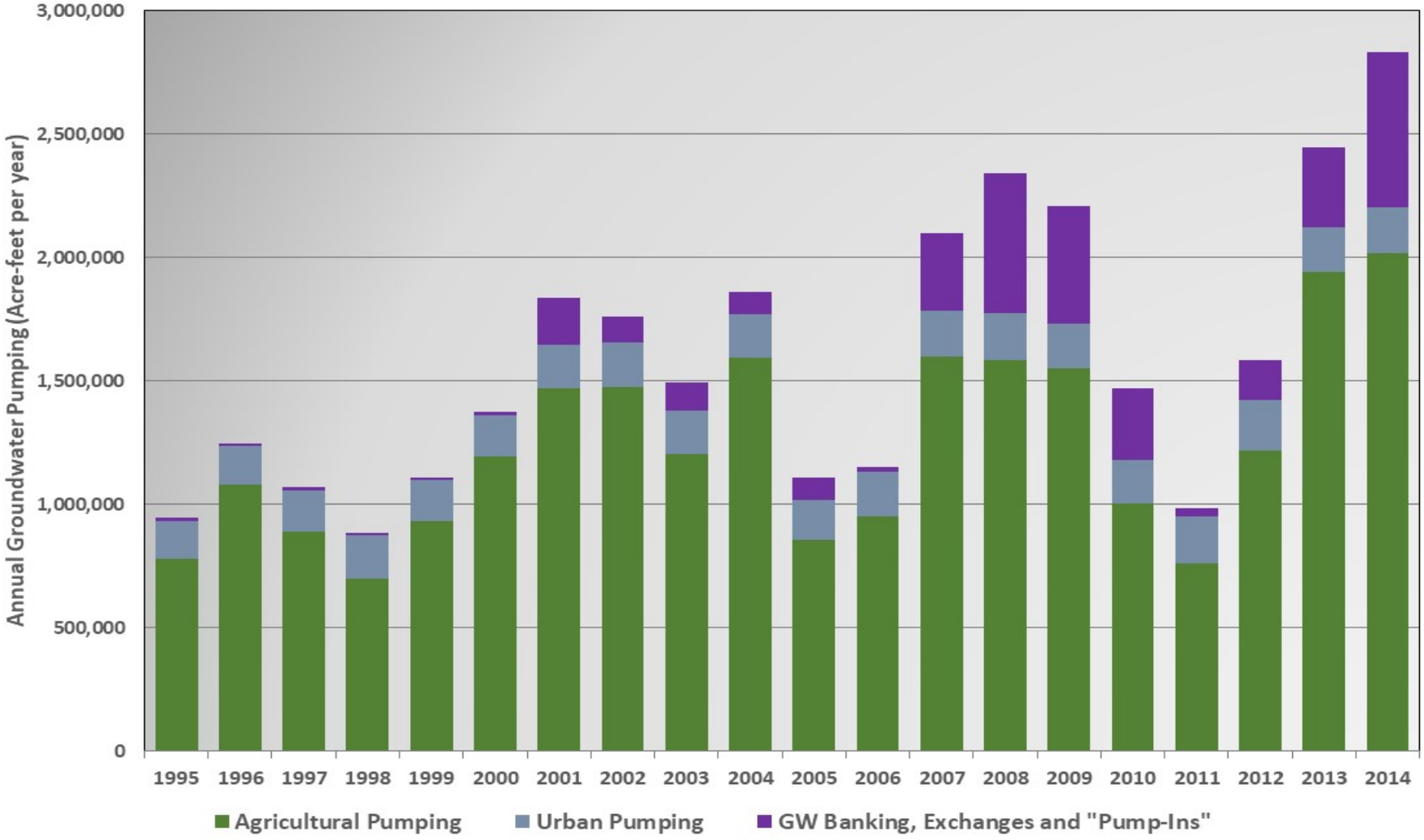
December 2019	Figure 10 C2VSimFG-Kern Average Annual Water Budget for Kern County Subbasin
TODD GROUNDWATER	



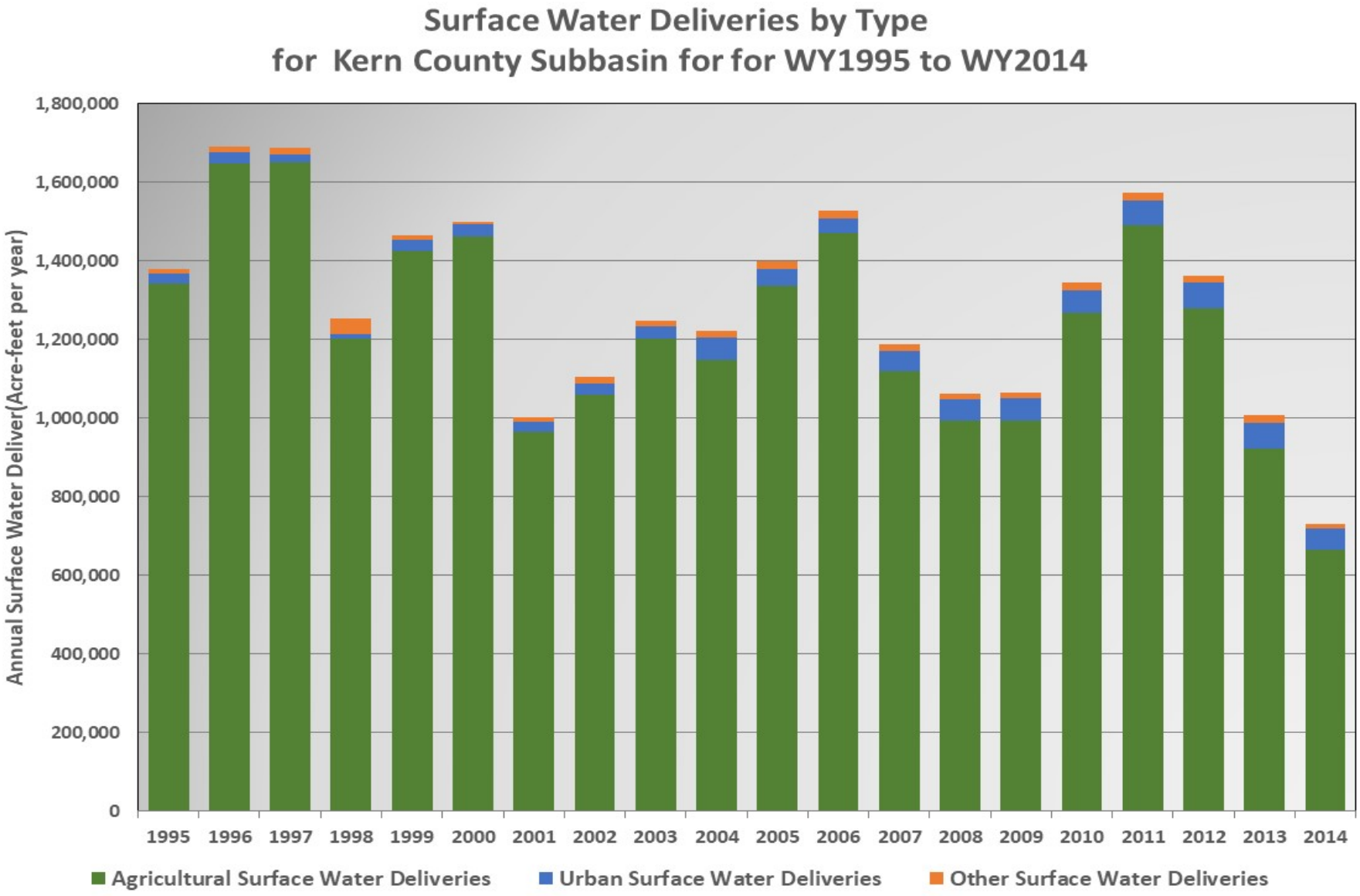
December 2019	Figure 11 Simulated Historical Change in Groundwater Storage for Kern County Subbasin
TODD GROUNDWATER	



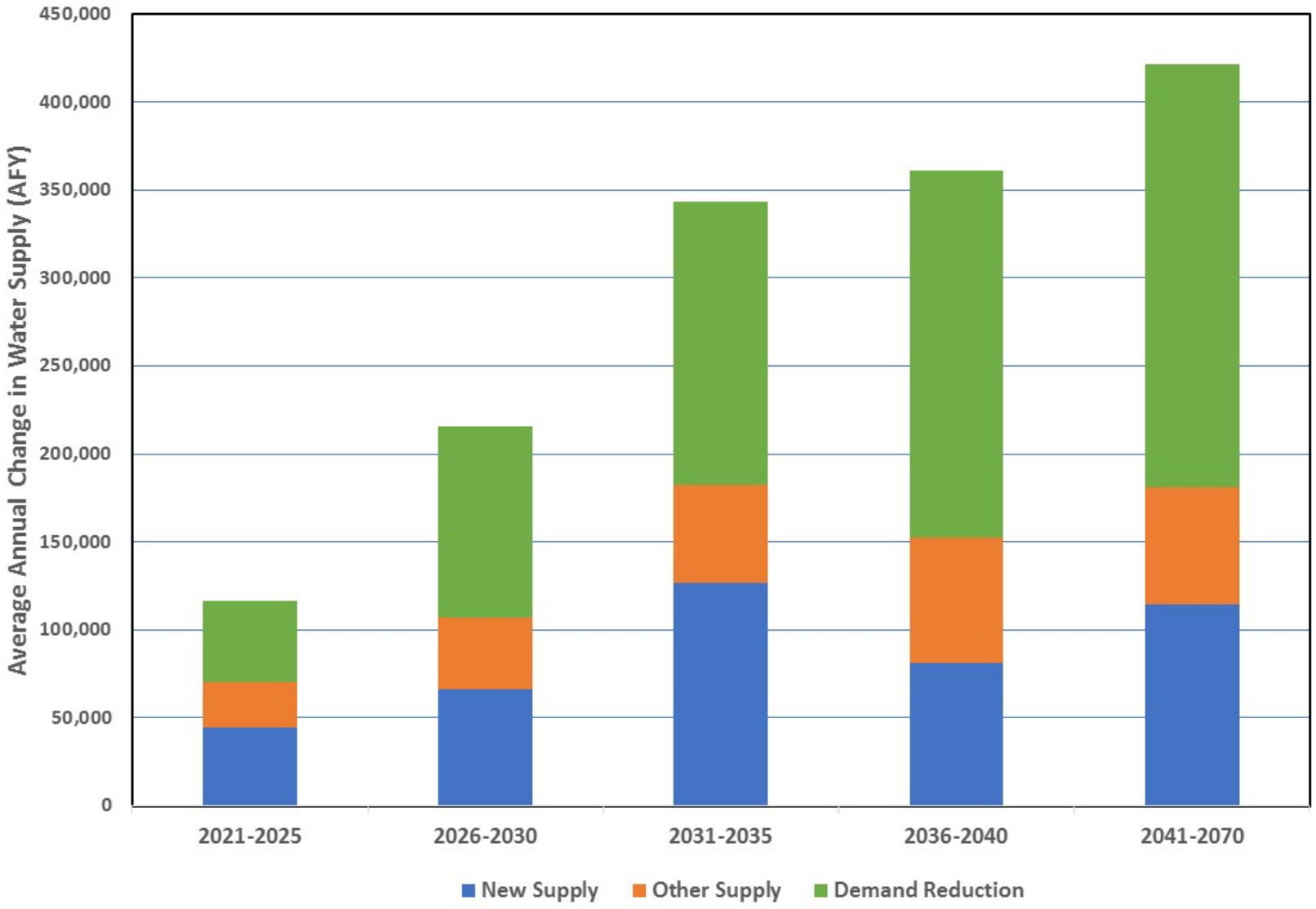
December 2019	Figure 12 Simulated Historical Recharge Operations for Kern County Subbasin
TODD GROUNDWATER	



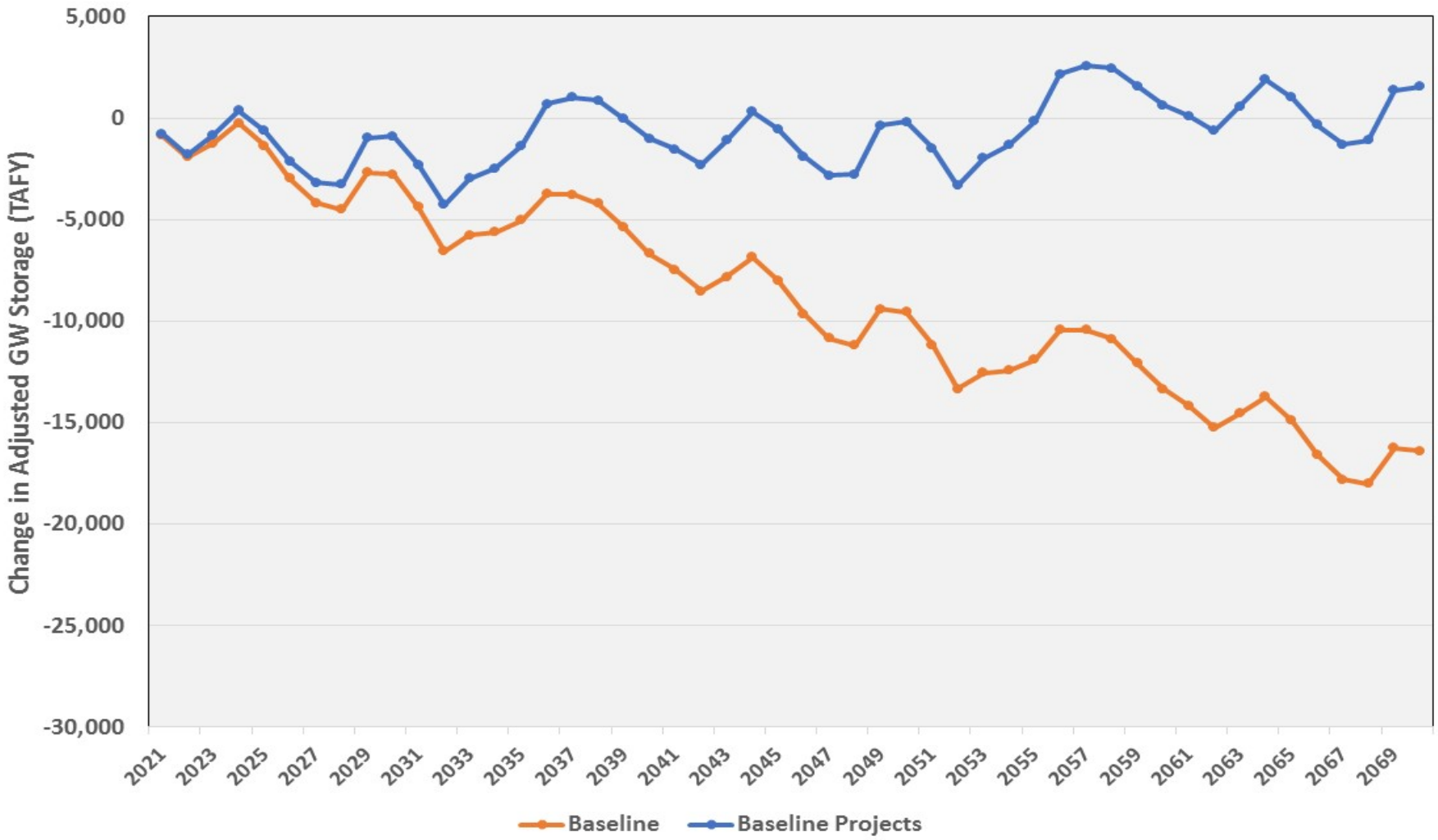
December 2019	Figure 13 Simulated Historical Groundwater Pumping for Kern County Subbasin
TODD GROUNDWATER	



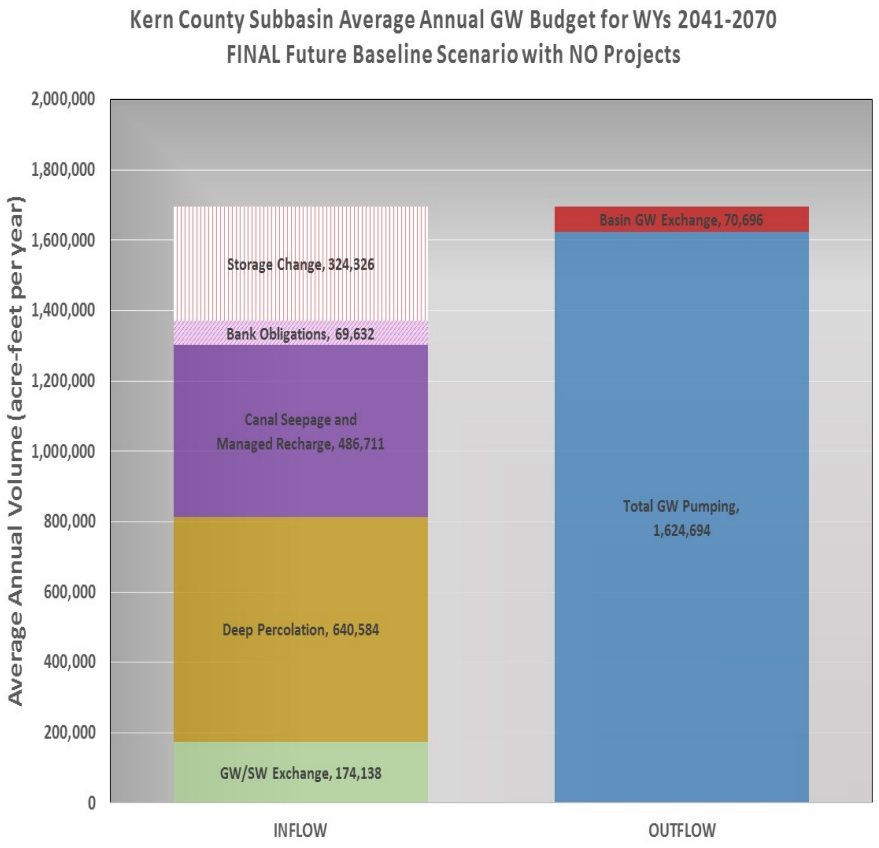
December 2019	Figure 14 Simulated Historical Surface Water Deliveries for Kern County Subbasin
TODD GROUNDWATER	

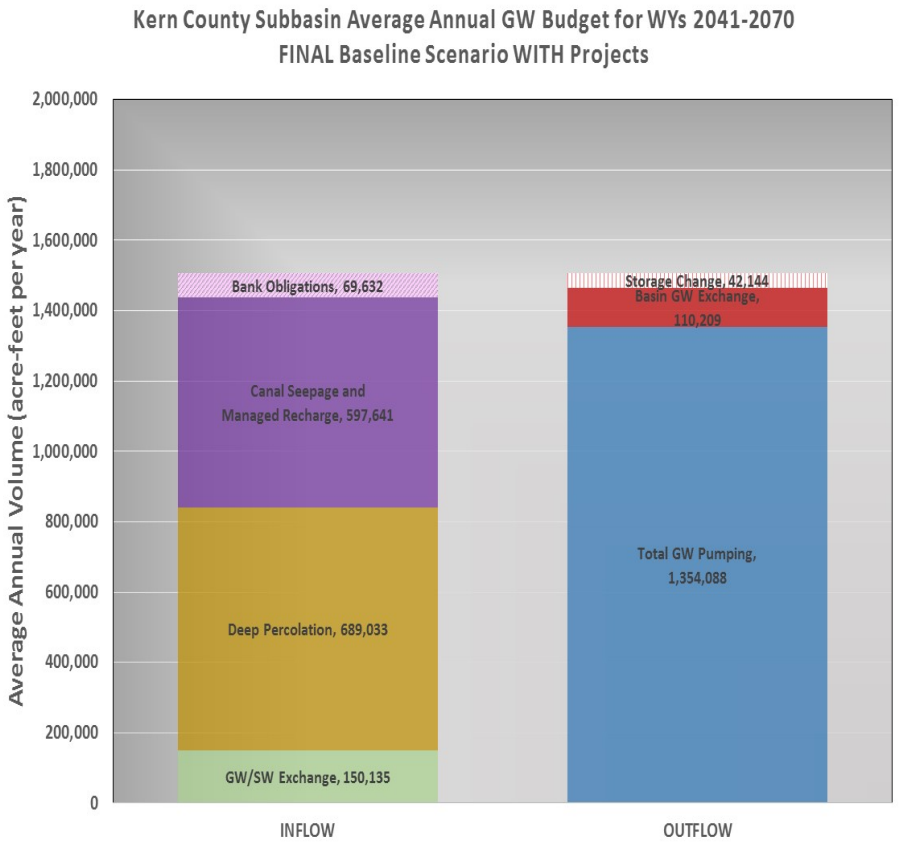


December 2019	Figure 15 Average Annual Benefit of Proposed SGMA Projects and Management Actions
TODD GROUNDWATER	

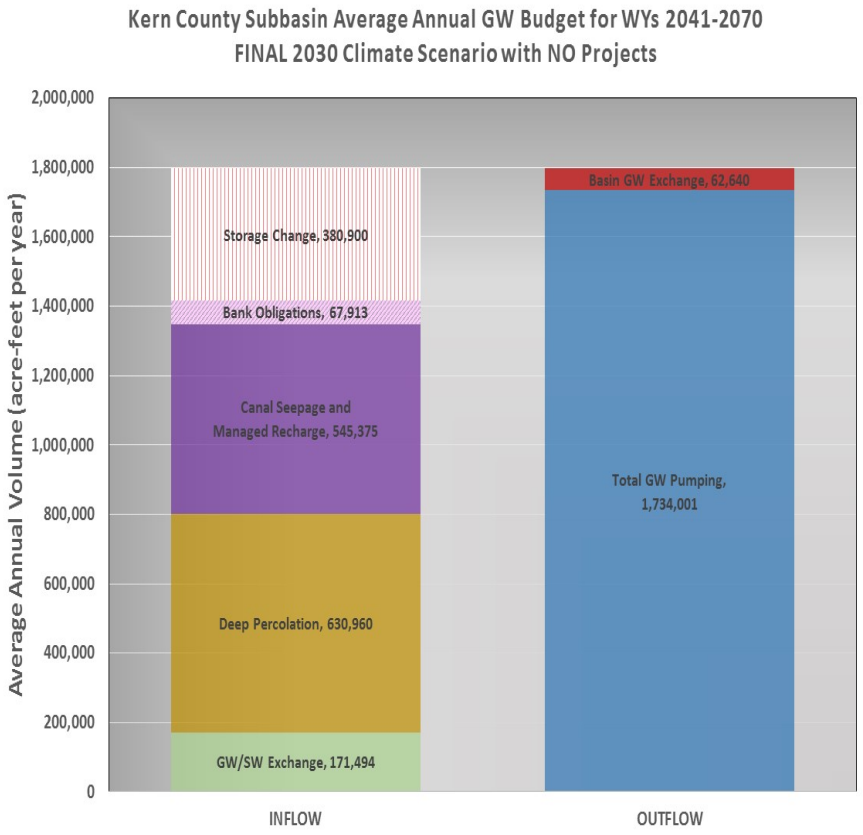


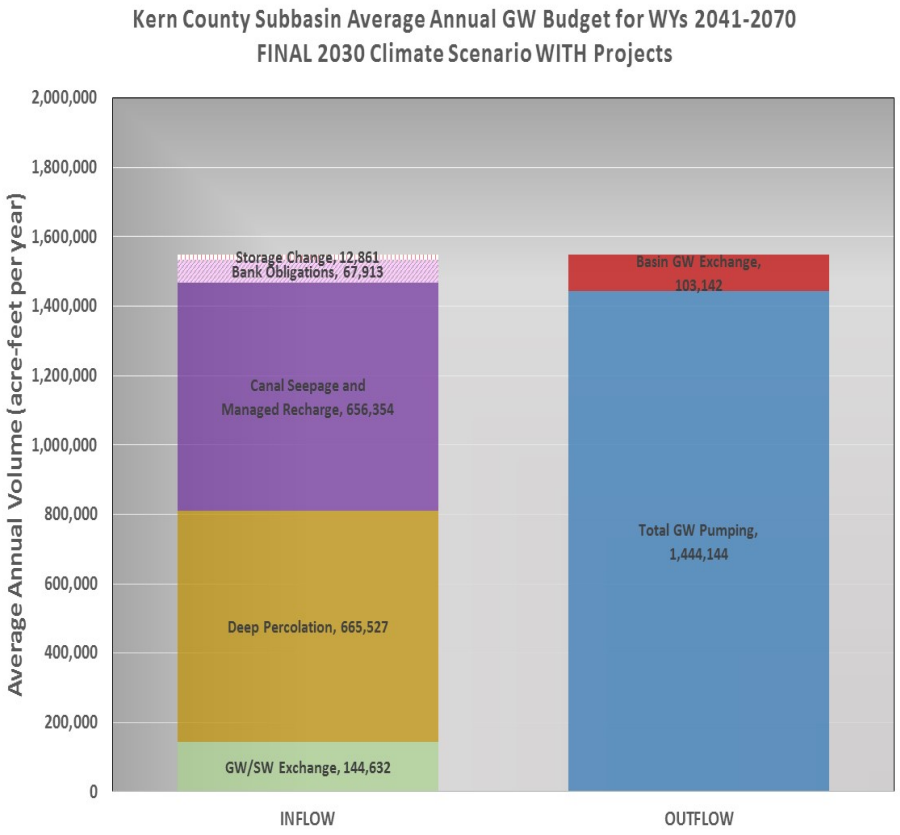
December 2019	Figure 16 Projected Future Change in Groundwater Storage for Baseline Conditions
TODD GROUNDWATER	



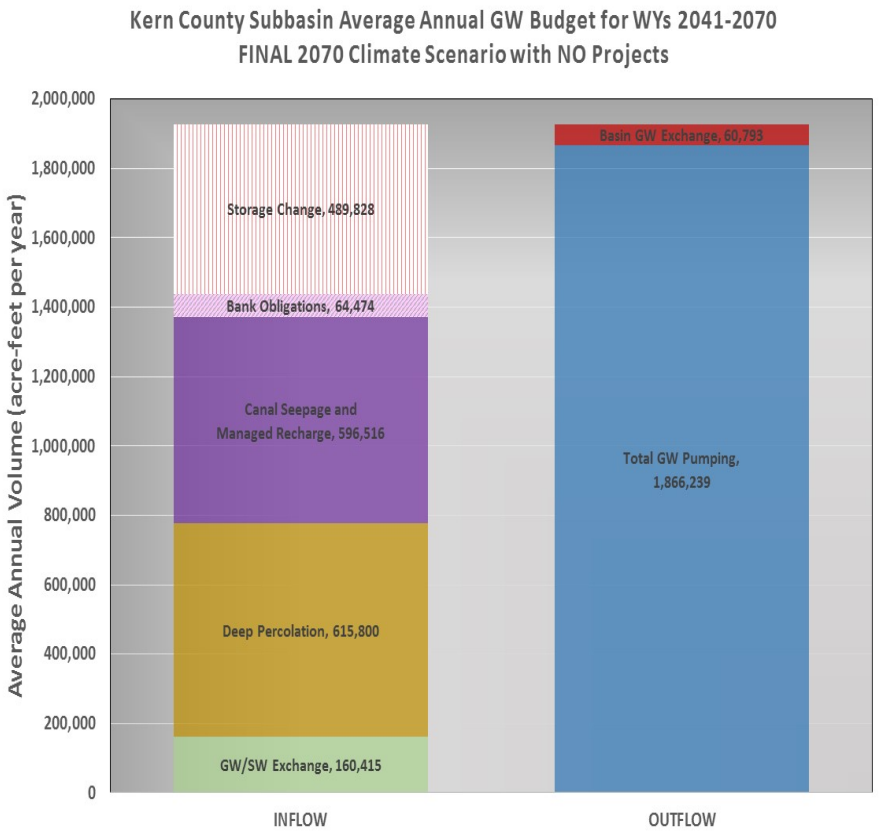


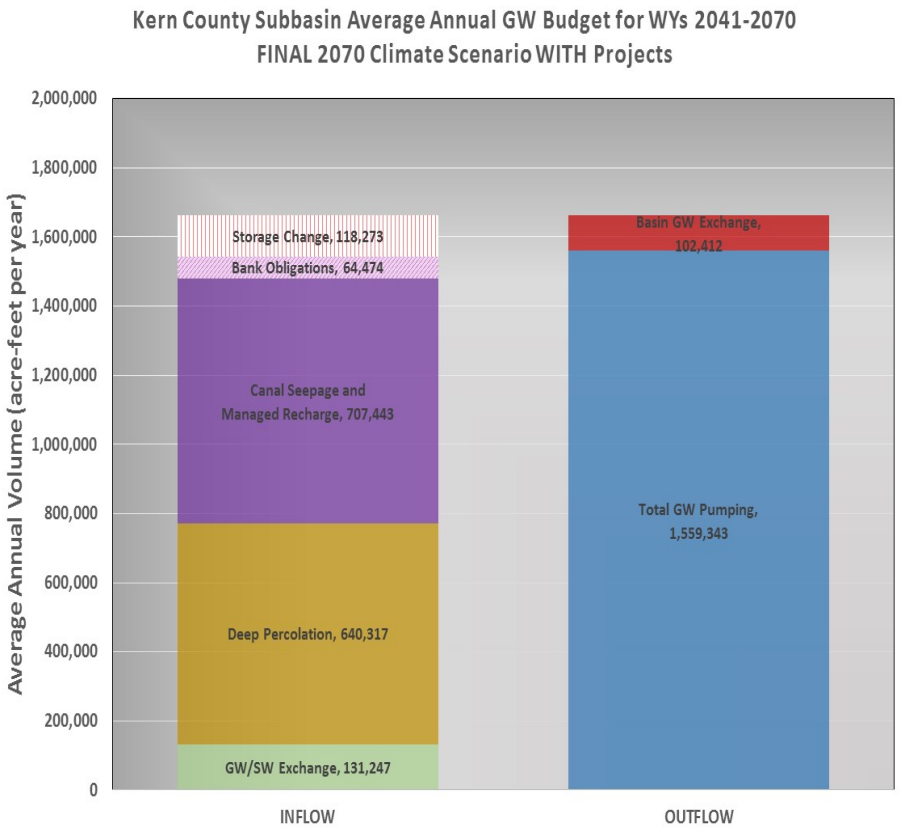
December 2019	Figure 17 Baseline Projected Future Average Annual Groundwater Budget for WY2041-2070
TODD GROUNDWATER	



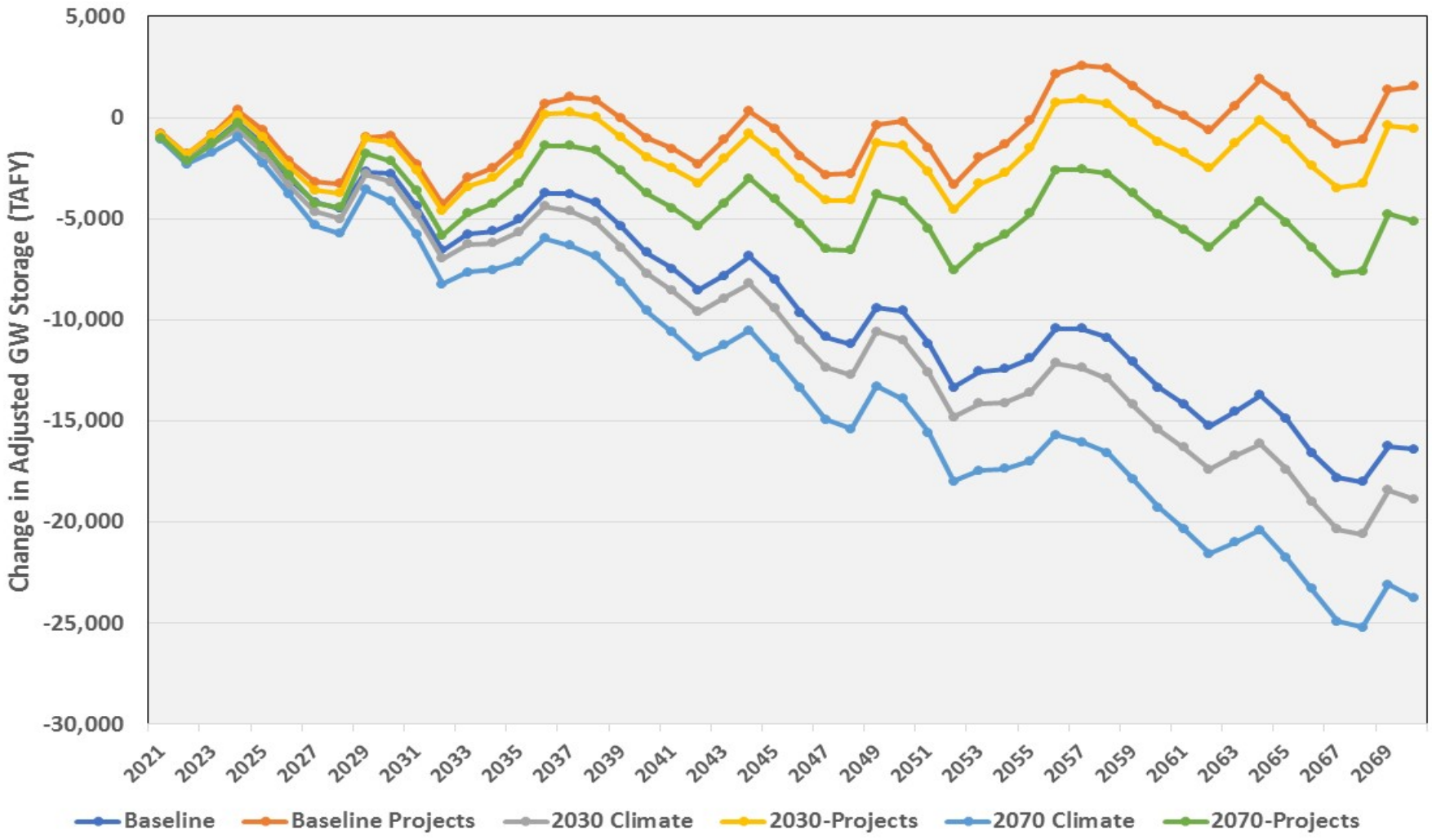


December 2019	Figure 18 2030 Climate Projected Future Average Annual Groundwater Budget for WY2041-2070
TODD GROUNDWATER	

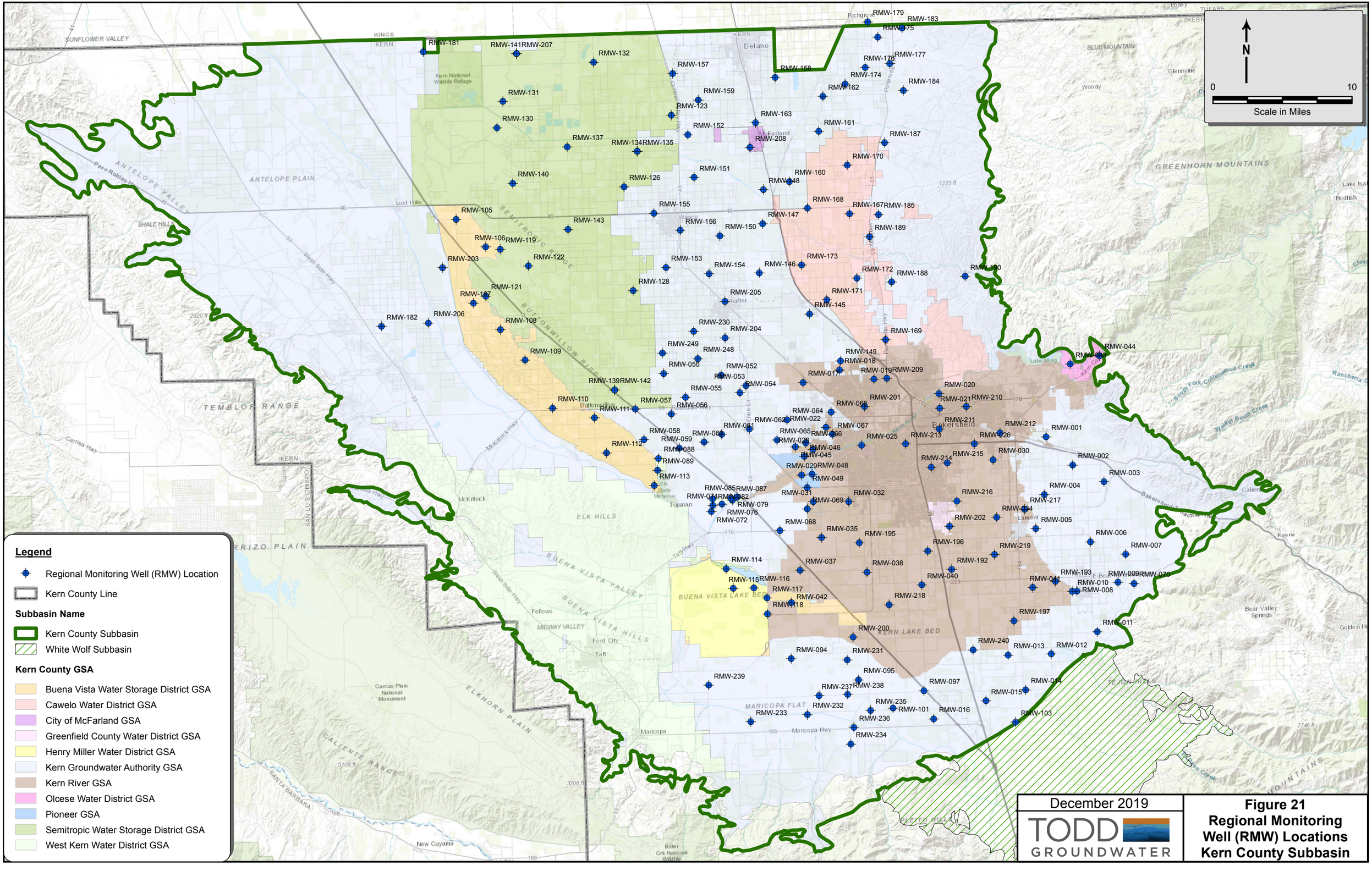


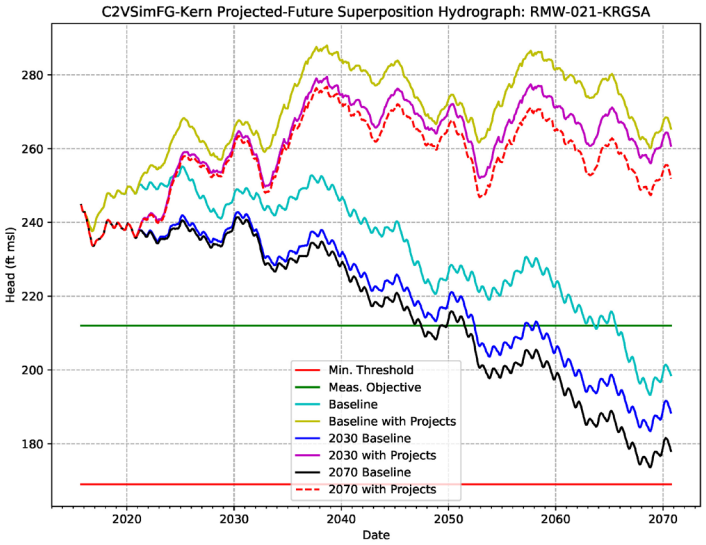


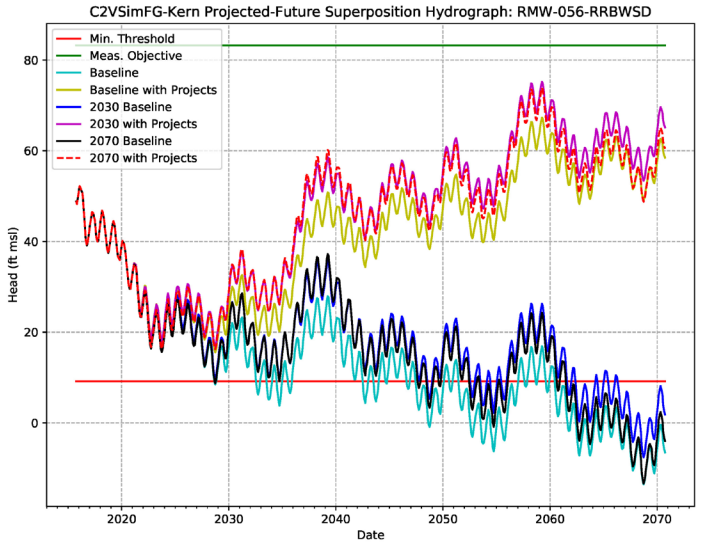
December 2019	Figure 19 2070 Climate Projected Future Average Annual Groundwater Budget for WY2041-2070
TODD GROUNDWATER	

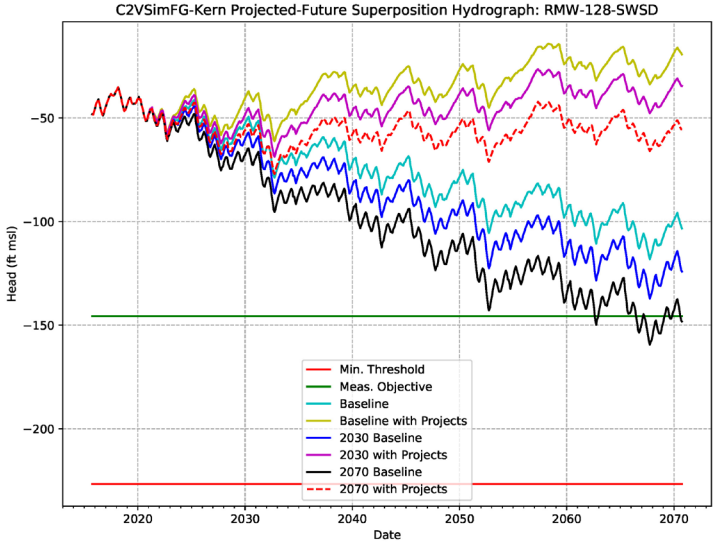


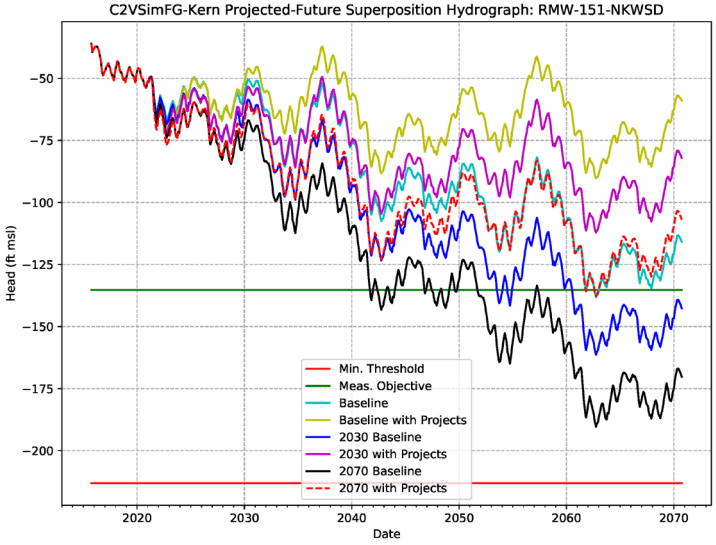
December 2019	Figure 20 Projected Future Change in Groundwater Storage for All Conditions
TODD GROUNDWATER	


N
0
10
Scale in Miles
Legend
Regional Monitoring Well (RMW) Location
Kern County Line
Subbasin Name
Kern County Subbasin
White Wolf Subbasin
Kern County GSA
Buena Vista Water Storage District GSA
Cawelo Water District GSA
City of McFarland GSA
Greenfield County Water District GSA
Henry Miller Water District GSA
Kern Groundwater Authority GSA
Kern River GSA
Olcese Water District GSA
Pioneer GSA
Semitropic Water Storage District GSA
West Kern Water District GSA
December 2019
TODD GROUNDWATER
Figure 21
Regional Monitoring Well (RMW) Locations
Kern County Subbasin





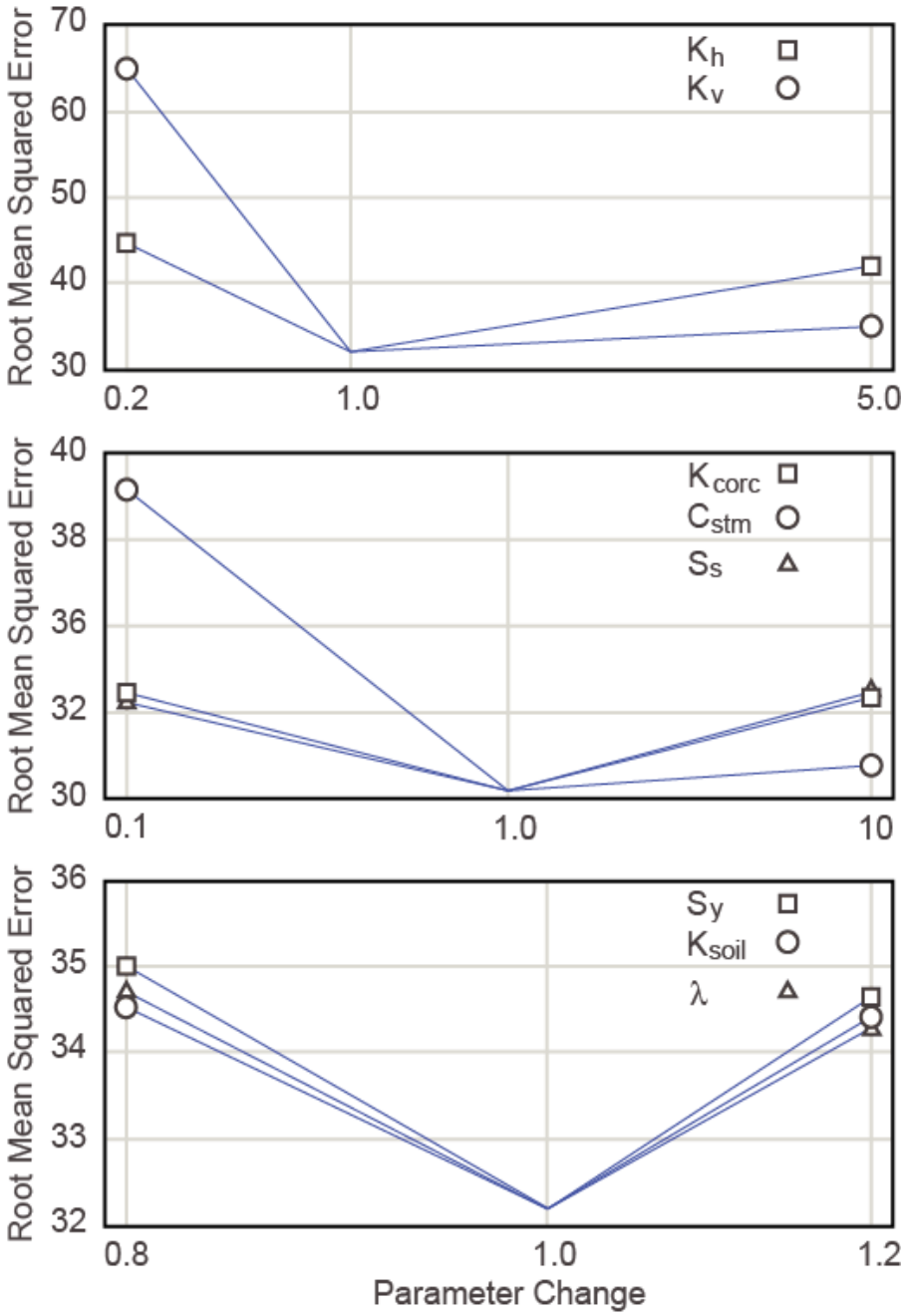




December 2019

TODD GROUNDWATER

Figure 22
Hydrographs for all Projected Future Conditions with SGMA Sustainability Criteria



Notes:
Sensitivity parameters modified and evaluated for Kern County Subbasin
Kh – horizontal hydraulic conductivity of aquifer
Kv – vertical hydraulic conductivity of aquifer

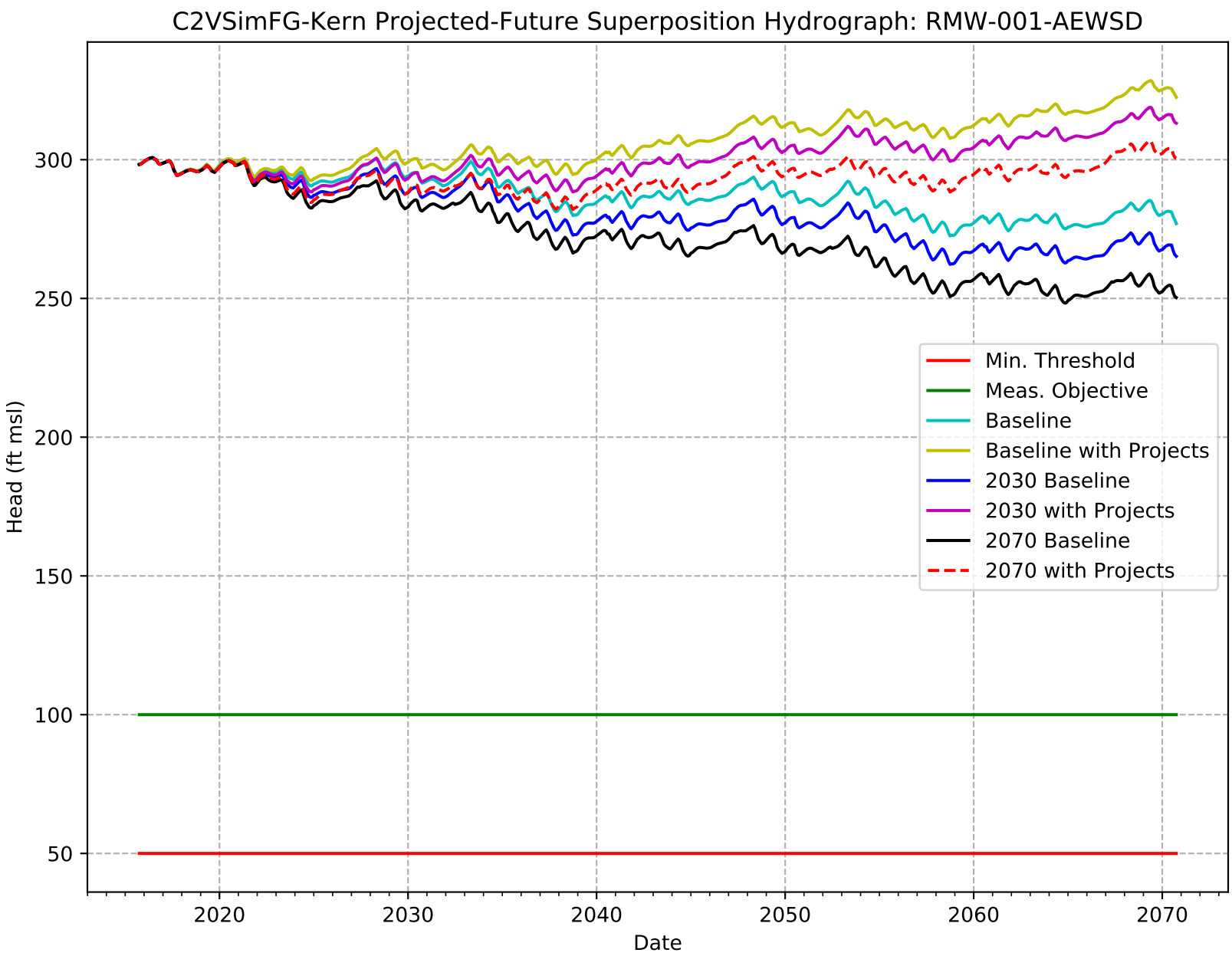
Kcorc - horizontal hydraulic conductivity of Corcoran Clay aquitard or equivalent
Cstm – streambed conductance of Kern River and Poso Creek
Ss – specific storage of aquifer

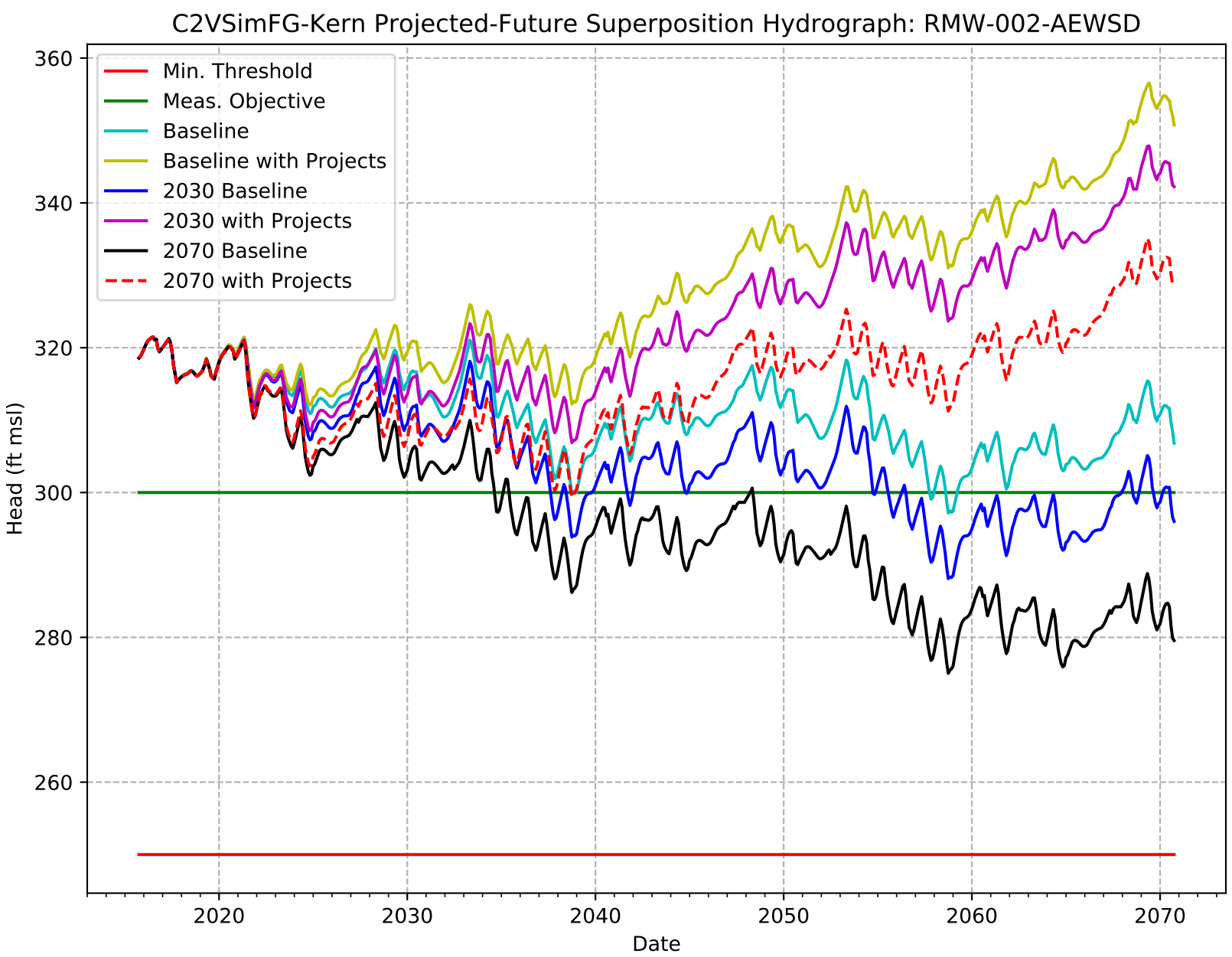
Sy – specific yield of aquifer
Ksoil –soil hydraulic conductivity in root zone
Λ –soil pore size distribution index in root zone

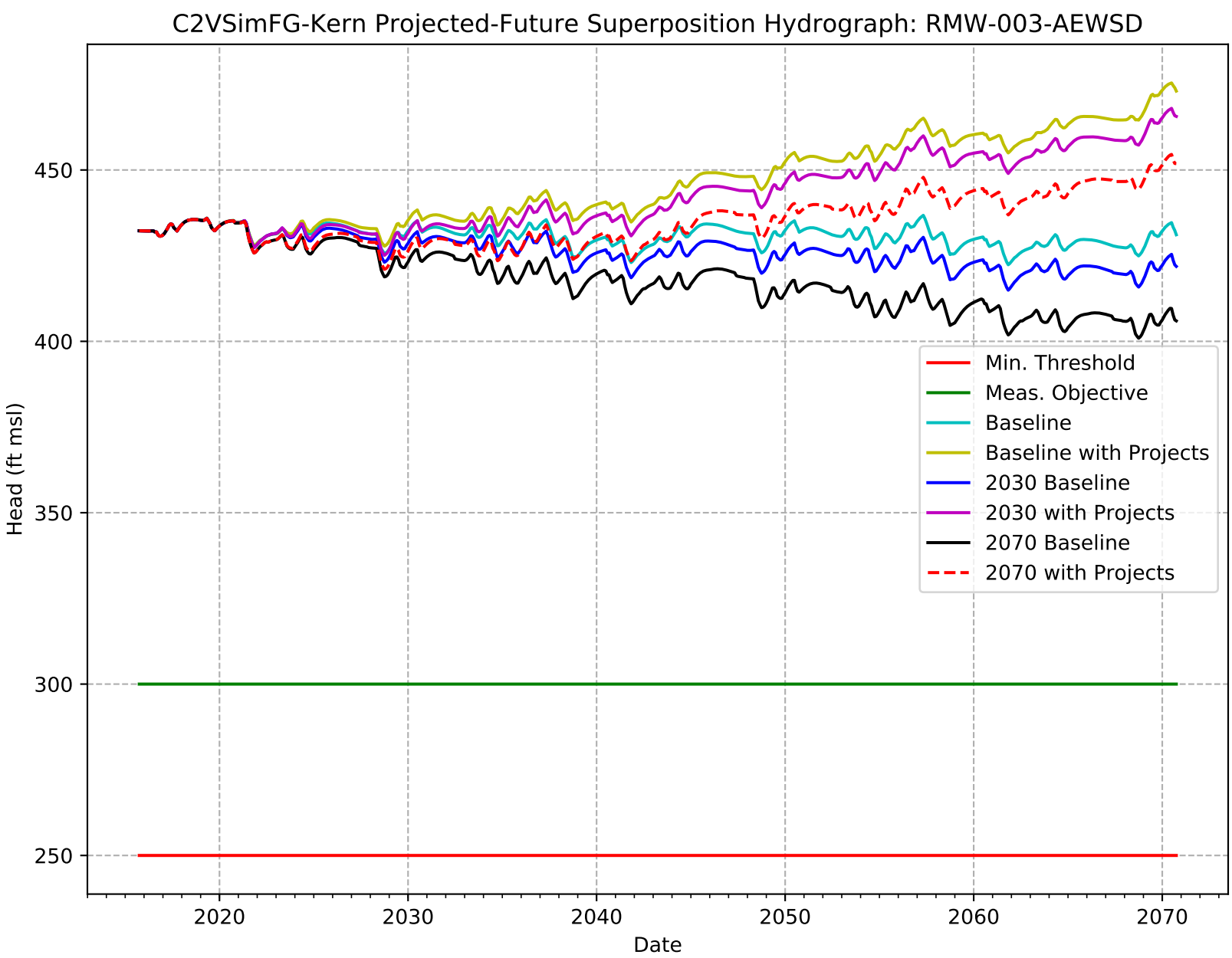
December 2019	Figure 23 C2VSimFG-Kern Sensitivity Analysis Results
TODD GROUNDWATER	

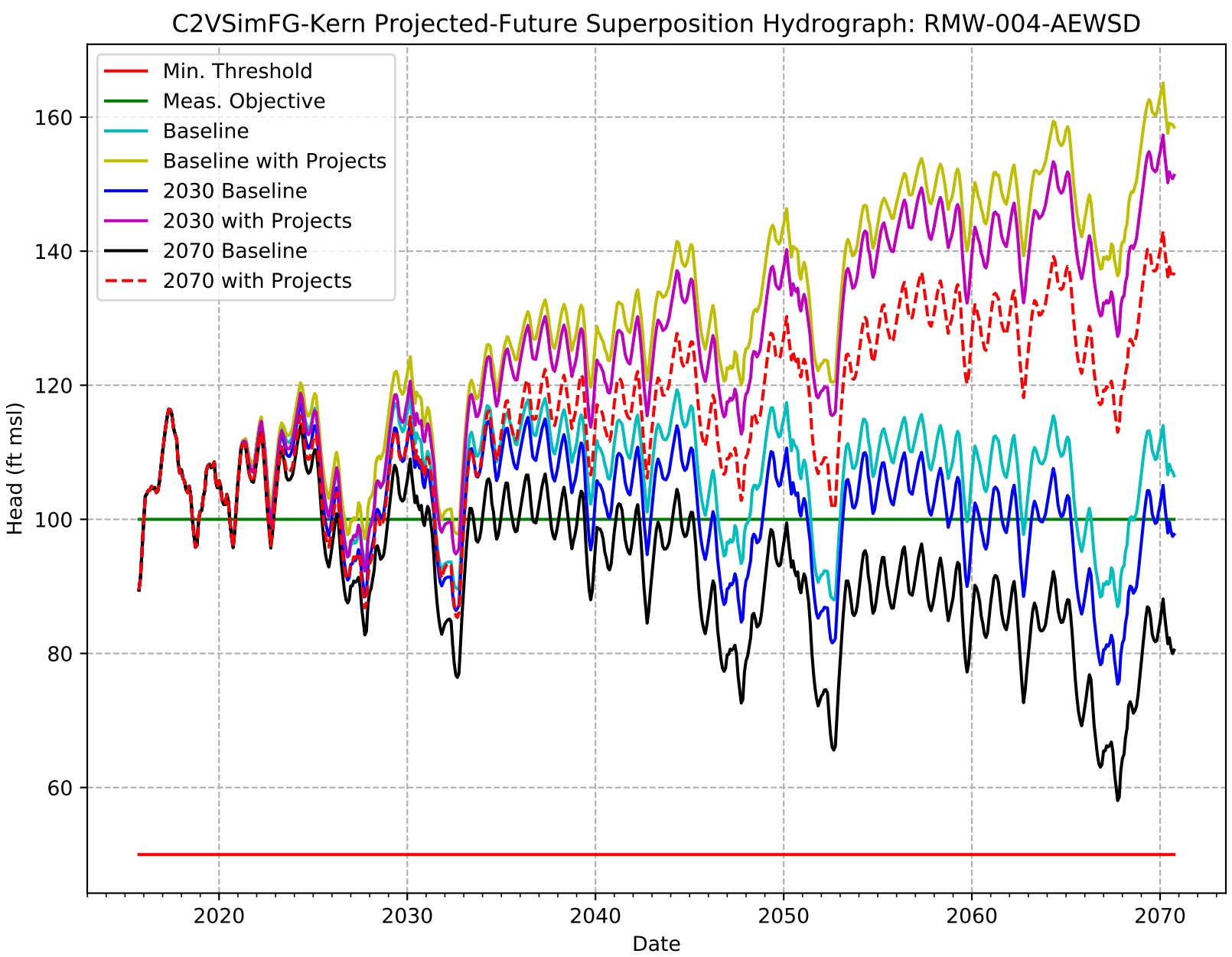
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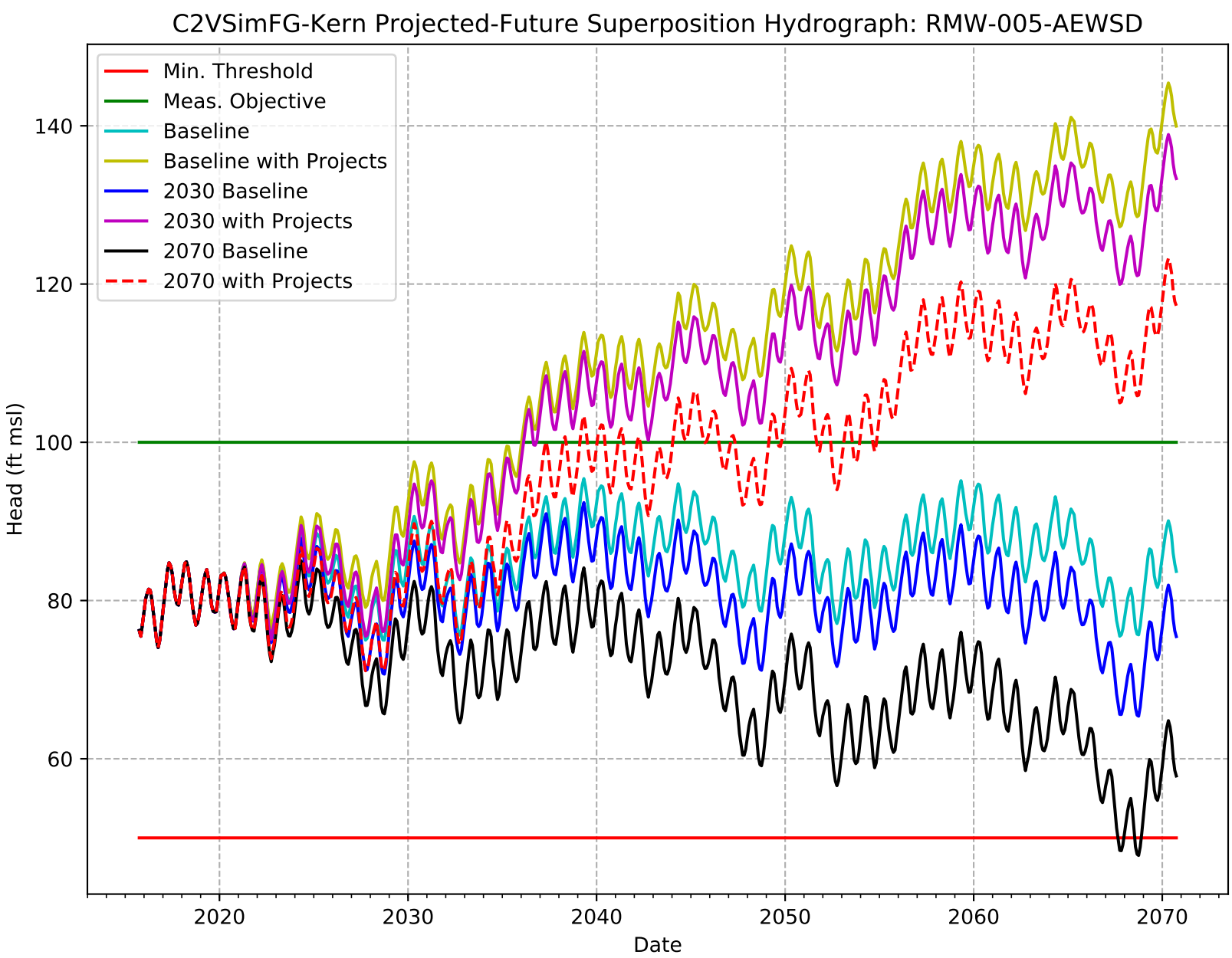
C2VSimFG-Kern Hydrographs at Regional Monitoring Wells in Kern County Subbasin for Projected Future Water Budget Simulations

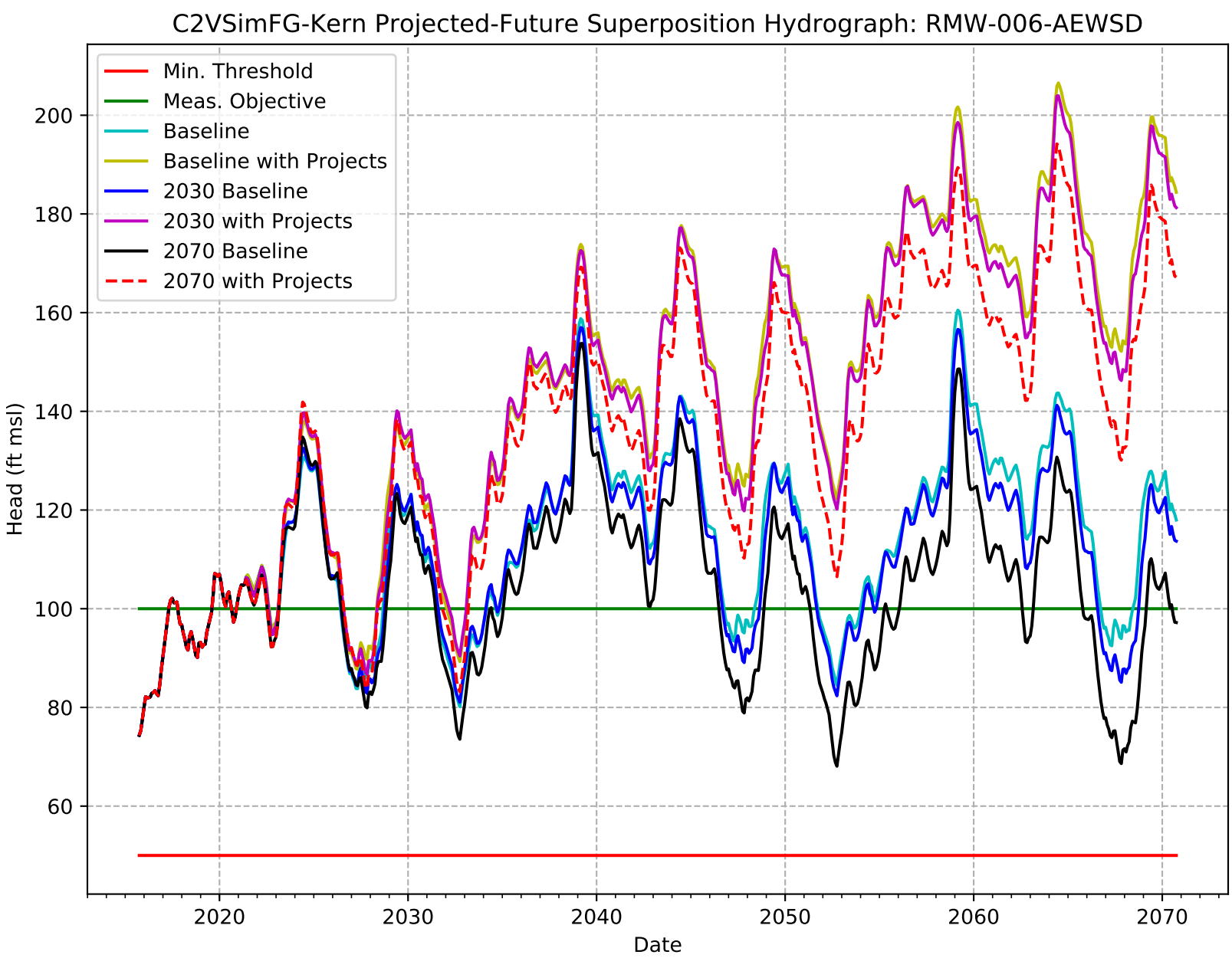

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-001-AEWSD
Head (ft msl)
300
250
200
150
100
50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

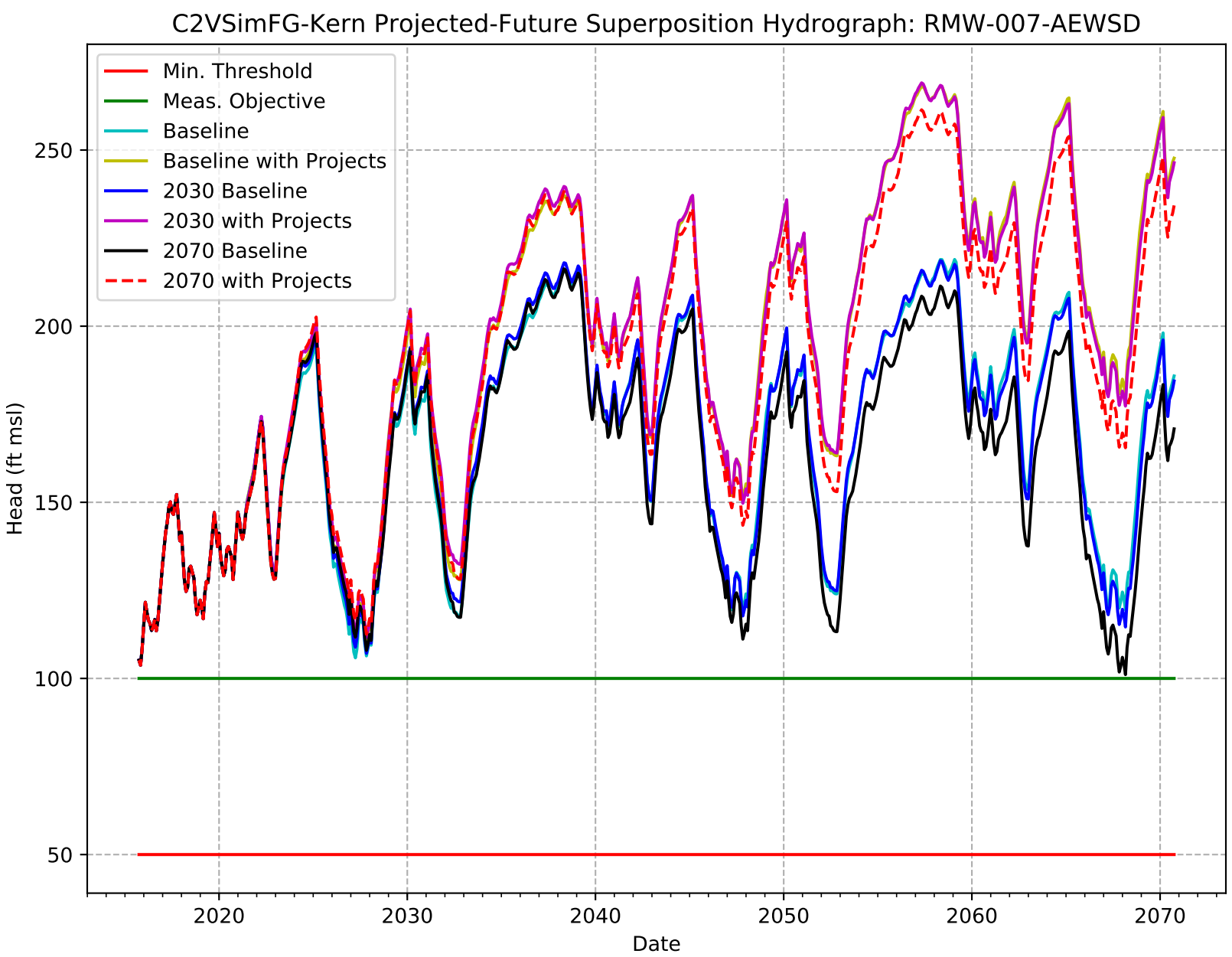

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-002-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
360
340
320
300
280
260
2020
2030
2040
2050
2060
2070
Date

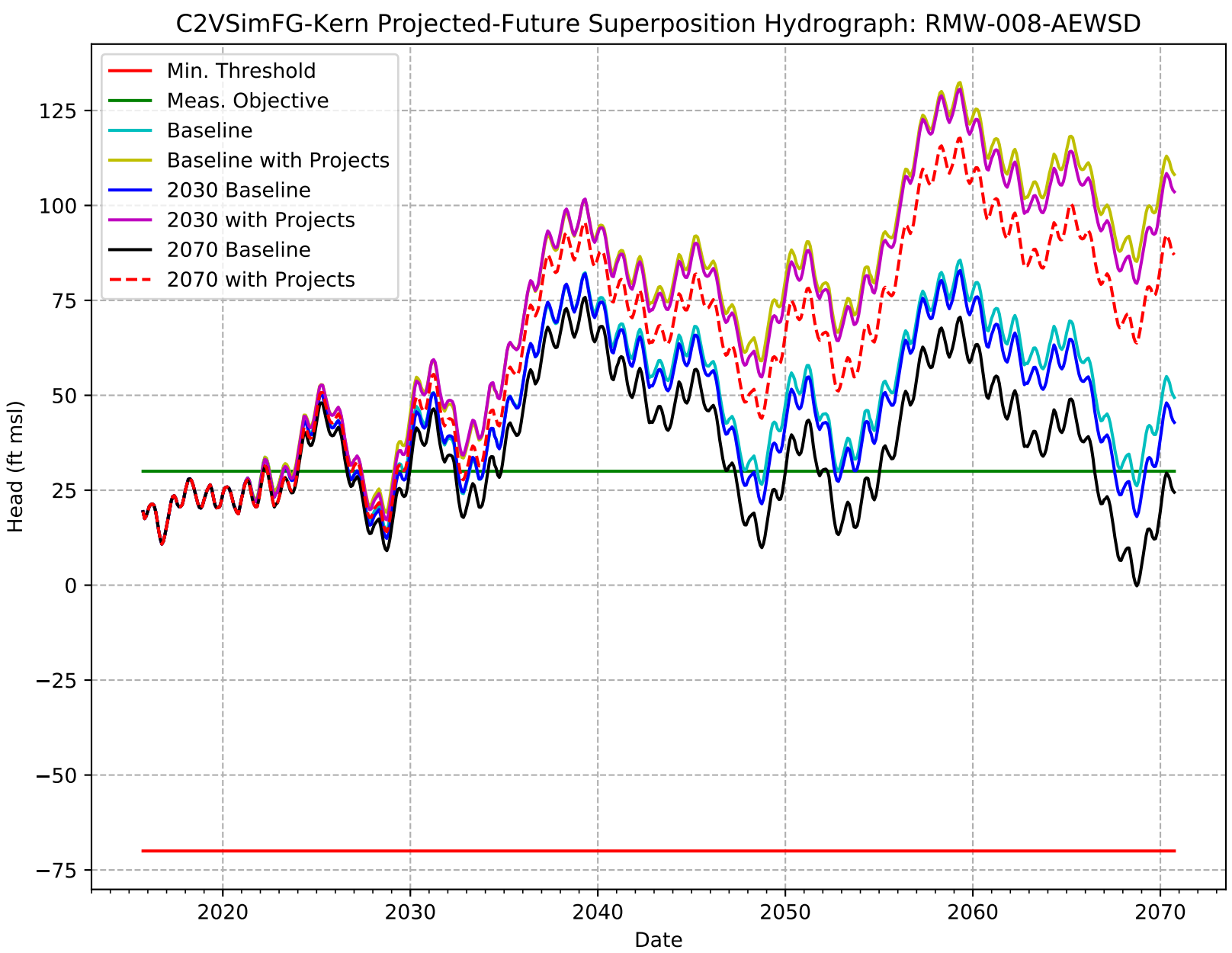

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-003-AEWSD
Head (ft msl)
450
400
350
300
250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

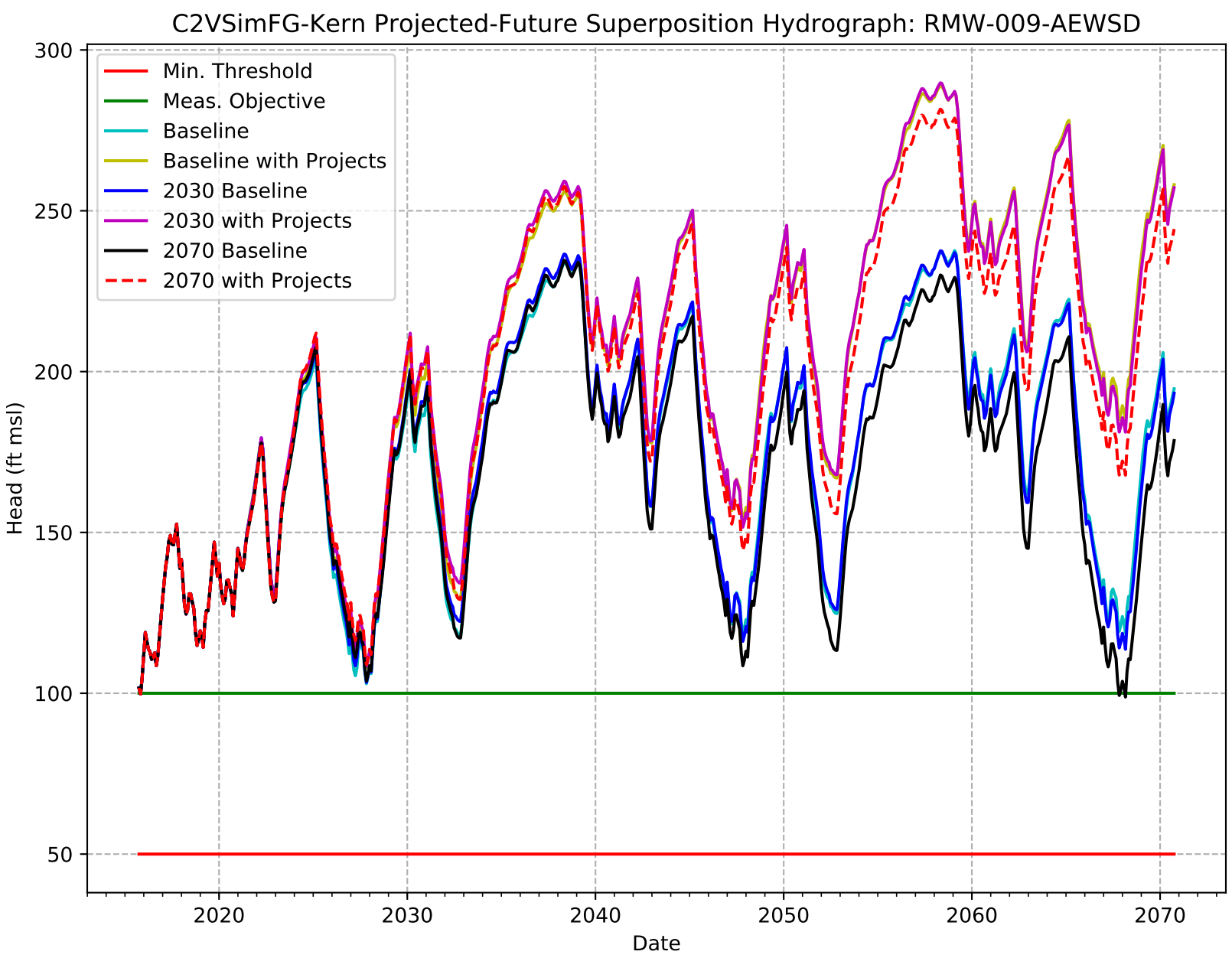

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-004-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

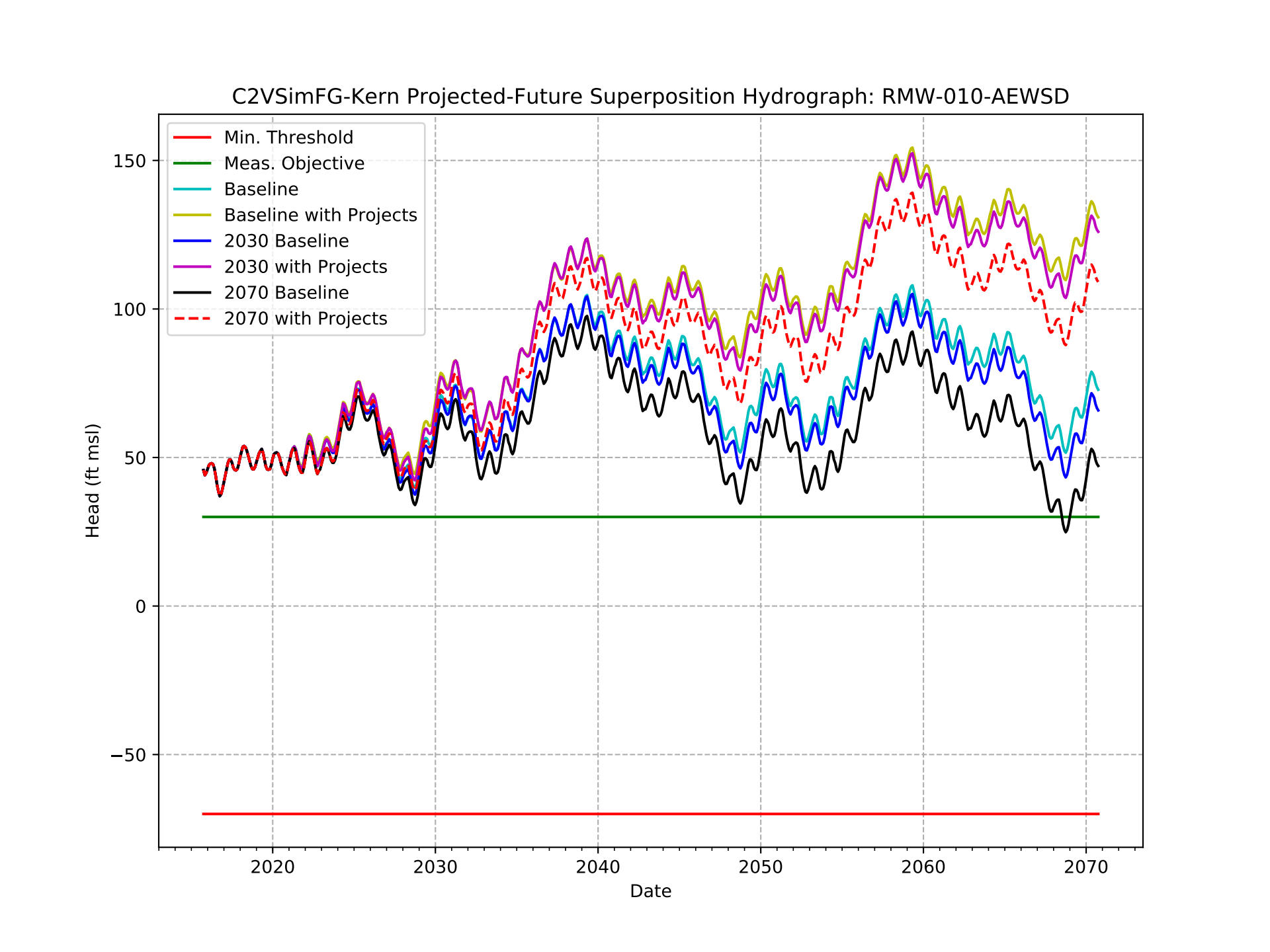

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-005-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

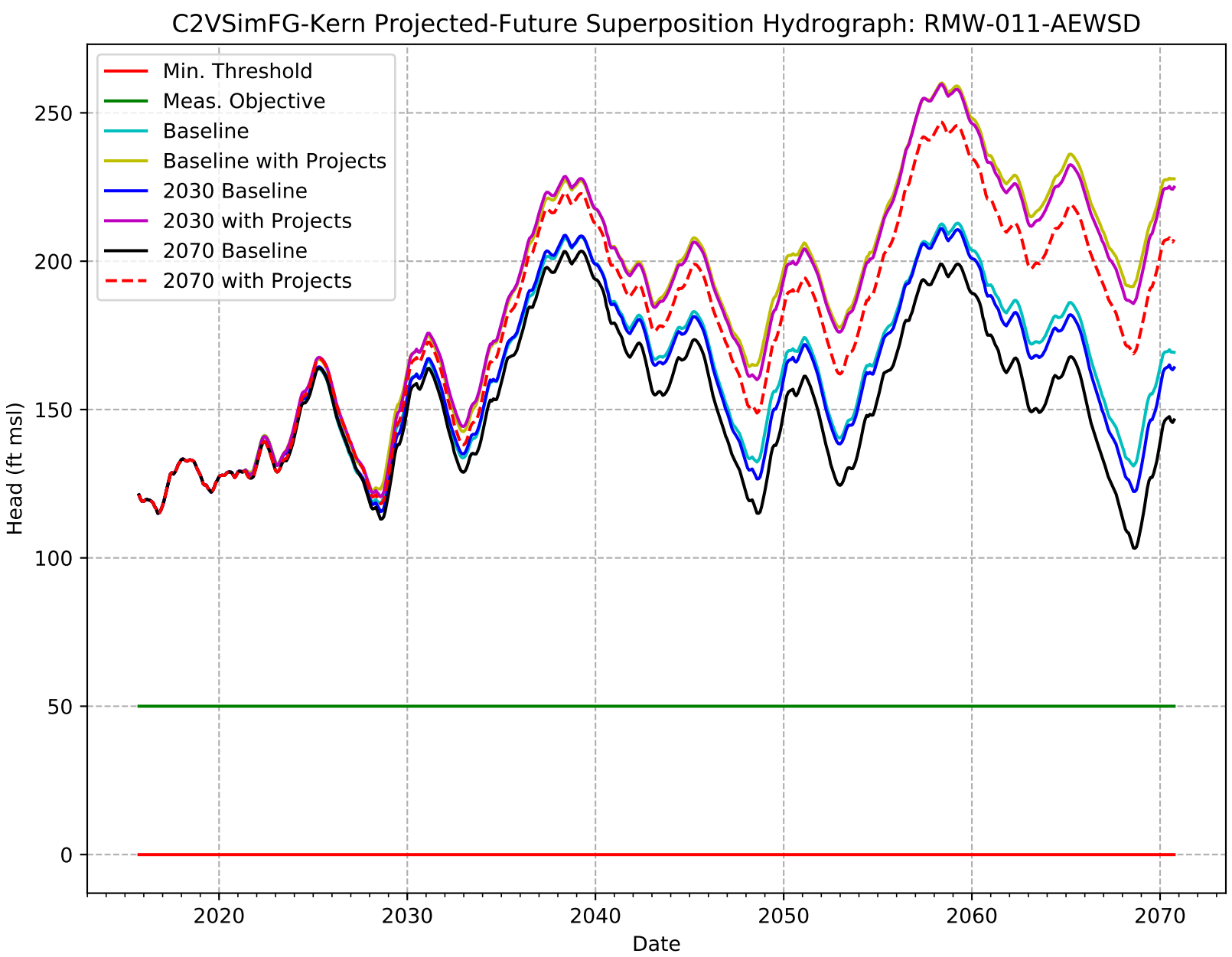

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-006-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

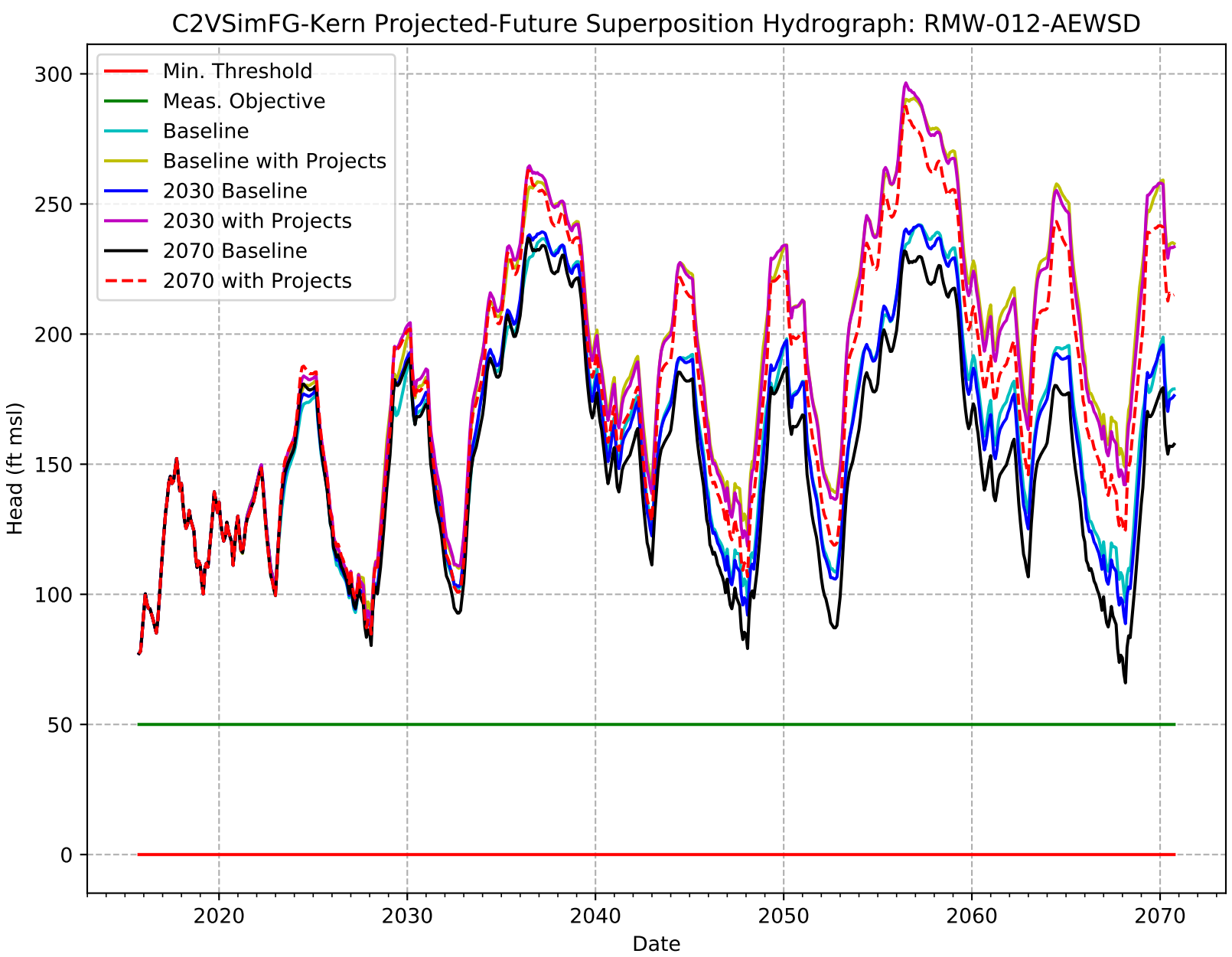

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-007-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
200
150
100
50
2020
2030
2040
2050
2060
2070
Date

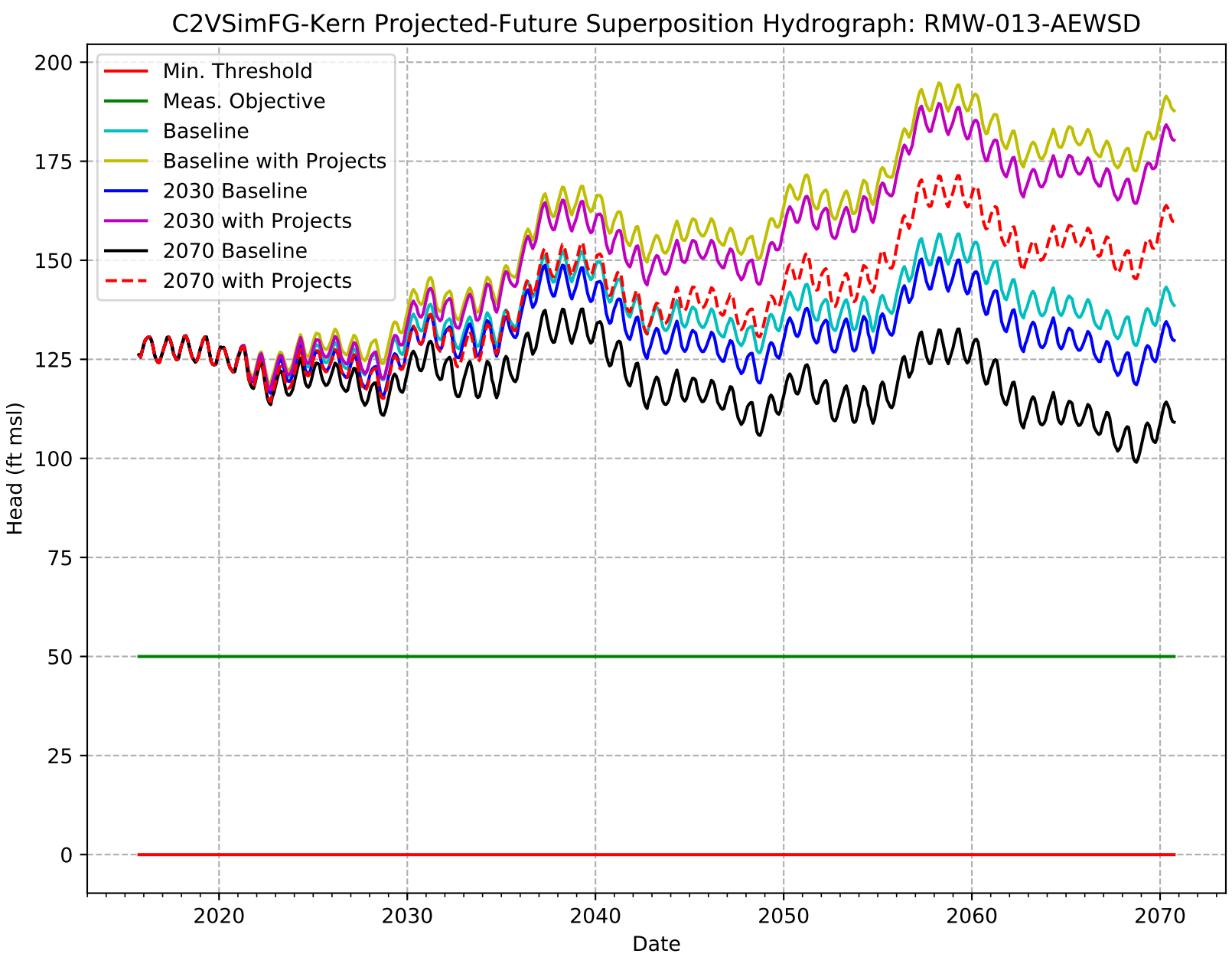

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-008-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
125
100
75
50
25
0
−25
−50
−75
2020
2030
2040
2050
2060
2070
Date

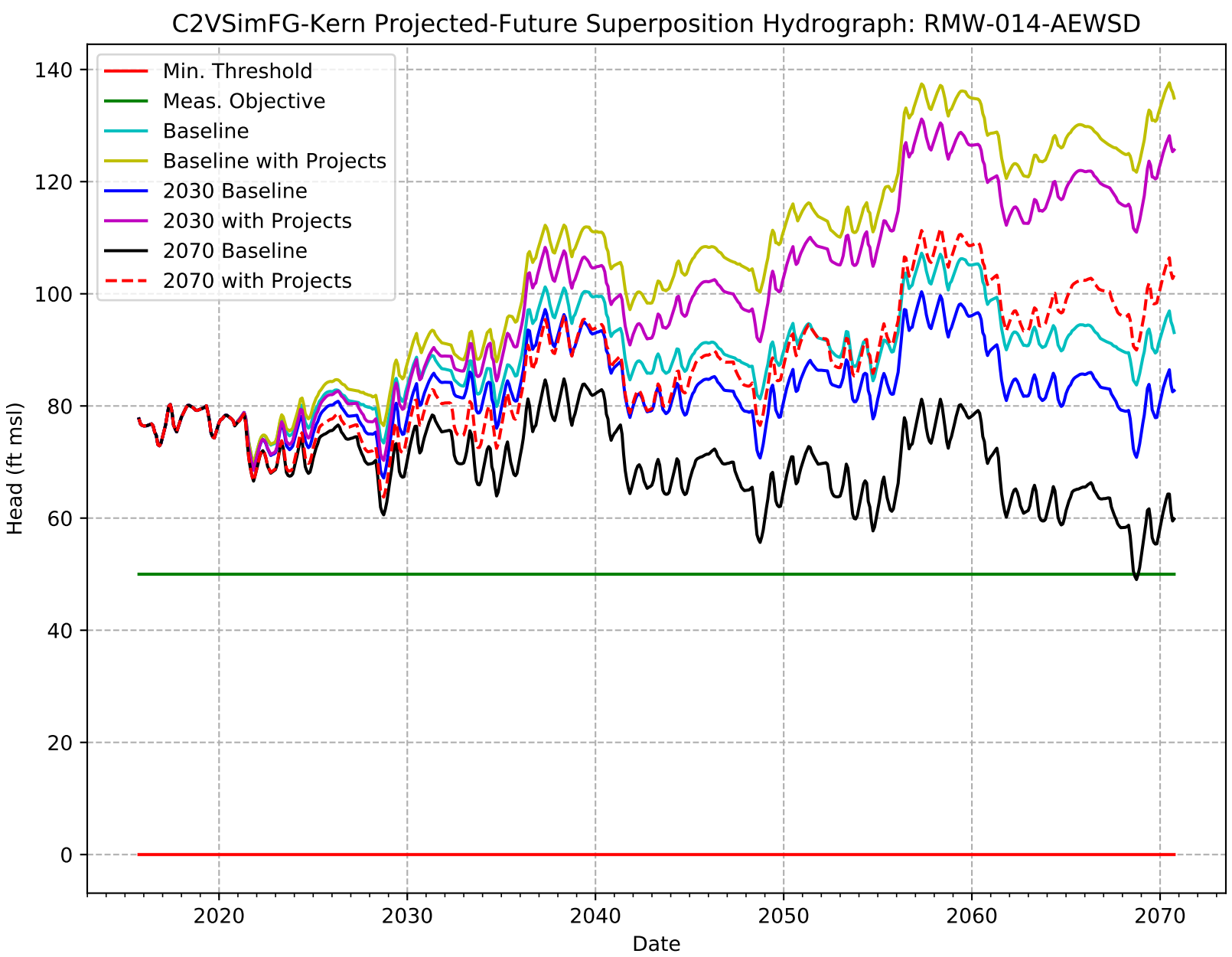

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-009-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
300
250
200
150
100
50
2020
2030
2040
2050
2060
2070
Date

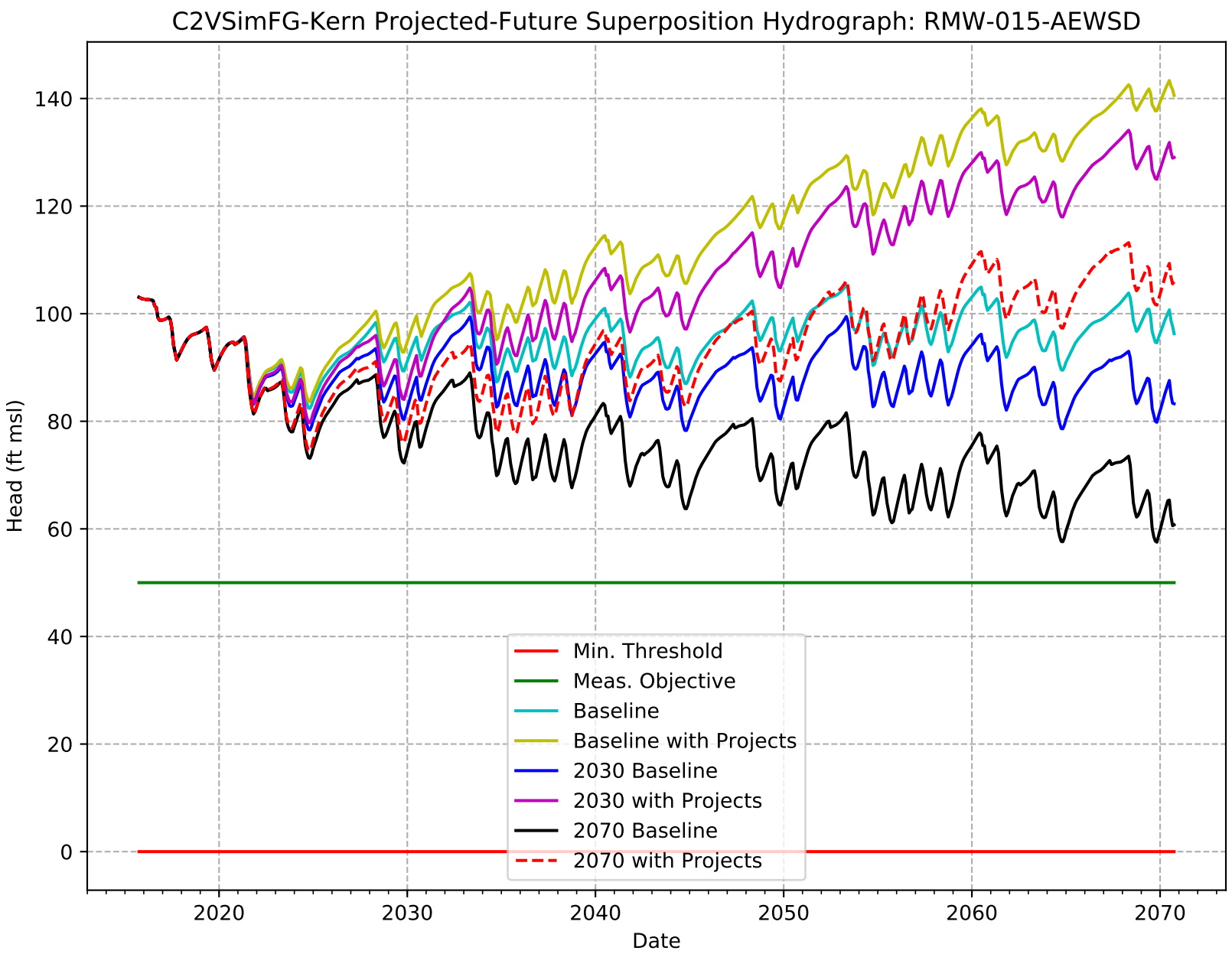

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-010-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
150
100
50
0
−50
Head (ft msl)
2020
2030
2040
2050
2060
2070
Date

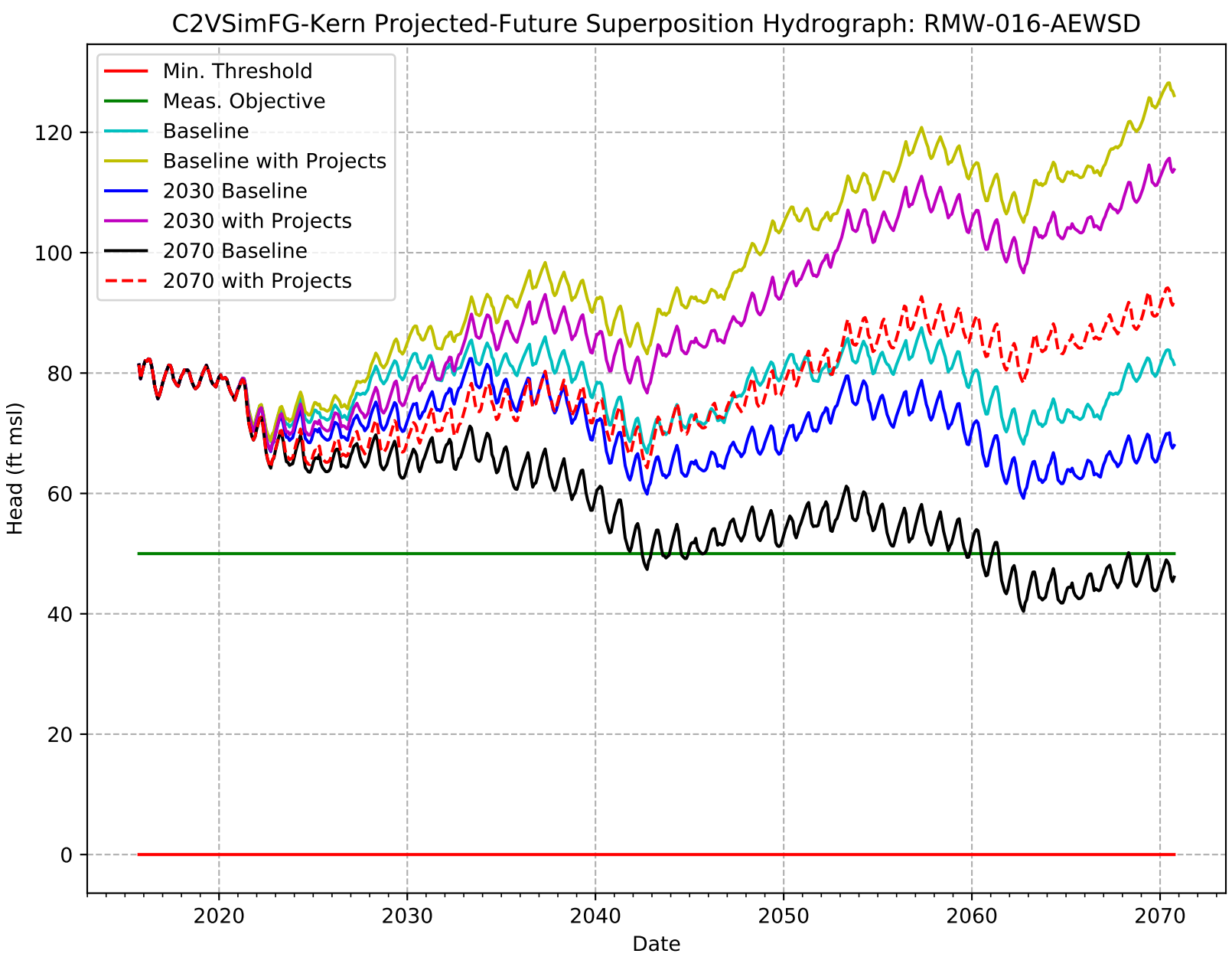

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-011-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date

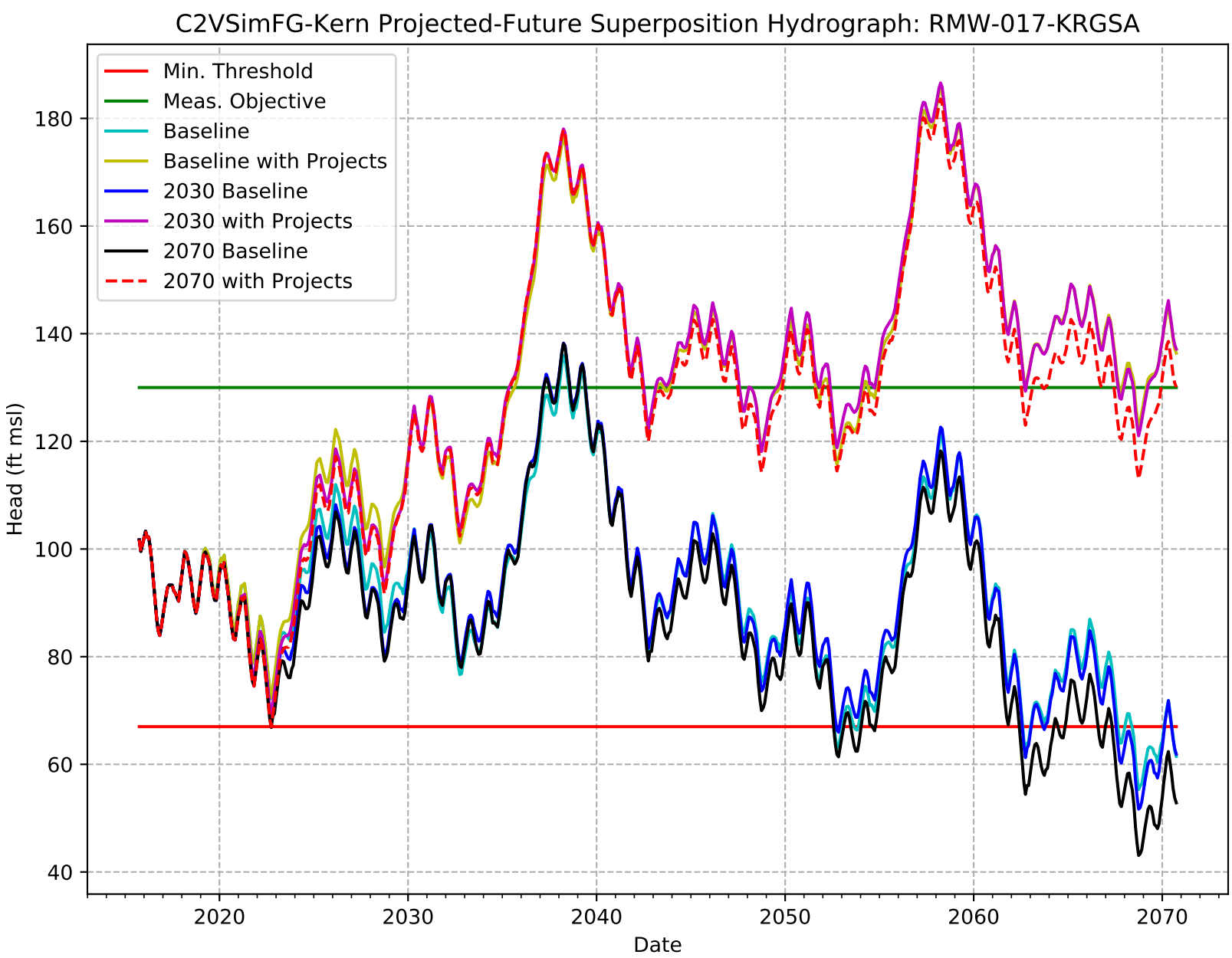

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-012-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
300
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date

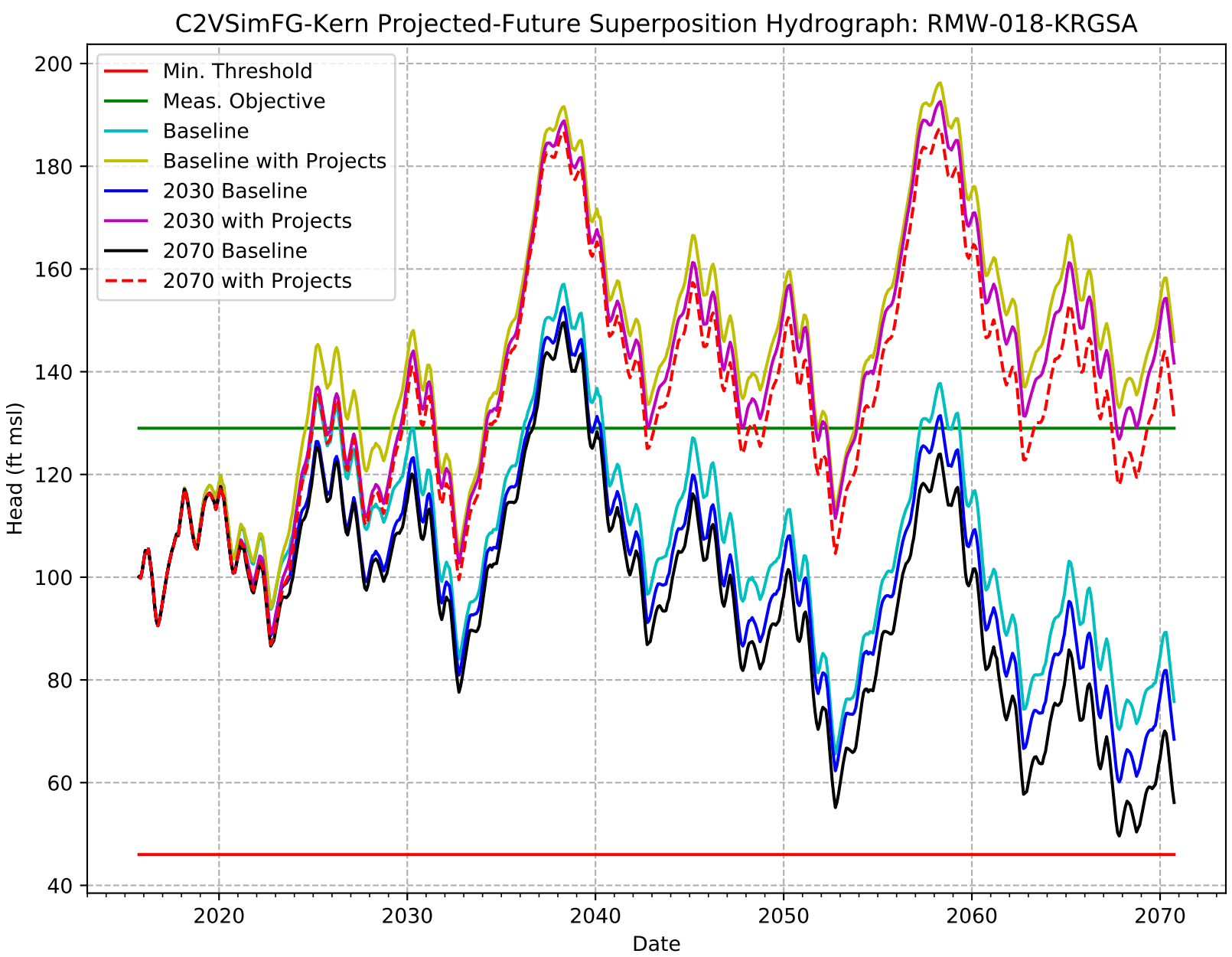

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-013-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
175
150
125
100
75
50
25
0
2020
2030
2040
2050
2060
2070
Date

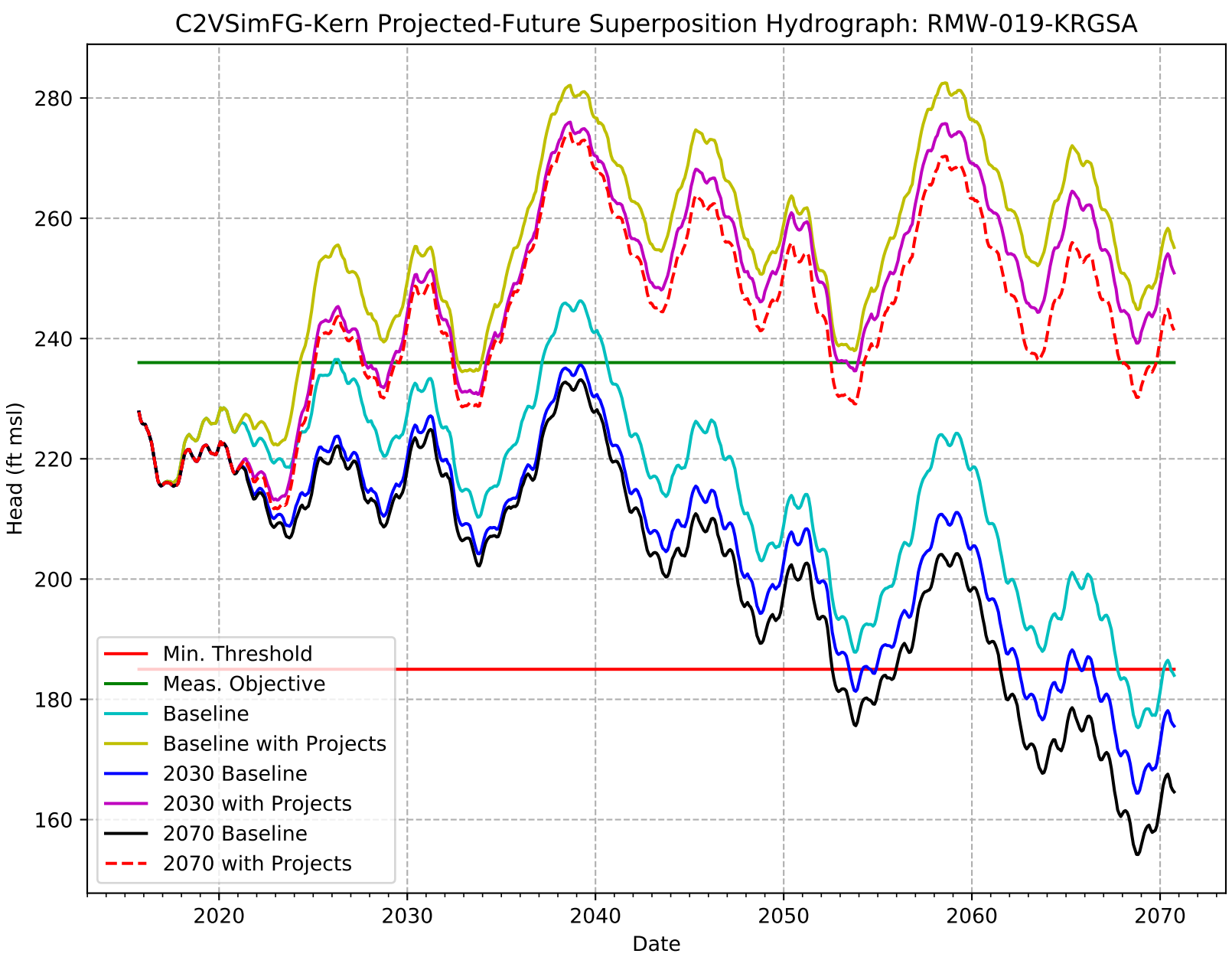

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-014-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
140
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

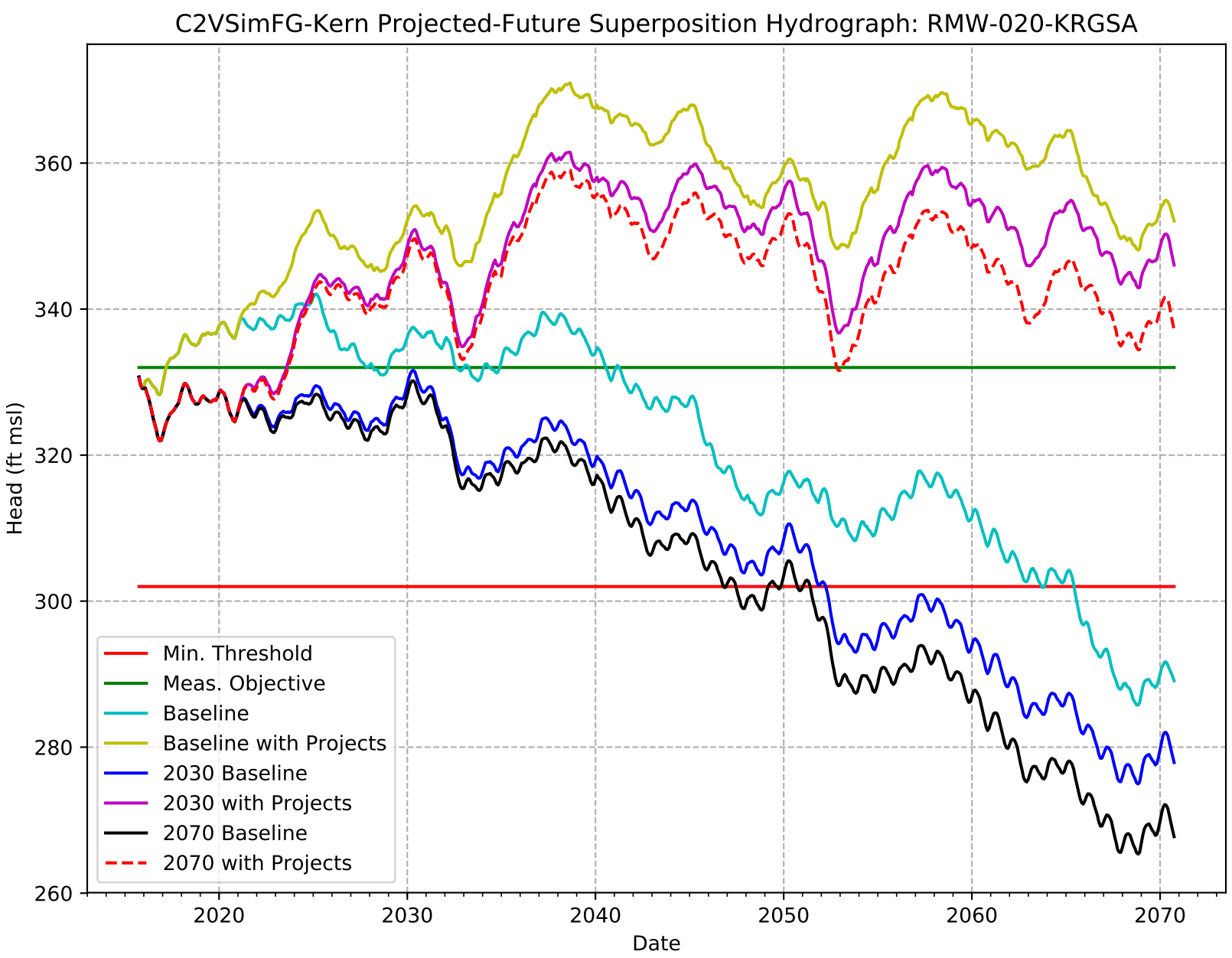

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-015-AEWSD
Head (ft msl)
Date
0
20
40
60
80
100
120
140
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

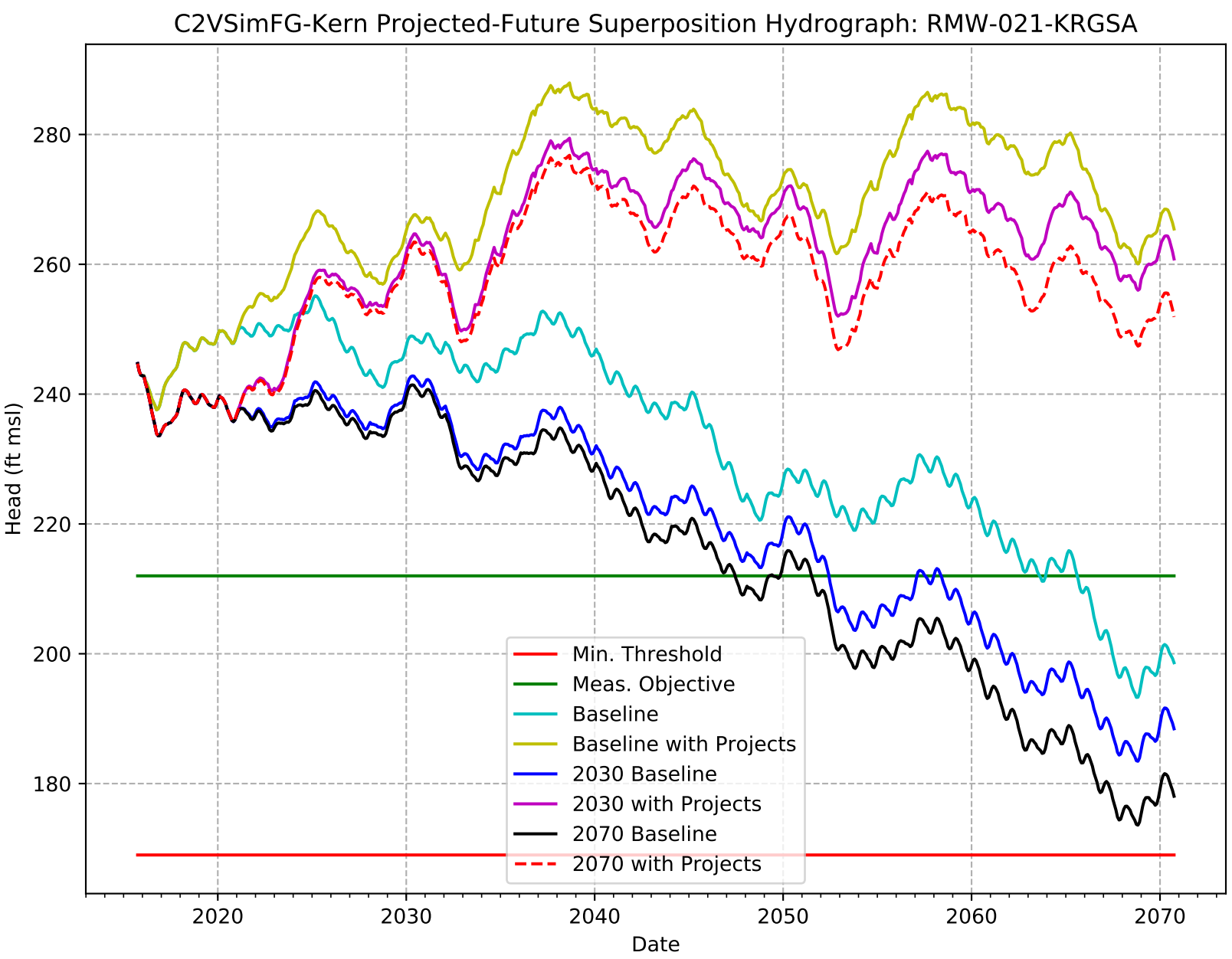

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-016-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

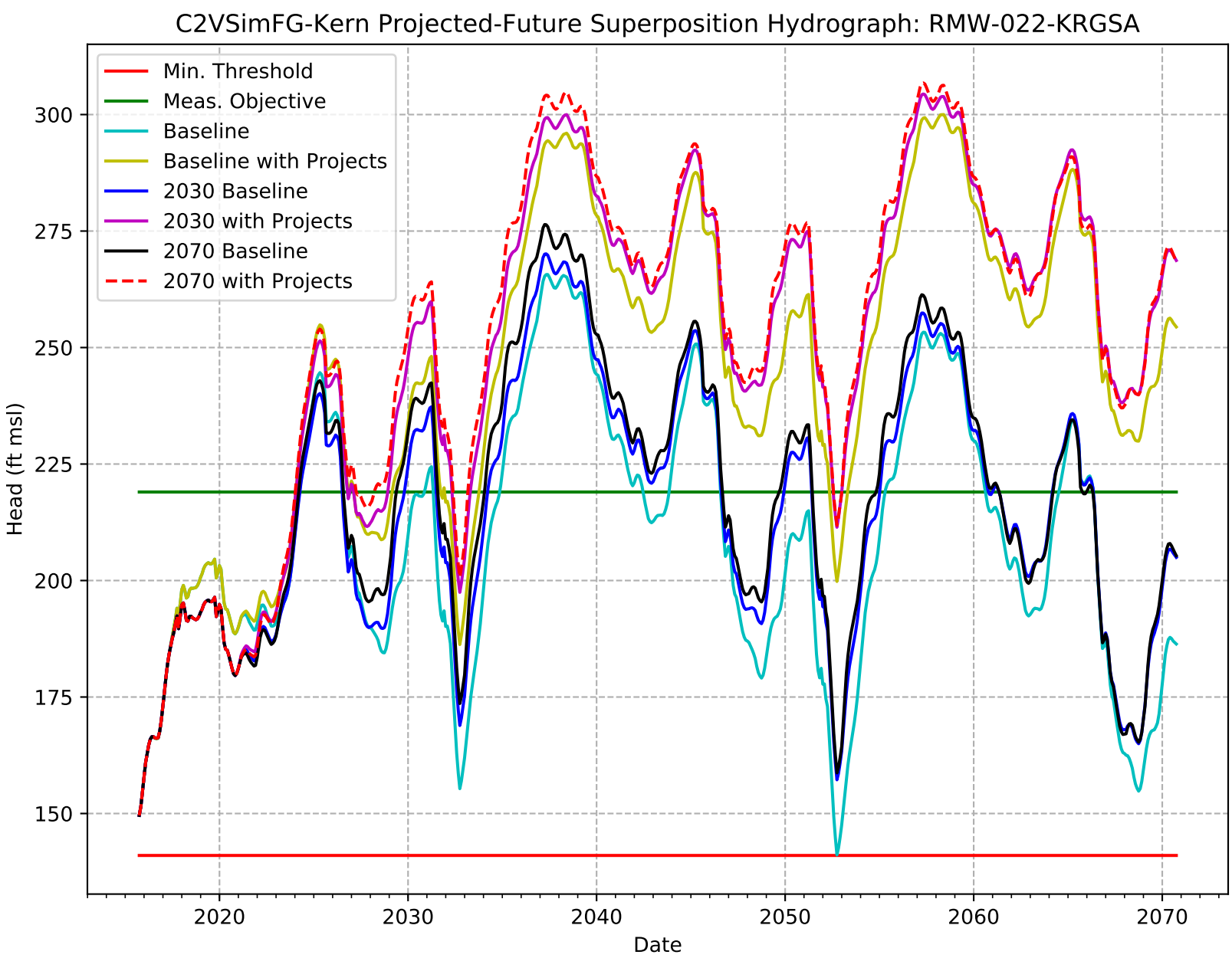

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-017-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date

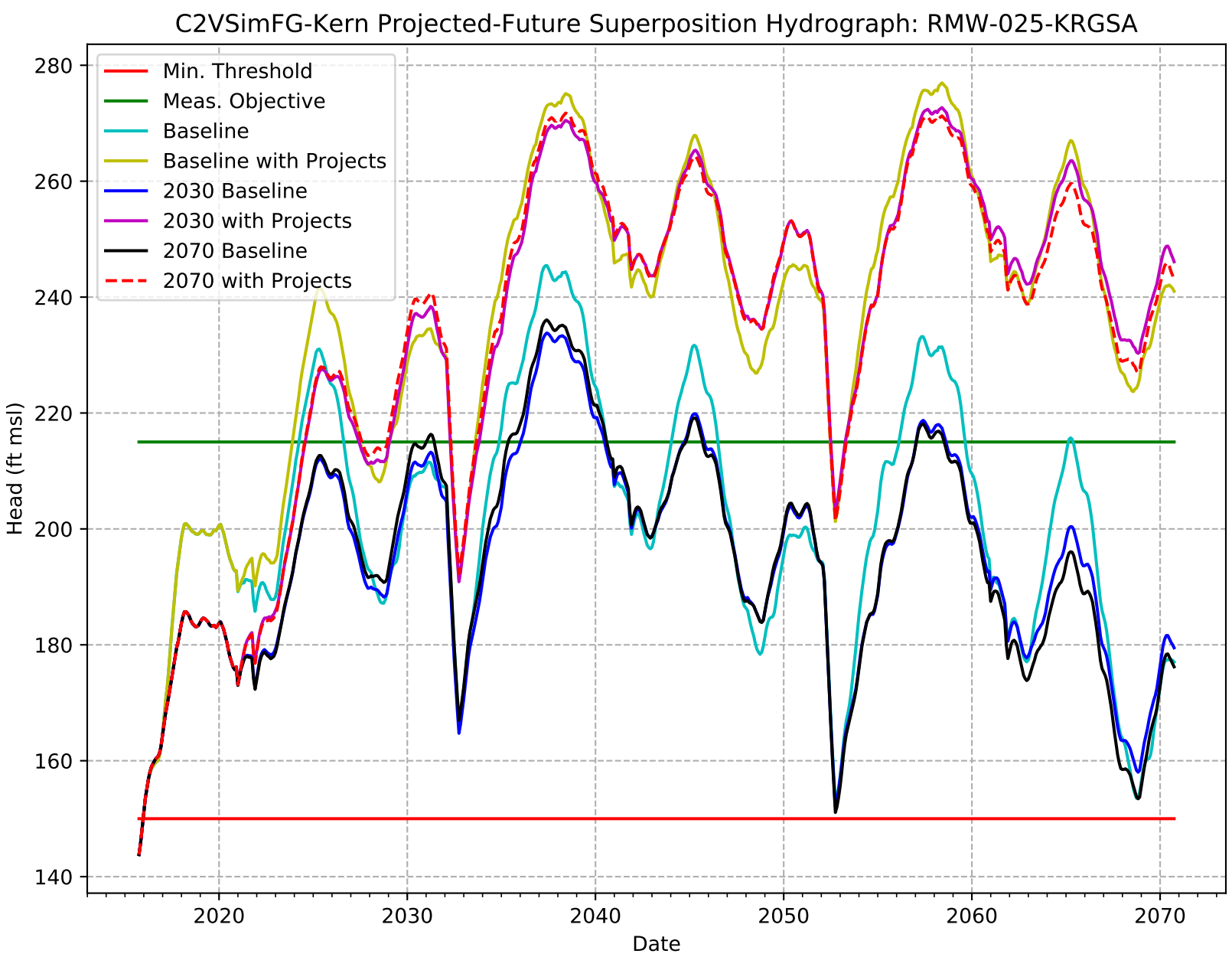

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-018-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date

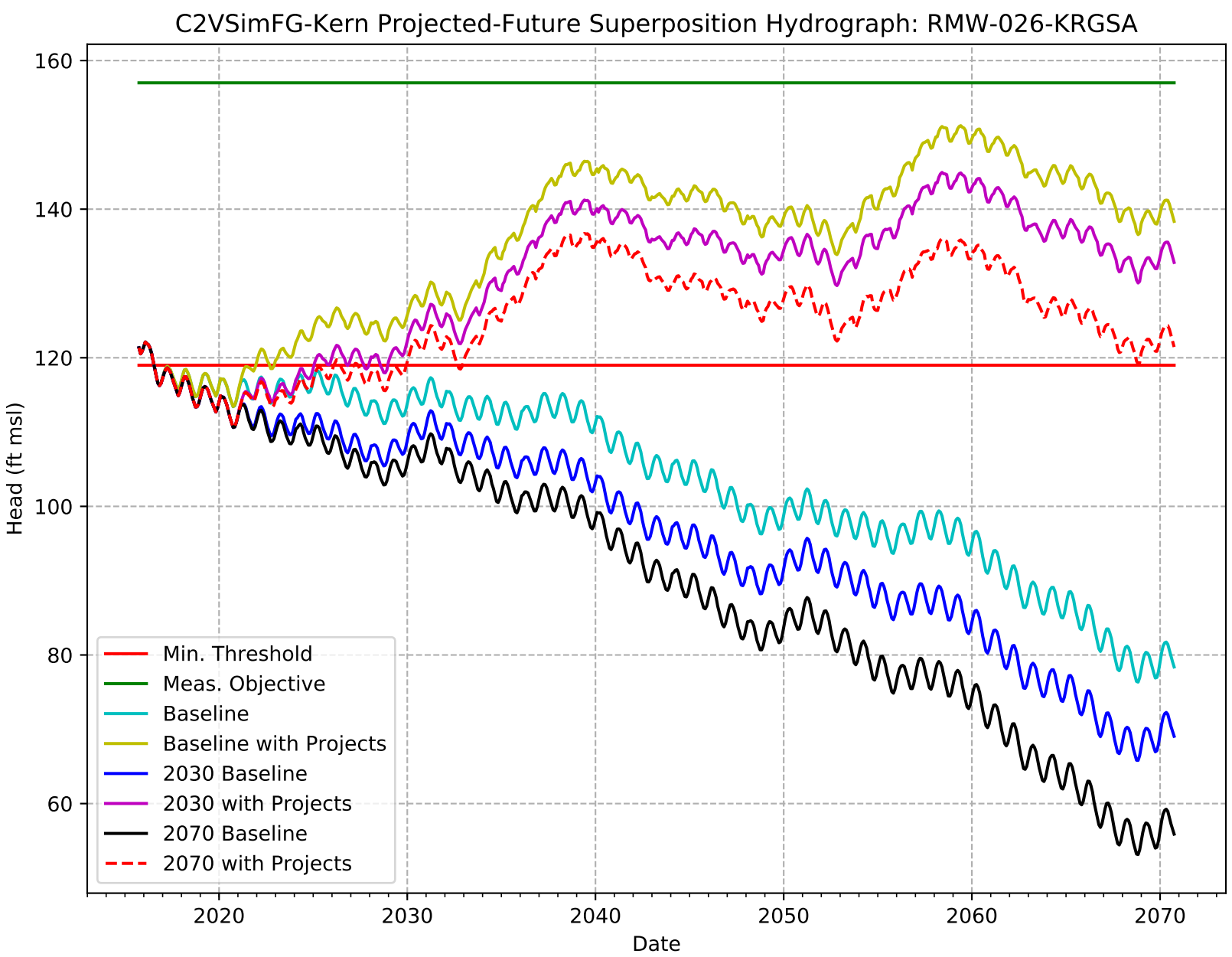

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-019-KRGSA
Head (ft msl)
280
260
240
220
200
180
160
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

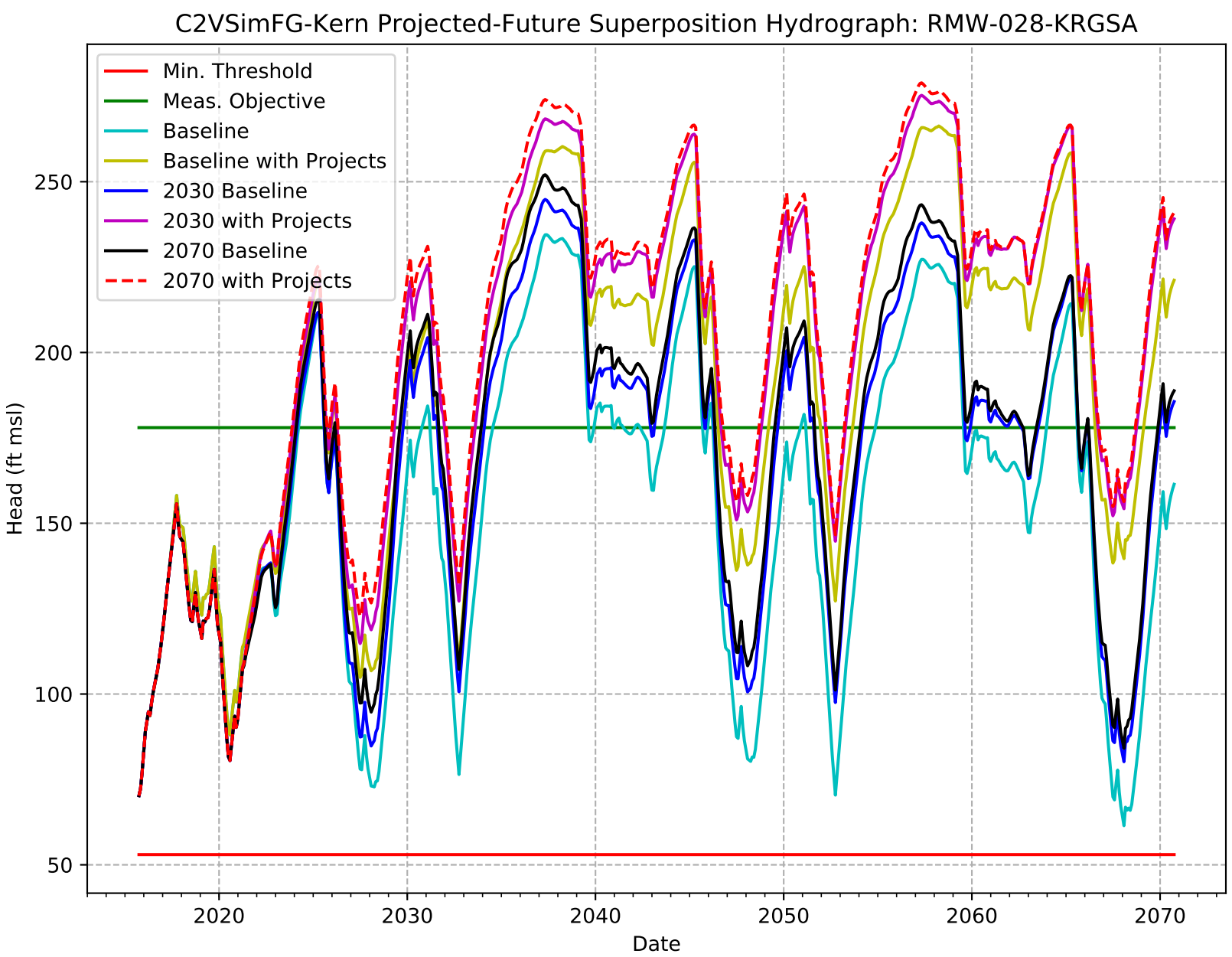

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-020-KRGSA
Head (ft msl)
360
340
320
300
280
260
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

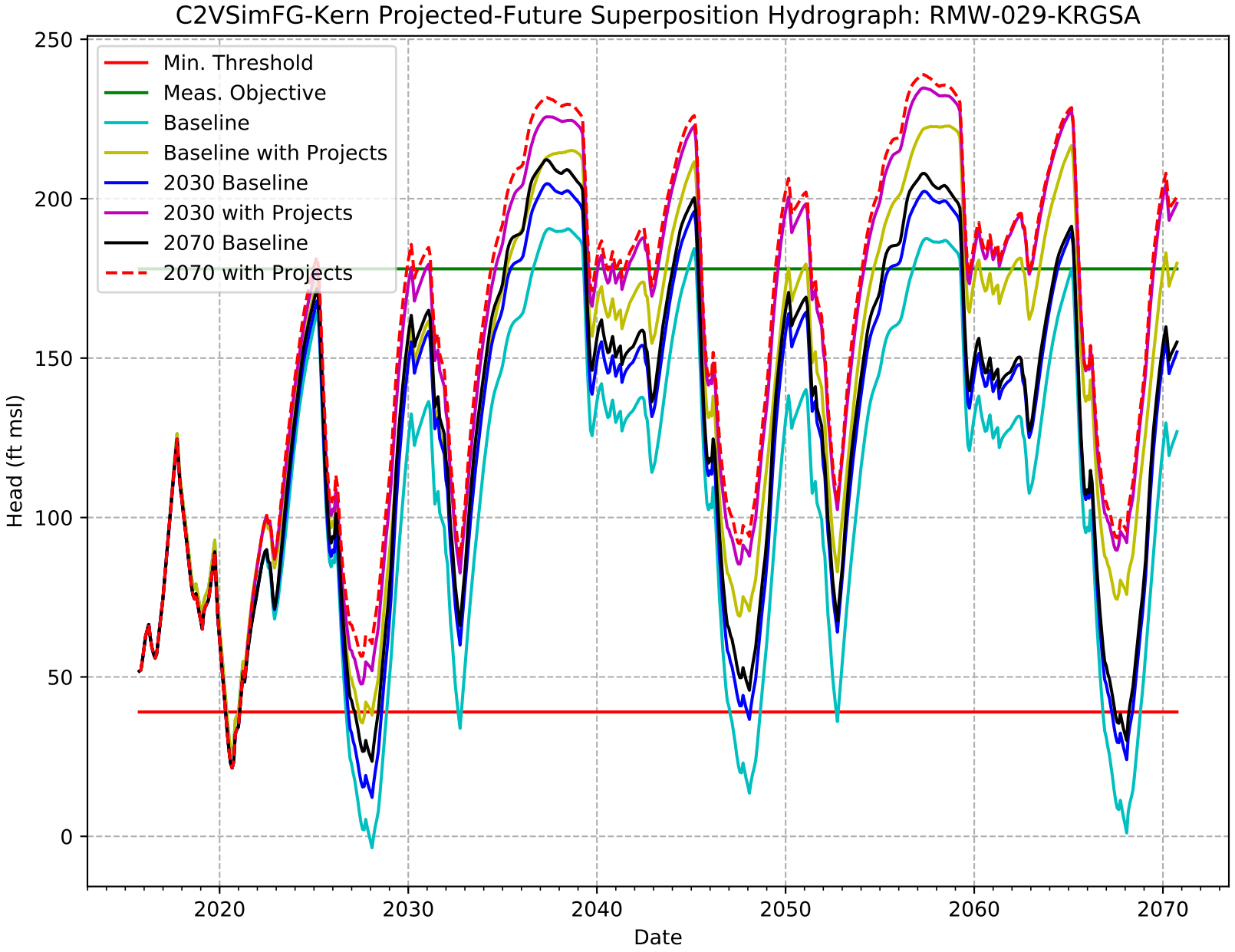

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-021-KRGSA
Head (ft msl)
280
260
240
220
200
180
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

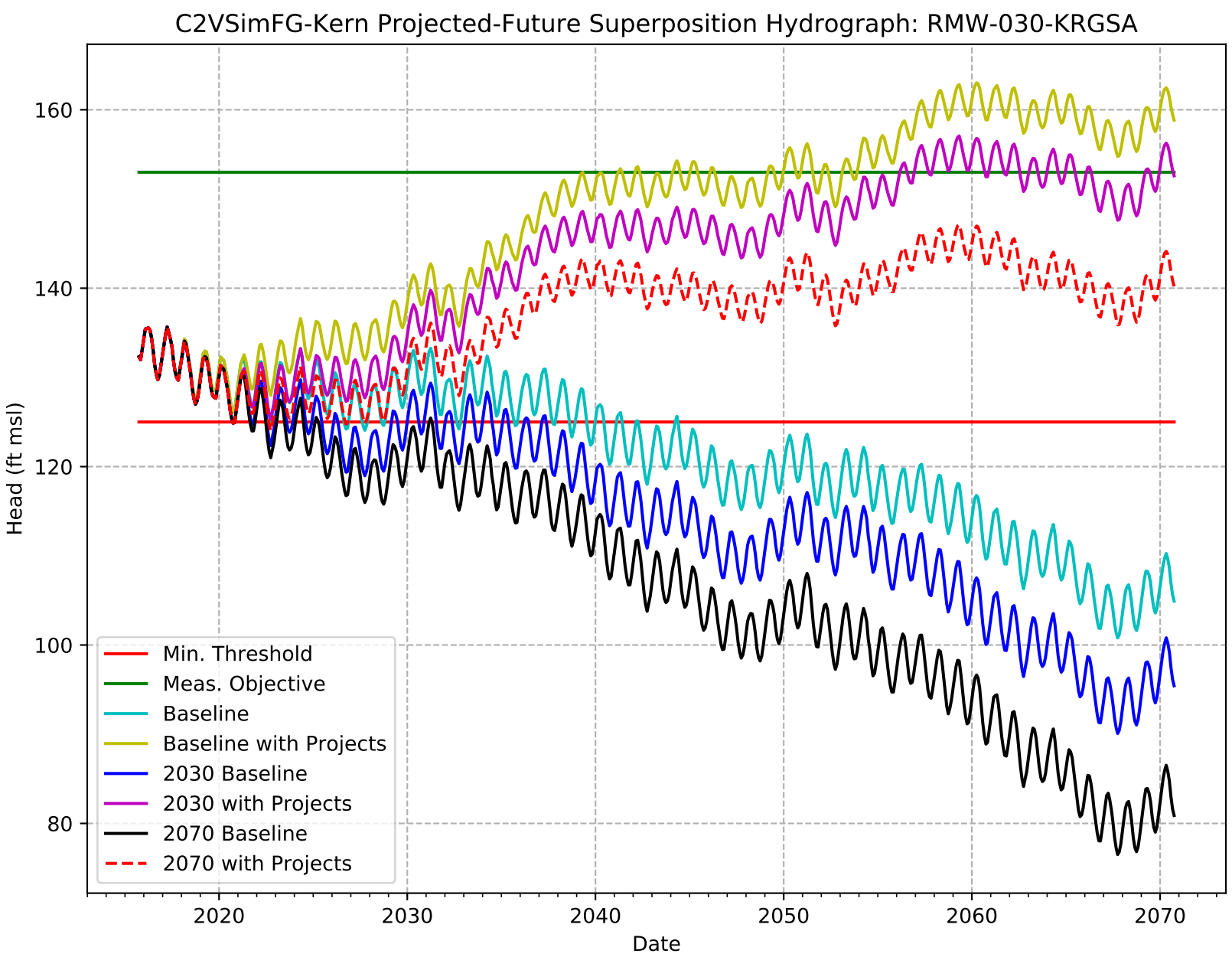

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-022-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
300
275
250
225
200
175
150
2020
2030
2040
2050
2060
2070
Date

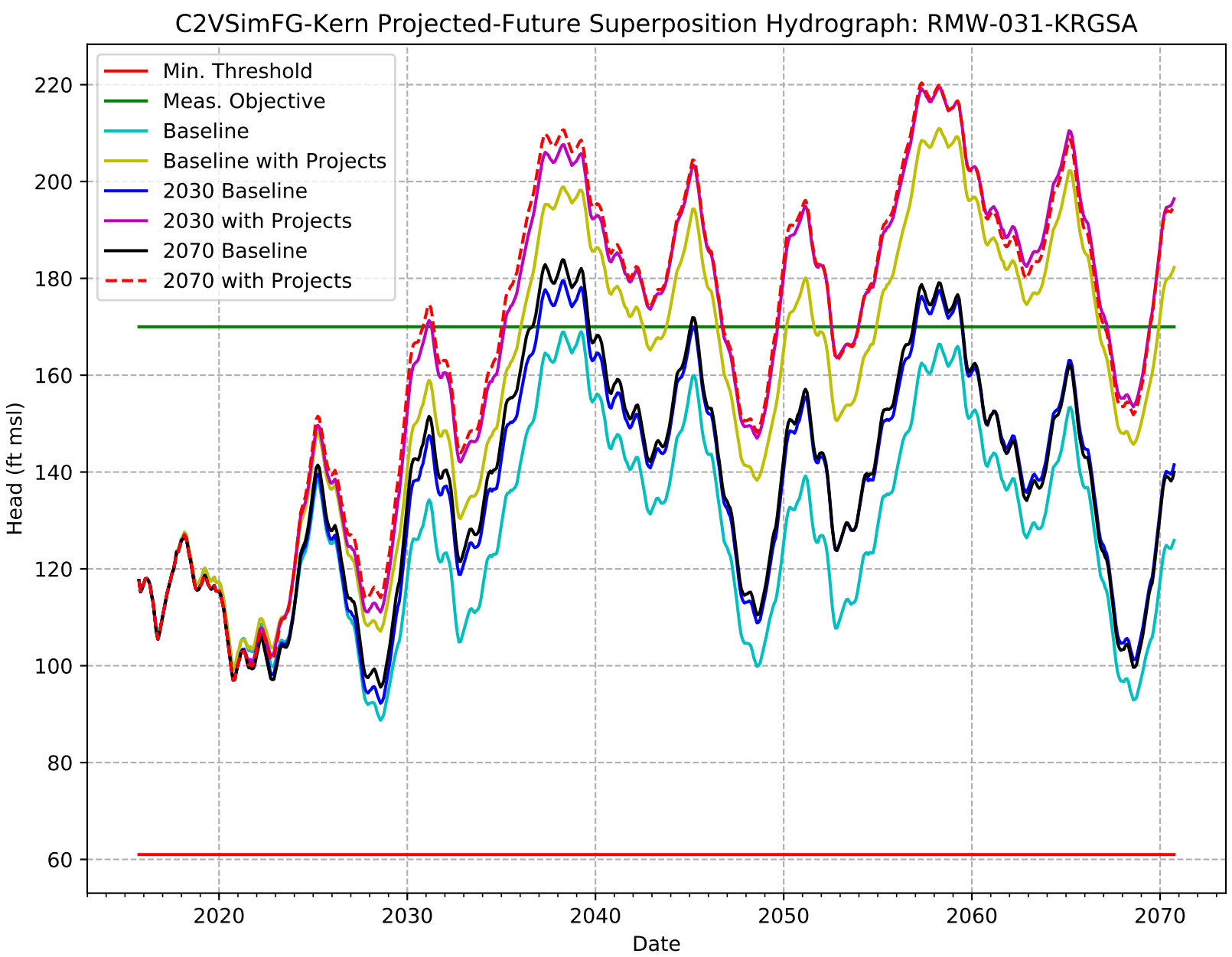

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-025-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
280
260
240
220
200
180
160
140
2020
2030
2040
2050
2060
2070
Date

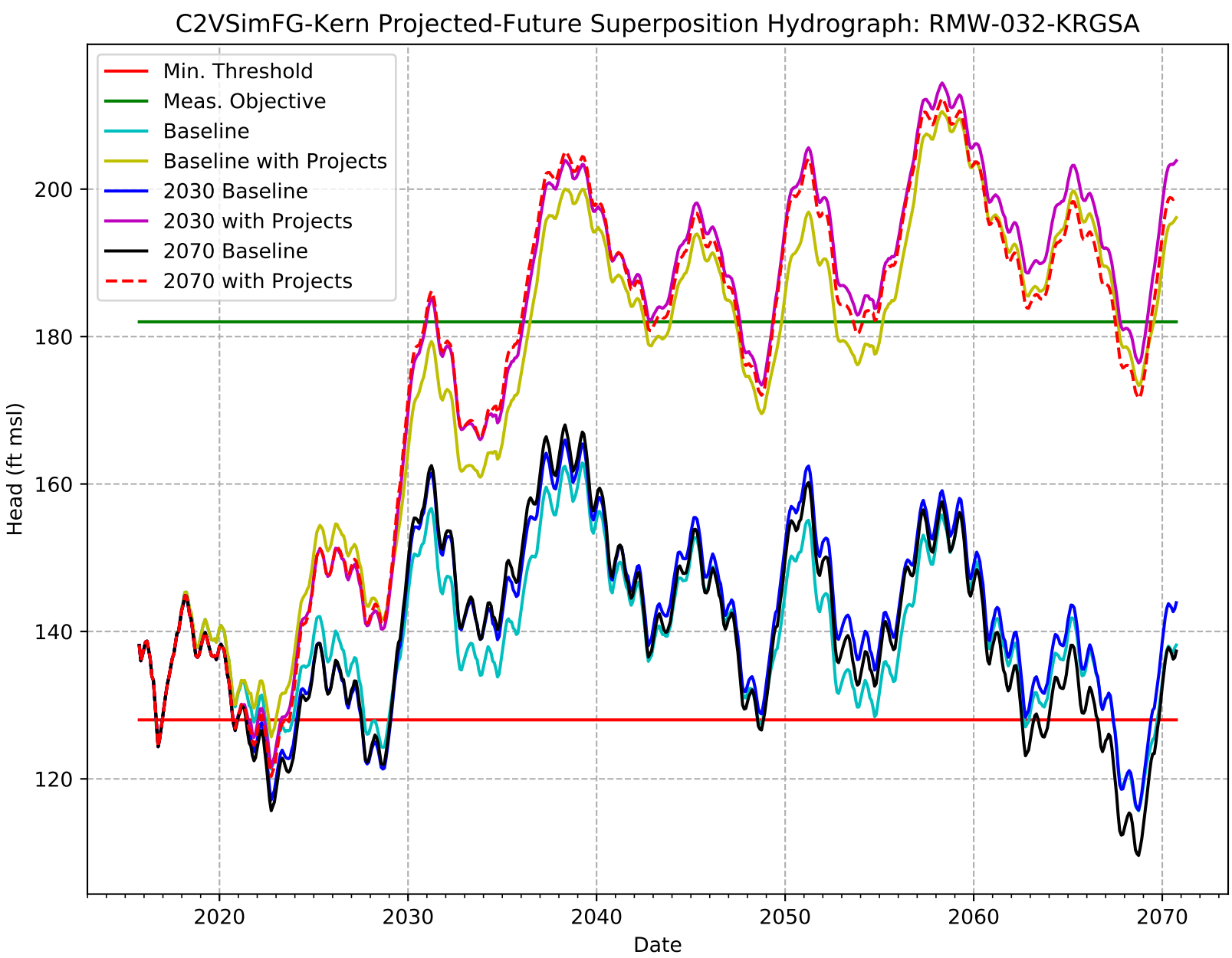

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-026-KRGSA
Head (ft msl)
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

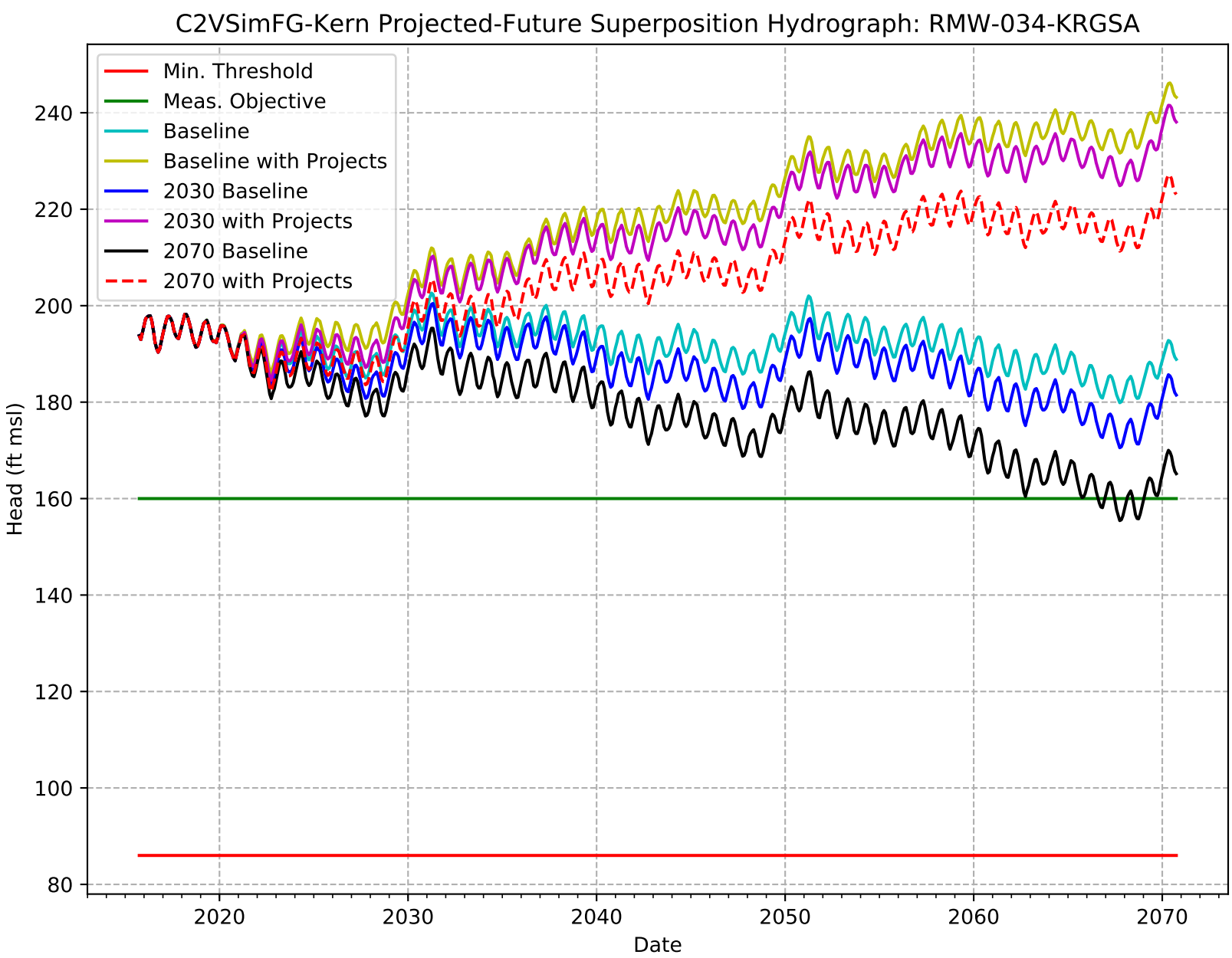

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-028-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
200
150
100
50
2020
2030
2040
2050
2060
2070
Date

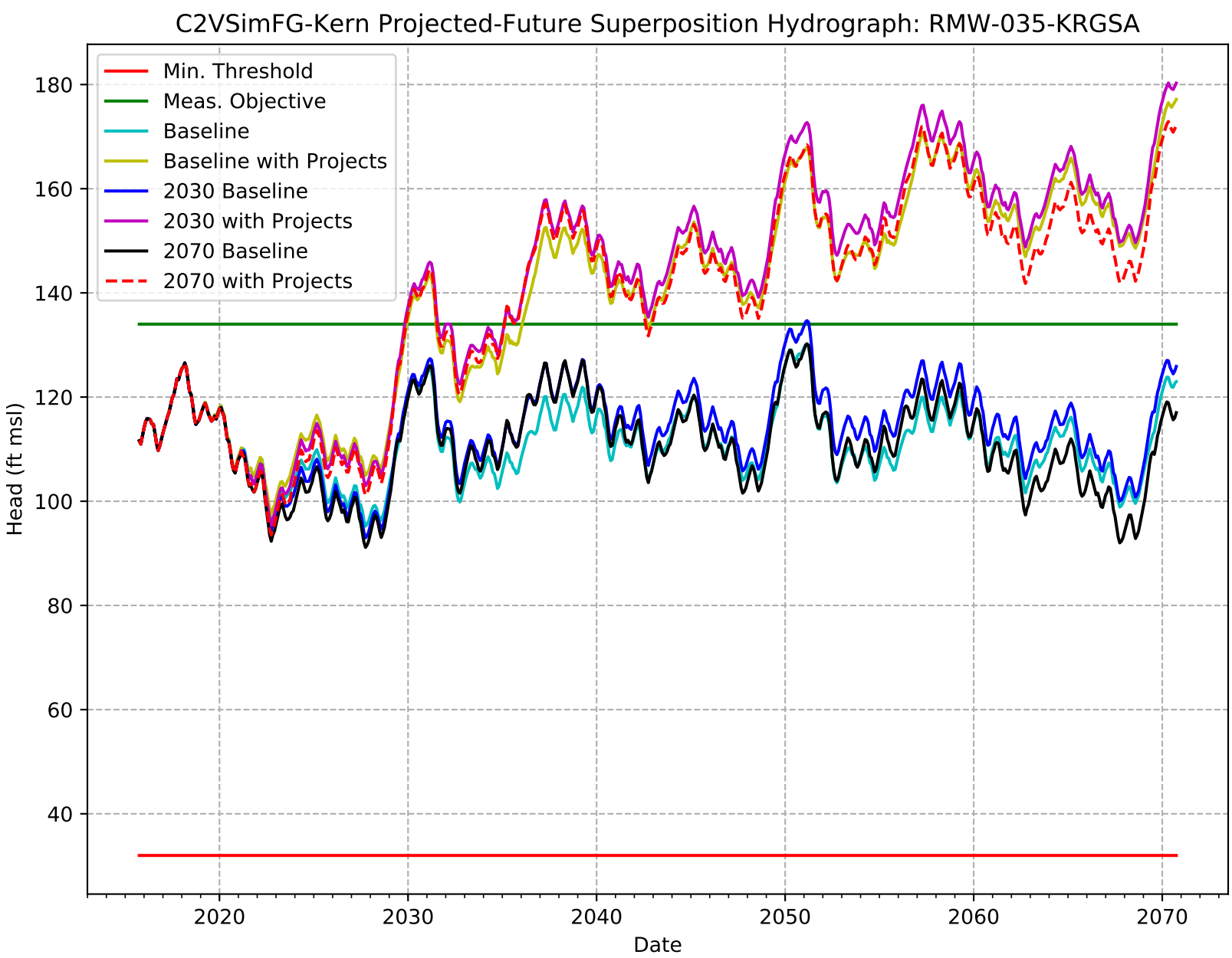

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-029-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date

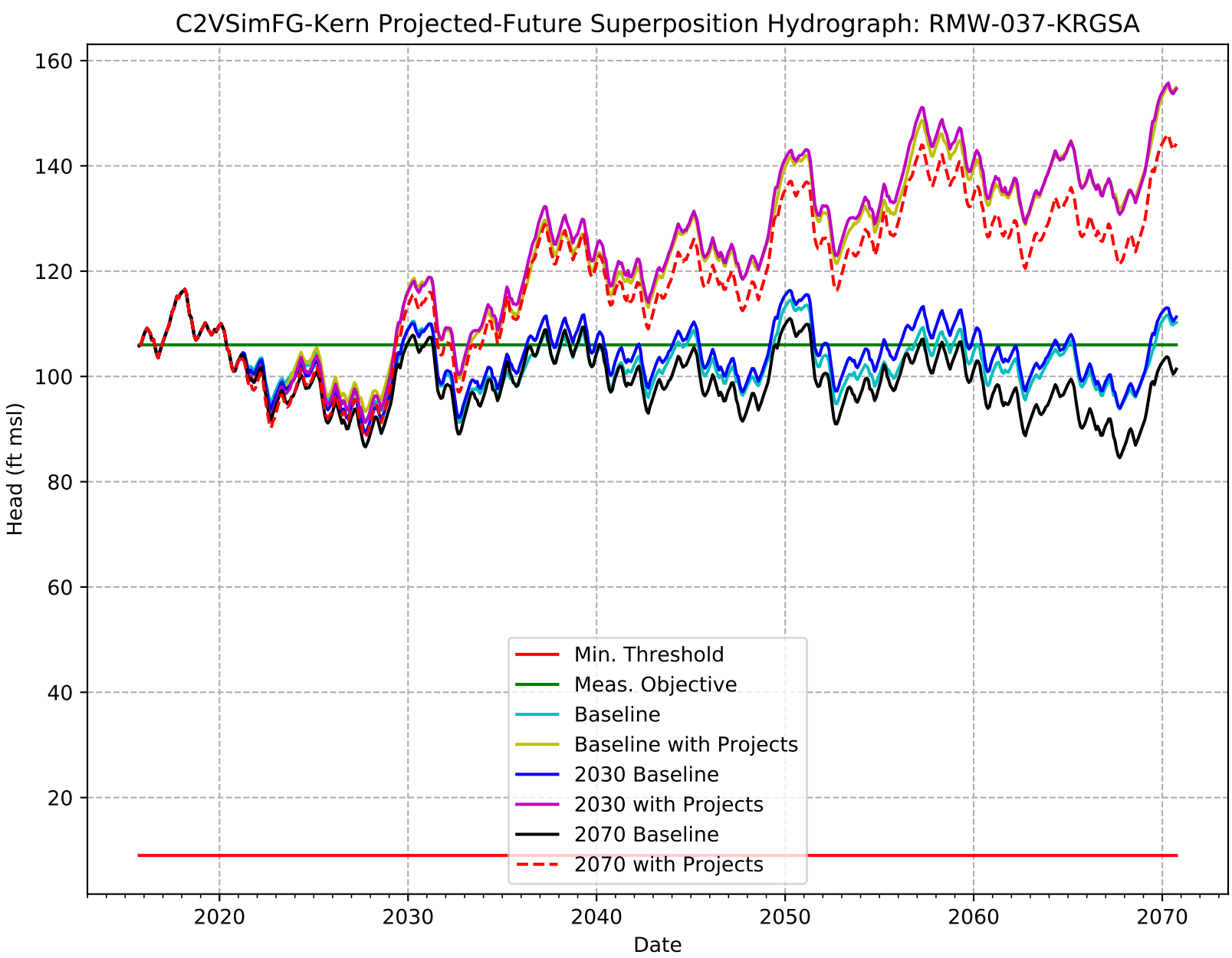

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-030-KRGSA
Head (ft msl)
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

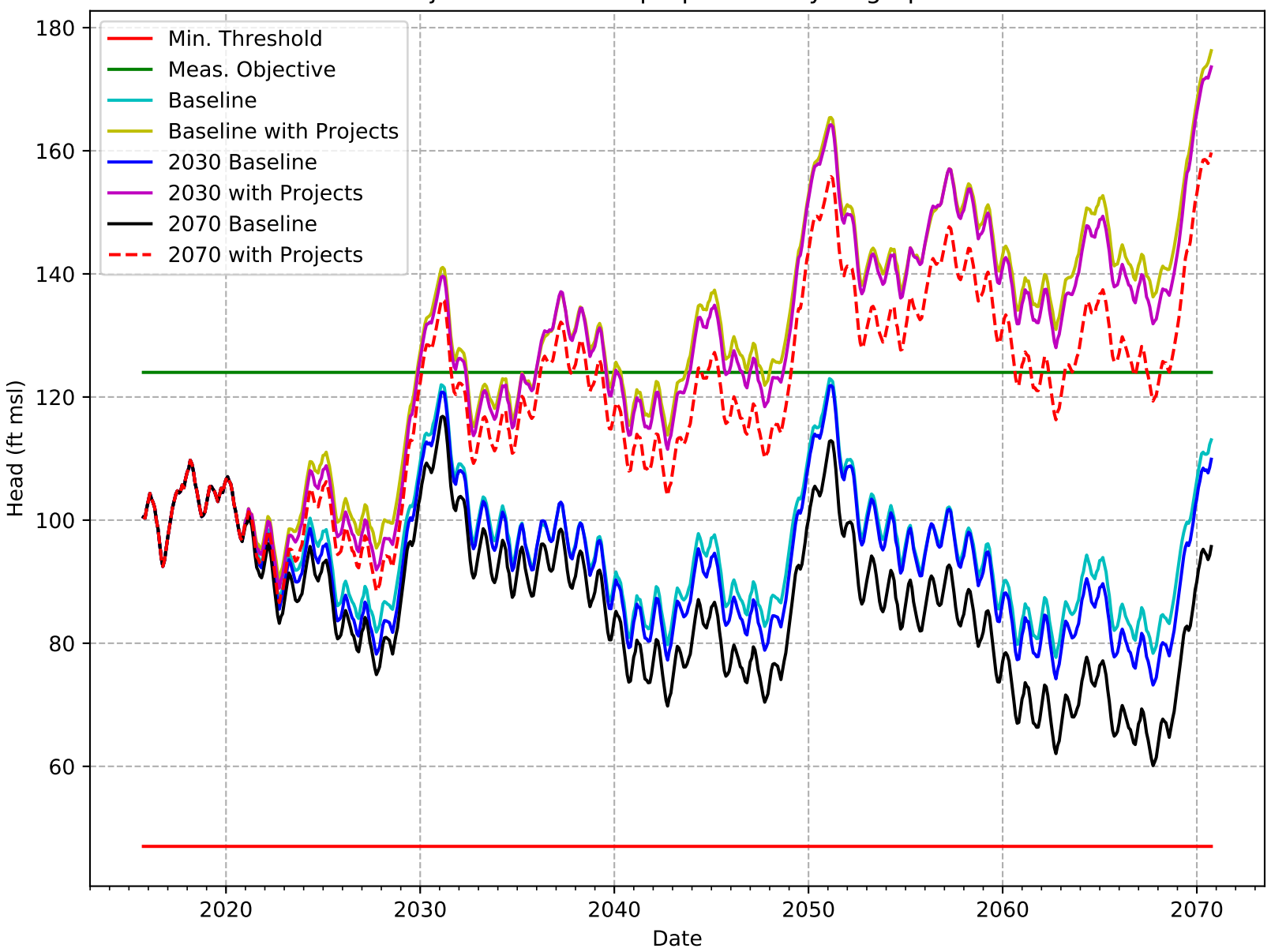

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-031-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
220
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

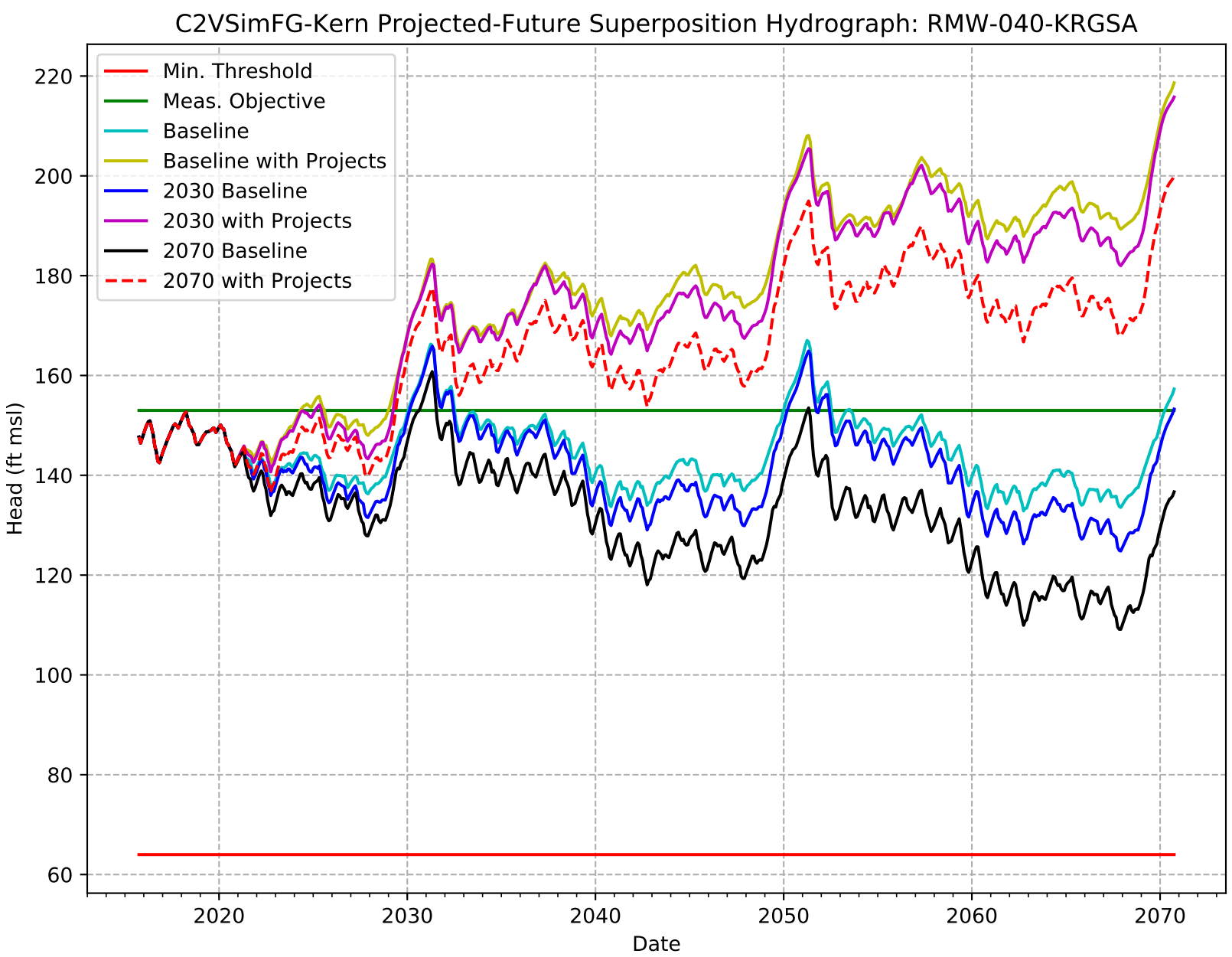

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-032-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date

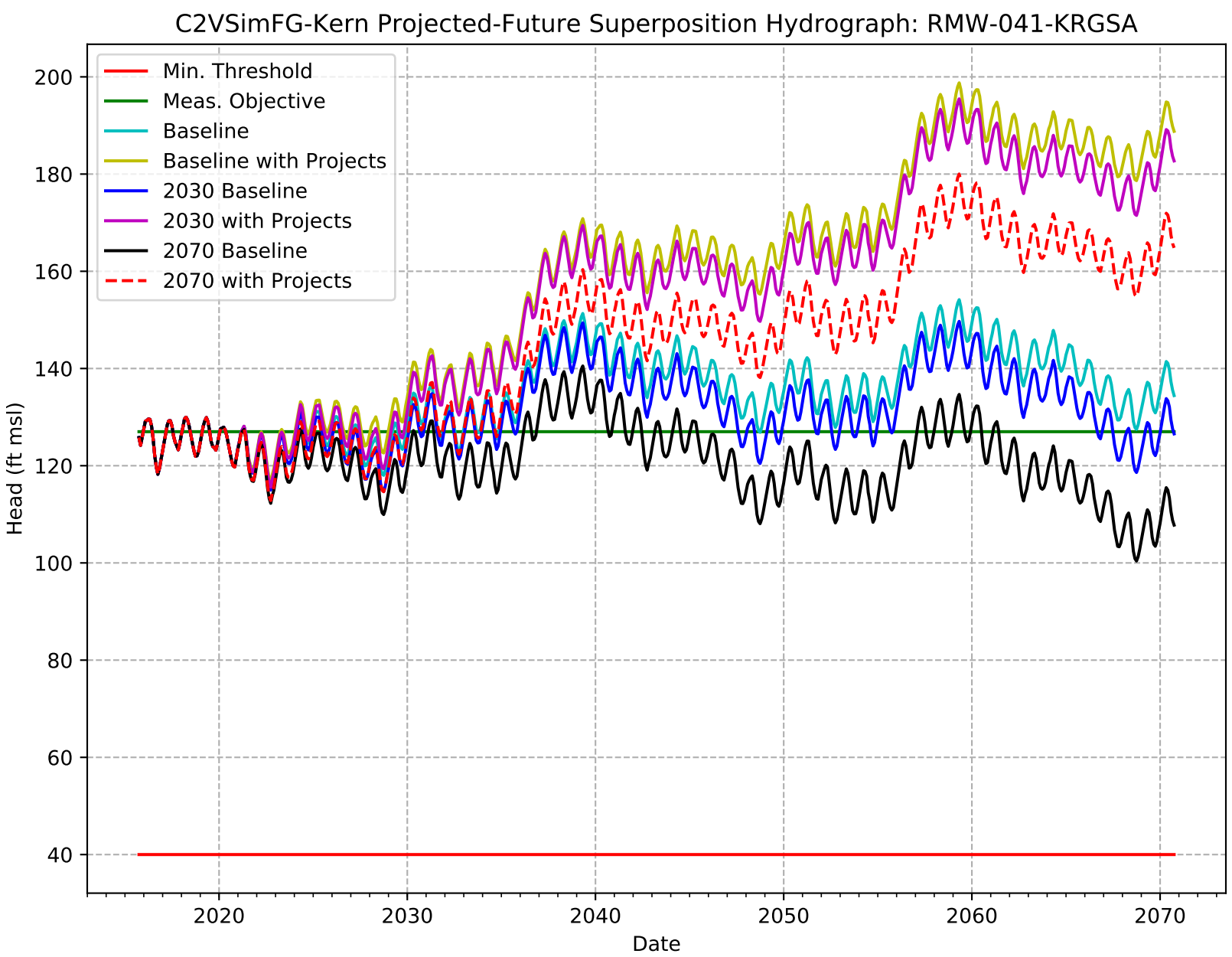

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-034-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
240
220
200
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date

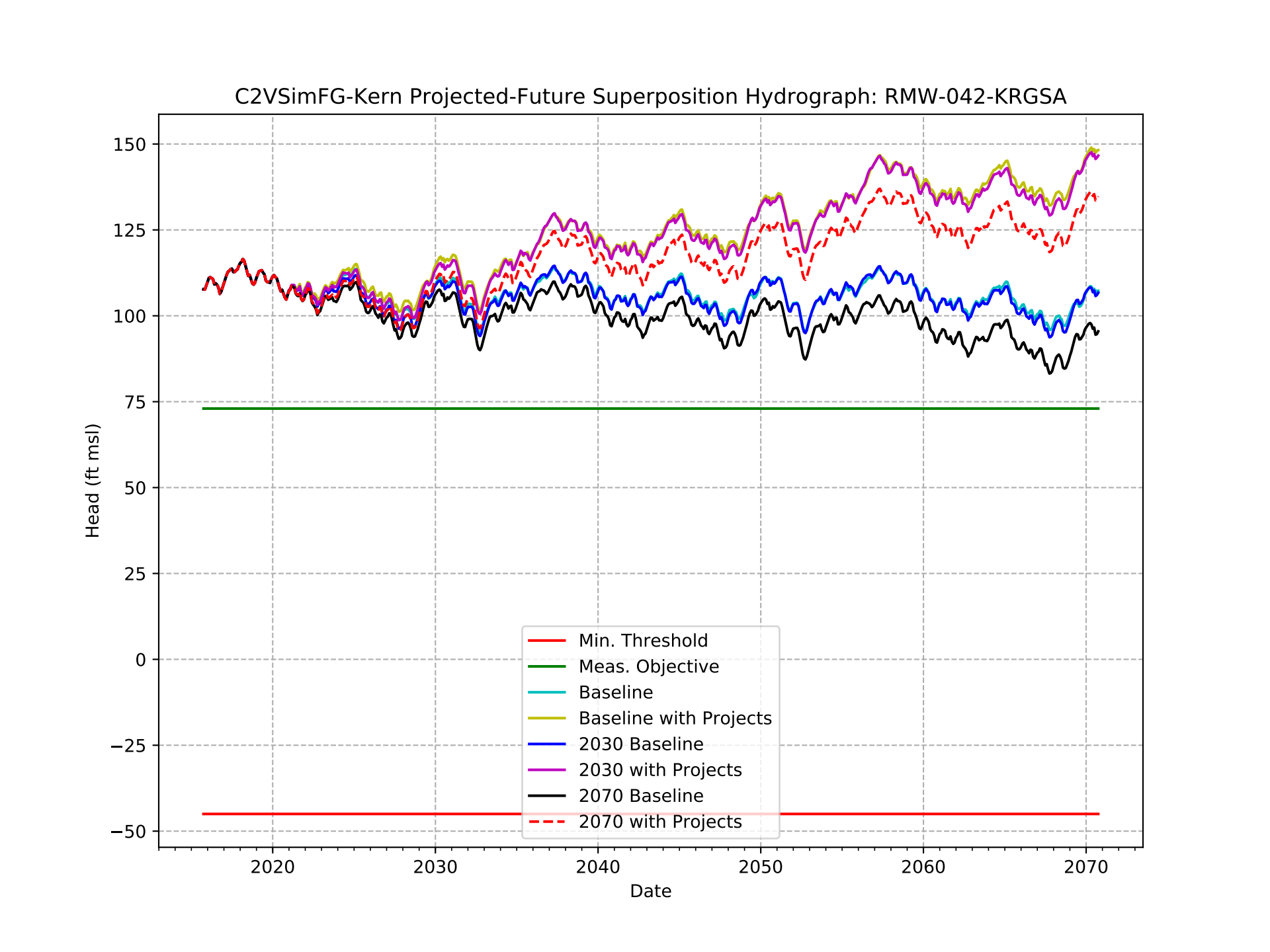

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-035-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date

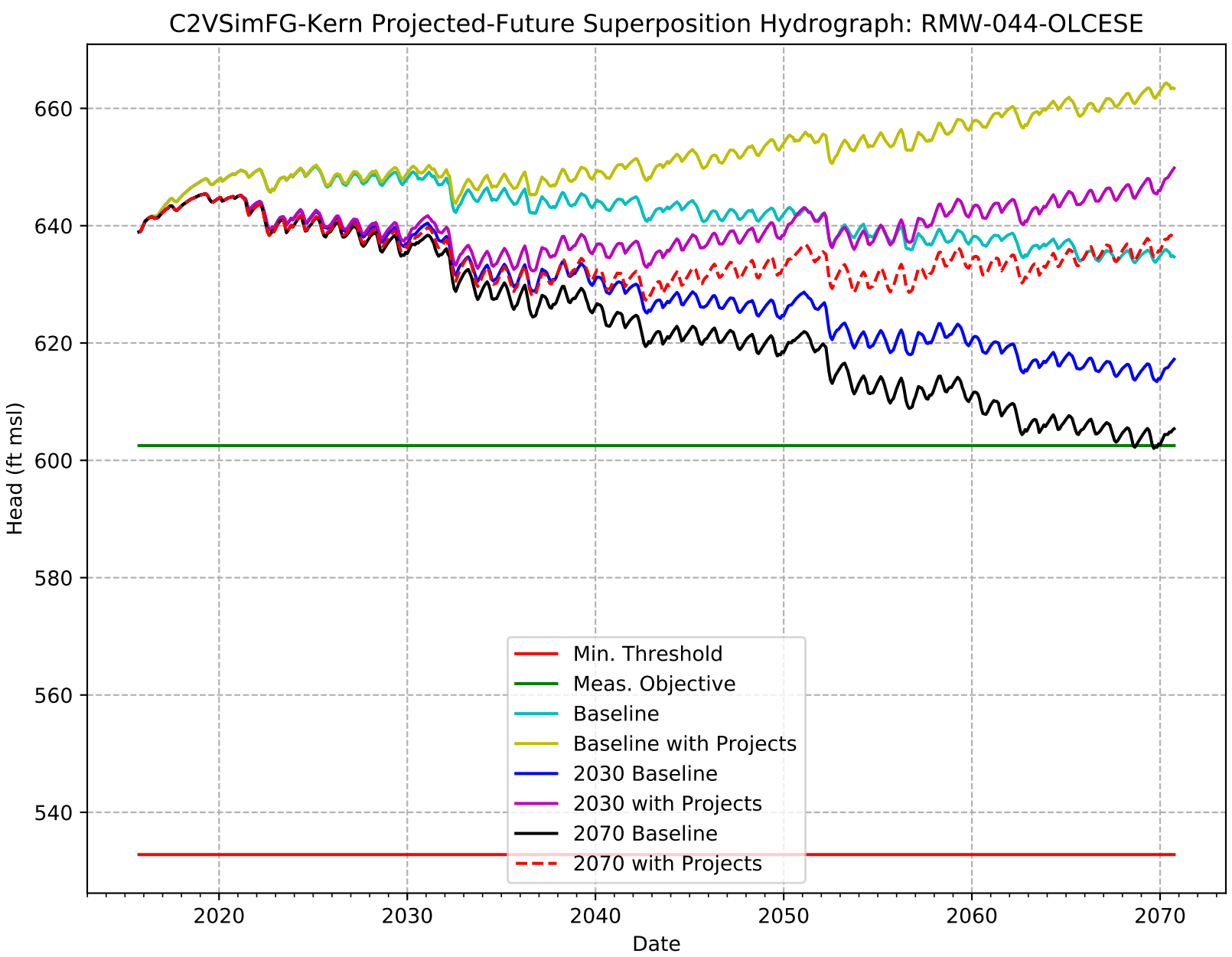

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-037-KRGSA
Head (ft msl)
160
140
120
100
80
60
40
20
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

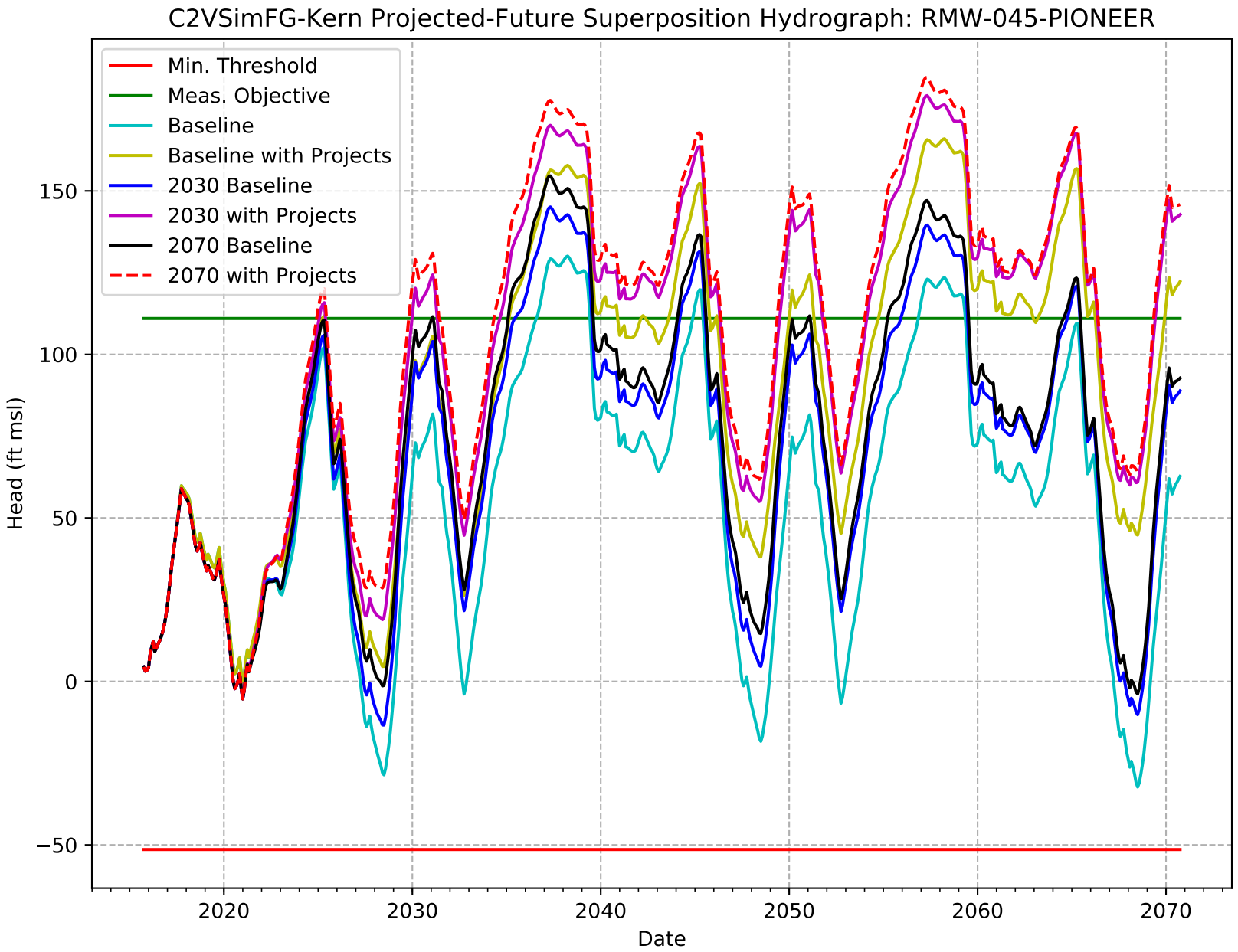

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-038-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

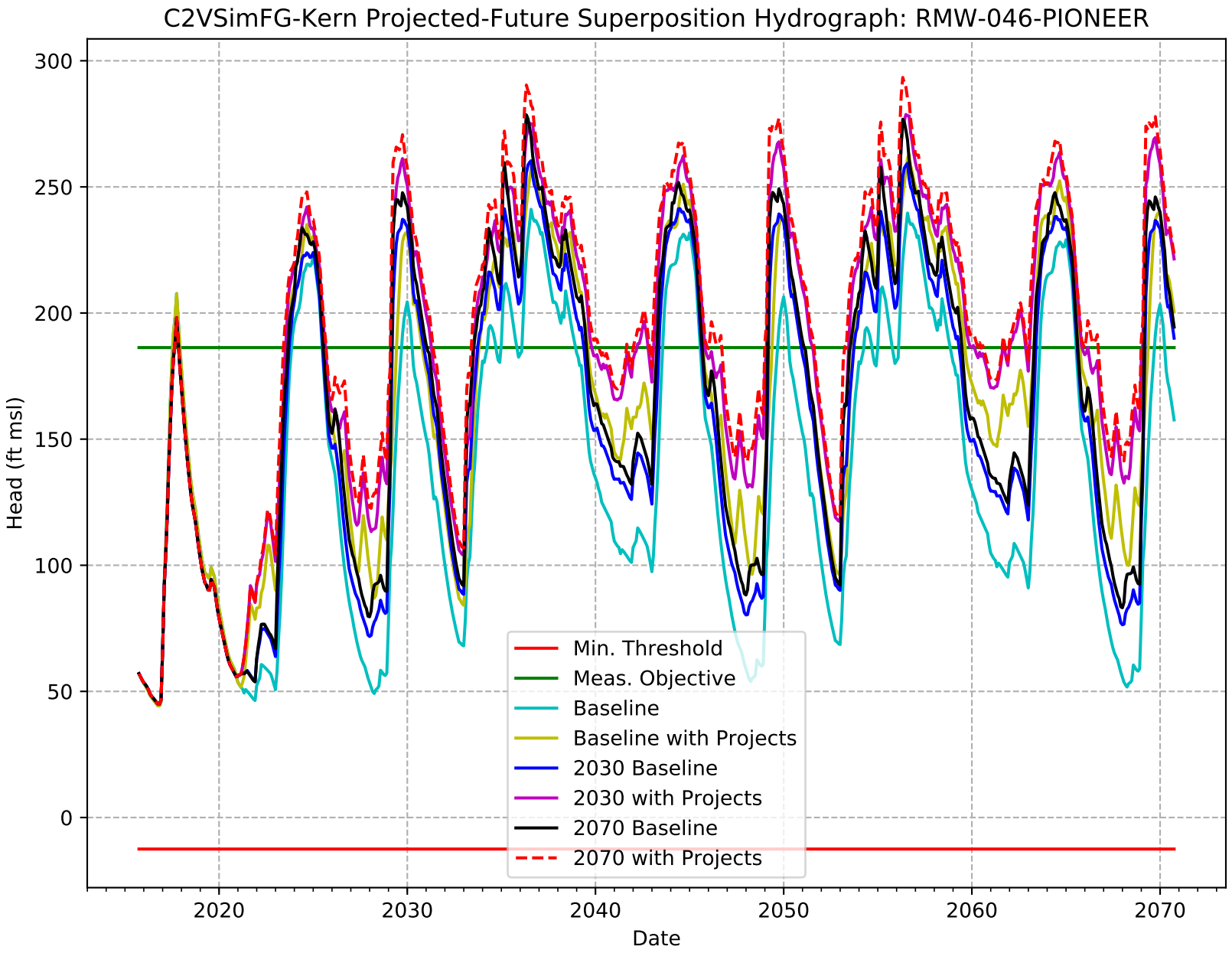

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-040-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
220
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

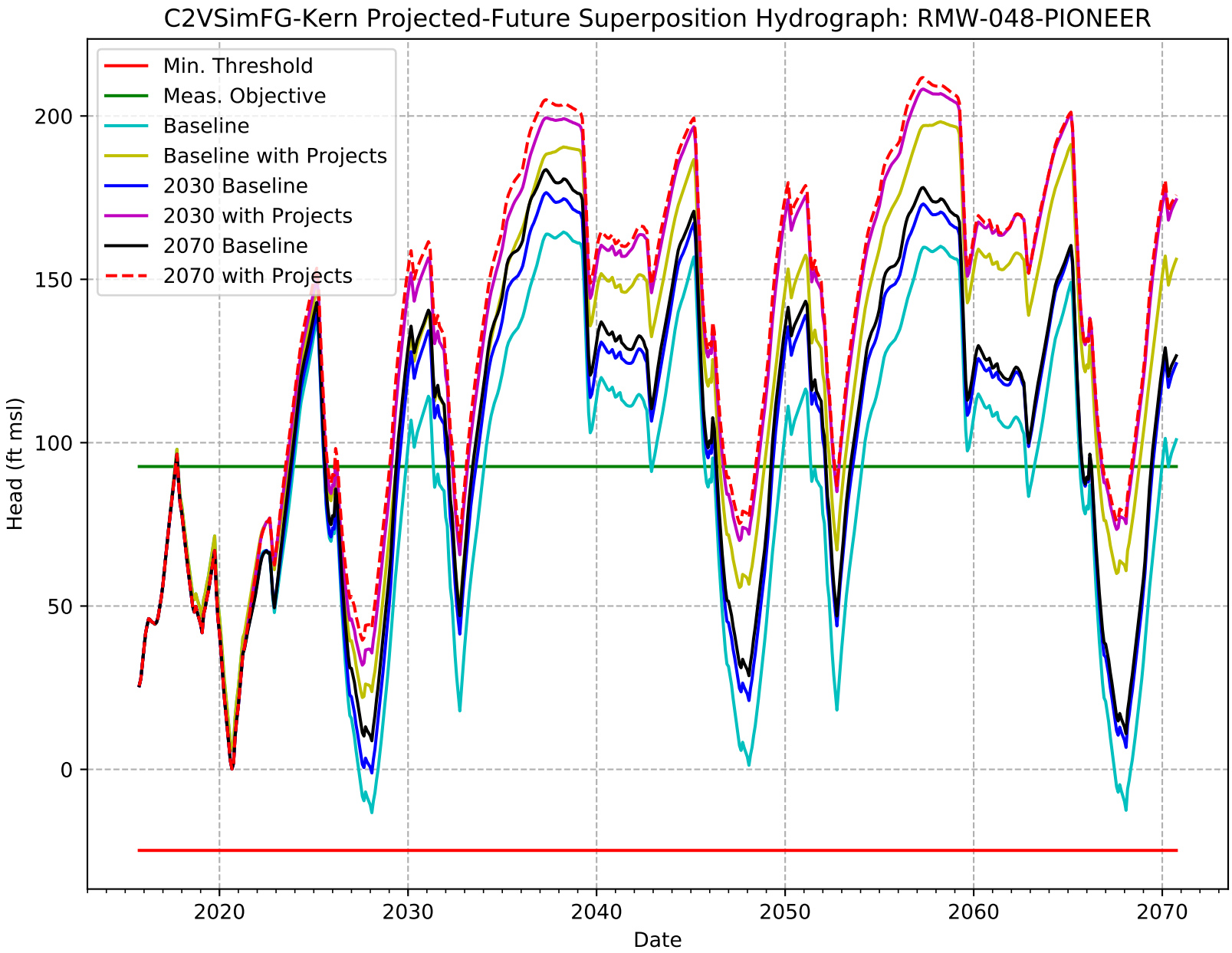

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-041-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date

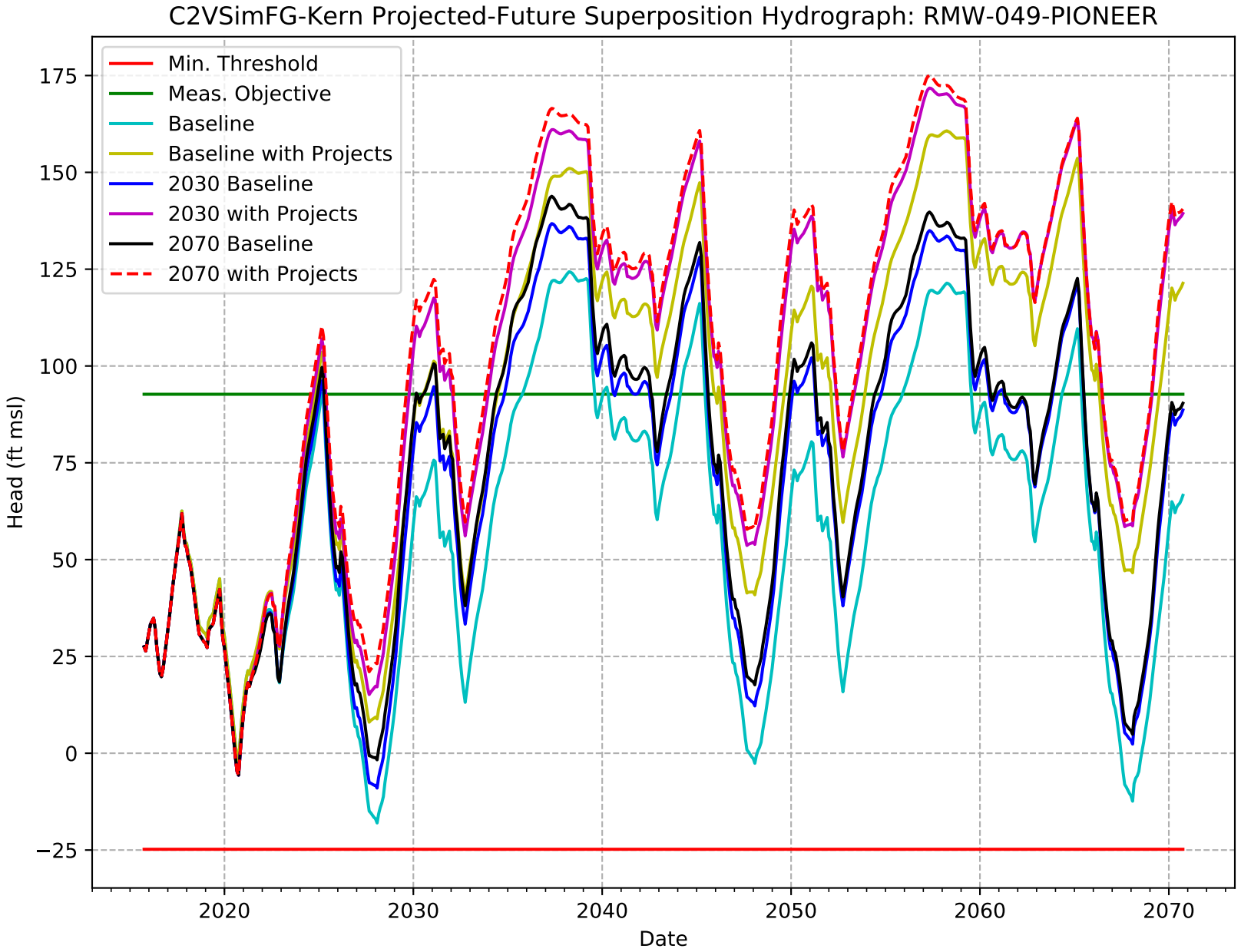

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-042-KRGSA
Head (ft msl)
150
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

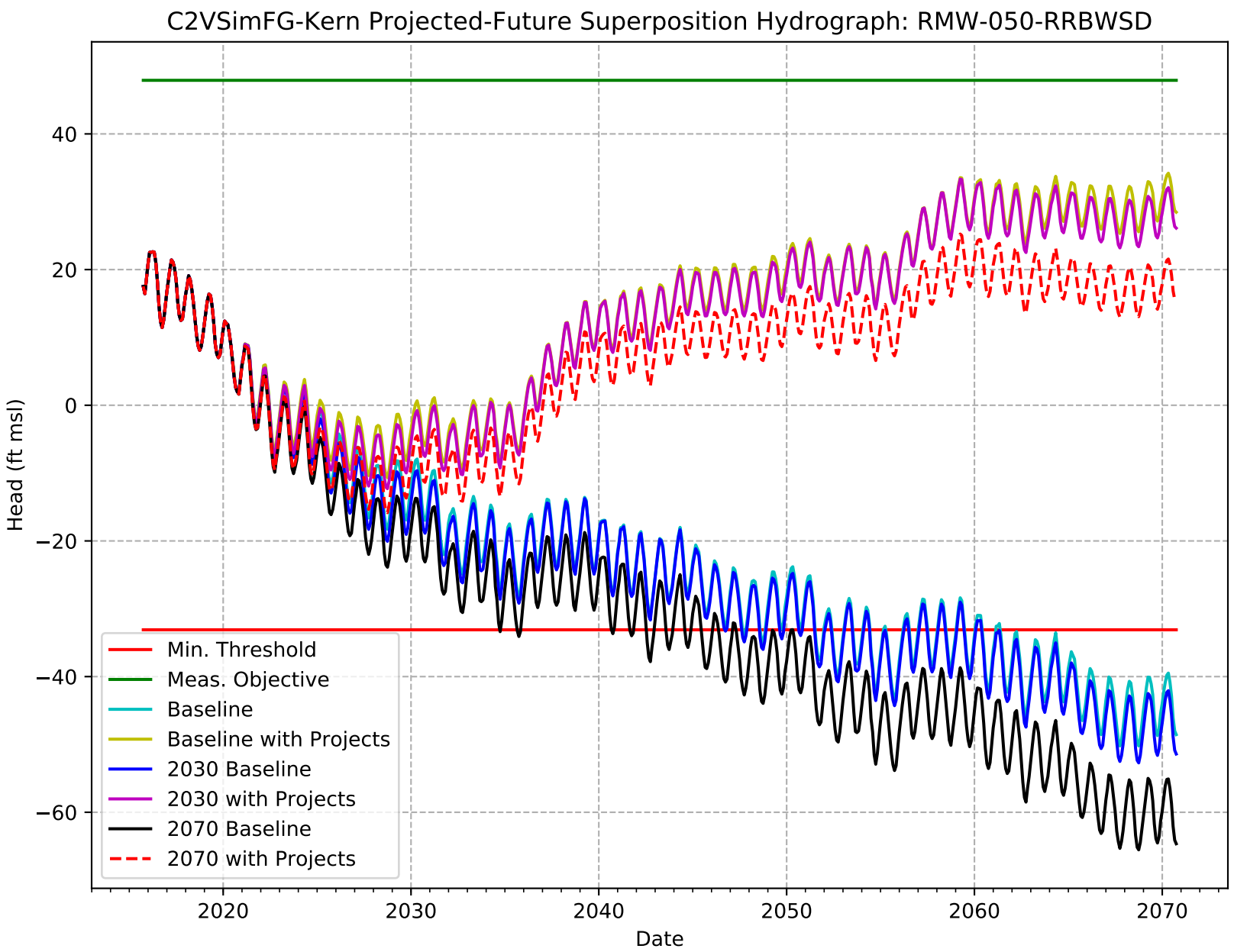

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-044-OLCESE
Head (ft msl)
660
640
620
600
580
560
540
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

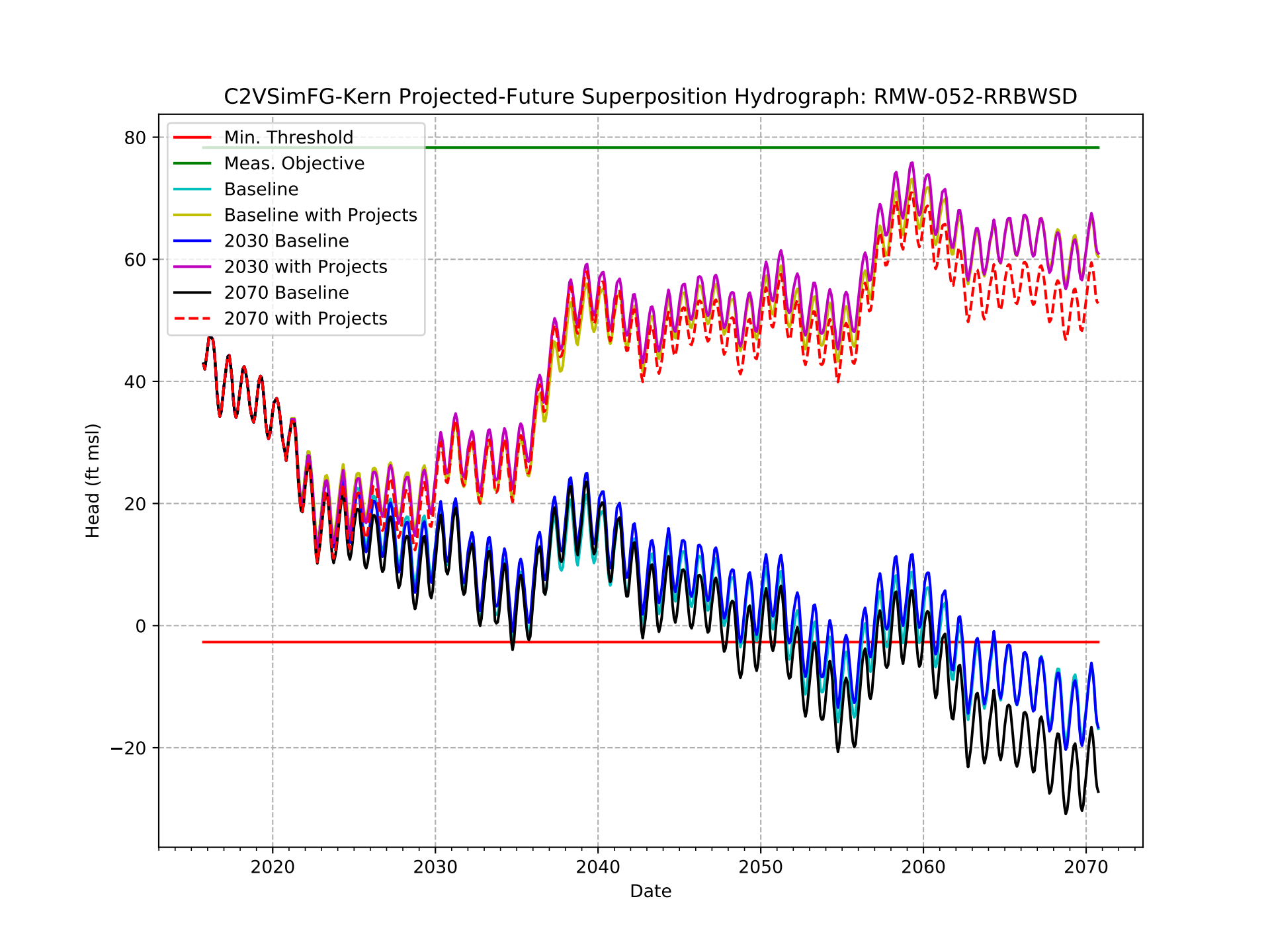

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-045-PIONEER
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date

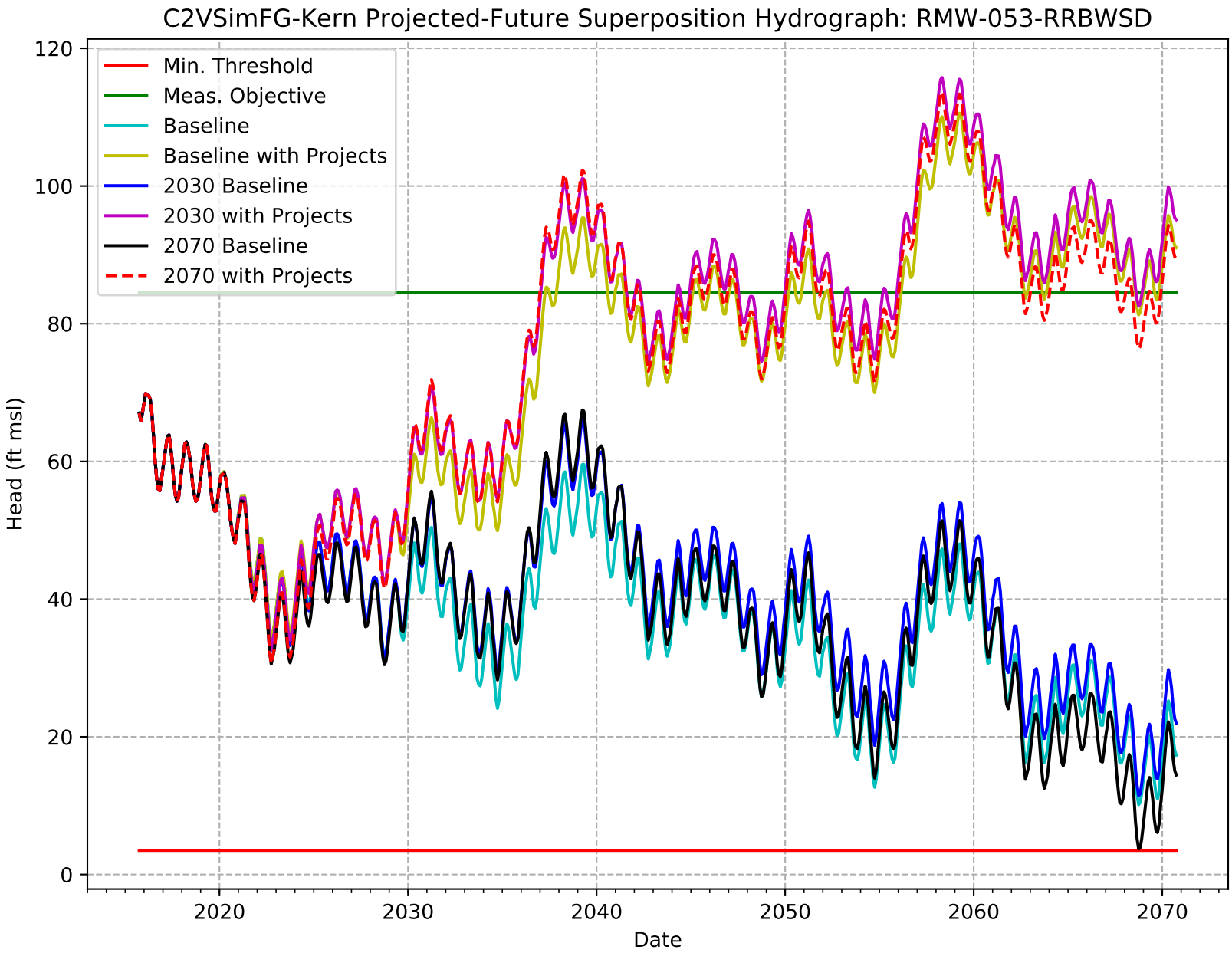

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-046-PIONEER
Head (ft msl)
300
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

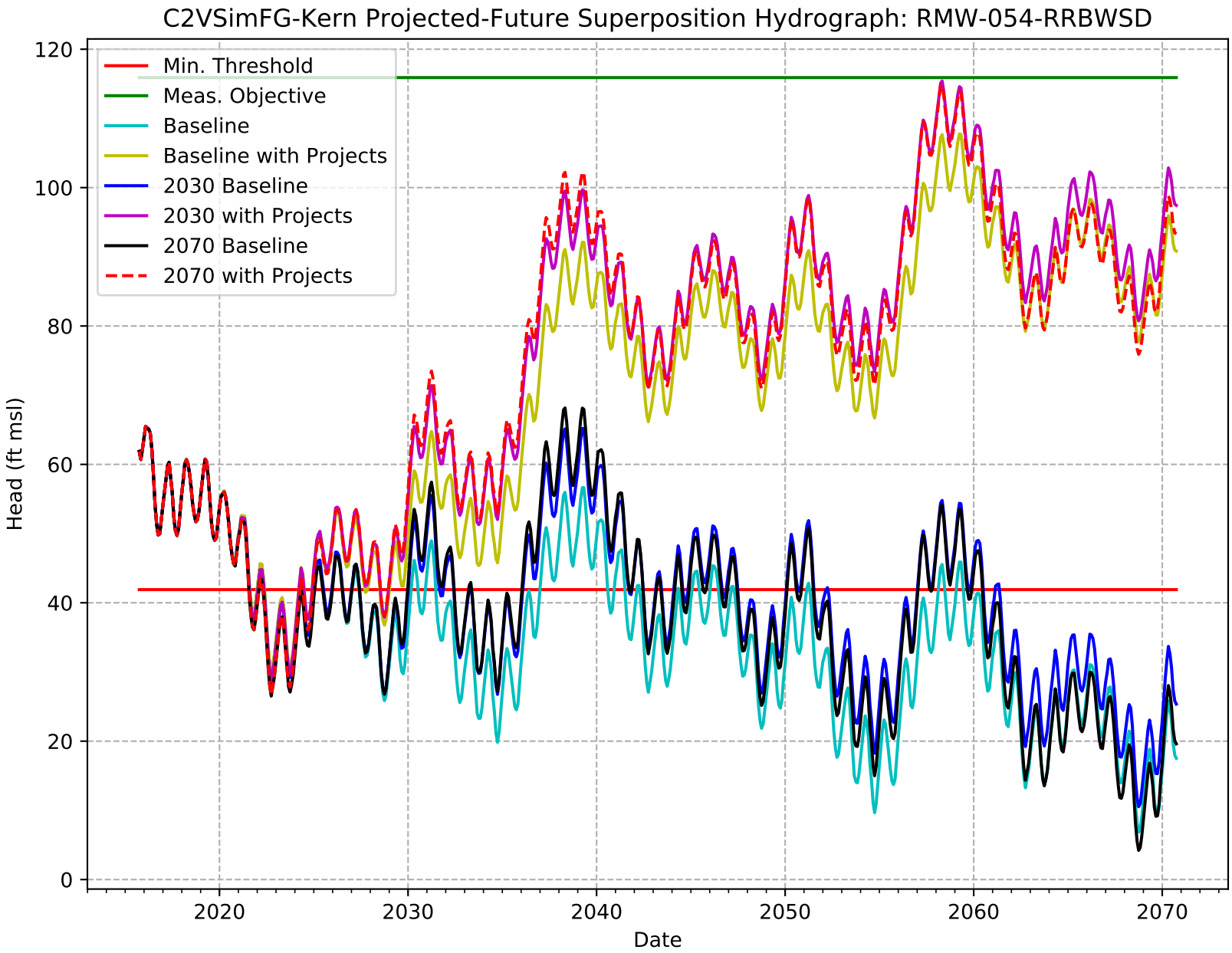

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-048-PIONEER
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date

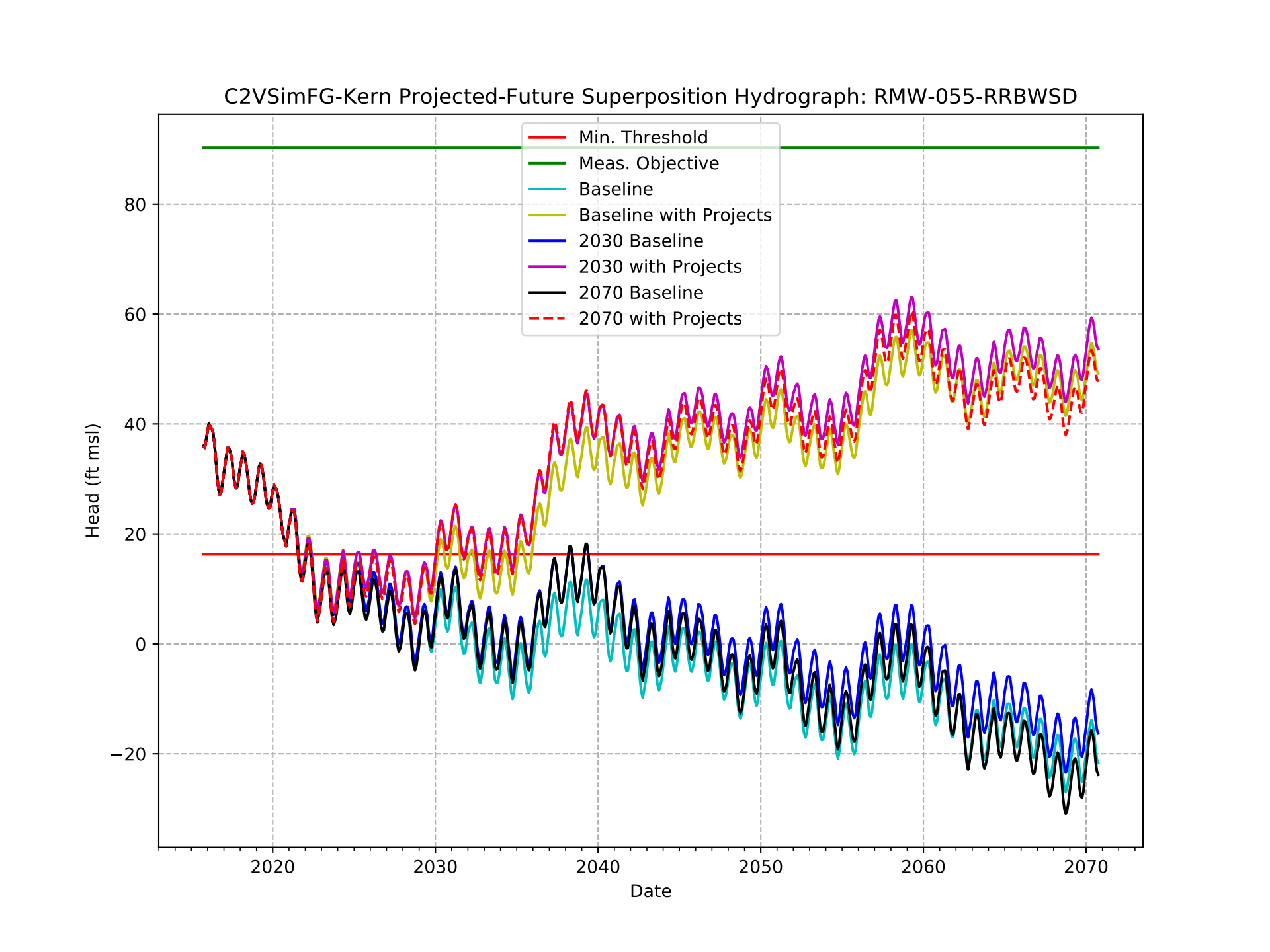

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-049-PIONEER
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
175
150
125
100
75
50
25
0
−25
2020
2030
2040
2050
2060
2070
Date

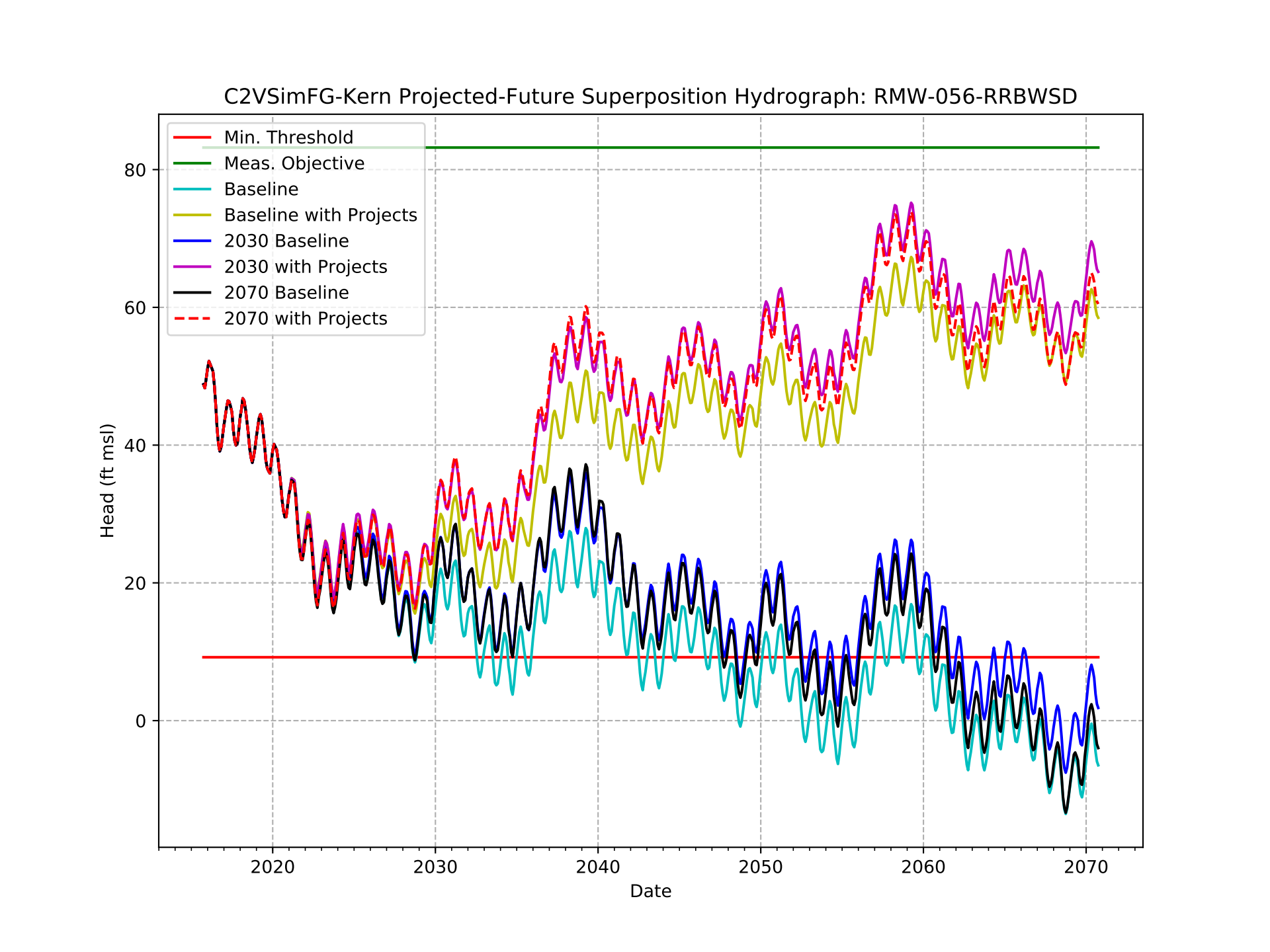

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-050-RRBWSD
Head (ft msl)
40
20
0
−20
−40
−60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

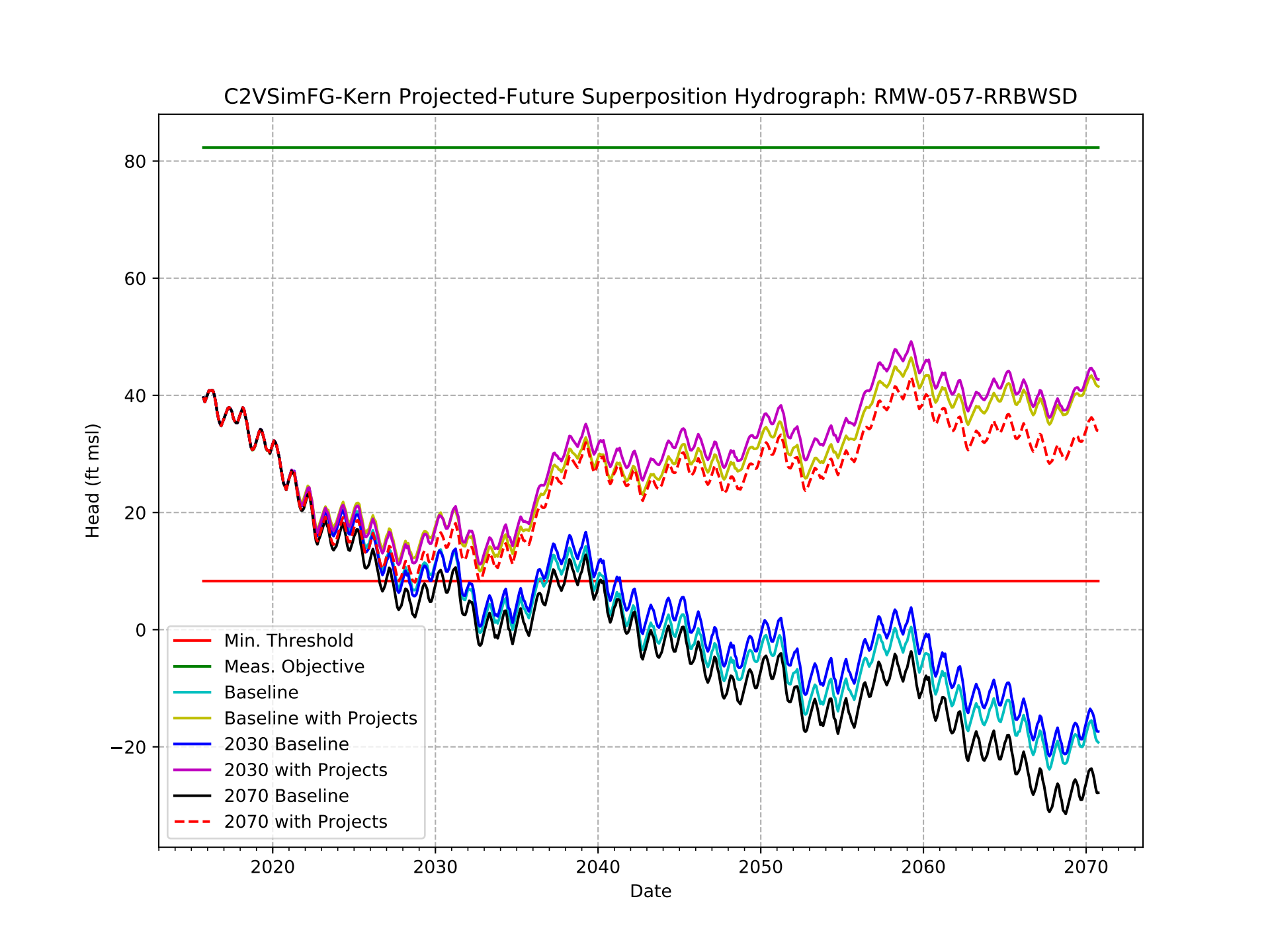

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-052-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
80
60
40
20
0
−20
2020
2030
2040
2050
2060
2070
Date

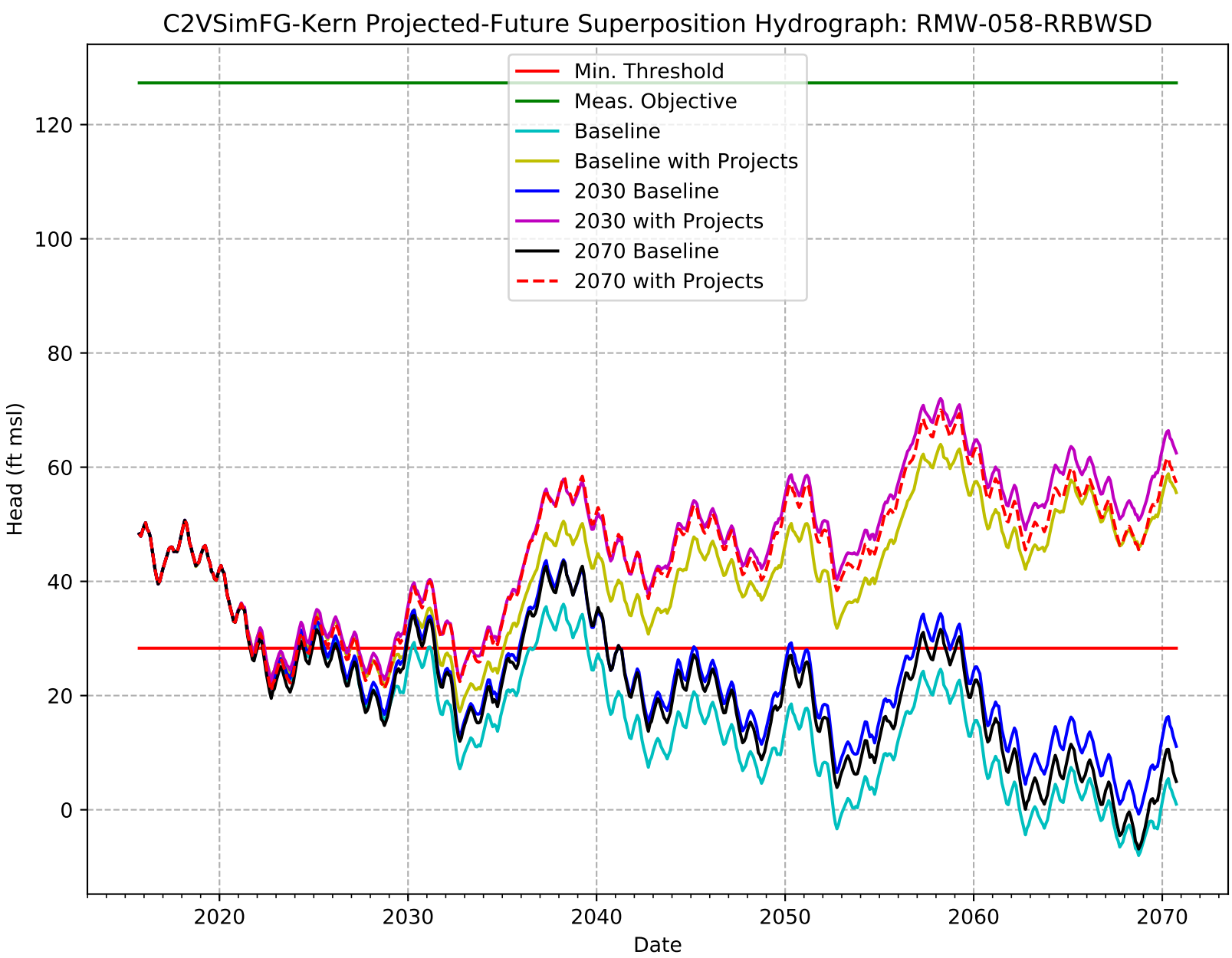

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-053-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
Date
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070

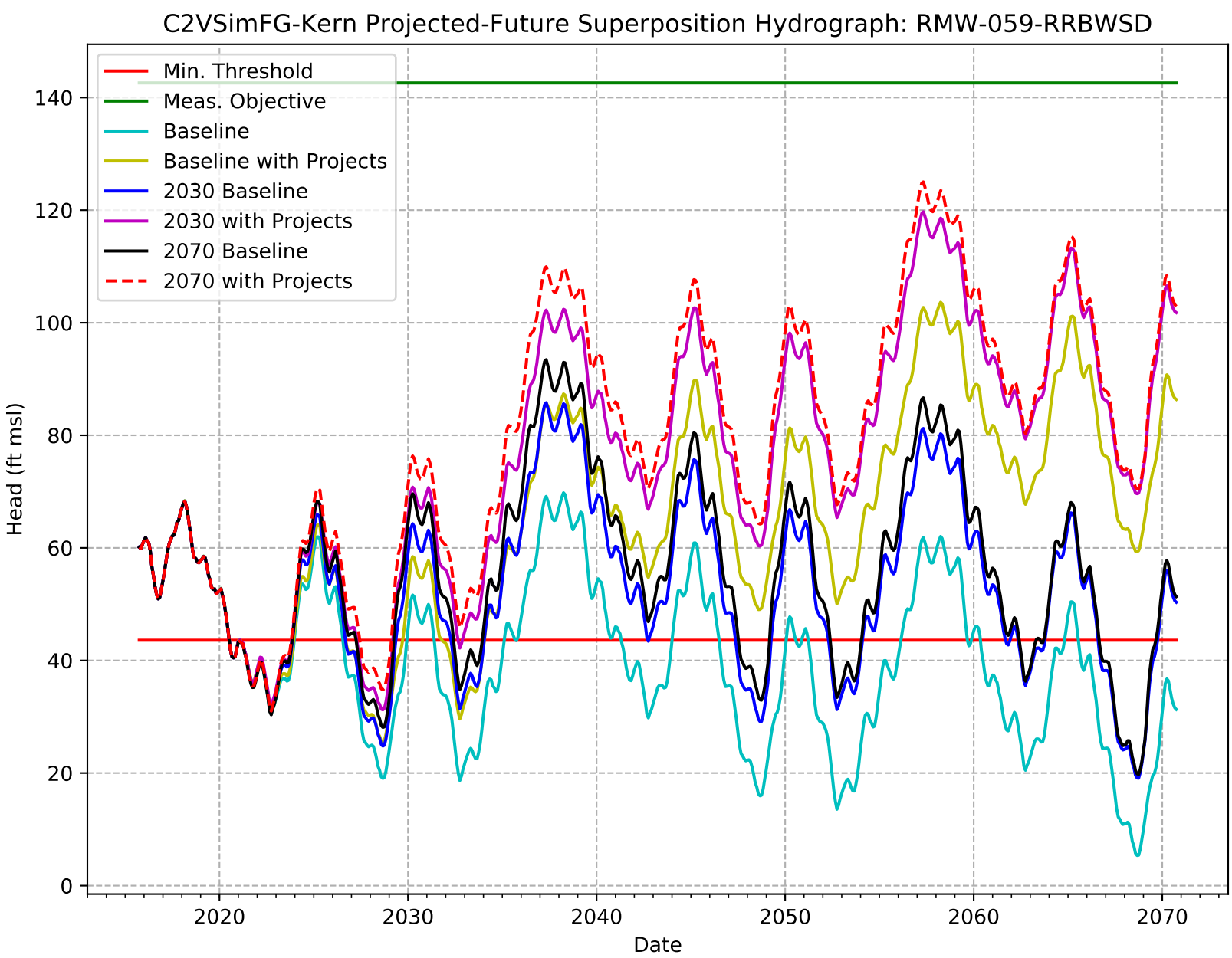

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-054-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
Date
0
20
40
60
80
100
120
2020
2030
2040
2050
2060
2070

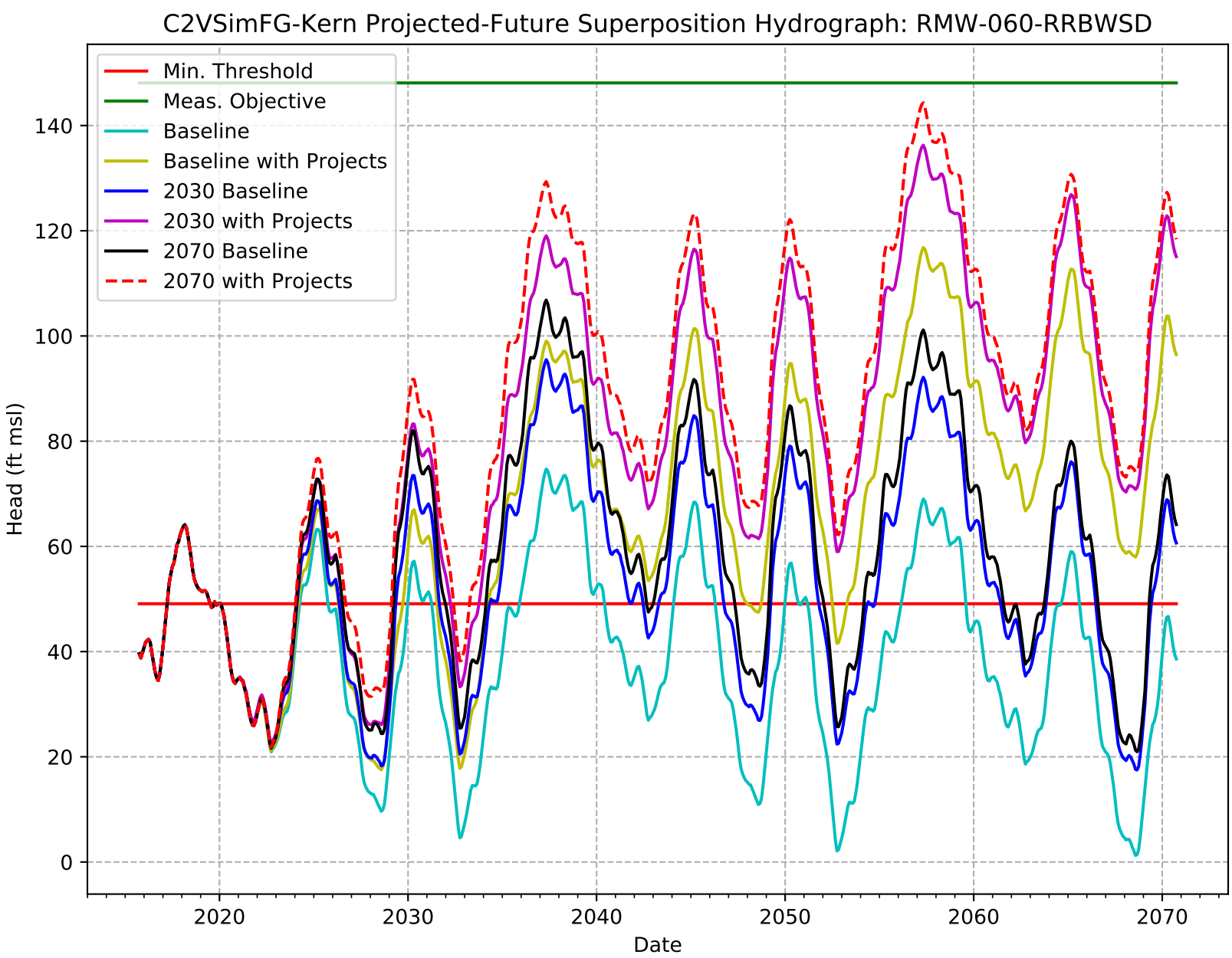

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-055-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
80
60
40
20
0
−20
2020
2030
2040
2050
2060
2070
Date

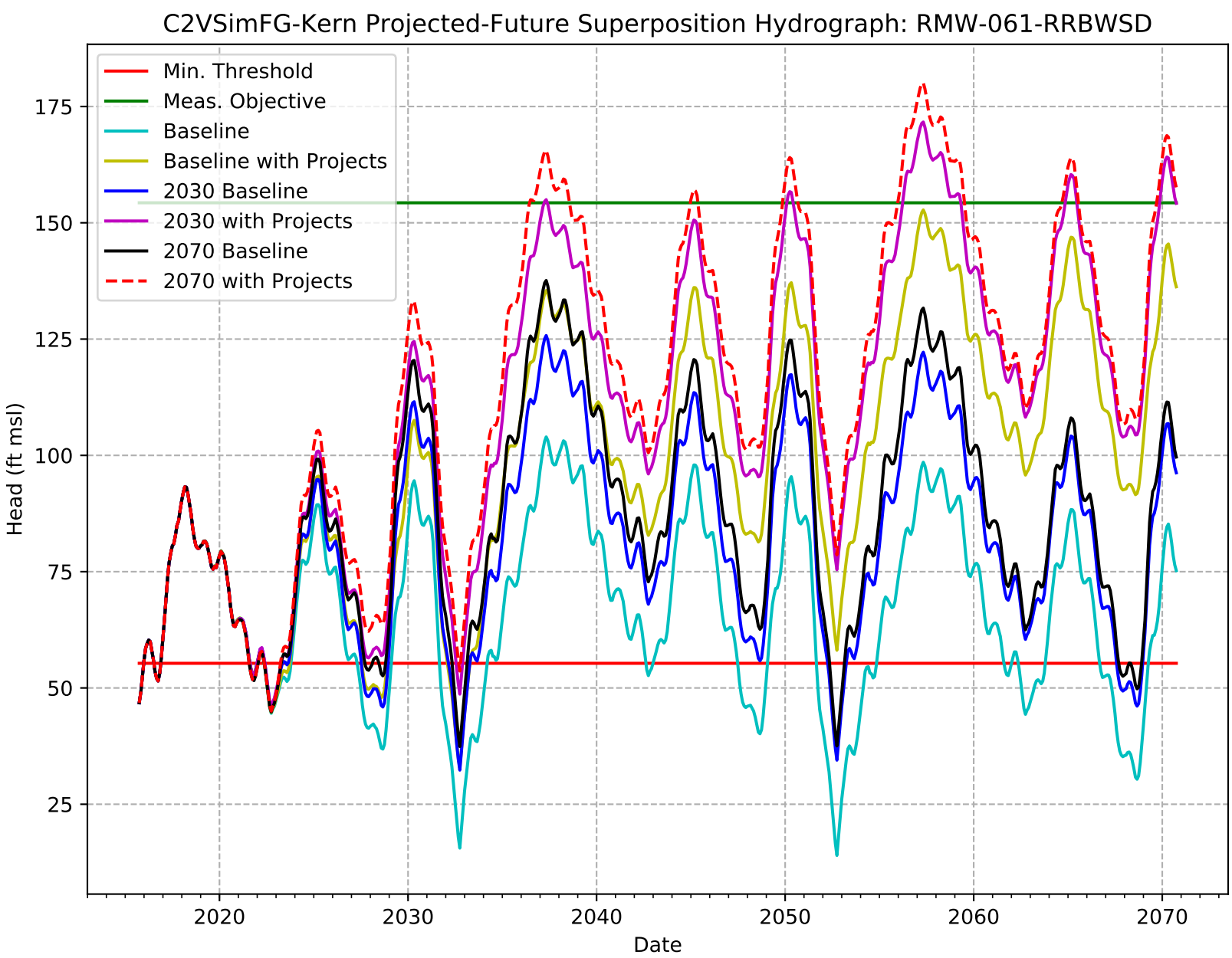

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-056-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

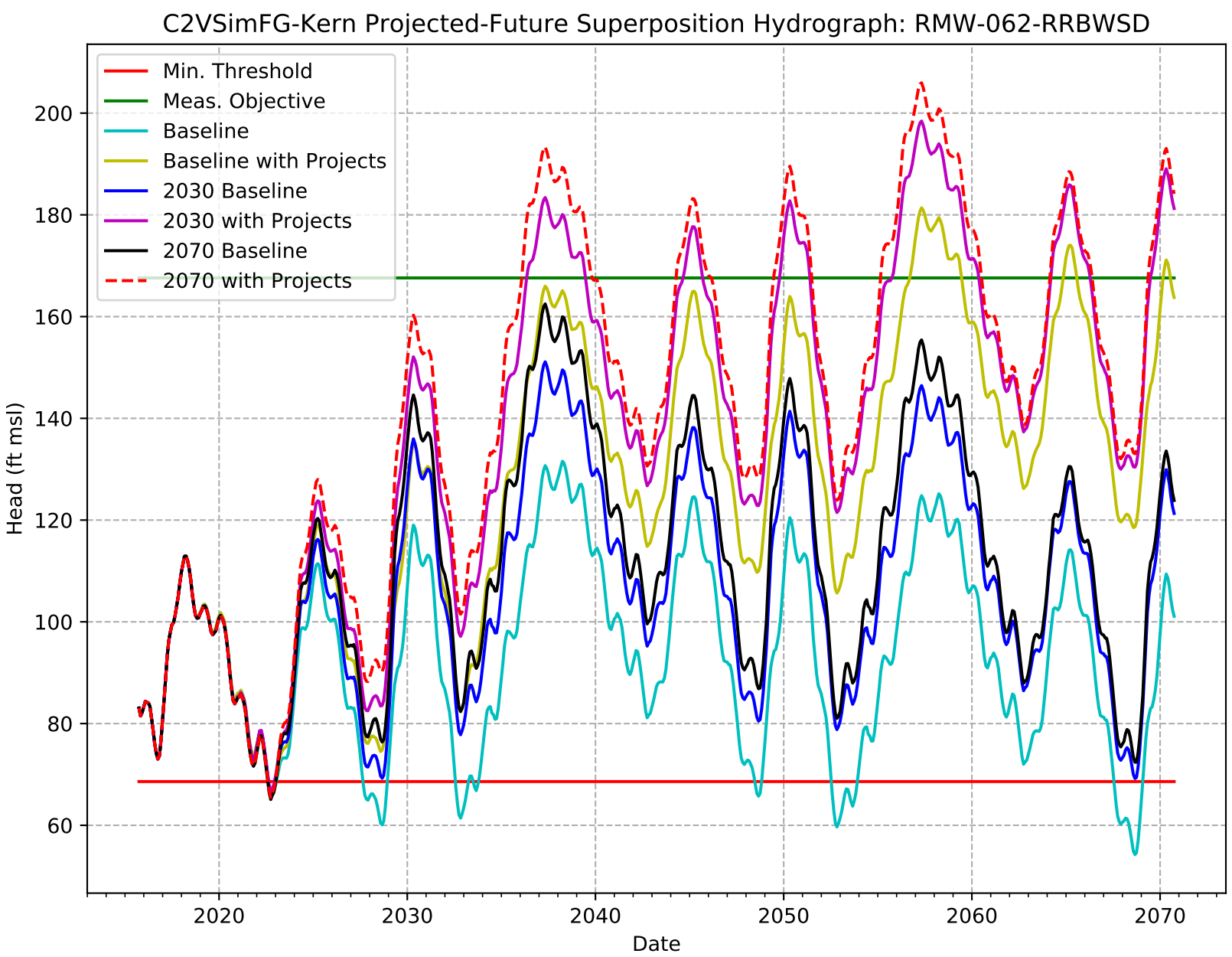

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-057-RRBWSD
Head (ft msl)
80
60
40
20
0
−20
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

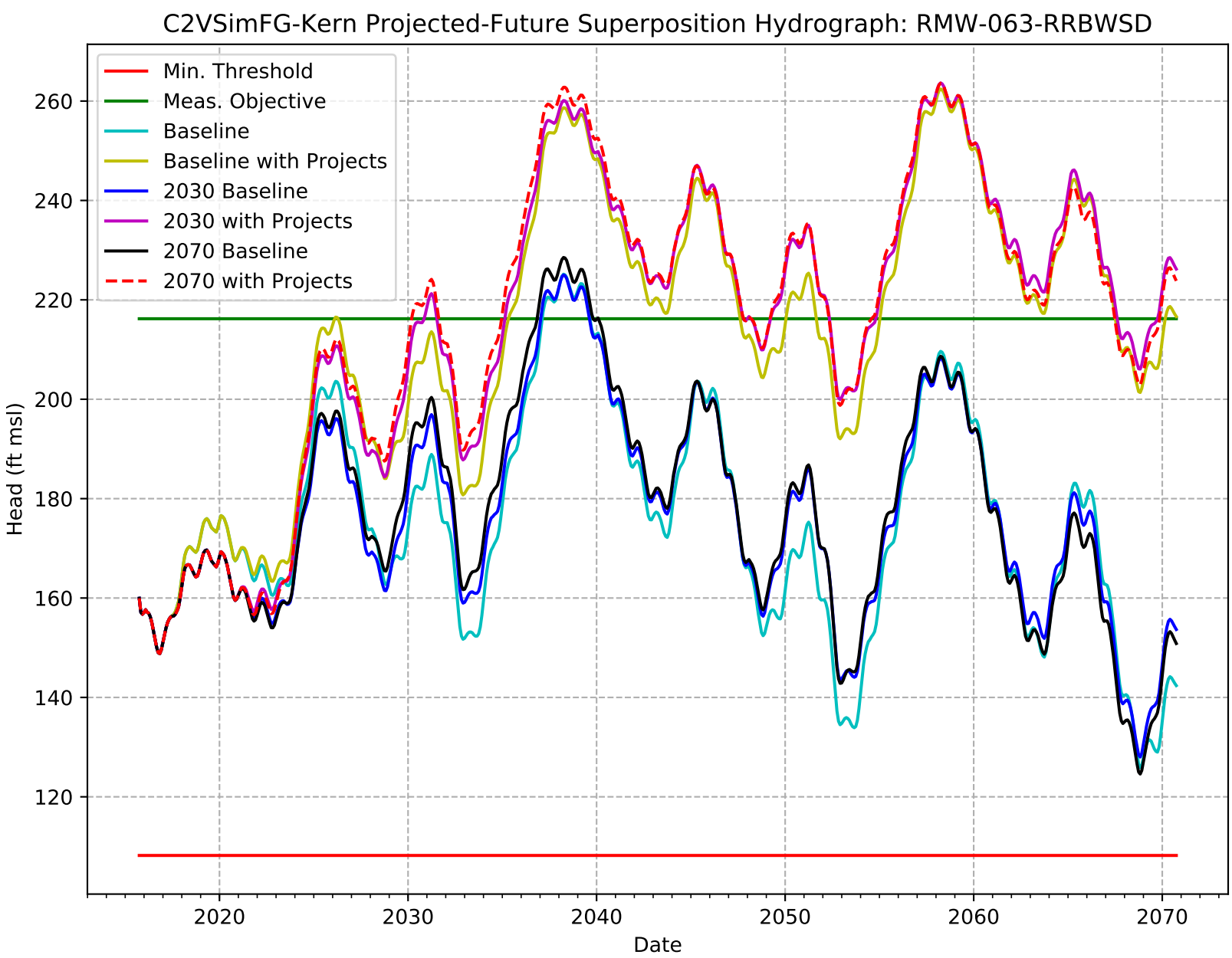

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-058-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

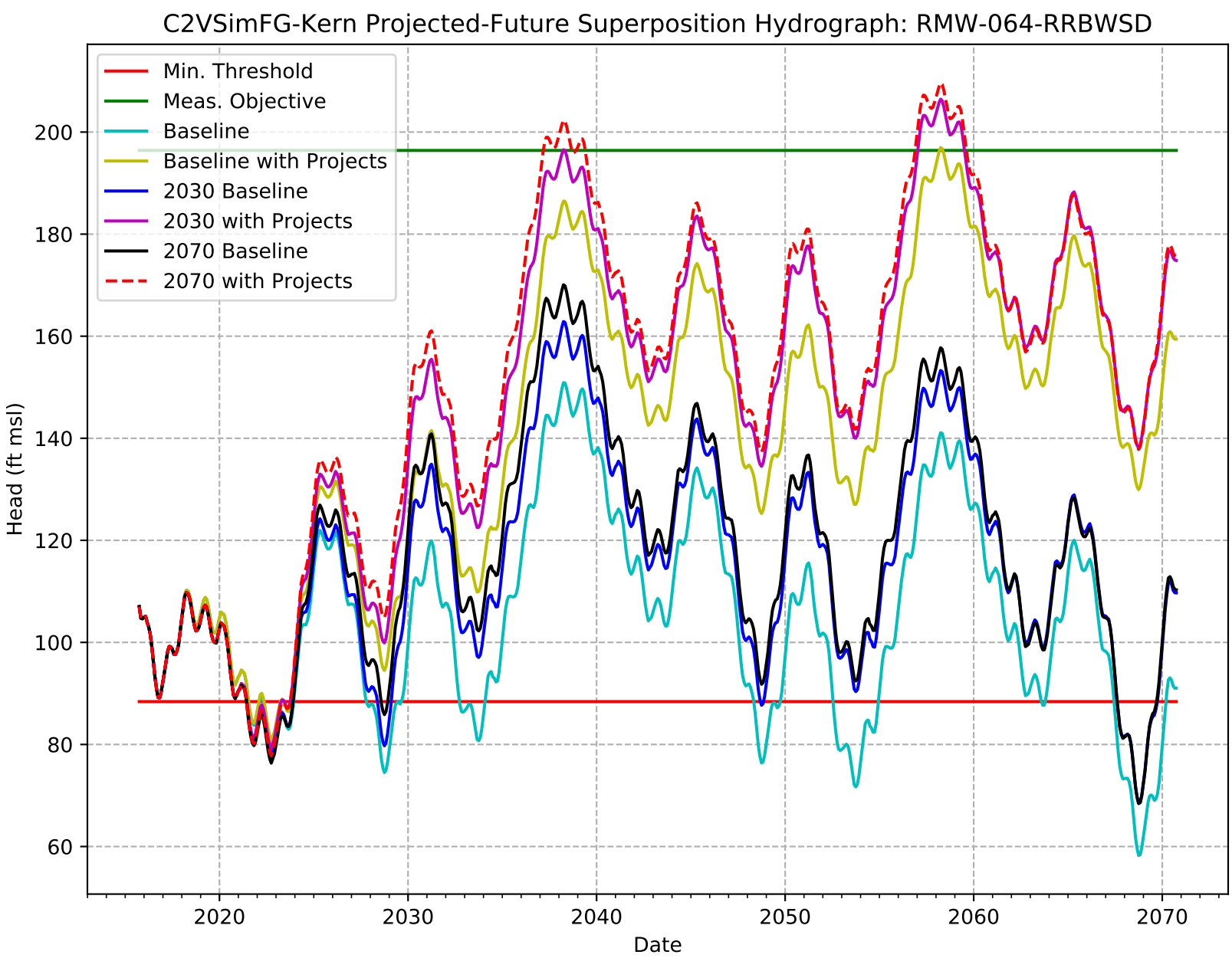

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-059-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
0
20
40
60
80
100
120
140
2020
2030
2040
2050
2060
2070
Date

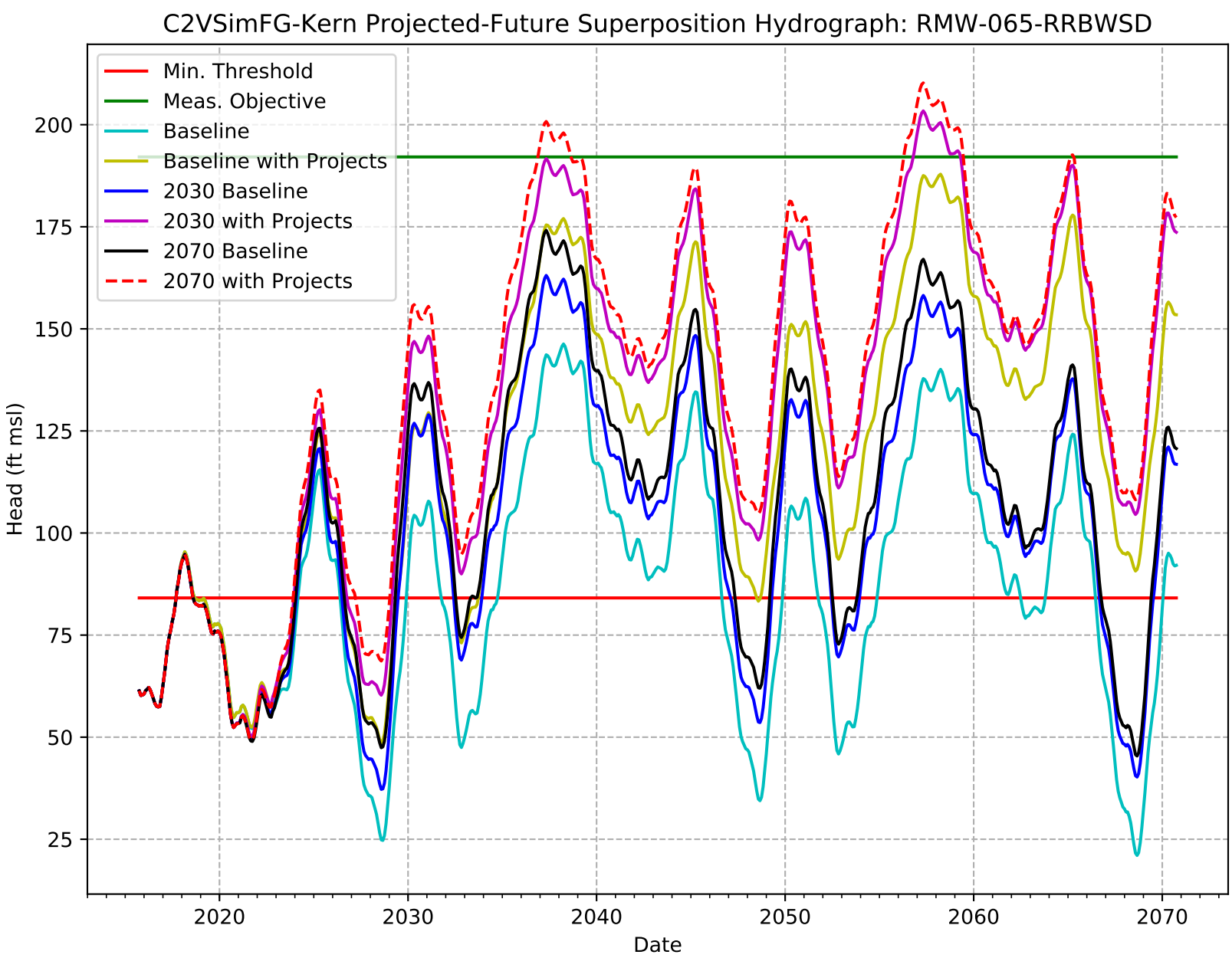

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-060-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
0
20
40
60
80
100
120
140
2020
2030
2040
2050
2060
2070
Date

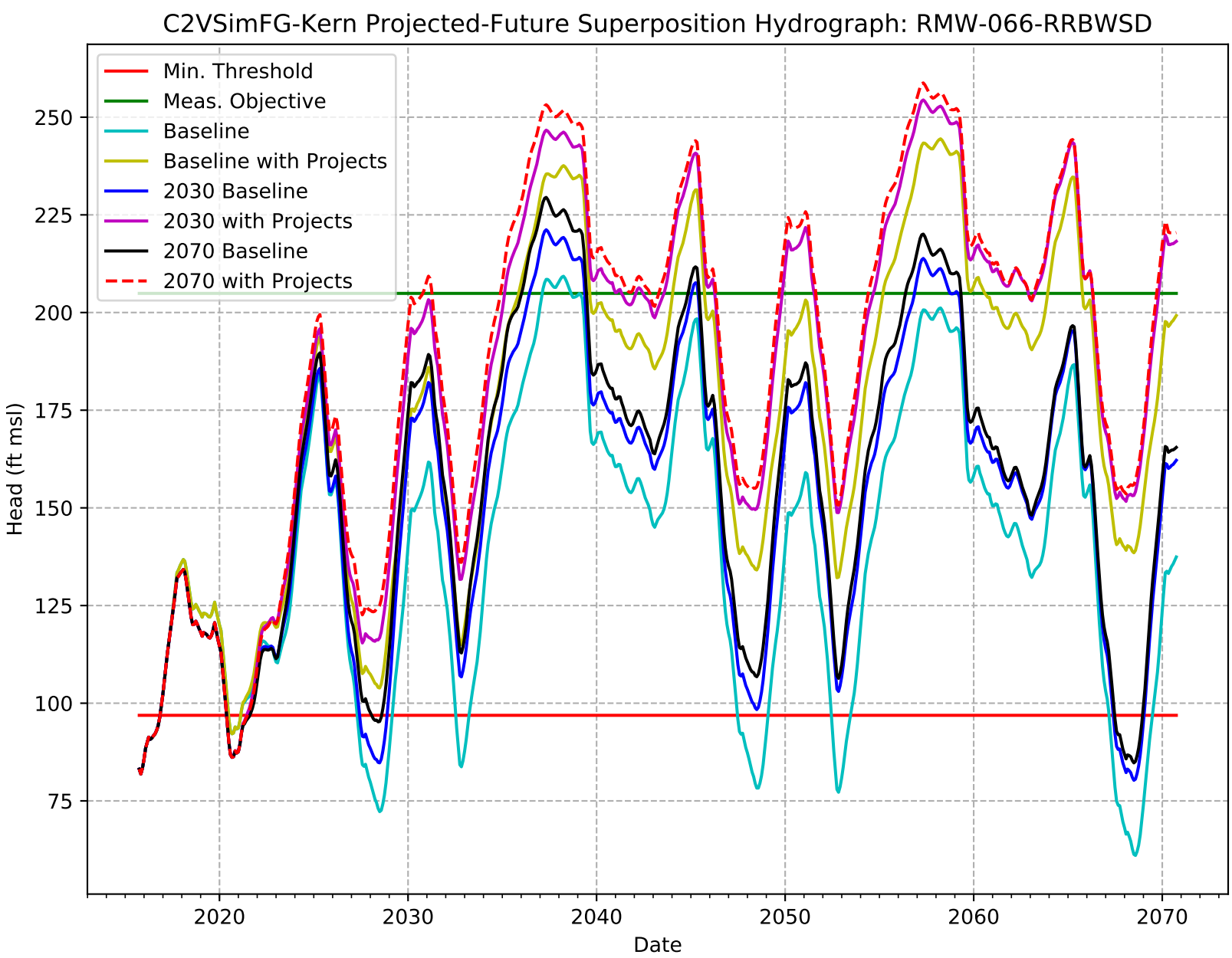

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-061-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
175
150
125
100
75
50
25
2020
2030
2040
2050
2060
2070
Date

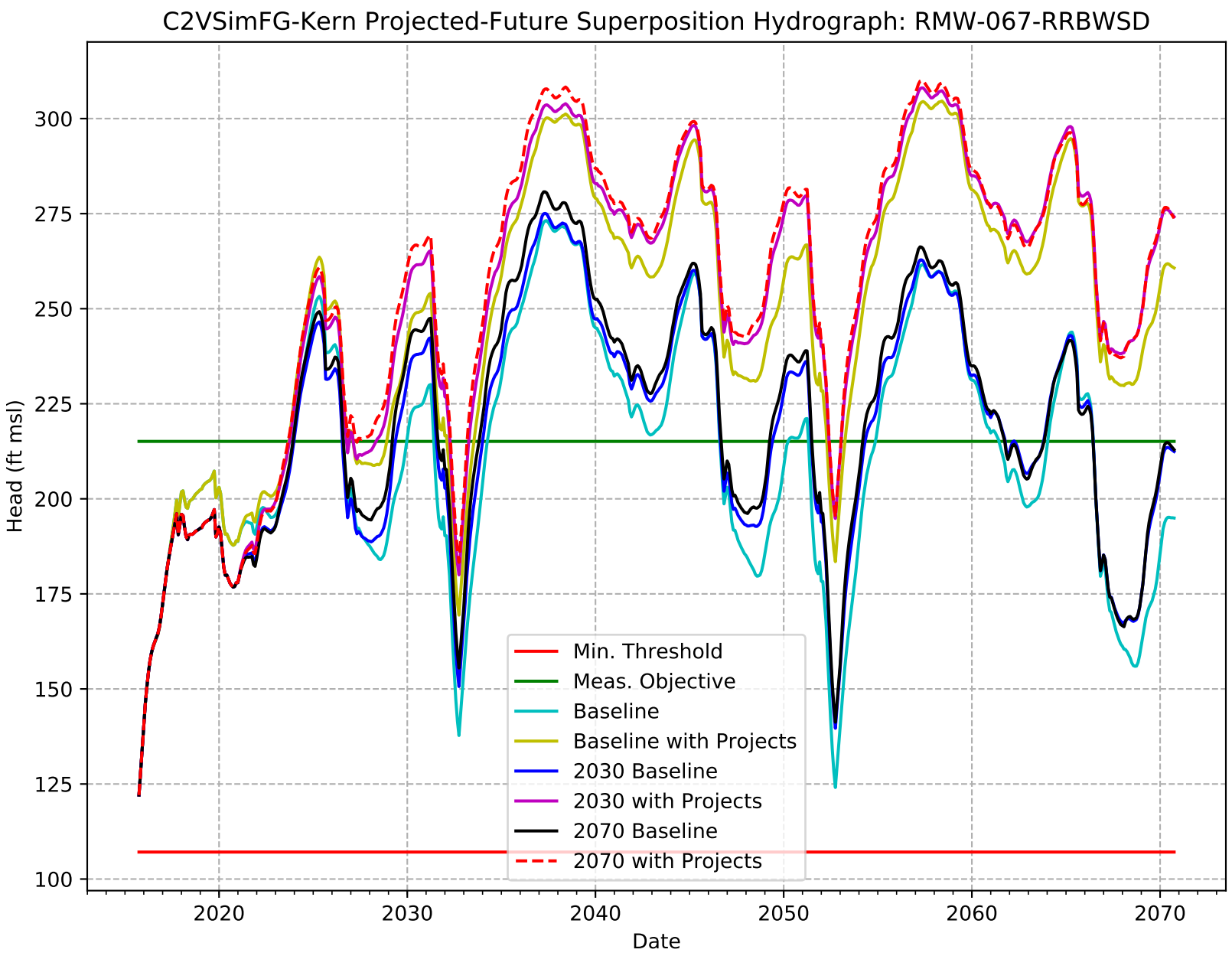

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-062-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

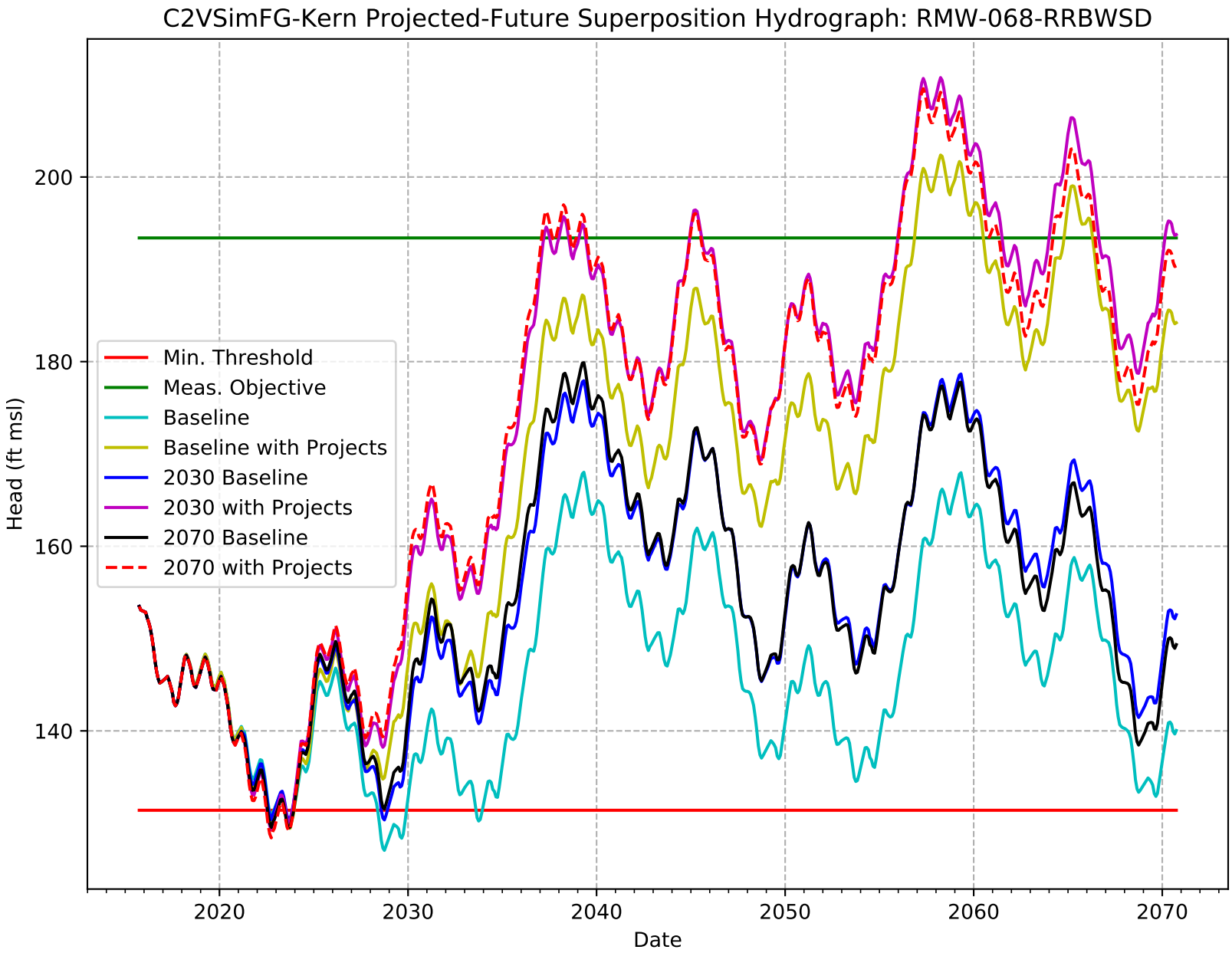

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-063-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
260
240
220
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date

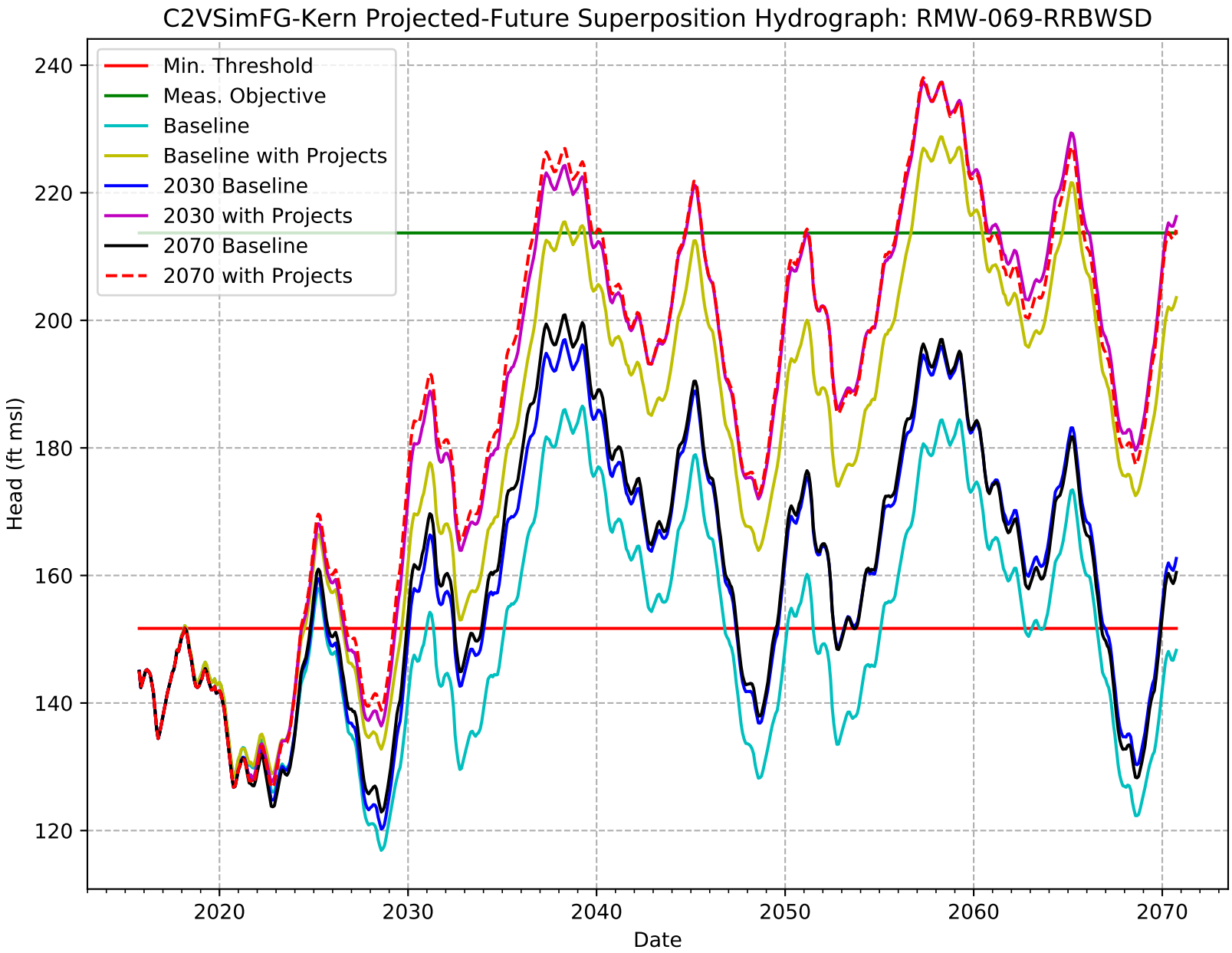

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-064-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

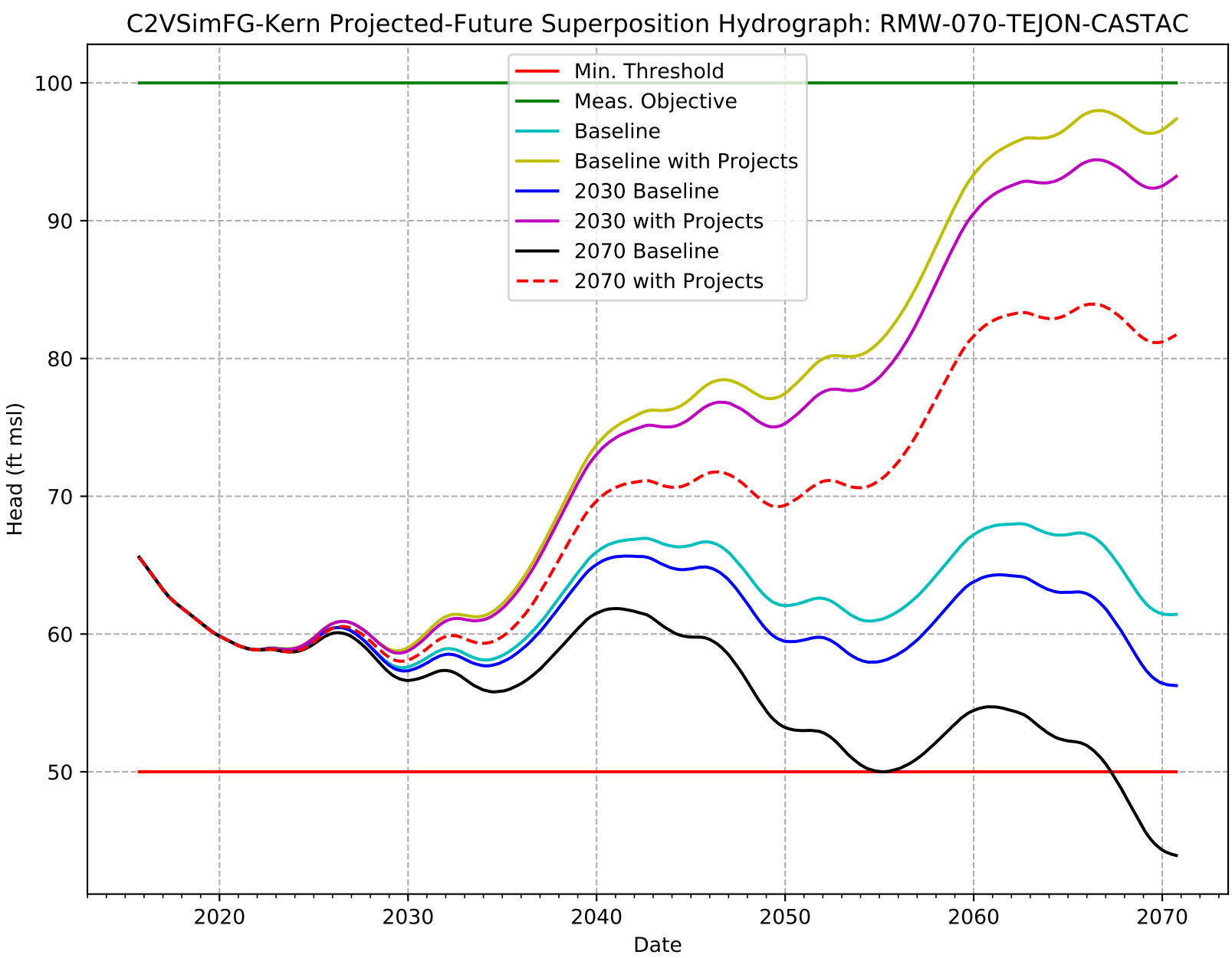

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-065-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
175
150
125
100
75
50
25
2020
2030
2040
2050
2060
2070
Date

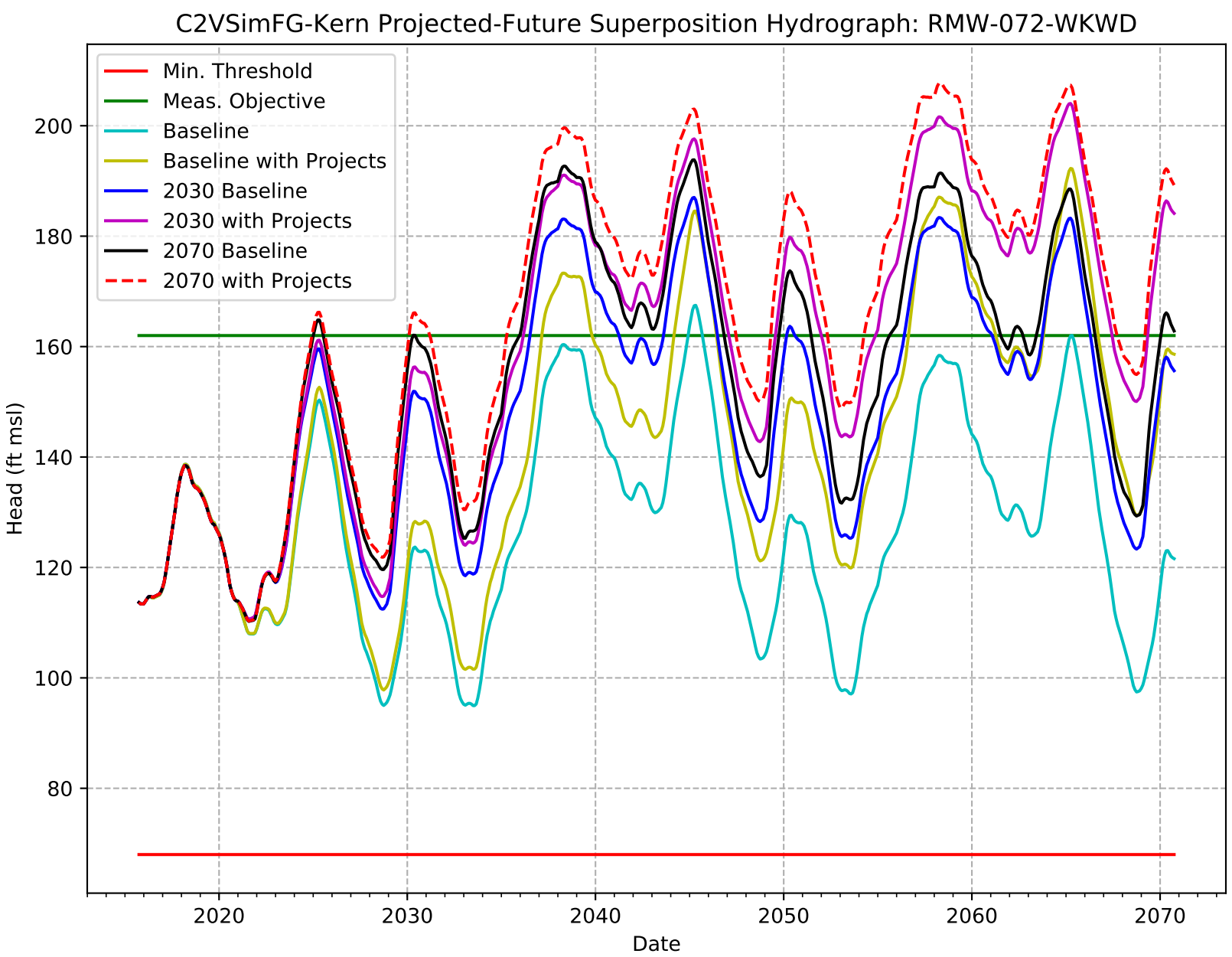

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-066-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
225
200
175
150
125
100
75
2020
2030
2040
2050
2060
2070
Date

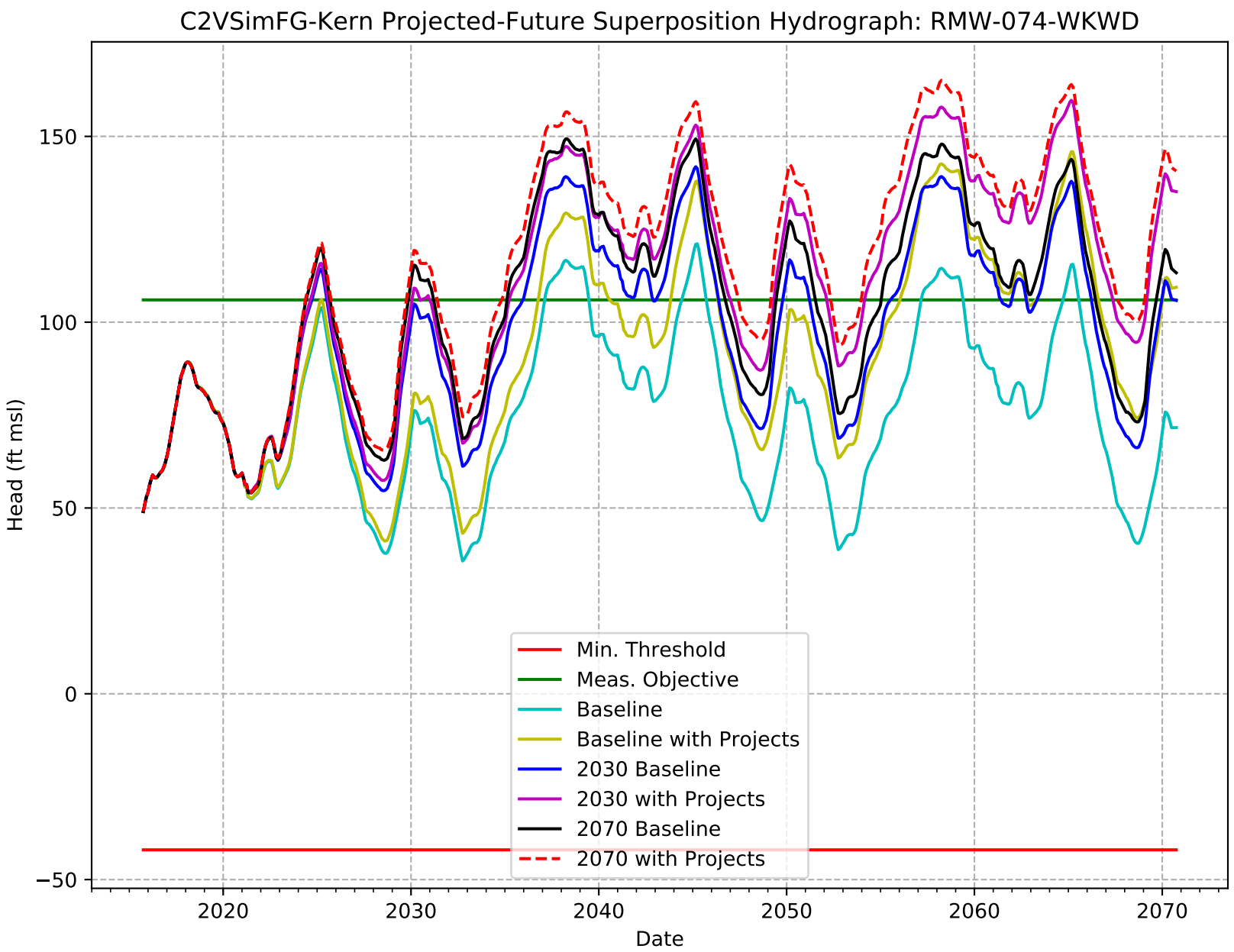

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-067-RRBWSD
Head (ft msl)
300
275
250
225
200
175
150
125
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

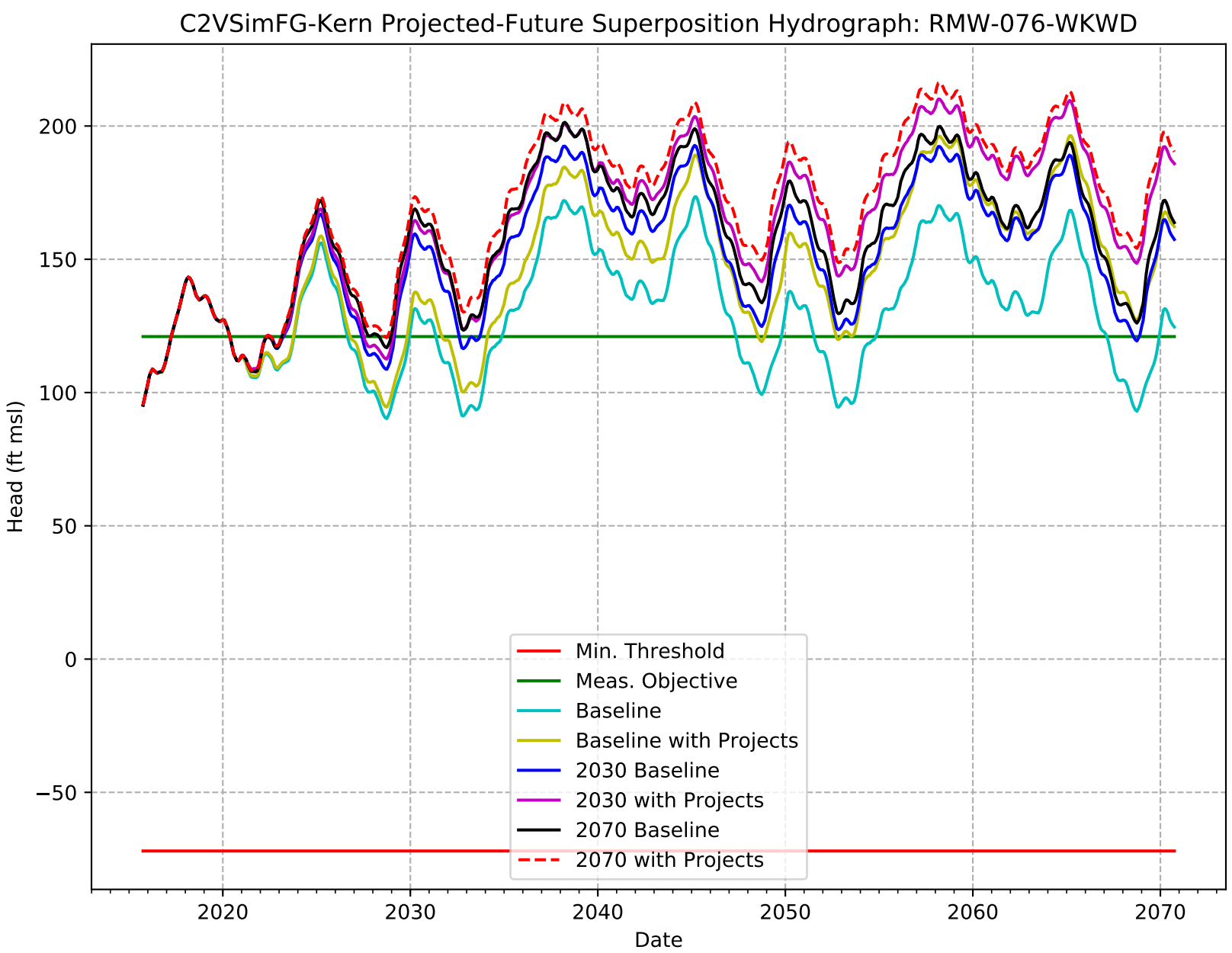

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-068-RRBWSD
Head (ft msl)
200
180
160
140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

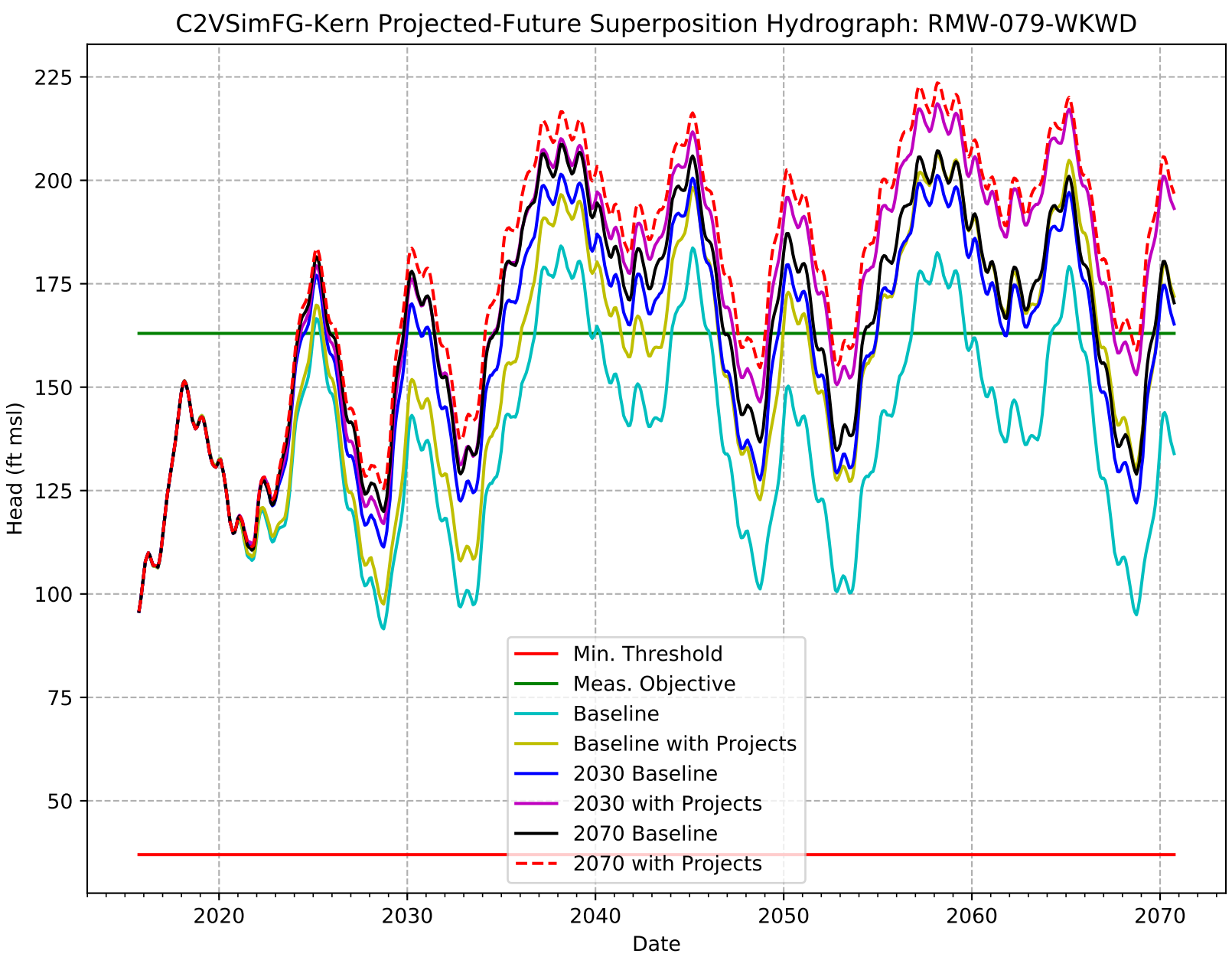

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-069-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
240
220
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date

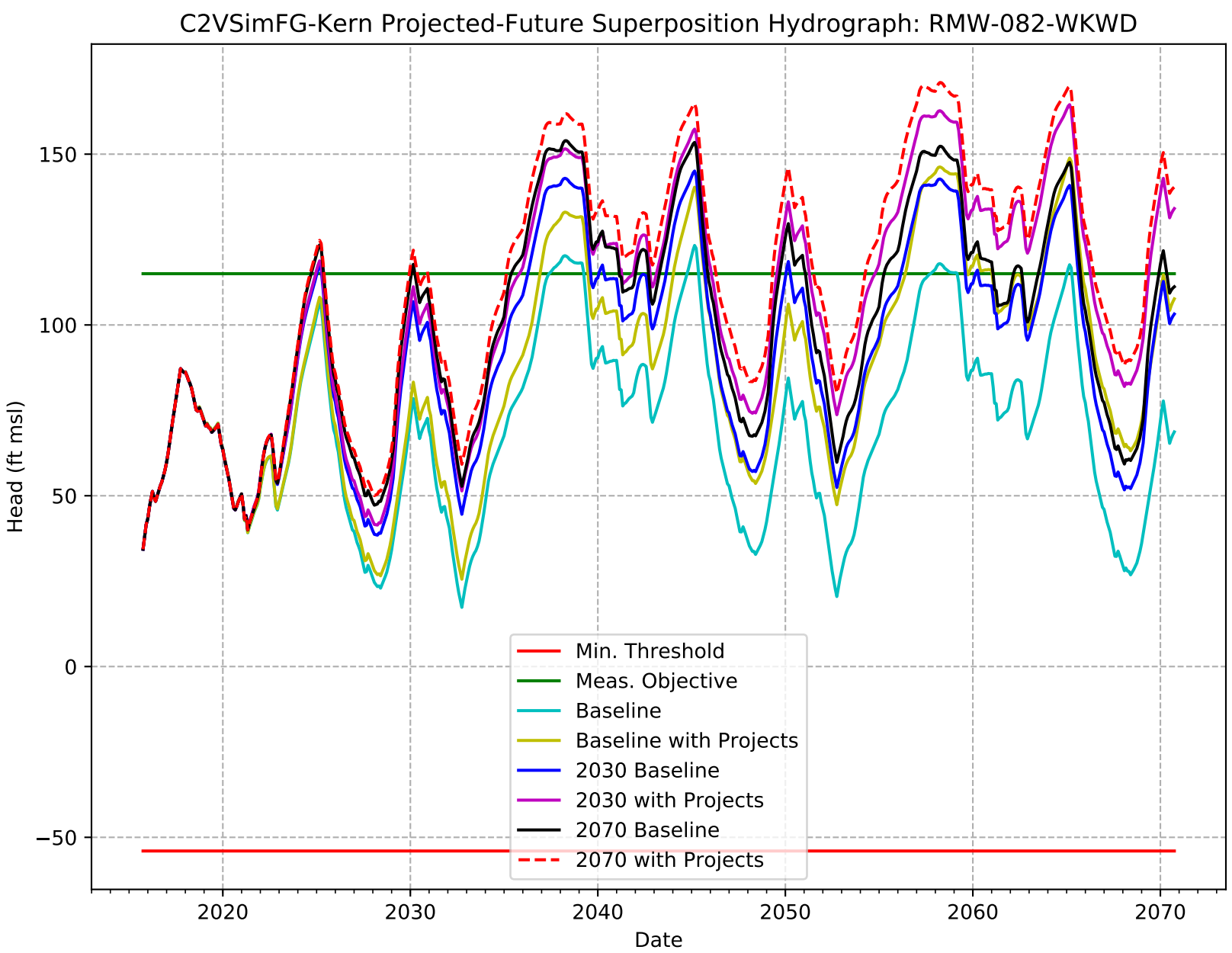

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-070-TEJON-CASTAC
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
90
80
70
60
50
2020
2030
2040
2050
2060
2070
Date

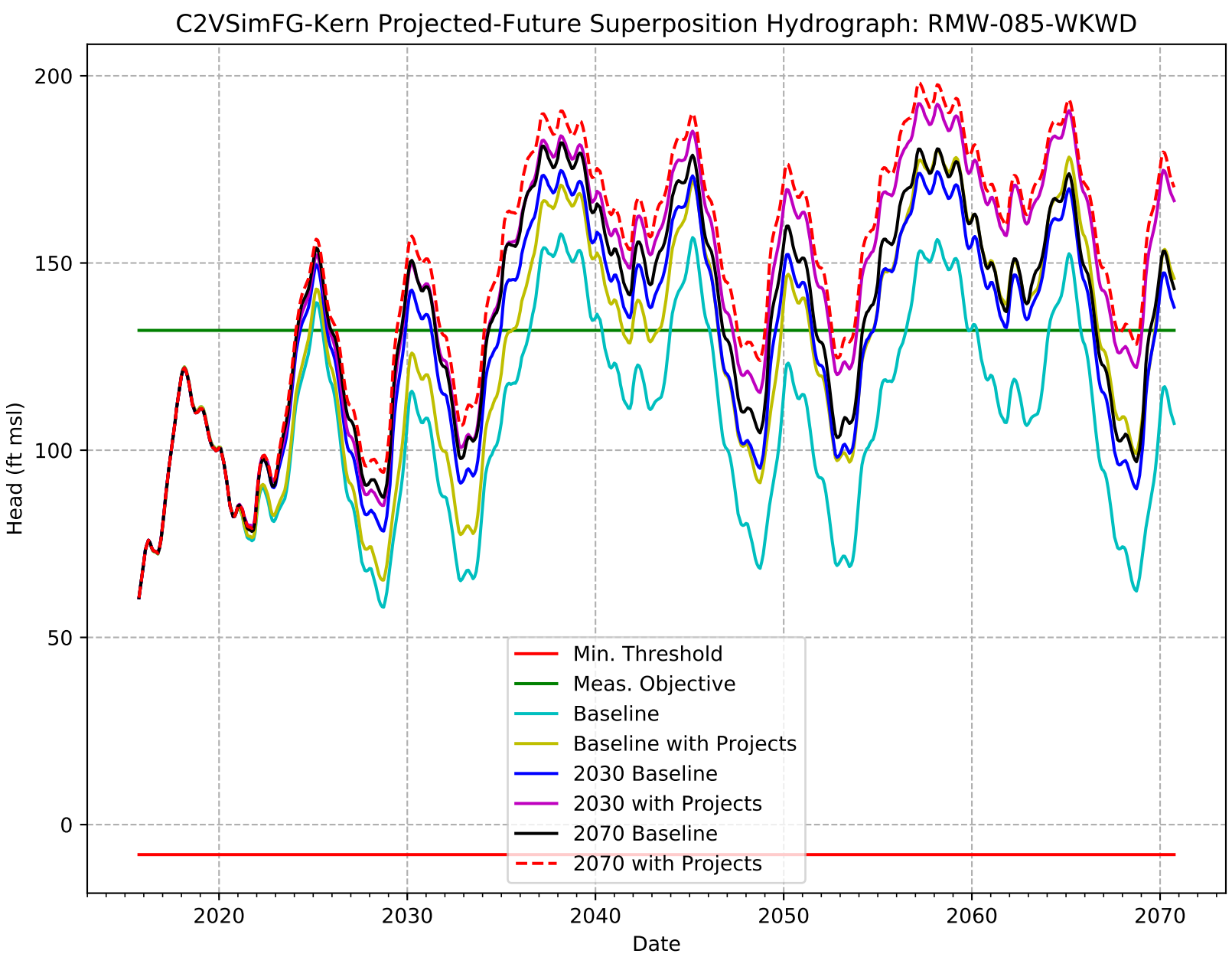

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-072-WKWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date

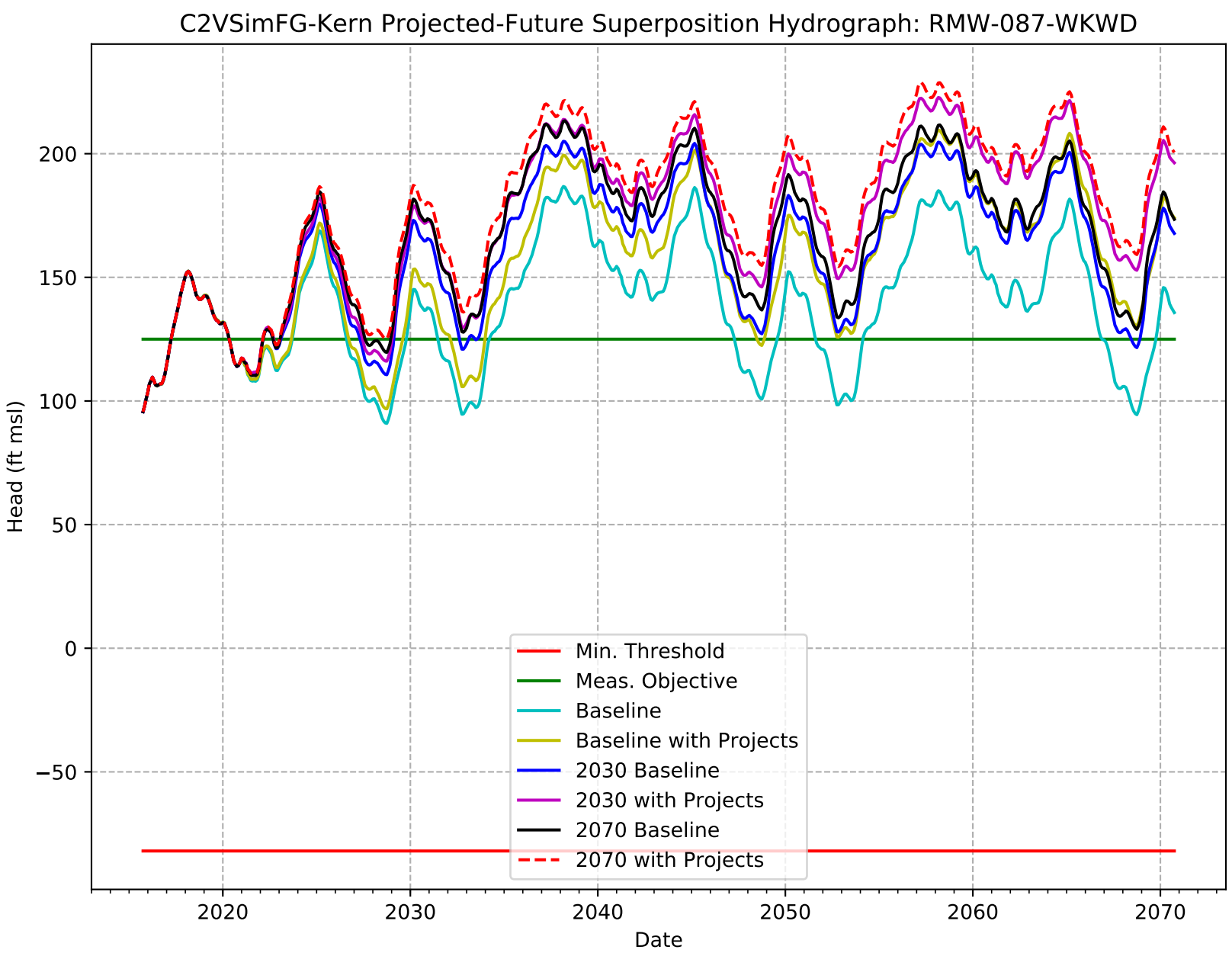

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-074-WKWD
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

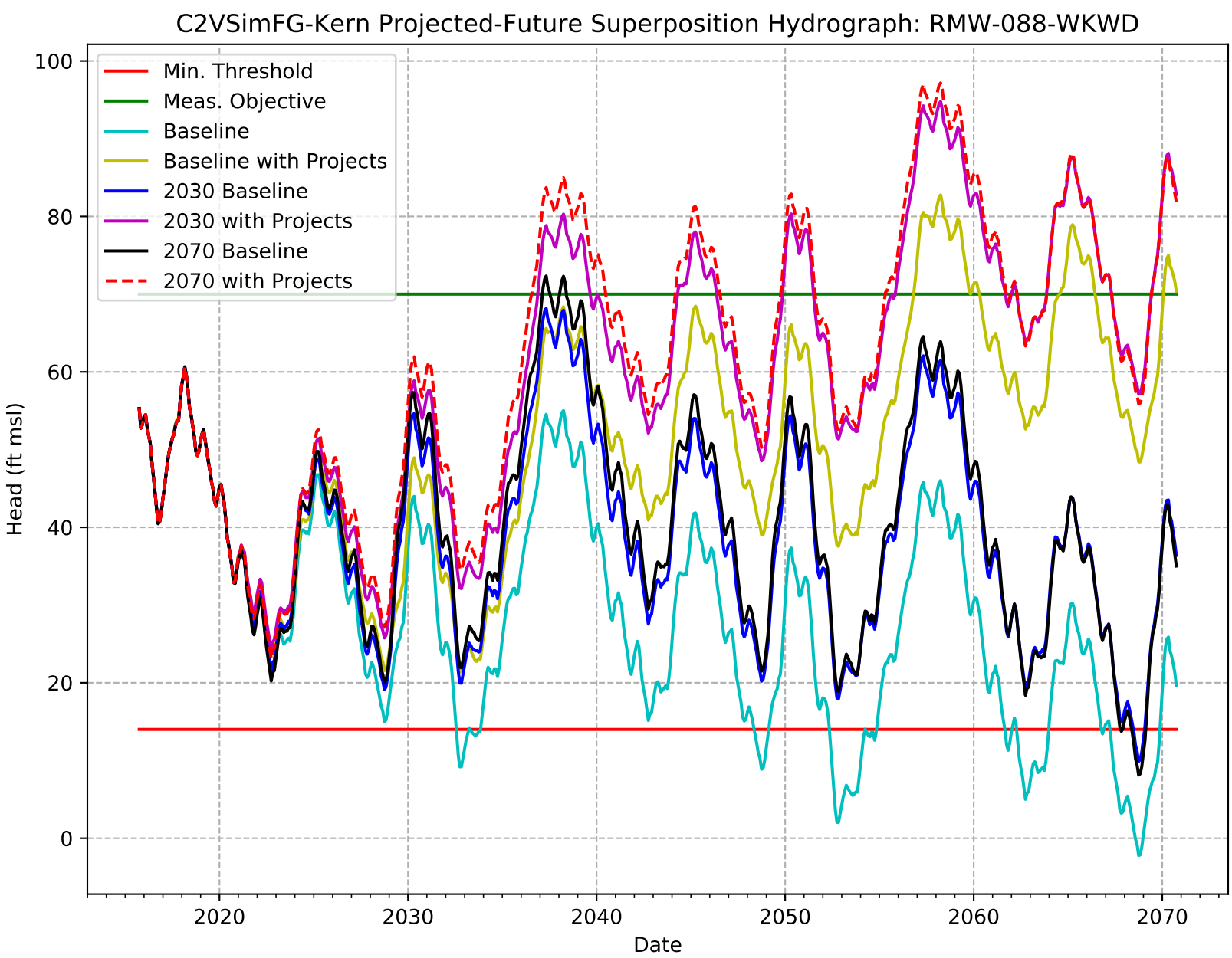

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-076-WKWD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

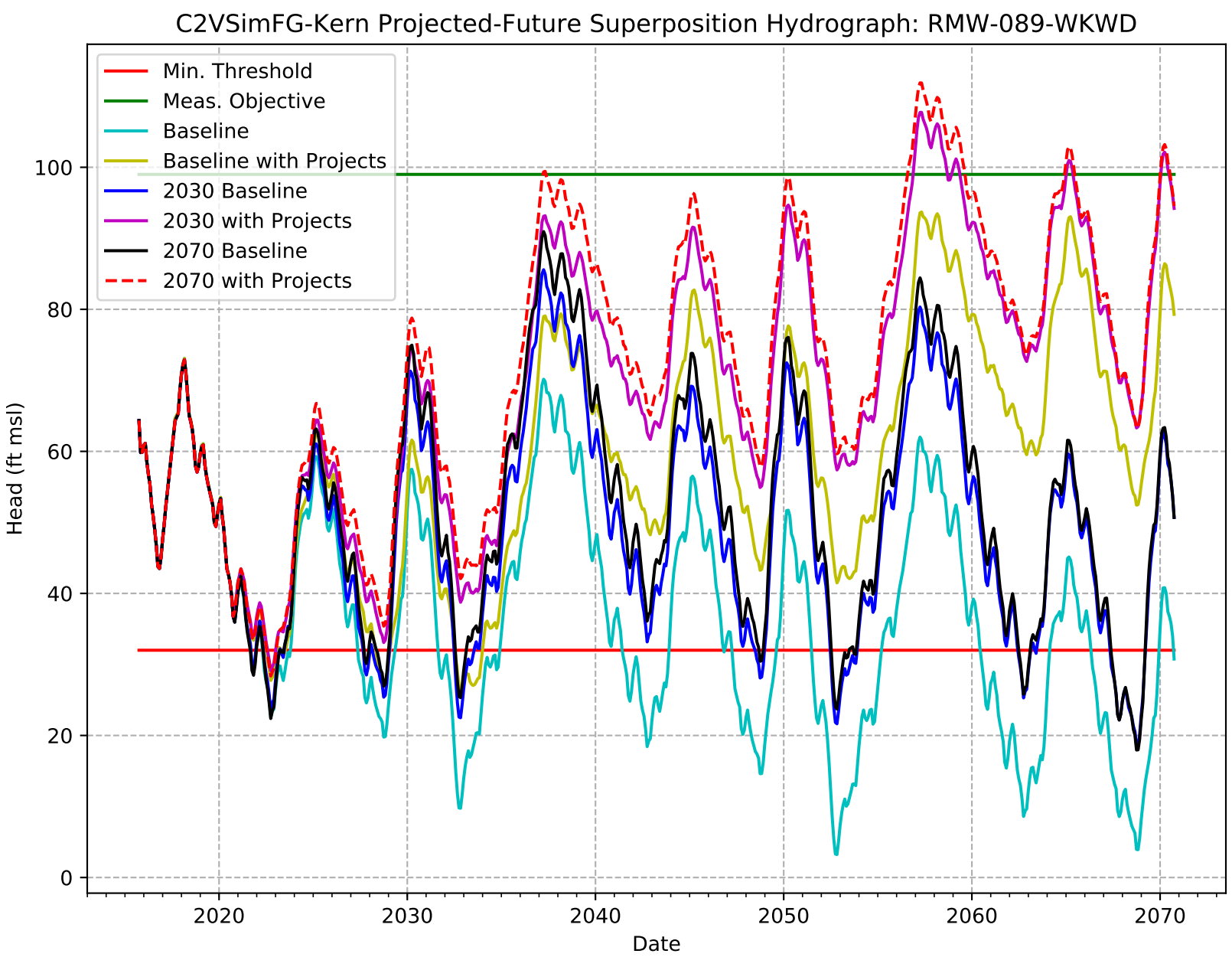

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-079-WKWD
Head (ft msl)
225
200
175
150
125
100
75
50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

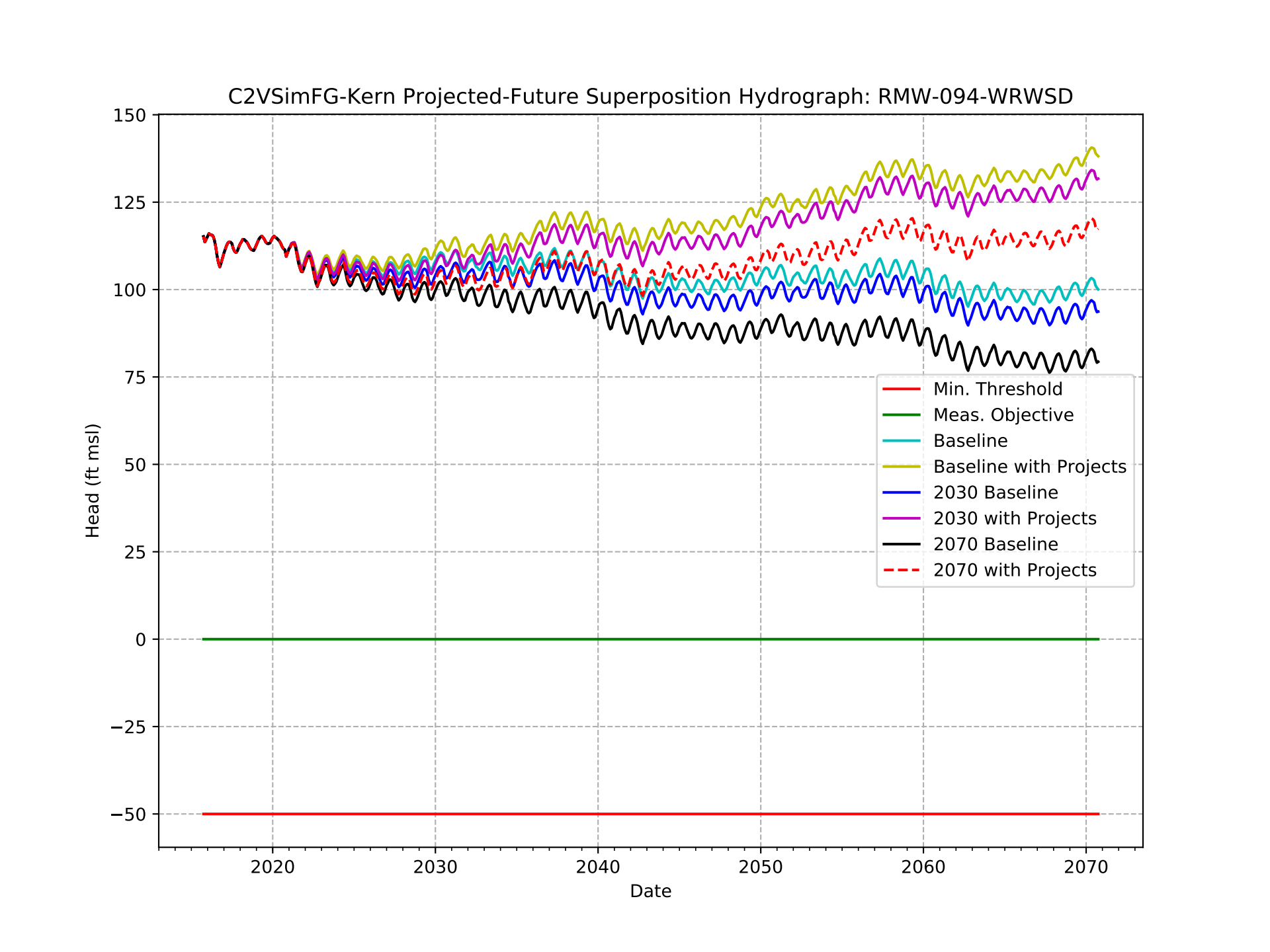

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-082-WKWD
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

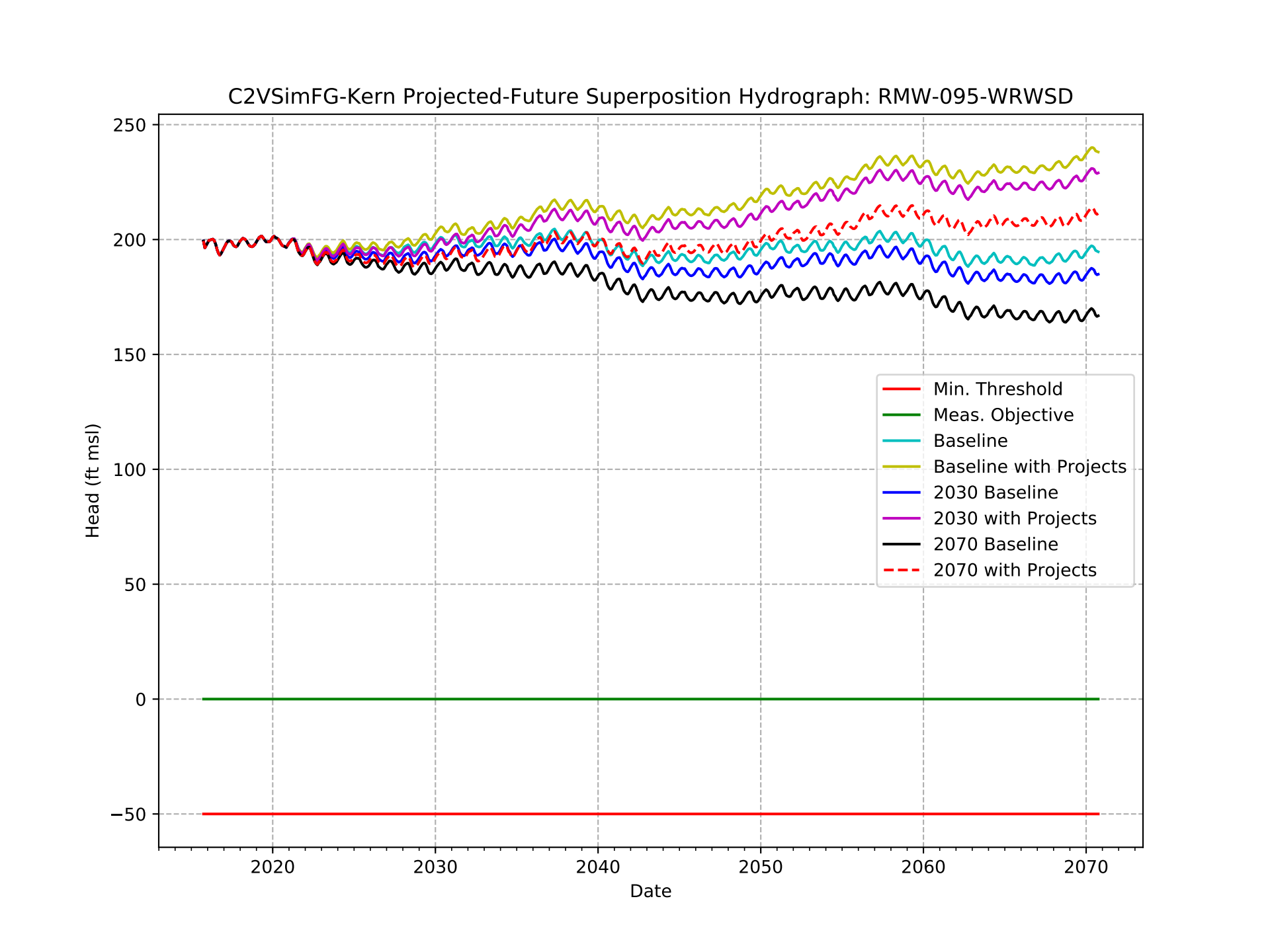

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-085-WKWD
Head (ft msl)
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

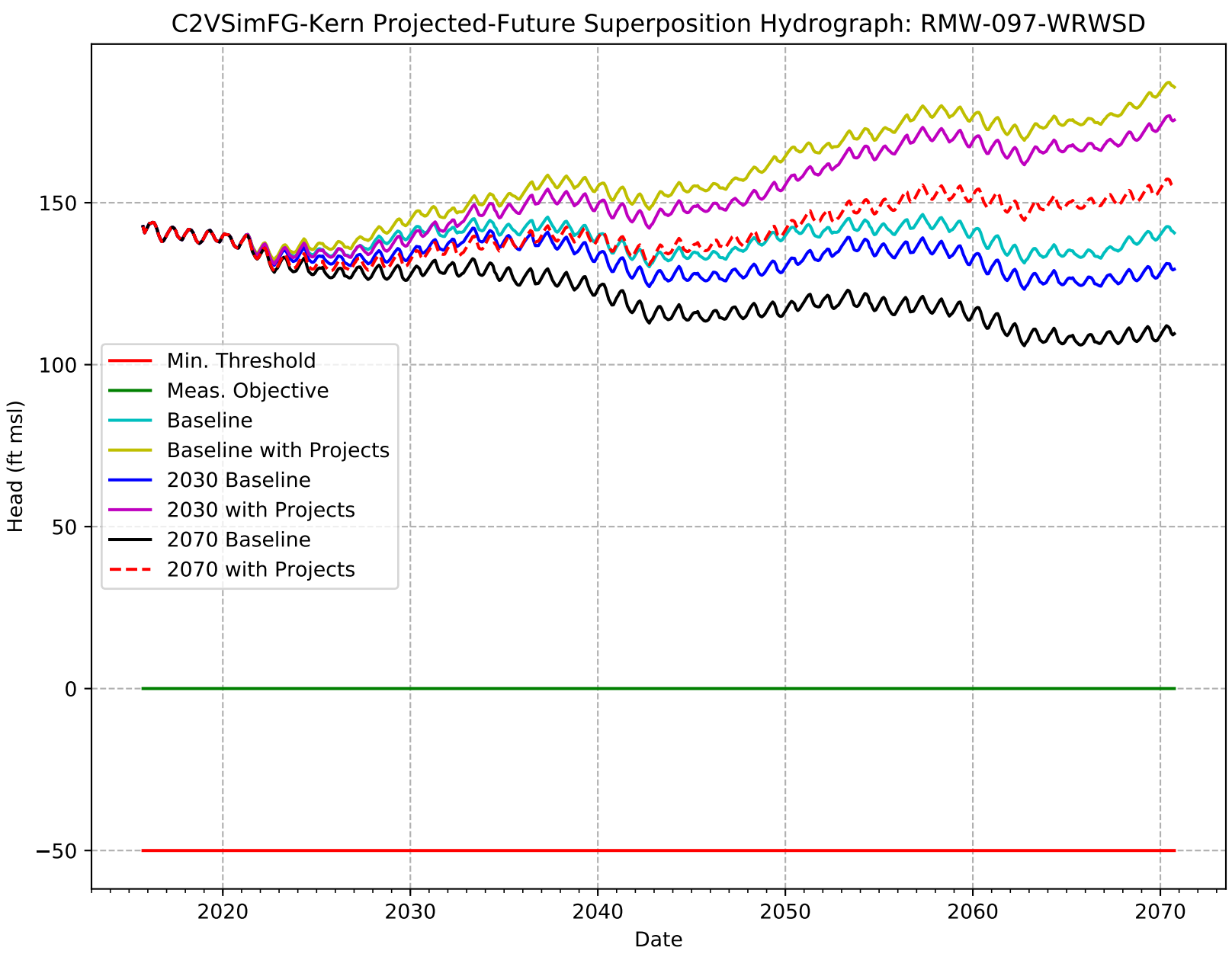

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-087-WKWD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

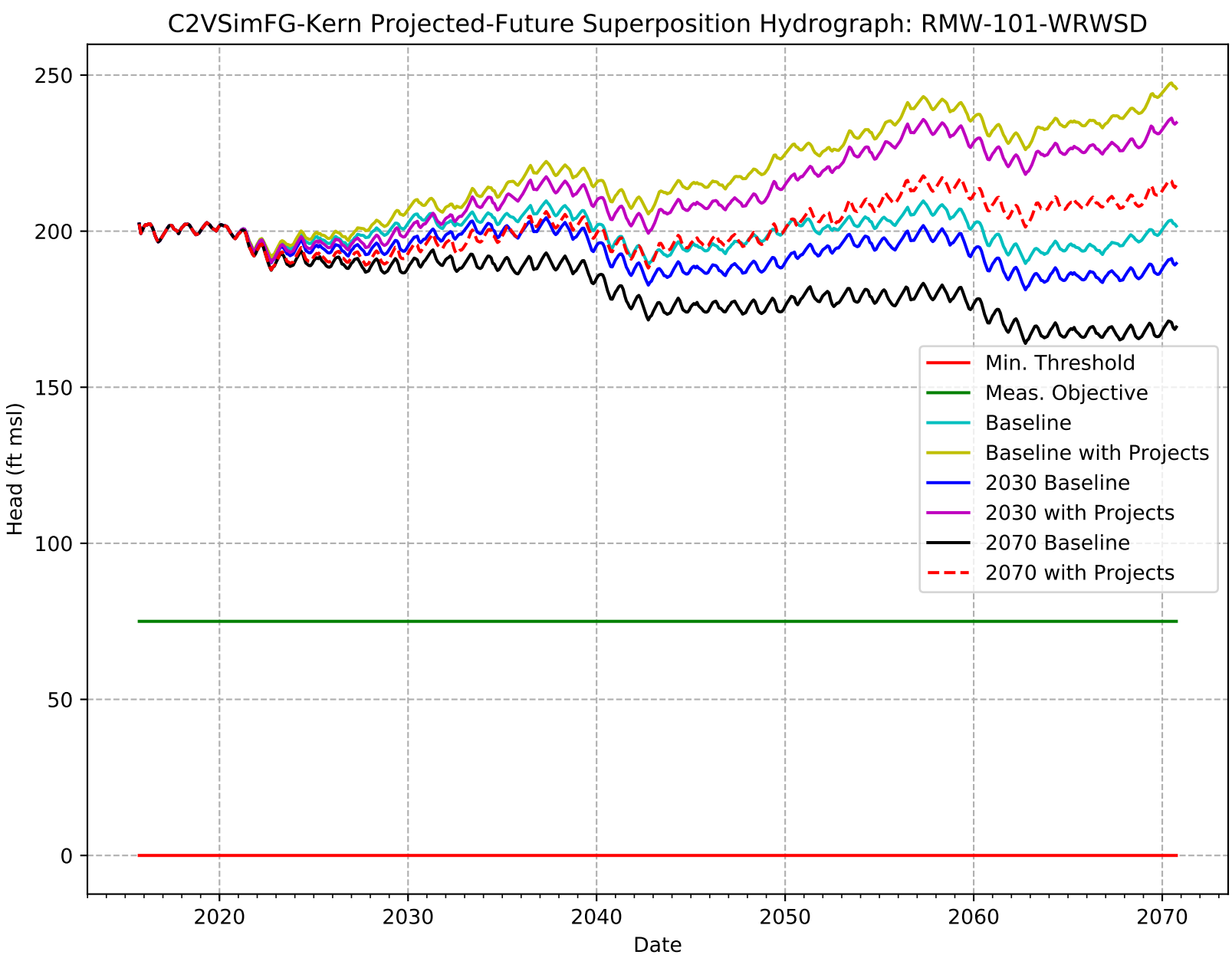

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-088-WKWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

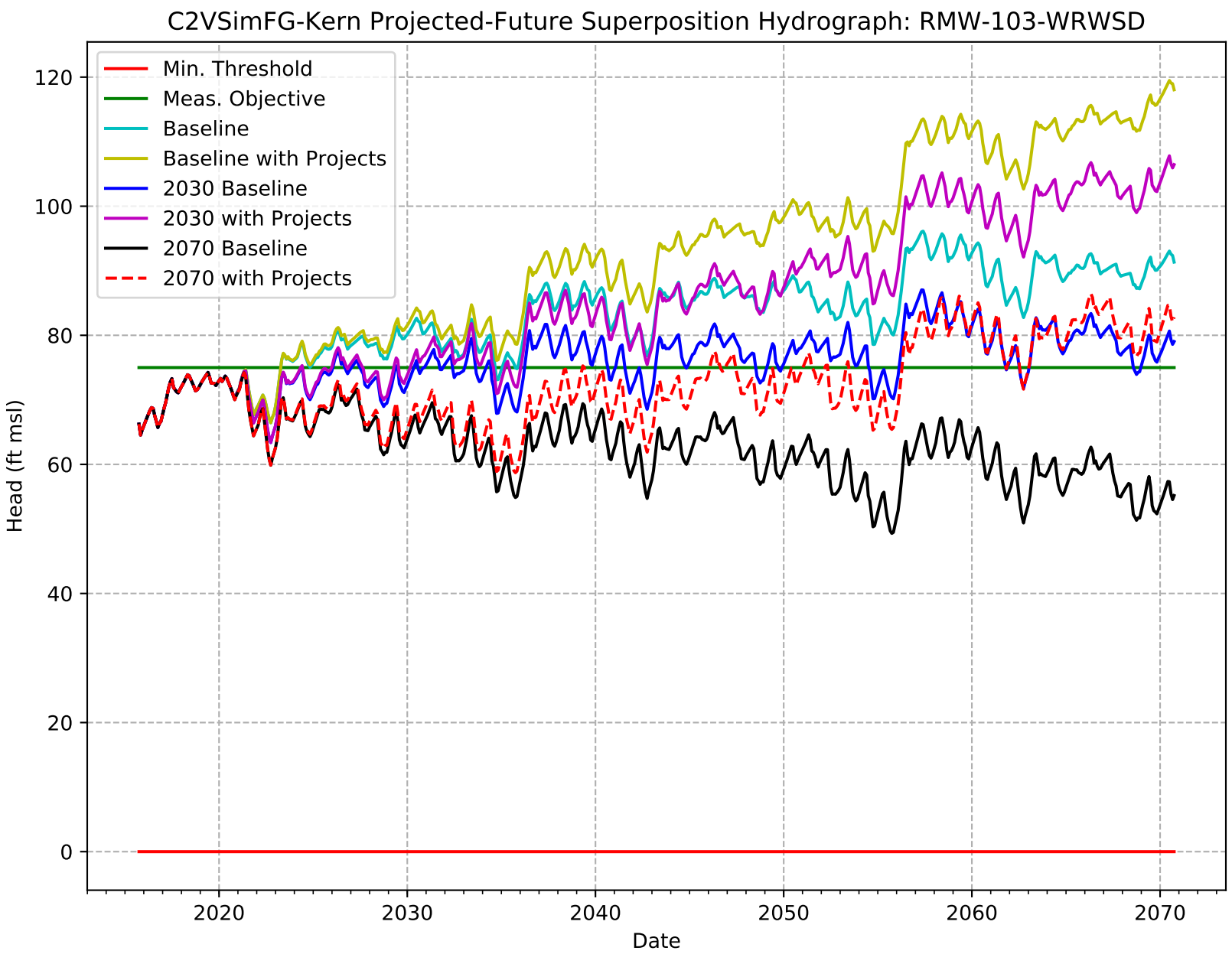

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-089-WKWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
0
20
40
60
80
100
2020
2030
2040
2050
2060
2070
Date

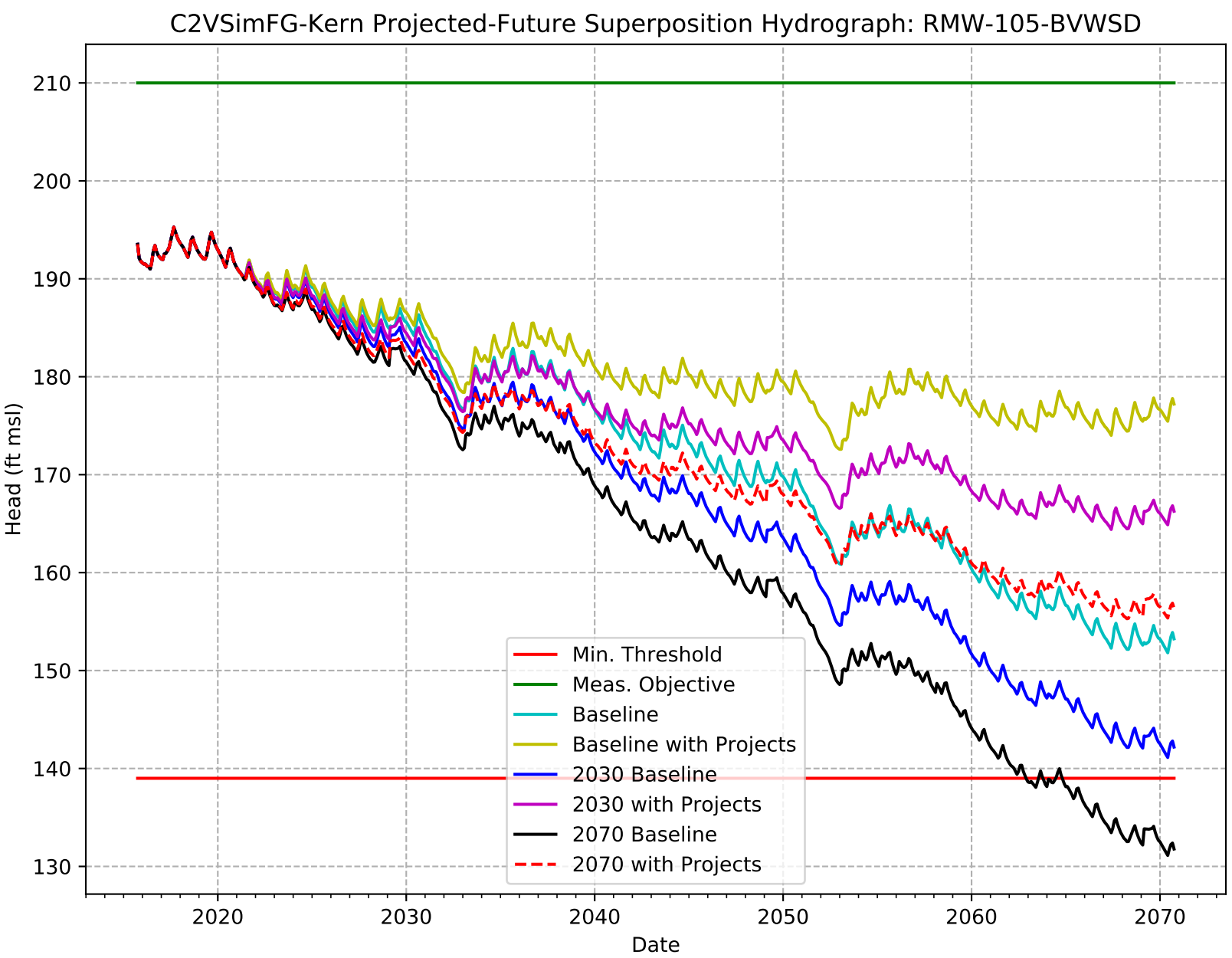

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-094-WRWSD
Head (ft msl)
Date
150
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

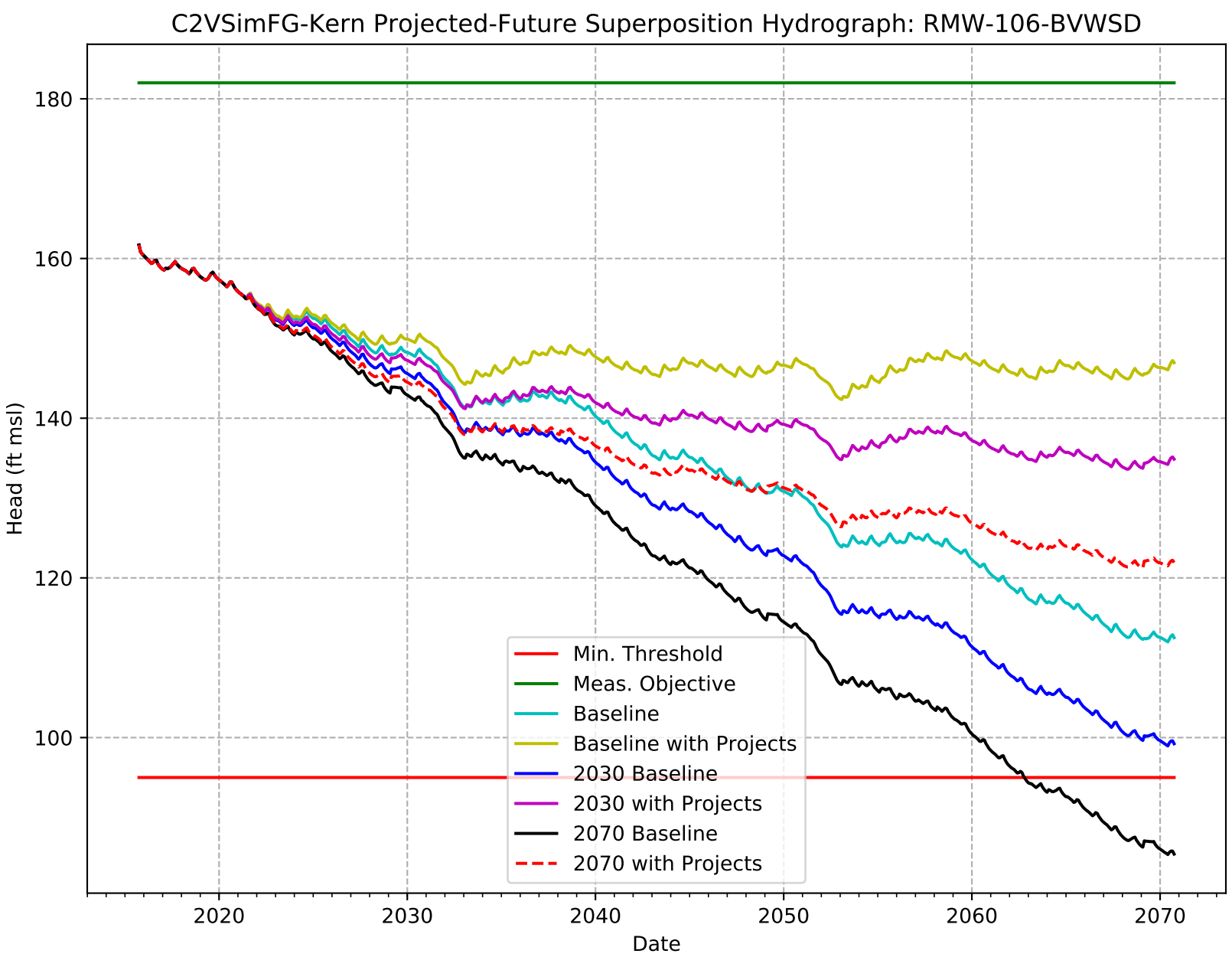

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-095-WRWSD
Head (ft msl)
250
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

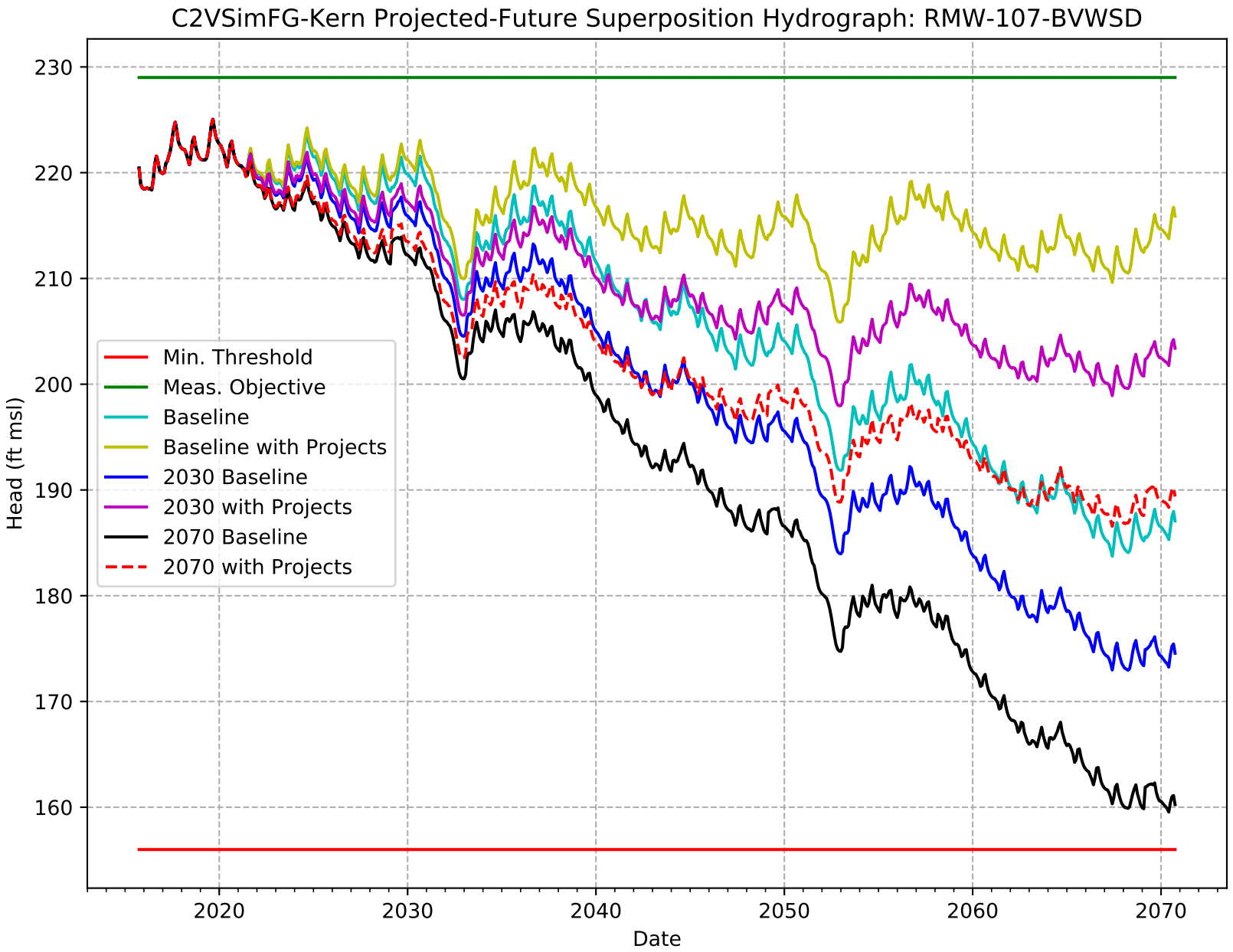

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-097-WRWSD
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

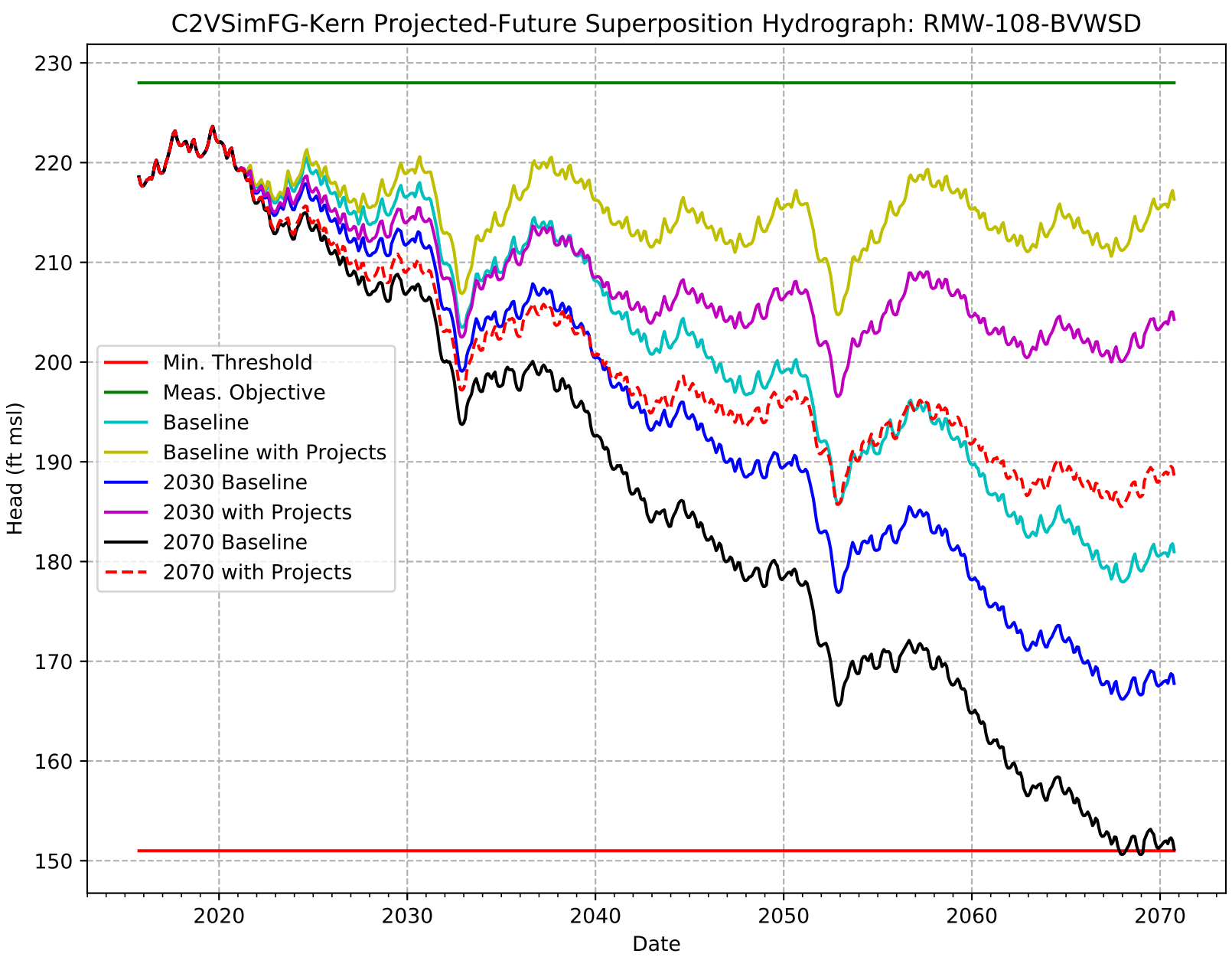

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-101-WRWSD
Head (ft msl)
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

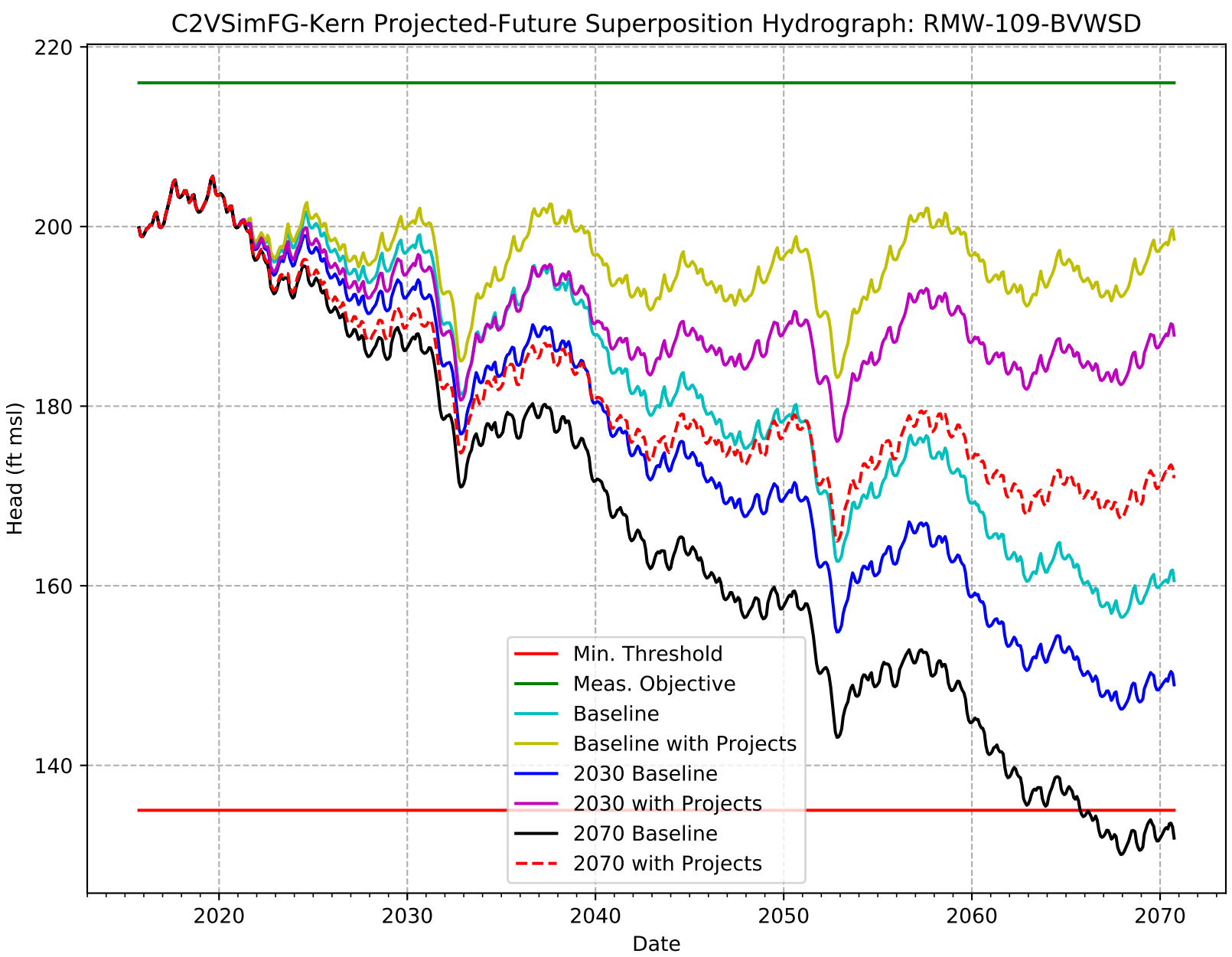

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-103-WRWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

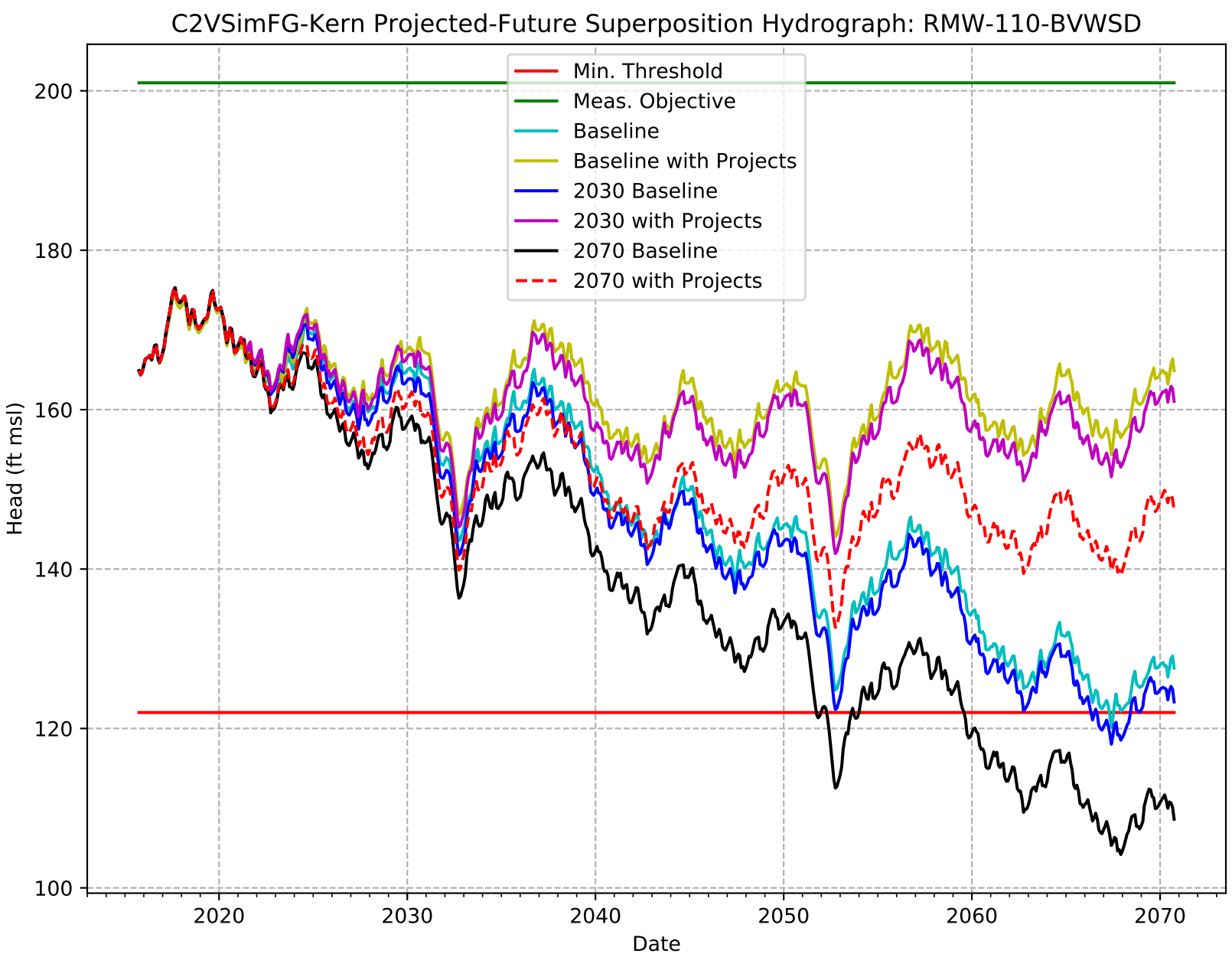

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-105-BVWSD
Head (ft msl)
210
200
190
180
170
160
150
140
130
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

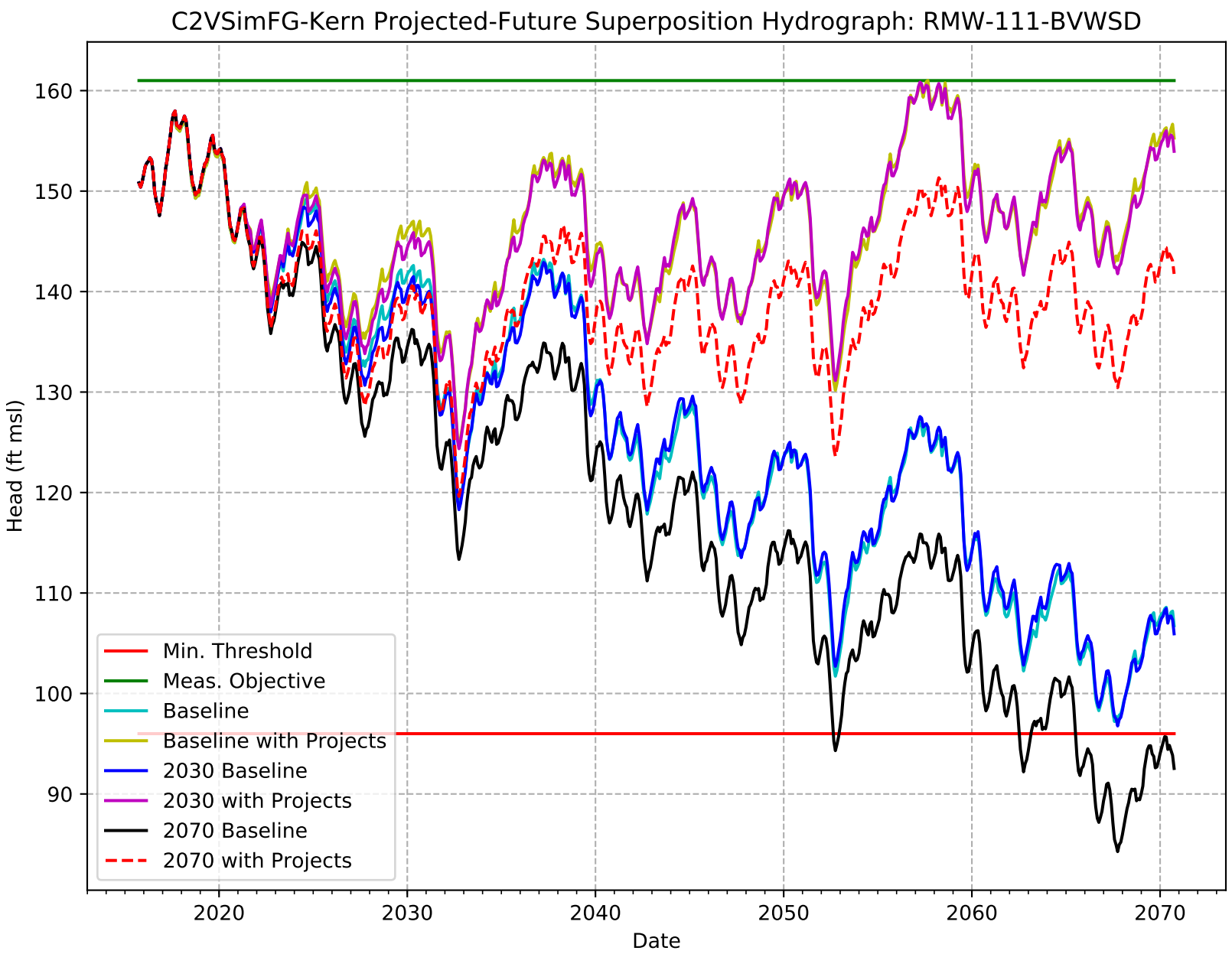

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-106-BVWSD
Head (ft msl)
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

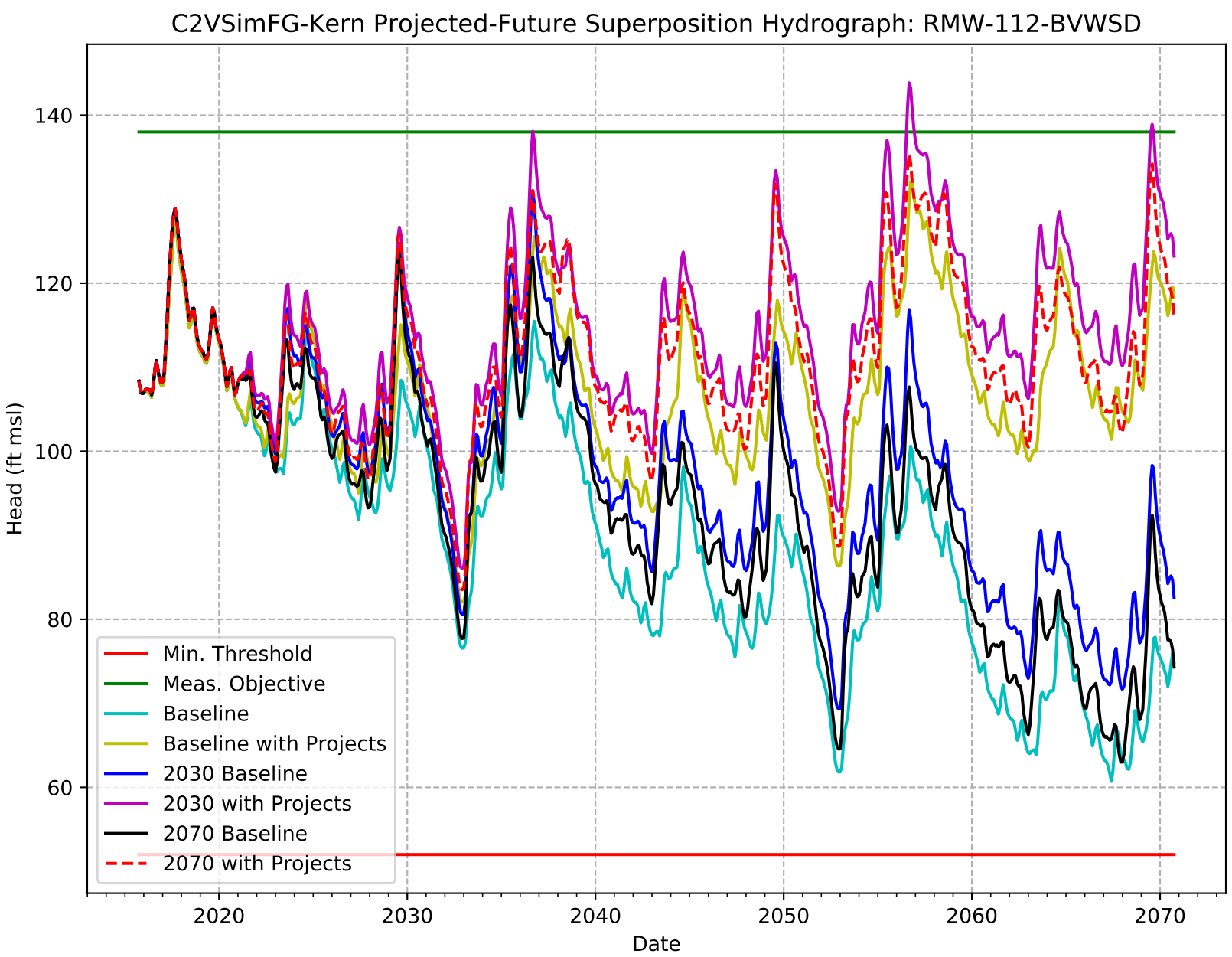

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-107-BVWSD
Head (ft msl)
Date
230
220
210
200
190
180
170
160
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

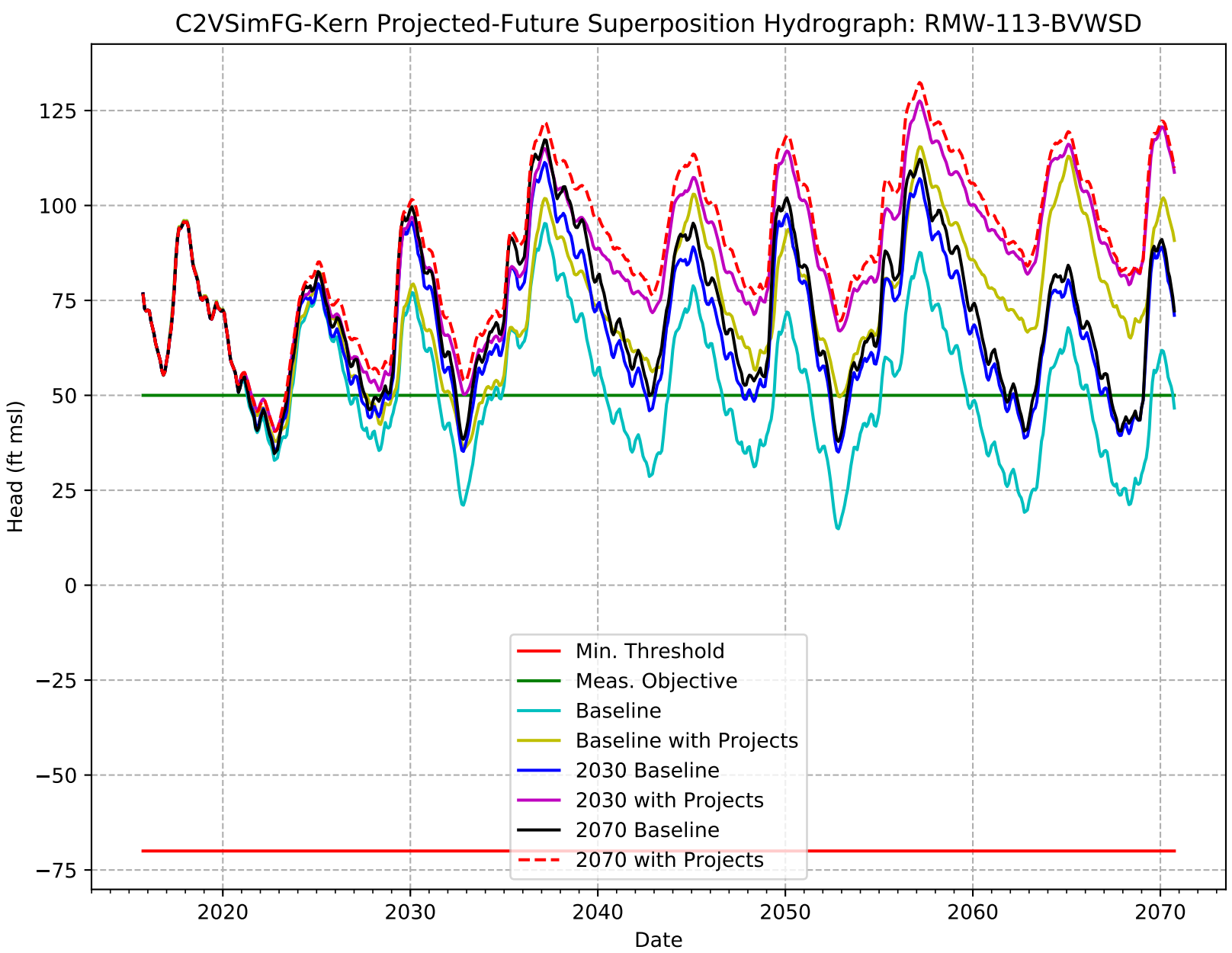

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-108-BVWSD
Head (ft msl)
Date
230
220
210
200
190
180
170
160
150
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

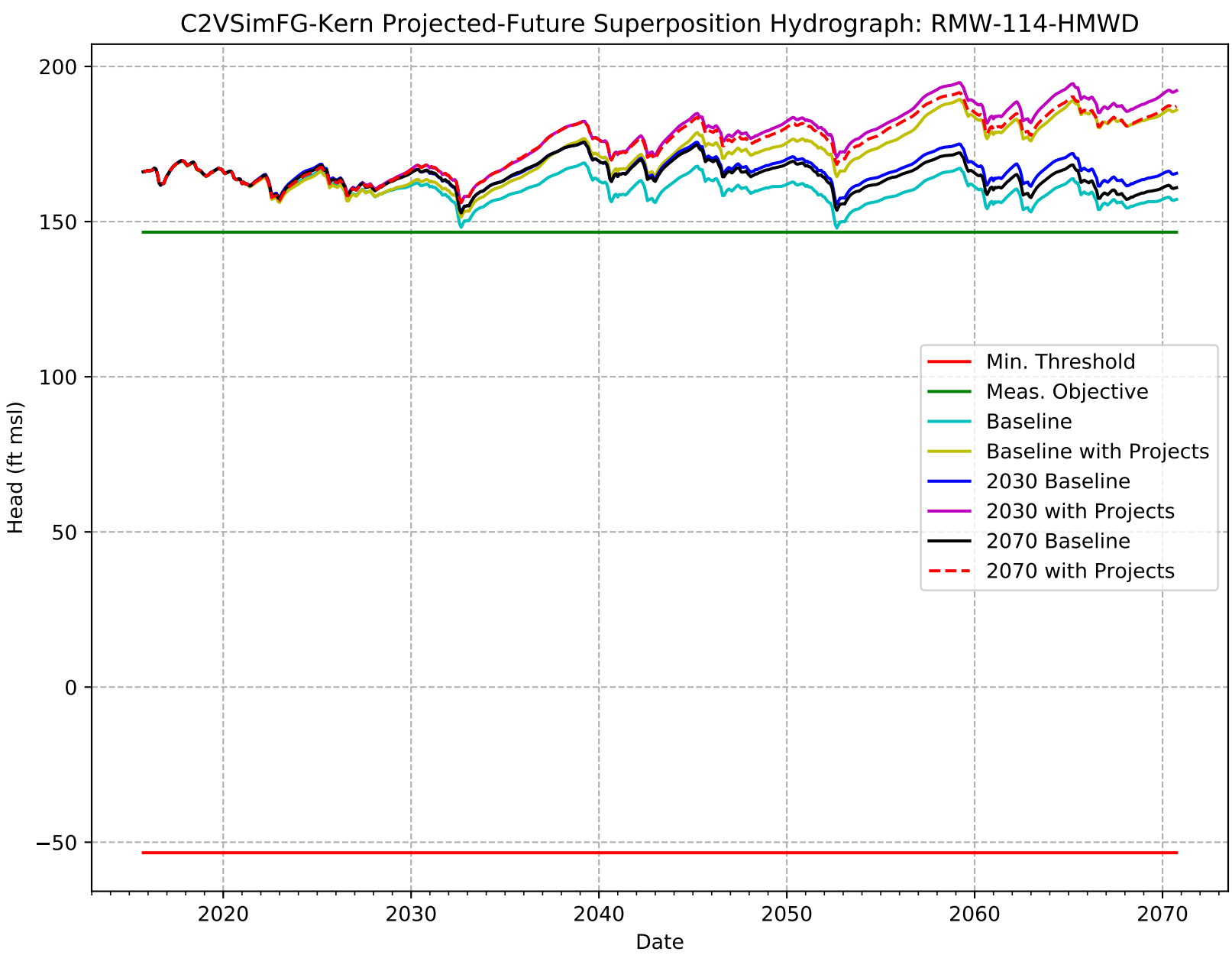

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-109-BVWSD
Head (ft msl)
220
200
180
160
140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

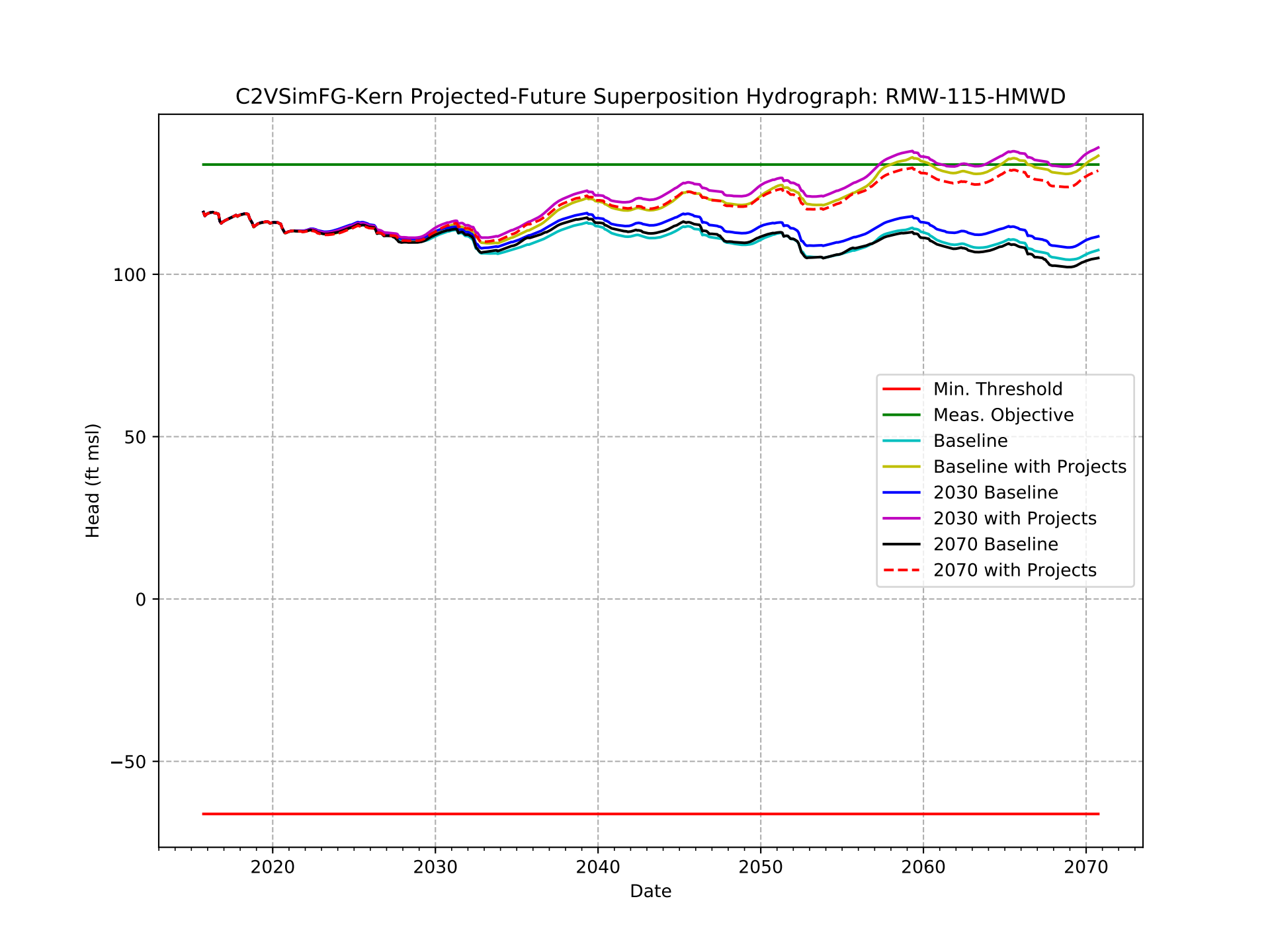

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-110-BVWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
Date
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070

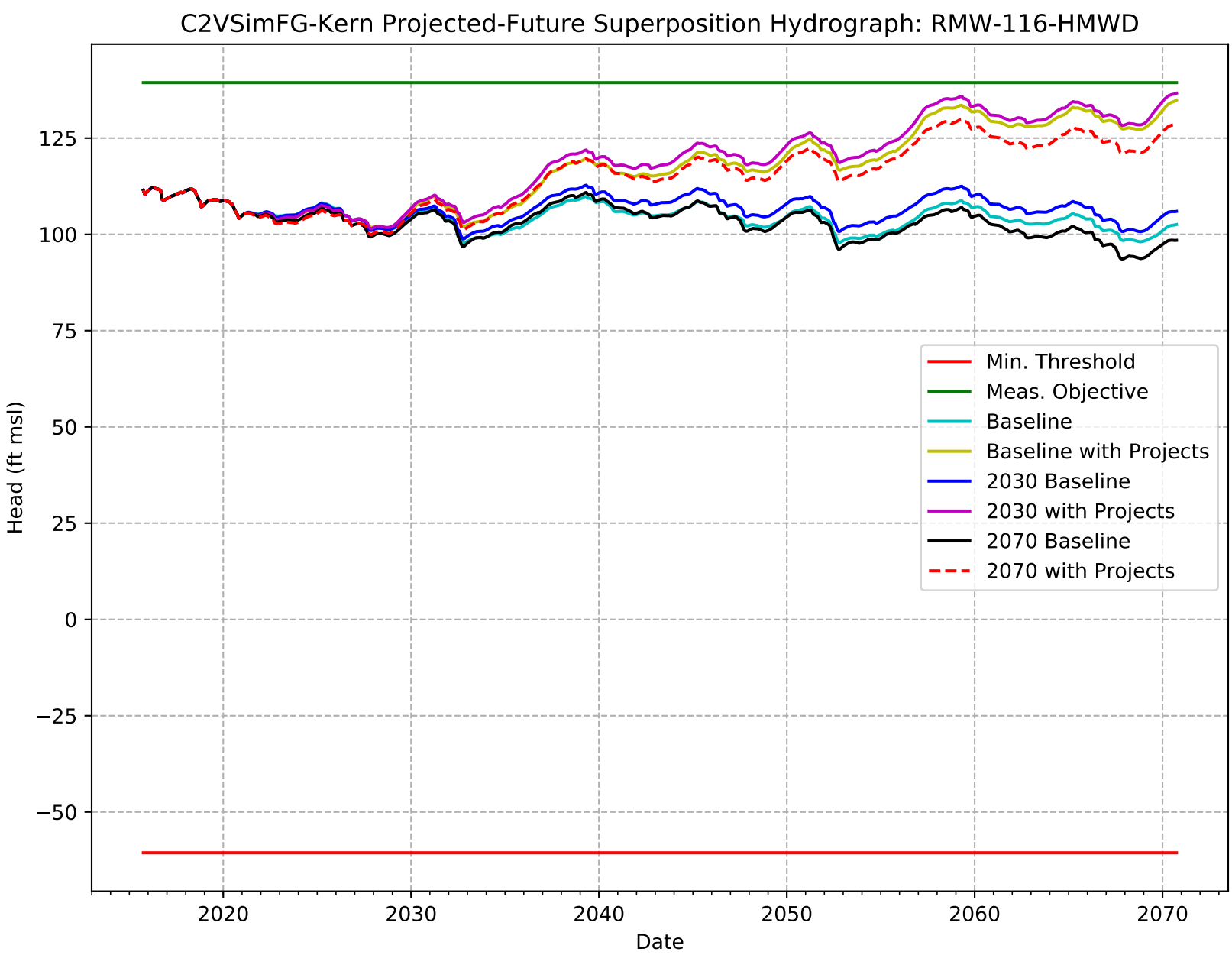

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-111-BVWSD
Head (ft msl)
160
150
140
130
120
110
100
90
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

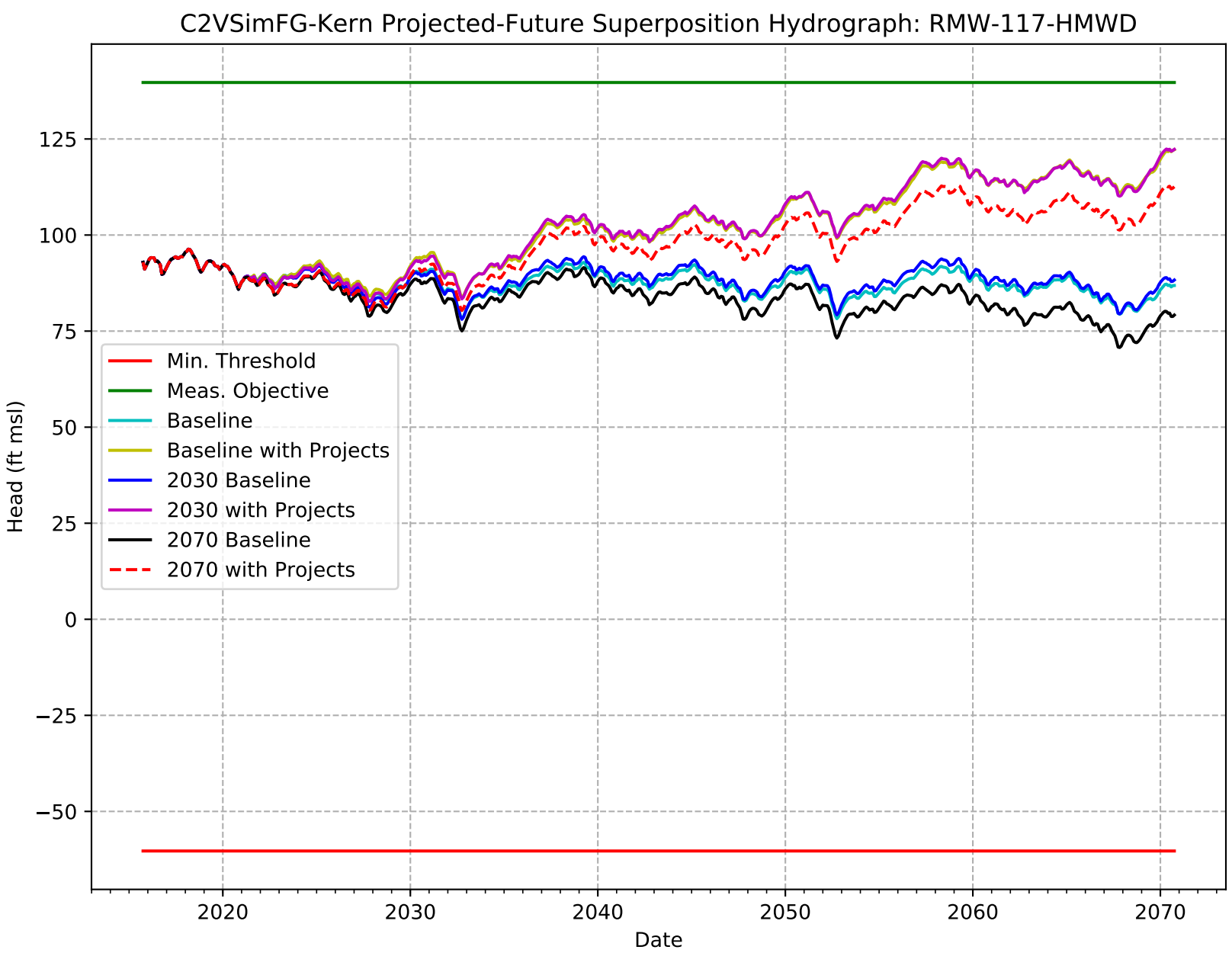

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-112-BVWSD
Head (ft msl)
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

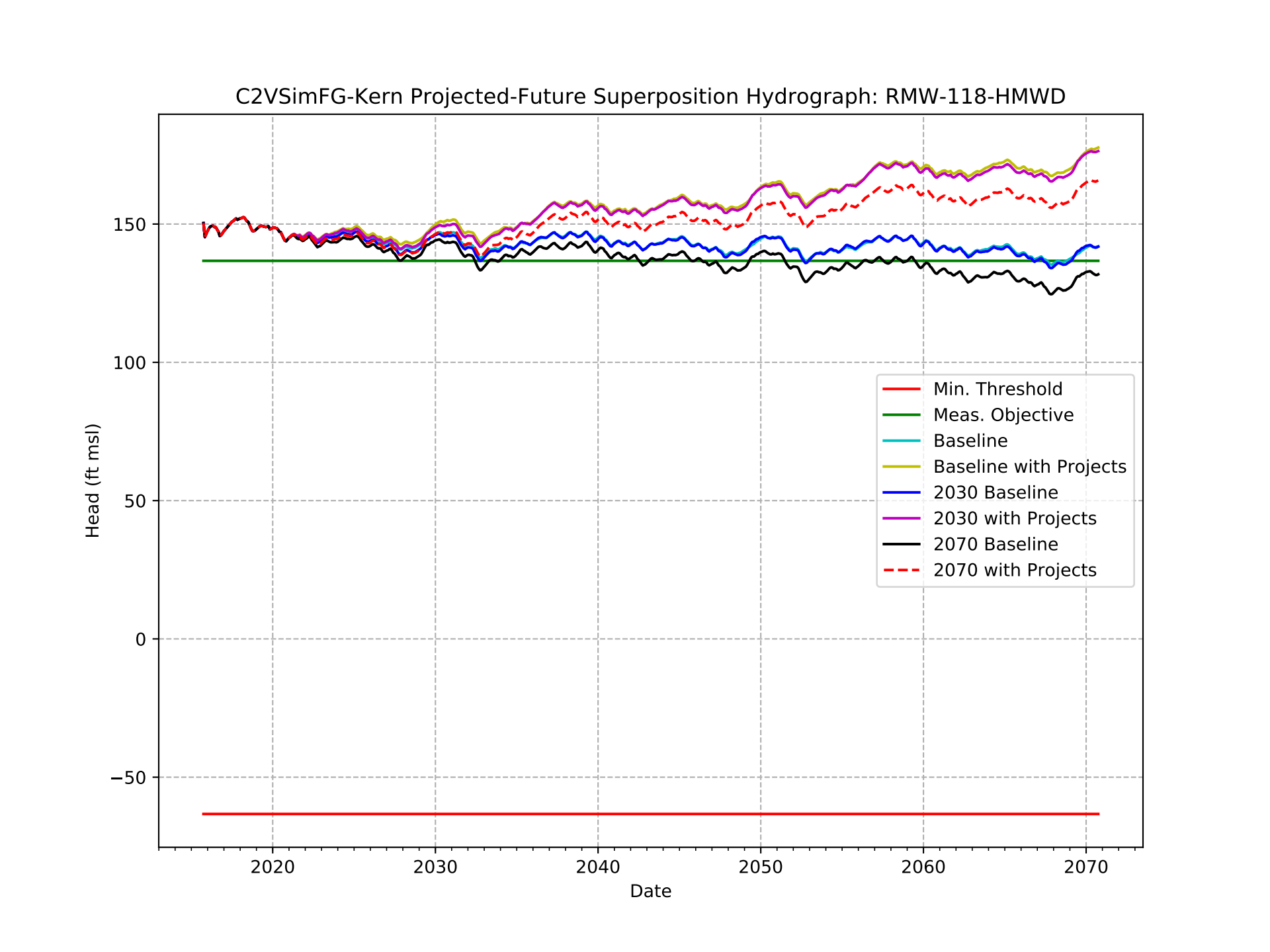

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-113-BVWSD
Head (ft msl)
125
100
75
50
25
0
−25
−50
−75
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

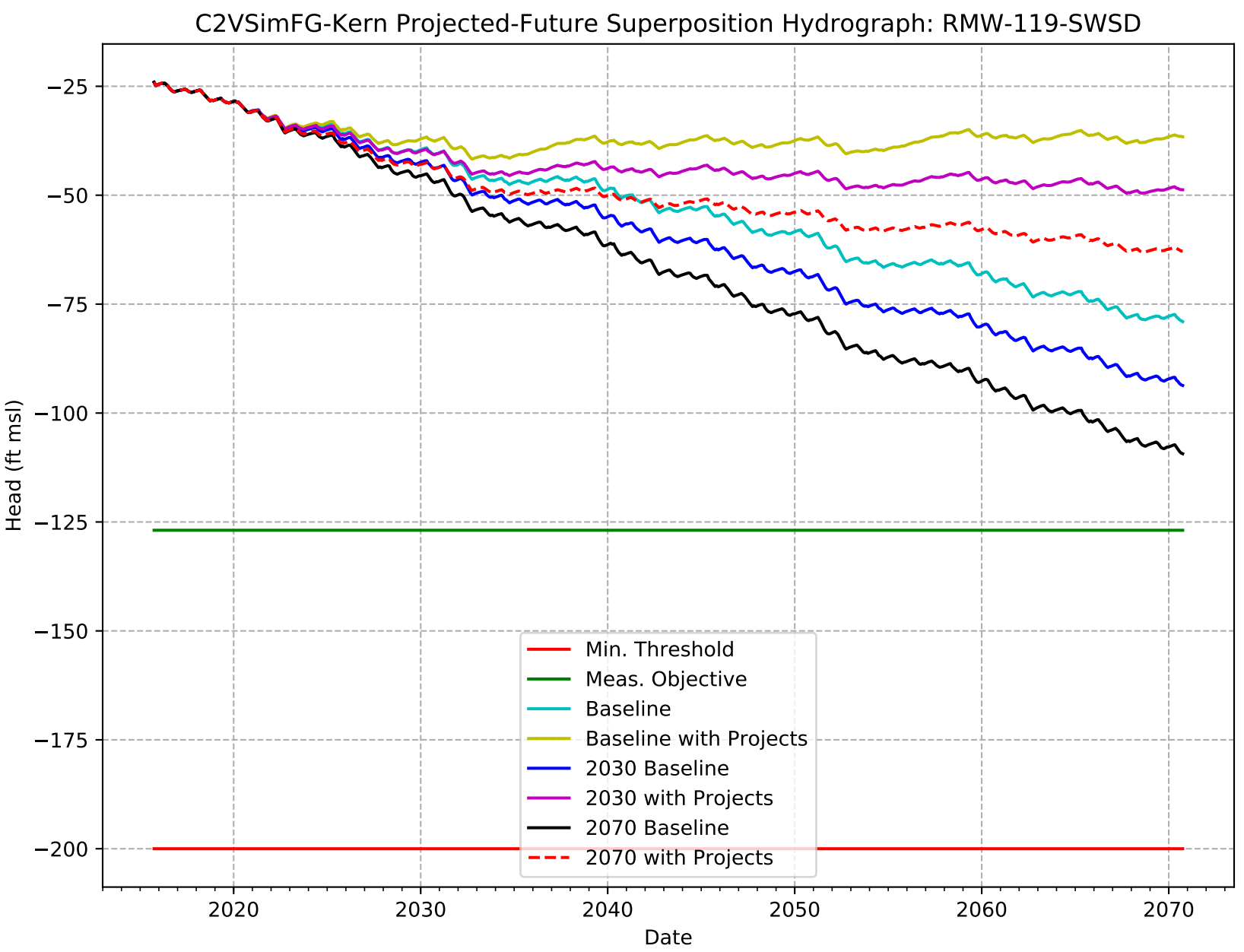

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-114-HMWD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

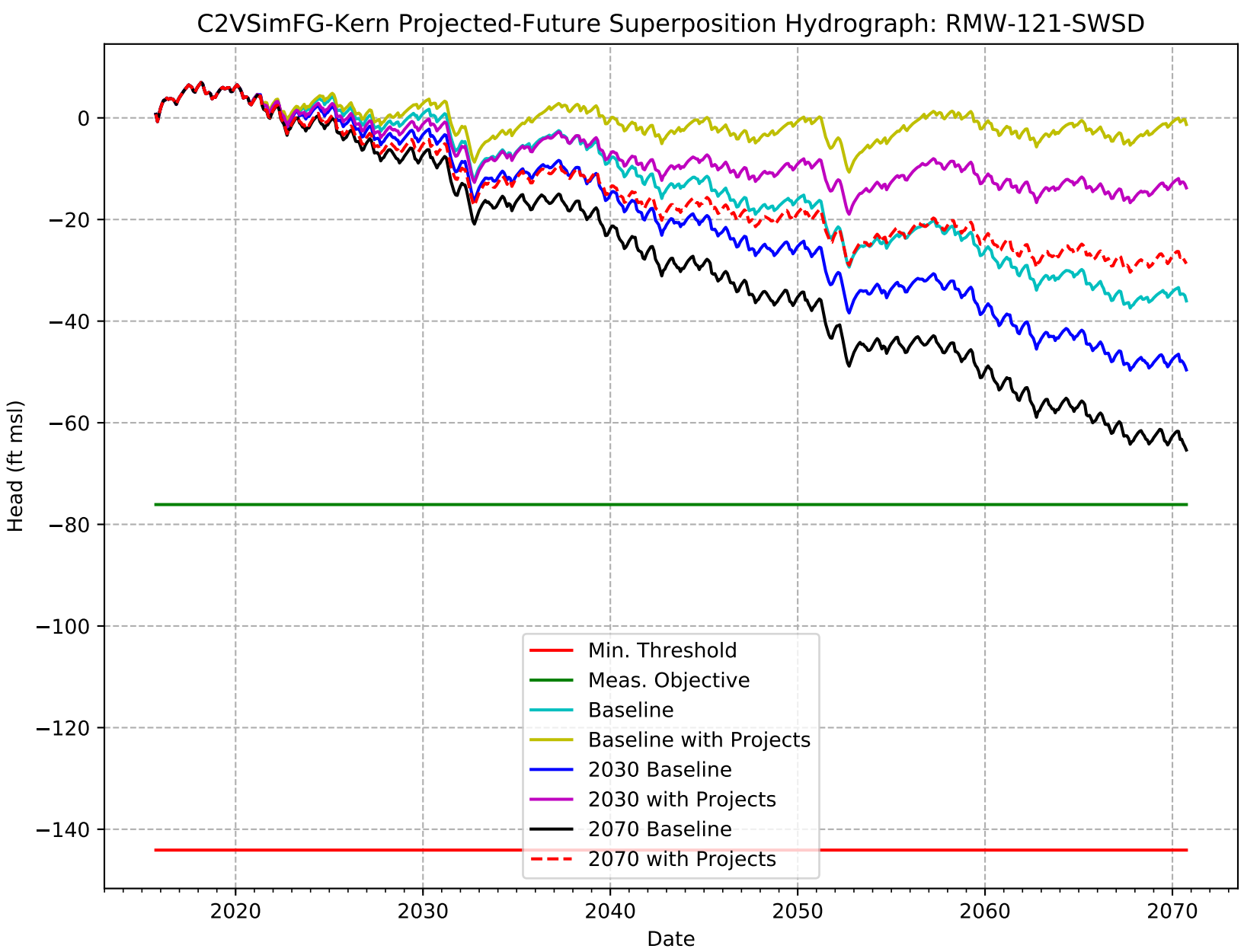

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-115-HMWD
Head (ft msl)
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

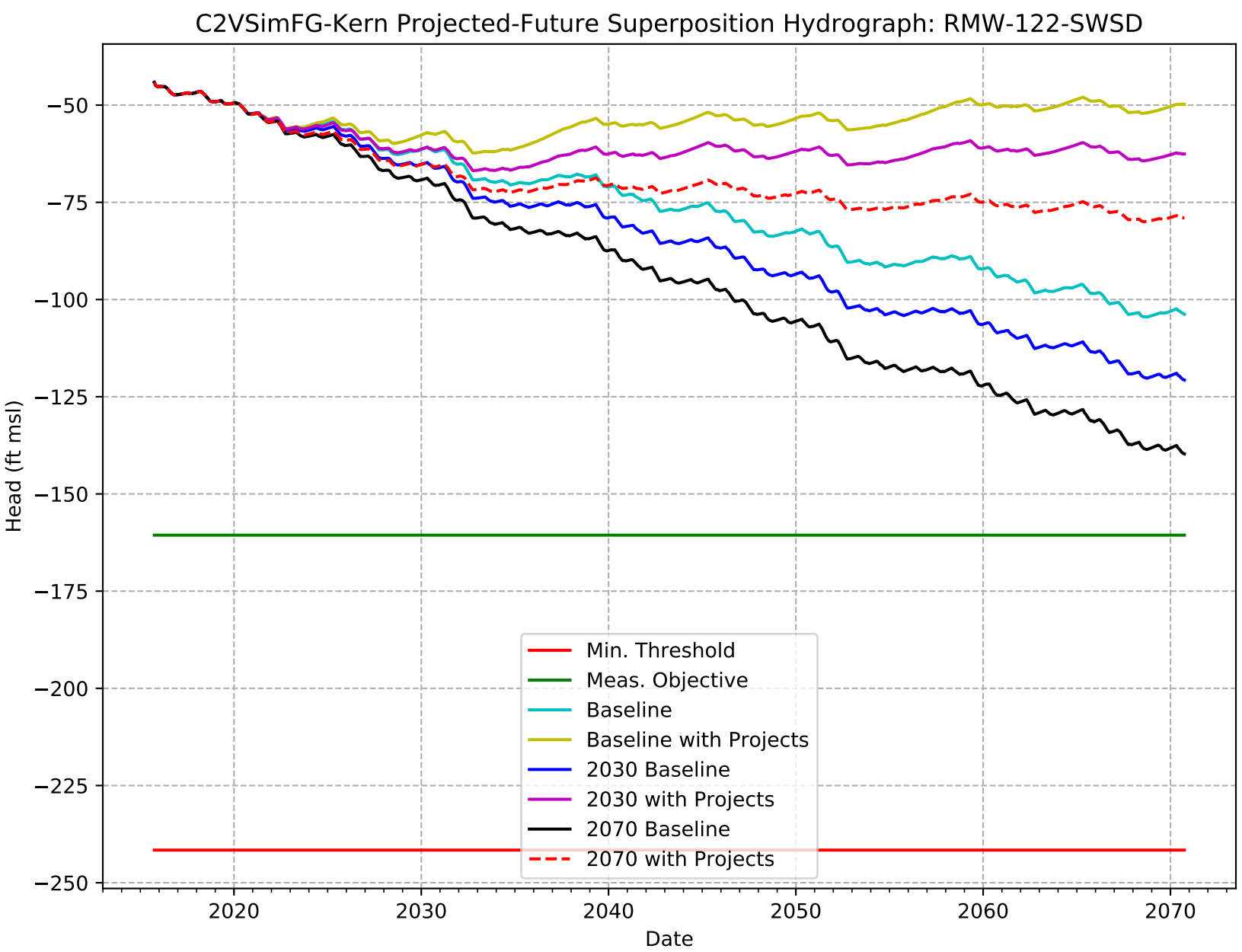

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-116-HMWD
Head (ft msl)
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

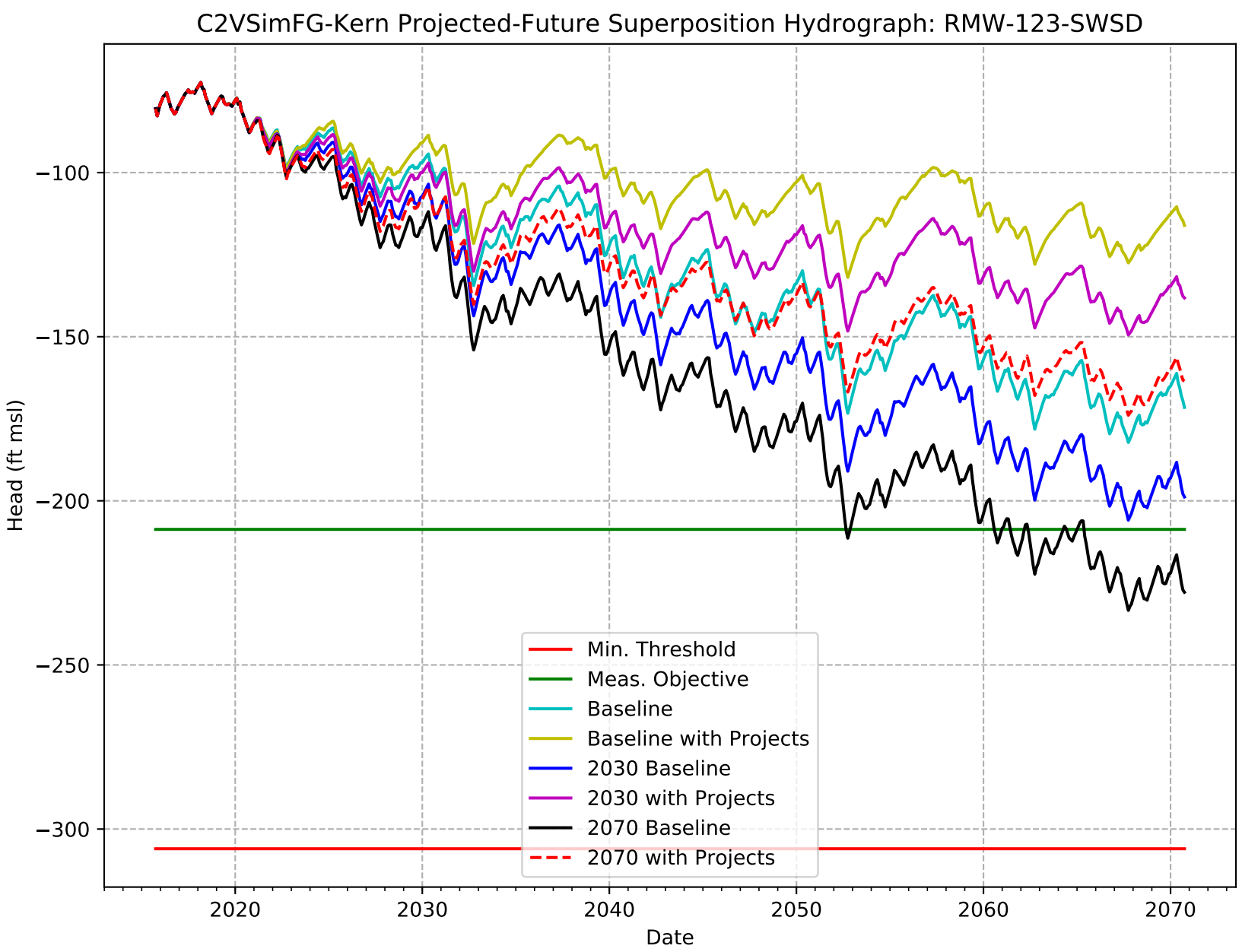

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-117-HMWD
Head (ft msl)
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

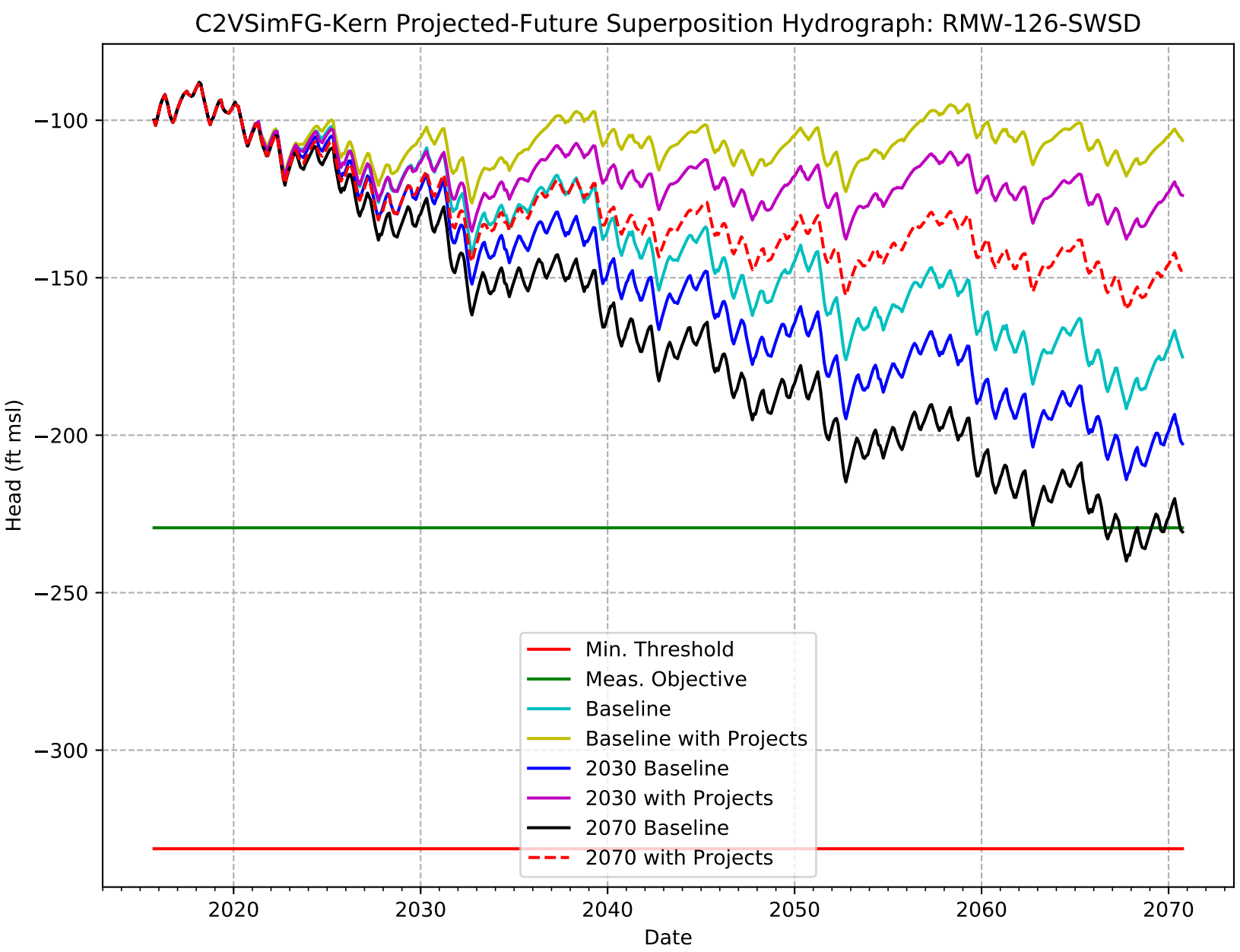

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-118-HMWD
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

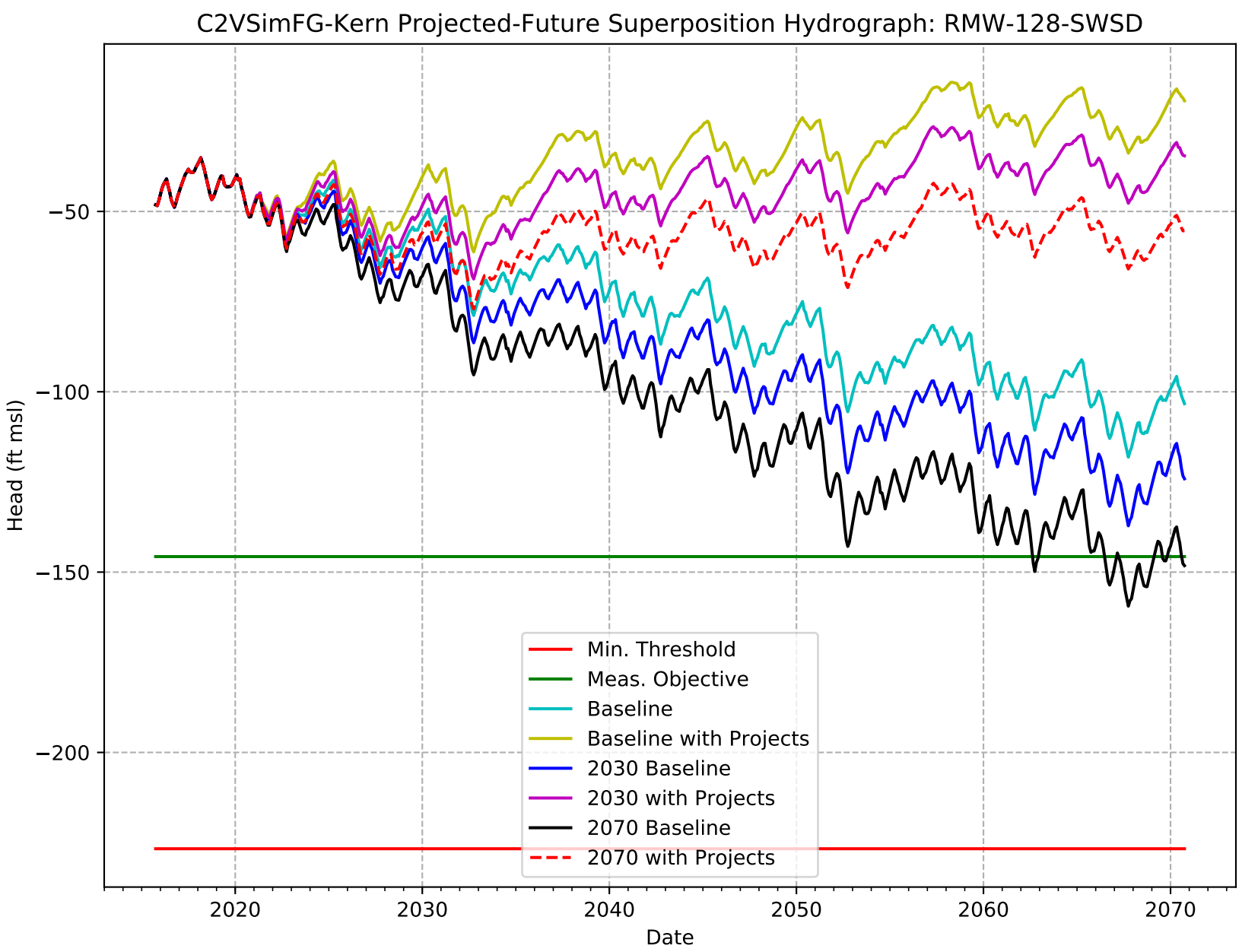

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-119-SWSD
Head (ft msl)
−25
−50
−75
−100
−125
−150
−175
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

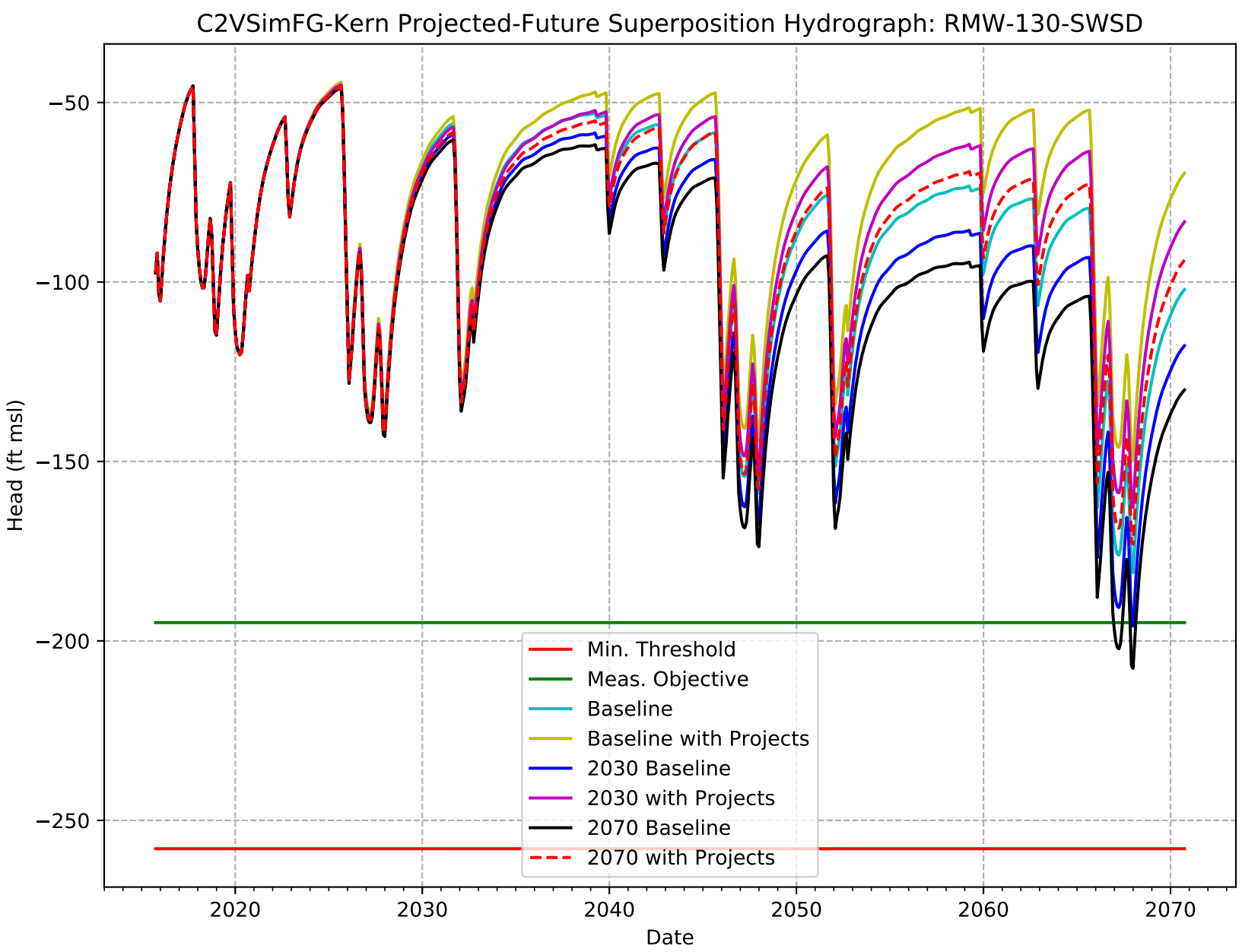

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-121-SWSD
Head (ft msl)
0
−20
−40
−60
−80
−100
−120
−140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

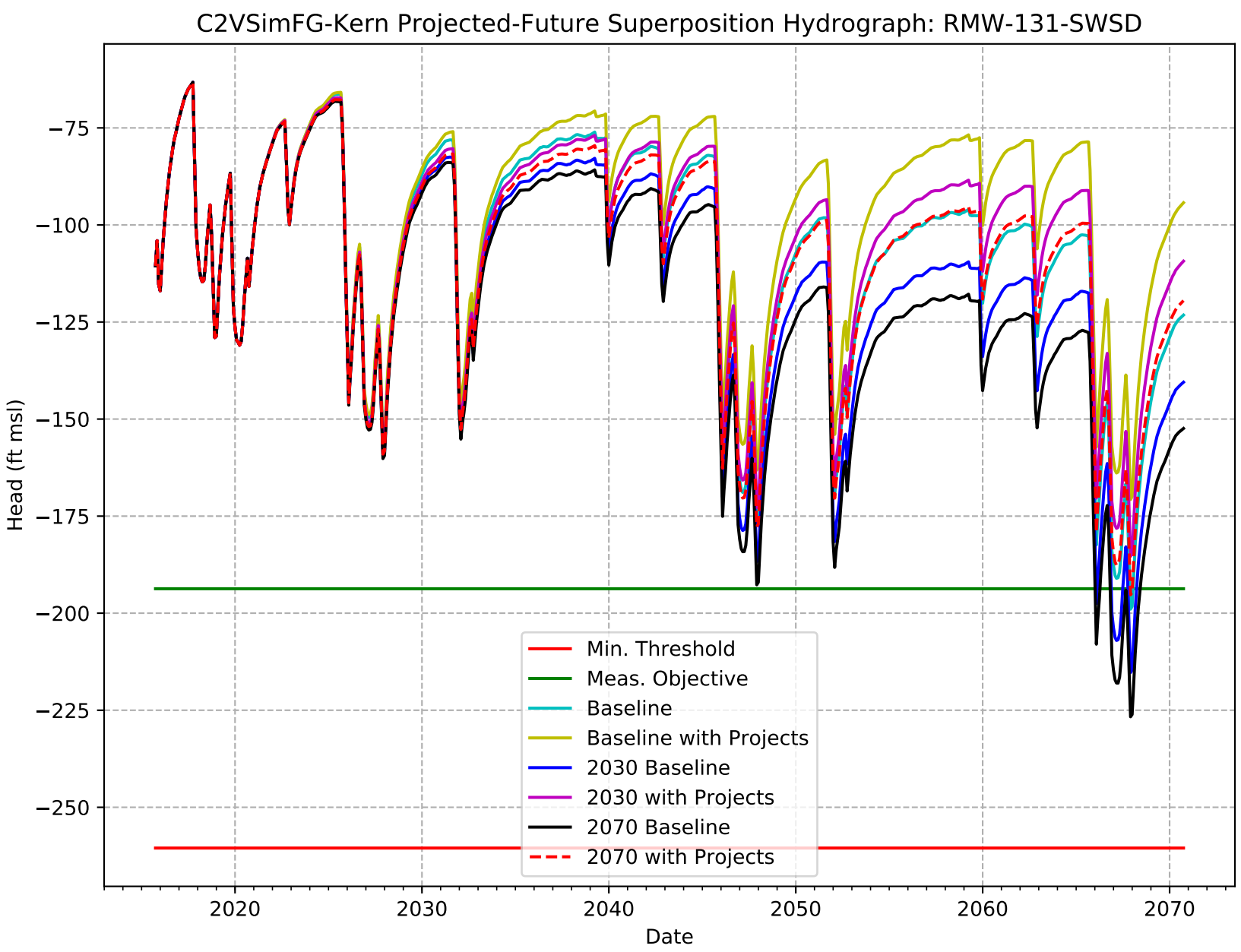

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-122-SWSD
Head (ft msl)
−50
−75
−100
−125
−150
−175
−200
−225
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

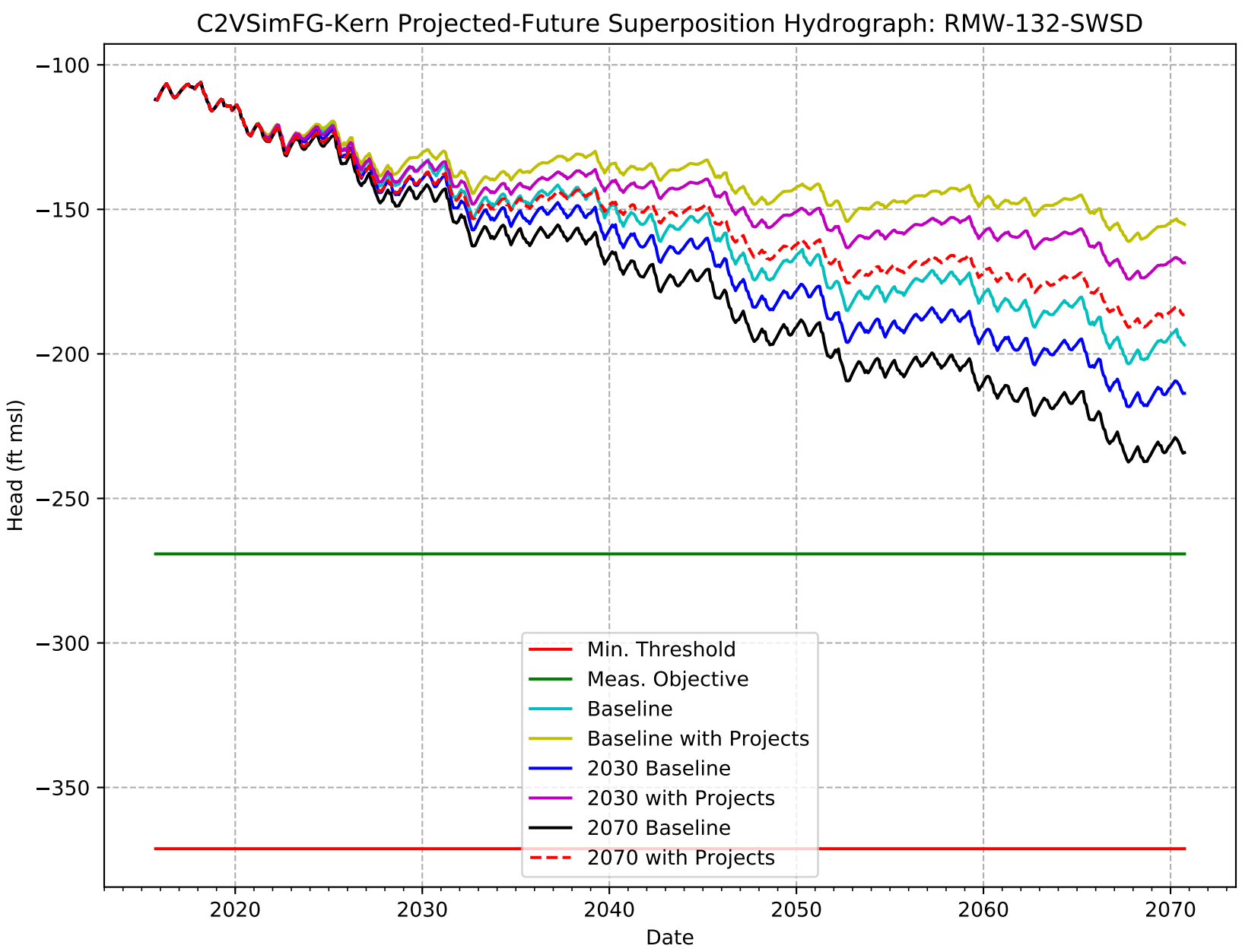

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-123-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

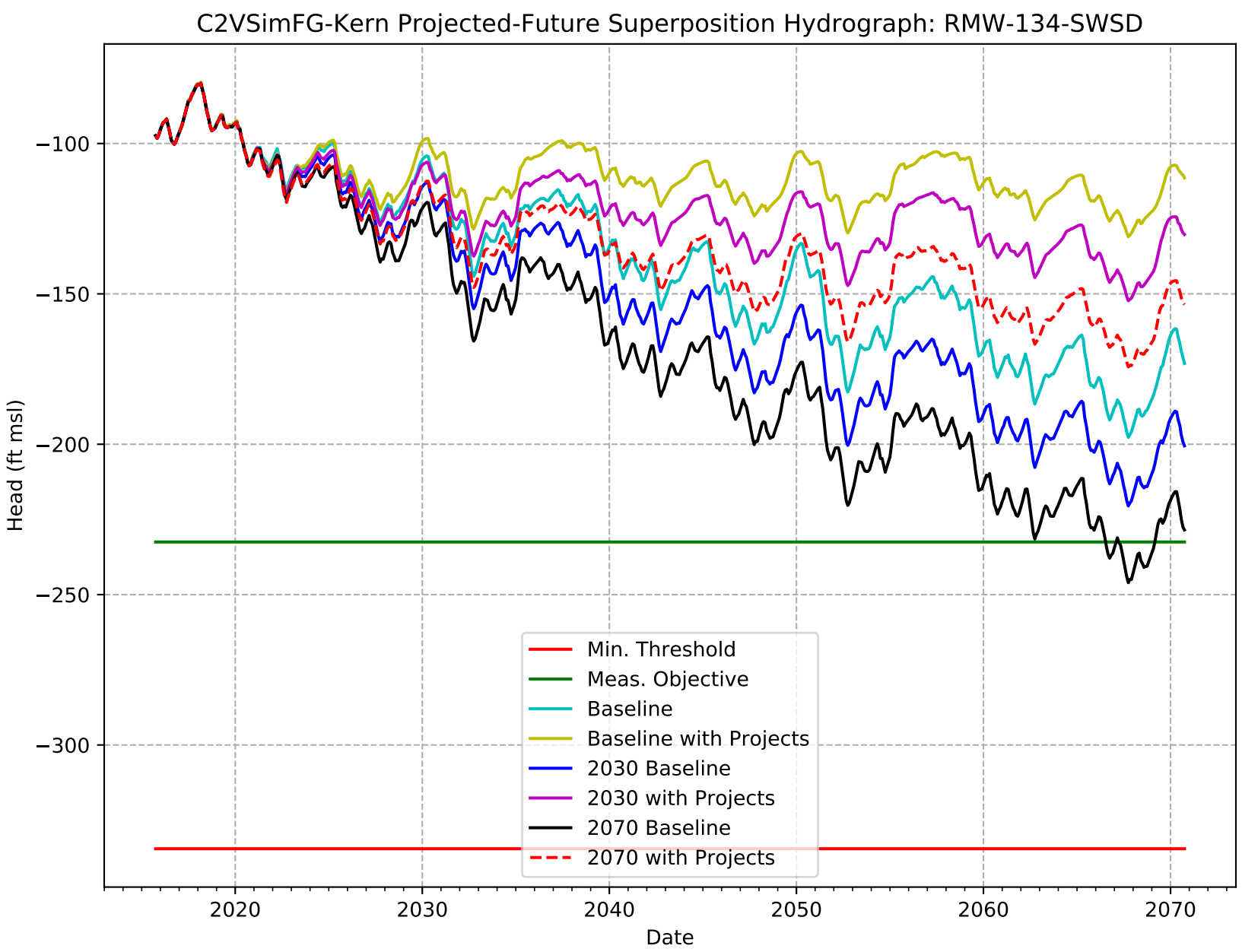

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-126-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

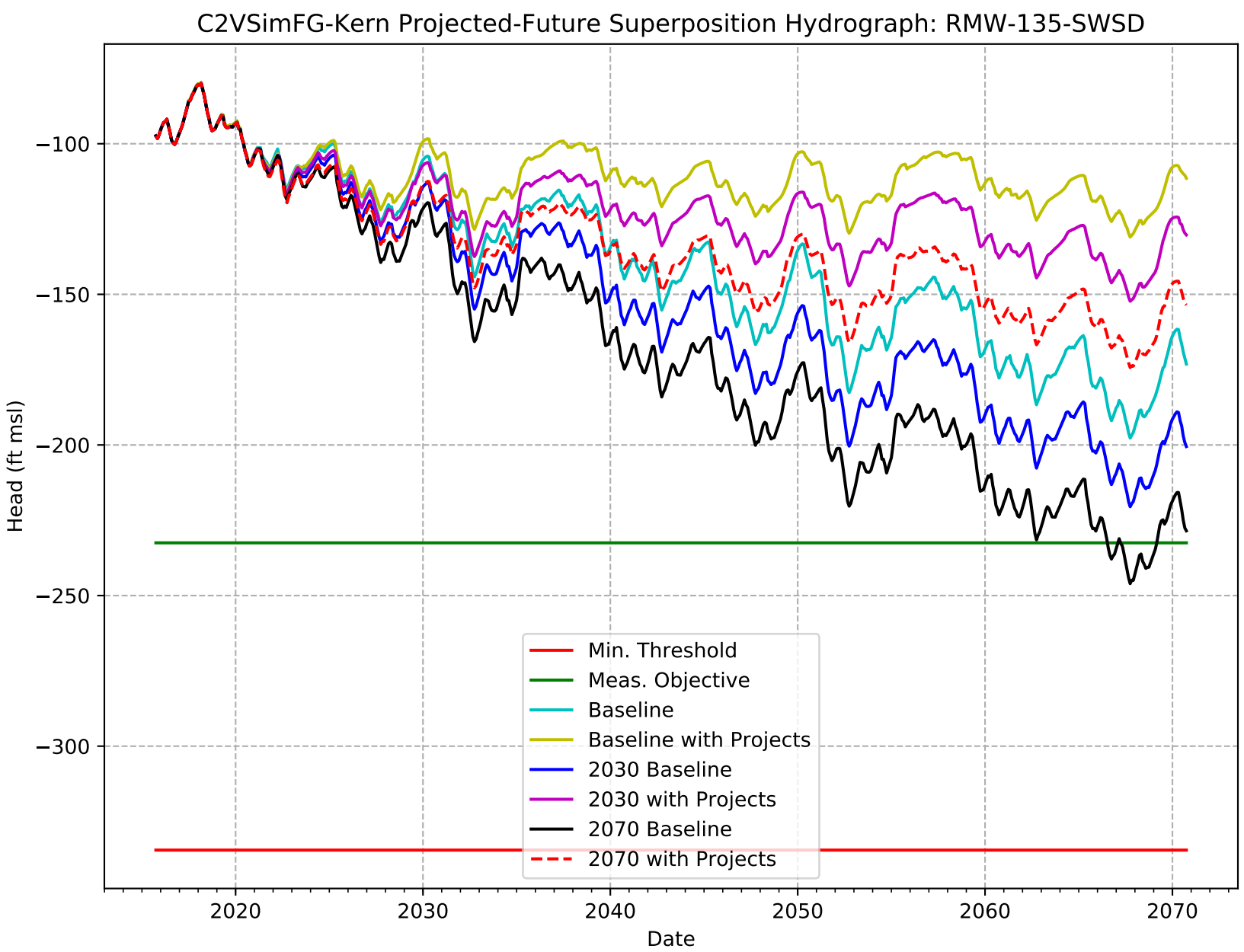

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-128-SWSD
Head (ft msl)
−50
−100
−150
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

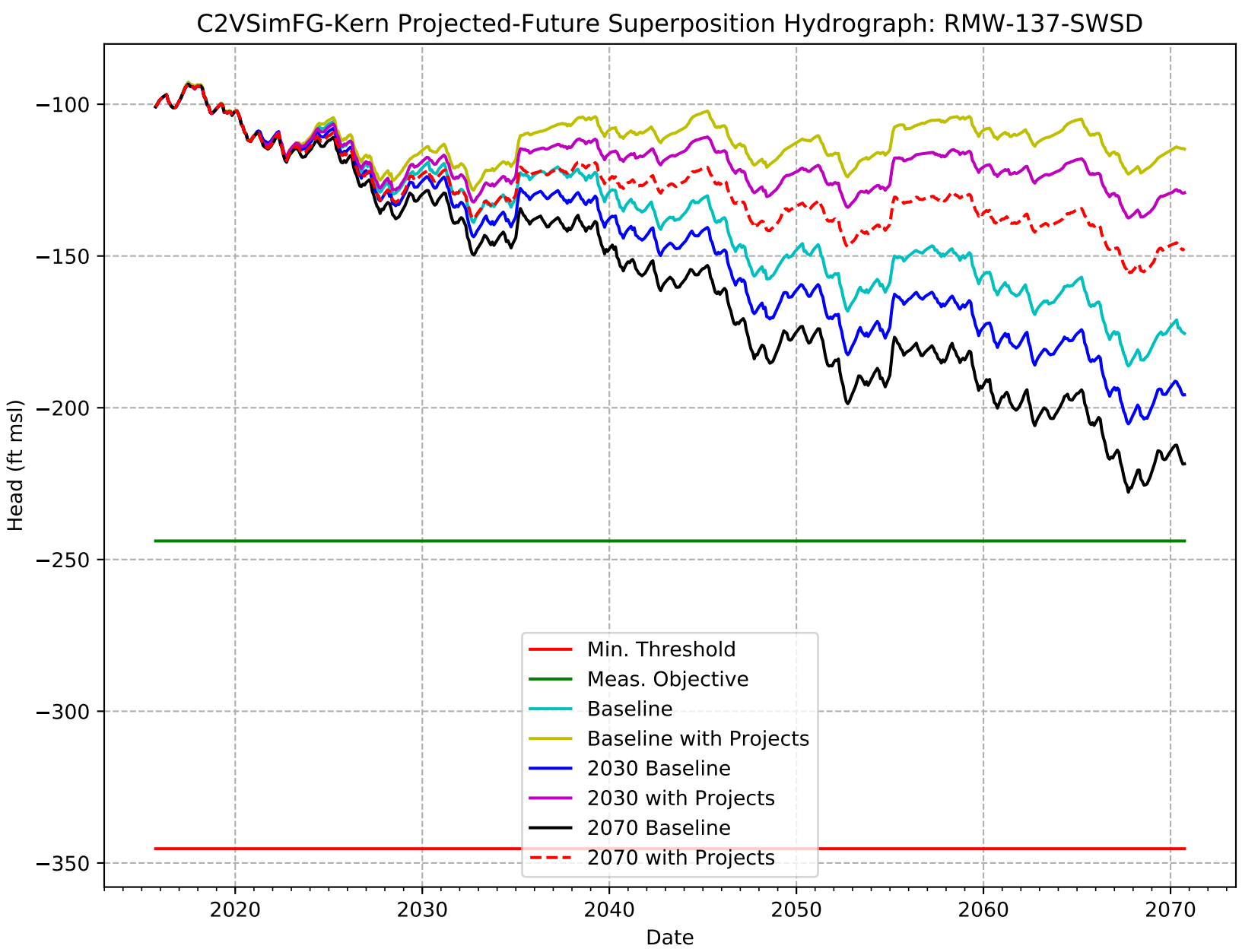

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-130-SWSD
Head (ft msl)
−50
−100
−150
−200
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

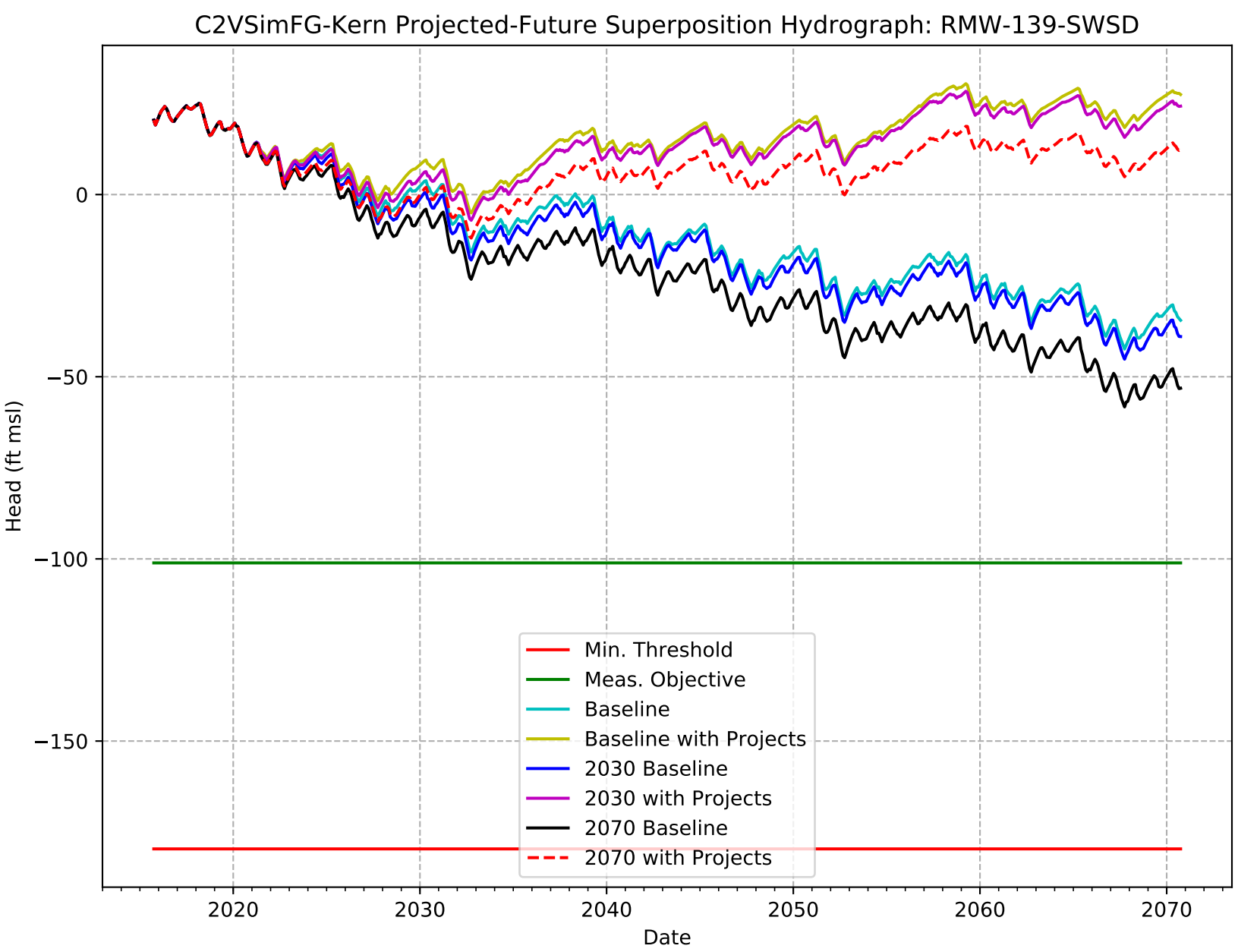

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-131-SWSD
Head (ft msl)
−75
−100
−125
−150
−175
−200
−225
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

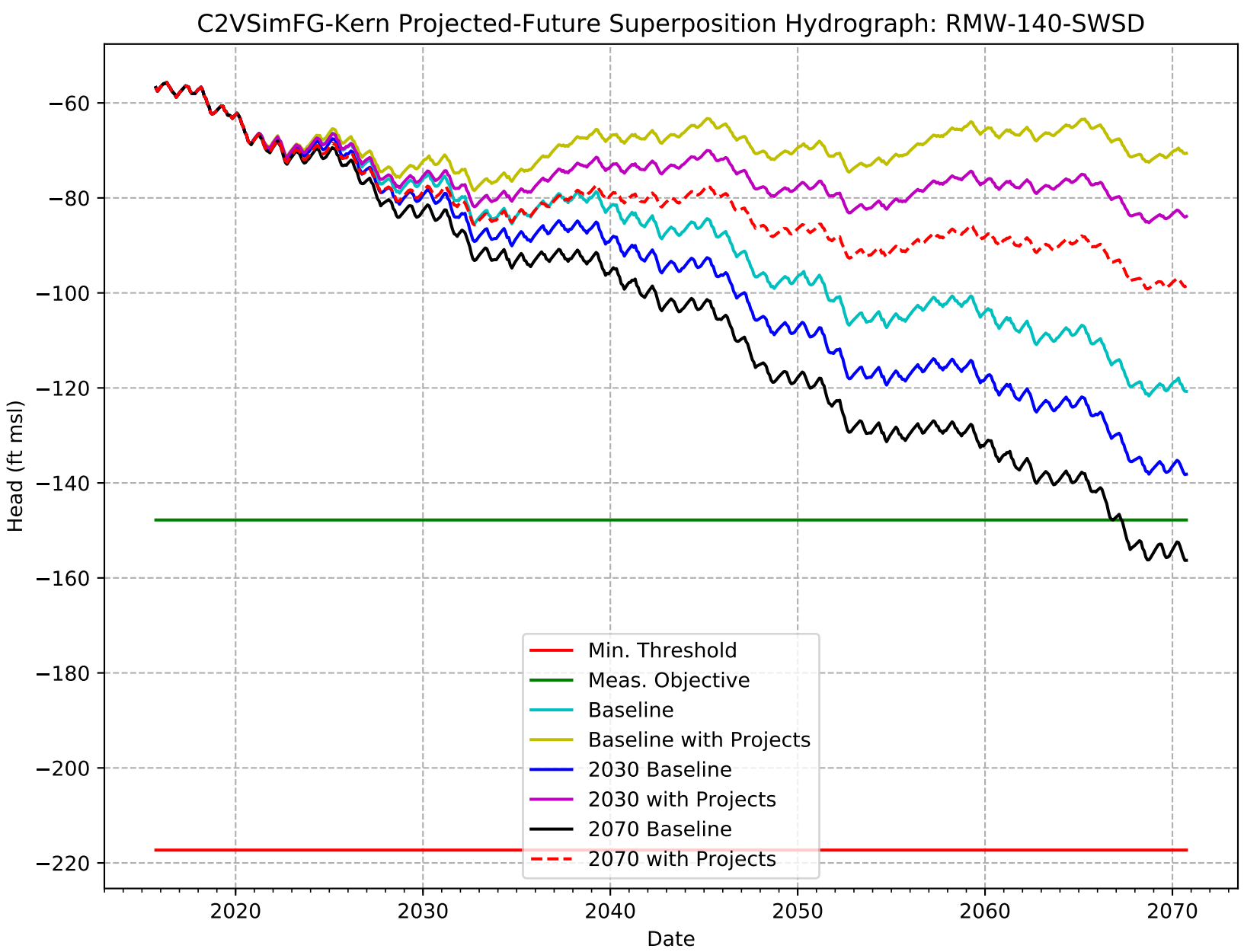

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-132-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
−350
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

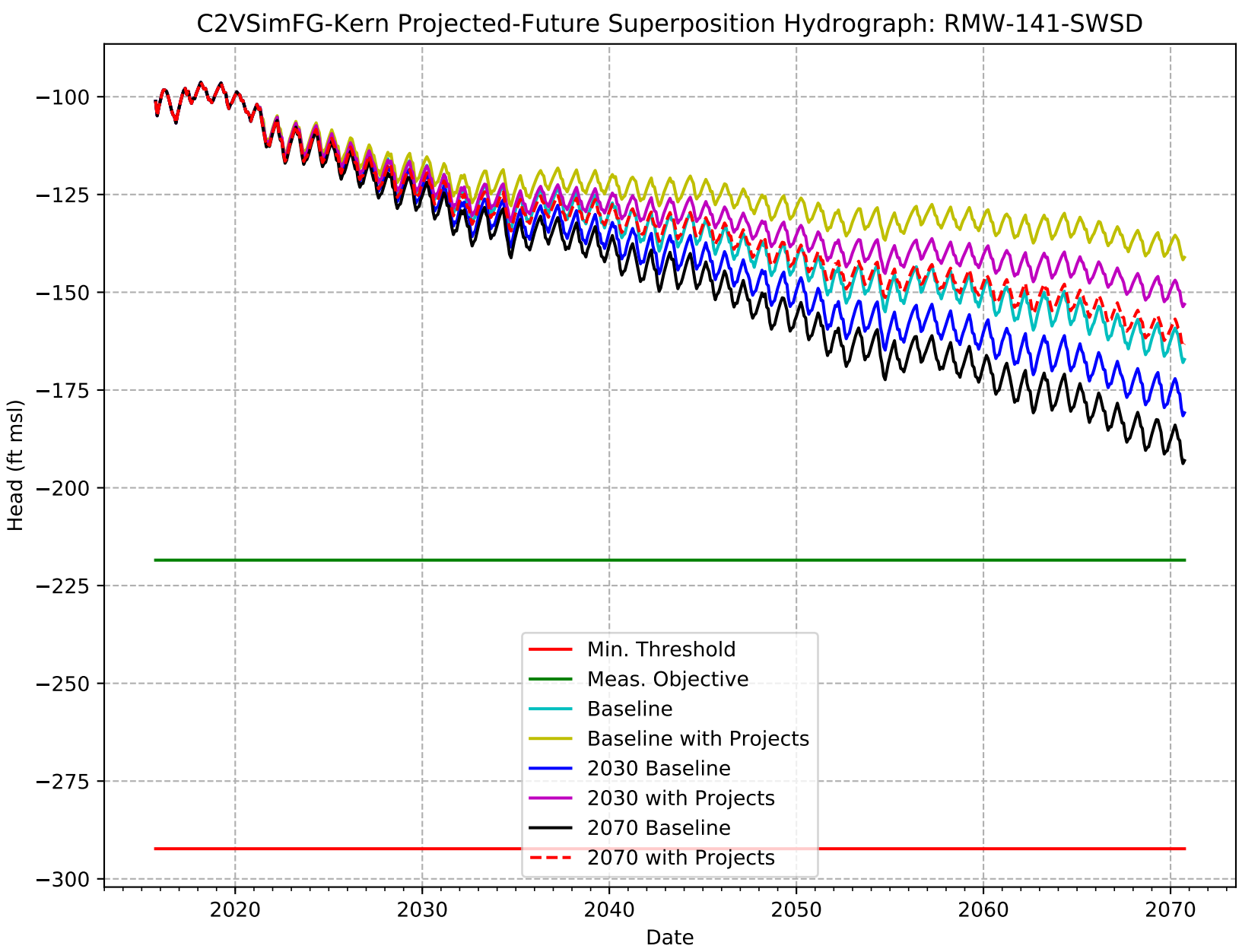

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-134-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

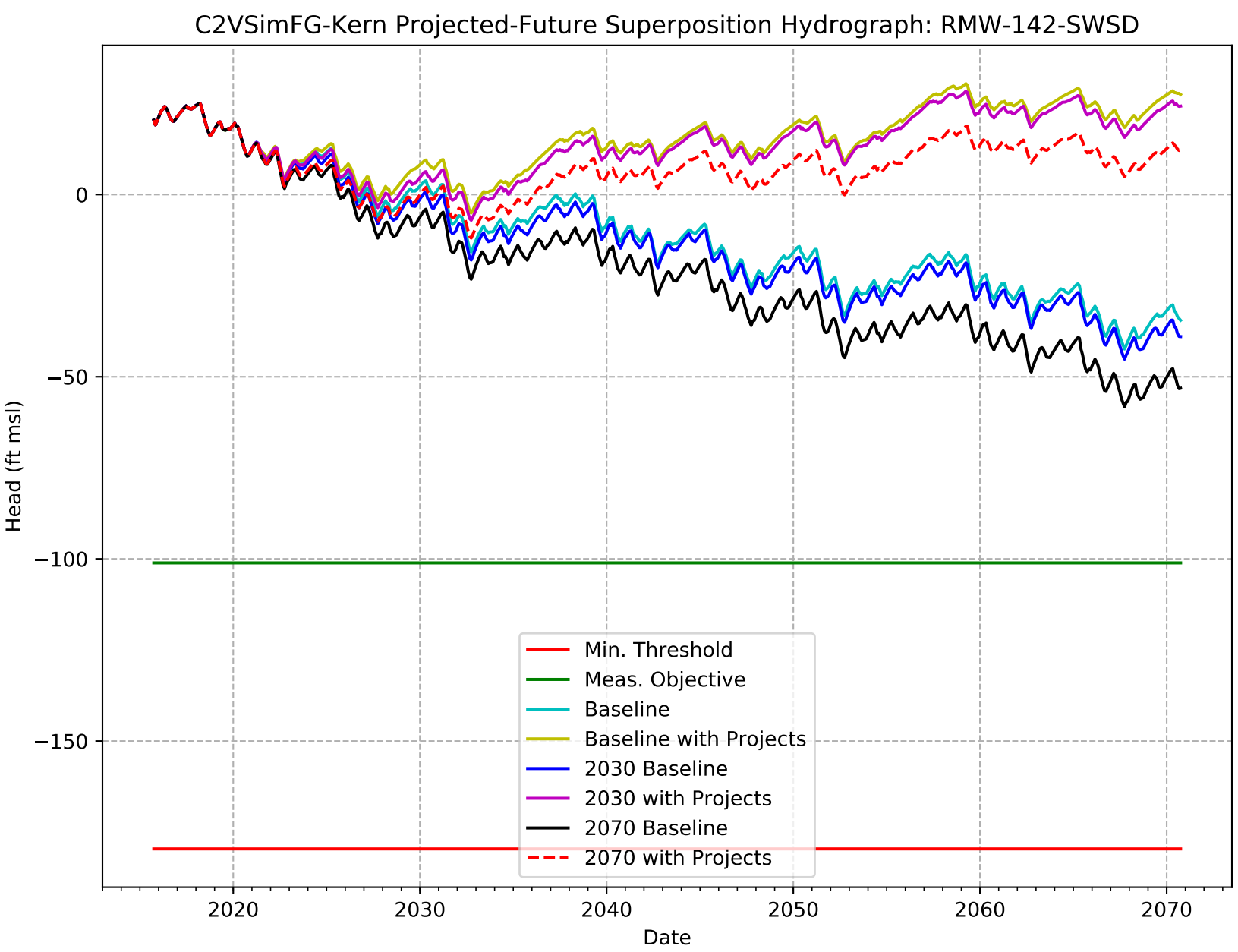

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-135-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

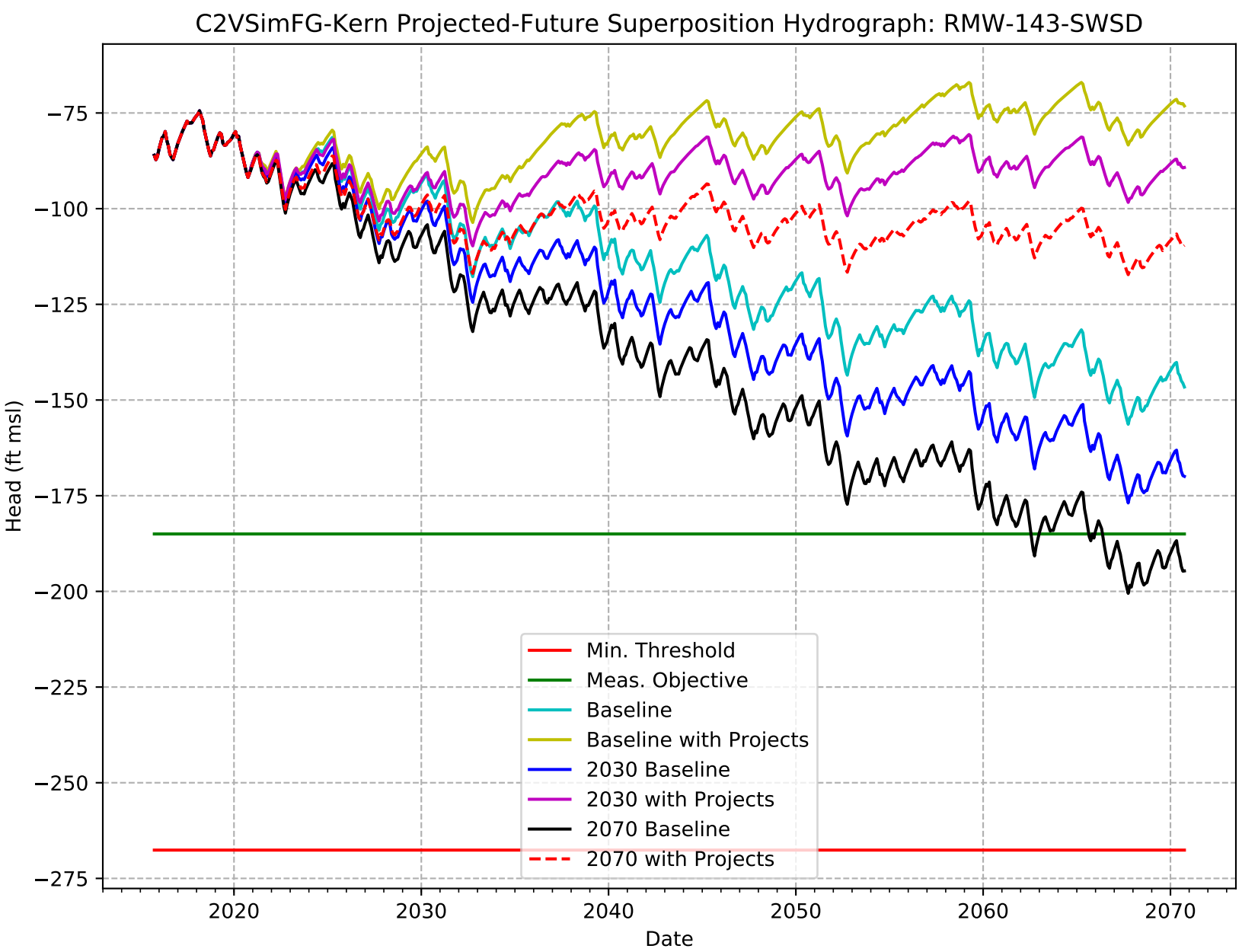

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-137-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
−350
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

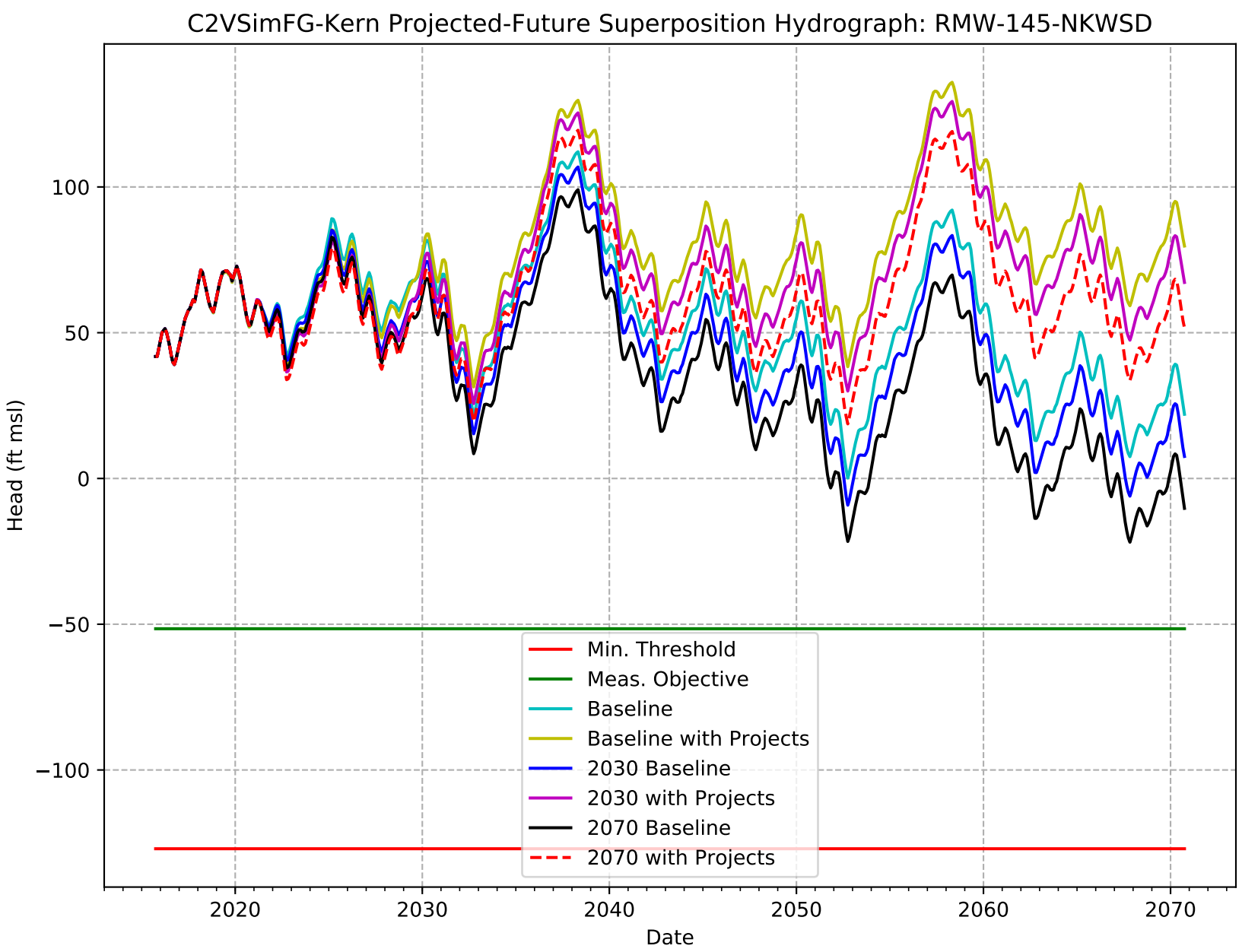

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-139-SWSD
Head (ft msl)
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

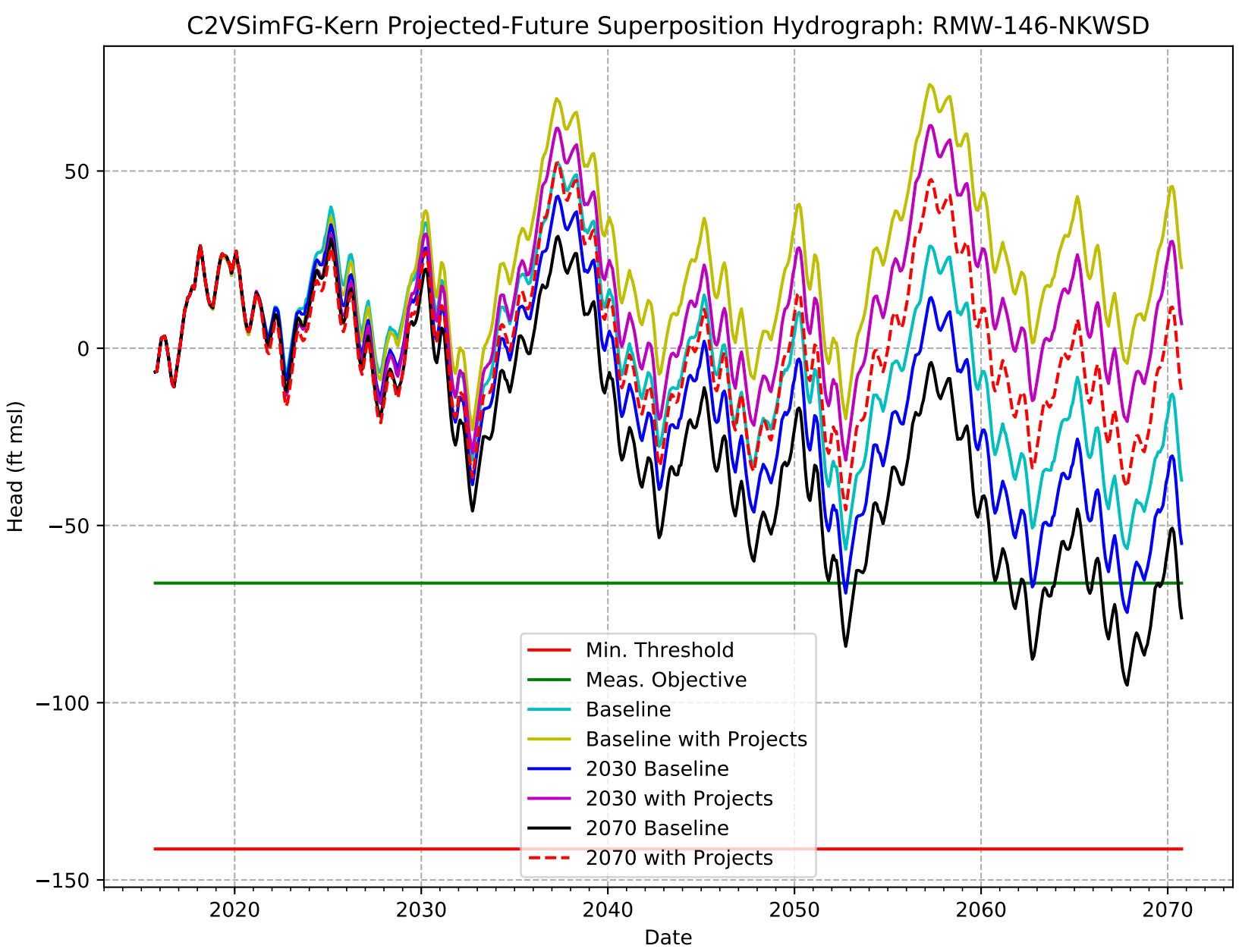

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-140-SWSD
Head (ft msl)
−60
−80
−100
−120
−140
−160
−180
−200
−220
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

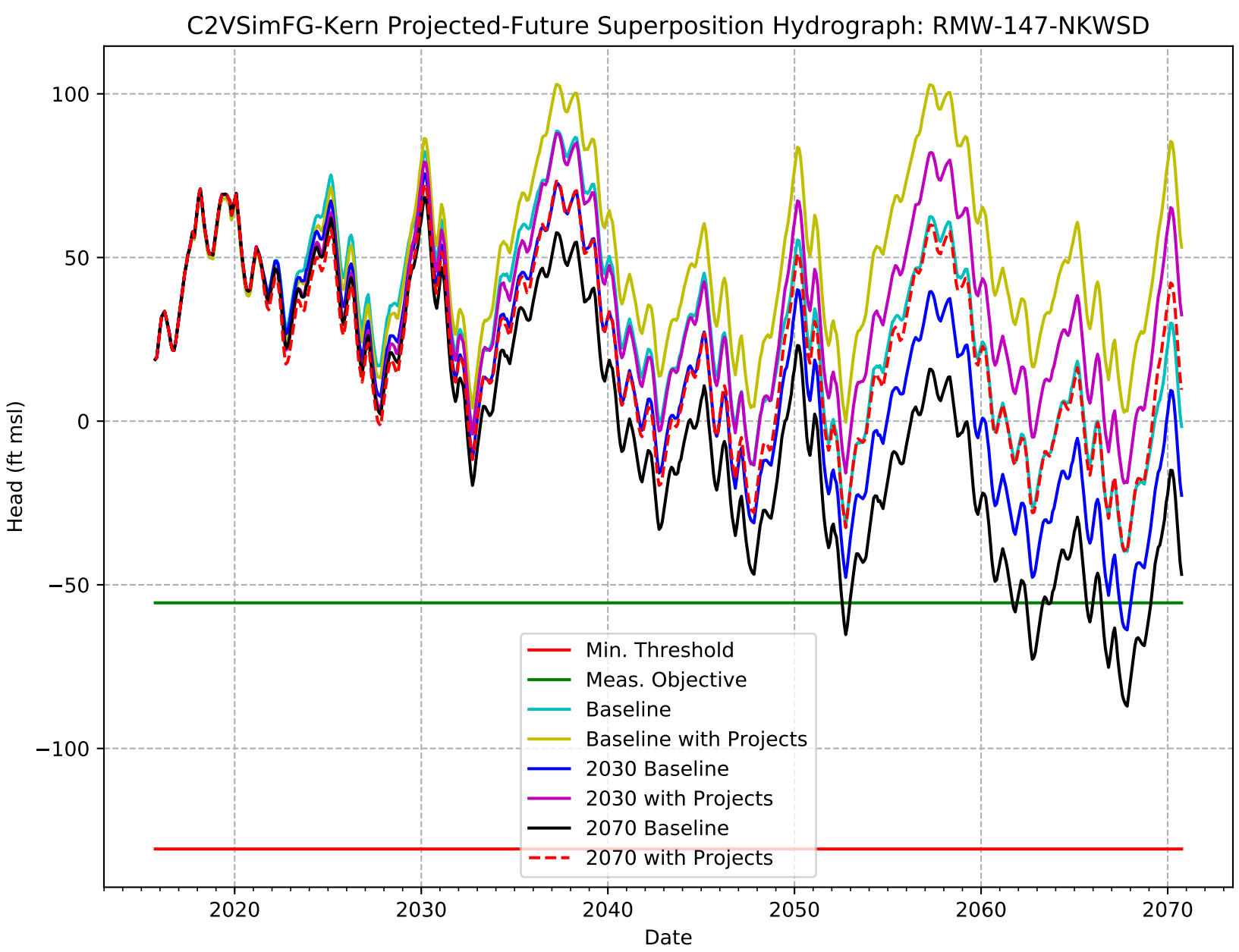

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-141-SWSD
Head (ft msl)
−100
−125
−150
−175
−200
−225
−250
−275
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

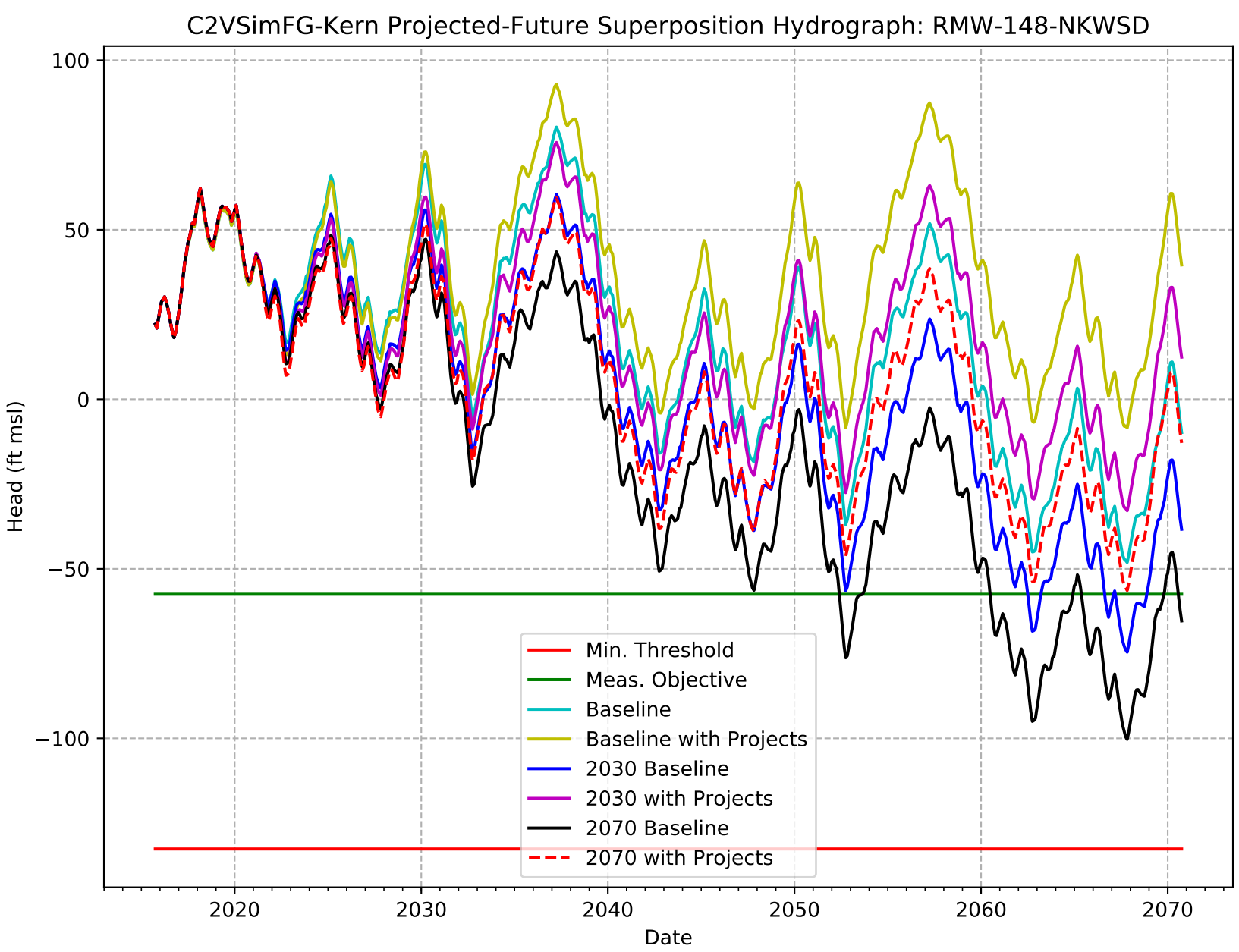

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-142-SWSD
Head (ft msl)
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

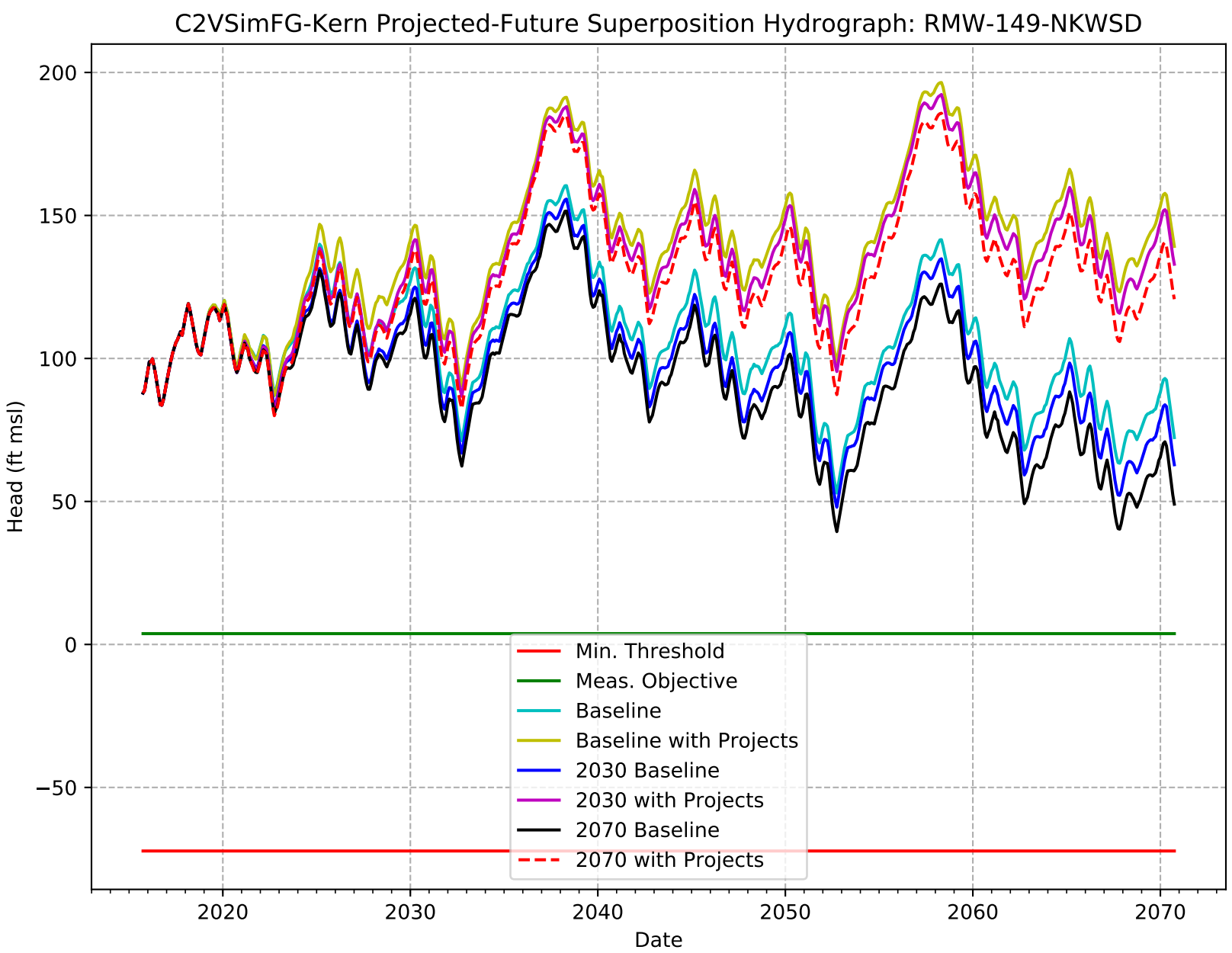

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-143-SWSD
Head (ft msl)
−75
−100
−125
−150
−175
−200
−225
−250
−275
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

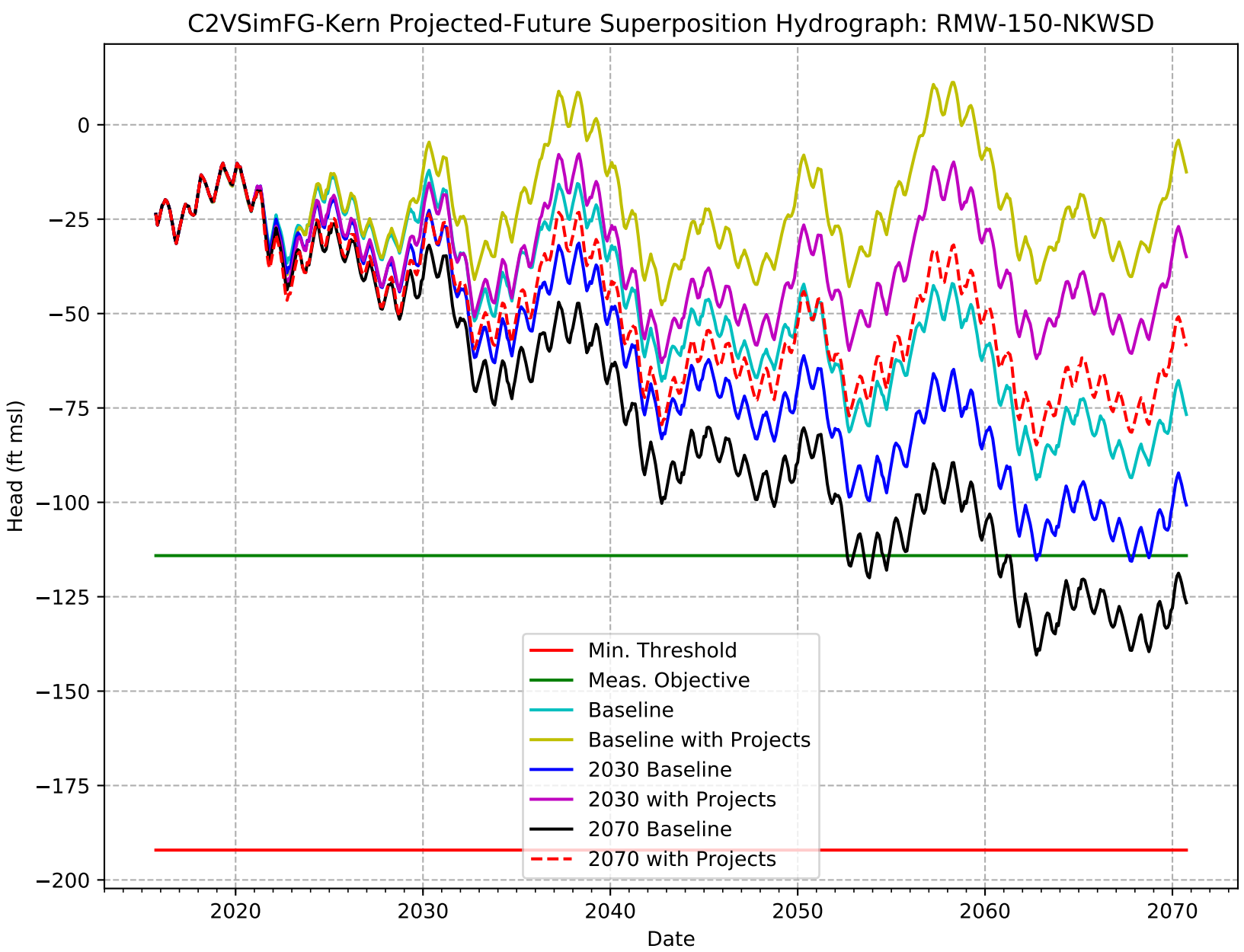

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-145-NKWSD
Head (ft msl)
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

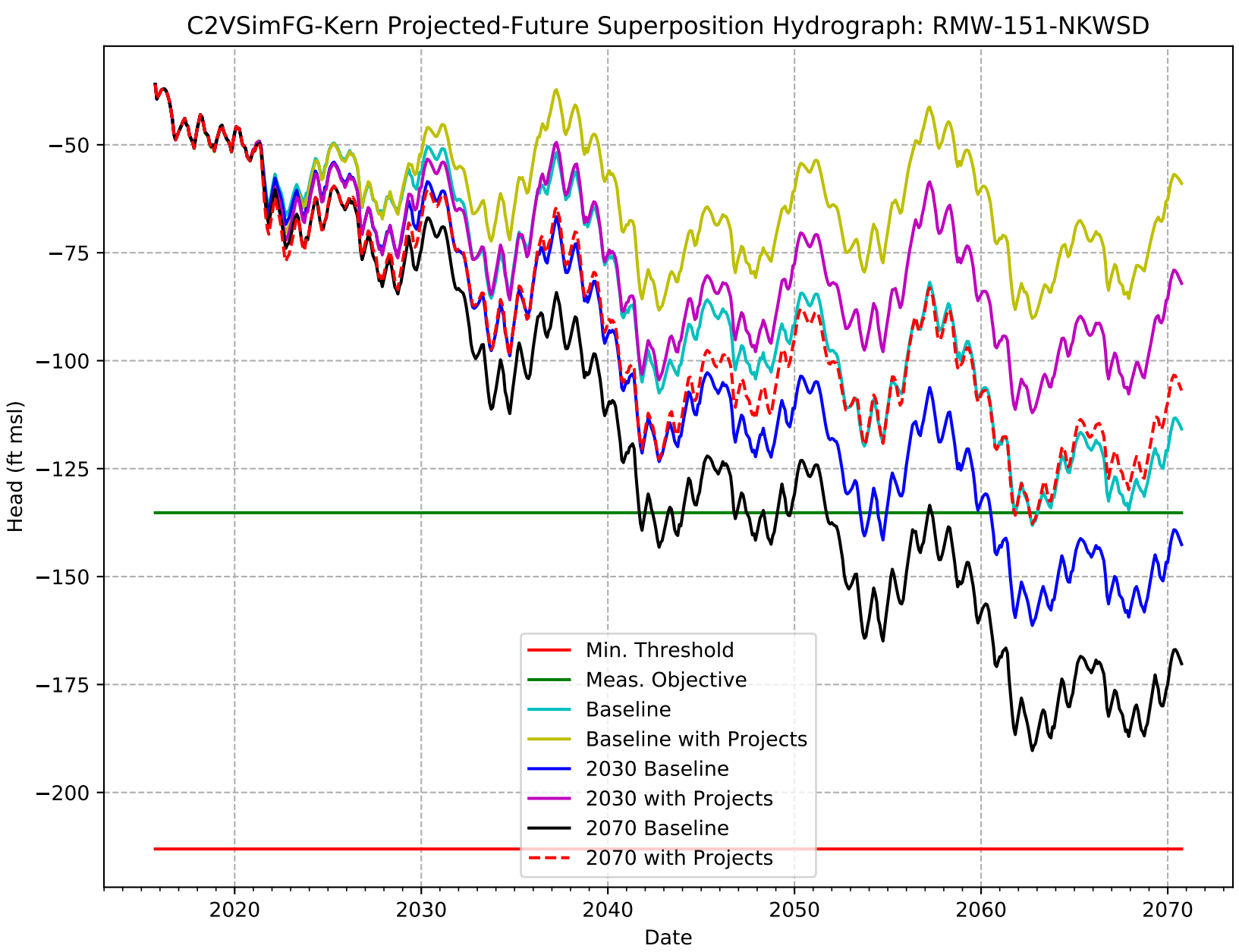

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-146-NKWSD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

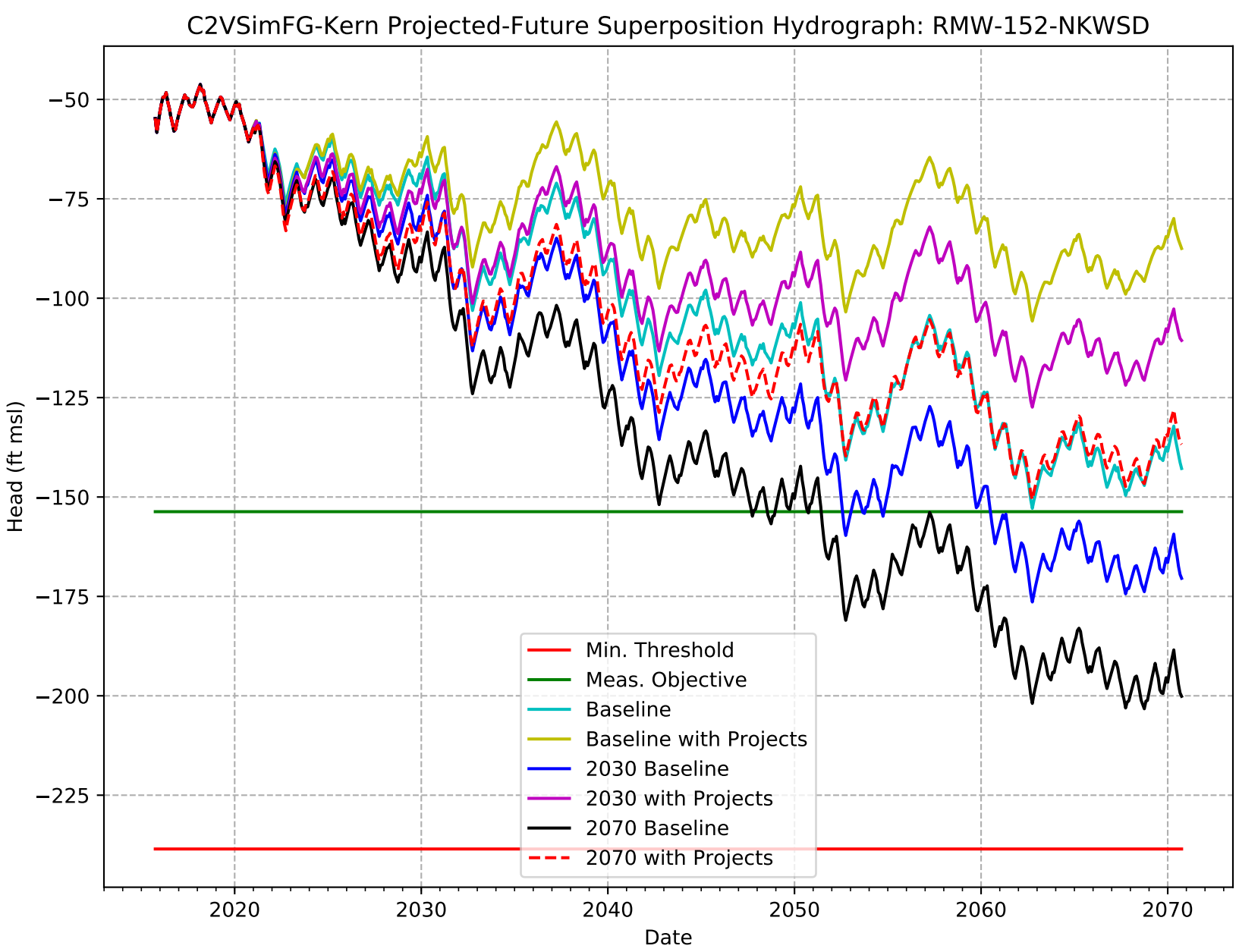

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-147-NKWSD
Head (ft msl)
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

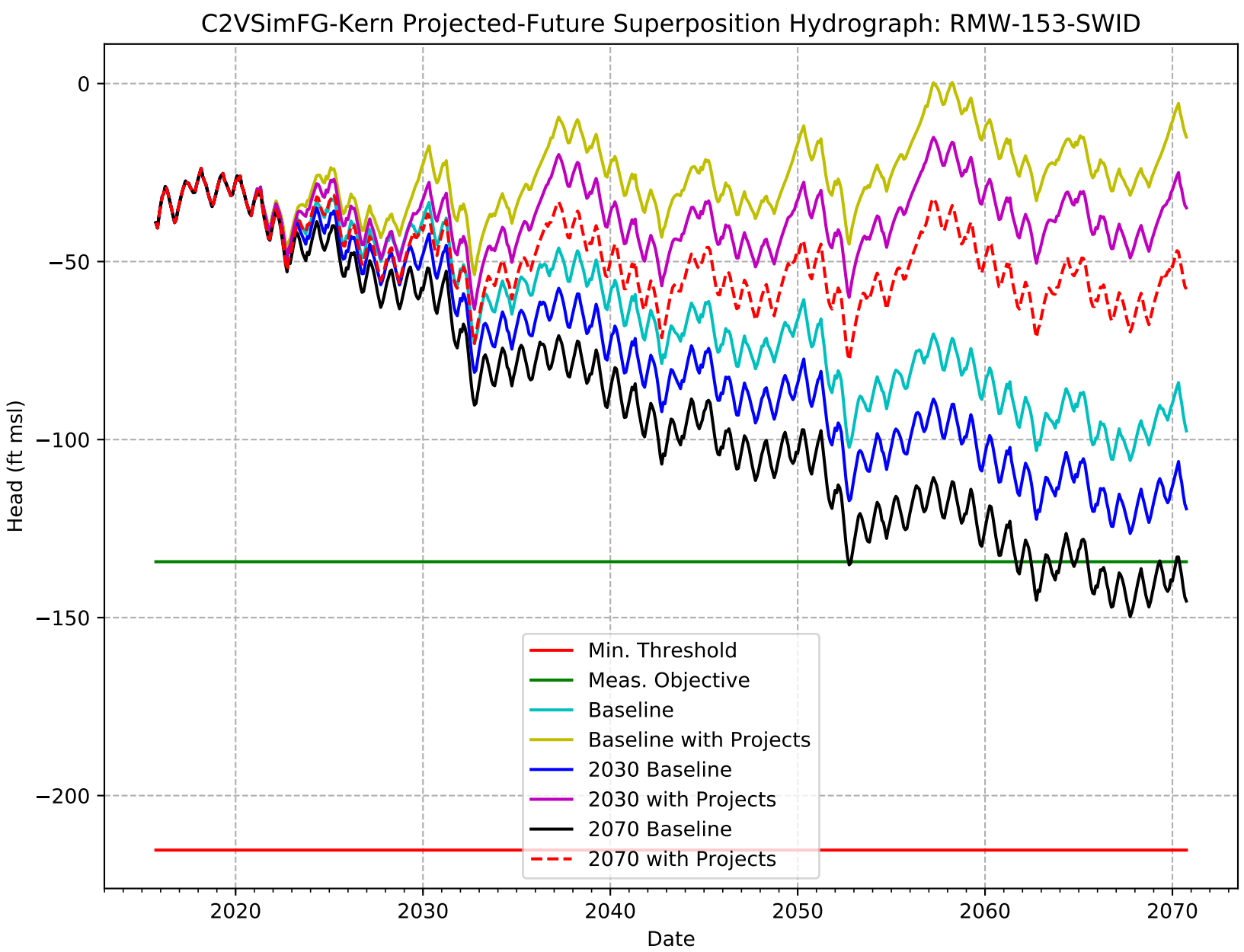

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-148-NKWSD
Head (ft msl)
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

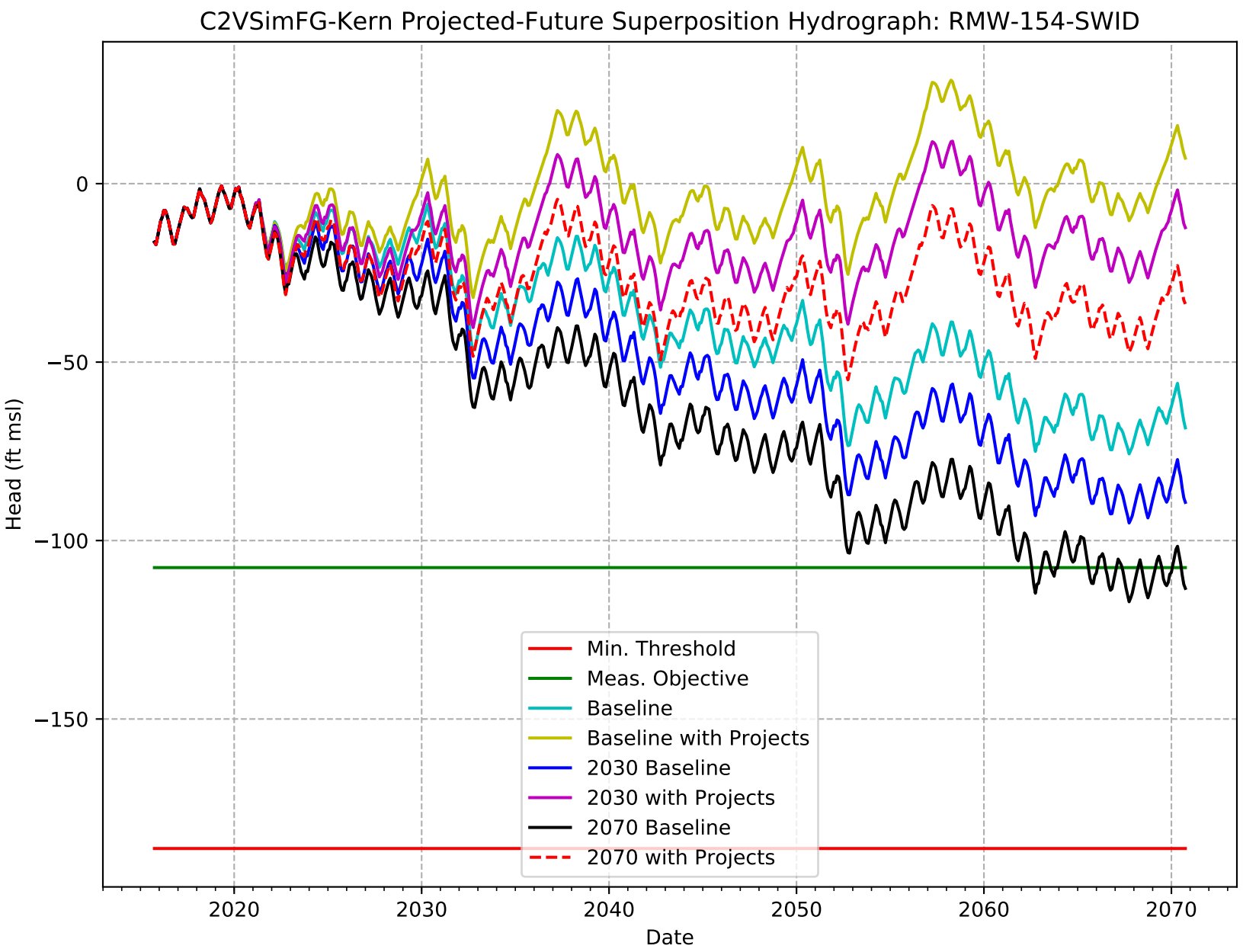

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-149-NKWSD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

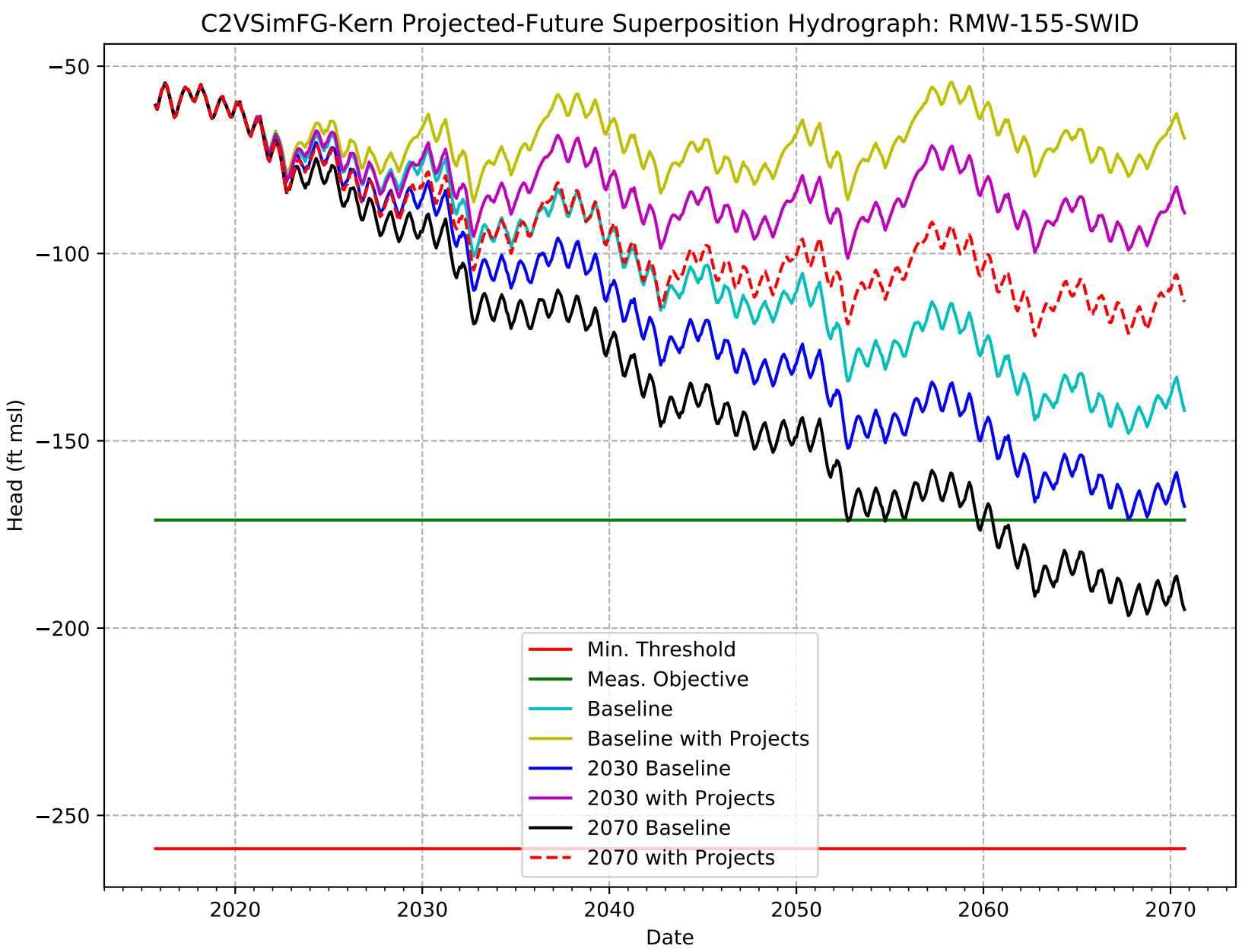

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-150-NKWSD
Head (ft msl)
0
−25
−50
−75
−100
−125
−150
−175
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

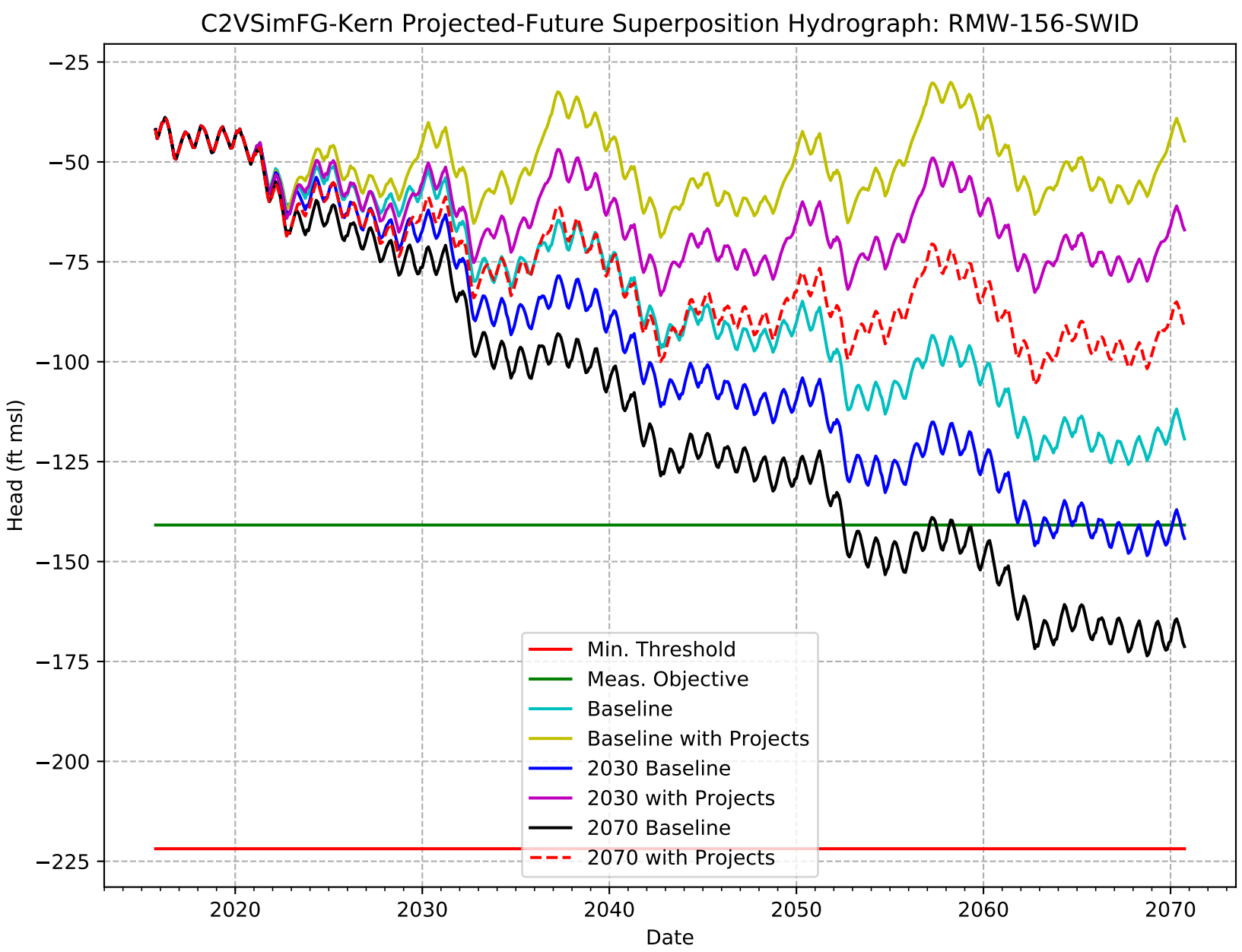

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-151-NKWSD
Head (ft msl)
−50
−75
−100
−125
−150
−175
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

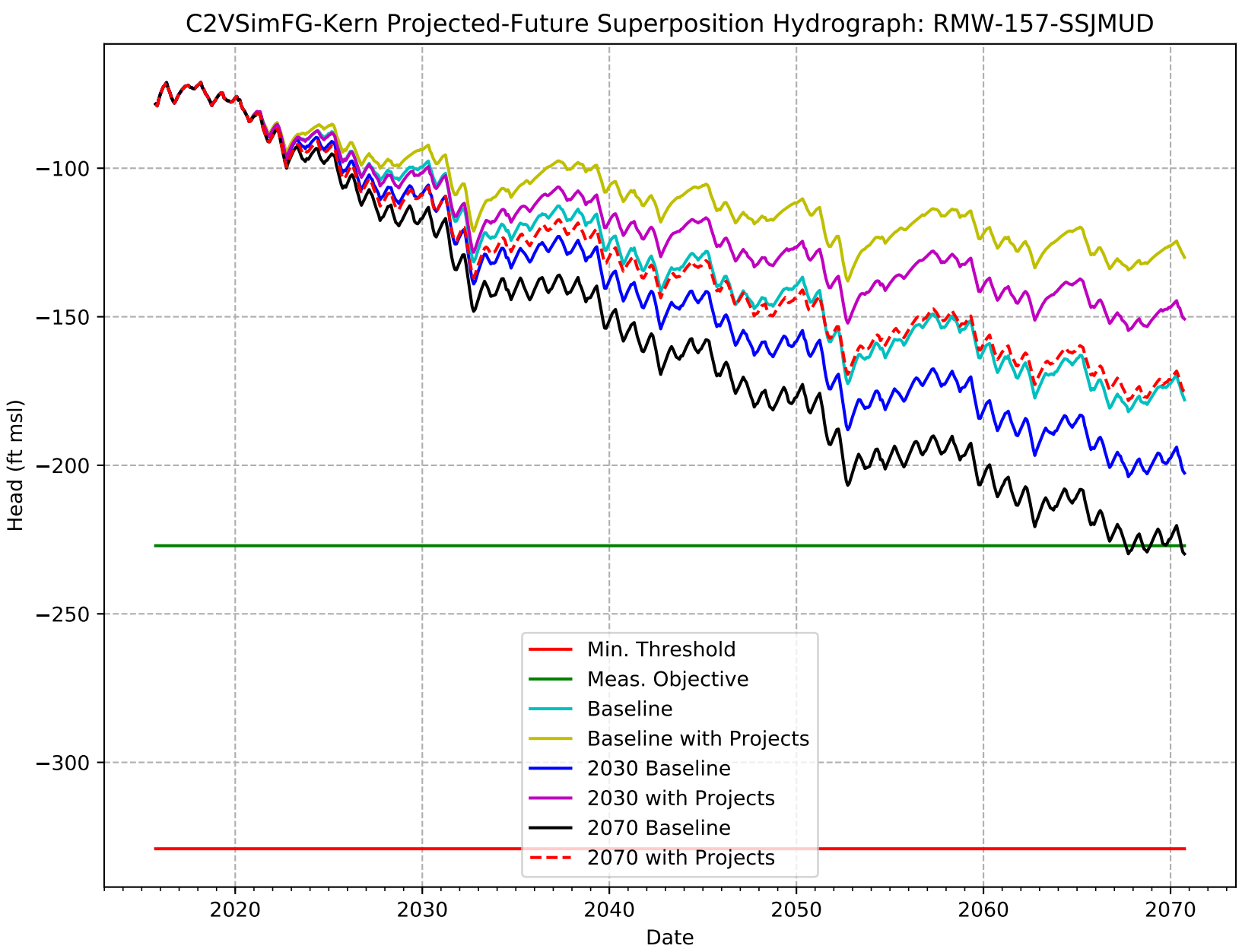

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-152-NKWSD
Head (ft msl)
−50
−75
−100
−125
−150
−175
−200
−225
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

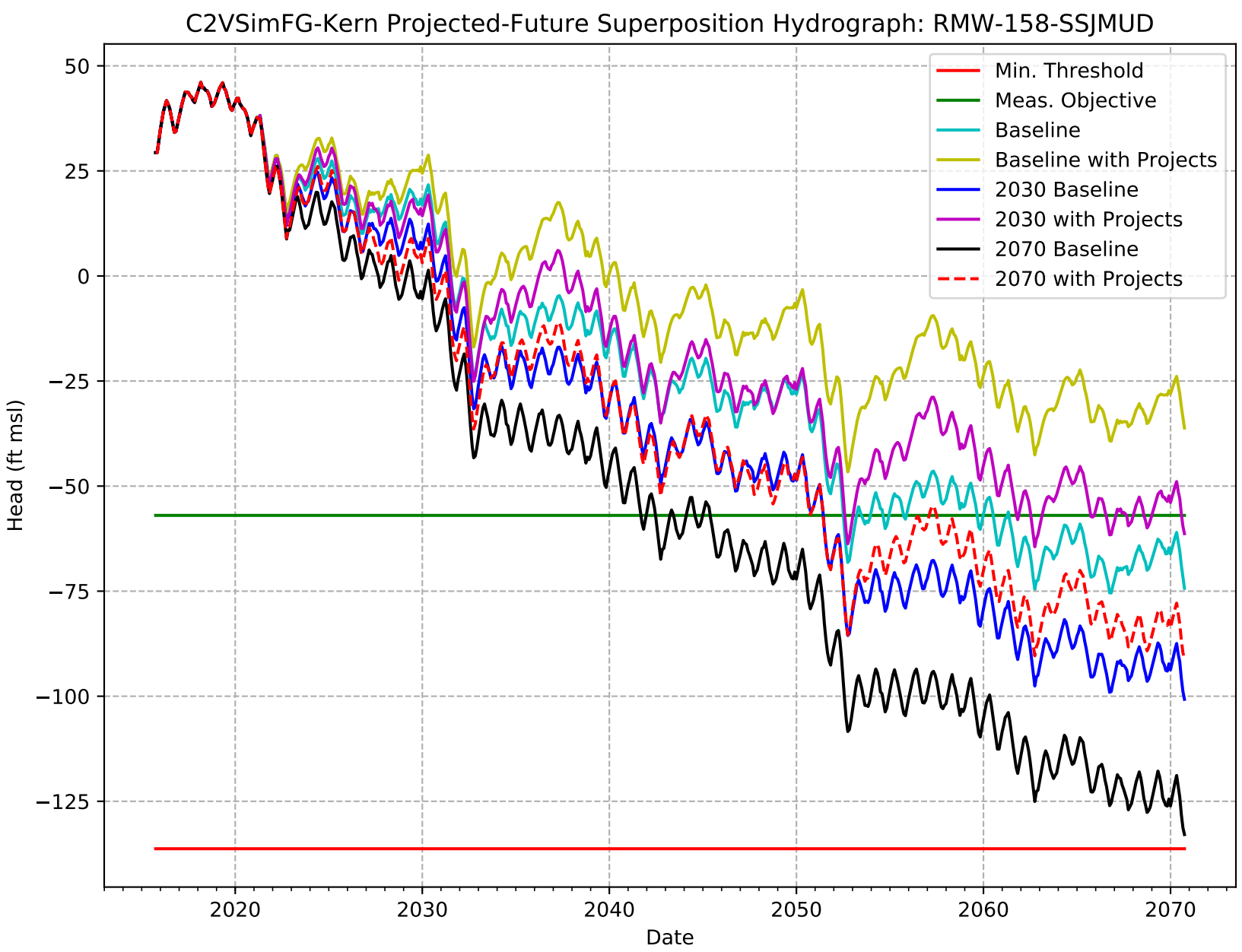

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-153-SWID
Head (ft msl)
0
−50
−100
−150
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

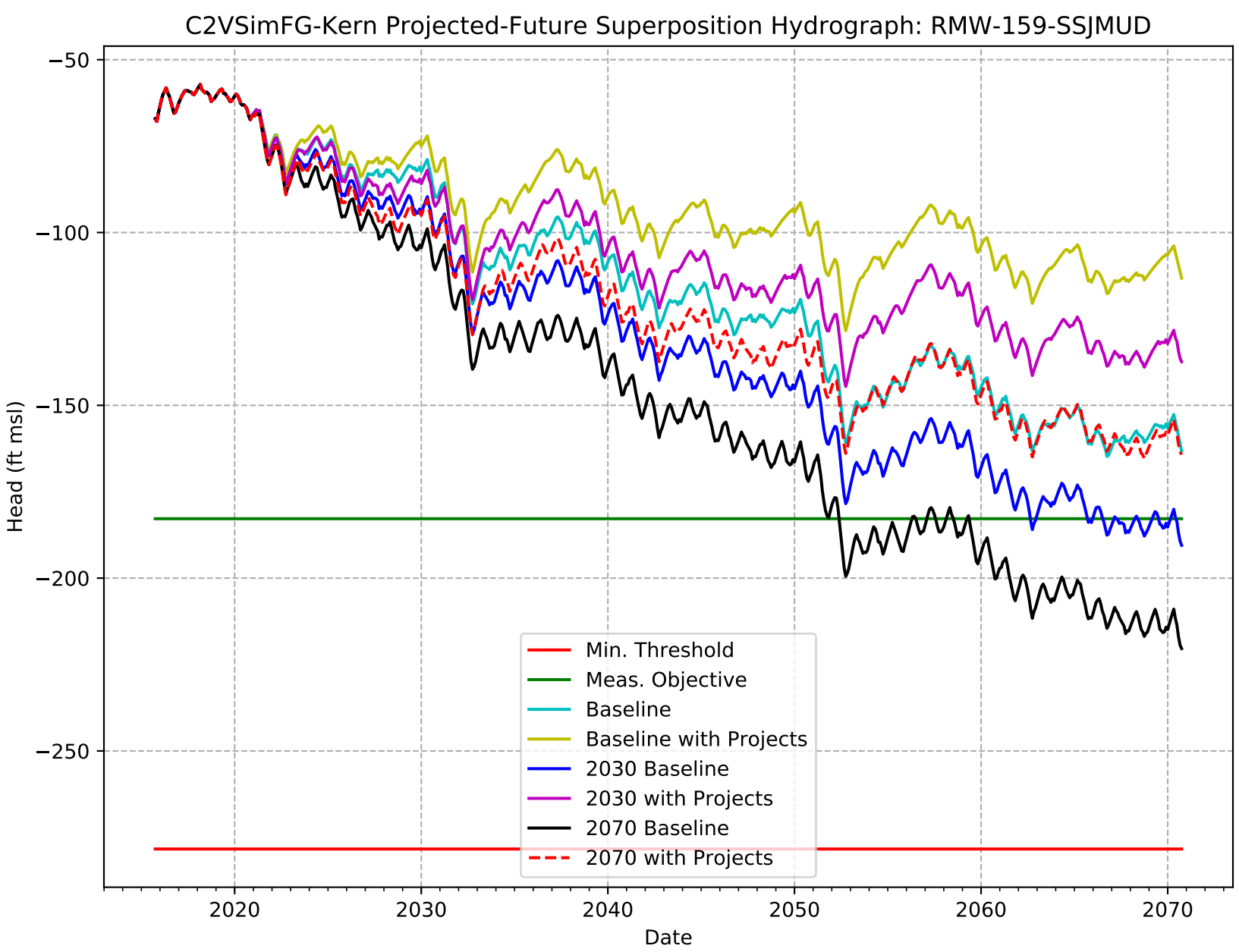

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-154-SWID
Head (ft msl)
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

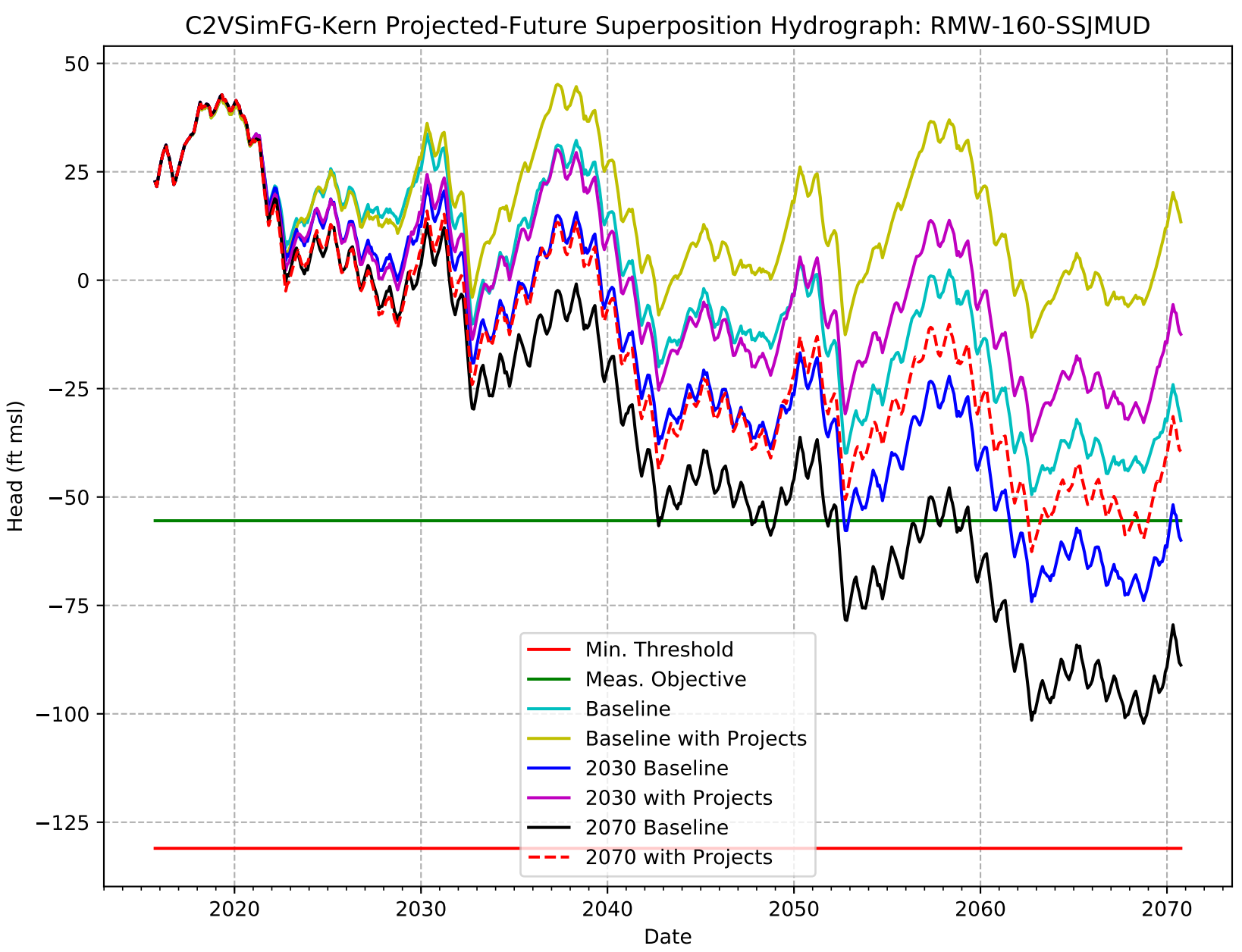

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-155-SWID
Head (ft msl)
−50
−100
−150
−200
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

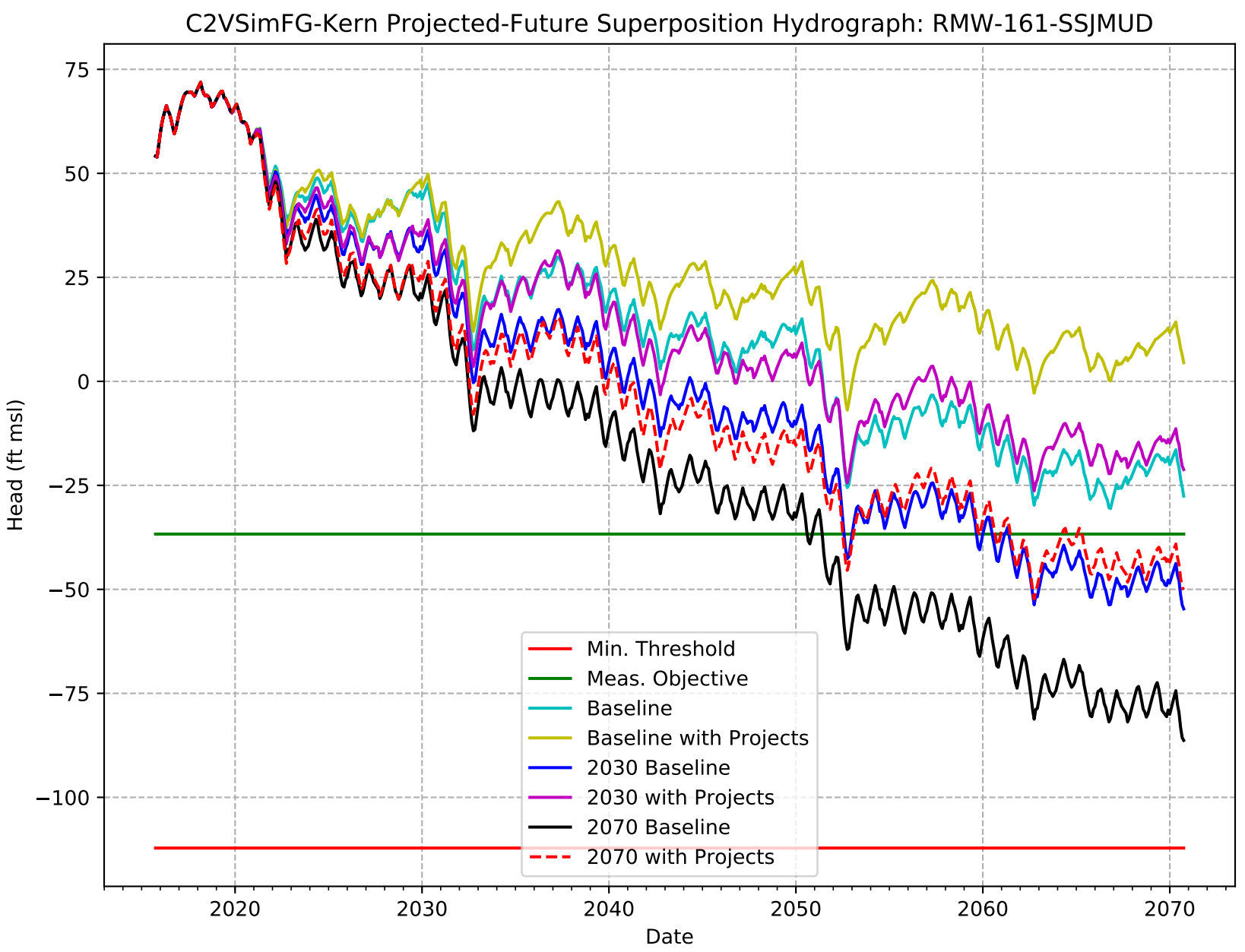

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-156-SWID
Head (ft msl)
−25
−50
−75
−100
−125
−150
−175
−200
−225
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

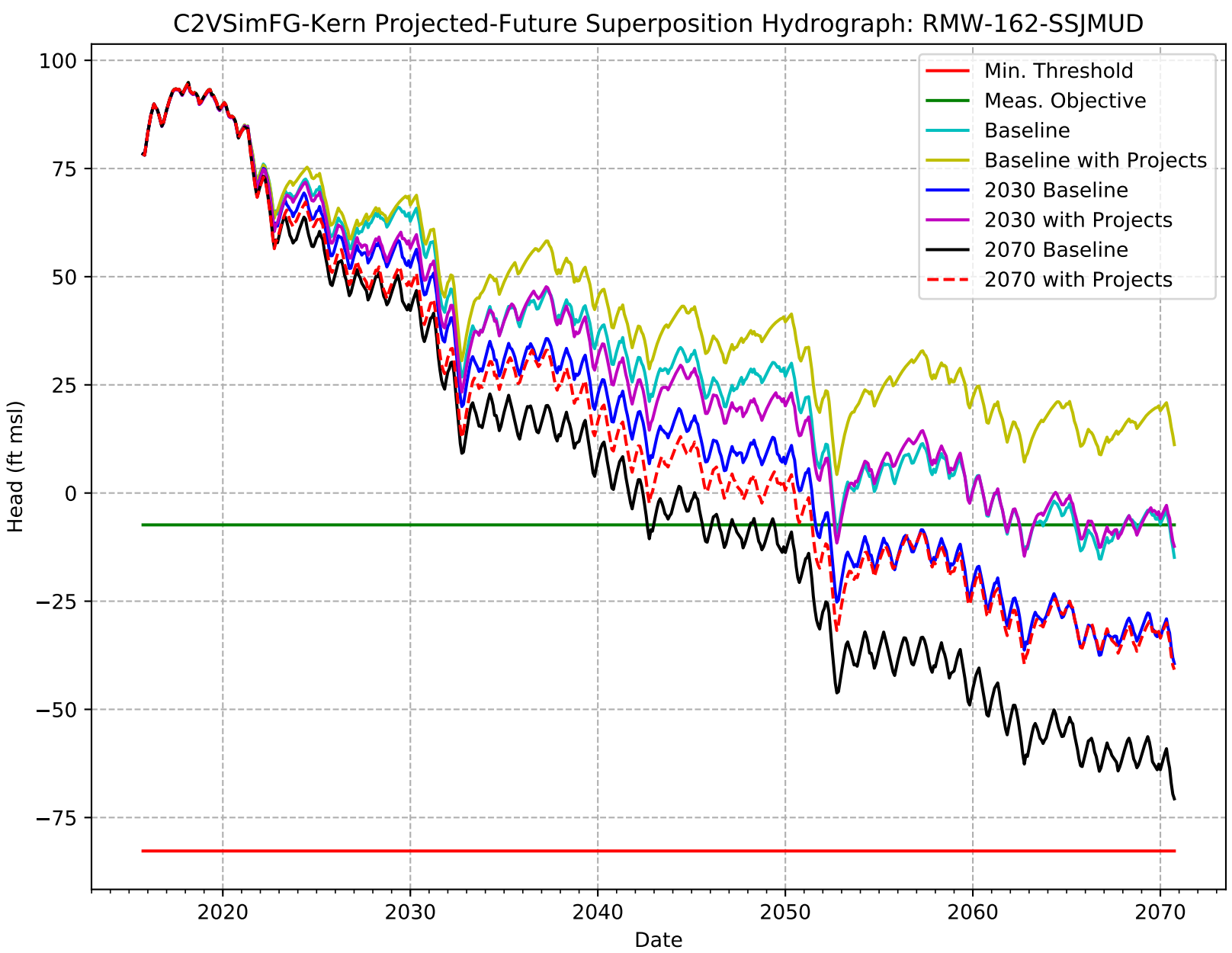

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-157-SSJMUD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

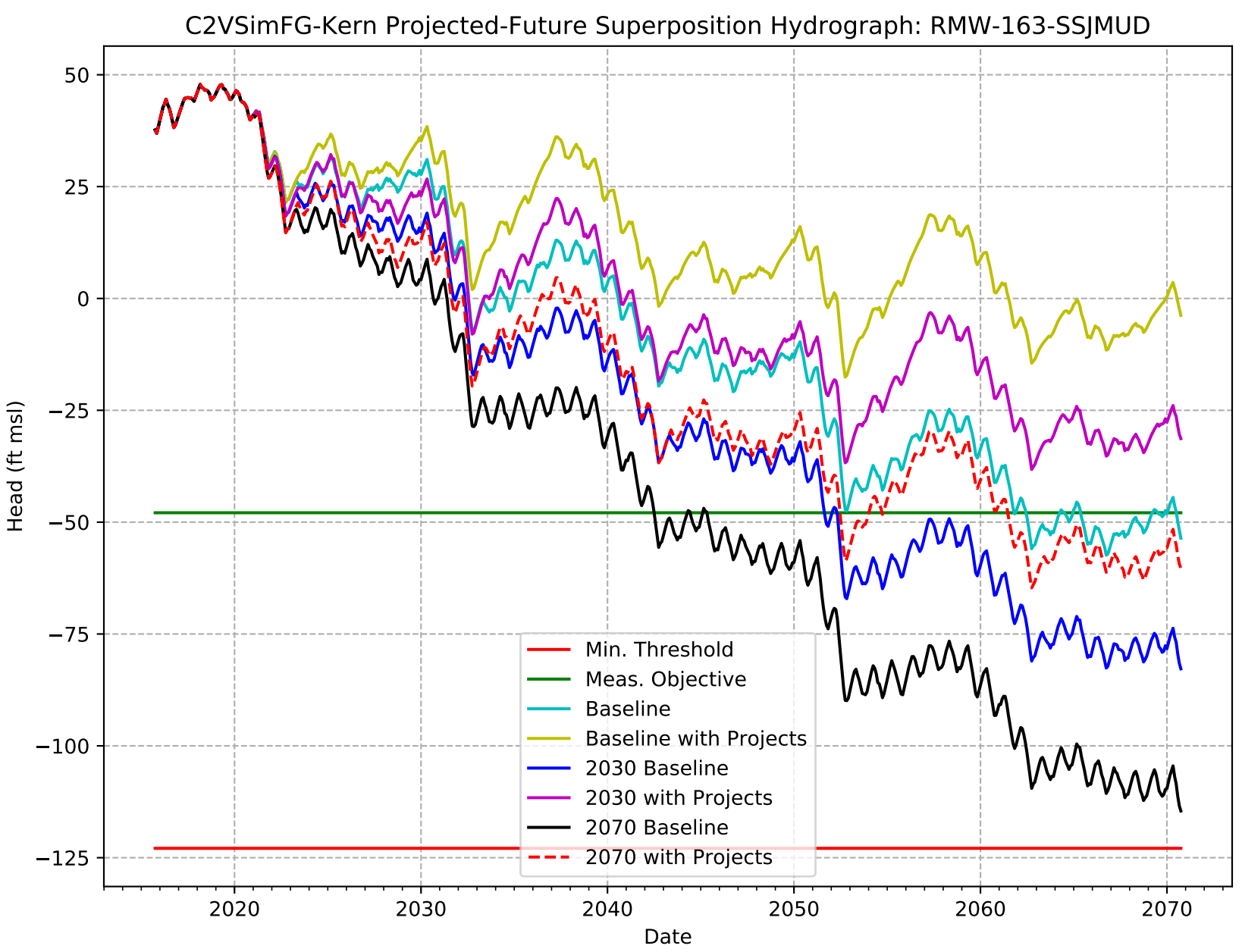

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-158-SSJMUD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date

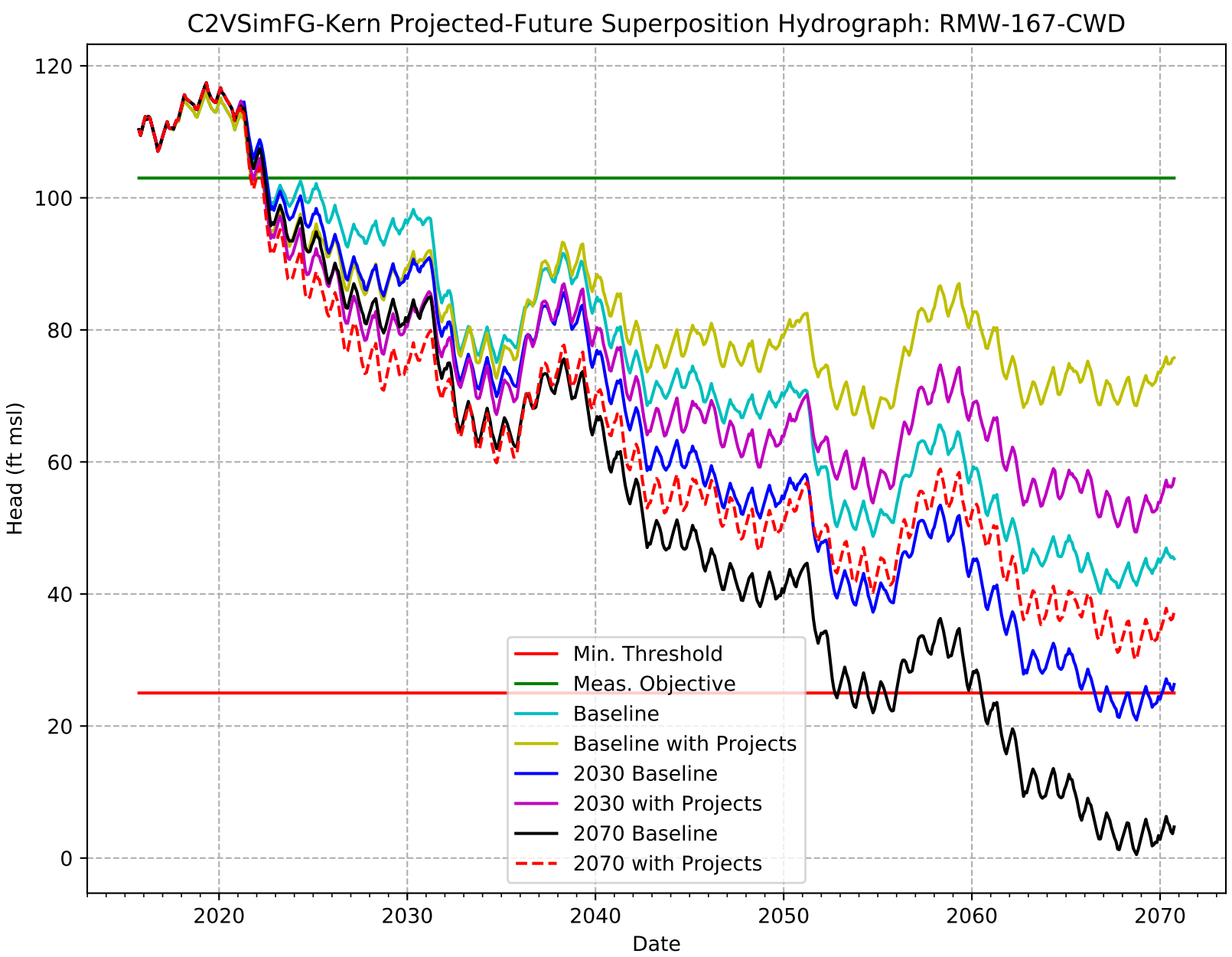

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-159-SSJMUD
Head (ft msl)
−50
−100
−150
−200
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

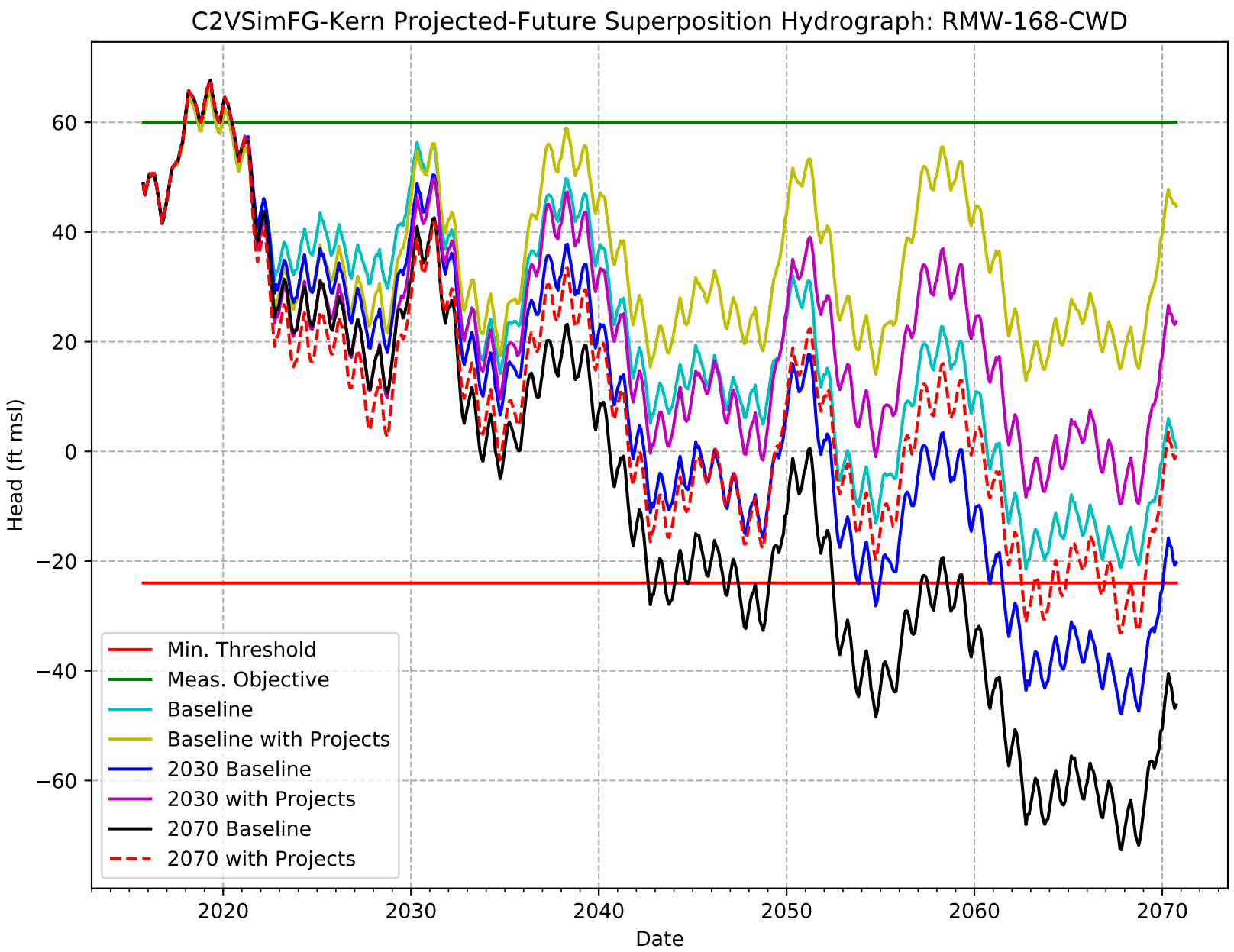

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-160-SSJMUD
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

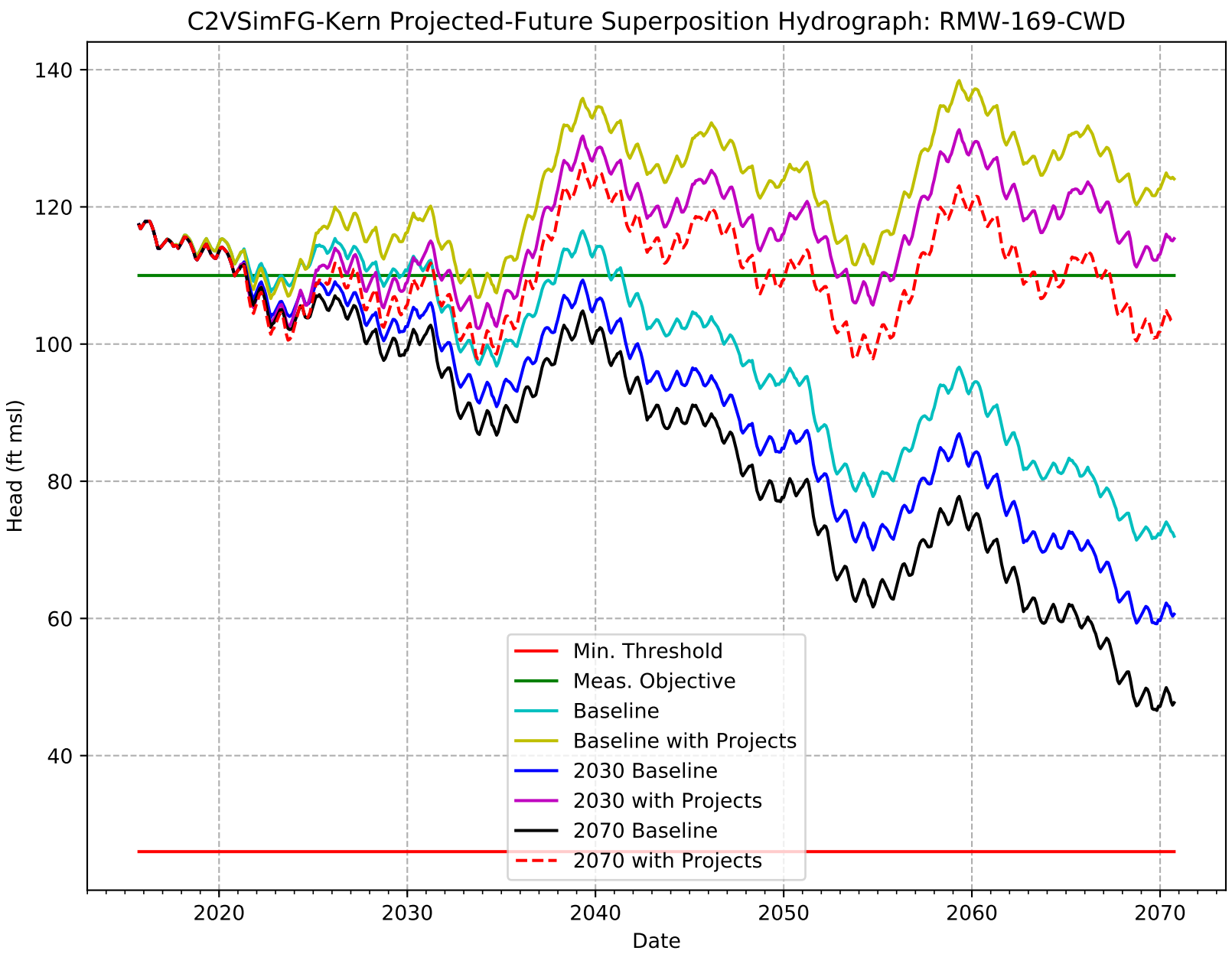

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-161-SSJMUD
Head (ft msl)
75
50
25
0
−25
−50
−75
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

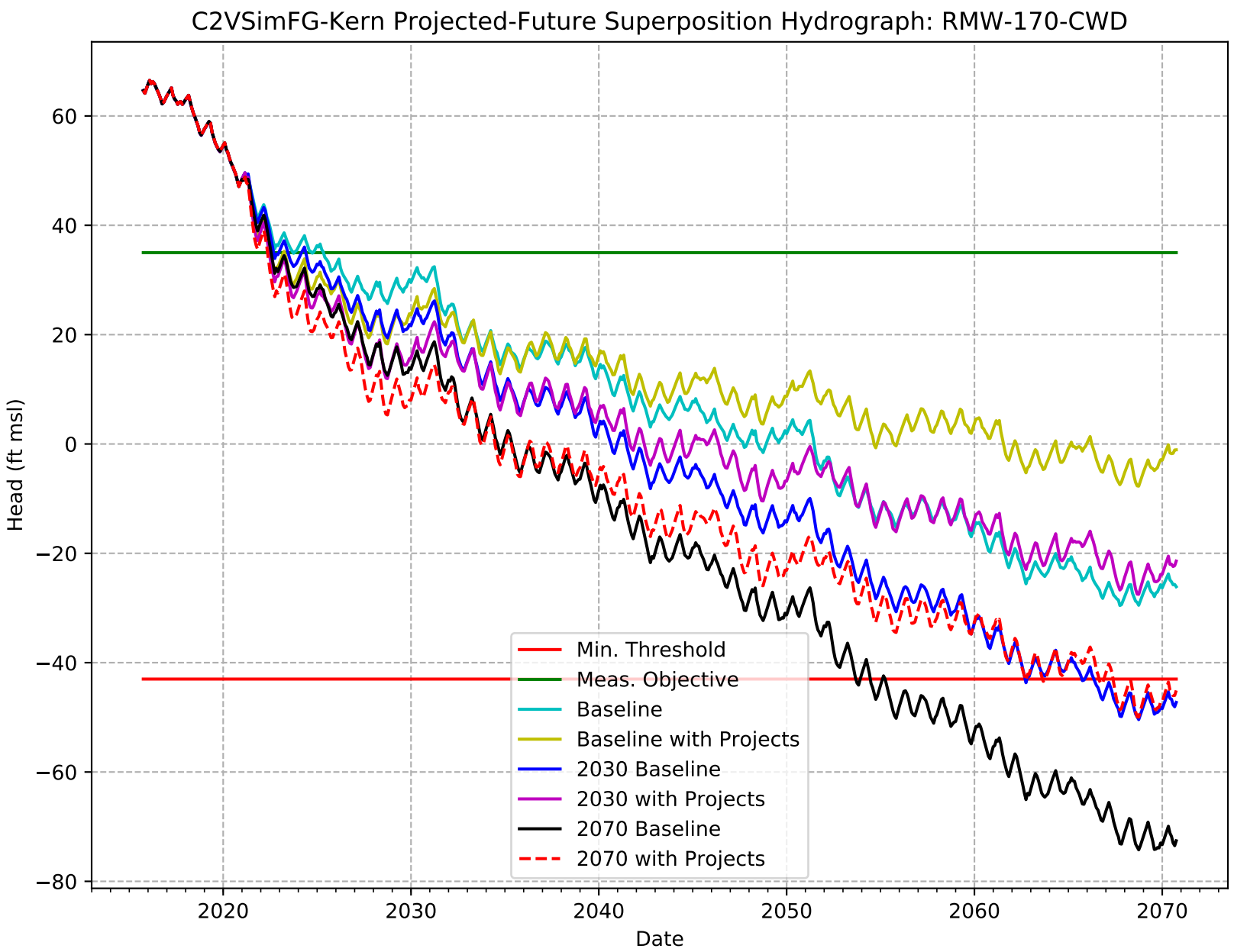

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-162-SSJMUD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
75
50
25
0
−25
−50
−75
2020
2030
2040
2050
2060
2070
Date

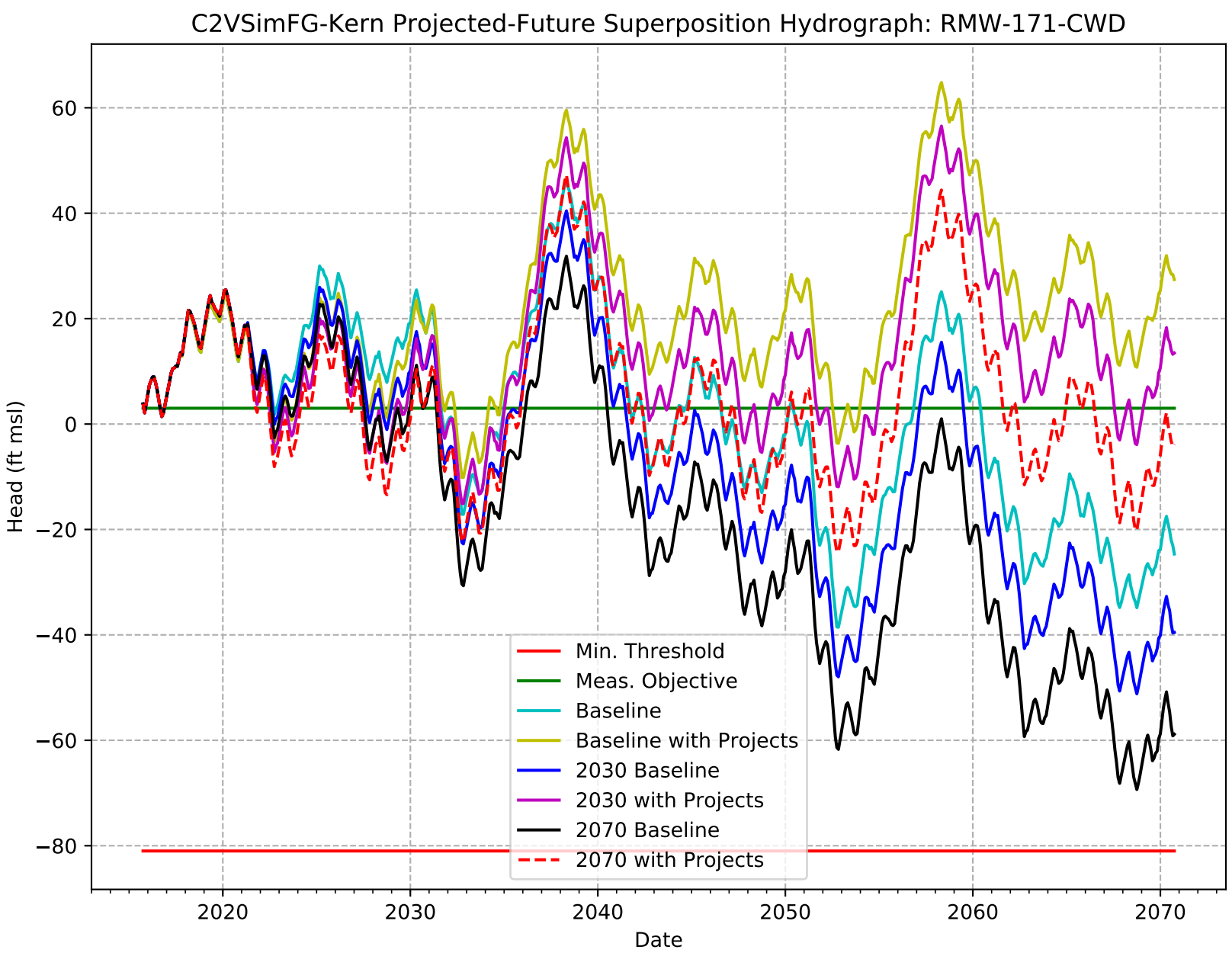

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-163-SSJMUD
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

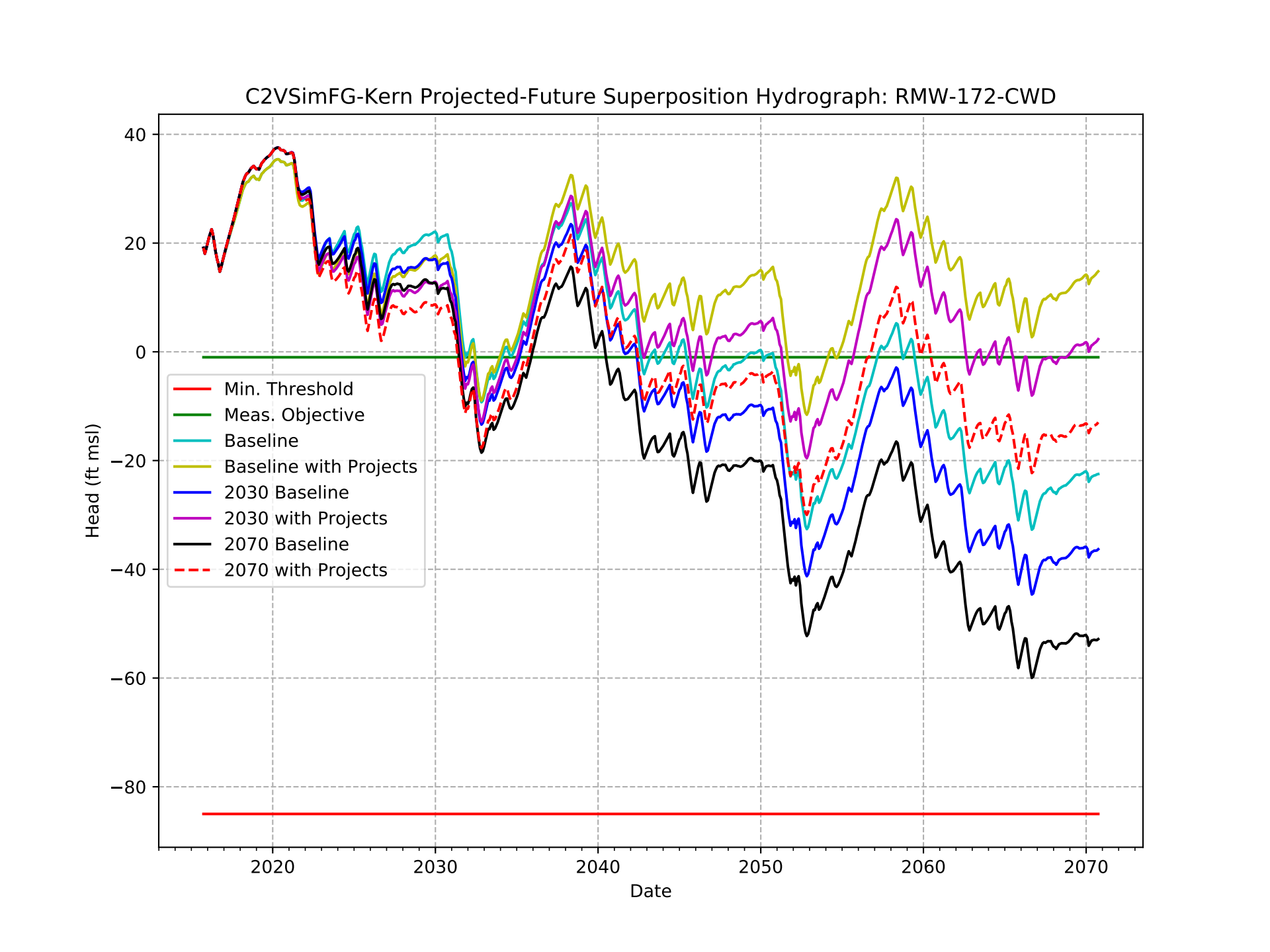

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-167-CWD
Head (ft msl)
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

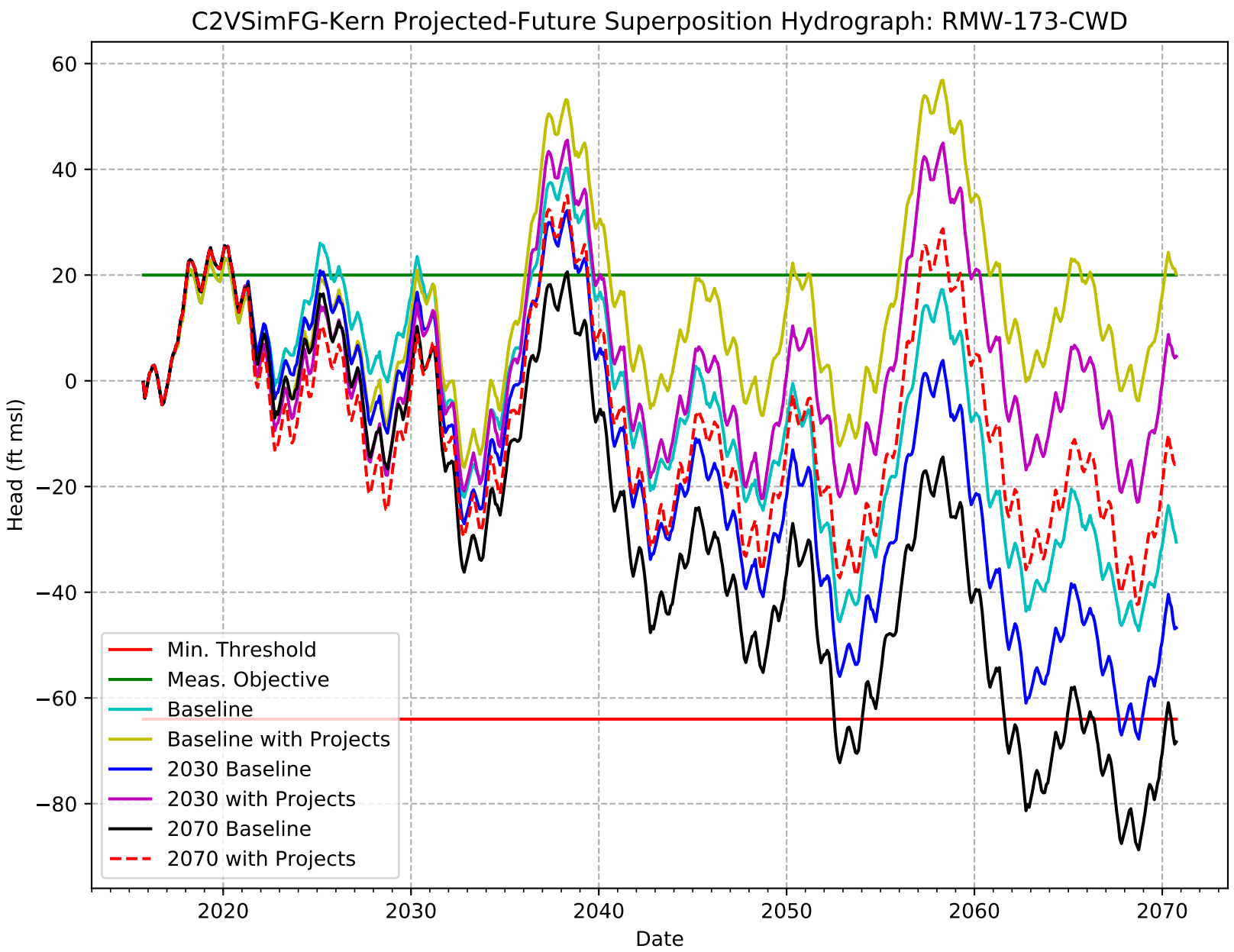

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-168-CWD
Head (ft msl)
60
40
20
0
−20
−40
−60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

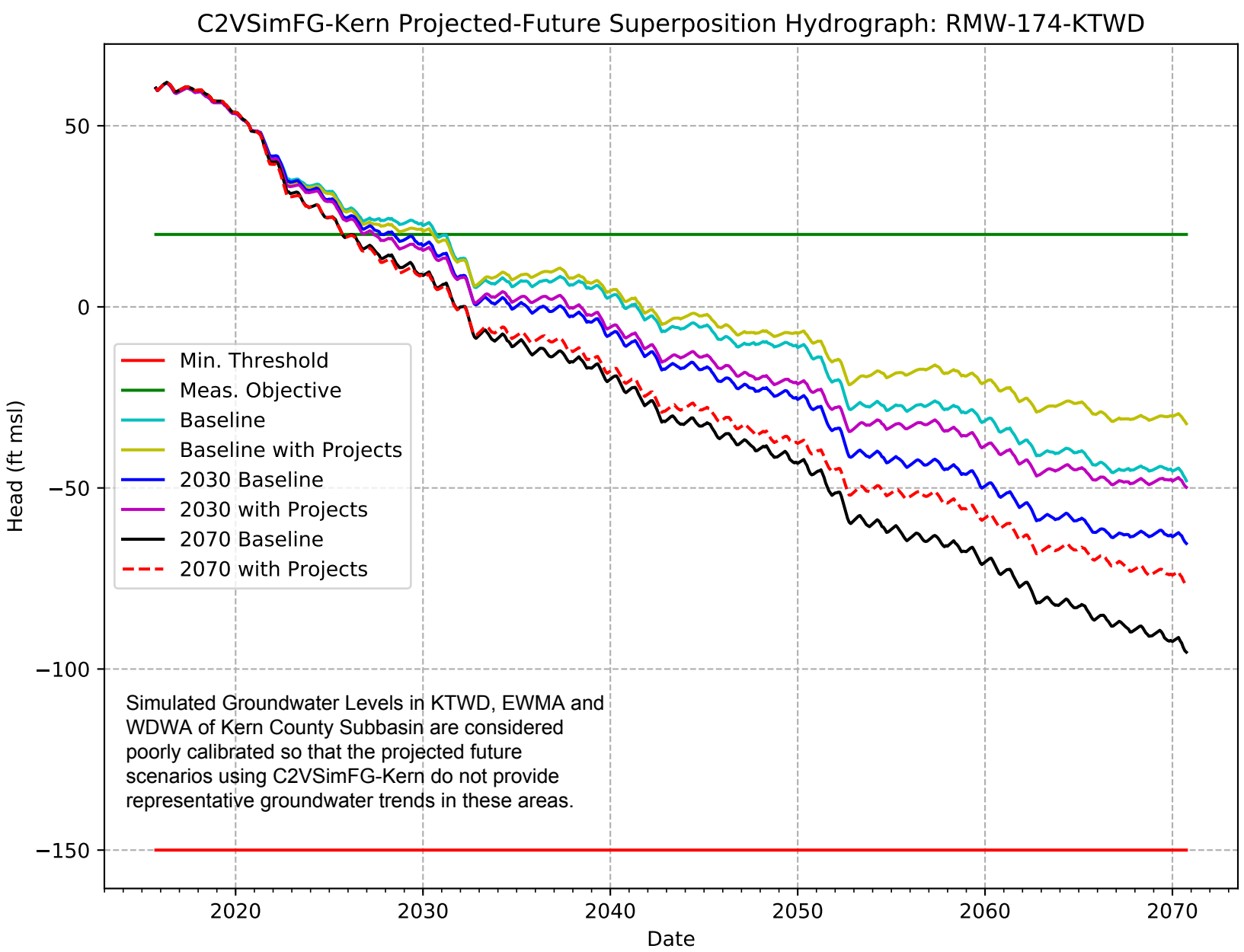

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-169-CWD
Head (ft msl)
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

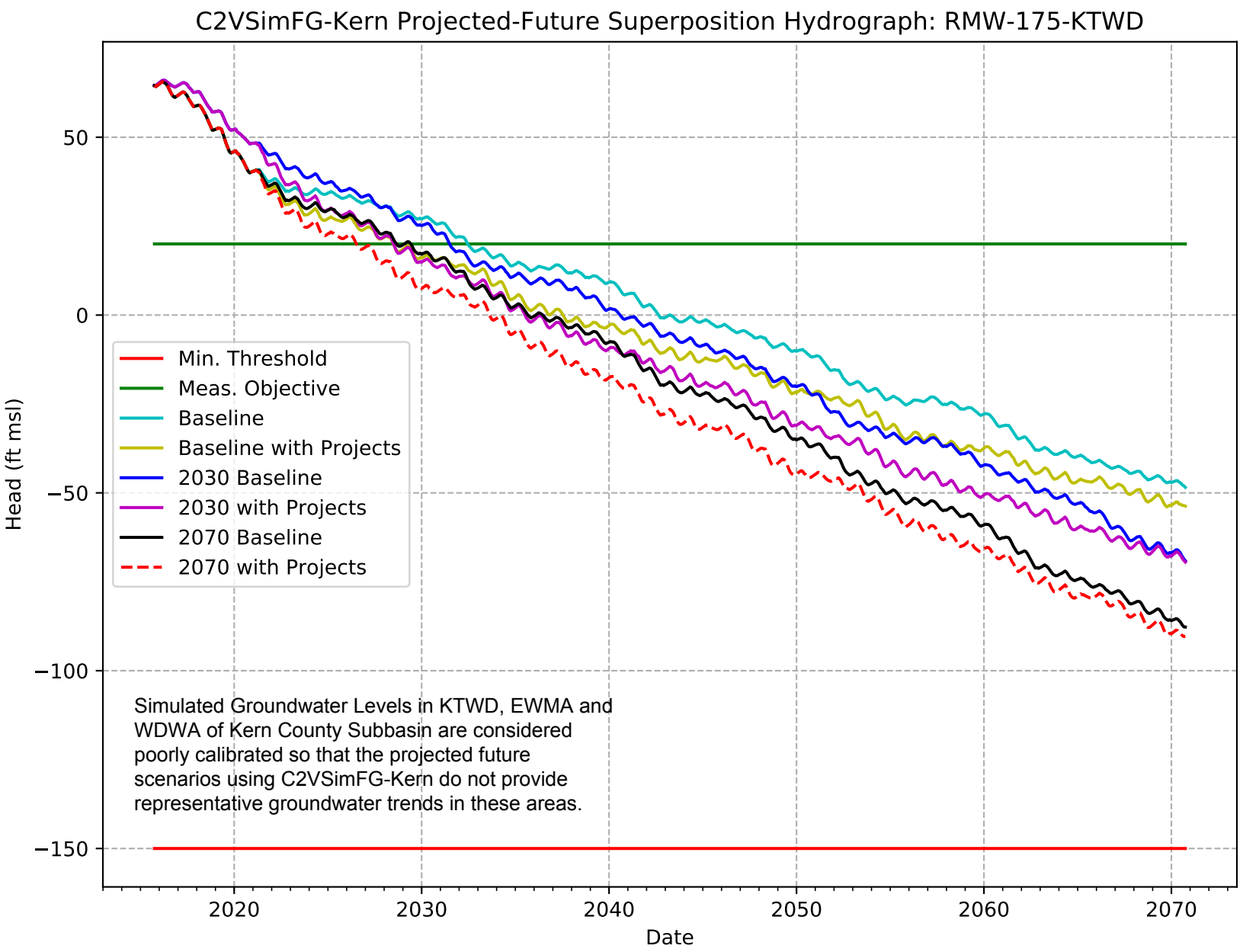

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-170-CWD
Head (ft msl)
60
40
20
0
−20
−40
−60
−80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

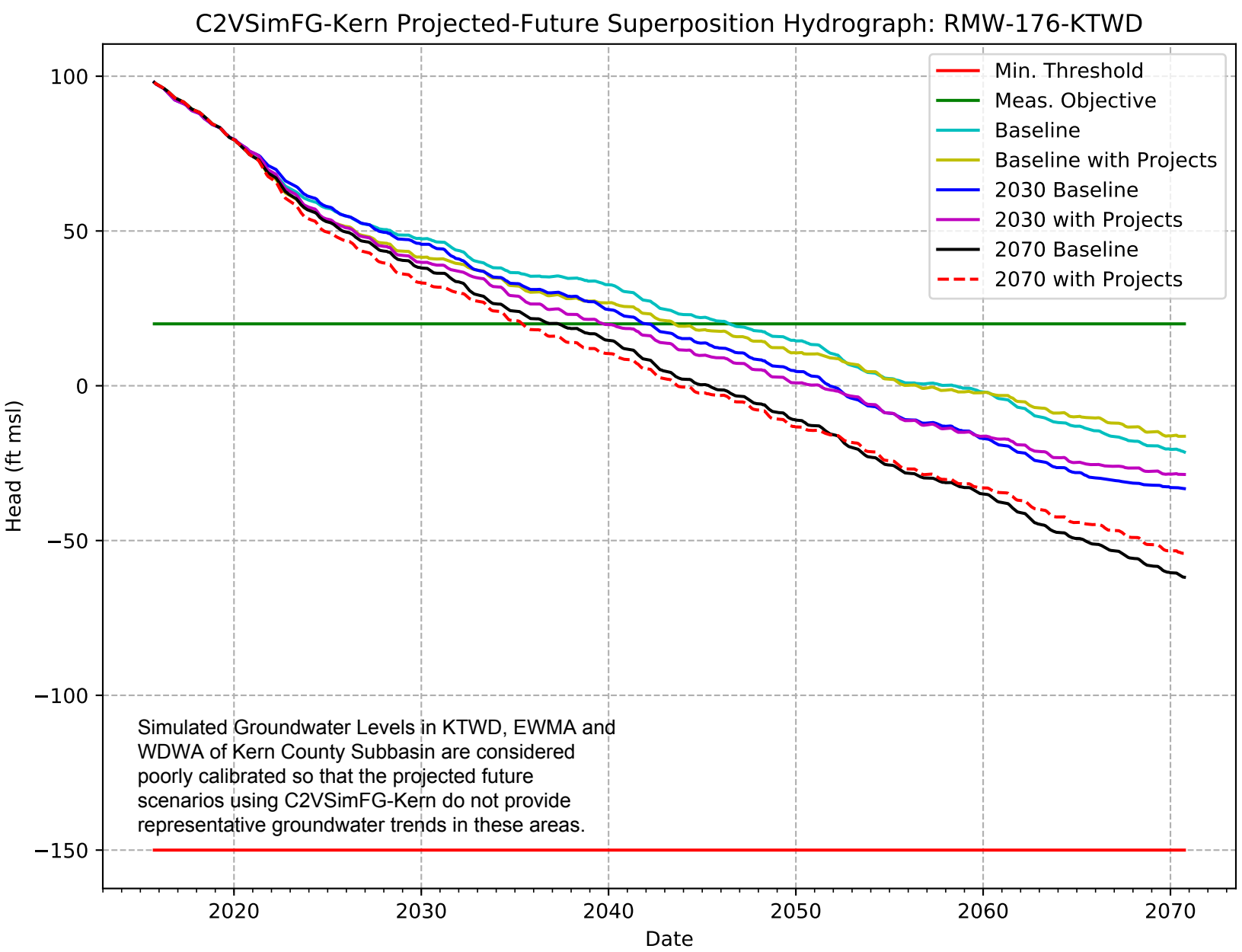

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-171-CWD
Head (ft msl)
60
40
20
0
−20
−40
−60
−80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

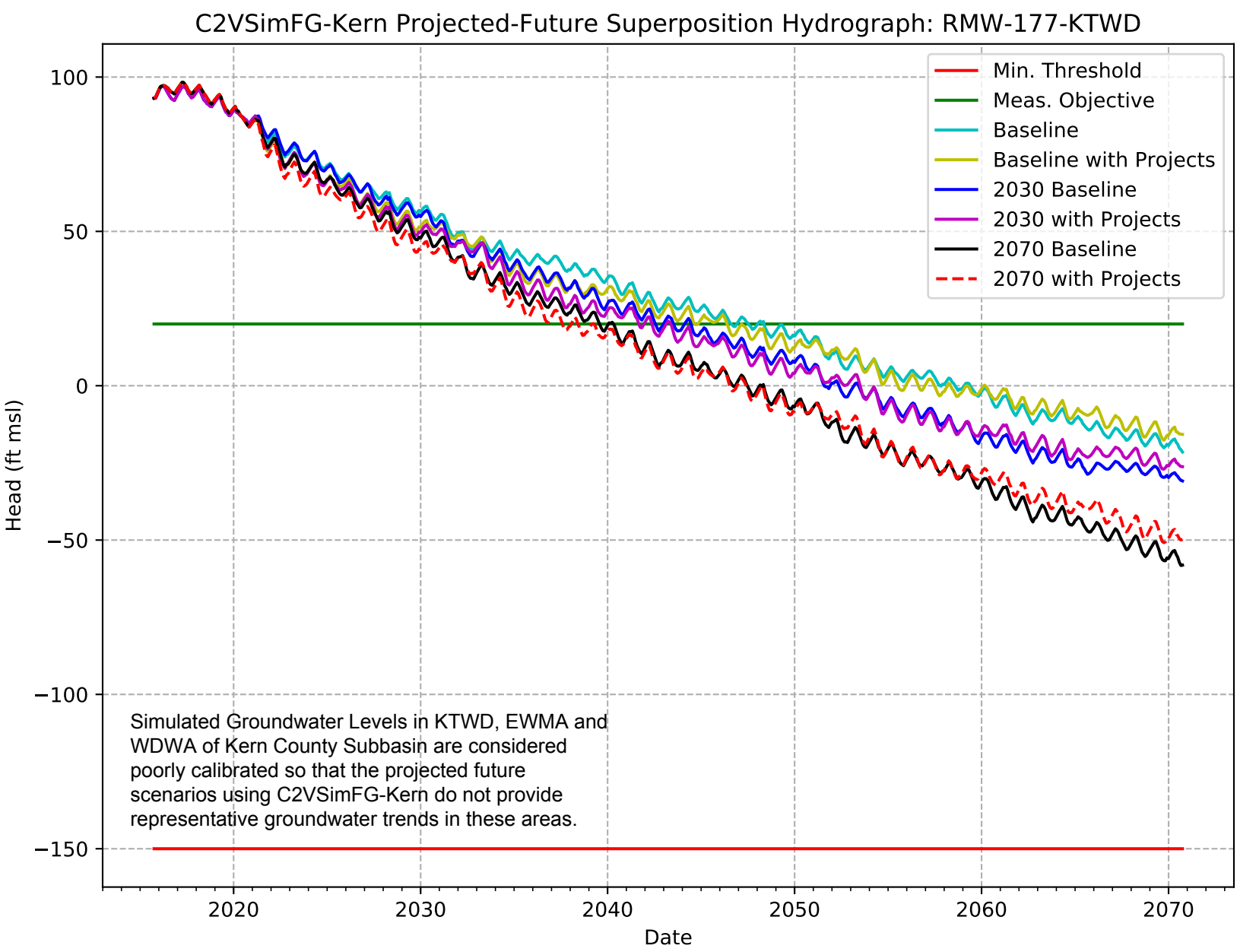

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-172-CWD
Head (ft msl)
Date
40
20
0
−20
−40
−60
−80
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

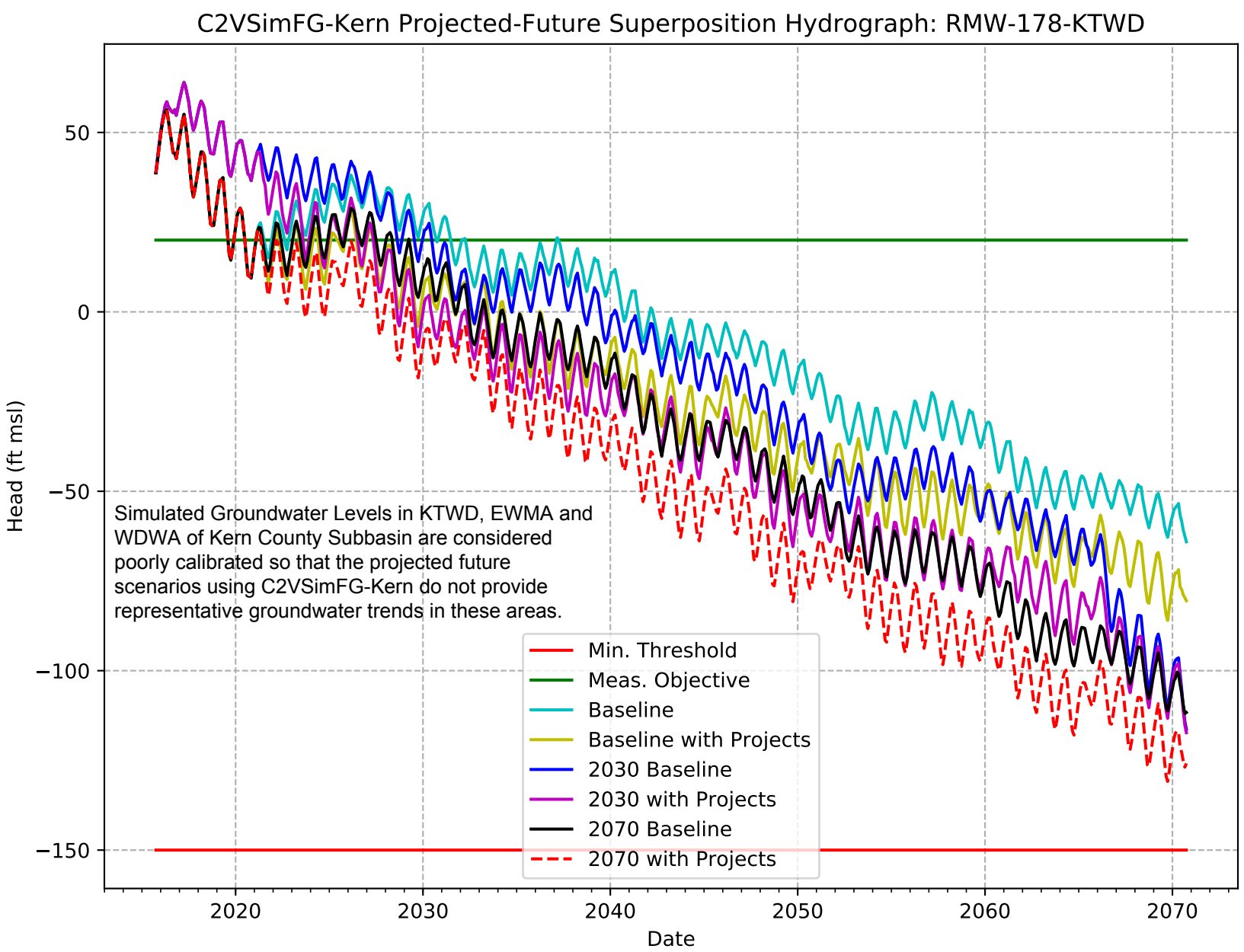

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-173-CWD
Head (ft msl)
60
40
20
0
−20
−40
−60
−80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

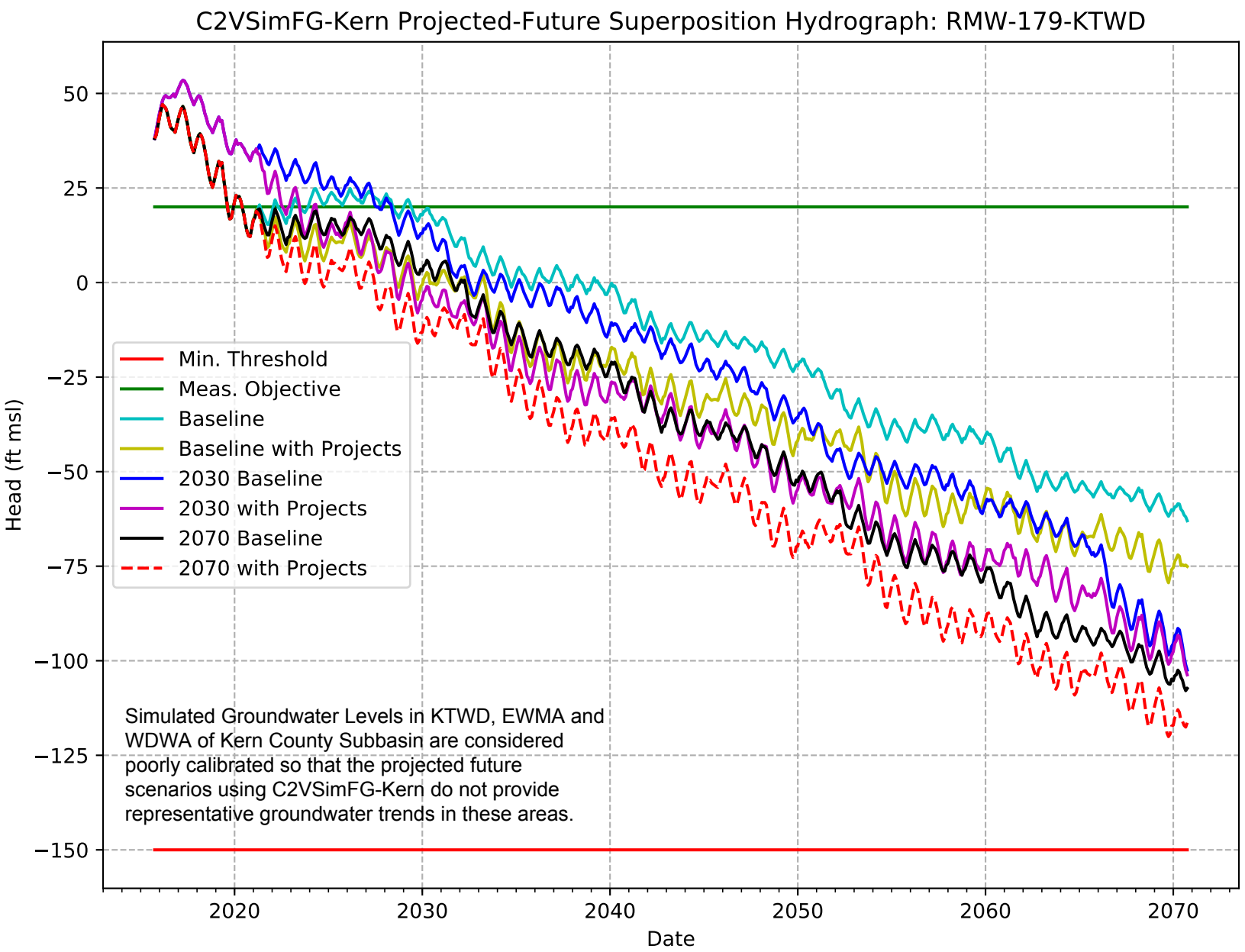

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-174-KTWD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

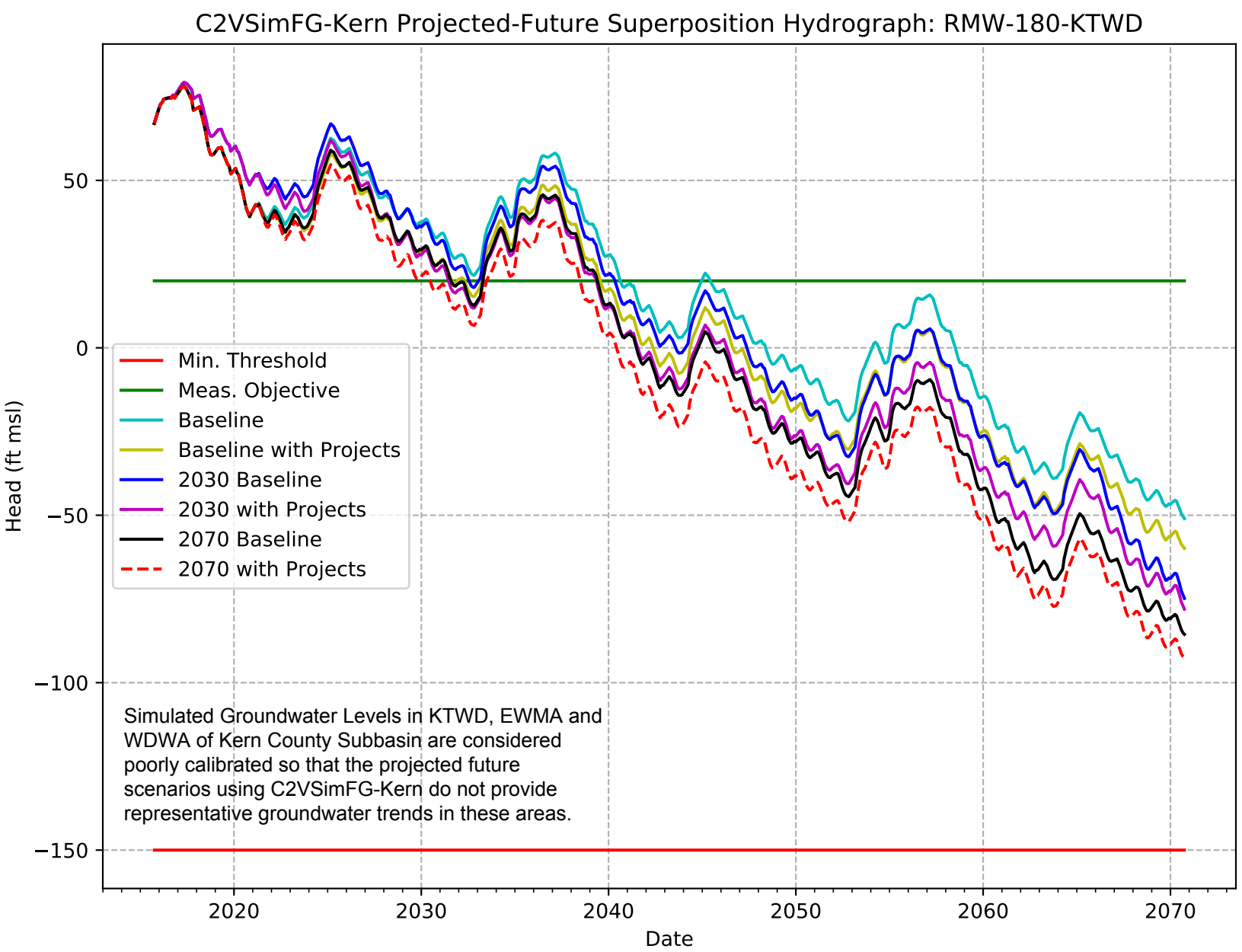

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-175-KTWD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

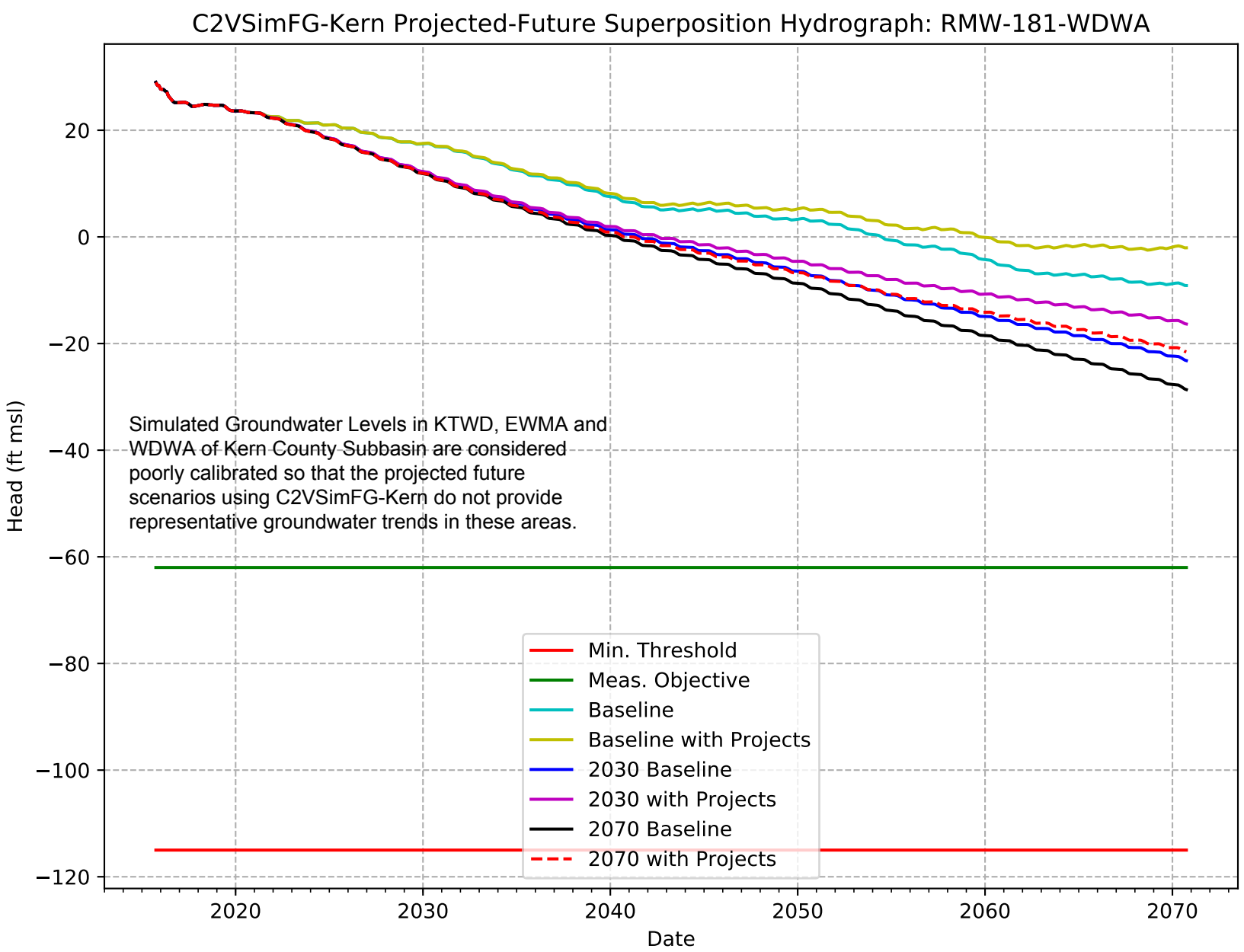

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-176-KTWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

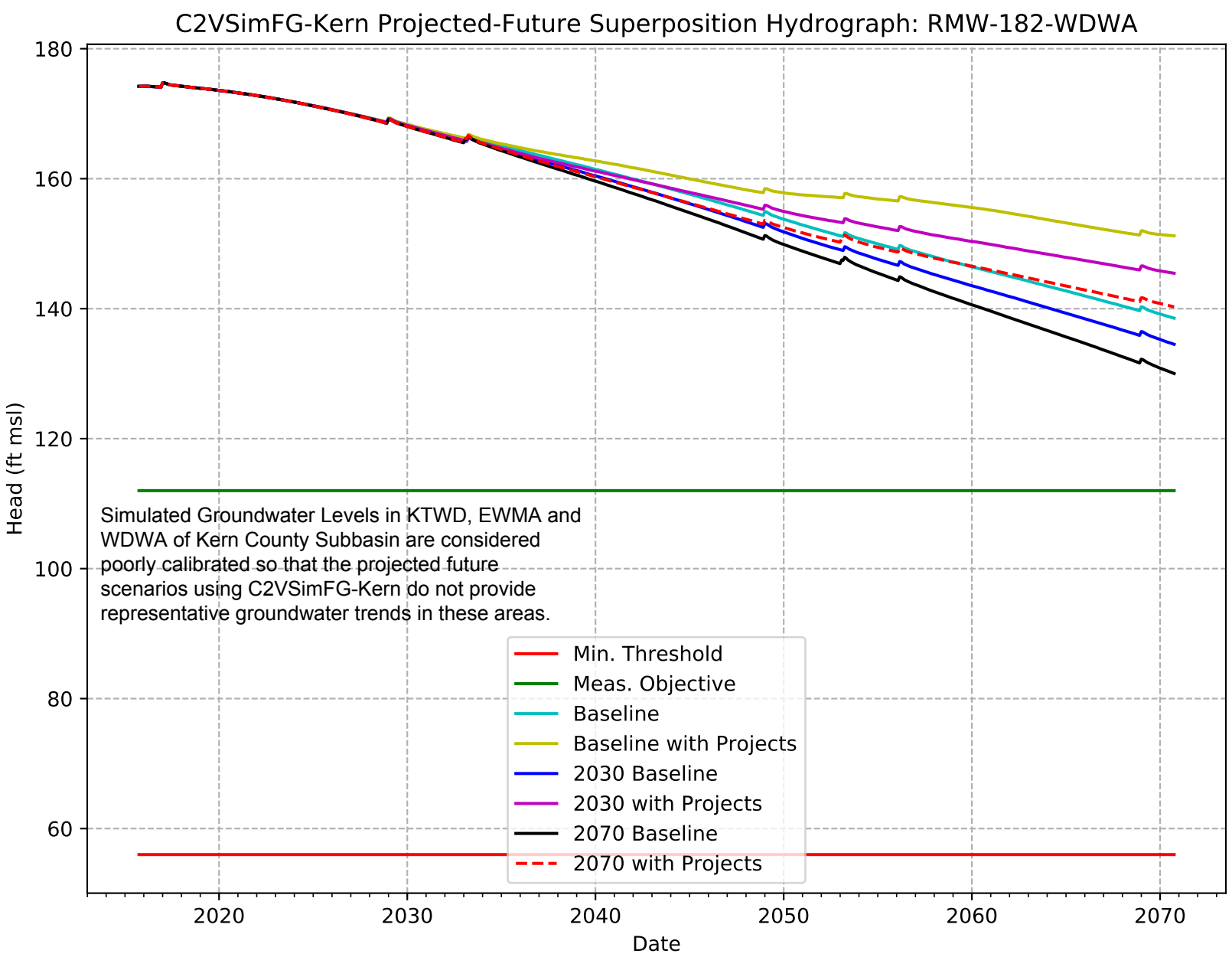

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-177-KTWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

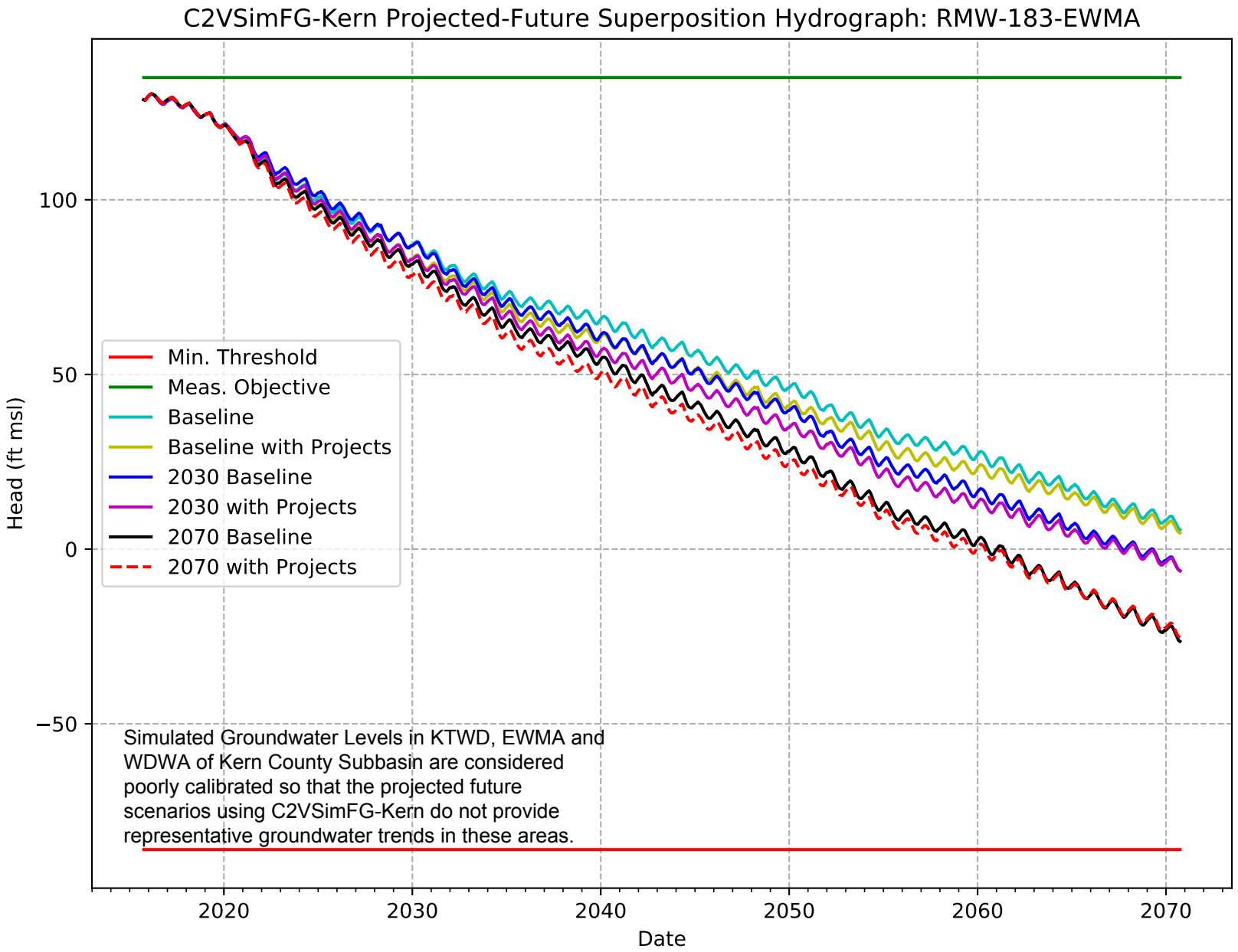

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-178-KTWD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

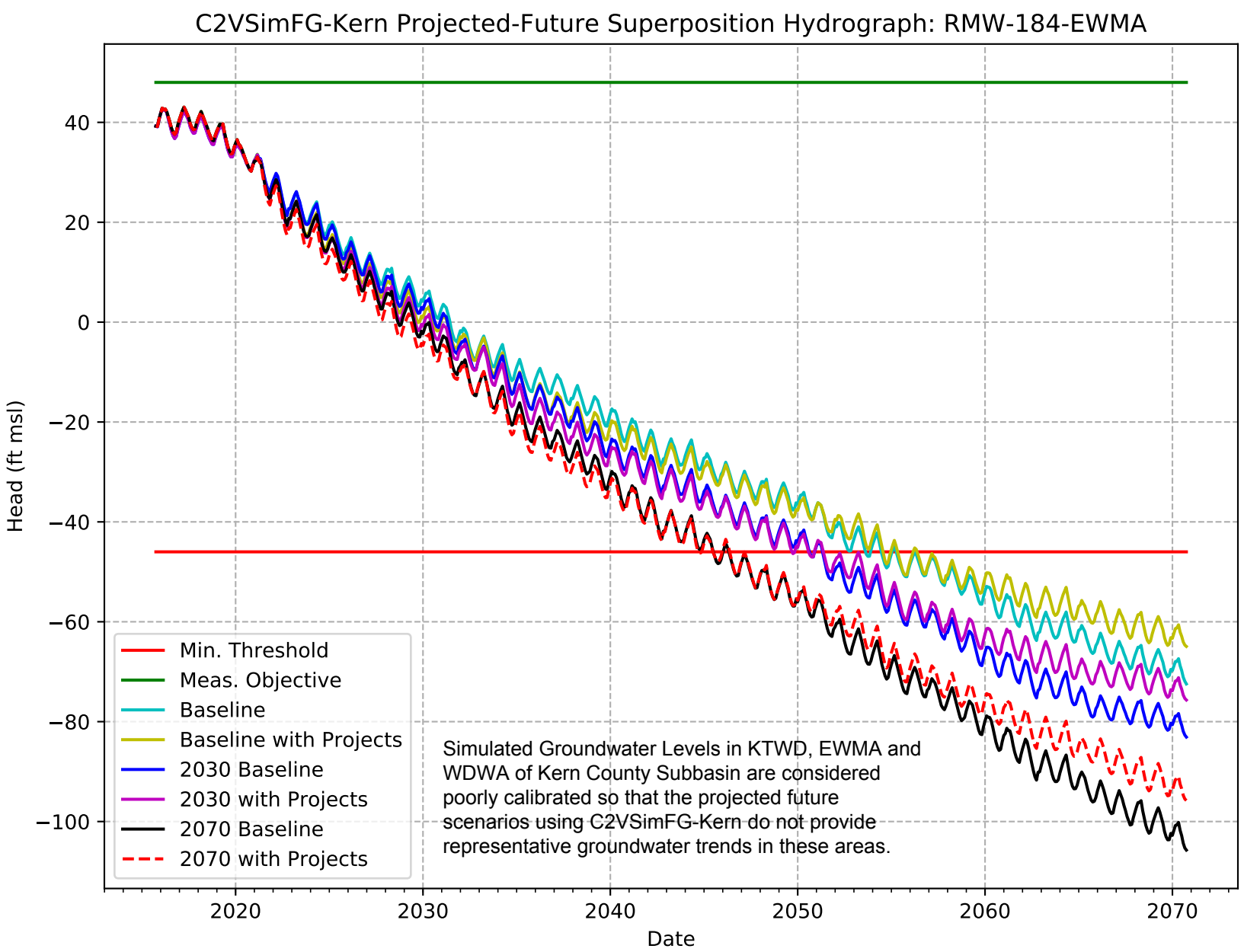

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-179-KTWD
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and
WDWA of Kern County Subbasin are considered
poorly calibrated so that the projected future
scenarios using C2VSimFG-Kern do not provide
representative groundwater trends in these areas.

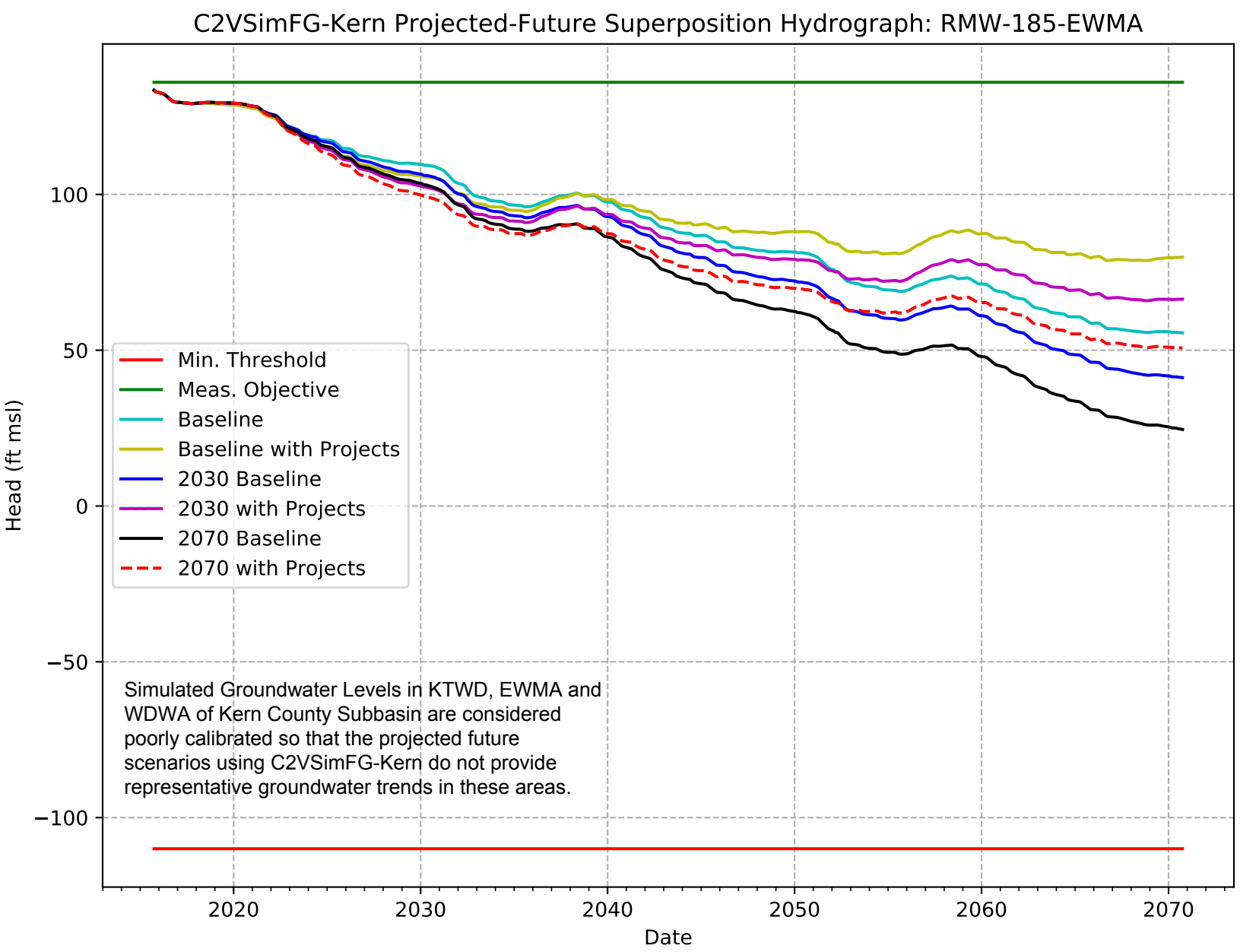

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-180-KTWD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

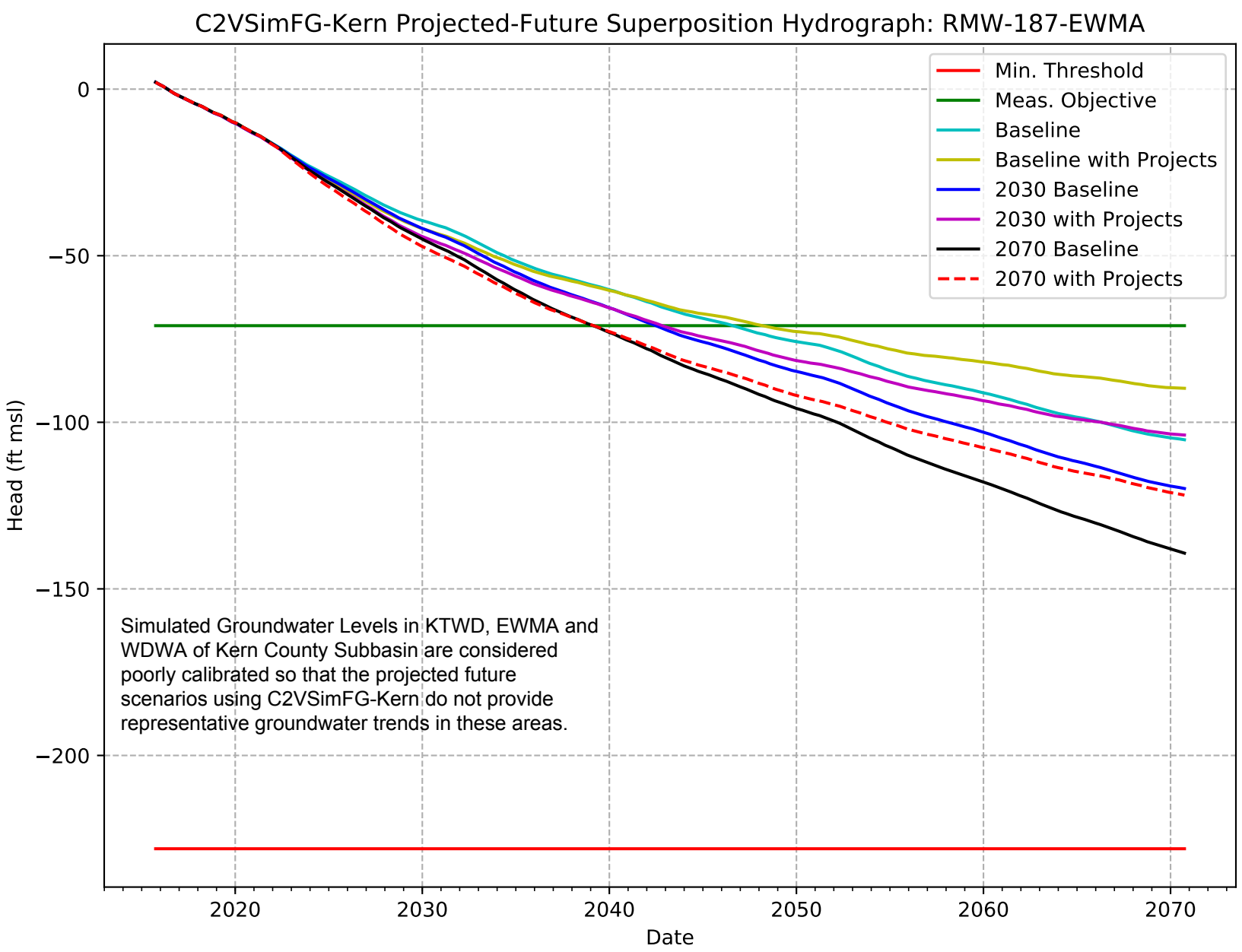

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-181-WDWA
Head (ft msl)
20
0
−20
−40
−60
−80
−100
−120
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

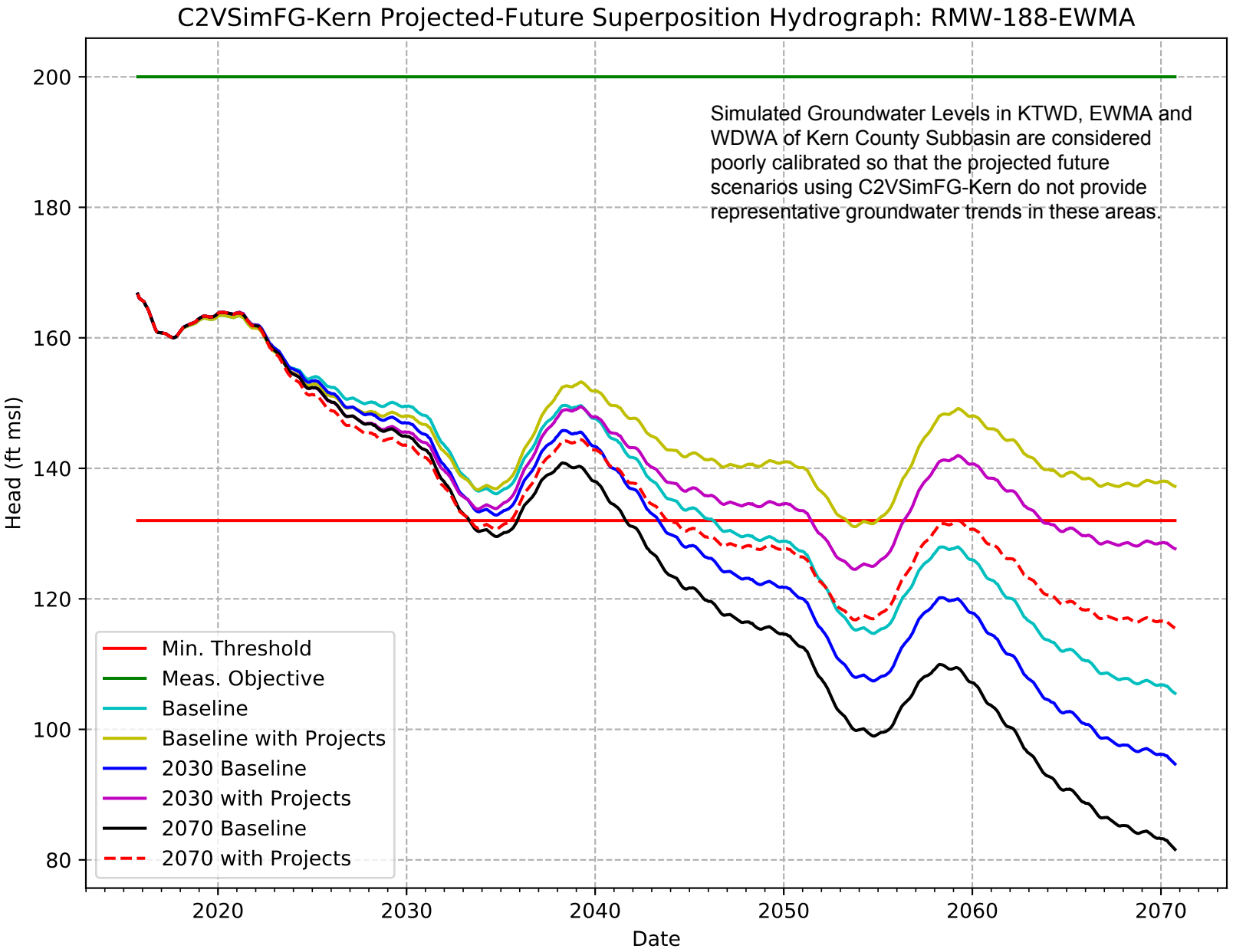

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-182-WDWA
Head (ft msl)
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

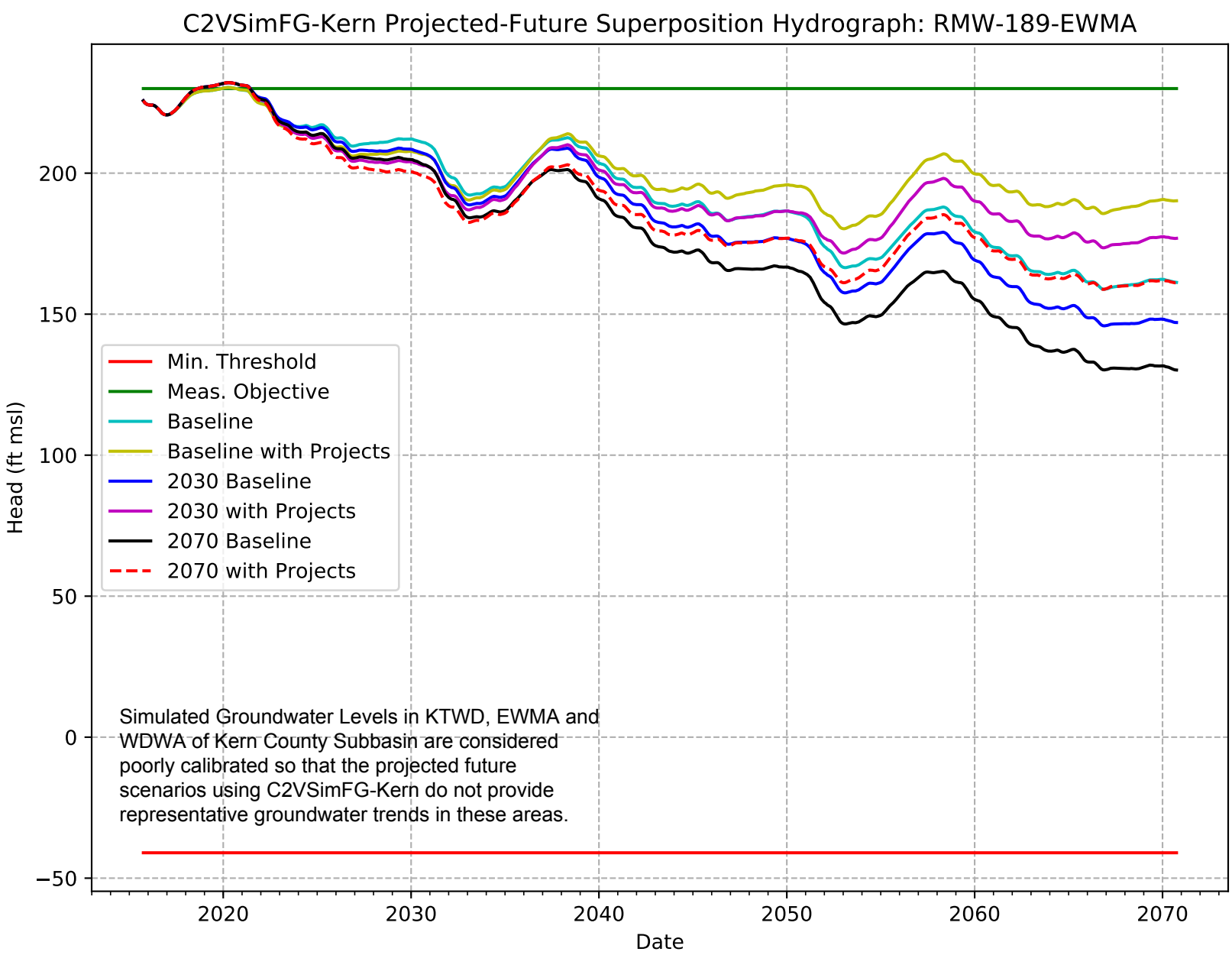

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-183-EWMA
Head (ft msl)
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

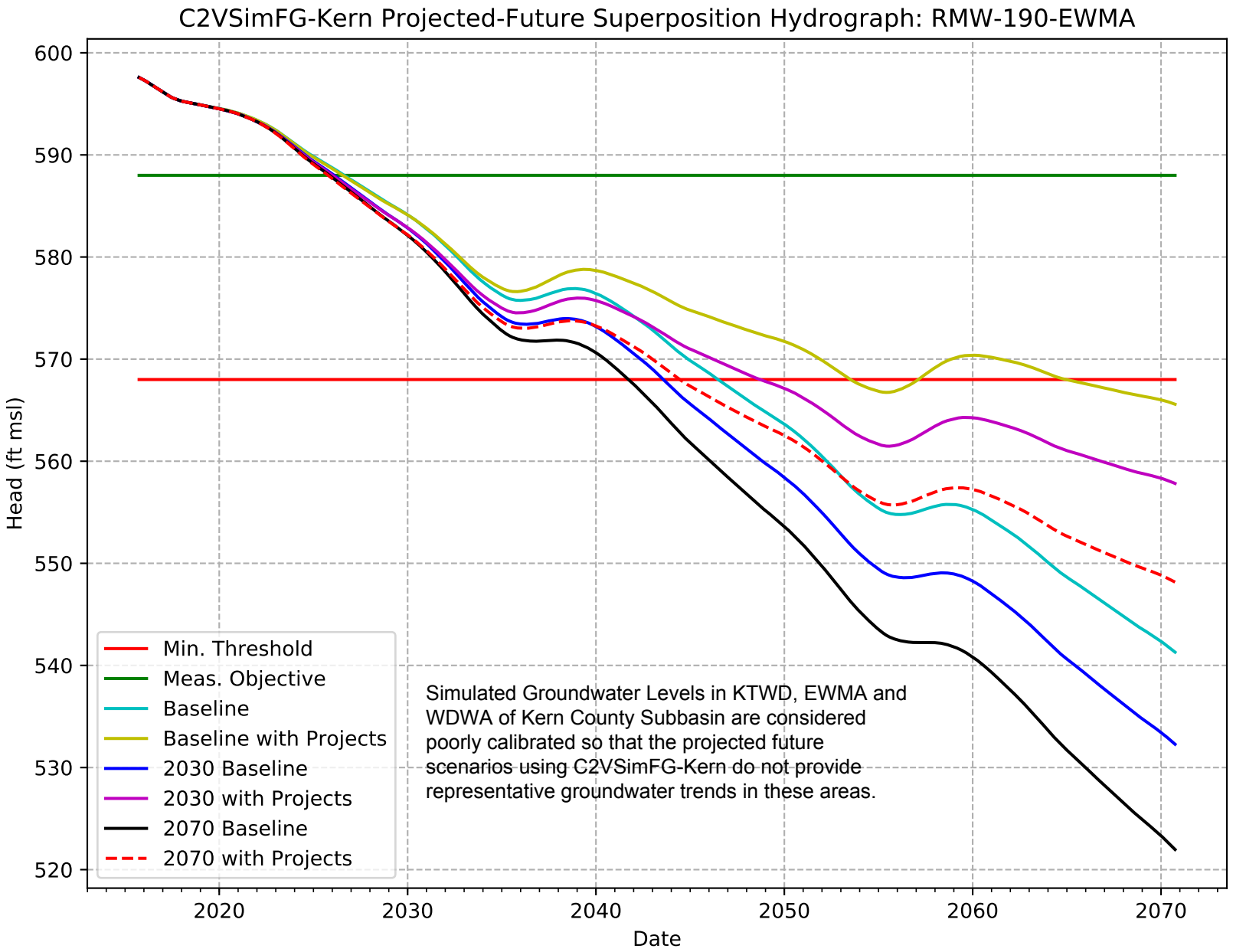

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-184-EWMA
Head (ft msl)
40
20
0
−20
−40
−60
−80
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

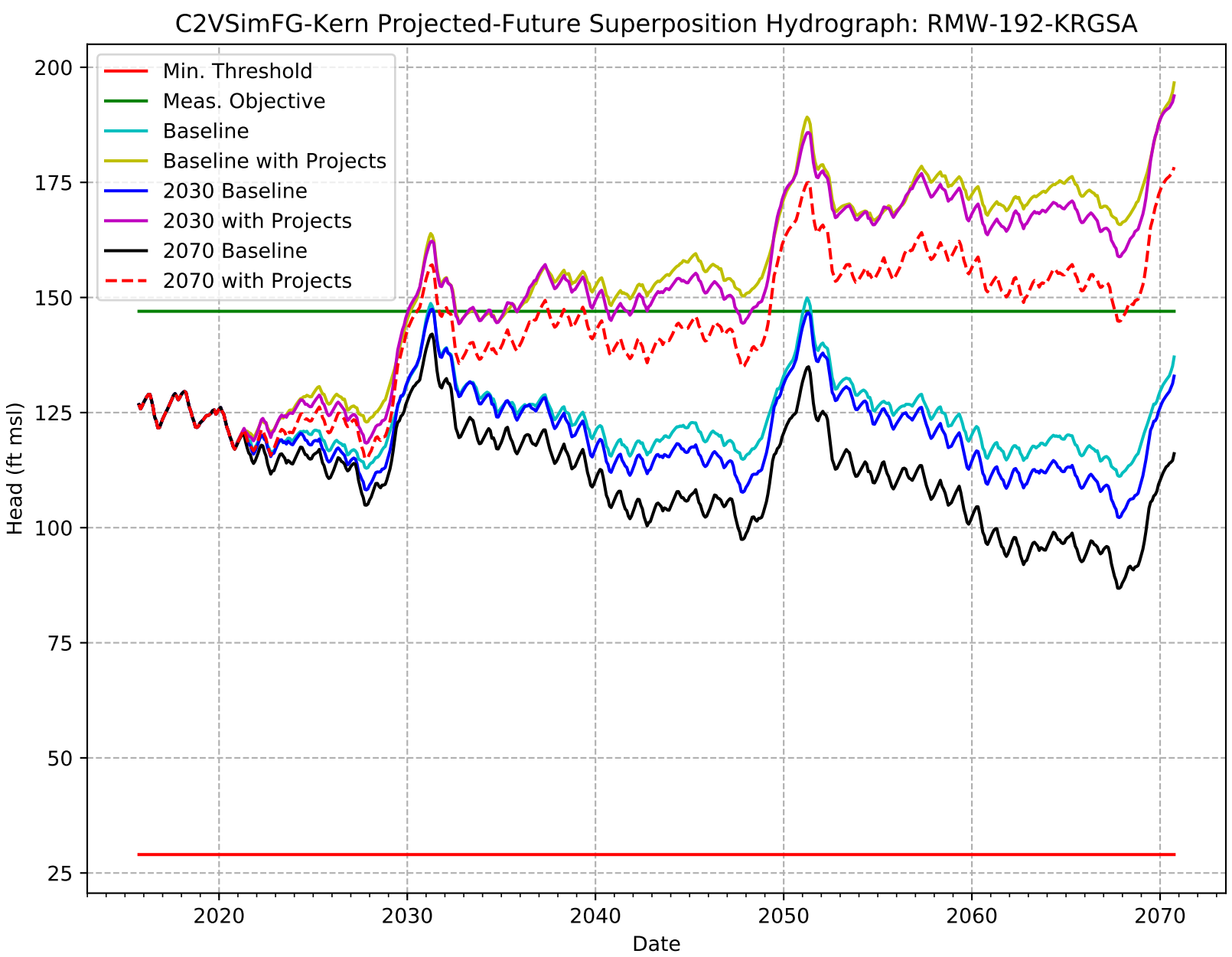

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-185-EWMA
Head (ft msl)
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

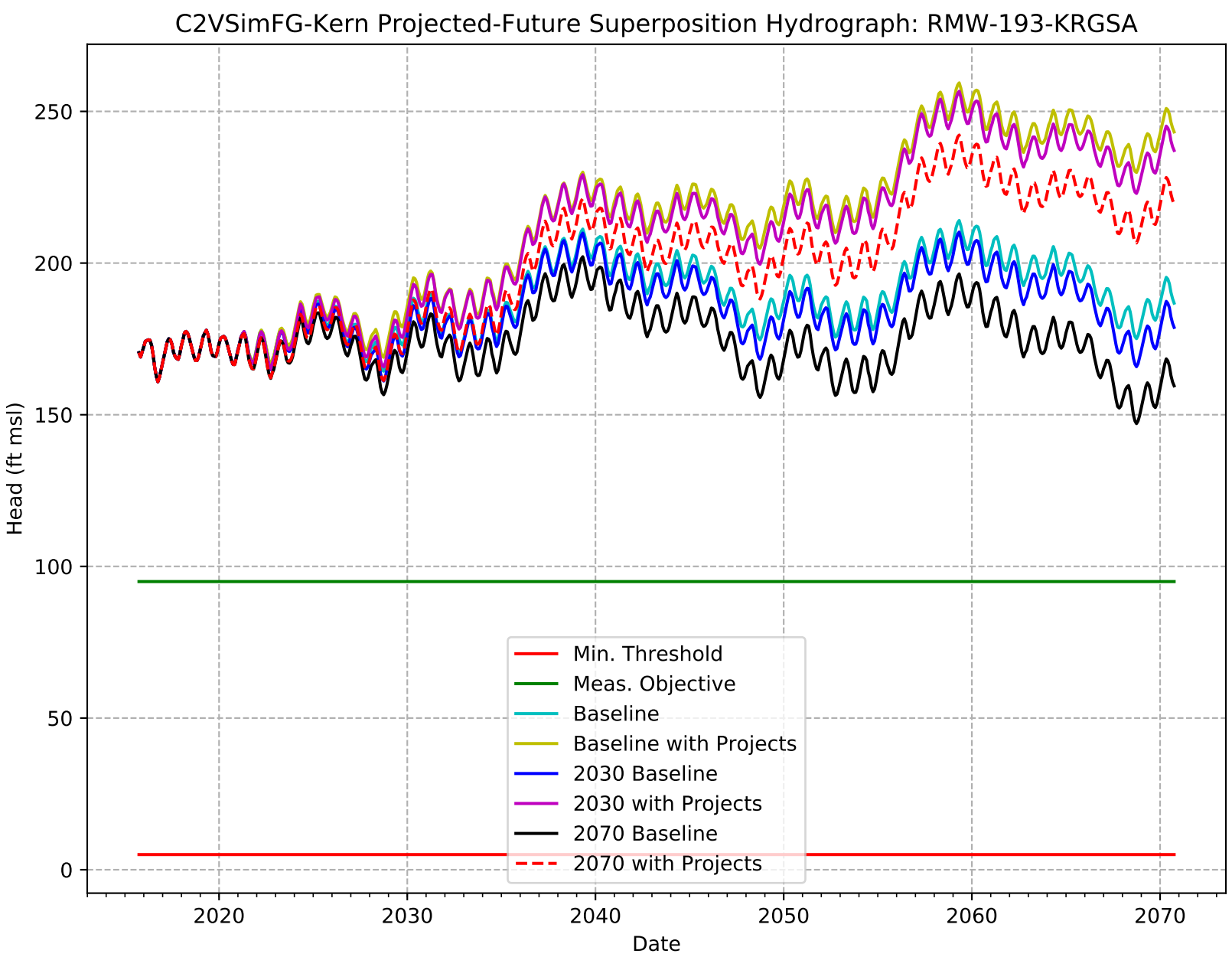

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-187-EWMA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
0
−50
−100
−150
−200
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

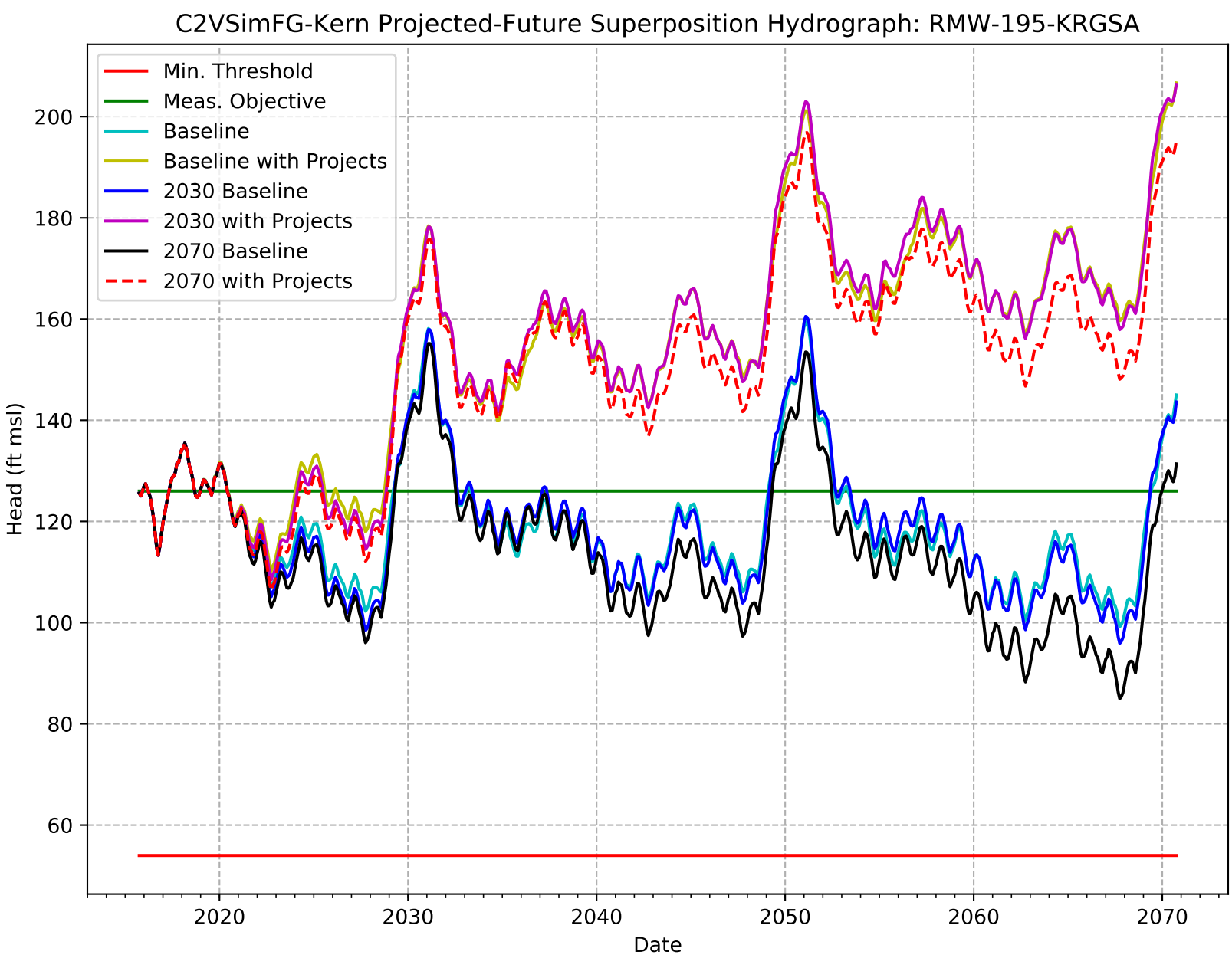

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-188-EWMA
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Head (ft msl)
Date
200
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

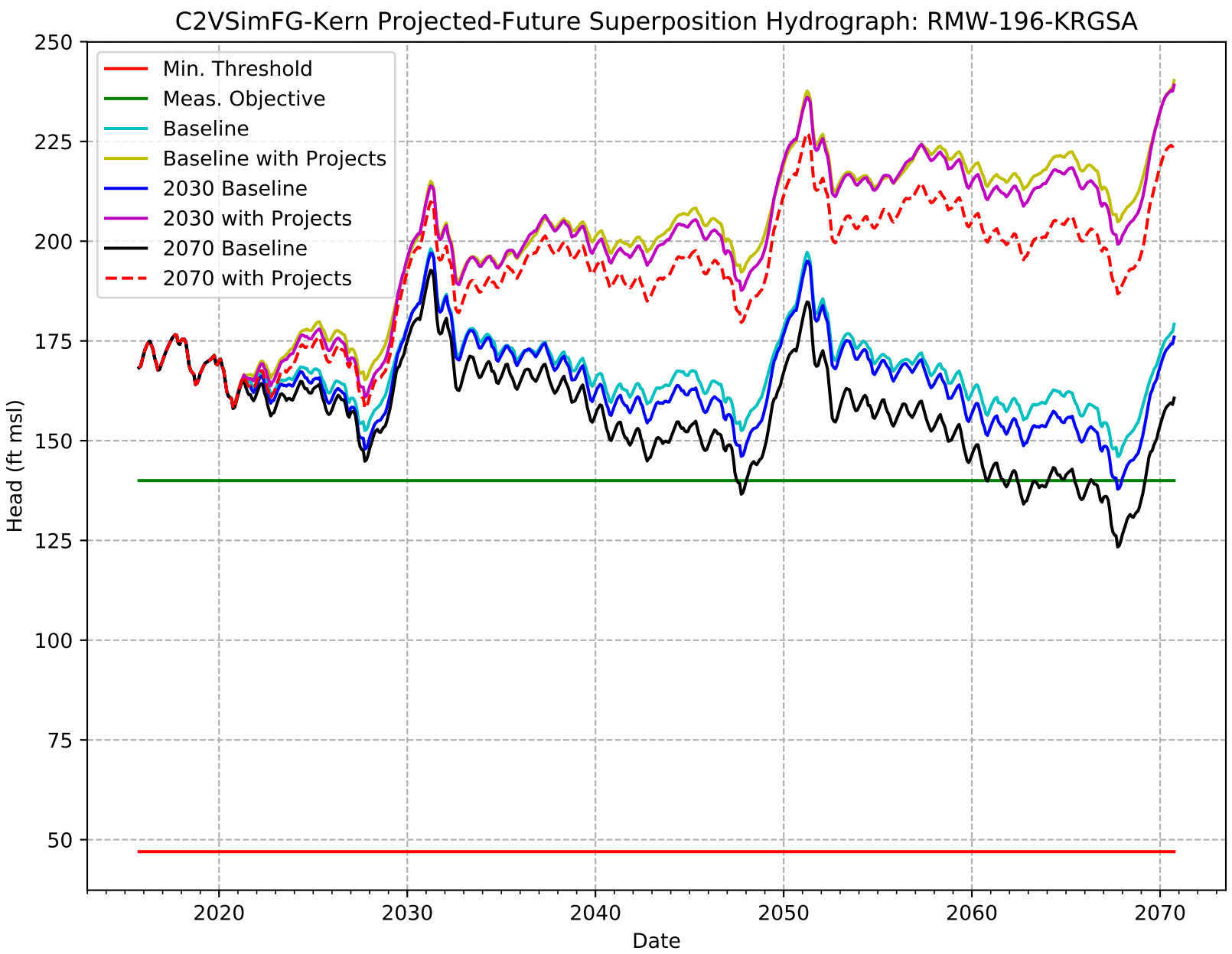

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-189-EWMA
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

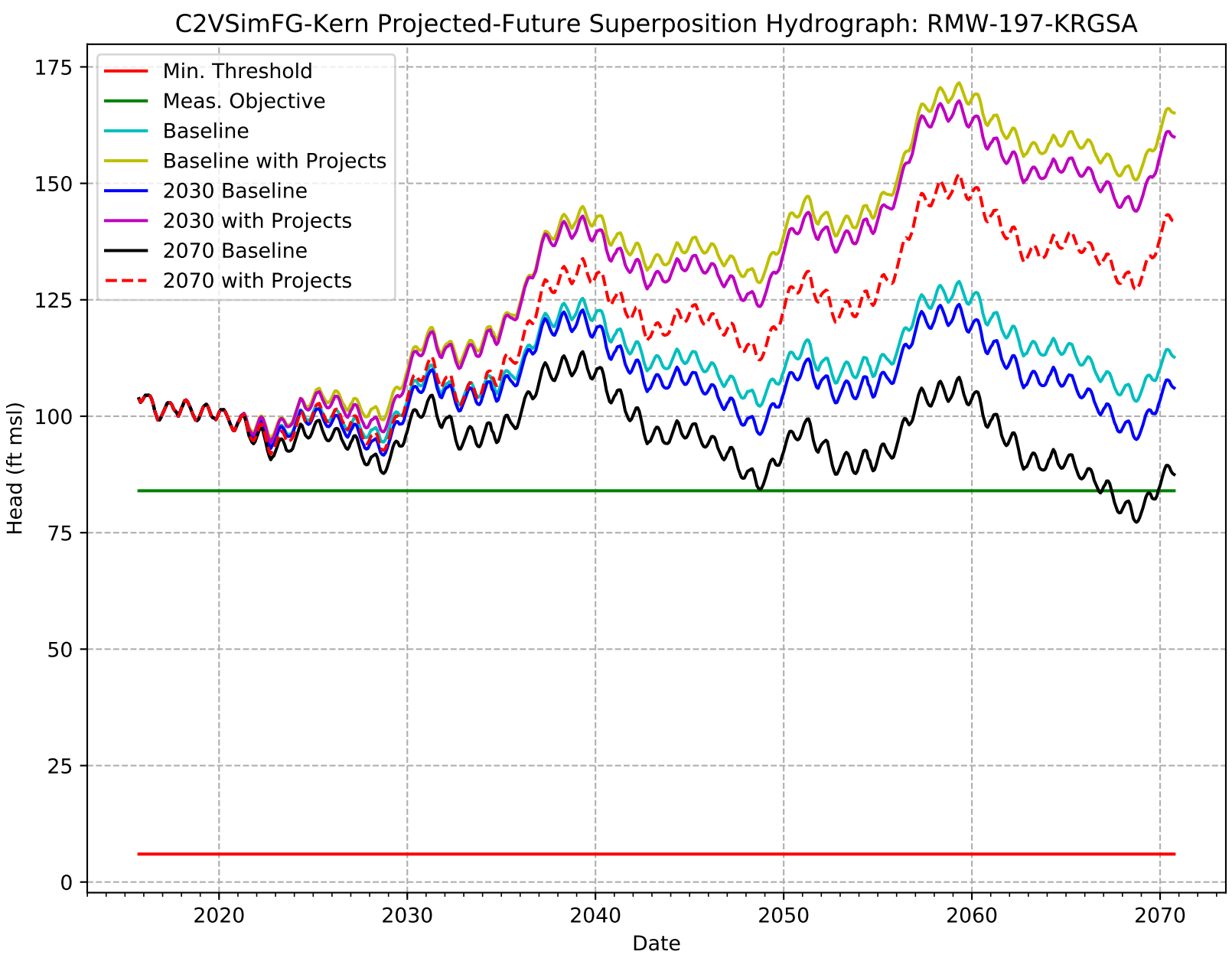

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-190-EWMA
Head (ft msl)
600
590
580
570
560
550
540
530
520
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

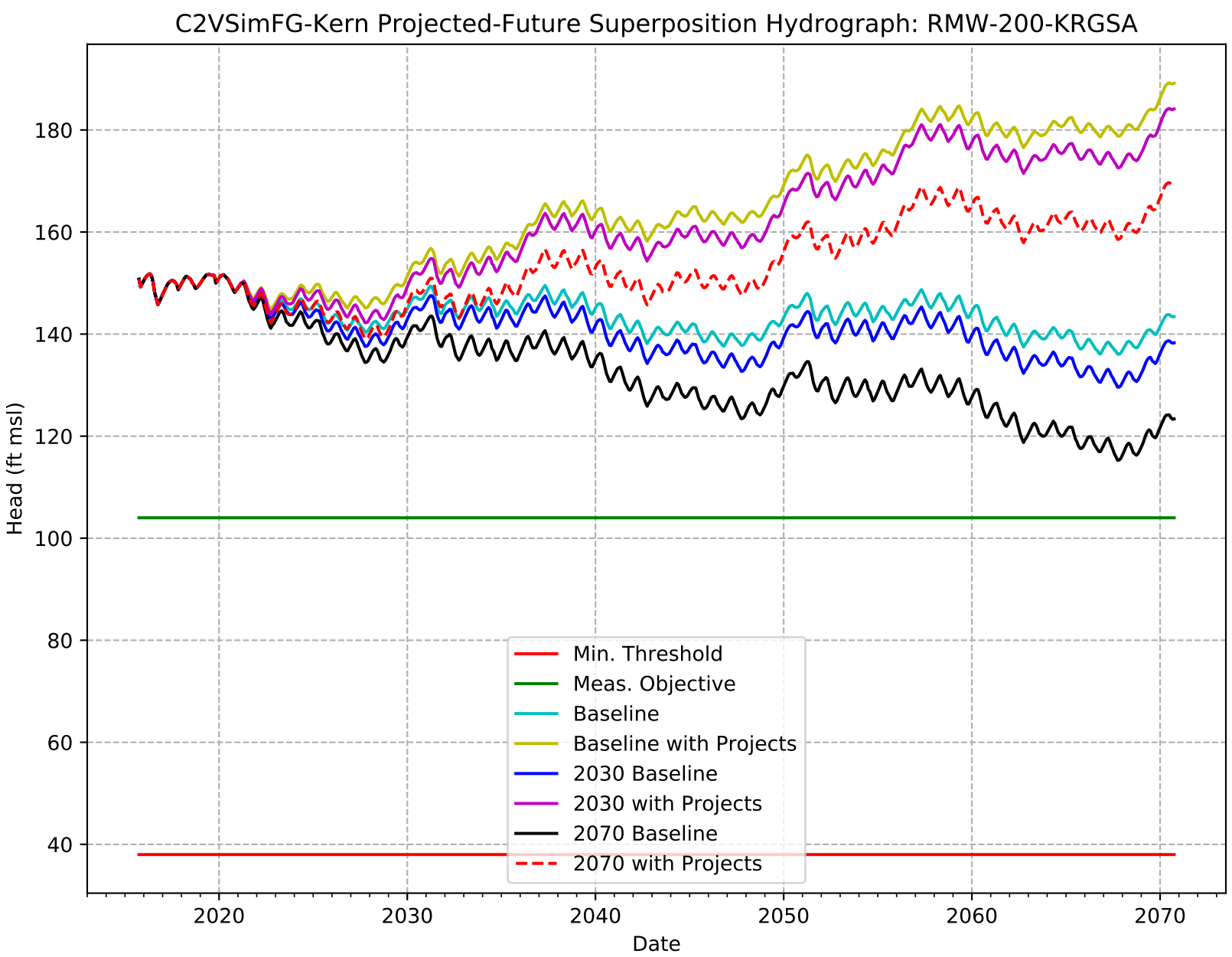

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-192-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
175
150
125
100
75
50
25
2020
2030
2040
2050
2060
2070
Date

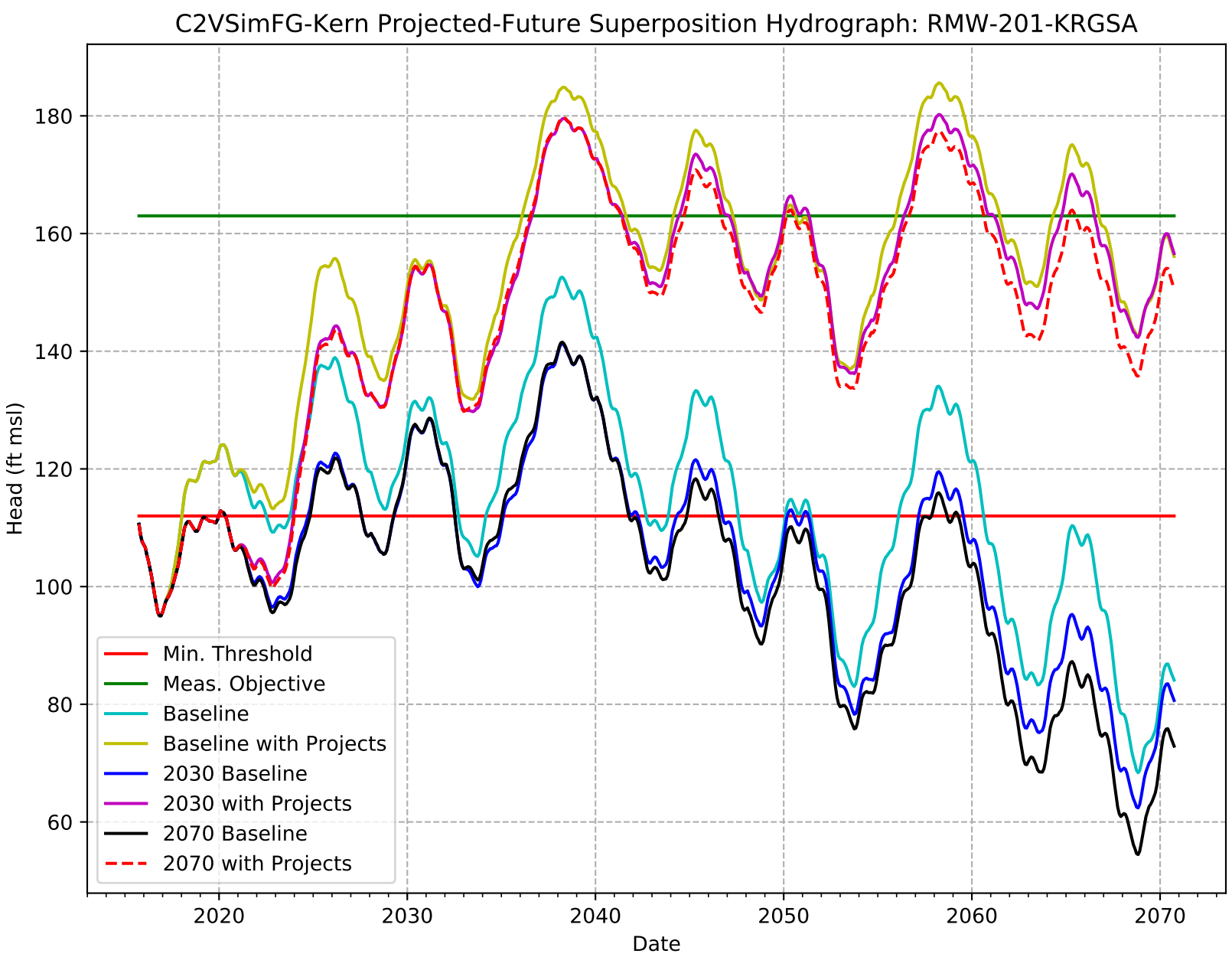

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-193-KRGSA
Head (ft msl)
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

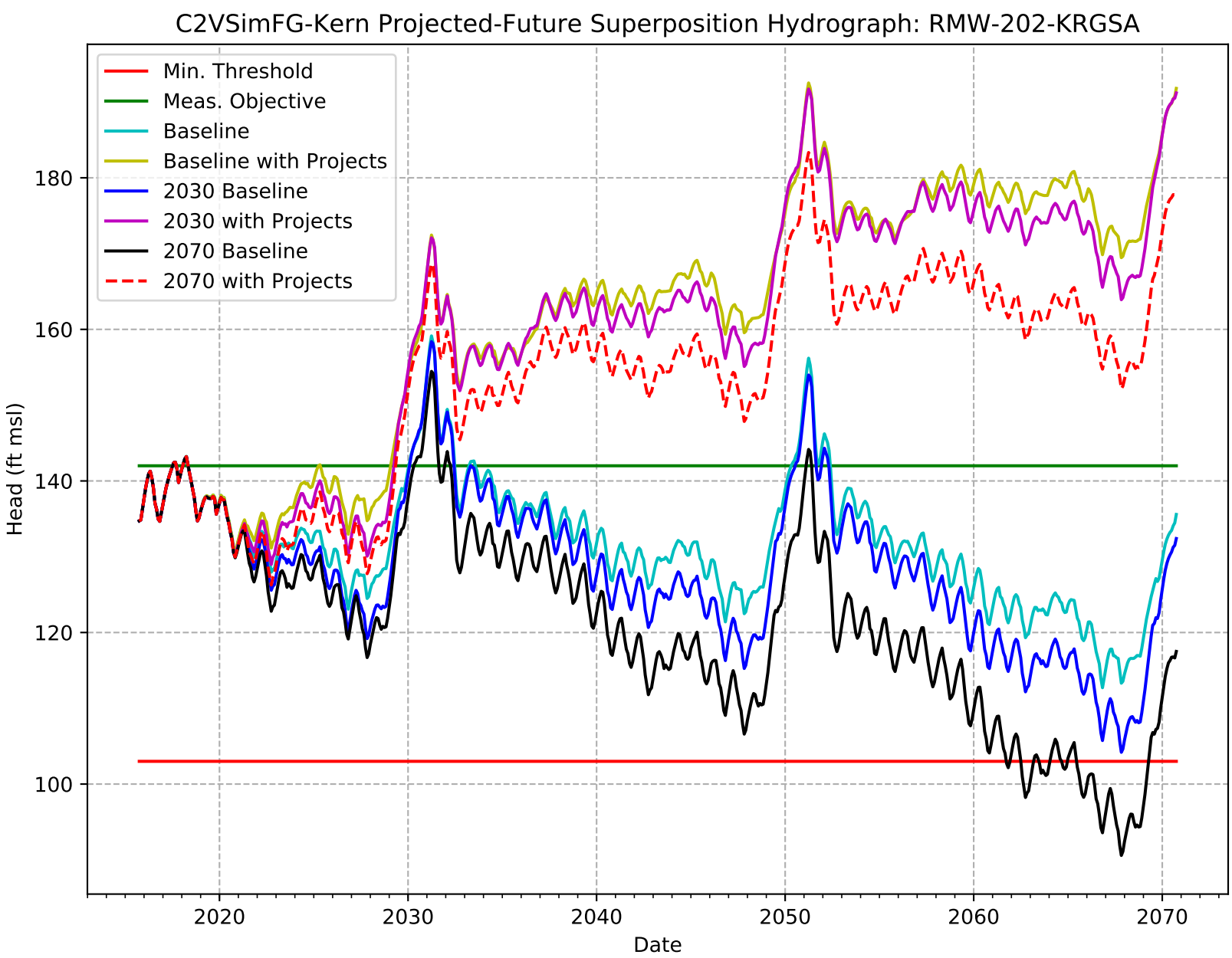

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-195-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

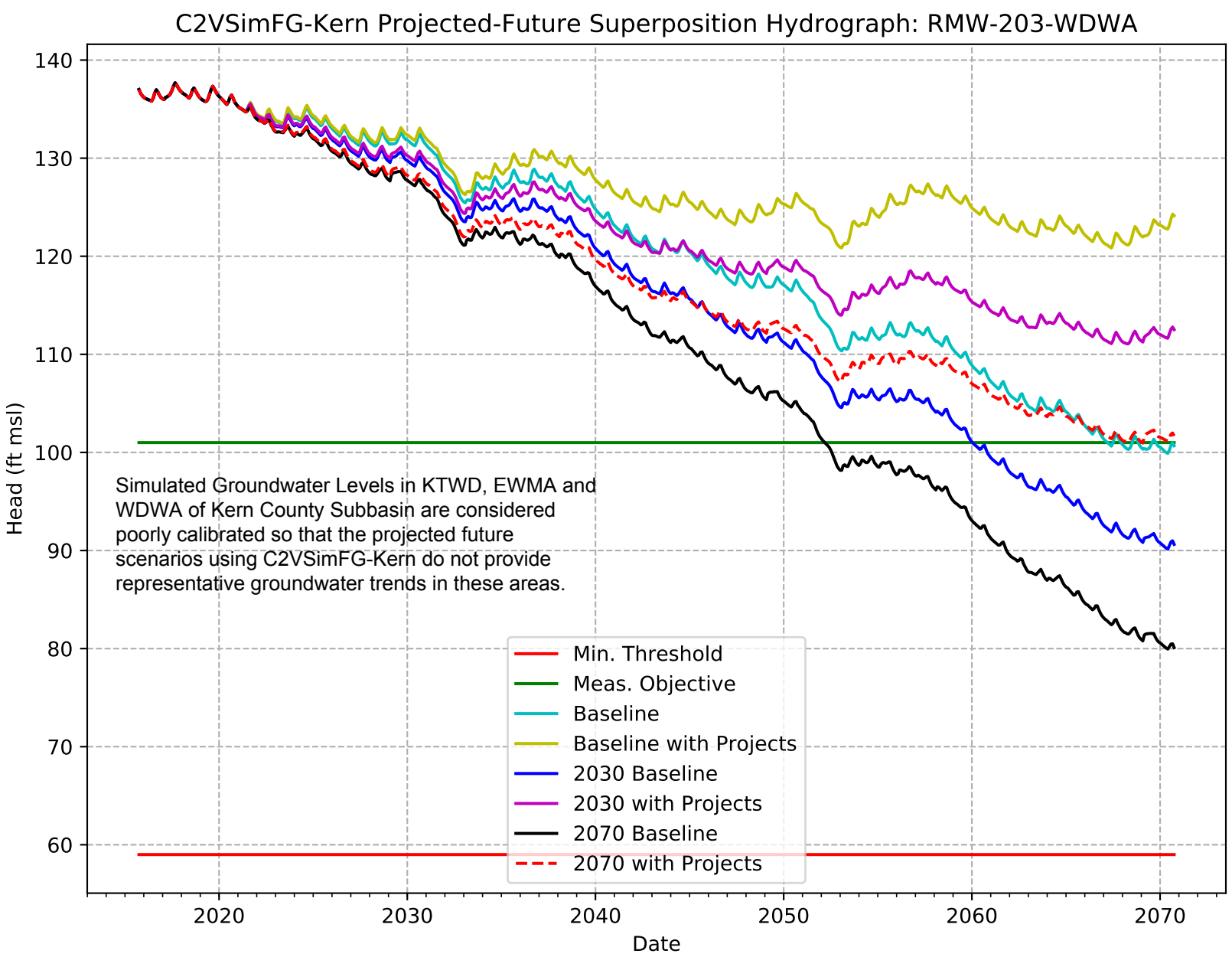

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-196-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
225
200
175
150
125
100
75
50
2020
2030
2040
2050
2060
2070
Date

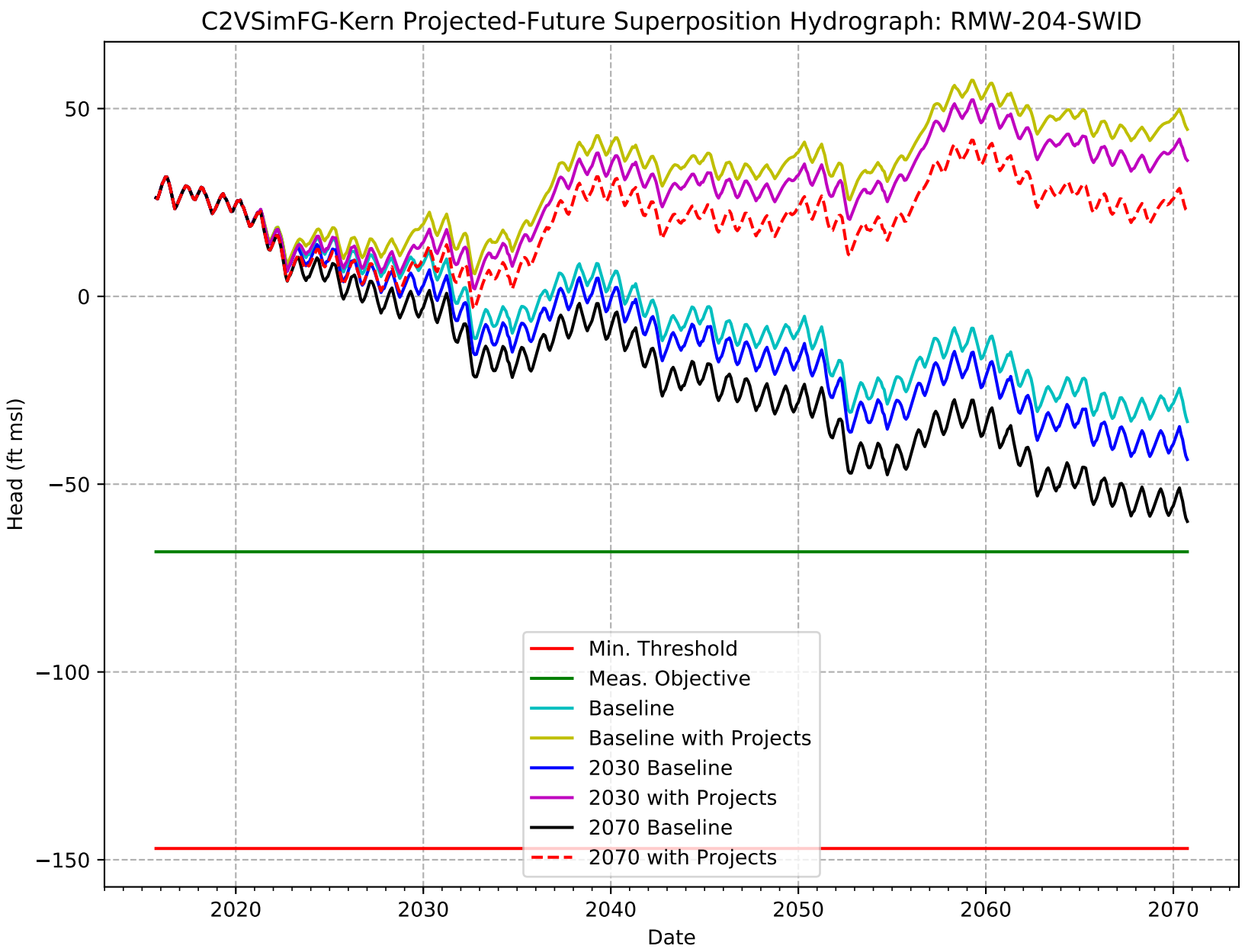

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-197-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
175
150
125
100
75
50
25
0
2020
2030
2040
2050
2060
2070
Date

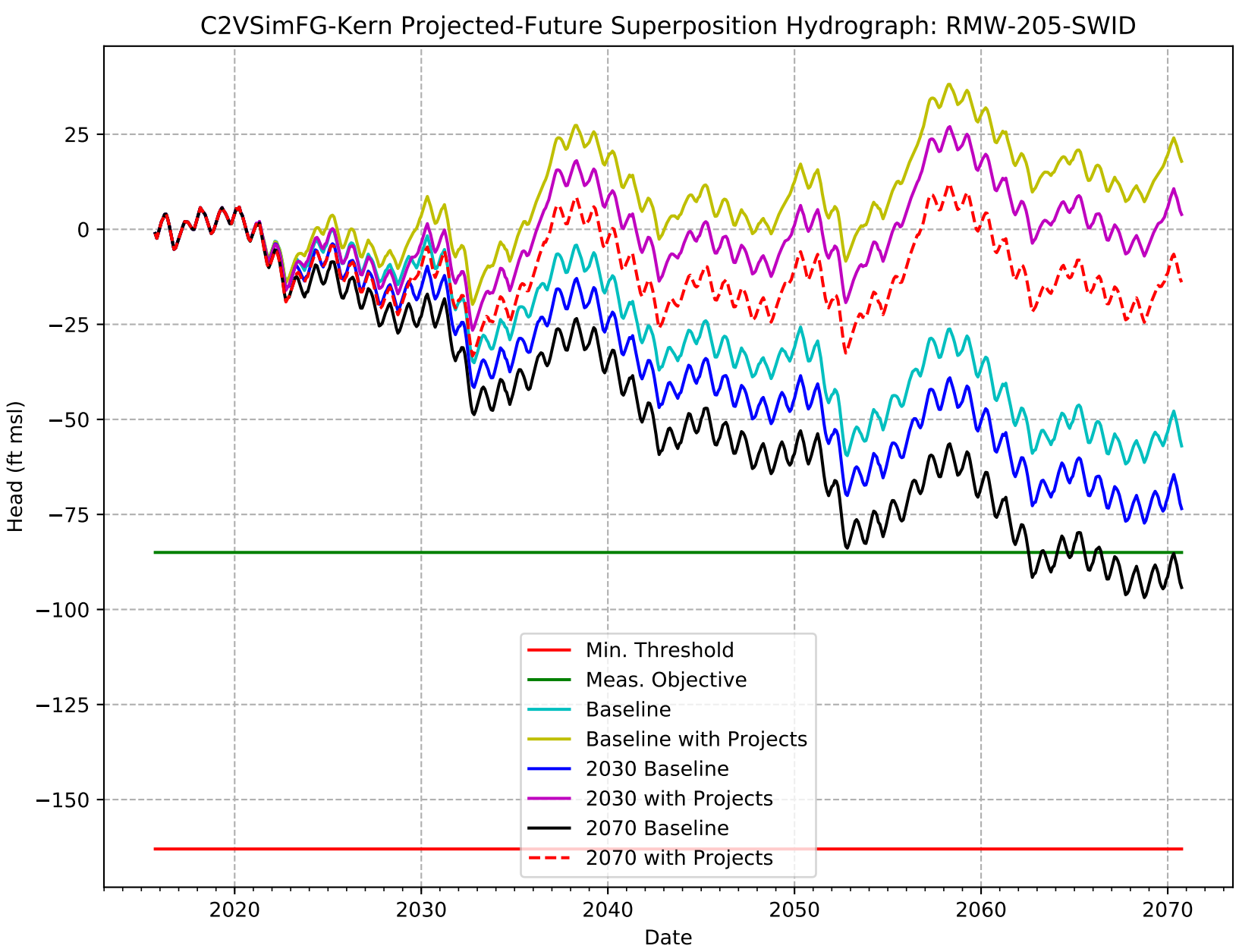

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-200-KRGSA
Head (ft msl)
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

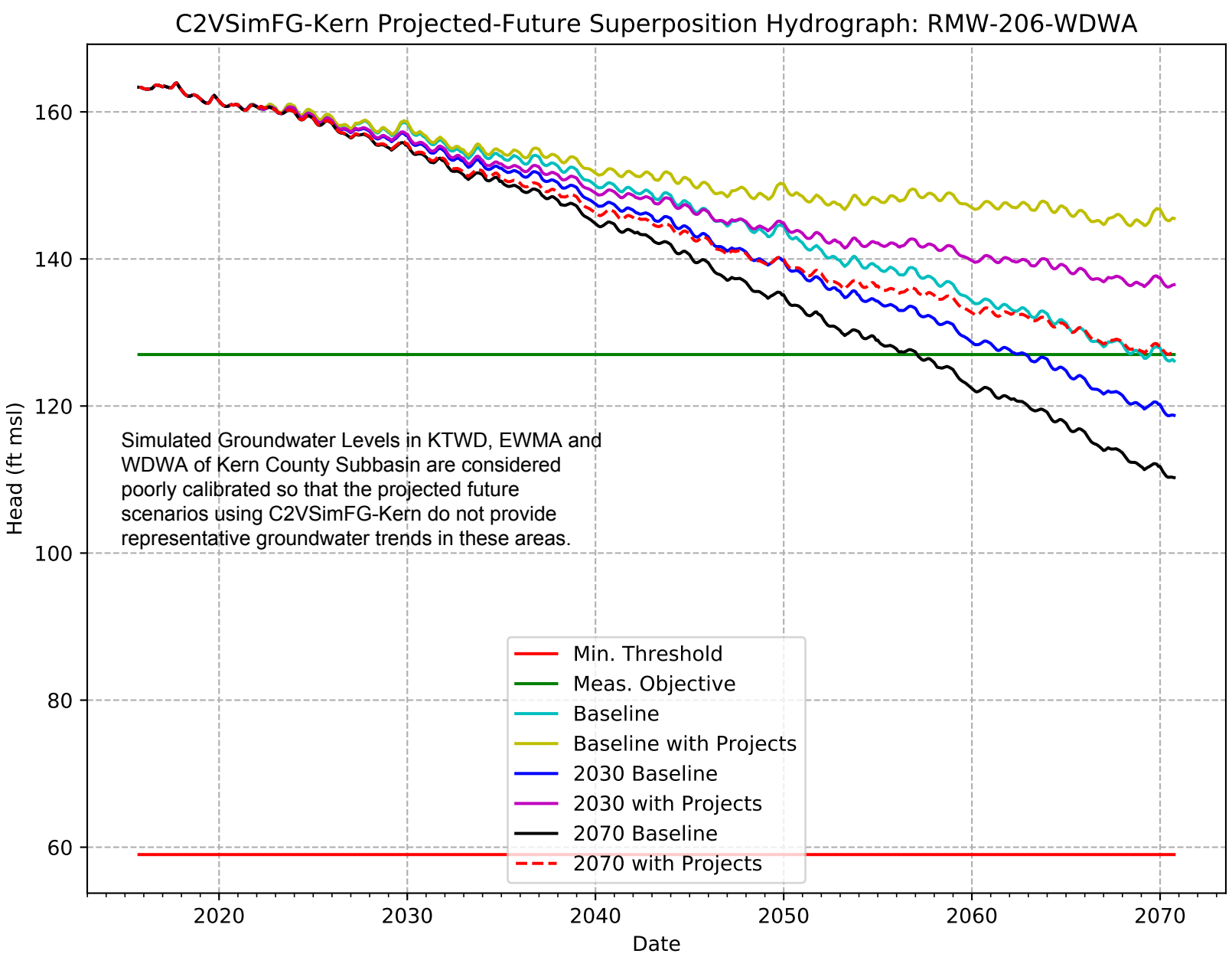

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-201-KRGSA
Head (ft msl)
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

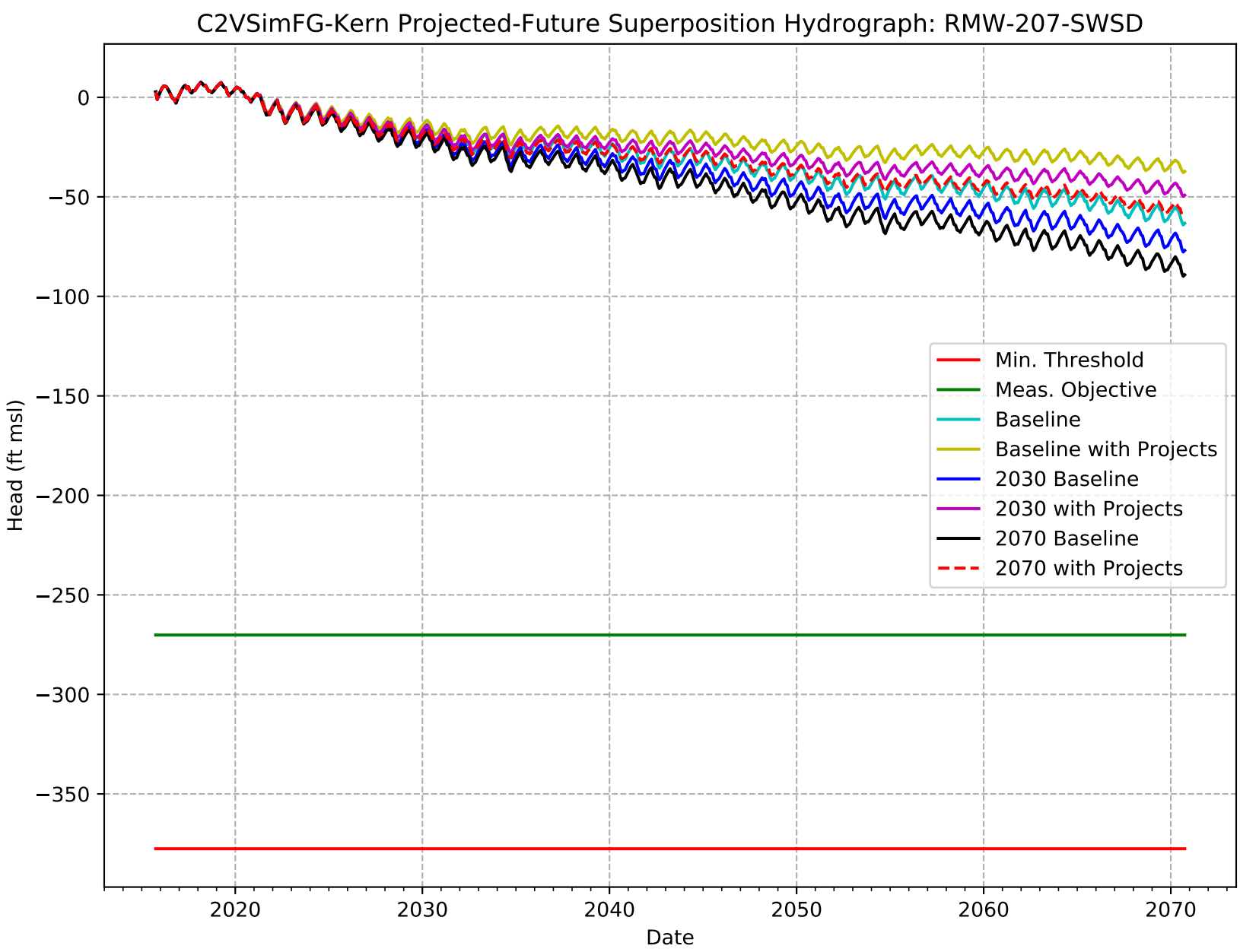

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-202-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date

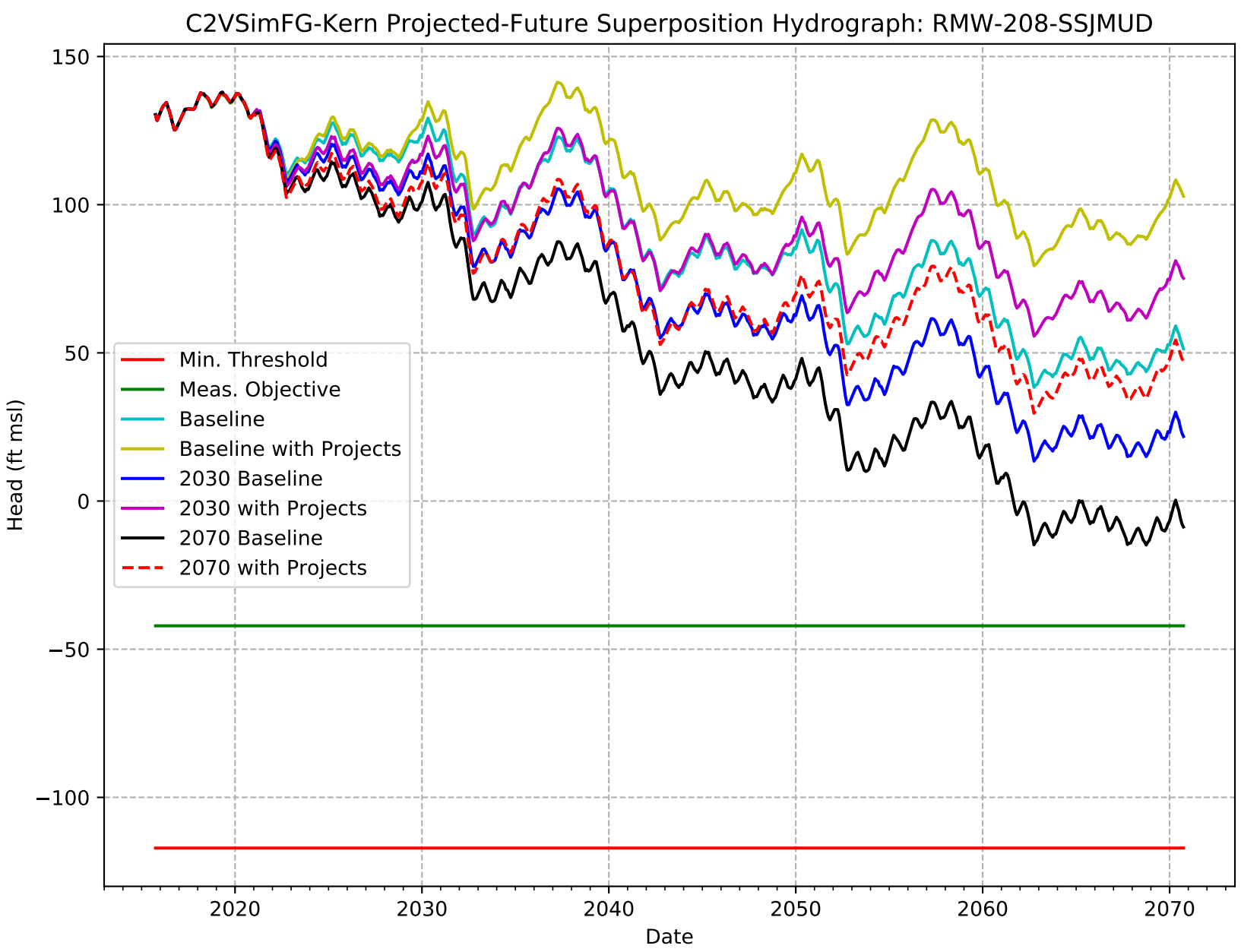

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-203-WDWA
Head (ft msl)
Date
140
130
120
110
100
90
80
70
60
2020
2030
2040
2050
2060
2070
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

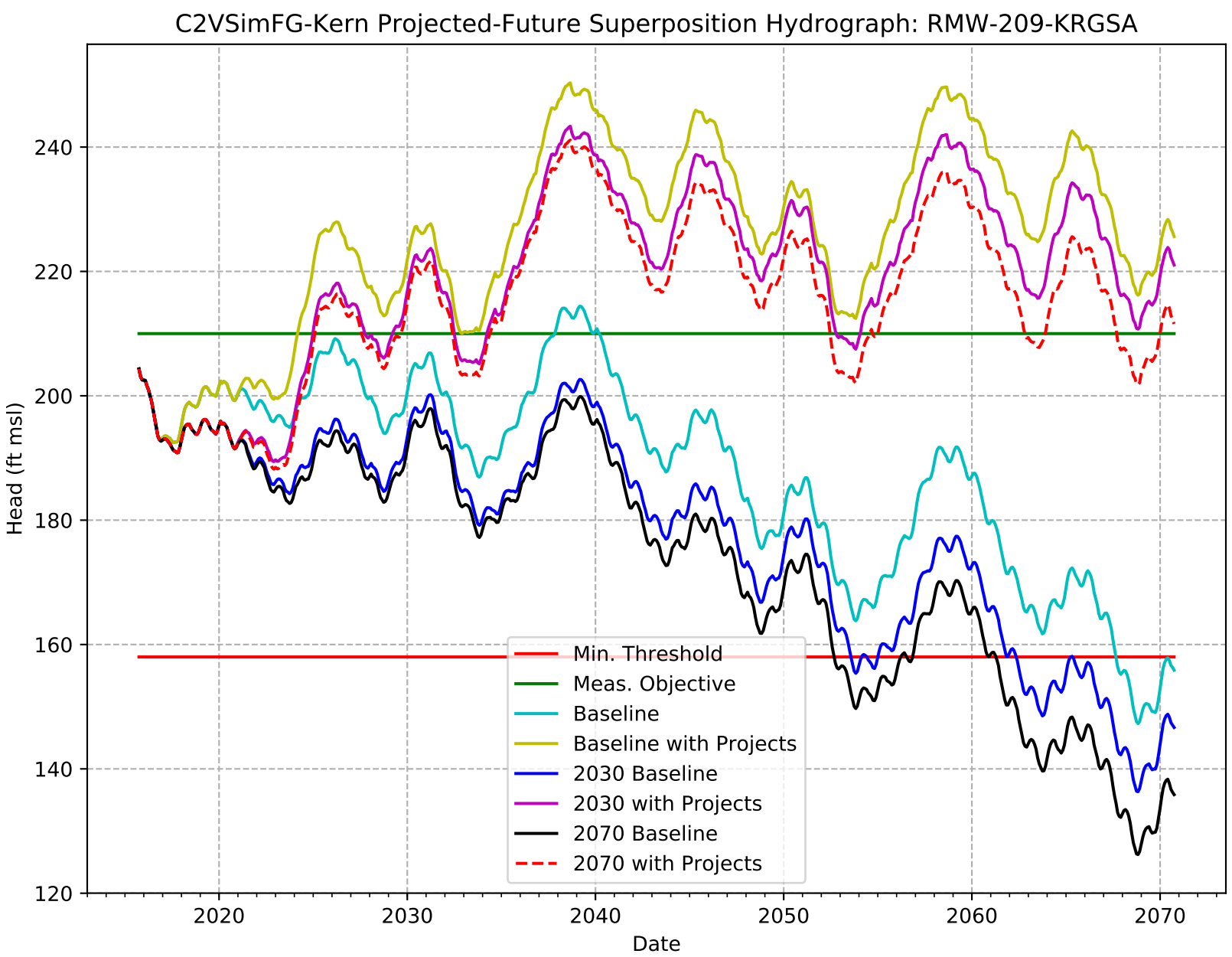

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-204-SWID
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

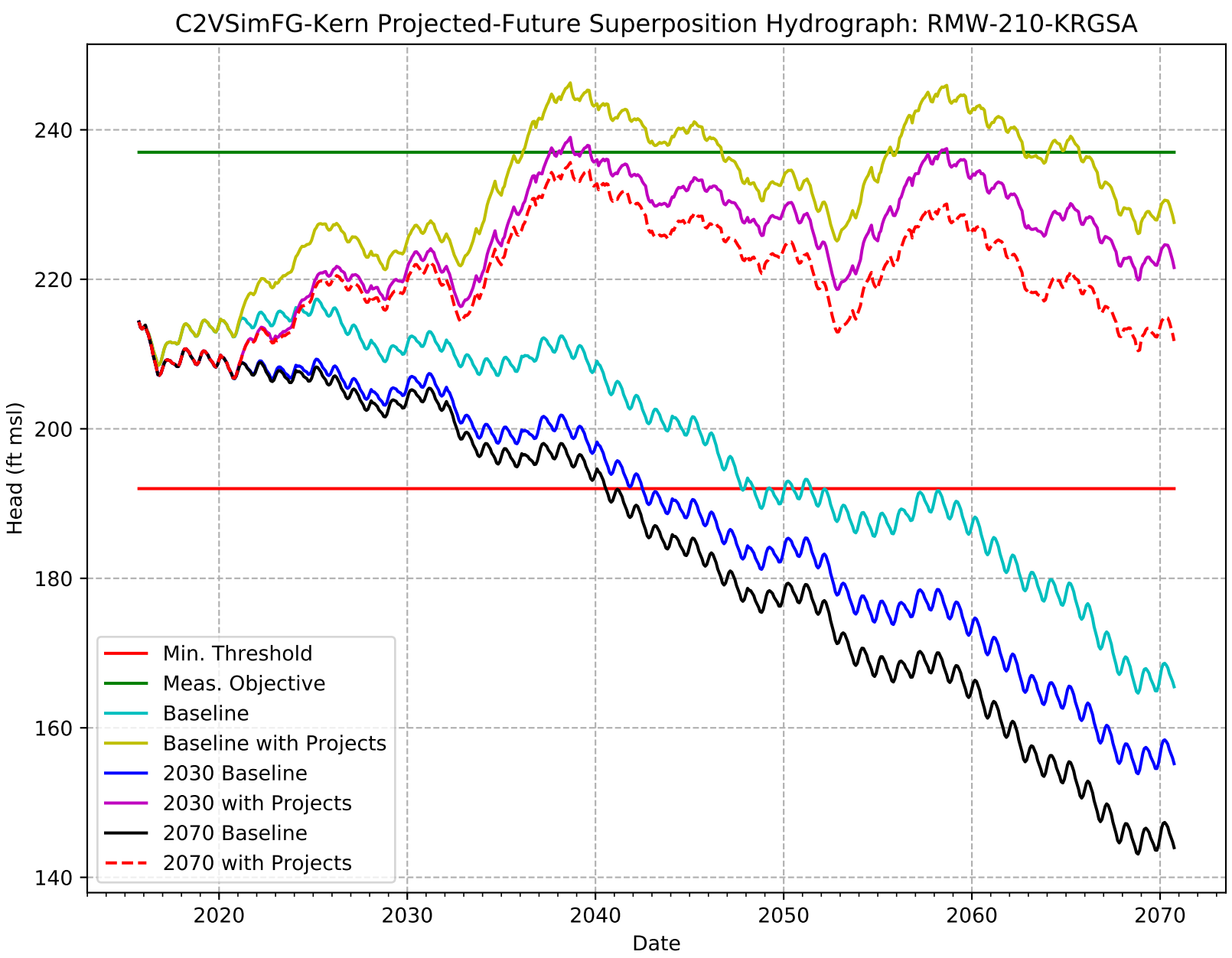

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-205-SWID
Head (ft msl)
25
0
−25
−50
−75
−100
−125
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

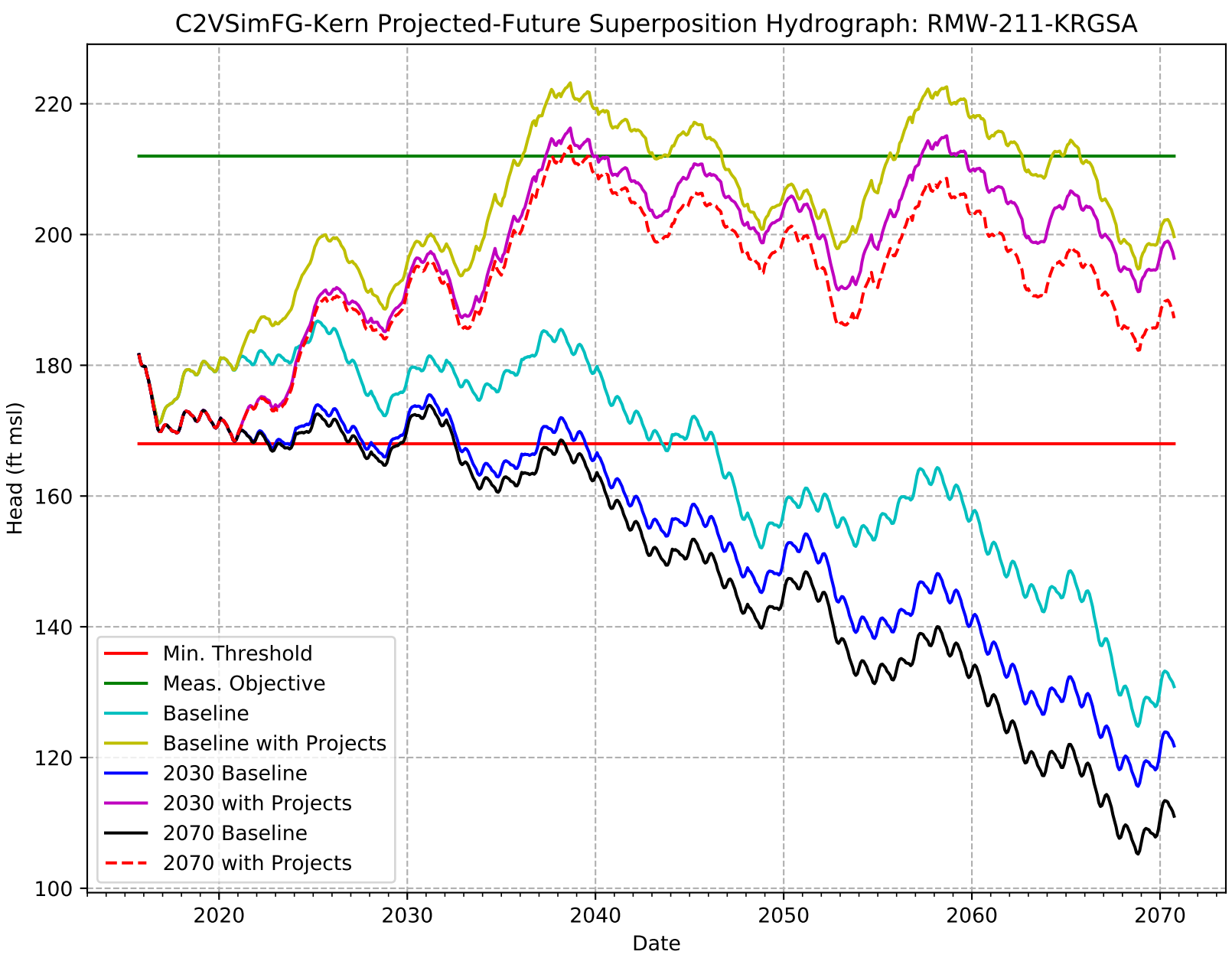

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-206-WDWA
Head (ft msl)
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

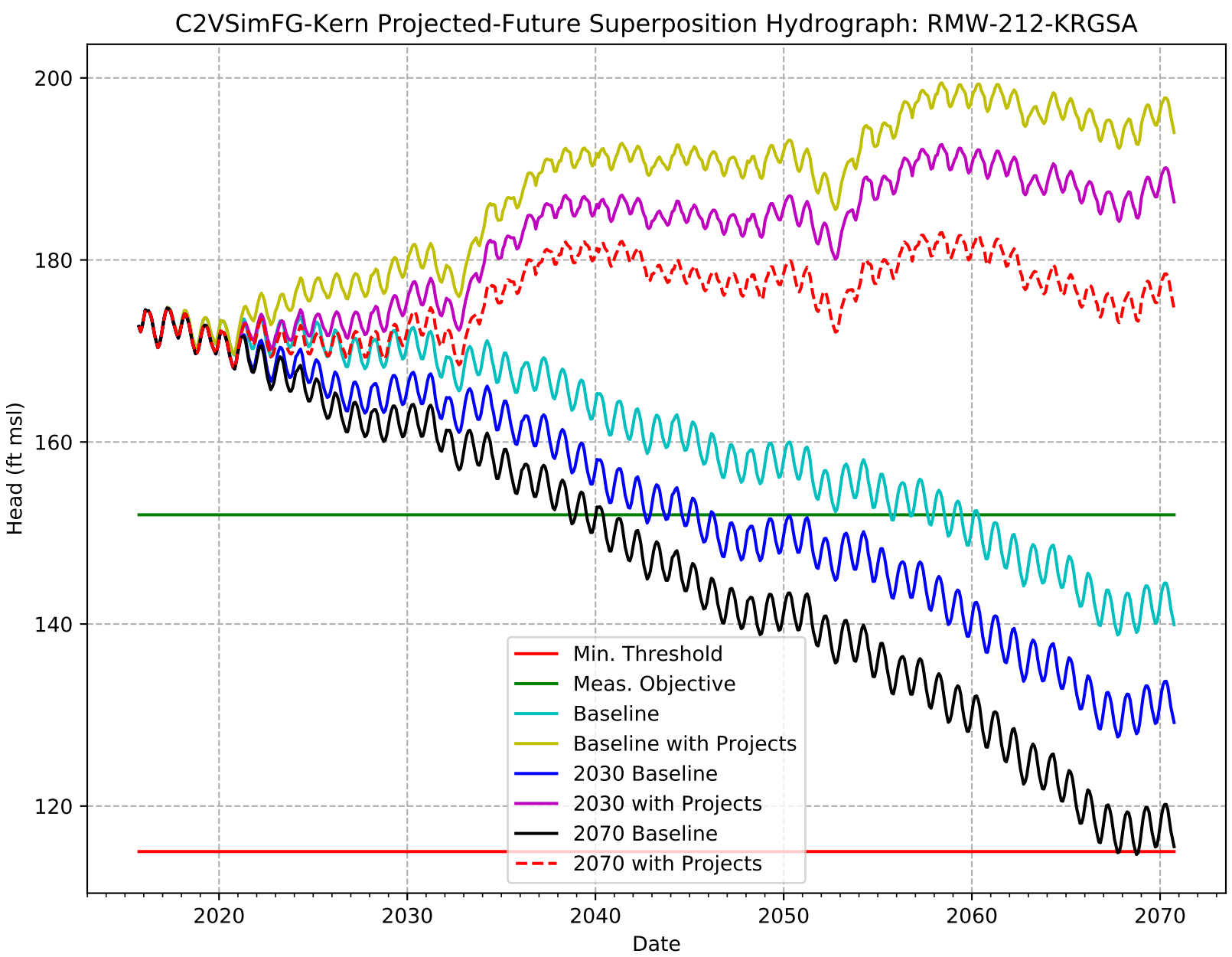

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-207-SWSD
Head (ft msl)
0
−50
−100
−150
−200
−250
−300
−350
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

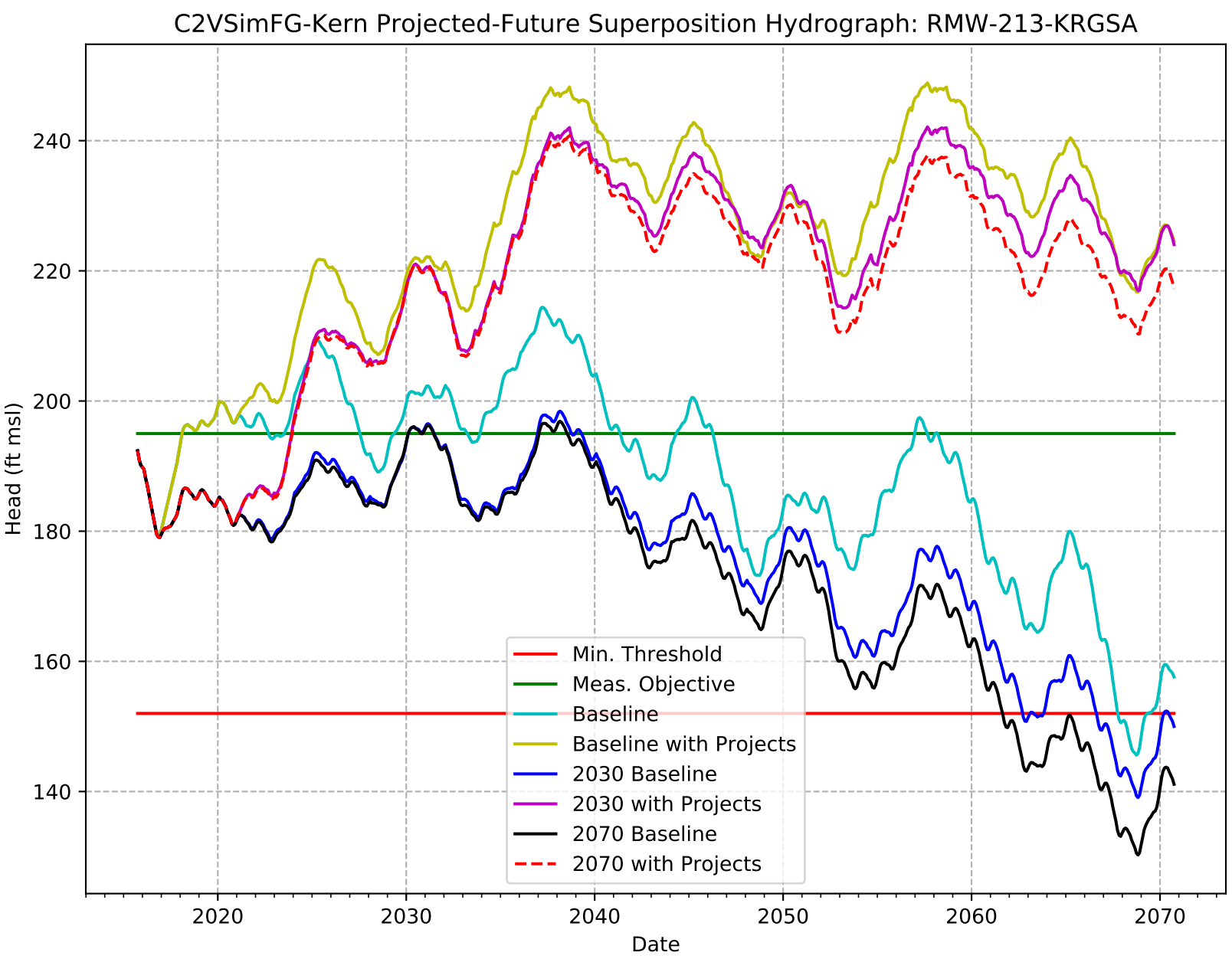

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-208-SSJMUD
Head (ft msl)
Date
150
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

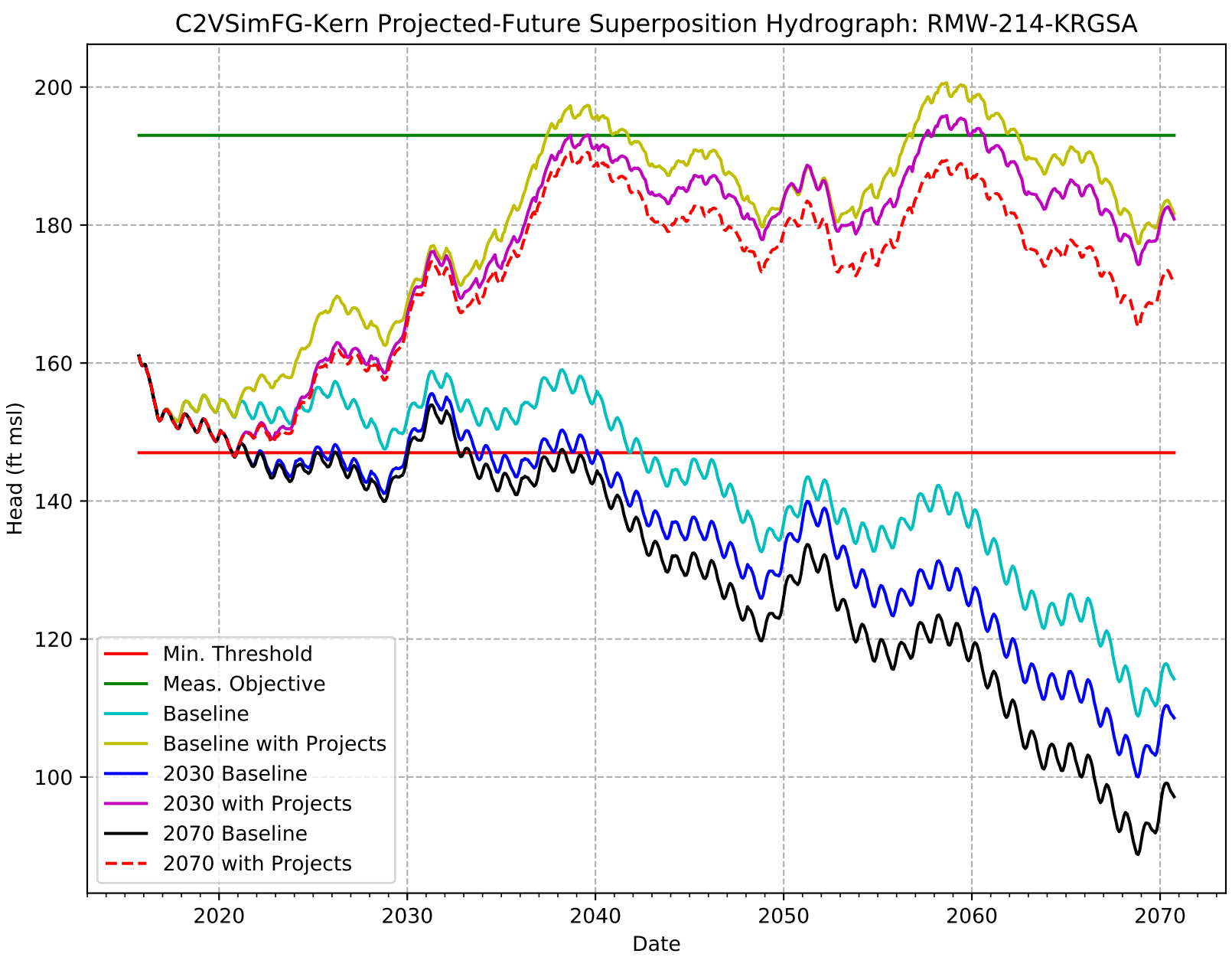

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-209-KRGSA
Head (ft msl)
240
220
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

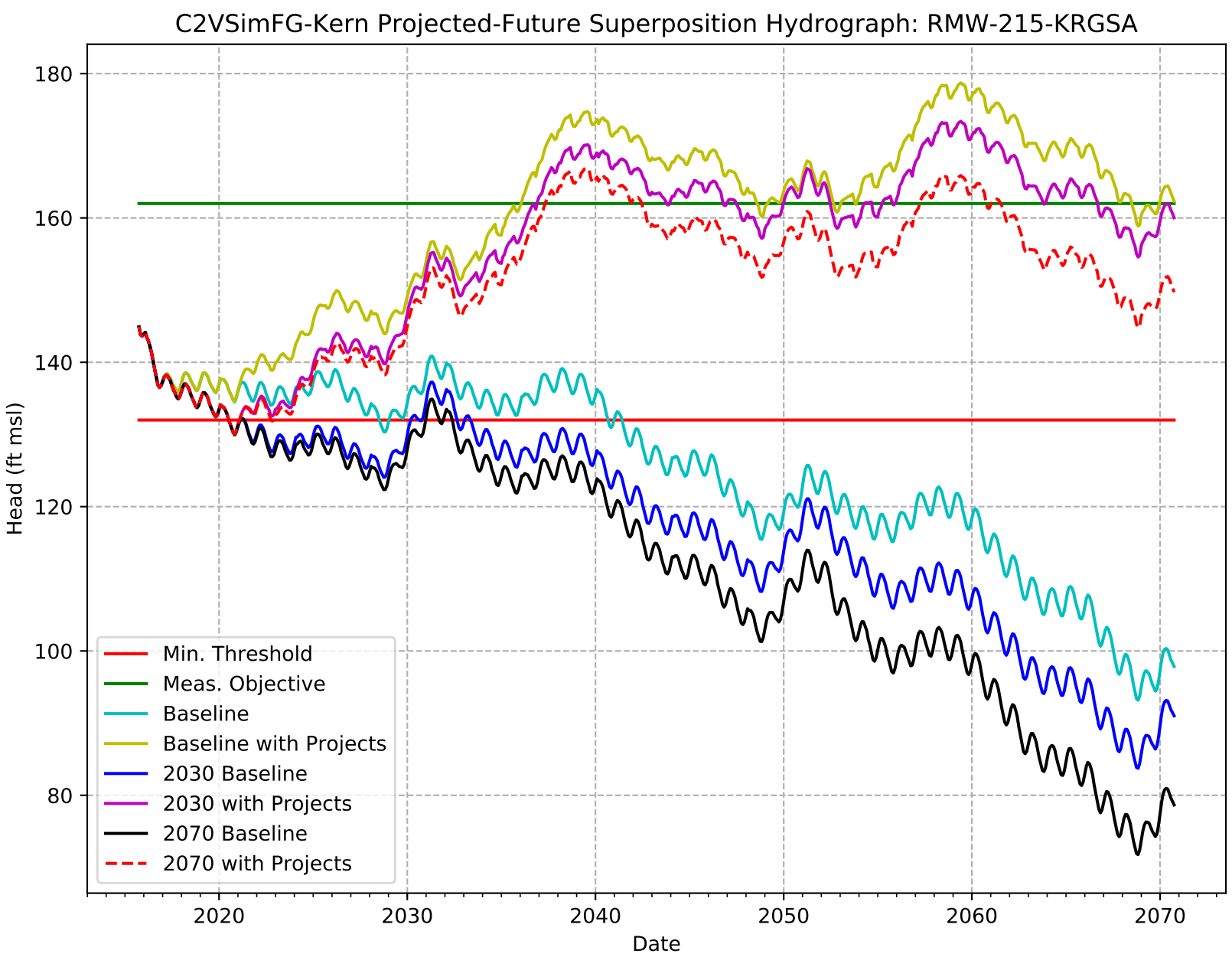

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-210-KRGSA
Head (ft msl)
240
220
200
180
160
140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

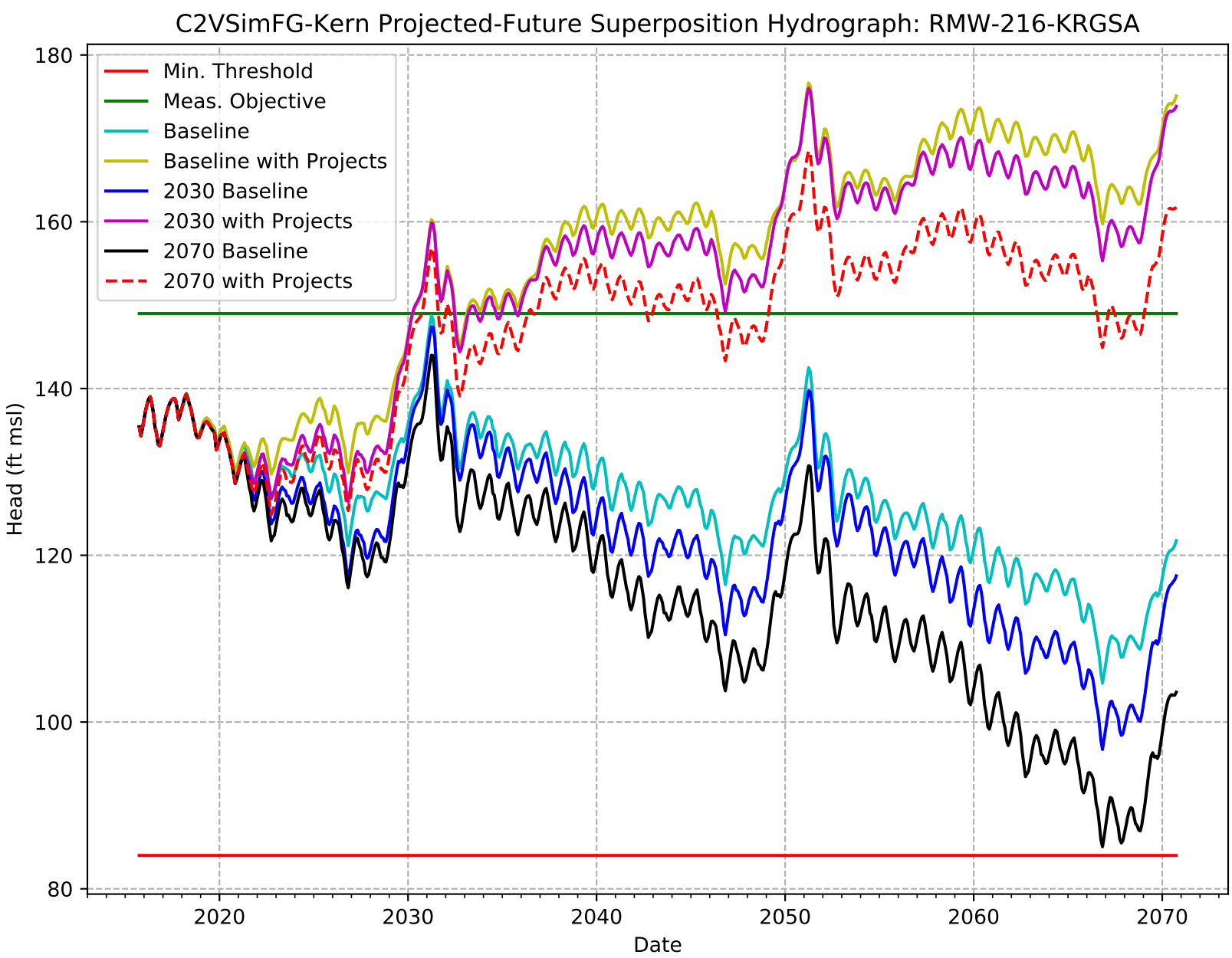

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-211-KRGSA
Head (ft msl)
Date
220
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

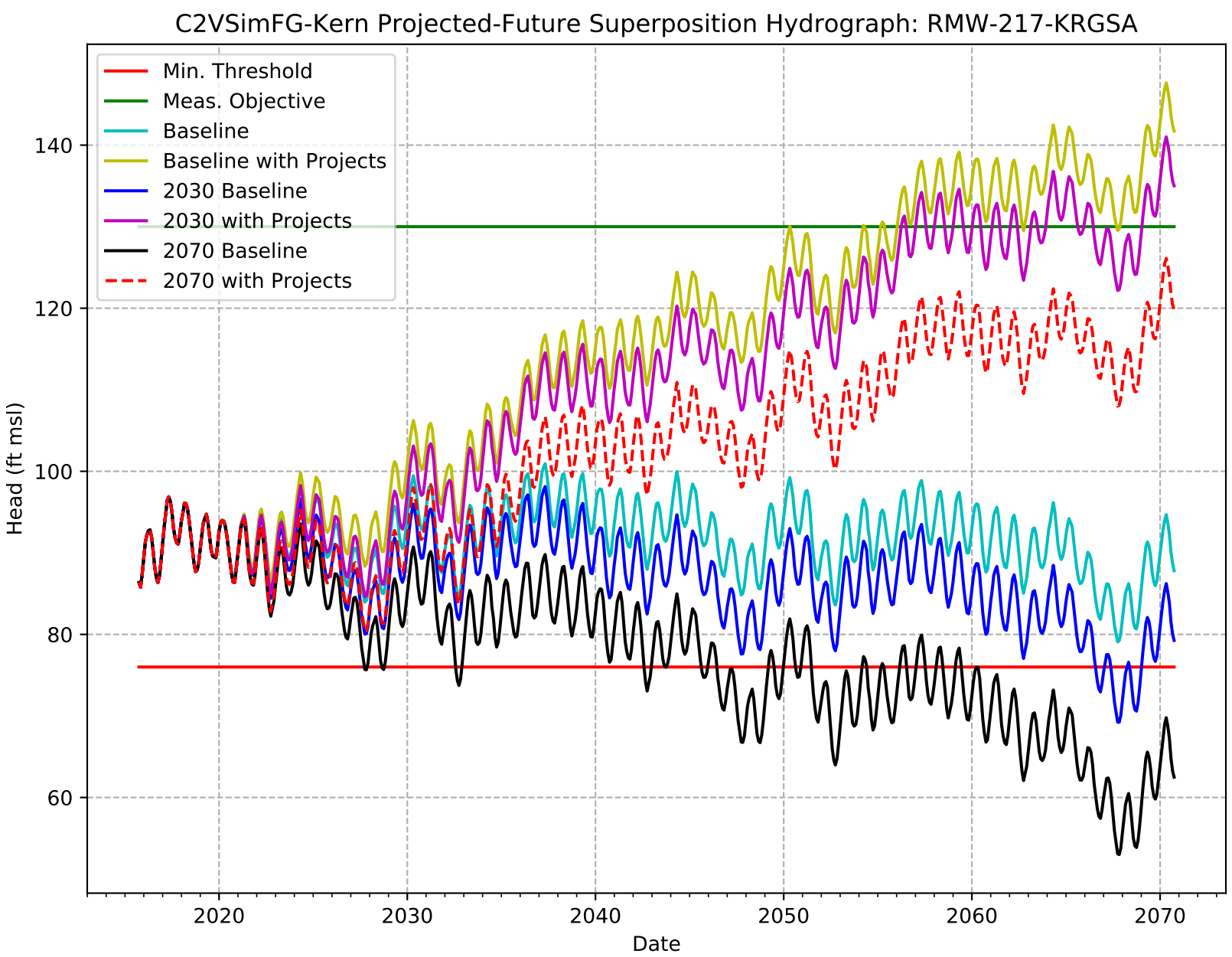

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-212-KRGSA
Head (ft msl)
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

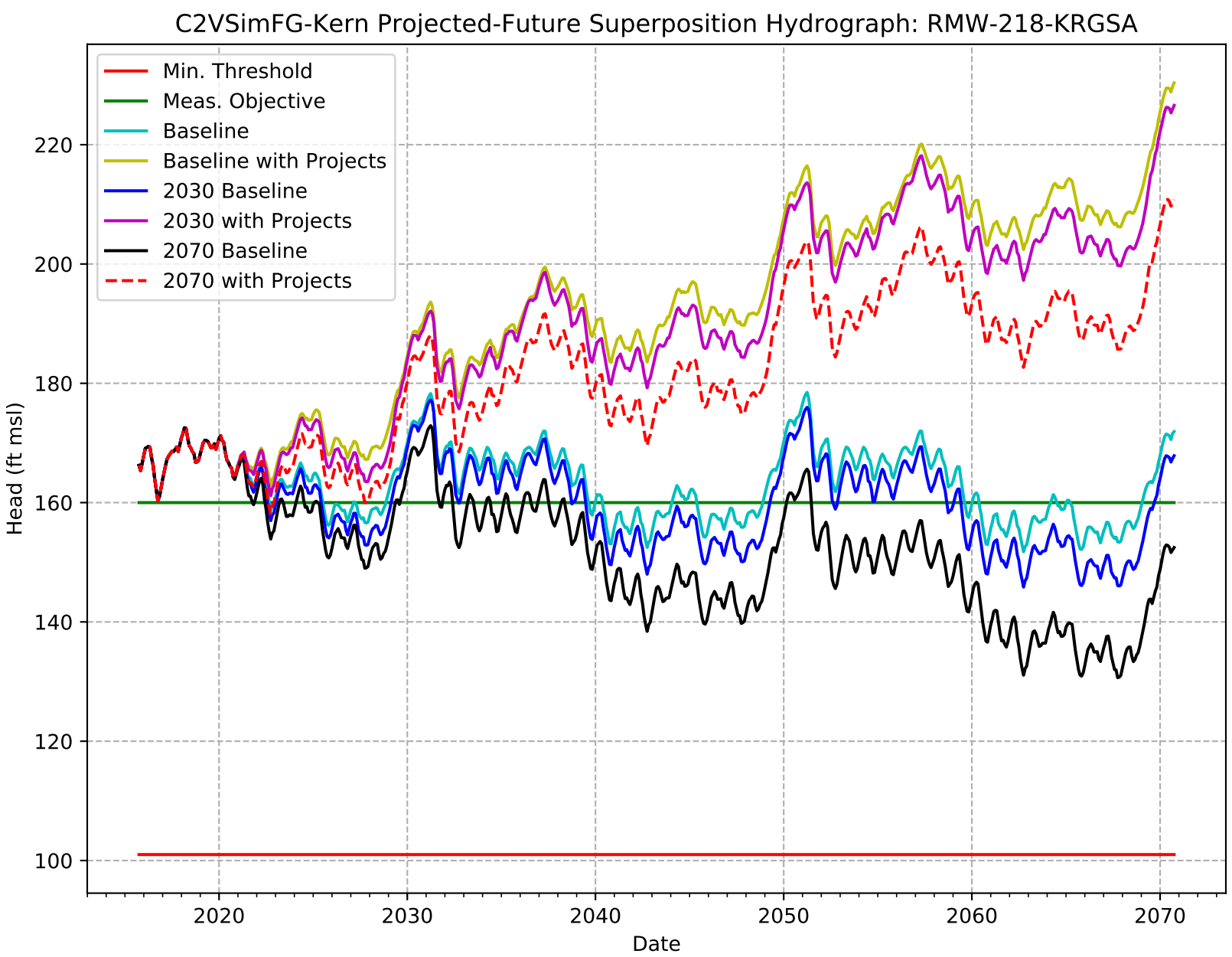

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-213-KRGSA
Head (ft msl)
240
220
200
180
160
140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

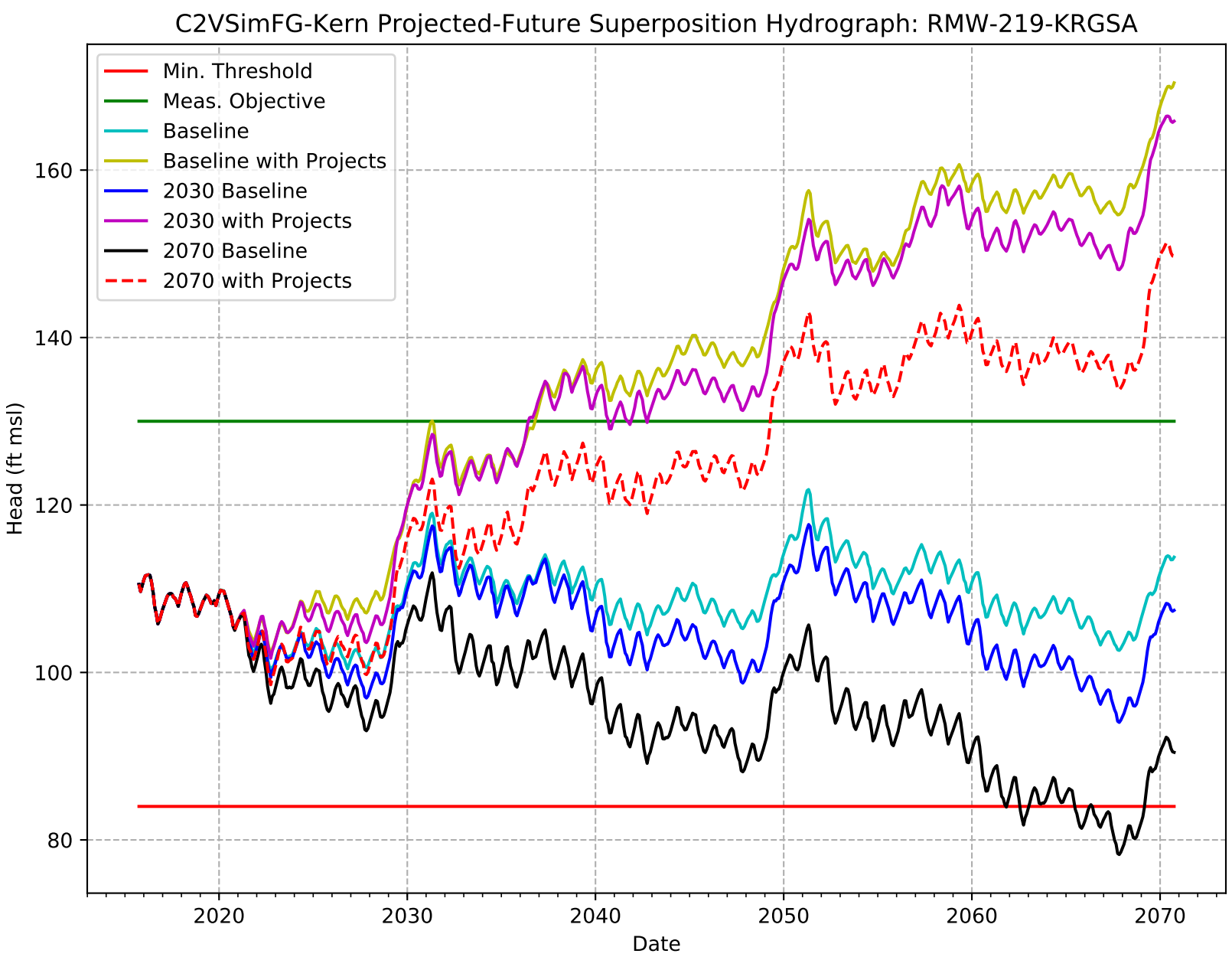

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-214-KRGSA
Head (ft msl)
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

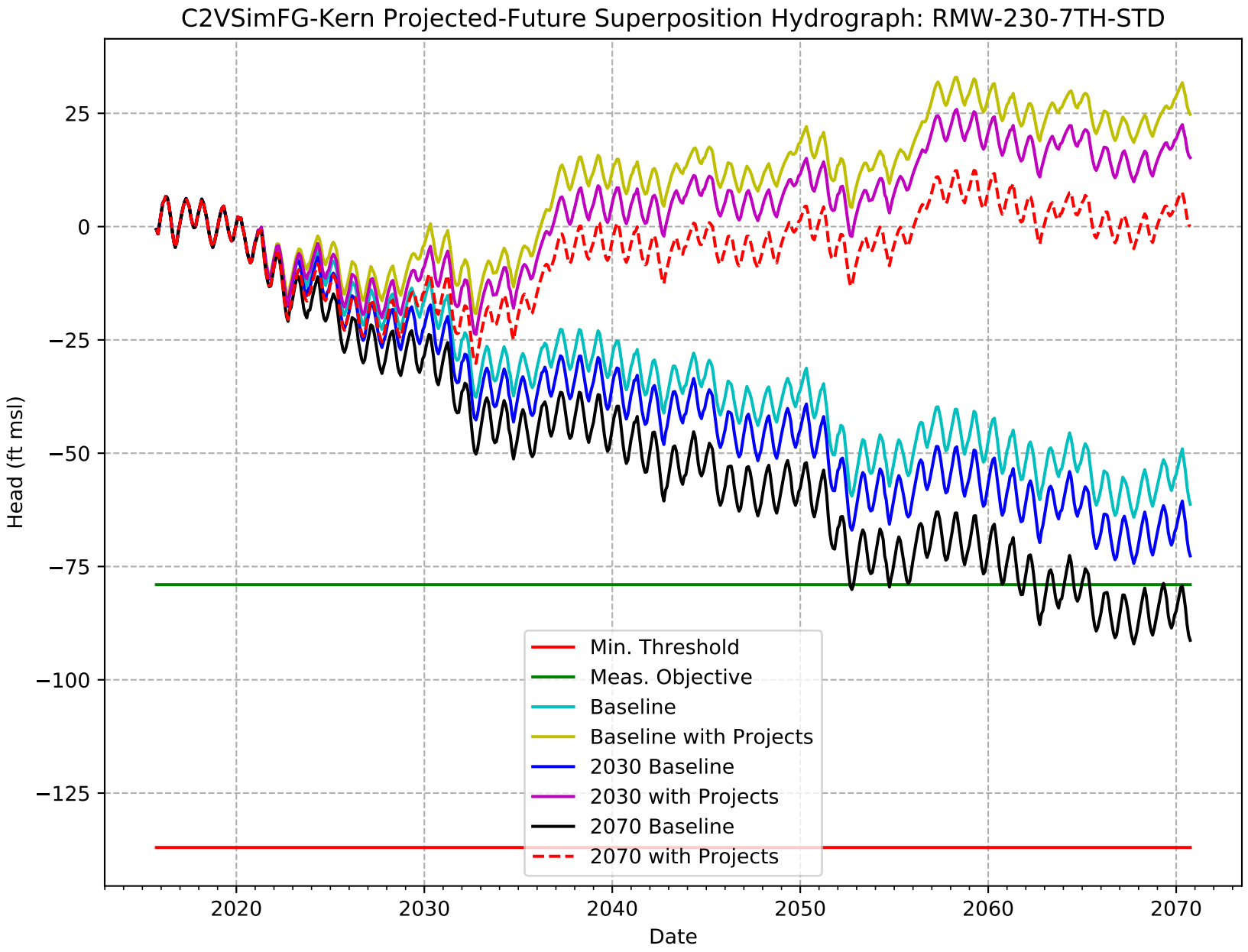

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-215-KRGSA
Head (ft msl)
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

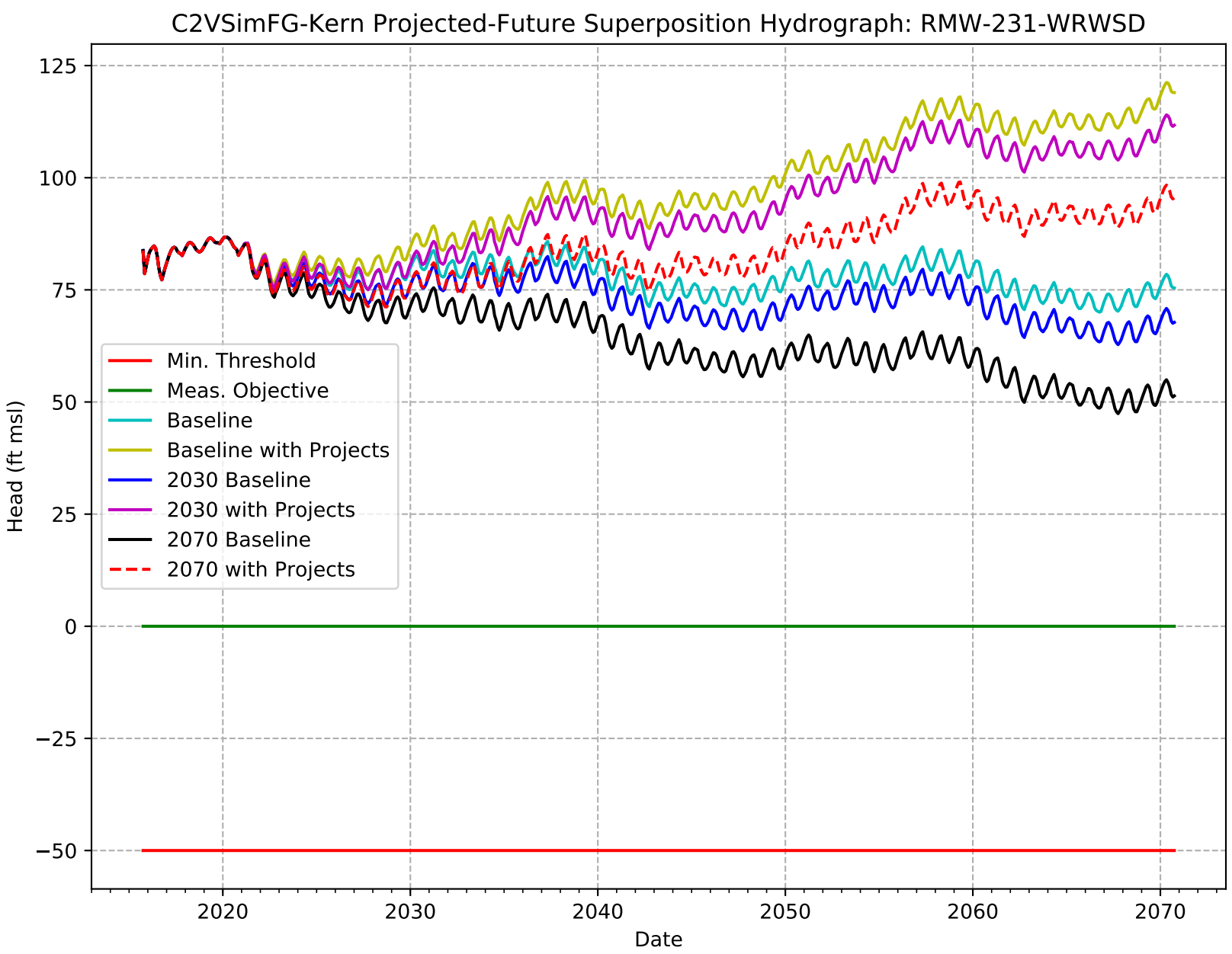

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-216-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date

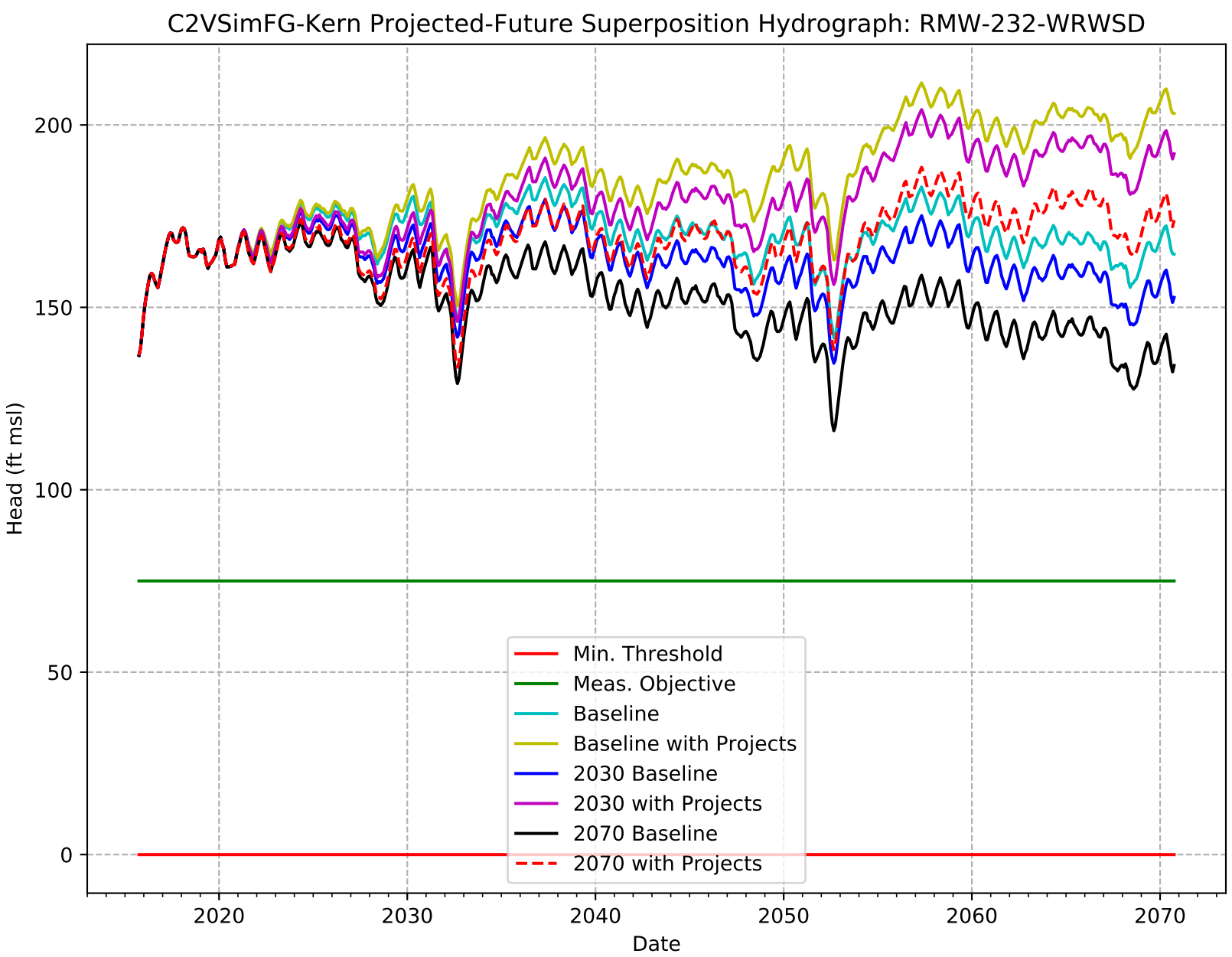

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-217-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

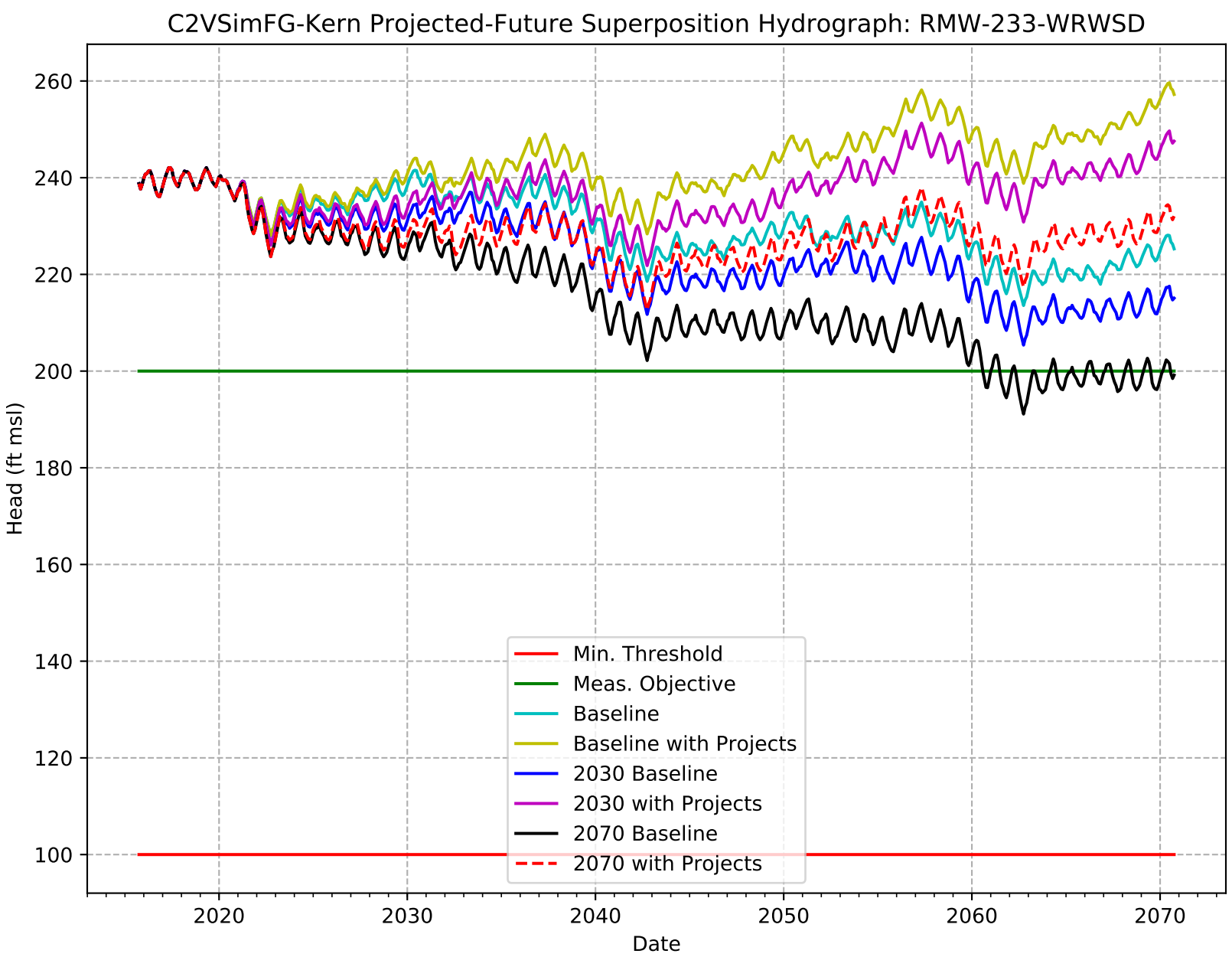

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-218-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
220
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date

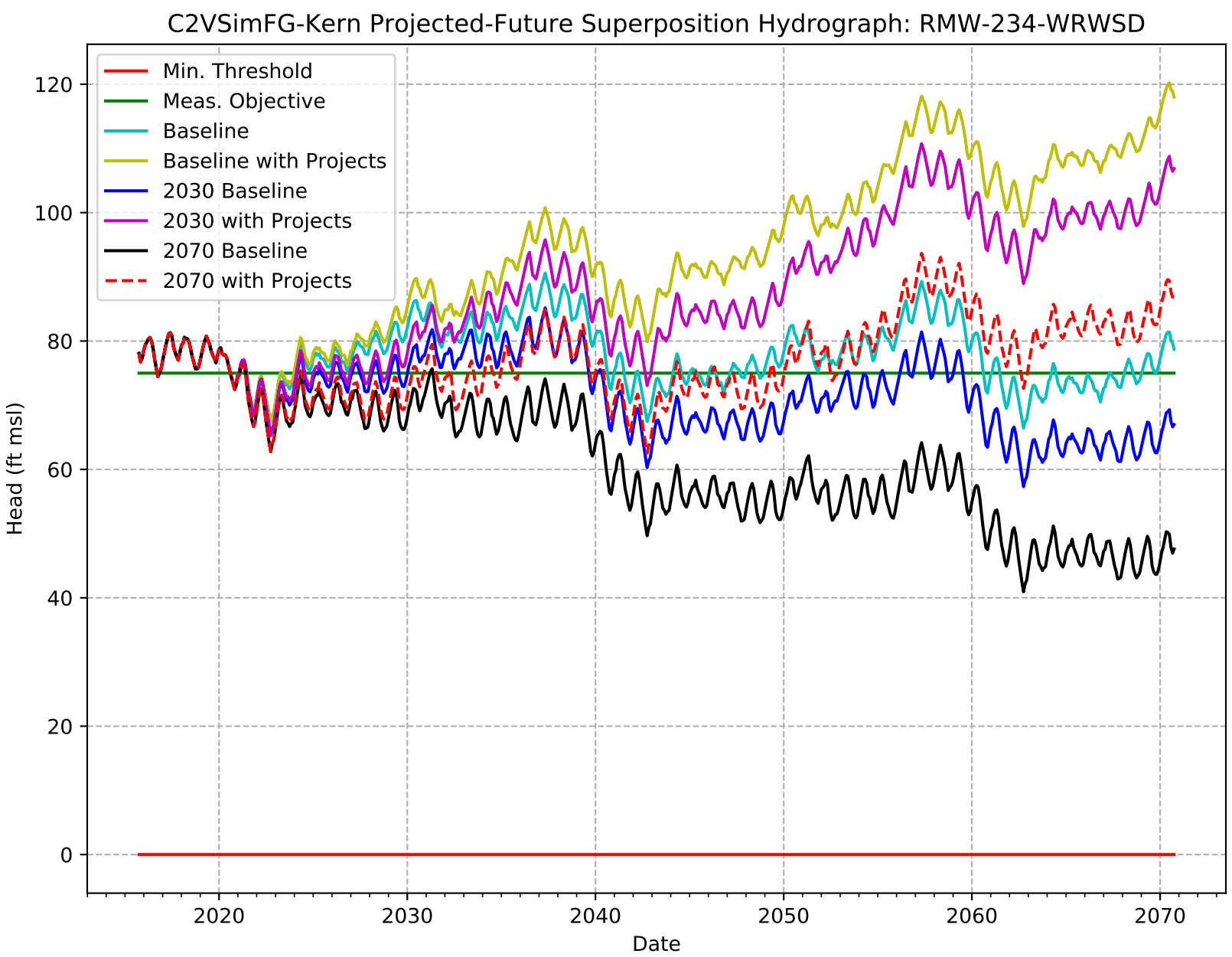

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-219-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date

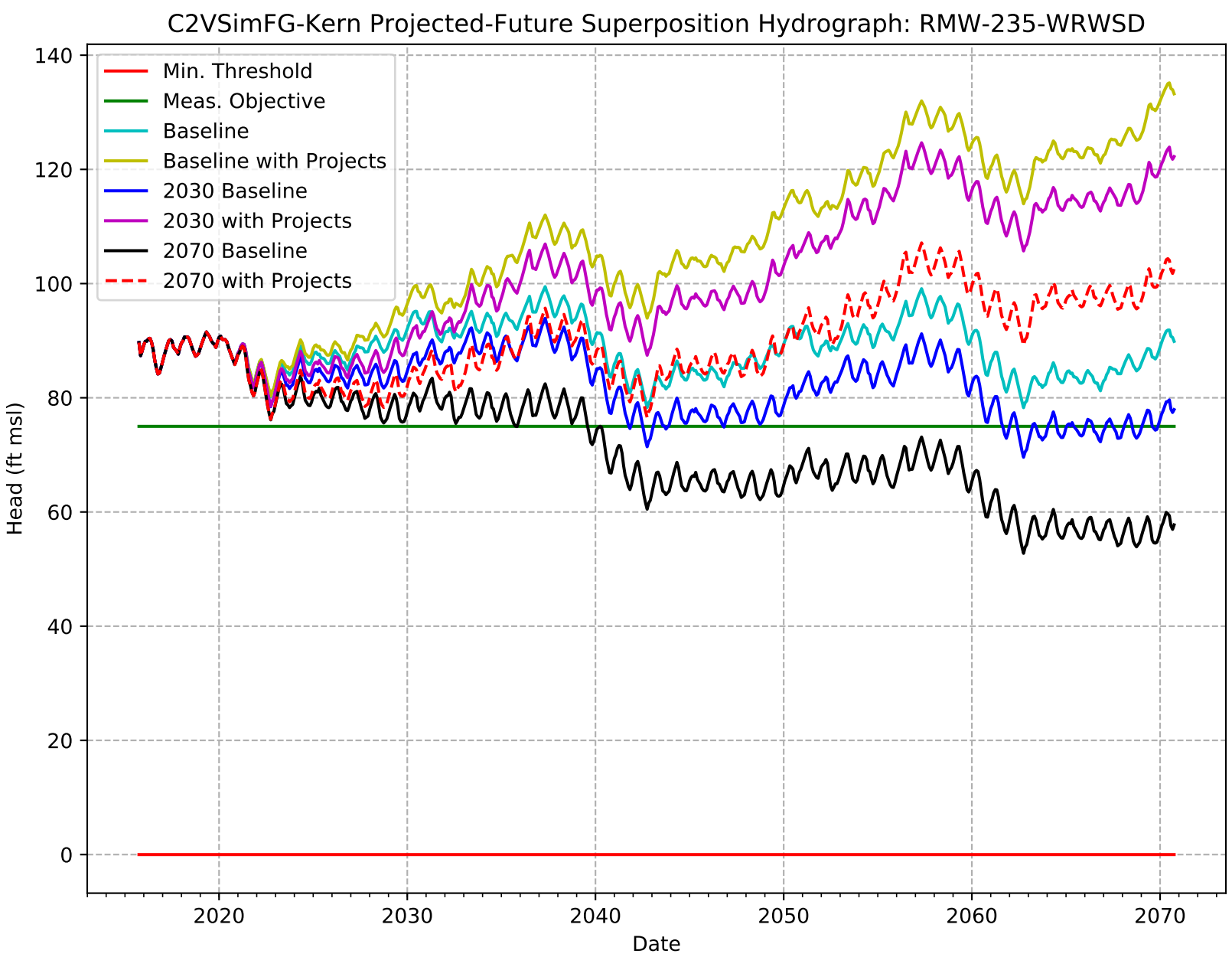

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-230-7TH-STD
Head (ft msl)
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

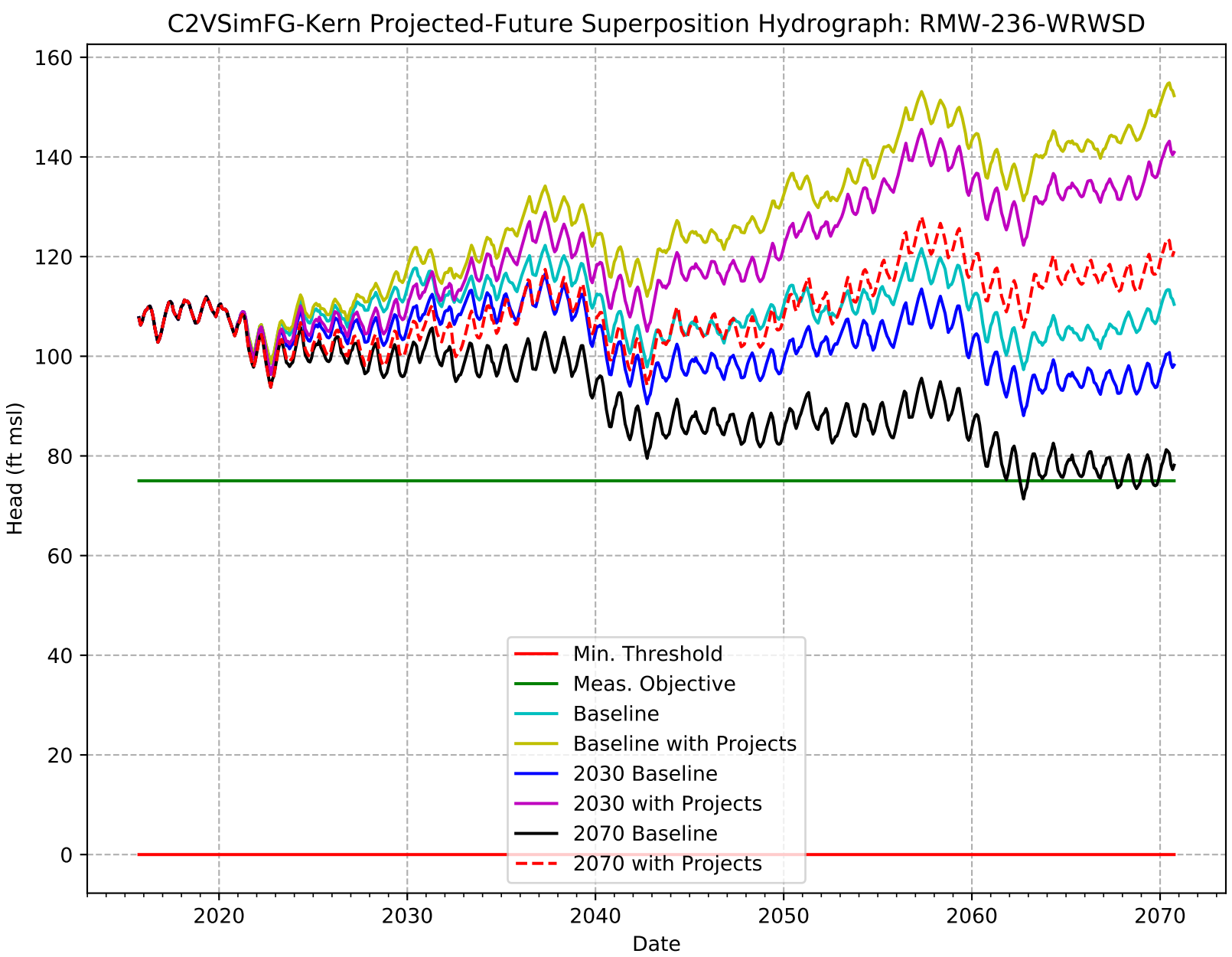

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-231-WRWSD
Head (ft msl)
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

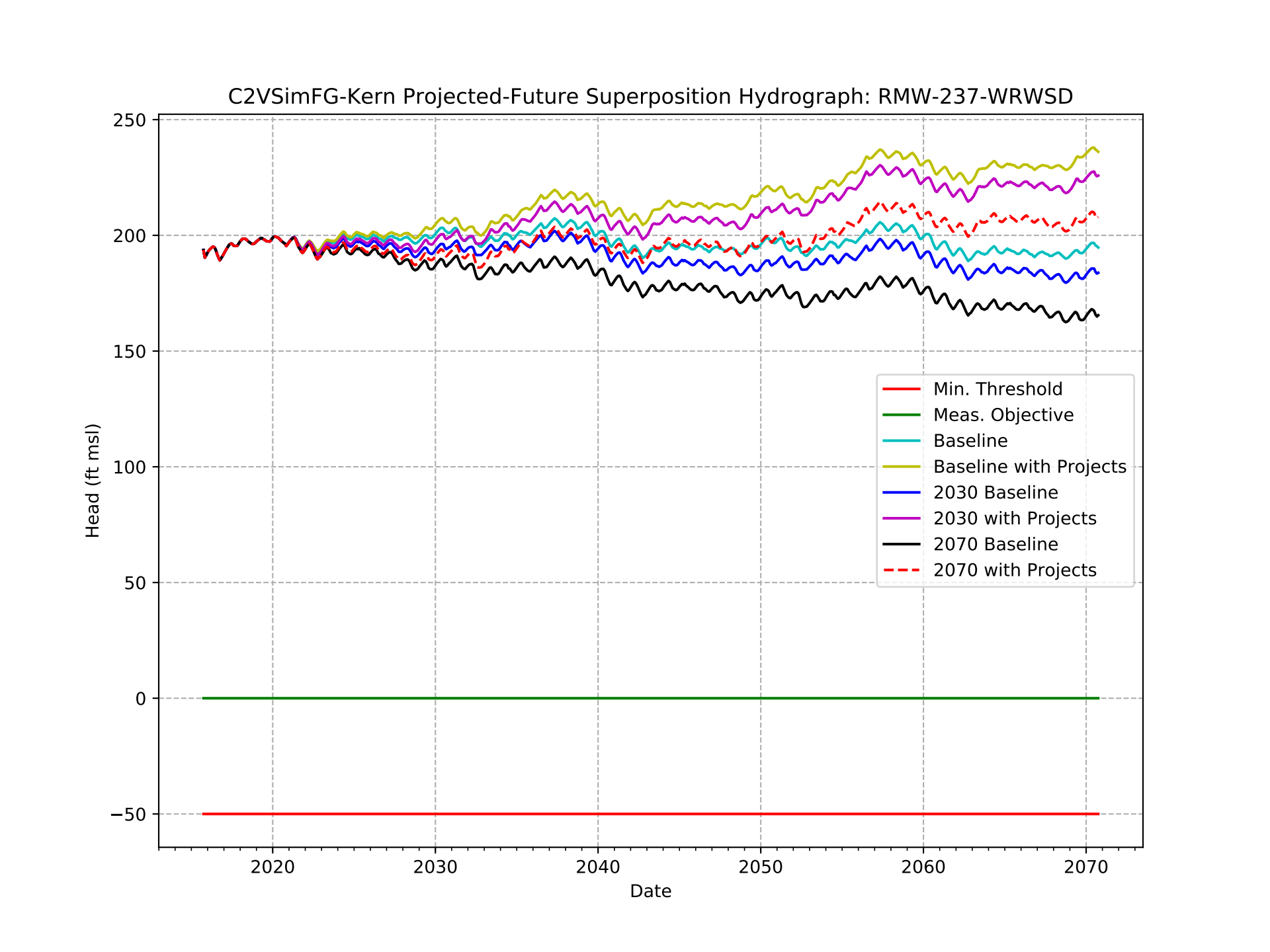

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-232-WRWSD
Head (ft msl)
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

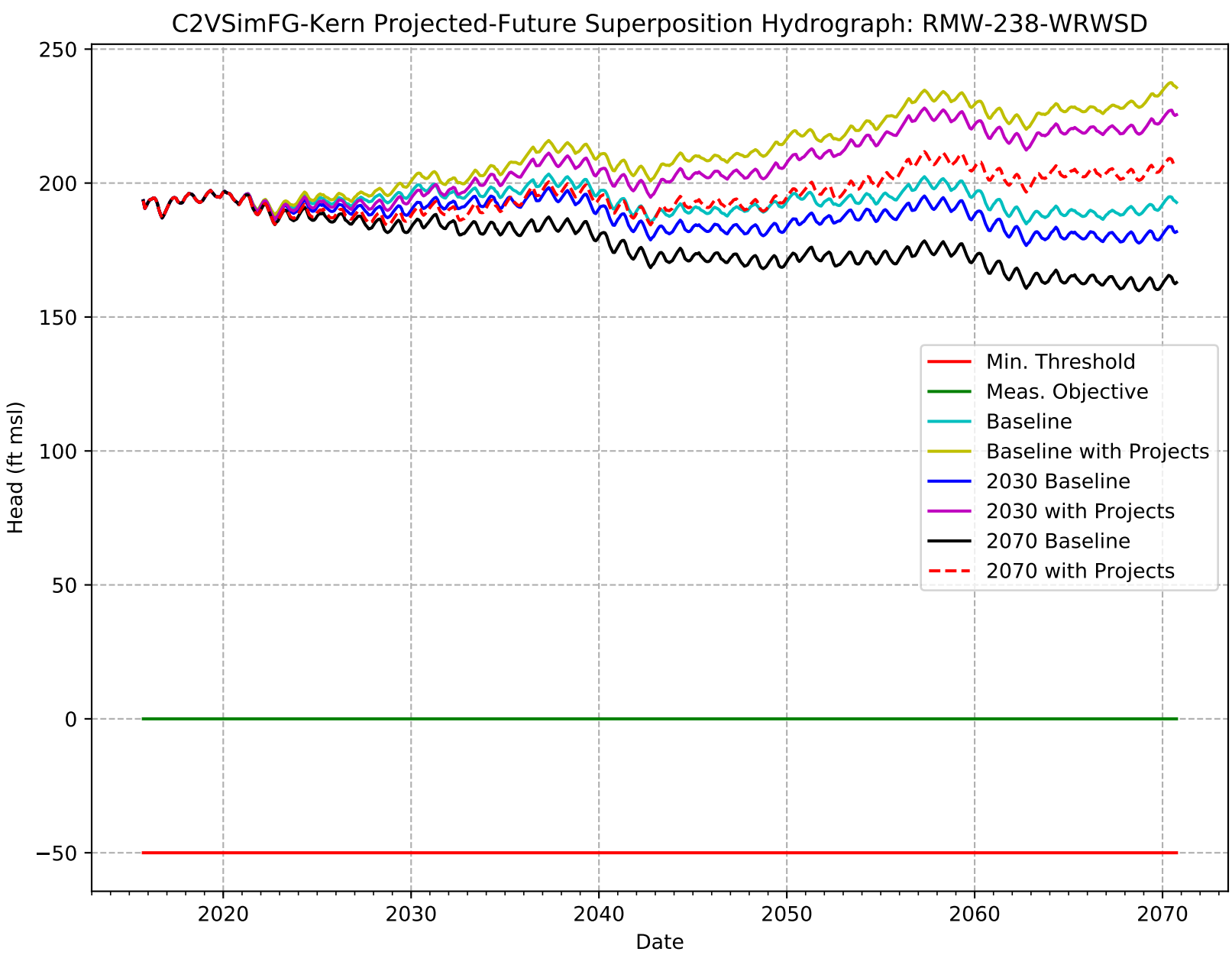

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-233-WRWSD
Head (ft msl)
260
240
220
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

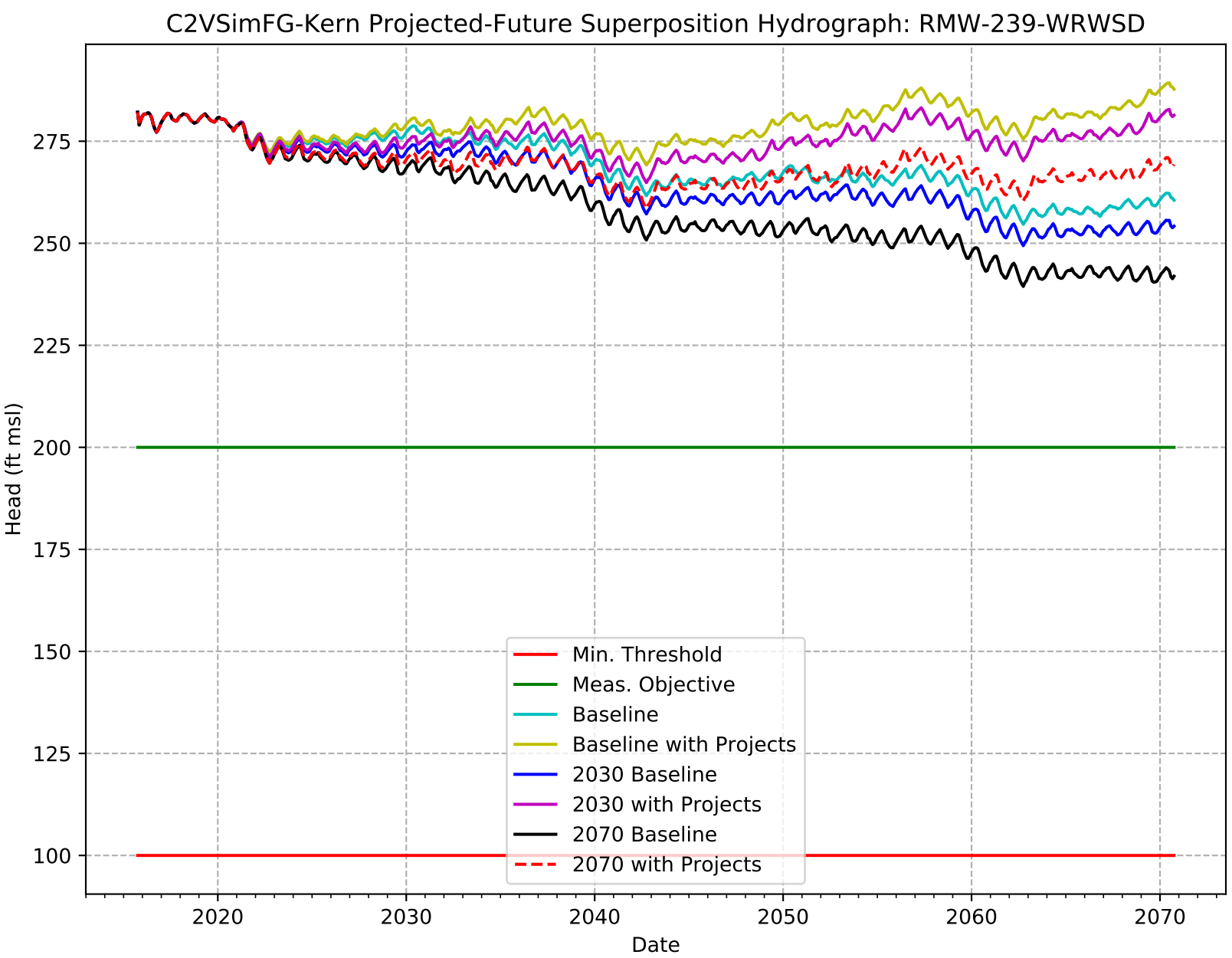

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-234-WRWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

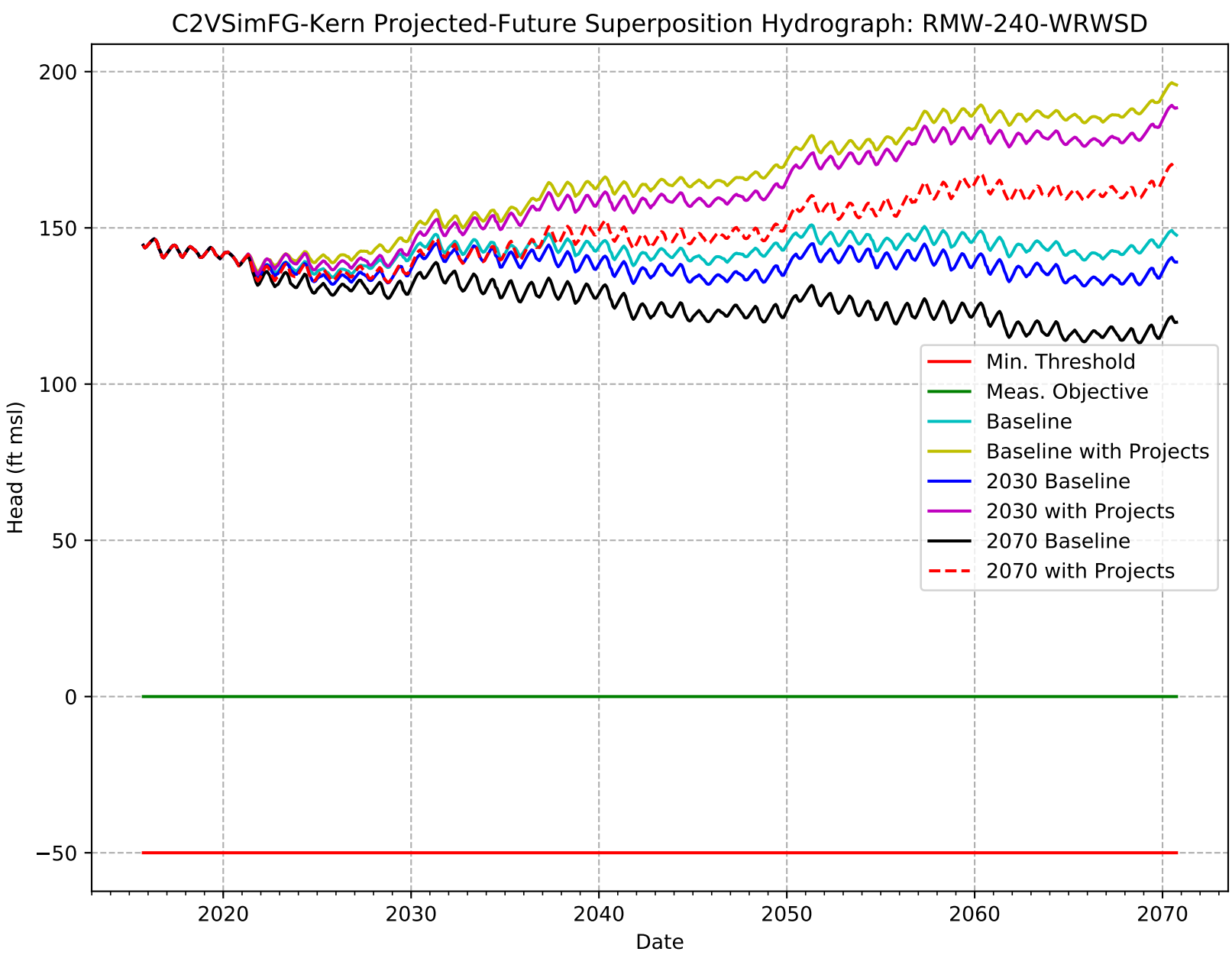

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-235-WRWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
Date
140
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070

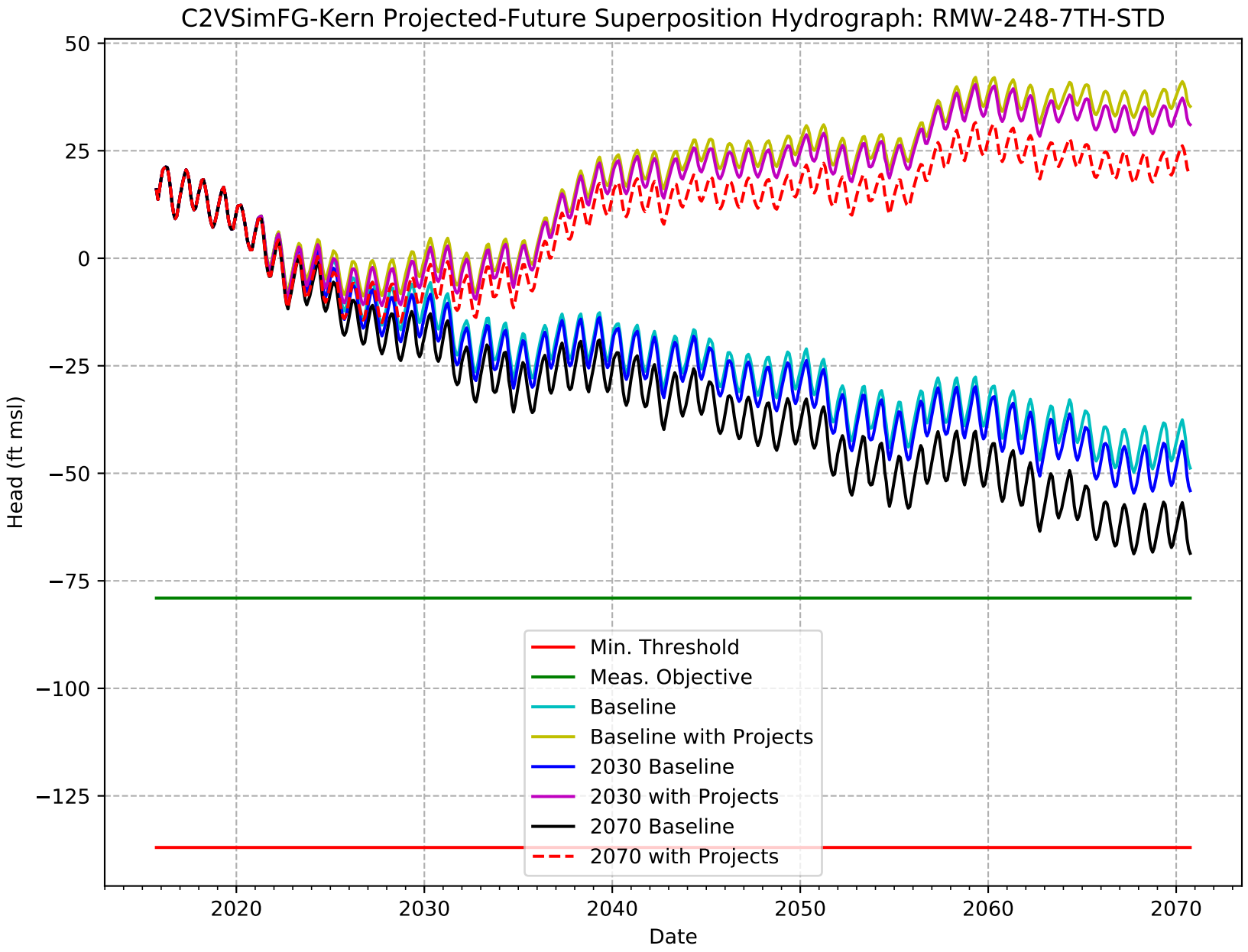

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-236-WRWSD
Head (ft msl)
Date
160
140
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

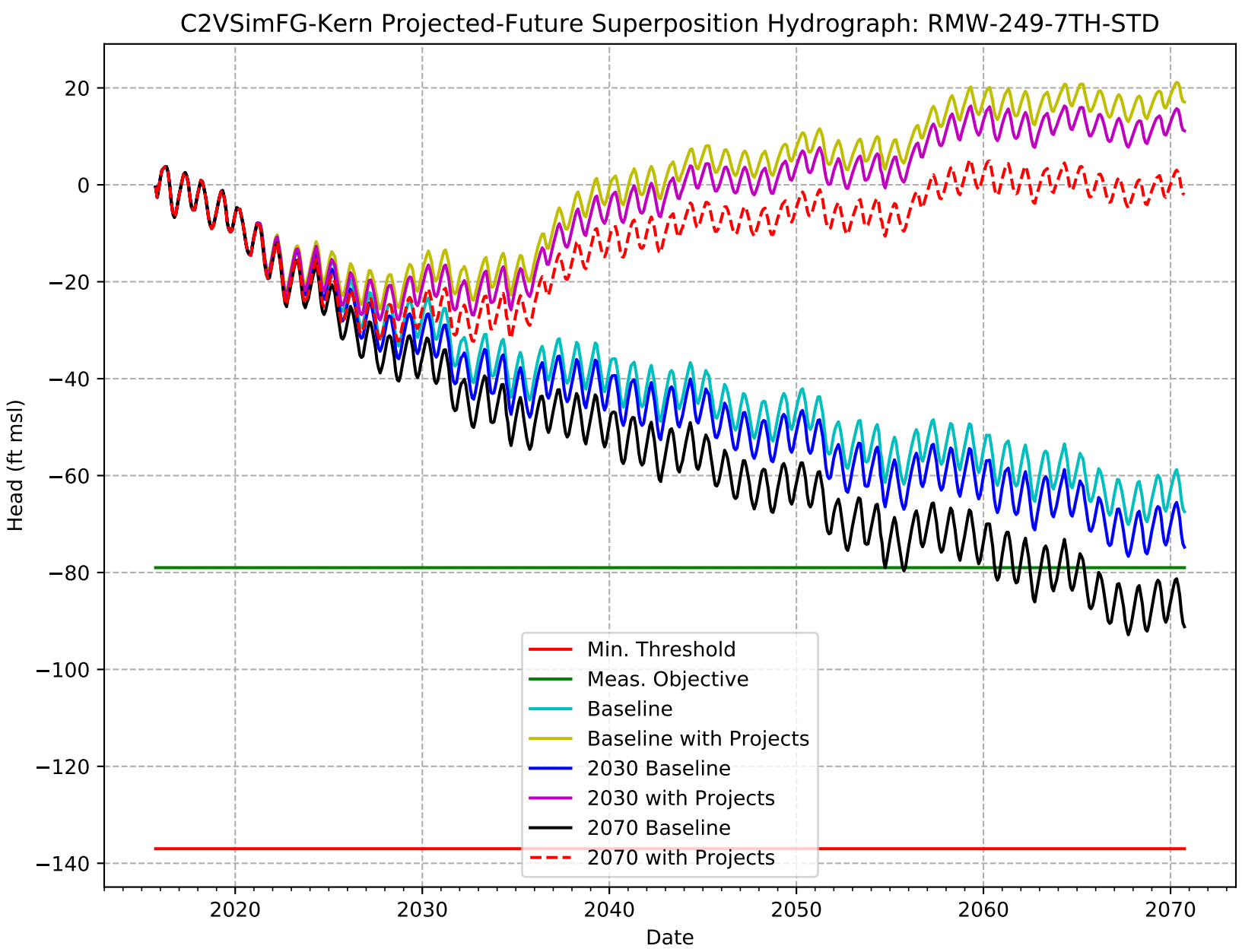

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-237-WRWSD
Head (ft msl)
250
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-238-WRWSD
Head (ft msl)
250
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-239-WRWSD
Head (ft msl)
275
250
225
200
175
150
125
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-240-WRWSD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-248-7TH-STD
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-249-7TH-STD
Head (ft msl)
20
0
−20
−40
−60
−80
−100
−120
−140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

BASELINE CONDITIONS

ENTITY	TOTAL DEMAND	TOTAL WATER SUPPLY	NET WATER BUDGET
Kern Groundwater Authority	1,939,409	1,683,128	-256,281
Henry Miller GSA	40,884	35,791	-5,093
Olcese Water District GSA	2,650	3,202	552
Kern River GSA	305,310	276,157	-29,153
Kern River GSA - App. K Properties	1,308		-1,308
Buena Vista GSA	103,950	126,936	22,986
Non-districted lands*	18,013		-18,013
Totals	2,411,524	2,125,214	**-286,310**

Todd Groundwater Modeling Result for Baseline Condition: **-324,326**

Todd Groundwater Modeling Result for Historical Change in Groundwater in Storage: **-277,114**

***Most of the irrigated non-districted lands are now being managed/covered under SGMA by the GSAs**

The Kern County Subbasin GSAs have collaboratively developed the above water budget table to present an inventory of supply and demand using a "checkbook approach". The checkbook approach provides a mechanism for coordinated water accounting among the GSAs and does not include subsurface flows. The table was used to examine local water budget conditions and to prevent double-counting of water supplies. Although developed separately from the C2VSimFG-Kern model, the sum of the water budget deficits compares relatively well with model results; model deficits shown at the bottom of the table are larger due to inclusion of Subbasin subsurface outflows, which are not included in the checkbook approach.

APPENDIX 3

Undesirable Results Definitions

Introduction:

- **Management areas shall be identified by the basin and shown on exhibit "A".**
- **Representative Monitoring Locations shall mean the locations within the basin which are identified and designated by the GSA's for purposes of monitoring sustainability indicators.**
- **Critical Infrastructure shall mean facilities which are utilized to provide public services such as water, utilities, and or transportation service for a region.**
- **Prolonged Drought – The undesirable results herein take into account the accommodation of a prolonged drought as defined in DWR's BMP.**

Chronic Lowering of Water Levels –
The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

This is determined when the minimum threshold for groundwater levels are exceeded in at least three(3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the subbasin (as measured by each Management Area). Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.

Groundwater Storage –
The point at which significant and unreasonable impacts, as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended drought period. (10-years?)

This is determined when the volume of storage (above the groundwater level minimum thresholds) is depleted to an elevation lower than the groundwater level minimum threshold in at least three(3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the subbasin (as measured by the acreage of each Management Area).

Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.

Degraded Water Quality Trends –
The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

This is determined when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three(3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the designated monitoring points within the basin. Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.

Land Subsidence Trends –
The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure.

This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.

Monitoring Network & Protocols

Monitoring Network shall be developed to be capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:

1) Demonstrate progress toward achieving measurable objectives described in the Plan
2) Monitor impacts to the beneficial uses and users of groundwater
3) Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds
4) Quantify annual changes in water budget components

Monitoring Network shall be designed to ensure adequate coverage of sustainability indicators. If management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the basin setting and sustainable management criteria specific to that area. To the extent possible, the use of existing monitoring data and infrastructure should be utilized to meet the needs for characterization, historical record documentation and continued monitoring requirements.

Monitoring Network shall describe the scientific rationale for the monitoring site selection and for each sustainability indicator, the quantitative values for the minimum threshold, measurable objective and interim milestones shall be indicated at each monitoring site.

Monitoring Protocols developed shall include a description of technical standards, data collection methods, and other procedures or protocols for monitoring sites or other data collection facilities to ensure that the monitoring network utilizes comparable data and methodologies. There is no definitive rule for the density of groundwater monitoring points needed in a basin. The table below provides guidance for the density of monitoring wells per hundred square miles. One important item to consider is how the definitions of undesirable results will be impacted to provide the necessary information to indicate compliance.

Reference	Monitoring Well Density (wells per 100 miles2)
Heath (1976)	0.2 - 10
Sophocleous (1983)	6.3
Basins pumping more than 10,000 acrefeet/year per 100 miles	4.0
Basins pumping between 1,000 and 10,000 acre-feet/year per 100 miles	2.0
Basins pumping between 250 and 1,000 acre-feet/year per 100 miles	1.0
Basins pumping between 100 and 250 acre-feet/year per 100 miles	0.7

Measuring Groundwater Levels

Given the significant variations in groundwater elevations throughout the Kern subbasin which are due to variations in hydrologic conditions, no single groundwater elevation surface should be considered a representation of groundwater flow directions in this basin.

Requirements for well selections:

- A long-term access agreement that includes year-round site access to allow for increased monitoring frequency
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact, type of information to be collected, latitude, longitude and elevation
- Monitoring location should also track all modifications to the site in a modification log

The following data collection protocols are to be followed within the Kern subbasin:

- Groundwater level data shall be sufficient to produce seasonal maps of potentiometric surfaces or water table surfaces throughout the basin that clearly identify changes in groundwater flow direction and gradient.
- Use the Well Data form provided (see attached)
- Groundwater level data shall be collected from each principal aquifer in the basin
- Collection of data between the approved time frames only
    - January 15th to March 30th
    - September 15th to November 15th
- A weighted water level meter or other CASGEM approved measuring device will be used to measure the depth to groundwater
- Depth to groundwater must be measured relative to an established Reference Point on the well casing. If no mark or reference point is apparent, the person performing the measurement should measure the depth to groundwater from the north side of the top of the well casing
- The elevation of the Reference Point of the well must be referenced to the North American Vertical Datum of 1988. The accuracy of the reference point should be consistent with CASGEM established guidelines.
- Each well's Reference Point will be cataloged to ensure identical procedures are followed for subsequent measurements.
- The data collector should remove the appropriate cap, lid or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement should follow a period of time to allow the water level to equilibrate.
- Depth to groundwater must be measured to the accuracy associated with the approved monitoring method or device.
- The water level meter shall be decontaminated after measuring each well.
- The data collector shall calculate the groundwater elevation as:
    - GWE = RPE – DTW
    - GWE = Groundwater Elevation

    - RPE = Reference Point Elevation
    - DTW = Depth to Water
- The data collector must ensure that all measurements are consistent units of feet, tenths of feet or hundredths of feet. Measurements and Reference Point Elevations should not be recorded in feet and inches.

Groundwater Quality

Groundwater quality monitoring networks shall be designed to demonstrate that the degraded water quality sustainability indicator is being observed for the purpose of meeting the definition of the sustainability goal.

Requirements for well selections:

- A long-term access agreement that includes year-round site access to allow for increased monitoring frequency
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact, type of information to be collected, latitude, longitude and elevation
- Monitoring location should also track all modifications to the site in a modification log
- The use of existing water quality data within the basin should be done to the greatest extent possible
- Monitoring network should consist largely as a supplemental monitoring locations where known groundwater contamination plumes are under existing regulatory management

The following data collection protocols are to be followed within the Kern subbasin:

- Monitor groundwater quality data from each principal aquifer in the basin
- Data should be sufficient for mapping movement of degraded water quality
- Data should be sufficient to assess groundwater quality impacts to beneficial uses and users
- Data should be sufficient to evaluate whether management activities are contributing to water quality degradation.
- All analyses should be performed by a laboratory certified under the State Environmental Laboratory Accreditation Program
- Samples will be collected according to the standards listed in the Standard Methods for the Examination of Water and Wastewater, USGS National Field Manual for the Collection of Water Quality Data
- Prior to sampling, the sampler must contact the laboratory to schedule laboratory time, obtain appropriate sampler containers, and clarify any sample holding times or sample preservation requirements
- Each well used for groundwater quality monitoring must have a unique identifier. This identifier must appear on the well housing or the well casing to avoid confusion
- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead. Samples are not to be taken/collected from storage tanks, at the end of long pipe runs or after any water treatment infrastructure

- Samples will be taken/collected only after the appropriate volume of water has been purged from the casing and field parameters have stabilized
- Sampler will clean the sampling port and/or sampling equipment. The sampling port and/or sampling equipment must be free of any contaminants
- Groundwater elevation in the well should be measured following the protocols described in the groundwater level measuring protocols
- Field parameters of pH, electrical conductivity and temperature should be collected for each sample. Lab pH analysis are typically unachievable due to short hold times.
- All field instruments should be calibrated daily and evaluated for drift throughout the day
- Sample containers should be labeled prior to sample collection. The sample label must include:
    - Sample ID (well ID)
    - Sample date and time
    - Sample personnel
    - Sample location
    - Preservative used
    - Analytes and analytical method
- Samples shall be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection
- Samples requiring preservation must be preserved as soon as practically possible
- Samples to be analyzed for metals should be field-filtered prior to preservation. Do not collect an unfiltered sample in a preserved container
- Samples will be chilled and maintained at 4 C to prevent degradation of the sample
- Samples will be shipped under a chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions
- Custody Seal will be used by the field technician if a third-party transportation service is used
- A Field Sampling Log will include:
    - Sampler's identification
    - Well identification
    - Climatic conditions
    - Depth to water prior to purging
    - Type of purging and sampling device
    - Purging rate and volume
    - Relative well yield volume
    - Field parameter measurements (pH, temperature, EC, DO)
    - Type and number of samples collected
    - Date and time collected

Change in Groundwater Storage

Since the groundwater storage is not a directly measurable condition, it does rely heavily on the collection of accurate groundwater levels. The changes in groundwater levels reflect changes in storage and can thus be estimated with assumptions of thickness of units, porosity, and connectivity. These observations will be essential for use in calculating the water budget.

A water budget is a foundational tool used to compile water flows (supplies) and outflows (demands). It is an accounting of the total groundwater and surface water entering and leaving a basin or user-defined area. The difference between flows and outflows is a change in the amount of water stored.

Coordination of Water Budget Data to comply with groundwater storage:

- Surface water supply
- Total water use
- Water budget
- Sustainable yield

The change in the annual volume of groundwater storage between seasonal high conditions shall be quantified in the water budget.

Land Subsidence

Land subsidence protocols are to be set up to identify the rate and extent of land subsidence, which maybe measured by extensometers, surveying, remote sensing technology, or other appropriate method. To the extent possible, the use of existing data should be utilized.

Prior to development of a specific subsidence monitoring network a screening level analysis should be conducted. The screening of subsidence occurrence should include:

- Review of the HCM and understanding of grain-size distributions and potential for subsidence to occur
- Review of any known regional or correlative geologic conditions where subsidence has been observed.
- Review of historic range of groundwater levels in the principal aquifers of the basin
- Review of historic records of infrastructure impacts, including but not limited to damage to pipelines, canals, roadways or bridges or well collapse potentially associated with land surface elevation changes
- Review of remote sending results such as InSAR or other land surface monitoring data
- Review of existing CGPS surveys

This basin has decided to work together on this protocol with a consultant to obtain the required data.

See the attached for the coordinated effort by all the GSAs in the Kern Subbasin pertaining to Land Subsidence.



Kern Groundwater Authority
Basin Setting

Kern County, California

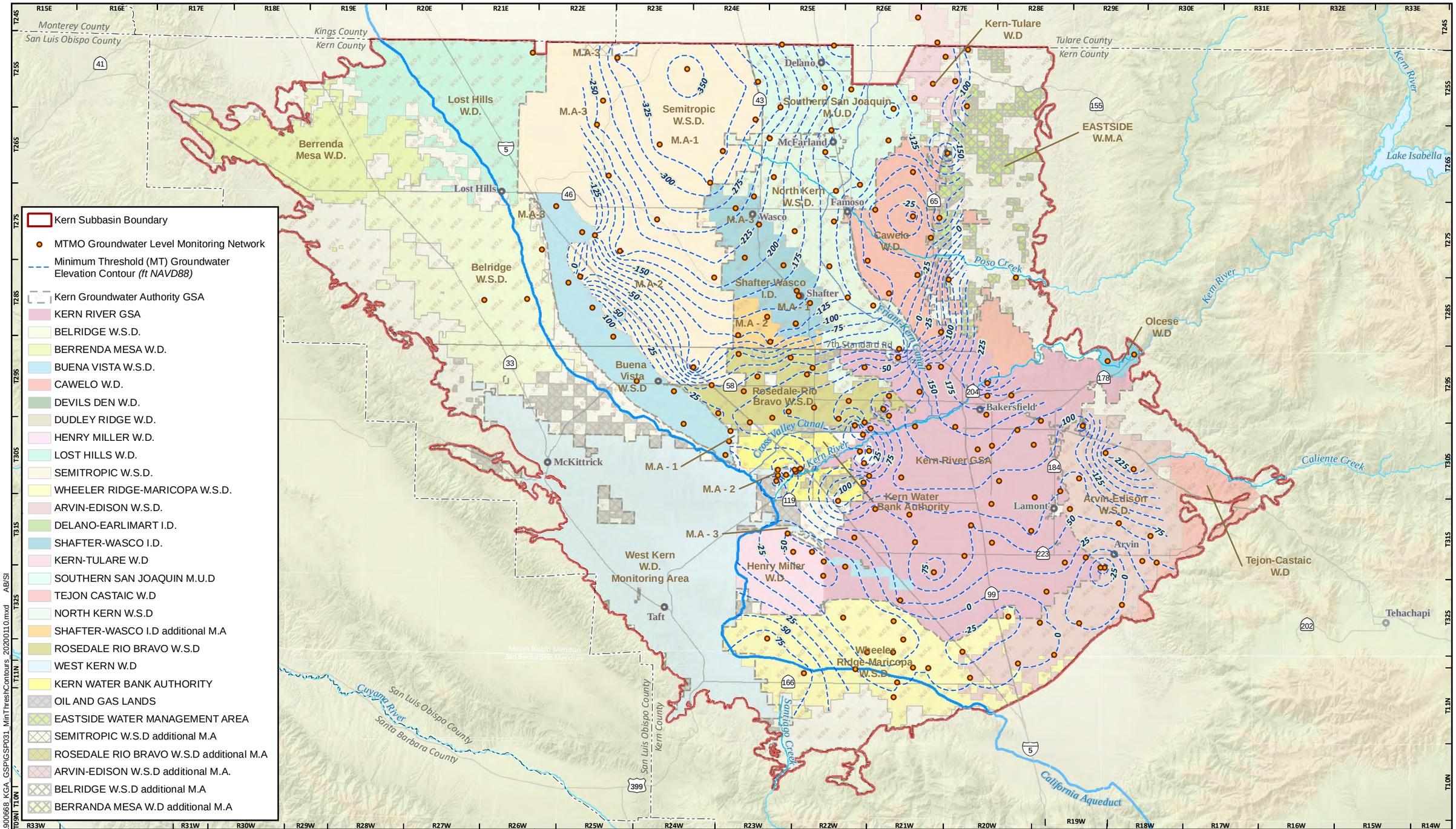
GEI Consultants

REGIONAL GROUNDWATER LEVEL MONITORING NETWORK

DECEMBER 2019

FIGURE 3-1

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Kern Groundwater Authority
Basin Setting

Kern County, California

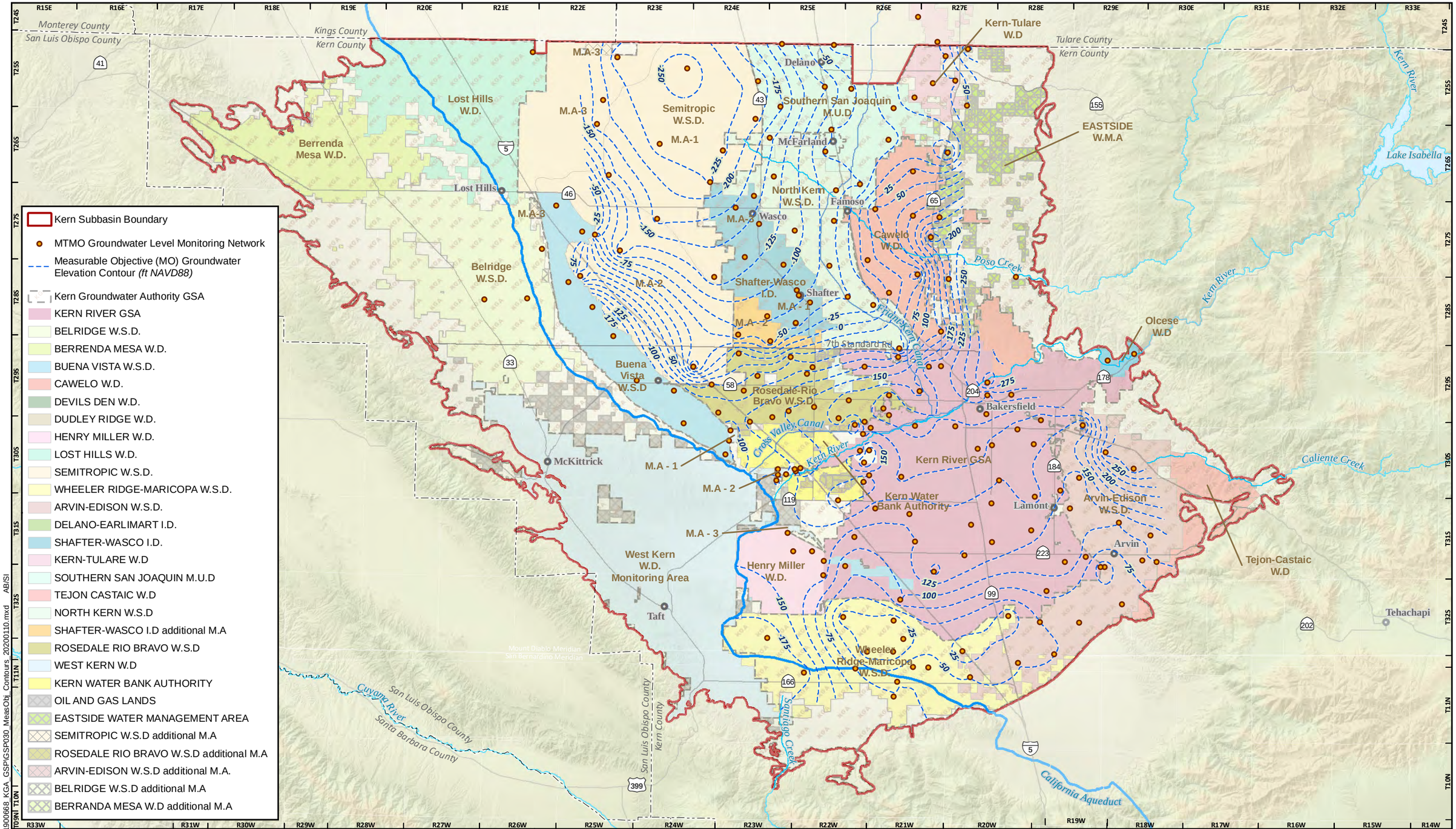
GEI Consultants

REGIONAL MINIMUM THRESHOLD GROUNDWATER ELEVATION CONTOURS

DECEMBER 2019

FIGURE 3-2

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Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

REGIONAL MEASURABLE OBJECTIVE GROUNDWATER ELEVATION CONTOURS

DECEMBER 2019

FIGURE 3-3

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Kern Subbasin Boundary
Monitored for Water Quality Only
Monitored for Water Quality and GWE
Kern Groundwater Authority GSA
KERN RIVER GSA
BELRIDGE W.S.D.
BERRENDA MESA W.D.
BUENA VISTA W.S.D.
CAWELO W.D.
DEVILS DEN W.D.
DUDLEY RIDGE W.D.
HENRY MILLER W.D.
LOST HILLS W.D.
SEMITROPIC W.S.D.
WHEELER RIDGE-MARICOPA W.S.D.
ARVIN-EDISON W.S.D.
DELANO-EARLIMART I.D.
SHAFTER-WASCO I.D.
KERN-TULARE W.D
SOUTHERN SAN JOAQUIN M.U.D
TEJON CASTAIC W.D
NORTH KERN W.S.D
SHAFTER-WASCO I.D additional M.A
ROSEDALE RIO BRAVO W.S.D
WEST KERN W.D
KERN WATER BANK AUTHORITY
OIL AND GAS LANDS
EASTSIDE WATER MANAGEMENT AREA
SEMITROPIC W.S.D additional M.A
ROSEDALE RIO BRAVO W.S.D additional M.A
ARVIN-EDISON W.S.D additional M.A.
BELRIDGE W.S.D additional M.A
BERRANDA MESA W.D additional M.A
Monterey County
San Luis Obispo County
Kings County
Kern County
Tulare County
Santa Barbara County
Lost Hills W.D.
Berrenda Mesa W.D.
Belridge W.S.D.
Buena Vista W.S.D
Semitropic W.S.D.
Southern San Joaquin M.U.D
North Kern W.S.D.
Shafter-Wasco I.D.
Rosedale-Rio Bravo W.S.D
Kern River GSA
Kern Water Bank Authority
Henry Miller W.D.
West Kern W.D. Monitoring Area
Wheeler Ridge-Maricopa W.S.D
Kern-Tulare W.D
Cawelo W.D.
EASTSIDE W.M.A
Olcese W.D
Tejon-Castaic W.D
Arvin-Edison W.S.D.
M.A-1
M.A-2
M.A-3
M.A - 1
M.A - 2
M.A - 3
Delano
McFarland
Wasco
Famoso
Lost Hills
McKittrick
Taft
Lamont
Arvin
Bakersfield
Tehachapi
Lake Isabella
Kern River
Poso Creek
Friant-Kern Canal
Caliente Creek
Cuyama River
Santiago Creek
California Aqueduct
7th Standard Rd
Mount Diablo Meridian
San Bernardino Meridian
0 3.5 7 14 21
Miles
N
S
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W
Kern Groundwater Authority
Basin Setting
Kern County, California
GEI Consultants
REGIONAL GROUNDWATER QUALITY MONITORING NETWORK
DECEMBER 2019
FIGURE 3-4
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10Jan2020

T E C H N I C A L M E M O R A N D U M

TO: Kern County Subbasin GSAs

FROM: GEI Consultants, Inc.

DATE: October 25, 2019

RE: IMPROVEMENTS TO REGIONAL SUBSIDENCE MONITORING IN THE KERN COUNTY SUBBASIN

This memorandum was prepared, in coordination with the Kern County Subbasin GSAs, to fill data gaps in the Kern County Subbasin subsidence monitoring network. It prioritizes areas of interest, at a subbasin-level, that require additional subsidence monitoring. It also includes the design approach and parameters to be monitored, and references DWR guidelines regarding subsidence monitoring design.

Background and Purpose

The development of a network to monitor sustainability indicators, including subsidence, is one of the requirements of the Groundwater Sustainability Plans (GSPs) to be submitted to the Department of Water Resources (DWR) for compliance with the Sustainable Groundwater Management Act (SGMA).

To achieve and comply with the requirements of SGMA as it pertains to subsidence and knowing that in the Kern County Subbasin there lacks sufficient data, this memo was generated for the benefit of the entire Kern Subbasin GSAs as a coordinated effort. In each individual GSPs of the Kern Subbasin, existing land surface elevation and land subsidence monitoring is identified, along with data gaps within the existing network. This memo describes the process and rationale for identifying subsidence areas of interest (AOIs) to address data gaps, the current monitoring network, and the location of future monitoring points. The memo includes the following objectives for monitoring, which are applicable to land subsidence:

1. Demonstrate progress toward achieving measurable objectives described in the management area and throughout the Subbasin;
2. Monitor impacts to the beneficial uses and users of groundwater, surface land uses, and critical infrastructure; and
3. Monitor changes in groundwater conditions (or land subsidence) relative to measurable objectives and minimum thresholds.

The monitoring network is designed to monitor impacts to surface land uses or critical infrastructure as stated in the Subbasin-wide definition of undesirable results for land subsidence (KGA, 2019 emphasis added):

> *The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure.*
>
> *This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.*

One of the purposes for improving the subsidence monitoring network is to collect additional data at each AOI to fill data gaps so that sustainable management criteria (SMCs) can be set. As more data are gathered for the AOIs, Kern County Subbasin GSAs and stakeholders can establish SMCs to avoid undesirable results stemming from subsidence.

AOI Screening and Monitoring Approach

The first step in the subsidence monitoring approach is to identify AOIs based on the presence of critical infrastructure or other surface land uses. These AOIs can then be evaluated based on the decision-making criteria listed below to determine if monitoring is required. This process is illustrated in Figure 1.

An AOI requires monitoring if the following three criteria apply:

1. Infrastructure or surface land uses are susceptible to land subsidence.
2. Significant land subsidence has been observed in screening from Interferometric Synthetic-Aperture Radar (InSAR) or other remote sensing techniques.
3. The subsidence is caused by groundwater extraction.

Where data gaps exist in evaluating the criteria, additional investigation may be necessary. For example, further investigation at AOI-2 is necessary to evaluate if groundwater extraction is causing subsidence.

Monitoring Parameters

If the area is identified as an AOI that requires monitoring, then the following actions should be taken:

A. Groundwater level monitoring near the AOI,
B. Ground-truthing of subsidence detected by InSAR (CGPS, extensometer, or level surveying), and
C. Monitoring of the critical infrastructure.

As depicted in Figure 1, the process for establishing monitoring points includes locations with susceptible critical infrastructure where InSAR and/or other historical and recent monitoring has detected recent subsidence that is likely caused by groundwater extraction.

Regional Coordination

Regional coordination of monitoring is key to the design of the network in the subbasin because regional groundwater extraction is a main driver of subsidence. In addition, many of the critical infrastructure are regional and may require coordination for access within the vicinity and data sharing.

Subsidence associated with oil and gas activities may also occur in the subbasin. However, any subsidence potentially associated with oil and gas activities is regulated by the California Division of Oil, Gas, and Geothermal Resources (DOGGR) under the California Public Resources Code and is therefore separate from SGMA requirements. Coordination between groundwater and oil and gas stakeholders may be needed where there is potential for both activities to cause subsidence that impacts critical infrastructure.

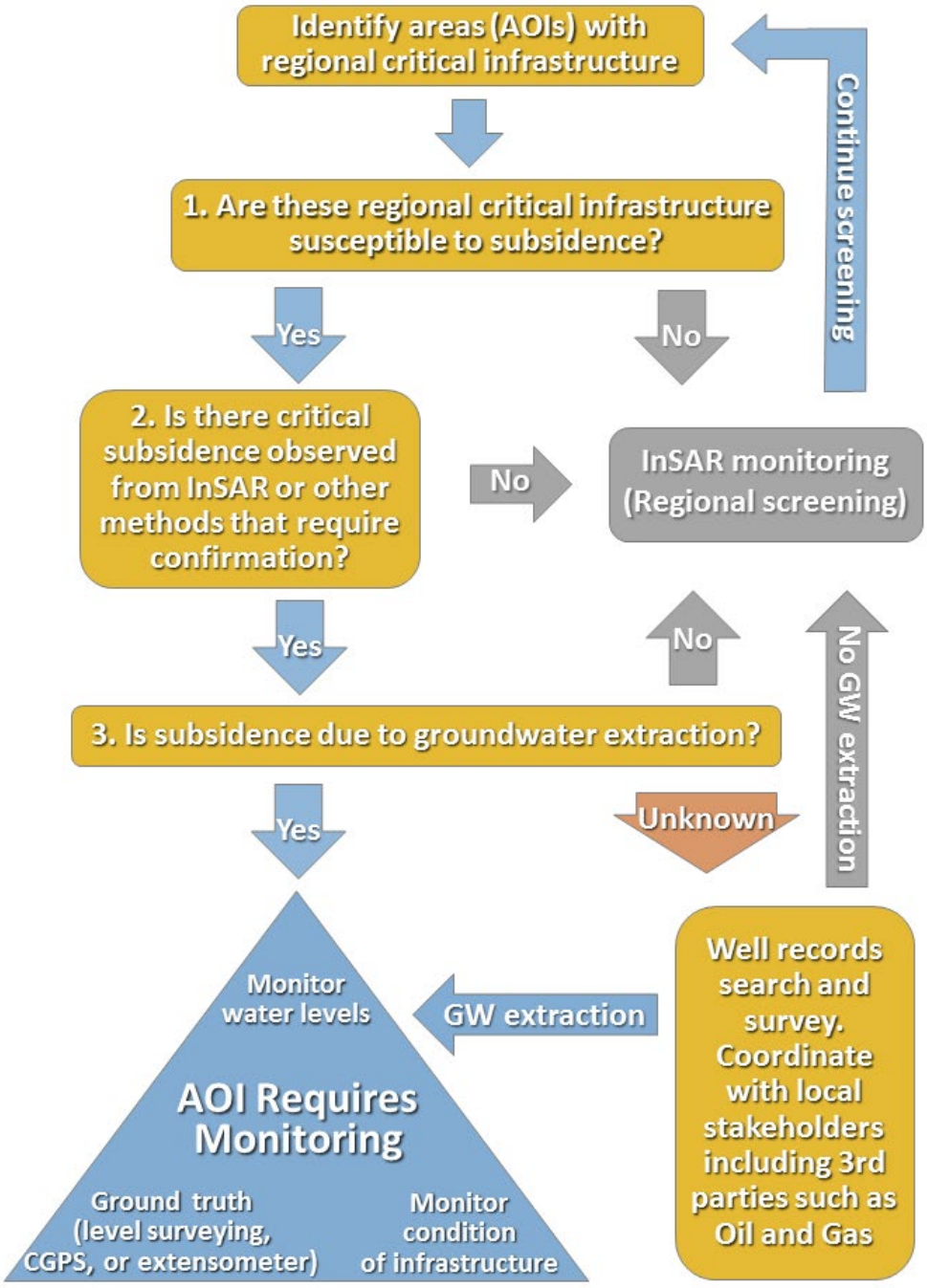


Figure 1. Subsidence Monitoring Decision Making Process and Criteria.

Improvements to Monitoring Network

Timeline and Approach

Five AOIs were identified, in order of priority, to improve the subbasin monitoring network (AOI-1 to AOI-5). Two of these areas are located along the Friant-Kern Canal (FKC), two are along the California Aqueduct, and one area is for monitoring changes in land surface elevation along the northern boundary of the subbasin where a significant amount of subsidence has been reported in the InSAR data.

It is anticipated that these sites will be evaluated in order of priority and may take up to several years to design and implement monitoring points.

Each monitoring site design will consider the following:

1. Confirm groundwater extraction is the cause of subsidence (if necessary),
2. Land siting and ownership,
3. Site access,
4. Monitoring design (CGPS or extensometer),
5. Confirmation that data for all three monitoring parameters can be collected (a. groundwater elevations, b. subsidence, and c. condition of infrastructure), and
6. Connection to the monitoring network and data sharing.

The subsidence monitoring network AOIs are presented on Figure 2. AOI-1 was selected to monitor along the FKC where subsidence has been detected near the northern boundary of the subbasin. AOI-2 was selected where the California Aqueduct has had historical impacts partially attributed to subsidence. AOI-3 along the FKC south of Poso Creek has had subsidence detected and reported by the North Kern WSD. AOI-4 along the California Aqueduct has had subsidence reported by DWR Division of Engineering (DOE) and InSAR, and AOI-5 along the northern boundary of the subbasin is not associated with critical infrastructure but is the location of high cumulative subsidence at the boundary of the subbasin and may be indicative of conditions in the neighboring subbasins which have the potential to impact the conditions of the Kern County Subbasin.

Groundwater Elevations

A key parameter in evaluating subsidence as a sustainability indicator for groundwater management is understanding groundwater level changes with respect to subsidence, particularly regional changes in water level. Figure 3 presents the regional water level monitoring points (RMWs) from the draft GSP with respect to the five AOIs for subsidence monitoring. The following are observations of RMWs within AOI vicinity:

- AOI-1 has a few surrounding RMWs; however, none are within 1 mile of the FKC.
- AOI-2 has one RMW within a mile of the Aqueduct and the AOI.
- AOI-3 has one RMW in the central portion about 1 mile from FKC.
- AOI-4 has two RMWs within the vicinity of the Aqueduct.
- AOI-5 has no RMWs within 1 mile.

Recommendation

Where possible, subsidence monitoring stations should be installed within 1 mile of a reliable RMW. If necessary, a new RMW may be installed to provide a point at which groundwater level may be collected in proximity to the land surface elevation monitoring point.

AOIs listed on subsequent pages

AOI-1. FKC Milepost 120 to 130

This high priority area is located along the FKC between Mileposts 120 to 130 (Figure 2), east-northeast of the City of McFarland. The purpose of this AOI is to monitor subsidence along the FKC and its related infrastructure. At times, InSAR monitoring has reported up to 5 inches per year of subsidence in areas surrounding this segment of the FKC. At present, no significant impacts to the FKC have been reported along this portion of the canal's alignment. According to leveling survey data from Friant Water Authority (FWA, 2019), the FKC invert may have subsided from 2 ft to 3 ft below original as-built elevations between Mileposts 120 to 135. Continued lowering of the canal invert can decrease freeboard from the original as-built conditions, which may contribute to reduction in emergency storage capabilities and delivery options of the Canal.

In contrast, beyond the subbasin's northern boundary, subsidence has caused significant impacts to the FKC conveyance capabilities between Mileposts 101 to 108.

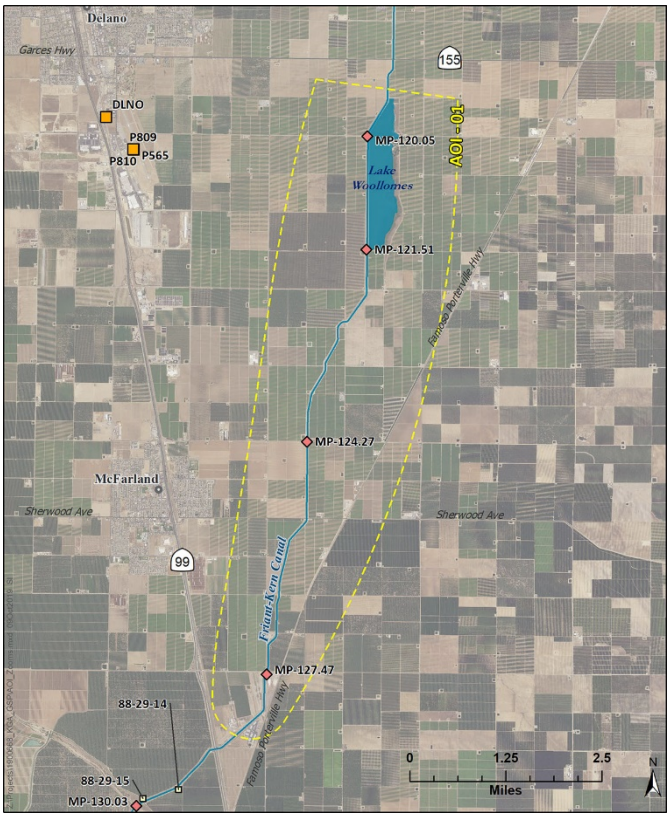


Figure 4. AOI-1. FKC Milepost 120 to 130
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR, and previous level surveying was performed by FWA at the mileposts labeled on Figures 2 and 4. There are no other active monitoring points except for InSAR along this stretch.

New Monitoring Approach

A new CGPS station that monitors at the ground surface any subsurface subsidence, regardless of the depth interval, is recommended because the only known cause of subsidence in this area is attributed to groundwater extraction. This CGPS data will complement any manual level surveys that may incorporate the FWA reported measuring points. CGPS data may also provide on-demand data as needed.

Coordination of Monitoring

Subsidence monitoring along the FKC benefits local stakeholders, CVP contractors, and the FWA. It is anticipated that this monitoring can be coordinated with FWA to share data as well as potentially share resources and cost.

Any level surveying along the canal from the United States Bureau of Reclamation (USBR) Friant-Kern benchmarks (Figure 2) will require coordination with the FWA.

AOI-2. California Aqueduct Milepost 196 to 215

This high priority area is the segment of the California Aqueduct where an embankment failure occurred at Milepost 208 in June 2011 (DWR, 2017). This failure is partially attributed to subsidence. The cause of this subsidence is unknown and is therefore a subject of monitoring at this location. This area is along the Aqueduct between Mileposts 196 to 215 in the western central subbasin (Figure 2). In addition to embankment failure, other consequences of subsidence include loss in freeboard in the Aqueduct. This area has experienced at least 2 feet of subsidence since the Aqueduct was constructed.

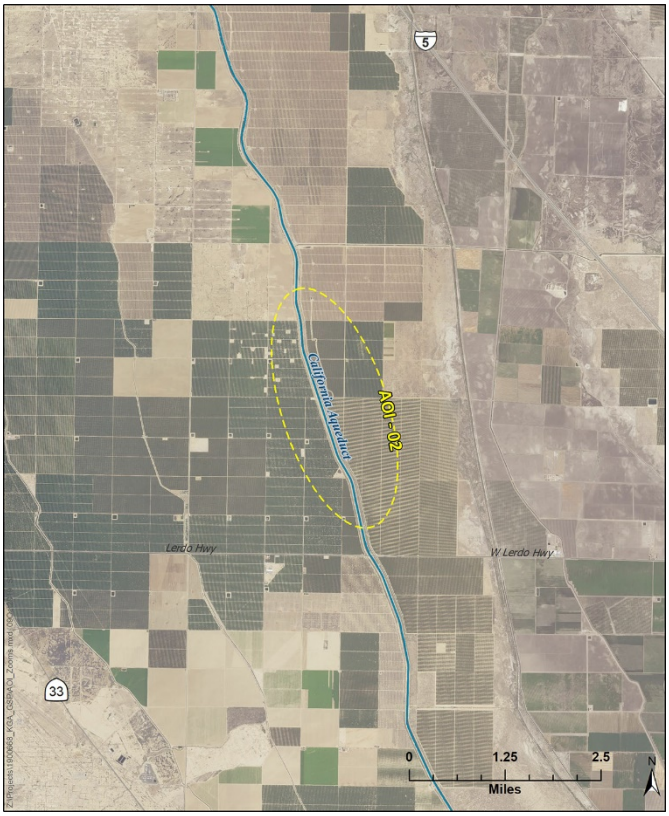


Figure 5. AOI-2. CA Aqueduct Milepost 196 to 215
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR and is monitored with level surveys every three to seven years by the DWR's DOE. There are no other active monitoring points along this stretch.

New Monitoring Approach

The source of subsidence, either by groundwater extraction activities or other activities, will be investigated by performing well records searches from DWR well completion records, the Kern County Public Health Department well permit records, and the DOGGR's databases. If necessary, a field well survey may be performed. Coordination may be needed with local stakeholders to confirm the magnitude of groundwater extracted within 1 mile of this portion of the Aqueduct's alignment and the volume of fluids extracted and injected by oil and gas activities within 1 mile of this alignment. A third potential source for subsidence in this area could be hydrocompaction, which was identified during the initial design and construction of the Aqueduct. Pre-consolidation of soil was performed during initial construction so hydrocompaction is likely not significant, however, it cannot be ruled out at this time.

If it is determined that groundwater extraction is playing a role in subsidence for this area, a monitoring point should be installed away from the footprint of the Aqueduct to avoid potential signatures of hydrocompaction if any exist. If there is question of whether some of the subsidence is related to nearby oil and gas activities, then an extensometer should be installed in the interval where groundwater production occurs. An extensometer will provide data of subsidence pertaining to intervals with groundwater production, whereas a CGPS would capture any subsidence regardless of the depth interval.

Coordination of Monitoring

Subsidence monitoring along the Aqueduct benefits local stakeholders, State Water Project (SWP) contractors, and the DWR's DOE. It is anticipated that this monitoring can be coordinated with DWR to share data as well as potentially share resources and cost.

AOI-3. FKC Milepost 130 to 137

This medium priority area is located along the FKC between Mileposts 130 to 137 (Figure 2), southwest of Famoso and Poso Creek. The purpose of this AOI is to monitor subsidence along the FKC infrastructure where InSAR and local stakeholders have reported subsidence in the surrounding area. As with AOI-1, no significant impacts to the FKC have been reported along this stretch. According to leveling survey data from the FWA (2019), the FKC invert may have subsided from 2 ft to 3 ft below original as-built elevation between Mileposts 120 to 135. Continued lowering of the canal invert can decrease freeboard from the original as-built conditions, which may contribute to reduction in emergency storage capabilities and delivery options of the Canal.

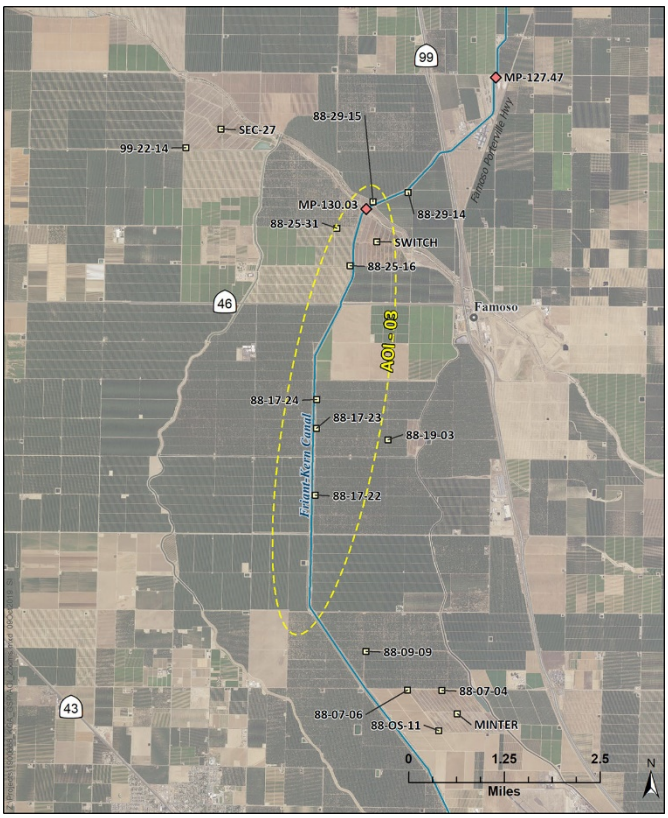


Figure 6. AOI-3. FKC Milepost 130 to 137
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR, and previous level surveying was performed by the FWA at Mileposts labeled on Figure 2. Local districts monitor this stretch regularly as labeled on Figures 2 and 6. Currently there are no continuous monitoring points along this stretch.

New Monitoring Approach

A CGPS station that monitors from the ground surface, any subsurface subsidence regardless of the depth interval, is recommended because the only known cause of subsidence in this area is attributed to groundwater extraction. This CGPS data will complement manual level surveys from local district surveys. CGPS data will also provide nearly on-demand data as needed.

Where possible, this station should be tied in to benchmark surveys performed by local districts.

Coordination of Monitoring

Subsidence monitoring along the FKC benefits local stakeholders, CVP contractors, and the FWA. It is anticipated that this monitoring can be coordinated with FWA to share data as well as potentially share resources and cost.

Any level surveying along the canal from USBR Friant-Kern benchmarks (Figures 2 and 6) will require coordination with the FWA.

AOI-4. California Aqueduct Milepost 267 to 271

This medium priority area is located along the Aqueduct between Milepost 267 to 271 near Old River Road. InSAR data report subsidence southwest and along I-5 and southwest toward the Aqueduct along Old River Road. A former CGPS station (BKR1/2) located about 5 miles north of the Aqueduct along Old River Road also reported significant subsidence; however, this station has since been decommissioned (2016).



Figure 7. AOI-4. CA Aqueduct Milepost 267 to 271
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR, and is monitored by level surveying every three to seven years by the DWR's DOE. There are no other active monitoring points along this stretch.

New Monitoring Approach

Groundwater extraction is potentially the source of subsidence, so a continuous monitoring station such as a CGPS or extensometer will be installed. Other potential sources could be oil and gas extraction and hydrocompaction. A DOGGR records search may provide sufficient information to understand the extent of oil and gas extraction in this area. Although hydrocompaction may not be significant because of pre-consolidation practices during Aqueduct construction, nonetheless, in order to avoid potential signatures of hydrocompaction, a monitoring point should be installed away from the footprint of the Aqueduct. If feasible during the siting study, the site location may be selected to the north between the Aqueduct and former BKR1/2.

Where possible, this station should be tied in to benchmark surveys performed by local districts.

Coordination of Monitoring

Subsidence monitoring along the Aqueduct benefits local stakeholders, SWP contractors, and the DWR's DOE. It is anticipated that this monitoring can be coordinated with DWR to share data as well as potentially share resources and cost.

AOI-5. Central-Northern Boundary of Subbasin

This medium priority area is in the northern quarter of T25S-R24E and T25S-R25E. Currently, this AOI does not have recognized susceptible critical infrastructure. It has significant subsidence reported both historically (USGS level surveys) and recently (InSAR). A CGPS station in this area will provide a needed ground truthing point to confirm InSAR readings and will act as a useful monitoring point to gauge progress of groundwater management along the border of the subbasin in relation to neighboring subbasins to the north.



Figure 8. AOI-5 Central-Northern Boundary of Subbasin
(symbol legend on Figure 2)

Existing Monitoring

Currently, this area is screened by InSAR. There are no other active monitoring points along this stretch.

New Monitoring Approach

Groundwater extraction is potentially the source of subsidence, so a CGPS or extensometer monitoring station should be installed. Where possible, this station should be tied in to benchmark surveys performed by local districts.

Coordination of Monitoring

Subsidence monitoring along the subbasin boundary benefits local stakeholders in Kern County subbasin and adjacent subbasins. In the future, data may be shared with neighboring GSAs for coordination.

Monitoring and Design Guidelines

According to the BMP (DWR, 2016), Leveling surveys and CGPS surveys must follow, at a minimum, guidelines in the *CalTrans Survey Manual*: https://dot.ca.gov/programs/right-of-way/surveys-manual-and-interim-guidelines. Extensometer resources from USGS are also listed in the BMP (DWR, 2016).

In addition to CalTrans guidance, UNAVCO has provided many CGPS design specifications on their website. UNAVCO offers a robust CGPS monument design (deep drill based monument [DDBM] that minimizes interference in data recording from soil expansion and temperature effects. Attachments 1 and 2 include example specifications for CGPS stations from CalTrans and UNAVCO, respectively. Attachment 3 includes sample extensometer designs for reference.

Rough Costs to Consider

For subbasin-wide monitoring to be implemented with the recommended AOIs in this memorandum, Kern Subbasin stakeholders will coordinate how the work will be implemented. Below is a brief summary of rough costs expected for the installation of each monitoring solution. Costs do not include ongoing management and maintenance of the stations. Actual costing will be confirmed during procurement and the planning process.

Level Surveying and Benchmarks (not proposed in this memo, but is an alternative approach).

- Install benchmarks where none available along linear features every 1/8 to 1/4 mile in area of interest.
- Each ~$500 to $2500 installation
- Initial Survey (5 to 8 monuments per day). ~$1500-$2500 per day (includes reporting).
- Subsequent Surveys (8 to 10 monuments per day). ~$1500-$2500 per day (includes reporting).

CORS CGPS Station

- ~$30k to $100k depending on equipment (purchase and installation). This may not include programming and digital network setup.
- DWR may be able to provide technical assistance, and at a minimum, review design specifications if DWR concurrence is wanted. DWR has not at this time offered any current specifications or assistance in developing designs.
- Optional outside consulting may be recommended for design and programming.

Extensometer

Drilling and installation costs ~$200k to $300k (design and operation not included).

Conclusions

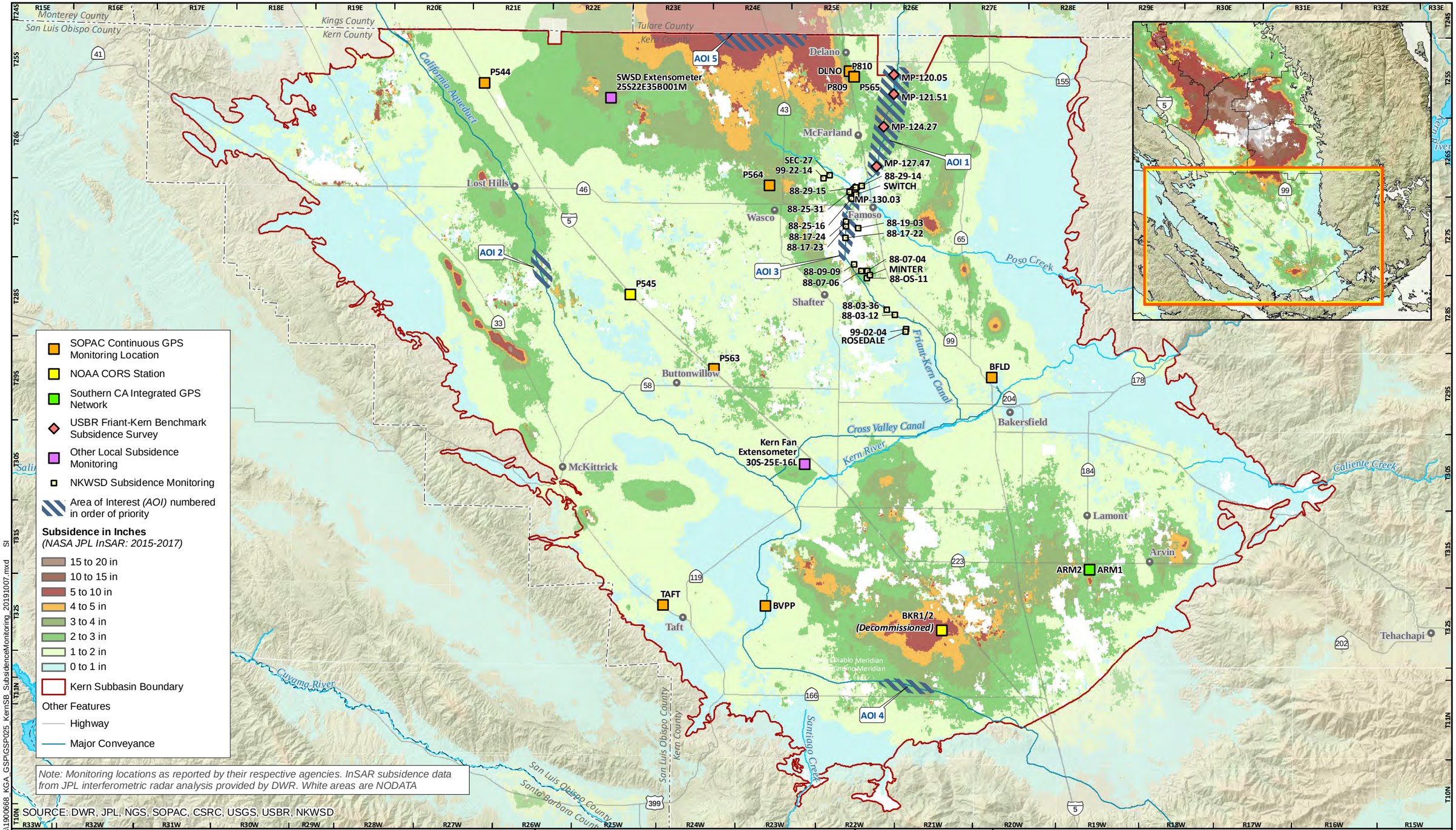
This memorandum was prepared, in coordination with subbasin stakeholders, to improve the Kern County Subbasin subsidence monitoring network. It prioritizes areas of interest, at a subbasin-level, that require additional subsidence monitoring. Figures 2 and 3 present the AOIs for future monitoring points and associated water level monitoring wells (RMWs). AOIs are listed in order of highest priority for investigation and monitoring installation. Figures 4 to 8 present aerial images of these areas. In AOIs where groundwater extractions and oil and gas activities may be contributing to subsidence, extensometers will be installed in lieu of CGPS points in order to monitor the depth interval of groundwater extractions. Where subsidence monitoring is required, monitoring water levels and the condition of infrastructure is necessary. Where groundwater extraction is not causing subsidence, the AOI can be screened by the region-wide InSAR subsidence monitoring network.

References

DWR. 2016. Monitoring Networks and Identification of Data Gaps. Best Management Practices (BMP) for the Sustainable Management of Groundwater. December.

DWR. 2017. California Aqueduct Subsidence Study. San Luis Field Division. San Joaquin Field Division. June.

Kern Groundwater Authority (KGA). 2019. Groundwater Sustainability Plan of Kern County Subbasin. Public Draft. August.



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

REGIONAL SUBSIDENCE MONITORING NETWORK

OCTOBER 2019 **DRAFT** FIGURE 2

07-Oct-2019 Z:\Projects\1900668_KGA_GSP\GSP025_KernSB_SubsidenceMonitoring_20191007.mxd SI

Kern Subbasin Boundary

Monitored for Water Quality Only

Monitored for Water Quality and GWE

Kern Groundwater Authority GSA

KERN RIVER GSA

BELRIDGE W.S.D.

BERRENDA MESA W.D.

BUENA VISTA W.S.D.

CAWELO W.D.

DEVILS DEN W.D.

DUDLEY RIDGE W.D.

HENRY MILLER W.D.

LOST HILLS W.D.

SEMITROPIC W.S.D.

WHEELER RIDGE-MARICOPA W.S.D.

ARVIN-EDISON W.S.D.

DELANO-EARLIMART I.D.

SHAFTER-WASCO I.D.

KERN-TULARE W.D

SOUTHERN SAN JOAQUIN M.U.D

TEJON CASTAIC W.D

NORTH KERN W.S.D

SHAFTER-WASCO I.D additional M.A

ROSEDALE RIO BRAVO W.S.D

WEST KERN W.D

KERN WATER BANK AUTHORITY

OIL AND GAS LANDS

EASTSIDE WATER MANAGEMENT AREA

SEMITROPIC W.S.D additional M.A

ROSEDALE RIO BRAVO W.S.D additional M.A

ARVIN-EDISON W.S.D additional M.A.

BELRIDGE W.S.D additional M.A

BERRANDA MESA W.D additional M.A

0 3.5 7 14 21

Miles

0.48 in

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

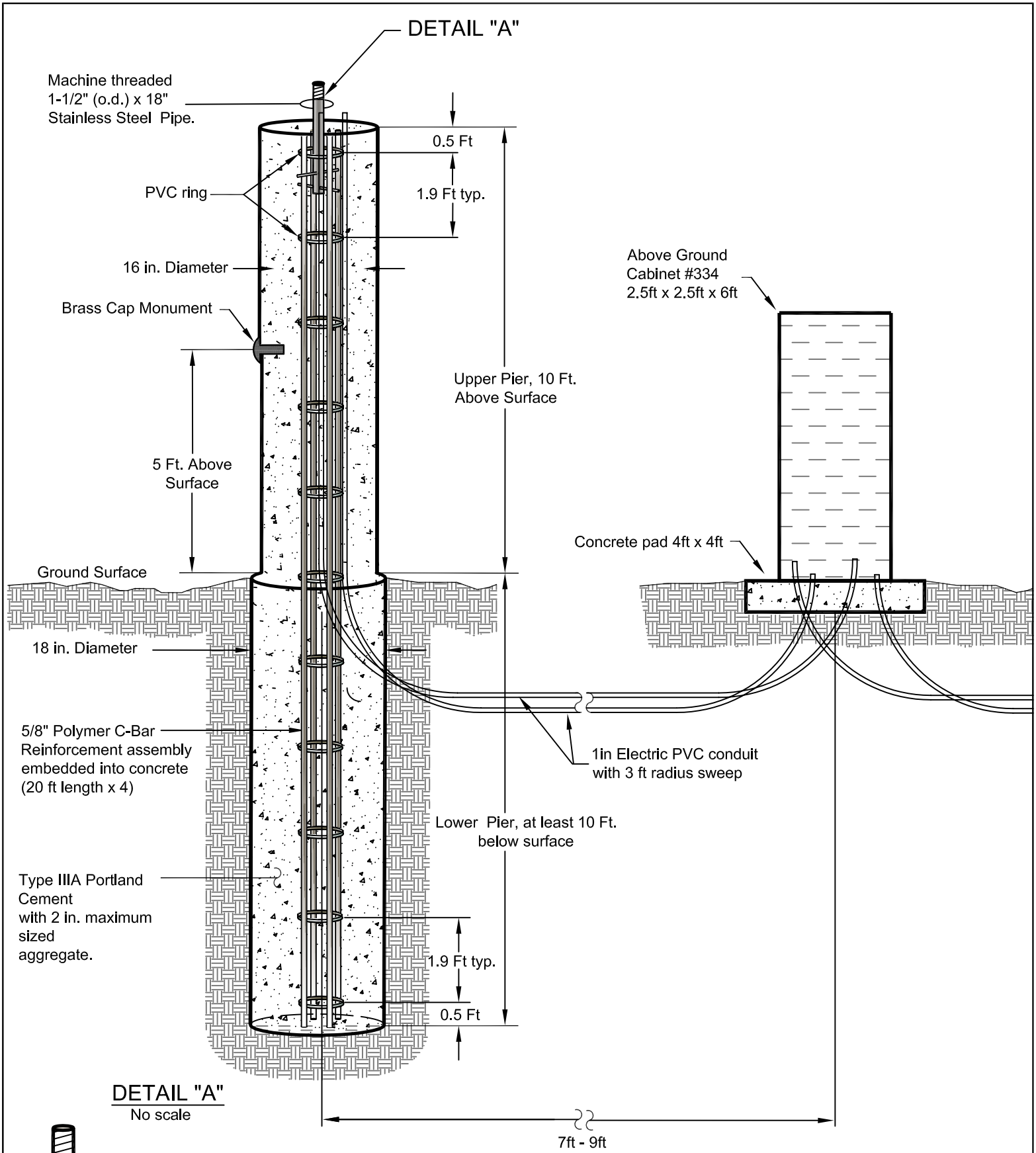
GEI Consultants

REGIONAL GROUNDWATER QUALITY MONITORING NETWORK

DECEMBER 2019 **DRAFT** FIGURE 3

Z:\Projects\1900668_KGA_GSPGSP040_MTMO_WQ_MonNetwork_20200110.mxd AB/SI 10Jan2020

Attachment 1. CGPS CDOT Design



Caltrans
855 M Street, Suite 200, Fresno, CA 92721

Monument CVSRN

TAFT MS
Station Name

CENTRAL VALLEY SPATIAL REFERENCE NETWORK

C V S R N

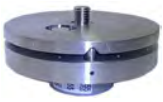
Design By: GC	Revision: Feb 20, 2007
Drawn By: PNP	Scale: None
File: Monument TAFT	
Date:Feb 20, 2007	Sheet 1 of 1

Attachment 2. CGPS UNAVCO Design and Resources

Deep Drilled Braced Monument Overview

Article ID: 300 | Rating: Unrated | Last Updated: Wed, Oct 26, 2011 at 6:49 PM

Deep Drilled Braced Monument

Back to comparison table	Mount Commonly Used	Stability	Cost	Install Time	Labor	Substrate	Site Impact
	 SCIGN mount	high	$7,500-15,000	2-4 d	3-4	BR, U	high

The deep drilled braced monument (UNAVCO DDBM*) provides for a high degree of stability and longevity and can be anchored in bedrock or unconsolidated material. It is in the form of a tripod, each leg extending into the ground up to about 40 feet and welded at the top with gusset reinforcements. If site access is an issue and bedrock is available, the short drilled braced monument is the next best alternative to this type. The UNAVCO DDBM is used throughout the PBO network. It is based on the SCIGN design used at older installations in the SCIGN, BARGEN, PBO and PANGA networks.

* Modified from the original SCIGN DDBM design of Duncan Agnew and Frank Wyatt.



Site ASHM of the BARGEN network, Nevada, Utah, and California.

Pros

- high stability
- longevity
- can be installed in either bedrock or unconsolidated materials

Cons

- labor and tool intensive (requires a drilling rig and crew)
- expensive (can be $7,500 to $15,000, depending on drilling)
- time intensive (requires 2-4 days)
- may not be able to install in some remote locations... depends upon ease of site access
- large construction disturbance footprint

Design and Construction

A drilling contractor is required to install this monument. The cost of installation can typically range between $6,000 and $10,000 depending upon factors such as the type of drilling rig used, distance the drill rig and crew need to travel to site (mobilization/de-mobilization), foundation material (ground) being drilled, etc.

- Driller's Instructions (.pdf)

Documents

- Deep Drilled Braced Monument Technical Drawings in .pdf format:
  - Full
  - Above Surface
  - Top
  - Construction
  - Site Layout
  - Sub-surface
- Deep Drilled Braced Monument Alignment Tool Diagrams in .pdf format:
  - sign-01-01-010.pdf
  - sign-01-01-020.pdf
  - sign-01-01-030.pdf
  - sign-01-02-010.pdf
  - sign-01-02-020.pdf
  - sign-01-02-030.pdf

Installation Photos

- Construction Photos

Approximate Cost

$7,500-15,000 depending principally on drilling (substrate, distance drill rig needs to travel to and from the site)

This cost is for the monumentation only; the antenna mount (e.g. SCIGN mount) is not included.

Materials

- 21-foot 1.25" diameter schedule 40 stainless steel pipe, threaded (5 per site)

- 10-foot 1.25" diameter schedule 40 stainless steel pipe, threaded (5 per site)
- 1.25" schedule 40 stainless steel threaded adapters (5 per site)
- 3 weld gussets
- threaded adapter (if using the SCIGN antenna mount; see below)
- 2.5" diameter schedule 40 PVC (for each leg and for center post)
- foam wrapper (for each leg and for center post)
- rebar (for each leg and for center post)
- duct tape (for foam)
- concrete (provided by drillers)
- water (provided by drillers)
- welding rod
- gas for the generator (if there is no AC hookup)
- string, paint, nails, and wood stakes (for marking legs)

Tools

- generator (if there is no AC hookup)
- compass
- reel measuring tape (30m/100ft)
- leg alignment tool
- mallet
- large vice grips (2 or more)
- grinder
- vertical and angle level(s)
- welder
- file, pick, brush, gloves, helmet, long-sleeved shirt, hat (for welding)

Mount Commonly Used



The SCIGN mountis the antenna mount most commonly used with the deep drilled braced monument, although it is only required when using the SCIGN radome. Otherwise, any other leveling mount, such as the SECO 2072-series antenna mount, is acceptable.

GPS Deep Drilled Braced Monument Installation
Driller Instructions

Overview

The deep drilled braced GPS monument (DDBM) is designed to create a highly rigid and immobile structure isolated from surface soil movement and cemented in place at depth. The monument consists of 5 legs (stainless steel pipes) placed into drilled holes, and welded together above the surface to create a "tripod" frame. Of the 5 legs, the center leg is vertical and the 4 other legs are installed at angles to brace the vertical leg.

The Plate Boundary Observatory (PBO) project will require the installation of at least 600 of these DDBM monuments throughout the Western US and Alaska. We hope to locate a small number of highly skilled contractors throughout the Western US and Alaska to install these monuments during the next five years. This scope of work is for a one-time installation project consisting of a small number (1-5) of these installations. This will allow us to evaluate the contractor for possible future work within PBO. Please provide a quote for services based upon the scope of work outlined below.

Material

Contractor to supply to the following material:

1) A sufficient amount of grout to fill 5-35 foot deep holes (4.5"-6" diameter) will be used. Contractor will assure the following:

   a) Type I, II Portland cement and Class F Flyash shall be used for grout materials.
   b) Flyash shall replace 10-15% of the volume of Portland cement.
   c) Grout shall be proportioned to have a water to cementitious material ratio of 0.50.
   d) If using pre-packaged grout, grout shall be 1118 Grout supplied by Surecrete, Seattle, WA, or an approved equal meeting these specifications. Grout 1119 should be used for applications when water is present in the hole.

2) Water sufficient to mix grout. Final mix should be consistency of a milk shake.

All other material will be supplied by UNAVCO.

Construction Procedure

<u>Drilling/Casing/Pipe Placement</u>

1) Drill rig type and size selection shall be determined by contractor such that equipment used is most suited to site geology and hole precision requirements.

2) UNAVCO shall provide to the contractor a summary of expected site conditions such as surface topography and subsurface material.

3) Contractor shall drill 5 holes of 4.5" diameter to minimum depths of 35 ft.
   a) Center hole shall be drilled at vertical orientation plus/minus 2 degrees.
   b) Four angled holes shall be drilled at 35 degrees from vertical plus/minus 2.5 degrees.

4) Holes drilled at precise locations specified by UNAVCO engineering staff. Frequent measurement of hole inclination during drilling shall be made to ensure holes are drilled to exact specifications. The centerlines of all 5 holes shall intersect at a single point plus/minus 3". This point of intersection shall be located 62" above the surface, at the center leg. On level ground, each of the 4 angled legs will enter the ground at 43.5" from the center leg.

5) All holes shall be drilled straight enough so that PVC casing can be installed in the top 15.5 ft of each hole, and that the steel pipe can be freely lowered, not forced, for its entire 35 ft length.

6) Hole depth is to be determined by actual measurement after drilling. If necessary, loose material may need to be removed from the bottom of the holes to achieve required depth.

7) 2.5" PVC casing (wrapped with insulation) shall be installed in upper 15.5 ft of each hole immediately after drilling. It may be necessary to use drill rig to push casing into hole.

8) Contractor shall assist UNAVCO staff in placement of steel piping immediately after drilling and casing installation. 1.25" schedule 40 steel pipe shall be installed inside casing in each hole to a depth of 32-38 ft.

9) A single 5 foot vertical hole shall be drilled for the equipment enclosure.

10) UNAVCO is responsible for siting and alignment.

11) Contractor shall assist in the clearing of cuttings from the hole, during the drilling operation.

Grout Installation

1) Contractor shall provide grouting material and water for mixing.

2) All five legs are to be cemented in place with expansive grout.

3) Contractor shall prepare the pumpable grout to a "milkshake" consistency. Jobsite conditions may affect actual quantities of water needed.

4) Following steel pipe installation, contractor shall pump grout down steel pipes until grout fills pipe and pipe-casing annulus, and is seen emerging from top of annulus. Due to small clearances within pipe and at pipe-casing annulus, high pressures may be encountered during grout placement.

5) Contractor shall place grout such that no air bubbles are introduced. Ensuring a continuous flow of grout through pipe and back up through annulus requires proper grout handling, mixing, and pumping equipment and procedures.

6) Contractor shall neatly finish grout at surface of casing such that water will not puddle around monument legs.

Site Documentation and Cleanup

Contractor shall assist UNAVCO personnel in compiling site documentation including:

1) Depths of holes. All drilling documentation including drilled, measured, tamped, and shimmed pipe depths shall be recorded by contractor.

2) Grout information. Time of day, grout sack ID#, grout amount sifted, mixed, pumped, and lost shall all be monitored by contractor and reported to UNAVCO engineer for recording.

3) Contractor shall be responsible for removal of hazardous materials (i.e. hydraulic fluid, diesel fuel and/or contaminated soil) and debris. Site shall be left in suitable condition.

4) Contractor shall be responsible for containing and disposing of excess grouting material and debris such as cement bags, trash, and cigarette butts.

5) Contractor shall be responsible for leveling and raking of areas that were disturbed by drill rig and support vehicles at the site.

Miscellaneous

1) Contractor is responsible for hotel and per diem for the drilling crew.

2) Contractor shall assist UNAVCO personnel in any tasks related to GPS site installation such as pipe/coupling preparation, installation of pipe and insulation piping.

3) UNAVCO will mark for Underground Services Alert.

4) UNAVCO will provide maps, directions and relevant access information for drilling access.

5) Contractor's equipment and tools are the sole responsibility of the contractor. UNAVCO will not reimburse the contractor for any lost or damaged equipment.

All work shall be done to highest professional standards.

GPS/GNSS Receiver Comparison Table

	Receiver	Multi-GNSS ?	Available as special buy	Available on loan	Serviceable at UNAVCO	File Size (24 hr, 15 s	Memory	Time lasts recording at 15 s	Power draw w/ antenna	Time lasts on 18amphr battery
	Alert Geomatics/XEOS Resolute Polar	Y	Y	Y	N	4.2MB	8GB	5.2 years	1.2 - 2W	1 Week
	Ashtech ProFlex 500 CORS	Y	Y	N	Y	N/A	8MB + Ext. USB	N/A	<5W	>1.5 days
	Javad Sigma	Y	N	N	N	N/A	up to 2 GB	N/A	4 W	1.9 days
	Leica GR25	Y	Y	N	N	1.6 MB 1.2 MB (zip)	up to 32 GB SD card	54 years on an 32 GB card	N/A	N/A
	Leica GR10	Y	Y	N	N	1.6 MB 1.2 MB (zip)	up to 32 GB SD card	54 years on an 32 GB card	3.5 W	2.5 days

	Septentrio PolaRx5	Y	Y	N	N	N/A	up to 32 GB	N/A	2-4 W	4.5 days
	Septentrio PolaRx4	Y	Y	N	N	N/A	up to 7.4 GB	N/A	6.1W	1.25 days
	Septentrio AsteRx3 HDC	Y	Y	N	N	N/A	N/A	N/A	N/A	N/A
	Septentrio AsteRx2el HDC	N	Y	N	N	N/A	N/A	N/A	N/A	N/A
	Topcon NetG5	Y	Y	N	Y	6.8 MB (default messages)	up to 32 GB	~10 years	4 W	1.9 days
	Topcon Net-G3 and Net-G3A	Y	Y	N	Y	6.8 MB (default messages)	up to 8 GB CF card	3.2 years	4 W	1.9 days
	Topcon GB-1000	Y	N	Y	Y	4.6 MB	1 GB internal, 1 GB CF card	1.2 years	3.9+ W	1.9 days

	Trimble NetR9	Y	Y	Y	Y	0.9 MB	8 GB Internal + External USB	24 years at 8 GB	3.8 W	2.4 days
	Trimble NetR8	Y	N	Y	Y	0.9 MB	4 GB	12 years	4.3 W	1.8 days
	Trimble NetR5	Y	N	N	Y	1.4 MB	256 MB	6 months	4.8 W	1.6 days
	Trimble NetRS	N	N	Y	Y	800 kb	1 GB	3.5 years	3.4 W	2.25 days
	Trimble R7	N	N	Y	Y	1 MB	up to 2 GB CF card	- 4 mo.- 5.5 yearsor 512 files	3.7 W	2 days
	Trimble 5700	N	N	Y	Y	1 MB	up to 2 GB CF card	- 4 mo. - 5.5 yearsor 512 files	3 W	2.5 days

	Trimble 4800/5800/R8	N	N	N	N	-	0 MB	requires external data collection	varies: 6+ W - 2.5 W	1.25 - 3 days
No longer supported	**Receiver**	**GNSS ?**	**Available as special buy**	**Available on loan**	**Serviceable at UNAVCO**	**File Size (24 hr, 15 s)**	**Memory**	**Time lasts recording at 15 s**	**Power Draw**	**Time lasts on 18amphr battery**
	Allen Osborne TurboRogue	N	N	N	N	2.2 MB turbo binary 900 kb conan binary	low	low	high	low
	Ashtech Z-12	N	N	N	N	1.8 MB	32 MB or less	18 days or less	12 W	15 hrs
	Ashtech MicroZ & ICGRS	N	N	N	Y	3.8 MB	- 32-128 MB	8 days - 1 month	8 W	23 hrs
	Canadian Marconi AllStar	N	N	N	N		0 MB	requires external data collection		
	Trimble 4000	N	N	N	N	1.8 MB	10 MB or less	5 days	10 W	18 hrs

	Trimble 4700	N	N	N	N		0 MB	requires external data collection	4.5 W	1.7 days

Available as special buy: Special pricing is available to UNAVCO members and associate members on select equipment. For more information see the GNSS Equipment Purchase Information page.
Available on loan: UNAVCO maintains a large pool of GPS and related equipment, available on loan to member and associate member institutions and NSF-funded programs. To submit a request, fill out the Online Support Request Form .
Serviceable at UNAVCO: UNAVCO is licensed to repair select GNSS receivers and antennas. For more information see the Equipment Repairs page.
File size (24 hr, 15 s): File size for a 24 hour-long file collected at a 15 second sample rate. File size is approximate and varies based on # of satellites tracked and frequencies recorded. File sizes shown here were taken from site data in the UNAVCO data archive.
Memory: Memory for receivers from the dealer may vary; values are given for UNAVCO-owned receivers.
Time last recording at 15 s: Estimated length of time the receiver can record at its given internal memory at a sample rate of 15 seconds.
Power draw: Estimated power draw in Watts. The power draw varies depending on the other equipment e.g. antenna(s) connected to the receiver.
Time lasts on 18 amphr battery: Estimated length of time the receiver can operate on the 12 volt, 18 amphr battery standard for UNAVCO campaign systems, without a solar panel. Time will vary based on temperature and battery health.

UNAVCO Resources: GNSS Antennas

Dual frequency (L1/L2) Choke Ring Antennas provide geodetic-quality GNSS measurements for surveying, map
Typical dual-frequency choke ring antennas maintain a stable phase center that has less than 1 mm of drift. T
on the geodetic research standard and features aluminum choke rings and a Dorne Margolin antenna elemen
have a low power consumption, and have excellent multipath rejection characteristics. Less-expensive but alsc
available as well. The UNAVCO Facility currently supports the following GNSS antennas.

GPS/GNSS Antennas Used by UNAVCO

	Trimble Choke Ring	MENU • NGS antenna calibration (Trimble GNSS Choke Ring, TRM59800.00 SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=TRM59800.00_SCIT.atx) • NGS antenna calibration (TRM29659.00 SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=TRM29659.00_SCIT.atx) • Note: Trimble GNSS Choke Ring TRM59800.80 is a TRM29659.00 reworked with a wide-band low noise amplifier (LNA) for GNSS. The TRM59800.00 and TRM59800.80 elements are identical in construction, the two antenna types are assumed to show similar phase center corrections. The TRM59800.80 calibrations are copies of the TRM59800.00 calibrations.
	Ashtech Choke Ring	• NGS antenna calibration (ASH701945G_M SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH701945G_M_SCIT.atx) • NGS antenna calibration (ASH701945E_M SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH701945E_M_SCIT.atx) • NGS antenna calibration (ASH701945C_M SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH701945C_M_SCIT.atx) • NGS antenna calibration (ASH701945B_M SCIT) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH701945B_M_SCIT.atx) • NGS antenna calibration (ASH700936D_M NONE) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=ASH700936D_M_NONE.atx) • Preliminary Report on Data Quality with a Trimble 5700 GPS Receiver and an Ashtech Choke Ring Antenna (2002) (http://kb.unavco.org/kb/article.php?id=237)

	Trimble Zephyr Geodetic	• NGS antenna calibration (TRM41249.00 NONE) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=TRM41249.00_NONE.atx) • NGS antenna calibration (TRM57971.00_NONE) (http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=TRM57971.00_NONE.atx) • Trimble Zephyr Geodetic - Dimensions (from Trimble) (http://kb.unavco.org/kb/article.php?id=240) • The Design and Performance of the Zephyr Geodetic Antenna (Trimble publication) (http://kb.unavco.org/kb/article.php?id=241)
	Trimble Zephyr	• NGS antenna calibration (TRM39105.00) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM39105.00)
	Topcon PG-A1	• NGS antenna calibration (TPSPG_A1+GP) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TPS&Antenna=TPSPG_A1,GP) • Topcon PG-A1 Antenna Dimensions (.pdf) (http://kb.unavco.org/kb/assets/102/TPSPG_A1GP.pdf)
no photo available	AOA TurboRogue SNR-800	• NGS antenna calibration (AOAD/M_T) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=AOA&Antenna=AOAD/M_T)
no photo available	Trimble L1/L2 microcentered geodetic with groundplane	• NGS antenna calibration (TRM33429.20+GP) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM33429.20,GP)
no photo available	Trimble Permanent L1/L2	• NGS antenna calibration (TRM23903.00) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM23903.00)
no photo available	Trimble Geodetic Compact L1/L2	• NGS antenna calibration (w/ ground plane) (TRM22020.00+GP) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM22020.00,GP) • NGS antenna calibration (w/o ground plane) (TRM22020.00-GP) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM22020.00-GP)

MENU

no photo available	Trimble 4000SST L1/L2 Geodetic	• NGS antenna calibration (TRM14532.00) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM14532.00)
no photo available	Trimble 4000SSE Kinematic L1/L2	• NGS antenna calibration (TRM14532.10) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=TRM&Antenna=TRM14532.10) MENU
	UNAVCO/Micro Pulse L1	• NGS antenna calibration (MPL1370W) (http://www.ngs.noaa.gov/cgi-bin/query_cal_antennas.prl?Model=MPL&Antenna=MPL1370W) • UNAVCO/Micro Pulse L1 - How to make UNAVCO's L1 antenna (http://kb.unavco.org/kb/article.php?id=635)

Setting up GPS/GNSS Antennas

- Introduction to GNSS Antenna Set-up Methods for Campaigns (http://kb.unavco.org/kb/article.php?id=71)
  An introduction for inexperienced surveyors including antenna height measurement methods and g
- How to use declination to align the GNSS antenna to true north (http://kb.unavco.org/kb/article.php?id=61)
  Antennas are typically aligned to true north to keep measurements both within and between campa that the location of the antenna phase center is modeled correctly.
- Geographic Magnetic Calculator (http://www.resurgentsoftware.com/GeoMag.html)
  Link to software you can download and use to calculate the declination in your study area.

Development and Testing of GPS/GNSS Antennas

- Choke Ring Antenna Calibrations (http://kb.unavco.org/kb/article.php?id=311)
- Equipment Power Usage Testing (http://kb.unavco.org/kb/article.php?id=235)
- Antenna Phase Center Plots (.pdf) (http://kb.unavco.org/kb/assets/242/phaseplots.pdf) (L1 and L2 phase center p Trimble Zephyr Geodetic, Trimble Zephyr, and Leica Choke Ring antennas)
- Iridium & GPS Antenna Interference Test (2008) (http://kb.unavco.org/kb/article.php?id=110)
- Assessing the Impact of the SCIGN Radome on Geodetic Parameter Estimates (2007) (http://kb.unavco.or
- Development of an antenna and multipath calibration system for Global Positioning System sites (2 (http://kb.unavco.org/kb/article.php?id=254)
- UNAVCO 2004 GPS Campaign System Testing in Support of the Plate Boundary Observatory (PBO) ((http://kb.unavco.org/kb/article.php?id=5)
- UNAVCO 2003 GPS Receiver and Antenna Testing in Support of the Plate Boundary Observatory (PB (http://kb.unavco.org/kb/article.php?id=15)
- Multipath characteristics of GPS signals as determined from the Antenna and Multipath Calibration (http://kb.unavco.org/kb/article.php?id=253)
- Preliminary report on data quality with a Trimble 5700 GPS receiver and an Ashtech Choke Ring Ant (http://kb.unavco.org/kb/article.php?id=237)

UNAVCO Resources: Permanent GNSS Station Enclosures

Article ID: 381 | Rating: 1/5 from 2 votes | Last Updated: Wed, Aug 24, 2016 at 8:36 PM

UNAVCO Resources: Permanent GNSS Station Enclosures

UNAVCO has installed and supports a large variety of equipment enclosures for both AC and DC GNSS sites, from enclosures specifically designed for solar systems (the SunWize battery enclosure) to simple storage containers modified to accommodate cable pass-throughs. We can work to find the most suitable enclosure given the budget and the location of each permanent or semi-permanent GNSS installation. Below is a list of enclosures used within the last several years in UNAVCO-supported projects; click on the photographs to see sample content lists and more photos of actual installations. For standard UNAVCO campaign enclosures, check out UNAVCO Campaign GNSS Systems .

	SunWize Premium F-Series Battery Enclosure	The SunWize F-Series 4-battery enclosure is used throughout the Plate Boundary Observatory network, as well as in several other permanent GPS station networks in the US. Benefits include reasonable strength (the enclosure is made of aluminum), security (two key locks secure the enclosure), both internal and external knockouts for passing wires and cables, weatherproof seals, and a generous amount of space. Drawbacks include cost ($700-$1000 as of February 2009), size (if on-site space is limited or if equipment must be shipped), and mounting requirements (enclosure is designed to be mounted on a post, which must be cemented into the ground and strong enough to support batteries).
	Hardigg Case	Hardigg (now owned by Pelican Products) makes rugged, well-sealed plastic enclosures which are stackable, easy to handle, and UV resistant. Connectors are recessed within the ribs of the case to reduce the risk of damage during shipping.

	JOBOX	JOBOX chests, made by Delta Consolidated Industries, Inc. , are durable, weatherproof metal enclosures that UNAVCO has used in several long-term installations, including the EarthScope-sponsored Rio Grande Rift network. Chests are secured with key locks. The major drawback of the JOBOX is weight; boxes are heavy and cumbersome, thus not ideal for shipping and for transporting by foot over long distances. Cost of the box shown here is approximately $300-400 (as of February 2009).
	Pelican Case (large)	The Pelican case is easily portable, can be used to transport equipment, and is weatherproof. The case shown here, as deployed in the EarthScope-sponsored Rio Grande network, contains 2 100 amphr batteries in addition to the GPS receiver. The case is difficult to destroy and can be locked with padlocks. Cost is approximately $250-$300 (February 2009). Smaller cases are available (see below), and have been used in networks with year-round, reliable sunlight where large battery banks are not required.
	Pelican Case (small)	Like the larger Pelican cases (above), the smaller Pelican case is weatherproof and can be used to transport equipment. A smaller case is ideal if space is not an issue--specifically, if the requirement for amount of power stored is small (e.g. in a year-round sunny environment, as is common near the equator). The case is difficult to destroy and can be locked with padlocks. Networks utilizing small Pelican cases include Afar, Ethiopia, and Sierra Negra, Galapagos. Cost for the case shown here is approximately $125 (February 2009).
	Commercial Electrical Enclosure	Electrical boxes can be often purchased 'locally,' in major cities, rather than being shipped. Boxes may include knock-outs for passing cables through and locking options, like the box shown here. Electrical boxes are often sturdy, made of either strong plastic or of metal, and may or may not be weatherproof. Networks utilizing local electrical enclosures include Calabria, Italy and Bangladesh. Typical price range is about $100-$300.

	Storage Container	A heavy-duty storage container, such as the Contico Tuff Box, designed for the back of a truck or other outdoor use may work well for an equipment enclosure. They are generally low cost (about $70 for the container shown here, as of February 2009), available in most US cities, rugged, and lockable with padlocks. The case shown here fits four sealed 100 Amphr batteries along with the GPS and communications equipment. Used as enclosures in the Peatland Bog, Minnesota network.

Cellular Modem Summary

Article ID: 357 | Rating: Unrated | Last Updated: Wed, Oct 28, 2009 at 3:12 PM

Cellular Modem Summary

Cellular modems need to be very robust as the inherent disadvantages of the analog cellular phone system become especially evident with high speed data transfers. Cellular coverage could be of a quality not compatible with high speed data transfers and handshaking protocols. Often more than one cellular provider offers coverage in an area and it is worthwhile to investigate several options. A good voice communication does not translate into an acceptable data communication. Your choice of cellular modem and cellular phone should be able to run off 12VDC, even if AC power is available, to facilitate DC (battery) backup.

Suggested Minimum Requirements

- 12 VDC power
- V.32, V.32bis communication protocols
- V.42, MNP error correction/data compression
- RTS/CTS hardware flow control
- High speed baud rates (2.4-19.2 kbps)
- Compatible with CCITT and Bell standards
- Support industry-standard AT command set
- Compatible with RS-232 Control Signals

Information on radio modems used by UNAVCO

Proxicast LANCell Gateway



Used throughout the Plate Boundary Observatory (PBO) network, Western U.S.

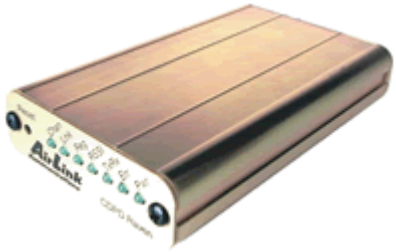
- UNAVCO summary of Proxicast cellular modems and networking

ZyXEL U-1496P



- ZyXEL U-1496P Portable Cellular Modem Summary Page

Raven II CDPD



- How to use the Raven II CDPD modem with the Lantronix MSS100 serial-to-ethernet device

Attachment 3. Extensometer Design

SAMPLE DESIGN
FOR REFERENCE

PAGE No.	DRAWING No.	DRAWING TITLE
1	100	TITLE SHEET
2	300	TYPICAL RAT HOLE
3	301	GRADING AND FOUNDATION PAD
4	302	EXTENSOMETER UNIT
5	303	BUILDING
6	304	SCHEMATIC DIAGRAM OF EXTENSOMETER

REV	DATE	DESCRIPTION	SUB	APP'D

APPROVED BY:

_____ DATE: _____

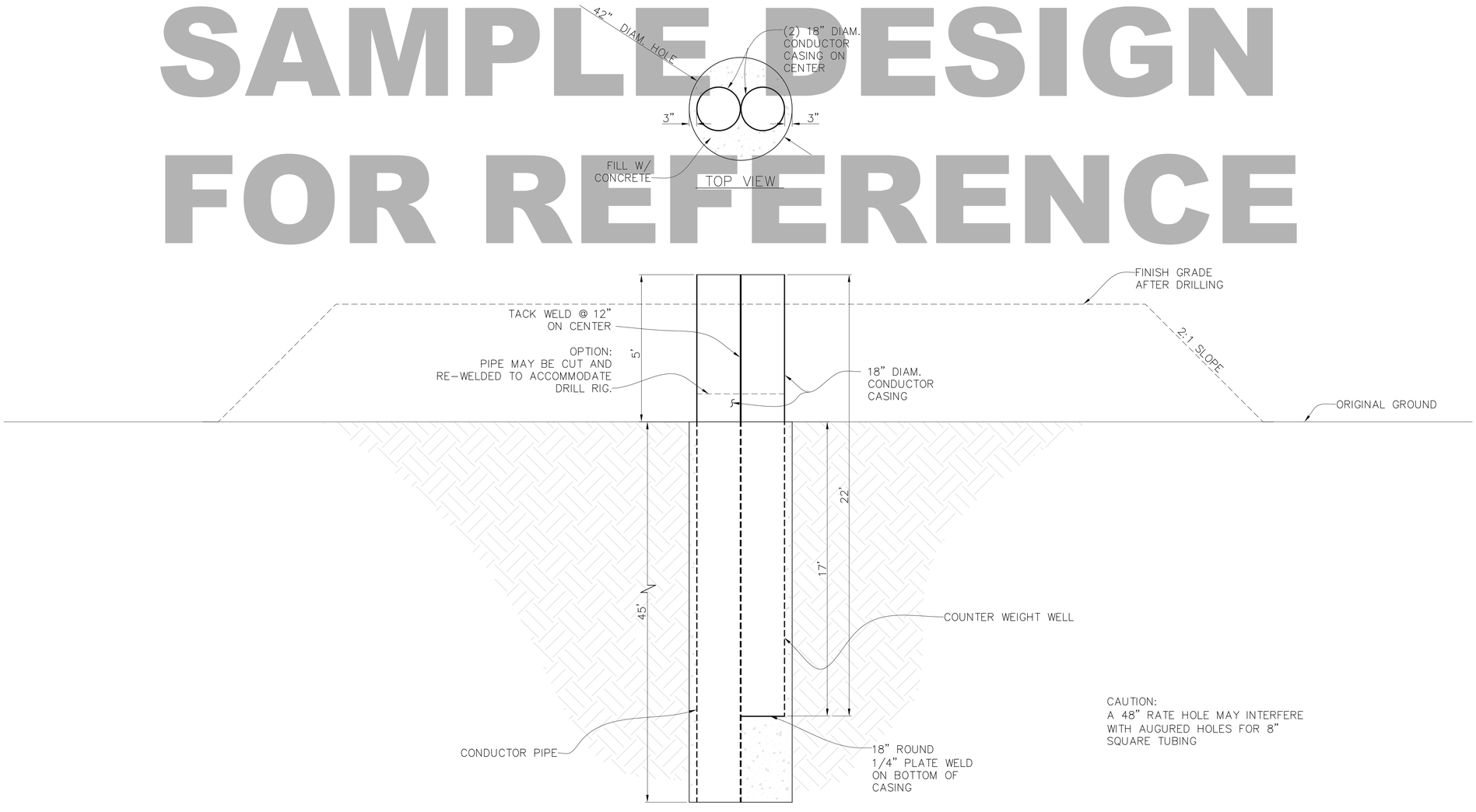
APPROVED

DATE

EXTENSOMETER CONSTRUCTION
TITLE SHEET

DRAWING NUMBER
100

SAMPLE DESIGN
FOR REFERENCE



CAUTION:
A 48" RATE HOLE MAY INTERFERE WITH AUGURED HOLES FOR 8" SQUARE TUBING

TYPICAL 42" RAT HOLE

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APPROVED BY:

DATE: _____

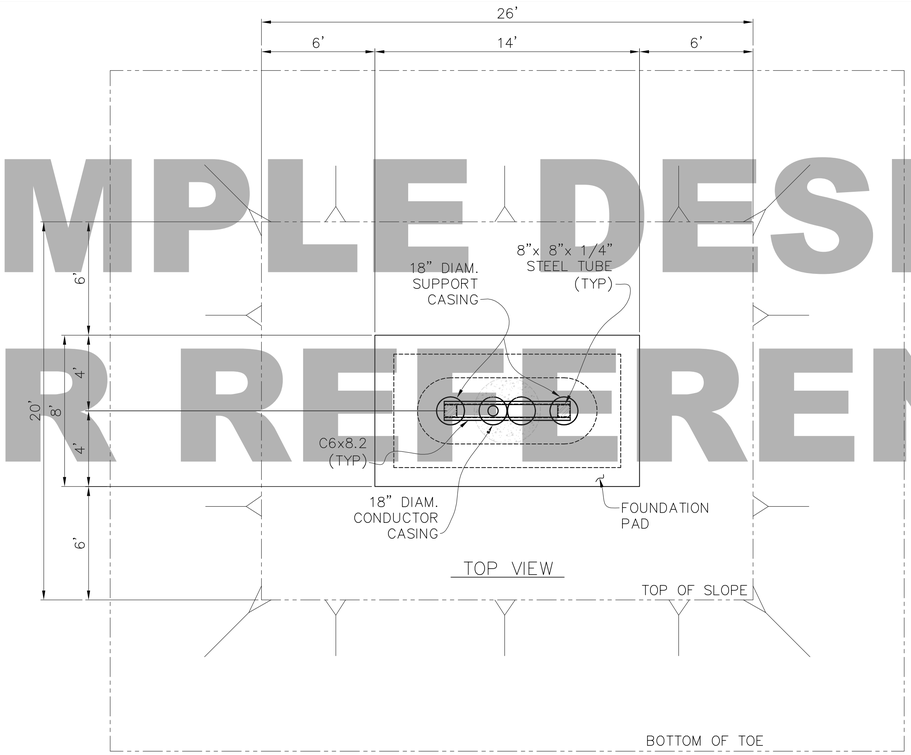
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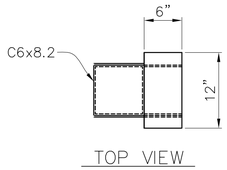
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EXTENSOMETER CONSTRUCTION
TYPICAL RAT HOLE

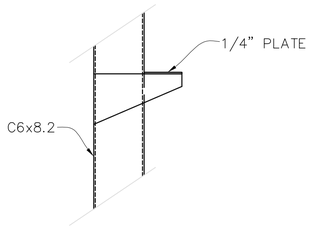
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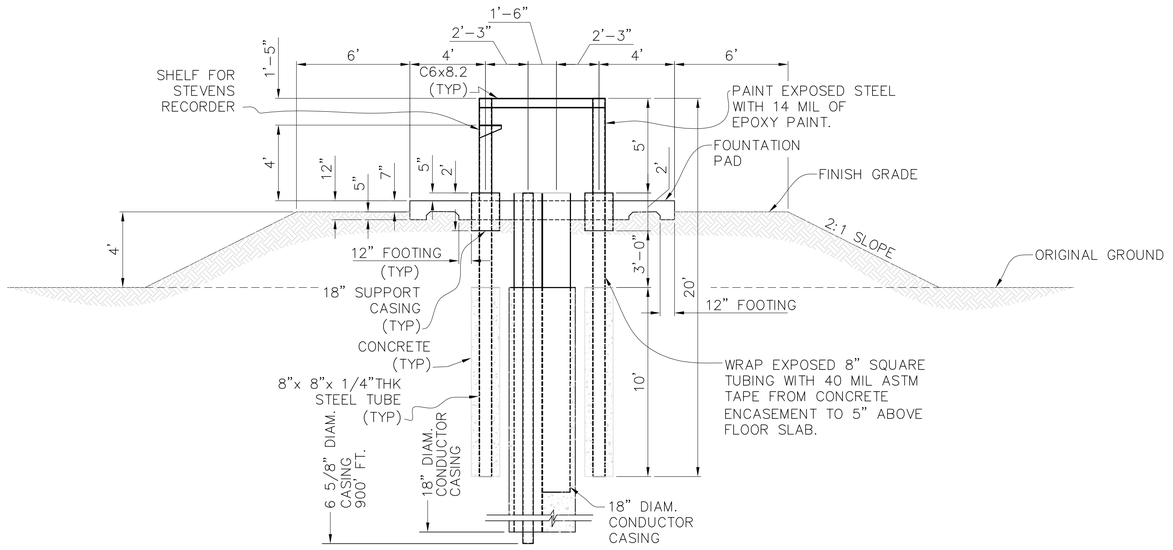




TOP VIEW



SHELF FOR STEVENS RECORDER



REV	DATE	DESCRIPTION	SUB	APP'D

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DATE:

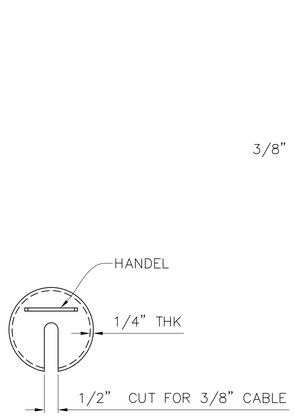
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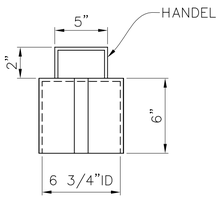
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EXTENSOMETER CONSTRUCTION
GRADING AND FOUNDATION PAD

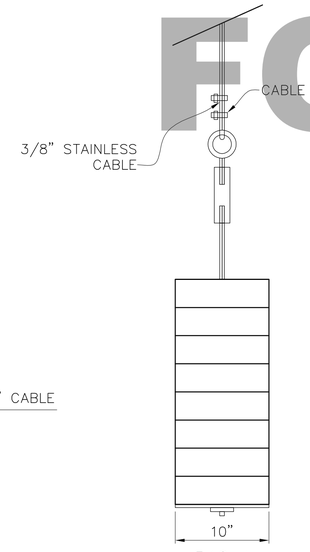
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SAMPLE DESIGN
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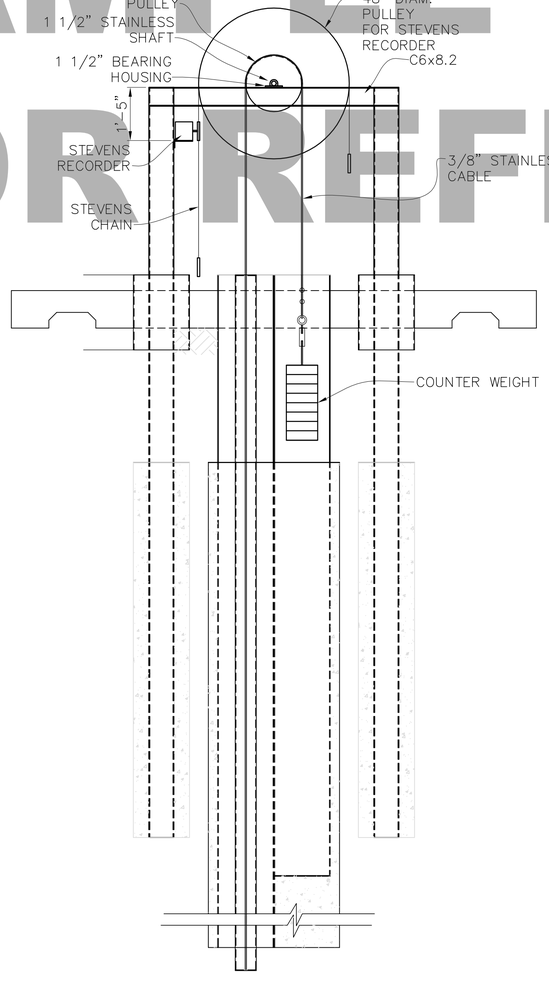




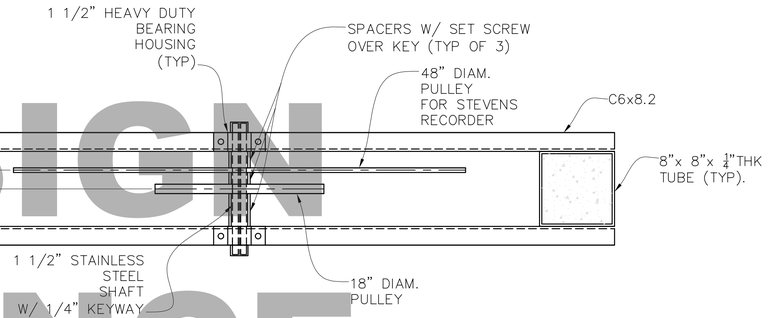
CASING CAP



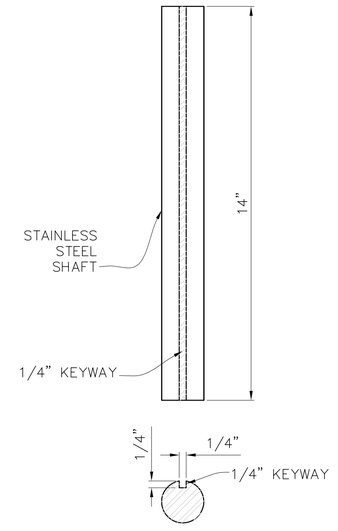
540 lbs
COUNTER WEIGHT



PULLEY ASSEMBLY



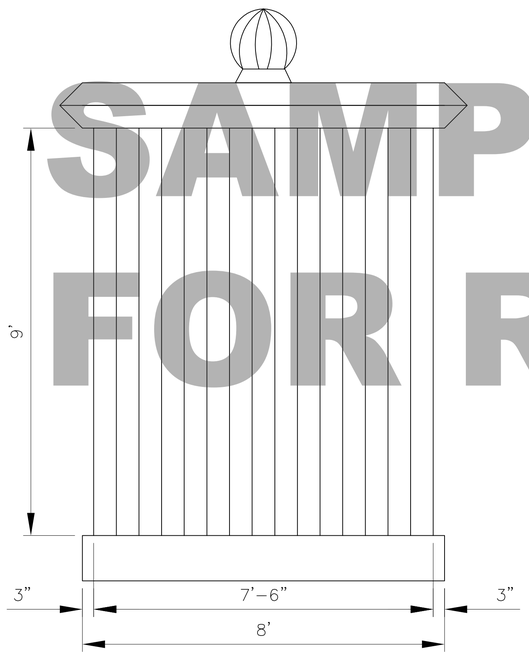
TOP VIEW



1 1/2" SHAFT

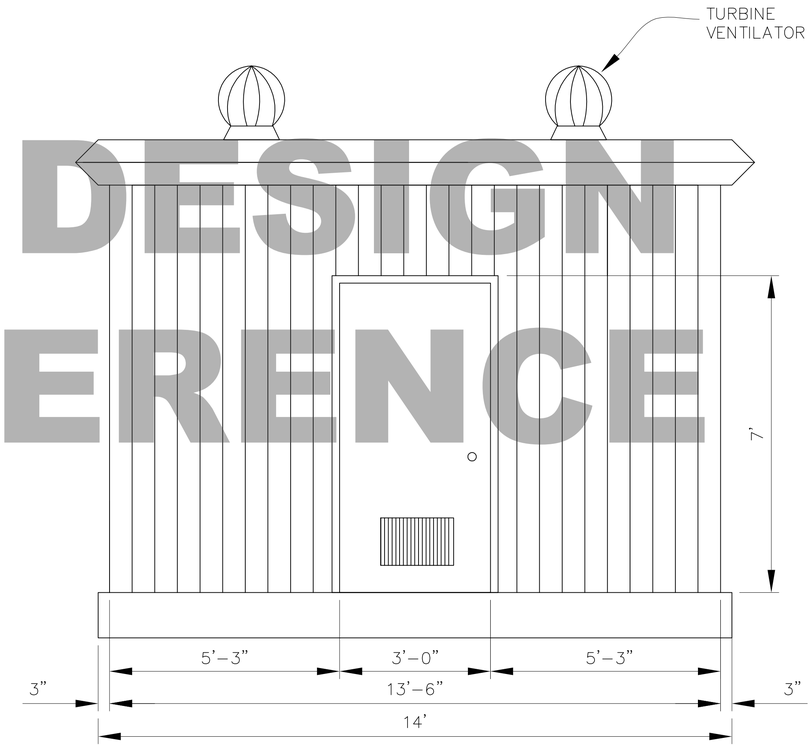
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						DATE
						DRAWING NUMBER 302

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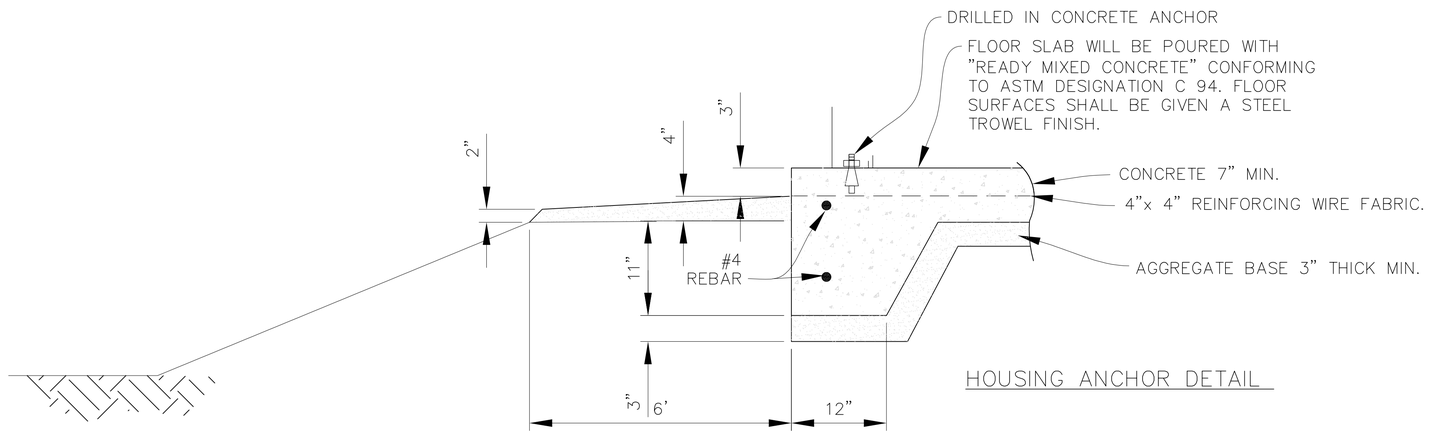


ENDWALL

ARMCO STEELOX BUILDING SYSTEMS TEC-LINE
1 BUILDING OR EQUIVALENT



SIDE VIEW



HOUSING ANCHOR DETAIL

REV	DATE	DESCRIPTION	SUB	APP'D

APPROVED BY:

DATE: _____

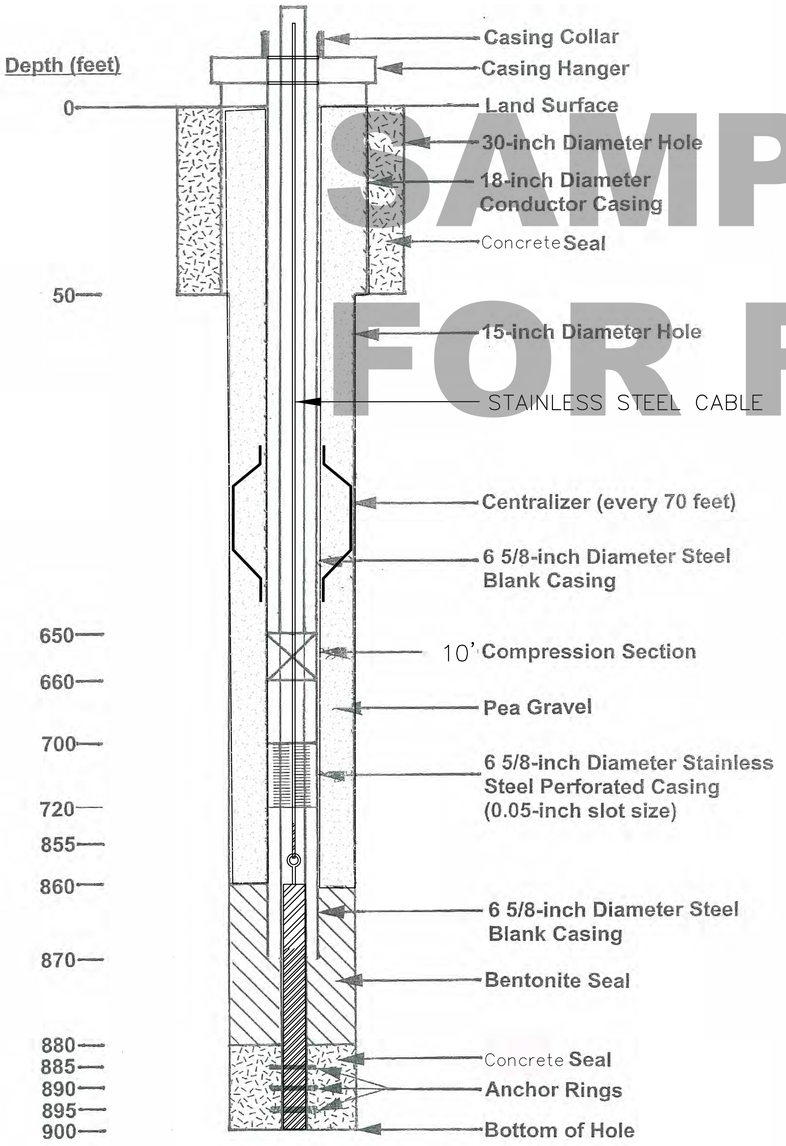
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EXTENSOMETER CONSTRUCTION
BUILDING

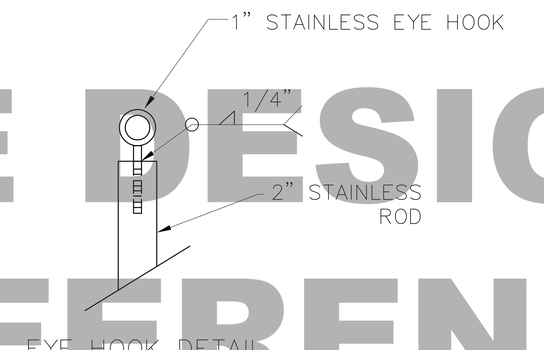
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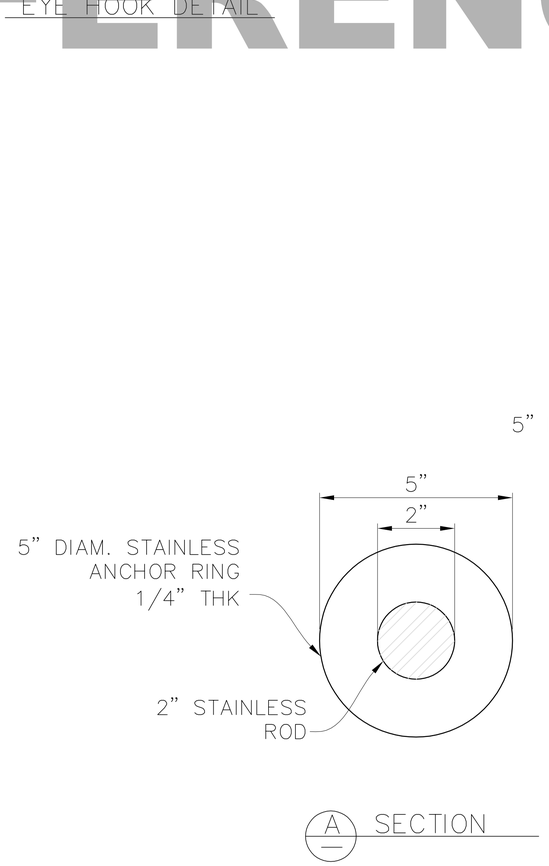
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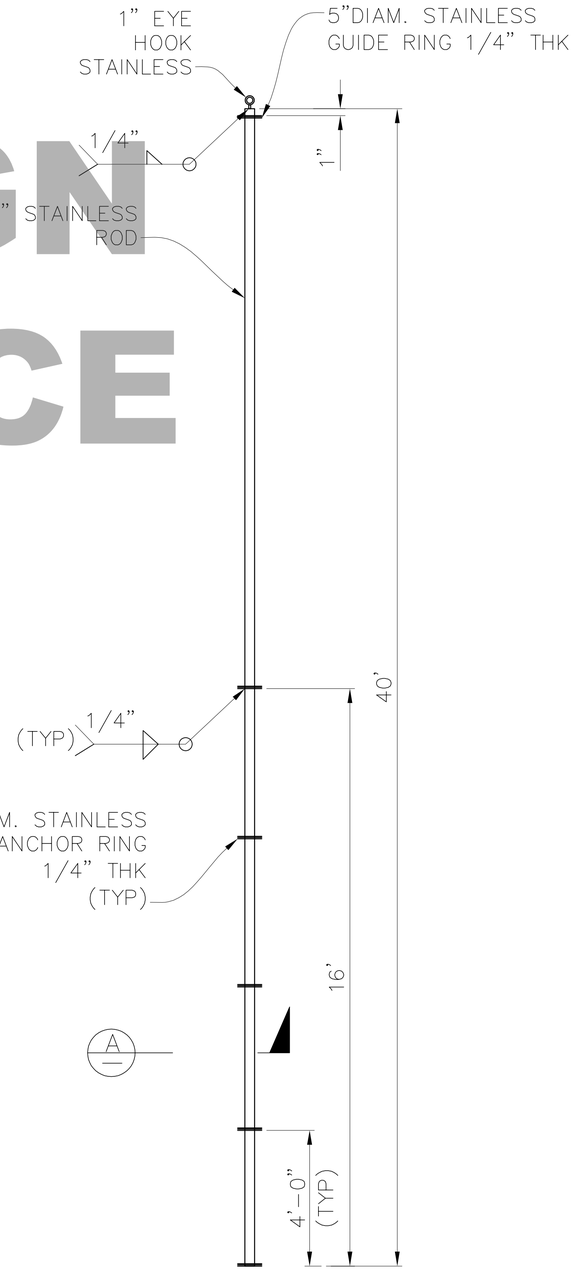
SAMPLE DESIGN
FOR REFERENCE



SCHEMATIC DIAGRAM OF EXTENSOMETER







REV	DATE	DESCRIPTION	SUB	APP'D

APPROVED BY: _____ DATE: _____

APPROVED

EXTENSOMETER CONSTRUCTION
SCHEMATIC DIAGRAM OF EXTENSOMETER

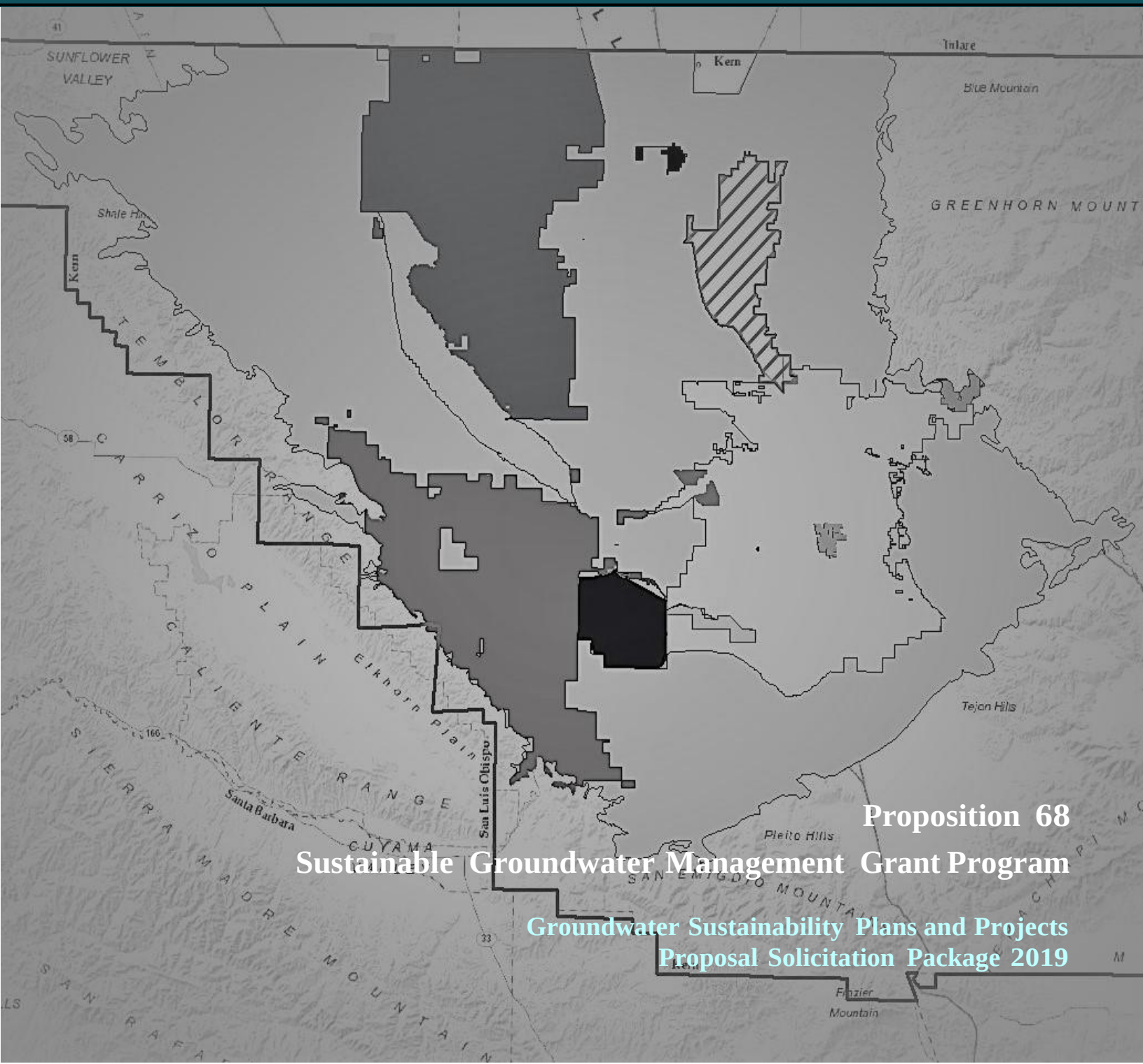
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DRAWING NUMBER
304

APPENDIX 5

At this time, the Kern subbasin is working on the development of a basin-wide coordinated Data Management System. Please see the following documents related to that development of an application to DWR Prop 68 Grant requesting funds for the development. For the current year of annual reporting, see the following document related to a coordinated basin-wide cost share agreement.

Kern County Subbasin Groundwater Sustainability Plan Support 2019 Grant Application



Proposition 68

Sustainable Groundwater Management Grant Program

Groundwater Sustainability Plans and Projects

Proposal Solicitation Package 2019

Proposal Full View

Applicant Information				
Organization Name*	Kern River GSA			
Point Of Contact	**First Name:***	Kristin	**Last Name:***	Pittack
	Email:*	kpittack@bakersfieldcity.us		
	Division Name:	City of Bakersfield	**Phone:***	(661) 3263646 Ext:
	Address Line 1:*	1600 Truxtun Avenue	**Address Line 2:**	
	City:*	Bakersfield	**State:***	California
	Zip:*	93301		
Point Of Contact Position Title*	Water Resources Planner			
Proposal Name*	Kern County Subbasin Groundwater Sustainability Plan Support - Phase II			
Proposal Objective*	The Kern County Subbasin is a critically overdrafted groundwater basin of high priority, located in the Southern San Joaquin Valley. The Proposal covers the entire Kern County Subbasin and is submitted by the Applicant, the Kern River Groundwater Sustainability Agency (KRGSA), on behalf of all the GSAs and participating entities in the Subbasin. The overarching goal of the proposed Subbasin Data Management System (DMS) Development project is to initiate the key steps to develop and build a Subbasin DMS. This DMS will ultimately support SGMA compliance by Subbasin GSAs by providing (1) improved coordination of groundwater monitoring and management actions and (2) the ability to meet the reporting and implementation requirements of SGMA for the Kern County Subbasin. To meet this goal, the project objectives are to retain a contractor to develop, manage, and coordinate use of the DMS with the GSAs and participating agencies; identify the data types that would be required to monitor GSP implementation and Subbasin progress toward sustainability; and investigate, select, and procure a commercially available or custom-designed DMS with an appropriate configuration that combines technical rigor, flexibility, ease of use, and expansion capabilities to store data in text, spreadsheet, graphical, and map-based formats. Some aspects of the DMS project, such as development of a User's Manual and DMS review and assessment, will be funded by the grant but may also be subject to GSA funding if needed. These tasks are included in the project Work Plan to provide context for the work to be completed under this Round 3 Planning funding request.			

Budget Information	
Other Contribution	$0.00
Local Contribution	$0.00
Federal Contribution	$0.00
Inkind Contribution	$0.00
Amount Requested*	$500,000.00
Total Proposal Cost*	$500,000.00

Geographic Information						
Latitude*	**DD(+/-):**	35	**MM:**	25	**SS:**	39
Longitude*	**DD(+/-):**	119	**MM:**	19	**SS:**	37
Longitude/Latitude Clarification	Location of the approximate center of the Kern County Subbasin.					
Location	The Kern County Subbasin is located in the center of the southern end of the San Joaquin Valley.					
County*	Kern					
Ground Water Basin	5-022.14 San Joaquin Valley-Kern County					
Hydrologic Region	Tulare Lake					
Watershed	115 7557 South Valley Floor; 116 7558 South Valley Floor					

Legislative Information	
Assembly District*	32nd Assembly District, 34th Assembly District
Senate District*	16th Senate District, 18th Senate District
US Congressional District*	District 21 (CA), District 23 (CA)

Project Information

Project Name: Subbasin Data Management System Development Project	
Implementing Organization	Kern River GSA
Secondary Implementing Organization	All of the Kern County Subbasin GSAs
Proposed Start Date	2/1/2020

Proposed End Date	7/31/2022
Scope Of Work	The scope of the project includes Grant Administration, Stakeholder Engagement / Outreach, GSP Development: Subbasin DMS Scoping and Development, and Review and Assessment. Deliverables include: executed contract with database development consultant; list of data types to be collected; report and recommendation on available formats for required information; and possibly recommendation and GSA Boards' decision to select a DMS package.
Project Description	The Kern County Subbasin is the largest Subbasin in California, with a complex water management structure, a large portfolio of local and imported water sources, and numerous large groundwater banking projects, collectively providing local and State-wide benefits for water supply. Given this framework, numerous structures for data management have been developed by local agencies for their own objectives, resulting in disparate data sets and isolated pieces of information. The Kern County Subbasin GSAs recognize the need to develop a centralized, Subbasin-wide DMS. Accordingly, the GSAs are cooperating on this proposal to support monitoring, evaluation, reporting, management, and, importantly, GSP implementation. The Subbasin GSAs have previously coordinated and collaborated on the basin-wide water modeling for GSP development and thus believe that this is the next step forward. The immediate need for a centralized DMS is highlighted by the GSAs' ongoing cooperative efforts for annual reporting. In order to comply with the requirements of SGMA for standardized reporting, and to coordinate on a Subbasin-wide basis for consistent data evaluation, it is crucial that a DMS be developed for the entire Subbasin that will allow the various GSAs to gather and share information regarding local groundwater conditions. The proposed DMS planning and scoping project will ultimately support Subbasin GSAs by providing (1) improved coordination of groundwater monitoring and management actions and (2) the ability to meet the reporting and implementation requirements of SGMA for the Kern County Subbasin.
Project Objective	The project objectives are to retain a contractor to develop, manage, and coordinate use of a Subbasin-wide DMS; identify the data types required to monitor the Subbasin's progress toward sustainability; and investigate, select, and procure a DMS with an appropriate configuration that combines technical rigor, flexibility, ease of use, and expansion capabilities to store data in text, spreadsheet, graphical, and map-based formats.

Project Benefits Information
No records found.

Budget Information	
Other Contribution	$0.00
Local Contribution	$0.00
Federal Contribution	$0.00
Inkind Contribution	$0.00
Amount Requested*	$500,000.00
Total Project Cost*	$500,000.00

Geographic Information						
Latitude*	**DD(+/-):**	35	**MM:**	25	**SS:**	39
Longitude*	**DD(+/-):**	119	**MM:**	19	**SS:**	37
Longitude/Latitude Clarification	Location of the approximate center of the Kern County Subbasin.					
Location	The Kern County Subbasin is located in the center of the southern end of the San Joaquin Valley.					
County*	Kern					
Ground Water Basin	5-022.14 San Joaquin Valley-Kern County					
Hydrologic Region	Tulare Lake					
Watershed	115 7557 South Valley Floor; 116 7558 South Valley Floor					

Legislative Information	
Assembly District*	32nd Assembly District, 34th Assembly District
Senate District*	16th Senate District, 18th Senate District
US Congressional District*	District 21 (CA), District 23 (CA)

Section : Questions

Q1. Project Description:

Provide a brief abstract of the proposal. This abstract must provide an overview of the proposal including the main issues and priorities addressed in the proposal. (25 words or less)*

This Proposal develops a data management system (DMS) that covers the Kern County Subbasin and allows Subbasin GSAs to improve GSP coordination, and implementation.

Q2. Previous Funding:

Has the applicant received prior funding through the Proposition 1 SGWP Round 2 grant?*

a) • Yes
b) No

If so, how much funds did the applicant receive?

$1,500,000

Q3. Project Representative:

Provide the name and details of the person responsible for signing and executing the grant agreement for the applicant. Persons that are subcontractors to be paid by the grant cannot be listed as the Project Representative. Other entities included in the GSA can be listed here.*

Rodney Palla
Chair, Kern River Groundwater Sustainability Agency
1600 Truxtun Avenue
Bakersfield, California, 93301
(661) 326-3767

Q4. Project Manager:

Provide the name, title, and contact information of the Project Manager from the applicant agency or organization that will be the day-to-day contact on this application.*

Kristin Pittack
Water Resources Planner, City of Bakersfield
1600 Truxtun Avenue
Bakersfield, CA 93301
(661) 326-3646

Q5. Eligibility:

Has the applicant met the requirements of DWR's CASGEM Program?*

a) • Yes
b) No

Q6.1. Eligibility:

Is the applicant an agricultural water supplier?*

a) Yes
b) • No

Q6.1.a Eligibility:

If yes, has the applicant submitted a complete Agricultural Water Management Plan (AWMP) to DWR?

a) Yes
b) No

Q6.1.b Eligibility:

If yes, has the AWMP been verified as complete by DWR?

a) Yes
b) No

Q6.1.c Eligibility:

If the AWMP has not been submitted, explain and provide the anticipated submittal date.

Q7.1. Eligibility:

Is the applicant an urban water supplier?*

a) Yes
b) • No

Q7.1.a Eligibility:

If yes, has the applicant submitted a complete Urban Water Management Plan (UWMP) to DWR?

a) Yes
b) No

Q7.1.b Eligibility:

If yes, has the UWMP been verified as complete by DWR?

a) Yes
b) No

Q7.1.c Eligibility:

If the UWMP has not been submitted, explain and provide the anticipated date for submittal.

Q8.1 Eligibility:

Is the applicant a surface water diverter?*

a) Yes
b) No

Q8.1.a Eligibility:

If yes, has the applicant submitted to the SWRCB their surface water diversion reports in compliance with requirements outlined in Part 5.1 (commencing with §5100) of Division 2 of the Water Code?

a) Yes
b) No

Q8.1.b Eligibility:

If the reports have not been submitted, explain and provide the anticipated date for meeting the requirements.

Q9. Eligibility:

Does the proposal include any of the following activities:

1.) The potential to adversely impact a wild and scenic river or any river afforded protection under the California or Federal Wild and Scenic Rivers Act
2.) Acquisition of land through eminent domain
3.) Design, construction, operation, mitigation, or maintenance of Delta conveyance facilities
4.) Acquisition of water except for projects that will provide fisheries or ecosystem benefits or improvements that are greater than required currently applicable environmental mitigation measures or compliance obligations
5.) Pay any share of the costs of remediation recovered from parties responsible for the contamination of a groundwater storage aquifer
6.) Projects or groundwater planning activities associated with adjudicated groundwater basins.

If yes, the project is not eligible for grant funding.*

a) Yes (not eligible for grant funding)
b) No

Q10. Eligibility: Consistency with California SB 985– Stormwater Resource Planning Act:

To satisfy SB 985 requirements, stormwater and dry weather capture project must be listed in a SWRP that is consistent with the relevant code provisions enacted by SB 985 (Water Code §10562 (b)(7)) as determined by the SWRCB.

a) This Project is Consistent

Q11. DA Cost Share Waiver or Reduction:

Are you applying for cost share waiver or reduction as a DA? Fill out Attachment 6 – DAC, SDAC, and/or EDA, as appropriate.*

a) Yes; See Attachment 6
b) No

Q12. Certification:

By submitting the application, the Project Director is certifying that:
a) The applicant is an eligible entity;
b) He/She is aware that any attachment exceeding the page limit listed in the attachment templates will not be reviewed;
c) He/She is aware that, once the proposal is submitted in GRanTS, any privacy rights and other confidentiality protections offered by law with respect to the application package and project location are waived; and
d) He/She has read and agrees to all of the Terms and Conditions of the grant agreement.*

a) • Yes (Certified)
b) No

Section : Climate Risk in Investments

Climate Risk in Investment

Q13: Does the organization have a strategic business plan?

a) • Yes
b) No

If Yes, please submit a copy.

Last Uploaded Attachments: Q13_Prop 68 Cost Share Packet_combined.pdf

Q14: Has the organization conducted a climate change vulnerability assessment?

a) Yes
b) • No

If Yes, please submit a copy.

Q15: Does the organization have a main contact person for climate change?

a) Yes
b) • No

If Yes, to what position in the origination does that person report?

Q16: Has the organization considered the risk of climate change in its capital reserves and investments? (Open ended; one-three paragraphs, with specific examples, should suffice).

This Proposal involves funding of a planning effort rather than an implementation project. As such, the Subbasin Data Management System Development project would not involve activities that could emit greenhouse gases or affect carbon sequestration. The project would have no effect related to climate change. Therefore, documentation of climate change effects is not applicable for this Proposal, applicant, or project proponents.

Section : Attachments

Attachment 1:Authorizing Documentation (e.g. resolution)

Upload Authorizing Documentation here. The Attachment is mandatory.*

Last Uploaded Attachments: Att1_SGM_AuthDoc_1of1.pdf

Attachment 2: Eligibility Applicant Documentation

Upload Eligibility Applicant Documentation here. The attachment is mandatory.*

Last Uploaded Attachments: Att2_SGM_EligDoc_1of1.pdf

Attachment 3: Work Plan

Upload Work Plan here. (Applicant MUST use supplied template) The attachment is mandatory.*

Last Uploaded Attachments: Att3_SGM_WrkPlan_1of1.pdf

Attachment 4: Budget

Upload Budget here. (Applicant MUST use supplied template) The attachment is mandatory.*

Last Uploaded Attachments: Att4_SGM_Budget_1of1.pdf

Attachment 5: Schedule

Upload Schedule here. (Applicant MUST use supplied template) The attachment is mandatory.*

Last Uploaded Attachments: Att5_SGM_Schedule_1of1.pdf

Attachment 6: SDAC, DAC, and/or EDA

Upload SDAC, DAC, and/or EDA (as applicable) here.

Last Uploaded Attachments: Att6_SGM_SDAC-DAC-EDA_1of1.pdf

KERN RIVER GSA

Rodney J. Palla, Chair
Bob Smith
Gene Lundquist

October 21, 2019

To: Kern Groundwater Authority
Buena Vista WSD GSA
Henry Miller WD GSA
Olcese WD GSA

Re: Reimbursement Agreement for the Kern County Subbasin – DWR Proposition 68 Grant Application Development and Grant Administration.

The Kern River Groundwater Sustainability Agency (KRGSA), the Kern Groundwater Authority (KGA), the Buena Vista WSD Groundwater Sustainability Agency (BVGSA), the Henry Miller WD Groundwater Sustainability Agency (HMGSA), and the Olcese WD Groundwater Sustainability Agency (OGSA) wish to participate in the Reimbursement Agreement for the Kern County Subbasin – DWR Proposition 68 Grant Application Development and Grant Administration (Grant).

On behalf of the Subbasin, the KRGSA has approved a contract with Horizon Water and Environment (Horizon) which includes a scope of work with the following tasks: 1) Develop and Submit Grant Application ($19,950); 2) Support Database Project Lead in Developing RFP for Database Developer ($1,990); and 3) Grant Administration ($27,680). Horizon's proposal for the scope of work is provided as Attachment 1. All parties agree to cost share this effort according to following terms and conditions:

The participant signatories below will pay their share of the proposed budget of $49,620 as shown on Attachment 2. The first two (2) tasks will be invoiced upon approval of this Agreement. Task three (3) will be billed as future Grant Administration work is performed. All payments shall be due 45 days after the receipt of invoice from the City of Bakersfield.

If the above terms and conditions are acceptable, please sign and date all copies of this letter and return them to the KRGSA. A fully executed original will be returned to all GSA's.

Sincerely,

Rodney Palla
Chairman

Accepted:

Kern Groundwater Authority

By:_____

Title:_____

Date:_____

Buena Vista WSD GSA

By:_____

Title:_____

Date:_____

Henry Miller WD GSA

By:_____

Title:_____

Date:_____

Olcese WD GSA

By:_____

Title:_____

Date:_____

Sincerely,

Rodney Palla
Chairman

Accepted:

Kern Groundwater Authority

By: _____

Title: CHAIR

Date: 10-23-2019

Buena Vista WSD GSA

By: _____

Title: _____

Date: _____

Henry Miller WD GSA

By: _____

Title: _____

Date: _____

Olcese WD GSA

By: _____

Title: _____

Date: _____

Sincerely,

Rodney Palla
Chairman

Accepted:

Kern Groundwater Authority

By:_____

Title:_____

Date:_____

Buena Vista WSD GSA

By:_____

Title: Engineer - Manager

Date: 10-22-19

Henry Miller WD GSA

By:_____

Title:_____

Date:_____

Olcese WD GSA

By:_____

Title:_____

Date:_____

Sincerely,

Rodney Palla
Chairman

Accepted:

Kern Groundwater Authority

By:_____

Title:_____

Date:_____

Buena Vista WSD GSA

By:_____

Title:_____

Date:_____

Henry Miller WD GSA

By: Jeff Ulrich

Title: PRESIDENT

Date: 10-22-19

Olcese WD GSA

By:_____

Title:_____

Date:_____

Sincerely,

Rodney Palla
Chairman

Accepted:

Kern Groundwater Authority

By:_____

Title:_____

Date:_____

Buena Vista WSD GSA

By:_____

Title:_____

Date:_____

Henry Miller WD GSA

By:_____

Title:_____

Date:_____

Olcese WD GSA

By:_____

Title: James L. Nickel, President

Date: Oct. 22, 2019

Kern County Subbasin – DWR Proposition 68 Grant Application Development

Revised Proposal for Consultant Services Provided by Horizon Water and Environment

October 10, 2019

Horizon will develop a Proposition 68 grant application/proposal for the Kern County Subbasin based on the grant requirements provided by DWR. This application will rely heavily on materials Horizon previously developed preparing the Proposition 1 grant application. Horizon will update those materials as appropriate to reflect the status of current GSPs in the Kern County Subbasin.

Using these existing materials as a starting point, Horizon will develop the grant application efficiently and ensure that the information provided for the Prop 68 grant is consistent with, and builds on, the Proposition 1 grant received in 2017.

This scope of work assumes that one project will be included in the grant application:

- Project 1: Subbasin data management system development

Horizon will work with the appropriate GSAs to receive good baseline information or a project description for the project. Horizon will then use our grant application expertise to articulate how the project aligns and supports the primary objectives of the Proposition 68 Grant and why the Kern County Subbasin is an excellent fit for this grant. Following award of grant funding, Horizon will administer the grant reporting and invoicing process.

Horizon's work will be organized into the following tasks:

Task 1: Develop and Submit Grant Application

Develop Draft Application Materials

- Horizon will use the grant application requirements to frame and structure the grant submittal documents.
- Horizon will review DWR-provided templates to collect and organize project information for the grant application forms and Attachments (e.g., Work Plan, Schedule, Budget) and distribute them to the appropriate project leads.
- Horizon will coordinate data requests with the GSA staff members who will be serving as the project leads for the target project. Horizon will edit/adjust the project information as necessary to support the grant application.
- Horizon will generate draft grant application materials, including necessary text to populate the online GRanTS application tabs and required Attachments.
- Horizon will distribute the draft grant application materials to the KRGSA and other project lead GSAs for their review, with a due date to receive requested edits and/or comments.

Finalize Grant Application Materials

- Horizon will finalize the grant application materials based upon GSA review and feedback described above. Horizon will send final grant application materials to KRGSA and other project lead GSAs for final review and approval prior to DWR submittal.

Submit Grant Application to DWR

- Horizon will complete the online GRanTS application information tabs, and upload all Attachments, before DWR's application period deadline of 1 p.m. on November 1.

Task 2: Support Database Project Lead in Developing RFP for Database Developer

- Horizon will coordinate with Basin Database project lead (KGA, KRGSA, or a committee) to confirm the general database objectives and needs.
- Horizon will develop a draft RFP for review by project lead.
- Horizon will revise and develop final RFP for review and use by project lead.

This task assumes that the project lead, rather than Horizon, will administer the proposal process, including distribution of RFP, review and evaluation of proposals, and contracting of selected firm.

Task 3: Grant Administration *(pending award)*

Grant Initiation, Agreements, and Templates

- Following notification of grant award, Horizon will coordinate with DWR, KRGSA, and KGA to finalize grant materials.

Grant Implementation, Reporting, and Invoicing

- Horizon will develop and distribute templates for quarterly reports, invoices, and backup documentation.
- Horizon will identify deadlines for submittal of information from KRGSA and KGA and will review and clarify the submitted information each quarter to ensure that it meets grant requirements.
- Following review and revision, Horizon will submit reports and invoices to DWR.
- Horizon will coordinate with DWR regarding any needed revisions to submitted materials.
- Throughout the grant period, Horizon will communicate regularly with KRGSA and KGA to maintain the flow of information.

Grant Completion and Closeout

- Horizon will coordinate and review the project's draft Project Completion Report.
- Horizon will assist KRGSA and KGA in developing the Grant Completion Report.
- Horizon will coordinate and upload all completion reports to DWR.
- Horizon will develop a post-performance report template.
- Horizon will coordinate with project leads and DWR in grant closeout.

Cost Estimate:

Task		Estimated Cost
1.	Develop and Submit Grant Application	$19,950
2.	Support Database Project Lead in Developing RFP for Database Developer	$1,990
3.	Grant Administration *(pending award)*	$27,680
	Total	**$49,620**

Schedule:

Horizon will complete the grant submittal process on or before the DWR deadline of November 1, 2019, at 1:00 p.m. Tasks 2 and 3 will be completed following notification of grant award.

Attachment 2

Funding Contribution and Participation Percentages

Total Horizon Contract Amount: $49,620.00
Funding Request for App/RFP: $21,940.00

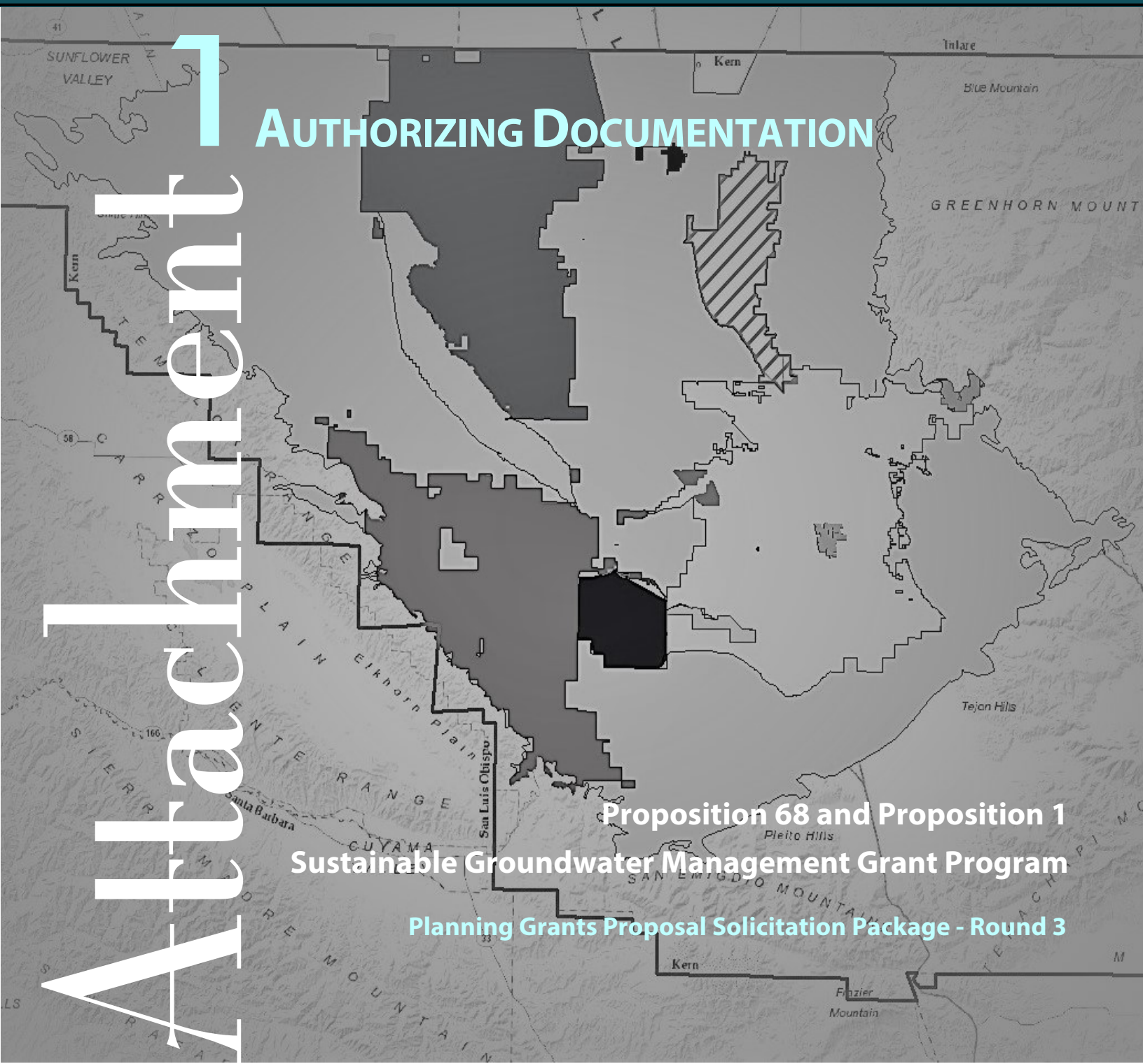
	Funding Entity	Funding Request
1	Arvin-Edison Water Storage District	$953.91
2	Buena Vista Water Storage District	$953.91
3	Bellridge Water Distrct	$953.91
4	Berrenda Mesa Water District	$953.91
5	Cawelo Water District	$953.91
6	City of Bakersfield	$953.91
7	Eastside Water Management Area	$953.91
8	Henry Miller	$953.91
9	Improvement District No. 4	$953.91
10	Lost Hills Water District	$953.91
11	Kern Delta Water District	$953.91
12	Kern-Tulare Water District	$953.91
13	Kern Water Bank Authority	$953.91
14	North Kern Water Storage District	$953.91
15	Olcese Water District	$953.91
16	Rosedale-Rio Bravo Water District	$953.91
17	Semitropic Water Storage District	$953.91
18	Shafter-Wasco Irrigation District	$953.91
18	Shafter-Wasco 7th Standard Annex	$953.91
19	South San Joaquin Municipal Utilities District	$953.91
20	Tejon-Castac Water District	$953.91
21	West Kern Water District	$953.91
22	Wheeler Ridge-Maricopa Water Storage District	$953.91
	Totals	$21,940.00

Note:
Managers/GSAs all agreed to use Horizon and to split the costs per agency.
Above funding request to cover Grant App. DMS RFP. Future Grant Admin to be billed per agency as costs incured (monthly).

Invoices:

KGA:	$16,216.52
KRGSA:	$2,861.74
BV	$953.91
Henry Miller:	$953.91
Olcese	$953.91
	$21,940.00

Kern County Subbasin Groundwater Sustainability Plan Support - Phase II 2019 Grant Application



Attachment 1

Authorizing Documentation

Proposition 68 and Proposition 1

Sustainable Groundwater Management Grant Program

Planning Grants Proposal Solicitation Package - Round 3

Introduction....1
Applicant Authorizing Documentation....1
Authorizing Resolution....2

Introduction

Attachment 1 includes authorizing documentation for submittal of this Proposition 68 and Proposition 1 Sustainable Groundwater Management Grant Program, Planning Grants Proposal Solicitation Package – Round 3 grant application. The applicant has provided a resolution adopted by the applicant's governing body designating an authorized representative to submit the application and execute an agreement with the State of California for a Sustainable Groundwater Management Grant.

Applicant Authorizing Documentation

The Kern River Groundwater Sustainability Agency (KRGSA) is pleased to serve as the applicant for Kern County Subbasin Groundwater Sustainability Plan Support – Phase II grant application. The Kern County Subbasin Groundwater Sustainability Plan Support – Phase II application includes one project led by and supporting all the GSAs in the Kern County Subbasin. The proposed project will benefit the entire Kern County Subbasin.

KRGSA is a Groundwater Sustainability Agency (GSA) formed in 2016 under Section 10723.8 of the California Water Code and is comprised of public agency members including the City of Bakersfield, the Kern Delta Water District, and the Kern County Water Agency Improvement District No. 4. An excerpt from the GSA application package submitted to the California Department of Water Resources' (DWR's) Sustainable Groundwater Management Section on April 12, 2016, is included as supporting documentation with Attachment 2, Appendix A. Further information and the entire GSA application package may be found on KRGSA's website: http://www.kernrivergsa.org.

The Round 3 Planning Grants Proposal Solicitation Package states that eligible applicants are GSAs, member agencies of the GSAs, or member agencies of an approved Alternate to a GSP for the basin for which the application is submitted. The KRGSA is a GSA for a portion of the Kern County Subbasin (Basin Number 5-22.14) and, as such, is an eligible applicant for this Proposition 68 and Proposition 1 Sustainable Groundwater Management Grant Program, Planning Grants Proposal Solicitation Package – Round 3 grant application.

The KRGSA Executive Board adopted Resolution KRGSA 001-19 on October 21, 2019, authorizing KRGSA to submit this application to obtain a grant under the Sustainable Groundwater Management Grant Program and execute an agreement with the State of California to receive a grant under the Proposition 68 and Proposition 1 Sustainable Groundwater Management Grant Program, Planning Grants Proposal Solicitation Package – Round 3 grant opportunity. A copy of the resolution is included on the following pages.

RESOLUTION NO. KRGSA 001-19

A RESOLUTION BY THE KERN RIVER GROUNDWATER SUSTAINABILITY AGENCY (KRGSA) THAT APPLICATION BE MADE TO THE CALIFORNIA DEPARTMENT OF WATER RESOURCES TO OBTAIN A GRANT UNDER THE SUSTAINABLE GROUNDWATER PLANNING GRANT PROGRAM FOR THE KERN COUNTY SUBBASIN GROUNDWATER SUSTAINABILITY PLAN SUPPORT - PHASE II

WHEREAS, the California Department of Water Resources (DWR) is administering the Sustainable Groundwater Management (SGM) Grant Program Planning Grants using funds authorized by the California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access for All Act of 2018 (Proposition 68) and the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1); and

WHEREAS, DWR will award $50 million for projects that develop and implement groundwater plans and projects; and

WHEREAS, Proposition 68 requires a minimum cost share of 25% of the total project cost, and Proposition 1 requires a minimum cost share of 50% of the total project cost; and

WHEREAS, only one grant will be awarded per basin; and

WHEREAS, the KRGSA represents all potential applicants in the kern subbasin, and

WHEREAS, DWR requires a resolution to be adopted by the applicant's governing body designating an authorized representative to submit the application and execute and agreement with the State of California for a SGM Grant; and

NOW, THEREFORE, BE IT RESOLVED, by the KRGSA as follows:

1. The above recitals and findings are true and correct and are incorporated herein by reference.

2. That application be made to the California Department of Water Resources to obtain a grant under the 2019 Sustainable Groundwater Planning Grant Program pursuant to the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1) (Water Code Section 79700 et seq.) and/or the California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access for All Act of 2018 (Proposition 68) for the Kern

County Subbasin Groundwater Sustainability Plan Support - Phase II.

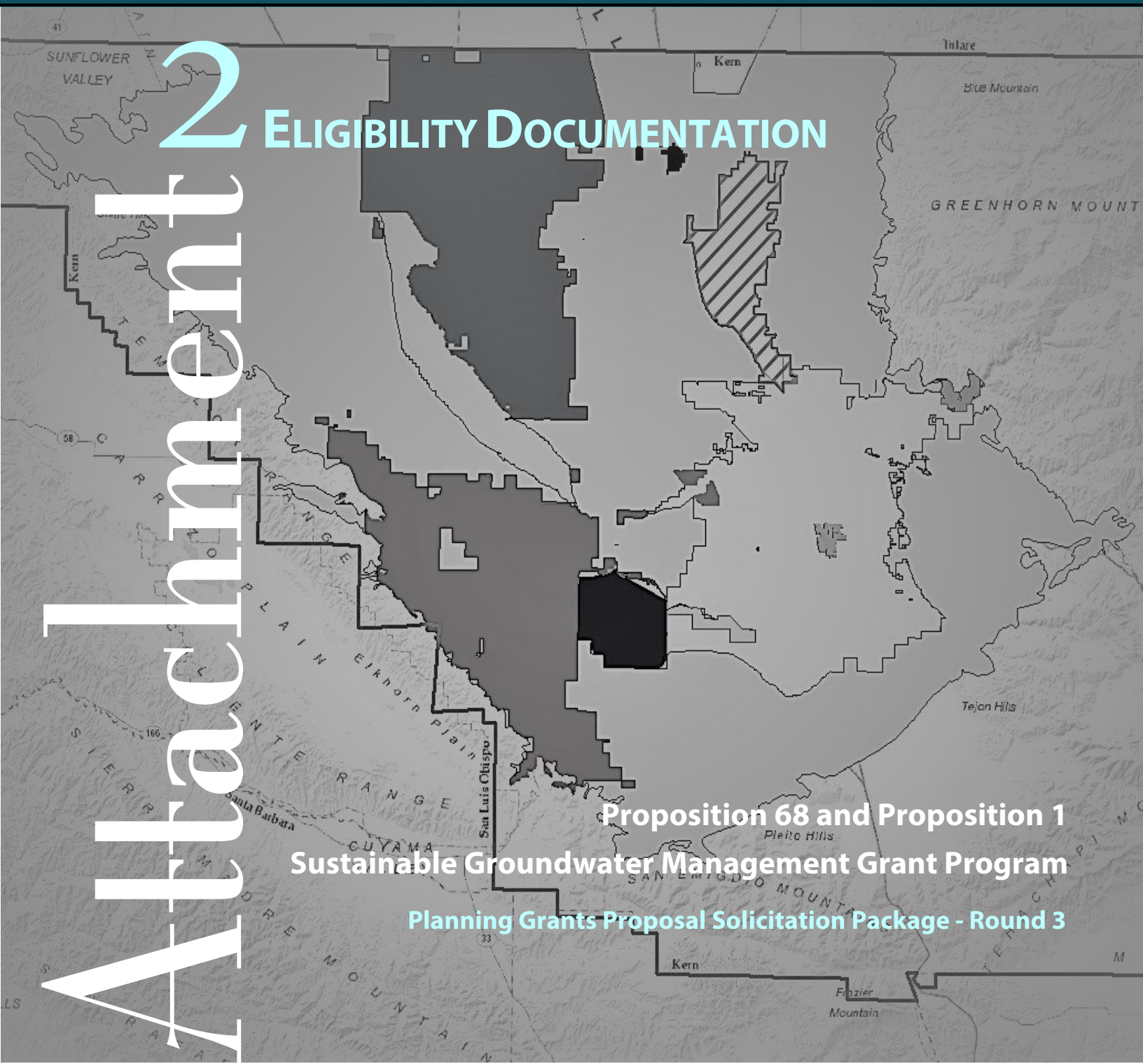
3. That the Board Chair of the KRGSA or his designee is hereby authorized and directed to prepare the necessary data, conduct investigations, file such application, and execute a grant agreement with the California Department of Water Resources and make amendments or changes thereto.

--------oo000oo--------

I HEREBY CERTIFY that the foregoing Resolution was passed and adopted by the Kern River Groundwater Sustainability Agency on OCT 2 1 2019,

Rodney S. Palla, Chairman

Kern County Subbasin Groundwater Sustainability Plan Support - Phase II 2019 Grant Application



Attachment 2

ELIGIBILITY DOCUMENTATION

Proposition 68 and Proposition 1

Sustainable Groundwater Management Grant Program

Planning Grants Proposal Solicitation Package - Round 3

Introduction....2
A. Applicant Information....2
B. Agricultural Water Management Compliance....3
C. CASGEM Basin Prioritization and Compliance....3
CASGEM Monitoring Data – Current Submittal Status....6
Conclusion....7
D. Climate Change....7
E. Groundwater Management Compliance....7
F. Open and Transparent Water Data....8
G. Public Utilities and Mutual Water Companies....8
H. Stormwater Resource Plan (SWRP) Compliance....8
I. Surface Water Diverter Compliance....8
K. Urban Water Management Compliance....9

Tables

Table 2-1. Kern County Subbasin Monitoring Entities and Data Submittal Status....6

Figures

Figure 2-1. Kern County Subbasin Area with Established Monitoring Entities....4
Figure 2-2. Kern County Subbasin Areas with Established Monitoring Entities and DAC Areas....5

Appendices

Appendix A. Kern River Groundwater Sustainability Agency GSA Application Package (excerpt)
Appendix B. Compliance Documentation

Introduction

Attachment 2 includes eligibility documentation for this Groundwater Sustainability Plan Support – Phase II Grant Application. Attachment 2 includes the following sections as required by the Proposal Solicitation Package (PSP):

A. Applicant Information
B. Agricultural Water Management Compliance
C. CASGEM Basin Prioritization and Compliance
D. Climate Change
E. Groundwater Management Compliance
F. Open and Transparent Water Data
G. Public Utilities and Mutual Water Companies
H. Stormwater Resource Plan (SWRP) Compliance
I. Surface Water Diverter Compliance
J. Sustainable Water Use and Demand Reduction
K. Urban Water Management Compliance
L. Water Metering Compliance

A. Applicant Information

The Kern River Groundwater Sustainability Agency (KRGSA) is pleased to serve as the applicant for Kern County's Kern County Subbasin Groundwater Sustainability Plan Support – Phase II grant application. The Kern County Subbasin Groundwater Sustainability Plan Support – Phase II application includes one project led by and supporting all the GSAs in the Kern County Subbasin. . The proposed project will benefit the entire Kern County Subbasin.

The Kern County Subbasin has been identified as a critically overdrafted, high priority groundwater basin. The Proposal objective is to implement a high-priority project that provides direct groundwater planning benefits to the Subbasin, meets Groundwater Sustainability Plan (GSP) regulations, and meets the California Department of Water Resources' (DWR's) evaluation criteria for Sustainable Groundwater Management Grant Program, Round 3 Planning Grants funding.

This project is entitled Subbasin Data Management System Development and it will develop a critical groundwater sustainability planning element encompassing all parts of the Subbasin. The proposed project includes the following primary objectives to initiate developing the Subbasin's Data Management System (DMS): (1) conduct stakeholder outreach and engagement activities, (2) procure consultant assistance for DMS development, (3) identify DMS information requirements, (4) research and select the appropriate DMS approach for the Subbasin, (5) procure or design the DMS and refine and customize the DMS as needed, and (6) develop data protocols and templates (7) train GSA staff . If additional funding is required, the GSAs in the Kern subbasin have agreed to work together to either locate additional funding or to fund. This project is critical to meet immediate Kern County Subbasin GSP planning needs, as well as essential for the next steps in basin coordination and Sustainable Groundwater Management Act (SGMA) compliance requirements.

KRGSA is a Groundwater Sustainability Agency formed in 2016 under § 10723.8 of the California Water Code and is comprised of public agency members including the City of Bakersfield, the Kern Delta Water District, and the Kern County Water Agency Improvement District No. 4. An excerpt from the GSA application package submitted to DWR's Sustainable Groundwater Management Section on April 12, 2016, is included as supporting documentation in Appendix A to this Attachment 2. Further information may be found on KRGSA's website: http://www.kernrivergsa.org.

The Round 3 Planning Grants PSP states that eligible applicants are GSAs, member agencies of the GSAs, or member agencies of an approved Alternate to a GSP for the basin for which the application is submitted. KRGSA is a GSA for a significant portion of the critically overdrafted, high priority Kern County Subbasin (Basin Number 5-22.14) and as such is an eligible applicant for this Proposition 68 and Proposition 1 Sustainable Groundwater Management Grant Program, Planning Grants PSP – Round 3 grant application.

The KRGSA Executive Board adopted Resolution KRGSA 001-19 on October 21, 2019, authorizing KRGSA to submit this application on behalf of the entire Kern subbasin to obtain a grant under the Sustainable Groundwater Management Grant Program and execute an agreement with the State of California to receive a grant under the Proposition 68 and Proposition 1 Sustainable Groundwater Management Grant Program, Planning Grants PSP – Round 3 grant opportunity. A copy of the resolution is included in Attachment 1.

B. Agricultural Water Management Compliance

Agricultural Water Management eligibility for the applicant for this Proposal is discussed in this section.

The applicant, KRGSA, is not an agricultural water supplier. No agricultural water suppliers will receive funding from the proposed grant through a joint-powers agreement or other legal agreement. The project will be implemented by the applicant, KRGSA, and KGA on behalf of all the GSAs in the Subbasin. KGA is also a GSA within the basin, and KGA is not an agricultural water supplier. Neither the applicant nor the additional project proponent, KGA, is an agricultural water supplier, and as such these entities are not required to develop or submit Agricultural Water Management Plans (AWMPs).

Therefore, documentation of Agricultural Water Management Compliance is not applicable for this Proposal, applicant, or project proponents.

It is noted that while the applicant, KRGSA, is not an agricultural water supplier, one of the member agencies of the KRGSA is the Kern Delta Water District, which is required to develop and submit an AWMP. The Kern Delta Water District is in full agricultural water management compliance, having submitted and received DWR approval, with documentation provided in Appendix B.

C. CASGEM Basin Prioritization and Compliance

This section discusses California Statewide Groundwater Elevation Monitoring (CASGEM) eligibility status for the overall Proposal, project proponents, and the proposed project. The Subbasin Data Management System Development project proposed in this application package will benefit the entire Kern County Subbasin, identified as groundwater Subbasin number 5-022.14. Pursuant to Water Code § 10933(b) and Bulletin 118, DWR has designated the Kern County Subbasin as high priority and critically overdrafted.

Determining CASGEM compliance status for the overall Kern County Groundwater Basin (5-022.14) requires identifying:

(1) whether the entirety of the groundwater basin is monitored through identification and establishment of monitoring entities, and

(2) if monitoring data is uploaded to CASGEM regularly each spring and fall, once monitoring entities are established.

For the portion of high-priority basins that do not have a CASGEM monitoring entity, the grant applicant will not be eligible to receive grant funding (Water Code § 10933.7(a)). Consistent with Water Code § 10933.7(b), if the applicant area is demonstrated to be a DAC or SDAC, the project will be considered eligible for grant funding not withstanding CASGEM compliance.

The Subbasin Data Management System Development project will be implemented by the applicant, KRGSA, in collaboration with KGA on behalf of and in coordination with all the GSAs in the Subbasin. The applicant, KRGSA, is not identified as a CASGEM monitoring entity for the basin. KGA is also a GSA within the Kern County Subbasin. KGA is not a CASGEM monitoring entity. Neither the applicant nor the additional project proponent, KGA, is serving as a CASGEM monitoring entity for the basin. However, approximately 46% of the

Kern County groundwater basin is CASGEM compliant as described below, based on established monitoring entities that provide data to DWR's CASGEM program. This project includes a basin-wide project that will benefit the entire Subbasin, including the 54% non-CASGEM compliant area, of which 90% is characterized as Disadvantaged Community and, as such, is exempt from the requirement for CASGEM compliance.

Figure 2-1, below, depicts the Kern County Subbasin, showing areas where CASGEM monitoring entities have been established (green), and areas where CASGEM monitoring entities are not yet established (gray). This map shows that 46% of the basin is CASGEM compliant in terms of having established monitoring entities that meet CASGEM requirements.

Figure 2-1. Kern County Subbasin Area with Established Monitoring Entities

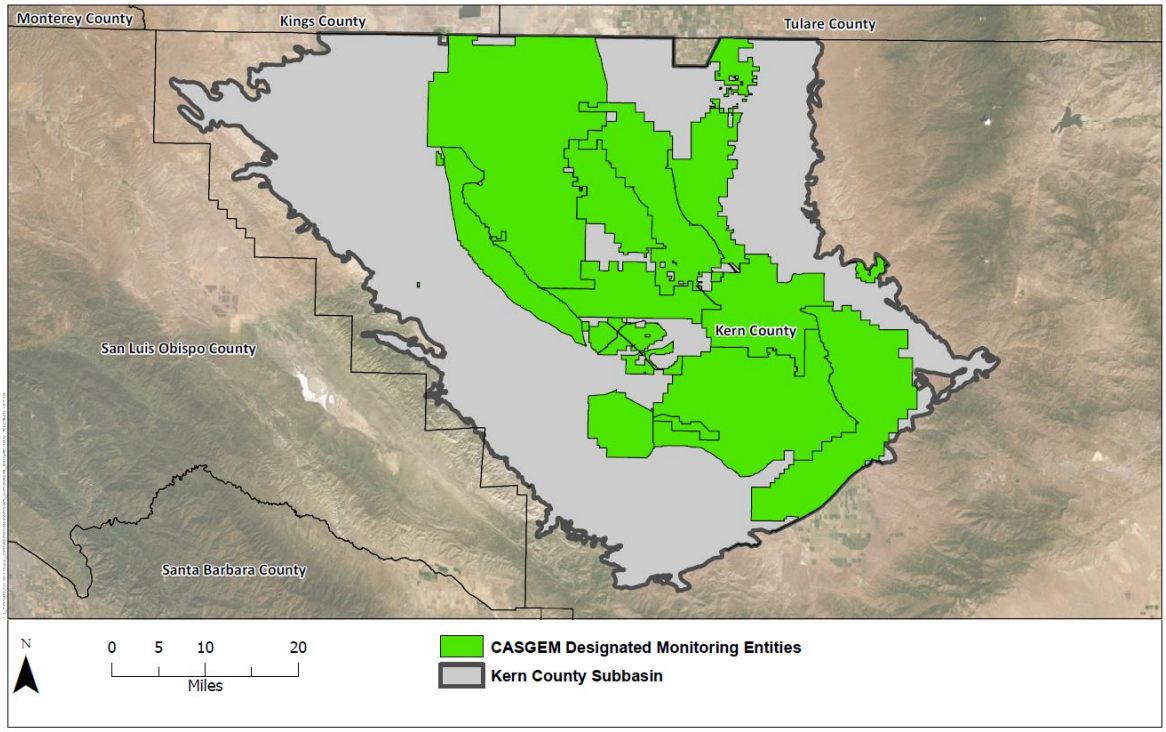
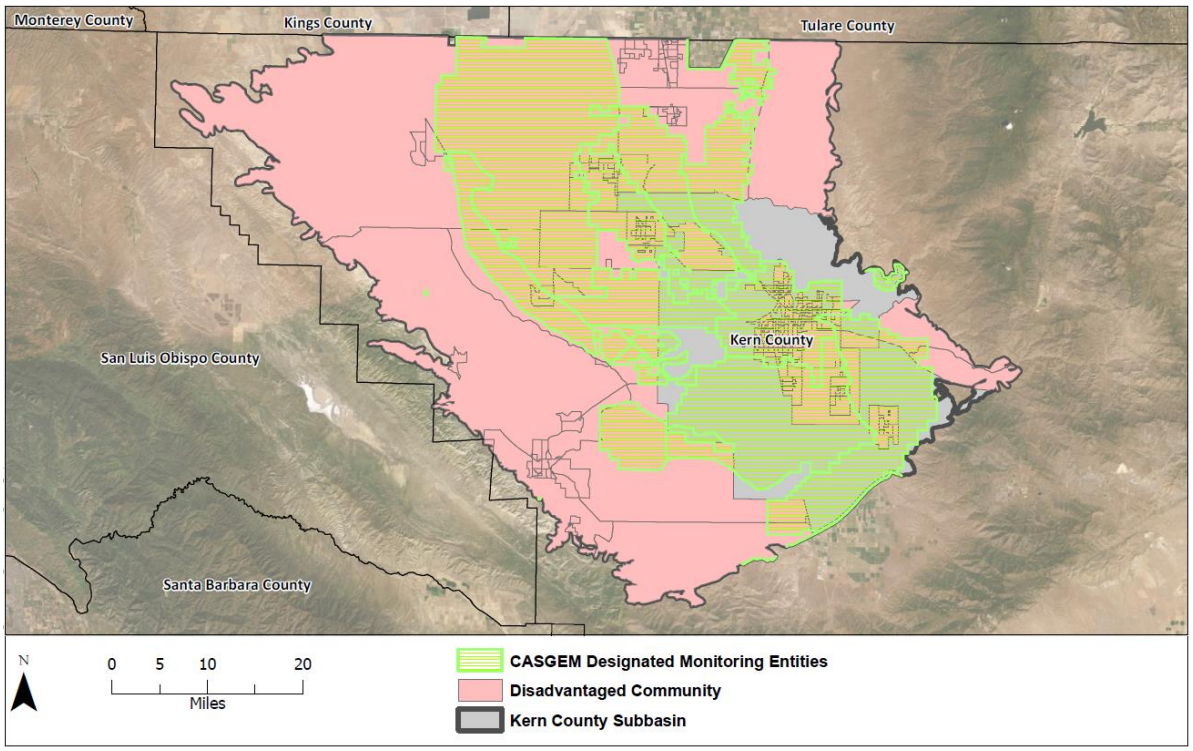


Figure 2-2, below, depicts the Kern County Subbasin, showing CASGEM compliant areas and DAC boundaries within the Subbasin (data acquired from DWR's DAC Mapping tools). This map shows that, within the 54% of the basin that is not CASGEM compliant (in terms of not having established monitoring entities); 90% of that area is characterized as a DAC, and as such, exempt from the PSP requirement for CASGEM compliance. It is noteworthy that only 5.6% of the Subbasin is both not CASGEM compliant and not DAC.

Figure 2-2. Kern County Subbasin Areas with Established Monitoring Entities and DAC Areas



CASGEM Monitoring Data – Current Submittal Status

Table 2-1, below, is featured on DWR's CASGEM website, and presents a list of the established CASGEM monitoring entities for the basin. The table also shows latest elevation data submitted as of October 23, 2019. This table shows that established monitoring entities are providing current elevation data.

Table 2-1. Kern County Subbasin Monitoring Entities and Data Submittal Status

Monitoring Entity	Groundwater Basin/ Subbasin Name	Groundwater Basin/ Subbasin Number	Authority Type	Last Elevation Data Submitted	Associated Well Count
Arvin-Edison Water Storage District	Kern County	5-022.14	Ground Water Management Agency	3/12/2019 5:01:00 PM	41
Cawelo Water District	Kern County	5-022.14	Ground Water Management Agency	3/11/2019 6:48:00 PM	7
Deer Creek & Tule River Authority	Kern County	5-022.14	Local Agency Pursuant to WC Part 2.75	2/25/2019 12:00:00 AM	3
Kern County Water Agency Improvement District No. 4	Kern County	5-022.14	Local Agency Pursuant to WC Part 2.75	3/6/2019 3:46:00 PM	5
Kern River Fan Group	Kern County	5-022.14	Voluntary Cooperative Groundwater Monitoring Association	4/1/2019 12:00:00 AM	34
Kern Water Bank Authority	Kern County	5-022.14	Voluntary Cooperative Groundwater Monitoring Association	7/16/2019 12:00:00 AM	15
Kern-Tulare Water District	Kern County	5-022.14	Local Agency Pursuant to IRWM	10/8/2019 12:00:00 AM	25
North Kern Water Storage District	Kern County	5-022.14	Local Agency Pursuant to WC Part 2.75	5/8/2019 12:00:00 AM	9
Semitropic Water Storage District	Kern County	5-022.14	Local Agency Pursuant to WC Part 2.75	6/8/2019 12:00:00 AM	46
Shafter-Wasco Irrigation District	Kern County	5-022.14	Local Agency Pursuant to WC Part 2.75	2/1/2019 12:00:00 AM	8
West Kern Water District	Kern County	5-022.14	Ground Water Management Agency	8/7/2019 12:00:00 AM	49

Source: DWR's CASGEM website.

The monitoring entities listed in Table 2-1 above are providing elevation data submitted for Kern County Subbasin and encompass approximately 46% of the Subbasin area. The other 54% of the Kern County Subbasin is not yet CASGEM compliant.

Conclusion

As described above, approximately 46% of the Kern County Groundwater Subbasin is CASGEM compliant from the perspective of having established monitoring entities, as well as from the perspective of providing monitoring data to DWR's CASGEM program. Figure 2-2 illustrates that, of the 54% of the basin that is not CASGEM compliant, 90%, or the great majority, is a DAC and, as such, exempt from the PSP requirement for CASGEM compliance. The remaining areas that are still not compliant and not DAC, 5.6% of the Subbasin, will not receive grant funding.

CASGEM compliance is sufficiently demonstrated for the Kern County Groundwater Subbasin for purposes of this grant proposal.

D. Climate Change

This section discusses Climate Change eligibility status for the overall Proposal. The SGM Grant Program 2019 Guidelines document requires that applicants seeking funding must demonstrate that the applicant's project contributes to addressing the risks in the region to water supply and water infrastructure arising from climate change (Water Code § 79742(e)). To the extent practicable, applicants must measure the amount of greenhouse gas emissions reduced and carbon sequestered resulting from an implementation project funded by the SGM Grant Program (Public Resources Code § 80001(b)(7)).

This Proposal involves funding of a planning effort rather than an implementation project. As such, the Subbasin Data Management System Development project would not involve activities that could emit greenhouse gases or affect carbon sequestration. The project would have no effect related to climate change. Therefore, documentation of climate change effects is not applicable for this Proposal, applicant, or project proponents.

E. Groundwater Management Compliance

This section discusses Groundwater Management Compliance eligibility status for the overall Proposal. The SGM Grant Program 2019 Guidelines document requires that, for groundwater implementation projects that directly affect groundwater levels or quality, the applicant must self-certify that one or more option below has been, or is currently, being satisfied.

SGMA (Water Code § 10720 et seq.) specifies actions for critically overdrafted groundwater basins, high and medium priority basins, and low and very low priority basins. Groundwater project proponents must demonstrate how their project is consistent with SGMA efforts in the basin. To be eligible to receive Implementation grant funds, applicants must be from a medium or high priority basin with either:

- An adopted GSP that has been submitted to DWR for review and deemed complete by DWR, or
- An approved Alternative to a GSP.

This Proposal involves funding of a planning effort rather than an implementation project that directly affects groundwater levels or quality. The proposed project, the Subbasin Data Management System (DMS) Development, will develop a critical groundwater sustainability tool encompassing all parts of the Subbasin. The proposed project consists of scoping and development of the DMS including activities such as: (1) conducting stakeholder outreach and engagement activities, (2) procuring consultant assistance for DMS development, (3) identifying DMS information requirements, (4) researching and selecting the appropriate DMS approach for the Subbasin, and (5) procuring and designing the DMS and customizing it as needed. This proposed project is critical to meet Kern County Subbasin GSP, basin coordination, and SGMA compliance needs.

This Proposal is entitled Kern County Subbasin Groundwater Sustainability Plan Support – Phase II. The first phase of this GSP support work is currently underway and is being funded under a Proposition 1 SGMA Round

2 Planning Grant entitled Kern County Subbasin Groundwater Sustainability Support – 2017 Grant Application. Activity under the Proposition 1 grant includes generating a GSP for KRGSA to be submitted to DWR as a deliverable. As of this writing (October 2019) the GSP is in draft form and will be submitted to DWR on or before January 31, 2020.

F. Open and Transparent Water Data

This section discusses Open and Transparent Water Data Compliance for the overall Proposal. The SGM Grant Program 2019 Guidelines document requires that recipients of State funds through grants or contracts for research or projects relating to the improvement of water or ecological data shall, as a condition of the receipt of a grant or contract, adhere to the protocols developed pursuant to subdivision (a) for data sharing, transparency, documentation, and quality control (Water Code § 12406(b)). KRGSA will adhere to all required data sharing, transparency, and documentation protocols.

G. Public Utilities and Mutual Water Companies

This section discusses Public Utilities and Mutual Water Companies Compliance for the overall Proposal. The SGM Grant Program 2019 Guidelines document requires that a project proposed by a public utility regulated by the Public Utilities Commission or a mutual water company shall have a clear and definite public purpose and shall benefit the customers of the water system and not the investors (Water Code § 79712(b)(1)).

This Proposal involves funding of a planning effort rather than an implementation project. The Subbasin Data Management System Development project it will develop a critical groundwater sustainability tool encompassing all parts of the Subbasin. The proposed project consists of scoping and development of the DMS. Once the planned DMS becomes operational, the collected data will inform understanding of existing and projected groundwater levels; consequently, this knowledge will contribute to addressing and reducing risks in the region to water supply and water infrastructure arising from climate change. This is a clear and definite public purpose and benefits the customers and residents of the entire project area, the Kern County Subbasin. There are no investors associated with this project, and there shall be no benefits to investors as a result of this project.

H. Stormwater Resource Plan (SWRP) Compliance

This section discusses Stormwater Resource Plan Compliance for the overall Proposal. The SGM Grant Program 2019 Guidelines document states that Senate Bill (SB) 985 (Water Code § 10563(c)) requires the development of a SWRP or functionally equivalent plan for stormwater and dry weather runoff capture projects to receive grant funds through these provisions.

This Proposal involves funding of a planning effort, not an implementation project. As such, the Subbasin Data Management System Development project would not involve activities that could affect stormwater or dry weather resources. Since this project will conduct no construction, a Stormwater Resource Plan will not be needed.

I. Surface Water Diverter Compliance

Surface Water Diverter eligibility for the overall Proposal is discussed in this section. The SGM Grant Program 2019 Guidelines document states that a diverter of surface water is not eligible for a water grant or loan awarded or administered by the State unless it complies with surface water diversion reporting requirements outlined in Part 5.1 of Division 2 of the Water Code.

The applicant, KRGSA, is not a surface water diverter. No surface water diverters will receive funding from the proposed grant through a joint-powers agreement or other legal agreement. The project included in this proposal will be implemented by the applicant, KRGSA, in collaboration with KGA on behalf of all the GSAs in the Subbasin. KGA is also a GSA within the basin, and KGA is not a surface water diverter. Neither the applicant nor the additional project proponent, KGA, is a surface water diverter, and as such these entities are not required to submit to the State Water Resources Control Board (SWRCB) surface water diversion reports in

compliance with requirements outlined in Part 5.1 (commencing with Section 5100) of Division 2 of the Water Code.

Therefore, documentation of Surface Water Diverter Compliance is not applicable for this proposal, applicant, or project proponents.

It is noted that while the applicant, KRGSA, is not a surface water diverter, two of the member agencies of the KRGSA are surface water diverters. The City of Bakersfield and Kern Delta Water District have longstanding water rights on the Kern River. Both these member agencies are in full compliance with regard to submitting diversion reports with the SWRCB.

J. Sustainable Water Use and Demand Reduction

This section addresses Sustainable Water Use and Demand Reduction eligibility for the overall Proposal. The SGM Grant Program 2019 Guidelines document states that SBx7-7 (Water Code § 10608 et seq.) conditions the receipt of a water management grant or loan for urban water suppliers on gallons per capita per day reduction targets with the end goal of a 20% reduction by 2020.

As discussed below in Section K, Urban Water Management Compliance, the applicant, KRGSA, is not an urban water supplier. No urban water suppliers will receive funding from the proposed grant through a joint-powers agreement or other legal agreement. The Sustainable Water Use and Demand Reduction criterion is not applicable for this Proposal.

K. Urban Water Management Compliance

Urban Water Management eligibility for the applicant for this Proposal is discussed in this section. The applicant, KRGSA, is not an urban water supplier. No urban water suppliers will receive funding from the proposed grant through a joint-powers agreement or other legal agreement. The project included in this proposal will be implemented by the applicant, KRGSA, in collaboration with KGA on behalf of and in coordination with all the GSAs in the Subbasin. KGA is also a GSA within the basin, and KGA is not an urban water supplier. Neither the applicant nor the additional project proponent, KGA, is an urban water supplier, and as such these entities are not required to develop or submit Urban Water Management Plans, to maintain compliance with Sustainable Water Use and Demand Reduction, Part 2.55 of Division 6 (Water Code Section 10608 *et seq*.), or to comply with water metering requirements contained in Water Code Section 525 et seq.

Therefore, documentation of Urban Water Management Compliance is not applicable for this proposal, applicant, or project proponents.

It is noted that while the applicant, KRGSA, is not an urban water supplier, two of the KRGSA member agencies, the Kern County Water Agency Improvement District No. 4 and the City of Bakersfield, are required to develop and maintain an Urban Water Management Plan (UWMP) that is submitted to DWR for review. Kern County Water Agency Improvement District No. 4 is in full urban water management compliance, having submitted and received DWR approval on its 2015 UWMP, which is included in Appendix B. The City of Bakersfield's UWMP was submitted on June 30, 2017. Documentation is also included in Appendix B.

L. Water Metering Compliance

This section addresses Water Metering Compliance eligibility for the overall Proposal. The Round 3 Planning Grants Proposal Solicitation Package states that any urban water supplier applying for State grant funds for wastewater treatment projects, water use efficiency projects, drinking water treatment projects, or for a permit for a new or expanded water supply, shall demonstrate that they meet the water meter requirements in Water Code § 525 et seq.

The applicant, KRGSA, is not an urban water supplier. The project included in this proposal will be implemented by the applicant, KRGSA, in collaboration with KGA on behalf of and in coordination with all the GSAs in the Subbasin. KGA is also a GSA within the basin, and KGA is not an urban water supplier. Neither the applicant nor the additional project proponent, KGA, is an urban water supplier.

This Proposal is not seeking funding for a wastewater treatment project, water use efficiency project, drinking water treatment project, or permit for a new or expanded water supply.

Therefore, the Water Metering Compliance criterion is not applicable for this proposal, applicant, or project proponents.

It is noted that while the applicant, KRGSA, is not an urban water supplier, two of the KRGSA member agencies, the Kern County Water Agency Improvement District No. 4 is a treated water wholesaler and provides a supply to four customers. All connections are metered; however, ID4 is not required to obtain documentation because it is not a retail urban water supplier.

Appendix A

Kern River Groundwater Sustainability Agency
GSA Application Package (excerpt)

April 12, 2016 GSA application package cover letter submitted to DWR's Sustainable Groundwater Management Section

Full application package may be found on KRGSA's website: http://www.kernrivergsa.org

Kern River Groundwater Sustainability Agency

April 12, 2016

Mark Nordberg, GSA Project Manager
Sustainable Groundwater Management Section
California Department of Water Resources
P.O. Box 942836
Sacramento, California 94236-0001

Re: Notice of Decision to Become a Groundwater Sustainability Agency

Dear Mr. Nordberg,

Per Section 10723.8(a) of the California Water Code, the City of Bakersfield, the Kern Delta Water District, and the Kern County Water Agency Improvement District No.4 hereby give notice of their decision to form the Kern River Groundwater Sustainability Agency (GSA) for a portion of the Kern County Subbasin (Basin Number 5-22.14, DWR Bulletin 118) within the San Joaquin Valley Groundwater Basin.

The Sustainable Groundwater Management Act (SGMA), passed in 2014, requires that all basins designated as high- or medium-priority basins that are subject to critical overdraft conditions are to be managed under a groundwater sustainability plan (GSP) or coordinated GSPs (Section 10720.7). The Kern County Subbasin is a high-priority basin and is identified as having critical overdraft conditions. Information regarding the status of groundwater basins is provided by the California Department of Water Resources (DWR) at: http://www.water.ca.gov/groundwater/sgm/cod.cfm.

This GSA notification and supporting materials are submitted to DWR within 30 days of the decision to form the GSA by its member agencies per Water Code §10723.8(a).

Water Code §10723.8(a)(1) requires that this GSA notification include information regarding the service area boundaries of the GSA and the boundaries of the basin the GSA intends to manage. Exhibit 1 includes three maps to satisfy the requirements of Water Code §10723.8(a)(1). Map (A) shows the Kern River GSA boundary. Map (B) shows the Kern River GSA boundary within the Kern County Subbasin. Map (C) shows the boundaries of the service areas of the agencies that comprise the Kern River GSA. The digital GIS data corresponding to the GSA boundary maps shown in Exhibit 1 are included with this submittal and provided on compact disc.

Water Code §10723.8(a)(1) also requires information regarding other agencies managing or proposing to manage groundwater within the basin. At the time of this Kern River GSA Notification submittal to DWR, it is our understanding that the Buena Vista Water Storage District has submitted a Notification to Form a GSA with DWR for a portion of the Kern County Subbasin. Within the Kern County subbasin, we understand that other agencies may be considering or proposing to form GSAs to manage groundwater resources in their own services areas. To our knowledge at this time, the following entities have held either a public hearing or expressed interest in forming a GSA: the Kern Groundwater Authority (KGA) and the Olcese Water District. We understand that the Greenfield County Water District has held a public hearing, passed a resolution to form a GSA, and will be submitting their Notification to Form a GSA with DWR.

On March 1, 2016 the governing Board of the Kern Delta Water District held a public hearing (Water Code §10723.b) regarding formation of the Kern River GSA. On March 15, 2016 the Board passed Resolution 2016-03 wherein the District resolved to become a GSA in cooperation with the City of Bakersfield and Improvement District No.4 of the Kern County Water Agency for the portion of the Kern County Subbasin as shown in Exhibit 1. Exhibit 2 contains a copy of the approved resolution to form the Kern River GSA by the governing Board of the Kern Delta Water District. Exhibit 3 includes details regarding the public noticing of the March 1, 2016 hearing by the Kern Delta Water District. The noticing process was consistent with the requirements of Section 6066 of the California Government Code.

On March 2, 2016 the City Council of Bakersfield held a public hearing (Water Code §10723.b) regarding formation of the Kern River GSA. On March 30, 2016 the City Council passed Resolution 039-16 wherein the City resolved to become a GSA in cooperation with the Kern Delta Water District and Improvement District No.4 of the Kern County Water Agency for the portion of the Kern County Subbasin as shown in Exhibit 1. A copy of Resolution 039-16 is included in Exhibit 2. Details regarding the public noticing of the March 2, 2016 hearing by the City Council are provided in Exhibit 3 and are consistent with the requirements of Section 6066 of the California Government Code.

On March 31, 2016 the Board of Directors of the Kern County Water Agency on behalf of Improvement District No.4 held a public hearing (Water Code §10723.b) regarding formation of the Kern River GSA. On March 31, 2016 the Board of Directors passed Resolution 11-16 wherein the Kern County Water Agency, Improvement District No.4 resolved to become a GSA in cooperation with the Kern Delta Water District and the City of Bakersfield for the portion of the Kern County Subbasin as shown in Exhibit 1. A copy of Resolution 11-16 is included in Exhibit 2. Details regarding the public noticing of the March 31, 2016 hearing by the Board of Directors are provided in Exhibit 3 and are consistent with the requirements of Section 6066 of the California Government Code.

Exhibit 4 provides a memorandum of understanding (MOU) between the Kern Delta Water District, City of Bakersfield, and Kern County Water Agency Improvement District No.4 to form the Kern River GSA and manage groundwater resources sustainably within the GSA boundary. Please note that Exhibit C-1 to the MOU in Exhibit 4 contains a list of additional agencies that have joined the Kern River GSA. Exhibit 5 includes additional supporting documents related to these additional agencies that have joined the Kern River GSA.

Per California Water Code §10723.2, GSAs shall consider the interests of all beneficial uses and users of groundwater within their service area, as well as those responsible for implementing Groundwater Sustainability Plans (GSPs). Exhibit 6 lists interested parties developed pursuant to Water Code §10723.2 and describes how these users and uses will be considered during the development and operation of the Kern River GSA and implementation of the GSP for the Kern River GSA. If additional interested parties are discovered, they too will be included in the development and operation of the GSA and the development and implementation of the agency's sustainability plan (Water Code 10723.8(a)(4)).

Water Code §10723.4 states that a GSA shall also establish and maintain a list of persons interested in receiving notices regarding plan preparation, meeting announcements, and availability of draft plans, maps, and other relevant documents. Any person may request, in writing, to be placed on the list of interested persons. The Kern River GSA will establish and maintain such a list of persons interested in receiving notices.

Except for the authorities granted to a GSA pursuant to Part 2.74 of Division 6 of the California Water Code (SGMA), no new bylaws, ordinances, or authorities have been adopted by the District or City at this time of forming the Kern River GSA (Water Code §10723.8(a)(3)).

The undersigned hereby represents that the information required by California Water Code §10728.3 is included within this notice and that the notification process is complete.

If you have any further questions or require any clarification regarding the information provided in this GSA Notification submittal, please do not hesitate to contact one of our GSA program coordinators as identified on the following page.

Thank you,

Rodney Palla
President, Board of Directors, Kern Delta Water District

Harold Hanson
Vice Mayor, City of Bakersfield

Ted Page
President, Board of Directors, Kern County Water Agency

GSA Program Coordinators

Art Chianello
Water Resources Manager
Water Resources Department
(661) 326-3715
achianel@bakersfieldcity.us

Mark Mulkay
General Manager
Kern Delta Water District
(661) 834-4656
mulkay@kerndelta.org

David Beard
Manager
Kern County Water Agency
Improvement District No. 4
(661) 634-1400
dbeard@kcwa.com

Exhibits:

Exhibit 1: GSA Maps – including (A) map of Kern River GSA boundary, (B) map of Kern River GSA boundary within Kern County Subbasin, and (C) map of Kern River GSA showing member agencies service area boundaries

Exhibit 2: GSA Forming Resolutions by Kern Delta Water District, City of Bakersfield, and Improvement District No. 4 of the Kern County Water Agency

Exhibit 3: Public Hearing Noticing Information for GSA Member Agencies

Exhibit 4: Memorandum of Understanding (MOU) Between the City of Bakersfield, Kern Delta Water District, and Improvement District No.4 of the Kern County Water Agency

Exhibit 5: Supporting Documents for Entities Also Joining the Kern River GSA

Exhibit 6: List of Interested Parties

Exhibit 7: List and Map of Disadvantaged Communities (DAC) in GSA

Appendix B

Compliance Documentation

UWMP Documentation

AWMP Documentation

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

August 30, 2016

Mr. David Beard
Improvement District No. 4 Manager
Kern County Water Agency
3200 Rio Mirada Drive
Bakersfield, California 93308

RE: Urban Water Management Plan Requirements Addressed

Dear Mr. Beard:

The Department of Water Resources (DWR) has reviewed the Kern County Water Agency's 2015 Urban Water Management Plan (UWMP) that was received on June 24, 2016. The California Water Code (CWC) directs DWR to report to the California State Legislature once every five years on the status of submitted UWMPs. In meeting this legislative reporting requirement, DWR reviews all submitted UWMPs.

DWR's review of the Kern County Water Agency's 2015 UWMP has found that the UWMP addresses the requirements of the CWC. DWR's review of plans is limited to assessing whether suppliers have addressed the required legislative elements. In its review, DWR does not evaluate or analyze the supplier's UWMP data, projections or water management strategies. This letter acknowledges that the Kern County Water Agency's 2015 UWMP addresses the CWC requirements. The results of the review will be provided to DWR's Financial Assistance Branch.

If you have any questions regarding the review of the UWMP or urban water management planning please call Gwen Huff at 916-651-9672.

Sincerely,

Vicki Lake
Unit Chief
Urban Water Use Efficiency
(916) 651-0740

Electronic cc: Luis Avila
DWR

Jeff Eklund
Provost & Pritchard Consulting Group

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY

EDMUND G. BROWN JR., *Governor*

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

RECEIVED
JUL 14 2017
CITY OF BAKERSFIELD
WATER RESOURCES

July 11, 2017

Art Chianello
Water Resources Manager
City of Bakersfield
1000 Buena Vista Road
Bakersfield, California 93311

RE: Urban Water Management Plan Submittal

Dear Mr. Chianello:

This is to inform you that the Department of Water Resources has received the 2015 Urban Water Management Plan for City of Bakersfield on June 30, 2017.

DWR reviews Plans as quickly as possible and in the order they are received. If you require an expedited review, please contact me.

Please feel free to contact Gwen Huff at (916) 651-9672 if you have any questions or would like to discuss the review of 2015 Urban Water Management Plans. Contact Ms. Huff, also, if you require an expedited review.

Vicki Lake
Unit Chief
Urban Water Use Efficiency
Department of Water Resources
(916) 651-0740

2015 Agricultural Water Management Plans List

2015 Agricultural Water Management Plans List

SBX 7-7 Plans

- Alta ID Water Management Plan
  - Vol 1 of 4
  - Vol 2 of 4
  - Vol 3 of 4
  - Vol 4 of 4
- Browns Valley ID 2016 AWMP
- Buena Vista 2015 AWMP
- Butte WD 2016 AWMP
- Byron Bethany ID_AWMP_Final_20171024
- Camrosa WD 2015 AWMP
- Carpinteria Valley WD 2015 AWMP
- Casitas MWD 2016 UWMP-AWMP
- Cawelo WD 2016 AWMP
- Corcoran AWMP Prepared Pursuant to Water Code Section 10826
- Consolidated ID 2016 AWMP
- Dudley Ridge 2015 AWMP
- Feather River Regional AWMP
  - Biggs-West Gridley WD 2015 AWMP
  - Richvale Irrigation District (2015 AWMP Update)
  - Western Canal Water District (WCWD)
- KernDelta WD 2015 AWMP
- Laguna ID AWMP 2015
- Lone Tree MWC 2016 AWMP
- Merced ID 2015 AWMP
- Modesto ID 2015 AWMP
- North Kern WSD 2015 AWMP
- Oakdale ID 2015 AWMP
- Orland Unit WUA AWMP 2017
- Rancho California WD 2015 AWMP UPDATE
- RD #2068 2016 AWMP
- Reclamation District #2035 2016 AWMP
- Riverdale ID 2016 AWMP

- San Diego Regional 2015 AWMP Part 1 | Part 2
- Semitropic WSD 2015 AWMP
- South San Joaquin ID AWMP 2015
- South Sutter WD 2015 AWMP
- Sutter Extension WD 2016 AWMP Final
- Turlock ID 2015 AWMP
- Ventura Co 2015 AWMP
- Wheeler Ridge-Maricopa 2015 AWMP
- Woodbridge ID 2016 AWMP
- Yolo County Flood Control and Water Conservation District
- Yuba Co WA 2015 AWMP

Federal Plans

- Arvin-Edison Water Basin plan
- Banta-Carbona ID 2015 WMP
- Central California ID WMP FINAL 6-2014
- Chowchilla WD 2015 Update
- Columbia Canal Co 2012 WMP
- Colusa Co WD WMP Oct2014
- Delano-Earlimart ID WMP
- Firebaugh Canal WD 2011 WMP
- Fresno Irrigation District Agricultural Water Management Plan
- Sacramento River Settlement Contractors WMP
  - RD 108 Water Measurement Program
  - Sutter Mutual WC Water Measurement Program
  - Sacramento River Settlement Contractors WMP 9.13.13 Update
  - GCID Water Measurement Compliance 2016 Update
  - Sacramento River Settlement Contractors 2016 Drought Mgmt Plan
- James ID 2016 AWMP
- Kern-Tulare WD 2016 AWMP
- Lindmore ID 2016 WMP & Supplemental Report
- Lower Tule River 2012 WMP Update
- Madera ID WMP 2014-04-01
- Maine Prairie WD 2015 WMP 2.2017
- Orange Cove ID 2015 WCP & Addendum
- Orland-Artois WD 2015 WMP
- Panoche WD WCP Final 3-24-14

- Patterson ID WMP 2016 Update
- Pixley ID 2012 WMP Update
- San Benito COWD 2015 WMP
- San Luis Canal Co WMP Final 6-2014
- San Luis WD 2015 Supplement Report
- Shafter-Wasco ID 2015 Addendum to WMP
- Solano ID 2015 AWMP
- Stockton-East WD 2015 AWMP 2017.08.01
- Tulare ID Water Management Plan
  - Agricultural Water Measurement Master Plan
  - Drought Management Plan
  - Water Management Plan 2010
  - Water Supply Summary
- West Stanislaus ID 2014 WMP
- Westlands WD Water Mangement Plan
  - Westlands WD Water Shortage Contingency Plan 4.13.2017
  - Westlands WD WMP 2012
  - Westlands WD Worksheet Supply and Demand Final 4.13.2017
  - Water Supply Summary
- Westside WD 2013 WMP

Wednesday, November 01, 2017

Water Suppliers Required and Submitted (<25,000 due 7/1/2016)	Date Received	2015 & 2016 Plan Type/Date	>25,000 acres or as noted	Review Completed
Lone Tree MWC	7/1/2015	SBX7-7	10-25,000 acres	X
Columbia Canal Co.	8/10/2015	CVPIA	10-25,000 acres	X
Firebaugh Canal W.D.	8/10/2015	CVPIA	10-25,000 acres	X
Central California ID	8/10/2015	CVPIA/ 2014		X
San Luis Canal Co	8/10/2015	CVPIA/ 2014		X
Corcoran ID	8/18/2015	SBX7-7/ 2015		X
Arvin-Edison WSD	11/12/2015	CVPIA/ 2013-updated		X
Tulare Lake Basin WSD	11/12/2015	SBX7-7/ 2015		X
San Benito WD	11/16/2015	CVPIA/ 2015		X
Alta ID	12/9/2015	SBX7-7/ 2015		X
Turlock ID	12/10/2015	SBX7-7/ 2015		X
Lower Tule River ID	12/21/2015	CVPIA/ 2012		X
Pixley ID	12/21/2015	CVPIA/ 2012		X
Chowchilla WD	12/22/2015	CVPIA/ 2015-updated		X
South San Joaquin ID	12/22/2015	SBX7-7/ 2015		X
Kern Delta WD	12/28/2015	SBX7-7/ 2015		X
Modesto ID	12/29/2015	SBX7-7/ 2015		X
Biggs-West Gridley WD	1/13/2016	SBX7-7/ 2015		X
North Kern WSD	1/19/2016	SBX7-7/ 2015		X
Dudley Ridge WD	1/20/2016	SBX7-7/ 2015	10-25,000 acres	X
Laguna ID	1/27/2016	SBX7-7/ 2015		X
Tulare ID	1/28/2016	CVPIA/ 2015-updated		X
Nevada ID	2/1/2016	SBX7-7/ 2015		X
Ventura Co Waterworks Dist 1	2/11/2016	SBX7-7/ 2015	<10,000 acres	
Shafter-Wasco ID	2/11/2016	CVPIA/ 2015-updated		X
Yolo Co FC&WCD	2/11/2016	SBX7-7/ 2015		X
Fresno ID	2/18/2016	CVPIA/ 2015		X
Western Canal WD	2/26/2016	SBX7-7/ 2015		X
Richvale ID	2/29/2016	SBX7-7/ 2015		X
Solano ID	2/29/2016	CVPIA/ 2016		X
Buena Vista WSD	3/4/2016	SBX7-7/ 2015		X

Carlsbad MWD*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
City of Escondido*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
City of Oceanside*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
City of Poway*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
Fallbrook Public Utilities District*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
Olivenhaim MWD*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
Ramona MWD*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
Rincon del Diablo MWD*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
San Dieguito WD*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
Santa Fe ID*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
Vallecitos WD*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
Yuima MWD*	3/15/2016	SBX7-7/ 2015	<10,000 acres	
Valley Center MWD*	3/15/2016	SBX7-7/ 2015	10-25,000 acres	**X**
Rainbow MWD*	3/15/2016	SBX7-7/ 2015	10-25,000 acres	**X**
Camrosa WD	3/29/2016	SBX7-7/ 2015	<10,000 acres	
Oakdale ID	3/29/2016	SBX7-7/ 2015		**X**
Semitropic WSD	4/1/2016	SBX7-7/ 2015		**X**
Yuba County WA	4/4/2016	SBX7-7/ 2015	Wholesaler	
Wheeler-Ridge-Maricopa WSD	4/6/2016	SBX7-7/ 2015		**X**
Carpinteria Valley WD	4/22/2016	SBX7-7/ 2015	<10,000 acres	
South Sutter WD	4/29/2016	SBX7-7/ 2015		**X**
Rancho California WD	6/23/2016	SBX7-7/ 2016	10-25,000 acres	**X**
Patterson ID	6/28/2016	CVPIA/ 2016 Update	10-25,000 acres	**X**
Woodbridge ID	6/29/2016	SBX7-7	10-25,000 acres	**X**
Cawelo WD	6/29/2016	SBX7-7		**X**
Casitas MWD	7/1/2016	SBX7-7	<10,000 acres	
Merced ID	7/21/2016	SBX7-7		**X**
Browns Valley ID	7/22/2016	SBX7-7	10-25,000 acres	**X**
Reclamation District 2035	7/29/2016	SBX7-7	10-25,000 acres	**X**
Consolidated ID	8/9/2016	SBX7-7		**X**
James ID	8/26/2016	CVPIA	10-25,000 acres	**X**
Kern-Tulare WD	8/31/2016	CVPIA	10-25,000 acres	**X**
Reclamation District No. 2068	9/14/2016	SBX7-7	10-25,000 acres	**X**
West Stanislaus I.D.	9/16/2016	CVPIA	10-25,000 acres	**X**

Westside W.D.	9/21/2016	CVPIA	10-25,000 acres	**X**
Riverdale I.D.	11/15/2016	SBX7-7	10-25,000 acres	**X**
Sutter Extension WD	11/17/2016	SBX7-7	10-25,000 acres	**X**
Glenn-Colusa ID**	12/16/2016	CVPIA/Sac River		**X**
Butte WD	1/4/2017	SBX7-7	10-25,000 acres	
Princeton-Codora-Glenn ID**	1/6/2017	CVPIA/Sac River	<10,000 acres	**X**
Meridian Farms**	1/6/2017	CVPIA/Sac River	<10,000 acres	**X**
Anderson-Cottonwood ID**	1/6/2017	CVPIA/Sac River	<10,000 acres	**X**
Reclamation District No. 1004**	1/6/2017	CVPIA/Sac River	10-25,000 acres	**X**
Provident ID**	1/6/2017	CVPIA/Sac River	10-25,000 acres	**X**
Natomas MWC**	1/6/2017	CVPIA/Sac River	10-25,000 acres	**X**
Sutter Mutual WC**	1/6/2017	CVPIA/Sac River		**X**
Reclamation District No. 108**	1/6/2017	CVPIA/Sac River		**X**
San Luis WD	1/10/2017	CVPIA		**X**
Delano-Earlimart ID	1/30/2017	CVPIA		**X**
Maine Prairie W.D.	3/7/2017	CVPIA	10-25,000 acres	**X**
Westlands WD	4/13/2017	CVPIA		**X**
Banta-Carbona I.D.	4/19/2017	CVPIA	10-25,000 acres	**X**
Orland-Artois WD	4/25/2017	CVPIA		**X**
Madera ID	4/25/2017	CVPIA		**X**
Colusa Co. WD	5/2/2017	CVPIA		**X**
Orland Unit WUA	5/11/2017	SBX7-7	10-25,000 acres	**X**
Stockton-East WD	8/8/2017	CVPIA		**X**
Orange Cove ID	8/28/2017	CVPIA		**X**
Lindmore ID	9/15/2017	CVPIA	10-25,000 acres	**X**
Panoche WD	9/26/2017	CVPIA		**X**
Byron Bethany I.D.	10/31/2017	CVPIA	10-25,000 acres	

*San Diego Regional AWMP

**Sac R. Settlement Contractors

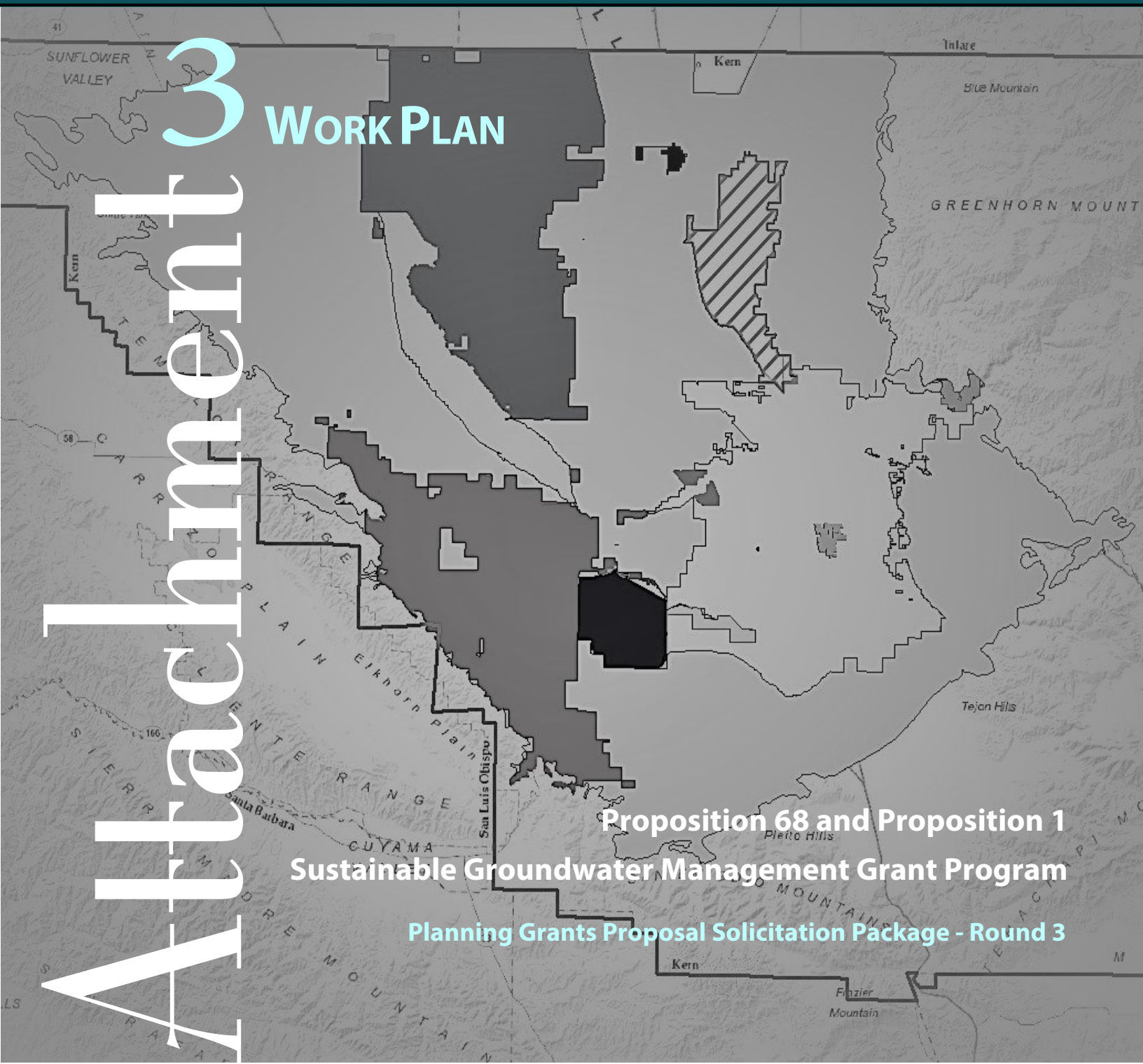
Water Suppliers Required, In Progress (<25,000 due 7/1/2016)	**2015-2016 Plan Type/Date**	**>25,000 acres or as noted**
Kings River W.D.	SBX7-7	10-25,000 acres
Ivanhoe I.D.	CVPIA	10-25,000 acres
Saucelito I.D.	CVPIA	10-25,000 acres
Terra Bella I.D.	CVPIA	10-25,000 acres
Tule Lake ID	CVPIA	
Water Suppliers Required, Not Submitted (<25,000 due 7/1/2016)		
Belridge WSD	SBX7-7	
Berrenda Mesa WD	SBX7-7	
Central San Joaquin WCD	CVPIA	
Del Puerto WD	CVPIA	
Lost Hills WD	SBX7-7	
Palo Verde ID	RRA***	
Southern San Joaquin MUD	CVPIA	
Angiola WD		
Bard WD	CVPIA	10-25,000 acres
Exeter I.D.	CVPIA	10-25,000 acres
Henry Miller W.D.	SBX7-7	10-25,000 acres
Lindsay-Strathmore I.D.	CVPIA	10-25,000 acres
Porterville I.D.	CVPIA	10-25,000 acres
Reclamation District No. 999	SBX7-7	10-25,000 acres
St. Johns W.D.	SBX7-7	10-25,000 acres

***Reclamation Reform Act of 1982

Kern County Subbasin Groundwater Sustainability Plan Support - Phase II 2019 Grant Application

Attachment 3

Work Plan



Proposition 68 and Proposition 1

Sustainable Groundwater Management Grant Program

Planning Grants Proposal Solicitation Package - Round 3

Work Plan **1**

Project Justification **1**

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Appendices

See Appendix C in Attachment 6, SDAC-DAC-EDA

Work Plan

Grant Proposal Title:	**Kern County Subbasin Groundwater Sustainability Plan Support – Phase II**
Applicant:	**Kern River Groundwater Sustainability Agency**

Project Justification

A. Project Description

The Kern County Subbasin (Subbasin 5-022.14) is identified as a critically overdrafted basin where numerous water and irrigation districts, municipalities, industries, mutual water companies, small water systems, and Kern County residents rely on the shared groundwater resources. In compliance with the Sustainable Groundwater Management Act (SGMA), 11 groundwater sustainability agencies (GSAs) have been formed to cooperatively manage local groundwater in a sustainable manner within the Subbasin.

This proposal includes one critically important project, Kern County Subbasin Data Management System Development, which will be implemented by all the GSAs in the Kern County Subbasin. KRGSA is submitting this application on behalf of the entire Subbasin.

KRGSA on behalf of the Kern County Subbasin was awarded $1,500,000 in Proposition 1 SGMA Planning Grant funds for a suite of six GSP Development project components supporting the entire Kern County Subbasin and proposed under the 2017 Round 2 SGMA grant opportunity. These six project components are well underway and successfully nearing completion at the time of this writing. Given the funding guidelines associated with this 2019, Round 3 SGM Planning Grant opportunity, this proposal requests an additional $500,000 in Planning Grant funds, which if awarded, will mean that the Kern County Subbasin will have been awarded the published maximum of $2,000,000 in Proposition 68 and Proposition 1 SGM Planning Grant funding. The Kern County Subbasin is one of the most important groundwater resources in the state, given its large size, high population growth, large number of irrigated acres, reliance on groundwater, and historical groundwater impacts. In light of these relatively high basin prioritization criteria, the Subbasin supports numerous large groundwater banking projects of statewide importance, including the Kern Water Bank, among others. This Subbasin is deserving of earning up to the maximum of grant funding due to the importance of this Subbasin and its various planning needs and challenges.

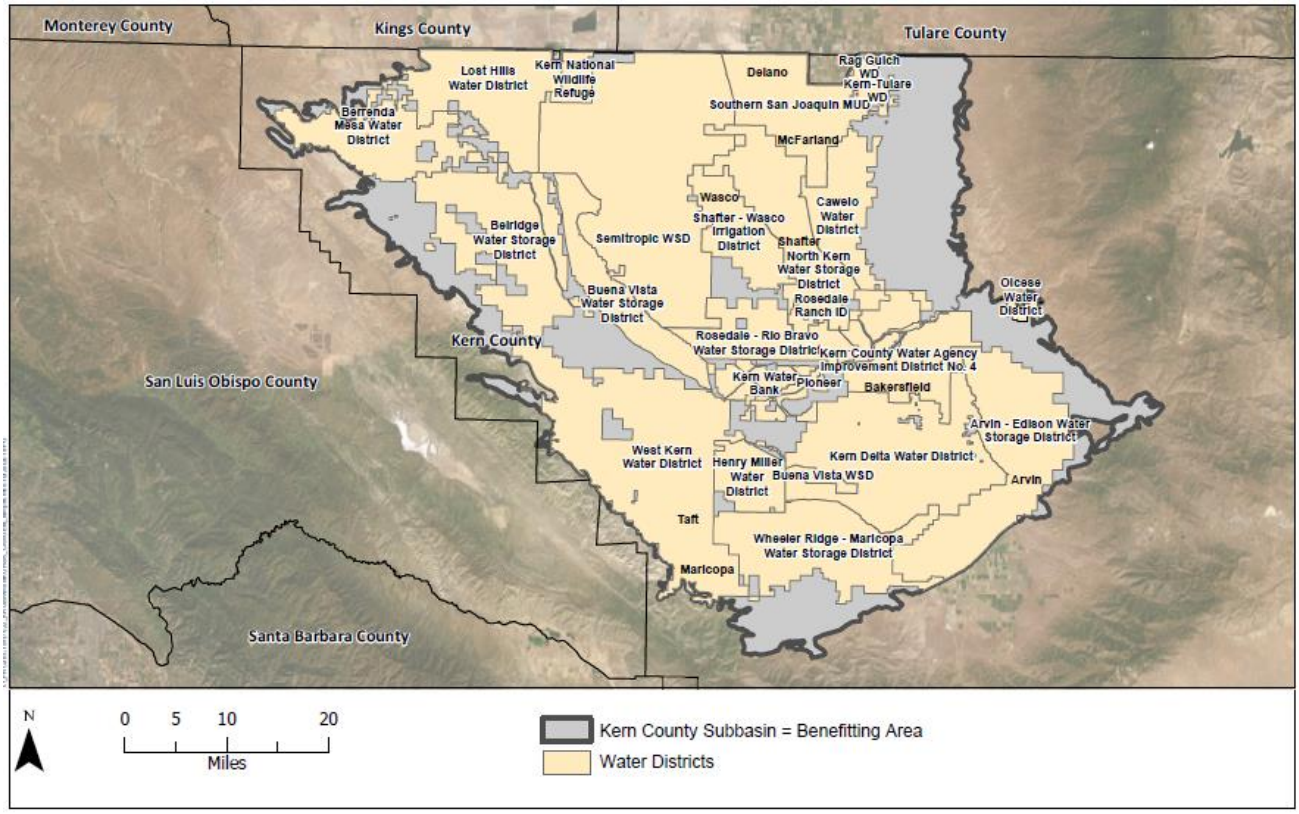
This project included in this proposal and described below will parlay the available $500,000 in Planning Grant funds to effectively initiate a data management system (DMS) that will benefit all GSAs in the Subbasin and directly support the cross-basin coordination effort.

Background and Need for the Project

Covering about 2,834 square miles, Kern County Subbasin is the largest subbasin in California with a complex water management structure, a large portfolio of local and imported water sources, and numerous large groundwater banking projects, collectively providing both local and State-wide benefits for water supply. The map provided in **Figure 3-1** below shows the boundaries of the Kern County Subbasin, which is also the area that would benefit from the proposed project, as well as the boundaries of the multiple water districts within the Subbasin. The general locations of Disadvantaged

Communities (DACs) are shown in bold-face type; a map showing the areas occupied by DACs is provided as Figure 6-1 in Attachment 6.

Figure 3-1. Kern County Subbasin and Benefitting Area



Given this framework, numerous approaches and systems for data management have been developed over time by each local agency for its own objectives – including regulatory compliance. This has resulted in a myriad of disparate data sets with different organizational structures, temporal and spatial scales, data standards, and assumptions regarding data accuracy and reliability. GSP regulations (Article 3, Section 352.6) require agencies to develop and maintain a data management system that is "capable of storing and reporting information relevant to the development or implementation of the Plan and monitoring of the basin."

The Kern County Subbasin GSAs recognize the need to develop a centralized DMS on a Subbasin-wide basis. Accordingly, the GSAs in the Kern County Subbasin are cooperating on this proposal for a Subbasin-wide DMS to support monitoring, evaluation, reporting, management, and, importantly, GSP implementation. It is recognized that compilation of individual DMSs will require significant manipulation and re-structuring to create a centralized relational DMS that is populated with consistent data sets across the Subbasin.

One of the hallmarks of SGMA is a call for the integrated coordination of groundwater resources across a subbasin planning area. For the Kern County Subbasin, developing a shared, common, and consistent platform across the Subbasin is essential to continue the coordination developed with the C2VSim water modeling, monitoring network, and now annual reporting.

The immediate need for a centralized DMS is highlighted by the GSAs' ongoing cooperative efforts for annual reporting. Specifically, GSAs are working together to collaboratively prepare one Annual Report for each reporting period that covers the entire Subbasin rather than submitting a separate Annual Report from each GSA. As codified in SGMA, Chapter 6, Section 10728 of the California Water Code states:

> "On April 1 following the adoption of a groundwater sustainability plan and annually thereafter, a groundwater sustainability agency shall submit a report to the department containing the following information about the basin managed in the groundwater sustainability plan:
>
> (a) Groundwater elevation data.
>
> (b) Annual aggregated data identifying groundwater extraction for the preceding water year.
>
> (c) Surface water supply used for or available for use for groundwater recharge or in-lieu use.
>
> (d) Total water use.
>
> (e) Change in groundwater storage."

In order to comply with the requirements of SGMA for standardized reporting, and to coordinate on a Subbasin-wide basis for consistent data evaluation, it is crucial that a DMS be developed for the entire Subbasin that will allow the various GSAs to gather and share information regarding local groundwater conditions on a shared and consistent data platform.

Project Goals and Objectives

The overarching goal of the proposed Subbasin Data Management System Development project is to initiate the key steps to develop and build the Subbasin DMS, which will ultimately support Subbasin GSAs by providing (1) improved coordination of groundwater monitoring and management actions and (2) the ability to meet the reporting and implementation requirements of their respective groundwater sustainability plans (GSPs) and the California Department of Water Resources (DWR).

It is noted that the total cost to complete the entire DMS development for the Kern Subbasin will likely exceed the available grant funding of $500,000 under the Sustainable Groundwater Management (SGM) Grant Program, Round 3 (this grant application). This application is submitted to initiate the key steps to develop and build the Subbasin DMS. This Work Plan and the associated Budget and Schedule describe tasks to be funded under this grant and within the available funding, as well as additional tasks that will likely require additional funding, above and beyond this SGM Planning Grant, to be shared among Subbasin GSAs who have already developed successful cost sharing structures for numerous components of the GSP including coordinated development of the Subbasin-wide integrated surface water-groundwater model (C2VSimFG-Kern). The Subbasin GSAs are committed to providing sufficient funds and resources to complete the project.

The work plan steps requested under this grant will provide the necessary DMS framework, addressing needs and processes such as accessibility, transparency, functionality, reliability, and data sharing, among others. The DMS project description, budget, and schedule information provided in Attachments 3, 4, and 5 describe the tasks that will be conducted under the funding support of this grant.

The project objectives are as follows:

- Identify data types to be included in the DMS and required to monitor GSP implementation and Subbasin progress toward sustainability. (funded under this grant)
- Investigate and compare commercially available DMS packages and custom systems to determine the most appropriate and cost-effective format for the Kern County Subbasin DMS. (funded under this grant)

- Select a preferred DMS approach. (funded under this grant)
- Procure or design the DMS and customize as needed with an appropriate configuration that combines technical rigor, flexibility, ease of use, and expansion capabilities to store data in text, spreadsheet, graphical, and map-based formats. (partially funded under this grant; The any additional funding to be provided by Subbasin GSAs)
- Develop data templates that allow each GSA or participating agency to submit the required data in a consistent format that can be combined and adjusted to present information in both local and Subbasin-wide formats to meet DWR reporting requirements. (funded under this grant)
- Develop a DMS User's Manual and train GSA staff to gather, submit, and update the required data on a regular basis and in a consistent format. (funded under this grant
- Coordinate with local stakeholders, non-member agencies, and disadvantaged communities (DACs), such as the Cities of Shafter and Arvin and portions of the City of Bakersfield, that have potential activities, tasks, and/or components that are complementary to the DMS development project. (funded under this grant)

Tools to Be Developed

The proposed Subbasin Data Management System Development project will initiate the key steps to develop and build a critically important DMS for the Kern County Subbasin. Specific tools to be developed during implementation of this grant-funded scoping and development effort include the following:

- A process for identifying necessary data types;
- A comparison/decision-making tool for evaluating commercially available DMS packages and custom systems against the needs and resources of the Subbasin;
- The DMS itself, customized to meet the data needs of the Subbasin GSAs; and
- A DMS User's Manual to train GSA staff in the use of the DMS.

Differentiation from Round 2 Funding

KRGSA is the administering agency for Round 2 funding of six projects under the Kern County Subbasin Groundwater Sustainability Plan Support – 2017 Grant Application (DWR Agreement No. 4600012955):

- Component 1: Grant Administration (KRGSA responsibility)
- Component 2: Groundwater Modeling (KRGSA responsibility)
- Component 3: Groundwater Model Peer Review (KGA responsibility)
- Component 4: Hydrogeologic Conceptual Model and Groundwater Conditions (KGA responsibility)
- Component 5: Groundwater Sustainability Plan Coordination (KGA responsibility)
- Component 6: GSP Development (KRGSA responsibility)

No funding was requested from DWR in Round 2 for the purpose of developing a DMS for the Subbasin, nor is funding being applied to such efforts. The DMS development project included in this proposal is a new and unique project and in no manner duplicative of work included under the six components included in the Round 2 Proposition 1 grant.

Historically, individual GSAs and their member agencies have developed separate systems to comply with various regulations; however, the GSAs in the Kern County Subbasin recognized the need to develop a centralized DMS on a Subbasin-wide basis to specifically conform to the needs of the GSAs and reporting entities to support the Subbasin GSPs. Accordingly, the Subbasin GSAs are cooperating on this proposal for a Subbasin-wide DMS to support monitoring, evaluation, reporting, management, and, importantly, GSP implementation. Compiling the individual DMSs into a coherent system will require significant manipulation and re-structuring to create a centralized relational DMS that is populated with consistent data sets across the Subbasin.

The work being undertaken with Round 2 grant funds, which involves development of GSPs for GSAs in the Subbasin in compliance with SGMA, is proceeding in accordance with DWR-mandated deadlines and will be completed on schedule. No cost overruns have been identified for Round 2 projects, and no additional funding will be required for completion of these projects. No Round 3 funding is intended to be allocated toward these projects.

The Kern County Subbasin Data Management System Project being proposed for Round 3 funding will allow the GSAs to comply with the requirements of SGMA Article 2 (§ 352.6), which requires each GSA to develop and maintain a DMS that is capable of storing and reporting information relevant to the development or implementation of a GSP and monitoring of the basin. Also required under SGMA is the development of a coordinated DMS for the Subbasin (Article 8, § 357.4). The project will assist the GSAs in meeting the requirements of SGMA annual reporting to DWR by April 1 of each year following adoption of its GSP (§ 356.2), as well as the reporting standards provided in Article 3 (§ 352.4) and reporting provisions found in Article 4 (§ 353.4).

B. Project Benefits

Covering about 2,834 square miles, Kern County Subbasin is the largest subbasin in California with a complex water management structure, a large portfolio of local and imported water sources, and numerous large groundwater banking projects, collectively providing both local and State-wide benefits for water supply. Accordingly, the GSAs are cooperating on this proposal for a Subbasin-wide DMS to support monitoring, evaluation, reporting, management, and, importantly, GSP implementation.

The project has two primary benefits that relate to the Subbasin, DACs within the Subbasin area, and all beneficial users of Subbasin groundwater: (1) development of a Subbasin-wide database that will allow consistent collection and comparison of data from multiple GSAs; and (2) improved watershed coordination among the GSAs.

- Database Development: The project will allow the Subbasin GSAs to identify and develop a DMS suitable for collection, storage, and analysis of the various types of data to be generated to support their GSPs. The project will allow the Subbasin GSAs to comply with the requirements of SGMA Article 2 (§352.6), which requires each GSA to develop and maintain a DMS that is capable of storing and reporting information relevant to the development or implementation of a GSP and monitoring of the basin. The proposed project will develop a common data system that all GSAs in the Subbasin can use, and this will enable better coordination across the various GSAs. The goal of the DMS is to support Subbasin GSAs by providing (1) improved coordination of groundwater monitoring and management actions and (2) the ability to meet the reporting and implementation requirements of groundwater sustainability plans (GSPs) and the California Department of Water Resources (DWR).
- Watershed Coordination: Located in the largest county and the southern end of the DWR Tulare Lake Hydrologic Region, the Kern County Subbasin involves numerous large and small watersheds of the Sierra Nevada, San Emigdio and Tehachapi mountains, and the

Coast Ranges. As demonstrated through the Integrated Regional Water Management Planning (IRWMP) Group process, Subbasin agencies associated with these contributing watersheds have coordinated on multiple projects over the years and have continued working together collaboratively during the GSP process. To comply with SGMA requirements SGMA for standardized reporting, and to coordinate on a Subbasin-wide basis for consistent data evaluation, it is crucial that a DMS be developed collaboratively for the entire Subbasin, allowing GSAs to combine and share data and information regarding local groundwater conditions using a consistent and comprehensive data platform.

The Kern County Subbasin Groundwater Sustainability Plan Support – Phase II 2019 Grant Application includes outreach, engagement, and support to benefit DACs throughout the entire Subbasin. During numerous community outreach meetings, DAC representatives have been engaged with questions and comments on Subbasin data.

The following DAC communities within the Kern County Subbasin are identified as cities or Census Designated Places (CDPs) in DWR's DAC database. All communities qualifying as DACs within the Kern County Subbasin will benefit as a result of the DMS project.

Arvin
Buttonwillow CDP
Delano
Edmundson Acres CDP
Ford City CDP
Fuller Acres CDP
Greenfield CDP
Lamont CDP
Lost Hills CDP
Maricopa
McFarland
McKittrick CDP
Mettler CDP
Mexican Colony CDP
Oildale CDP
Richgrove CDP
Shafter
Smith Corner CDP
South Taft CDP
Taft
Taft Heights CDP
Tupman CDP
Valley Acres CDP
Wasco
Weedpatch CDP

The project would include outreach to DAC staff that are required to report under SGMA. Accessibility of data has been a highly sensitive issue to many stakeholders in the Subbasin with concerns about transparency and privacy. Consistent communication and transparency of the DMS development process will be key to obtaining support from the Subbasin's beneficial users of groundwater. To support this budget category for Stakeholder Engagement, technical meetings will be held with the DAC staff that are required to report data to DWR, to obtain buy-in to the Subbasin DMS process.

As part of the IRWMP process, various groups were formed in the Kern County Subbasin as a means of developing a collaborative approach involving the governing group of water management districts, regional Stakeholders, and all other Interested Parties (e.g., landowners, public, local communities), all of which were working on regional water management planning and implementation activities.

DACs are directly represented in the IRWM groups through a DAC Representative, an elected member of the governing Regional Water Management Group who addresses the issues and needs of these areas. Moreover, the DACs are represented by a DAC "Work Group" consisting of individual participants from the following identified groups or communities: Ducor Community Services District, Buttonwillow County Water District, Bishop Acres Mutual Water Community, Semitropic School District, Pond Union School District, City of McFarland, City of Delano, City of Wasco, Lost Hills Utility District, Blackwells Corner, and Earlimart Public Utility District. The IRWM Group gives substantial consideration to the issues and needs of these DACs during all regional planning and implementation activities. The IRWM Group has worked closely with DACs for many years to identify DAC concerns and to promote potential solutions, either as standalone projects or programs or as a component of IRWM grant submissions.

Letters of support for the Kern County Subbasin Groundwater Sustainability Plan Support – Phase II 2019 Grant Application – including a joint letter signed by the agencies required to report under SGMA in the Subbasin – have been provided by several beneficial stakeholders and can be found in Attachment 6, Appendix C. As noted previously, outreach to DACs will continue to occur throughout development of the DMS. With grant funding, the DMS project will be better situated to conduct outreach to, engage, and include DACs and DAC concerns so that DACs will benefit from easier access to groundwater sustainability information.

C. Technical Expertise

The GSAs and participating agencies in the Kern County Subbasin have been working cooperatively for several years to develop GSPs that accurately depict the groundwater management conditions of the Subbasin. Accordingly, the Subbasin GSAs are familiar with the data types and sources in the Subbasin as well as the need to combine and share information. This process will ensure the accuracy of their respective GSPs within the larger Subbasin context and contribute to the success of management actions being proposed for implementation. This need for cooperative and consistent data collection, recordation, management, and use is the impetus for the Data Management System Development project being proposed for this grant.

Agencies involved in this project all involve talented engineers available to lead and assist with this proposed project. All of the agencies are familiar with groundwater data and have experience in groundwater monitoring and management. Thereby, agencies clearly contain the technical expertise to lead in the development of a Subbasin DMS. Many of the agencies also contain web-based technical expertise to provide oversight for potential development of web-based systems and/or complex database structures. GSAs have already demonstrated their collective technical expertise to lead and provide oversight for complex technical projects, including the development of a numerical integrated surface water–groundwater model for GSP applications. Data collection efforts for that model were successfully undertaken by agencies and their technical consultants. GSAs will employ rigorous *Request for Proposal/Qualifications* process to ensure that qualified and competent technical agents are retained for the complex DMS tasks.

KRGSA on behalf of the all the GSAs in the Kern County Subbasin was awarded $1,500,000 in Proposition 1 SGMA Planning Grant funds for a suite of six GSP Development project components supporting the entire Kern County Subbasin and proposed under the 2017 Round 2 SGMA grant opportunity. These six project components supported by the Proposition 1 planning grant have, and continue to, contribute to development of the all the GSPs in the Kern County Subbasin, which are currently undergoing public review and successfully nearing completion at the time of this writing. GSPs are on schedule to comply with the SGMA requirement that all GSPs for critically overdrafted basins be submitted to DWR by January 31, 2020. This success of the technical components of multiple GSPs, funded in part by a DWR grant, again demonstrates the ability of the GSAs to lead a large, complex technical project such as the DMS development, assisted again with DWR funding.

Letters of support for the Kern County Subbasin Groundwater Sustainability Plan Support – Phase II 2019 Grant Application have been provided by several beneficial stakeholders and can be found in Attachment 6, Appendix C.

Project Details

D. Scope of Work and Deliverables

a. Scope of Work

Subbasin Data Management System Development

Implementing Agency: KRGSA

Task (a): Grant Administration (funded under this grant)

This task includes managing and administering the project including invoicing, reporting, and grant contract administration.

1. **Grant Management**
   Coordinate with DWR and conduct administrative responsibilities to execute a Grant Agreement and ensure that all contract requirements are met.
2. **Invoicing**
   Prepare and submit to DWR invoices including back up documentation. Backup will be collected and organized by budget category, along with an Excel compatible summary document detailing the contents of the backup documentation.
3. **Report Preparation**
   Prepare and submit quarterly Progress Reports prepared in accordance with Exhibit F. Prepare and submit draft Grant Completion Report prepared in accordance with Exhibit F. Prepare a Final Grant Completion Report addressing the DWR Project Manager's comments and submit to DWR in accordance with the provisions of Exhibit F.

Deliverables:

- Executed Grant Agreement
- Invoices and associated backup documentation
- Quarterly Progress Reports
- Draft and Final Grant Completion Report

Task (b): Stakeholder Engagement / Outreach (funded under this grant)

Accessibility of data has been a highly sensitive issue to many stakeholders in the Subbasin with concerns about transparency and privacy. Consistent communication and transparency of the DMS development process will be key to obtaining support from the Subbasin's beneficial users of groundwater. To support this budget category for Stakeholder Engagement, technical meetings will be held with the DAC staff that are required to report data to DWR, to obtain buy-in to the Subbasin DMS process.

1. **Technical Meetings**
   Hold technical meetings with staff of DACs that are required to report data to DWR.

Deliverables:

- Meeting agenda with DAC staff
- Workshop presentation documentation

Task (c): GSP Development: Subbasin DMS Scoping and Development

1. **Retain Consultant to Assist with DMS Development** (funded under this grant)

This task includes (a) generating a Request for Proposals (RFP) seeking a qualified professional consulting firm that will assist with development, management, and coordination of the Data Management System (DMS), (b) issuing the RFP, and (c) contracting with the selected firm.

During RFP development, the GSAs will work together in a series of meetings to identify high-level goals and basin needs for ongoing data management. Considerations will include, but not be limited to, data coordination, transparency, sharing, and GSP-required components such as those needed to assist with the Subbasin water budget. Data tracking as required under SGMA will also be considered, including the need to track specific DWR-defined categories for water sources and sectors. In addition, DWR has not yet developed the online forms that may need to be completed for GSP annual reporting and may require specific data formatting in the DMS. Accordingly, the DMS will need to be sufficiently flexible to meet a variety of GSA needs.

The GSA group will discuss and identify a range of alternatives for various DMS levels of sophistication ranging from a relatively simply Subbasin-wide relational database to various web-based platforms with broader functionality and visualization tools. In addition, GSAs will reach out to GSAs in other subbasins to gain insight from "lessons learned" as others use existing DMS structures for SGMA purposes. In this manner, the GSAs will ensure that the RFP is written to target firms capable of providing the required technical services. The GSAs may prefer a phased approach, requiring different consulting services for each phase.

Deliverables:

- RFP
- Executed contract

2. **Identify Information Requirements for DMS** (funded under this grant)

This task involves coordination with all the GSAs in the Subbasin and their groundwater consulting firms, to identify the types and sources of data required to monitor GSP implementation, to evaluate groundwater conditions, and to document Subbasin progress toward sustainability. The DMS consultant will work collaboratively with GSAs, a technical DMS subcommittee, and/or a designated Subbasin consultant to develop a list of necessary data types, sources, and preferred formats (e.g., text, spreadsheet, graphical, and map-based formats) for each, which will be presented to all the GSAs in the Subbasin for input and approval.

Considerations will be given to data structures and formats being used for other monitoring programs in the Subbasin to provide efficiencies for agencies with multiple reporting obligations. The structure of State and local databases may also need to be considered if data will be downloaded periodically from existing sources. Some of this work will be accomplished in parallel with Task (c)(1) above to inform the needs of the RFP. Remaining work will be conducted in consultation with the DMS consultant to bring the required details of the DMS into focus.

Deliverables:

- List of data types and sources to be collected to meet ongoing requirements under SGMA

3. **Investigate and Select an Appropriate DMS** (funded under this grant;

The DMS Consultant (contractor) will investigate and compare commercially available DMS packages and custom systems to determine the most cost-effective and usable format for the DMS. The comparison will focus on DMS features determined to be of highest priority by the GSAs and will include items such as levels of security, data entry and uploading, QA/QC, spatial or graphical visualization, potential linkage to other systems, an appropriate user interface, and, importantly, ease of use. Costs of software, support/upgrades, copyright protections, or other

proprietary restrictions will be documented. The contractor will also consider the technical expertise of those users responsible for entering, uploading, and managing the system for the future. A flexible system that can be readily modified with additional modules or functions in the future may be desirable. Costs will be provided for both development and maintenance of the DMS.

The contractor will prepare a report identifying the commercially available packages and custom systems, detailing the advantages and disadvantages of each and offering a series of recommendations for GSA Boards' consideration.

Deliverables:

- Report with recommendation for GSA Boards' consideration
- GSA Boards' decision to select a DMS package

4. **Procure/Design and Customize the Selected DMS** (funded under this grant; additional funding to be provided by GSAs if needed)

   Following the GSA Boards' decision, the contractor will procure or design the selected DMS and customize as needed with an appropriate configuration that combines technical rigor, flexibility, ease of use, and expansion capabilities to store data in text, spreadsheet, graphical, and map-based formats, as needed. The system will be implemented according to the requirements identified in Task (c)(2).

   Deliverables:

   - Documentation of the Kern County Subbasin DMS

5. **Develop Data Protocols and Templates** (funded under this grant)

   The contractor will develop data templates that allow each GSA or participating agency to submit the required data in a consistent format that can be combined and adjusted to present information in both local and Subbasin-wide formats to meet DWR reporting requirements. Templates and tables will also be developed for DMS output and reporting. Importantly, protocols and a quality assurance/quality control (QA/QC) process will be developed and documented that considers data entry, uploading, downloading, and DMS accessibility. Protocols will also consider data protection and DMS security.

   Deliverables:

   - Data templates and tables

6. **Develop DMS User's Manual and Train GSA Staff** (funded under this grant)

   GSA staff will be trained in data collection, appropriate use of templates, and uploading procedures to ensure that all GSAs are providing consistent information to the DMS. In addition to the system documentation of the DMS system produced in Task (c)(4), the contractor will develop a functional user's manual that describes templates, outlines DMS protocols, and provides step-by-step procedures for a variety of users and uses.

   Deliverables:

   - Training session or module for GSA staff
   - User's Manual

7. **Review and Assessment of DMS** (funded by GSAs as needed)
   Monitoring and assessment activities will include initial review of the DMS by primary users (GSA staff and their groundwater consultants) to determine the suitability of templates for uploading

data and the suitability of the database for combining and using data. Numerous test runs of the new DMS will be conducted to work out system bugs and/or address functional issues. It is anticipated that one reporting period can be managed with the new DMS to provide a test case for future use. After grant completion, the DMS will be assessed on an ongoing basis for potential upgrades, additions or modifications to data, and other DMS adjustments to be funded by the GSAs.

Deliverables:

- Initial review and recommendations for modifications

Task (d): Monitoring / Assessment

This project is a planning effort and does not involve on-the-ground monitoring activities.

Deliverables:

- Initial review and recommendations for modifications

b. Project Deliverables

Deliverables to be provided as a result of implementing the proposed project will include the following items, presented by task:

Task (a): Grant Administration (funded under this grant)

Deliverables:

- Executed Grant Agreement
- Invoices and associated backup documentation
- Quarterly Progress Reports
- Draft and Final Grant Completion Report

Task (b): Stakeholder Engagement / Outreach (funded under this grant)

Deliverables:

- Technical meeting agenda with DAC staff that will be required to report data

Task (c): GSP Development: Subbasin DMS Scoping and Development

1. **Retain Consultant to Assist with DMS Development** (funded under this grant)

   Deliverables:

   - RFP
   - Executed contract

2. **Identify Information Requirements for DMS** (funded under this grant)

   Deliverables:

   - List of data types and sources to be collected to meet ongoing requirements under SGMA

3. **Investigate and Select an Appropriate DMS** (funded under this grant)

   Possible Deliverables to be provided under this grant:

   - Report with recommendation for GSA Boards' consideration

- GSA Boards' decision to select a DMS package

4. **Procure/Design and Customize the Selected DMS** (funded under this grant; additional funding to be provided by GSAs if needed)

   Deliverables:

   - Documentation of the DMS

5. **Develop Data Protocols and Templates** (funded under this grant)

   Deliverables:

   - Data templates and tables

6. **Develop DMS User's Manual and Train GSA Staff** (funded under this grant; additional funding to be provided by GSAs if needed)

   Deliverables:

   - Training session or module for GSA staff
   - User's Manual

7. **Review and Assessment of DMS** (funded by GSAs as part of GSP process)

   Deliverables:

   - Initial review and recommendations for modifications

Task (d): Monitoring / Assessment (funded by GSAs as part of GSP process)

This project is a planning effort and does not involve on-the-ground monitoring activities.

Environmental Compliance and Permitting

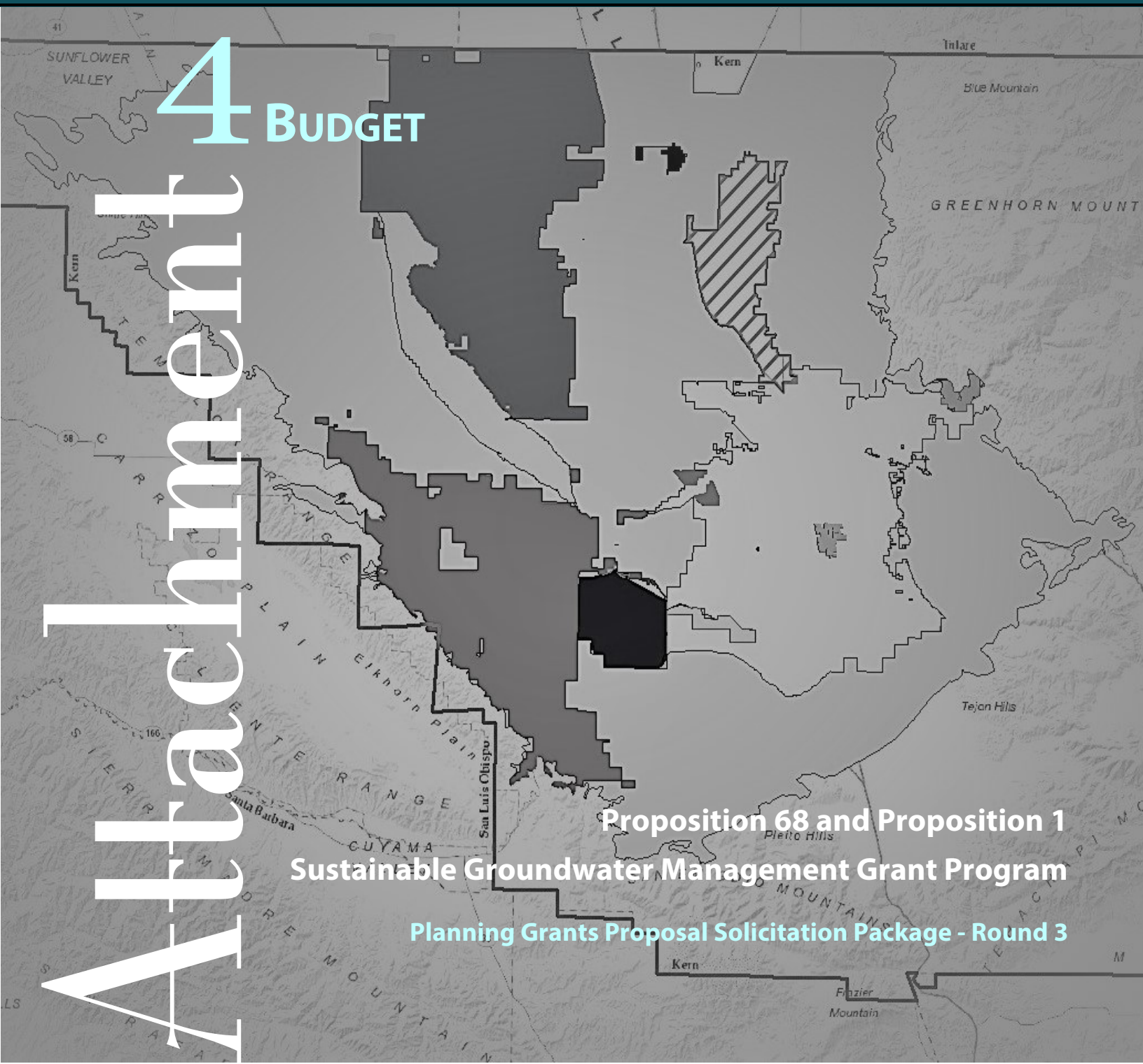
This Proposal covers the selection and development of a DMS for use by the entire Kern Subbasin to comply with SGMA. The Subbasin Data Management System Development Project does not qualify as a "Project" as defined under CEQA. Under CEQA, a "Project" refers to an action that has the potential to result in a physical change to the environment (Pub. Res. Code § 21065). This proposal consists of research, planning, and data collection and will not result in any foreseeable impact on or alteration of the physical landscape in any shape, matter, or form. Therefore, CEQA does not apply to this Proposal.

Miscellaneous

E. Project Support

A joint letter of support for the project, signed by the members of the entire Kern County Subbasin as well as participating DAC entities, is included in Attachment 6, Appendix C.

Kern County Subbasin Groundwater Sustainability Plan Support - Phase II 2019 Grant Application



Attachment 4 Budget

Proposition 68 and Proposition 1

Sustainable Groundwater Management Grant Program

Planning Grants Proposal Solicitation Package - Round 3

Grant Proposal Summary Budget Table 1
Proposal/Component Detailed Budget Table 2
Budget Description 3

Grant Proposal Summary Budget Table

Table 5A – Grant Proposal Summary Budget (No Components)

Grant Proposal Title: Kern County Subbasin Groundwater Sustainability Plan Support – Phase II

Applicant: Kern River Groundwater Sustainability Agency (KRGSA)

Grant Proposal serves a need of a DA?: X Yes ☐ No

Local Cost Share requested: ☐ 25% ☐ 15% ☐ 10% X 0%

Budget Categories[1]	(a) Requested Grant Amount	(b) Local Cost Share: Non-State Fund Source[2]	(c) Total Cost	(d) % Local Cost Share (Col (b)/ Col (c))
(a) Grant Agreement Administration	$25,000	$0	$25,000	0%
(b) Stakeholder Engagement / Outreach	$2,500	$0	$2,500	0%
(c) GSP Development – Subbasin DMS Scoping and Development	$472,500	$0	$472,500	0%
(d) Monitoring / Assessment	$0	$0	$0	$0
Grand Total *Sum rows (a) through (d) for each column*	**$500,000**	**$0**	**$500,000**	**0%**

[1] Only these Budget Categories shall be used. Tasks can be added for more detail.

[2] List sources of funding: *Assumes DAC waiver for local cost share*

Proposal/Component Detailed Budget Table

Table 6A – Proposal Detailed Budget (No Components)

Grant Proposal Title: Kern County Subbasin Groundwater Sustainability Plan Support - Phase II

Applicant: Kern River Groundwater Sustainability Agency (KRGSA)

Budget Categories[1]	(a) Requested Grant Amount	(b) Local Cost Share: Non-State Fund Source[2]	(c) Total Cost
(a) Grant Administration	**$25,000**	**$0**	***$25,000***
Task 1. Grant Management	$4,000	$0	
Task 2. Invoicing	$9,000	$0	
Task 3. Report Preparation	$12,000	$0	
(b) Stakeholder Engagement / Outreach	**$2,500**	**$0**	***$2,500***
Task 1. Technical Meetings	$2,500	$0	
(c) GSP Development: Subbasin DMS Scoping and Development	**$472,500**	**$0**	***$472,500***
Task 1. Retain Consultant to Assist with DMS Development	$2,500	$0	
Task 2. Identify Information Requirements for DMS	$2,500	$0	
Task 3. Investigate and Select an Appropriate DMS	$5,000	$0	
Task 4. Procure/Design and Customize the Selected DMS	$457,500	$0	
Task 5. Develop Data Protocols and Templates	$2,500	$0	
Task 6. Develop DMS User's Manual and Train GSA Staff	$2,500	$0	
Task 7. Review and Assessment of DMS	$0	$0	
(d) Monitoring / Assessment	**$0**	**$0**	
Grand Total *Sum rows (a) through (d) for each column*	***$500,000***	***$0***	***$500,000***

[1] Only these Budget Categories shall be used. Tasks can be added for more detail.

[2] List sources of funding: *Assumes DAC waiver for local cost share*

Budget Description

The Kern County Subbasin Groundwater Sustainability Plan Support – Phase II proposal includes one project, which will benefit the entire Kern County Subbasin. Since only one component (or project) is proposed, Grant Administration has been included with the budget for the project, and the required budget templates 5A and 6A, intended for proposals that do not include multiple components, have been completed and presented above.

This section summarizes costs included in each budget category and describes how the values included in Table 6A, Proposal Detailed Budget, for the Kern County Subbasin Groundwater Sustainability Plan Support – Phase II were developed.

Budget Category (a): Grant Administration

The Direct Project Administration provided by KRGSA on behalf of all the GSAs in the Kern County Subbasin will support this project and will also oversee the implementation of overall grant funding such as executing a grant agreement with DWR, conducting reporting and invoicing, and ensuring that grant requirements are met. These tasks ensure that the project will be completed, DWR receives Quarterly and Final Project Completion Reports, invoicing and record-keeping are current, and other grant administrative functions are completed.

The Grant Administration budget was developed in order to keep these administration costs to within 5% of the award amount and maximize the grant funding utilized for the Subbasin Data Management System Development project, which is the critical GSP planning need in the Subbasin at this time. The total Budget Category (a) costs are therefore estimated at $25,000 – 5% of the total grant amount of $500,000.

The total of $25,000 for this Budget Category (a) includes $4,000 for Grant Administration, $9,000 for Invoicing, and $12,000 for Report Preparation. The Administration budget is well within DWR's guidance to keep costs to within 10% of the Grant Request. The Grant Administration budget is considered reasonable as it does not exceed 5% of the overall project budget and is consistent with DWR's guidance. This cost estimate is considered standard and was developed based on KRGSA, KGA, and the other GSA experience managing IRWM and SGMA grants in recent years.

The Grant Administration work will include effort from KRGSA's legal and accounting functions, as well as project managers as well as the GSAs in the Kern subbasin who will coordinate with KRGSA, assuring the timely completion of reporting tasks detailed in the Work Plan. A consultant may be added to assist the project team. Grant Administration effort may exceed amounts included in this budget; additional effort and costs required to complete the Grant Administration task will constitute Other Cost Share.

It is anticipated that a full DA waiver for Local Cost Share will be received for this Proposal. In anticipation of the full waiver, no Local Cost Share has been included with the Proposal Budget. Please see Attachment 6 – SDAC, DAC, EDA for documentation and narrative describing Disadvantaged Areas within the Kern County Subbasin project area.

Budget Category (b): Stakeholder Engagement / Outreach

The total cost of Stakeholder Engagement / Outreach, Budget Category (b), is $2,500, included as Grant Request. This cost estimate was developed based on KRGSA, KGA, and other the GSA experience in conducting Stakeholder Engagement and Outreach work in recent years and through development of Groundwater Sustainability Plans for the Subbasin. These costs represent a minimal level of Stakeholder Engagement associated specifically with this proposed grant-funded project, in order that the bulk of available grant funding can be allocated to implementation of the Subbasin Data Management System Development project, which is the critical GSP planning need in the Subbasin at this time.

If the actual level of effort needs to exceed amounts included in this budget to achieve project objectives, the additional costs required to complete the task will be paid by the GSAs.

It is anticipated that a full DA waiver for Local Cost Share will be received for this Proposal. In anticipation of the full waiver, no Local Cost Share has been included with the Proposal Budget. Please see Attachment 6 – SDAC, DAC, EDA for documentation and narrative describing Disadvantaged Areas within the Kern County Subbasin project area.

Budget Category (c): GSP Development: Subbasin DMS Scoping and Development

The total cost of GSP Development: Subbasin DMS Scoping and Development, Budget Category (c), is $472,500, included as Grant Request. This total Budget Category (c) cost of $472,500 constitutes the bulk of requested grant funding, in order to launch the scoping and development of the Subbasin's critical GSP planning effort, to develop a DMS for the Subbasin. This $472,500 Category (c) grant request is spread the anticipated seven tasks that will result in a fully functioning DMS. $2,500 is budgeted for Task 1, which includes developing a Request for Proposals and ultimately contracting with a Data Management System professional consultant to lead the DMS development process. Task 2 is budgeted at $2,500 and includes identification of the information requirements for the DMS. Allocated for Task 3, to investigate and ultimately select an appropriate DMS for the Subbasin is $5,000. Task 4 constitutes the bulk of the grant request in the amount of $457,500. Task 4, Procure, Design, and Customize the Selected DMS, is the focus of the Kern County Subbasin to accomplish the coordination of monitoring, management, and annual reporting going forward. Tasks 5 and 6 are supportive tasks to complete the development of a basin-wide coordinated DMS. Each of these tasks is allocated $2,500. Task 7, Review and Assessment of DMS, would be funded by the GSAs as part of their ongoing GSP process.

Budget Category (d): Monitoring / Assessment

This project is a planning effort and does not involve on-the-ground monitoring activities.

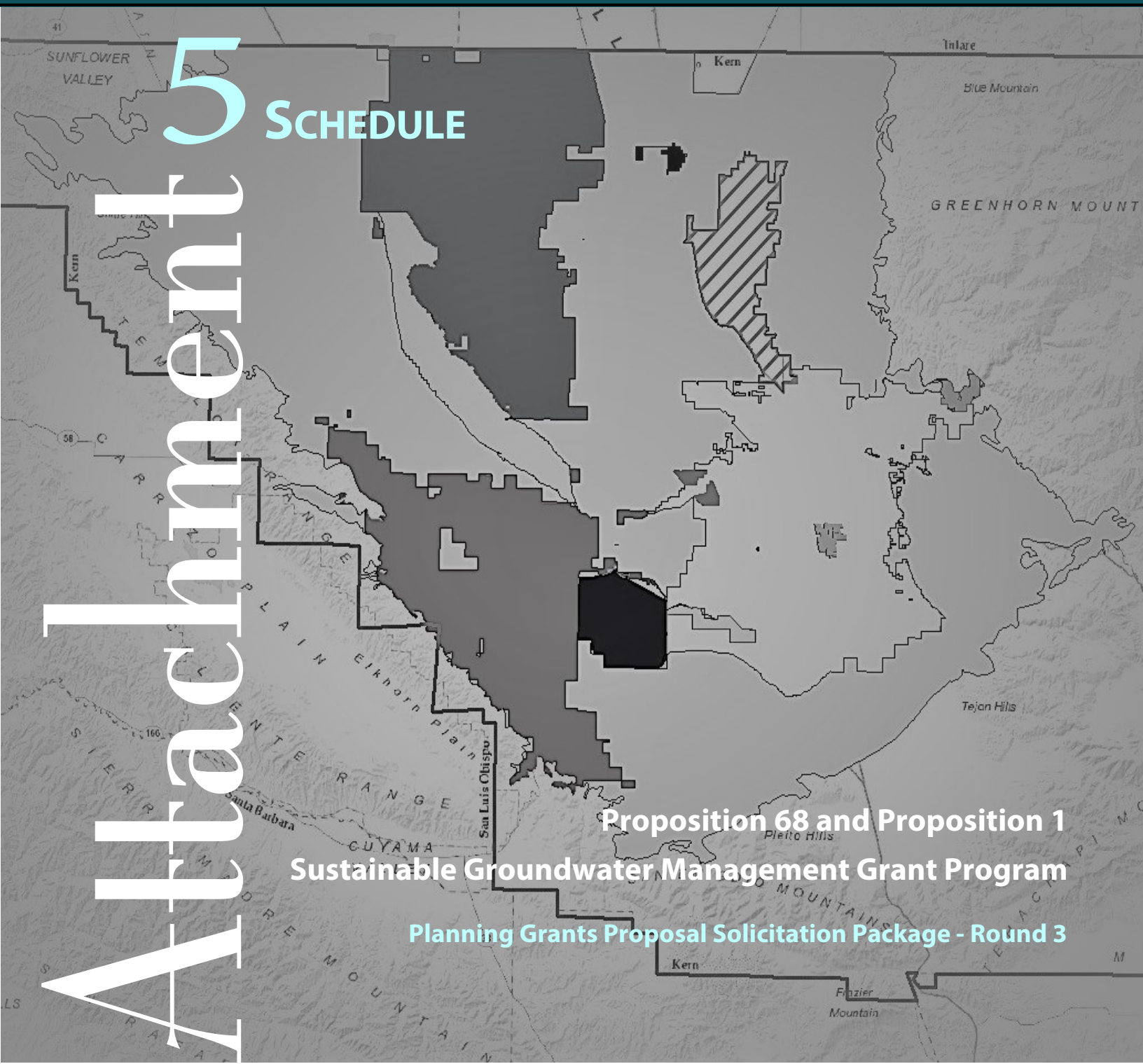
As described in Attachment 3, Work Plan, the intent is to make as much progress as possible toward development of a fully functioning DMS. The GSAs have committed to continue ongoing collaborative efforts towards accomplishing Subbasin-wide tasks to support GSP planning and implementation. The GSAs will support each task in the workplan as needed with the necessary level of effort to meet the project goals.

This cost estimate was developed based on KRGSA, KGA, and other GSA experience in contracting with professional consultants in recent years and through development of Groundwater Sustainability Plans for the Subbasin, as well as with input from consultants and industry professionals knowledgeable about DMS development and the data collection needs of the Subbasin's GSAs.

As described in Attachment 3, Work Plan, it is anticipated that the cost to fully develop an operational DMS for the Subbasin will far exceed grant funding available under this Round 3 Planning Grant opportunity. Additional resources beyond the funding available through this grant will be provided by Subbasin GSAs as necessary to complete the project and achieve a workable DMS that meets Subbasin needs. The Subbasin GSAs will coordinate to fund any additional project costs and have a demonstrated track record of doing so on many other GSP-related projects.

It is anticipated that a full DA waiver for Local Cost Share will be received for this Proposal. In anticipation of the full waiver, no Local Cost Share has been included with the Proposal Budget. Please see Attachment 6 – SDAC, DAC, EDA for documentation and narrative describing Disadvantaged Areas within the Kern County Subbasin project area.

Kern County Subbasin Groundwater Sustainability Plan Support - Phase II 2019 Grant Application



Schedule 1
Schedule Description 2
Environmental Compliance and Permitting 2

Tables

Table 7A. Grant Proposal Schedule (No Components) 2

Figures

None

Appendices

None

Schedule

Table 7A – Grant Proposal Schedule (No Components)

Grant Proposal Title: Kern County Subbasin Groundwater Sustainability Plan Support – Phase II

Applicant: Kern River Groundwater Sustainability Agency (KRGSA)

Categories	Start Date *(Earliest Start Date)*	End Date *(Latest End Date)*
(a) Grant Administration	**3/1/2020**	**7/31/2022**
Task 1. Grant Management	3/1/2020	7/31/2022
Task 2. Invoicing	6/1/2020	7/31/2022
Task 3. Report Preparation	6/1/2020	7/31/2022
(b) Stakeholder Engagement / Outreach	**4/1/2020**	**4/30/2022**
Task 1. Technical Meetings	4/1/2020	4/30/2022
(c) GSP Development: Subbasin DMS Scoping and Development	**2/1/2020**	**4/30/2022**
Task 1. Retain Consultant to Assist with DMS Development	2/1/2020	6/30/2020
Task 2. Identify Information Requirements for DMS	2/1/2020	9/30/2020
Task 3. Investigate and Select an Appropriate DMS	6/30/2020	4/30/2021
Task 4. Procure/Design and Customize the Selected DMS	5/1/2021	4/30/2022
Task 5. Develop Data Protocols and Templates	5/1/2020	4/30/2022
Task 6. Develop DMS User's Manual and Train GSA Staff	10/1/2021	4/30/2022
Task 7. Review and Assessment of DMS	7/1/2021	4/3/2022
(d) Monitoring / Assessment	N/A	N/A

Schedule Description

The Kern County Subbasin Groundwater Sustainability Plan Support – Phase II proposal includes one project, which provides benefits for the entire Kern County Subbasin. Since there are no additional components included with this proposal, Grant Administration has been included with the Work Plan, Budget, and Schedule for the single project, and the required Schedule Table 7A, intended for proposals that do not include multiple components, has been completed and presented above.

This section summarizes the schedule established (and presented in Table 7A) for the Kern County Subbasin Groundwater Sustainability Plan Support – Phase II proposal.

The tasks listed in the schedules align with the same tasks identified and described in the Work Plan (Attachment 3) and Budget (Attachment 4), and use March 2020 as the assumed award date of the grant and launch of Grant Administration. Project implementation will likely begin prior to notification of award, potentially by February 2020.

All project implementation work will be complete by the end of April 2022. The schedule for Grant Administration extends through July 2022 when all final reports and invoicing will be complete for the grant.

The anticipated order of activities for completion of the project is as follows:

- Category (c), GSP Development: Subbasin DMS Scoping and Development, will begin immediately upon grant award with the process of hiring a DMS consultant (Task 1). The selected consultant will assist the GSAs with identifying information requirements for the DMS (Task 2). Task 2 begins concurrently with Task 1 to allow the identification of requirements to inform the RFP process in Task 1; the task continues to allow communication and consultation with the DMS Consultant on system requirements. After working collaboratively with the GSAs in Task 2, the DMS consultant will then investigate and recommend appropriate DMS options for selection by the GSAs' Boards (Task 3). KRGSA and KGA, on behalf of all the Subbasin GSAs, will procure the selected DMS and the consultant will customize it as needed (Task 4). This process is expected to continue through April 2022 with ongoing adjustments and customization. Task 4 is expected to be partially funded by the GSAs when grant funds are expended for this task. Concurrently with this process, the consultant and GSAs will develop protocols and data templates (Task 5), and will train GSA staff to use and populate the DMS following completion of these tasks (Task 6). Task 7 commences in 2021 when the DMS development is underway and continues throughout the grant period, allowing additional modifications to the DMS as the project is implemented.
- Category (b), Stakeholder Engagement/Outreach, will involve coordination of technical meetings with stakeholders and DACs throughout the process of DMS scoping and development.
- Category (a), Grant Administration, will involve management of the grant, invoicing, and report preparation before, during, and after completion of the grant activities.
- Category (d), Monitoring / Assessment, does not apply to this project as it is a planning effort and does not involve on-the-ground monitoring activities.

Environmental Compliance and Permitting

The Kern County Subbasin Groundwater Sustainability Plan Support – Phase II proposal includes one project, which will benefit the entire Kern County Subbasin. This project, Subbasin Data Management System Development, is effectively a planning effort; no construction will take place under this project.

This grant proposal covers the preparation of Groundwater Sustainability Plans (GSPs) within the Kern County Subbasin. Under Water Code § 10728.6, CEQA does not apply to the preparation and adoption of Groundwater Sustainability Plans. Therefore, this Proposal is exempt from California Environmental Quality Act (CEQA) requirements.

The proposed Subbasin Data Management System Development project will initiate the key steps to develop and build a Subbasin DMS, which will ultimately support Subbasin GSAs by providing (1) improved coordination of groundwater monitoring and management actions and (2) the ability to meet the reporting and implementation

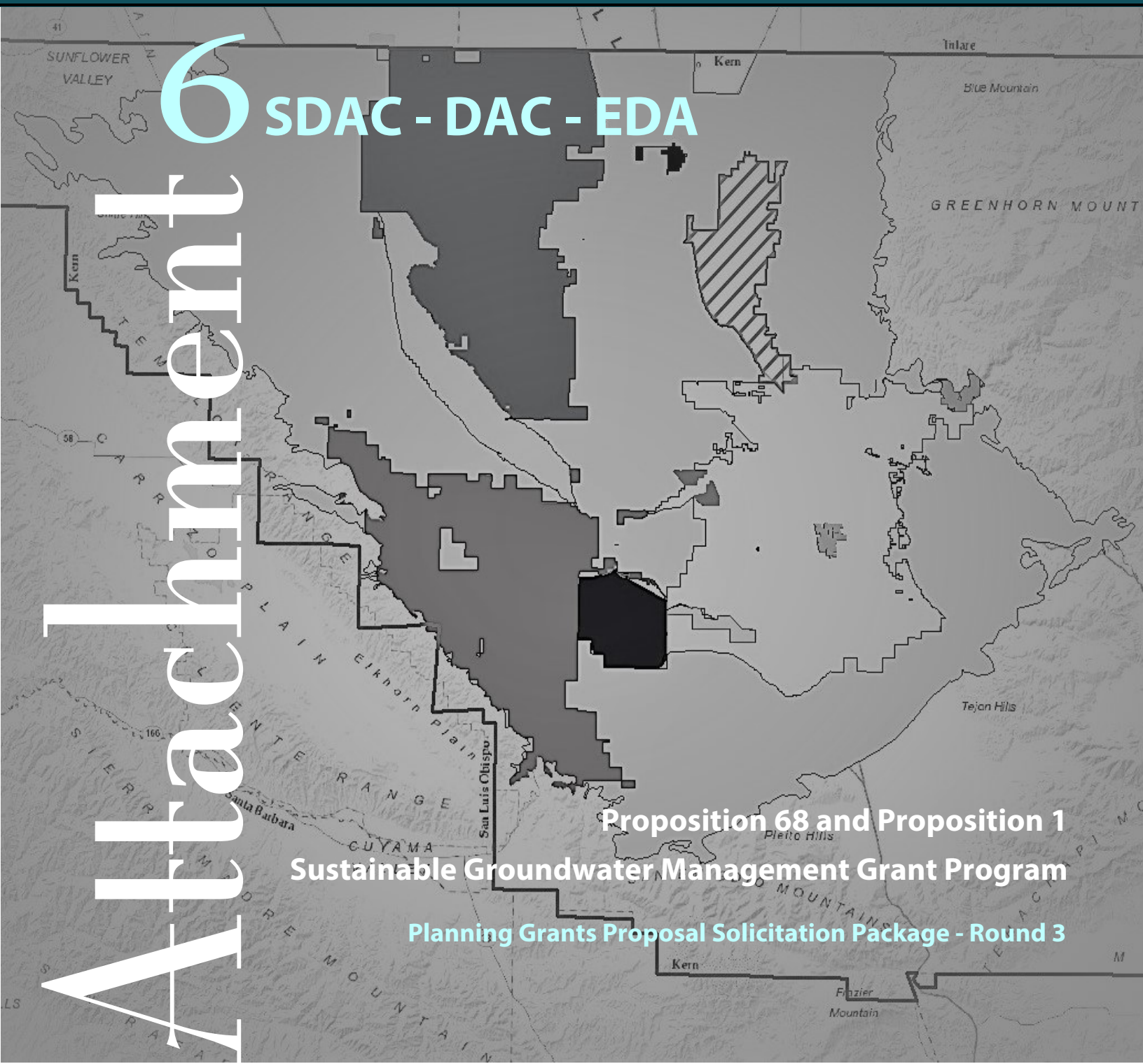
requirements of their respective GSPs and DWR. The development of a DMS does not meet the definition of a "Project" under CEQA, as it will not create any foreseeable impact on or alter the physical landscape in any shape, manner, or form. Under CEQA, a "Project" refers to an action that has the potential to result in a physical change to the environment (Pub. Res. Code § 21065). Therefore, CEQA does not apply to this project.

Development of a Subbasin Data Management System will not require any permits or regulatory agency approvals. Therefore, a process and schedule for securing permits and approvals is not necessary, and has not been included in this Proposal.

Kern County Subbasin Groundwater Sustainability Plan Support - Phase II 2019 Grant Application

Attachment 6

SDAC - DAC - EDA



Proposition 68 and Proposition 1

Sustainable Groundwater Management Grant Program

Planning Grants Proposal Solicitation Package - Round 3

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Location of DACs within the Proposal Area 1
DAC Support and Outreach 3

Figures

Figure 6-1. Disadvantaged Communities in the Kern County Subbasin 2

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Introduction

According to Water Code § 79505.5, a disadvantaged community (DAC) is "a community with an annual median household income that is less than 80 percent of the Statewide annual median household income." These communities, widely dispersed throughout California and the Kern County Subbasin, are especially sensitive to groundwater overdraft and decreases in local water quality such as that in the Kern County Subbasin.

Attachment 6 – SDAC-DAC-EDA addresses the existence of DAC areas located within the Kern County Subbasin, and includes a map showing the Proposal benefit area and the location of DACs.

Location of DACs within the Proposal Area

The Kern County Subbasin (Proposal benefit area) is located in the Southern San Joaquin Valley, is a critically overdrafted, high priority groundwater basin and is home to numerous DAC Communities. The GSAs in the Kern County Subbasin identified DACs throughout the Subbasin by using the DWR's DAC Mapping Tool and ArcGIS Map Package. Geographically, the Kern County Subbasin is comprised of 79.5 percent Disadvantaged Communities.

The GSAs in the Subbasin have accurately discerned and mapped where DAC communities exist within the Subbasin. Figure 6-1, below, illustrates the Proposal benefit area and the location of DACs within the Kern County Subbasin.

The DAC Mapping tool and ArcGIS Map Package provide US Census data identifying DACs by "Block Groups", "Tracts", and "Places." The specific dataset used in the tool is the *US Census American Community Survey (ACS) 5-Year Data: 2012 – 2016* (with an MHI of $63,783 and hence calculated DAC threshold of $51,026).

According to the US Census Bureau:

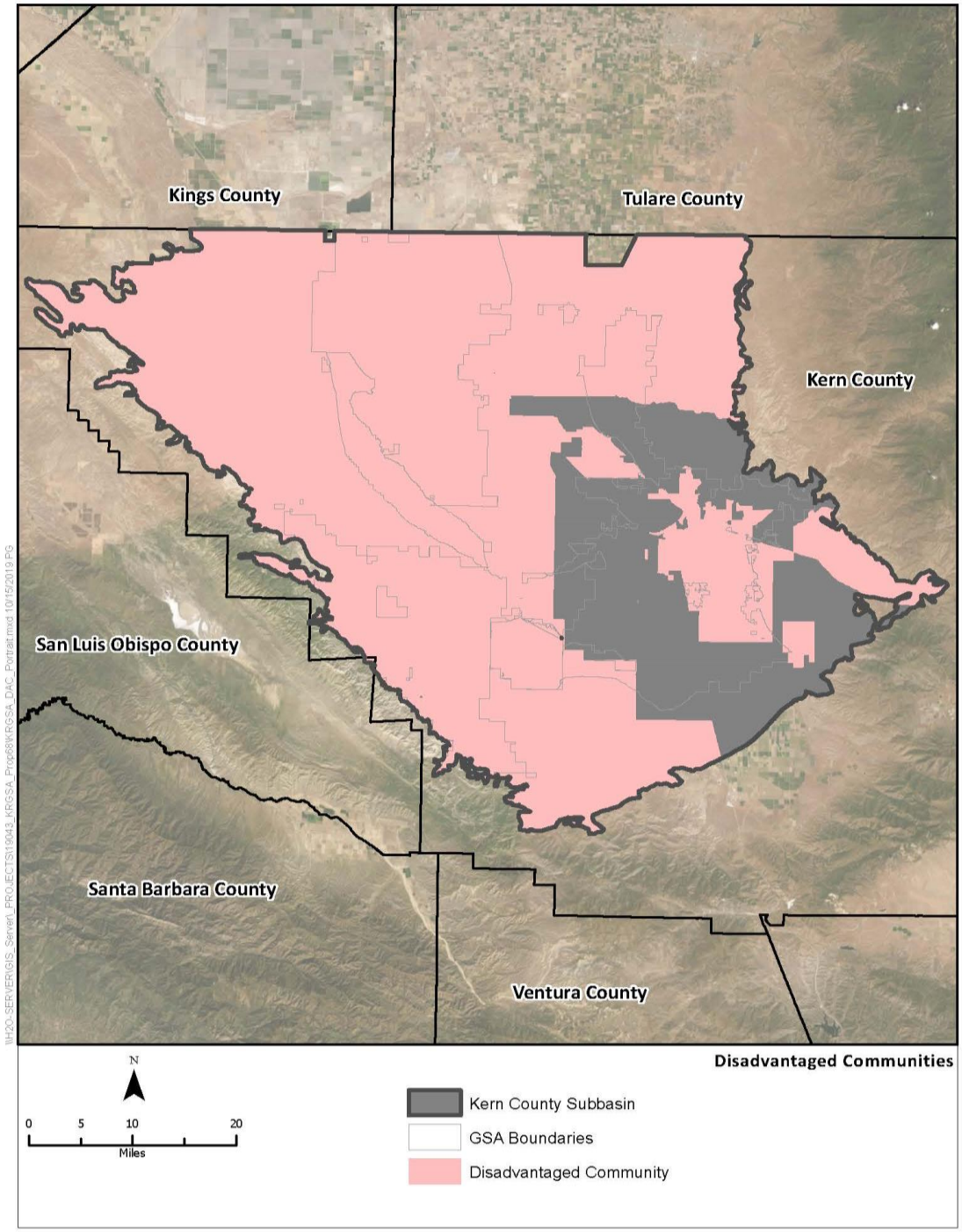
- Block Groups are statistical divisions of census tracts, generally defined to contain between 600 and 3,000 people.
- Census Tracts are small, relatively permanent statistical subdivisions of a county or equivalent entity. Census tracts generally have a population size between 1,200 and 8,000 people, with an optimum size of 4,000 people.
- Places can be defined as either incorporated or designated. Incorporated Places usually consist of a city, town, village, or borough, but can have other legal descriptions or boundaries. Designated Places usually coincide with visible features or the boundary of an adjacent incorporated place or another legal entity boundary, have no legal status, nor do these places have officials elected to serve traditional municipal functions.

For more information on the DAC Mapping Tool or ArcGIS Mapping Package, please visit: http://www.water.ca.gov/irwm/grants/resources_dac.cfm.

All communities qualifying as Disadvantaged Communities within the Kern County Subbasin (block groups, census tracts, and places) will benefit as a result of the Subbasin Data Management System Development project included in this Kern County Subbasin Groundwater Sustainability Plan Support – Phase II Proposal.

Figure 6-1 shows the location and extent of all Disadvantaged Communities within the Kern County Subbasin. These Disadvantaged Areas make up 79.5 percent of the Subbasin and Project area. All communities qualifying as DACs within the Kern County Subbasin will benefit as a result of the proposed project.

Figure 6-1. Disadvantaged Communities in the Kern County Subbasin



DAC Support and Outreach

The Kern County Subbasin Groundwater Sustainability Plan Support – Phase II grant application includes outreach, engagement, and technical support to benefit DACs throughout the entire Subbasin. All the GSAs in the Subbasin conduct regular Board meetings on a monthly basis to support development of their respective GSPs. All the GSAs in the Subbasin have undertaken coordination activities with the DACs in the Subbasin. Several of the DACs are represented by board members on the GSAs in the Subbasin.

The following DAC communities within the Kern County Subbasin are identified as cities or Census Designated Places (CDPs) in DWR's DAC database. All communities qualifying as DACs within the Kern County Subbasin will benefit as a result of the DMS project.

Arvin
Buttonwillow CDP
Delano
Edmundson Acres CDP
Ford City CDP
Fuller Acres CDP
Greenfield CDP
Lamont CDP
Lost Hills CDP
Maricopa
McFarland
McKittrick CDP
Mettler CDP
Mexican Colony CDP
Oildale CDP
Richgrove CDP
Shafter
Smith Corner CDP
South Taft CDP
Taft
Taft Heights CDP
Tupman CDP
Valley Acres CDP
Wasco
Weedpatch CDP

As part of the DMS project, the GSAs in the Subbasin would conduct outreach to all the DACs that will be required to report to DWR under SGMA. GSA staff would work with local DACs within their boundaries, relying on the existing relationships they have established and maintained during the GSP development process.

A joint letter of support for the Kern County Subbasin Groundwater Sustainability Plan Support – Phase II 2019 Grant Application endorsed by the GSAs and stakeholders that would benefit from the project is provided in Appendix C. As noted previously, outreach to DACs will continue to occur throughout development of the DMS. With grant funding, the DMS project will be better situated to conduct outreach to, engage, and include DACs and DAC concerns so that DACs will benefit from easier access to groundwater sustainability information.

Appendix C

Joint Letter of Support

HENRY MILLER WATER DISTRICT

TEJON-CASTAC WATER DISTRICT

Olcese Water District

November 15, 2019

Mr. Zaffar Eusuff, Program Manager
Financial Assistance Branch
California Department of Water Resources
PO Box 942836
Sacramento, CA 94326-0001

Ms. Kelley List, Project Manager
Sustainable Groundwater Management
Program, Round 3 Planning Grant
California Department of Water Resources
901 P Street
Sacramento, CA 94236

Subject: Letter of Support for Kern River Groundwater Sustainability Agency Leading the Kern County Subbasin Proposition 1 Round 3/Proposition 68 Planning Grant Application

Dear Mr. Eusuff and Ms. List:

The undersigned groups are submitting this letter in support of the Sustainable Groundwater Management – Proposition 1 Round 3/Proposition 68 Planning Grant Application submitted by the Kern River Groundwater Sustainability Agency (KRGSA), in coordination with the all the GSAs in the Kern County Subbasin. The demographics of the Subbasin service area establish it as a geographic area of largely disadvantaged communities in need of assistance and support. As representatives and water providers of Disadvantaged Communities (DACs) in the Kern County Subbasin, we jointly support this effort to achieve sustainable groundwater planning in the Kern County Subbasin.

Since the enactment of the Sustainable Groundwater Management Act (SGMA), the Kern County Subbasin GSAs have worked together to achieve sustainable groundwater management. Through a collaborative process involving more than a dozen member agencies and landowner representatives,

GSAs in the Kern County Subbasin have coordinated on numerous GSP activities, including the following milestones:

- Produced a Subbasin-wide Sustainability Goal for achieving and maintaining sustainable groundwater management;
- Developed Sustainable Management Criteria to apply to the entire Subbasin, while allowing flexibility for local GSA control;
- Coordinated on a Subbasin-wide monitoring network and agreed on monitoring protocols for coordinated monitoring and groundwater evaluations;
- Shared costs and tasks for the development of a Subbasin-wide integrated surface water–groundwater model to analyze Subbasin water budgets and to support an evaluation of projects and management actions;
- Held two widely attended SGMA Open Houses to allow stakeholders to discuss the GSP process and requirements directly with GSA managers;
- Hosted numerous community, Board, public outreach, and stakeholder meetings, including many that were focused on the disadvantaged communities in the Subbasin; and
- Organized numerous committees to guide policy decisions, coordinate communication and outreach activities, and provide a forum for GSA managers to discuss and coordinate GSP elements.

While individual GSAs and their member agencies have developed separate Groundwater Sustainability Plans (GSPs) to comply with the SGMA regulations, the Kern GSAs recognized the need to develop a centralized, Subbasin-wide data management system (DMS) to support monitoring, evaluation, reporting, management, and, importantly, GSP implementation. We recognize that compilation of our individual systems will require significant manipulation and re-structuring to create a centralized relational DMS that is populated with consistent data sets across the Subbasin. For this reason, the GSAs of the Kern County Subbasin have agreed to coordinate to submit a Proposition 1 Round 3/Proposition 68 Planning Grant Application to take the first key steps in this process. Participating in the DWR grant funding program through continued Subbasin-wide Groundwater Sustainability Planning efforts is a good and essential step forward for DAC communities in the Kern County Subbasin.

We are pleased and supportive to see the inclusion and participation of Disadvantaged Communities and related stakeholders in the Kern County Subbasin's Groundwater Sustainability Planning efforts, and we believe that funding from this Grant Application will contribute to basin-wide groundwater planning efforts and benefit our community members. By funding the KRGSA's grant application in the full allotment of $500,000, DWR will ensure that all that disadvantaged communities in the Kern County Subbasin will benefit from improved groundwater management and sustainability. The grant funds will be instrumental to the DACs in the Kern County Subbasin by providing the mechanism for meeting their reporting requirements under SGMA and also providing the ability to review each other's data in the Subbasin.

We hope that DWR will fully fund the Kern County Subbasin Round 3 Planning Grant Application, and we look forward to seeing the benefits of this program within all of our service areas in the near future.

Sincerely,

Art Chianello
Water Resources Manager
City of Bakersfield

David Beard
Manager
Improvement District No. 4
Kern County Water Agency

Holly Melton
Water Resources Manager
Kern County Water Agency

L. Mark Mulkay
General Manager
Kern Delta Water District

Phil Nixon
General Manager
Westside District Water Authority

Jeof Wyrick
President
Henry Miller Water District

Dennis Atkinson
President of the Board
Tejon-Castac Water District

James L. Nickel
President
Olcese Water District

Jason Gianquinto
General Manager
Semitropic Water Storage District

Richard A. Diamond
General Manager
North Kern Water Storage District

Jonathan Parker
General Manager
Kern Water Bank Authority

Raul Barraza, Jr.
General Manager
Arvin Community Service District

Chad Hathaway
Board President
Eastside Water Management Area

Steven C. Dalke
General Manager
Kern-Tulare Water District

David Ansolabehere
General Manager
Cawelo Water District

Sheridan Nicholas, P.E.
Engineer-Manager
Wheeler Ridge-Maricopa Water Storage District

Tim Ashlock
Manager
Buena Vista GSA

Dana Munn
General Manager
Shafter-Wasco Irrigation District

Eric Averett
General Manager
Rosedale-Rio Bravo Water Storage District

Jeevan Muhar, P.E.
Engineer-Manager
Arvin-Edison Water Storage District

Greg A. Hammett
General Manager
West Kern Water District

KERN
GROUNDWATER AUTHORITY

November 20, 2019

To: **Kern River GSA**
Buena Vista WSD GSA
Henry Miller WD GSA
Olcese WD GSA

Re: Reimbursement Agreement for Annual Reporting of the Kern Sub-basin

The Kern Groundwater Authority (KGA), the Kern River Groundwater Sustainability Agency (KRGSA), the Buena Vista WSD Groundwater Sustainability Agency (BVGSA), the Henry Miller WD Groundwater Sustainability Agency (HMGSA), and the Olcese WD Groundwater Sustainability Agency (OGSA) wish to participate in the Reimbursement agreement for the Kern County Subbasin – 2020 Annual Reporting Requirement under SGMA.

On behalf of the Subbasin, the KGA has approved a contract with TODD Groundwater (Attachment 1) which includes a scope of work with the following tasks:
1) Prepare Data Requests and Templates ($10,554)
2) Prepare Groundwater Elevation Contour Maps ($26,749)
3) Review and Compile Hydrographs ($9,458)
4) Compile and Present Water Supply Data ($19,373)
5) Analyze Change in Groundwater in Storage ($32,518)
6) Document Progress in GSP Implementation ($10,639)
7) Prepare Drafts/Final Annual Report and Submit to DWR ($32,322)
8) Communication and Meetings ($33,216)
for a total amount of the contract of $174,830.

Also, on behalf of the Subbasin, the KGA has approved a contract with ITRC (Attachment 2) which includes a scope of work with the following tasks:
1) Provide monthly and annual ITRC-METRIC actual crop evapotranspiration (ETc) for the Kern Subbasin for 2017-2019.
2) Data will be extracted for each GSA within the subbasin and each irrigated field in each GSA monthly for 2017-2019
3) Data will be provided tabularly and monthly ETc images will be provided in GIS format
4) Short report discussing the general process and overall results will be provided
for a total amount of the contact of $16,000

All parties agree to cost share this effort according to following terms and conditions:

1. The participant signatories below will pay their share of the proposed budget of $190,830 as shown on Exhibit 1.
2. All payments from shall be due 45 days after the receipt of invoice from the KGA

If the above terms and conditions are acceptable, please sign and date this letter and return them to the KGA.

Sincerely,

KGA
Vice Chair

Accepted:

Kern River GSA

By:_____

Title:_____

Date:_____

Buena Vista WSD GSA

By:_____

Title:_____

Date:_____

Henry Miller WD GSA

By:_____

Title:_____

Date:_____

Olcese WD GSA

By:_____

Title:_____

Date:_____

Sincerely,

KGA
Vice Chair

Accepted:

Kern River GSA

By:

Title:

Date: 12/5/19

Buena Vista WSD GSA

By:

Title:

Date:

Henry Miller WD GSA

By:

Title:

Date:

Olcese WD GSA

By:

Title:

Date:

Sincerely,

KGA
Vice Chair

Accepted:

Kern River GSA

By: _____

Title: _____

Date: _____

Buena Vista WSD GSA

By: _____

Title: Engineer - Manager

Date: 1-8-2020

Henry Miller WD GSA

By: _____

Title: _____

Date: _____

Olcese WD GSA

By: _____

Title: _____

Date: _____

Sincerely,

KGA
Vice Chair

Accepted:

Kern River GSA

By: _____

Title: _____

Date: _____

Buena Vista WSD GSA

By: _____

Title: _____

Date: _____

Henry Miller WD GSA

By: Jeff Wyrick

Title: PRESIDENT

Date: 11-19-19

Olcese WD GSA

By: _____

Title: _____

Date: _____

Sincerely,

KGA
Vice Chair

Accepted:

Kern River GSA

By: _____

Title: _____

Date: _____

Buena Vista WSD GSA

By: _____

Title: _____

Date: _____

Henry Miller WD GSA

By: _____

Title: _____

Date: _____

Olcese WD GSA

By: _____

Title: James L. Nickel, President

Date: Dec 17, 2019

ATTACHMENT 1

TODD GROUNDWATER

November 19, 2019

MEMORANDUM

To: Kern Groundwater Authority (KGA)
Patty Poire, Kern County Subbasin GSP Plan Manager

Cc: Kern River Groundwater Sustainability Agency (KRGSA)
Art Chianello, David Beard, and Mark Mulkay, KRGSA Plan Managers

From: Phyllis Stanin, Vice President

Re: Proposal – Preparation of GSP Annual Report for WY 2019
Kern County Subbasin Groundwater Sustainability Plans (GSP)

The Kern Groundwater Authority (KGA) is leading Subbasin-wide coordination efforts for development of Groundwater Sustainability Plans (GSP) including annual reporting on GSP implementation. Subbasin GSAs are cooperating in preparation of this first GSP Annual Report covering Water Year (WY) 2019 for the Kern County Subbasin. Todd Groundwater has been asked to prepare a proposal to prepare and submit the 2019 Annual Report.

The Kern County Subbasin is required to submit adopted GSPs covering the entire Subbasin to the Department of Water Resources (DWR) by January 31, 2020. Annual Reports are due to DWR "by April 1 of each year following the adoption of the Plan." (§356.2). Accordingly, the 2019 Annual Report is due to DWR by April 1, 2020, only two months after submittal of the GSPs.

1 APPROACH

Collectively, the extensive analyses and hydrogeologic products available in Subbasin GSPs provide a firm foundation for the 2019 Annual Report. Monitoring sites have already been identified, data are being collected, and water budget results are readily available from the historical and current study periods. We envision working cooperatively with Subbasin agencies and their consultants to compile and incorporate information that either is currently available or is being collected as part of GSP implementation.

Preparation of the 2019 Annual Report will follow regulatory guidance. Regulatory requirements for the GSP Annual Reports are provided in Article 7 of the GSP regulations (§ 356). Reporting standards for Annual Report data are provided in Article 3 (§352.4) and reporting provisions can be found in Article 4 (§353.4).

This first Annual Report will require extra analysis of the Subbasin water budget to "bridge" the time period between the end of the Subbasin current Study Period (WY 2015) and the reporting period of WY 2019. Although GSP Annual Reports are designed to describe conditions from the preceding water year only (i.e., WY 2019), regulations also require water budget results (i.e., change in groundwater in storage) to use "historical data to the greatest extent available, including from January 1, 2015 to the current reporting year." (§356.2 (b)(1)(B) and §356.2 (b)(5)(B)). The bridge analysis, combined with the GSP current Study Period, will cover the requirement of "January 1, 2015 to the current reporting year." GSP analyses from the Subbasin-wide historical and current Study Periods –covering WY 1995 through WY 2015 – can be used to satisfy the requirement of "historical data to the greatest extent available."

Regulations only appear to require historical data for hydrographs and change in groundwater in storage. Additional data, including reporting of groundwater extractions, surface water, and total water use by sectors, appear to only refer to the preceding year and not the "bridge" period.

It is anticipated that we will require clarification and interaction with DWR on several issues for the 2019 Annual Report. We recommend working directly with the Subbasin Plan Manager (Patty Poire) on any communications with DWR to ensure that the 2019 Annual Report will comply with regulations. In coordination with the Plan Manager, we will confirm with DWR the specific time period for which these other data sets must cover, seek DWR acceptance of recommended methods to incorporate into the 2019 Annual Report, and work with agencies to comply with DWR requirements.

In our role as the Watermaster Engineer for the Antelope Valley Watermaster, we have been submitting SGMA-compliant annual reports to DWR for several years. Although requirements for adjudicated basins are significantly different from critically over-drafted basins, many of the requested data sets and attachments are the same. This provides us with some insight as to how GSP annual reporting might be managed by DWR; some of these insights are incorporated into this scope of services, as relevant.

2 SCOPE OF SERVICES

In order for Subbasin agencies to begin planning for the required components of the 2019 Annual Report, an example template of the report has been prepared and provided with this proposal as **Attachment 1**. The template has been annotated with a mix of GSP requirements, assumptions for report development, and example text. Annotations also include assumptions and details of our proposed scope of services to allow agencies to better visualize how Subbasin data will be compiled, analyzed, and used in the Annual Report. Accordingly, **Attachment 1** serves as a companion document to this scope of services and is incorporated into the scope by reference.

Tasks associated with the proposed scope of services are summarized below. Also, please refer to **Attachment 1** for GSP requirements and additional assumptions and details for including the information in the 2019 Annual Report.

Table 1: 2019 Annual Report, Kern County Subbasin

Todd Groundwater

	Task	Principal QA/QC $245	PM $245	Senior Engineer $230	Senior Hydrogeo $220	Staff Hydrogeo $165	Total Labor Hours	Total Labor	2% Comm Fee	GIS/ Graphics $125	Admin Costs $115	Other Direct Costs	10% Expense Fee	Total Costs
1	Prepare Data Requests and Templates		8	24		16	48	$ 10,120	$ 202	$ -	$ 230		$ -	$ 10,554
2	Prepare Groundwater Elevation Contour Maps		8	18	60	24	110	$ 23,260	$ 465	$ 3,000	$ -		$ -	$ 26,749
3	Review and Compile Hydrographs		6	16		16	38	$ 7,790	$ 156	$ 1,500	$ -		$ -	$ 9,458
4	Compile and Present Water Supply Data		14	36	14	12	76	$ 16,770	$ 335	$ 2,250	$ -		$ -	$ 19,373
5	Analyze Change in Groundwater in Storage		24	48	40	12	124	$ 27,700	$ 554	$ 4,000	$ 230		$ -	$ 32,518
6	Document GSP Progress		16	24		6	46	$ 10,430	$ 209	$ -	$ -	$ -	$ -	$ 10,639
7	Prepare Drafts/Final Annual Report and Submit to DWR	12	40	36	16	12	116	$ 26,520	$ 530	$ 5,000	$ 230		$ -	$ 32,322
8	Management, Communication and Meetings	4	80	24	12		120	$ 28,740	$ 575	$ 1,500	$ 460	$ 1,750	$ 175	$ 33,216
	Project Budget	**16**	**196**	**226**	**142**	**98**	**678**	**$ 151,330**	**$ 3,027**	**$ 17,250**	**$ 1,150**	**$ 1,750**	**$ 175**	**$ 174,830**

Task 1: Prepare Data Requests and Templates

The first step in this process involves development of a data request memorandum by Todd Groundwater, which will provide a list of data requirements from all Subbasin agencies and include data templates to facilitate data compilation and presentation. Todd Groundwater assumes introducing the data request memorandum and templates at a KGA-coordinated Subbasin Managers' Meeting, tentatively scheduled for November 8, 2019 (included in Task 8).

Task 2: Prepare Groundwater Elevation Contour Maps

We will obtain water level data from individual agencies for Spring and Fall 2019 measurements. We assume that data will be provided for the GSP water level monitoring sites but would be pleased to incorporate more data, if available. We will also work with KCWA, who leads an extensive water level monitoring program and may be able to provide additional data to improve map accuracy. Given the need for developing separate maps for each Principal Aquifer, the KCWA supplemental data from wells without construction information may not be included.

It is our understanding that GSAs have identified two primary Principal Aquifers that can be mapped in the Subbasin. Groundwater elevation contour maps will be prepared for each Principal Aquifer for Spring and Fall 2019 (4 total maps). It is also our understanding that two deeper Principal Aquifers, the Olcese Formation and the Santa Margarita Formation, have been identified in limited areas in the eastern Subbasin. If sufficient data are available for contouring groundwater elevations in these aquifers, we can also include them in the Annual Report. We assume that all groundwater elevations available for contouring will be provided by others (except for KRGSA data, which we will produce separately from this proposal).

We assume that groundwater level data will be provided in electronic (Excel) spreadsheets and include, at a minimum, well identifiers (matching hydrographs), date, X/Y or Lat/Long (with datum), depth to water, reference point elevation, water level elevations, and associated Principal Aquifer. GIS shapefiles are also appreciated, if available.

Data will be contoured initially using commercially-available software and then iteratively hand-modified for more accurate representations of groundwater elevations across the Subbasin. We will work directly with individual agencies if data issues are identified or if we require further clarification. If agencies have already developed groundwater elevation contour maps and wish to use the current contours, we can coordinate with the agency to obtain electronic maps or discuss other options. Several drafts of water level contour maps will be developed for review by individual agencies, as needed.

Task 3: Review and Compile Hydrographs

Groundwater elevation hydrographs will be compiled from Subbasin agencies for inclusion in the Annual Report. Hydrographs should be formatted to adhere with the *Data and*

Reporting Standards as prescribed in §352.4(e) of the GSP regulations and summarized in Section 2.2 of **Attachment 1**. In brief, each hydrograph should include a unique site identification number, ground surface elevation, and use the same scale to the greatest extent practical.

We will work with agencies to ensure relatively similar hydrograph formats including the same horizontal scale of October 1, 1994 through September 30, 2019 (WY 1995 – WY 2019), as needed; similar formats may facilitate DWR review. Closely-spaced hydrographs should incorporate the same vertical scales to the extent practicable in adherence with GSP regulations. Hydrographs may also include annotations to allow for easy well identification and understanding by DWR reviewers.

Overall trends and fluctuations as shown by the hydrographs for WY 2016 through WY 2019 will be described briefly in the context of water year type and the groundwater elevation contour maps. A map showing the location of submitted hydrographs will be developed and PDF files of each hydrograph will be included in an appendix of the Annual Report.

Task 4: Compile and Present Water Supply Data

Working with the individual agencies, Todd Groundwater will compile water supply data for the following categories:

- Groundwater Extractions
- Surface Water Supply
- Total Water Use.

For groundwater extractions, total extraction amounts for the preceding year are required, along with a map showing locations and volumes of production. Although data can be combined to report a total extraction from the Subbasin, some local data will be needed to develop groundwater extraction maps. First, we recommend development of a map showing general locations of active wells by type (agricultural, urban, banking recovery, etc.). This will illustrate concentrations of the various extraction types across the Subbasin. To meet the requirement of volumes, we recommend development of various "bubble" maps that illustrate relative volumes for various areas using circles of increasing diameter. We will recommend appropriate illustrations after a review of the available extraction data.

We will emphasize to DWR that management actions are being implemented for estimating groundwater extractions, but those actions were not in place in WY 2019. Therefore, the data will represent estimates, and can potentially be based on extractions associated with recent time periods as provided in the C2VSimFG-Kern model; extractions could be adjusted for current changes in local land use or known changes in extractions, as needed.

In addition to the map, groundwater extractions must be tabulated by water use sector (generally Urban, Agricultural, Managed Recharge, and Other - see Section 3 of **Attachment 1**). Methods and accuracy of measurements must also be included.

Data for total surface water supply (Section 4 in **Attachment 1**) are more likely to be available, but volumes are also required to be tabulated by water use source type. This categorization may be complicated for parties that frequently use water exchanges as part of their ongoing operations. We are assuming that surface water supply data will be provided to us by others (except for the KRGSA agencies), similar to the process conducted for the C2VSimFG-Kern model development.

Groundwater extractions and surface water supply will be combined for Total Water Use in Section 5 of the 2019 Annual Report. As indicated in **Attachment 1**, total water use must be categorized by both water use sector and water source type.

As noted in Sections 3, 4, and 5 of **Attachment 1**, DWR categories of water use sectors, methods/accuracy of measurement, and water use sources have been pulled from the DWR website used for SGMA reporting in adjudicated basins. Given the similarity of the SGMA reporting website organization and the requirements in the GSP regulations of Article 7, it seems reasonable to conclude that this organization will be maintained for reporting data in the GSP annual reports. Data requests and templates will be developed for these water use sectors, measurement methods, accuracy of measurements, and water source types for inclusion, as available (**Attachment 1**).

DWR will recognize that previous data were not likely collected in a manner to differentiate among these categories and some categorization of data will not be available for this first Annual Report. We will confirm with DWR that some data categorization will be unavailable and also that these data only need to be reported for WY 2019; GSP regulations do not indicate that these data need to be provided on an historical basis.

Finally, much of the requested data in this task overlaps with requirements for the updates of Agricultural Water Management Plans (AWMP) and Urban Water Management Plans (UWMPs) for 2020, due in 2021. We will note in the Annual Report that many of these requested data sets are currently being developed/revised in compliance with other planning processes, and data in this Annual Report will be superseded with improved data sets in future annual reports.

Task 5: Analyze Change in Groundwater in Storage

GSP regulations (§ 356.2 (b)(5)(B)) for the Annual Report require both a map and graph of changes in groundwater in storage be developed over the entire groundwater basin that meet the following requirements:

- Graphs depicting the annual and cumulative change in groundwater in storage "based on historical data to the greatest extent available, including from January 1, 2015 to the current reporting year," and
- "Change in groundwater in storage maps for each principal aquifer in the basin".

These requirements presents numerous technical challenges for the Kern County Subbasin (see also the discussion in Section 6.1 of **Attachment 1**).

Based our November 8, 2019, discussion at the Kern County Manager's Meeting, Todd Groundwater will develop change in groundwater in storage maps and graphs for the entire Kern County Subbasin using the C2VSimFG-Kern model. By doing so, we continue to update and use the primary DWR modeling tool with our local Kern County updates for evaluating basin conditions. For this task, we will use a methodology consistent with that used to develop change in groundwater storage graphs for the C2VSimFG-Kern Model Results technical memorandum, which is included in the KGA Umbrella and KRGSA GSPs. Using this approach, we will maintain consistency of method in presenting the basinwide change in groundwater in storage.

For this task, we will request WY2016 through WY2019 data from each district for measured managed water supply and demand data following the methodology used to update the C2VSimFG-Kern model for the Kern County historical water budgets. To meet this Annual Report schedule, this data needs to be delivered to Todd Groundwater no later than January 10, 2020. We will provide data templates to each district to provide monthly data for the following:

- Surface water imports and diversions (inflows and outflows) by source
- Application of surface water imports by category (e.g. irrigated agriculture, urban, managed aquifer recharge, or other uses).
- Groundwater banking and managed aquifer recharge by water district or agency,
- Groundwater banking pumping for export from the basin,
- Metered district groundwater recovery pumping,
- Metropolitan Bakersfield urban water deliveries and wastewater disposal, and
- Any other locally relevant water supply use or demands.

Todd Groundwater will update the natural hydrology for precipitation and flows in gauged streams (Kern River and Poso Creek). Precipitation data will be updated using publicly-available precipitation data from the PRISM Climate Group at Oregon State University. The monthly rainfall data for Kern County for WY2016 through WY2019 will be mapped into C2VSimFG-Kern input files. The Kern River and Poso Creek streamflow for WY2016 through WY2019 will be updated based on locally measured weir data.

Kern County GSAs will also separately contract with the Irrigation Training & Research Center (ITRC) at Cal Poly San Luis Obispo to deliver evapotranspiration (ET) using remote sensing data across the entire subbasin for determining agricultural demand corresponding to the WY 2016 through WY 2019. Todd Groundwater will utilize the ITRC ET data to develop ET rates for Kern County for this period for model input. To meet this Annual Report schedule, this data needs to be delivered to Todd Groundwater no later than January 17, 2020.

As mentioned previously, GSP regulations require a graph depicting the annual and cumulative change in groundwater in storage "based on historical data to the greatest extent available, including from January 1, 2015 to the current reporting year." (§ 356.2 (b)(5)(B)). To meet this requirement, the updated C2VSimFG-Kern subbasin-wide results will be appended to the historical C2VSimFG-Kern results for WY 1995 – WY 2015. One annual

change in groundwater storage map will be developed for each year from WY2016 through WY2019 for the entire Kern County Subbasin using the C2VSimFG-Kern model results.

We will work with agencies to determine the best method for meeting this requirement and then coordinate through the Plan Manager to confirm acceptance of the method by DWR. Additional details are provided in Section 6.2 of **Attachment 1**.

Task 6: Document Progress in GSP Implementation

For this section, Todd Groundwater will work with individual agencies to obtain descriptions and information relating to GSP implementation plans and progress. For the 2019 Annual Report, this section will likely be relatively brief. DWR will recognize that the GSPs were only submitted two months prior to the preparation of this Annual Report and will understand that there will not be substantial progress in plan implementation. Nonetheless, we will document any ongoing activities toward plan implementation that agencies would like to include. In particular, the collection of the preceding year monitoring data and preparation of this First Annual Report are significant steps toward implementation.

Task 7: Prepare Administrative Draft, Draft, and Final Annual Report and Submit to DWR

Based on the tasks above, an Administrative Draft will be prepared for review by Subbasin agencies. Given the condensed schedule, this Administrative Draft will be provided in early February to allow agency input into the development process. It is recognized that the Administrative Draft will contain deficiencies, but the early release will allow comments on analysis methods and results prior to finalization of the technical analysis.

Comments will be incorporated into the Administrative Draft to develop a Draft Annual Report (probably release in early March). This will provide a more complete document for agency review and comment. A Final Draft will also be available prior to submittal for any last-minute minor additions or corrections. The target for the Final Draft is March 13. Todd Groundwater will coordinate with the Plan Manager on submittal of the report prior to the deadline of April 1.

Task 8: Communications and Meetings

As indicated above, there will be a need for communication with Subbasin GSAs and KGA member agencies to obtain comparable data across the entire Subbasin for inclusion in the 2019 Annual Report. Communications will include individual calls/emails with Subbasin agencies, conference calls during periodic meetings of GSA managers, and local in-person meetings to present progress to date and discuss outstanding items or issues.

The preparation of the Annual Report will occur at a busy time for Subbasin agencies. Finalization of GSPs and preparation for GSP submittals will be ongoing. To keep to the expedited schedule of the 2019 Annual Report, a significant amount of communication will be needed to allow Subbasin agencies to focus on required details of the 2019 Annual Report.

To expedite the process, Todd Groundwater will coordinate directly with the Subbasin Plan Manager, Patty Poire, to ensure timely data compilation, review, and incorporation of the required analyses to meet GSP Annual Report requirements. In particular, any questions or contacts with DWR regarding clarifications of Annual Report requirements will be coordinated through the Subbasin Plan Manager.

For budget and planning purposes, four in-person meetings are assumed as part of this scope. Because of the large number of attendees, the KGA Managers Meetings – typically held on Friday mornings – will be used as a forum for data requests, discussion, and comments regarding the Annual Report preparation process. These four meetings, along with the primary objectives and tentative dates, are summarized as follows:

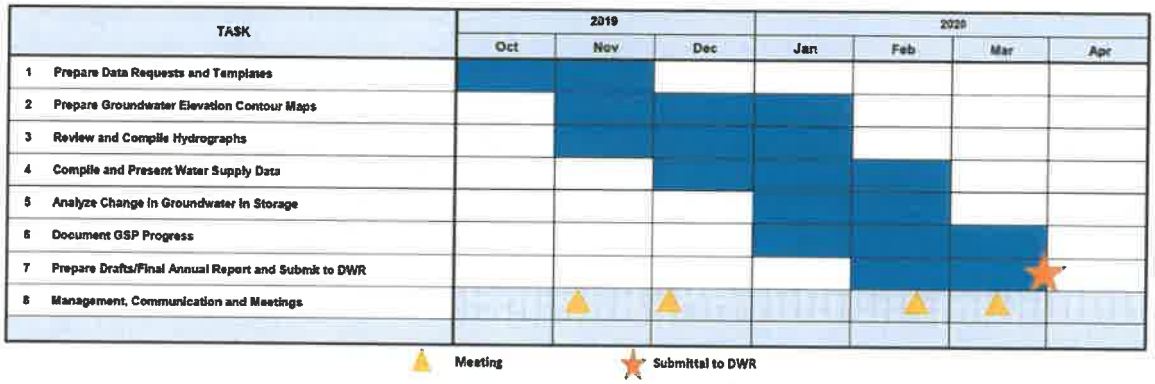
- Meeting No. 1: Provide data request memorandum and templates to agencies and discuss approach for technical analyses including historical change in groundwater in storage; tentatively scheduled for November 8, 2019
- Meeting No. 2: Finalize technical approach for Change in Groundwater in Storage and other technical analyses; tentatively scheduled for December 6, 2019
- Meeting No. 3: Review Administrative Draft Annual Report and address deficiencies; tentatively scheduled for February 21, 2019
- Meeting No. 4: Review Final Draft Annual Report; tentatively scheduled for March 13, 2019.

3 BUDGET AND SCHEDULE

Execution of the scope of work described herein is estimated to cost $174,830. This cost allows for a variety of technical methods to be considered and employed to meet regulatory requirements and the condensed schedule for Annual Report development. Table 1 shows costs by task, along with estimated labor hours and rates.

Our work on the Annual Report can begin in October with additional work on approach for Annual Report items. Technical work can begin in November when water level data from Fall 2019 have been collected and requested data have been compiled. With a submittal date of April 1, 2020, most of the work on the 2019 Annual Report will occur over four months (November through February) with final review and edits of the report targeted for March 2020. A proposed schedule, including the four meetings described in Task 8 is shown below.

Proposed Schedule for 2019 Annual Report, Kern County Subbasin



Please let us know if you have questions regarding this proposal. For the 2019 Annual Report, time is of the essence, and we stand ready to move the effort forward as soon as possible.

ATTACHMENT 1: EXAMPLE ANNOTATED TEMPLATE FOR 2019 ANNUAL REPORT

KERN COUNTY SUBBASIN

GROUNDWATER SUSTAINABILITY AGENCIES

Kern County Subbasin

Groundwater Sustainability Plans (GSPs)

First Annual Report
Water Year 2019

April 1, 2020

DRAFT

TODD GROUNDWATER

2490 Mariner Square Loop, Suite 215
Alameda, CA 94501
510.747.6920
www.toddgroundwater.com

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No table of contents entries found.

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Figure 3	Kern County GSPs
Figure 4	Groundwater Elevation Contour Map, Principal Aquifer 1, Spring 2019
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Figure 8	Location Map, Water Level Hydrographs in Appendix A
Figure 9	Location and Type of Groundwater Extraction Wells (several maps may be needed for meeting regulatory requirements of this item)
Figure 10	Change in Groundwater in Storage for WY 2019 (required *map*)
Figure 10	Annual and Cumulative Change in Groundwater in Storage, WY 1995 – WY 2019 (required *graph*)

Other figures, as needed

Appendices

APPENDIX A:	Hydrographs of Groundwater Elevations and Water Year Type, October 1, 1994 through September 30, 2019, including Location Map
APPENDIX B:	Coordination Agreement (or refer to original in GSPs)

List of Acronyms

AFY acre feet per year

...

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EXECUTIVE SUMMARY

*Provide an **executive summary** and **location map** depicting the basin covered by the report (Reg. § 356.2(a)).*

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1 INTRODUCTION

Include general information and location map for the basin covered by the report (Reg. § 356.2(a)).

This First Annual Report (2019 Annual Report) for the collective implementation of the Groundwater Sustainability Plans (GSPs) in the Kern County Subbasin is being prepared under the guidance of Water Code Section 10728. The 2019 Annual Report provides data and information for the entire Kern County Subbasin, including 11 GSAs that have cooperated in the preparation of five GSPs. Subbasin GSAs and GSP are shown on Figures 2 and 3, respectively.

1.1 PURPOSE OF THE 2019 ANNUAL REPORT

The purpose of the 2019 Annual Report is to demonstrate that the GSPs in the Kern County Subbasin are being implemented in a manner that will achieve the sustainability goals that have been developed for the Subbasin and individual GSAs. The 2019 Annual Report provides an update on the groundwater conditions for **Water Year 2019**, and documents progress on GSP implementation. Data and analyses cover the period from October 1, 2018 through September 30, 2019; historical analyses are provided for context for some components, as required by the regulations.

Specifically, for this First Annual Report, some additional analyses have been required to cover the time period from October 1, 2015 through September 30, 2019 (WY 2016 through WY 2019). Inclusion of data from this four-year period provides a bridge between the end of the Current Study Period (WY 2015) of the Subbasin GSPs and the reporting period for this 2019 Annual Report (i.e., WY 2019).

1.2 COORDINATED SUBMITTAL

Describe process by which Subbasin data were submitted and compiled.

All of the GSAs in the Kern County Subbasin have cooperated to prepare and submit this First Annual Report.

Figures and tables will be included for the GSAs and GSPs in the Subbasin.

As required by GSP regulations, this Annual Report contains... ***summarize organization and contents***.

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2 GROUNDWATER ELEVATIONS

§ 356.2(b)(1)(A) Describe and present graphically, groundwater elevation data from monitoring wells identified in the monitoring network.

2.1 GROUNDWATER ELEVATION CONTOUR MAP FOR EACH PRINCIPAL AQUIFER

§ 356.2(b)(1)(A) ...illustrating, at a minimum, seasonal high and seasonal low. Assume submittal of 2 sets of maps with this Annual Report – Spring and Fall 2019, with a map per Principal Aquifer (4 maps total). Will we have Santa Margarita maps from Kern Tulare and others on the Eastside?

Assume that water level data will be provided in Excel and include, at a minimum, well identifiers (matching hydrographs), date, depth to water, reference point elevation, and water level elevations.

Data will be contoured initially using commercially-available software and then iteratively hand-modified for more accurate representations of groundwater elevations across the Subbasin. Multiple drafts of water level contour maps will be developed for review by individual agencies, as needed.

2.2 HYDROGRAPHS FROM WY 1995 THROUGH SEPTEMBER 2019

Assume that wells in the GSP monitoring networks used for GSP compliance monitoring will be provided by each agency for inclusion in the 2019 Annual Report. Hydrographs can be provided as pdf, described briefly in this section, and incorporated in an appendix.

Section will include and describe:

- Table of Wells and Submitting Agencies
- Figure 8: Hydrograph Location Map.
- Hydrographs to be included in Appendix A.

Hydrograph requirements for Annual Report *§ 356.2(b)(1)(B)*:

- Groundwater elevations
- Water Year Type
- Historical data to the greatest extent possible (WY 1995 – WY 2019)
- Locations, tied to the same datum

Hydrograph requirements from Data and Reporting Standards §352.4(e):

- Hydrographs shall be submitted electronically in accordance with the procedures in Article 4.
- Hydrographs shall include a unique site identification number and the ground surface elevation for each site
- Hydrographs shall use the same datum and scaling to the greatest extent practical

We assume that all submitted hydrographs from each agency will have the same horizontal scale beginning with October 1, 1994 and ending with September 30, 2019. The horizontal axis will have major tick marks for each water year (WY 1995 through WY 2019).

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3 GROUNDWATER EXTRACTIONS

GSP requirements in § 356.2(b)(2).

3.1 SUMMARY EXTRACTIONS BY SUBBASIN FOR WY 2019

Total groundwater extractions for the Subbasin for the preceding water year (WY 2019) will be summarized and provided in this section. Data should be collected by "best available measurement methods."

3.2 TABLE OF EXTRACTIONS

Based on our SGMA reporting in Adjudicated Basins, we anticipate the following formats from DWR regarding extraction data reporting. Data may not be available for all sectors for this first report.

- Water Use Sector (including volume, explanation, and uncertainty)
    - Urban
        - Large Landscape
        - Commercial
        - Industrial
        - Residential
    - Agricultural
    - Managed Wetlands
    - Managed Recharge
    - Other Sector

- Measurement Method (direct or estimate)
    - Meters
    - Electrical Records
    - Land use
    - Groundwater model
    - Reported by pumper
    - Other

- Accuracy of Measurements
    - Low, medium, high

3.3 EXTRACTIONS MAP

Map that illustrates the general location and volume of groundwater extractions § 356.2(b)(2).

This map will be developed with various formats, depending on the data provided. At a minimum, we assume preparation of a map will showing extraction wells by well type (agricultural, municipal, etc.), using available information from the agencies. To meet the criteria of showing volumes of extractions, we anticipate developing various "bubble" maps showing groundwater extractions for general areas.

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4 SURFACE WATER SUPPLY

§ 356.2(b)(3) Surface water supply used or available for use, for groundwater recharge or in-lieu use shall be reported based on quantitative data that describes the annual volume and sources for the preceding water year.

4.1 TOTAL SURFACE WATER USE

Total surface water use will be reported for the Kern County Subbasin, including a summary of the methods used to determine the volume and the associated uncertainty (high, medium, low). These data will be compiled from the individual agencies in the Subbasin.

4.2 SURFACE WATER BY SOURCE TYPE

Tables will be developed to document the volumes and associated uncertainty by Water Source Type:

- Local Surface Deliveries
- Local Imported Deliveries
- Colorado River Deliveries
- CVP Base and Project Deliveries
- Other Federal Deliveries
- State Water Project Deliveries
- Recycled Water
- Desalination Water
- Other

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5 TOTAL WATER USE

§ 356.2(b)(4) Total water use.

Provide total volume of water used in the Subbasin for WY 2019, including the method used to determine and the level of uncertainty (low, medium, high)

- Collected using the best available measurement methods
- Table containing total water use by:
    - Water Use Sector
        - Urban
            - Large Landscape
            - Commercial
            - Industrial
            - Residential
        - Agricultural
        - Managed Wetlands
        - Managed Recharge
        - Other Sector
    - Water Source Type
        - Groundwater
        - Surface water
        - Recycled or reused water
        - Other

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6 CHANGE IN GROUNDWATER IN STORAGE

6.1 MAP OF CHANGE IN GROUNDWATER IN STORAGE FOR THE SUBBASIN

*§ 356.2(b)(5)(A) Change in **groundwater in storage maps** for each principal aquifer in the basin.*

GSP regulations require an annual change in groundwater in storage map for the entire Kern County Subbasin be included in the Annual Report. We will follow up with DWR whether this requirement is for only the preceding year (WY 2019) or whether it applies to all four intervening water years (WYs 2016 through 2019).

Based our November 8, 2019, discussion at the Kern County Manager's Meeting, Todd Groundwater will develop change in groundwater in storage maps and graphs for the entire Kern County Subbasin using the C2VSimFG-Kern model. By doing so, we continue to update and use the primary DWR modeling tool with our local Kern County updates for evaluating basin conditions. For this task, we will use a consistent methodology to that used to develop change in groundwater storage graphs for the C2VSimFG-Kern Model Results technical memorandum that is included in the KGA Umbrella and KRGSA GSPs. Using this approach, we will maintain consistency of method in presenting the basinwide change in groundwater storage. One annual change in groundwater storage map will be developed for each year from WY2016 through WY2019 for the entire Kern County Subbasin using the C2VSimFG-Kern model results.

6.2 GRAPHS OF CHANGE IN GROUNDWATER IN STORAGE

§ 356.2(b)(5)(A) Graphs of Change of Groundwater in Storage showing:

- Water Year Type (Wet, Above Normal, Below Normal, Dry, Critically Dry)
- Groundwater Use
- Annual Change in groundwater in storage
- Cumulative change in groundwater in storage
- Based on historical data, to the greatest extent available, including from January 1, 2015 to the current reporting year

GSP regulations require a graph depicting the annual and cumulative change in groundwater in storage "based on historical data to the greatest extent available, including from January 1, 2015 to the current reporting year." (§ 356.2 (b)(5)(B)).

For the Kern County Subbasin, this graph will present annual changes in groundwater in storage from the C2VSimFG-Kern model. Model results provide an annual change in groundwater in storage for each year in the historical and current study periods (WY 1995 – WY 2015). New water budget analyses will be developed for the remaining time period WY 2016 – WY 2019. To meet the regulatory requirement for this graph, the updated C2VSimFG-Kern subbasin-wide results will be appended to the historical C2VSimFG-Kern results for WY 1995 – WY 2015.

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7 PROGRESS IN GSP IMPLEMENTATION

§ 356.2(b)(5)(C) A description of progress towards implementing the Plan, including achieving interim milestones, and implementation of projects or management actions since the previous annual report.

For this section, we assume receipt of text from each GSAs/Districts that describes ongoing implementation of each GSP. A brief description of the projects and management actions being implemented will be included, as relevant. This section is not meant to repeat information in the recently-submitted GSPs and will simply refer to the GSPs as appropriate.

In particular, this section will describe relevant monitoring data and how these data are being used. GSP monitoring data can be summarized/included in an appendix. We will confirm with DWR how much of the data and formats are required to accompany the submission of the Annual Report.

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8 REFERENCES AND TECHNICAL STUDIES

To be listed as needed.

DRAFT

9 APPENDICES

- Hydrographs and other data.
- Possible inclusion of other information, if determined to be needed by DWR.

DRAFT

ATTACHMENT 2

ITRC
moving water in new directions

Agreement for ITRC-METRIC 2017-2019

Date: October 7, 2019

To: Patty Poire, Planning Manager
Kern Groundwater Authority
ppoire@kerngwa.com, Mobile: (661)706-1989

From: Dan Howes, Ph.D., P.E.
Project Manager/Senior Engineer
Irrigation Training and Research Center
Cal Poly/ San Luis Obispo, CA 93407
Cell: 858-354-0504
djhowes@calpoly.edu

Subject: **Proposal for ITRC-METRIC evapotranspiration for Kern Subbasin (2017-2019)**

This proposal is being submitted to Kern Groundwater Authority (KGWA) by the Irrigation Training and Research Center (ITRC) at Cal Poly State University, San Luis Obispo.

Scope of Work

Update of ITRC-METRIC 2017-2019 Water Year and Calendar Year

ITRC will provide monthly and annual ITRC-METRIC actual crop evapotranspiration (ETc) for the Kern Subbasin for 2017-2019. The following items will be completed:

1. Data will be extracted for each GSA within the subbasin and each irrigated field in each GSA monthly for 2017-2019. We can also provide the data for parcels (larger than 5 acres).
2. Data will be provided tabularly and monthly ETc images will be provided in GIS format.
3. Short report discussing the general process and overall results will be provided.

Cost: **$16,000**

Deliverables

ETc data in tabular (MS EXCEL) and other formats (such as imager) provided on a flash drive or file transfer service.

Timeline for Project

Assuming the full 2019 results are desired, report and data will be provided by February 1, 2020. If water year only results are desired, results will be provided by November 20, 2019.

Contract

The person responsible for technical aspects of this contract will be:

Dan Howes
Project Manager, Irrigation Training and Research Center
Cal Poly
San Luis Obispo, CA 93401-0730
djhowes@calpoly.edu

The contract will be administered by:

Cal Poly Corporation
Building #15
One Grand Avenue
San Luis Obispo, CA 93407

Note: Dr. Howes should be the contact person.

Budget

The total budget is a fixed price Fee for Service of $16,000. The full amount will be invoiced when the draft results are transmitted to KGWA. The Cal Poly Corporation requests that a KGWA representative agree to the Standard Terms and Conditions, which are attached to this proposal. The signed approval can be scanned and submitted via e-mail to Dan Howes.

Invoicing and Payment

ITRC will submit to KGWA (Patty Poire), an invoice of the full fixed cost when transmitting the draft results.

Payment should be made payable to "Cal Poly Corporation" and sent to:

Dr. Dan Howes
Irrigation Training and Research Center (ITRC)
One Grand Ave
Bldg 8A
California Polytechnic State University
San Luis Obispo, CA 93407-0730

Authorization/Approval

Name of authorized ITRC representative: Daniel Howes

Signature of ITRC representative — date: 10/7/2019

Named of authorized Kern GWA representative: Patty Poire

Signature of the representative: — date: 11/20/2019

Irrigation Training & Research Center (ITRC)
Standard Terms and Conditions

THIS AGREEMENT is between the **Kern Groundwater Authority ("Client")** and the Cal Poly Corporation, a separate non-profit auxiliary organization for the California Polytechnic State University, hereinafter referred to as **"ITRC."**

1) **Ordering**: Clients may order services (specify a "Scope of Work") by submitting a written purchase order, a written request for services, by sending confirming e-mail, or by placing a telephone order. The Client must subsequently confirm all telephone orders in writing or via e-mail confirmation prior to commencement of work.
2) **Change Orders:** A Client may request additions or changes to an Order, but must be confirmed by written notice. Email is an acceptable form of writing. The Client will remain responsible for all work performed under the original agreement up until the time ITRC is officially notified of the change.
3) **Suspending or Stopping ITRC's Performance**: The Client may direct ITRC to suspend a portion or all of the work to be performed. In such case, the Client will remain responsible for all work performed up until the time ITRC became aware of Client's desire to discontinue the services. Any uncompleted services in progress at the time of discontinuation will be billed on a prorated basis, as determined by ITRC.
4) **Confidentiality:** ITRC shall keep documents and information identified by Client as confidential to the extent permitted by law, and will not disclose any such information to third parties. ITRC may publish announcements and summaries containing *non-confidential information* about this project in campus newsletters and annual report and other published documents on campus.
5) **Warranties**: Client understands that ITRC performs services only as specified by Client in the Services Agreement accepted by ITRC. ITRC does not make any express or implied warranties or guarantees of any kind to the Client. By their very nature, technical services, testing, analysis and other ITRC services are limited to expected measurement variability. ITRC represents that the Services shall be performed within the limits agreed with Client, and in a manner consistent with the level of care and skill ordinarily exercised by other providers of similar services under similar circumstances.
6) **Ownership of Data:** Data or information provided to ITRC by the Client shall remain the Client's property. Upon full payment to ITRC for all services provided by ITRC, data or information generated by ITRC for the Client shall become the Client's property. ITRC will retain exclusive ownership of any and all analytical methods, Quality Assurance/Quality Control protocols, and equipment developed by ITRC for performance of work by ITRC. ITRC Reports are for the exclusive use of the Client to whom they are addressed. The name of ITRC, Cal Poly Corporation, or California Polytechnic State University, or any symbols of them are not to be used by Client without prior written approval by the appropriate authorized representative.
7) **Indemnification:** Client and ITRC agree that by performing services hereunder, ITRC does not assume, shorten, cancel or undertake to discharge any duty or responsibility of Client to any other party or parties. No one other than Client shall have any right to rely on any Report or other representation or conduct of ITRC, and ITRC disclaims any obligations of any nature whatsoever with respect to such person. Client and ITRC agree, in consideration of ITRC under-taking to perform the ordered service(s) to protect, defend, indemnify, same harmless and exonerate each other from any and all claims, damages, expenses, either direct or consequential for injuries to persons or property arising out of or in consequence of the performance of the services hereunder unless caused by the sole negligence of the other party.
8) **Insurance:** Cal Poly Corporation maintains insurance coverage for its employees to perform professional services. If Client seeks greater protection than is provided by Cal Poly Corporation insurance, Client should obtain appropriate protection from suppliers or insurers.
9) **Limitation of Liability:** If ITRC should be found liable for any losses or damages attributable to the services hereunder in any respect, its liability shall in no event exceed the amount of the fee paid by Client for such services and Client's sole remedy at law or in equity shall be the right to recover up to such amount.
10) **Force Majeure:** Whenever performance by either party is delayed or prevented by an extraordinary event beyond the control of Client or ITRC, such delay or prevention shall be excused and the time of performance extended for the duration of the causative factor. In no event shall the occurrence of any such conditions excuse the Client of its obligations hereunder if services have been performed by ITRC.
11) **Payment of Invoices:** Client agrees to pay all invoices to ITRC within 30 days of invoice date, and if payment is not timely received, the Client agrees to pay a late payment charge on the unpaid balance at the maximum allowed by law.
12) **Governing Law**: This Agreement shall be governed in accordance with the laws of the State of California.

EXHIBIT 1

Funding Contributions

Total Contracts	$190,830.00	
Todd Groundwater	$174,830.00	
ITRC	$16,000.00	

	Funding Entity	Funding Request
1	Arvin-Edison Water Storage District	$8,674.09
2	Buena Vista Water Storage District	$8,674.09
3	Cawelo Water District	$8,674.09
4	City of Bakersfield	$8,674.09
5	Eastside Water Management Area	$8,674.09
6	Henry Miller	$8,674.09
7	Improvement District No. 4	$8,674.09
8	Kern Delta Water District	$8,674.09
9	Kern County Water Agency - Pioneer Project	$8,674.09
10	Kern-Tulare Water District	$8,674.09
11	Kern Water Bank Authority	$8,674.09
12	North Kern Water Storage District	$8,674.09
13	Olcese Water District	$8,674.09
14	Rosedale-Rio Bravo Water District	$8,674.09
15	Semitropic Water Storage District	$8,674.09
16	Shafter-Wasco Irrigation District	$8,674.09
16	Shafter-Wasco 7th Standard Annex	$8,674.09
17	South San Joaquin Municipal Utilities District	$8,674.09
18	Tejon-Castac Water District	$8,674.09
19	West Kern Water District	$8,674.09
20	Westside District Water Authority	$8,674.09
21	Wheeler Ridge-Maricopa Water Storage District	$8,674.09
	Totals	$190,830.00

Invoices:

KGA:	$138,785.45
KRGSA:	$26,022.27
BV	$8,674.09
Henry Miller:	$8,674.09
Olcese	$8,674.09
	$190,830.00

ATTACHMENT C
Resolution to Form Kern Groundwater Authority Groundwater Sustainability Agency

KERN GROUNDWATER AUTHORITY
RESOLUTION NO. 2
RESOLUTION ELECTING FORMATION OF THE KERN GROUNDWATER AUTHORITY GROUNDWATER SUSTAINABILITY AGENCY

WHEREAS, the California Legislature has adopted, and the Governor has signed into law, the Sustainable Groundwater Management Act of 2014 ("SGMA"), which requires the sustainable management of groundwater; and

WHEREAS, the legislative intent is to provide for sustainable management of groundwater basins, to enhance local management of groundwater, to establish minimum standards for sustainable groundwater management; and

WHEREAS, in order to exercise the authority granted in SGMA, a local agency or combination of local agencies may elect to form a Groundwater Sustainability Agency (GSA); and

WHEREAS, the Kern Groundwater Authority is a joint powers authority composed of local agencies, as SGMA defines that term; and

WHEREAS, specific members of the Kern Groundwater Authority have executed a Special Activities Agreement for the purpose of coordinating and electing to be a GSA under the organization of the Kern Groundwater Authority ("Participating Members"); and

WHEREAS, every member of the Kern Groundwater Authority was provided the opportunity to participate in the formation of a GSA under the Kern Groundwater Authority; and

WHEREAS, the Kern Groundwater Authority overlies a portion of the Kern County Subbasin (designated basin number 5-022.14) in the California Department of Water Resources' (DWR) groundwater basin system, which has been designated by DWR as a high-priority basin in critical overdraft; and

WHEREAS, Section 10723.8 of the SGMA requires that a local public agency electing to be a GSA notify the DWR of its election and intention to undertake sustainable groundwater management within the agency's jurisdictional boundary; and

WHEREAS, pursuant to Government Code 6066, notice of a public hearing on the Kern Groundwater Authority election to elect to be a GSA has been published as required by law; and

WHEREAS, on April 26, 2017, the Kern Groundwater Authority held a public hearing to consider adoption of this Resolution; and

WHEREAS, the Kern Groundwater Authority, pursuant to the vote of the Participating Members, wishes to exercise the powers and authorities of a GSA granted by SGMA and to begin the process of cooperatively preparing a Groundwater Sustainability Plan (GSP) with other GSAs as appropriate.

NOW, THEREFORE BE IT RESOLVED THAT:

1. The Kern Groundwater Authority hereby finds that the facts set forth in the recitals to this Resolution are true and correct, and establish the factual basis for the Kern Groundwater Authority adoption of this Resolution.

2. The Kern Groundwater Authority hereby elects to become a GSA to manage groundwater within the boundaries of the Participating Members.

3. The Board authorizes the General Manager or his designee within 30 days of adopting this Resolution, to inform the Department of Water Resources of the Kern Groundwater Authority election and take such other and further steps as necessary to comply with the SGMA and the Department of Water Resources requirements.

4. This Resolution shall take effect immediately upon its adoption.

PASSED AND ADOPTED at a meeting of the Board of Directors of the Kern Groundwater Authority on April 26, 2017, by the following vote:

AYES: Directors Pascoe, James, Couch, Pandol, Taube, Andrew, Selvidge, Regan, Franz, Poire, MacIlvaine, Mullins, Barraza, Jr.
NOES: None
ABSTAINING: None

ATTEST:

Lori Honea, Secretary

ATTACHMENT D

Notification of Intent to Develop a Groundwater Sustainability Plan

KERN
GROUNDWATER AUTHORITY

December 20, 2017

Mr. Trevor Joseph
Sustainable Groundwater Management Section Chief
California Department of Water Resources
P. O. Box 94236
Sacramento, CA 94236

Re: Notification of Intent to Develop a Groundwater Sustainability Plan

Dear Mr. Joseph:

The purpose of this letter is to notify you that the Kern Groundwater Authority Groundwater Sustainability Agency (KGA) intends to develop a Groundwater Sustainability Plan (GSP) pursuant to Water Code Section 10727.8 for its service area within the Kern County Subbasin (Basin Number 5-22.14, DWR Bulletin 118). The KGA is an exclusive GSA whose formation was posted by DWR on April 21, 2016.

The KGA is engaged in several coordination and outreach efforts across the Kern County Subbasin, as well as within the more specific service area of the KGA. The KGA actively participates in technical and planning meetings and forums with other GSAs in the Kern County Subbasin, recognizing that the findings of the KGA's GSP will need to be coordinated with other GSP development efforts occurring in parallel within the Kern County Subbasin. In addition to the monthly KGA Board of Directors meetings, the KGA holds monthly public meetings to review and discuss on-going planning activities in support of the GSA and GSP development process. These meetings welcome public input and feedback to the GSA and the GSP development process.

The KGA will also be holding educational workshops specifically intended for the interested parties and general public living, working and operating farms and businesses in the KGA service area. These additional workshops will have an educational focus to inform attendees on the overall role and purpose of the GSA, describe the method and process to develop the GSP, and solicit input on the development of the GSP. An initial workshop in 2018 will focus on public involvement and seek input on approaches, such as an Advisory Committee, to regularly acquire input from a wide variety of public stakeholders, and from disadvantaged communities in particular. One of the key goals of the public workshops will be to hear comments and feedback from the public that can be used to further inform the GSP development process.

1800 30th Street, Suite 280, Bakersfield, CA 93301 • Tel: (661) 616-6500 • Fax: (661) 616-5890 • www.kerngwa.com

The KGA has established a website at: http://kerngwa.com/. This website is already actively in use and will continue to provide the public with key information regarding the GSA and GSP development process including the dates of public meetings and workshops. The KGA website also makes our resource planning and GSP documents available to the public.

If you have any questions regarding our GSP development process, please don't hesitate to contact me at the phone number or email below.

Sincerely,

Terry L. Erlewine
Kern Groundwater Authority

Cc: City of Delano
City of Wasco
City of Shafter
City of Arvin
County of Kern
City of McFarland

Kern Groundwater Authority Groundwater Sustainability Agency
Groundwater Sustainability Plan

ATTACHMENT E

Communication and Engagement Plan

Kern Groundwater Authority

Communication & Engagement Plan

Kern County, California
Adopted May 2018
Updated August 2019
Updated December 2019
Updated January 2020

Prepared for:

KERN GROUNDWATER AUTHORITY

Kern Groundwater Authority
1800 30th Street, Suite 280, Bakersfield, California 93301

Prepared by:

Provost & Pritchard Consulting Group
1800 30th Street, Suite 280, Bakersfield, California 93301

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Report Prepared for:

Kern Groundwater Authority

1800 30th Street, Suite 280

Bakersfield, CA 93301

Contact:

Patty Poire, Planning Manager

Telephone: (661) 479-7171

Email: ppoire@kerngwa.com

Website: www.kerngwa.com

Report Prepared by:

Provost & Pritchard Consulting Group

Trilby Barton, Public Outreach Coordinator

Contact:

Telephone: (661) 616-5900

Email: tbarton@ppeng.com

Note: This Communication & Engagement Plan is a living document and will be updated as necessary throughout the GSP development, public review, and implementation phases.

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Abbreviations

AB.....Assembly Bill
C&E.....Communication & Engagement
DAC.....Disadvantaged Community
DDW.....Division of Drinking Water
DWR.....Department of Water Resources
FKC.....Friant-Kern Canal
GSA.....Groundwater Sustainability Agency
GSP.....Groundwater Sustainability Plan
ILRP.....Irrigated Lands Regulatory Program
JPA.....Joint Powers Authority
KGA.....Kern Groundwater Authority
MCL.....Maximum contaminant levels
PSA.....Public service announcement
SB.....Senate Bill
SDAC.....Severely Disadvantaged Community
SRT.....Sequoia Riverlands Trust
SGMA.....Sustainable Groundwater Management Act
SWRCB.....State Water Resources Control Board

Introduction

SGMA Overview

The Sustainable Groundwater Management Act (**SGMA**) is a combination of three bills signed by California Governor Jerry Brown in 2014: Assembly Bill (**AB**) 1739, Senate Bill (**SB**) 1168, and SB 1319. SGMA provides local agencies with the framework to manage groundwater basins in a sustainable manner. The legislation recognizes that groundwater is most effectively managed at the local level, and local agencies will need to achieve groundwater sustainability by 2040.

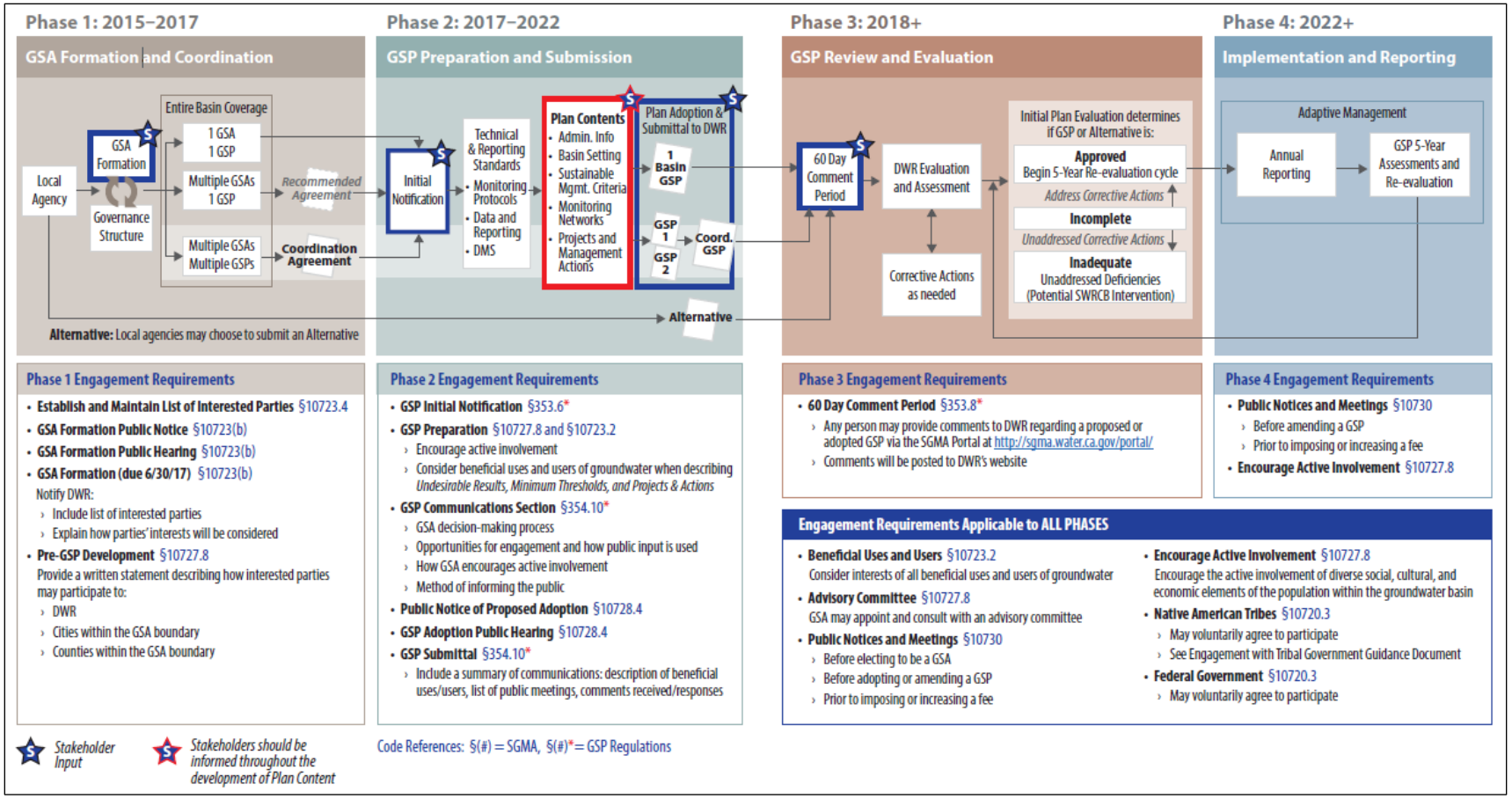
In SGMA, sustainable groundwater management is defined as management of groundwater supplies in a manner that can be maintained in planning and implementation phases without causing undesirable results. Undesirable results include significant and unreasonable chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, land subsidence, and interconnected surface waters.

Implementation of SGMA and outreach requirements are broken down into four phases (**Figure ES-1**):

- **Phase 1: GSA Formation and Coordination –** Phase 1 ranged from 2015 to 2017, and during this phase, local agencies created groundwater sustainability agencies (**GSA**). The responsibility of a GSA is to develop and implement a groundwater sustainability plan (**GSP**) that will consider all beneficial uses and groundwater users within the basin. GSAs were required to be formed by June 30, 2017.
- **Phase 2: GSP Preparation and Submission –** The second phase of SGMA implementation ranged from 2017 to 2019. During this phase, GSAs developed GSPs with measurable objectives and milestones that ensure basin sustainability. A basin may be managed by a single GSP or multiple-coordinated GSPs. The California Department of Water Resources (**DWR**) developed regulations for evaluating GSPs and alternatives to GSPs by June 1, 2016.
- **Phase 3: GSP Review and Evaluation –** For the Kern Groundwater Authority (**KGA**), Phase 3 was held in late 2019, and consisted of a public review period. The public review period was held 90 days prior to the adoption of the GSP. Once the GSP has been submitted to the DWR by January 31, 2020, DWR will hold another 60-day review and comment period for stakeholders.
- **Phase 4: Implementation and Reporting –** Following the submission of the GSP, the KGA will immediately begin the implementation of efforts described in the GSP to reach sustainability within the basin. This will be an ongoing phase, as the goal of SGMA is to reach sustainability by 2040.

Communication & Engagement Plan

As required by SGMA, GSAs must consider the interests of all beneficial uses and users of groundwater and include them in the GSP development process. The Kern Groundwater Authority's Communication & Engagement (**C&E**) Plan addresses how stakeholders within the boundary will be engaged through stakeholder education and opportunities for input and public review during the development and implementation of the GSP. This plan provides an overview of the KGA, its stakeholders, and decision-making process; identifies opportunities for public engagement and discussion of how public input and responses will be used; describes how the KGA encourages the active involvement of diverse, social, cultural, and economic elements of the population within the KGA boundary; and the methods to be used to inform the public stakeholders about the progress of GSP development, public review and implementation.



Source: GSP Stakeholder Communication and Engagement Guidance Document, California Department of Water Resources, June 2017

Figure Intro-1. Stakeholder Engagement Requirements by Phase

I. Goals and Desired Outcomes

This section of the Communication & Engagement Plan provides a description of the Kern Groundwater Authority, defines the goals of how to address the challenges, regulatory requirements and opportunities, and how to reach the desired outcomes of communication efforts.

A. Description and Background of the Kern Groundwater Authority

I.A.1 GSA Description & Boundary

SGMA requires all high- and medium-priority groundwater basins, as designated by the DWR Bulletin 118, to be managed by a GSA or multiple GSAs. Part of the Tulare Lake Basin, the Kern County Groundwater Sub-basin is a high-priority basin that is in critical groundwater overdraft. The Kern County Groundwater Sub-basin currently has 10 GSAs (listed in **Table I-1**).

Table I-1. GSAs in Kern Sub-basin

GSAs within the Kern Sub-basin		
Buena Vista Water Storage District	Cawelo GSA	Greenfield County Water District
Henry Miller Water District	Kern Groundwater Authority	Kern River GSA
McFarland GSA	Olcese GSA – Olcese Water District	Pioneer GSA
Semitropic Water Storage District	West Kern Water District	

On April 26, 2017, the Kern Groundwater Authority, a joint-powers authority (**JPA**), elected to become an official GSA for the portion of the Kern County sub-basin designated in **Figure I-1**. The KGA provides local policy makers, stakeholders and the public with a forum to monitor, report and/or discuss groundwater activities, and identify and address any local groundwater issues. The KGA was formed for the purpose of SGMA, which includes but is not limited to the following activities: coordinating groundwater management programs and activities, identifying and addressing issues pertaining to sustainable groundwater management, and establishing a framework for local groundwater management.

Kern Groundwater Authority's member entities are listed in **Table I-2**. These members overlie the larger portion of the Kern County Subbasin (Basin Number 5-022.14, DWR Bulletin 118) of the San Joaquin Valley Basin, which create the GSA's boundary. The boundary stretches along the northwest, northeast and southern parts of Kern County, California (**Figure I-1**), and includes agricultural lands, urban and industrial areas, and oil fields.

Table I-2. Kern Groundwater Authority Member Entities

Kern Groundwater Authority Member Agencies		
Arvin Community Services District	Arvin-Edison Water Storage District	Cawelo Water District
City of Shafter	Eastside Water Management Area*	Kern County Water Agency
Kern-Tulare Water District	Kern Water Bank Authority	North Kern Water Storage District
Rosedale-Rio Bravo Water Storage District	Semitropic Water Storage District	Shafter-Wasco Irrigation District
Southern San Joaquin Municipal Utility District	Tejon-Castaic Water District	West Kern Water District
Westside District Water Authority	Wheeler Ridge-Maricopa Water Storage District	

*Associate member

Under SGMA, the KGA is responsible for submitting a GSP to the DWR by January 31, 2020 and works cooperatively with the other Kern County Sub-basin GSAs to meet the sustainability requirements for the sub-basin as a whole. The KGA is also working with the other Kern County Sub-basin GSAs, and will continue to do so, on the communication and engagement of all beneficial users.

Throughout the SGMA phases, the KGA's Board of Directors, KGA Planning Manager and general managers of each member agency will be responsible for collecting and organizing data, engaging and retaining experts and consultants, and soliciting feedback from beneficial users of groundwater and interested parties within the GSA boundary. The specific roles of the Board of Directors and committees are described in **Section II.A**.

I.A.2 Industries, DACs, Municipalities

I.A.2.1 Industries

Collaboration meetings will be held with the companies and organizations within the following industries to make sure their organizational visions and groundwater needs for facility operations and conservation efforts are taken into consideration during GSP development and implementation phases.

I.A.2.1.1 Agriculture

The primary industry within the KGA is agriculture, as Kern County is currently the number one agricultural-producing county in the United States. The top five commodities produced in Kern County are grapes, almonds, citrus, pistachios and milk, according to the Kern County Agricultural Crop Report published by the Kern County Ag Commissioner's office. These top five crops comprise over $4.3 billion of the over $7 billion in gross value of crops produced within Kern County. Other top commodities produced in Kern County include: carrots, cattle and calves, potatoes, cherries, pomegranates, alfalfa, and silage and forage. As the primary industry, agriculture is the largest private employer in the county, with on-farm employment accounting for 15 percent of all jobs within Kern County, according to California's State Employment Development Department

With a substantial amount of KGA's acreage in agriculture production, it is important agriculture industry stakeholders are involved and informed during the development and public review phases of the GSP, as implementation will have a significant direct impact on the industry, and ultimately the local, state and national economies. KGA will continue to reach out to the Kern County farmers and will work with them collaboratively.

I.A.2.1.2 Food Processing

Kern County is one of the nation's top agricultural producing counties, and a prime location for the food processors to establish their part of the farm-to-table process. Four of the top 10 food processing companies in Central California are established in Kern County, accounting for nearly 15,000 jobs for the local workforce. Because of their significant impact on the economy within the Kern Sub-basin, direct tie to the agricultural industry and substantial reliance on groundwater supplies to operate their facilities, food processors are a crucial piece of groundwater sustainability management within the KGA boundary.

I.A.2.1.3 Oil Production

Kern County is not only one of the nation's top agricultural producing counties, but also one of the nation's top oil producing counties. Oil and agricultural production have shared the surface of Kern County lands for over 100 years and under current conditions will continue sharing. To be exact, the largest landowners within the county are oil companies who produce oil from those land holdings, and also lease those lands for activities such as grazing and the production of agricultural crops, depending on the location within the Kern subbasin. With the passing of SGMA, the oil industry has participated in many workshops and are considered as one of the beneficial users of groundwater within the county. KGA and its members will continue to seek out the oil industry for participation in the process of the GSP development and implementation and consider their industry not only as a beneficial user of groundwater, but also as the provider of additional water from activities of drilling oil.

I.A.2.1.4 Environmental

There are several environmental organizations within the KGA who focus on land conservation efforts (listed in **Table II-4**). The Kern Wildlife Refuge and Kern River Parkway Foundation are two specific organizations that need to be engaged. The KGA will reach out to these organizations to discuss their land conservation needs so that a healthy regional watershed with ecologically functional waterways can be taken into consideration for GSP development and implementation. Collaboration efforts may be put into place for certain groundwater sustainability projects such as the development of recharge basins.

I.A.2.2 DACs

Communication and educational outreach efforts with disadvantaged communities (**DAC**) and severely disadvantaged communities (**SDAC**) is essential for the development and implementation of the KGA's GSP, and residents are generally dedicated to bettering their communities, particularly when it comes to their water supplies. Important information that will be essential to communicate to and engage DACs will include an explanation of SGMA, water conservation education and soliciting feedback. A composite listing of the 22 DACs and SDACs, along with their populations and number of households, within the GSA boundary are listed in **Table I-3** and laid out in **Figure I-2**.

By including DACs and SDACs in communication efforts during the development, public review and implementation phases of the GSP, residents will be more likely to participate and provide feedback that could be crucial to long-term solutions for groundwater sustainability within their communities. Any feedback received from DAC/SDAC residents will be reviewed by the KGA Board of Directors and Stakeholder Committee and taken into consideration during the GSP development phase. During Phase I: GSA Formation & Coordination, the local DACs were engaged in the process and invited to participate in the formation process and with member-representation on the KGA's Board of Directors. The City of Shafter and Arvin Community Services District currently hold Board of Directors seats.

Table I-3. Disadvantaged Communities within the Kern Groundwater Authority

Community	Population	Households	DAC/SDAC
Buttonwillow	1,371	378	SDAC
City of Arvin	20,028	4,595	SDAC
City of Delano	52,883	10,549	SDAC
City of McFarland	12,784	2,817	SDAC
City of Shafter	17,261	4,434	DAC
City of Wasco	25,865	5,264	DAC
Cherokee Strip	295	68	SDAC
Derby Acres	324	145	SDAC
Dustin Acres	295	128	DAC
Edmundson Acres	274	54	SDAC
Fellows	106	37	DAC
Ford City	4,154	1,323	SDAC
Lost Hills	2,194	452	SDAC
Maricopa	1,158	395	SDAC
McKittrick	112	38	DAC
Mettler	88	31	DAC
Mexican Colony	216	63	SDAC
Smith Corner	661	137	SDAC
South Taft	1,680	471	DAC
Tupman	176	45	DAC
Valley Acres	717	227	DAC
Weedpatch	2,170	583	SDAC

I.A.2.3 Municipalities

The municipalities within the KGA are listed in **Table I-4**. These municipalities will be engaged in outreach efforts throughout the GSP development, public review and implementation phases, as described in **Section II.C**. School districts will be an integral part of outreach efforts, particularly within DACs, and are outlined in **Figure I-4** and **Figure I-5**. Further detail on how school districts will be engaged is described in **Section II.C**.

Table I-4. Municipalities within the Kern Groundwater Authority

Municipalities within the Kern Groundwater Authority			
Arvin Community Services District	City of Delano	City of McFarland	City of Maricopa
City of Shafter	City of Taft	City of Wasco	

I.A.3 KGA's Decision-Making Process

The KGA's decision-making process is broken down by the roles of the Board of Directors and Stakeholder Committee. The roles of these KGA entities and their responsibilities are outlined below and described in more detail in **Section II.A**.

- **Board of Directors –** Adopt general policies regarding development and implementation of the GSP
- **Executive Policy Committee** – Need-only committee to provide direction on finances and other issues
- **KGA/GSA Managers Committee –** Meets weekly to coordinate all of the GSPs within the subbasin, which is then presented at the monthly Stakeholder Committee meeting to seek input.

B. Goals/Desired Outcomes of GSP Development

The overall, main goal of the KGA is to establish and execute a plan that will sustain and manage groundwater within the Kern Sub-basin in a way that is cost-effective with minimal negative impacts to the beneficial uses and users.

C. Communication Objectives to Support the GSP

The ultimate goal of communication objectives during the formation/coordination, GSP development, public review and implementation phases of the SGMA compliance, is to encourage active involvement of diverse, social, cultural, and economic elements of the population within the GSA boundary. The KGA will give beneficial users and users of groundwater opportunities to engage in the GSP process, provide educational outreach opportunities for stakeholders while reaching out through specific communication avenues (**Section V**). As primary stakeholders, members of the Board of Directors and Stakeholder Committee are direct representatives of their districts, communities and industries, and it is important for them to continually gather feedback/input, and concerns/needs of their constituents and report back to their respective meetings. Any primary or secondary stakeholder input received will be reviewed and taken into consideration during GSP development.

I.C.1 Phase 1: GSA Formation and Coordination

Phase 1: GSA Formation and Coordination has been completed. This phase stretched from 2015 through 2018, and consisted of forming the KGA, establishing the List of Interested Parties (**Section II.D**), establishing the Stakeholder Committee, and creating the Communication & Engagement Plan to outline communication efforts for the GSP development, public review and implementation phases. Stakeholder input was utilized during the GSA formation phase, as beneficial users and stakeholders with interests in groundwater usage within the KGA's boundary were notified via public meeting notices as soon as the process began.

I.C.2 Phase 2: GSP Preparation and Submission

Phase 2: GSP Preparation and Submission spanned from 2017 through 2019. With the goal to have the draft GSP in the fourth quarter of 2019, 2018 was primarily the technical development of the plan, while working with the Board of Directors and Stakeholder Committee, as well as primary stakeholders (**Section II.A**), for feedback and input. During 2018 and 2019, public outreach meetings and interaction with secondary

stakeholder groups (**Section II.B**) and other community organizations and entities (**Section II.C**) were held with the purpose of educating and informing stakeholders about SGMA and the GSP process, while also soliciting feedback and input from these groups via Stakeholder Surveys (**Section III.A**) to consider and possibly include feedback and input into the GSP.

I.C.3 Phase 3: GSP Review and Evaluation

During 2019, Phase 3: GSP Review and Evaluation, the communication and engagement efforts continued. Once the draft of the GSP was completed late in the third quarter of 2019, the public review process began in the fourth quarter. A 90-day comment period was held, with the GSP draft posted on the KGA's website for primary and secondary stakeholders to conveniently download and review. Outreach meetings were held and presentations given to stakeholders during this phase at the same locations. These meetings focused on an overview of the GSP content, while giving stakeholders a public forum to provide their feedback and comments.

Once the public review period was complete, public comments were taken into consideration and incorporated into the final version of the KGA's GSP before submission to the DWR by January 31, 2020. Following submittal, stakeholders will be given a second 60-day comment period through the DWR's SGMA portal at http://sgma.water.ca.gov/portal/. Comments will be posted to the DWR's website prior to the state agency's evaluation, assessment and approval.

I.C.4 Phase 4: Implementation and Reporting

Phase 4: Implementation and Reporting will begin once the plan is submitted by January 31, 2020. Even while the DWR is reviewing the GSP, SGMA-implementation at the GSA-level must begin. During the implementation phase, communication and engagement efforts will be shifted to educational and informational awareness of the requirements and processes for reaching groundwater sustainability. Active involvement of all stakeholders is encouraged during this phase, and public notices are required for any public meetings and prior to imposing, and later increasing, any fees.

D. Overriding Concerns, Major Concerns or Challenges

Through preliminary discussions with primary stakeholders during the KGA's Stakeholder Committee meetings, overriding concerns, major concerns or challenges are centralized around economic impacts to the agricultural industry, which will also have a direct impact on DACs. Economic impacts could include loss of jobs and loss of tax revenue due to the decreased land values of fallowed ground. Many of DAC residents are employed by the agricultural industry, and many infrastructure improvement projects within these communities are facilitated by the County of Kern and funded through state and federal funding secured with the assistance of technical providers. The agricultural industry and DACs will be the main target audiences for direct outreach meetings because of the significant impact SGMA implementation will have on these two users of groundwater.

A summary of additional top concerning issues affecting groundwater, and the effect of SGMA on agriculture and rural communities/DACs is listed in **Table III-1**.

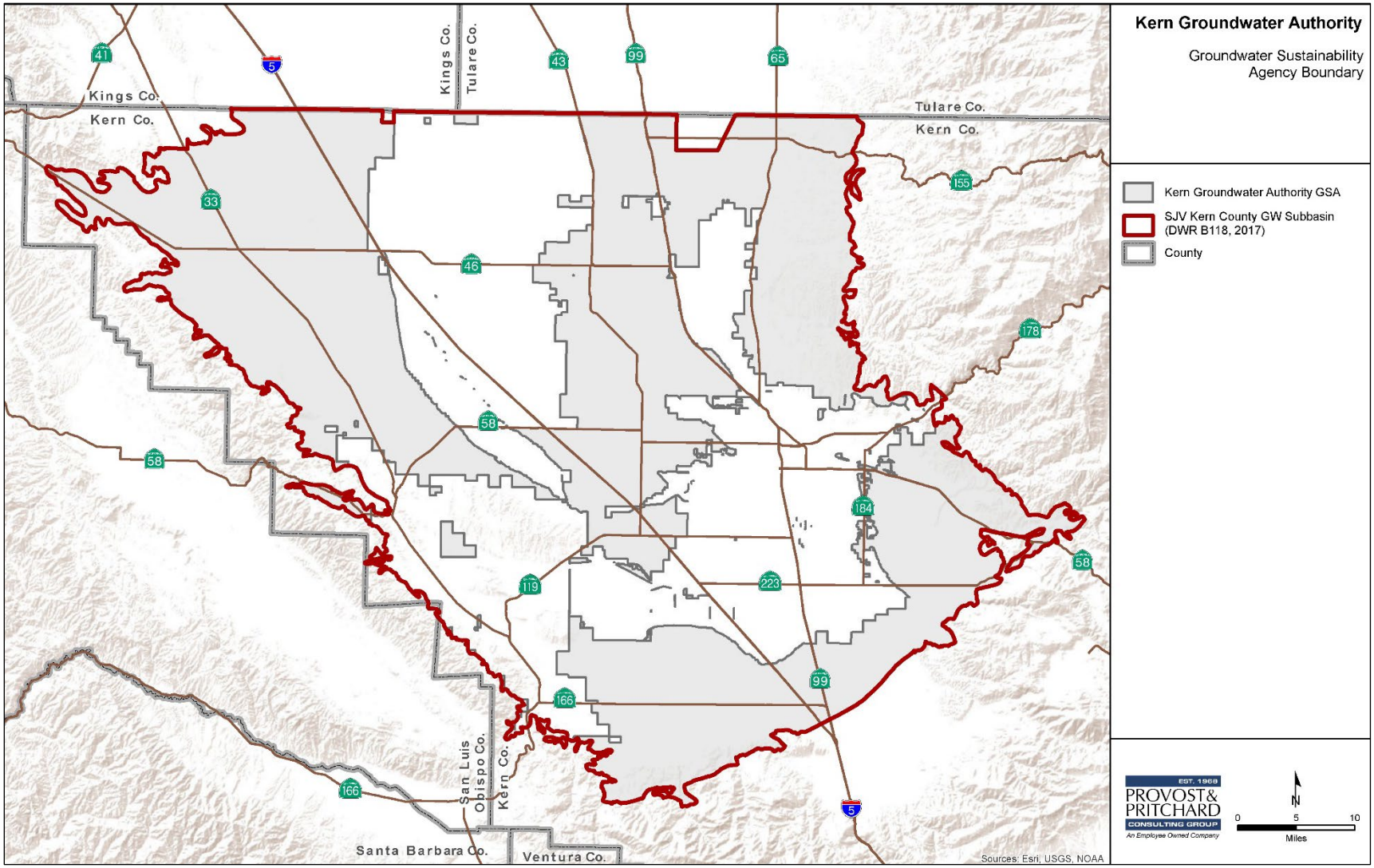


Figure I-1. Kern Groundwater Authority GSA Boundary

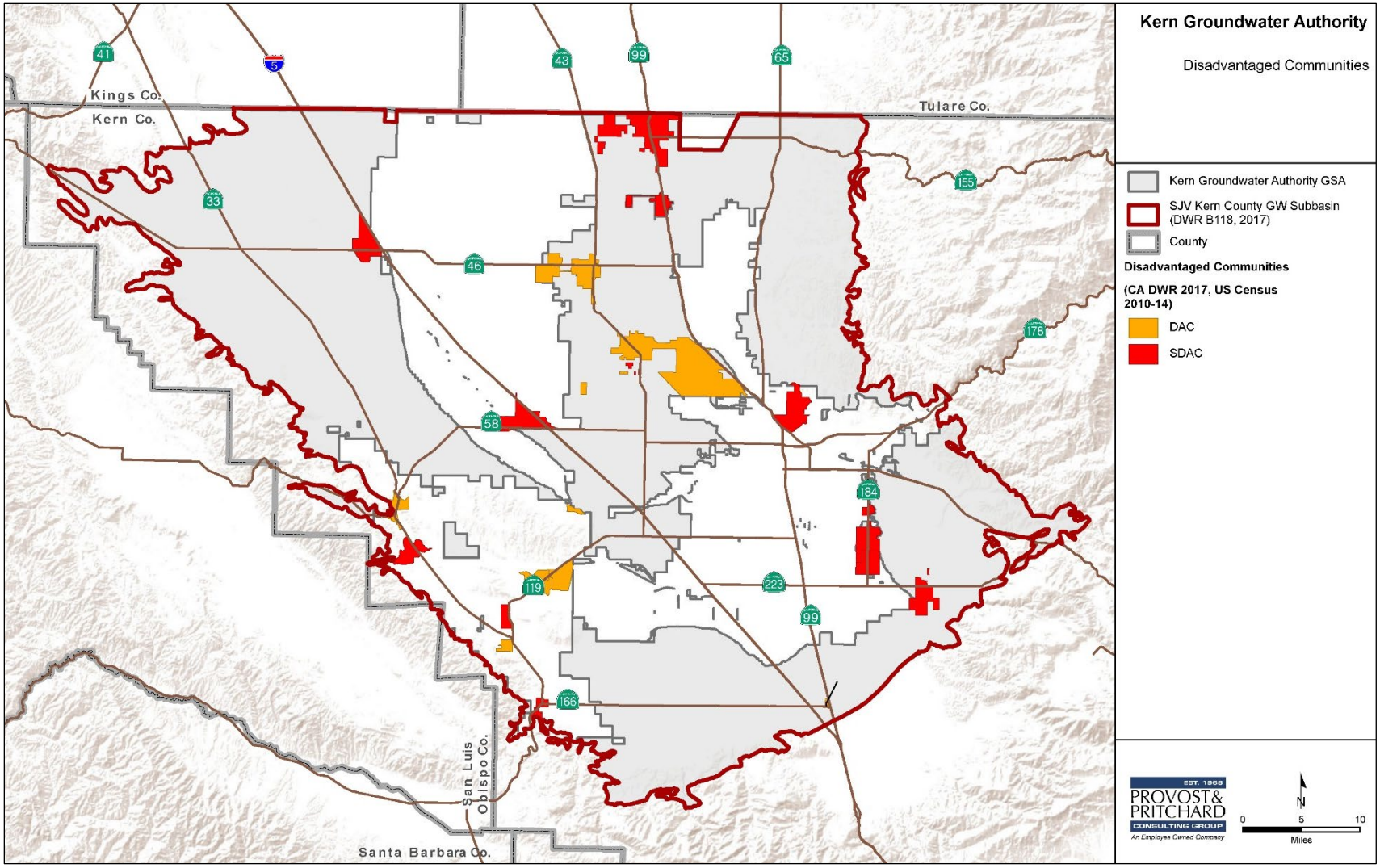


Figure I-2. Disadvantaged Communities within the Kern Groundwater Authority

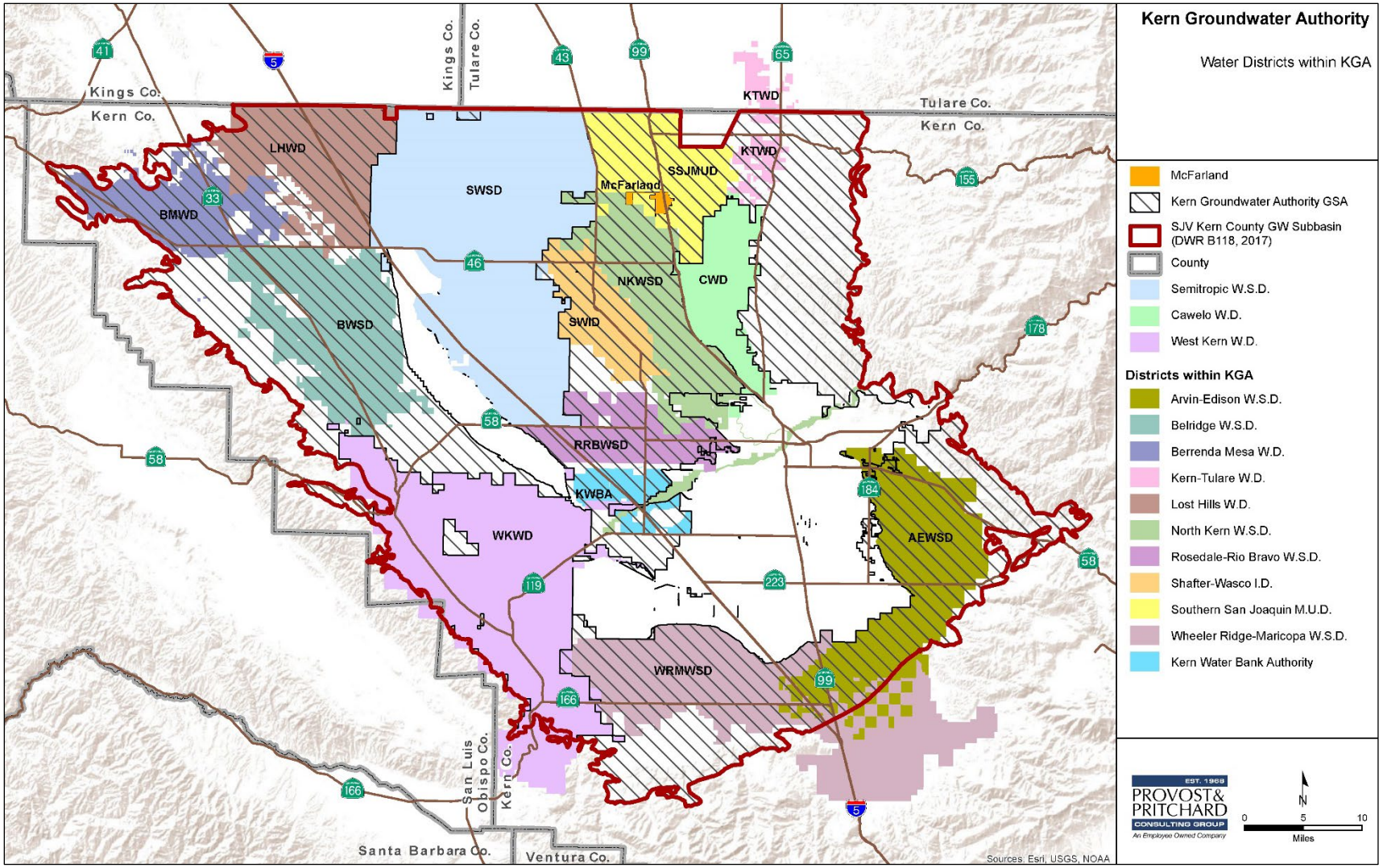


Figure I-3. Kern Groundwater Authority Public Agencies and Water/Irrigation Districts

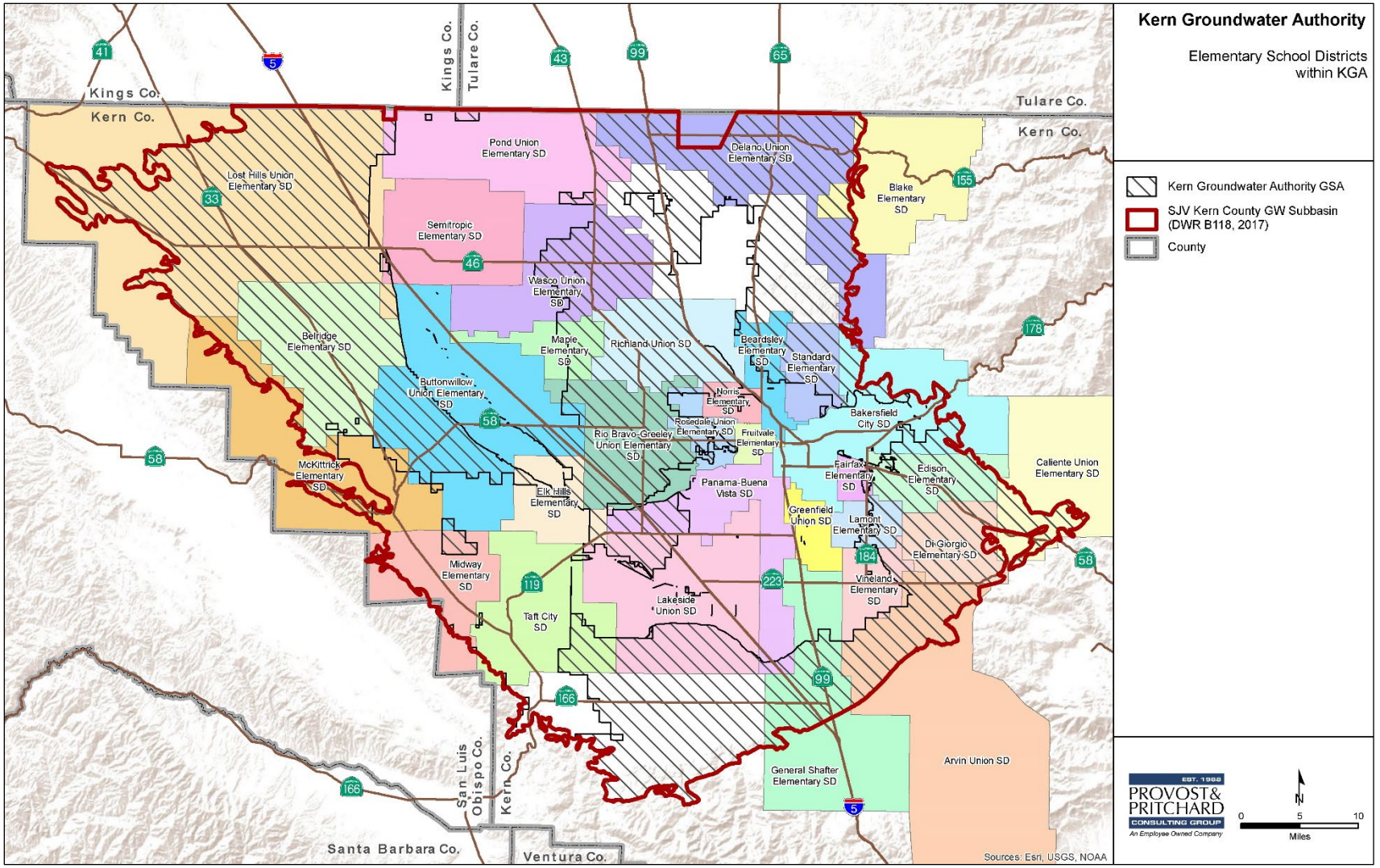


Figure I-4. Elementary School Districts within Kern Groundwater Authority

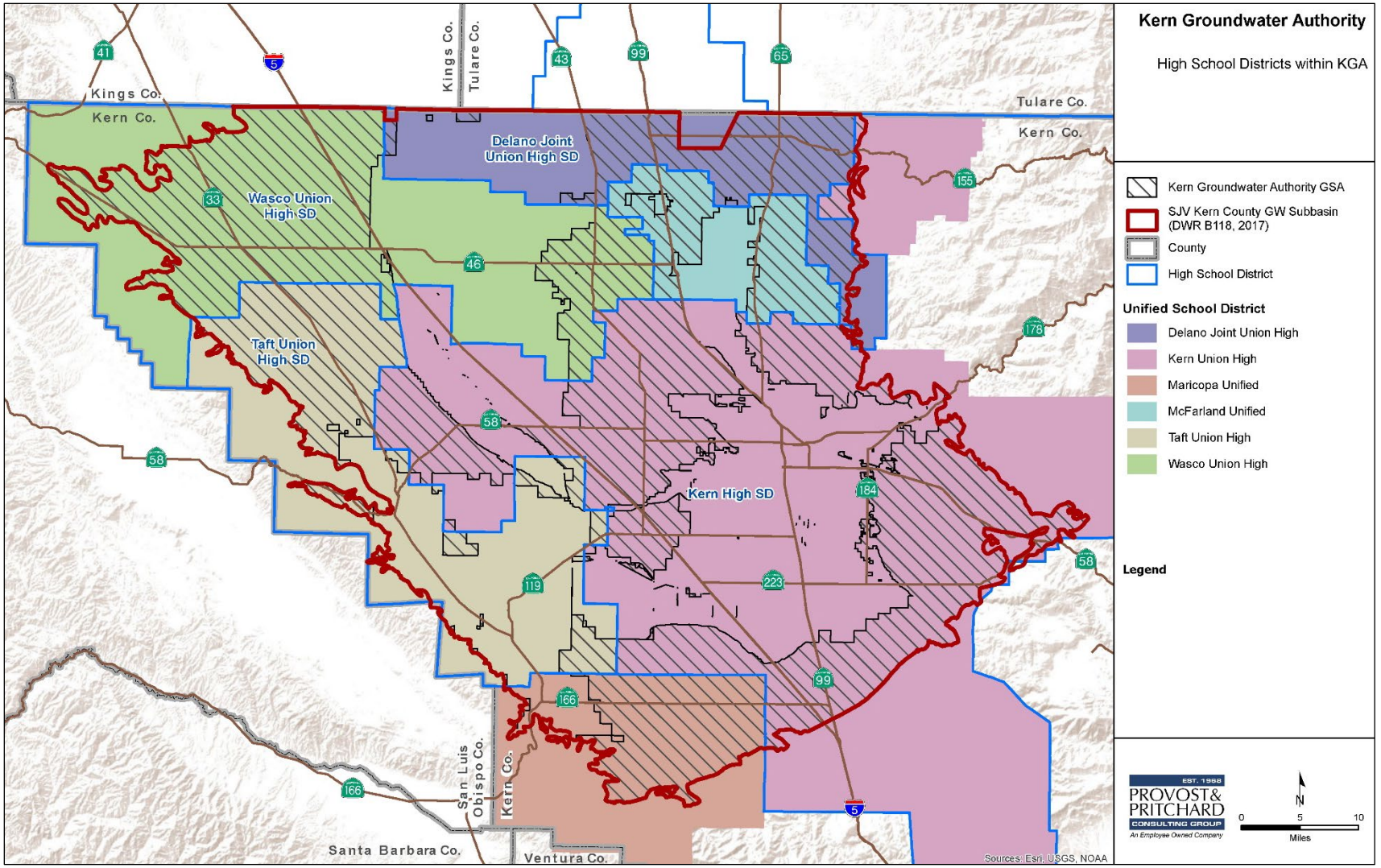


Figure I-5. High School Districts within Kern Groundwater Authority

II. Audience Identification

A. Primary Stakeholder Groups

The primary stakeholder groups of the Kern Groundwater Authority are members of the Board of Directors and Stakeholder Committee. Their specific roles in the communication and engagement process are discussed in this section.

II.A.1 Role of Board of Directors

The Kern Groundwater Authority's Board of Directors is the governing body of the GSA and was formed to adopt general policies regarding development and implementation of the GSP. The Board is comprised of one representative and an alternate from each of the general member agencies (**Table I-1**).

The Board of Directors meetings are held on the fourth Wednesday of every month at the Kern County Administration Building, located at 1115 Truxtun Avenue in Bakersfield, unless otherwise posted on the KGA's website, www.kerngwa.com/board-of-directors.html.

II.A.2 Role of KGA/GSA Managers Committee

The KGA/GSA Managers Committee meets weekly to coordinate the developments of all five groundwater sustainability plans in the Kern Subbasin. The committee is comprised of KGA management and managers from each GSA. The meetings are held every Friday at 8 a.m. at the Rosedale-Rio Bravo Water Storage District office, located at 849 Allen Road in Bakersfield.

II.A.3 Role of Stakeholder Committee

In Section 10727.8 "Public Notification and Participation; Advisory Committee" of the Sustainable Groundwater Management Act, GSAs may appoint and consult with an advisory committee for the purpose of developing and implementing a GSP. Through this advisory committee, the GSA is able to encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin prior to and during the development and implementation of the GSP.

In the general interest of encompassing representatives of all interests of the sub-basin, Kern Groundwater Authority established a Stakeholder Committee. These representatives encompass residential, agricultural, environmental, rural, domestic well, and municipal interests. The specific role of the KGA's Stakeholder Committee is to serve as a sounding board for the ideas/concepts developed by the KGA/GSA Managers Committee. Their comments and input have been and will continue to be encouraged and considered in the development of SGMA concepts and implementation.

The Stakeholder Committee meets on the first Monday of every month at 3 p.m. at the Rosedale-Rio Bravo Water Storage District, located at 849 Allen Road in Bakersfield, California, unless otherwise posted on the KGA's website: www.kerngwa.com/stakeholders.html.

B. Secondary Stakeholder Groups

Secondary stakeholder groups have been identified by the Kern Groundwater Authority, based on discussions of interests identified in SGMA, Section 10723.2 "Consideration of All Interests of All Beneficial Uses and Users of Groundwater" (**Table II-1**).

Table II-1. Consideration of All Interests of All Beneficial Uses and Users of Groundwater

SGMA, Section 10723.2. Consideration of All Interests of All Beneficial Uses and Users of Groundwater		
Agricultural Users	Domestic Well Owners	Municipal Well Operators
Public Water Systems	Local Land Use Planning Agencies	Environmental Users of Groundwater
Surface Water Users	Federal Government	California Native American Tribes
Disadvantaged Communities	Entities monitoring and reporting groundwater elevations in all or part of a groundwater basin	

Based on these discussions, secondary stakeholders to be targeted for communication and engagement during the GSP development, public review and implementation phases have been narrowed to those with financial, political, business or personal stakes in the management and sustainability of groundwater within the jurisdiction of the Kern Groundwater Authority. These secondary stakeholders are listed in **Table II-2**.

Table II-2. Secondary Stakeholder Groups with Interests in the Kern Groundwater Authority

Secondary Stakeholder Groups with Interests in the Kern Groundwater Authority		
Agricultural Users	Domestic Well Owners	Municipal Well Operators
Public Water Systems	Local Land Use Planning Agency	Environmental User
Surface Water Users	Native American Tribes	Disadvantaged Communities
City Resident*	Food Processor*	Industrial User/Oil Producer*
Entity monitoring and reporting groundwater elevations in all or part of a groundwater basin		

*Additional secondary stakeholder groups identified by the KGA

Secondary stakeholder groups will be engaged through public outreach meetings and email blasts. These meetings will be held during Phase 2: GSP Preparation and Submission, Phase 3: GSP Review and Evaluation, and Phase 4: Implementation and Reporting.

II.B.1 Native American Tribes

Native American Tribes within the KGA boundary will be invited to participate in GSP development. The KGA will reach out to them by sending them a letter about SGMA and the KGA along with a stakeholder survey. These tribes are listed in **Table II-3**.

Table II-3. Native American Tribes in the Kern Groundwater Authority

Native American Tribe	Contact	Contact Information
Kitanemuk & Yowlumne Tejon Indians (Yowlumne Kitanemuk)	Delia Dominguez, Chairperson	115 Radio Street Bakersfield, CA 93305 Telephone: (626) 339-6785 Email: deedominguez@juno.com

Source: Native American Heritage Commission, Native American Contacts (January 18, 2018)

C. Community Organizations, Public Agencies and Other Entities

There are many community organizations, public agencies and other entities throughout the KGA's boundary that will be utilized to reach out to secondary stakeholders. These resources identified as avenues for outreach opportunities are listed in **Table II-4**. Additional community organizations, public agencies and entities may be added to the list as GSP development and implementation phases move forward, and additional connections are made between the KGA and the communities within its boundary.

The Kern Groundwater Authority will communicate with these resources and request opportunities to give presentations at their respective meetings. If a Board of Director or Stakeholder Committee member is currently involved with or has contacts within a community organization, public agency or other entity, they may present on behalf of the KGA to further outreach efforts. Presentations may include an overview on SGMA and why it is important to the audience, explanation and updates of the GSP development process including an awareness of the public review period, and education of GSP requirements during the implementation phase. In addition, the KGA and the member districts will work with these organizations and agencies to distribute stakeholder surveys, public outreach meeting notices, and educational information via email distribution, social media posts, and printed materials (handouts).

II.C.1 School Districts

School districts within the KGA boundary are also listed in **Table II-4**. While many of the schools receive their water from the cities they are located in, they are an avenue for communicating with stakeholders whose students attend the schools, particularly families within DACs/SDACs.

Table II-4. Community Organizations and Public Agencies

Community Organization & Public Agencies	Secondary Stakeholder Group(s)	Website	KGA Member Entity Responsible for Outreach
Agriculture Organizations			
California Citrus Mutual	Agricultural Users, Domestic Well Owners, Surface Water Users	https://www.cacitrusmutual.com/	Kern Groundwater Authority
California Women for Agriculture – Kern Chapter	Agricultural Users, Domestic Well Owners, Surface Water Users	Email: kerncountycwa@gmail.com	Kern Groundwater Authority
Kern River Watershed Coalition Authority (KRWCA) – Irrigated Lands Regulatory Program	Agricultural Users, Domestic Well Owners, Surface Water Users	http://www.krwca.org	Kern Groundwater Authority
Kern County Cattlewomen	Agricultural Users, Domestic Well Owners, Surface Water Users, Environmental	http://www.kerncattlewomen.org/	Kern Groundwater Authority
Kern County Cattlemen's Association	Agricultural Users, Domestic Well Owners, Surface Water Users, Environmental		Kern Groundwater Authority
Kern County Farm Bureau, Kern County Young Farmers & Ranchers	Agricultural Users, Domestic Well Owners, Surface Water Users	https://kerncfb.com/	Kern Groundwater Authority
University of California Cooperative Extension – Kern County	Agricultural Users, Domestic Well Owners, Surface Water Users	http://cekern.ucanr.edu/	Kern Groundwater Authority
DACs/Environmental Justice Organizations			
Center for Race, Poverty & the Environment (Delano office)	DACs and SDACs, Environmental Users	https://crpe-ej.org/en/	Kern Groundwater Authority
Community Water Center	DACs and SDACs	http://www.communitywatercenter.org/	Kern Groundwater Authority
Leadership Counsel for Justice & Accountability	DACs and SDACs	http://www.leadershipcounsel.org/	Kern Groundwater Authority
Rural Communities Association Corporation	Agricultural Users, Domestic Well Owners, Environmental, DACs	http://www.rcac.org/	Kern Groundwater Authority
Self-Help Enterprises	DACs and SDACs	https://www.selfhelpenterprises.org/	Kern Groundwater Authority

Community Organization & Public Agencies	Secondary Stakeholder Group(s)	Website	KGA Member Entity Responsible for Outreach
Environmental Organizations			
Audubon California	Environmental Users	http://ca.audubon.org/	Kern Groundwater Authority
California Waterfowl	Environmental Users	https://www.calwaterfowl.org/	Kern Groundwater Authority
Ducks Unlimited	Environmental Users	http://www.ducks.org/california/california-state-district-chairmen	Kern Groundwater Authority
Sequoia Riverlands Trust	Environmental, Agricultural Users	http://sequoiariverlands.org/	Kern Groundwater Authority
Sierra Club – Kern-Kaweah Chapter, Buena Vista Group	Environmental Users	https://www.sierraclub.org/kern-kaweah/buena-vista-group	Kern Groundwater Authority
Tejon Ranch Conservancy	Environmental, Agricultural Users	http://www.tejonconservancy.org/	Kern Groundwater Authority
The Nature Conservancy	Environmental	http://www.nature.org	Kern Groundwater Authority
Irrigation Districts/Water Districts/Water Agencies			
Arvin Community Services District	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	https://www.arvincsd.com/	Arvin Community Services District
Arvin-Edison Water Storage District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	http://www.aewsd.org/	Arvin-Edison Water Storage District
Kern County Integrated Regional Water Management Group	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems, DACs, Municipal Well Operators, Environmental Users	http://www.kernirwmp.com/	Kern Groundwater Authority
Cawelo Water District	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	http://www.cawelowd.org/	Cawelo Water District
Eastside Water Management Area (white area within Kern County)	Agricultural Users, Domestic Well Owners	Jim Beck (661) 333-7091; jbeck@hgcpm.com	Eastside Water Management Area, Kern Groundwater Authority

Community Organization & Public Agencies	Secondary Stakeholder Group(s)	Website	KGA Member Entity Responsible for Outreach
Kern County Water Agency	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	http://www.kcwa.com/	Kern Groundwater Authority
Kern-Tulare Water District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems		Kern-Tulare Water District
Kern Water Bank Authority	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	http://www.kwb.org/	Kern Water Bank Authority
North Kern Water Storage District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	http://northkernwsd.com/	North Kern Water Storage District
Rosedale-Rio Bravo Water Storage District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	http://www.rrbwsd.com/	Rosedale-Rio Bravo Water Storage District
Semitropic Water Storage District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	http://www.semitropic.com/	Semitropic Water Storage District
Shafter-Wasco Irrigation District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	http://www.swid.org/	Shafter-Wasco Irrigation District
Southern San Joaquin Municipal Utility District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	http://www.ssjmud.org/	Southern San Joaquin Municipal Utility District
Tejon-Castaic Water District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems		Tejon-Castaic Water District
Water Association of Kern County	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	http://www.wakc.com/	Kern Groundwater Authority

Community Organization & Public Agencies	Secondary Stakeholder Group(s)	Website	KGA Member Entity Responsible for Outreach
West Kern Water District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	http://www.wkwd.org/	West Kern Water District
Westside District Water Authority	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems		Westside District Water Authority
Wheeler Ridge-Maricopa Water Storage District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs, Public Water Systems	https://wrmwsd.com/	Wheeler Ridge-Maricopa Water Storage District
Municipal Agencies/Chambers of Commerce			
Arvin Chamber of Commerce	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems, DACs, Municipal Well Operators	http://www.arvinchamberofcommerce.com/	Arvin Community Service District
Greater Bakersfield Chamber of Commerce	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems, DACs, Municipal Well Operators	https://www.bakersfieldchamber.org/	Kern River Groundwater Authority
City of McFarland	Public Water Systems, Municipal Well Operators, DACs	https://www.mcfarlandcity.org/	Southern San Joaquin Municipal Utility District
City of Shafter	Public Water Systems, Municipal Well Operators, DACs	https://www.shafter.com/	Shafter-Wasco Irrigation District
City of Taft	Public Water Systems, Municipal Well Operators, DACs	http://www.cityoftaft.org/	West Kern Water District
City of Wasco	Public Water Systems, Municipal Well Operators, DACs	http://www.ci.wasco.ca.us/	Shafter-Wasco Irrigation District
County of Kern – Board of Supervisors and County Management	Domestic Well Owners, Surface Water Users, DACs, Municipal Well Operators, Public Water Systems	https://www.kerncounty.com/	Kern Groundwater Authority
Greater Lamont Chamber of Commerce	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems, DACs, Municipal Well Operators	https://lamontchamber.wildapricot.org/	Arvin-Edison Water Storage District

Community Organization & Public Agencies	Secondary Stakeholder Group(s)	Website	KGA Member Entity Responsible for Outreach
Shafter Chamber of Commerce	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems, DACs, Municipal Well Operators	http://www.shafterchamber.org/	Shafter-Wasco Irrigation District
Taft District Chamber of Commerce	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems, DACs, Municipal Well Operators	https://www.taftchamber.com/	West Kern Water District
Wasco Chamber of Commerce	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems, DACs, Municipal Well Operators	Post Office Box 783, Wasco, California 93280 Telephone: (661) 758-2746	Shafter-Wasco Irrigation District
School Districts & Parent-Teacher Associations			
Arvin Union School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://www.arvinschools.com/	Arvin Community Services District, Arvin-Edison Water Storage District
Bakersfield City School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.bcsd.com/	Arvin-Edison Water Storage District
Beardsley Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://beardsleyschool.org/	Kern Groundwater Authority, County of Kern
Belridge Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://belridgeschool.org/	Belridge Water Storage District
Blake Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs		Kern Groundwater Authority, County of Kern
Buttonwillow Union Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.buttonwillow.k12.ca.us/	Belridge Water Storage District, Rosedale-Rio Bravo Water Storage District
Caliente Union Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs		Arvin-Edison Water Storage District
Delano Union Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.duesd.org/	Southern San Joaquin Municipal Utility District, Kern-Tulare Water District, Lost Hills Water District
Delano Joint Union High School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.djuhsd.org/	Southern San Joaquin Municipal Utility District

Community Organization & Public Agencies	Secondary Stakeholder Group(s)	Website	KGA Member Entity Responsible for Outreach
Di Giorgio Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://digiorgio.k12.ca.us/	Arvin-Edison Water Storage District
Edison Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.edison.k12.ca.us/	Arvin-Edison Water Storage District
Elk Hills Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://elkhills.k12.ca.us/	Kern Water Bank Authority
Fairfax Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.fairfax.k12.ca.us/	Arvin-Edison Water Storage District
General Shafter Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://generalshafter.org/	Arvin-Edison Water Storage District, Wheeler Ridge-Maricopa Water Storage District
Kern High School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.kernhigh.org/	Arvin-Edison Water Storage District, Wheeler-Ridge Maricopa Water Storage District, Kern Water Bank Authority, Rosedale-Rio Bravo Water Storage District, North Kern Water Storage District
Lakeside Union School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.lakesideusd.org/	Wheeler Ridge-Maricopa Water Storage District
Lamont Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.lamontschooldistrict.org/	Arvin-Edison Water Storage District
Lost Hills Union School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.losthills.k12.ca.us/	Lost Hills Water District, Berrenda Mesa Water District
Maple Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	Telephone: (661) 746-4439	Shafter-Wasco Irrigation District
Maricopa Unified School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://www.musd20.org/	Wheeler Ridge-Maricopa Water Storage District
McKittrick Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	Telephone: (661) 762-7303	Belridge Water Storage District

Community Organization & Public Agencies	Secondary Stakeholder Group(s)	Website	KGA Member Entity Responsible for Outreach
Midway Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://midwayschooldistrict.org/	Kern Groundwater Authority
Norris School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.norris.k12.ca.us/	North Kern Water Storage District
Panama-Buena Vista School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.pbvusd.k12.ca.us/	Kern Water Bank Authority, Rosedale Rio Bravo Water Storage District
Pond Union Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://www.pond.k12.ca.us/	Southern San Joaquin Municipal Utility District, North Kern Water Storage District
Richland Union School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.richland.k12.ca.us/	Shafter Wasco Irrigation District, North Kern Water Storage District
Rio Bravo-Greeley Union School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://www.rbgusd.k12.ca.us/	Rosedale-Rio Bravo Water Storage District, Kern Water Bank Authority
Rosedale Union Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.ruesd.net/	North Kern Water Storage District, Rosedale-Rio Bravo Water Storage District
Standard Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://std-elem.standard.k12.ca.us/	Kern Groundwater Authority
Taft City School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://taftcityschools.com/	West Kern Water District
Taft Union High School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.taft.k12.ca.us/	West Kern Water District
Vineland Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	http://vineland.k12.ca.us/	Arvin-Edison Water Storage District
Wasco Union Elementary School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.wuesd.org/	North Kern Water Storage District, Shafter-Wasco Irrigation District
Wasco Union High School District	Agricultural Users, Domestic Well Owners, Surface Water Users, DACs	https://www.wascouhsd.org/	Shafter-Wasco Irrigation District

Community Organization & Public Agencies	Secondary Stakeholder Group(s)	Website	KGA Member Entity Responsible for Outreach
Service Clubs			
Kiwanis Club of Taft	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	http://taftkiwanis.org/	West Kern Water District
Kiwanis Club of Shafter	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	http://www.kiwanisdiv33.com/skhome.htm	Shafter-Wasco Irrigation District
Rotary Club of Taft	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	https://portal.clubrunner.ca/2865/	West Kern Water District
Shafter Lions Club	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	Post Office Box 1264, Shafter, California 93263; Email: gtalvarado5@yahoo.com	Shafter-Wasco Irrigation District
Shafter Rotary Club	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	http://rotarydistrict5240.org/clubinfophoto/shafter	Shafter-Wasco Irrigation District
Taft Midway-Sunset Lions Club	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	123 N. 10th Street, Taft, California 93268; Telephone: (661) 763-4977	West Kern Water District
Wasco Elks Lodge	Agricultural Users, Domestic Well Owners, Surface Water Users, Public Water Systems	Telephone: (661) 758-2235	Shafter-Wasco Irrigation District
Industries			
California Independent Petroleum Association (CIPA)	Industrial (Oil Production)	Telephone: (661) 395-5287; Email: willie@cipa.org	Kern Groundwater Authority

D. Interested Persons List

SGMA Section 10723.4 "Maintenance of Interested Persons List" states: *"The groundwater sustainability agency shall establish and maintain a list of persons interested in receiving notices regarding plan preparation, meeting announcements, and availability of draft plans, maps, and other relevant documents. Any person may request, in writing, to be placed on the list of interested persons."* In compliance with the SGMA requirement, the Kern Groundwater Authority maintains a list of interested persons, and routinely distributes meeting notices and relevant information to the stakeholders who have requested to be included.

Over 300 individuals have signed up or been added to the Interested Persons List, and the KGA will continue to grow this contact list through the process discussed in **Section V.A.4**.

III. Audience Survey and Mapping

Through ongoing communications and public education and outreach efforts described in **Section V**, primary and secondary stakeholders will have the opportunity to have a voice in the GSP development process. This section discusses in detail the preliminary discussion with primary stakeholders, and implementation of the Stakeholder Survey, which will be a valuable source in collecting feedback from target audiences who have vested interests in how the implementation of the GSP will affect their interests.

A. Stakeholder Survey

III.A.1 Identification of Stakeholder Issues, Interests and Challenges

Stakeholder issues, interests and anticipated challenges are routinely discussed in Board of Directors and Stakeholder Committee meetings. Stakeholder Committee members represent the interests of the secondary stakeholders identified for the KGA (**Table II-2**). Two stakeholder surveys were developed and circulated to solicit input to identify issues, interests and challenges stakeholders are facing and concerned about. **Table III-1** summarizes preliminary responses, which were taken into consideration during the GSP development process and used as a basis for the development of fact sheets and public meeting presentations for secondary stakeholder groups.

Table III-1. Stakeholder Issues, Interests & Challenges

Stakeholder Issues, Interests & Challenges	
Top Concerning Issues Affecting Groundwater:	• Economic impacts (loss of jobs, loss of complete industries, loss of tax revenue due to decrease in land values of fallowed ground) • Overpumping and the subsequent legislation (over-regulation) • Long term quantity and quality • Government regulations and involvement • Fallowing of farmland (loss of production) • Water allocations for domestic use vs. agriculture production with SGMA implementation • Dry wells
Top Concerns of SGMA:	• Economic impacts (loss of jobs, loss of tax revenue due to decrease in land values of fallowed ground) • New regulations (i.e. SGMA and ILRP), and the impacts on investments and livelihoods • Legal rights to groundwater (concerns of unequal representation amongst landowners) • Water usage (surface water vs. groundwater) • Decreased quality of food for California and the United States as a whole • Concerns that the agriculture industry will have to pay for SGMA implementation for all of the beneficial users of groundwater

III.A.2 Survey Questions

Secondary stakeholders needed to have an opportunity to be heard during the GSP development process, in addition to the involvement of the primary stakeholders who represent their interests. The Stakeholder Survey process is a way to gather information from these individuals. The process for conducting the Stakeholder Surveys is discussed in **Section V.A.4**. The final Stakeholder Surveys are included in **Appendix B**, in both English and Spanish.

III.A.2.1 Initial Stakeholder Survey

The initial Stakeholder Survey circulated by KGA and its members was based on survey questions recommended by the DWR, which are listed below. A memorandum with the survey results is included in **Appendix B.** The KGA Board of Directors adjusted the wording on a few of the questions:

1. Are you familiar with Sustainable Groundwater Management Act (SGMA) regulations?
2. Are you currently working on or discussing groundwater management in this region?
3. Do you own or manage/operate land in this region?
4. Do you manage water resources? If yes, what is your role?
5. What is your primary interest in land or water resources management?
6. Do you have concerns about groundwater management? If so, what are they?
7. Do you have requests or recommendations regarding groundwater management? If so, what are they?

The Kern Groundwater Authority incorporated additional questions into the survey to further define the needs and concerns of the users within the GSA boundary:

1. Where are you getting your water supply?: City or Community Water System, Surface, Groundwater, Both Groundwater & Surface Water, Unknown
2. Agriculture & Domestic Well Users: What is your well(s) depth?
3. Agriculture & Domestic Well Users: Has your well(s) ever gone dry? If so, when (month/year)?
4. If you are an Agricultural User, do you: Irrigate, Dry Farm, Graze Livestock, Other
5. How reliable is your current groundwater supply?
6. If you grow crops, do you use irrigation for frost protection?
7. Any other information the Kern Groundwater Authority should be aware of or take into consideration while developing the GSP?

If follow-up questions were needed further into the GSP development phase, a second Stakeholder Survey would have been developed and circulated amongst stakeholders who completed the initial round of surveys.

III.A.2.2 Agriculture-Focused Stakeholder Survey

A second Stakeholder Survey was developed and tailored specifically for agriculture stakeholders. Questions and options from the Ag-Focused Stakeholder Survey are listed below. A memorandum with the survey results is included in **Appendix B**.

1. We have included a map of the Kern Groundwater Authority irrigation and water districts. Please indicate below which districts you have land parcels. (check all that apply)
2. How many total acres do you farm (all land owned, leased and/or managed)?
3. In a typical year, how much of the following crops, animals or land do you manage/own? Options included: fruit trees, nut trees, row crows, seed crops, vegetables, grain, grapes, hay/alfalfa, livestock on pasture/rangeland, dairy (total head), food processor/production, or "other" land use.
4. Which of the following sources of water and management do you typically utilize under the following conditions (dry years, normal years, wet years)? Water source/management options included: irrigation through surface water only, irrigation through groundwater only, irrigation through a mixture of surface and groundwater, wastewater land applied, and no irrigation.
5. If you do use irrigation, which of the following methods of delivery do you use? Option included furrow/flood, sprinklers, drip, microsprinkler, center pivot, and "other."

6. In response to water scarcity, please indicate if you currently use the following practices and your likelihood to use the following practices in the future. Practices listed included: drill more wells, restore existing wells, make existing wells deeper, pump more groundwater than previous years, drip irrigation, water monitoring technology, fallow fields, soil moisture sensors, change to a less water intensive crop, reduce livestock stocking rates, leaf sampling to measure plant-water status, purchase additional water, purchase crop insurance, and "other."
7. Please rate the level of importance these potential groundwater conditions are to you (with "1" being the most concerning, "5" being the least concerning). If you have additional concerns, please indicate them in the "Other" category. Groundwater conditions listed for rating included: lowering of groundwater levels, reduction in groundwater storage, water quality degradation, local subsidence, depletions of surface water, and "other."
8. The following are a list of management options that have been used on the West Coast for water management. Please provide your level of preference for these types of management (ranging from strongly against to strongly support, and not familiar). Management options listed included: individual recharge credits (i.e. winter flooding), water metering, water trading through markets, public program highlighting farmers implementing water saving practices, farmer adoption of water management practices, district investment in conjunctive use infrastructure (i.e. water storage), groundwater replenishment fees, fixed quota for water pumping allocated to each farmer, incentives for water saving practices, moratorium on drilling new wells, permits for drilling new wells, and "other."
9. If groundwater is required in the future, which of the following monitoring methods would you prefer (ranging from strongly not preferred to strongly preferred)? Methods of determining water allocation listed included: well metering, use satellite estimates and ground truth, and use standard crop water requirement indexes.
10. Should disputes arise over SGMA implementation, what is your preferred means of reconciliation (ranging from strongly not preferred to strongly preferred)? Dispute options included: State Water Resources Control Board, groundwater sustainability agency, County Board of Supervisors, Superior Court system, arbitration, and "other."
11. If you have any additional information or feedback regarding SGMA, water management, or farming in Kern County that should be taken into consideration while developing the Groundwater Sustainability Plan, please provide the information below.

III.A.3 Stakeholder Survey Distribution

Printed and online distribution methods for the Stakeholder Survey are described in **Section V.A.3.2** and **Section V.A.4**. Surveys were part of the KGA's Board of Directors agenda every month to review results and discuss submitted stakeholder input. The result summaries from both surveys are include in **Appendix B**.

B. "Lay of the Land" Overview

Results from Stakeholder Surveys will be compiled into a "Lay of the Land Overview" to categorize the feedback received so the technical team can utilize the information during the GSP development phase. This data will be sorted by:

- Type of stakeholder
- Key interests related to groundwater

- Key issues (documented or specific issues of past events)
- Which section of the GSP is this applicable to?

Preliminary results from stakeholder surveys completed in April 2018 are listed in **Table III-1**. These results will be used as a basis for the development of fact sheets and key messages and talking points (**Section IV**).

III.B.1 Types of Stakeholders

Types of stakeholders with the greatest interests in the GSP development and resulting implementation efforts to reach groundwater sustainability include agricultural users, domestic well owners, municipal well operators, public water systems, environmental users, surface water users, and disadvantaged communities.

Stakeholder surveys are geared more specifically for agricultural users, domestic well owners, surface water users, and residents of disadvantaged communities. Representatives of municipal well operators, public water systems and environmental users are integral parts of the primary stakeholder group, and are a more specific, smaller target audience. Surveys will not be tailored specifically for their interests, as information can be more easily gained and addressed through one-on-one conversations and collaborative discussions.

III.B.2 Stakeholder Key Interests Related to Groundwater

The key interests of stakeholders related to groundwater within the KGA boundary include:

- Drinking water
- Domestic, everyday usage
- Agriculture – Farming, ranching (livestock)
- Industrial, food processing, oil production, power generation
- Recreational
- Environmental ecosystem management areas

III.B.3 Key Documented Issues

Several key documented water resources issues have affected, or have the potential to affect, the interests of stakeholders within the Kern Groundwater Authority boundary. As key documented issues arise throughout GSP development, public review and implementation phases, they will be added to this section.

- **Dry Wells –** Several private wells within Kern County have gone dry for various reasons including drought implications and poor infrastructure of the existing wells. Self-Help Enterprises and the County of Kern are working with owners to mitigate the situation.

IV. Messages and Talking Points

Key messages and talking points will be broken down by phases and stakeholder groups, as different factors and issues will affect different groundwater interests. These messages and talking points are also prone to evolve as the GSP is developed, leaving this section open to being amended and finetuned as communication and engagement efforts move forward.

Fact sheets reflecting key messages will be developed and tailored for the specific GSP development, public review and implementation phases, and made available for public education efforts described in **Section V.A.3.2**.

IV.A.1 Key Messages & Talking Points

IV.A.1.1 Universal Key Messages

Universal key messages will be a consistent part of fact sheets and talking points throughout all phases of GSP development, public review and implementation.

- What is SGMA
- Common Uses of Groundwater
- What is the Role of a GSA
- KGA Purpose Statement – Establish and execute a plan that will sustain and manage groundwater within the Kern Sub-basin in a way that is cost-effective, with minimal negative impacts to the beneficial uses and users.

IV.A.1.2 Phase 1: GSA Formation and Coordination

The Phase 1: GSA Formation and Coordination has been completed. During this phase, key messages centered around developing the Board of Directors, official formation of the GSA, and soliciting individuals who represent the interests of all beneficial usages and users of groundwater within the KGA boundary to fill the seats of the Stakeholder Committee.

IV.A.1.3 Phase 2: GSP Preparation and Submission

The first fact sheet will be developed and made available on the KGA website, as well as distributed at public outreach meetings and community organization presentations, and with stakeholder surveys. In addition to the universal key messages, the fact sheet for the GSP development and submission phase will include:

- Timeline of the GSP process
- Industry-related water usage – Common practices and conservation efforts (tailored specific to district stakeholders)
- Industry-related educational statistics for community and economic impacts (tailored specific to district stakeholders)
- Top concerns – Everyday usage/lifestyle impacts, economic impacts, land fallowing
- Direction on providing input/voicing concerns (outreach meetings, stakeholder surveys)
- Importance of imported water for people and economic viability

IV.A.1.4 Phase 3: GSP Review and Evaluation

Once the draft of the KGA's GSP is completed, a second fact sheet will be developed. This fact sheet will also consist of the universal key messages, while the rest of the content will be focused on:

- Timeline of the GSP process
- Main points/overview of the GSP
- Process for public review of GSP draft and providing comments to the KGA
- Additional key messages may be added for this phase.

IV.A.1.5 Phase 4: Implementation and Reporting

Once the KGA's GSP has been submitted to the DWR, the implementation phase will begin, and key messages will be developed with a focus on implementation efforts that affect the secondary stakeholder groups, which will likely result in more than one fact sheet. As with the previous phases, universal key messages will be included.

IV.A.2 Likely Questions or Issues and Responses

The "Likely Questions or Issues" list in **Table IV-1** will evolve through the GSP development, public review and implementation phases. This table will expand as additional questions surface throughout the phases, and responses will be updated as the KGA's GSP is developed and answers are more clearly defined.

Table IV-1. Likely Questions or Issues

Likely Question or Issue	Response	Phase
"Will I have to fallow my land?"	That information has not been determined yet, as we are in the preliminary stages of GSP development.	Phase 1 & 2
"How can I voice my concerns about how SGMA is going to affect me?"	The public is invited to attend Stakeholder Committee meetings and Board of Director meetings to be informed about the progress of GSA and GSP development. Public outreach meetings will be held in 2018, and stakeholder surveys may be completed online via www.kerngwa.com, which will give the public a direct voice into the development of the GSP.	Phase 2
"How much water are we going to be able to pump?"	That information has not been determined yet, as we are in the preliminary stages of GSP development.	Phase 1 & 2
"Are our ag pumps going to be metered? If so, who is going to pay for it?"	That information has not been determined yet, as we are in the preliminary stages of GSP development.	Phase 1 & 2
"What types of management actions and/or projects can improve groundwater conditions?"	That information has not been determined yet, as we are in the preliminary stages of GSP development.	Phase 1 & 2
"Can groundwater management activities improve water challenges in DACs?"	That information has not been determined yet, as we are in the preliminary stages of GSP development.	Phase 1 & 2

V. Venues for Engaging

There are a variety of opportunities, venues and methods for the Kern Groundwater Authority to connect with and engage stakeholders throughout GSA formation, GSP development, GSP review, and GSP implementation phases. Stakeholder groups identified in **Section II** will be engaged in communication efforts as detailed below.

A. Direct Stakeholder Outreach

V.A.1 Collaboration Meetings – Primary Stakeholders

As detailed in **Section II.A**, regular meetings with primary stakeholder groups will be held during their regularly scheduled times. Members of the public and partners from other local agencies are encouraged to attend Board of Directors and Stakeholder Committee meetings to voice their thoughts and concerns throughout the GSP development, public review and implementation phases. Meeting notices and agendas are routinely distributed to the Interested Parties List and are posted on www.kerngwa.com.

Primary stakeholder meetings are held:

- **Board of Directors Meetings –** Fourth Wednesday of every month at 8 a.m. at the Kern County Administration Building, located at 1115 Truxtun Avenue in Bakersfield, California.
- **Stakeholder Committee Meetings –** First Monday of each month at 3:30 p.m. at the Rosedale-Rio Bravo Water Storage District, located at 849 Allen Road in Bakersfield, California.

V.A.2 Educational/Outreach Public Meetings

V.A.2.1 Secondary Stakeholders

Educational/outreach public meetings will be scheduled for Phase 2: GSP Preparation and Submission, Phase 3: GSP Review and Evaluation, and Phase 4: Implementation and Reporting (see **Section VI** for the proposed meeting schedule). These meetings will be important as the GSP will affect all groundwater users within the KGA jurisdiction, and the impact of the SGMA implementation is significant. Stakeholders are already inquiring about the impacts of implementation, while many stakeholders are unaware of the SGMA. Spanish translation services will be available at educational/outreach public meetings.

- **Phase 2: GSP Preparation and Submission –** Public meetings held during Phase 2 were geared towards an overview of SGMA, overview of the GSP development process, public review and implementation (what stakeholders can expect), distribution of stakeholder surveys, and question/answer sessions. This segment of public meetings gave secondary stakeholders an opportunity to be involved in GSP development and share their thoughts and concerns. Possible venues within the KGA are listed in **Table V-1**.
- **Phase 3: GSP Review and Evaluation –** During Phase 3, the draft of the KGA's GSP was distributed for public review. During the public review period, public meetings were held at the same venues as during Phase 2 (**Table V-1**). Presentations included an overview of the GSP and gave stakeholders the opportunity to comment on the draft in a public forum.

- **Phase 4: Implementation & Reporting –** Public meetings will be crucial during Phase 4 and will likely be ongoing to educate stakeholders on implementation requirements and guide them through the steps to compliance and groundwater sustainability.

V.A.2.2 Community Organizations & Others

Community organizations, public agencies and other entities are listed in **Table II-3**, and will be contacted to schedule opportunities to present at their respective meetings throughout the GSP development phase. Presentations will include an overview on SGMA and why it is important to them, an explanation of the GSP development process, including an awareness of the public review period. In addition, the KGA will work with these organizations and agencies to distribute stakeholder surveys, public outreach meeting notices, and educational information via email distribution, social media posts, and printed materials.

V.A.2.3 Meeting Notification Process

Stakeholders will be invited to public meetings through distribution of meeting notices to KGA's district/member agency distribution lists, community organizations' contact lists, and press releases and public service announcements. Press releases will be distributed to local media outlets announcing the meeting dates, times and locations. Local community organizations, such as the Kern County Farm Bureau and Self-Help Enterprises, will be asked to distribute meeting notices via email blasts to their membership/contact lists. When implementation begins, and specific stakeholders need to be informed of upcoming compliance requirements, addresses of property owners within the KGA boundary can be obtained through the County of Kern. Postcards are most cost effective for mailing and can later be used to expedite meeting check-in and track attendance, if required during the implementation phases.

V.A.2.4 Ideal Venues

Venue locations will need to have a capacity to hold large audiences. The location list in **Table V-1** will be updated with additional information and other venue possibilities as meetings are scheduled, and venue availability and rental price is confirmed. KGA will work with disadvantaged communities and community organizations such as Self-Help Enterprises and Leadership Counsel for Justice & Accountability to hold outreach meetings at convenient times and locations within the DACs/SDACs.

Table V-1. Potential Public Meeting Venues & Locations

Venue	Location
Kern Ag Pavilion, Kern High School District	Bakersfield
Wasco Elk's Lodge	Wasco, Shafter
Shafter Veteran's Building	Wasco, Shafter
Arvin Veteran's Hall	Arvin

V.A.3 Printed Communication

V.A.3.1 Branding

Branding is defined as the process of creating distinctive and durable perceptions in the minds of a target audience. A brand is a specific look – a persistent, consistent, unique identity for an organization, making it easy for an audience to identify an organization through its consistent and frequent use of branding. The KGA has developed a brand that will be incorporated in all forms of communication and engagement with the public, which includes consistent usage of the official logo, fonts and colors. The KGA Branding Summary is included in **Appendix A**.

V.A.3.2 Printed Materials

Printed materials will incorporate the visual imagery established through branding efforts and will be tailored for specific means of communication throughout the phases of GSP development, public review and implementation. All printed materials will be translated into Spanish.

- **Fliers –** Fliers will be designed and tailored for secondary stakeholder audiences and will encompass infographics and text with key messages that are pertinent for that phase of GSP development. Distribution will be via website posting, direct mail, email, and direct distribution as handouts at schools, community organization meetings, KGA outreach meetings, or door-to-door. For outreach to DACs/SDACs, any fliers created will be available in both English and Spanish languages.
- **Fact Sheets –** Fact sheets will be developed and updated for each of the GSP phases and will include a section with an overview of SGMA facts, and development, public review and implementation timelines. Fact sheets will be available for download at www.kerngwa.com, distributed at public meetings and community organizations/entities meetings, and emailed to the Interested Parties List and other community organizations' email distribution lists. Fact sheets will be available in both English and Spanish languages.
- **Letter Correspondence –** When letter correspondence is necessary, particularly during the public review and implementation phases, letters will be distributed via email or direct mail. Letters will include pertinent facts and explanations that need to be communicated to specific stakeholder groups.
- **Presentation Materials –** Power Point presentations will be utilized at educational/outreach public meetings. If a Power Point isn't possible to display for a meeting, display boards printed at 24-inch x 36-inch or larger in size will be used and set up on easels. Handouts of presentations and smaller versions of display boards can be distributed to stakeholders in attendance, emailed to the Interested Parties list, and posted on www.kerngwa.com for access by stakeholders as a recap of the meeting.
- **Stakeholder Surveys –** Digital creation and distribution of Stakeholder Surveys is discussed in **Section V.A.4**. For stakeholders who do not have access to the Internet to complete Stakeholder Surveys online, hard copies were available at educational/outreach public meetings and were distributed via direct mail upon request. Water districts distributed surveys in the monthly invoices sent to their customers, and via email blasts sent to their members. A Spanish version was also created for distribution within DACs/SDACs. As hard copy results are received, they were added to the Google Form version of the Stakeholder Survey in-house to efficiently tabulate survey results.
- **Newsletter –** Annual or bi-annual newsletters will be created during the GSP implementation phase to inform stakeholders of compliance requirements and groundwater sustainability updates, opportunities and programs within the Kern sub-basin. The newsletter will be distributed to those on the Interested Parties List and will be finetuned to include others who have specific roles and compliance requirements during GSP implementation.
- **Other Printed Materials –** Other printed materials may be needed to be developed during the GSP development, public review and implementation phases. These documents will also be available in both English and Spanish versions.

V.A.4 Digital Communication

Digital communication outlets will also be designed to incorporate KGA's branding and will be a significant mode of communication through the GSP development, public review and implementation phases.

- **Website –** Public meeting notices, agendas and minutes of the Board of Directors and Stakeholder Committee meetings are posted on the KGA's website, www.kerngwa.com. This website serves as an integral resource for primary, secondary and other community stakeholders within the KGA's boundary. Electronic files of printed materials, presentations and other educational resources, and a direct link to the Stakeholder Survey (English and Spanish versions) are accessible via the website.

  As Fact Sheets are created during the development, public review and implementation phases, a webpage with the same content will be incorporated into the current website sitemap and will be updated as the Fact Sheet is updated/redesigned. This will serve as a way for stakeholders to easily educate themselves on the GSP process and phases.

- **Stakeholder Surveys –** Stakeholder surveys were discussed in **Section III.A**, and were used for the deliberate polling of secondary stakeholders to give them a direct voice in the GSP development phase. Stakeholder surveys were created via Google Forms, and links to English and Spanish versions of the survey are posted on the www.kerngwa.com website and were utilized in email blasts to the Interested Parties list. Google Forms is free of charge to use, and survey results were easily exported into Excel to sort through for the KGA's member agencies and districts. The distribution process of stakeholder hard copies is described in **Section V.A.3.2**, and a copy of the final survey (English and Spanish versions) is included in **Appendix B**.

- **Email Distribution –** As required by SGMA 10723.4 "Maintenance of Interested Persons List," KGA maintains a contact list and regularly distribute emails to those who have expressed interest in the GSA's progress. These emails consist of meeting notices and other documents that are pertinent to the KGA and communication efforts. This process will continue.

  As outreach meetings are held, the email distribution list will grow through direct contact with stakeholders. As this list expands, a Constant Contact account will be established to more easily send out email blasts of news, digital versions of the newsletter, and updates to relevant to the interests of primary and secondary stakeholders within the KGA. A "Stay Informed About the Kern Groundwater Authority" form is posted on www.kerngwa.com/contact-us.html so website visitors can sign up for the email distribution list directly.

  Email blasts for meeting notices, stakeholder surveys, public review notices, and other crucial information will be coordinated with community organizations and stakeholder groups by utilizing their distribution lists. Examples of these organizations are Kern County Farm Bureau, Self-Help Enterprises, chambers of commerce, and irrigation districts within the KGA boundary. A complete working list of organizations are listed in **Table II-3**.

- **Social Media –** Coordination for social media posts announcing upcoming meetings, stakeholder surveys, public review notices, and other crucial information will be coordinated with public agencies, community organizations and stakeholder groups who operate social media sites through Facebook, Instagram, Twitter, and others. A working list of these organizations and the number of followers are listed in **Table V-2**.

Table V-2. Public Agencies & Community Organizations Social Media Outlets

Community Organization	Social Media Outlet/URL	Number of Followers
Arvin Chamber of Commerce	Facebook: @ArvinChamber	101
Audubon California	Facebook: @audubonca	134,044
Bakersfield Host Lions Club	Facebook: @bakersfieldhostlions	512
California Citrus Mutual	Facebook: @CaliforniaCitrusMutual	1,056
California Women for Agriculture – Kern County	Facebook: @Kern-County-California-Women-for-Agriculture	341
Center for Race, Poverty & the Environment	Facebook: @CRPE.EJ	3,992
City of Shafter	Facebook: @CityOfShafter	3,771
Community Water Center	Facebook: @communitywatercenter	1,722
County of Kern	Facebook: @CountyofKern	1,182
Ducks Unlimited	Facebook: @BakersfieldDucksUnlimited	619
Greater Lamont Chamber of Commerce	Facebook: @lamontchamberkern	953
Kern County Cattlewomen	Facebook: @KCCattleWomen	899
Kern County Cattlemen's Association	Facebook: @Kern-County-Cattlemens-Association	119
Kern County Farm Bureau	Facebook: @KernCountyFarmBureau	1,025
Kern County Farm Bureau Young Farmers and Ranchers	Facebook: @KernYoungFarmersAndRanchers	546
Leadership Counsel for Justice and Accountability	Facebook: @Leadership-Counsel-for-Justice-and-Accountability	865
Self-Help Enterprises	Facebook: @selfhelpenterprises	2,570
Sequoia Riverlands Trust	Facebook: @sequoiariverlands	1,928
Shafter Chamber of Commerce	Facebook: @shafterchamberofcommerce	698
Shafter Lions Club	Facebook: @shafterlions	226
Tejon Ranch Conservancy	Facebook: @tejonranchconservancy	4,410
The Nature Conservancy in California	Facebook: @natureconservancycalifornia	29,930

V.A.5 Media Coverage

Press releases and public service announcements (**PSA**) will be written and distributed to the media list of local newspaper publications, and television/radio stations. These press releases and PSAs will focus on notification of public engagement opportunities such as targeted stakeholder meetings, stakeholder survey circulation, public review/comment processes and opportunities, and GSP implementation.

Direct story pitches will be made when necessary via direct communication with news outlets throughout GSP development and implementation phases. These story pitches will focus on GSP development status

updates, how public input is being used, and general overview of SGMA and how it will affect stakeholders (residents and industry) within the KGA boundary.

Table V-3. Kern County Media Outlets

Media Outlet	Coverage Area
Arvin Tiller	Arvin-Lamont
Bakersfield Californian	Bakersfield
Kern Business Journal	Kern County
Ridgecrest Daily Independent	Ridgecrest
Taft Independent	Taft
Taft Midway Driller	Taft
The Shafter Press	Shafter, Kern County

VI. Implementation Timeline

The timeline for implementing the KGA's Communication & Engagement Plan will be broken down by phase:

- Phase 1: GSA Formation and Coordination – 2015 through 2017 (**Figure VI-1**)
- Phase 2: GSP Preparation and Submission – 2017 through 2019 (**Figure VI-2**)
- Phase 3: GSP Review and Evaluation – 2019 through 2020 (**Figure VI-3)**
- Phase 4: Implementation and Reporting – 2020 and ongoing

The timelines for Phase 1, Phase 2 and Phase are complete, but the timeline for Phase 4 will be developed following as implementation progresses.

Timeline Key:

Deadlines & KGA Interaction with DWR | Kern Groundwater Authority Board Meetings | Kern Groundwater Authority Stakeholder-Specific Outreach

September 2014: Sustainable Groundwater Management Act (SGMA) signed into law.

Phase 1: GSA Formation and Coordination

2015

January	February	March	April	May	June	July	August	September	October	November	December
Jan. 21, 2015: KGA Board of Directors Meeting	**Feb. 25, 2015:** KGA Board of Directors Meeting	**March 25, 2015:** KGA Board of Directors Meeting	**April 22, 2015:** KGA Board of Directors Meeting	**May 27, 2015:** KGA Board of Directors Meeting	**June 24, 2015:** KGA Board of Directors Meeting		**Aug. 26, 2015:** KGA Board of Directors Meeting	**Sept. 23, 2015:** KGA Board of Directors Meeting	**Oct. 28, 2015:** KGA Board of Directors Meeting	**Nov. 16, 2015:** KGA Board of Directors Meeting	**Dec. 21, 2015:** KGA Board of Directors Meeting

2016

June 30, 2016: DWR adopts regulations for evaluating GSPs.

January	February	March	April	May	June	July	August	September	October	November	December
Jan. 27, 2016: KGA Board of Directors Meeting	**Feb. 24, 2016:** KGA Board of Directors Meeting	**March 21, 2016:** KGA Special Board of Directors Meeting	**April 27, 2016:** KGA Board of Directors Meeting	**May 18, 2016:** KGA Board of Directors Meeting	**June 29, 2016:** KGA Special Board of Directors Meeting		**Aug. 24, 2016:** KGA Board of Directors Meeting	**Sept. 28, 2016:** KGA Board of Directors Meeting	**Oct. 24, 2016:** KGA Board of Directors Meeting **Oct. 24, 2016:** SGMA Stakeholder Outreach Workshop, Kern Ag Pavilion	**Nov. 14, 2016:** KGA Special Board of Directors Meeting **Nov. 1, 2016:** SGMA Stakeholder Outreach Workshop, Kern Co. Water Agency **Nov. 15, 2016:** SGMA Stakeholder Outreach Workshop, Kern Ag Pavilion **Nov. 28, 2016:** SGMA Stakeholder Outreach Workshop, Kern Co. Admin Bldg.	**Dec. 19 2016:** KGA Board of Directors Meeting **Dec. 5, 2016:** SGMA Stakeholder Outreach Workshop, Kern Ag Pavilion **Dec. 20, 2016:** SGMA Stakeholder Outreach Workshop, Kern Co. Admin Bldg.

2017

April 26, 2017: KGA elected to become official GSA.

January	February	March	April	May	June	July	August	September	October	November	December
Jan. 25, 2017: KGA Board of Directors Meeting	**Feb. 22, 2017:** KGA Special Board of Directors Meeting	**March 22, 2017:** KGA Special Board of Directors Meeting	**April 26, 2017:** KGA Board of Directors Meeting	**May 15, 2017:** KGA Special Board of Directors Meeting	**June 19, 2017:** KGA Special Board of Directors Meeting	**July 19, 2017:** KGA Board of Directors Meeting	**Aug. 23, 2017:** KGA Board of Directors Meeting	**Sept. 27, 2017:** KGA Board of Directors Meeting	**Oct. 25, 2017:** KGA Board of Directors Meeting	**Nov. 16, 2017:** KGA Board of Directors Meeting	**Dec. 20, 2017:** KGA Board of Directors Meeting

Figure VI-1. Kern Groundwater Authority's Communication & Engagement Timeline – Phase 1: GSA Formation and Coordination

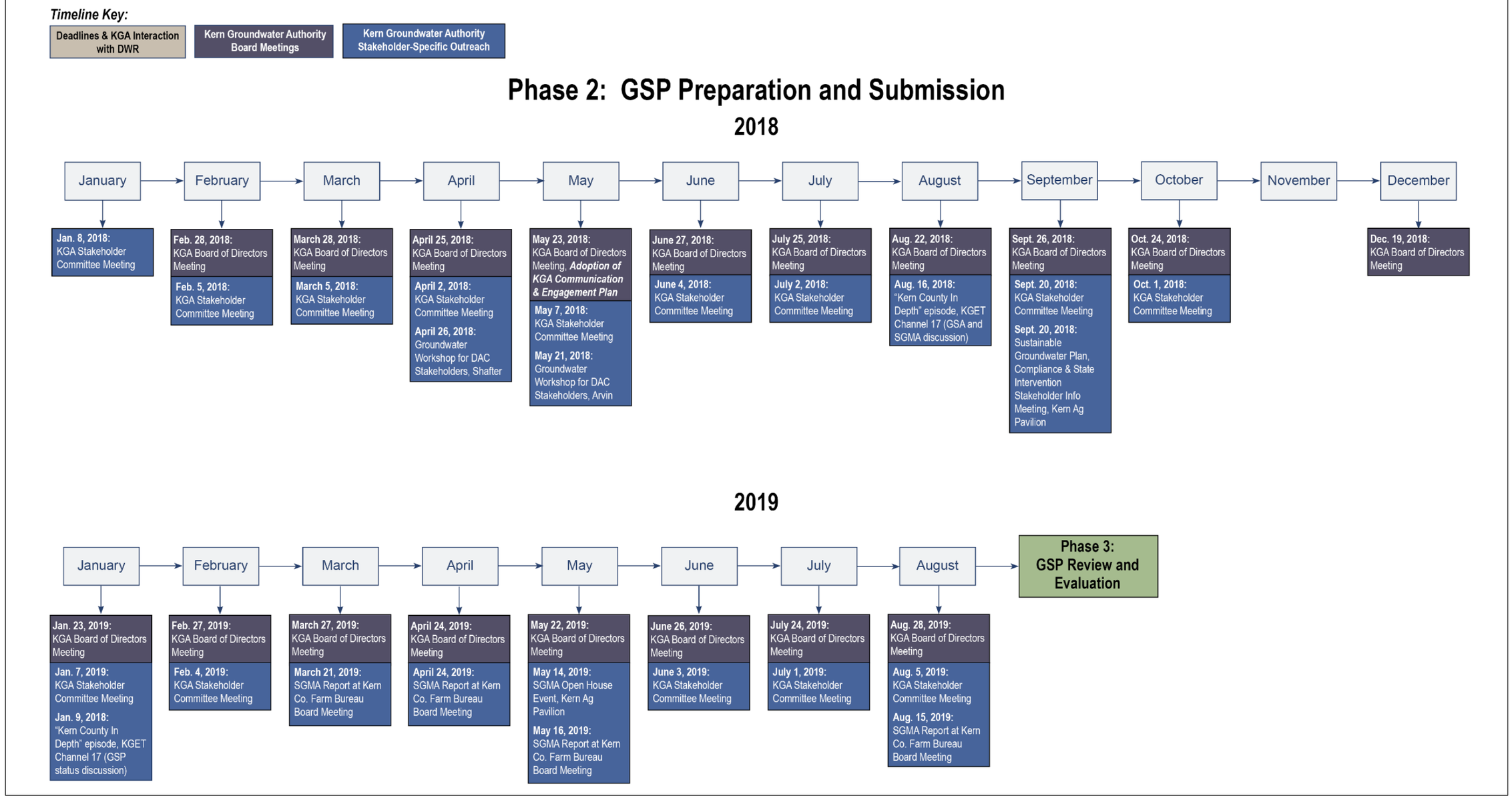


Figure VI-2. Kern Groundwater Authority's Communication & Engagement Timeline – Phase 2: GSP Preparation and Submission, and Phase 3: GSP Review and Evaluation

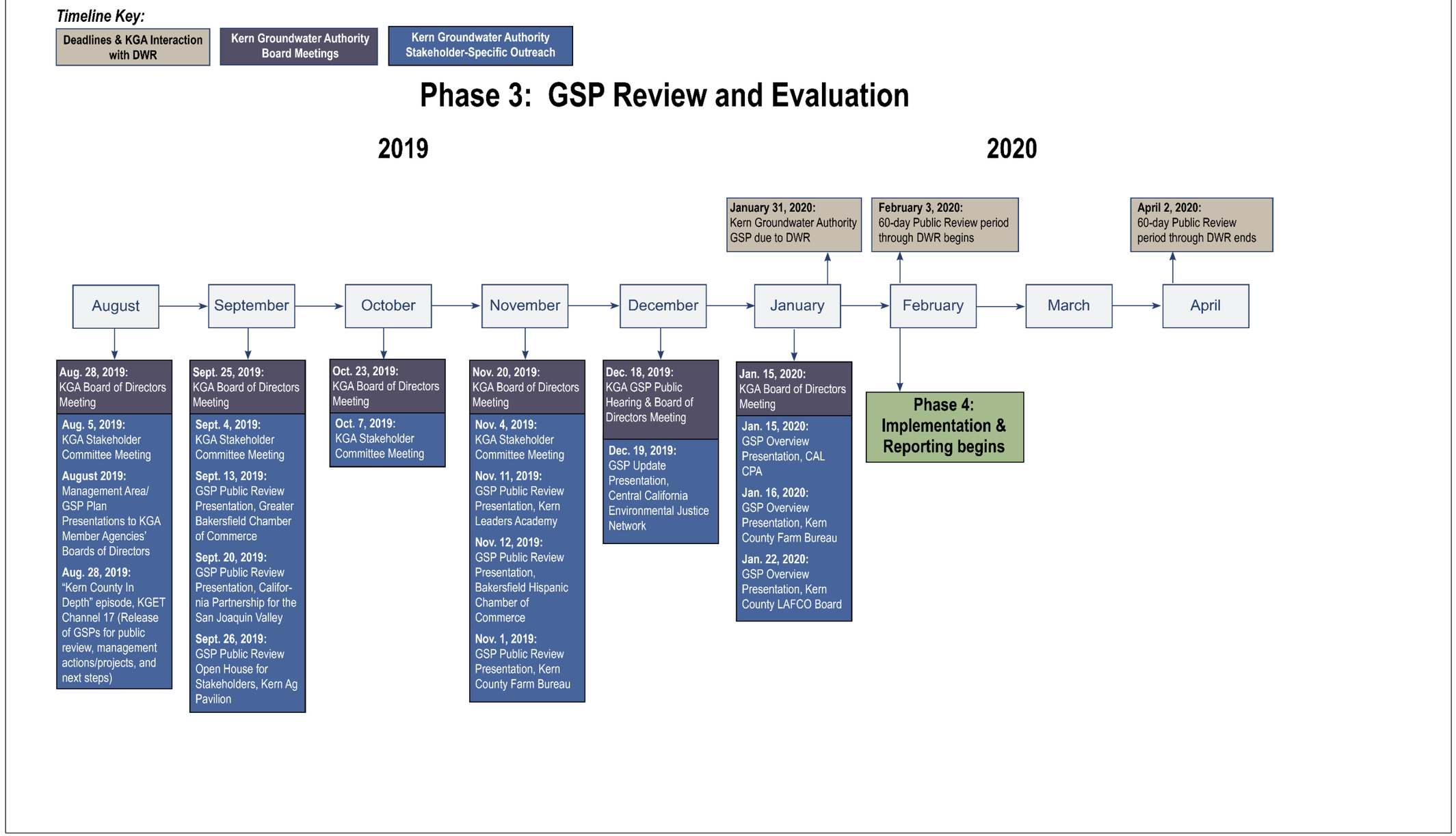


Figure VI-3. Kern Groundwater Authority's Communication & Engagement Timeline – Phase 3: GSP Review and Evaluation

VII. Evaluation and Assessment

A. Evaluation and Assessment Process

Having an established "checks and balances" process is essential in keeping public outreach goals on target. SGMA and the resulting GSP will affect everyone within the sub-basin, and outreach efforts must be all-encompassing. To evaluate and assess how outreach efforts are performing as compared to the goals and objectives detailed in the Communication & Engagement Plan, the Kern Groundwater Authority has established a process:

VII.A.1 Monthly Outreach Reports to Planning Manager

The Public Outreach Coordinator will provide monthly updates to the Planning Manager and Board of Directors (through board meeting attendance or memorandums). These updates will include, but will not be limited to:

- Status of upcoming outreach events, and recaps of past outreach events
- Results and status updates of stakeholder surveys
- Communication & Engagement Plan milestone updates/revisions
- Review/input and approval of printed materials (fliers, fact sheets, talking points, etc.)

VII.A.2 Quarterly Milestone Review

Once per quarter, a more in-depth discussion with the Stakeholder Committee and/or Board of Directors for feedback regarding communication and engagement efforts for the stakeholder groups the specifically represents. These discussions will cover:

- What has worked well?
- What hasn't worked as planned or could be finetuned for more effective results?
- Lessons learned
- Outreach needs that should be added to the implementation timeline
- Next steps

Following the quarterly review with the Stakeholder Committee and/or Board of Directors, the KGA's Planning Manager and Public Outreach Coordinator will meet to review public outreach status updates of tasks outlined in the adopted Communication & Engagement Plan, budget analysis, and feedback from the Board of Directors and/or Stakeholder Committee. Milestone updates will also be discussed, as necessary, to keep up to date with GSP development and implementation phases, and then taken to the Stakeholder Committee for discussion and subsequent approval.

Appendix A

Kern Groundwater Authority Branding Summary

Kern Groundwater Authority Branding Summary

KERN
GROUNDWATER AUTHORITY

Color Scheme

- Dark Blue ("Kern"): CMYK (96-91-45-54); RGB (21-25-58)
- Black ("Groundwater Authority" and lines): CMYK (0-0-0-100); RGB (35-31-32)

Appendix B

Stakeholder Surveys

KERN GROUNDWATER AUTHORITY

Stakeholder Survey

Date: _____

Stakeholder Type (check all that apply):

☐	Agricultural User	☐	Domestic Well Owner/User	☐	Municipal Well Operator
☐	Public Water Systems	☐	Local Land Use Planning Agency	☐	Environmental User
☐	Surface Water User	☐	Native American Tribe	☐	Disadvantaged/Rural Community Resident
☐	City Resident	☐	Food Processor	☐	Industrial User/Oil Producer
☐	Entity monitoring and reporting groundwater elevations in all or part of the groundwater basin				

Note: Please complete your name and contact information if you'd like to be added to the GSA's email and mailing list for future updates and information regarding Sustainable Groundwater Management Act (SGMA) and the Kern Groundwater Authority.

Name: _____

Address: _____

City: _____ **State:** _____ **Zip:** _____

Email: _____ **Telephone:** _____

1. **Are you familiar with Sustainable Groundwater Management Act (SGMA) regulations?** ☐ Yes ☐ No

2. **Are you currently working on or discussing groundwater management in this region?** ☐ Yes ☐ No

3. **Do you own or manage/operate land in this region?** ☐ Yes ☐ No

4. **Where are you getting your water supply?**
   ☐ City or Community Water System ☐ Surface ☐ Groundwater
   ☐ Both Groundwater & Surface Water ☐ Unknown

5. **Agriculture & Domestic Well Users: What is your well(s) depth?** _____

6. **Agriculture & Domestic Well Users: Has your well(s) ever gone dry?** ☐ Yes ☐ No
   If yes, when (month/year)? _____

7. **If you are an Agricultural User, do you:** ☐ Irrigate ☐ Dry Farm ☐ Graze Livestock
   ☐ Other: _____

8. **How reliable is your current groundwater supply?** _____

   _____

   _____

9. **If you grow crops, do you use irrigation for frost protection?** ☐ Yes ☐ No

10. **Do you manage water resources?** ☐ Yes ☐ No
    If yes, what is your role? _____

11. What is your primary interest in land or water resources management? _____

12. Do you have concerns about groundwater management? ☐ Yes ☐ No

If so, what are they? _____

13. Do you have requests or recommendations regarding groundwater management? ☐ Yes ☐ No

If so, what are they? _____

14. Any other information the Kern Groundwater Authority should be aware of or take into consideration while developing the Groundwater Sustainability Plan (GSP)?

Please return completed surveys to the Kern Groundwater Authority by emailing tbarton@ppeng.com, faxing to (661) 479-7172, or mail to Kern Groundwater Authority, 1800 30th Street, Suite 280, Bakersfield, CA 93301.
Stakeholder Surveys may also be completed online by visiting www.kerngwa.com.

KERN GROUNDWATER AUTHORITY

Encuesta de Partes Interesadas

Fecha: _____

Tipo de Interesado (marque todas que apliquen):

☐	Usuario agrícola	☐	Propietario / usuario de pozo doméstico	☐	Operador municipal de pozos
☐	Sistema de agua público	☐	Agencia local de planificación del uso de la tierra	☐	Usuario ambiental
☐	Usuario de agua superficial	☐	Tribu native americana	☐	Residente de comunidad desventajada/ rural
☐	Residente de la ciudad	☐	Procesador de alimentos	☐	Usuario industrial/Productor de petróleo
☐	Entidad que monitorea y reporta elevaciones de aguas subterráneas en toda o parte de la cuenca de agua subterránea				

Nota: Por favor complete su nombre y la información de contacto si desea ser agregado a la lista de correo electrónico de la GSA y lista de correo para futuras actualizaciones e información sobre la Ley del Manejo Sostenible del Agua Subterránea (SGMA) y la Autoridad de Aguas Subterráneas de Kern (KGA GSA).

Nombre: _____

Dirección Postal: _____

Ciudad: _____ **Estado:** _____ **Código postal:** _____

Correo Electrónico: _____ **Teléfono:** _____

1. **¿Está usted familiarizado con las regulaciones de la ley de Manejo Sostenible del Agua Subterránea (SGMA)?** ☐ Sí ☐ No

2. **¿Está usted actualmente involucrado en actividades o discusiones Sobre el manejo de aguas subterráneas en esta regíon?** ☐ Sí ☐ No

3. **¿Usted es propietario o administra/opera tierra en esta región?** ☐ Sí ☐ No

4. **¿De dónde recibe su suministro de agua?**
   ☐ Sistema de agua de la ciudad o la comunidad ☐ Superficie ☐ Agua subterránea
   ☐ Agua subterránea y superficial ☐ No sé

5. **Usuarios de pozos Agrícolas Y Domésticos: ¿Cuál es la profundidad de su pozo(s)?** _____

6. **Usuarios de poza Agrícolas Y Doméesticos: ¿Alguna vez se ha secado su pozo(s)?** ☐ Sí ☐ No
   ¿Si la respuesta es sí, cuándo (mes/año)? _____

7. **Si eres un usuario agrícola, qual haces:** ☐ Irrigar ☐ Granja seca ☐ Pastoreo
   ☐ Otro: _____

8. **¿Qué tan seguro es su suministro de agua subterránea, corrientemente ?** _____

   _____

   _____

9. **Si cultiva, ¿utiliza el riego para la protección contra las heladas?** ☐ Sí ☐ No

10. **¿Usted administra recursos de agua?** ☐ Sí ☐ No
    Si la respuesta es sí, ¿cuál es su papel? _____

11. ¿Cuál es su interés principal en el manejo de recursos de agua o tierra? _____

12. ¿Tiene preocupaciones acerca el manejo de las aguas subterráneas? ☐ Sí ☐ No

Si la respuesta es sí, ¿cuáles son? _____

13. ¿Tiene used alguna recomendación sobre el manejo de agua subterráneas? ☐ Sí ☐ No

Si la respuesta es sí, ¿cuáles son? _____

14. ¿Tiene used alguna otra información pertinente que debería tener en cuenta el Kern Groundwater Authority GSA para desarroler el Plan de Sostenibilidad de Aguas Subterránease (GSP)?

Por favor regrese la encuesta terminada al Kern Groundwater Authority GSA enviando un corre electrónico a tbarton@ppeng.com , manduando un fax al (661) 478-7172, o por correo a Kern Groundwater Authority GSA, 1800 30th Street, Suite 280, Bakersfield, CA 93301.

Esta Encuesta de Partes Interesadas también se puede completer visitando la página www.kerngwa.com.

130 N. Garden Street
Visalia, CA 93291-6362
Tel: (559) 636-1166
Fax: (559) 636-1177
www.ppeng.com

Memorandum

To:	Kern Groundwater Authority Board of Directors
From:	Trilby Barton, Public Outreach Coordinator, Provost & Pritchard Consulting Group
Subject:	Stakeholder Survey Results – Final Report
Date:	December 12, 2018

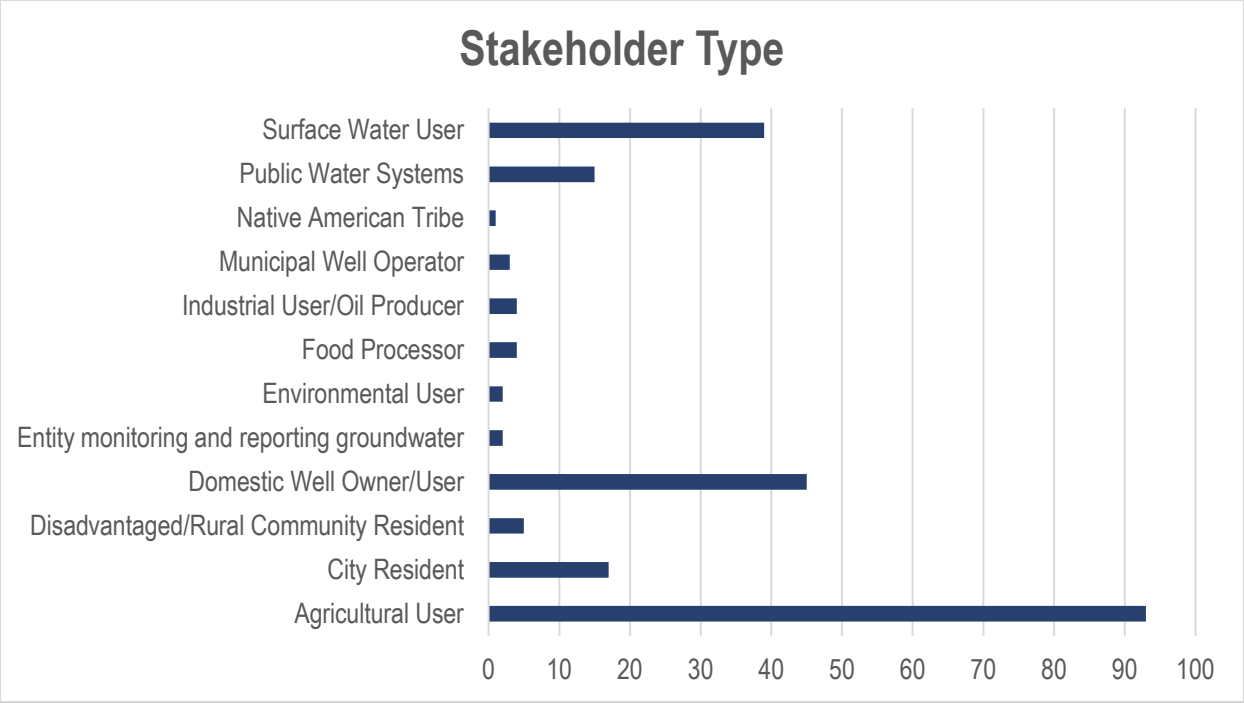
Hard copies and the link to the online version of the Kern Groundwater Authority's Stakeholder Survey (in both English and Spanish) were circulated throughout Kern County. For the final report, the data was sorted through, and duplicate entries were removed. **Kern Groundwater Authority received a total of 123 responses**.

Reponses were received from nearly all stakeholder types identified in the Kern Groundwater Authority's Communication & Engagement Plan. Most responses were received from agricultural users, with domestic well owner/users and surface water users, and city residents following.

Overall, stakeholders are primarily concerned about the economic impacts that SGMA will have on the agriculture and industrial groundwater users within the Kern Groundwater Authority boundaries.

This memo summarizes the data and comments received from the stakeholders who completed the survey.

Final Report of Kern Groundwater Authority Stakeholder Survey Results

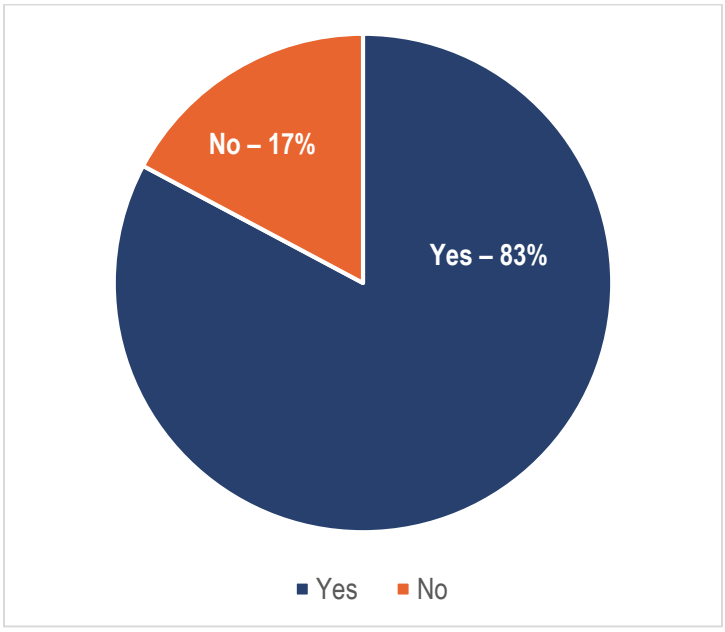


Stakeholder Type Summary:

Agricultural User	93	Domestic Well Owner/User	45
Municipal Well Operator	3	Public Water Systems	15
Local Land Use Planning Agency	0	Environmental User	2
Surface Water User	39	Native American Tribe	1
Disadvantaged/Rural Community Resident	5	City Resident	17
Food Processor	4	Industrial User/Oil Producer	4
Entity monitoring and reporting groundwater elevations in all or part of the groundwater basin			2

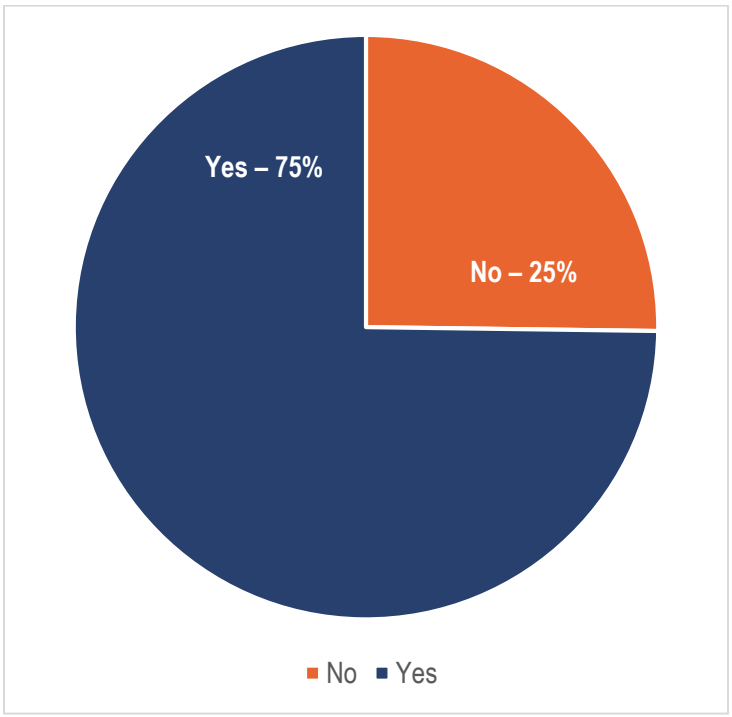
1. Are you familiar with Sustainable Groundwater Management Act (SGMA) regulations?

(122 responses)

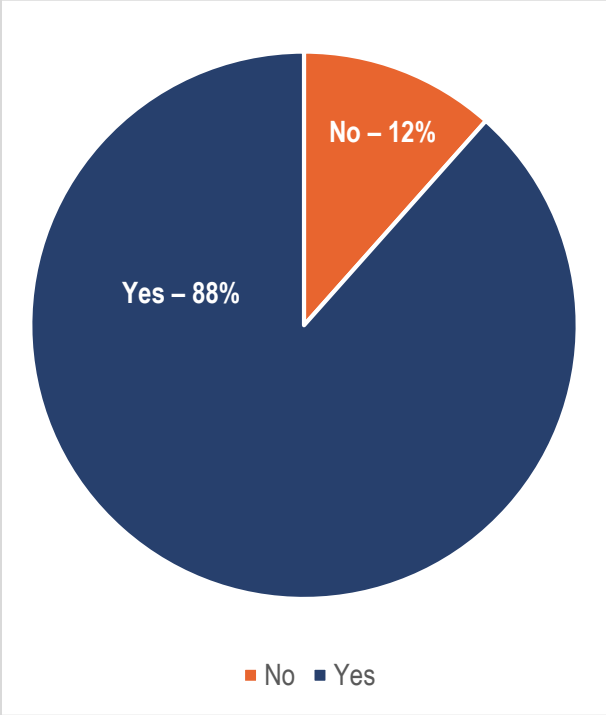


2. Are you currently working on or discussing groundwater management in this region?

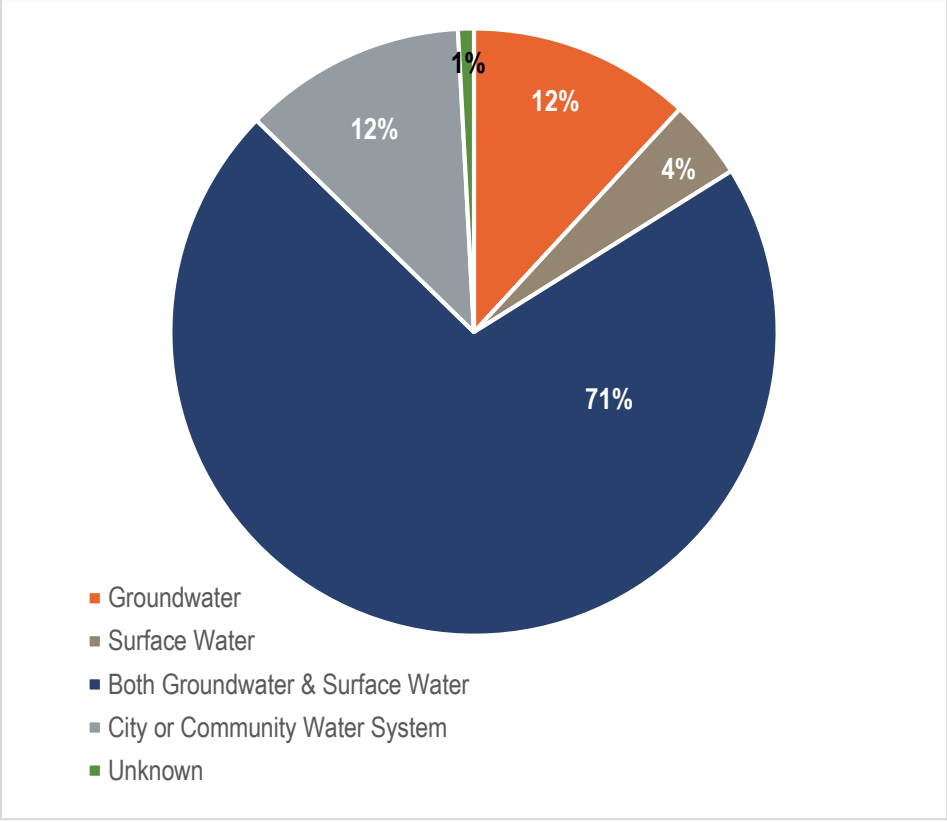
(119 responses)



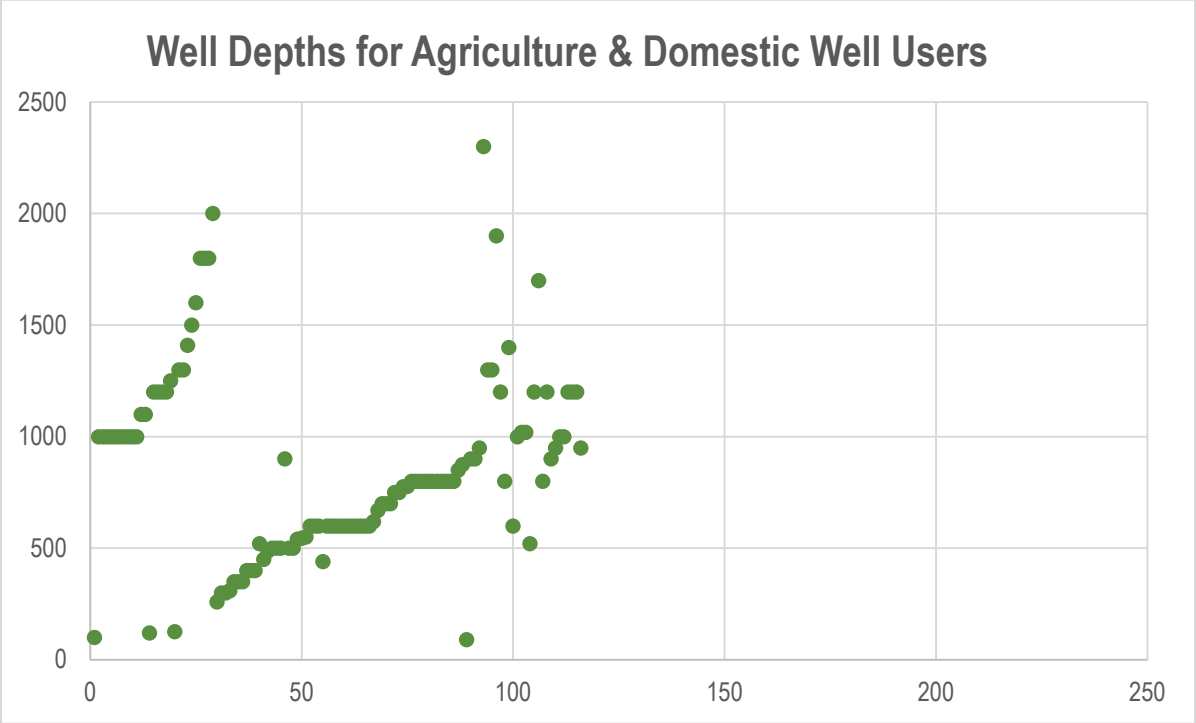
3. Do you own or manage/operate land in this region? *(121 responses)*



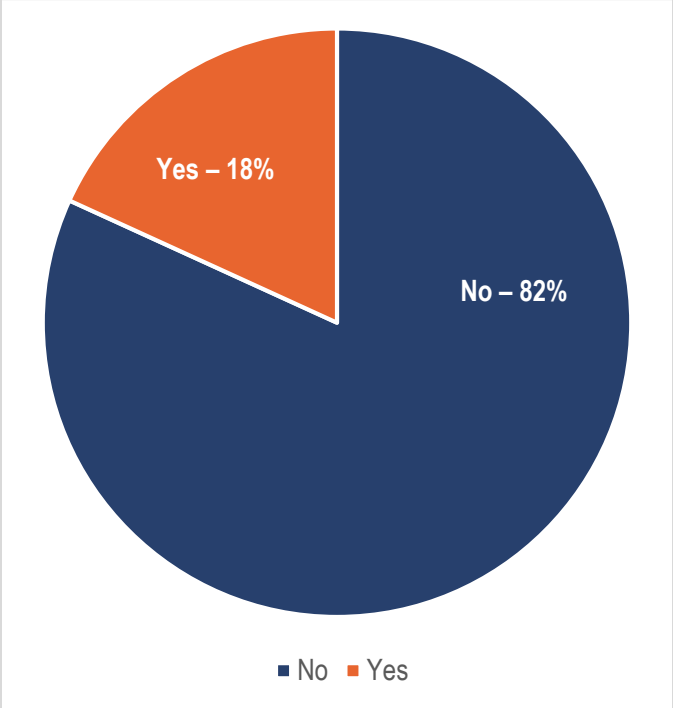
4. Where are you getting your water supply? *(118 responses)*



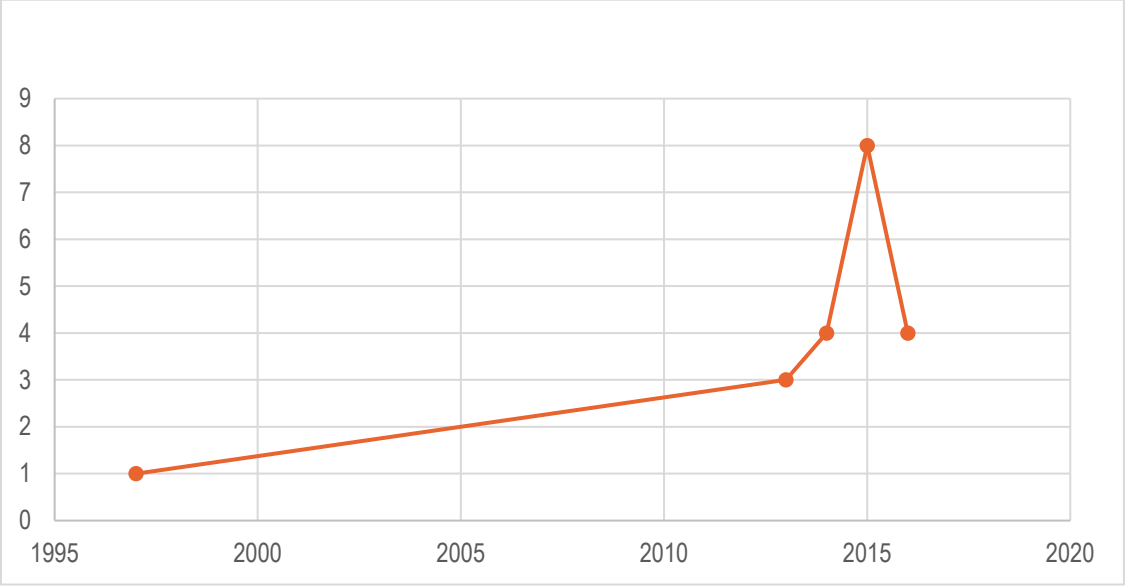
5. Agriculture & Domestic Well Users: What is your well(s) depth? *(92 responses)*



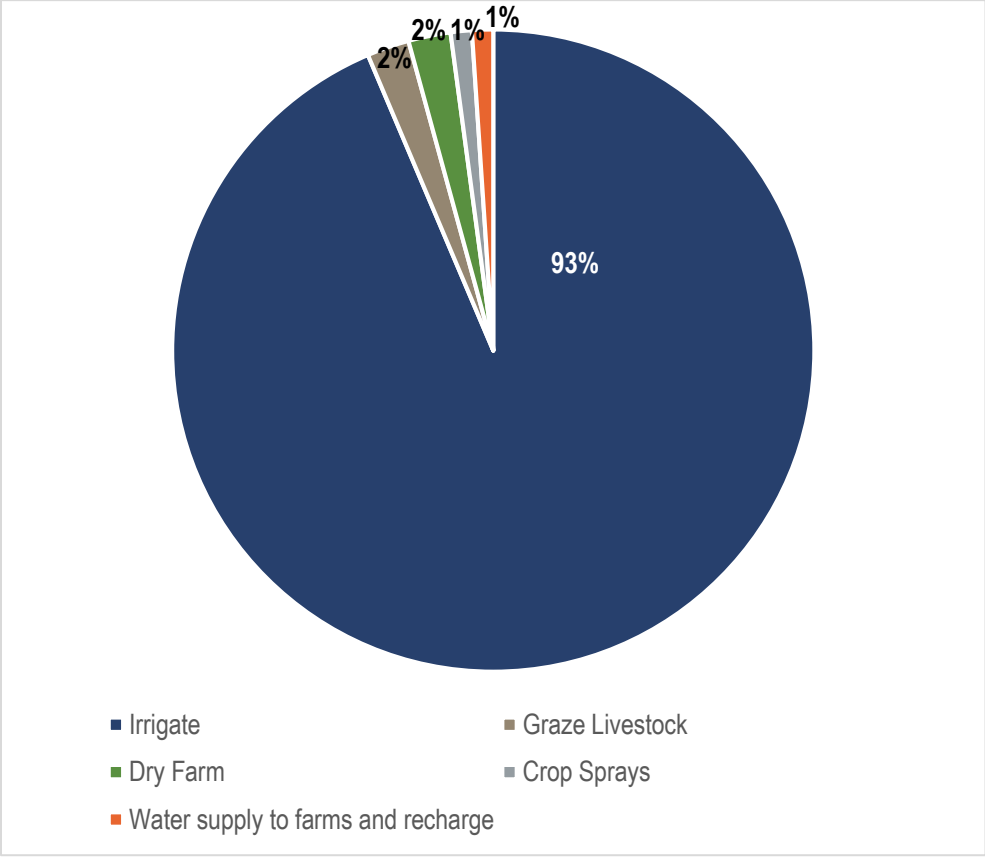
6. Agriculture & Domestic Well Users: Has your well(s) ever gone dry? *(99 responses)*



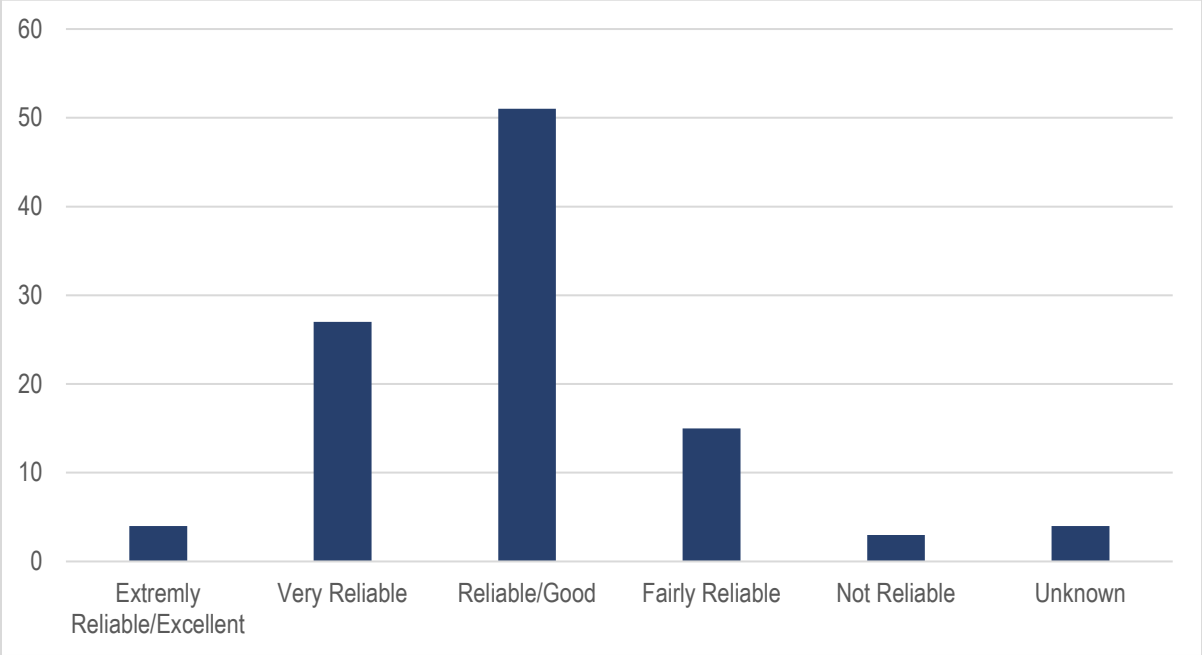
If yes, when? *(20 responses)*



7. If you are an Agricultural User, do you: *(94 responses)*



8. How reliable is your current groundwater supply? *(104 responses)*



Additional comments regarding groundwater reliability:

Currently receiving decent district water so not pumping too much, although it's early in our season

We rely on combination of surface water from AEWSD and Wheeler Ridge-Maricopa districts, and groundwater from wells on our property.

Supplied through district

Standing water level did not drop even during drought.

I've only used my well one time in 25 years

It has been reliable. Serves small residential units that do not have yards, one-room units, one-bedroom units, no washer hookup, serves retired and migrant workers.

It is reliable, however lower aquifer levels increase contamination levels for nitrates, which recently forced us to shut down a municipal well.

Part of Arvin-Edison. No wells on our property but have district wells.

Our water districts have historically done a good job providing water to our ranches. While our water levels have dropped, they are still providing adequate water.

Reliable because I've spent money on them and have maintained them

Reliable in conjunction with surface water

Reliable, but water quality is a bit poor on some wells.

Reliable, pump lowered 2016 in response to drought

Production has stayed steady for 10+ years

Well is for domestic use only, poor quality water but reliable

We feel our current groundwater supply is reliable at this time.

Water deep but well are troublesome

Water supply is not a problem it is basin standards not met.

Average 350 gallons

Unknown given the state's undelivered water

Water quality concerns are becoming more important each year for the current groundwater supply.

Fairly reliable as we invested significant capital in 2013 and 2014 to rehab most of our older wells.

Relatively reliable. Had to extend bowls on one well.

Sufficient for our current needs

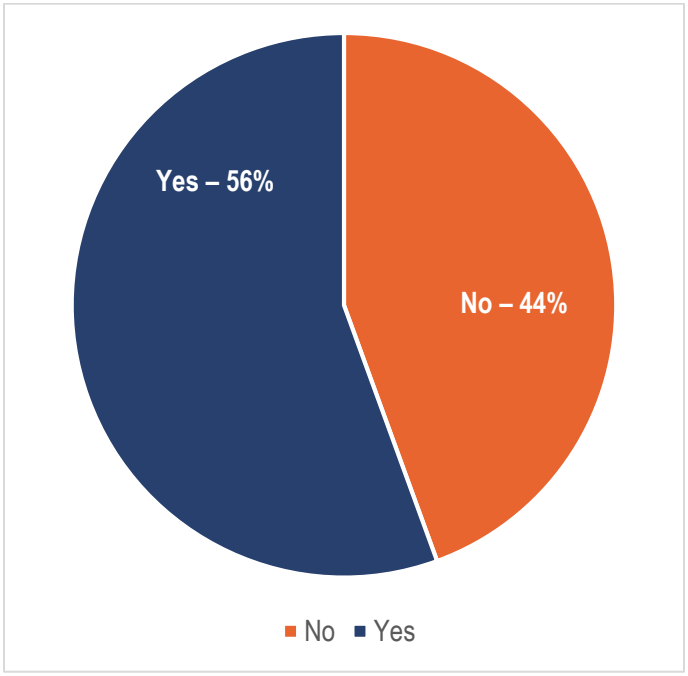
Sufficient for supplemental supply for surface water in most years

Variable. One well is reliable, another is iffy

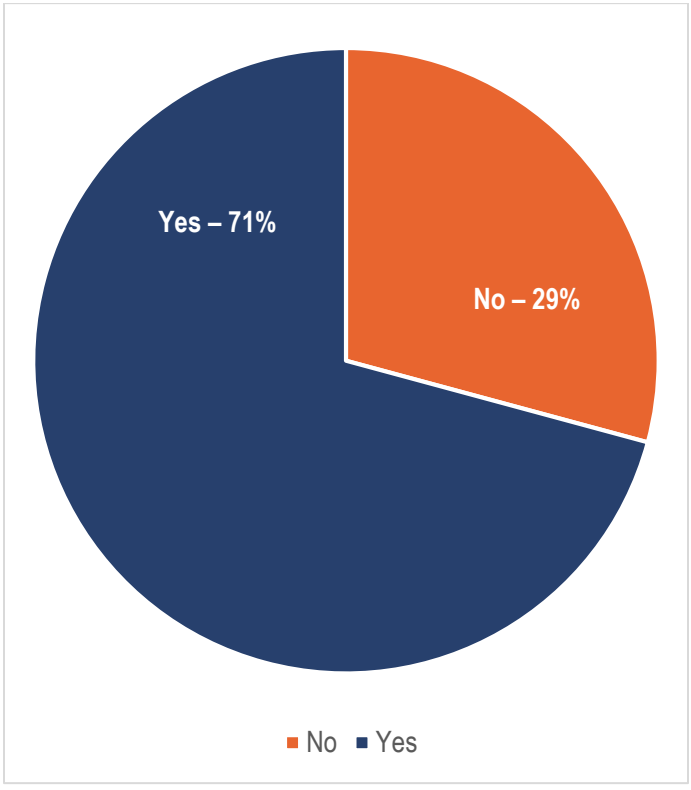
Volume is ok, quality becomes the issue.

Groundwater supply has decreased in quality over the last couple years rapidly.

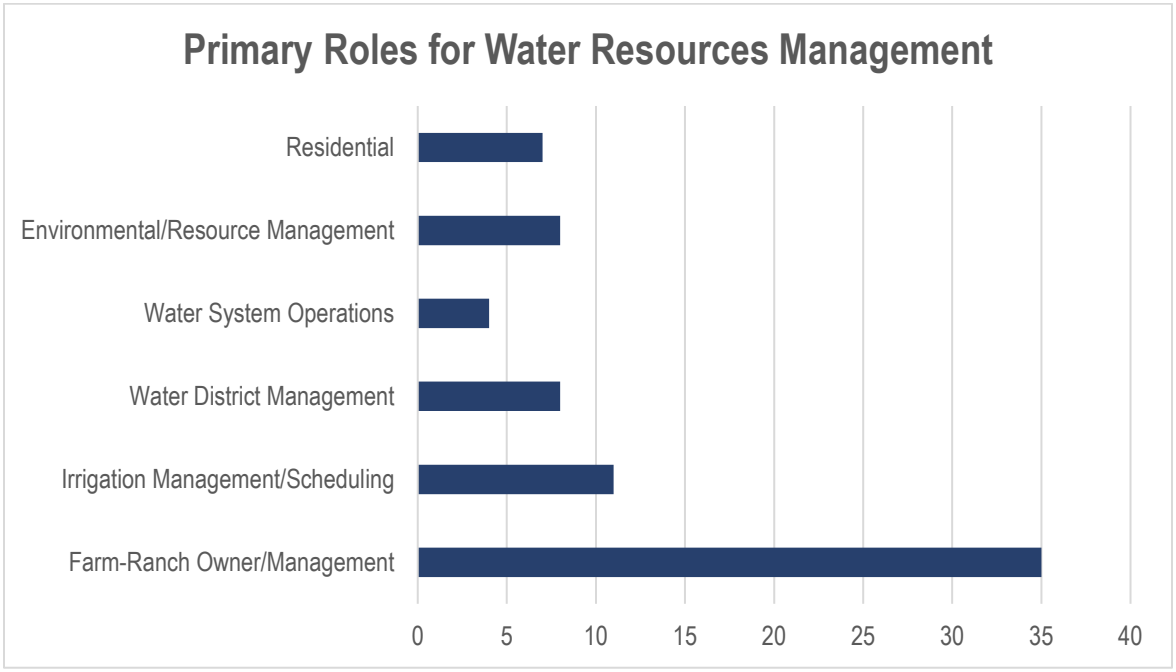
9. If you grow crops, do you use irrigation for frost protection? *(99 responses)*



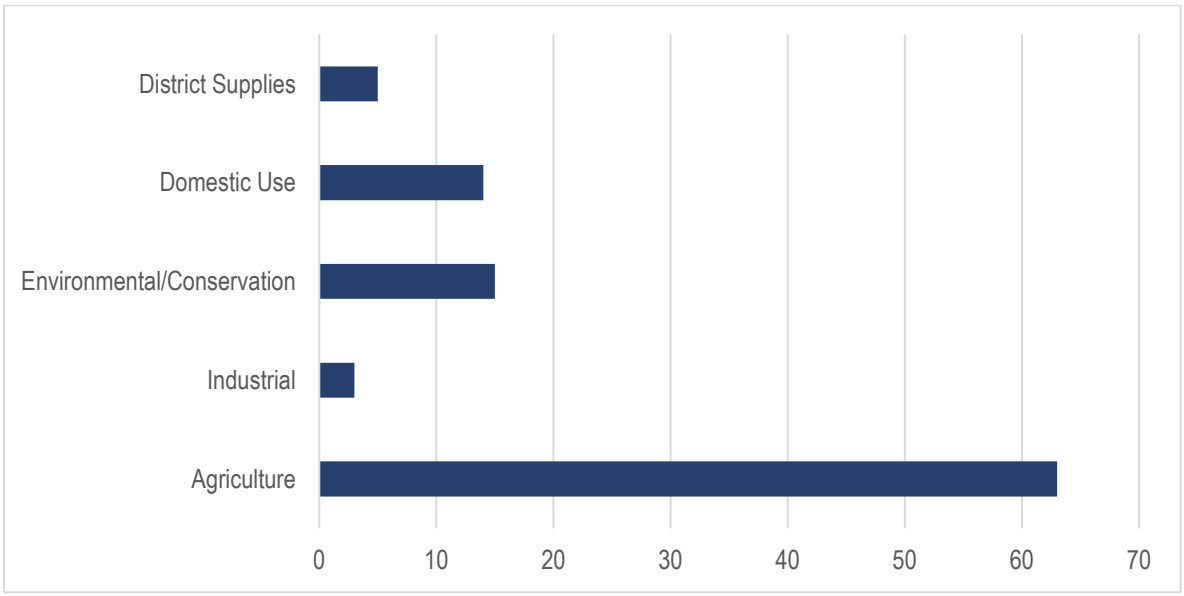
10. Do you manage water resources? *(113 responses)*



If yes, what is your role? *(73 responses)*



11. What is your primary interest in land or water resources management? *(100 responses)*



Additional comments regarding primary interests in land or water resources management:

Continued supply of quality & quantity to farm my property

Ensuring our farming operations continue to have access to irrigation water to maintain our crop production.

Farm Management and water for future generations.

Farming is my livelihood. Without water I can't do what I do.

Future availability for my ranch and all other farmers.

Future water availability. Restrictions on pumping groundwater.

Having enough water for personal use and for growing crops

Having enough water to farm our ground

I am a farm banker. SGMA will drastically affect my customers and my bank.

I have a strong interest in water resource management as we farm a large number of permanently planted acreage. We have invested a lot of money into the development of permanent crops and have made efforts to effectively manage our water use as efficiently as possible.

I want to grow crops. I want to continue to live on my farm using well water.

Ensuring adequate supply for our perennial crops

Long term sustainability of farmland (productive)

Maintaining local and personal control with the least outside regulation possible.

My hope is to be able to farm well into the future. If we don't become sustainable in the near future, we won't have a farming option in a couple years.

Producing crops and staying in business

Making sure we have enough water to grow our crops to feed the world

Sustainability and cost, sustainability for future food production, sustainability for water supplies in agriculture

Preparing information on SGMA for CEO and farm managers to make decisions on planting and long-term business planning

That I be able to continue to irrigate my crops

That water remains available for irrigation

To conserve & use less water to get the same production results

To conserve options for water usage when consider crops

To continue to farm without fallowing acreage

Without water land is invaluable. We employ 3,000 people out of a 21,000-person town. If we fallow our lands, we and every other company will not have enough work for the people.

to use water most economically

As an industrial user, need to ensure continued access to volume of groundwater necessary for operations

Keeping water available for my business

Survival of business

Conservation and efficiency of resources

Finite and necessary resource

For water resources to get used properly

Safety, health and environmental professional

My primary interest is managing both surface and groundwater as efficiently and effectively as possible while remaining cognizant of the value of the resources, both land and water.

Need help getting resources for management in using groundwater

Subsidence

Regulation and water

To know & understand the rules/regulations up and coming. Also, to connect with others that are interested in monitoring solutions as we are in this business

Use water wisely

compliance

Follow up with membership in water coalitions.

Continuing to secure, affordable, reliable and high-quality groundwater for the city of Wasco.

Domestic water for low income families

In a community that has a well for our only water source.

Making sure we have enough water to provide the residents of the city

Making sure small systems needs are met and not forgotten alongside larger water users.

Providing quality drinking water and notification to customers

Quality of water.

to do away with the environmentalists and let fish swim for themselves

To have adequate supply of surface and/or ground water to be able to grow and sustain my permanent crops.

To irrigate all the permanent crops, trees and vines with maximum efficiency in use of available water so that I do not run short of water and that trees do not suffer in any way.

We make our living by growing crops. We have land payments, taxes, high costs in well drilling that we must pay for. Therefore, we must be able to continue to farm so we continue to use our resources in a productive yet not wasteful manner.

We make our living growing crops and we need to be able to maintain our land for survival, therefore, we have always tried to manage our water to our best ability.

We need water to be able to farm in the central valley.

Small disadvantaged community with one well and 18 connections.

That we always have clean and enough water

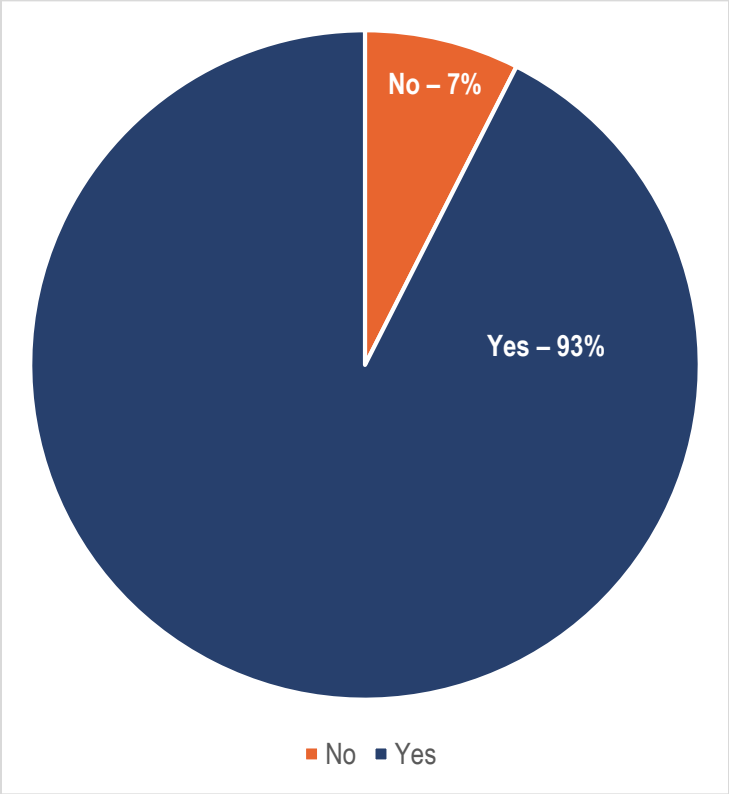
To continue uninterrupted municipal and farm use.

To have water when needed that is safe for drinking, cooking, etc.

Why do residents have to ration water (weekly watering schedules) while our groundwater is being pumped into the California Aqueduct and sent to LA or elsewhere?

United States

12. Do you have concerns about groundwater management? *(107 responses)*



If so, what are they? *(91 responses)*

That the ability to pump groundwater will be taken away.

Amounts we can pump and quality.

As a white zone owner, I am concerned about how we are going to reach sustainability and still make a living.

As the Public Works Director of a city that provides municipal water, I have a direct interest in groundwater. All of our water is supplied via groundwater wells.

Availability

Bureaucrats can raise my rates or cut me off from water.

Concern with endangered species act and how it's the reason for SGMA.

Concerned that private land owners will be burdened with record keeping and reporting to regulatory agencies.

Defining rainfall as groundwater so land can be taxed

Delivery system statewide

Fallowing ground and hurting the economy

Future groundwater pumping restrictions. Who is going to mandate groundwater pumping restrictions?

Government control

Government interference

Government involvement

Government regulation and interference

Government regulations and involvement

Granite Construction has several rural sites which depend exclusively on groundwater resources. Our concern is primarily that as SGMA rules are implemented our sites' operations are not materially impacted.

How much control will the government enforce upon growers? What practical experience do any of the

Need a great deal of underground water storage programs and a fair, effective water trading mechanism in the San Joaquin Valley basins.

Need more surface water and stop sending rainfall out to the Pacific Ocean.

No new water storage has been constructed in over 50 years, now we will be told how much we can pump. That would be a great idea and a must for the future IF we had enough water storage to farm for the year in tough years too! Legal issues are greatly reducing our surface water also. We make payments on our ground and need to farm every inch of it. We can't be cut short because we don't have water.

Over regulation

Over watering

Overpumping and the subsequent legislation. Over regulation.

Quality and supply

Quality of water

Recycling of wastewater for household and industrial users

Running out of water and creating an enforcement where smaller growers can't compete

Scientifically-based determination of sustainable yield of basin/sub-basin & management areas

SGMA limitations

SGMA poses significant challenges, and the uncertainty around how it will be implemented is concerning

SGMA, Sacramento politicians, Water Quality Control Board, DWR, oil industry contamination, etc.

Shortage

Someone will tell me I cannot pump water for my permanent crops

Subsidence in Tulare County reducing Friant Kern Canal capacity

Sustainability

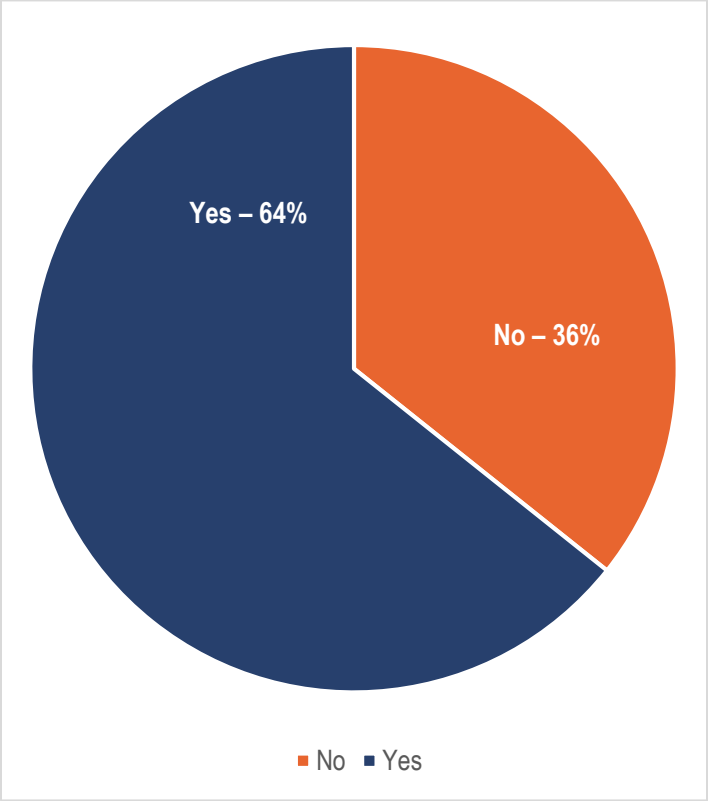
Sustainability - keeping our groundwater within our basin

government agencies/employees and/or mandator's have in the day to day irrigation practices, field experience?	
How much will government control cost us in money and loss of property rights?	That assumptions made regarding subsidence are in alignment with modeling being done by the subsidence team at DWR.
How will it be regulated? Who is appointed to the committee that ultimately will decide how water will be allocated?	That in dry years when there is inadequate surface water, we won't be able to draw enough groundwater to grow and/or sustain my permanent crops.
I am concerned that in the future I will be restricted in my use of groundwater during periods of drought. I do not consider groundwater as a primary source of water but as a reserve to be used in case of drought to augment restricted surface water availability.	That significant farm land acreage in my region will be taken out of production.
I am concerned that SGMA will become a method for taxation without representation or services.	That the state doesn't come in too heavy-handed, and that they allow us to work into SGMA over time.
I am concerned with our ability to continue to farm the permanent acreage we have developed. I am concerned that a GSP might lack a certain level of flexibility to allow for the transfer of pumping credits across the County or not allow for a proper phase in period that would allow a market to develop for water and/or water credits.	That the underground water basin is sufficient for Kern and not all used for Los Angeles
I fear the overdraft is too big of a problem in the Valley. Subsidence is another major concern.	That the water is protected from any type of contamination
I feel the average person does not feel the importance of farming and would prefer to take away our water and sell it to places like Los Angeles. We seem to already have allowed districts to drill wells and pump water out from underneath us to sell out of our area.	The irrigation canal that has replenished water levels for 100 years has been dry the last several years.
I hope within SGMA we are flexible in amounts we can pump to survive through the dry years	The limits will be put on small domestic users that may not be large enough to be heard.
I think evapotranspiration satellite technology will help balance our water use with taxation to the land user for overuse than trying to meter and police all our wells.	The prioritization of surface water allocation between the public, agriculture and the environment. Need more surface water deliveries to correct groundwater overdraft. Any reduction in irrigable acres needs to allow for viable economic adjustment over an extended timeframe.
I understand the reasoning behind SGMA, and sustainability is needed, but it needs to be combined with advocacy for more surface water. It was lack of surface water that caused the issues we face: if our surface water supply was more reliable, agriculture would not need to use as much groundwater.	To know what the water level is and how much water we can use and for how long
I understand we must manage our groundwater, I do not understand why some districts have been able to pump water out from underneath us and send it to LA. Also growers that have been allowed to plant on the westside where there has never been ag, only to help drain our groundwater. Those of us that have paid high dollars for ground that has both ground and surface water are now being punished.	To make sure water is available to meet demands of farming
If we can actually get a plan in action in time	Water usage is low for almonds
If we do not increase the supply of surface water by raising the level of existing reservoirs and making	We already do a good job with conservation in agriculture. Any more reduction in groundwater

more reservoirs to catch every drop of rain water, no matter how many restrictions we put on groundwater we cannot solve the problem. The only solution to solve the groundwater problem is to make more surface water available.	supply will have a direct correlation to a reduction of jobs. It would decimate many communities throughout the valley.
I'm afraid the government will over regulate and make it impossible to farm efficiently.	We are approaching the deadline for monitoring each location. Self Help will be helping us. Our concern is always the cost. My second concern is that it requires a great deal of time for small mutual water companies to comply with all the regulations.
Individuals vs. subbasin	We must manage water to survive.
Insufficient supply for our perennial crops due to extraction restrictions/limitations and/or restricted surface water.	We need more surface water.
Is SGMA going to limit our availability to access groundwater as a source of agriculture irrigation water? If it does, how will we obtain water in order to maintain our permanent crops of almonds and pistachios?	We need reliable surface water restored to our area so that groundwater recharge can offset groundwater pumping.
It appears that state water management problems are landing squarely on the shoulders of farming. This is going to put most small farmers out of business while corporate farming and municipalities thrive. This is a big mistake.	We paid for our well and shouldn't have to show how we use our water to grow our crops. We are all drip & fan jets, so yes we save and do not waste water
Lack of flexibility upon GSP implementation	What costs will be involved to comply? What limits will there be and on what acreage? Metering and monitoring, reporting regulations.
Long term quantity and quality	What will be the end result in restrictions and when?
Long term sustainable use of groundwater	Will there be a prioritization? Others vs. food? Who decides my future? Will I have enough water to grow my crops? If my surface water is curtailed outside of my control, will I be able to make up for that short fall by using my well as needed? Will there be a water market developed to purchase extra water?
Making sure that the rights of property owners are not over looked to solve this issue.	Will we be stopped from pumping our agricultural wells when our permanent crops need water?
Might run out of water on our domestic well and we don't have another source	Will we get enough water?
Monitor the oil wells because they can pollute the entire underground water system.	Will we have water? What regulatory issues? Loss of production of farm land
More government regulations	Yes, limiting groundwater consumption will limit the acres that can be farmed on well water as a primary source. Surface water quality trends are also in a decline and a higher reliance on low quality water gives me pause.
My concern with SGMA is the fact that our groundwater pumping will be limited in conjunction with not getting full allocation of surface water. I understand overdrafting has caused many issues like poor water quality, land subsidence and a water table that continues to drop. But if our groundwater pumping is cut and our surface water is cut, what are we supposed to do with our investment into permanent crops.	

13. Do you have requests or recommendations regarding groundwater management?

(98 responses)



If so, what are they? *(65 responses)*

Allow farmers more input. We aren't interested in depleting our resources.

Allow more imported water into our region from the north.

An even playing field for all participants

Banking, trades, surface water exchanges, all would help implementation by giving farmers book to adapt

Better communication of GSP development/GSA communication with individual growers

Bring in more surface water to make up for the pending cutbacks on pumping.

Build storage so we can save groundwater!!!

continue communication

Delete land from the Kern water basin that does not have any useable underground water.

Depending on SGMA implementation specifics, we need the ability to bank and trade water as much as possible.

Develop a method of transferring rights to groundwater (i.e. so-called pumping credits). Before

Make it cost effective.

Make sure growers have access to enough groundwater to grow their crops.

More groundwater banking, restore SWP water deliveries to 100%/

More proactive groundwater storage programs within each GSA, including any assessments required for water acquisition and infrastructure.

More water storage reservoirs

None with SWID (who sent us this survey), but many with Semitropic Water District

On-farm recharge is vital to long-term sustainability.

Please continue providing information on SGMA and how it will affect day-to-day farmers who may not be as inclined to "self-education" as most.

Please help local farmers with water or to build new wells.

Possibly opening up a resource or management division for small water mutuals.

Quality of water

limiting extractions outright, attempt to achieve sustainability through the means (i.e. fallowing program, tax on excess extraction, etc.), recharge programs

Develop a water market! Allow water transfers among other water users, farmers. Require the environmentalists to play their part.

Do not constrain groundwater availability to ag users.

Educated, practical, honest people making decisions.

Fixing the Friant so we can receive surface water

Flexibility

Focus on maximum flexibility that will still obtain groundwater equilibrium. GSA should help (where possible) to establish a free market where water and/or water credits can trade among land owners.

Get the state water infrastructure brought up to present day needs and standards.

How will the city manage groundwater so residential usage is managed, not just taxed? Crops before grass.

I admire the GSA's efforts and urge the GSA to continue involving the diverse set of stakeholders that have been engaged so far.

If the state of California wishes to regulate groundwater pumping, then the state and federal systems should guarantee any shortage in the form of surface water deliveries.

Implement groundwater banking credits, ensure areas not within irrigation districts pick up slack as they have not been paying into groundwater banking programs, look at ways to implement wastewater reuse from Bakersfield if possible.

Import more surface water.

Increase surface flows so we are less dependent on groundwater.

Increase surface water flows to reduce dependency on groundwater.

Rely on water districts

Request to be kept in the loop on any issues that may affect the City of Wasco's water supply.

Rural operations and construction projects often only have access to groundwater for operations/dust suppression. We are interested in flexibility of points of extraction (for construction purposes) and insuring that evaluations of current usage include both our construction and mining operations (this is often overlooked in basin usage evaluation as we are neither an agricultural nor residential/municipal service user).

We need flexibility in dry years.

Stop watering the fish.

That we as agricultural water users do our best to utilize surface water but be allowed to pump enough groundwater to grow our crops. I would suggest allowing a certain amount of groundwater to be used annually but averaging it out over a five-year period allow for drier and wetter years.

When we get plenty of surface water, no one would like to pump groundwater by spending so much money in drilling deep wells and electric motors.

The small domestic users keep their water rights.

There should be an equal conservative effort to water storage and infrastructure as regulating SGMA. We can limit pumping but let's figure out a way to capture water throughout the state and increase our efficiency with surface water.

To maintain the right to pump or sell the groundwater now and in the future.

Please put farming as a top priority for water use in the state of California.

To work together to create a plan for a sustainable aquifer

Vote for right-minded politicians, state and federal

We growers conserve as much water as possible. I see the city of Bakersfield wasting water every day – seven days a week, 365 days a year, and nothing has changed since SGMA has come about. What more restrictions will be placed on all farmers? What restrictions will be placed on all non-farm users? Who is exempt? The prison's "CDCR" (California Department of Corrections) wastes millions of gallons

of water per year. Who will address this issue? I am a prior correctional officer, I saw the waste firsthand."

Involve the small communities in decisions

We need to be able to go into this cautiously and not make big cuts at once.

We need to stop allowing our groundwater to leave our county. If its pumped here, it should stay here.

Keep us informed in a timely manner.

We should not over-react and limit that amount of pumping we do too drastically. It should be done slowly and monitored.

We want to see resource management at the basin-level with uniform and consistent methodologies (e.g., accounting, analysis etc.) Sufficient stakeholder engagement and facilitation are of concern as well.

Leave as is, just monitor.

What methods can we use to control groundwater?

Leave me alone. My use of water does not affect anyone in the San Joaquin Basin.

Whatever basin plan is approved, the adjustments to land and water use relationships are implemented over the longest period of time allowed by law.

Less government involvement and flawed environmental agendas

While M&I and ag need to work together, it can't turn into a situation where ag just gets the leftovers that environmental and M&I don't want.

Let us know in advance if you will be stopping us from using our wells.

14. Any other information the Kern Groundwater Authority should be aware of or take into consideration while developing the Groundwater Sustainability Plan? *(41 responses)*

Allow groundwater use averaging over a five-year span.

Quality of water

Board meetings get too in the weeds. Need a place for higher level policy discussion.

Should be district-based not basin-based

Small rural county communities need access to potable water - much of the water is naturally or chemically contaminated. Large cities deal with the problem better due to financial ability. Small systems cannot.

Businesses and livelihoods are at stake. No one is going to be regulated out of business without a fight.

Somehow consider the sizeable investment that growers (perennial crops, especially) have in their crops and development of infrastructure (i.e. irrigation and trellising), and their desire (need) to preserve the value of this investment, such that as many options as possible will need to be explored to accomplish this.

California needs more water storage like dams to help with water management

Stop the west side (that has never had water) from pumping water out from underneath us and sending it to LA and letting the two largest growers in the area from monopolizing it. Stop Semitropic Water District from drilling more wells just to send the water out of Kern County.

Conservation should be for all.

Thank you in advance for you work. You are doing a great service for our industry. It does not go unnoticed.

Continue to provide as much feedback as possible with regards to possible direction of GSP so that we are able to better plan for future knowing how/if a market for water will be developed.

That producing food products are crucial to people of our state and country, whether they realize it or not, and should be protected the best we can.

Do what you can to let public know it's the environmentalists that stop the pumps that have created the current groundwater problems. Work to change the regulations and let the fish fend for themselves.

Don’t have us do unnecessary paperwork. Some of us are just small entities and just want to make a living.

Groundwater should remain a reserve to be used in periods of restricted water availability from the CVP and SWP.

Groundwater pumping should be phased in very slowly (20-50 years): 1) To better monitor groundwater levels and replenishment over time; 2) To better understand where replenishment flows originate for each basin; 3) To allow farmers time to rotate out of permanent crops; 4) To allow water markets and pumping right markets to be formed within basins or water districts.

Groundwater shall not be a marketable resource to be exported or sold across county lines.

I am trying to understand current hydrological inflows and outflows of the area, so not at this point although this will change soon.

I feel that every water user in the state should submit a water management plan just like ag. If you use water in your home and/or business, you should be required to fill out a report just like the state is asking of us (farmers). I feel this is a one-sided implementation of SGMA, I would also like to see the restrictions placed on all consumers be the same across the board. If Sacramento is serious about a fix, this is a fair and impartial way of doing it. I doubt any of this will be taken seriously and implemented across the board, but I remain hopeful

Integration of management areas within basin those with surface vs those dependent on groundwater only.

Is land that is converted from ag to homes helpful for the district?

Much land that has no useable groundwater and has no effect on the basin has been included in the basin boundary.

My groundwater level has not changed substantially in many years.

No, if the action suggested above is taken, we do not need anything else to do at present we are not hitting the target. We are only beating around the bush, or I can say we are putting the cart before the horse.

Our situation took a long time to develop and will take commitment, patience and time to resolve.

Permanent crops are harder to lose than fallowing row crops or alfalfa!

That no restrictions should be put on pumping groundwater from those orchards and vineyards which do not get any district irrigation water, otherwise those orchards and vineyards will die, and part of California will become desert. That will be a big state and national loss.

The loss of jobs, complete industries, the tax base from the working class, housing developments; consumption by more homes means less water for ag.

The required amount of water to farm different crops should not be determined by the GSA or the districts. Farmers/users should have that right.

The runoff from rainfall on the West side of Kern County does not get into the basin groundwater supply. The groundwater that comes from fractured shale formations does not affect the water supply or quality in the basin.

Use common sense, not agenda-driven emotions.

We have several people in our GSA continuing to use groundwater and not surface water. This must be addressed.

We look to be active in developing viable on-farm recharge.

We need transitional pumping.

When I shower, my skin stings, this hasn't always been true. I'm concerned that the water is irritating my skin and making my psoriasis worse.

With so many different standing water depths across the country don't take a one-size fits all.

Without the help from Self Help Enterprises, we would be out of water and with no hope since it is a disadvantaged community. Elizabeth B. has been a wonderful helper.

Yes, now will small growers be able to meet the need of the crop if limits are mandated on how much water we can pump? Large growers and farmers can leave part of their land fallow and use that water on another area of their ranch to meet their water needs.

Yes, start campaigning to do away with saving the delta smelt.

KERN GROUNDWATER AUTHORITY

Agriculture Stakeholder Survey

Please return completed surveys to the Kern Groundwater Authority by emailing tbarton@ppeng.com, fax to (661) 479-7172, or mail to Kern Groundwater Authority, 1800 30th Street, Suite 280, Bakersfield, CA 93301.

Stakeholder Surveys may also be completed online by visiting www.kerngwa.com.

Date: _____

Note: Please complete your name and contact information if you'd like to be added to the GSA's email and mailing list for future updates and information regarding Sustainable Groundwater Management Act (SGMA) and the Kern Groundwater Authority.

Name: _____

Address: _____

City: _____ **State:** _____ **Zip:** _____

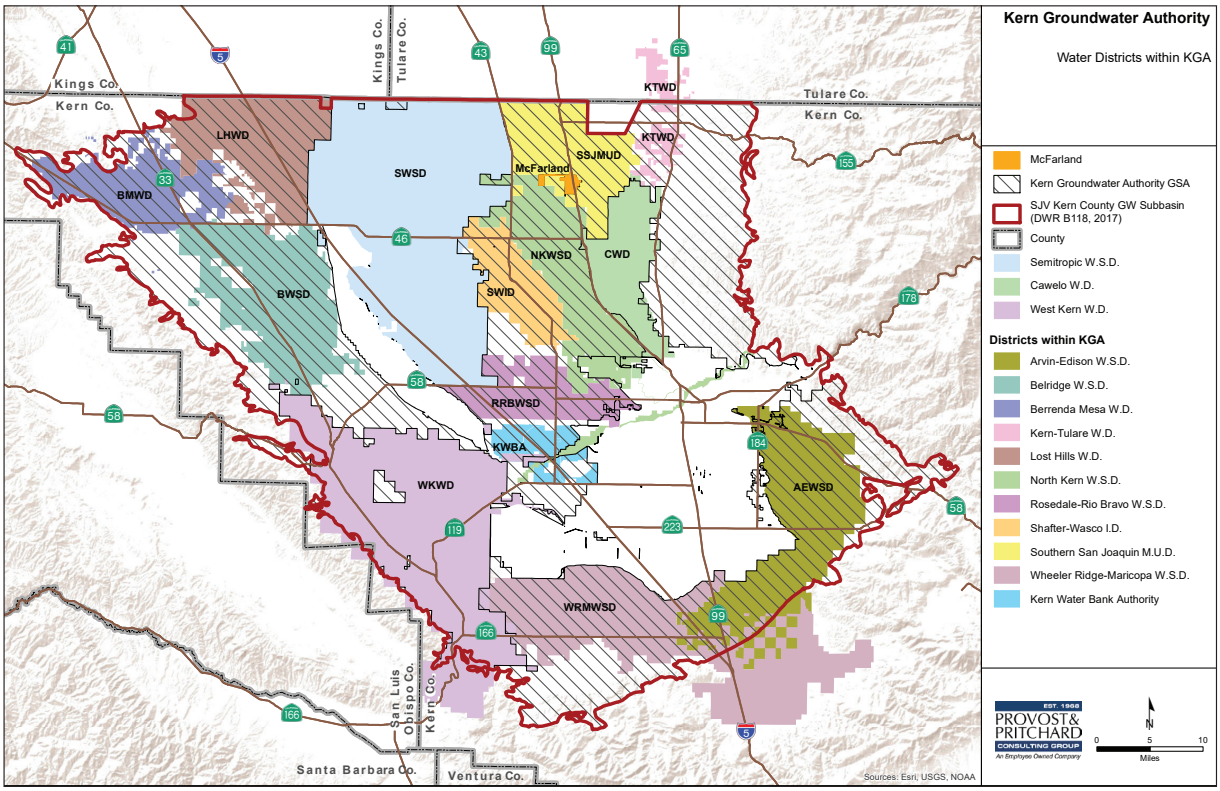
Email: _____ **Telephone:** _____

APN(s) for lands farmed/managed: _____

_____

1. **We have included a map of the Kern Groundwater Authority irrigation and water districts. Please indicate below which districts in which you have land parcels.** ***Check all that apply.***

- ☐ Arvin Community Services District (ACSD)
- ☐ Arvin-Edison Water Storage District (AEWSD)
- ☐ Cawelo Water District (CWD)
- ☐ City of Shafter
- ☐ County of Kern
- ☐ Kern County Water Agency (KCWA)
- ☐ Kern-Tulare Water District (KTWD)
- ☐ Kern Water Bank Authority (KWBA)
- ☐ North Kern Water Storage District (NKWSD)
- ☐ Rosedale-Rio Bravo Water Storage District (RRBWSD)
- ☐ Semitropic Water Storage District (SWSD)
- ☐ Shafter-Wasco Irrigation District (SWID)
- ☐ Southern San Joaquin Municipal Utility District (SSJMUD)
- ☐ Tejon-Castaic Water District (TCWD)
- ☐ West Kern Water District (WKWD)
- ☐ Westside District Water Authority (WDWA)
- ☐ Wheeler Ridge-Maricopa Water Storage District (WRMWSD)



2. **How many total acres do you farm (all land owned, leased and/or managed)?:** _____

3. **In a typical year, how much of the following crops, animals or land do you manage/own?**

Crop or Land Type	Acres Managed or Owned
Fruit trees	
Nut trees	
Row crops	
Seed crops	
Vegetables	
Grain	
Grapes	

Crop or Land Type	Acres Managed or Owned
Hay/alfalfa	
Livestock on pasture/rangeland	
Dairy *(total head)*	
Food Processor/Production	
Other land use *(please indicate)*:	

4. **Which of the following sources of water and management do you typically utilize under the following conditions?**

Water Source/Management	Dry Years	Normal Years	Wet Years
Irrigation through surface water only			
Irrigation through groundwater only			
Irrigation through a mixture of surface and groundwater			
Wastewater land applied			
No irrigation			

5. **If you do use irrigation, which of the following methods of delivery do you use?** ***Check all that apply.***

☐ Furrow/flood ☐ Sprinklers ☐ Drip ☐ Microsprinkler ☐ Center pivot

☐ Other *(please indicate)*: _____

6. **In response to water scarcity, please indicate if you currently use the following practices and your likelihood to use the following practices in the future.**

Practice	Currently Use	Future Use					
		Very Unlikely	Unlikely	Somewhat Unlikely	Somewhat Likely	Likely	Very Likely
Drill more wells							
Restore existing wells							
Make existing wells deeper							
Pump more groundwater than previous years							
Drip irrigation							
Water monitoring technology							
Fallow fields							
Soil moisture sensors							
Change to a less water intensive crop							
Reduce livestock stocking rates							
Leaf sampling to measure plant-water status							
Purchase additional water							
Purchase crop insurance							
Other:							

7. **Please rate the level of importance these potential groundwater conditions are to you *(with "1" being the most concerning, 5 being the least concerning)*. If you have additional concerns, please indicate them in the "Other" category.**

Groundwater Condition	Rating of Concern
Lowering of groundwater levels	
Reduction in groundwater storage	
Water quality degradation	
Local subsidence	
Depletions of surface water	
Other *(your opinion)*:	
Other *(your opinion)*:	

8. **The following are a list of management options that have been used on the West Coast for water management. Please provide your level of preference for these types of management:**

Management Option	Strongly Against	Against	Somewhat Against	Somewhat Support	Support	Strongly Support	Not Familiar
Individual recharge credits (i.e. winter flooding)							
Water metering							
Water trading through markets							
Public program highlighting farmers implementing water saving practices							
Farmer adoption of water management practices							
District investment in conjunctive use infrastructure (i.e. water storage)							
Groundwater replenishment fees							
Fixed quota for water pumping allocated to each farmer							
Incentives for water saving practices							
Moratorium on drilling new wells							
Permits for drilling new wells							
Other *(your opinion)*:							
Other *(your opinion)*:							

9. **If groundwater monitoring is required in the future, which of the following monitoring methods would you prefer?**

Method of Determining Water Allocation	Strongly Not Preferred	Not Preferred	Somewhat Not Preferred	Somewhat Preferred	Preferred	Strongly Preferred
Well metering						
Use satellite estimates and ground truth						
Use standard crop water requirement indexes						

10. Should disputes arise over SGMA implementation, what is your preferred means of reconciliation?

Dispute Option	Strongly Not Preferred	Not Preferred	Somewhat Not Preferred	Somewhat Preferred	Preferred	Strongly Preferred
State Water Resources Control Board						
Groundwater Sustainability Agency						
County Board of Supervisors						
Superior Court System						
Arbitration						
Other:						

11. If you have any additional information or feedback regarding SGMA, water management or farming in Kern County that should be taken into consideration while developing the Groundwater Sustainability Plan (GSP), please provide the information below:

Please return completed surveys to the Kern Groundwater Authority by emailing tbarton@ppeng.com, fax to (661) 479-7172, or mail to Kern Groundwater Authority, 1800 30th Street, Suite 280, Bakersfield, CA 93301.

Stakeholder Surveys may also be completed online by visiting www.kerngwa.com.

130 N. Garden Street
Visalia, CA 93291-6362
Tel: (559) 636-1166
Fax: (559) 636-1177
www.ppeng.com

Memorandum

To:	Kern Groundwater Authority Board of Directors
From:	Trilby Barton, Public Outreach Coordinator, Provost & Pritchard Consulting Group
Subject:	Ag-Focused Stakeholder Survey Results – Monthly Progress Report
Date:	June 21, 2019

Hard copies and the link to the online version of the Kern Groundwater Authority's Ag-Focused Stakeholder Survey are being circulated throughout Kern County. The survey has been distributed by member districts and is available online at www.kerngwa.com. **To date, Kern Groundwater Authority has received 68 responses**. This memo summarizes the responses received to date.

Progress Report of Kern Groundwater Authority Stakeholder Survey Results

1. Please indicate which irrigation/water district in which you have land.

(68 responses, multiple answers per respondent)

District Name	Number of Responses	District Name	Number of Responses
Arvin Edison Community Services District	0	Rosedale-Rio Bravo Water Storage District	6
Arvin-Edison Water Storage District	10	Semitropic Water Storage District	9
Cawelo Water District	4	Shafter-Wasco Irrigation District	30
City of Shafter	2	Southern San Joaquin Municipal Utility District	31
County of Kern	4	Tejon-Castaic Water District	0
Kern County Water Agency	2	West Kern Water District	2
Kern-Tulare Water District	5	Westside District Water Authority	5
Kern Water Bank Authority	3	Wheeler Ridge-Maricopa Water Storage District	3
North Kern Water Storage District	8		

2. How many total acres do you farm (all land owned, leased and/or managed)?

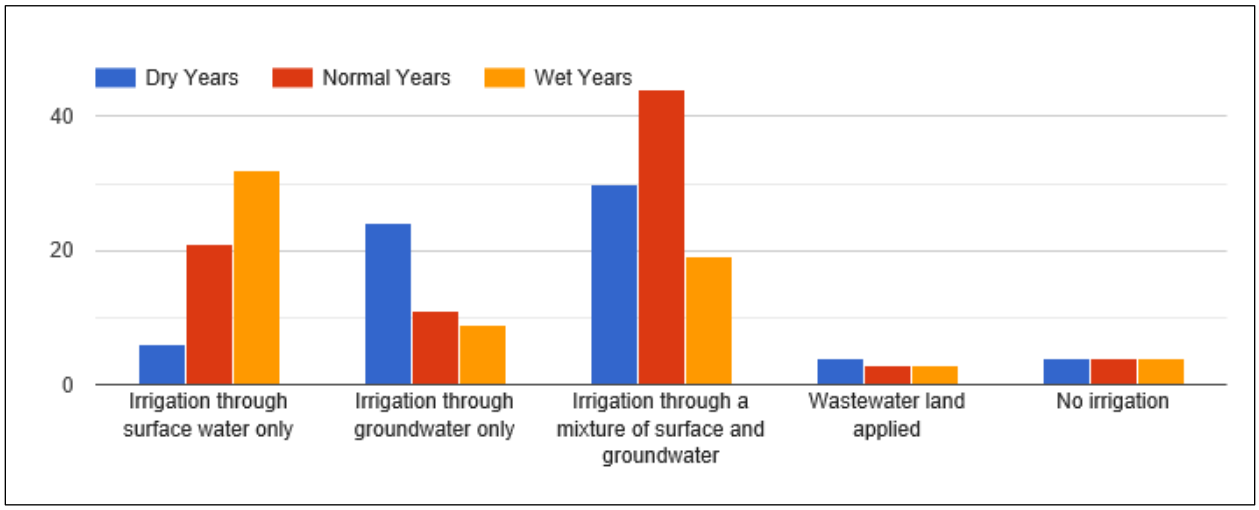
(58 responses)

Total Acres Farmed	Total Acres Farmed	Total Acres Farmed
4	207	1,000
8	220	1,160
17	230	1,200 (x2)
20	235	1,250 (x2)
35	254	1,500
39.25	257	1,722
40	266	1,921.27
42.21	280	2,044
54	350	2,630
55	370	3,000
56.5	375 (x2)	3,500
100 (x2)	467	4,415
135.33	516	5,000
143	600	6,000
155	640	15,000
156	770	29,000
160	825	
161.82	890	

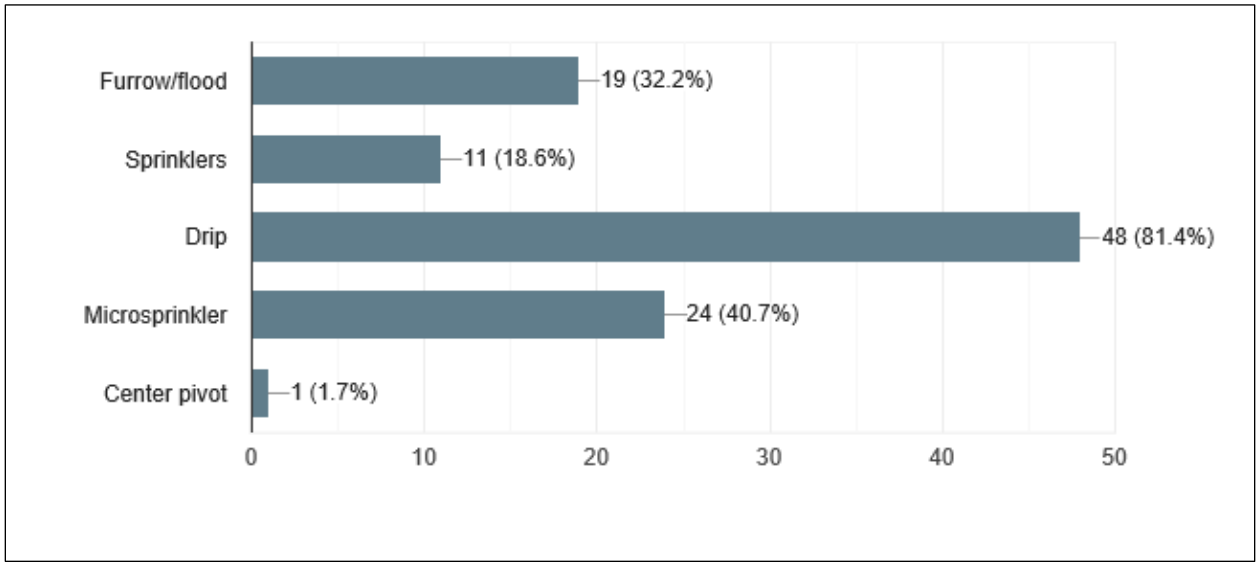
3. In a typical year, how much of the following crops, animals or land do you manage/own?

Crop or Land Type	Acres Managed or Owned	Crop or Land Type	Acres Managed or Owned
Fruit trees	Ranges from 5-6,000 acres *(23 responses)*	Grapes	Ranges from 100-1,500 acres *(9 responses)*
Nut trees	Ranges from 8-15,000 acres *(47 responses)*	Hay/alfalfa	Ranges from 17-1,000 acres *(8 responses)*
Row crops	Ranges from 65-3,000 acres *(8 responses)*	Livestock on pasture/rangeland	Ranges from 4-17,000 acres *(4 responses)*
Seed crops	*0 responses*	Dairy (total head)	*0 responses*
Vegetables	70-1,500 acres *(2 responses)*	Food Processor/Production	*0 responses*
Grain	Ranges from 250-2,000 acres *(6 responses)*	Other land use (please indicate):	Ranges from 20 to 681 acres of fallowed ground *(3 responses)*

4. Which of the following sources of water and management do you typically utilize under the following conditions?



5. If you do use irrigation, which of the following methods of delivery do you use? Check all that apply. *(59 responses)*



6. In response to water scarcity, please indicate if you currently use the following practices and your likelihood to use the following practices in the future. *(Table lists number of responses.)*

Practice	Currently Use	Future Use					
		Very Unlikely	Unlikely	Somewhat Unlikely	Somewhat Likely	Likely	Very Likely
Drill more wells	6	14	10	6	5	4	6
Restore existing wells	11	12	3	4	9	7	5
Make existing wells deeper	3	14	11	9	8	2	2
Pump more groundwater	7	7	8	3	13	5	7

Practice	Currently Use	Future Use					
		Very Unlikely	Unlikely	Somewhat Unlikely	Somewhat Likely	Likely	Very Likely
than previous years							
Drip irrigation	35	4	1	1	5	5	17
Water monitoring technology	28	2	1	3	6	4	18
Fallow fields	4	11	14	3	4	9	1
Soil moisture sensors	27	2	1	2	7	6	13
Change to a less water intensive crop	4	24	8	7	2	4	1
Reduce livestock stocking rates	1	14	4	1	2	0	4
Leaf sampling to measure plant-water status	13	4	3	2	12	11	4
Purchase additional water	11	5	6	4	7	12	13
Purchase crop insurance	23	3	1	4	6	8	16
Other: *(5 responses)*	Bank water and purchase water credits; Vacant land for sale; Bank water; Groundwater recharge; deep root irrigation						

7. **Please rate the level of importance these potential groundwater conditions are to you** *(with "1" being the most concerning, 5 being the least concerning).* **If you have additional concerns, please indicate them in the "Other" category.** *(Table lists number of responses.)*

Groundwater Condition	Rating of Concern *(1 most concerning, 5 least concerning)*				
	1	2	3	4	5
Lowering of groundwater levels	37	21	2	4	0
Reduction in groundwater storage	28	16	11	4	6
Water quality degradation	13	15	21	9	5
Local subsidence	16	12	11	6	17
Depletions of surface water	43	9	6	2	5

Other *(your opinion)*: There is no potable water under the surface of our land in the white area. We do not have any wells, or use any groundwater, but have been included in the basin anyway. The drinking water for our livestock comes from springs located in the mountains outside of the basin.

It is all politics!!!!! California has plenty of water, use common sense!!

Get rid of the "enviros"; to hell with the fish

Limiting access/use

To rid bureaucratic time wasters; to rid enviros stopping the pumps

Worry about Semitropic groundwater degradation and other areas in our district

Government interferences

8. The following are a list of management options that have been used on the West Coast for water management. Please provide your level of preference for these types of management: *(Table lists number of responses.)*

Management Option	Strongly Against	Against	Somewhat Against	Somewhat Support	Support	Strongly Support	Not Familiar
Individual recharge credits (i.e. winter flooding)	3	2	1	6	17	25	3
Water metering	11	10	8	12	12	8	1
Water trading through markets	4	5	5	8	13	24	4
Public program highlighting farmers implementing water saving practices	2	0	3	12	23	21	1
Farmer adoption of water management practices	2	1	1	9	24	26	0
District investment in conjunctive use infrastructure (i.e. water storage)	3	0	1	3	12	41	1
Groundwater replenishment fees	14	10	13	10	6	3	7
Fixed quota for water pumping allocated to each farmer	24	8	9	11	6	1	2
Incentives for water saving practices	2	2	0	16	18	20	3
Moratorium on drilling new wells	13	12	16	5	3	2	4
Permits for drilling new wells	5	6	8	8	22	10	3
Other *(your opinion)*:	None						

9. If groundwater monitoring is required in the future, which of the following monitoring methods would you prefer? *(Table lists number of responses.)*

Method of Determining Water Allocation	Strongly Not Preferred	Not Preferred	Somewhat Not Preferred	Somewhat Preferred	Preferred	Strongly Preferred
Well metering	17	8	7	9	17	5
Use satellite estimates and ground truth	7	12	15	11	6	2
Use standard crop water requirement indexes	5	10	13	15	6	5

10. Should disputes arise over SGMA implementation, what is your preferred means of reconciliation? *(Table lists number of responses.)*

Dispute Option	Strongly Not Preferred	Not Preferred	Somewhat Not Preferred	Somewhat Preferred	Preferred	Strongly Preferred
State Water Resources Control Board	18	9	5	7	0	13
Groundwater Sustainability Agency	7	2	5	15	16	8
County Board of Supervisors	20	12	4	6	9	2
Superior Court System	23	16	2	4	4	3
Arbitration	3	11	3	9	4	2
Other *(4 responses):* I want the state to delete our land from the basin boundary, then I will not have any dispute to reconcile; Stop running water to the Pacific Ocean; A farmer-controlled Advisory Board						

11. If you have any additional information or feedback regarding SGMA, water management or farming in Kern County that should be taken into consideration while developing the Groundwater Sustainability Plan (GSP), please provide the information below: *(14 responses)*

Allow water banking where it is easiest conveyed and allow those groundwater banking credits to be used in the basin where it is need. If a white area landowner is able to purchase water and can bank it in Arvin or Lost Hills allow this to happen vs spending hundreds of thousands of dollars to convey that water to the particular area where is will be pumped out of. Use the Kern River as a water bank and who ever leaves the water in the river gets the credit for their district no matter where is actually is recharged too. It's one Basin. Why spend millions building additional water banks and conveyance systems when you have the best recharge ground and conveyance system already in place. In addition, think how beautiful our city could be if we had water running though the river more often. WORK TOGETHER for solutions that is best for the basin and allow those benefits to be spread across to all the districts who contribute to the solution.

Important that market is established that allows for creation of an asset (water pumping credit) that can be traded in open market. This would (hopefully) cause water to be used for highest and best use and still allow for flexibility we need in industrial agriculture.

Need ground water

No new water storage has been constructed in over 30 years. Now we will be told how much we can pump. It would of great advantage for our future if we had enough water storage to farm our crop during tough years. Legal issues are greatly reducing our surface water! We make payments on our ground and we need to farm every inch of it. We can't be cut short because of a lack of water. Build a storage so we can save ground water!

Pretty well explained above, we do not have any wells within the basin boundary, do not use any groundwater, do not have any farming and do not want to be included in any of the water wars.

We should have an aggressive program promoting groundwater recharge wherever and whenever possible.

I'm not in support of mega growers only buying farmland in order to resell water to places like L.A. to make a killing off of. Needs to be against the law and downright illegal. The extra water should go to farmers or storage for drought years... not to make profit on!!!

Water trading through markets seems like our best option. Also, connecting farms with conservation easements to facilitate retiring their land.

Work more closely with oil field-produced water and pipe it to other water districts.

Ensure growers fully understand current water consumption. At this point most growers don't have a strong handle on water use which leads to fear of SGMA implementation. Although fearful for agriculture, a program such as this is necessary. With current estimates, groundwater credits and groundwater markets will allow farming to continue in one method or another.

Best to have all district board presidents meet quarterly to work out ways to exchange any surplus water and to work out the details.

Give us the water. Don't send the water out to the ocean. Don't send water to fish that have not been in the area for over 50 years.

I know we can't keep depleting our underground basin, but we need to increase storage and use a more common-sense approach for water. Stop flushing our water to sea.

Some of the proposals presented are ridiculous. Mitigation features presented - farmers paying for municipal wells and housing (rural) well development.

Farmers aren't the end users of water. Consumers are. We are efficient and food is a basic need for survival. It's a shame our state has the best farm land in the world wants to eliminate the profession. We're highly regulated more so than anywhere else in the world. Farming for a century on our land and living on it and investing in, it's hard to move away.

Appendix C

List of Kern Groundwater Authority Public Outreach Efforts

List of Kern Groundwater Authority Public Outreach Efforts

Throughout the SGMA process, the Kern Groundwater Authority held public outreach efforts to engage stakeholders in the development of the Groundwater Sustainability Plan. These KGA-wide meetings and events are listed by phase in a timeline format in Figure VI-1, Figure VI-2, and Figure VI-3, and are listed below in **Table C-1**. Supporting materials for all events and meetings are available at www.kerngwa.com.

The KGA member agencies also held district-specific outreach efforts during the process, and those events and meetings are noted in their specific chapters of the GSP.

Table C-1. List of KGA Public Outreach Efforts

Meeting/Event	Date/Location
2015	
KGA Board of Directors Meeting	January 21, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	February 25, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	March 25, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	April 22, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	May 27, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	June 24, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	August 26, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	September 23, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	October 28, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	November 16, 2015, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	December 21, 2015, Kern County Administration Building, Bakersfield
2016	
KGA Board of Directors Meeting	January 27, 2016, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	February 24, 2016, Kern County Administration Building, Bakersfield
KGA Special Board of Directors Meeting	March 21, 2016, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	April 27, 2016, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	May 18, 2016, Kern County Administration Building, Bakersfield
KGA Special Board of Directors Meeting	June 29, 2016, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	August 24, 2016, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	September 28, 2016, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	October 24, 2016, Kern County Administration Building, Bakersfield
SGMA Stakeholder Outreach Workshop	October 24, 2016, Kern Ag Pavilion, Bakersfield
KGA Special Board of Directors Meeting	November 14, 2016, Kern County Administration Building, Bakersfield

Meeting/Event	Date/Location
SGMA Stakeholder Outreach Workshop	November 1, 2016, Kern County Water Agency, Bakersfield
SGMA Stakeholder Outreach Workshop	November 15, 2016, Kern Ag Pavilion, Bakersfield
SGMA Stakeholder Outreach Workshop	November 28, 2016, Kern County Administration Building, Bakersfield
SGMA Stakeholder Outreach Workshop	December 5, 2018, Kern Ag Pavilion, Bakersfield
SGMA Stakeholder Outreach Workshop	December 20, 2018, Kern County Administration Building, Bakersfield
2017	
KGA Board of Directors Meeting	January 25, 2017, Kern County Administration Building, Bakersfield
KGA Special Board of Directors Meeting	February 22, 2017, Kern County Administration Building, Bakersfield
KGA Special Board of Directors Meeting	March 22, 2017, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	April 26, 2017, Kern County Administration Building, Bakersfield
KGA Special Board of Directors Meeting	May 15, 2017, Kern County Administration Building, Bakersfield
KGA Special Board of Directors Meeting	June 19, 2017, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	July 19, 2017, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	August 23, 2017, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	September 27, 2017, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	October 25, 2017, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	November 16, 2017, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	December 20, 2017, Kern County Administration Building, Bakersfield
2018	
KGA Stakeholder Committee Meeting	January 8, 2018, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Stakeholder Committee Meeting	February 5, 2018, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Board of Directors Meeting	February 28, 2018, Kern County Administration Building, Bakersfield
KGA Stakeholder Committee Meeting	March 5, 2018, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Board of Directors Meeting	March 28, 2018, Kern County Administration Building, Bakersfield
KGA Stakeholder Committee Meeting	April 2, 2018, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Board of Directors Meeting	April 25, 2018, Kern County Administration Building, Bakersfield
Groundwater Workshop for Disadvantaged Community Stakeholders	April 26, 2018, Shafter
KGA Stakeholder Committee Meeting	May 7, 2018, Rosedale-Rio Bravo Water Storage District, Bakersfield
Groundwater Workshop for Disadvantaged Community Stakeholders	May 21, 2018, Arvin
KGA Board of Directors Meeting	May 23, 2018, Kern County Administration Building, Bakersfield
KGA Stakeholder Committee Meeting	June 4, 2018, Rosedale-Rio Bravo Water Storage District, Bakersfield

Meeting/Event	Date/Location
KGA Board of Directors Meeting	June 27, 2018, Kern County Administration Building, Bakersfield
KGA Stakeholder Committee Meeting	July 2, 2018, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Board of Directors Meeting	July 25, 2018, Kern County Administration Building, Bakersfield
"Kern County In Depth" – Television program discussion of the establishment of GSAs and SGMA overview	Aired August 16, 2018, KGET Channel 17 (reran on Saturdays for four subsequent weeks, segment archive links on KGET website)
KGA Board of Directors Meeting	August 22, 2018, Kern County Administration Building, Bakersfield
KGA Stakeholder Committee Meeting	September 20, 2018, Rosedale-Rio Bravo Water Storage District, Bakersfield
Sustainable Groundwater Plan, Compliance & State Intervention Stakeholder Informational Meeting	September 20, 2018, Kern Ag Pavilion, Bakersfield
KGA Stakeholder Committee Meeting	October 1, 2018, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Board of Directors Meeting	October 24, 2018, Kern County Administration Building, Bakersfield
KGA Board of Directors Meeting	December 19, 2018, Kern County Administration Building, Bakersfield
2019	
KGA Stakeholder Committee Meeting	January 7, 2019, Rosedale-Rio Bravo Water Storage District, Bakersfield
"Kern County In Depth" – Television program discussion of Kern County withdrawal from KGA and status of GSPs	Aired January 9, 2019, KGET Channel 17 (reran on Saturdays for four subsequent weeks, segment archive link on KGET website)
KGA Board of Directors Meeting	January 23, 2019, Greater Bakersfield Chamber of Commerce, Bakersfield
KGA Stakeholder Committee Meeting	February 4, 2019, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Board of Directors Meeting	February 27, 2019, Greater Bakersfield Chamber of Commerce, Bakersfield
SGMA Report at Kern County Farm Bureau Board Meeting	March 21, 2019, Kern County Farm Bureau, Bakersfield
KGA Board of Directors Meeting	March 27, 2019, Greater Bakersfield Chamber of Commerce, Bakersfield
SGMA Report at Kern County Farm Bureau Board Meeting	April 24, 2019, Kern County Farm Bureau, Bakersfield
KGA Board of Directors Meeting	April 24, 2019, Klein, DeNatale & Goldner Law Offices, Bakersfield
SGMA Open House Event	May 14, 2019, Kern Ag Pavilion, Bakersfield
SGMA Report at Kern County Farm Bureau Board Meeting	May 16, 2019, Kern County Farm Bureau, Bakersfield
KGA Board of Directors Meeting	May 22, 2019, Greater Bakersfield Chamber of Commerce, Bakersfield
KGA Stakeholder Committee Meeting	June 3, 2019, Rosedale-Rio Bravo Water Storage District, Bakersfield

Meeting/Event	Date/Location
KGA Board of Directors Meeting	June 26, 2019, Klein, DeNatale & Goldner Law Offices, Bakersfield
KGA Stakeholder Committee Meeting	June 3, 2019, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Stakeholder Committee Meeting	July 1, 2019, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Board of Directors Meeting	July 24, 2019, Greater Bakersfield Chamber of Commerce, Bakersfield
KGA Stakeholder Committee Meeting	August 5, 2019, Rosedale-Rio Bravo Water Storage District, Bakersfield
SGMA Report at Kern County Farm Bureau Meeting	August 15, 2019, Kern County Farm Bureau, Bakersfield
KGA Board of Directors Meeting	August 28, 2019, Klein, DeNatale & Goldner Law Offices, Bakersfield
"Kern County In Depth" – Television program discussion of the release of the GSPs, management actions/projects, and next steps	Original air date August 28, 2019, KGET Channel 17 (reran on Saturdays for four subsequent weeks, segment archive link on KGET website)
Management Area/GSP Plan Presentations to KGA Member Agencies' Board of Directors	August 6, 2019, Kern Water Bank August 8, 2019, Kern-Tulare Water District and Cawelo Water District August 13, 2019, Rosedale Rio-Bravo Water Storage District August 14, 2019, Wheeler Ridge-Maricopa Water Storage District, Semitropic Water Storage District, Shafter-Wasco Irrigation District, and Tejon Castac Water District August 15, 2019, Arvin-Edison Water Storage District and Eastside Water Management Area August 20, 2019, North Kern Water Storage District August 21, 2019, Southern San Joaquin Municipal Utility District, Kern County Water Agency, and Westside District Water Authority August 27, 2019, West Kern Water District August 28, 2019, Kern Groundwater Authority
KGA Stakeholder Committee Meeting	September 4, 2019, Rosedale-Rio Bravo Water Storage District, Bakersfield
GSP Public Review Presentation	September 13, 2019, Greater Bakersfield Chamber of Commerce
GSP Public Review Presentation	September 20, 2019, California Partnership for the San Joaquin Valley
GSP Public Review Open House for Stakeholders	September 26, 2019, 5:30-7 p.m., Kern Ag Pavilion, Bakersfield
KGA Board of Directors Meeting	September 25, 2019, Klein, DeNatale & Goldner Law Offices, Bakersfield
KGA Stakeholder Committee Meeting	October 7, 2019, Rosedale-Rio Bravo Water Storage District, Bakersfield
KGA Board of Directors Meeting	October 23, 2019, Greater Bakersfield Chamber of Commerce, Bakersfield
KGA Stakeholder Committee Meeting	November 4, 2019, Rosedale-Rio Bravo Water Storage District, Bakersfield
GSP Public Review Presentation	November 11, 2019, Kern Leaders Academy
GSP Public Review Presentation	November 12, 2019, Bakersfield Hispanic Chamber of Commerce

Meeting/Event	Date/Location
KGA Board of Directors Meeting	November 20, 2019, Klein, DeNatale & Goldner Law Offices, Bakersfield
GSP Public Review Presentation	November 21, 2019, Kern County Farm Bureau
KGA GSP Public Hearing & Board of Directors Meeting	December 18, 2019, Klein, DeNatale & Goldner Law Offices, Bakersfield
GSP Update Presentation	December 19, 2019, Central California Environmental Justice Network
2020	
KGA Board of Directors Meeting	January 15, 2020, Klein, DeNatale & Goldner Law Offices, Bakersfield
GSP Overview Presentation	January 15, 2020, CAL CPA
GSP Overview Presentation	January 16, 2020, Kern County Farm Bureau
GSP Overview Presentation	January 22, 2020, Kern County LAFCO Board

Kern Groundwater Authority Groundwater Sustainability Agency
Groundwater Sustainability Plan

ATTACHMENT F

Public Comments

Commentor	Ref #	Comment	Response
Kern Groundwater Authority Received Comments			
Kern County Farm Bureau	FB-1	The Kern County Farm Bureau (KCFB) is submitting this letter on behalf of its members expressing the open and transparent process that the Kern Groundwater Authority (KGA) provided during the development of the Groundwater Sustainability Plan (GSP) required under the Sustainable Groundwater Management Act (SGMA).	Comment Noted.
Kern County Farm Bureau	FB-2	During the last two plus years of the KGA's formation and subsequent development of the GSP, the KGA has attended and presented monthly to the KCFB's board, members, and guests. Most importantly, with the approval of the KCFB, the KGA continuously sought input, recommendations, and suggestions from the KCFB members. In addition to these efforts, the KGA partnered with the KCFB to hold several "Open House" workshops with the Department of Water Resources (DWR) and State Water Board staff in attendance as willing participants thus providing the KCFB's members and all other beneficial users of groundwater in the Kern Subbasin the opportunity to talk one-on-one with staff.	Comment Noted.
Hancock Farmland Services	HFS-1	The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water, for example xxx,xxx acre-feet and not associated with a given gross or net area.	There is no allocation of native yield at this time. The use of the native yield at this time is a component of developing a basic water budget. The water model for the Kern subb describes in detail the native yield and how the water model derives to the Kern subbasin number. There are no determination of any water rights or allocations.
Hancock Farmland Services	HFS-2	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	Comment Noted. See Kern Water Bank Authority Response
Hancock Farmland Services	HSF-3	GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration.	Remote sensing is also another mechanism that is being explored at this time. The KGA is working with DWR to amend a current grant program to accommodate the usage of t funds to begin the development of a program to establish remote sensing systems.
Westchester	WGIM-1	The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water, for example xxx,xxx acre-feet and not associated with a given gross or net area.	Comment noted. See Hancock Farmland Services HFS-1 response.
Westchester	WGIM-2	... GSAs and MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible without creating undesirable results, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity.	Comment Noted: The KGA also agrees with the recommendation to utilize the best available data and science.
Westchester	WGIM-3	As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated and consistent across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled).	Comment Noted: Each individual management area and GSA have different water supplies, water amounts and water banking projects thus the coordination occurred during t development of the water model for future projections. SGMA requires to respect water rights.
Westchester	WGIM-4	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	Comment Noted: See Kern Water Bank Authority response
Westchester	WGIM-5	GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater.	The GSAs in the Kern County subbasin are currently engaged in the development of a coordinated basin-wide data management system (DMS). That process has just begun w submittal of an application to DWR for Prop 68 grant funds. As that moves forward, the design of the DMS is vital to the management/tracking of groundwater and surface wa use.
Westchester	WGIM-6	GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration.	Comment Noted: See Hancock Farmland Services HSF-3 response
Wonderful Orchards	WO-1	It is imperative that the final GSP properly address the quantification of native yield. The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource.	Comment Noted: See Hancock Farmland Services HFS-1 response
Wonderful Orchards	WO-2	In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield.	Comment Noted: See Hancock Farmland Services HFS-1 response
Wonderful Orchards	WO-3	In addition, GSAs should initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations of native yield that are coordinated across the subbasin.	Comment Noted: The KGA will continue to hold stakeholder workshops throughout the implementation of the GSP.
Wonderful Orchards	WO-4	Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next.	Comment Noted: Water Markets are mentioned in several individual management area plans as management projects/actions. As a basin, the discussion is continuing betwee GSAs. The KGA will continue to hold stakeholder workshops throughout the implementation of the GSP.
Wonderful Orchards	WO-5	GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity	Comment Noted: See Westchester WGIM-2
Wonderful Orchards	WO-6	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	Comment Noted: See Hancock Farmland Services HFS-2 response
Wonderful Orchards	WO-7	GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater.	Comment Noted: See Westchester WGIM-5 response.

Commentor	Ref #	Comment	Response
Dept of Fish and Wildlife	DFW-1	The Department recommends continued data collection to reduce uncertainty around shallow groundwater, and concurrently, around the presence of GDEs. Until such time as a GOE can be verified through field work or increased resolution of groundwater mapping reliant on hydrologically robust baselines, the Department recommends including all potential GDEs in the MAP as beneficial users of groundwater	Comment Noted. The KGA management area plans that have the condition of shallow groundwater have addressed. See Semitropic, Arvin-Edison and Westside management plans for those areas indicated in the comment letter dated 11-25-2019.
Dept of Fish and Wildlife	DFW-2	i. Revise the sustainable management criteria and accompanying narrative by accounting for undesirable results for environmental beneficial users of groundwater. Clarify how species and habitat groundwater needs were considered in the identification of sustainable management criteria. ii. Revise sustainable management criteria to reflect a 'Critically Overdrafted' subbasin designation by seeking to improve current groundwater conditions rather than allowing for continued aquifer depletions over the next two decades.	Comment Noted. The process in developing the Sustainable Management Criteria was an open door policy at several workshops, public KGA board meetings and open house workshop with all the GSAs in the Kern subbasin. Significant and undesirable results are based on local conditions as required not as a best case.
Dept of Fish and Wildlife	DFW-3	The Department recommends that the GSP clarify locations of existing shallow groundwater monitoring wells used to create the shallow groundwater elevation contour map provided within the MAP (Figure 2-27). Additionally, the figure should show overlap potential GDEs with shallow monitoring well locations to vet vegetation groundwater reliance. This figure and associated information would clarify monitoring data gaps and serve as an assessment tool when verifying GDEs.	Comment Noted. The KGA management area plans that have the condition of shallow groundwater have addressed.
Dept of Fish and Wildlife	DFW-4	Many of the Duck Clubs in the MAP area are currently supported by the Department'sCalifornia Waterfowl Habitat Program to ensure the adequate maintenance of habitat critical to wetland-dependent species. Implementation of pumping allowances identified in Figure 5-3 would eliminate all wildlife value associated with these wetlands. To continue to share in the support of this valuable public benefit, the Department recommends that the Semitropic Water Storage District Groundwater Sustainability Agency create additional pumping allowances and/or supplemental water supply opportunities for lands that support wetland habitat. The Department also requests confirmation that all Department-owned lands within Semitropic Water Storage District jurisdiction (see Comment #1) will be granted an equitable native groundwater yield allocation under new Landowner Water Budget management actions (starting page 187).	Comment Noted. The KGA management area plans that have the condition of shallow groundwater have addressed.
The Nature Conservancy	TNC-1	Section 2.1.5.1 Description of Beneficial Uses and Users in the Basin (p. 23) California Water Code §1305(f) defines beneficial uses of waters of the State as including "preservation and enhancement of fish, wildlife, and other aquatic resources and preserves." Section 2.1.5.1 states that beneficial users are stakeholders who have an interest in or need groundwater use. The discussion focuses on active groundwater pumpers but does not mention environmental uses or environmental stakeholders. Section 2.2.1.4 focuses on criteria for determination of groundwater with beneficial use for human consumption or mineral extraction, but omits references in the California Water Code to environmental beneficial uses. **Please describe the other beneficial uses and users of groundwater in the Subbasin identified by the Water Code including: GDEs; managed wetlands; Protected Lands, including preserves, wildlife refuges, conservation areas, recreational areas and other protected lands; and Public Trust Uses, including wildlife, aquatic habitat, fisheries, recreation and navigation.**	Comment Noted. In the KGA Communication and Engagement Plan beneficial users are described including environmental organizations such as the ones that are mentioned i comment.
The Nature Conservancy	TNC-2	Section 2.2.1.4 Kern County Subbasin Boundaries, Criteria for the Extent of Groundwater with Beneficial Use in the Subbasin (p. 40) The types and locations of environmental uses, species and habitats supported, and the designated beneficial environmental uses and users of surface waters that may be affected by groundwater extraction in the Subbasin should be specified. **Please identify any environmental uses and users of groundwater in the plan area, and take particular note of the species with protected status. The following are resources that can be used:** **- Natural Communities Commonly Associated with Groundwater dataset (NC Dataset) - https://gis.water.ca.gov/app/NCDatasetViewer/;** **- A list of freshwater species located in the Kern County Subbasin in Attachment C of this letter; and** **- The California Department of Fish and Wildlife's California Natural Diversity Database (CNDDB)**.	Comment Noted. See individual management area plans for those areas that have species and habitats.
The Nature Conservancy	TNC-3	Section 2.1.2 Plan Area Setting (pp. 13-14) The GSP provides a description of the groundwater well types and well density; however, there is no discussion of instream flow requirements, if any, or how the water infrastructure is in compliance with regulatory requirements to protect species of concern in the surface waters within the Subbasin. **Please provide a description of any current and planned instream flow requirements or regulatory requirements for protection of species of concern in the Kern River, Poso Creek and Caliente Creek. If there are no requirements in place or planned, then please state that in the GSP.**	Comment Noted. See individual management area plans for those areas that have those surface water indicated. Also, the Kern River is not located within the KGA jurisdictior boundary, see KRGSA for additional information.
The Nature Conservancy	TNC-4	Section 2.1.3 Existing Plans in the Plan Area (pp. 14-15) This section summarizes the Kern County General Plan and general plans for cities within the GSP area. The plan descriptions are focused on goals and policies directly related to groundwater resources and do not include policies and goals related to surface water resources that may be connected to groundwater. **We suggest adding a discussion of General Plan goals and policies related to the protection and management of GDEs and aquatic resources that could be affected by groundwater withdrawals. Please include a description of any land use or environmental plans relevant to wetlands, aquatic resources and other GDEs and ISWs and their relationship to the GSP. Please include a discussion of how implementation of the GSP may affect and be coordinated with General Plan policies and procedures regarding the protection of wetlands around the Kern Wildlife Refuge, aquatic resources and other GDEs and ISWs.**	Comment Noted. The General Plan goals and policies are under the jurisdiction of the planning public agency thus the KGA nor any management area plan has the authority to change/adopt any policies requested. The KGA and the individual management area plans where the planning public agenices are located within are communicating about the plan updates coming in 2020 and when there is a general plan amendment occurring.
The Nature Conservancy	TNC-5	Section 2.1.3 Existing Plans in the Plan Area (pp. 14-15) This section is focused on discussion of agriculture and irrigation needs, demands, and types of irrigation, and the groundwater resources policies and goals in general plans. It does not include any other applicable land use or environmental plans that may contain information relevant to the GSP and ISWs. This section should identify Habitat Conservation Plans (HCPs) or Natural Community Conservation Plans (NCCPs) within the Subbasin and if they are associated with critical, GDE or ISW habitats. **Please identify all relevant HCPs and NCCPs within the Subbasin and address how GSP implementation will coordinate with the goals of these HCPs or NCCPs.**	Comment Noted. The Metropolitan Bakersfield Habitat Conservation Plan is located within the jurisdiction of the KRGSA. Currently, there are no known HCPs or NCCPs adopt within the KGS jurisdiction boundary.

Commentor	Ref #	Comment	Response
The Nature Conservancy	TNC-6	Section 2.1.4 Existing and Ongoing Water Resource Programs (pp. 15-19) Per the GSP Regulations (23 CCR §354.34 (a) and (b)), monitoring must address trends in groundwater *and related surface conditions* (emphasis added). In order for this section to provide the appropriate context and help assure integration of GSP implementation with other ongoing regulatory programs, additional information on water use management and monitoring programs relevant to wetlands, sensitive or critical habitat, and GDEs and their relationship to the GSP should be provided. **- Please provide a description of resource management plans, monitoring activities and responsibilities by State, Federal and local agencies and jurisdictions related to aquatic resources and GDEs that could be affected by groundwater withdrawals, and list them in Table 2-1.** **- The Critical Habitat for Threatened and Endangered Species website maintained by US Fish and Wildlife Service (https://fws.maps.arcgis.com/home/webmap/viewer.html?webmap=9d8de5e 265ad4fe09893cf75b8dbfb77) identifies multiple lands with endangered and threatened species in the Subbasin, for instance, Buena Vista Lake Ornate Shrew (Sorex ornatus relictus) occurs within the area. Please review and discuss the potential groundwater reliance of critical species in the Subbasin. Please include a discussion regarding the management of critical habitat for these aquatic species and its relationship to the GSP.** **- Other GDEs and sensitive habitats. Please include a discussion of any monitoring programs related to GDEs and sensitive habitats.**	Comment Noted. Table 2-1 are those programs that the member agencies of the KGA are being implemented within each management area. Since the State and Federal are n members of the KGA their responsbilities are not listed. The table information was provided by the member agencies and for more detail information see individual manageme plans where GDEs and sensitive habitat are located.
The Nature Conservancy	TNC-7	Section 2.1.4.4 Well Permitting Process (p. 20) and Section 2.1.4.5 Plan Elements from CWC Section 10727.4 (g) Well Construction Policies (p. 21) These sections discuss the Kern County Public Health Services Department Water Well Program, which issues permits to construct, reconstruct, and destroy water wells. The discussion does not provide any details regarding the potential effects of the permitting and construction of new wells on aquifer systems, GDEs and ISWs. - **Please discuss that future well permitting and well construction must be coordinated with the GSP to assure achievement of the Plan's sustainability goals.** **- Please state how the well permitting process incorporates protection of GDEs and ISWs within the Subbasin.** **- The State Third Appellate District recently found that Counties have a responsibility to consider the potential impacts of groundwater withdrawals on public trust resources when permitting new wells near streams with public trust uses (ELF v. SWRCB and Siskiyou County, No. C083239). Please include a discussion of the need for well permitting programs to comply with this requirement.**	Well permits within the Subbasin are issued by the Kern County Public Health Services Department and will continue under SGMA, meaning that Kern County retains jurisdictio the issuing of water well permits. The County has implemented a supplmental well application for SGMA that is distributed to the KGA/GSAs in the Kern subbasin for the individ management area plan or GSA to contact the applicant of the well permit to advise of the local groundwater conditions and consideration of local measurable objectives and mi threasholds prior to the construction of the well. The process developed for well permits was coordinated with all the GSAs in the Kern subbasin and Kern County to limit as m impacts to all beneficial users within the Kern subbasin. The process has been in existence for over a year and has assisted new water well applicants to understand SGMA pric investing in the construction of new water wells.
The Nature Conservancy	TNC-8	Section 2.2.1.5 Bottom of Subbasin (p. 41) The bottom boundary of the Subbasin should be more precisely defined in accordance with DWR guidance. As noted on page 9 of DWR's Hydrogeologic Conceptual Model BMP (https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_HCM_Final_2016-12- 23.pdf) "the definable bottom of the basin should be at least as deep as the deepest groundwater extractions." Thus, groundwater extraction well depth data should also be included in the determination of the basin bottom. This will prevent the possibility of extractors with wells deeper than the basin boundary (defined by the base of freshwater) from claiming exemption of SGMA due to their well residing outside the vertical extent of the basin boundary. **Please characterize groundwater well extractions from the deepest wells in relation to defining the basin bottom. If the bottom boundary of the Subbasin has not been clearly defined in certain management areas, please identify this as a data gap and elaborate in the monitoring section how and where additional observations can be made to reconcile this data gap.**	Comment Noted. The basin is defined within the Basin Setting. See individual management area plans.
The Nature Conservancy	TNC-9	Section 2.2.1.6 Principal Aquifers and Aquitards (pp. 44-53) The GSP includes a relatively robust description of the geologically diverse aquifers in the Subbasin with differing zones of confined, semiconfined and unconfined groundwater conditions, in addition to "shallow zones" stated to be present locally in the northwestern and southern portions of the central Subbasin. The GSP states these are "not a part of active groundwater extraction, but data are included in the groundwater conditions section of this report to evaluate changes over time." On page 53, environmental users are identified as beneficial groundwater users of the primary aquifers in the Subbasin. Please note that a Principal Aquifer is defined in the GSP regulations as including "aquifers or aquifer systems that store, transmit, and yield significant … quantities of groundwater to … springs, or surface water systems" (23 CCR §351(aa). As such, if the shallow aquifer interacts with surface water systems or provides groundwater necessary to sustain GDEs or other environmental beneficial users, it should be considered a Principal Aquifer. No description, data or information is provided regarding the potential effect of groundwater extraction from groundwater production aquifers on the uppermost shallow aquifers and groundwater bearing zones, whether perched aquifers exist, and how the shallow aquifers or zones are connected to and interact with surface water and GDEs. **Please provide additional description of the shallow aquifers within the Subbasin including characteristics of interconnections with surface water and GDEs, vertical groundwater gradients, connections with underlying production aquifers, and the resulting potential interaction of groundwater pumping with ISWs and GDEs. Please state whether localized perched aquifers are present in the Subbasin. Describe any data gaps. The function and significance of the Shallow Aquifers that provide groundwater to ISWs and GDEs should be summarized in Table 2-3.** **Please describe whether the existence of Aquifer Exemptions has any bearing or implications related to environmental beneficial uses of groundwater.**	Comment Noted. In the Kern subbasin, shallow aquifers are not aquifers that interconnect with the surface as is indicated in the cross sections in the GSP and individual manag area plans. See individual management area plans where shallow aquifers are located within for specific actions to be taken by the management area plan.
The Nature Conservancy	TNC-10	Section 2.2.1.7 Data Gaps and Uncertainty (p. 53) **If data are not present to produce the information requested in the comment above, please clearly identify this as a data gap. Please elaborate in the monitoring section how and where additional observations are to be conducted in order to address this data gap.**	Comment Noted. See individual management area plans where shallow aquifers are located within for specific actions to be taken by the management area plan.
The Nature Conservancy	TNC-11	Section 2.2.1.8 Cross Sections (pp. 54-55) Regional basin-wide geologic cross sections are provided in Figures 2-19a through 2- 19g. These cross-sections do not include a graphical representation of the manner in which the very shallow groundwater or perched water may interact with ISWs or GDEs that would allow the reader to understand this topic. **Please include near- surface cross sections or insets that depict the conceptual understanding of shallow groundwater and ISW interactions at different locations, including perched and regional aquifers and GDEs.**	Comment Noted.
The Nature Conservancy	TNC-12	Section 2.3.1.1 Elevation and Flow Directions (pp. 64-66) This section states that the depth to groundwater in the Shallow Zone ranges from 5 to 25 feet. Inference is made that groundwater levels in the Shallow Zone is relatively constant and is typically perched on fine grained sedimentary units and likely disconnected from the productive aquifer system. No specific data or hydrogeologic analysis is provided to substantiate these important claims. **Please provide any available stratigraphic data, hydrograph data, pumping test data or other information to substantiate these claims. If the data are not available, please identify this as a data gap.**	Comment Noted. Made changes to add additional data references.

Commentor	Ref #	Comment	Response
The Nature Conservancy	TNC-13	Section 2.3.7 Interconnected Surface Water Systems (pp. 88-90) The regulations [23 CCR §351(o)] define ISWs as "surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted." "At any point" has both a spatial and temporal component. Even short durations of interconnection between groundwater and surface water can be crucial for surface water flow and support of environmental users and uses of groundwater and surface water. ISWs can be either gaining or losing. The text states (p. 88) that "Within the Subbasin, there are no interconnected natural surface water systems in monitored areas associated with the pumping zone of the regional aquifer system" and "Since the advent of groundwater pumping in the Subbasin and subsequent impoundment and regulation of flow of the Kern River, groundwater levels near the river are no longer connected with the river bed by a continuous saturated zone." However, the data provided to substantiate these broad claims cover only portions of the surface water flow system. The models cited as substantiation were not constructed for the purpose of identifying potential ISWs and GDEs, but are regional models constructed for supply management. In fact, the text also states (p. 90) that the Kern River has gained flow during some years and the upper reach of the Kern River in the Subbasin has been identified as gaining. The connection between surface water and groundwater is mentioned as a data gap in Section 2.3.7.4 (p. 90). Furthermore, the depth to water in the shallow aquifer is quite shallow as discussed above (5 to 20 feet below ground surface), which strongly suggests that interaction between the shallow aquifer and surface water may be occurring. Because there are uncertainties in the hydraulic connection between rivers / streams and shallow groundwater, ISWs should not be disregarded in the GSP. The GSP regulations require reliance on the best available information and clear identification of data gaps when sufficient information is not available.	Comment Noted. Kern River is not within the jurisdiction of the KGA. Please review the information related to the Kern River in the KRGSA GSA for further specific details.
The Nature Conservancy	TNC-13 (Cont)	**Please provide additional data or analysis to substantiate the nature of the hydrologic relationship between the shallow aquifer and production aquifers and ISWs. If data are not available to verify that such a connection does not exist, acknowledge where ISWs may exist and identify appropriate sustainable management criteria, monitoring networks and management actions for sustainable ISW management or to address data gaps. Data could include groundwater level data from shallow or nested monitoring wells, comparison of stream stages to groundwater levels, modeling information or additional gaging data. Please elaborate how and where additional observations (shallow monitoring wells, stream gauges, and nested / clustered wells) along surface water features can be used to address data gaps in the Monitoring Network section of the GSP to improve identification of ISWs rather than prematurely disregarding them in the GSP.**	Comment Noted. Additional information provided.
The Nature Conservancy	TNC-14a	Section 2.3.8 Groundwater-Dependent Ecosystems (pp. 90-92) We applaud KGA for using the NCCAG database, developed through a collaboration between DWR, California Department of Fish and Wildlife (CDFW) and TNC, to identify potential GDEs, and then evaluate the NCCAG results to identify GDEs; however, the approach used is based on narrative analysis and quantitative data are not used. In addition, no determination is presented as to which NCCAG polygons represent GDEs. **Please refer to Attachment D of this letter for best practices in using groundwater data to verify whether NCCAGs are GDEs.**	Comment Noted. During the development of the Basin Setting, several workshops were held to seek input/information from beneficial users to better work together and accommodate their concerns. The Basin Setting was first posted on the KGA website in May 2019.
The Nature Conservancy	TNC-14b	Section 2.3.8 Groundwater-Dependent Ecosystems (pp. 90-92) The text states (p. 91): "Groundwater potentiometric surfaces from Kern Fan Monitoring Reports (KCWA, 2016) indicate that underlying aquifers are not connected with stream channels. Some flow in the Kern River, as well as in Poso Creek and other mountain-front creeks, is likely to be sustained periodically by release of bank storage (surface water stored in stream banks), but the underlying groundwater is too deep to sustain flow in the valley floor." This contradicts the statements on page 90 that the Kern River has gained flow during some years and the upper reach of the Kern River in the Subbasin are identified as gaining. If there are insufficient groundwater level data in the upper aquifer where gaining reaches are located or where bank storage is inferred to occur, then the NCCAGs in these areas should be included as GDEs in the GSP until data gaps are reconciled in the monitoring network. **Please identify any data gaps related to identifying and mapping GDEs. If there are data gaps, please describe in detail in the monitoring plan how the data gaps will be addressed.**	Comment Noted. See response above. See individual management area plans for those plans that are identifying data gaps and how the plans are going to manage going forwa
The Nature Conservancy	TNC-14c	Section 2.3.8 Groundwater-Dependent Ecosystems (pp. 90-92) The text states (p. 92): "The conditions in the center of the Subbasin suggest that the groundwater production aquifer does not reach the shallow subsurface. The production aquifer lies at depths that prevent surface water expressions or accessibility for vegetation." **Please support this statement with specific groundwater level data that indicate a gap in the saturated zone between the production aquifers and shallow groundwater, and define the extent of the NCCAG dataset polygons that are excluded from consideration as GDEs on this basis.**	Comment Noted. See individual management area plans for more detailed information addressing GDEs in their management area.
The Nature Conservancy	TNC-14d	Section 2.3.8 Groundwater-Dependent Ecosystems (pp. 90-92) The text states (p. 92): "Based on the NCCAG dataset along the margins of the Subbasin where spring-fed streams exist, further confirmation is needed to evaluate the presence of GDEs." If there are insufficient groundwater level data in the upper aquifer where these stream-fed springs exist, then the NCCAGs in these areas should be included as GDEs in the GSP until data gaps are reconciled in the monitoring network. **Please identify any data gaps related to identifying and mapping GDEs. If there are data gaps, please describe in detail in the monitoring plan how the data gap will be resolved.**	Comment Noted. See indivudal management areas plans for specific handling of data gaps.
The Nature Conservancy	TNC-14e	Section 2.3.8 Groundwater-Dependent Ecosystems (pp. 90-92) Because data gaps have been identified in Section 2.2.1.7 (p. 53) Section 2.3.7.4 (p. 90) and Section 2.3.8.2 (p. 92) related to shallow groundwater conditions and the identification of ISWs and GDEs within the Subbasin, final determination of the extent of GDEs in the Subbasin has yet to be completed. **Please revise the GDE analysis in the GSP by conducting more substantial, data-based evaluation focusing on GDE identification in the GSP, clearly identify which NCCAG polygons are excluded, which polygons are determined to be GDEs and which polygons are uncertain at this time and will be verified as data gaps are address.** SGMA defines GDEs as "ecological communities and species that depend on *groundwater emerging from aquifers or on groundwater occurring near the ground surface* " (emphasis added). **Confirmation of GDEs should be performed based on depth to groundwater in the shallow zone, and additional information provided as to whether the shallow zone may be affected by groundwater withdrawal from the production aquifers. Please refer to Appendix D of this letter for best practices for using groundwater data to verify a connection to groundwater.**	Comment Noted. See response to comments above relating to GDEs and specific impacts/relationship to shallow zones. See individual management area plans for specific ha of data gaps.
The Nature Conservancy	TNC-14f	Section 2.3.8 Groundwater-Dependent Ecosystems (pp. 90-92) In the scientific literature, it is generally acknowledged that GDEs can rely on groundwater for *some or all* of their requirements (emphasis added). GDEs can rely on multiple water sources simultaneously and at different temporal and/or spatial scales (e.g., precipitation, river water, reservoir water, soil moisture in the vadose zone, groundwater, applied water, treated wastewater effluent, urban stormwater, irrigated return flow). SGMA defines GDEs as "ecological communities and species that depend on groundwater *emerging from aquifers* or on groundwater occurring near the ground surface" (emphasis added). **Therefore, we recommend using depth to groundwater contour maps derived from subtracting groundwater levels from a DEM, as described above, to identify whether a potential connection to groundwater exists for the wetlands mapped in Attachment H of the GSP. Please refer to Attachments D and E of this letter for best practices for using local groundwater data to 1) verify whether polygons in the NC Dataset are supported by groundwater in an aquifer, and 2) verify whether ecosystem decline or recovery is correlated with groundwater levels.**	Comment Noted.

Commentor	Ref #	Comment	Response
The Nature Conservancy	TNC-14g	Section 2.3.8 Groundwater-Dependent Ecosystems (pp. 90-92) Very little description is provided regarding the nature and function of identified GDEs in the west-central and south-central portions of the Subbasin, their potential sensitivity to groundwater and surface water supply changes, or their relative habitat value. **We recommend the inclusion of a discussion regarding the nature and characteristics of GDEs.**	Comment Noted.
The Nature Conservancy	TNC-14h	Section 2.3.8 Groundwater-Dependent Ecosystems (pp. 90-92) **Please provide information on the historical or current groundwater conditions near the GDEs or the ecological conditions present.** Refer to GDE Pulse (https://gde.codefornature.org or Attachment E of this document) or other locally available data (e.g. leaf area index, evapotranspiration or other data developed from remote sensing) and depth to groundwater trends in and around GDE areas, as well as trends in plant growth (e.g., NDVI) and plant moisture (e.g., NDMI). Below is a screenshot example of data available in GDE Pulse for NC Dataset polygons found in the Subbasin.	Comment Noted.
The Nature Conservancy	TNC-14i	**We recommend an ecological inventory (see Appendix III, Worksheet 2 of the GDE Guidance) for all potential GDEs that includes vegetation or habitat types and rank the GDEs as having a high, moderate or low value. Explain how each rank was characterized.**	Comment Noted.
The Nature Conservancy	TNC-14j	**Please identify whether any endangered or threatened freshwater species of animals and plants, or areas with critical habitat were found in or near any of the GDEs. Some organisms rely on uplands and wetlands during different stages of their lifecycle.** Resources for this include the list of freshwater species located in the Subbasin that can be found in Attachment C of this letter, the Critical Species Lookbook, and CDFW's CNDDB database.	Comment Noted.
The Nature Conservancy	TNC-15	Section 2.4 Water Budget (p. 92) The GSP refers to Attachment J for water budget information. In Attachment J, Section 3.7.1 discusses the development of evapotranspiration (ET) rates for each land cover type (p. 11). **Please provide a breakdown of ET for native and riparian vegetation (such as wetlands, riparian vegetation, phreatophytes and other communities). Please evaluate the spatial relationship of native vegetation ET to NCCAG polygons to determine the groundwater use by this beneficial user for inclusion in the water budget. Identify any data gaps and outline the actions needed to address them.**	Comment Noted. The ETc rates for the entire Kern subbasin were coordinated with satellite data and provided to each individual management area and GSA to evaluate their individual areas. The data obtained from the ITRC- METRIC study covers the entire Kern subbasin. The Kern subbasin water modeling budget provides an overview of the data. review more specific ETc beakdown, please see individual management area plans or GSA.
The Nature Conservancy	TNC-16a	Section 3.1 Sustainability Goal (p. 139) The sustainability goal of the Kern County Subbasin is to "Achieve sustainable groundwater management…Maintain its groundwater use within the sustainable yield of the basin…Operate within the established sustainable management criteria…maintain sustainability over the implementation and planning horizon." The GSP regulations (23 CCR §354.24) require that "[t]he Plan shall include a description of the sustainability goal, … a discussion of the measures that will be implemented to ensure that the basin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved … and maintained … ." The stated sustainability goal recites regulatory requirements and does not provide a description of the goal relative to the basin setting and beneficial uses. The goal does not mention environmental uses and users of groundwater and does not mention undesirable results. **Please clarify the sustainability goal and expand its description to ensure that all beneficial uses and users of groundwater are identified as being protected from undesirable results, and in particular, include GDEs, ISWs and related critical habitats.**	Comment Noted. The Sustainability Goal was coordinated/developed for the entire Kern County subbasin which includes all beneficial uses and users located within the Kern C subbasin. The KGA held workshops seeking input into the development of the Sustainability Goal as well as held a Board meeting to seek additional input prior to finalizing. D those meetings, it was addressed that the Sustainability Goal is for the benefit of all beneficial uses and users in the Kern Subbasin and environmental is considered a beneficial
The Nature Conservancy	TNC-16b	**Since GDEs and ISWs may be present in the Subbasin (please see comments under Checklist Items 16-20) they should be recognized as beneficial users of groundwater and should be specifically included in the Sustainability Goal. In addition, a statement about any intention to address pre-SGMA impacts should be included.**	Comment Noted. See responses above concerning relationship of beneficial uses and users to the Sustainability Goal. No statement is required concering addressing pre-SGM impacts.
The Nature Conservancy	TNC-16c	The GSP states that there is no ISW connectivity for the Kern River; however, there isn't any data, analysis and / or other information provided to support this broad conclusion. **Please include ISWs in the Sustainability Goal until/unless sufficient data is available and provided to verify the status of ISWs.**	Comment Noted. The Kern River is not located within the jurisdictional boundary of the KGA, see the KRGSA for more detailed information.
The Nature Conservancy	TNC-16d	GDEs are dependent, in part, on suitable water quality; however, the GSP only considers water quality for irrigation and domestic use. **Given that there are potential GDEs in the Subbasin and that they may be affected by water quality, they should be included in the Sustainability Goal and addressed in the Water Quality section.**	Comment Noted. It is stated that water quality could affect beneficial users in the Kern subbasin and are addressed in the GSP as well as in the individual management area pla GDEs are considered beneficial users.
The Nature Conservancy	TNC-17	Section 3.2 Minimum Thresholds and Measurable Objectives (pp. 145-150) Minimum thresholds and measurable objectives for chronic lowering of groundwater levels, reduction of groundwater storage and degraded water quality do not include environmental beneficial users, such as ISWs or GDEs. **For each of these applicable sustainable management criteria, please include a discussion of GDEs (see comments under checklist items 16-20) and whether the minimum thresholds, measurable objectives and interim milestones will help achieve the sustainability goal as it pertains to the environment. Please modify Section 3.2.2 to specifically address impacts from degraded water quality to the plant and wildlife communities within GDEs.**	Comment Noted. The development of the minimum thresholds and measureable objectives were established based on the impacts to all beneficial uses and users within the K subbasin. Specifications to just address plant and wildlife was considered as the thresolds and objectives were being set. For more specific information see indvidual manage area plans.
The Nature Conservancy	TNC-18	Section 3.2.2.2 Potential Effects of Chronic Lowering of Groundwater Levels (p. 141) GDEs are a beneficial user of groundwater in the Subbasin. **Unless evidence is provided to verify the exclusion of GDEs please modify this section of the GSP to identify GDEs as one of the beneficial uses and users of groundwater that could experience significant and unreasonable effects as a result of chronic lowering of groundwater levels.**	Comment noted. See response to comments above.
The Nature Conservancy	TNC-20	Section 3.1.5 (Undesirable Results for depletion of) Interconnected Surface Water (p. 144) The GSP states (p.144) that "Though many studies have been conducted in the Subbasin, including in areas such as the Kern River and Poso Creek, results do not show evidence of surface water within the Subbasin to be interconnected. As there are no known natural interconnected surface water systems within the KGA boundary, this sustainability indicator is not included in this GSP." As noted in the prior comments, several areas have been identified as potential ISWs and GDEs, and substantial data gaps exist. As such, the above statement contradicts other information provided in the GSP, and serves as an acknowledgement of data gaps. It is not an appropriate basis for removing this sustainability indicator from the GSP under the GSP regulations. **Unless evidence is provided to verify the exclusion of GDEs and ISWs, please modify this section of the GSP to include a statement that 1) there are potential ISWs, and 2) provide an assessment of potential undesirable results.**	Comment Noted. See indivudal management areas plans for specific handling of data gaps.
The Nature Conservancy	TNC-21	Section 3.1.5 (Undesirable Results for depletion of) Interconnected Surface Water (p. 144) The GSP states (p.144) that "… there is no interconnected surface water under the influence of groundwater pumping in the principal aquifer in this area and no impacts to interconnected surface water have been observed." As noted in the prior comments, areas of shallow groundwater and gaining stream reaches are known to exist in the Subbasin. No quantitative data have been provided to assess the extent of hydraulic connection between shallow groundwater and the underlying production aquifers. As such, the above statement is insufficiently supported by data and is actually a substantial data gap. **Unless evidence is provided to verify the potential influence of groundwater extraction on GDEs and ISWs, please modify this section of the GSP to include a statement that the data are insufficient to assess whether GDEs can experience significant and unreasonable effects as a result of groundwater extraction in the Subbasin and provide an assessment of potential undesirable results. Please also identify that existing data gaps will be addressed and the presence or absence of GDEs will be verified with monitoring wells screened at the appropriate depths.**	Comment Noted.
The Nature Conservancy	TNC-22	Section 3.2 Undesirable Results (for each sustainability indicator) (pp. 139-144) This section only describes undesirable results relating to human beneficial uses of groundwater and neglects environmental beneficial uses / users that could be adversely affected by chronic groundwater level decline or other undesirable results. **Please add "possible adverse impacts to potential GDEs and ISWs" to the list of potential undesirable results.**	Comment Noted. As the Undesirable Results were being developed and considered all beneficial uses and users were considered. There were several workshops seeking information/input during the development period.

Commentor	Ref #	Comment	Response
The Nature Conservancy	TNC-23a	Section 3.2 Undesirable Results (for each sustainability indicator) (pp. 139-144) The GDE Pulse web application developed by TNC provides easy access to 35 years of satellite data to view trends of vegetation metrics, groundwater depth (where available), and precipitation data. This satellite imagery can be used to observe trends for NC Dataset polygons within the Subbasin. Over the past 10 years (2009- 2018), some NC Dataset vegetation polygons have experienced adverse impacts to vegetation growth and moisture in the western portion of the Subbasin. **Please review these spatial patterns and, where possible, correlate them with water level trends. Any indications of adverse trends and any data gaps should be identified.**	Comment Noted.
The Nature Conservancy	TNC-23b	**For each identifiable GDE unit with supporting hydrological datasets, please include the following:** **- Plot and provide hydrological datasets;** **- Define the baseline period in the hydrologic data;** **- Classify GDE units as having high, moderate, or low susceptibility to changes in groundwater; and** **- Explore cause-and-effect relationships between groundwater changes and GDEs.**	Comment Noted.
The Nature Conservancy	TNC-23c	**For identifiable GDE units without supporting hydrological datasets please describe data gaps and / or insufficiencies.**	Comment Noted.
The Nature Conservancy	TNC-23d	**Compile and synthesize biological data for each GDE unit by:** **- Describing biological resources for each GDE unit; and** **- Describing data gaps / insufficiencies.**	Comment Noted.
The Nature Conservancy	TNC-23e	**Describe possible effects on potential ISWs, GDEs, land uses, and property interests, including:** **- Cause-and-effect relationships between potential ISWs and GDEs with groundwater conditions** **- Impacts to potential ISWs and GDEs that are considered to be "significant and unreasonable;"** **- Known hydrological thresholds or triggers (e.g., instream flow criteria, groundwater depths, water quality parameters) for significant impacts to relevant species or ecological communities;** **- Land uses should include recreational uses (e.g., fishing/hunting, hiking, boating); and** **- Property interests should include and consider privately and publicly protected conservation lands and opens spaces, including wildlife refuges, parks, and natural preserves.**	Comment Noted.
The Nature Conservancy	TNC-24	Section 3.3 Monitoring Network (pp. 150-169) The GSP proposes to coordinate and use existing monitoring networks of Kern Groundwater Authority and its districts / member agencies for groundwater elevations and storage, groundwater quality, and land subsidence. The text (p. 151) states that the monitoring network will monitor impacts to the beneficial uses and users of groundwater and goes on to state that "*depletions of interconnected surface water are not pertinent to the monitoring network.*"(emphasis added) As discussed in previous comments, unless data are provided to support this broad statement, due to uncertainties in the hydraulic connection between rivers / streams and GDEs with shallow groundwater, ISWs and related GDEs should not be disregarded in the GSP. The GSP should include a description of how groundwater conditions will be monitored to assess the potential effects of groundwater withdrawals on ISWs and GDEs. In addition, this section should include a description of how hydrological data gaps and insufficiencies will be addressed in the monitoring network. **Please modify the description of the monitoring network to provide methodologies, data and other information to address the data gaps associated with GDEs and ISWs. This modification should include 1) locating new wells that are appropriately screened to detect changes in groundwater levels in the uppermost water table and the connectivity of GDEs and ISWs with the upper unconfined or shallow zone aquifer; and 2) identifying or installing additional stream gauges in areas where there is potential for ISWs and GDEs. Please expand on the discussion of how the new well and stream data will be used to improve ISW mapping and inform an adequate analysis, and how the data will be used to verify possible GDEs.**	Comment Noted. The development of the monitoring network was established based on the benefits/impacts to all beneficial uses and users within the Kern subbasin. As ha stated previously, environmental is considered a beneficial use in the Kern subbasin and as such was considered in the development of the monitoring network. Several Stakel workshops were held during the development of the monitoring networl seeking input from all beneficial users. The locating of new wells and additional stream gauges are addressed in individual management area plans and GSAs. The monitoring network is considered an adaptive management plan and will be addressed annually as data is obta and submitted to DWR. This data will be available as it becomes available.
The Nature Conservancy	TNC-25	Section 3.3 Monitoring Network (pp. 150-169) As stated above in the comments for Checklist Items 8-10, **please address data gaps along the Kern River and tributary creeks identified earlier in the GSP in this section of the GSP to improve ISW mapping in companion or future GSPs (e.g., through shallow monitoring wells, stream gauges, and nested/clustered wells).**	Comment Noted. The Kern River is not located within the jurisdictional boundary of the KGA, see the KRGSA GSP for more detailed information.
The Nature Conservancy	TNC-23a	Section 4 Projects and Management Actions (p. 175) Table 4-1 in this chapter lists many important projects and management actions including allocation changes, imports, surface water diversions, pumping allowances, conveyance and recharge projects, and addition of percolation basins; however, the descriptions only identify benefits to water level, groundwater storage, water quality and water supply. Maintenance or recovery of groundwater levels and construction of recharge facilities may have potential environmental benefits. It would be advantageous to recognize these benefits so as to demonstrate multiple benefits from a funding and prioritization perspective. - **For the projects already identified, please consider stating how ISWs and GDEs will benefit or be protected, or what other environmental benefits will accrue.** - If ISWs and GDEs will not be adequately protected by the listed projects and management actions, **please consider additional management actions and projects targeted for protecting ISWs and GDEs.** - **Please describe how the projects and management actions will be evaluated to assess whether adverse impacts to GDEs may occur and/or will be mitigated or prevented.** - For examples of case studies on how to incorporate environmental benefits into groundwater projects, please visit our website: https://groundwaterresourcehub.org/case-studies/recharge-case-studies/	Comment Noted. Management projects/actions are to the benefit of all beneficial uses and users within the Kern subbasin. The costs associated to the management projects/actions will also be considered as costs to all beneficial uses and users as well. This process will occur during the implementation period of 20 years and with transpar and open conversations/workshops. Please see indivudal management areas plans for specific management projects/actions pertaining to GDEs and ISW.
Leadership Counsel	LC-1	The Draft GSP is Incomplete, and Must Include Additional Information For the Public to Evaluate the GSP	The KGA GSP includes a summary of all the management area plans. For specific information pertaining to drinking water impacts on disadvantaged communities and protecte groups, please review the individual management area plans. During the development of the management area plans, each KGA member engaged in stakeholder out reach to communities/groups located within their area. Also, two disadvantaged communities are represented on the KGA board of directors who have voiced/voted their concerns du the entire process. The KGA held Stakeholder meetings to engage and seek input from all beneficial uses and users during the development of the KGA GSP and management a plans.
Leadership Counsel	LC-2	The Kern Groundwater Authority GSA Is Responsible for the Disproportionate and Disparate Impacts That Its Policies and Activities Will Have on Disadvantaged Communities Belonging to Protected Groups	Comment noted. Please see response LC-1
Leadership Counsel	LC-3	The Coordination Agreement Does Not "Explain How the Plans Implemented Together, Satisfy the Requirements of the Act."	The Coordination Agreement follows the requirements of SGMA and provides a dispute Resolution within the agreement.
Leadership Counsel	LC-4	Inadequate Consideration of Public Input Undermines the Validity and Efficacy of the Draft GSP	Disadvantaged communities are represented on the KGA board of directors. These directors have been active in voicing/voting their concerns through the entire process has b instrumental in providing their insights for their communities. The KGA held several workshops during all hours of the day, provided stakeholder surveys in both English and S at those workshops as well as on-line (see the Communication & Education Plan for those events). As the implementation process moves forward, the KGA and its members p continue the insights from all communities.
Leadership Counsel	LC-5	The Kern Subbasin Undesirable Results Do Not Comply with Existing Law	Comment noted. The KGA developed the GSP in compliance with all requirements and believe it will achieve sustainability as defined by SGMA.

Commentor	Ref #	Comment	Response
Leadership Counsel	LC-6	The GSP's Minimum Thresholds and Measurable Objectives Are Not Adequate	As stated in the response in LC-1, the management area plans provide greater detail on how the minimun thresholds and measurable objectives were developed in their area. T KGA GSA and its management area plans are adaptive planning documents which allow for the adjustment of minimum thresholds and measurable objectives as the implement process begins. Any adaptive management will be the result of stakeholde input and consideration of beneficial use.
Leadership Counsel	LC-7	The Monitoring Network is Inadequate With Respect to Groundwater Levels and Groundwater Quality	Comment noted. The KGA developed the GSP in compliance with all requirements and believe it will achieve sustainability as defined by SGMA.
Leadership Counsel	LC-8	Current Projects and Management Actions are Inadequate	The KGA members developed projects and management actions in order to achieve sustainability as defined by SGMA. The KGA GSP is an adaptive management planning docu that will be reviewed annually with a 5 year update. Each management area plan under the direction of the managers has vented all their individual management projects/acti their workshops looking for input from all beneficial users.
Leadership Counsel	LC-9	The GSA Must Clearly Commit to a Drinking Water Protection Program for the Kern Subbasin	Comment noted. Thank you for your comment and we took it under consideration.
Leadership Counsel	LC-10	Recharge In or Near Disadvantaged Communities and Domestic Well Clusters	Comment noted. Please see response LC-8
Leadership Counsel	LC-11	Establish Pumping Buffer Zones That Protect Disadvantaged Communities and Clusters of Domestic Wells	Comment noted. Please see response LC-1 & LC-8
Leadership Counsel	LC-12	Warning Against a Groundwater Market	Comment noted. The KGA appreciates the comment, considered its content but respectfully does not agree with the conclusion.
Leadership Counsel	LC-13	Multi-benefit projects	Comment noted. Please see response LC-1 & LC-8
Leadership Counsel	LC-14	Funding of Projects and Management Actions	Comment noted. The KGA appreciates the comment, considered its content but respectfully does not agree with the conclusion.
Leadership Counsel	LC-15	The Draft GSP Threatens to Infringe on Water Rights	Comment noted. The KGA appreciates the comment, considered its content but respectfully does not agree with the conclusion.
Leadership Counsel	LC-1	The Draft GSP Conflicts with the Reasonable And Beneficial Use Doctrine	Comment noted. The KGA appreciates the comment, considered its content but respectfully does not agree with the conclusion.
Leadership Counsel	LC-1	The Draft GSP Conflicts with the Public Trust Doctrine	Comment noted. The KGA appreciates the comment, considered its content but respectfully does not agree with the conclusion.
Arvin Edison Water Storage District Received Comments			
Leadership Counsel	3	The Draft GSP is Incomplete, and Must Include Additional Information For the Public to Evaluate the GSP	•The Arvin-Edison MA Plan includes complete information on consideration of drinking water impacts as disadvantaged communities, sustainable management criteria, and Pr and Management Actions (P/MAs) •See further comment responses below. •See KGA response to this comment for further information.
Leadership Counsel	3	The Kern Groundwater Authority GSA Is Responsible for the Disproportionate and Disparate Impacts That Its Policies and Activities Will Have on Disadvantaged Communities Belonging to Protected Groups	•See KGA response to this comment.
Leadership Counsel	4	The Coordination Agreement Does Not "Explain How the Plans Implemented Together, Satisfy the Requirements of the Act"	•See KGA response to this comment.
Leadership Counsel	5	Inadequate Consideration of Public Input Undermines the Validity and Efficacy of the Draft GSP	•See comment response below. •See KGA response to this comment for further information.
Leadership Counsel	6	The GSP states that the JPA was "written to provide open ...communication to all beneficial users," and "each member of the KGA held their own outreach programs and opportunities for beneficial users to participate in the development of their individual management area plans, which is included in their individual management area plans;"17 however, this was not the case. For example, the member agency that has jurisdiction over residents with whom we work in the GSA area, the **Arvin-Edison Water Storage District**, did not adequately reach out to disadvantaged community residents or include their feedback in their GSP. For example, the **Arvin WSD's** website contains no information on SGMA or GSP meetings. We understand from conversations with staff that the agency sent notices to its list serv, but there is no way to sign up for the list serv on the website, and without knowing when and where meetings are occuring the public could not go to a meeting to sign up and be added to the interested parties list serv. Therefore the GSA's choice to delegate GSP development to member agencies did not provide an open and transparent process as required under SGMA.	AEWSD conducted substantial stakeholder outreach and engagement during the Arvin-Edison Management Area Plan (MA Plan) development process. This outreach is describ **Section 5.5** of the MA Plan, as well as the Stakeholder Communication and Engagement Plan (SCEP) included as **Appendix E**. AEWSD outreach efforts included: •letters sent to all landowners and all interested parties; •distribution and compilation of a Stakeholder Survey (direct mail in AEWSD billing statements); •AEWSD website does include an email and AEWSD Executive Secretary maintains a list of interested parties for mass emails regarding notices; •Multiple AEWSD/ACSD informational meetings with flyers mailed and emailed ahead of time, including one to LCJA on 29 May 2019; •Multiple letters sent to all Public Water Systems in the MA Plan area; •Site visits to certain well owners to discuss domestic well status and location and regarding development of a monitoring network; •Letters to "white land" owners; •Multiple public stakeholder workshops, some held in triplicate (including with some outside of regular business hours) in the City of Arvin with Spanish language translation. T group Self Help Enterprises (SHE) attended and presented at three of the workshops. The above outreach efforts are in addition to those performed by the KGA. **A list of meetings during which GSP and SGMA were discussed is included in Appendix E of the M which was updated to reflect additional recent meetings.** This includes 39 public meetings of the AEWSD Board between 2/9/2016 and 11/12/2019 where opportunity was provided for public comment. The topic of stakeholder engagement was also addressed in AEWSD's email response (dated 11/7/2019; attached below) to questions from LCJA **Additional information on the stakeholder engagement process was added to Section 5.5.2.** ACSD's outreach efforts during the MA Plan development process included: •April 3, 2017: ACSD Board Meeting •April 17, 2017 ACSD Board Meeting •May 1, 2017 ACSD Board Meeting •November 6, 2017 ACSD Board Meeting •December 18, 2017 ACSD Board Meeting •January 3, 2018 ACSD Board Meeting •April 2, 2018 ACSD Board Meeting •May 7, 2018 ACSD Board Meeting •May 21, 2018 ACSD Board Meeting •September 24, 2018 ACSD Board Meeting •November 5, 2018 ACD Board Meeting •November 19, 2018 ACSD Board Meeting •January 22, 2019 ACSD Board Meeting •March 4, 2019 ACSD Board Meeting •April 1, 2018 ACSD Board Meeting •July 15, 2019 ACSD Board Meeting •September 3, 2019 ACSD Board Meeting •Since May 6, 2019 General Manager Updates Board of Directors every meeting on all Kern Basin GSA's Manager's Meetings or other meetings and items pertaining to SGMA.

Commentor	Ref #	Comment	Response
Leadership Counsel	6 - 7	The **Arvin-Edison Water Storage District ("Arvin-Edison WSD")** states in its GSP ("**Arvin GSP**") that it considered disadvantaged communities by engaging representatives of the Arvin CSD ("Arvin CSD"), which contains disadvantaged community residents; by creating a Stakeholder Communication and Engagement Plan; and by "welcom[ing] public participation" at stakeholder workshops, **Arvin-Edison WSD** board meetings, **Arvin CSD** board meetings, KGA GSA events and meetings, a stakeholder survey, letters to landowners, and small or one-on-one meetings with individual stakeholders.18 However, as a community-based organization working directly with residents in Arvin, we were not included in these conversations until August 15, 2019 when we attended the **Arvin- Edison WSD** Board meeting where they presented their GSP chapter to its board for approval. Residents we work with did not have any knowledge of the GSP development process in the **Arvin-Edison Management Area.** They had heard about SGMA, but had a minimal understanding of what it entailed and were not aware of their local GSP development.	•ACSD is a co-author of the Arvin-Edison MA Plan and was directly involved in its preparation. Specific portions of the MA Plan that were prepared by and/or pertain to the ACS are listed in **Section 4.** •As described in **Appendix E** of the MA Plan, SHE, a community development organization focused on low-income communities, worked alongside AEWSD and ACSD on stakeh outreach matters and SHE representatives were present at stakeholder workshops. AEWSD provided Spanish language translation services. •Because AEWSD does not provide water service to any Arvin residents, it does not "serve a substantial number of non-English speaking people" and therefore the Bilingual Se Act, mentioned in the LCJA letter, does not apply to AEWSD. •ACSD also worked directly with other community organizations and groups regarding SGMA, including Committee for a Better Arvin (CBA) a subgroup of the Center for Race P and the Environment. CBA sent a support letter on December 3, 2019 describing the active ways in which ACSD/AEWSD involved then in the SGMA process. •Residents of the City of Arvin were sent flyers announcing informational meetings by direct mail and electronic mail (see **Appendix E**). •Records of meeting attendance show that several attendees identified themselves as Arvin residents (see **Appendix E**). •Residents that work directly with LCJA are encouraged to request a meeting with AEWSD/ACSD for a GSP update or other district purposes.
Leadership Counsel	7	Additionally, as mentioned above, **Arvin-Edison WSD** did not maintain a list of interested parties that the public could access; their website contains no sign-up, and no meeting notices or agendas about GSP development meetings were published in any publicly available fora. In addition to this violation of public engagement requirements under SGMA, the members agency did not follow the Brown Act by publishing public meeting notices and agendas before meetings, and does not have agendas or meeting minutes on its website so that such materials are available to the public.19	•The SCEP Section 4 describes the process for stakeholder identification by AEWSD and the KGA. A list of interested parties was identified in the SCEP and continuously update during the MA Plan development process. •AEWSD website does include an email address that would provide anyone to be included as an interested party •All AEWSD customers and interested parties are on the AEWSD list serv and thus receive announcements from AEWSD, including meeting announcements and agendas. •Engagement of ACSD customers was handled by ACSD, in coordination with SHE and other community organizations, including CBA. •AEWSD follows all applicable public noticing requirements. The topic of public noticing and Brown Act compliance was also addressed in AEWSD's email response (dated 11/7 attached below) to questions from LCJA. •References made to Kern River GSA appear to be an error however future stakeholder engagement will follow the SCEP as outlined in **Appendix E**
Leadership Counsel	8	The Kern Subbasin Undesirable Results Do Not Comply with Existing Law	•The Undesirable Results definitions in the Arvin-Edison MA Plan were developed in accordance with existing law (SGMA). •See KGA response to this comment for further information.
Leadership Counsel	11	The GSP's Minimum Thresholds and Measurable Objectives Are Not Adequate	•See comment response below. •See KGA response to this comment for further information.
Leadership Counsel	12	The KGA GSA did not ensure that minimum thresholds created by member agencies considered the interests of all beneficial user groups, or prioritize the security of drinking water in the subbasin, in developing minimum thresholds. For example, the **Arvin-Edison Management Area GSP** did not consider the impact on drinking water users in setting its minimum thresholds. The A**EWSD Management Area Draft GSP** details how it calculated historical water lows and divided the Management Area into four sections based on historical low groundwater levels and agency jurisdiction, and how it adjusted the minimum thresholds to protect the canal that brings surface water to farmers.39 However, in did not evaluate or consider how many wells could go dry from its proposed minimum thresholds, or adjust for effects on drinking water. Therefore it did not consider impacts on drinking water beneficial users, or ensure the protection of drinking water as a the highest beneficial use of water.	•AEWSD did conduct an extensive analysis of water quality based on the available data (see **Section 8.5** and **Figures GWC-9 through GWC-13**, and **Appendix H**) and in consulta with representatives of beneficial users of the water (e.g., ACSD). •Arsenic is the one constituent identified by ACSD as having the potential to be influenced by groundwater management activities, and was thus selected for use as a Sustainat Management Criterion (see **Section 14.4.1**). •As stated in a footnote in the MA Plan, "SGMA does not empower GSAs to develop or enforce water quality standards; that authority rests with the State Water Resources Co Board (SWRCB) Division of Drinking Water and the County. Because of the limited purview of GSAs with respect to water quality, and the rightful emphasis on those constituen may be related to groundwater quantity management activities, the only constituent of concern applicable within the Arvin-Edison Management Area is arsenic in the vicinity of City of Arvin and ACSD. Furthermore, drinking water quality regulations for public water systems apply at the point of delivery to customers, not in the raw water source, and A blends water from its various well sources." •All monitoring sites will be sampled for the constituents identified in the Groundwater Quality Concerns section (**Section 8.5.1**), as well as other relevant groundwater quality parameters (see **Section 16.1.4**). Collection of additional data during plan implementation will be used to refine SMC definitions, as discussed in **Section 13.4**. •All ACSD wells are sampled regularly in accordance with their SWRCB permit. •The Representative Monitoring Site (RMS) was selected by ACSD, based on the list of considerations described in detail in **Section 16.1.4**. •The topic of groundwater quality SMCs and monitoring networks was also addressed in AEWSD's email response (dated 11/7/2019; attached below) to questions from LCJA.
Leadership Counsel	14 - 15	As in the case of groundwater levels, it is clear that the GSA has not considered the potential impact on drinking water users, in particular disadvantaged communities who are less able to afford solutions to treat contaminated drinking water. This has resulted in minimum thresholds and measurable objectives like those in the Arvin GSP, which will only be monitoring for compliance with sustainable management criteria in one well location, and has set the minimum threshold at the drinking water MCL for the contaminant, and the measurable objective at 75% of the MCL. The member agency is only monitoring for compliance with arsenic standards, despite the agency's knowledge of the existence of "nitrate…total dissolved solids (TDS), boron, iron and manganese…within or near the **Arvin-Edison Management Area** above drinking water standards and/or agricultural water quality goals."	
Leadership Counsel	15	The lack of sufficient groundwater quality sustainable management criteria in areas like **Arvin** is likely to lead to critical drinking water impacts, and will be disproportionately felt by disadvantaged communities, who are less able to afford treatment solutions.	•The sustainable management criteria (SMCs) for degraded water quality were developed by AEWSD and ACSD with direct consideration of the drinking water beneficial use (s **Section 14.4**). •The water quality SMCs and monitoring in the MA Plan are in addition to the drinking water standards and monitoring requirements to which ACSD is held under its drinking w permit from the State Water Resources Control Board (SWRCB) Division of Drinking Water (see **Section 14.4**).
Leadership Counsel	15	The GSA has also not specified what actions will be taken if water contamination approaches minimum thresholds, or how minimum thresholds will be triggered. Member agencies such as the **Arvin-Edison WSD** have not specified this in their plans.	•As a public water supplier, ACSD has the responsibility to provide safe drinking water, under regulatory oversight by the SWRCB Division of Drinking Water, which is separate f SGMA. •Under its water system permit from the SWRCB, ACSD provides for water treatment and monitoring of water quality, separate from SGMA. •SGMA does not require that a GSP describe the process that will take place if water quality measurements approach Minimum Thresholds. •**Section 14.4.2** of the MA Plan specifies the Minimum Threshold for groundwater quality as the exceedance of Maximum Contaminant Levels (MCL) for arsenic at the Represer Monitoring Site (i.e., ACSD Well #14). This description of the MT therefore does include a description of "how minimum thresholds will be triggered" (i.e., by an exceedance of t for arsenic over four consecutive bi-annual measurement). •ACSD operates its wells under permit from the SWRCB which has its own monitoring schedule and reporting requirements.
Leadership Counsel	17	The Monitoring Network is Inadequate With Respect to Groundwater Levels and Groundwater Quality	•See comment response below. •See KGA response to this comment for further information.
Leadership Counsel	18	The groundwater quality monitoring network does not adequately capture impacts on drinking water users. In the case of the **Arvin GSP**, the member agency will only monitor for compliance with its minimum threshold and measurable objective for Arsenic once a year in one well, ACSD Well #14, which is one of the wells that provide drinking water to the community of Arvin.	•As described above, ACSD monitors its supply wells for a list of constituents described in and on a schedule set by its drinking water system permit from the SWRCB. The wate quality monitoring in this MA Plan is in addition to the monitoring conducted by ACSD under its permit. •The topic of groundwater quality monitoring networks was also addressed in AEWSD's email response (dated 11/7/2019; attached below) to questions from LCJA.
Leadership Counsel	18	Second, only measuring for compliance with arsenic measurable objectives and minimum thresholds does not protect against increases in other contaminants that exist in other parts of the management area (boron, nitrates, TDS, 123-TCP, iron and manganese). These contaminants could extend, move or increase due to groundwater management activities and pumping patterns. The Arvin GSP does plan to monitor for these contaminants in seven other wells outside of Arvin, but has not set minimum thresholds and measurable objectives for these wells, and does not have plans to do so.	•Arsenic was chosen as the only constituent for defining SMCs because it is currently the only constituent determined to be related to water management activities (i.e., water (see **Section 13.4.2**). Other constituents are either naturally occurring or regulated pursuant to different programs. Additional data collection and analysis, as described in the M Plan, will be used to inform the consideration of water quality issues in the future. •The topic of groundwater quality SMCs was also addressed in AEWSD's email response (dated 11/7/2019; attached below) to questions from LCJA.
Leadership Counsel	18	Furthermore, Arvin is currently experiencing 123-TCP contamination that threatens the health of Arvin residents, so the GSP must monitor for compliance with 123-TCP standards in particular.	•ACSD has recently installed a treatment system for 1,2,3-TCP in one of its production wells to address this occurrence of contamination (see **Section 17.2.3**). •ACSD has also included in this MA Plan, and is currently implementing, a project to mitigate arsenic and 1,2,3-TCP in its raw water supply through well replacement (see **Secti 19.1.2**). •ACSD has never been out of compliance with 1,2,3-TCP as SWRCB set the MCL to take effect January 1, 2018. Wells that contained 1,2,3-TCP were taken offline in January 201 the MCL for 1,2,3-TCP was implemented. Arvin CSD is in litigation with Dow Chemical and Shell Oil Co. to collect on damages to the wells that were affected.

Commentor	Ref #	Comment	Response
Leadership Counsel	19	Third, the well that was chosen, ACSD Well #14, was chosen because it does not have contaminants that are known to exist in wells in the northern part of the management area, which are not currently in use by Arvin CSD, according to our conversation with Arvin-Edison WSD staff at the Kern Subbasin Open House on September 26th, 2019. However, avoiding monitoring contaminated areas defeats the purpose of groundwater quality monitoring under SGMA, which is to measure the concentration and spread of contaminant plumes to ensure that groundwater management activities and pumping do not aggravate existing contamination. The GSA should ensure that the member agency instead monitors for all existing contaminants at minimum throughout the area and especially in areas where contamination is known to exist, and sets minimum thresholds and measurable objectives that apply to all monitoring wells.	•ACSD Well #14 was chosen by ACSD as it is considered representative of wells in the ACSD area that constitute the majority of drinking water beneficial use in the MA Plan are **Section 16.1.4**). •AEWSD staff has never, at the 9/26/2019 Kern Subbasin Open house nor at any other time, ever contended that the reason for selection of the ACSD Well #14 was, as the com states, "because it does not have contaminants that are known to exist in wells in the northern part of the management area." •ACSD chose this well as it is the northern most active well in its water system. This well would serve as an early indicator that would allow detection of any early signs of wate quality degradation. Well #14 does contain levels of Arsenic which are below the MCL, but would be a good indicator of groundwater conditions.
Leadership Counsel	20	Current Projects and Management Actions are Inadequate	•See comment response below. •See KGA response to this comment for further information.
Leadership Counsel	20	The GSA has allowed member agencies like the Arvin-Edison WSD to use a "glidepath" approach that increases surface water and groundwater recharge before demand reduction measures are implemented.67	•Supply augmentation projects and demand reduction management actions (as needed) are to be implemented in a balanced approach under the "glide path" laid out in the Ar Edison MA Plan (see **Section ES.10**; **Section 9.4.5**; **Section 17.1.4**; and **Table PMA-2**).
Leadership Counsel	20	The Arvin GSP contains two projects for treating water quality in Arvin, but these projects were already under way and fully funded so should not be included in the GSP. The GSP has no overall drinking water protection program to protect residents against dry wells and contaminated drinking water from its policies and groundwater management activities.	•These two projects were identified by ACSD as projects to include in the MA Plan because they aim to address the water quality sustainability indicator and relevant beneficial (i.e., drinking water supply).
Leadership Counsel	21	The GSA Must Clearly Commit to a Drinking Water Protection Program for the Kern	•See KGA response to this comment.
Leadership Counsel	22	Recharge In or Near Disadvantaged Communities and Domestic Well Clusters	•See KGA response to this comment.
Leadership Counsel	22	Establish Pumping Buffer Zones That Protect Disadvantaged Communities and Clusters of Domestic Wells	•See KGA response to this comment.
Leadership Counsel	22	Warning Against a Groundwater Market	•See KGA response to this comment.
Leadership Counsel	22	Multi-benefit projects	•See KGA response to this comment.
Leadership Counsel	22	Funding of Projects and Management Actions	•See comment response below. •See KGA response to this comment for further information.
Leadership Counsel	22	Furthermore, any proposed assessments that will pay for projects may not place a disproportionate financial burden on disadvantaged communities. Small disadvantaged communities like Arvin should not be required to pay fees for GSP implementation.	•**Section 17.11** of the MA Plan describes the various funding sources that may be used to pay for the planned P/MAs. •**Section 18.2.2** and **Section 19.2.2** list the funding sources identified by AEWSD and ACSD, respectively, to support general GSP implementation. •The topic of GSP funding was also addressed in AEWSD's email response (dated 11/7/2019; attached below) to questions from LCJA. •ACSD and AEWSD have created a Memorandum of Understanding with regards to SGMA. It shall be noted that ACSD was not asked to contribute financially, which for ACSD s to be a substantial cost savings. •ACSD does participate financially with the KGA, but the KGA is set up for participating agencies to pay based on acreage which made being a voting member readily accessible DAC like Arvin and Shafter.
Leadership Counsel	23	The Draft GSP Threatens to Infringe on Water Rights	•See KGA response to this comment.
Leadership Counsel	23	The Draft GSP Conflicts with the Reasonable And Beneficial Use Doctrine	•See KGA response to this comment.
Leadership Counsel	23	The Draft GSP Conflicts with the Public Trust Doctrine	•See KGA response to this comment.
Wonderful Orchards/Wonderful Citrus	1	**Quantification of Native Yield** It is imperative that the final GSP properly address the quantification of native yield. The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource. For example, a district or pumper located adjacent to the foothills does not necessarily have a superior claim to native yield over someone located in the center of the basin just because they are geographically closer to the source of mountain front recharge. Similarly, a district or pumper located in a cone of depression does not necessarily have a superior claim to native yield just because groundwater is flowing toward them. Surface water entering the groundwater via seepage in natural channels, including the Kern River and small streams, may be attributable to the native yield depending upon the circumstances of that seepage. A thorough technical and legal analysis is necessary to determine appropriate sources contributing to the native yield and to quantify these supplies.	•"Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). •***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that "the "water accounting" approach described in the Coordinat Agreement and Appendices thereto does attempt to evaluate the water budget using certain management assumptions (e.g., a uniform "native yield component to all lan within the Basin). However, nothing in this water budget information results in or is intended to be a determination of water rights within the Arvin-Edison Management A*** •Implementation of P/MAs, including actions to further refine issues related to water budgets, is described in **Section 18.1.2**. •See KGA response to this comment for further information.
Wonderful Orchards/Wonderful Citrus	2	**Allocation of Native Yield** In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield. Currently, the GSP references native yield in terms of acre-feet per gross acre for water budget purposes. Appendix J of the GSP indicates the subbasin native yield is approximately 0.144 acre-feet per acre. It is our understanding that subsequent to the release of the draft GSP, all MAPs and other GSPs in the basin agreed to utilize the same number for their water budgets. If referencing native yield this way is necessary, the GSP should clarify that it is for initial water budget purposes ONLY, is non-precedent setting, and is not a determination of individual landowner allocations or groundwater rights. Alternatively, in the 2020 plans subbasin native yield could be described as a total volume of water and not associated with a given gross or net area. In addition, GSAs should initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations of native yield that are coordinated across the subbasin. The allocation methodology should be consistent with various legal considerations drawn from applicable case law and be generally consistent with groundwater rights, recognizing that GSAs do not have statutory authority to make a final determination of water rights. An equal-per-gross acre approach to allocations is not likely to be consistent with established water rights doctrine, which must recognize many equitable considerations in addition to acreage owned, to determine a legally defensible allocation. Further information regarding allocation methodology can be found in Groundwater Pumping Allocations Under California's Sustainable Groundwater Management Act – Environmental Defense Fund and New Current Water & Land, July 2018.	•***Section 18.1.4 which describes Stakeholder Engagement as part of MA Plan implementation, has been modified to include a statement that any actions to establish lando level allocations of native yield will be conducted through a robust stakeholder engagement process.*** •See KGA response to this comment for further information. •Also see response to
Wonderful Orchards/Wonderful Citrus	2	**Groundwater Markets** Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next.	•The MA Plan includes in its portfolio of P/MAs a management action to evaluate and potentially implement a groundwater marketing and trading system (see **Section 17.2.2**). •As described in **Section 18.1.2,** implementation of P/MAs, including the potential establishment of a market-based system, will include performance of any appropriate furthe studies and analysis, including engineering, economic/financial, and/or legal, as appropriate. •See KGA response to this comment for further information.
Wonderful Orchards/Wonderful Citrus	2	**Pumping Restrictions** Wonderful understands that there are instances where it may be necessary to restrict pumping in order to achieve basin-wide sustainability. If this becomes a necessity, the GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity. As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled).	•Demand reduction Management Actions are included in the MA Plan as one element in a portfolio of P/MAs (see **Section 17**). •The P/MA implementation timetable is based on a phased/incremental "glide path" approach (see **Section 17.1.4**). •P/MA implementation will entail, in many cases, performing studies and/or analysis to refine concepts into actionable projects or policies (see **Section 18.1.2**). ***Section 18.1.2 modified to clarify that such studies will be based on using the best available data and science.*** •See KGA response to this comment for further information.

Commentor	Ref #	Comment	Response
Wonderful Orchards/Wonderful Citrus	3	**Groundwater Recharge and Banking** GSAs must develop clear policies and conditions that protect existing investment in groundwater banking and banked inventory, and without interference with existing rules and regulations. GSAs must also find a way to incentivize additional investment, such as on-farm recharge, and allow flexibility for recharged or banked water to be freely transferable (subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results). Where possible, GSPs should also identify management areas that may benefit from additional recharge and banking. We also recommend that GSAs work to develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	•As described in **Section 18.1.2**, implementation of P/MAs, including projects to enhance recharge and projects to manage and/or capture floodwater, will include performanc any appropriate further studies and analysis, including engineering, economic/financial, and/or legal, as appropriate. •See KGA response to this comment for further information.
Wonderful Orchards/Wonderful Citrus	3	**Measurement and Data Management** Finally, GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	•The comment is noted. •***Section 8.1 has been added to the MA Plan to describe data sources used in MA Plan development and how this local DMS will be coordinated with the basin-wide DMS.*** •***Appendix I has been added to the MA Plan to list additional water quality data sources that will be evaluated during MA Plan implementation.*** •The Plan implementation section includes an action to refine the local DMS to comply with (coordinate with) the basin-wide DMS (see **Sections 18.1.1** and **18.1.3**). •See KGA response to this comment for further information.
Farmland Reserves	1	**Allocation of Groundwater Rights.** Though not specifically addressed, we are concerned that the overlying right to extract groundwater will be allocated among all District landowners based on gross acreage. While this is a simple approach to what can be a complex issue, it ignores accepted principles of law intended to more fairly allocate this right among those who have historically used groundwater for irrigation purposes-and made substantial investments based on that use. We wish to at least see identification of this issue in the Chapter and an acknowledgment that it will not be decided now. If the District determines that the issue is broader, then we leave it to the District to address it at the Umbrella GSP level. Any implication that the District has decided to allocate the overlying groundwater rights based simply on gross acreage could invite some to pursue premature legal action to challenge the District's conclusion, which might not be necessary depending on the success of the proposed actions in the Chapter. While this issue certainly affects our interests, we are equally concerned about avoiding unnecessary legal challenges made by others and the instability that would bring to the sub-basin.	•"Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). •***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that "the "water accounting" approach described in the Coordinat Agreement and Appendices thereto does attempt to evaluate the water budget using certain management assumptions (e.g., a uniform "native yield component to all lan within the Basin). However, nothing in this water budget information results in or is intended to be a determination of water rights within the Arvin-Edison Management A*** •Implementation of P/MAs, including actions to further refine issues related to water budgets, is described in **Section 18.1.2**. •See KGA response to this comment for further information.
Farmland Reserves	2	**Native Yield.** The Chapter identifies a coordinated estimated native yield of 0.15-.0.30 acre feet per acre across the KGA. We understand and acknowledge that some number needed to be identified for Water Budget and planning purposes and support the use of these numbers for such purposes. However, these numbers should not be seen as establishing a precedent or used to establish some legal right. Therefore, a statement emphasizing the above points should be made - the planning purpose nature of these numbers and not establishing legal precedent. Additionally, in coordinating with other members of the KGA under the Umbrella GSP, the District should push for a consistent native yield and related methodology across the sub-basin. We understand that this can be a politically charged process, but we are confident the District can provide support for a consistent approach, which will enable a more stable sub-basin.	•"Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). •***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that the "native yield" is for planning purposes only and not a determination of actual legal ground water rights.*** •Implementation of P/MAs, including actions to further refine issues related to allocations of groundwater, is described in **Section 18.1.2**. •See KGA response to this comment for further information.
Farmland Reserves	3	**Groundwater Market.** This issue might be premature at this point. However, the Chapter could address the possibility of a market for the exchange or transfer of groundwater credits. If a market system were contemplated, we would encourage such a system to be as flexible as possible (within the requirements of SGMA, the Chapter and the Umbrella GSP) to facilitate the needs of farmers with lands in different areas of the sub-basin and those with the ability to store surface water underground. Again, this might be premature at this time, but a mention of the District's position to support a flexible groundwater market could help move the discussion forward once the Umbrella GSP is submitted to the Department of Water Resources and agencies begin the implementation process.	•The MA Plan includes in its portfolio of P/MAs a management action to evaluate and potentially implement a groundwater marketing and trading system (see Section 17.2.2). •As described in Section 18.1.2, implementation of P/MAs, including the potential establishment of a market-based system, will include performance of any appropriate further studies and analysis, including engineering, economic/financial, and/or legal, as appropriate. •See KGA response to this comment for further information.
Hancock Financial Services	1	**Allocation of Native Yield** The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water, for example xxx,xxx acre-feet and not associated with a given gross or net area. In the event that allocations of any sort are distilled to a landowner or property level, HFS encourages the GSAs in the basin to initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations that are coordinated across the basin. The allocation methodology should be consistent with various legal considerations drawn from applicable case law and attempt to be consistent with groundwater rights, recognizing that GSAs do not have statutory authority to make a final determination of water rights. An equal-per-gross acre approach to allocations is not likely to be consistent with established water rights doctrine, which must recognize many equitable considerations, in addition to acreage owned, to determine a legally defensible allocation. Further information regarding allocation methodology can be found in Groundwater Pumping Allocations Under California's Sustainable Groundwater Management Act – EDF and NCWL, dated July, 2018	•"Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). •***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that "the "water accounting" approach described in the Coordinat Agreement and Appendices thereto does attempt to evaluate the water budget using certain management assumptions (e.g., a uniform "native yield component to all lan within the Basin). However, nothing in this water budget information results in or is intended to be a determination of water rights within the Arvin-Edison Management A*** •Implementation of P/MAs, including actions to further refine issues related to water budgets, is described in **Section 18.1.2.** •***Section 18.1.4 which describes Stakeholder Engagement as part of MA Plan implementation, has been modified to include a statement that any actions to establish lando level allocations of native yield will be conducted through a robust stakeholder engagement process.*** •See KGA response to this comment for further information.
Hancock Financial Services	1	**Groundwater Recharge and Banking** GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	•As described in **Section 18.1.2**, implementation of P/MAs, including projects to enhance recharge and projects to manage and/or capture floodwater, will include performanc any appropriate further studies and analysis, including engineering, economic/financial, and/or legal, as appropriate. •See KGA response to this comment for further information.
Hancock Financial Services	3	**Refinement and Validation of Consumptive Use Calculations Based on ET Measurement** HFS supports use of efficient and accurate systems to determine groundwater use. GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration. These methodologies should be developed in consultation with the vendor providing ET data to ensure it is applicable and useful in creating the best available data set. Additionally, GSAs and/or MAs should establish criteria and procedures to address apparent inaccuracies in the ET calculations. An obvious use of the procedure would be in instances where the grower can demonstrate that applied water, plus precipitation, is less than the calculated ET. In these instances, and subject to any requirements established by the GSA, the grower's use of groundwater should be reduced to the applied water total as the ET calculation should not be greater than applied water.	•The comment is noted. •See KGA response to this comment for further information.

Commentor	Ref #	Comment	Response
Westchester Group Investment Management	1	**Allocation of Native Yield** The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water and not associated with a given gross or net area. In the event that allocations are to be made at a landowner or property level, WGIM encourages the KGA and other GSAs in the basin to initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations that are coordinated across the basin. The allocation methodology should be consistent with various legal considerations drawn from applicable case law and attempt to be consistent with groundwater rights, recognizing that GSAs and Management Areas (MAs) do not have statutory authority to make a final determination of water rights. An equal-per-gross acre approach to allocations is not likely to be consistent with established water rights doctrine, which must recognize many equitable considerations, in addition to acreage owned, to determine a legally defensible allocation. Further information regarding allocation methodology can be found in Groundwater Pumping Allocations Under California's Sustainable Groundwater Management Act – EDF and NCWL, dated July, 2018.	•"Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). ***•Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that the "the "water accounting" approach described in the Coordi Agreement and Appendices thereto does attempt to evaluate the water budget using certain management assumptions (e.g., a uniform "native yield component to all lan within the Basin). However, nothing in this water budget information results in or is intended to be a determination of water rights within the Arvin-Edison Management A*** •Implementation of P/MAs, including actions to further refine issues related to allocations of groundwater, is described in **Section 18.1.2.** ***•Section 18.1.4 which describes Stakeholder Engagement as part of MA Plan implementation, has been modified to include a statement that any actions to establish landa level allocations of native yield will be conducted through a robust stakeholder engagement process.*** •See KGA response to this comment for further information.
Westchester Group Investment Management	1	**Pumping Restrictions** We understand that there are instances where it may be necessary to restrict pumping in order to achieve basin-wide sustainability. If this becomes a necessity, the GSAs and MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible without creating undesirable results, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity. As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated and consistent across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled).	•Demand reduction Management Actions are included in the MA Plan as one element in a portfolio of P/MAs (see **Section 17**). •The P/MA implementation timetable is based on a phased/incremental "glide path" approach (see **Section 17.1.4**). •P/MA implementation will entail, in many cases, performing studies and/or analysis to refine concepts into actionable projects or policies (see Section 18.1.2). ***Section 18.1.2 modified to clarify that such studies will be based on using the best available data and science.*** •See KGA response to this comment for further information.
Westchester Group Investment Management	2	**Groundwater Recharge and Banking** GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked water inventory, and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	•As described in **Section 18.1.2**, implementation of P/MAs, including projects to enhance recharge and projects to manage and/or capture floodwater, will include performanc any appropriate further studies and analysis, including engineering, economic/financial, and/or legal, as appropriate.
Westchester Group Investment Management	2	**Measurement and Data Management** GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	•The comment is noted. ***•Section 8.1 has been added to the MA Plan to describe data sources used in MA Plan development and how this local DMS will be coordinated with the basin-wide DMS.*** •Appendix I has been added to the MA Plan to list additional water quality data sources that will be evaluated during MA Plan implementation. •The Plan implementation section includes an action to refine the local DMS to comply with (coordinate with) the basin-wide DMS (see **Sections 18.1.1** and **18.1.3**). •See KGA response to this comment for further information.
Westchester Group Investment Management	3	**Refinement and Validation of Consumptive Use Calculations Based on ET Measurement** WGIM supports use of efficient and accurate systems to determine groundwater use. GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration. These methodologies should be developed in consultation with the vendor providing ET data to ensure it is applicable and useful in creating the best available data set. Additionally, GSAs and/or MAs should establish criteria and procedures to address apparent inaccuracies in the ET calculations. An obvious use of the procedure would be in instances where the grower can demonstrate that applied water, plus precipitation, is less than the calculated ET. In these instances, and subject to any requirements established by the GSA, the grower's use of groundwater should be reduced to the applied water total as the ET calculation should not be greater than applied water.	•The comment is noted. •See KGA response to this comment for further information.
California Department of Fish and Wildlife	1	The Plan Area narrative does not identify Department-owned lands.	•The Arvin-Edison MA Plan identifies lands owned by the California Department of Fish and Wildlife in **Section 5.1.3** and on **Figure PA-2.** •See KGA response to this comment for further information.
California Department of Fish and Wildlife	2	The GSP identifies an 'environmental' category of beneficial user but does not specify how impacts to environmental beneficial uses and users of groundwater were considered throughout the GSP.	•The process used to assess the potential occurrence of "environmental" uses/users of groundwater in the Management Area is based on depth to groundwater based on avai data from wells in the principal aquifer, as described in **Section 8.2, 8.7** and **8.8**. This process was informed by the TNC (2019) guidance for evaluation of GDEs. •See KGA response to this comment for further information.
California Department of Fish and Wildlife	3	The GSP identifies the potential for interconnected surface waters but dismisses further evaluation of interconnectivity and abdicates oversight of shallow groundwater-surface water communication.	•The process used to assess the potential occurrence of interconnected surface water in the Management Area is based on depth to groundwater (similar to the process used f evaluation of GDEs, which was done consistent with TNC (2019) guidance; see below) based on available data from wells in the principal aquifer, as described in **Section 8.2** an •See KGA response to this comment for further information.
California Department of Fish and Wildlife	4	The GDE identification section, pursuant to 23 CCR§ 354.16 (g), identifies ecosystems that may depend on groundwater. A report completed by the California Department of Water Resources (CDWR) (1997) shows that a large area of Kern County has 0 to 10 feet to depth to free water below the surface (see CDWR Figures 2, 3 and 5). Based on the presence of shallow groundwater, the Department supports the further investigation of GDEs and recommends including additional references for a more robust GDE evaluation. The Department recognizes that Natural Communities Commonly Associated with Groundwater (NCCAG) (Klausmeyer et al. 2018) provided by CDWR is a good starting reference for GDEs. There are additional resources available for evaluating GDE locations and habitat types, as well as information for State and Federal listed species. These recommended references include, but not limited to the following tools and other resources: the California Department of Fish and Wildlife (CDFW) Vegetation Classification and Mapping Program (VegCAMP) (CDFW 2019A); the CDFW California Natural Diversity Database (CNDDB) (2019B); the California Native Plant Society (CNPS) Manual of California Vegetation (CNPS 2019A); the CNPS California Protected Areas Database (CNPS 2019B); the United States Fish and Wildlife Service (USFWS) National Wetlands Inventory (2018); the USFWS online mapping tool for listed species critical habitat (2019); the United States Forest Service CALVEG ecological grouping classification and assessment system (2019); and other publications by Klausmeyer et al. (2019), Rohde et al. (2018), The Nature Conservancy (TNC) (2014, 2019), and Witham et al. (2014).	•The process used to assess the potential occurrence of GDEs in the Management Area is based on depth to groundwater based on available data from wells in the principal aq as described in **Section 8.2** and **8.8**. ***•Section 8.8 was modified to include mention the use of the TNC (2019) guidance and criteria therein.*** •The criteria used to remove NCCAG from the list of potential GDEs is a depth to water greater than 30 feet, which is based on guidance from The Nature Conservancy (2019). •See KGA response to this comment for further information.

Commentor	Ref #	Comment	Response
California Department of Fish and Wildlife	5	The identification of undesirable results and selection of minimum thresholds are based on an extended 10-year drought period and exclude Sustainable Management Criteria for surface water depletions.	•Because interconnected surface waters are determined to not occur within the MA Plan area, based on depth to groundwater data from the principal aquifer, sustainable management criteria for Depletion of Interconnected Surface Waters are deemed not applicable/necessary. •See KGA response to this comment for further information.
California Department of Fish and Wildlife	"Other"	Implementation of Future Project Actions Related to SGMA: Comments related to: •The CDFW's role as "Trustee Agency for fish and wildlife resources", and •The CDFW's role as a "Responsible Agency under CEQA" that "may need to exercise regulation authority as provided by the Fish and Game Code for implementation of projects related to the GSP that are also subject to CEQA".	•Comments are noted. •Permitting requirements for each P/MA included in the MA Plan are discussed in **Section 17.6** and in **Table PMA 1**. Work efforts related to P/MA implementation, including stu and environmental (CEQA) documentation, are discussed in **Section 18.1.2**. •See KGA response to this comment for further information.
The Nature Conservancy	9	**Notice and Communication** Please describe the other beneficial uses and users of groundwater in the Subbasin identified by the Water Code including: GDEs; managed wetlands; Protected Lands, including preserves, wildlife refuges, conservation areas, recreational areas and other protected lands; and Public Trust Uses, including wildlife, aquatic habitat, fisheries, recreation and navigation. Please identify any environmental uses and users of groundwater in the plan area, and take particular note of the species with protected status.	•The Arvin-Edison MA Plan identifies lands owned by the California Department of Fish and Wildlife in **Section 5.1.3** and on **Figure PA-2**. •See KGA response to this comment for further information.
The Nature Conservancy	10	**Plan Area Setting** Please provide a description of any current and planned instream flow requirements or regulatory requirements for protection of species of concern in the Kern River, Poso Creek and Caliente Creek. If there are no requirements in place or planned, then please state that in the GSP.	***•Section 7.2.5 of the MA Plan was updated to include a statement that there are no in-stream flow requirements set for any creeks that flow into the Arvin-Edison Manage Area, including Caliente Creek.*** •See KGA response to this comment for further information.
The Nature Conservancy	10	**Existing Plans in the Plan Area** We suggest adding a discussion of General Plan goals and policies related to the protection and management of GDEs and aquatic resources that could be affected by groundwater withdrawals. Please include a description of any land use or environmental plans relevant to wetlands, aquatic resources and other GDEs and ISWs and their relationship to the GSP. Please include a discussion of how implementation of the GSP may affect and be coordinated with General Plan policies and procedures regarding the protection of wetlands around the Kern Wildlife Refuge, aquatic resources and other GDEs and ISWs. Please identify all relevant HCPs and NCCPs within the Subbasin and address how GSP implementation will coordinate with the goals of these HCPs or NCCPs.	•**Section 5.3** of the MA Plan includes information about land use plans (i.e., General Plans), including a summary of goals, policies and implementation measures related to land water use. •See KGA response to this comment for further information.
The Nature Conservancy	10	**Existing and Ongoing Water Resource Programs** Please provide a description of resource management plans, monitoring activities and responsibilities by State, Federal and local agencies and jurisdictions related to aquatic resources and GDEs that could be affected by groundwater withdrawals, and list them in Table 2-1. Please review and discuss the potential groundwater reliance of critical species in the Subbasin. Please include a discussion regarding the management of critical habitat for these aquatic species and its relationship to the GSP. Please include a discussion of any monitoring programs related to GDEs and sensitive habitats.	•See KGA response to this comment for further information.
The Nature Conservancy	11	**Well Permitting Process, Well Construction Policies** Please discuss that future well permitting and well construction must be coordinated with the GSP to assure achievement of the Plan's sustainability goals. Please state how the well permitting process incorporates protection of GDEs and ISWs within the Subbasin. Please include a discussion of the need for well permitting programs to comply with this requirement.	•**Sections 5.3.4** and **5.4** of the MA Plan includes discussion of the Kern County Well Permitting Process. •See KGA response to this comment for further information.
The Nature Conservancy	11	**Hydrogeologic Conceptual Model – Bottom of the Subbasin** Please characterize groundwater well extractions from the deepest wells in relation to defining the basin bottom. If the bottom boundary of the Subbasin has not been clearly defined in certain management areas, please identify this as a data gap and elaborate in the monitoring section how and where additional observations can be made to reconcile this data gap.	•**Section 7.1.3** of the MA Plan describes the definition of the bottom of the basin, which includes consideration of the deepest groundwater wells. •See KGA response to this comment for further information.
The Nature Conservancy	12	**Hydrogeologic Conceptual Model – Principal Aquifers and Aquitards** Please provide additional description of the shallow aquifers within the Subbasin including characteristics of interconnections with surface water and GDEs, vertical groundwater gradients, connections with underlying production aquifers, and the resulting potential interaction of groundwater pumping with ISWs and GDEs. Please state whether localized perched aquifers are present in the Subbasin. Describe any data gaps. The function and significance of the Shallow Aquifers that provide groundwater to ISWs and GDEs should be summarized in Table 2-3. Please describe whether the existence of Aquifer Exemptions has any bearing or implications related to environmental beneficial uses of groundwater.	•**Section 7.1.**4 of the MA Plan mentions the occurrence of the "A"-Clay which may result in localized perched groundwater in some areas. •**Section 7.3.2** of the MA Plan mentions that these perched zones are often poor quality and do not yield significant or economic amounts of water to wells, springs, or surface systems, and are therefore not considered part of the principal aquifer. •See KGA response to this comment for further information.
The Nature Conservancy	12	**Hydrogeologic Conceptual Model – Data Gaps and Uncertainty** If data are not present to produce the information requested in the comment above, please clearly identify this as a data gap. Please elaborate in the monitoring section how and where additional observations are to be conducted in order to address this data gap.	•See KGA response to this comment for further information.
The Nature Conservancy		**Hydrogeologic Conceptual Model – Cross-Sections** Please include near-surface cross sections or insets that depict the conceptual understanding of shallow groundwater and ISW interactions at different locations, including perched and regional aquifers and GDEs.	•See KGA response to this comment for further information.
The Nature Conservancy	13	**Hydrogeologic Conceptual Model - Elevation and Flow Directions** Please provide any available stratigraphic data, hydrograph data, pumping test data or other information to substantiate these claims. If the data are not available, please identify this as a data gap.	•See KGA response to this comment for further information.
The Nature Conservancy	14	**Interconnected Surface Water Systems** Please provide additional data or analysis to substantiate the nature of the hydrologic relationship between the shallow aquifer and production aquifers and ISWs. If data are not available to verify that such a connection does not exist, acknowledge where ISWs may exist and identify appropriate sustainable management criteria, monitoring networks and management actions for sustainable ISW management or to address data gaps. Data could include groundwater level data from shallow or nested monitoring wells, comparison of stream stages to groundwater levels, modeling information or additional gaging data. Please elaborate how and where additional observations (shallow monitoring wells, stream gauges, and nested / clustered wells) along surface water features can be used to address data gaps in the Monitoring Network section of the GSP to improve identification of ISWs rather than prematurely disregarding them in the GSP.	•The process used to assess the potential occurrence of interconnected surface water in the Management Area is based on depth to groundwater (similar to the process used f evaluation of GDEs, which was done consistent with TNC (2019) guidance; see below) based on available data from wells in the principal aquifer, as described in **Section 8.2** an •See KGA response to this comment for further information.

Commentor	Ref #	Comment	Response
The Nature Conservancy	14	Groundwater-Dependent Ecosystems Please identify any data gaps related to identifying and mapping GDEs. If there are data gaps, please describe in detail in the monitoring plan how the data gaps will be addressed. Please support this statement with specific groundwater level data that indicate a gap in the saturated zone between the production aquifers and shallow groundwater, and define the extent of the NCCAG dataset polygons that are excluded from consideration as GDEs on this basis. Please identify any data gaps related to identifying and mapping GDEs. If there are data gaps, please describe in detail in the monitoring plan how the data gap will be resolved. Please revise the GDE analysis in the GSP by conducting more substantial, data-based evaluation focusing on GDE identification in the GSP, clearly identify which NCCAG polygons are excluded, which polygons are determined to be GDEs and which polygons are uncertain at this time and will be verified as data gaps are address. Confirmation of GDEs should be performed based on depth to groundwater in the shallow zone, and additional information provided as to whether the shallow zone may be affected by groundwater withdrawal from the production aquifers. Please refer to Appendix D of this letter for best practices for using groundwater data to verify a connection to groundwater. Therefore, we recommend using depth to groundwater contour maps derived from subtracting groundwater levels from a DEM, as described above, to identify whether a potential connection to groundwater exists for the wetlands mapped in Attachment H of the GSP. Please refer to Attachments D and E of this letter for best practices for using local groundwater data to 1) verify whether polygons in the NC Dataset are supported by groundwater in an aquifer, and 2) verify whether ecosystem decline or recovery is correlated with groundwater levels. We recommend the inclusion of a discussion regarding the nature and characteristics of GDEs. Please provide information on the historical or current groundwater conditions near the GDEs or the ecological conditions present. We recommend an ecological inventory (see Appendix III, Worksheet 2 of the GDE Guidance) for all potential GDEs that includes vegetation or habitat types and rank the GDEs as having a high, moderate or low value. Explain how each rank was characterized. Please identify whether any endangered or threatened freshwater species of animals and plants, or areas with critical habitat were found in or near any of the GDEs. Some organisms rely on uplands and wetlands during different stages of their lifecycle.	•The process used to assess the potential occurrence of GDEs in the Management Area is based on depth to groundwater based on available data from wells in the principal aq as described in Section 8.2 and 8.8. •***Section 8.8 was modified to include mention of the use of TNC (2019) guidance and criteria therein.*** •The criteria used to remove NCCAG from the list of potential GDEs is a depth to water greater than 30 feet, which is based on guidance from The Nature Conservancy (2019). •See KGA response to this comment for further information.
The Nature Conservancy	17	**Water Budget** Please provide a breakdown of ET for native and riparian vegetation (such as wetlands, riparian vegetation, phreatophytes and other communities). Please evaluate the spatial relationship of native vegetation ET to NCCAG polygons to determine the groundwater use by this beneficial user for inclusion in the water budget. Identify any data gaps and outline the actions needed to address them.	•ET information used in the water budget analysis is from the ITRC-METRIC study and includes all lands, including non-irrigated lands. •See KGA response to this comment for further information.
The Nature Conservancy	17	**Sustainability Goal** Please clarify the sustainability goal and expand its description to ensure that all beneficial uses and users of groundwater are identified as being protected from undesirable results, and in particular, include GDEs, ISWs and related critical habitats. Since GDEs and ISWs may be present in the Subbasin (please see comments under Checklist Items 16-20) they should be recognized as beneficial users of groundwater and should be specifically included in the Sustainability Goal. In addition, a statement about any intention to address pre-SGMA impacts should be included. Please include ISWs in the Sustainability Goal until/unless sufficient data is available and provided to verify the status of ISWs. Given that there are potential GDEs in the Subbasin and that they may be affected by water quality, they should be included in the Sustainability Goal and addressed in the Water Quality section.	•The sustainability goal for the MA Plan area is stated in **Section 2** and **Section 12**, and does include mention of beneficial uses including environmental. •See KGA response to this comment for further information.
The Nature Conservancy	18	**Minimum Thresholds and Measurable Objectives** For each of these applicable sustainable management criteria, please include a discussion of GDEs (see comments under checklist items 16-20) and whether the minimum thresholds, measurable objectives and interim milestones will help achieve the sustainability goal as it pertains to the environment. Please modify Section 3.2.2 to specifically address impacts from degraded water quality to the plant and wildlife communities within GDEs.	•Because GDEs are determined to not occur within the MA Plan area, based on depth to groundwater data from the principal aquifer, sustainable management criteria for Depl Interconnected Surface Waters are deemed not applicable/necessary. •See KGA response to this comment for further information.
The Nature Conservancy	19	**Undesirable Results** Please add "possible adverse impacts to potential GDEs and ISWs" to the list of potential undesirable results. Please review these spatial patterns and, where possible, correlate them with water level trends. Any indications of adverse trends and any data gaps should be identified. For each identifiable GDE unit with supporting hydrological datasets, please include the following: For identifiable GDE units without supporting hydrological datasets please describe data gaps and / or insufficiencies. Compile and synthesize biological data for each GDE unit by: Describe possible effects on potential ISWs, GDEs, land uses, and property interests, including:	•Because GDEs and ISW are determined to not occur within the MA Plan area, based on depth to groundwater data from the principal aquifer, sustainable management criteria Depletion of Interconnected Surface Waters are deemed not applicable/necessary. •See KGA response to this comment for further information.

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The Nature Conservancy	20	**Monitoring Network** Please modify the description of the monitoring network to provide methodologies, data and other information to address the data gaps associated with GDEs and ISWs. This modification should include 1) locating new wells that are appropriately screened to detect changes in groundwater levels in the uppermost water table and the connectivity of GDEs and ISWs with the upper unconfined or shallow zone aquifer; and 2) identifying or installing additional stream gauges in areas where there is potential for ISWs and GDEs. Please expand on the discussion of how the new well and stream data will be used to improve ISW mapping and inform an adequate analysis, and how the data will be used to verify possible GDEs. Please address data gaps along the Kern River and tributary creeks identified earlier in the GSP in this section of the GSP to improve ISW mapping in companion or future GSPs (e.g., through shallow monitoring wells, stream gauges, and nested/clustered wells).	•See KGA response to this comment for further information.
The Nature Conservancy	21	**Projects and Management Actions** For the projects already identified, please consider stating how ISWs and GDEs will benefit or be protected, or what other environmental benefits will accrue. Please consider additional management actions and projects targeted for protecting ISWs and GDEs. Please describe how the projects and management actions will be evaluated to assess whether adverse impacts to GDEs may occur and/or will be mitigated or prevented.	•Because GDEs and ISW are determined to not occur within the MA Plan area, based on depth to groundwater data from the principal aquifer, P/MAs to benefit and protect GD ISW are deemed not applicable/necessary. •See KGA response to this comment for further information.
Cawelo Water District Received Comments			
Grow View Enterprises	CGSA-1	The draft Chapter proposes several projects to help the District and its Groundwater Sustainability Agency achieve your sustainable groundwater management goals. In terms of the potential annual benefit, one of the significant projects is the purchase of new water supplies. We agree.	Cawelo GSA acknowledges the support for the acquisition of new water supplies.
Grow View Enterprises	CGSA-2	Grow View Enterprises recently sent the District a request made on behalf of certain of our affiliated landowners to connect, at their expense, to the District's existing water distribution system to allow for the delivery of surface water to the lands identified in that request. Those lands are currently served exclusively with groundwater. If excess District surface water is available, such a connection would allow these landowners to purchase District water and provide an additional funding source for the District's purchase of new water supplies. At the same time, a connection would allow the landowners to pursue private acquisitions of water supplies for conveyance into the District. Both possibilities would benefit the sustainability efforts of the District by lessening reliance on groundwater and bolstering the identified project to purchase new water supplies. Accordingly, a comment we have on the draft Chapter is that the Chapter should reflect a willingness by the District to allow landowners in the District's non-service area to connect to the District's water distribution system and become part of the District's service area. While individual situations will differ, any unique terms and conditions can be established for each. The Chapter should show the District's willingness to expand its service area as part of the project to allow for an increased delivery of the new water supply purchases the District proposes as a groundwater sustainability project.	As noted in the comment letter, potential connection to the Water District's water distribution system is a Cawelo Water District (CWD) matter. The Cawelo GSA supports landowners' efforts to bring into the GSA or CWD area additional imported water supplies to help meet demand. CWD has a history of allowing its landowners to connect the private systems to the CWD water distribution system and coordinating delivery of landowner owned water per CWD policies and oversite.
Wonderful Orchards/Citrus	CGSA-3	**Quantification of Native Yield**[1] It is imperative that the final GSP properly address the quantification of native yield. The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource. For example, a district or pumper located adjacent to the foothills does not necessarily have a superior claim to native yield over someone located in the center of the basin just because they are geographically closer to the source of mountain front recharge. Similarly, a district or pumper located in a cone of depression does not necessarily have a superior claim to native yield just because groundwater is flowing toward them. Surface water entering the groundwater via seepage in natural channels, including the Kern River and small streams, may be attributable to the native yield depending upon the circumstances of that seepage. A thorough technical and legal analysis is necessary to determine appropriate sources contributing to the native yield and to quantify these supplies. [1] Native yield as defined in Section 4.2.1 of Appendix J to the GSP.	Cawelo GSA agrees the Native Yield quantification needs to be properly addressed. Currently, for purposes of developing this initial Cawelo GSP/Management Area Plan, the l available data was used to determine an initial Native Yield value for the Cawelo GSA area which is presented in Section 4.7.2. Cawelo GSA acknowledges the Native Yield valu to be refined with additional studies and/or research and endeavors to update the Native Yield quantification as new data becomes available and coordination within the Kern County Subbasin continues.
Wonderful Orchards/Citrus	CGSA-4	**Allocation of Native Yield** In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield. Currently, the GSP references native yield in terms of acre-feet per gross acre for water budget purposes. Appendix J of the GSP indicates the subbasin native yield is approximately 0.144 acre-feet per acre. It is our understanding that subsequent to the release of the draft GSP, all MAPs and other GSPs in the basin agreed to utilize the same number for their water budgets. If referencing native yield this way is necessary, the GSP should clarify that it is for initial water budget purposes ONLY, is non-precedent setting, and is not a determination of individual landowner allocations or groundwater rights. Alternatively, in the 2020 plans subbasin native yield could be described as a total volume of water and not associated with a given gross or net area. In addition, GSAs should initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations of native yield that are coordinated across the subbasin. The allocation methodology should be consistent with various legal considerations drawn from applicable case law and be generally consistent with groundwater rights, recognizing that GSAs do not have statutory authority to make a final determination of water rights. An equal-per-gross acre approach to allocations is not likely to be consistent with established water rights doctrine, which must recognize many equitable considerations in addition to acreage owned, to determine a legally defensible allocation. Further information regarding allocation methodology can be found in Groundwater Pumping Allocations Under California's Sustainable Groundwater Management Act – Environmental Defense Fund and New Current Water & Land, July 2018.	The initial Native Yield volume has been updated per Section 4.7.2. At this time, the total volume for the Cawelo GSA has been estimated using best available data and further described by averaging that volume over the acreage within the Cawelo GSA area. This is not an allocation of Native Yield and is merely a method to communicate the average Yield in the Cawelo GSA area. For initial plan purposes, the Cawelo GSA, and in coordination with the KGA and other GSAs, has agreed to use an initial estimate of 0.15 AF per which is roughly equivalent to the Cawelo GSA initial calculations. The Cawelo GSA and other management areas within the Kern County Subbasin need to better understand science supporting the Native Yield and the legal concerns surrounding potential allocation of Native Yield. Cawelo GSA will continue to gather additional information to better inform the Native Yield values and potential allocation of Native Yield. Cawelo GSA will participate in regio coordinated efforts for Native Yield work.

Commentor	Ref #	Comment	Response
Wonderful Orchards/Citrus	CGSA-5	**Groundwater Markets** Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next.	It is necessary to gather additional data to better understand groundwater dynamics and how groundwater levels, established Minimum Thresholds and Measurable Objectiv groundwater users in general may be impacted by a potential groundwater transfer market.
Wonderful Orchards/Citrus	CGSA-6	**Pumping Restrictions** Wonderful understands that there are instances where it may be necessary to restrict pumping in order to achieve basin-wide sustainability. If this becomes a necessity, the GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity. As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled).	Cawelo GSA will consistently endeavor to coordinate with other management areas in the Kern County Subbasin on SGMA matters and as they relate to the GSPs. For this initial Plan, there are no proposed management actions to limit pumping in the Cawelo GSA area. Management actions include acquiring additional water supplies and necessary reduce demand.
Wonderful Orchards/Citrus	CGSA-7	**Groundwater Recharge and Banking** GSAs must develop clear policies and conditions that protect existing investment in groundwater banking and banked inventory, and without interference with existing rules and regulations. GSAs must also find a way to incentivize additional investment, such as on-farm recharge, and allow flexibility for recharged or banked water to be freely transferrable (subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results). Where possible, GSPs should also identify management areas that may benefit from additional recharge and banking. We also recommend that GSAs work to develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	The Cawelo GSA has deferred potential groundwater recharge and banking to the CWD. The CWD is currently developing a landowner recharge/banking program.
Wonderful Orchards/Citrus	CGSA-8	**Measurement and Data Management** Finally, GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	The Cawelo GSA anticipates participating in a coordinated Subbasin effort to develop a DMS that is appropriate for the management areas of the Subbasin.
Farmland Reserve	CGSA-9	1. Allocation of Groundwater Rights. Though not specifically addressed, we are concerned that the overlying right to extract groundwater will be allocated among all District landowners based on gross acreage. While this is a simple approach to what can be a complex issue , it ignores accepted principles of law intended to more fairly allocate this right among those who have historically used groundwater for irrigation purposes-and made substantial investments based on that use. We wish to at least see identification of this issue in the Chapter and an acknowledgment that it will not be decided now. If the District determines that the issue is broader, then we leave it to the District to address it at the Umbrella GSP level. Any implication that the District has decided to allocate the overlying groundwater rights based simply on gross acreage could invite some to pursue premature legal action to challenge the District's conclusion, which might not be necessary depending on the success of the proposed actions in the Chapter. While this issue certainly affects our interests, we are equally concerned about avoiding unnecessary legal challenges made by others and the instability that would bring to the sub-basin.	At this time, the total Native Yield volume for the Cawelo GSA has been estimated and further described by averaging that volume over the acreage within the Cawelo GSA are is not an allocation of Native Yield and is merely a method to communicate the average Native Yield in the Cawelo GSA area. For initial plan purposes, the Cawelo GSA, and in coordination with the KGA and other GSAs, has agreed to use an initial estimate of 0.15 AF per acre which is roughly equivalent to the Cawelo GSA initial calculations. The Caw GSA and other management areas within the Kern County Subbasin need to better understand the science supporting the Native Yield and the legal concerns surrounding pot allocation of Native Yield before an allocation can be issued. Cawelo GSA will continue to gather additional information to better inform the Native Yield values and potential allocation of Native Yield. Cawelo GSA will participate in regio coordinated efforts for Native Yield work.
Farmland Reserve	CGSA-10	2. Native Yield. The Chapter identifies a coordinated estimated native yield of 0.15-0.30 acre feet per acre across the KGA. We understand and acknowledge that some number needed to be identified for Water Budget and planning purposes and support the use of these numbers for such purposes. However, these numbers should not be seen as establishing a precedent or used to establish some legal right. Therefore, a statement emphasizing the above points should be made - the planning purpose nature of these numbers and not establishing legal precedent. Additionally, in coordinating with other members of the KGA under the Umbrella GSP, the District should push for a consistent native yield and related methodology across the sub-basin. We understand that this can be a politically charged process, but we are confident the District can provide support for a consistent approach, which will enable a more stable sub-basin.	See the above response
Farmland Reserve	CGSA-11	3. Groundwater Market. This issue might be premature at this point. However, the Chapter could address the possibility of a market for the exchange or transfer of groundwater credits. If a market system were contemplated, we would encourage such a system to be as flexible as possible (within the requirements of SGMA, the Chapter and the Umbrella GSP) to facilitate the needs of farmers with lands in different areas of the sub-basin and those with the ability to store surface water underground. Again, this might be premature at this time, but a mention of the District's position to support a flexible groundwater market could help move the discussion forward once the Umbrella GSP is submitted to the Department of Water Resources and agencies begin the implementation process	It is necessary to gather additional data to better understand groundwater dynamics and how groundwater levels, established Minimum Thresholds and Measurable Objectiv groundwater users in general may be impacted by a potential groundwater transfer market. The Cawelo GSA Board of Directors have publicly stated they believe flexibility is key to the success of SGMA and the GSPs, and that it is necessary for the future of farming.
Eastside Water Management Authority Received Comments			
Kern County Water Agency – Pioneer Project Received Comments			
No Comments Received			
Kern Tulare Water District Received Comments			
Wonderful Orchards		Refer to KGA Summary of Comments	Refer to KGA Response
Kern Water Bank Received Comments			

Commentor	Ref #	Comment	Response
Hancock Farmland Services	HFS-2	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	The KWBA concurs with the comment that existing banking projects need to continue operating as they have. Water banking projects in the Kern County subbasin are critical to reaching the sustainability goals of SGMA. The projects store available surplus surface water during wet years for later recovery in dry years, thereby reducing the reliance on groundwater by others in the subbasin. The projects operate under agreements with other basin stakeholders – developed during the CEQA process – that provide for project monitoring and mitigation measures which reduce any potential impacts to less than significant. Moreover, the projects, by their nature, do not contribute to any of the six undesirable results listed in SGMA.
Westchester	WGIM-4	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	See above comment.
Wonderful Orchards	WO-6	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	See above comment.
North Kern Water Storage District & Shafter-Wasco Irrigation District Received Comments			
Farmland Reserve		"Though not specifically addressed, we are concerned that overlying right to extract groundwater will be allocated among all District landowners based on gross acreage…it ignores accepted principles of law intended to more fairly allocate this right among those who have historically used groundwater for irrigation purposes -- and made substantial investments based on that use."	We have discussed adding language to the Water Budget section of the plan to address the fact that there is currently no in-district allocation of water to the landowners. The language in the Projects & Mgmt Actions section, dealing with in-district allocation as a mgmt action has been revised to address this, as well.
Farmland Reserve		"These numbers should not be seen as establishing a precedent or used to establish some legal right. Therefore, a statement emphasizing the above points should be made."	The discussion on native yield in the Water Budget section of the plan addresses this.
Farmland Reserve		"The Chapter could address the possibility of a market for the exchange or transfer of groundwater credits."	At this time, such a discussion is premature. There is no framework within the districts or the basin at large to allow for the exchange or transfer of groundwater credits. We ca reasonably address this in the plans for 2020 submittal.
Hancock Farmland Services		"The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water, for example xxx,xxx acre-feet and not associated with a given gross or net area."	The discussion on native yield in the Water Budget section of the plan addresses this already. Further emphasis on the "planning budget" role of the Native Yield estimate has b added to the final draft of the plan.
Hancock Farmland Services		"GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.)."	At this time, the framework to offer such incentives does not exist and would require the districts' boards to develop & adopt policy to put it in place. In the time required to pr the 2020 submittal of the plan, we cannot develop the structure and policy required to implement this. However, this is discussed in the Projects & Mgmt Actions section of the and will be considered for implementation after the 2020 plan submittal, when the districts have an opportunity to develop the policy and framework necessary for such progr
Hancock Farmland Services		"GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration. These methodologies should be developed in consultation with the vendor providing ET data to ensure it is applicable and useful in creating the best available data set. Additionally, GSAs and/or MAs should establish criteria and procedures to address apparent inaccuracies in the ET calculations. An obvious use of the procedure would be in instances where the grower can demonstrate that applied water, plus precipitation, is less than the calculated ET. In these instances, and subject to any requirements established by the GSA, the grower's use of groundwater should be reduced to the applied water total as the ET calculation should not be greater than applied water."	This is already included in the Projects and Management Actions section and is part of the larger action of refining data for the calculation of Water Budget components in futur updates.
Wonderful Orchards		"The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource."	The districts have identifed as a management action the coordinated effort to further refine water budget components in the Kern County Subbasin Model. The Model and wat budget components will continue to be refined in coordination with the KGA and other GSAs in the basin.
Wonderful Orchards		"In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield. Currently, the GSP references native yield in terms of acre-feet per gross acre for water budget purposes. Appendix J of the GSP indicates the subbasin native yield is approximately 0.144 acre-feet per acre. It is our understanding that subsequent to the release of the draft GSP, all MAPs and other GSPs in the basin agreed to utilize the same number for their water budgets. If referencing native yield this way is necessary, the GSP should clarify that it is for initial water budget purposes ONLY, is non-precedent setting, and is not a determination of individual landowner allocations or groundwater rights. Alternatively, in the 2020 plans subbasin native yield could be described as a total volume of water and not associated with a given gross or net area."	The discussion on native yield in the Water Budget section of the plan addresses this already. Further emphasis on the "planning budget" role of the Native Yield estimate has b added to the final draft of the plan. In terms of native yield allocation to the parcel/landowner level, there is no framework currently in place to do so. The development the pol and framework necessary to implement such an allocation cannot be completed in time for the 2020 plan submittal.
Wonderful Orchards		"Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next."	At this time, such a discussion is premature. There is no framework within the districts or the basin at large to allow for the exchange or transfer of groundwater credits. We ca reasonably address this in the plans for 2020 submittal.
Wonderful Orchards		"Wonderful understands that there are instances where it may be necessary to restrict pumping in order to achieve basin-wide sustainability. If this becomes a necessity, the GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity. As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled)."	As described in the Management Actions subsection of the Management Area Plan, policies for instituting pumping restrictions have not been developed for the 2020 plan subm This has been identifed as a potential management action, should the districts or the basin in general determine that it cannot maintain its path to sustainability through the pro and other management actions to be implemented.

Commentor	Ref #	Comment	Response
Wonderful Orchards		"GSAs must develop clear policies and conditions that protect existing investment in groundwater banking and banked inventory, and without interference with existing rules and regulations. GSAs must also find a way to incentivize additional investment, such as on-farm recharge, and allow flexibility for recharged or banked water to be freely transferrable (subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results). Where possible, GSPs should also identify management areas that may benefit from additional recharge and banking. We also recommend that GSAs work to develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.)."	At this time, the framework to offer such incentives does not exist and would require the districts' boards to develop & adopt policy to put it in place. In the time required to pr the 2020 submittal of the plan, we cannot develop the structure and policy required to implement this. However, this is discussed in the Projects & Mgmt Actions section of the and will be considered for implementation after the 2020 plan submittal, when the districts have an opportunity to develop the policy and framework necessary for such progr
Wonderful Orchards		"GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	A coordinated DMS is already being developed. However, that effort is currently focused at the district/MA level due to the precision of the data being used. Parcel-level alloca not at this time being done in the subbasin. It is premature to consider a basin-wide water market, as the data available does not allow for that level of allocation to be done. Fo consideration in the 2020 plan submittal, we do not have adequate time or resources for the development of such a framework.
Pacific Ag Management		Landowner would like to see RRID's ability to access future water supplies such as flood or highflow water from the Kem River made available to the District or additional waters that may become available. Landowner requests consideration of RRID's right to an ongoing, guaranteed share of such water as it is made available to the District.	This is already addressed in the RRID-specific projects in Section 5.4 of this plan. These projects are conceptual in nature, but they will be further defined as the district impleme SGMA.
Pacific Ag Management		In regard to the produced water available to the District, Landowner requests that RRID be granted increased access to this water to be delivered in the form of pumping credits	This is already addressed in the RRID-specific projects in Section 5.4 of this plan. These projects are conceptual in nature, but they will be further defined as the district impleme SGMA.
Pacific Ag Management		Landowner requests that the District consider using its positive water budget balance (Inflows less Outflows) for the purpose of offsetting any RRID water budget deficit.	The water budget for RRID has been revised based on the addition of the projects into the projected baseline water budget for years 2030 and 2070.
Pacific Ag Management		Landowner understands that recharge opportunities are an integral part of sustaining agricultural operations as the RRID area transitions to urban development. Recharge provides positive hydrological benefits as well as additional pumping opportunities for landowners. Landowner supports the enlargement, creation, and maintenance of recharge facilities within RRID, along with use of the RRID canal system as a recharge area and supplement to RRID water supplies.	This is already addressed in the RRID-specific projects in Section 5.4 of this plan. These projects are conceptual in nature, but they will be further defined as the district impleme SGMA.
Pacific Ag Management		Conveyance capacity is critical in order to effectively and strategically manage the movement of water supplies, both at the agency and at the landowner level. Landowner supports the proposed Calloway Canal improvements. Additionally, Landowner requests that RRID be given greater access to pipeline capacity when surplus water exists and that RRID canals be enhanced and expanded to the benefit of RRID landowners.	Continued maintenance of existing conveyance to RRID is already included as part of the RRID-specific projects discussed in Section 5.4 of this plan.
Pacific Ag Management		As an RRID stakeholder, Landowner is appreciative of North Kern Water Storage District's and Kern Groundwater Authority's support of agricultural land owners and their commitment to the effective management of RRID's water supplies and agricultural lands. The City of Bakersfield and the Kern River Groundwater Sustainability are critical strategic partners for RRID. Landowner is confident that a partnership between the agencies and respective landowners will ensure the continued viability of agricultural operations in RRID and a successful transition to urban development.	Per the terms of the Coordination Agreement between KGA and the other Kern GSAs, and NKWSD and SWID's membership in KGA, the Districts already coordinate with KRGSA Coordination between the Districts and KRGSA will continue through the SGMA implementation process and beyond.
Westchester Group Investment Mgmt		The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water and not associated with a given gross or net area. In the event that allocations are to be made at a landowner or property level, WGIM encourages the KGA and other GSAs in the basin to initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations that are coordinated across the basin.	The discussion on native yield in the Water Budget section of the plan addresses this already. More language can be added to emphasize the "planning budget" role of the Nati estimate.
Westchester Group Investment Mgmt		GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked water inventory, and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	At this time, the framework to offer such incentives does not exist and would require the districts' boards to develop & adopt policy to put it in place. In the time required to pr the 2020 submittal of the plan, we cannot develop the structure and policy required to implement this. However, this is discussed in the Projects & Mgmt Actions section of the and will be considered for implementation after the 2020 plan submittal.
Westchester Group Investment Mgmt		GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	A coordinated DMS is already being developed. However, that effort is currently focused at the district/MA level due to the precision of the data being used. Parcel-level alloca not at this time being done in the subbasin. It is premature to consider a basin-wide water market, as the data available does not allow for that level of allocation to be done. Fo consideration in the 2020 plan submittal, we do not have adequate time or resources for the development of such a framework.
Westchester Group Investment Mgmt		"WGIM supports use of efficient and accurate systems to determine groundwater use. GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration. These methodologies should be developed in consultation with the vendor providing ET data to ensure it is applicable and useful in creating the best available data set. Additionally, GSAs and/or MAs should establish criteria and procedures to address apparent inaccuracies in the ET calculations. An obvious use of the procedure would be in instances where the grower can demonstrate that applied water, plus precipitation, is less than the calculated ET. In these instances, and subject to any requirements established by the GSA, the grower's use of groundwater should be reduced to the applied water total as the ET calculation should not be greater than applied water."	This is already included in the Projects and Management Actions section and is part of the larger action of refining data for the calculation of Water Budget components in futur updates.
BDII Investments		"Landowners would like RRID to be able to purchase produced water resources conveyed and/or banked in NKWSD facilities. These volumes appear to be available sources of water in the GSP that could become an integral source of water for acres (sic) within RRID. Landowners would like RRID to improve future water supplies by purchasing flood water or high-flow water from the Kern River when it is available and before that water is offered to areas outside the managed areas within the GSP. Landowners would also like to see RRID purchase surplus water from NKWSD when available to help mitigate the deficit in RRID before these surplus supplies are sold outside the GSP management area. Landowners believe that RRID should continue to improve conveyance and turnout facilities that could be used to supply lands with excess Kern River flow when its available."	This is already addressed in the RRID-specific projects in Section 5.4 of this plan. These projects are conceptual in nature, but they will be further defined as the district impleme SGMA.
BDII Investments		"Landowners would encourage RRID to participate in groundwater banking and the use of recharge facilities in NKWSD for the benefit of RRID. This will allow RRID to develop a more stable long-term supply and pump groundwater in years when there is little or no access to excess Kern River water. Landowners would encourage RRID to explore potential banking and development of recharge facilities within the RRID service area."	This is already addressed in the RRID-specific projects in Section 5.4 of this plan. These projects are conceptual in nature, but they will be further defined as the district impleme SGMA.

Commentor	Ref #	Comment	Response
City of Shafter		"The City's specific comments, concerns, and suggestions have been made to ensure that the description of the City's water system and demond are accurate."	These items were addressed through discussions with the cities and accounted for in the Water Budget: Urban Demand sections of the plan.
City of Shafter		"The City's specific comments, concerns, and suggestions have been made to ensure that [...] the City's beneficial uses are recognized and protected and that the plan does not inadvertently include language that could be misinterpreted to adversely affect the City's water rights or ability to utilize those rights to the benefit of public health and safety."	As described in the plan, SGMA does not alter existing water rights. With input from the cities (through their MOU with the Districts), this comment has been further addressed final draft of the plan.
City of Shafter		"Two critical pieces that the plan should ultimately address are minimum thresholds and measurable objectives set for specific water quality constituents to ensure that water quality does not degrade beyond current conditions."	As discussed in the existing conditions portion of the Basin Setting and the discussions in Section 3 which pertain to water quality, the Sustainable Management Criteria for groundwater levels are being used as a proxy for water quality at this time, in addition to continued monitoring of the constituents of concern coincidental with the monitoring groundwater levels and cooperation and compliance with existing water quality programs.
Leadership Council		"The Draft GSP is incomplete and must include additional information for the public to evaluate the GSP. The Draft GSP omits critical data regarding the consideration of drinking water impacts on disadvantaged communities and protected groups, sustainable management criteria that consider all beneficial users, and projects and management actions that address significant and unreasonable impacts to beneficial users."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with the statement, as the information that Leadership Council claims is missir the GSP is actually included in the management area plans, as appropriate to each respective management area.
Leadership Council		"The KGA is responsible for the disproportionate and disparate impacts that its policies and activities will have on disadvantaged communities belonging to protected groups."	This comment is directed to the KGA GSP and will be addressed by KGA. While the KGA is the GSA entity submitting the plan on behalf of its members, the JPA forming the KGA that each member is responsible for the implementation of SGMA within their respective plan areas. The KGA GSP and its management area plans were developed in considerat all beneficial uses of water and the beneficial users of the groundwater in the subbasin.
Leadership Council		"The Coordination Agreement does not "explain how the plans, implemented together, satisfy the requirements of the Act."	This comment is directed to the KGA GSP and will be addressed by KGA.
Leadership Council		"The GSP was not crafted in a way that adequately considered the input of disadvantaged communities, either at the GSA level or the member agency level."	This comment is directed to the KGA GSP and will be addressed by KGA, pertaining to the KGA level engagement. With respect to the member level engagement, SGMA leaves t manner and frequency of public outreach and engagement to the discretion of the GSA. As described in the introduction of the management area plan, both NKWSD and SWID monthly publicly-noticed meetings which serve as an opportunity for members of the public to provide feedback to the districts regarding the plan's development and implementation. Furthermore, the districts were active participants in the KGA-level outreach activities as well as hosts of their own workshops, which were publicly-noticed, a coordination with the cities of Shafter and Wasco and with Oildale Mutual Water Co on the development of the plan.
Leadership Council		"The Kern Subbasin Undesirable Results do not comply with existing law."	The definitions for undesirable results were developed in coordination with the other GSAs and take into consideration "significant and unreasonable" impacts to the groundwa which affect all beneficial users. Such beneficial uses include agriculture, domestic, and municipal & industrial.
Leadership Council		"It is not clear what the impacts from reaching this undesirable result will be on beneficial users, and instead seems to be an arbitrary determination of what is "significant and unreasonable."	The impact analysis performed by the GSAs in the subbasin contributed to the development of the undesirable results for declining groundwater level.
Leadership Council		"Like the proposed definition of undesirable results for groundwater levels, the proposed definition of undesirable results for degraded water quality are 'when the minimum threshold for when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area)."	The comment letter cites an incorrect definition. The definition for the undesirable result for water quality is "when the minimum threshold for a groundwater quality constitue concern is exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the designated monitoring points within Subbasin."
Leadership Council		"The GSP's minimum thresholds and measurable objectives were not established in a way that considered the interests of beneficial users including domestic well owners and disadvantaged communities."	The KGA GSP outlines the methods used by its members to establish the Sustainable Management Criteria (SMCs) within their respective plan areas. For the NKWSD-SWID management plan area, projected groundwater levels based on recent historical hydrology were used to analyze the impact to known agricultural, domestic, and municipal wel While impacts were identified at the minimum thresholds in some management areas, these impacts were determined to not meet the definition of "significant and unreasonat
Leadership Council		"As in the case of groundwater levels, it is clear that the GSA has not considered the potential impact on drinking water users, in particular disadvantaged communities who are less able to afford solutions to treat contaminated drinking water."	As with the groundwater level SMCs, the KGA GSP outlines the methods used by its members to establish the Sustainable Management Criteria (SMCs) within their respective p areas. Based on the analysis in the Basin Setting subsection on existing water quality conditions, it was determined appropriate to use groundwater levels as a proxy for water c in addition to water quality and water level measurement at the representative monitoring sites will be coincidental.
Leadership Council		"GSAs must monitor impacts to groundwater for drinking water beneficial users,54 including disadvantaged communities on domestic wells, and must avoid disparate impacts on protected groups pursuant to state law. The GSA's monitoring network does not comply with SGMA regulations, and fails to capture drinking water impacts to disadvantaged communities and domestic wells[...] To ensure the monitoring network adequately captures impacts to all beneficial users, the GSA must ensure the following: Ensure the proposed monitoring network contains representative monitoring wells in or near all disadvantaged communities and clusters of domestic wells in the GSA area; Ensure that monitoring wells and representative monitoring wells in or near disadvantaged communities and clusters of domestic wells are able to measure the groundwater levels at the depth at which the drinking water wells are screened; Explicitly describe any future representative monitoring wells and identify the proposed locations. When assessing the monitoring network data gaps, the GSP must prioritize installing new monitoring wells in locations where disadvantaged communities, small water systems, and domestic well users reside."	The coordinated basin-wide monitoring network was developed using the DWR BMP on SGMA Monitoring Networks, which discusses recommended well density and what constitutes a "SGMA compliant" representative monitoring site. It also allows for (and encourages) GSAs to use existing monitoring programs already in place for collecting dat the Sustainability Indicators identified in a basin's plan. Domestic wells are typically shallow or in the first occurence of groundwater and are, therefore, not representative of t groundwater conditions of the basin as a whole. Further, there are existing programs with which domestic wells and community wells must comply. These have been identifiec Basin Setting and Monitoring Network sections in the discussions of existing programs. In areas of the basin where the well density does not meet the standards used in the pla proposed well locations have been identified. Per discussion and comments from the cities of Shafter and Wasco, three additional wells have been added to the monitoring net within the NKWSD-SWID management area.
Leadership Council		The groundwater quality monitoring network does not adequately capture impacts on drinking water users.[...] First, measuring for Arsenic (as in Arvin-Edison WSD) only once a year does not provide the member agency or the GSA with frequent enough information to respond to severe drinking water contamination in a reasonable amount of time. If the member agency's management actions, projects, or decisions to let groundwater decline increase drinking water contamination for families in the management area, the member agency could go a whole year without detecting these impacts. [...] Second, only measuring for compliance with arsenic measurable objectives and minimum thresholds does not protect against increases in other contaminants that exist in other parts of the management area (boron, nitrates, TDS, 123-TCP, iron and manganese). These contaminants could extend, move or increase due to groundwater management activities and pumping patterns. [...] However, avoiding monitoring contaminated areas defeats the purpose of groundwater quality monitoring under SGMA, which is to measure the concentration and spread of contaminant plumes to ensure that groundwater management activities and pumping do not aggravate existing contamination.	The monitoring of water quality for the basin will include the use of data from existing programs (e.g. Title 22, ILRP, CV-SALTS) and sampling coincidental with groundwater leve measurements at the representative monitoring sites. As such, the water quality data collected through SGMA will be more frequent than once a year. The constituents of conc be tested in the water quality sampling at representative monitoring sites vary between the management areas. Therefore, the constituents analyzed will differ according to the management area plan. The selection of representative monitoring sites discouraged the use of wells with existing MCL exceedances because of the nature of the definition of undesirable results for degradation of groundwater quality. The occurence of an increase in concentration for constituents of concern in a representative monitoring site will, b of it being a representative site, will be indicative of the migration of existing contamination.
Leadership Council		The projects and management actions set forth in the Draft GSP do not demonstrate a path towards achieving sustainability goals in the plan, and do not adequately account for the needs of disadvantaged communities pertaining to protected groups under state law. The GSA has allowed member agencies like the Arvin-Edison WSD to use a "glidepath" approach that increases surface water and groundwater recharge before demand reduction measures are implemented. This places the majority of the plan's success on surface water resources, which are variable and may not be able to be procured. The GSA should instead ensure that member agencies implement demand reduction strategies from the beginning so that groundwater levels do not plummet. A critical problem with the structure of the GSA is that member agencies cannot share the cost or responsibility for critical GSA-wide projects. Many more financially powerful agricultural and water banking member agencies could and should be part of a strategy to protect drinking water resources in the GSA area, especially given that they use much larger quantities of groundwater and their continued pumping will likely lead to dry wells and groundwater contamination issues for the most vulnerable homes in the GSA area.	The KGA and its members have the authority under SGMA to prioritize projects and management actions, as they see fit, to demonstrate that the basin can reach sustainability 2040. The prioritization of projects to increase imported supply for use by districts' customers or for water banking projects protects groundwater for beneficial use in the basi facilitiating in-lieu banking (where surface water is used whenever it is available, replacing groundwater pumping) or by maintaining groundwater levels through replenishment banking projects. These projects do not run contrary to the mandate to protect groundwater quality. In fact, with groundwater levels as a proxy Sustainability Indicator for wat quality, these projects achieve both the maintenance of groundwater levels and water quality. The agricultural and water banking agencies in the basin, as the customers payin water deliveries and funding projects via land assessments in their respective districts, can and should be a beneficiary of the projects which they are funding.
Leadership Council		"The KGA GSA should implement or incentivize recharge basins or other recharge activities throughout the subbasin wherever DACs and clusters of domestic wells exist. The GSA should encourage these kinds of recharge projects with health co-benefits over on-farm recharge, which is likely lead to accelerate groundwater contamination."	It is at the discretion of the KGA's member agencies to identify projects to fund, as well as opportunities to collaborate with DACs. SWID, since its founding, has used its import supplies to maintain groundwater levels and water quality to the benefit of the beneficial users within the district, including the cities of Shafter and Wasco and domestic well us NKWSD has also operated in the same manner since its founding as a water storage district. Future projects and management actions which deal specifically with the DACs and domestic wells may be considered for subsequent updates to the GSP and management area plans.
Leadership Council		"For areas vulnerable to declining water levels and loss of production capacity, the KGA GSA should adopt management actions that establish geographical protection areas (buffer zones) by establishing bans, pumping limitations or community-specific management areas around disadvantaged communities and domestic well clusters."	The development of these buffer zones would be predicated on the development of a shallow-zone specific monitoring network and SMCs. As discussed in the response to the Monitoring Network comments, these shallow zones are not representative of groundwater conditions throughout the basin. Furthermore, the framework necessary to imple pumping restrictions or bans does not exist within the KGA or its members. Such policy would not be developed or implemented in time for the 2020 submittal.

Commentor	Ref #	Comment	Response
Leadership Council		"We also strongly recommend against a groundwater market in the KGA GSA area. The GSP includes potential groundwater market and trading programs. Groundwater markets raise concerns from the perspective of domestic well users and disadvantaged communities."	At this time, the framework to establish a groundwater market in the basin does not exist. The policies and framework that would need to be developed by the KGA and its mer is too complex to be completed in time for consideration in the 2020 submittal. Additionally, any groundwater market developed by the KGA or its members would have to com with SGMA (i.e. prevent localized impacts to the Sustainability Indicators in its implementation).
Leadership Council		"The GSAs should implement and incentivize multi-benefit projects such as wetlands restoration or stormwater drainage ponds that would eliminate flooding and increase groundwater recharge in disadvantaged communities."	It is at the discretion of the KGA's member agencies to identify projects to fund. Future projects and management actions which provide benefits beyond SGMA may be conside subsequent updates to the GSP and management area plans.
Leadership Council		"Although there are multiple short-term funding sources to leverage for SGMA-related projects, the GSA's and member agencies' operating budgets must be a reliable source of funding over the long-term of GSP implementation, and the GSA and member agencies cannot rely on grant funding for long-term projects and programs that benefit disadvantaged communities. The GSA and member agencies must be responsible for addressing the drinking water issues caused by their policy decisions and activities."	It is entirely appropriate that the KGA's members, when working in collaboration with DACs on a project to benefit groundwater quantity and quality in the basin, seek funding such projects through state and federal grant funding programs. Grant funding, where the districts are eligible, is applied for to defray the cost of projects (which often far exce award amount). The remaining costs of projects and management actions are to be funded with the districts' operating budgets or through special assessments.
Leadership Council		"the Draft GSP allows continued overdraft above the safe yield of the basin, such that drinking water wells (especially domestic wells) will continue to go dry, infringing on the rights of overlying users of groundwater. The GSP must be revised to protect the rights of residents of disadvantaged communities and/or low-income households who hold water rights to groundwater."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with the statement, as the KGA GSP and its included management area plans h demonstrated, the combination of projects, management actions, and established SMCs will bring the basin into balance with its groundwater management by 2040.
Leadership Council		"The reasonable and beneficial use doctrine applies here given the negative impacts of the Draft GSP on groundwater supply and quality, which are likely to unreasonably interfere with the use of groundwater for drinking water and other domestic uses. As the Draft GSP authorizes waste and unreasonable use, it conflicts with the reasonable and beneficial use doctrine and the California Constitution."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with Leadership Council's statement regarding the plan's authorization of "wa and unreasonable use". The beneficial uses of water in the basin include other uses beyond domestic consumption. As such, it is entirely appropriate and in the authority of the that impacts to groundwater be analyzed in consideration of all beneficial uses identified in the plan.
Leadership Council		"The "public trust" doctrine has recently been applied to groundwater where there is a hydrological connection between the groundwater and a navigable surface water body. In Environmental Law Foundation , the court held that the public trust doctrine applies to "the extraction of groundwater that adversely impacts a navigable waterway" and that the government has an affirmative duty to take the public trust into account in the planning and allocation of water resources. The court also specifically held that SGMA does not supplant the requirements of the common law public trust doctrine. In contrast to these requirements, the Draft GSP does not consider impacts on public trust resources, or attempt to avoid insofar as feasible harm to the public's interest in those resources."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with Leadership Council's position in that the Basin Setting of the KGA GSP an management area plans have adequately demonstrated that there are no interconnected surface waters in the basin and that this is the existing condition of the basin.
Rosedale-Rio Bravo Water Storage District Received Comments			
Wonderful Orchards	WO-1	It is imperative that the final GSP properly address the quantification of native yield. The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource.	See KGA WO-1 Response
Wonderful Orchards	WO-2	In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield.	See KGA WO-2 Response
Wonderful Orchards	WO-3	In addition, GSAs should initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations of native yield that are coordinated across the subbasin.	See KGA WO-1 Response
Wonderful Orchards	WO-4	Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next.	See KGA WO-1 Response
Wonderful Orchards	WO-5	GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity	See KGA WO-1 Response
Wonderful Orchards	WO-6	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	See KGA WO-1 Response
Wonderful Orchards	WO-7	GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater.	See KGA WO-1 Response
Semitropic Water Storage District Received Comments			
Central Valley Joint Venture	CV1	We hope future proposed allocations and management actions in Semitropic weigh the value of wetlands as beneficial users of groundwater and support their continued existence.	Agree that managed wetlands have value, and there is nothing in the GSP to the contrary. Will weigh the value and reasonable water needs of managed wetla relation to other beneficial uses of groundwater in preparing future water budgets.
California Waterfowl	CW1	The ET water budgets in the GSP are inadequate for continued operation of the managed wetlands. Without an affordable replacement water supply , the water budgets would lead to the complete eradication of managed wetlands in the Semitropic Water Storage District in 20 years.	Agree that managed wetlands have value, and there is nothing in the GSP to the contrary. Will weigh the value and reasonable water needs of managed wetl in relation to other beneficial uses of groundwater in preparing future water budgets.
California Waterfowl	CW2	… recommends that ET allocations for managed wetlands be set on par with agricultural and other users atr 4.2 acre-feet for five years or until a sufficient data on ET rates for managed wetlands becomes available.	Acknowledge the data gap with respect to ET of managed wetlands. Will be including a MA for the continued refinement of ET on managed wetlands. Will a the initial water budget for managed wetlands to 4.2 acre-feet with the approriate ramp-down over the implementation period
California Waterfowl	CW3	Unless a surface water supply can be found to make up the difference between the proposed groundwater budget for managed wetlands, the water budget should be increased to a minimum of 4.2 acre-feet per acre. The cost of surface water should not exceed the cost of pumping groundwater …	Will adjust the initial water budget for managed wetlands to 4.2 acre-feet with the appropriate ramp-down over the implementation period.
California Waterfowl	CW4	How can a surface water supply be provided? … allow flood flows in the Tulare Lake Basin to be used on managed wetlands. … provide access to State Water Project supplies to augment groundwater pumping.	Will consider joint projects for development of Poso Creek flood flows. Will consider access to SWP conveyance capacity for supplemental water supplies, including but not limited to water transfers. These will be included and considered in the development of individual projects and management actions.
California Waterfowl	CW5	The total number of acres in managed wetlands …is very small in comparison to the number of acres in trees and other crops. An increase in the water budget will have a small effect on the groundwater available to agriculture.	All lands will be treated equally with respect to access to native yield and proportionate participation in District programs.
Rancho Visalia	RV1	**The Et Estimates Are Seriously Flawed** The first and most obvious conclusion from the above is that the Et estimates for Rancho Visalia are nowhere near accurate, both as to its undeveloped land and its flooded wetland ponds. This may be because the methodology used to determine the Et works well for agricultural land but does not work for natural, undeveloped land, wetlands or ponds. This is not surprising given that ag land loses water through the much higher Et rates associated with growing and exporting crops whereas duck clubs are composed of only natural, undeveloped land or flooded ponds/wetlands.	ET for undeveloped land is assumed to equal precipitation and therefore there is no net demand for undeveloped properties. Acknowledge the data gap with respect to ET of managed wetlands and duck clubs. Will be including a MA for the continued refinement of ET on managed wetlands. ET is a measurement of consumptive use, not applied water.

Commentor	Ref #	Comment	Response
Rancho Visalia	RV2	**Restricted Water Budgets for Duck Clubs Will Cause Significant and Irreversible Environmental Harm** Imposing duck club water budgets of 1.5 af/ac/yr, as is proposed for the year 2020 in the draft Groundwater Sustainability Plan, will severely impede those clubs' ability to maintain year -round or even seasonal wetlands. Allowing the clubs to only extract .5 af/ac/yr, or worse, just the .15 af/ac/yr Native Yield, when the proposed GSP is fully implemented in 2040, will all but eliminate those wetlands, even for clubs such as Rancho Visalia which only floods about one sixth of its Special GPSC land.	We acknowledge the values of managed wetlands and duck clubs, but are required under SGMA to sustainabily manage the Subbasin without altering the wa rights of landowners. Accordingly, all lands are being treated equally with initial allocation of available native yield in the Subbasin.
Rancho Visalia	RV3	**Any Over-Extraction by Duck Clubs Would Be Insignificant** ….duck club wetlands make up just 2 percent of the 140,000 acres of irrigated land and 1.3 percent of the total acreage within the SWSD. If duck clubs were allowed to extract the 3.5 af/ac/yr necessary to adequately flood their 2,800 acres of ponds, this would total just 9,800 af/yr. This is just .08 percent of the 123,900 af/yr reduction in groundwater pumping required under SGMA. In short, allowing the clubs to extract sufficient water to maintain their wetlands would have no measurable impact on the groundwater levels yet would avoid most of the environmental harm.	It is the expectation that a finite native yield will be developed for the entire Subbasin and that will be allocated among all lands equally. Providing some lanc higher native yields will require a reduction in the native yield allocated to other lands. Moreover, SGMA defines groundwater sustainablity in terms of the avoidance of six (6) defined undesirable results. Allocations of native yield are merely one tool (among many) to achieve sustainability within statutorily-man timeframes.
Rancho Visalia	RV4	**The finalized GSP Should Allow Duck Clubs to Extract Sufficient Groundwater to Sustain Year-round Wetlands on a Perpetual Basis.** **…** allowing duck clubs to extract sufficient water to adequately maintain their ponds would cause virtually no measurable groundwater reduction yet would avoid most of the environmental damage. For these reasons, the example duck club Water Budget should be modified so as to allow clubs to extract 3.5 af/ac/yr for their wetlands.	See Response to Comment RV2. The GSP is predicated on tracking consumptive use (ET), not applied water.
Larry Frey	LF1	Objection to the proposed District plan to not allow a farmer to carry-over from year to year, or a number of years, on a one-to-one basis without a fee the Incremental Pumping allowance portion of his yearly water right.	Comment to be considered through the development process of the Landowner Budgets Management Action.
Fresno Irrigation District	FID1	The project ("Tulare Lake") is fundamentally flawed, as Semitropic has not established that it has the right to export Kings River water to Kern County as the project requires.	The ultimate yield of the Tulare Lake Project will be determined pursuant to the water right proceeding now being conducted by the State Water Resources C Board. Any water supply developed through the implementation of any of the projects identified in Table 5-1 will reduce the District's obligation to retire properties as identified in the third management action.
Kings River Water Association	KR1	The project ("Tulare Lake") is fundamentally flawed, as Semitropic has not established that I has the right to export Kings River water to Kern County as the project requires.	The ultimate yield of the Tulare Lake Project will be determined pursuant to the water right proceeding now being conducted by the State Water Resources C Board. Any water supply developed through the implementation of any of the projects identified in Table 5-1 will reduce the District's obligation to retire properties as identified in the third management action.
North Kings Groundwater Sustainability Agency	NK1	The project ("Tulare Lake") is fundamentally flawed, as Semitropic has not established that I has the right to export Kings River water to Kern County as the project requires.	The ultimate yield of the Tulare Lake Project will be determined pursuant to the water right proceeding now being conducted by the State Water Resources C Board. Any water supply developed through the implementation of any of the projects identified in Table 5-1 will reduce the District's obligation to retire properties as identified in the third management action.
Hancock Farmland Services	HF1	The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water, for example xxx,xxx acre-feet and not associated with a given gross or net area.	Agree that references to native yield are for initial water budget purposes only, are not precedent-setting, and are not a determination of the water rights of individual landowners or other water users.
Hancock Farmland Services	HF2	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	Agree that existing groundwater banking projects and banking inventory should be protected in accordance with contractual requirements and that incentive additional recharge and banking projects should be developed.
Hancock Farmland Services	HF3	GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration.	Agree, Landowner information is important for validating the Et Measurements.
Westchester	W1	The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water, for example xxx,xxx acre-feet and not associated with a given gross or net area.	Agree that references to native yield are for initial water budget purposes only, are not precedent-setting, and are not a determination of the water rights of individual landowners or other water users.
Westchester	W2	… GSAs and MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible without creating undesirable results, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity.	To the extent pumping restrictions are adopted in the future, they will be implemented in accordance with SGMA (including but not limited to the requiremer water rights not be altered) and best available science.
Westchester	W3	As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated and consistent across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled).	To the extent pumping restrictions are adopted in the future, they will be implemented in accordance with SGMA (including but not limited to the requiremer water rights not be altered) and best available science.
Westchester	W4	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	Same as Hancock HF2
Westchester	W5	GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater.	Agree, this is contemplated as an item for coordination relative to all GSA's within the basin

Commentor	Ref #	Comment	Response
Westchester	W6	GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration.	Same as Hancock HF3
Wonderful Orchards	WO1	It is imperative that the final GSP properly address the quantification of native yield. The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource.	The KGA has identified the "Study of Native Yield for the Kern Subbasin" as a management action that will include all GSAs in the Subbasin. This Management Action will work to develop a common and agreed to native yield value for the entire Subbasin and appropriate methodology for allocation of the native yield accordance with SGMA.
Wonderful Orchards	WO2	In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield. Currently, the GSP references native yield in terms of acre-feet per gross acre for water budget purposes. .... If referencing native yield this way is necessary, the GSP should clarify that it is for initial water budget purposes ONLY, is non-precedent setting, and is not a determination of individual landowner allocations or groundwater rights	Clarification regarding planning level water budget and native yield analysis can be added to the GSP. Agree that references to native yield are for initial wate budget purposes only, are not precedent-setting, and are not a determination of the water rights of individual landowners or other water users.
Wonderful Orchards	WO3	Alternatively, in the 2020 plans subbasin native yield could be described as a total volume of water and not associated with a given gross acreage.	Agree with respect to GSA or Management Area; however, utilization of native yield at the landowner level requires an allocation. The initial policy direction allocate native yield equally to all acres within the Subbasin.
Wonderful Orchards	WO4	In addition, GSAs should initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations of native yield that are coordinated across the subbasin.	Opportunities for stakeholder input will be provided during the planning and implementation of the Landowner Water Budget Management Action in early 2(
Wonderful Orchards	WO5	An equal-per-gross acre approach to allocations is not likely to be consistent with established water rights doctrine, which must recognize many equitable considerations in addition to acreage owned, to determine a legally defensible allocation.	To the extent pumping restrictions are adopted in the future, they will be implemented in accordance with SGMA (including but not limited to the requiremer water rights not be altered) and best available science. The comment is unclear regarding what is meant by "equitable considerations."
Wonderful Orchards	WO6	Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next.	Water markets will be considered as potential future management actions.
Wonderful Orchards	WO7	GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity. ... As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled)	Same as Westchester W2 Agreed - is reflected in the development of the IPA and gradual reduction of IPA to 0 by 2040 With regard to ramp-down schedules, not all lands are equal with respect to surface water supplies; therefore the sustainable yield for each property will vary across the Subbasin and accordingly the ramp-down schedules will vary.
Wonderful Orchards	WO8	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	Same as Hancock HF2 Agree and will continue to consider through implementation of projects and management action.
Wonderful Orchards	WO9	GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions.	Same as Westchester W5 1) Agree - however the level of detail (district vs landowner) many vary and will need to be discussed further. 2) Market interface will be considered as markets develop. Should not be limited to just groundwater.
Wonderful Orchards	WO10	GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	Agree - all data needs to be verifiable and defensible at the District and landowner level.
Major Dhillon	MD1	The SGMA draft report(hereinafter as "Report") completely favors the farmers who are getting State water or contracting for surface water. They have access to surface and as well as to the well water, whereas land owners who have no access to surface water are at big disadvantage especially with the new allocation that Semitropic is using	See Section 5.2.3 for clarification. Additonal clarification to be provided in additional information developed through implementation of the Landowner Wate Budget Management Action in early 2020.
Major Dhillon	MD2	The Semitropic water Storage District(hereinafter as "District") did not give any opportunity to land owners if they wish to participate in a program called "Developed land" where a landowner can also pay the water assessment of $137 + per acre. We the land owners who were not provided the opportunity to participate in the Developed land definition MUST BE PROVIDED AN OPPORTUNITY TO PARTICIPATE IF THEY WISH	Disagree - See Prop 218 for New Lands Surcharge
Major Dhillon	MD3	The District has given no consideration to properties which are enrolled in Williamson Act.	Under California law, lands enrolled in the Williamson Act are not exempt from the requirements of SGMA.
Maricopa Orchards	MO1	**Section 2.7.2** 1) Can properties not currently in the in-lieu program enroll? 2) What if growers pay for infrastructure to be part of the program? 3) I don't understand the terminology in the section labeled "Construct additional irrigation distribution systems". What does absorptive capacity and related priorities mean? 4) Water in storage by banking partners may help the groundwater levels generally but any of it can be called upon so should this be recognized? 5) How will the landowner pumping agreement be affected by SGMA? 6) Where is the surface water storage capacity located? 7) On Third Party Banking, how will SGMA affect the in-lieu banking program?	1) yes 2) will be considered 3) one on one discussion for clarification 4) Banked water is not water supply of the District, with the exception of the 10% leave behind. 5) no impact to a landowners Groundwater Pumping Agreement is expected relative to recovery of banked water via the agreement on behalf of the district f bankers. There could be an impact with respect to a landowners ability to wheel water due to compliance with the SGMA Sustainability Indicators 6) Temp storage at Goose Lake under agreement with Goose Lake Holding Co. and surcharge spresding facilities at Scofield. 7) Do not foresee an impact relatative to an existing bankers first priority recharge rights.
Maricopa Orchards	MO2	**Section 3.3.1.1** Does this mean that upper zone pumping is unlimited for now and will just be monitored? How does this effect the Agua Via/WAP projects? There needs to be clear contract language re the assumption of risk for the service providers.	No - This is a data gap. MT and MO for the upper aquifer will be developed in the future

Commentor	Ref #	Comment	Response
Maricopa Orchards	MO3	**Section 3.3.2 and 3.3.3** Seem not to address the issues for MOs/MTs -for example, doesn't SWSD need to monitor subsidence and, if below a specified level, then would require a management action?	The KGA and the District have identified the understanding of subsidence as a data gap and have committed to maintaing existing monitoring sites and establ additonal sites to better understand the specific causes of subsidence in the subbasin. With this information we will establish MO & MT in the District.
Maricopa Orchards	MO4	**General, Water Budget** Allow Growers to determine their order of use. However, with the knowledge that you cannot roll over native yield. Allow Growers to decide if they want to manage their allocation year to year or if they want to opt into the average -How can SWSD guarantee the then current average SWP? Isn't that taking water from the basin to incrementally benefit SWP contract holders? What if contract holders want to bank their surplus water on their own account (either through the SWRU or via the new recharge program?) (Section 5.2.3.2) When will landowners be expected to start using the water budget? 2020 or 2021?	Good input - will consider when developing Landowner Water Budgets
Maricopa Orchards	MO5	**General** The GSP punts to a later 5-year update in many instances. This could be a red flag for DWR. Banking partners should be able to use or sell their banked water in SWSD to growers who have deficits without having to recover from SWSD wells. Query whether there should be a discount to the recovery charge per AF?	Noted
Maricopa Orchards	MO6	**General, Subsidence at the Aqueduct** Additional monitoring should be completed due to subsidence may not be directly linked to Semitropic.	Agree
Maricopa Orchards	MO7	**General, Expiration of Credits on Recharge** Semitropic should not have expiration dates or increasing leave behind factors on water stored via recharge or credit carryover. It will encourage pumping in an effort not to lose stored water.	Good input - will consider when developing Landowner Water Budgets
Maricopa Orchards	MO8	**5.2.3.2, Incremental Pumping Allowance** 1) We are pleased with this glide path approach. This gives growers the opportunity to plan and reach sustainability by 2040. 2) What if the IPA results in undesirable results? 3)Doesn't a larger IPA for non-contract growers reward those that have been benefitting from the overdraft?	1) Comment noted. 2) If IPA results in undesirable results it will require adaptive management. 3) Potentially in the short term, but IPA is reduced to zero by 2040.
Maricopa Orchards	MO9	**Chapter 5** 1) Potentially add ASR as a project that growers/district can use as a tool for recharge. 2) Why is brackish water desalination limited to only 1,800 AF? 3) For Poso Creek MAR, would SWSD allow growers to take flood water and recharge in their own facilities? 4) For SWRU, what type of storage is referenced? 5) Will the pilot program for private recharge continue?	1) Considered as enhanced recharged 2) place holder for proposed project 3) Potentially 4) Primarily in-leu groundwater storage 5) likely yes
Maricopa Orchards	MO10	**Table 5-1** Various spelling errors.	Noted
Maricopa Orchards	MO11	**General, Landowner Classifications** Let landowners that have parcels that are paying a portion of the GPSC to opt in to pay the entirety.	Not at this time
Maricopa Orchards	MO12	**General, Water Markets** Allow basin-wide market and do coordination agreement with neighboring districts (regional).	Will be considered in the future as water market develop within and between districts in the Subbasin. Consideration will need to be given to location of groundwater extractions to avoid concentration of withdrawal and the potential for undesirable results
Maricopa Orchards	MO13	**Kings River Water/ State Water Project** 1) Has any assumption been made regarding there being less Kings River flood water? 2) Has any assumption been made regarding there being less SWP due to projections of long-term allocations being lowered given climate change and expected biological opinion limitations?	1) Planning level estimate. Project yield would reduce obligation to retire lands within the District (MA 3) 2) Currently using DWR provided delivery estimates for 2030 and 2070
Audobon	A1	The proposed consumptive use allocation for duck clubs will result in severe near-term and long-term declines in wetlands in the Semitropic GSA.	Currently, not enough data to make this determination. Additional analysis on consumptive use (ET) and fate of pumped groundwater is required.
Audobon	A2	The evapotranspiration (ET) of flooded wetlands and native uplands is currently poorly understood by Semitropic GSA and should be identified as a data gap. The Incremental Pumping Allowance for wetlands should be set to give an initial ET allocation of 4.2 acre-feet per acre, on par with other irrigated lands, while the ET data gap is addressed in the first five years of the GSP implementation.	Will Modify initial IPA for wetlands to allow up to 4.2AF/Ac of consumptive use Address ET data gap in ongoing ET refinement efforts as an MA
Audobon	A3	Recharge from imported surface water to Kern National Wildlife Refuge should be reflected in proposed water budgets for managed habitat. State and federal lands should be allocated native supply and Semitropic GSA should work with federal and state agencies to develop an appropriate trading system to support habitat *(accounting for recharge from Refuge water supplies)*	Clarification / refinements to the Landowner Water Budget Management Action will be considered as part of the process of approving the same for implemen
Audobon	A4	P. i: Executive Summary, paragraph 2. The beneficial users of water in the Tulare Lake Region are described as "agricultural; municipal and domestic; industrial; and environmental." In the proceeding sentence the environmental users are not included as being supported by groundwater. However groundwater in this region supports managed wetlands that are important migratory bird habitat, provide recreational opportunities, and contribute to the economic viability of local communities.	Agree to change the identified sentence to include managed wetlands
Audobon	A5	P 4. 1.4.1 Plan Area Setting. It is unclear if the "146,000 acres of irrigated lands" includes managed habitat and wetlands. Please clarify if managed wetlands, i.e. 'duck clubs', are included as irrigated lands	Comment noted - numbers ajusted in text
Audobon	A6	Additionally, clarification on how riparian versus native vegetation was classified is absent and would be helpful to understand why the "native vegetation" directly surrounding the Kern River Channel is not "riparian vegetation	Will provide clarification based on sources. I believe this data came from DWR and its their classification system.
Audobon	A7	In Figure 1-2 approximately 1/3 of the area is identified as riparian and native vegetation. This should be noted in the description of land use in this section because of its significance.	Change made to the text to say "Land use within SWSD consists mainly of agricultural production and environmental land uses, as shown in Figure 1-2."
Audobon	A8	1-3 does not show any of the native and riparian vegetation areas from Figure 1-2, many of which are known to be GDEs, as identified by the DWR's Natural Communities Commonly Associated with Groundwater dataset (https://gis.water.ca.gov/app/NCDatasetViewer/) and the Nature Conservancy's GDE Pulse tool (https://gde.codefornature.org/#/home).	Figures have been update to properly reflect areas of the District that are groundwter dependent. No requirement to overlay habitats on that map.
Audobon	A9	P 8. L. Impacts on Groundwater Dependent Ecosystems. Within SWSD there are significant and important habitat areas supported by supplemental water and these managed wetlands heavily rely on pumped groundwater or applied surface water.	Our statement currently is: "There is the potential for Groundwater Dependent Ecosystems (GDE) in the western portion of the District and along Poso Creek. However, the presence of GDE's has not been verified. Section 2.3 of this GSP provides an overview of the available information regarding GDEs in the District. GDEs are not the same as managed wetlands.

Commentor	Ref #	Comment	Response
Audobon	A10	P 9. 1.5.2 Beneficial Uses and Users. DWR Bulletin 118 identifies beneficial uses and users that include the environment. Under the list for "Users of groundwater", "landowners" should include managed habitat and duck clubs, especially since "duck clubs" are identified under section 5.2.3.1 as a unique "Landowner Class" and an example water budget was created for duck clubs in see Figure 5.3.	The change has been made to the text: As required by Section 354.10(a) of the GSP emergency regulations, beneficial use and users in the District's portion of the Subbasin have been identified. The beneficial uses of groundwater in the Plan Area, consistent with the uses identified in DWR Bulletin 118, are: •Agricultural •Municipal and Industrial •Domestic •Environmental Users of groundwater have been identified as landowners, agricultural operations (including farms, dairies, and food processors), rural residents, managed wet and unincorporated
Audobon	A11	P 45. 2.2.7.2 Direct Recharge. It should be noted that percolation not only occurs from "applied water that passes below the crop roots zones, and unlined canals," but may also occur on managed wetlands within the SWSD service area. Managing wetlands to be multiple benefit may provide an opportunity to increase acreage of managed recharge in this region. Direct recharge on managed wetlands should be treated consistent with direct recharge on irrigated agricultural lands.	Noted change was made to the text.
Audobon	A12	P 46. 2.2.9 Sources and Point Delivery for Imported Water Supplies. It should be noted that the Kern National Wildlife Refuge receives water from the State Water Project through agreements with the Bureau of Reclamation, the State, and via conveyance agreements with Buena Vista Water Storage District. As pointed out in 2.2.8 Surface Water Bodies, the Kern National Wildlife Refuge relies on these deliveries of surface water, though these water supplies are becoming less reliable. These surface deliveries have benefited the SWSD management area by providing the use of surface water in-lieu of local groundwater resources, and creating a source for groundwater recharge from the delivered surface water.	Acknowledge that this supply was not accounted for, but neither was the demand or conveyance losses for delivery of Refuge water.
Audobon	A13	P 58. Table 2-4. Land Uses Within SWSD. Duck clubs and overall managed habitat should be a separate land use in this table. It is not clear where the acres for Kern National Wildlife Refuge or the various private duck clubs are represented in this table. This land use, managed habitat, has an applied water demand similar to agriculture and should be included in current and projected water budgets.	Table was removed from text. Numbers inconsistent with other figures
Audobon	A14	P 77. 2.3.7 Interconnected Surface Water Systems. In this section it states that "In order to sustain the managed wetlands in the study area, imported surface water is needed," suggesting that these habitats rely solely on surface water. This is correct for some managed wetlands, such as those found at Kern National Wildlife Refuge. Most private wetlands, operated as duck hunting clubs, pump groundwater to support managed habitat and may access surface water at times. Furthermore, in the proceeding section, 2.3.8 Potential Groundwater Dependent Ecosystems, it describes areas with GDEs being associated with "managed wetlands and riparian areas" that are supported by a "combination of groundwater and imported surface water." These two sections contradict one another and consistency is needed.	Text as been changed as follows: Interconnected surface water systems are surface waters that are hydraulically connected by a continuous saturated zone to an underlying aquifer (DWR, 201 There are no known natural interconnected surface water systems in the study area. ~~The majority of surface water bodies in the study area, such as Jerry Slou Kern River Channel, receive managed surface water deliveries. In order to sustain the managed wetlands in the Semitropic area, imported surface water or pu groundwater is used. For example, the Kern National Wildlife Refuge (KNWR) is now sustained by imported surface water wheeled from the California Aqueduc conveyed by the Goose Lake Canal (USFS, 2005) or from groundwater pumping at the site. Any interconnected surface water systems in the Semitropic area a sustained by managed water deliveries of either Kern River water, imported surface water or local groundwater pumping.~~ The Poso Creek channel is the only channel that experiences natural recharge from the surrounding highlands. However, Poso Creek is ephemeral and only flo during limited wet periods.
Audobon	A15	P 82. Land Use Data. Though Kern National Wildlife Refuge relies solely on surface water, most managed wetlands in SWSD depend solely on groundwater. Some private wetlands do purchase surface water in select years. This distinction should be highlighted in this section.	The section reads as follows. Yellow highlight is suggested addition Land use data surrounding NCCAG vegetation and wetlands indicate actively managed wetlands as well as agricultural land. The agricultural lands may emplo groundwater pumping in dry years; however, it is unknown if pumping occurs in the upper zone. In general, the actively managed wetlands are reliant on a combination of surface water imports and ~~are therefore not dependent solely on~~ pumped groundwater. For example, the KNWR (Figures 2-48 and 2-49), is sustained by surface water imports.
Audobon	A16	P 82-83. 2.3.8.6 Shallow Groundwater and Land Use Discussion (third paragraph). The identification of sources that contribute to shallow groundwater should be identified. This information will be important to understanding how to maintain critical habitat areas and should be prioritized for monitoring efforts.	We state that "It is unknown if or from which aquifer zone groundwater pumping occurs for adjacent agricultural land."
Audobon	A17	P 93-94. 2.6 Management Areas within SWSD. Duck clubs and the Kern National Wildlife Refuge actively apply water to meet consumptive use needs so therefore should not be considered "undeveloped." These lands should be recognized as developed lands within their respective management areas.	Change to: "Management area 3 includes managed wetlands (private duck clubs), the Kern National Wildlife Refuge, undeveloped native lands." Not sure I see a reason to change the statement.
Audobon	A18	P 97. Increased Direct Recharge Capability. Managed wetlands, including Kern National Wildlife Refuge and duck clubs, can potentially provide a unique opportunity for in-lieu recharge while providing waterbird habitat. It is recommended that this be further evaluated for increasing recharge capacity within the service area.	Noted for future consideration
Audobon	A19	P 98. Implemented Third-Party Water Banking. The imported water for the Kern National Wildlife Refuge could be treated similarly to other lands in this section - as a source of continuous surface delivery in-lieu of groundwater use, and a source of recharge with delivery of the surface water through Goose Lake canal.	The refuge is not currently a third party banker. Not appropriate
Audobon	A20	P 154. Table 4-1. Potential Impacts of Overdraft with Corresponding Monitoring. There should be a unique row for managed habitats, as they will have the same impacts as "Irrigated Agriculture." Managed habitats pump groundwater (and when available rely on SWSD surface water) to meet irrigation and habitat needs.	Table 4-1 - In the User Group identification add: Irrigated Agriculture (including managed habitats)
Audobon	A21	P 156. 4.2.2.6 Consumptive Use. We understand that the District is not confident in the consumptive use estimates for managed habitat areas and would like to work together to improve this data set.	Noted - will include a management action for refinement of ET on managed wetlands
Audobon	A22	P 157. 4.3.3 Rationale for Design (paragraph after bullet points). To improve the understanding of how groundwater pumping can impact managed habitat, monitoring well locations may be available within duck clubs or state and federally managed habitats.	Will consider in future updates to monitoring network. No response in document suggested.
Audobon	A23	P 180. Table 5.1. Rows 4 & 7. As specific projects become further developed, managed habitat areas may offer ideal opportunities for recharge or temporary storage of water during high flow events. Projects that utilize habitat lands may lessen negative impacts to cultivated lands from flooding or intentional recharge. We recommend that the GSA investigate opportunities that can allow habitat areas to function both for habitat and to provide recharge or temporary storage. Additionally, knowing that water for recharge likely comes in large quantities over short timeframes, the existing configurations of managed habitat areas can make for useful retention areas, without risking the flooding on irrigated crops such as trees and vines. Expanding priorities that have added benefit, such as habitat and wildlife value, can also lead to non-target benefits (e.g. water filtration or recreation opportunities) and be accomplished through simple actions. This may open the door to additional funding sources that otherwise would not have been available if these benefits were not part of a project. Audubon is interested in helping the GSA investigate these potential opportunities to develop multi-benefit projects.	This concept is captured in the Tulare Lake project and the Poso Creek MAR project. Comment will be considered as projects are developed. No change to te table as suggested.
Audobon	A24	P 185. 5.2.1 Existing Projects and Management Actions (second bullet point). How will managed habitat lands fit into this program and fee structure given the uncertainties of managed habitat consumptive use? (See above comment related to consumptive use). Clarification here is recommended.	To be determined. We are awaiting additional data from Audubon re consumptive use.

Commentor	Ref #	Comment	Response
Audobon	A25	P 186-187. 5.2.2 Future Projects and Management Actions (bullet #6 and 8). For the management action that "will be developed in a manner which allows for the creation of a 'market' for the transfer of water among District landowners," will this be limited to transfer of Native Yield, or will it also include Incremental Pumping Allowances? Also, please clarify which water supplies this market is intended for. Additionally, what does the management action "equal access to participate proportionate to investment" mean? Managed habitats are a significant benefit to the public resource, are managed to provide critical habitat to migratory birds and other wildlife, and create recreational and economic benefits (i.e. hunting and wildlife viewing) to the community. Please clarify what is the "access" level that may vary by investment?	Water markets will be considered as future management actions.
Audobon	A26	P 189. Incremental Pumping Allowance (IPA). This section states, "The IPA will be established by the District and set such that on average no individual landowner will be short of a water supply at the initiation of the SGMA implementation period." The current estimate of Incremental Pumping Allowance for "duck clubs" is likely insufficient and will make duck clubs "short" at the initiation of the SGMA implementation period. This needs to be addressed to ensure that the duck clubs can continue to provide critical habitat to migratory birds and other wildlife during the transition period of GSP implementation.	Changing IPA to Temprorary Consumptive Use Allowance (TCA)
Audobon	A27	P 192. Special GPSC (Duck Clubs). Details and clarification of how consumptive use amounts were determined for managed habitat is needed. Has the District obtained any data from duck club operators regarding water use per acre? The Incremental Pumping Allowance should be increased to meet the consumptive use needs, similar to the standard GPSC designated lands. Furthermore, for Kern National Wildlife Refuge, the 'banked supplies' should recognize the seepage losses in the Goose Lake Canal that occur from the imported surface water, that is not imported by the SWSD. This is an independent source of surface water imported by the U.S. Bureau of Reclamation and conveyed per agreements with Buena Vista Water Storage District to lands that include a significant portion of Kern National Wildlife Refuge lands within the District. Audubon is interested in working with SWSD to improve information on habitat consumptive use in the management area.	Currently under review.
Dept of Fish and Wildlife	DFW1	The Department recommends continued data collection to reduce uncertainty around shallow groundwater, and concurrently, around the presence of GDEs. Until such time as a GOE can be verified through field work or increased resolution of groundwater mapping reliant on hydrologically robust baselines, the Department recommends including all potential GDEs in the MAP as beneficial users of groundwater	Will include a management action for identification and assesement of GDE and managed habitat water uses and needs. We do identify this as a data gap.
Dept of Fish and Wildlife	DFW2	i. Revise the sustainable management criteria and accompanying narrative by accounting for undesirable results for environmental beneficial users of groundwater. Clarify how species and habitat groundwater needs were considered in the identification of sustainable management criteria. ii. Revise sustainable management criteria to reflect a 'Critically Overdrafted' subbasin designation by seeking to improve current groundwater conditions rather than allowing for continued aquifer depletions over the next two decades.	i) no distinction on landowner use of water ii) NO - Sustainable management critieria developed using concensus position as to what constitutes a significant and undesireable result or worse case scena (not best case)
Dept of Fish and Wildlife	DFW3	The Department recommends that the GSP clarify locations of existing shallow groundwater monitoring wells used to create the shallow groundwater elevation contour map provided within the MAP (Figure 2-27). Additionally, the figure should show overlap potential GDEs with shallow monitoring well locations to vet vegetation groundwater reliance. This figure and associated information would clarify monitoring data gaps and serve as an assessment tool when verifying GDEs.	The District has added a management action to evaluate the presense of GDEs, in order to determine the appropriate level of monitoring required.
Dept of Fish and Wildlife	DFW4	Many of the Duck Clubs in the MAP area are currently supported by the Department's California Waterfowl Habitat Program to ensure the adequate maintenance of habitat critical to wetland-dependent species. Implementation of pumping allowances identified in Figure 5-3 would eliminate all wildlife value associated with these wetlands. To continue to share in the support of this valuable public benefit, the Department recommends that the Semitropic Water Storage District Groundwater Sustainability Agency create additional pumping allowances and/or supplemental water supply opportunities for lands that support wetland habitat. The Department also requests confirmation that all Department-owned lands within Semitropic Water Storage District jurisdiction (see Comment #1) will be granted an equitable native groundwater yield allocation under new Landowner Water Budget management actions (starting page 187)	Semitropic will support the Department in securing additional diversions from the Delta for environmental benefits in Semitropic, with no impacts to Semtrop SWP allocations. All allocations of native groundwater yield will be undertaken in accordance with SGMA, including but not limited to the requirement that v rights not be altered.
Bob Bostick Duck Club	BB1	I support Rancho Visalia's proposal to allow private wetland owners in the Special GPSC to extract 3.5 ac/ft/yr for the acres of land paying the Special GPSC. This would amount to approximately 10,000 ac/ft for the all of the private wetlands in the district and only 0.08 percent of the targeted reduction in groundwater pumping required by SGMA.	The Special GPSC lands have been give a TCA of 4.2 ac-ft per acre.
Bob Bostick Duck Club	BB2	In cooperation with NGOs like CWA and DU, WCB, CA DFW, US Fish and Wildlife, and TBWA develop a written plan and agree to execute the plan to connect all private wetlands to the Pintail Slough water delivery system.	Noted - will be considerd in development of future projects and management actions
Bob Bostick Duck Club	BB3	Agree to support efforts by the private wetland owners to obtain Environmental water to be used only by the wetlands.	Noted - will be considerd in development of future projects and management actions
Clean Water Action	CWA1	Disadvantaged communities are present in the District but are not identified. An ongoing study "Tulare Kern Funding Area Disadvantaged Community Involvement Program" is mentioned but not referenced, nor is there a description of what information is being developed and how it would be used in this plan, particularly since the information won't be available until after the plan is prepared. Instead the plan should use the DWR DAC mapping tool at https://gis.water.ca.gov/app/dacs/ , and identify the program listed above as a refinement of that information that can be used to improve implementation	Noted
Clean Water Action	CWA2	The CA MCLs are cited, however the OEHHA PHG for hexavalent chromium should be used since a standard is unavailable. No other criteria from the RWQCB Plan or Transportation Plan appear to be used.	Noted
Clean Water Action	CWA3	The beneficial uses, including environmental, are listed but no specific groups are mentioned. Kern National Wildlife Refuge (NWR) and Duck Clubs (i.e. private managed wetlands) are identified later in the document, but should be specifically listed as beneficial users of groundwater as Kern NWR uses groundwater for domestic purposes and Duck Clubs use groundwater to provision habitat. There is no mention of involvement in the GSP development by Kern NWR or the Duck Clubs, which is especially important given that this GSP contains one of the largest extents of these environmental beneficial users of all the critical basin GSPs. The Community Portal on the District Website was listed in the GSP as a means of engaging in the development of the GSP, but a more thorough description should be given of actions to engage environmental beneficial users.	Representative from the Kern NWR and private Duck Clubs were notified of all outreach and stakeholder opportunities. Representatives were present at public workshops held District and a GSA Board meetings. Comments were received and responded.

Commentor	Ref #	Comment	Response
Clean Water Action	CWA4	The types and locations of environmental uses, species and habitats supported, and the designated beneficial environmental uses and users of surface waters that may be affected by groundwater extraction in the Subbasin should be specified. The GSP should explicitly identify any environmental uses and users of groundwater in the plan area, and take particular note of the species with protected status. The following are resources that can be used: ● Natural Communities Commonly Associated with Groundwater dataset (NC Dataset): https://gis.water.ca.gov/app/NCDatasetViewer/ ● The list of freshwater species located in the Kern County Subbasin can be found here: https://groundwaterresourcehub.org/sgma-tools/environmental-surface-water-beneficiaries/ ● The California Department of Fish and Wildlife's California Natural Diversity Database (CNDDB): https://www.wildlife.ca.gov/Data/CNDDB ● Land Use Datasets on the Department of Water Resources' SGMA Data Viewer: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer	Noted - will consider in proposed management action to evaluate the presense of GDEs
Clean Water Action	CWA5	The GSP does not include a copy of the SCEP. An SCEP should be included in the GSP as an appendix or attachment.	The District has engaged in stakeholder engagement through out the development of the GSP, as documented in the GSP.
Clean Water Action	CWA6	The GSP should clearly identify how DAC beneficial users were engaged in the GSP planning process, by providing detailed information on the number of meetings held, general levels of attendance, what feedback was provided by community members, etc.	GSP identifies all public meetings. District will include attendance sheets from all meeting in Plan updates.
Clean Water Action	CWA7	The draft GSP states that stakeholders' input was considered during decision making processes, however, it does not describe how the input was incorporated. The GSP should provide detailed description about stakeholder input and responses and how are those were addressed by the decisions.	Noted - comments from all stakeholders where considered during the development process.
Clean Water Action	CWA8	Detailed information regarding the location and depths of domestic wells is currently lacking in the GSP. Domestic well location and construction information are essential for evaluating impacts of proposed MOs/MTs on domestic wells. The GSP should provide the locations and depths of all domestic and public supply wells in the GSA area using the best available information, and present this information on maps along with the proposed SGMA-compliance monitoring network so that the public can evaluate how well the monitoring network addresses these key beneficial users. If no better source is available, DWR has made well construction records available through its Well Completion Report Map application website: https://www.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37	Noted - will consider adding additonal detail on well impact analysis.
Clean Water Action	CWA9	The GSP should provide a more thorough assessment of GDEs, per the discussion provided in Question 2a above. The GSP should provide depth to groundwater contour maps and note the following best practices for doing so: ● Are the wells used for interpolating depth to groundwater sufficiently close (<5km) to NC Dataset polygons to reflect local conditions relevant to ecosystems? ● Are the wells used for interpolating depth to groundwater screened within the surficial unconfined aquifer and capable of measuring the true water table? ● Is depth to groundwater contoured using groundwater elevations at monitoring wells to get groundwater elevation contours across the landscape? This layer can then be subtracted from land surface elevations from a Digital Elevation Model (DEM) to estimate depth-to-groundwater contours across the landscape. This will provide much more accurate contours of depth to groundwater along streams and other land surface depressions where GDEs are commonly found. Depth to groundwater contours developed from depth to groundwater measurements at wells assumes that the land surface is constant, which is a poor assumption to make. It is better to assume that water surface elevations are constant in between wells, and then calculate depth to groundwater using a DEM of the land surface to contour depth to groundwater.	Noted - District is proposing a management action to evaluate the presense of GDEs and appropropriate monitoring requirements, if needed.
Clean Water Action	CWA10	The GSP should also provide maps of the representative monitoring network overlaid with location of DACs, GDEs, and any other sensitive beneficial users. Such maps will allow the reader to evaluate the adequacy of the network to monitor conditions near these beneficial users, and whether or not the GSP is compliant with 23 CCR § 354.34.(b)(2)	Noted
Clean Water Action	CWA11	The GSP should include a discussion regarding the nature and characteristics of the identified GDEs and potential GDEs, and should provide information on the current and historical groundwater conditions near the GDEs and corresponding GDE ecological conditions. The GSP should include an ecological inventory for all potential GDEs that includes vegetation or habitat types and rank the GDEs as having a high, moderate or low value.	Information is provided in the GSP
Clean Water Action	CWA12	The GSP should identify whether any endangered or threatened freshwater species of animals and plants, or areas with critical habitat have been identified in or near any of theGDEs. Note that some organisms rely on uplands and wetlands during different stages of their lifecycle. Resources for this include the list of freshwater species located in the Subbasin that can be found at https://groundwaterresourcehub.org/sgma-tools/environmental-surface-water-beneficiaries/ , the Critical Species Lookbook, and CDFW's CNDDB database.	Noted - District is proposing a management action to evaluate the presense of GDEs and appropropriate monitoring requirements, if needed.
Clean Water Action	CWA13	The GSP should provide data or analysis to document the statement of the absence of interconnected surface water systems within the GSA area. The GSP should also identify data gaps (e.g., lack of shallow or nested/clustered monitoring wells or stream gauges) and either reconcile them or provide a plan to address them as needed to improve identification of ISWs prior to disregarding them in the GSP.	Groundwater elevation data is presented in the GSP
Clean Water Action	CWA14	The GSP uses a superficial manner of addressing water budgets. Water supplies for the current water budget are presented and the water demand is compared as a total. The available water supply from the State Water Project (SWP) is based on DWR's 2017 Delivery Capacity Report. The quantities related to the SWP are adjusted for 2030.	Noted
Clean Water Action	CWA15	The water demand based on land uses and cropping was not adjusted for 2030. The GSP deferred to the analysis in the KGA Umbrella GSP for 2070 and no summary is provided.	
Clean Water Action	CWA16	The GSP should provide a breakdown of ET for all land-cover types, including managed wetlands, and native and riparian vegetation (such as wetlands, riparian vegetation, phreatophytes and other communities). The GSP should identify any data gaps and outline the actions needed to address them and the schedule for their implementation.	Noted - District is proposing a management action to evaluate the presense of GDEs and appropropriate monitoring requirements, if needed.
Clean Water Action	CWA17	The GSP should design management areas and the associated monitoring network to adequately assess and protect against impacts to all beneficial users, including DACs. It is recommended that the GSP discuss what, if any, differential impacts would be anticipated as a result of the separate management of these areas.	Noted
Clean Water Action	CWA18	The GSP should describe the well network to provide methodologies, data and other information to support the investigation and monitoring of the shallow zone, GDEs and ISWs. This modification should include 1) locating new wells that are appropriately screened to detect connectivity of GDEs and ISWs with the shallow zone, particularly in the northwest management area, and 2) identifying or installing stream gages, if possible, in areas where there is potential for ISWs and GDEs. Please expand on the discussion of how the new well and stream data will be used to improve ISW mapping and inform an adequate analysis, and how the data will be used to verify possible GDEs. The GSP should address data gaps (shallow monitoring wells, stream gages, and nested/clustered wells) to improve ISW mapping in future GSPs.	Noted - District is proposing a management action to evaluate the presense of GDEs and appropropriate monitoring requirements, if needed.
Clean Water Action	CWA19	Based on the presented information, domestic well uses are considered under URs and for the development of water level MOs and MTs, but DAC members are not explicitly considered. More detail and specifics regarding DAC members, including those that rely on smaller community drinking water systems, not only domestic wells, is necessary to demonstrate that these beneficial users were adequately considered.	The District has engaged in stakeholder engagement through out the development of the GSP, as documented in the GSP.
Clean Water Action	CWA20	The information about impacts on domestic wells presented in Appendix D is presented as an average depth. The draft GSP should include more detailed information about the potential impacts on sensitive drinking water users, such as 1) where the likely impacted wells are located, 2) what communities are most affected (including DACs), 3) an estimate of the size of the population that relies on these domestic wells, or 4) if the creation of a new or expanded community water system could address some or all of the population affected by the loss of domestic wells.	Noted

Commentor	Ref #	Comment	Response
Clean Water Action	CWA21	Undesirable results are not clearly identified in the plan. Instead an "undesirable results watch area" is created when 51% of identified representative monitoring sites exceed minimum threshold criteria and when multiple such watch areas are identified. However, there is no discussion of how many watch areas would trigger undesirable results, or whether those watch areas would be for the same sustainable management criteria or a mix. This seems to be contrary to the DWR definition of a minimum threshold in CCR § 351(t), which identifies a minimum threshold as "a numeric value for each sustainability indicator used to define undesirable results."	See section 3.2.2 of District GSP and KGA GSP
Clean Water Action	CWA22	The GSP states (page 158): "A minimum threshold for degraded water quality has not been set because historical data used to evaluate groundwater conditions does not indicate lowered water levels, at least at levels observed to date, resulting in degraded water quality. Regardless, groundwater sampling will continue: monitoring sites and parameters were strategically selected to inform on future degradation." The GSP should present a clear and detailed plan for evaluating and monitoring water quality parameters. Specifically, any plan to recharge groundwater must include groundwater quality monitoring, as recharge even with high quality water can mobilize contaminants.	Noted
Clean Water Action	CWA23	The GSP should include GDEs when developing MOs and MTs and whether the MOs and interim milestones will help achieve the sustainability goal as it pertains to environmental beneficial users. The water quality MOs does not consider the water quality needs of GDEs. The GSP should include impacts from degraded water quality on the plant and wildlife communities within GDEs. The GSP should include all potential MOs and MTs impacts on ISWs and GDEs in the analysis.	Noted - District is proposing a management action to evaluate the presense of GDEs and appropropriate monitoring requirements, if needed.
Clean Water Action	CWA24	The GSP should also discuss any potential undesirable results from degradation of water quality that may impact GDEs and freshwater species in the area.	Noted - District is proposing a management action to evaluate the presense of GDEs and appropropriate monitoring requirements, if needed.
Clean Water Action	CWA25	For each potential GDE unit with supporting hydrological datasets, the GSP should include: ● Plot and provide hydrological datasets for each GDE. ● Define the baseline period in the hydrologic data. ● Classify GDE units as having high, moderate, or low susceptibility to changes in groundwater. ● Explore cause-and-effect relationships between groundwater changes and GDEs.	Noted - District is proposing a management action to evaluate the presense of GDEs and appropropriate monitoring requirements, if needed.
Clean Water Action	CWA26	The GSP should include 1) an assessment of the nature of potential undesirable results to ISWs and GDEs; 2) recognition of the existence of potential ISWs and GDEs, unless adequate data can be provided to dismiss them, 3) a statement that the aquifers will be managed such that there will be no depletion of ISWs that results in a significant and unreasonable impact to GDEs; and 4) recognition of any data gaps and specific steps to verify the presence or absence of ISWs and GDEs with monitoring wells screened at the appropriate depths.	Noted - District is proposing a management action to evaluate the presense of GDEs and appropropriate monitoring requirements, if needed.
Clean Water Action	CWA27	We recommend that the sustainability goal explicitly include drinking water and nature because they are important beneficial uses of groundwater.	Noted
Clean Water Action	CWA28	The likely benefits and impacts to DAC members by the proposed projects and management actions are not clearly identified in the GSP. A discussion should be added for each project or management action to clearly identify the benefits to DAC drinking water users and potential impacts to the water supply. For all potential impacts, the project/management action should include a clear plan to monitor for, prevent, and/or mitigate against such impacts.	Noted
Clean Water Action	CWA29	For the projects already identified, describe and assess how ISWs and GDEs will benefit or be protected, or what other environmental benefits will accrue. If ISWs will not be adequately protected by those listed, include and describe additional management actions and projects targeted for protecting ISWs.	Noted - District is proposing a management action to evaluate the presense of GDEs and appropropriate monitoring requirements, if needed.
Clean Water Action	CWA30	For projects that construct recharge ponds, the GSP should consider identifying if there is habitat value incorporated into the design and how the recharge ponds can be managed as multiple-benefit projects to benefit environmental users. The GSP should include environmental benefits and multiple benefits as criteria for assessing project priorities. For examples of case studies on how to incorporate environmental benefits into groundwater projects, visit TNC's website: https://groundwaterresourcehub.org/case-studies/recharge-case-studies/	Noted
Pat MarchBanks	PM1	In conclusion, I encourage the District to Amend the draft SGMA policy. I request that you be more sensitive and considerate of the future water needs and embrace the value of these important wetlands that are within the District and take proper action to insure their survival.	Noted. Adjusts have been make to the water budget for duck clubs and is reflected in the revised GSP.
Valley Water	VW1	Long-term and sustainable management of California's groundwater basins is important, and Valley Water will encourage the Semitropic GSA's to make efforts towards curbing historic overdraft and other undesirable groundwater impacts in its portion of Kern County. In this regard, Valley Water also recognizes that groundwater bank 'leave behind' (i.e., 10-percent of all stored water provided to Semitropic for their use in local groundwater management), provided by Valley Water and the other banking partners, has proven a positive contribution to local groundwater levels. It is important to Valley Water that existing Semitropic Bank terms and conditions are protected as groundwater managers move forward with the requirements of SGMA. Valley Water will continue to monitor GSP development throughout the DWR review process, and will continue to work with Semitropic regarding annual banking operations. Additionally, as the Semitropic GSA moves forward with SGMA requirements and finalizing the GSP document, Valley Water would appreciate insight or notice from Semitropic on how contemplated actions could directly or indirectly impact the Semitropic Bank	Noted
Shafter-Wasco Irrigation District 7th Standard Annexation Management Area Plan Received Comments			
Rosedale – Rio Bravo Water Storage District (RRBWSD)		Our initial review of the Shafter Wasco & Annex GSP's did not find any statement or commitment to address the respective deficits using a proportional glide path. With that in mind, could you please identify what glide path your respective management areas will be implementing? Specifically, what level of projects and/or demand reduction strategies will be implemented to address any deficit within each of the five (5) year milestones identified within the DWR Guidance Document?	A response was provided to RRBWSD to clarify the location of the requested information in the Annex Area MA Plan (Executive Summary, Section 16, and Table PMA-2).
North of the River Municipal Water District (NORMWD)		We note that throughout the 7th Std Annex Plan, it references the waste water from the NORSD WWTP. In an effort to be concise and frame the comments below, we will not list every section or table that references the waste water; however, we request that you consider our comments directed at every such reference within the 7th Std Annex Plan upon your review of this letter and the plan itself and edit your plan to reflect that NORMWD is the owner of such groundwater and such waste water is being currently utilized via contracts for limited agricultural uses.	The information presented in the SWID Annex Area Management Area (MA) Plan is required by the Sustainable Groundwater Management Act (SGMA) and does not represent groundwater allocation or determination of water rights or claims. The water budget information presented in Section 8 contains both a physical accounting of water flows in a of the Management Area consistent with 23 CCR § 354.18 of the GSP regulations and current Waste Discharge Requirements, and a checkbook methodology consistent with th approach developed by the Kern Groundwater Authority GSA in coordination with other basin GSAs. While water rights are not addressed in the MA Plan, we welcome further discussion of water rights from any Basin landowner as part of SGMA implementation.
Southern San Joaquin Municipal Utility District Received Comments			
Farmland Reserve		"Though not specifically addressed, we are concerned that overlying right to extract groundwater will be allocated among all District landowners based on gross acreage…it ignores accepted principles of law intended to more fairly allocate this right among those who have historically used groundwater for irrigation purposes -- and made substantial investments based on that use."	We have discussed adding language to the Water Budget section of the plan to address the fact that there is currently no in-district allocation of water to the landowners. The language in the Projects & Mgmt Actions section, dealing with in-district allocation as a mgmt action has been revised to address this, as well.
Farmland Reserve		"These numbers should not be seen as establishing a precedent or used to establish some legal right. Therefore, a statement emphasizing the above points should be made."	The discussion on native yield in the Water Budget section of the plan addresses this.
Farmland Reserve		"The Chapter could address the possibility of a market for the exchange or transfer of groundwater credits."	At this time, such a discussion is premature. There is no framework within the districts or the basin at large to allow for the exchange or transfer of groundwater credits. We ca reasonably address this in the plans for 2020 submittal.
Wonderful Orchards		"The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource."	The districts have identifed as a management action the coordinated effort to further refine water budget components in the Kern County Subbasin Model. The Model and wat budget components will continue to be refined in coordination with the KGA and other GSAs in the basin.

Commentor	Ref #	Comment	Response
Wonderful Orchards		"In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield. Currently, the GSP references native yield in terms of acre-feet per gross acre for water budget purposes. Appendix J of the GSP indicates the subbasin native yield is approximately 0.144 acre-feet per acre. It is our understanding that subsequent to the release of the draft GSP, all MAPs and other GSPs in the basin agreed to utilize the same number for their water budgets. If referencing native yield this way is necessary, the GSP should clarify that it is for initial water budget purposes ONLY, is non-precedent setting, and is not a determination of individual landowner allocations or groundwater rights. Alternatively, in the 2020 plans subbasin native yield could be described as a total volume of water and not associated with a given gross or net area."	The discussion on native yield in the Water Budget section of the plan addresses this already. Further emphasis on the "planning budget" role of the Native Yield estimate has b added to the final draft of the plan. In terms of native yield allocation to the parcel/landowner level, there is no framework currently in place to do so. The development the pol and framework necessary to implement such an allocation cannot be completed in time for the 2020 plan submittal.
Wonderful Orchards		"Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next."	At this time, such a discussion is premature. There is no framework within the districts or the basin at large to allow for the exchange or transfer of groundwater credits. We ca reasonably address this in the plans for 2020 submittal.
Wonderful Orchards		"Wonderful understands that there are instances where it may be necessary to restrict pumping in order to achieve basin-wide sustainability. If this becomes a necessity, the GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity. As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled)."	As described in the Management Actions subsection of the Management Area Plan, policies for instituting pumping restrictions have not been developed for the 2020 plan subr This has been identifed as a potential management action, should the districts or the basin in general find that it cannot maintain it path to sustainability through the projects an management actions to be implemented.
Wonderful Orchards		"GSAs must develop clear policies and conditions that protect existing investment in groundwater banking and banked inventory, and without interference with existing rules and regulations. GSAs must also find a way to incentivize additional investment, such as on-farm recharge, and allowing flexibility for recharged or banked water to be freely transferrable (subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results). Where possible, GSPs should also identify management areas that may benefit from additional recharge and banking. We also recommend that GSAs work to develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.)."	At this time, the framework to offer such incentives does not exist and would require the districts' boards to develop & adopt policy to put it in place. In the time required to pr the 2020 submittal of the plan, we cannot develop the structure and policy required to implement this. However, this is discussed in the Projects & Mgmt Actions section of the and will be considered for implementation after the 2020 plan submittal, when the districts have an opportunity to develop the policy and framework necessary for such progr
Wonderful Orchards		"GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	A coordinated DMS is already being developed. However, that effort is currently focused at the district/MA level due to the precision of the data being used. Parcel-level alloca not at this time being done in the subbasin. It is premature to consider a basin-wide water market, as the data available does not allow for that level of allocation to be done. Fo consideration in the 2020 plan submittal, we do not have adequate time or resources for the development of such a framework.
Westchester Group Investment Mgmt		The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water and not associated with a given gross or net area. In the event that allocations are to be made at a landowner or property level, WGIM encourages the KGA and other GSAs in the basin to initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations that are coordinated across the basin.	The discussion on native yield in the Water Budget section of the plan addresses this already. More language can be added to emphasize the "planning budget" role of the Nativ estimate.
Westchester Group Investment Mgmt		GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked water inventory, and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	At this time, the framework to offer such incentives does not exist and would require the districts' boards to develop & adopt policy to put it in place. In the time required to pr the 2020 submittal of the plan, we cannot develop the structure and policy required to implement this. However, this is discussed in the Projects & Mgmt Actions section of the and will be considered for implementation after the 2020 plan submittal.
Westchester Group Investment Mgmt		GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	A coordinated DMS is already being developed. However, that effort is currently focused at the district/MA level due to the precision of the data being used. Parcel-level alloca not at this time being done in the subbasin. It is premature to consider a basin-wide water market, as the data available does not allow for that level of allocation to be done. Fo consideration in the 2020 plan submittal, we do not have adequate time or resources for the development of such a framework.
Westchester Group Investment Mgmt		"WGIM supports use of efficient and accurate systems to determine groundwater use. GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration. These methodologies should be developed in consultation with the vendor providing ET data to ensure it is applicable and useful in creating the best available data set. Additionally, GSAs and/or MAs should establish criteria and procedures to address apparent inaccuracies in the ET calculations. An obvious use of the procedure would be in instances where the grower can demonstrate that applied water, plus precipitation, is less than the calculated ET. In these instances, and subject to any requirements established by the GSA, the grower's use of groundwater should be reduced to the applied water total as the ET calculation should not be greater than applied water."	This is already included in the Projects and Management Actions section and is part of the larger action of refining data for the calculation of Water Budget components in futur updates.
Leadership Council		"The Draft GSP is incomplete and must include additional information for the public to evaluate the GSP. The Draft GSP omits critical data regarding the consideration of drinking water impacts on disadvantaged communities and protected groups, sustainable management criteria that consider all beneficial users, and projects and management actions that address significant and unreasonable impacts to beneficial users."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with the statement, as the information that Leadership Council claims is missir the GSP is actually included in the management area plans, as appropriate to each respective management area.
Leadership Council		"The KGA is responsible for the disproportionate and disparate impacts that its policies and activities will have on disadvantaged communities belonging to protected groups."	This comment is directed to the KGA GSP and will be addressed by KGA. While the KGA is the GSA entity submitting the plan on behalf of its members, the JPA forming the KGA that each member is responsible for the implementation of SGMA within their respective plan areas. The KGA GSP and its management area plans were developed in considerat all beneficial uses of water and the beneficial users of the groundwater in the subbasin.
Leadership Council		"The Coordination Agreement does not "explain how the plans, implemented together, satisfy the requirements of the Act."	This comment is directed to the KGA GSP and will be addressed by KGA.

Commentor	Ref #	Comment	Response
Leadership Council		"The GSP was not crafted in a way that adequately considered the input of disadvantaged communities, either at the GSA level or the member agency level."	This comment is directed to the KGA GSP and will be addressed by KGA, pertaining to the KGA level engagement. With respect to the member level engagement, SGMA leaves t manner and frequency of public outreach and engagement to the discretion of the GSA. As described in the introduction of the management area plan, SSJMUD holds monthly noticed meetings which serve as an opportunity for members of the public to provide feedback to the districts regarding the plan's development and implementation. Furthern the districts were active participants in the KGA-level outreach activities as well as hosts of their own workshops, which were publicly-noticed, and coordination with the cities Delano and McFarland on the development of the plan.
Leadership Council		"The Kern Subbasin Undesirable Results do not comply with existing law."	The definitions for undesirable results were developed in coordination with the other GSAs and take into consideration "significant and unreasonable" impacts to the groundwa which affect all beneficial users. Such beneficial uses include agriculture, domestic, and municipal & industrial.
Leadership Council		"It is not clear what the impacts from reaching this undesirable result will be on beneficial users, and instead seems to be an arbitrary determination of what is "significant and unreasonable."	The impact analysis performed by the GSAs in the subbasin contributed to the development of the undesirable results for declining groundwater level.
Leadership Council		"Like the proposed definition of undesirable results for groundwater levels, the proposed definition of undesirable results for degraded water quality are 'when the minimum threshold for when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area).”	The comment letter cites an incorrect definition. The definition for the undesirable result for water quality is "when the minimum threshold for a groundwater quality constitue concern is exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the designated monitoring points within Subbasin."
Leadership Council		"The GSP's minimum thresholds and measurable objectives were not established in a way that considered the interests of beneficial users including domestic well owners and disadvantaged communities."	The KGA GSP outlines the methods used by its members to establish the Sustainable Management Criteria (SMCs) within their respective plan areas. For the SSJMUD managem plan area, projected groundwater levels based on recent historical hydrology were used to analyze the impact to known agricultural, domestic, and municipal wells. While impa were identified at the minimum thresholds in some management areas, these impacts were determined to not meet the definition of "significant and unreasonable".
Leadership Council		"As in the case of groundwater levels, it is clear that the GSA has not considered the potential impact on drinking water users, in particular disadvantaged communities who are less able to afford solutions to treat contaminated drinking water."	As with the groundwater level SMCs, the KGA GSP outlines the methods used by its members to establish the Sustainable Management Criteria (SMCs) within their respective p areas. Based on the analysis in the Basin Setting subsection on existing water quality conditions, it was deemed appropriate to use groundwater levels as a proxy for water qual addition to water quality and water level measurement at the representative monitoring sites.
Leadership Council		"GSAs must monitor impacts to groundwater for drinking water beneficial users,54 including disadvantaged communities on domestic wells, and must avoid disparate impacts on protected groups pursuant to state law. The GSA's monitoring network does not comply with SGMA regulations, and fails to capture drinking water impacts to disadvantaged communities and domestic wells[...] To ensure the monitoring network adequately captures impacts to all beneficial users, the GSA must ensure the following: Ensure the proposed monitoring network contains representative monitoring wells in or near all disadvantaged communities and clusters of domestic wells in the GSA area; Ensure that monitoring wells and representative monitoring wells in or near disadvantaged communities and clusters of domestic wells are able to measure the groundwater levels at the depth at which the drinking water wells are screened; Explicitly describe any future representative monitoring wells and identify the proposed locations. When assessing the monitoring network data gaps, the GSP must prioritize installing new monitoring wells in locations where disadvantaged communities, small water systems, and domestic well users reside."	The coordinated basin-wide monitoring network was developed using the DWR BMP on SGMA Monitoring Networks, which discusses recommended well density and what constitutes a "SGMA compliant" representative monitoring site. It also allows for (and encourages) GSAs to use existing monitoring programs already in place for collecting dat the Sustainability Indicators identified in a basin's plan. Domestic wells are typically shallow or in the first occurence of groundwater and are, therefore, not representative of t groundwater conditions of the basin as a whole. Further, there are existing programs with which domestic wells and community wells must comply. These have been identifie Basin Setting and Monitoring Network sections in the discussions of existing programs. In areas of the basin where the well density does not meet the standards used in the pla proposed well locations have been identified. Per discussion and comments from the cities of Delano and McFarland, four additional wells have been added to the monitoring n within the SSJMUD management area.
Leadership Council		The groundwater quality monitoring network does not adequately capture impacts on drinking water users.[...] First, measuring for Arsenic (as in Arvin-Edison WSD) only once a year does not provide the member agency or the GSA with frequent enough information to respond to severe drinking water contamination in a reasonable amount of time. If the member agency's management actions, projects, or decisions to let groundwater decline increase drinking water contamination for families in the management area, the member agency could go a whole year without detecting these impacts. [...] Second, only measuring for compliance with arsenic measurable objectives and minimum thresholds does not protect against increases in other contaminants that exist in other parts of the management area (boron, nitrates, TDS, 123-TCP, iron and manganese). These contaminants could extend, move or increase due to groundwater management activities and pumping patterns. [...] However, avoiding monitoring contaminated areas defeats the purpose of groundwater quality monitoring under SGMA, which is to measure the concentration and spread of contaminant plumes to ensure that groundwater management activities and pumping do not aggravate existing contamination.	The monitoring of water quality for the basin will include the use of data from existing programs (e.g. Title 22, ILRP, CV-SALTS) and sampling coincidental with groundwater leve measurements at the representative monitoring sites. As such, the water quality data collected through SGMA will be more frequent than once a year. The constituents of conc be tested in the water quality sampling at representative monitoring sites vary between the management areas. Therefore, the constituents analyzed will differ according to the management area plan. The selection of representative monitoring sites discouraged the use of wells with existing MCL exceedances because of the nature of the definition of undesirable results for degradation of groundwater quality. The occurence of an increase in concentration for constituents of concern in a representative monitoring site will, b of it being a representative site, will be indicative of the migration of existing contamination.
Leadership Council		The projects and management actions set forth in the Draft GSP do not demonstrate a path towards achieving sustainability goals in the plan, and do not adequately account for the needs of disadvantaged communities pertaining to protected groups under state law. The GSA has allowed member agencies like the Arvin-Edison WSD to use a “glidepath” approach that increases surface water and groundwater recharge before demand reduction measures are implemented. This places the majority of the plan's success on surface water resources, which are variable and may not be able to be procured. The GSA should instead ensure that member agencies implement demand reduction strategies from the beginning so that groundwater levels do not plummet. A critical problem with the structure of the GSA is that member agencies cannot share the cost or responsibility for critical GSA-wide projects. Many more financially powerful agricultural and water banking member agencies could and should be part of a strategy to protect drinking water resources in the GSA area, especially given that they use much larger quantities of groundwater and their continued pumping will likely lead to dry wells and groundwater contamination issues for the most vulnerable homes in the GSA area.	The KGA and its members have the authority under SGMA to prioritize projects and management actions, as they see fit, to demonstrate that the basin can reach sustainability 2040. The prioritization of projects to increase imported supply for use by districts' customers or for water banking projects protects groundwater for beneficial use in the basi facilitiating in-lieu banking (where surface water is used whenever it is available, replacing groundwater pumping) or by maintaining groundwater levels through replenishment banking projects. These projects do not run contrary to the mandate to protect groundwater quality. In fact, with groundwater levels as a proxy Sustainability Indicator for wat quality, these projects achieve both the maintenance of groundwater levels and water quality. The agricultural and water banking agencies in the basin, as the customers payin water deliveries and funding projects via land assessments in their respective districts, can and should be a beneficiary of the projects which they are funding.
Leadership Council		"The KGA GSA should implement or incentivize recharge basins or other recharge activities throughout the subbasin wherever DACs and clusters of domestic wells exist. The GSA should encourage these kinds of recharge projects with health co-benefits over on-farm recharge, which is likely lead to accelerate groundwater contamination."	It is at the discretion of the KGA's member agencies to identify projects to fund, as well as opportunities to collaborate with DACs. SSJMUD is already collaborating with the City Delano to develop in-district recharge facilities which will be made available to the city when there is capacity available. Conversely, Delano will allow the district to utilize an exi stormwater catch basin as a spreading basin, when it is not in use to manage storm flows. Future projects and management actions which deal specifically with the DACs and domestic wells may be considered for subsequent updates to the GSP and management area plans.
Leadership Council		"For areas vulnerable to declining water levels and loss of production capacity, the KGA GSA should adopt management actions that establish geographical protection areas (buffer zones) by establishing bans, pumping limitations or community-specific management areas around disadvantaged communities and domestic well clusters."	The development of these buffer zones would be predicated on the development of a shallow-zone specific monitoring network and SMCs. As discussed in the response to the Monitoring Network comments, these shallow zones are not representative of groundwater conditions throughout the basin. Furthermore, the framework necessary to imple pumping restrictions or bans does not exist within the KGA or its members. Such policy would not be developed or implemented in time for the 2020 submittal.
Leadership Council		"We also strongly recommend against a groundwater market in the KGA GSA area. The GSP includes potential groundwater market and trading programs. Groundwater markets raise concerns from the perspective of domestic well users and disadvantaged communities."	At this time, the framework to establish a groundwater market in the basin does not exist. The policies and framework that would need to be developed by the KGA and its mer is too complex to be completed in time for consideration in the 2020 submittal. Additionally, any groundwater market developed by the KGA or its members would have to com with SGMA (i.e. prevent localized impacts to the Sustainability Indicators in its implementation).
Leadership Council		"The GSAs should implement and incentivize multi-benefit projects such as wetlands restoration or stormwater drainage ponds that would eliminate flooding and increase groundwater recharge in disadvantaged communities."	It is at the discretion of the KGA's member agencies to identify projects to fund. Future projects and management actions which provide benefits beyond SGMA may be conside subsequent updates to the GSP and management area plans.
Leadership Council		"Although there are multiple short-term funding sources to leverage for SGMA-related projects, the GSA's and member agencies' operating budgets must be a reliable source of funding over the long-term of GSP implementation, and the GSA and member agencies cannot rely on grant funding for long-term projects and programs that benefit disadvantaged communities. The GSA and member agencies must be responsible for addressing the drinking water issues caused by their policy decisions and activities."	It is entirely appropriate that the KGA's members, when working in collaboration with DACs on a project to benefit groundwater quantity and quality in the basin, seek funding such projects through state and federal grant funding programs. Grant funding, where the districts are eligible, is applied for to defray the cost of projects (which often far exce award amount). The remaining costs of projects and management actions are to be funded with the districts' operating budgets or through special assessments.
Leadership Council		"the Draft GSP allows continued overdraft above the safe yield of the basin, such that drinking water wells (especially domestic wells) will continue to go dry, infringing on the rights of overlying users of groundwater. The GSP must be revised to protect the rights of residents of disadvantaged communities and/or low-income households who hold water rights to groundwater."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with the statement, as the KGA GSP and its included management area plans h demonstrated, the combination of projects, management actions, and established SMCs will bring the basin into balance with its groundwater management by 2040.
Leadership Council		"The reasonable and beneficial use doctrine applies here given the negative impacts of the Draft GSP on groundwater supply and quality, which are likely to unreasonably interfere with the use of groundwater for drinking water and other domestic uses. As the Draft GSP authorizes waste and unreasonable use, it conflicts with the reasonable and beneficial use doctrine and the California Constitution."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with Leadership Council's statement regarding the plan's authorization of "wa and unreasonable use". The beneficial uses of water in the basin include other uses beyond domestic consumption. As such, it is entirely appropriate and in the authority of the that impacts to groundwater be analyzed in consideration of all beneficial uses identified in the plan.

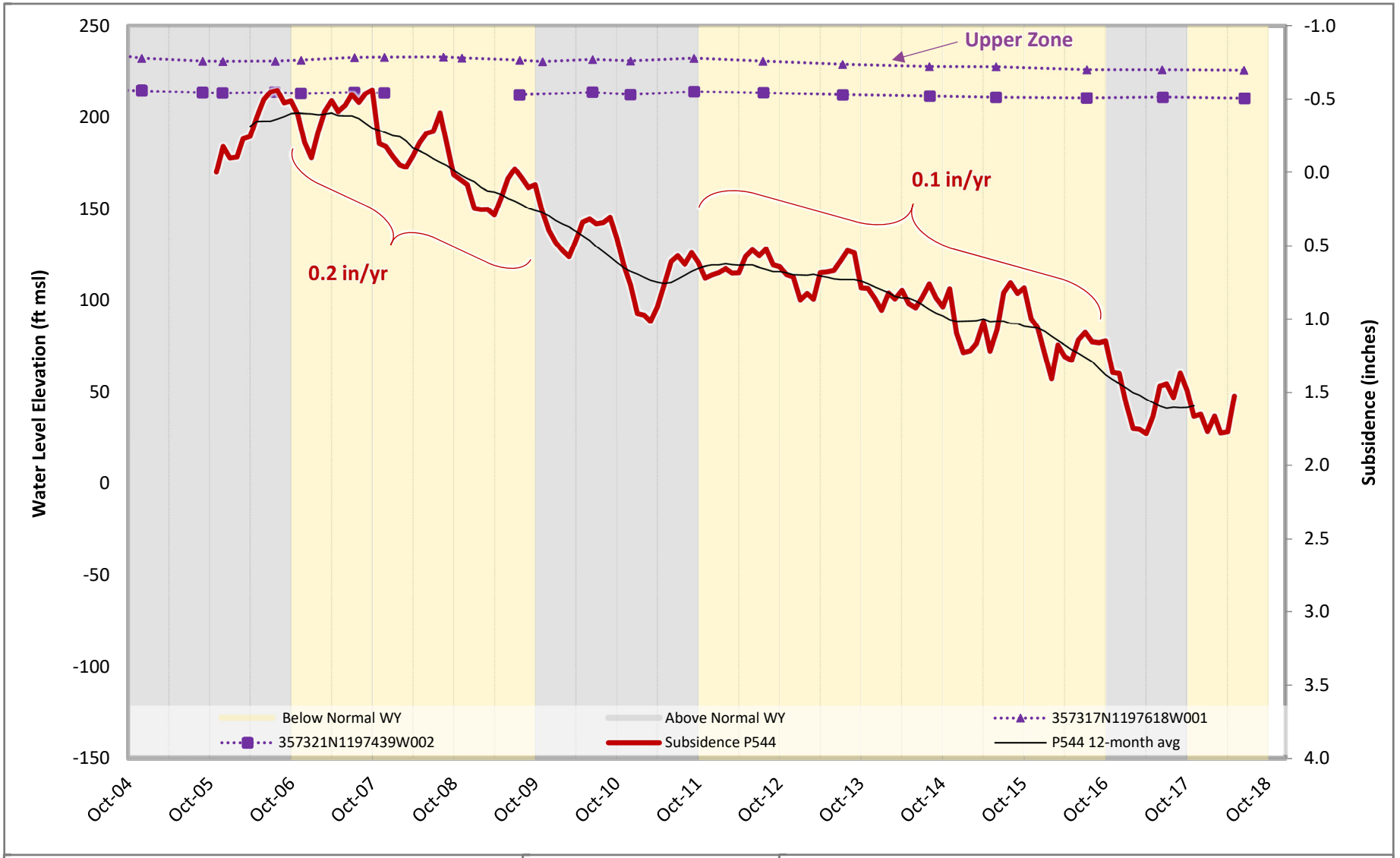
Commentor	Ref #	Comment	Response
Leadership Council		"The "public trust" doctrine has recently been applied to groundwater where there is a hydrological connection between the groundwater and a navigable surface water body. In Environmental Law Foundation , the court held that the public trust doctrine applies to "the extraction of groundwater that adversely impacts a navigable waterway" and that the government has an affirmative duty to take the public trust into account in the planning and allocation of water resources. The court also specifically held that SGMA does not supplant the requirements of the common law public trust doctrine. In contrast to these requirements, the Draft GSP does not consider impacts on public trust resources, or attempt to avoid insofar as feasible harm to the public's interest in those resources."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with Leadership Council's position in that the Basin Setting of the KGA GSP an management area plans have adequately demonstrated that there are no interconnected surface waters in the basin and that this is the existing condition of the basin.
Tejon-Castac Water District Received Comments			
No Comments Received			
West Kern Water District Received Comments			
Chevron	Letter-1	Include discussion of aquifer lower boundary as above top of the oil/exempt water-bearing zones below oil	Suggested text added to section
Chevron	Letter-2	Provide additional support for removing industrial/non-domestic GW wells in Western Management as "de mimimis extractors" (ES-1.4, Figures 1-13 - 1-15)	Added text to 5-year update to re-evaluate wells in the western management area to review potential uses that may not be de-minimus.
Chevron	Letter-3	In the Western Management Area, how will we evaluate subsidence and undesirable results?	Added text to 5-year update to re-evaluate potential for water use to affect sustainability indicators in the area
Chevron	Comment-1	Same as comment "Letter-2"	Added text to 5-year update to re-evaluate wells in the western management area to review potential uses that may not be de-minimus.
Chevron	Comment-2	Language change: The GSA area includes the WKWD boundary and adjacent oilfield properties owned by corporate and independent operators "*as well as Stateland and privately owned parcels*"	Suggested text added to section
Chevron	Comment-3	Per WC Section 10721(e), "De minimus extractor" defined as "a person who extracts, for domestic purposes, two acre-feet or less per year."	Added text to refine description without relying on 'de minimis'.
Chevron	Comment-4	An aquifer may not be suitable for beneficial use if: a) is not currently serving as a source of drinking water, b) it has commercially producible minerals or hydrocarbons, or c) it is not expected to supply a public water system and d) is either economically or technologically infeasible for treatment or recovery now or in the future for domestic, agricultural, or industrial use. The purpose of this plan is not to exempt aquifers, nor is it to define the maximum depth or water quality concentration at which groundwater is economically recoverable or treatable now or in the future. However, by applying the criteria of 40 CFR §144.3 and 40 CFR §146.4, active oil and gas aquifers and exempted aquifers are not a part of the groundwater basin for beneficial use. The following whichever is shallowest, are the lateral and vertical boundaries of the groundwater Subbasin: a) depth to producible minerals or hydrocarbons or primacy productive limits, b) depth to exempted aquifers, c) depth that makes recovery of water for domestic, commercial, or industrial purposes no longer economically or technologically feasible, or d) the depth at which groundwater cannot now or in the future serve as a source of drinking water. For example, water bearing zones below the depth to producible hydrocarbons are not within the groundwater basin; likewise, water bearing zones below an exempted aquifer are not within the groundwater basin	Suggested text added to section
Chevron	Comment-5	Language change: Separate GW quality and production "There is little or no groundwater production in the Western Management Area, so water quality in that area is not discussed in this section."	GSA's can only manage groundwater quality through groundwater pumping management. If there is no significant groundwater pumping in a region, the GSA cannot effectiveh manage groundwater quality in that area.
Chevron	Comment-6a	1. Consider moving Section 4.9 to this section. 2. Consistent with DWR Water Budget BMP, consider adding language to discuss how this is monitored and how you reach the conclusion it is not impacting GW quality. 3. Please provide reference for "one of the world's largest" or delete it.	Copied content from 4.9 to this section. Removed reference to largeness. Added consideration of coordination with oil producers on an approach to enhance water quali monitoring and reporting of oil produced water to ensure no degradation of groundwater quality due to oil pumping occurs under SGMA.
Chevron	Comment-6b	How have we reached the conclusion that oil production has not impacted groundwater quality?	
Chevron	Comment-6c	Cite "world's largest petroluem producing areas"	
Chevron	Comment-7	Language change: change "produced water ponds" to "percolation ponds"	changed
Chevron	Comment-8	Addition of 4 paragraphs written by Chevron (see comments on pg 120 of draft)	Added majority of text recommended
Chevron	Comment-9	Include a bibliography for cited references	Present in Section 3.9 and at the end of each section
Chevron	Comment-10	change title to "Treated Produced Water"	changed
Chevron	Comment-11	Change "Water produced water" to "treated produced water"	changed
Chevron	Comment-12	Change "evaporation ponds" to "percolation ponds"	changed
Chevron	Comment-13	Consider deleting sentence or providing data to support it: "This water is supplemented by water purchased from WKWD, which indicates that very little water is disposed of, since purchasing fresh water is more expensive than recycling water."	removed
Chevron	Comment-14	Replace last sentence with "Oilfield produced water is sourced from beneath the bottom of the basin."	changed
Chevron	Comment-15	To subsidence bullet point, add "and critical infrastructure."	changed
Chevron	Comment-16	Consider deleting "Most extensometers are located too far from the GSA area to provide useful insight into subsidence trends."	changed
Chevron	Comment-17	Add "critical" before "infrastructure"	changed
Chevron	Comment-18	Replace "large pipelines" with "large-scale linear infrastructure"	changed
TNC	General - 0	Use TNC's online tools and resources and TNC's checklist to better include nature in the GSP (see specifics below)	NCCAG Dataset was used to identify potential locations of GDEs
TNC	General - 1	Actively engage with environmental stakeholders	Outreach is addressed in KGA's Umbrella GSP
TNC	General - 2	For GDEs, utilize: NC Dataset on DWR website, GDE Pulse, and CNDDB	added text stating these uses are not known to exist in the plan area
TNC	General - 3	Potential effects on environmental beneficial users: Use Attachment C for list of freshwater species in Kern County Subbasin	Identification of endangered species is not a requirement under GSP regulations
TNC	General - 4a	ISWs and GDEs are not adequately identified	corrected 2.10.2 to ephemeral, added that there are no known flow requirements
TNC	General - 4b	connectivity of ISWs and GDEs with the Shallow Zone and Upper Unconfined Aquifer was not adequately characterized	There are no GDEs in management areas with non-deminimis pumping (North, South, and Lake Management Areas).
TNC	General - 4c	the plans to address GDE/ISW data gaps in the Subbasin characterization and monitoring networks need to be expanded	There are no GDEs in management areas with non-deminimis pumping (North, South, and Lake Management Areas).
TNC	General - 4d	set sustainable management criteria for all identified and potential GDEs/ISWs	There are no GDEs in management areas with non-deminimis pumping (North, South, and Lake Management Areas).
TNC	Checklist - 1	Describe any environmental beneficial uses and users of groundwater (i.e. GDEs, managed wetlands, fisheries, recreation, etc.) and species with protected status	Beneficial uses are addressed in KGA's Umbrella GSP
TNC	Checklist - 2	Describe current/planned habitat and flow requirements for streams in WKWD (or state if there are none)	Identification of endangered species is not a requirement under GSP regulations, added text about no flow requirements on WKWD GSA area's ephemeral streams
TNC	Checklist - 3	provide a description of monitoring activities and responsibilities by State, Federal and local agencies and jurisdictions related to aquatic resources and GDEs in the GSP plan area that could be affected by groundwater withdrawals	There are no GDEs in management areas with non-deminimis pumping (North, South, and Lake Management Areas).
TNC	Checklist - 4	review and discuss the potential groundwater reliance of critical species in the Subbasin. Please include a discussion regarding the management of critical habitat for these aquatic species and its relationship to the GSP.	Identification of endangered species is not a requirement under GSP regulations, added text about no flow requirements on WKWD GSA area's ephemeral streams
TNC	Checklist - 5	Please include a discussion of monitoring programs related to GDEs and sensitive or protected habitats.	There are no GDEs in management areas with non-deminimis pumping (North, South, and Lake Management Areas).

Commentor	Ref #	Comment	Response
TNC	Checklist - 6	Please include a discussion of how implementation of the GSP may affect and be coordinated with General Plan policies and procedures regarding the protection of wetlands, aquatic resources riparian vegetation, and other potential GDEs and ISWs, if applicable.	the General Plan does not have policies regarding the protection of wetlands, aquatic resources riparian vegetation, and other potential GDEs and ISWs,
TNC	Checklist - 7	Please identify all relevant HCPs and NCCPs within the WKWD GSP area, and address how GSP implementation will coordinate with the goals of these HCPs or NCCPs.	no HCPs or NCCPs are known to cover the managed management areas (North, South, Lake) of the WKWD GSP
TNC	Checklist - 8	discuss that future well permitting and well construction must be coordinated with the GSP to assure achievement of the sustainability goals, how the process incorporates protection of GDEs, and how well permitting programs must consider the potential impacts of GW extractor on public trust resources	Well permitting is performed by Kern County, not the WKWD GSA
TNC	Checklist - 9	Define the bottom of the boundary from deepest extraction wells. If data unavailable, describe this in data gaps.	Bottom of basin was updated to match KGA's Umbrella GSP
TNC	Checklist - 10	Show cross sections (that could show shallow/perched GW) - (Same as Umbrella comment on Section 2.2.1.6)	Cross Sections for the Kern County Subbasin are included in the KGA's Umbrella GSP
TNC	Checklist - 11	Describe shallow aquifers including interconnections with surface water, vertical GW gradients, and interactions with GDEs and state presence of perched aquifers (or identify as data gap if unavailable)	Section 2.8 contains aquifer information
TNC	Checklist - 12	Support statement of lack of springs with data, or identify as data gap	Figure 2-5 shows locations of springs
TNC	Checklist - 13	Potentially add gaps listed in comments above	None present
TNC	Checklist - 14	Provide more supporting data on why no ISWs are present (including Buena Vista Aquatic Recreational Area and ponds in north central)	Buena Vista Aquatic Recreational Area is not in the WKWD GSA Area. The ponds in the North and South Management areas are managed recharge ponds that are not naturally occuring - effects of pumping in these areas and recharge from the recharge ponds is explained in the water budgets section.
TNC	Checklist - 15	further describe the conceptual understanding of shallow groundwater and stream interactions with the aquifer system at different locations, including perched and unconfined aquifers and GDEs	The only non-managed surface water in the GSA are ephemeral streams, which are not managed, and are in the Western Management Area, which does not have pumping.
TNC	Checklist - 16	elaborate on the relationship between surface water in the BVARA and adjacent shallow and deeper groundwater levels. Since this is identified as a data gap, please describe how and where additional observations (shallow monitoring wells, nested / clustered wells, etc.) along surface water features can be used to reconcile this data gap	the BVARA is outside WKWD GSA, and therefore is not managable by the WKWD GSA. Identifying monitoring in the Lake Management area is identified as a part of implementa
TNC	Checklist - 17	Use GW contours (including seasonal and interannual fluctuations) to verify whether a connection between GDEs and GW exist	Groundwater Contours are provided in the KGA's Umbrella GSP
TNC	Checklist - 18	Expand GDE analysis of using GW data (using their attachments D and E) to verify is ecosystem decline/recovery is correlated with GWLs	NCCAG Dataset showed that there were no potential GDE's in the 3 managed management areas (North, South, Lake)
TNC	Checklist - 19	Provide more data-driven analysis of GDE identification, or identify in data gaps and resolve inconsistency in Umbrella GSP on pg 92	NCCAG Dataset showed that there were no potential GDE's in the 3 managed management areas (North, South, Lake)
TNC	Checklist - 20	Decribe nature and characteristics of GDEs including: GW conditions near GDEs, ecological inventory and ranking, and nearby endangered freshwater species	NCCAG Dataset showed that there were no potential GDE's in the 3 managed management areas (North, South, Lake)
TNC	Checklist - 21	Disaggregate ET of native and riparian vegetation further, or identify as data gap	ET is discussed in the KGA's Umbrella GSP
TNC	Checklist - 22	We recommend an ecological inventory (see Appendix III, Worksheet 2 of the GDE Guidance) for all potential GDEs that includes vegetation or habitat types and rank the GDEs as having a high, moderate or low value. Explain how each rank was characterized. Please identify whether any endangered or threatened freshwater species of animals and plants, or areas with critical habitat were found in or near any of the GDEs. Some organisms rely on uplands and wetlands during different stages of their lifecycle.	GSP Regulations do not require these activities.
TNC	Checklist - 23	Please expand the sustainability goal to describe that all beneficial users and GW users will be protected from undesirable results, including GDEs	Sustainability Goal and undesirable results are a coordinated statement that was developed by the KGA, and cannot be changed at this level
TNC	Checklist - 24	Include a statement about any intention to address pre-SGMA impacts	2015 is used as a key function of the identification of minimum thresholds. This is described in Section 7
TNC	Checklist - 25	Address how water quality would affect GDEs	NCCAG Dataset showed that there were no potential GDE's in the 3 managed management areas (North, South, Lake)
TNC	Checklist - 26	For each sustainable management criteria, discuss whether minimum threshold/measureable objectives/interim milestones addresses the environment's sustainability goal	Sustainability Goal and undesirable results are a coordinated statement that was developed by the KGA, and cannot be changed at this level
TNC	Checklist - 27	List GDEs as one of the beneficial users of GW and add "possible adverse impacts to potential GDEs and ISWs" to the list of potential undesirable results	Sustainability Goal and undesirable results are a coordinated statement that was developed by the KGA, and cannot be changed at this level
TNC	Checklist - 28	Correlate trends/spatial patterns of GDEs with GWL trends. Note adverse trends and/or data gaps. (Specific details of trends listed in Appendix B pf 17)	NCCAG Dataset showed that there were no potential GDE's in the 3 managed management areas (North, South, Lake)
TNC	Checklist - 29	Monitoring networks should include proposing (i) new wells to be located in the Western Management Area to be properly screened to analyze GDEs and (ii) stream gages in areas where there is potential for GDEs/ISWs	The western management area does not have significant pumping, and is not managed beyond monitoring for new groundwater use. Will consider monitoring should groundw use increase in the 5 year update.
TNC	Checklist - 30	Modify monitoring network to include water quality impacts on GDEs	Water quality is monitored by proxy, this covers GDEs (which are not present in the 3 managed management areas)
TNC	Checklist - 31	Resolve inconsisency stating "all streams are ephemeral" vs both "ephemeral and perennnial streams"	corrected 2.10.2 to ephemeral, added that there are no known flow requirements
TNC	Checklist - 32	For proposed projects, state how ISWs/GDEs could benefit or list additional management actions to protect GDEs/ISWs and how adverse impacts will be evaluated and mitigated	NCCAG Dataset showed that there were no potential GDE's in the 3 managed management areas (North, South, Lake)
Westside District Water Authority Received Comments			
Wonderful Orchards	WO-1	It is imperative that the final GSP properly address the quantification of native yield. The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource.	Comment noted. Please see Section 2.7-Water Budget of the WDWA Chapter GSP
Wonderful Orchards	WO-2	In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield.	Comment noted. Please see Section 2.7-Water Budget of the WDWA Chapter GSP
Wonderful Orchards	WO-3	In addition, GSAs should initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations of native yield that are coordinated across the subbasin.	Comment noted. The WDWA will participate in KGA discussions related to all Subbasin issues.
Wonderful Orchards	WO-4	Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next.	Comment noted. The WDWA will participate in KGA discussions related to all Subbasin issues.
Wonderful Orchards	WO-5	GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity	Comment noted. The WDWA will participate in KGA discussions related to all Subbasin issues.
Wonderful Orchards	WO-6	GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked inventory and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	Comment noted. The WDWA will participate in KGA discussions related to all Subbasin issues.
Wonderful Orchards	WO-7	GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater.	Comment noted. The WDWA will participate in KGA discussions related to all Subbasin issues. Please also see Setion 6.0- GSP Reporting and Periodic Evaluations of the WDWA Chapter GSP
Department of Fish and Wildlife	DWF-4	The Plan Area narrative does not identify Department-owned lands. … The Department also owns the Buttonwillow, *Lokern* , and Bakersfield Cactus Ecological Reserves, which are also located within the GSP area.	The WDWA has included text and a figure describing DWF lands (Lokern Ecological Resreve) witihn its management area.
Wheeler Ridge-Maricopa Water Storage District Received Comments			

Commentor	Ref #	Comment	Response
Chevron	1	An aquifer may not be suitable for beneficial use if: a) is not currently serving as a source of drinking water, b) it has commercially producible minerals or hydrocarbons, or c) it is not expected to supply a public water system and d) is either economically or technologically infeasible for treatment or recovery now or in the future for domestic, agricultural, or industrial use. The purpose of this plan is not to exempt aquifers, nor is it to define the maximum depth or water quality concentration at which groundwater is economically recoverable or treatable now or in the future. However, by applying the criteria of 40 CFR §144.3 and 40 CFR §146.4, active oil and gas aquifers and exempted aquifers are not a part of the groundwater basin for beneficial use. As described above, the following, whichever is shallowest, are the lateral and vertical boundaries of the groundwater Subbasin: a) depth to producible minerals or hydrocarbons or primacy productive limits, b) depth to exempted aquifers, c) depth that makes recovery of water for domestic, commercial, or industrial purposes no longer economically or technologically feasible, or d) the depth at which groundwater cannot now or in the future serve as a source of drinking water. For example, water bearing zones below the depth to producible hydrocarbons are not within the groundwater basin; likewise, water bearing zones below an exempted aquifer are not within the groundwater basin.	Section 7.1.3 was modified to clarify that in areas where pools in oil fields in the MA Plan area are at shallower depths than the base of fresh water, the bottom of the basin is d as the shallower depth of fresh water from the DOGGR oil field data.
Farmland Reserve	1	**Allocation of Groundwater Rights.** Though not specifically addressed, we are concerned that the overlying right to extract groundwater will be allocated among all District landowners based on gross acreage. While this is a simple approach to what can be a complex issue, it ignores accepted principles of law intended to more fairly allocate this right among those who have historically used groundwater for irrigation purposes-and made substantial investments based on that use. We wish to at least see identification of this issue in the Chapter and an acknowledgment that it will not be decided now. If the District determines that the issue is broader, then we leave it to the District to address it at the Umbrella GSP level. Any implication that the District has decided to allocate the overlying groundwater rights based simply on gross acreage could invite some to pursue premature legal action to challenge the District's conclusion, which might not be necessary depending on the success of the proposed actions in the Chapter. While this issue certainly affects our interests, we are equally concerned about avoiding unnecessary legal challenges made by others and the instability that would bring to the sub-basin.	• "Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see Section 9.1.3). • ***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that the "native yield" is for planning purposes only and no determination of actual legal ground water rights.*** • Implementation of P/MAs, including actions to further refine issues related to allocations of groundwater, is described in Section 18.2. • See KGA response to this comment for further information.
Farmland Reserve	2	**Native Yield.** The Chapter identifies a coordinated estimated native yield of 0.15-.0.30 acre feet per acre across the KGA. We understand and acknowledge that some number needed to be identified for Water Budget and planning purposes and support the use of these numbers for such purposes. However, these numbers should not be seen as establishing a precedent or used to establish some legal right. Therefore, a statement emphasizing the above points should be made - the planning purpose nature of these numbers and not establishing legal precedent. Additionally, in coordinating with other members of the KGA under the Umbrella GSP, the District should push for a consistent native yield and related methodology across the sub-basin. We understand that this can be a politically charged process, but we are confident the District can provide support for a consistent approach, which will enable a more stable sub-basin.	• "Native yield", as defined in the Coordinated Water Budget, is applied to all lands in the basin uniformly (see **Section 9.1.3**). • ***Section 9.1.3 was added to clarify the intended purpose of the water budget, and includes a statement that the "native yield" is for planning purposes only and no determination of actual legal ground water rights.*** • Implementation of P/MAs, including actions to further refine issues related to allocations of groundwater, is described in **Section 18.2**. • See KGA response to this comment for further information.
Farmland Reserve	3	**Groundwater Market.** This issue might be premature at this point. However, the Chapter could address the possibility of a market for the exchange or transfer of groundwater credits. If a market system were contemplated, we would encourage such a system to be as flexible as possible (within the requirements of SGMA, the Chapter and the Umbrella GSP) to facilitate the needs of farmers with lands in different areas of the sub-basin and those with the ability to store surface water underground. Again, this might be premature at this time, but a mention of the District's position to support a flexible groundwater market could help move the discussion forward once the Umbrella GSP is submitted to the Department of Water Resources and agencies begin the implementation process.	• The MA Plan includes in its portfolio of P/MAs a management action to evaluate and potentially implement a groundwater marketing and trading system (see **Section 1** • As described in **Section 18.2**, implementation of P/MAs, including the potential establishment of a market-based system, will include performance of any appropriate f studies and analysis, including engineering, economic/financial, and/or legal, as appropriate. • See KGA response to this comment for further information.

Kern Groundwater Authority Groundwater Sustainability Agency
Groundwater Sustainability Plan

ATTACHMENT G
Time Series Plots of Subsidence



Hydrogeologic Conceptual Model
Kern County Subbasin

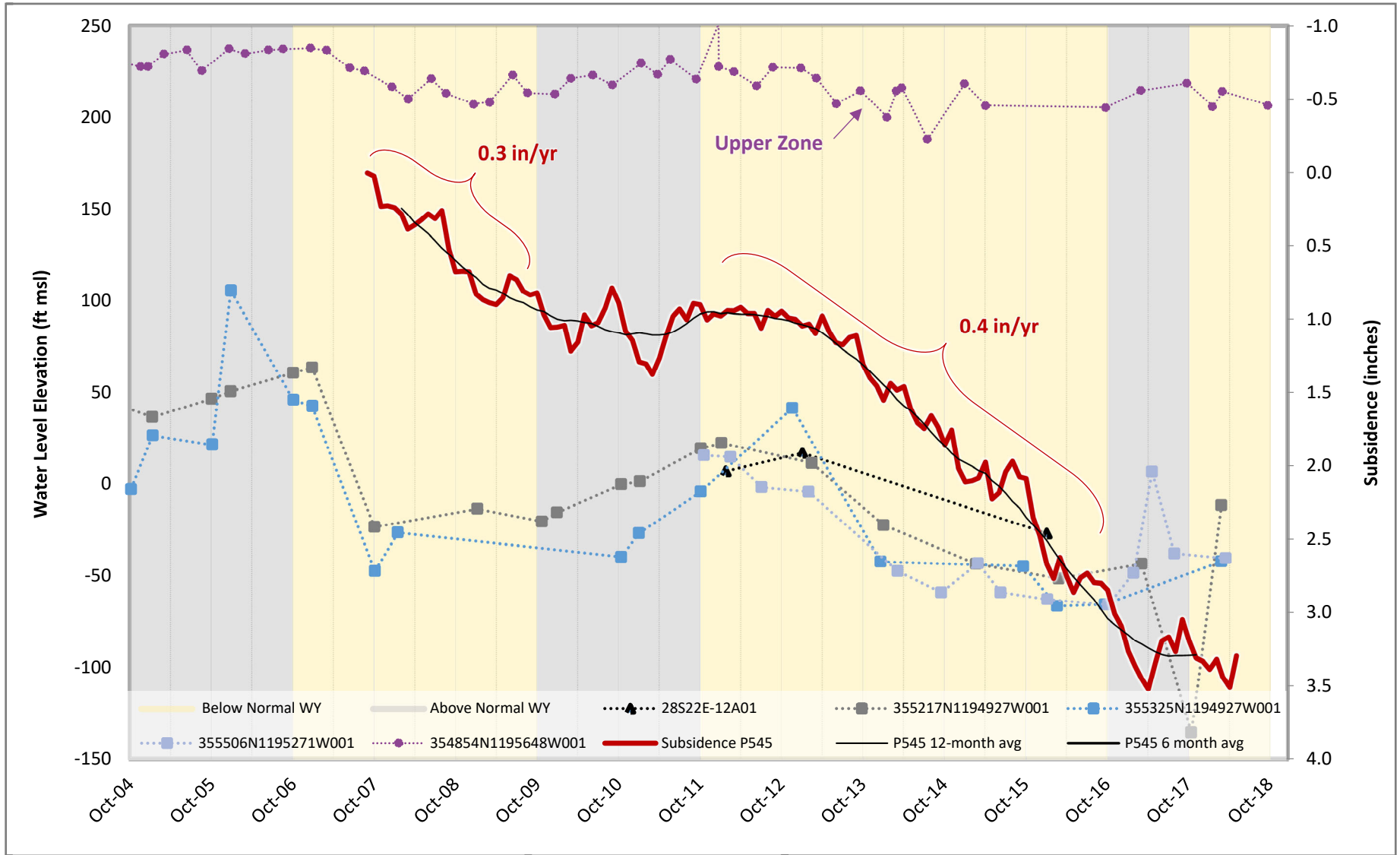
Kern County, CA

GEI Consultants

Time Series Plot:
P544 (Twisselman Road CGPS) Subsidence with Hydrographs

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

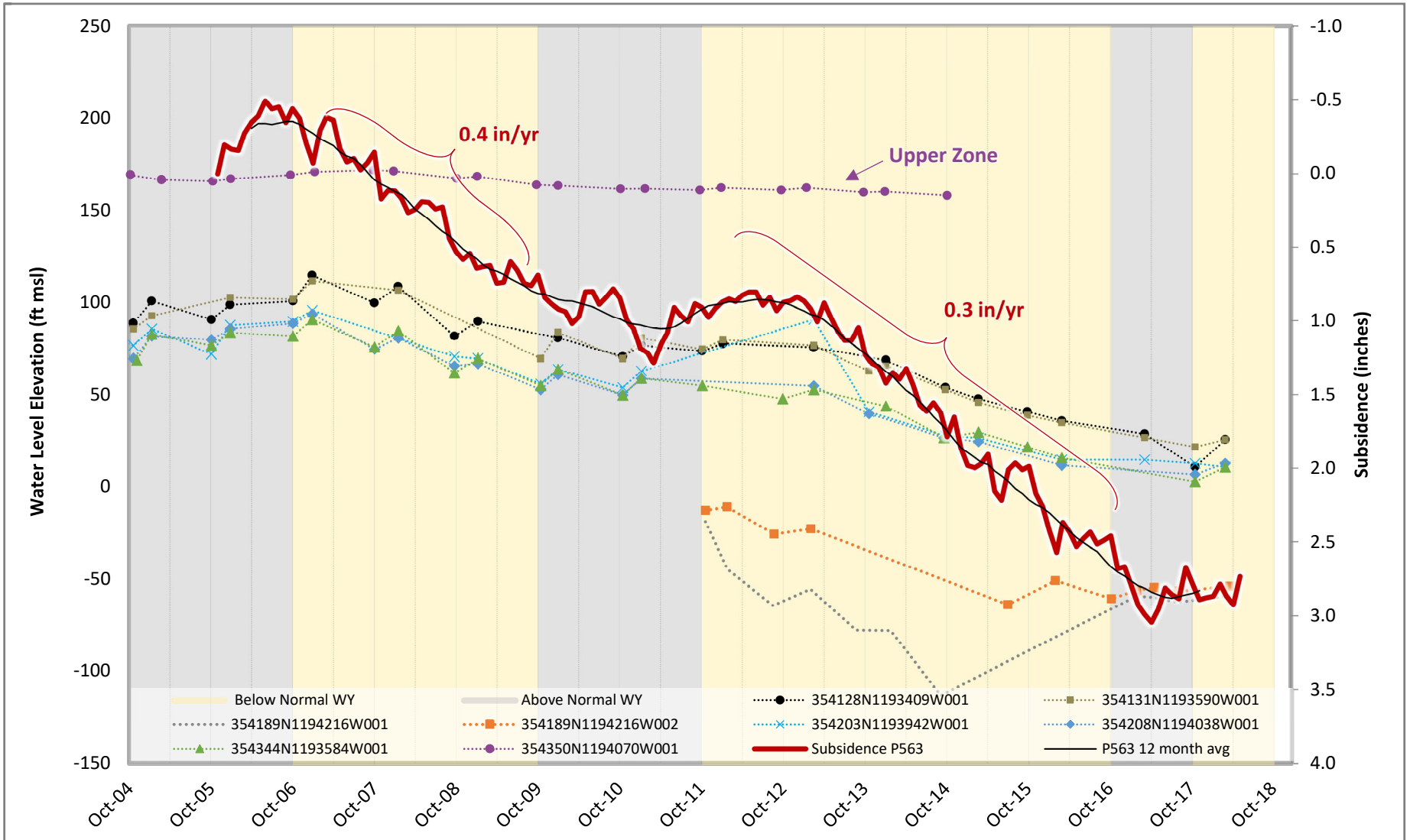
Kern County, CA

GEI Consultants

Time Series Plot:
P545 (Lerdo Highways CGPS) Subsidence with Hydrographs

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

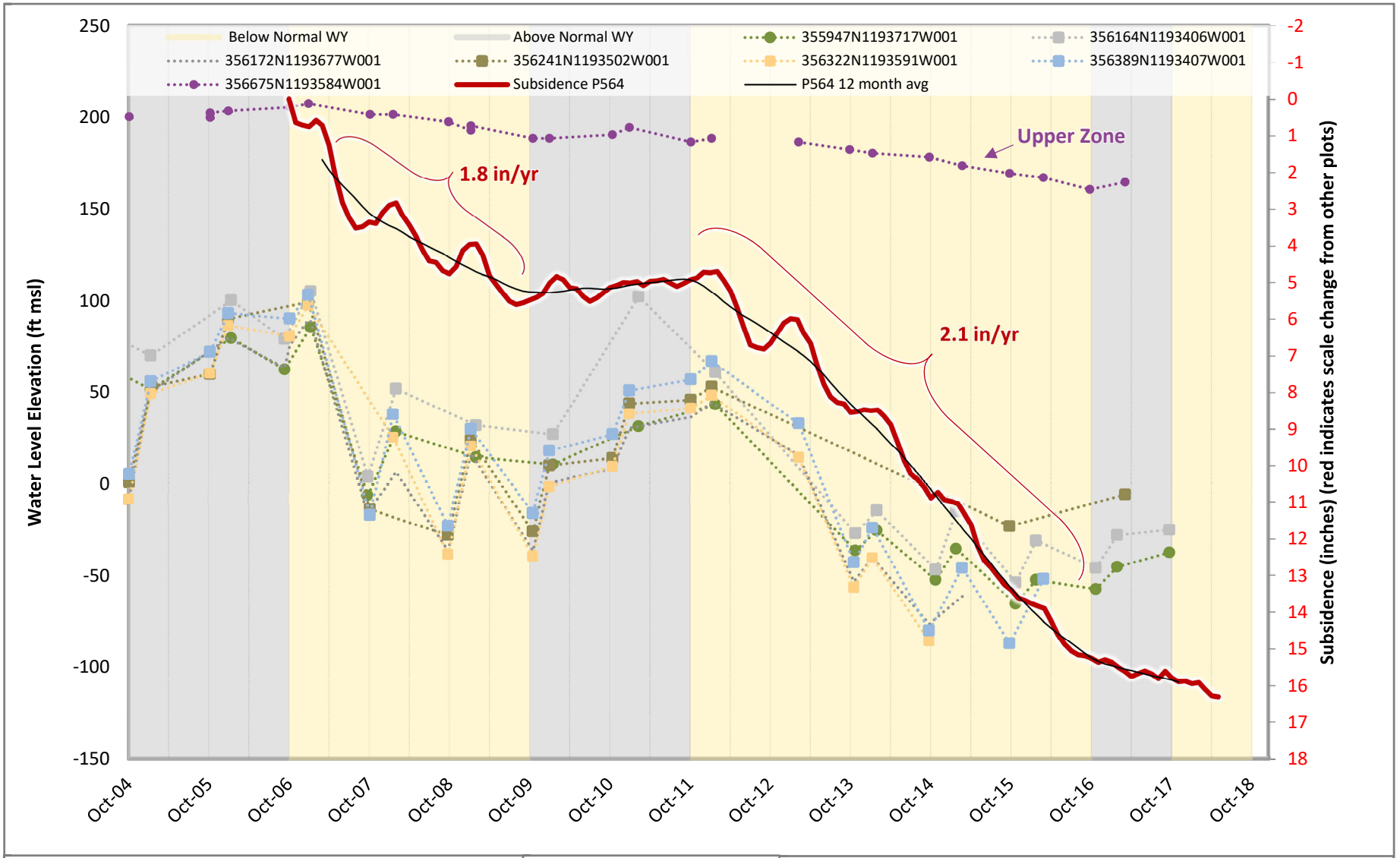
Kern County, CA

GEI Consultants

Time Series Plot:
P563 (Buttonwillow CGPS) Subsidence with Nearby Hydrographs

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

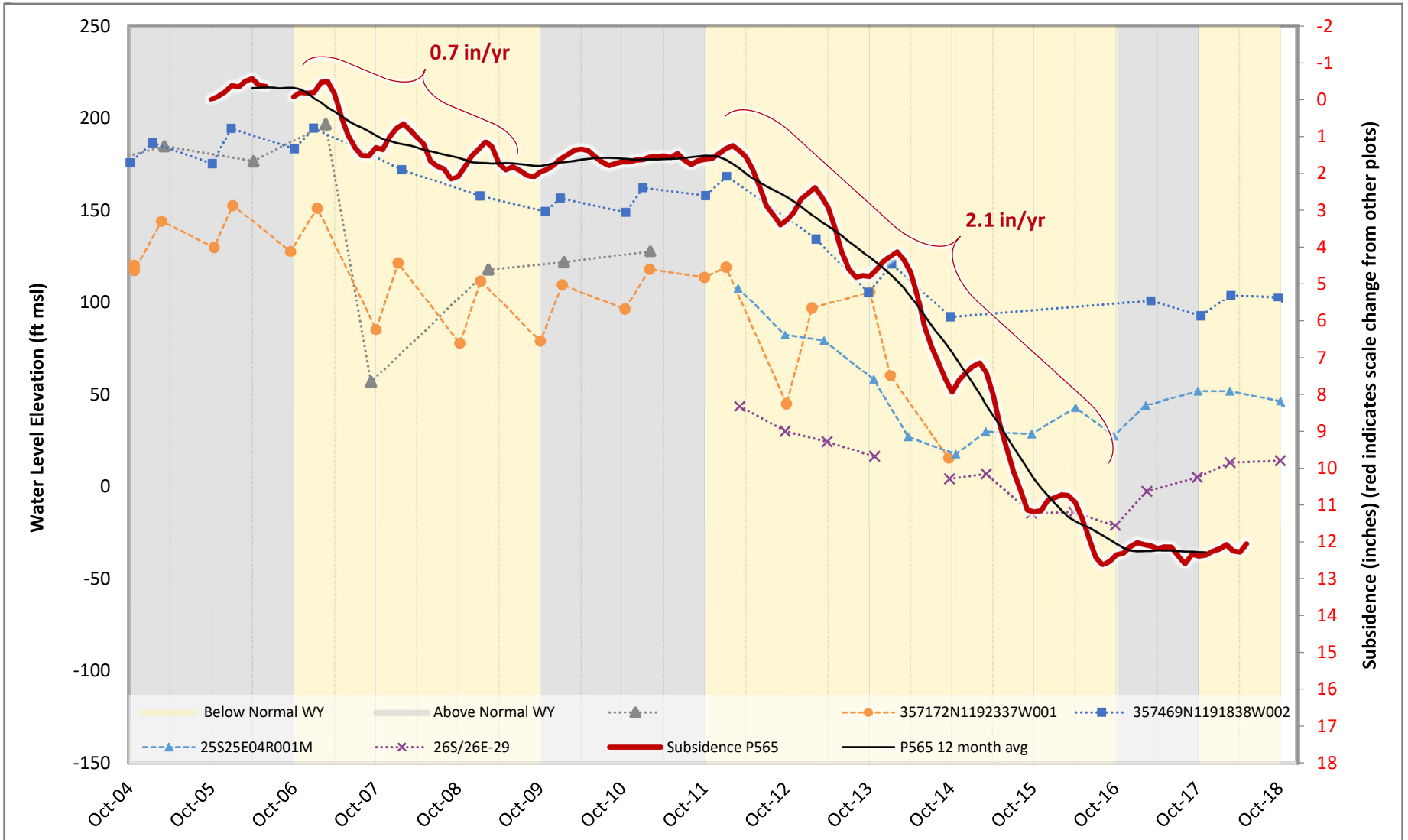
Kern County, CA

GEI Consultants

Time Series Plot:
P564 (Wasco CGPS) Subsidence and Nearby Hydrographs

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

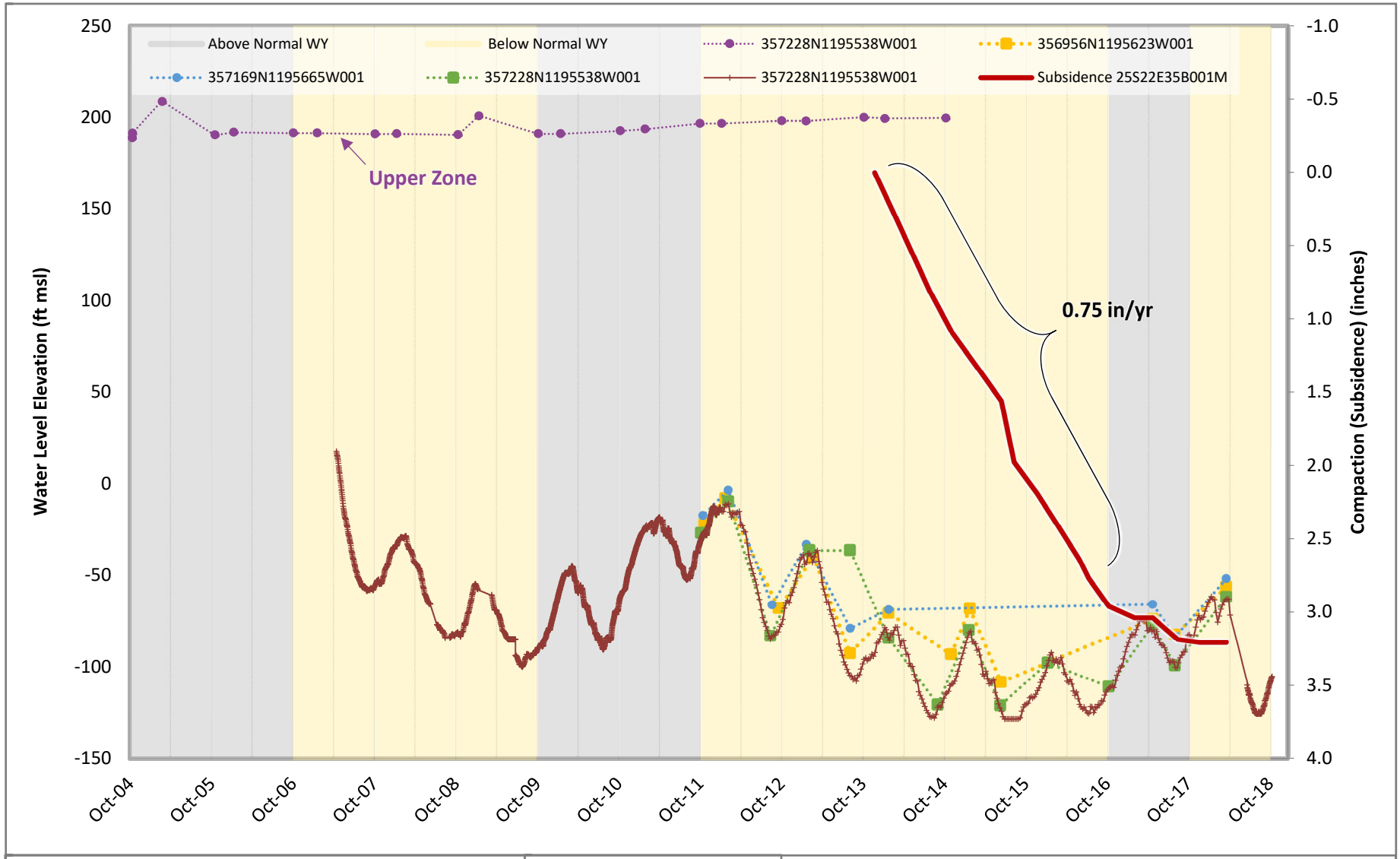
Kern County, CA

GEI Consultants

Time Series Plot:
P565 (Delano CGPS) Subsidence with Nearby Hydrographs

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

Kern County, CA

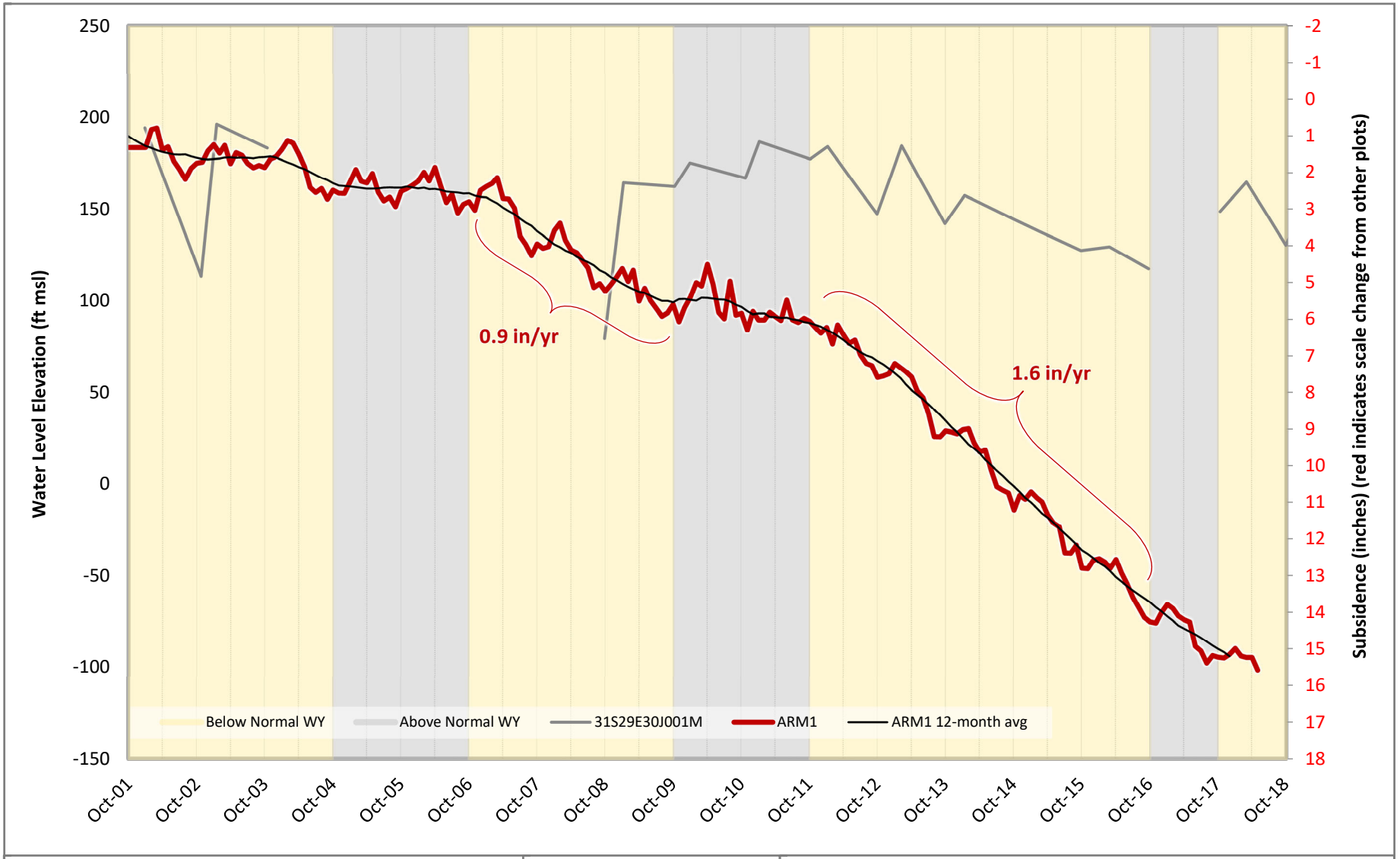
GEI Consultants

Time Series Plot:

SWSD Extensometer and Nearby Hydrographs

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

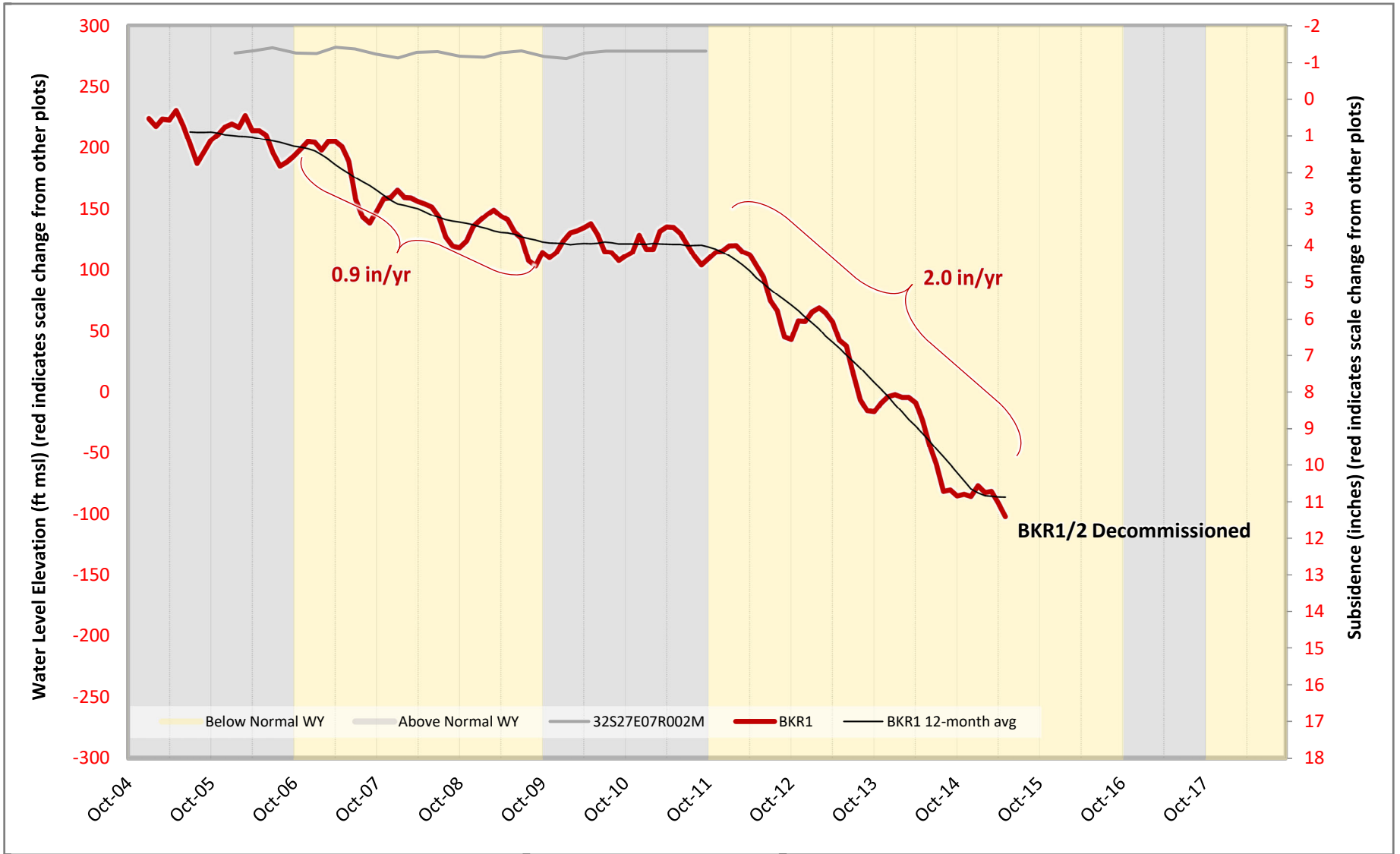
Kern County, CA

GEI Consultants

Time Series Plot:
ARM1 and 2 (Arvin CGPS) Subsidence

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

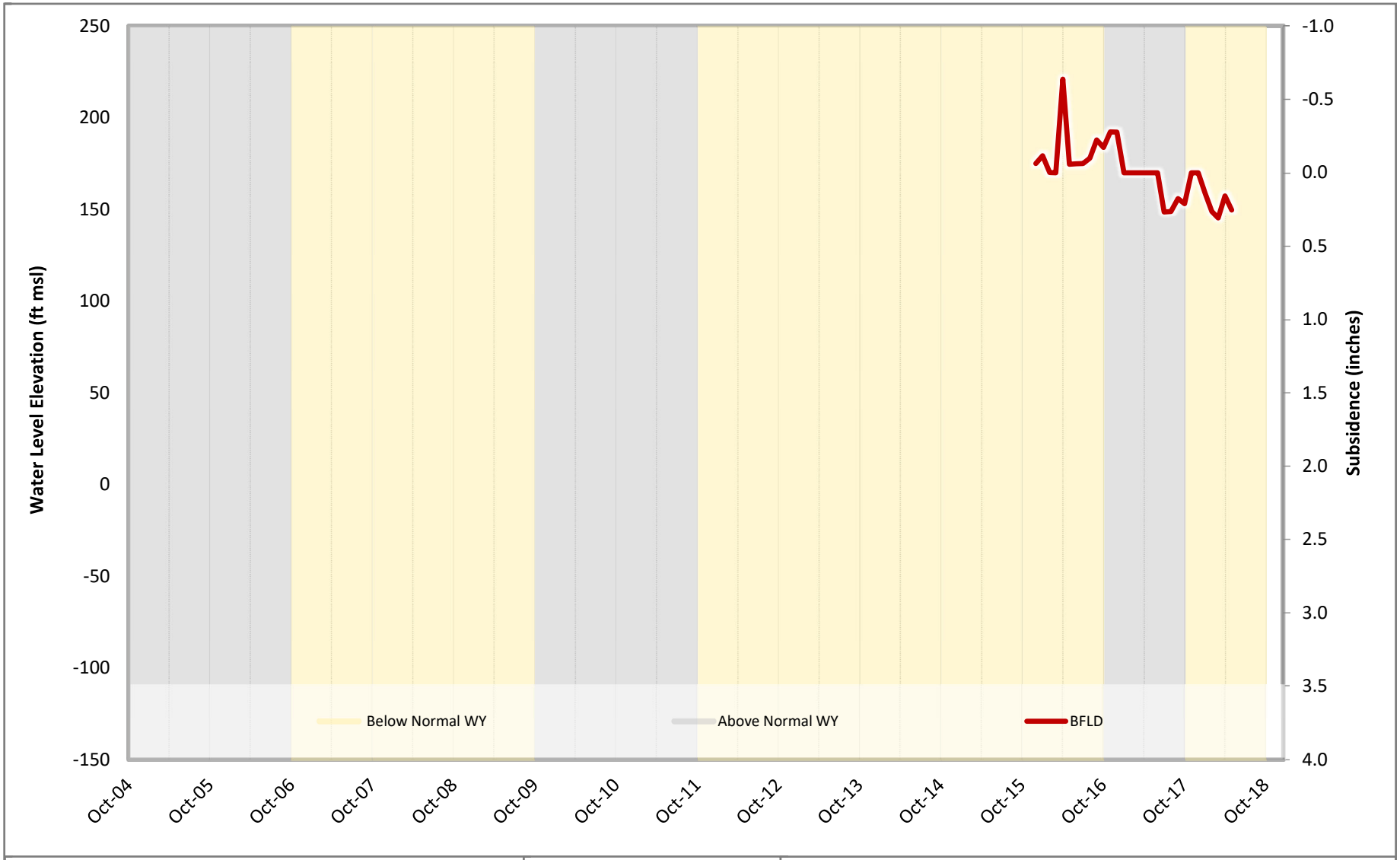
Kern County, CA

GEI Consultants

Time Series Plot:
BKR1 Subsidence and Nearby Hydrographs

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

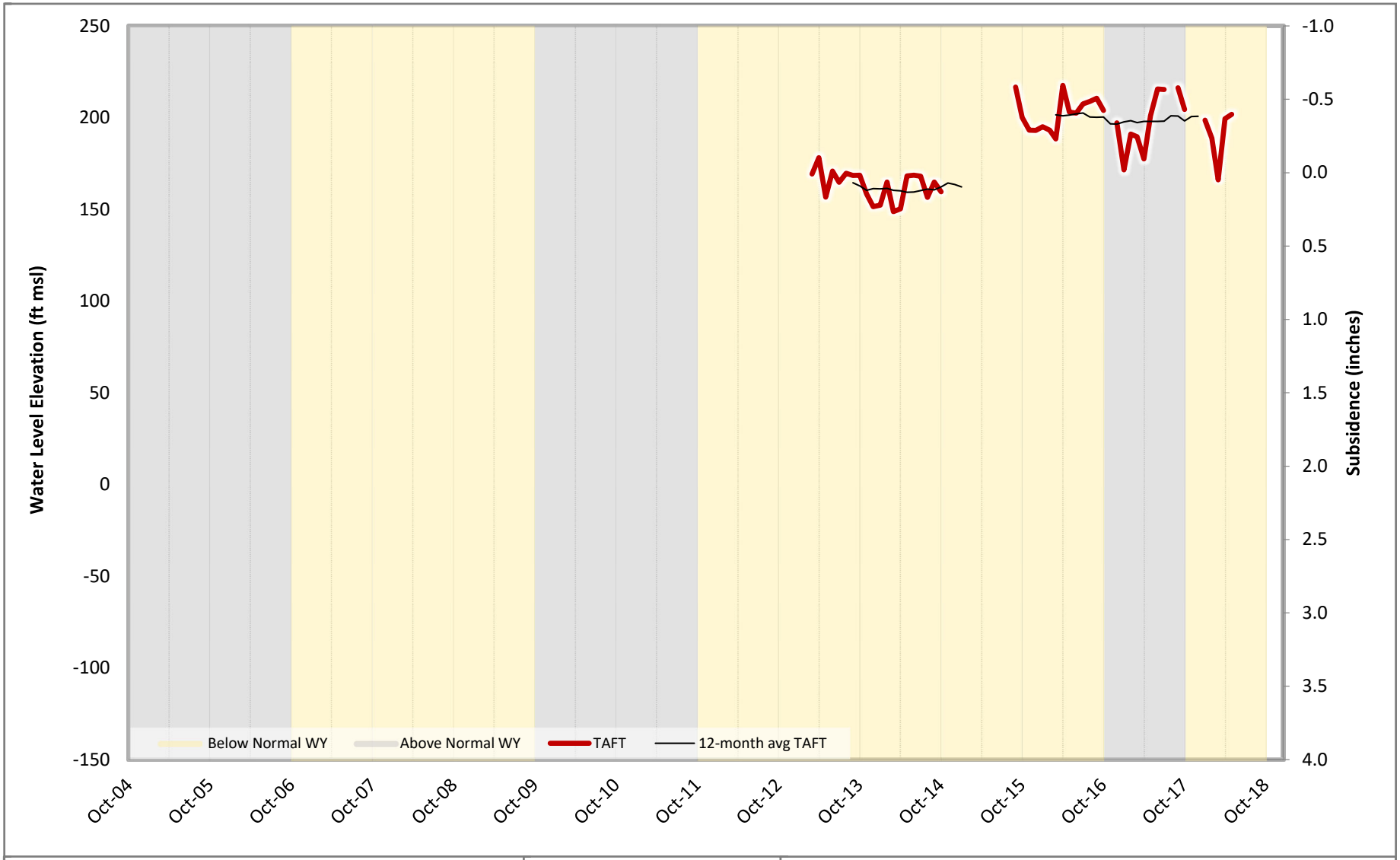
Kern County, CA

GEI Consultants

Time Series Plot:
BFLD Subsidence and Nearby Hydrographs

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

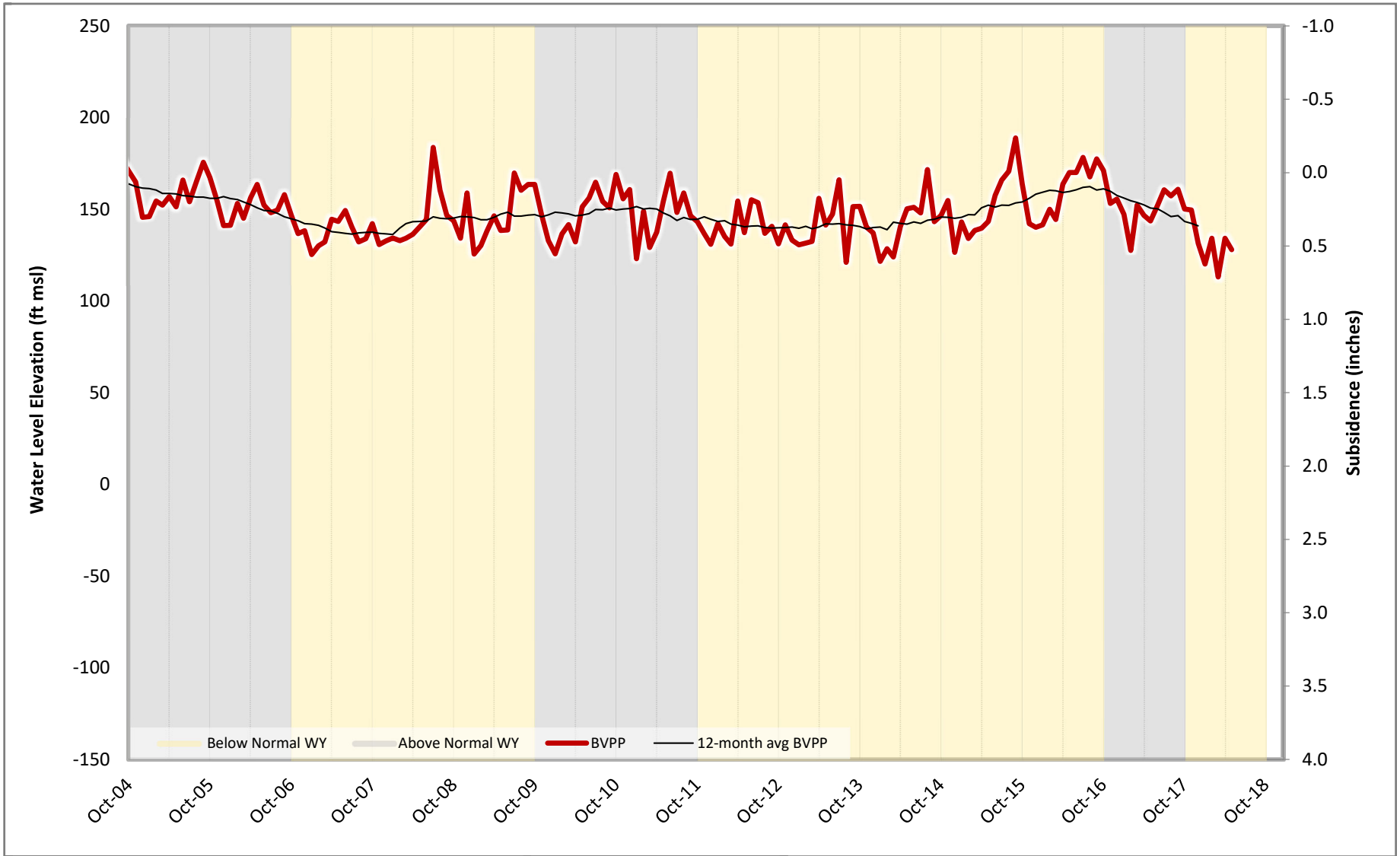
Kern County, CA

GEI Consultants

Time Series Plot:
TAFT Subsidence and Nearby Hydrographs

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

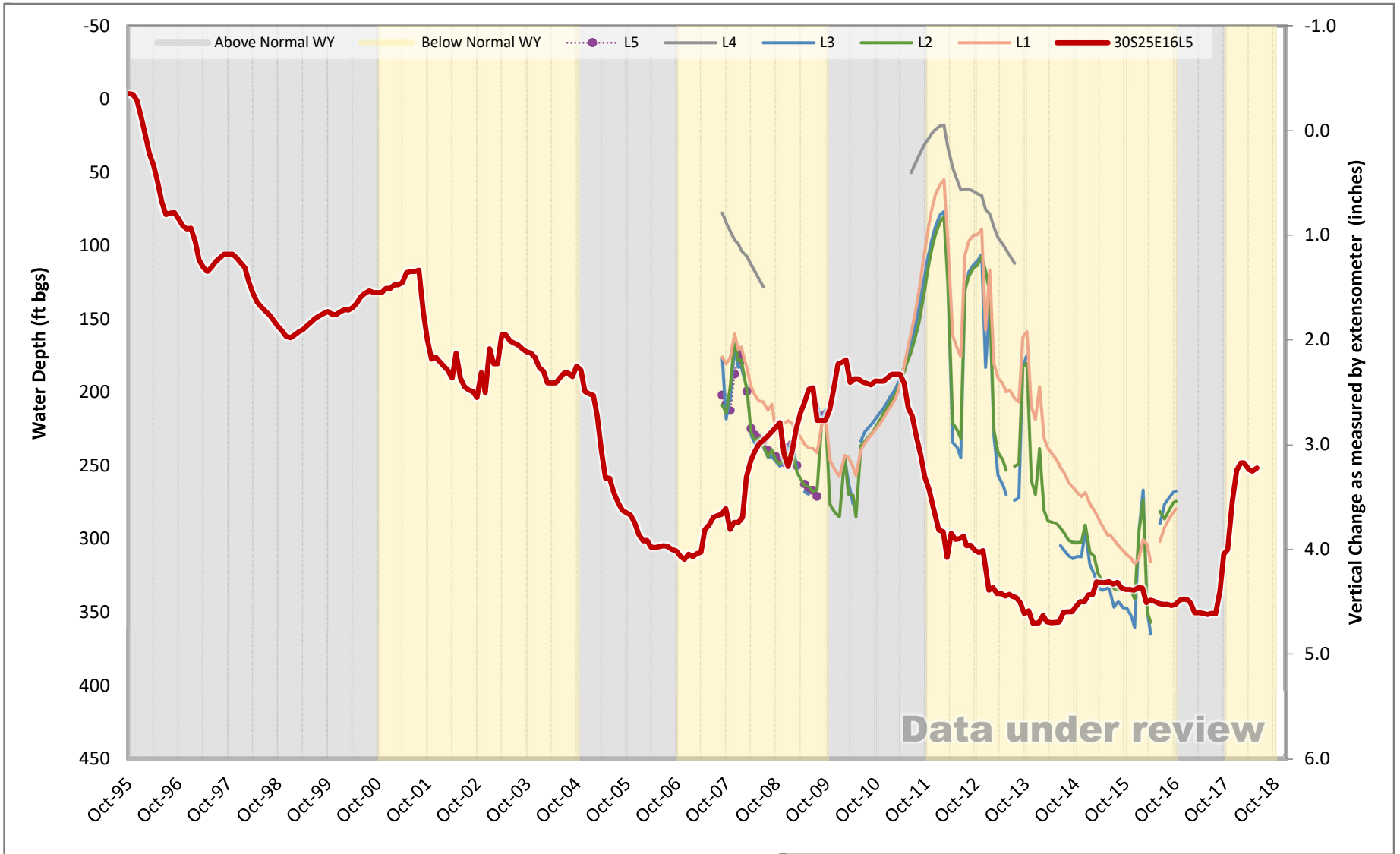
Kern County, CA

GEI Consultants

Time Series Plot:
BVPP Subsidence

February 2019

Figure X



Hydrogeologic Conceptual Model
Kern County Subbasin

Kern County, CA

GEI Consultants

Time Series Plot:
30S25E16L Kern Fan Extensometer with Nearby Hydrographs

May 2019 | **DRAFT** | **Figure X**

Kern Groundwater Authority Groundwater Sustainability Agency
Groundwater Sustainability Plan

ATTACHMENT H

SGMA Water Budget Development Using C2VSimFG-Kern in Support of the Kern County Subbasin Groundwater Sustainability Plans

TODD GROUNDWATER

January 7, 2020

MEMORANDUM

To: Mark Mulkay, Kern River GSA
Patty Poire, Kern Groundwater Authority GSA

From: Michael Maley, Todd Groundwater
Charles Brush, Hydrolytics LLC

Re: **SGMA Water Budget Development using C2VSimFG-Kern in support of the Kern County Subbasin Groundwater Sustainability Plans (GSPs)**

1. INTRODUCTION

In compliance with the Sustainable Groundwater Management Act (SGMA), the multiple Groundwater Sustainability Agencies (GSAs) of the Kern County Subbasin (**Figure 1**) have successfully coordinated on the development of Groundwater Sustainability Plans (GSPs). The Kern County Subbasin, the largest in the State, was designated as critically-overdrafted by the California Department of Water Resources (DWR). Water management in the Kern County Subbasin is complex. It involves more than 30 water districts/systems, contains large groundwater banking projects of State-wide importance, and provides large quantities of groundwater to support both large urban centers and one of the top agricultural-producing areas in the country. In addition, most agencies are involved in conjunctive management of local surface water, imported state and federal water, and groundwater.

Within this complex water management setting, GSAs recognized that a numerical modeling tool would be needed to meet GSP regulations for assessment of historical, current, and future projected water budgets that are developed on a Subbasin-wide basis (§357.4(b)(3)). The California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) is anticipated to be DWR's primary tool for evaluating water management in the Central Valley and is specifically referenced in the GSP regulations for application to GSP water budgets (§354.18(f)); therefore, C2VSim was selected by the GSAs for GSP compliance.

This technical memorandum describes the process and approach for selection, revisions, and application of the C2VSim to the Kern County Subbasin. The memorandum documents the development of Subbasin water budgets and presents the results. This document is being prepared as an attachment to Subbasin GSPs and as an attachment to the Kern County Subbasin GSAs' coordination agreement.

1.1 Background

During late 2016 and 2017, Subbasin GSAs held a series of meetings and workshops to evaluate potential modeling tools for GSP application. Although numerous existing models had been developed by various entities in the Subbasin over time, none of those models covered the entire Subbasin or incorporated all of the local water budget components necessary to meet GSP requirements.

During the time that the Subbasin was evaluating various modeling alternatives, DWR was in the process of updating the regional C2VSim model through water year (WY) 2015. In particular, the GSP regulations stated that DWR would provide the C2VSim model "for use by Agencies in developing the water budget." Todd Groundwater developed an approach for review, revisions, and application of the C2VSim model to the Kern County Subbasin. In March 2017, the Kern River GSA (KRGSA), on behalf of the Subbasin GSAs, entered into a contract with Todd Groundwater to conduct the proposed scope of work. The Kern Groundwater Authority (KGA), on behalf of the Subbasin GSAs, also retained Woodard & Curran to conduct a peer review of the Todd Groundwater C2VSim model revisions and application for the Kern County Subbasin.

DWR released the C2VSim Fine Grid Public Beta model (C2VSimFG-Beta) on May 18, 2018 (CNRA, 2018). An initial model review indicated that the C2VSimFG-Beta generally had good historical precipitation, streamflow, land use and crop acreage for the entire Central Valley. Historical water supply and demand data were also generally good in the Sacramento Valley and San Joaquin River hydrologic regions; however, data were considered less reliable in the Tulare Lake hydrologic region including Kern County. To address this concern, Todd Groundwater – working with all Subbasin GSAs –revised the Kern County portion of C2VSimFG-Beta for WY1985 to WY2015. This revised version of C2VSim for the Kern County Subbasin, referred to herein as the C2VSimFG-Kern model, was used to develop historical, current and projected-future water budgets in accordance with the requirements in the GSP regulations.

The Central Valley portion of Kern County contains two groundwater subbasins, the Kern County Subbasin (5-022.14) and the White Wolf Subbasin (5-22.18) based on DWR Bulletin 118 (DWR, 2016A). All of the agencies that deliver water in White Wolf Subbasin also deliver water in the Kern County Subbasin and participated in the C2VSim revision. The White Wolf Subbasin portion of C2VSimFG-Beta model was included in this update to ensure coordination of groundwater conditions between the two subbasins. These are considered separate groundwater basins under SGMA with the Kern County Subbasin listed by DWR as critically-overdrafted with a GSP deadline of January 30, 2020, whereas the White Wolf Subbasin is listed as medium priority with a GSP deadline of January 30, 2022. Therefore, only the model results for the Kern County Subbasin are evaluated and reported here.

1.2 General Approach

The current C2VSim model has a detailed finite element mesh that closely follows local hydrologic features. As a regional model, the C2VSimFG-Beta may over-generalize local conditions within the Kern County Subbasin so as to be inconsistent with local site-specific data and knowledge. To address this concern, the managed water supply and demand inputs were updated to better represent the local water balance. To do this, the more general assumptions in C2VSimFG-Beta were replaced with local data and knowledge that are regionally or locally significant over the WY1995 to WY2015 Hydrology Period. Local managed water supply input data (e.g., surface water deliveries, land use, irrigation demand, return flows, and groundwater banking) were collected and applied to C2VSim. Improvement of Kern County data focused on incorporating:

- Surface water delivery volumes, application areas and use by water district,
- Groundwater banking recharge, recovery and application of recovered water,
- Irrigation demand from recent analyses of remote sensing data of evapotranspiration in the Kern County Subbasin based (ITRC, 2017),
- Urban demand for the Subbasin focusing on Metropolitan Bakersfield, and
- Data on other water sources and demands of local significance to individual districts/GSAs.

Compiling the data needed for the model revision required a coordinated effort from the Subbasin GSAs (**Figure 1**) to provide locally derived data on managed water supply and demand that was used to revise the C2VSimFG-Beta for the Kern County Subbasin. The Subbasin GSAs also coordinated on selection of consistent study periods for the C2VSimFG-Kern water budget analyses. Based on technical considerations and a review of regional data, the following study periods were selected:

- Historical Water Budget - WY1995 through WY2014 (Section 3.2), and
- Current Water Budget - WY2015 (Section 3.2),
- Projected Water Budget - WY2021 through WY2070 using 50 years of hydrologic data based on historical data (Section 6.1).

Todd Groundwater also coordinated data collection and model revision efforts with a Technical Peer Review Team and local agencies to ensure input data were accurately represented in the model. Tabulated input data, model files and model-derived water budgets were provided to the Technical Peer Review Team for review of accuracy and appropriateness. Model input data and results were also provided to Kern County Subbasin water districts and local water purveyors for their review. Comments and data issues were reconciled and incorporated into the revised C2VSimFG-Kern model.

1.3 Acknowledgements

These regional model revisions were enhanced by the participation of the many agencies that provided local water budget input data. Todd Groundwater worked with the member agencies, and their consultants, including the Kern River GSA, Kern Groundwater Authority GSA, Henry Miller Water District GSA, Olcese Water District GSA, and Buena Vista GSA to coordinate acquisition of input data from other agencies in formats that could be easily incorporated into the C2VSim model. On-going review of interim model results by these agencies, including local zonal water budgets, groundwater hydrographs and other model results, helped ensure that the revised model reproduced local mass balance estimates across the Subbasin.

Woodard & Curran conducted an on-going peer review of model input files at the request of the GSAs in the Kern County Subbasin. Todd Groundwater worked with Woodard & Curran throughout the historical model revision process. The C2VSimFG-Kern input files for the Kern County Subbasin revised historical simulation were provided to DWR for incorporation into future C2VSim public releases.

Dr. Charles Brush of Hydrolytics LLC was added to the Todd Groundwater modeling team. As an early developer of C2VSim for DWR, he provided his experience and expertise with the C2VSim. This collaborative effort provided further assurance that the significant model revisions could be managed in an efficient manner to meet the expedited schedule for water budget development.

2. C2VSIM

C2VSim uses DWR's modeling code *Integrated Water Flow Model* (IWFM) and covers the entire California Central Valley. Kern County is located at the far southern end of the Central Valley (**Figure 2**). C2VSim simulates the full hydrologic cycle, calculating water demands and tracking water movement through surface water and groundwater systems, and is therefore well suited to support GSP development.

2.1 C2VSim Background

DWR developed C2VSim to simulate water demands and supplies in the Central Valley. C2VSim is an application of DWR's IWFM software. IWFM is an integrated hydrologic model that simulates water flows on the linked land surface, unsaturated zone, groundwater, and surface water flow systems. A key feature of IWFM is DWR's agricultural and urban water supply and demand management module that dynamically simulates the delivery of both surface water and groundwater supplies based on both water availability and calculated water demands, as affected by usage and climatic conditions.

The C2VSim is derived from a series of Central Valley hydrologic models developed by DWR and other agencies beginning in the early 1990s. Each model in this series has incorporated significant improvements over the previous version (Brush, Dogrul and Kadir, 2013). The groundwater flow system is modeled in IWFM using the finite element method and uses a highly efficient solver developed at UC Davis. The IWFM Demand Calculator (IDC) and land surface simulation process were developed with input from California irrigation management professionals. Given DWR's emphasis on water management, detailed water budgets produced by C2VSim provide strong representations of the surface water and groundwater flow systems and make it a preferred platform for developing water budgets.

2.2 C2VSImFG-Beta Model

DWR's 2018 release of C2VSimFG-Beta includes historical input data for WY1922 to WY2015. C2VSimFG-Beta includes historical precipitation, stream inflow, land use and crop acreage for the entire Central Valley. These data include monthly precipitation and annual land use for each model element and estimated monthly evapotranspiration for each modeled land use type and agricultural crop. Historical surface water data include monthly surface water inflow for each river entering the model boundary and monthly surface water diversions and deliveries.

The C2VSimFG-Beta finite element grid divides the Central Valley into 32,537 model elements (**Figure 2**). Element areas are small near streams and in developed areas and expand to larger sizes in undeveloped areas. Element sizes average 407 acres and range from 4 to 1,770 acres. Central Valley rivers and streams are represented with a network of 110 stream reaches. Surface water and groundwater inflows from uplands along the model boundary are simulated with 1,033 small watersheds. Within the Kern County Subbasin, the land surface elevation varies from 208 feet above mean sea level (msl) in the north to 3,922 feet above msl in the foothills.

The groundwater aquifer system is represented with four aquifer layers and one regional confining layer. The aquifer thickness in the Kern County Subbasin varies from 857 to 9,054 feet and the deepest aquifer location is 8,752 feet below msl. The Central Valley aquifer is simulated with the following hydrostratigraphic layers, listed from top to bottom:

- Shallow, unconfined aquifer,
- Regional confining layer,
- Active confined aquifer (contains high level of pumping),
- Inactive confined aquifer (contains limited pumping), and
- Saline confined aquifer.

C2VSimFG-Beta includes annual land use and crop acreages and monthly precipitation, evapotranspiration, stream inflows, surface water deliveries and specified groundwater pumping rates for WY1922 to WY2015. C2VSimFG-Beta uses IDC to dynamically calculate distributed monthly water demands, allocate available water supplies to meet these demands, and calculate unmetered groundwater pumping necessary to satisfy unmet demands. C2VSimFG-Beta produces detailed monthly water budgets for arbitrary sets of elements grouped into zones.

Water demands are calculated dynamically for each model element using the IWFM Demand Calculator (IDC) for agricultural, urban, native and riparian land use types. Agricultural demand is calculated based on annual crop type distribution mapping and user-specified evapotranspiration rates for 20 irrigated crop types and managed seasonal wetlands at the Kern National Wildlife Refuge. Agricultural water demand is determined based on a soil moisture balance that uses local soil properties to assess the amount of applied water (precipitation and specified surface water applications) available to meet the crop demand. If water demands in an element are not satisfied from these sources, the C2VSim model calculates the groundwater pumping needed to eliminate any deficit.

Urban demands are calculated based on population and per-capita water demands. Water demands for native, undeveloped, fallow or riparian settings are calculated from monthly evapotranspiration rates and the amount of precipitation. If water demands in an element are not satisfied, no applied water is provided to these areas, and the vegetation is assumed to be in a stressed state. Runoff of precipitation in developed and undeveloped areas within the Subbasin and surrounding small watersheds is calculated using methodology included in IWFM that is based on the Soil Conservation Service Curve Method (NRCS, 2004).

C2VSimFG-Beta was released after a preliminary model calibration. The distribution of aquifer parameters was based on a texture analysis of lithologic well logs compiled by the US Geological Survey (USGS, 2009) from Well Completion Reports submitted to DWR by well drillers. The texture analysis interpolated the percentage of coarse-grained material at each well location and depth of the C2VSimFG-Beta mesh. Aquifer parameters were then calculated for the model mesh based on the percentage of coarse-grained material and estimated properties for pure coarse- and fine-grained materials. Transmissivities were estimated using specific capacity tests, where available. Soil properties for each model element were derived from digitized soil maps published by the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS, 2018).

3. KERN COUNTY REVISIONS

C2VSimFG-Beta input files were revised to incorporate locally-derived managed water supply and demand data to better represent the local water budgets for the Kern County Subbasin. Additional revisions were made to C2VSimFG-Beta model to address issues that were identified with the physical representation of the Kern County Subbasin. The result of these Kern County specific modifications is a local version of C2VSimFG-Beta that is referred to here as C2VSimFG-Kern. The following provides a summary of the model modifications.

3.1 C2VSimFG-Kern Model

C2VSimFG-Kern input files incorporate locally-derived historical data for the Kern County and White Wolf subbasins to better represent local water conditions. These are two separate groundwater subbasins in the Kern County portion of the San Joaquin Groundwater Basin. The Kern County Subbasin is listed as critically-overdrafted by DWR with a GSP deadline of January 30, 2020, whereas the White Wolf Subbasin is listed as medium priority by DWR with a GSP deadline of January 30, 2022. C2VSimFG-Kern was not changed for areas outside of the Kern County Subbasin.

Historical surface water diversion, water bank recharge and water bank withdrawal information were collected from local GSAs, management areas, water agencies and purveyors. Urban land use was restricted to developed areas, and urban populations and per-capita water demands were updated. Model structure (elements, streams, stratigraphy, etc.) was not modified. Model parameters were not calibrated, although some model parameters were adjusted to improve model performance in specific geographic areas.

3.2 Simulation Time Period

GSP requirements indicate a need to identify an average hydrologic study period for purposes of the groundwater analyses in the basin-wide water budgets. In order to select a consistent study period, the Kern County Subbasin GSAs agreed upon an historical hydrologic study period covering WY1995 through WY2014 (October 1, 1994 through September 30, 2014). The selection of the historical hydrologic study period was based on a variety of technical criteria including:

- Covers at least 10 years consistent with GSP regulations (§354.18(c)(2)(B)),
- Contains 10 years characterized as above normal or wet years based on precipitation; also contains 10 years of below normal or dry years, including four critically dry years,
- 100 percent of the long-term average streamflow conditions on the Kern River, as indicated by an average annual Kern River Index of 100 percent (**Figure 4**),
- About 104 percent of long-term average precipitation (NOAA Bakersfield Meadows Field Airport Station),
- Widely-available high-quality data available across the Subbasin,
- Time period with current water management practices, intensive groundwater banking operations, and more recent land use patterns,
- Begins in a time of relatively stable water levels (October 1994), and
- Overlaps a time period with consistently developed basin-wide contour maps by Kern County Water Agency (KCWA).

For the historical water budget, it is desirable to define a base period when natural hydrology represents average conditions. C2VSimFG-Kern incorporates this 20-year base period of WY1995 through WY2014 with a 10-year spin-up period (WY1985 to WY1994).

Kern County water agencies provided locally-derived water budget data for WY1993 to WY2015 for this study so that data input extended beyond the historical base period. Additional water budget data prior to WY1993 were also collected where available and input into the model.

The simulation period for C2VSimFG-Kern was set to WY1986 to WY2015 (October 1, 1985 through September 30, 2015), allowing a 10-year spin-before the start of the historical base period. The C2VSimFG-Beta simulation period ran from October 1973 through September 2015 (WY1974 to WY2015). The period from October 1973 to September 1985 was not included in the simulation due to concerns about lack of comparable data from these earlier periods.

3.3 Data Compilation

Participating agencies compiled water budget input data sets (using their staff, consultants or other resources) and provided them to Todd Groundwater. Where appropriate, Todd Groundwater developed data templates that conformed to IWFM model data needs and used them to facilitate obtaining input data from local agencies. This included monthly data for the following:

- Surface water imports and diversions (inflows and outflows) by source, conveyance and application area,
- Groundwater banking and managed aquifer recharge by water district or agency,
- Groundwater recovery pumping of groundwater bank recharge for export from the basin,
- Groundwater recovery pumping of managed aquifer recharge for local use,
- Urban area population and per capita water use, and
- Crop evapotranspiration (ET) rates based an analysis of satellite data (ITRC, 2017).

In addition, groundwater banking data were compiled for the large Kern Fan banking projects. Recently developed crop ET rates derived from remote sensing data were used to develop monthly crop ET rates for agricultural crops. Urban land use was restricted to developed areas, urban populations and per-capita water demands were updated, and urban wastewater recharge operations were added.

3.4 Surface Water

Kern County surface water diversions in C2VSimFG-Beta were grouped by project or water source, and some surface water deliveries were applied to large regions rather than to individual districts. In addition, some local surface water deliveries were missing from C2VSimFG-Beta. For C2VSimFG-Kern, the 43 Kern County surface water diversions from C2VSimFG-Beta were replaced with 113 surface water diversions developed with data provided by local agencies.

The Arvin-Edison WSD, Wheeler Ridge-Maricopa WSD and Tejon-Castaic WD overlie both the Kern County and White Wolf subbasins. Surface water deliveries for these districts were apportioned to either the Kern County and White Wolf subbasins, based on data provided by Arvin-Edison WSD and Wheeler Ridge-Maricopa WSD, so that surface water deliveries to those areas could be tracked separately for the water budgets.

3.4.1 River and Stream Inflow

Inflows to the Kern River and Poso Creek at the Subbasin boundary are based on historical gauge data. Kern River inflows at the First Point gauge and downstream gauges were verified and updated based on the annual Kern River Hydrographic Reports produced by the City of Bakersfield (COB, 1985-2015). C2VSimFG-Beta contained Poso Creek inflows for WY1961 to WY1986. Poso Creek inflows for WY1987 to WY2015, based from flow records for the Coffee Canyon and Trenton stream gauges, were added to C2VSimFG-Kern based on data provided by the local agencies.

3.4.2 Surface Water Diversions

Monthly surface water diversion data for WY1995 to WY2015 were collected for 21 agencies and recharge projects in Kern County. The data from each water district or agency included monthly surface water inflow by source and monthly surface water outflow by destination.

The monthly surface water inflow and outflow data collected for this study did not have sufficient detail to track this water and create an accurate historical water budget for each canal for each month. The data did provide sufficient information to identify monthly surface water diversions from each source and deliveries to each end use. Therefore,

- All diversions from the Kern River were exported from the model and treated as imports at delivery locations,
- Diversions from Poso Creek and the Kern River Flood Channel (or Main Drain) were diverted from the appropriate stream nodes, and
- All other surface water deliveries (State Water Project (SWP), Central Valley Project (CVP), oil field recovery water, etc.) were treated as imports.

Each C2VSim surface water diversion is linked to two groups of model elements: the elements of the end use and the elements receiving the recoverable losses. A single set of elements was used for both purposes in C2VSimFG-Kern. Model elements for agricultural, urban and refuge deliveries were selected by overlaying the model grid on delivery areas maps. Model elements for recharge diversions were selected by overlaying the model grid on recharge basin maps.

Monthly water delivery data for the SWP, CVP and Kern River were also provided by the agencies. Monthly turnout-level deliveries for the SWP were also compiled from the monthly SWP Report of Operations published by DWR. Monthly CVP deliveries were compiled from the USBR Report of Operations. Monthly Kern River flow and diversions were compiled from Kern River Hydrographic Reports. Water agencies in the Kern County Subbasin trade and wheel water in real time to maximize water utilization, minimize waste and energy consumption, and meet immediate water needs. Water delivery reports from water suppliers (such as the CVP and SWP) generally identify the owner of delivered water, not where it was actually delivered.

Some surface water conveyances discharge water into stream or river channels for re-diversion downstream. A key part of the surface water system in Kern County is the Kern River. Kern River operations data were reviewed for calendar years 1970 to 2015. While **Table 1** summarizes surface water deliveries, **Table 2** summarizes Kern River diversions by turnout location as applied in C2VSimFG-Kern.

3.4.3 Surface Water Deliveries

Water flow through the Kern River and its associated canal system is very complex. Water is diverted from the Kern River into a parallel canal system at several locations, with some diverted water flowing

back to the river. Some water from the CVP and SWP are discharged into the Kern River for diversion downstream. Some water agencies are served from multiple diversion points along the Kern River. Several canals that receive water diverted from the Kern River also exchange water with other canals and receive some water from groundwater pump-in, so deliveries from many canals cannot be attributed to a single source. **Figure 5** shows the locations of the primary streams, regional surface water canals, and groundwater recharge locations in the Kern County Subbasin.

Each surface water diversion in C2VSim is allocated to a specified destination and water use. Five water use types are simulated in C2VSimFG-Kern: agricultural, urban, refuge, recharge and export. Agricultural and refuge diversions are applied to a group of model elements that corresponds to a surface water service area within a specific water agency or refuge. Urban diversions are allocated to an urban service area. Groundwater recharge diversions are allocated to the model element or elements where the receiving recharge basin is located. Three delivery fractions apportion each surface water diversion to application, loss to groundwater (recoverable loss), and loss to evaporation (non-recoverable loss). **Table 1** summarizes the annual surface water deliveries for agricultural use by water district in Kern County. **Table 3** summarizes surface water diversions for urban use, wastewater land disposal and wildlife refuge management in Kern County.

3.5 Groundwater Banking and Managed Aquifer Recharge Operations

In our preliminary discussions with the C2VSim developers at DWR, it was revealed that significant model uncertainty was related to incomplete data regarding groundwater banking and other managed aquifer recharge (MAR) operations in the Kern County Subbasin. Recognizing the importance of these groundwater banking projects for simulating groundwater conditions, the groundwater banking and MAR operations data was updated using the earliest available records.

3.5.1 Recharge and Recovery Data

A monthly time-series of recharge rates was determined for each recharge project. Recharge rates were allocated to individual recharge basins using the initial data whenever possible or were shared proportionally between basins based on historical rates. All Kern County recharge basin surface water deliveries were simulated as imports.

Recharge basin locations and recovery well locations were provided by each agency or project (**Figure 6**). The C2VSim finite element grid was overlaid onto a map of recharge basins to determine the model elements for each recharge location. Well location coordinates were added to C2VSimFG-Kern.

Monthly volumes for recharge at groundwater banking and managed aquifer recharge facilities were compiled for 16 agencies and projects (**Table 4**). This information originated from multiple sources, and included data provided by agencies, compiled from agency reports, and compiled from Kern River Hydrographic Reports. The data includes monthly recharge for years prior to 1995 for many projects. Several agencies and projects provided data for multiple recharge basins. Some groundwater wells used for recovery of banked water are also used for other purposes such as supplementing agricultural or urban surface water deliveries.

Recognizing that several of the large groundwater banking projects (especially those on the Kern Fan) pre-date the 20-year base period, and that future studies might simulate periods prior to 1985, all available historical data for groundwater banking operations was reviewed and updated. This included incorporating pre-1985 data for banking operations at

- Arvin-Edison WSD (1966-2015),
- Berrenda Mesa Project (1977-2015),
- Buena Vista WSD (1963-2015),
- City of Bakersfield 2800 Recharge Facilities (1973-2015),
- North Kern WSD (1956-2017), and
- Rosedale-Rio Bravo WSD (1980-2015).

3.5.2 Groundwater Recovery

Two types of recovery wells were added to the C2VSimFG-Kern. These include district-operated water wells that were used for out-of-district transfers or out-of-basin exports of groundwater, and wells used for recovering banked groundwater and distributing the pumped groundwater via the district's water conveyance system to provide water supply, typically for agricultural use, within the district. The locations of the specified groundwater recovery wells are shown on **Figure 6**. The specified groundwater recovery pumping input into C2VSimFG-Kern is summarized as follows:

- 229 time series for Kern County groundwater banking withdrawals were added,
- 313 simulated pumping wells and 225 pumping time series for local groundwater pumping by district-operated recovery wells were added, and
- Elemental agricultural, refuge and urban pumping was eliminated in areas where it has not historically occurred.

Recharge and withdrawal data for the Kern Fan banking projects, including the Kern Water Bank, Berrenda Mesa Project, Pioneer Project, and the City of Bakersfield 2800 Recharge Facilities were shared with the local banking authorities for verification. Banking data for district-specific groundwater banking projects were provided by these districts. A summary of the data input for groundwater recovery pumpage added to C2VSimFG-Kern is provided in **Table 5**.

3.5.3 Model Application

A separate diversion was created to deliver surface water to each recharge basin or set of geographically close jointly managed basins. A diversion time series of monthly application rates was then created for each recharge diversion from the available data. Each recharge diversion delivers water to the model elements coinciding with the receiving recharge basin(s). Recharge basins were simulated in C2VSimFG-Kern by setting the application delivery fraction to zero, the recoverable loss fraction to 94% and the evaporation loss to 6%.

Monthly groundwater recovery was generally provided by well field and destination (e.g., agriculture, urban, canal pump-in, or export). This information was used to develop a pumping time series for each well field and destination. Groundwater pumped for export from the Kern County Subbasin is summarized in **Table 6**. Recovery well locations and screen intervals were used to enter each recovery well into C2VSimFG-Kern. Recovery pumping time series were then allocated equally to all of the wells in each field.

Some well fields supply water to two different end uses, for example supplementing surface water deliveries within the district in some months and exporting water from the district in other months. This is handled in C2VSimFG-Kern by entering the well two times. Each entry is associated with a separate time series of pumping rates and delivery destination.

3.5.4 Groundwater Banking Obligations

The general operation of groundwater banking facilities is to recharge excess available surface water supplies during wet years by recharging to the groundwater and recovering this water by pumping in dry years when surface water supplies are limited. Groundwater banking programs store water in the Kern County Subbasin for use by local agencies and for export to out-of-basin entities.

For evaluating the groundwater sustainability, any water stored in the Kern County Subbasin that is contractually obligated to an out-of-basin entity does not contribute to the long-term groundwater sustainability because the owner of that water could call for its return at any time. However, this can be difficult to track because a common practice is to recover groundwater for local use to replace imported surface water that was sent to the out-of-basin entity.

C2VSimFG-Kern does not have a mechanism to track these complex contractual exchanges, so the tracking is done as a post processing step by assigning the portion of the groundwater recharge as an out-of-basin banking obligation.

The Kern County Subbasin GSAs provided the total out-of-basin banking obligation for their operations as of September 2014 for the historical assessment. As of September 2014, the out-of-basin banking obligation for the Kern County Subbasin totaled of 1,719,307 acre-feet, which, when averaged over the 20-year period, was 85,965 acre-feet per year (AFY). The 85,965 AFY is applied during post-processing of C2VSimFG-Kern historical water budget results.

3.6 Urban Water Demand

C2VSim calculates urban water demands for specified urban delivery zones, allocates specified surface water and groundwater supplies to meet these demands, and can optionally pump additional groundwater to satisfy unmet urban demands in each zone. Urban demands were represented with nine urban zones in C2VSimFG-Beta. These zones were reconfigured, and a tenth urban zone was added representing Metropolitan Bakersfield in C2VSimFG-Kern. Historical urban populations and per capita water use rates were reviewed and updated.

3.6.1 Urban Zones

C2VSimFG-Kern dynamically calculates urban water demands for urban zones using time-series data of urban populations and monthly per capita water use. The urban delivery zones of C2VSimFG-Beta were modified to better represent Kern County population centers, jurisdictional boundaries and urban water sources. Although Kern County urban water delivery systems are operated by many diverse entities, their water generally comes from two sources: surface water deliveries and agency-operated groundwater wells.

The nine Kern County urban zones in C2VSimFG-Beta for Kern County were numbered 97-105. The Urban Zone boundaries were adjusted, as shown on **Figure 7**, as follows:

- Portions of Urban Zones 97, 99, 100, and 102 in C2VSimFG-Beta were used to create Urban Zone 106 representing the Metropolitan Bakersfield area,
- Urban Zone 98 was extended southeast to near the Stockdale Highway to include unincorporated urban areas,
- The boundary of Urban Zone 99 was extended eastward to California State Route 65 to include small communities in this area, removing them from Urban Zone 100, and

- The northern boundary of Urban Zone 104 was moved north to correspond to the West Kern WD service area.

3.6.2 Urban Population and Per Capita Use

Historical annual urban populations for the urban zones were estimated using United States Census total population data from 1990, 2000 and 2010 (US Department of Commerce, 2018). Tabular historical census data and census block shapefiles were obtained from the IPUMS National Historical Geographic Information System Database (IPUMS 2018). These data were combined to produce maps of the geographic distributions of populations within Kern County. The historical populations for each Urban Zone were estimated by mapping census block centroids to the ten Urban Zones using ArcGIS. The 1990, 2000 and 2010 populations of each Urban Zone were then estimated as the sum of the populations of the associated census blocks. Populations for other years were estimated using interpolation and extrapolation. The population values by Urban Zone used for C2VSimFG-Kern are listed in **Table 7**.

3.6.3 Urban Water Use Specifications

Monthly historical urban water demands for Urban Zone 106 were calculated using water delivery data from the water purveyors in the Metropolitan Bakersfield area. Monthly historical urban water demands for the other urban zones in the Kern County Subbasin were estimated using available water use data from published urban water management plans for the communities served in those zones. The historical monthly water use in each zone was then divided by the historical population to obtain the monthly per capita urban water demand. Monthly historical per capita water demands for zones without urban water management data were estimated using the per capita water demand from zones with similar demographics.

The urban water use specifications indicate the portion of total urban water that is used indoors. In C2VSimFG-Kern, the portion used indoors becomes urban return flow, and the remainder is added to the urban root zone where it contributes to evapotranspiration and deep percolation. C2VSimFG-Beta included monthly urban water use specifications for each model subregion. The urban per capita water use was based on local water supply data and urban water management plans. **Table 8** lists the per capita water use data used for C2VSimFG-Kern.

3.6.4 Urban Wastewater

Urban wastewater for the Metropolitan Bakersfield area is treated at local wastewater treatment plants; however, wastewater disposal is primarily evaporation ponds or land disposal at locations outside of the Metropolitan Bakersfield area. C2VSimFG-Beta does not have a direct means to redirect wastewater to an outside location. Urban wastewater, based as the indoor use, is applied uniformly within the urban zone. To get around this limitation, application of wastewater for the Metropolitan Bakersfield area was turned off in C2VSimFG-Kern. The wastewater deliveries to evaporation ponds and land disposal areas from the wastewater treatment plants was assigned to the appropriate location using data provided by the plants. This conserved the water balance by not double counting wastewater, and it was applied at the appropriate locations for evaluating groundwater levels.

3.6.5 Model Application

Historical annual urban population estimates were placed in the C2VSimFG-Kern urban population input file. Historical monthly urban per capita water demand estimates for each urban zone were placed in the C2VSimFG-Kern urban per capita water use file. Urban demand was calculated by C2VSimFG-Kern and the water supply to meet these demands was met first by specified surface water and groundwater

pumping deliveries for urban use. The remaining water demand in each model element was met with groundwater pumped from the aquifer portion of that element.

3.7 Agricultural Crop Water Demand

C2VSim dynamically calculates agricultural crop water demands and allocates supplies to meet these demands for each model element. Agricultural demands are calculated for 20 crops using historical crop acreage data and crop evapotranspiration (ETc) rates. Crop water demands in each model element are first met with stored soil moisture, surface water deliveries and specified groundwater deliveries. If the agricultural demands are not satisfied, the model can optionally calculate the additional groundwater pumping required to satisfy the unmet demands and extract that water from the groundwater component of the model element.

C2VSimFG-Beta contained one set of monthly ETc rates for each model subregion that were applied to all years despite climatic variation. New monthly ETc rates for three model subregions (northeast, northwest, south) in Kern County were calculated for 1993-2015 using monthly remote sensing imagery and detailed annual crop maps. ETc for 1974-1992 were estimated from 1993-2015 values by using the values for similar water year types based on the San Joaquin Index. Satellite data were not available for 2012, so ITRC was unable to provide METRIC data for 2012. In C2VSimFG-Kern, 2013 was applied as an appropriate proxy for ETc data in 2012 because of their hydrologic similarity.

A remote sensing study of historical ETc rates across the entire Kern County Subbasin by the Irrigation and Training Research Center (ITRC, 2017) provided detailed basin-wide agricultural demands that corresponded to the WY1995 to WY2014 base period. These data were used to develop monthly ETc rates for the Kern County portion of the model.

3.7.1 ET Rates

The Irrigation Training and Research Center (ITRC) at California Polytechnic State University, San Luis Obispo, has developed a procedure to use remote sensing imagery from Landsat satellites to calculate historic ETc rates (ITRC, 2017). The Mapping of Evapotranspiration with Internal Calibration (METRIC) method was originally developed by Richard Allen of the University of Idaho. ITRC made several modifications to the original METRIC method to better match California data and conditions (named the ITRC-METRIC method). These modifications include using grass for reference evapotranspiration (ETo), incorporating a semi-automated calibration procedure and spatially interpolating ETo rates. An example of the METRIC ET data for the total annual ET in 2013 is provided in **Figure 8**.

ITRC used Landsat imagery for 1994-2015 (except 2012 when no imagery was available) and the ITRC-METRIC method to develop monthly raster maps of ETc at 30 x 30-meter resolution for the Kern County portion of the Central Valley (ITRC, 2017). The monthly ETc raster maps were used with annual DWR crop maps to calculate the average ETc by crop type for the three Kern County C2VSim subregions. ITRC-METRIC raster data were used to determine the exact areas of applied irrigation and total annual ETc. A raster pixel was assumed to be irrigated if the total annual ETc was greater than 20 inches.

The following data processing steps were used to determine monthly ETc rates for each crop and C2VSim subregion:

- Create irrigation coverages – ITRC-METRIC monthly ETc raster data were summed to calculate total annual ETc for each year for each raster location. The ArcGIS Reclassify tool was then used on each annual ETc raster to create a binary polygon coverage for each year for 1994-2015

(except 2012), setting the attribute "IRR" to 1 if total annual ETc was over 20 in/year, and to 0 if total annual ETc was equal to or less than 20 in/year.

- Create land use coverages – Annual DWR land use rasters were converted to polygon coverages with the attribute "Crop" set to the corresponding integer crop value used in C2VSimFG-Kern. The land use rasters were checked against GIS maps produced by the Kern County Agricultural Commissioner and errors in the DWR land use rasters were corrected. DWR land use maps for 1994-1997 were missing large areas of data, so the 1998 land use map was used to approximate the land use for 1994-1997.
- Create monthly zone maps – One zone shapefile was created for each month by using the ArcGIS Union tool to combine a shapefile of the three C2VSim subregions with the irrigation coverage (produced in step 1) and the land use coverage (produced in step 2). Each monthly zone polygon shapefile has three attributes: C2VSim subregion, binary irrigation indicator, and a land use crop value. The dissolve function was used to combine zones with identical parameters.
- Calculate average monthly ETc for each zone – The ArcGIS Zonal Statistics by Table tool was used to calculate the average ETc value for each zone for each month. The individual pixels in each monthly ETc raster were averaged within each zone (produced in step 3). ITRC-METRIC data for 2013 were used in place of missing data for 2012.
- Combine tables – The MS Access Append function was used to combine the monthly ETc tables into a master table of monthly ETc by crop and C2VSim subregion.
- Output data – Data from the Access database was exported in a form consistent with the C2VSimFG-Kern input files. The output was also summarized to show the average monthly ETc for the irrigated area of each crop type in each model subregion.

The monthly ETc rates for the three Kern County subregions for WY 1993-2015 were then replaced with the monthly ETc rates calculated using ITRC-METRIC data. The annual ETc rates applied to C2VSimFG-Kern by crop are listed in **Table 9**.

3.7.2 Irrigation Periods

The C2VSim Irrigation Periods file contains monthly parameters for each crop and subregion that indicate whether or not the crop is irrigated in that month. C2VSimFG-Beta irrigation periods for the three Kern County subregions were adjusted to match crop irrigation practices from ITRC-METRIC water usage. Refuge irrigation periods for the three Kern County subregions were also adjusted to match Kern NWR practices. Simulated irrigation water usage for the C2VSimFG-Kern better reflects observed irrigation practices.

3.8 Model Modifications

In general, the scope of work was to revise the managed water supply and demand for the Kern County Subbasin. During the course of this revision, several issues were identified with the hydrogeological conceptual model and simulation parameters that affected the historical water budget. The following summarizes modifications made in C2VSimFG-Kern to improve the model performance. Other issues identified regarding the hydrogeological conceptual model, model setup and simulation parameters that were not addressed in C2VSimFG-Kern but are recommended to be modified for future model updates, are listed in Section 8.5. A summary of the changes that were made in C2VSimFG-Kern are provided below.

3.8.1 Streambed Parameters

In the Kern County Subbasin, the Kern River and Poso Creek are the two largest streams. Both have multiple stream gauges along their courses including ones near where they enter the Kern County Subbasin from the Sierra Nevada. These are the only two streams that are simulated in the model using the IWFM stream module. Both are predominantly losing streams where surface water recharges groundwater, except during limited periods near the major groundwater banking operations west of Bakersfield when multi-year periods of recharge operations produce high groundwater levels.

As a part of the C2VSimFG-Kern update, the simulated recharge from the Kern River and Poso Creek were compared to changes in stream gauge measurements and estimated streambed losses to evaluate how well the model was simulating streambed seepage. For much of the Kern River, the amount of streambed seepage is estimated based on daily weir information and is documented in the annual Kern River Hydrographic Reports. The streambed parameters used in C2VSimFG-Beta were not providing a comparable volume and distribution of seepage along the Kern River streambed. In dry years, streamflow as not getting far enough downstream whereas in wet years the seepage was too low. Similarly, the Poso Creek streambed seepage showed similar issues based on comparisons to differences in stream gauge data along its course.

To address this, the Kern River and Poso Creek streambed parameters were manually modified until a reasonable approximation of the measured streambed seepage was achieved by C2VSimFG-Kern. In general, the streambed conductance was lowered whereas the stream wetted perimeter was increased. This provided the best balance in matching the measured dry, average and wet years flows in both streams.

Part of this issue is that C2VSimFG-Beta uses a simple form of the stream module in the simulation. This approach appears to work sufficiently well for the continuously flowing streams in the northern parts of the Central Valley but is not sufficient for simulating the highly variable flows that occur on the Kern River and Poso Creek. It is recommended that future revisions to C2VSimFG-Kern further evaluate issues in simulating streamflow and seepage in the Kern River and Poso Creek (see Section 8.5). This may include incorporating more advanced streamflow simulation features that are available in IWFM but that have not been utilized in C2VSimFG.

3.8.2 Small Watershed Runoff

In reviewing the small watershed contributions, it was determined that the runoff was not representing the variable nature of runoff in an arid region. Although this was not part of the originally planned model revisions, it affected the model results. Todd Groundwater revised the corresponding model parameters to be more representative of the local arid conditions in Kern County.

Runoff of precipitation from the surrounding small watersheds was calculated within C2VSimFG-Kern using methodology included in IWFM that is based on the SCS Curve Method (NRCS, 2004). The C2VSimFG-Beta results showed a steady baseflow that contributed water to the Kern County Subbasin continuously and did not show the appropriate variation in runoff expected between wet, average and dry years in the arid environment.

Two major issues were identified and revised. First, the SCS curve number was changed to allow a higher percentage of runoff in wet years to capture the flashy nature of runoff from these watersheds during differing climatic conditions. Second, IWFM uses a localized soil moisture water budget; however, soil, ET and other parameters were set that allowed for the continuous outflow from the

basins. These were changed to more appropriate values that limited baseflow from the very small watersheds while allowing baseflow from the larger watersheds. Parameters were varied to better match estimated watershed runoff from a local USGS study (Nady and Larragueta, 1983).

3.8.3 Root Zone Parameters

Areas of overly high root zone hydraulic parameters led to high volumes of deep percolation that required additional groundwater pumping to meet the overall water demand for irrigation. This issue was noted by local water district staff who recognized that the groundwater pumping and deep percolation from preliminary model results were significantly higher than what was found in practice. A review found areas of overlying hydraulic conductivity and other hydraulic parameters that caused this high percolation rate. Two types of issues were found. First, very high parameters were found in parts of the basin that were not consistent with local soil data. Second, the root zone parameters for lakebed and other heavy clay soil areas were too high. These areas were manually adjusted to be more in line with observed conditions. A more rigorous development of root zone parameters should be considered in the future as this issue demonstrates that it is a sensitive parameter.

3.8.4 Land Use Modifications

The agricultural land use and crop type distribution in the model for early period (1974-1990 and 1992-1996) from C2VSimFG-Beta used a regional distribution and did not accurately represent historical practices. This resulted in agricultural water use being distributed across the entire Kern County Subbasin including areas that did not have irrigated agriculture. To correct for this, land use and crop type data were modified to conform with irrigated agricultural areas in the early 1990s. The crop types were adjusted to be consistent with the Kern County Agricultural Commissioner reports for these years. This included capturing the appropriate crop types present in the Kern County Subbasin in the periods from 1974 through 1996. For example, there was a higher percentage of cotton produced during that period and a lower percentage of nut trees, which became one of the major crop types in the 2010s.

3.8.5 Westside Pumping Limits

Western Kern County contains large areas with poor groundwater quality. As a result, little or no agricultural or urban groundwater pumping occurs in this area. To simulate this, groundwater pumping was turned off in C2VSim-Kern in most of the area with poor groundwater quality. However, in the Westside District Water Authority Management Area, limited groundwater pumping does occur. The poor-quality water is mixed with surface water to supplement the imported water supply. To simulate this condition, the groundwater pumping rate in the Westside District Water Authority Management Area was estimated to be 10% of the surface water deliveries, and the automated groundwater pumping adjustment in C2VSimFG-Kern was turned off for these areas.

Subsequent to the completion of the historical model, GSP developers in the Westside area refined their estimate of pumping used to mix with delivered surface water to about 3,000 AFY, which is considerably lower than that used in the historical model. The Westside GSP developers included a management action to further refine the estimated groundwater use in the Westside GSP water districts. Therefore, the original assumption was left in this version of the historical model. The Westside District Water Authority Management Area GSP identifies a management action to further evaluate the groundwater pumping in their area. The results of their evaluation will be included in in future model updates.

3.8.6 Kern Wildlife Refuge pumping

C2VSimFG-Beta enabled groundwater pumping in the model elements representing the Kern National Wildlife Refuge. The Kern National Wildlife Refuge Water Management Plan (USBR, 2011) indicates that

during the simulation time period, the refuge was sustained entirely on imported surface water and occasional diversions of Poso Creek flood waters. No groundwater was pumped at the refuge during the simulation period 1985-2015. Groundwater pumping was used at some time in the past. Groundwater pumping and automated groundwater pumping adjustment were turned off for all model elements in the Kern National Wildlife Refuge.

In addition to the Kern National Wildlife Refuge, former rice fields and other areas are currently used for sustaining ponds at private duck hunting clubs in the northwestern portion of the Kern County Subbasin. Water use data for these operations were not available during the development of the historical model. This water includes a combination of surface water and groundwater, and this volume is considered to be very small relative to the overall basin water use. GSP developers included a management action to further refine the estimated water use for these facilities that will be addressed in future updates.

3.9 C2VSimFG-Beta Modifications

Minor changes were made to the C2VSimFG-Kern hydrogeological conceptual model and natural water budget components and are listed in **Table 10**. The architecture of the model including layering, discretization, boundary conditions, and aquifer properties was not revised. Aquifer parameters were adjusted in several areas to better match observed historical conditions, especially in areas with high historic recharge volumes such as the Kern Fan. Extremely high soil hydraulic conductivities in a small set of elements were reduced to more reasonable values. Stream-bed conductance values were modified in some stream reaches to better match simulated stream gains and losses to observed values. Minor adjustments to small watershed parameters were also made to match surface runoff to observed values.

Due to the number of modifications that were identified with the hydrogeological conceptual model and aquifer parameters during the C2VSimFG-Kern update, it is recommended that a more rigorous model update be conducted that will update the hydrogeological conceptual model and aquifer parameters to be consistent with that presented in the Kern County Subbasin GSPs. In addition, further calibration of C2VSimFG-Kern is recommended to update aquifer parameters in the Kern County Subbasin. Future calibration is further discussed in Section 8.5.

4. HISTORICAL AND CURRENT WATER BUDGETS FROM C2VSIMFG-KERN

C2VSimFG-Kern was used to develop historical (WY1995 to WY2014) and current (WY2015) water budgets for the Kern County Subbasin. The following summarizes the simulated water budgets from C2VSimFG-Kern. A summary of these results is provided below.

4.1 Historical and Current Water Budget

The simulated historical and current water budgets based on C2VSimFG-Kern are presented in **Tables 11A** and **11B** and are presented graphically on **Figures 9**. **Figure 10** presents the average annual historical water budget for the Kern County Subbasin. The results for the historical water budget are summarized under the following categories that are defined as:

- **Deep Percolation** – Precipitation and applied water that reaches the groundwater after simulated transport across the unsaturated zone. The simulated historical 20-year average is a net inflow of 669,398 AFY.
- **Managed Recharge and Canal Seepage**- Combined groundwater recharge from managed aquifer recharge operations, groundwater banking, and seepage from canals and other conveyance. The simulated historical 20-year average for Managed Recharge and Canal Seepage is a net inflow of 583,598 AFY. On Figure 10, this total is subdivided between out-of-basin groundwater banking obligations (85,965 AFY) and the remaining local recharge of 497,633 AFY.
- **Net Groundwater-Surface Water (GW/SW) Interactions** - Net volumetric exchange of surface water and groundwater between the aquifer and streams: Positive represents a net groundwater recharge, and negative represents a net groundwater discharge to the stream. The simulated historical 20-year average is a net inflow of 98,606 AFY.
- **Small Watershed Inflow** – Runoff, small stream inflow and subsurface inflow from the small watersheds and areas surrounding the groundwater basin. The simulated historical 20-year average is a net inflow of 48,760 AFY.
- **Groundwater (GW) Pumping** - Total groundwater pumping by wells. Groundwater banking recovery pumping is specified as fixed input values and agricultural and municipal pumping is calculated by C2VSimFG-Kern based on demand minus surface water diversions. The simulated historical 20-year average is a net outflow of 1,590,373 AFY.
- **Subsurface Flow with Adjacent Groundwater (GW) Basins** - Net subsurface groundwater flow to and from the Kern County Subbasin with adjoining groundwater basins: negative is a net flow out of the Subbasin and positive is a net flow into the Subbasin. The simulated historical 20-year average is a net outflow of 87,102 AFY.
- **Change in Groundwater Storage** - Sum of the inflow components (positive numbers) plus the outflow components (negative numbers): positive is an increase in storage typified by a rise in groundwater levels whereas a negative is a decrease in storage typified by a decline in groundwater levels. The simulated historical 20-year average is a decline in groundwater storage of 277,114 AFY.

The simulated change in groundwater storage varies over the 20-year historical period and is closely related to climatic conditions and surface water supply availability (**Figure 11**). During the periods

WY1995 to WY1999, WY2005 to WY2006 and WY2011, the groundwater storage volume was stable to increasing and correlates to the above average rainfall and surface water availability during these times. During the periods WY2000 to WY2004, WY2007 to WY2010 and Y2012 to WY2015, groundwater storage volume decreased, correlated to periods of drought and low surface water availability. The simulated historical groundwater recharge also reflects this climatic pattern with high deep percolation to groundwater and steep increases in managed aquifer recharge and canal seepage during the above average rainfall periods and lower groundwater recharge during the drought years (**Figure 12**).

Groundwater pumping for agriculture shows a general increasing trend from WY1995 to WY2014; however, groundwater pumping is lower in above average rainfall years and higher during droughts (**Figure 13)**. This general increasing trend follows a comparable decreasing trend in surface water deliveries over this same period. As shown on **Figure 14**, surface water deliveries show a general decreasing trend from WY1995 to WY2014; however, the surface water deliveries are higher in the above average rainfall years and lower during the droughts.

4.2 Sustainable Yield

Section 354.18(b)(7) of the GSP Regulations requires that an estimate of the basin's sustainable yield be provided in the GSP (or in the coordination agreement for basins with multiple GSPs). SGMA defines "sustainable yield" as:

> "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result."

SGMA does not incorporate sustainable yield estimates directly into sustainable management criteria. Sustainable yield is referenced in SGMA as part of the estimated basinwide water budget and as the outcome of avoiding undesirable results. Basinwide pumping within the sustainable yield estimate is neither a measure of, nor proof of, sustainability. Sustainability under SGMA is only demonstrated by avoiding undesirable results for the six sustainability indicators.

4.2.1 Determination of Sustainable Yield

To determine the sustainable yield for the Kern County Subbasin, the results of the C2VSimFG-Kern model were used with two methods to estimate the amount of groundwater pumping that would avoid the undesirable result of a reduction in groundwater storage over the historical base period 1995 to 2014. The results are shown in **Table 12** and are summarized below:

- **Sustainable Yield from Groundwater Pumping –** The model results produced an average annual groundwater pumping in the Kern County Subbasin of 1,590,373 AFY with a decline in groundwater storage of 277,114 AFY. Subtracting the groundwater storage decline from groundwater pumping produced a sustainable yield of approximately 1,313,000 AFY.

- **Sustainable Yield from Groundwater Recharge –** The model results produced an average annual groundwater recharge in the Kern County Subbasin of 1,400,362 AFY. The subsurface outflow from the GSA was estimated to be 87,102 AFY. Subtracting these outflow losses from the groundwater recharge produced a sustainable yield of approximately 1,313,000 AFY.

Sustainable yield estimates are part of SGMA's required basinwide water budget. In general, the sustainable yield of a basin is the amount of groundwater that can be withdrawn annually without causing undesirable results. This sustainable yield estimate can be helpful for evaluating the projects and programs needed to achieve sustainability. Although the SGMA regulations require a single value of sustainable yield calculated basinwide, it should be noted that the sustainable yield can be changed by implementation of recharge projects, variations in climate, or changes in stream flow conditions.

Using WY1995 to WY2014 as the base period, C2VSimFG-Kern results show declining groundwater levels and long-term reduction of groundwater storage. During this period, average annual inflow to the aquifer is 1,400,362 AFY, and outflow is 1,677,476 AFY (**Table 11A**). This yields an average annual deficit of 277,114 AFY. Based on these historical C2VSimFG-Kern results, the sustainable yield of the basin is approximately 1,313,000 AFY, with an estimated level of uncertainty on the order of plus or minus 10% to 20%.

4.2.2 Native Yield

Although not a SGMA requirement, the native yield is being used by Kern County GSAs for determining a portion of the groundwater allocation within the basin. The native yield is comparable to the sustainable yield except that the only recharge that is included in the calculation is the natural, unallocated portion of the groundwater recharge. For the Kern County Subbasin, this includes the groundwater recharge derived from precipitation and runoff from unallocated streams. The Kern River and Poso Creek, however, are allocated streams where specific agencies or parties have rights to specific volumes of flow.

The C2VSimFG-Kern model results over the historical base period WY1995 to WY2014 was again used for estimation of native yield. The model results were used to determine the amount of precipitation recharge over irrigated agricultural areas and the native/urban/undeveloped areas. The total and average annual volume of precipitation that percolates to groundwater during the WY1995 to WY2014 base period are listed in **Table 13**. The basinwide contribution is the relative proportion of the runoff along the basin margins from small, unallocated watersheds and inflow from the surrounding basin margin (from areas not defined as DWR groundwater basins). The results of this assessment based on the C2VSimFG-Kern results are shown in **Table 13** and are summarized below:

- The volume of precipitation that recharges the groundwater in the irrigated agricultural areas is 77,780 AFY.
- The volume of precipitation that recharges groundwater in the other areas is 132,981 AFY.
- The volume of inflow from unallocated small watersheds that recharges the groundwater in the irrigated agricultural areas is 48,760 AFY.

Totaling these inputs results in a native yield for the Kern County Subbasin of 259,520 AFY. The annual contribution per acre of approximately 0.144 acre-feet per acre is estimated by dividing the average annual contribution by the total area of the Kern County Subbasin (**Table 13**).

Similar to the sustainable yield, the native yield at this time is based on the available data. However, as data gaps are eliminated and management actions/plans are implemented, the native yield could change, and any changes to native yield will be included in future GSP amendments.

4.2.3 Application of Sustainable and Native Yield

In general, the sustainable yield of a basin is the amount of groundwater that can be withdrawn annually without causing undesirable results. The native yield is comparable to the sustainable yield except that the only recharge that is included in the calculation is the natural, unallocated portion of the groundwater recharge. The following estimates of the Kern County Subbasin sustainable and native yields are derived from the C2VSimFG-Kern historical model results for the purpose of supporting GSP assessment of the types and magnitude of projects and programs needed to achieve sustainability.

The C2VSimFG-Kern estimates of sustainable and native yield presented here are based on available data and the current level of model calibration. Therefore, these estimates are considered appropriate as guides to SGMA planning. However, the C2VSimFG-Kern sustainable and native yield estimates are initial water budget estimates that are not intended for determination of individual landowner allocations or groundwater rights. Additional technical and legal analysis, along with stakeholder involvement, is necessary to fully quantify the sustainable and native yields.

5. APPROACH FOR PROJECTED FUTURE WATER BUDGETS

Projected future Baseline water budgets for the Kern County Subbasin were developed using the C2VSimFG-Kern. These projected water budgets establish expected Baseline conditions to evaluate the impacts of GSP implementation. Three predictive scenarios were developed for the Kern County Subbasin, each representing a different expected future hydrologic condition, by adapting C2VSimFG-Kern as follows:

- Future Baseline Conditions: Repeat historical hydrology with expected future water supply,
- 2030 Climate Conditions: Adjust historical hydrology for 2030 climatic conditions and expected water supply, and
- 2070 Climate Conditions: Adjust historical hydrology for 2070 climatic conditions and expected water supply.

Projected future water budgets were developed for Baseline conditions and expected 2030 Climate Conditions and 2070 Climate Conditions over a 50-year planning and implementation horizon. These scenario models provide a basis of comparison for evaluating proposed sustainability management actions and projects over the SGMA planning and implementation horizon.

5.1 Assumptions

C2VSimFG-Kern was modified to incorporate projected future hydrology and land use using analog data from the historical C2VSimFG-Kern model. This approach meets GSP requirements using:

- A 50-year time-series of historical precipitation, evapotranspiration and stream flow information as the future Baseline hydrology conditions,
- The most recent land use, METRIC-based evapotranspiration, crop coefficient and urban population growth information as the Baseline condition for estimating future water demands,
- The most recent water supply projections as the Baseline condition for estimating future surface water supply,

- DWR Climate Change Guidance and Data Sets to incorporate estimated climate change conditions for the Kern County Subbasin,
- Specialized analysis of the Kern River watershed and estimated runoff volumes under climate change conditions,
- Specialized analysis of CVP deliveries to Kern County under climate change conditions incorporating implementation of the San Joaquin River Restoration Program, and
- Specialized analysis of SWP deliveries to Kern County under climate change conditions incorporating implementation of the OCAP Biological Opinion and recent changes in Table A and Article 21 allocations.

5.2 Projected Future SGMA Projects

Projected water budgets for the Kern County Subbasin were developed using the C2VSimFG-Kern to evaluate the performance of proposed management actions with respect to achieving groundwater sustainability. Participating agencies provided a list of projected future management actions to be implemented between WY2021 and WY2040. These projects were simulated under Baseline conditions, 2030 Climate Conditions and 2070 Climate Conditions through WY2070 using the C2VSimFG-Kern.

Proposed future projects and management actions were provided by GSAs. The types of proposed SGMA projects and management actions are summarized as follows:

- Demand Reduction is the volume of water reduced by changing the land use; these include:
    - Agricultural demand reduction projects through incentives or actions to reduce crop water use,
    - Fallowing of agricultural land and conversion of agricultural land to recharge basins, and
    - Conversion of agricultural land to urban land.
- New Supply groups together planned increases in imported water supplies; these include:
    - Increased surface water imports generally resulting from projected water purchases,
    - New water conveyance facilities including pipelines and reservoirs to increase flexibility, and
    - Expansion of surface water delivery areas to reduce groundwater usage.
- Other Supply groups together proposed projects to increase local water supplies; these include:
    - Recharging treated waste waters derived from both urban areas and oil production operations; increased recharge occurs in both existing and new locations,
    - Increased stream flow diversions; these include exercising riparian water rights and diverting flood flows,
    - Reallocation of water; generally reducing sales of surface water and banked groundwater and using this water within the agency, and
    - Brackish groundwater in areas not currently overdrafted will be treated and mixed with surface water to augment surface water supplies.

Some management actions are implemented gradually over many years, with savings increasing each year over the implementation period. Some management actions are implemented only in certain years (wet years, for example). The anticipated average-annual water supply benefit of the proposed SGMA projects and management actions steadily increases over the 20-year period from WY2021 to WY2040 to represent the implementation of the Kern County Subbasin GSPs. This increasing trend, as shown as

the average-annual water supply benefit over five-year increments on **Figure 15**, is summarized as follows:

- about 116,000 AFY over the first five-year period (WY2021-WY2025),
- about 216,000 AFY over the second five-year period (WY2026-WY2030),
- about 343,000 AFY over the third five-year period (WY2031-WY2035), and
- about 361,000 AFY over the fourth five-year period (WY2036-WY2040).

The anticipated water supply benefit of the proposed SGMA projects and management actions included in the C2VSimFG-Kern projected future simulations is 422,000 AFY over the period from WY2041 to WY2070. Benefits of implementing these projects and management actions over the 20-year implementation period are summarized in **Figure 15**.

6. PROJECTED FUTURE BASELINE DEVELOPMENT

Projected water budgets are required by GSP regulations to represent future conditions over a 50-year GSP planning and implementation horizon. A Baseline condition was developed that projects water supply, demand and operations based on current land use and expected water supply availability over 50 years. The Baseline then serves as a basis of comparison for evaluating proposed sustainability management actions and projects for achieving sustainability over the planning and implementation horizon. Each predictive scenario model simulates the 50-year planning and implementation period WY2021 to WY2070. Development of the projected future Baseline conditions is summarized below.

6.1 Projected Future Time Period Development

WY1995 to WY2014 was chosen as a historical hydrology period because detailed demand and supply data are available for this period, and most Subbasin water delivery infrastructure was fully developed by the middle of this period. The average Kern River inflow for this period is also very close to the long-term average Kern River inflow.

The projected future simulation period is based on repeating the WY1995 to WY2014 historical study period. This period is only 20 years long, so a 50-year sequence of historical hydrology was developed by repeating data from this period in the sequence as shown in **Table 14**. The development of this sequence is summarized as follows:

- Simulation period WY2021 to WY2032 used the historical period WY2003 to WY2014,
- Simulation period WY2033 to WY2052 used the historical period WY1995 to WY2014, and
- Simulation period WY2053 to WY2070 used the historical period WY1995 to WY2012.

This sequence was developed to match long-term average flows on the Kern River, and to ensure that the Baseline does not end in an extreme drought or extreme wet year. By starting the projected future simulation time sequence with WY2003, the 50-year hydrology period has approximately 100 percent of the long-term average streamflow conditions on the Kern River, as indicated by an average annual Kern River Index of 100 percent. The sequence includes the appropriate range of hydrologic conditions including extremely wet years and extended periods of drought.

C2VSimFG-Kern simulation results for the last timestep of the historical simulation (September 30, 2015) were used as initial conditions for all projected future simulations, including initial conditions for the root zone, saturated and unsaturated aquifer zones, and small watersheds. Since the historical C2VSimFG-Kern simulation period ends with WY2015, all projected future scenarios also include estimated hydrology for WY2016 to WY2020. Model input data for WY2016 to WY2020 was developed by repeating model input data for recent years based on correlation with the San Joaquin Index (DWR, 2019).

6.2 Development of Key Baseline Data Sets

Key required components for the Projected Future Baseline, as summarized in the DWR *Water Budget Best Management Practices* guidance document (DWR, 2016B) include the following:

- The projected Baseline hydrology conditions were developed using 50-years of historical precipitation and streamflow following the sequence outlined in Section 6.1.
- Surface water supplies are based on available information from DWR and others to project future water imports from the SWP, CVC - Friant-Kern Canal (FKC) and Kern River diversions. For the Kern River, recent diversion practices based on entitlements were used to develop water use consistent with the Baseline hydrology.
- WY2013 land use was used as current land use for all scenarios as drought conditions likely reduced agricultural production in WY2014 and WY2015.
- Consumptive use for agriculture and undeveloped lands was based on the recent land use and METRIC-based evapotranspiration. Following DWR guidance, METRIC data over the Baseline period was varied according to varying hydrologic conditions (e.g., water year type).
- Urban water demand was based on projections from recent urban water management plans to meet regulations for future water use. Urban demand was estimated in the model based on projected urban population growth and per capita water demand information (including recent regulatory guidance).
- Small watershed inflows used the same parameters as the historical C2VSimFG-Kern model; however, volumes varied based on changes in the precipitation and ET under the 2030 and 2070 climate change conditions.

Time-series input data were first developed for the Baseline scenario model for WY2021 to WY2070. Development of this time-series input data generally involved repeating time-series data from the historical C2VSimFG-Kern in the appropriate sequence. The following time-series data were developed for each scenario:

- Precipitation rates,
- Evapotranspiration rates,
- Surface water inflow rates,
- Surface water diversion and delivery rates, and
- Specified groundwater pumping rates.

Baseline scenario model time-series data files were then modified following DWR guidelines to produce time-series input data for the 2030 Climate Conditions and 2070 Climate Conditions scenario models. C2VSim input data were modified only in Kern County. C2VSim input data for areas outside of Kern County were not modified.

The baseline data sets were incorporated into the model files to develop the projected future water demand and supply under Baseline, 2030 Climate and 2070 Climate conditions. A summary of the development of the projected future water demand and supply is discussed below.

6.3 Projected Future Water Demand

The projected future water demand was developed using fixed WY2013 land use areas with historical evapotranspiration rates for the Baseline and modified evapotranspiration rates for the 2030 and 2070 climate scenarios and increasing urban populations.

6.3.1 Agricultural Water Demand

Evapotranspiration rates for the Baseline scenario model were developed by repeating input evapotranspiration rates from C2VSimFG-Kern in the appropriate sequence. DWR provided monthly change factors for ETo values under 2030 and 2070 central tendency climatic conditions on a 6 km x 6 km VIC grid for calendar years 1915 through 2011. The VIC grid IDs for each C2VSim subregion in the Kern County Subbasin Zone of Interest were identified and area weighted monthly ETo change factors were calculated for each subregion. Baseline scenario ETc rates for each subregion were then multiplied by the appropriate area-weighted ETo change factors to produce time-series ETc rates for the 2030 Climate Conditions and 2070 Climate Conditions scenarios. Factors for calendar years 1959-1961 were used as analogs for calendar years 2012-2014.

6.3.2 Urban Water Demand

Urban water demand calculations include an indoor component and an outdoor component. Indoor urban water demands are based on the urban population and monthly per capita water demand. Future urban populations for Kern County urban areas were estimated using California Department of Finance population projections. Future per capita urban water demands were estimated using projections from urban water management plans and California urban water conservation regulations, including SB 606 and AB 1668. Future outdoor urban water demands are based on ETc rates, which were modified as described in the Agricultural Water Demand section above.

6.3.3 Groundwater Banking Recovery

Future groundwater banking recovery rates were developed by repeating historical recovery rates in the appropriate sequence. No adjustments were made to Baseline rates or to rates for 2030 and 2070 climatic conditions.

6.4 Projected Future Water Supply

Projected future precipitation, stream inflow and surface water import time series were developed following DWR guidelines. Baseline future water supplies were developed by repeating historical values in the appropriate sequence. Surface water diversions were then adjusted to account for operational changes. Baseline water supplies were then modified to simulate 2030 and 2070 central tendency climatic conditions.

6.4.1 Precipitation Rates

Precipitation rates for the Baseline scenario model were developed by repeating input precipitation rates from C2VSimFG-Kern in the appropriate sequence. DWR provided monthly change factors for precipitation under 2030 and 2070 central tendency climatic conditions on a 6 km x 6 km VIC grid for calendar years 1915 through 2011. The VIC grid ID for each C2VSim element in the Kern County Subbasin Zone of Interest was identified and the Baseline scenario precipitation rates were multiplied by

the appropriate factors to produce time-series precipitation rates for the 2030 Climate Conditions and 2070 Climate Conditions scenarios. Factors for calendar years 1959-1961 were used as analogs for calendar years 2012-2014.

6.4.2 Surface Water Inflow Rates

Surface water inflow rates for Poso Creek and White River for the Baseline scenario model were developed by repeating input inflow rates from C2VSimFG-Kern in the appropriate sequence. DWR provided unimpaired streamflow change factor datasets for Central Valley streams, and an Excel spreadsheet tool to modify basin unimpaired streamflow using these change factors. The unimpaired streamflow change factors and spreadsheet were used to modify Baseline inflows to produce 2030 Climate Conditions and 2070 Climate Conditions scenario time series inflows for Poso Creek and White River.

Surface water inflow rates for Kern River at First Point for the Baseline scenario model were developed by repeating historical inflow rates from C2VSimFG-Kern in the appropriate sequence. Flows on the Kern River are regulated, so the unimpaired streamflow method was not appropriate for estimating future flows under 2030 and 2070 climatic conditions. Projected Kern River flows at First Point under 2030 and 2070 central tendency conditions were estimated by GEI (2018) for calendar years 1956-2010 hydrology. This analysis considered the impacts of changed runoff in each sub-watershed contributing to the Kern River to develop revised streamflow estimates for Kern River at First Point. Future scenario Kern River at First Point flows for calendar years 2011-2014 were estimated using flows for analog years with similar annual flows and monthly flow pattern. Analog years 1986, 1991, 1990 and 1961 respectively were used for 2011-2014 in the future scenarios.

6.4.3 Surface Water Deliveries

Surface water delivery rates for the Baseline scenario model were developed by first repeating input surface water delivery rates from the C2VSimFG-Kern in the appropriate sequence, and then modifying selected data sets. Surface water deliveries from in-basin sources such as Oil Field Recovery were held constant at WY2015 rates for all future scenarios.

The Kern County Subbasin is served by both the CVP and the SWP. Recent changes in CVP and SWP operations and their impacts on future surface water supplies are reflected in surface water diversion rates for the three scenarios. Future CVP deliveries will be affected by implementation of the San Joaquin River Restoration Program (SJRRP) that included the 2008 U.S. Fish & Wildlife Service biological opinion (BO) on the Long-Term Operational Criteria and Plan (OCAP) for coordination of the CVP and SWP. Future SWP deliveries will be affected by operational changes implemented between 2004 and 2008 including the OCAP BO, reduced Table A contract amounts and reduced Article 21 deliveries. DWR provided projected future deliveries from the CVP and SWP for WY1922 to WY2003, derived from CalSim-II modeling conducted for the Water Supply Investment Program (WSIP) (California Water Commission, 2016). DWR's CVP projections as provided do not fully incorporate these SJRRP operational changes. DWR's SWP delivery projections do not include the OCAP BO operational constraints, the reduced Table A amounts and reduced Article 21 water.

Future CVP delivery projections developed by the Friant Water Authority (FWUA) were used in place of DWR's CVP projections. FWUA (2018) used CalSim-II to develop projected surface water deliveries with SJRRP implementation under hydrological conditions representing the Current Baseline, 2030 and 2070 climate conditions by delivery class for WY1922 to WY2003, and estimated allocations to each CVP contractor. The 2015.c data set was used for Baseline scenario CVP deliveries, the 2030.c data set was

used for 2030 Climate Conditions scenario CVP deliveries, and the 2070.c data set was used for the 2070 Climate Conditions scenario CVP deliveries. CVP deliveries for WY2004 to WY2014 were estimated using deliveries for analog years WY1951 to WY1961; these analog years have a similar distribution of water availability.

The SWP projections provided by DWR for WY1995 to WY2003 and historical deliveries for WY2004 to WY2014 were modified to incorporate the impacts of SWP operational changes in the three scenarios. 2019 SWP Table A contract amounts were used to allocate these SWP deliveries to individual districts. In summary:

- Baseline Hydrologic Conditions
  - WY1995 to WY2003 conditions are based on 2030-Level CALSIM increased by 3.03 %,
  - WY2004 to WY2007 conditions are based on historical data adjusted for OCAP BO, and
  - WY2008 to WY2014 conditions are based on historical data with the assumption that OCAP BO adjustments are already factored into the data.
- 2030 Climate Change Hydrologic Conditions
  - WY1995 to WY2003 conditions are based on the 2030-Level CALSIM Projection,
  - WY2004 to WY2007 conditions are based on OCAP BO adjustment reduced by 3.03 %, and
  - WY2008 to WY2014 conditions are based on historical data reduced by 3.03%.
- 2070 Climate Change Hydrologic Conditions
  - WY1995 to WY2003 conditions are based on the 2070-Level CALSIM Projection,
  - WY2004 to WY2007 conditions are based on OCAP BO adjustment reduced by 8.09%, and
  - WY2008 to WY2014 conditions are based on historical data reduced by 8.09%.

Within the Kern County Subbasin, water users engage in complex real-time water trading and wheeling activities to maximize water utilization, minimize waste and energy consumption, and meet immediate water needs. It would be difficult to project future surface water deliveries in the Kern County Subbasin without the use of a surface water allocation model that simulates these water trading and wheeling activities. Therefore, for this modeling effort, monthly future scenario agricultural, urban and recharge deliveries from sources originating outside the basin were estimated by adjusting historical deliveries by the ratio of (total scenario inflows)/(total historical inflows) for each month, where total inflows are the sum of CVP deliveries, SWP deliveries and Kern River at First Point. In addition, Kern River at First Point flows above historical flows under the 2030 Climate Conditions and 2070 Climate Conditions scenarios were proportionally added to selected recharge deliveries. This method is deemed adequate for subbasin-level future scenario analyses.

Some future scenario data sets did not cover the entire period from October 1994 through September 2014. In these cases, data from an analog historical period with similar water availability was used to fill in the missing data. The analog years for each data type are summarized as:

- For CVP deliveries (CalSim-II data), WY1951 to WY1961 were used as analogs for missing WY2004 to WY2014 data; these analog years have a similar distribution of water availability.
- Projected future Kern River at First Point flows for calendar years 1986, 1991, 1990 and 1961 were used as analogs to missing calendar years 2011 through 2014; each of these analog years had a similar historical annual flow volume and monthly distribution.

- For climatic data adjustment factors, calendar years 1959-1961 were used as analogs to missing calendar years 2012-2014.

6.5 Development of Climate Change Conditions

Input data for the C2VSimFG-Kern were modified to simulate three future climatic scenarios. Historical precipitation, evapotranspiration, land use, population, surface water inflow and surface water delivery rates were replaced with projected future values for WY2016 to WY2070 for Future Baseline Conditions. The Future Baseline Conditions for WY2021 to WY2070 were then modified to simulate 2030 Climate Conditions and 2070 Climate Conditions. Water management agencies in the Kern County Subbasin provided a broad suite of proposed water management and conservation projects to increase water supplies and reduce water management demands. These projects are added to the C2VSimFG-Kern to assess the long-term impacts of these projects under the Baseline, 2030 Climate Conditions and 2070 Climate Conditions scenarios.

Projected water budgets under Future Baseline Conditions, 2030 and 2070 Climate conditions are used to evaluate the potential effects of future Baseline and extended dry conditions with respect to achieving sustainability. DWR published a *Modeling Best Management Practices* Guidance Document (DWR, 2016B) that outlines DWR recommendations for developing and running predictive scenarios. The C2VSimFG-Kern was modified following these recommendations to develop the Baseline scenario model. DWR also issued the *Guidance for Climate Change Data Use During Sustainability Plan Development* Guidance Document (DWR 2018A) that outlines how DWR recommends that climate change be addressed under SGMA. Baseline scenario data sets were modified using DWR climate change data sets for Kern County following procedures outlined in the guidance documents to develop the 2030 Climate Conditions and 2070 Climate Conditions scenario models. The adjustment factors for Baseline, 2030 Climate Change and 2070 Climate Change for SWP deliveries were developed based on consistent CalSim operations studies at current, 2030 and 2070 climate levels developed for Bay Delta Conservation Plan evaluation and provided by DWR Bay Delta Office staff. The WSIP studies provided on DWR's SGMA web site were not used due to the unavailability of a Baseline study with assumptions consistent with the 2030 and 2070 climate change studies.

6.6 Groundwater Banking Assumptions

Groundwater banking operations are simulated in the C2VSimFG-Kern with surface water diversions to recharge basins and specified pumping rates for groundwater extractions. All surface water deliveries were adjusted under the Baseline, 2030 Climate Conditions and 2070 Climate Conditions scenarios. Surface water deliveries to recharge basins were first adjusted by the same ratio as other surface water deliveries, then increased if Kern River flows were greater than historical flows. Specified pumping rates for groundwater extraction were not modified.

The out-of-basin banking obligations were assumed to follow a similar pattern where groundwater banking recharge would be affected by the limitation on surface water deliveries, but that banking recovery would remain similar to historical volumes. Therefore, the historical groundwater banking obligations were adjusted under the Baseline, 2030 Climate Conditions and 2070 Climate Conditions scenarios by the same percentage as the surface water deliveries; however, the groundwater banking recovery was assumed to remain the same. Based on the historical banking obligations and using that as a foundation going forward, no banking partner has ever requested the full amount of the water banked at any particular time even in the most recent drought years. All the banking obligation

agreements require limitations on amounts to be requested and delivered as well as "leave in" amounts that remain in the Kern County Subbasin. This historical management of banking obligations provides the Kern County Subbasin more flexibility for use of water as well as delivery of the obligations. For the projected future scenarios, the out-of-basin banking obligations were calculated as follows:

- For the Baseline scenarios, the out-of-basin banking obligations were calculated as 69,632 AFY based on surface water deliveries of about 81% of historical deliveries.
- For the 2030 Climate scenarios, the out-of-basin banking obligations were calculated as 67,913 AFY based on surface water deliveries of about 79% of historical deliveries.
- For the 2070 Climate scenarios, the out-of-basin banking obligations were calculated as 64,474 AFY based on surface water deliveries of about 75% of historical deliveries.

Tracking of banked groundwater obligations was done using the same post processing process as applied to the historical groundwater assessment by assigning the portion of the groundwater recharge as an out-of-basin banking obligation.

7. PROJECTED FUTURE C2VSIMFG-KERN SIMULATION RESULTS

The C2VSimFG-Kern was run for three scenarios that estimate hydrologic conditions of Baseline, 2030 Climate Conditions and 2070 Climate Conditions scenarios both with and without the proposed SGMA projects and management actions for a total of six projected future scenarios.

7.1 Projected Future Water Budgets

C2VSimFG-Kern calculates water budget components each month of the simulation period for each future scenario. Projected future water budgets developed based on the C2VSImFG-Kern simulation results with the proposed SGMA management actions were then compared to results for the future scenarios without the management actions to assess how these changes enhance groundwater sustainability within the Kern County Subbasin.

The average annual value of each water budget component summarizes the impacts over 50 years with current water demands. The water budget results for the six Projected Future Scenarios are presented in **Tables 16 through 21**, and include averages over three different periods, which include:

- **WY2021 to WY2040** – Implementation Period representing the 20-year period required by the SGMA regulations to implement projects and management actions to achieve sustainability.
- **WY2041 to WY2070** – Sustainability Period representing the 30-year hydrologic period following the Implementation Period to assess the long-term sustainability of the proposed projects and management actions with variable climatic conditions including periods with above average rainfall and extended droughts.
- **WY2021 to WY2070** – Simulation Period representing the entire 50-year projected future hydrologic conditions.

Changes to surface water diversions under the proposed projects and management actions included monthly increases or reductions to 37 model diversions and the addition of 7 new diversions. Ten new groundwater pumping wells were added to simulate a new groundwater pumping program. Agricultural

land use was converted to native vegetation in ten management areas, and to urban land use in three management areas. The projects and management actions included in the C2VSimFG-Kern scenarios with SGMA projects are described in the individual GSPs and management area plans. These changes were applied to a series of six C2VSimFG-Kern scenarios for Baseline, 2030 Climate Conditions and 2070 Climate Conditions both with and without SGMA projects. The results of these simulations are summarized in **Table 15** below.

Baseline simulation results indicate that the Kern County Subbasin has an average annual overdraft of 324,326 AFY. By implementing the proposed projects and management actions, the Subbasin is forecasted to achieve sustainability by 2040 with an estimated 42,144 AFY of annual surplus. With adjustments to account for limitations in the simulation (discussed in Section 7.2.1), the adjusted change in storage increases to 85,578 AFY.

Collectively, the C2VSimFG-Kern simulation results indicate that the currently proposed SGMA projects and management actions, once fully implemented, provide a reasonable approach to achieve sustainable management of the groundwater basin and can be adaptively managed to meet future challenges as necessary. A brief summary of each of the six projected future water budgets from C2VSimFG-Kern is provided below.

Table 15: Summary of Simulated Change in Groundwater Storage Results over the 2041 to 2070 Sustainability Period

C2VSimFG-Kern Model Scenario	Change in Groundwater Storage (AFY)	
	C2VSimFG-Kern Model Results	Adjusted Model Results
Historic	-277,114	-277,114
Baseline	-324,326	-324,326
Baseline with Projects	42,144	85,578
2030 Climate Change	-380,900	-372,120
2030 Climate with Projects	-12,861	46,829
2070 Climate Change	-489,828	-472,336
2070 Climate with Projects	-118,273	-45,969

7.1.1 Baseline Condition Water Budgets

The Baseline Scenarios simulate how the Kern County Subbasin aquifer would respond if the recent hydrology were repeated with current expected surface water availability and current land use. The Baseline Scenarios were run both with and without SGMA projects.

For the Baseline Scenario without SGMA Projects, the groundwater budget for WY2021 to WY2040 (**Table 16**) repeats the 20-year historical hydrologic period so it provides a direct comparison of the differences between the projected future Baseline without SGMA Projects and the historical condition. The primary difference between historical conditions and the projected future Baseline is a nearly 20% decrease in imported surface water deliveries primarily from the SWP due to the OCAP Biological

Opinion. This is replaced with additional groundwater pumping. As a result, total net aquifer outflows increase by about 20,200 AFY and total net aquifer inflows decrease by about 76,500 AFY. This is mostly because of increased groundwater pumping and decreased managed aquifer recharge due to a decline in imported SWP water. Over this period, the average groundwater pumping is 1,581,000 AFY, which includes agricultural pumping, urban pumping and exported water. This results in an additional loss of groundwater storage of about 56,300 AFY over the 50-year projected future Baseline period.

The Baseline Scenario with SGMA Projects simulates the proposed SGMA projects and management actions (Section 5.2) applied to the Baseline Scenario. No other changes were made except for the addition of the SGMA projects to provide a direct comparison of the relative benefits of about 422,000 AFY of proposed SGMA projects and management actions. The groundwater budget for the Baseline Scenario with SGMA Projects is provided in **Table 17**. Comparing the groundwater budget for WY2041 to WY2070 (**Table 17**) with the same period from the Baseline Scenario (**Table 16**) provides an evaluation of groundwater conditions after the SGMA projects and management actions have been fully implemented. As a result, total net aquifer inflows increase about 135,400 AFY due to increased managed aquifer recharge and deep percolation. The total net aquifer outflows decrease about 231,100 AFY due mostly to decreased groundwater pumping with agricultural demand reduction management actions.

The change in groundwater storage for the Baseline Scenario with SGMA Projects improves by about 366,500 AFY compared to the Baseline Scenario without SGMA Projects. This change results in a net gain in groundwater in aquifer storage over the WY2041 to WY2070 sustainability period of about 42,100 AFY. A comparison of the annual change in groundwater storage over the 50-year hydrologic period is presented in **Figure 16**. The time series shows that change in groundwater storage has stabilized to slightly increasing over the period from WY2041 to WY2070.

A comparison of the average annual water budget components for the two different Baseline Scenarios is presented in **Figure 17**. Over the WY2041 to WY2070 period, the average groundwater pumping of 1,354,000 AFY for the Baseline Scenario with SGMA Projects (which includes agricultural pumping, urban pumping and exported water) is over 270,000 AFY less than in the Baseline Scenario.

7.1.2 2030 Climate Change Water Budgets

The 2030 Scenarios simulate how the Kern County Subbasin aquifer would respond assuming hydrologic conditions representing a potentially drier climate and are based on the DWR Climate Change Guidance and Resource Guide (DWR, 2018A and 2018B). The 2030 DWR climate change factors were applied to the Baseline Scenario conditions. Additional adjustments were made to the imported surface water supplies from the SWP, CVP and Kern River, accounting for about an additional 2% decrease from the Baseline Conditions. The 2030 Climate Change Scenarios were run both with and without SGMA projects. Results for climate change budgets are illustrated in **Figures 18, 19, and 20**.

The groundwater budget for the 2030 Climate Scenario without SGMA Projects for WY2041 to WY2070 (**Table 18**) is compared the same period for the Baseline Scenario without SGMA Projects to assess the relative change due to the climate change assumptions. The results show a net increase in aquifer inflows of about 44,700 AFY, however, the aquifer net outflows increase by about 101,200 AFY. This is mostly attributed to the climate shift to earlier rainfall making more surface water available for managed aquifer recharge during the winter but less available for irrigation in the summer, resulting in higher groundwater pumping. The net change in groundwater storage is an additional decline of about 56,600 AFY due to the climate change impacts.

The 2030 Climate Scenario with SGMA Projects simulates the proposed SGMA projects and management actions (Section 5.2) applied to the 2030 climate change conditions. No other changes were made to this scenario. The groundwater budget for the 2030 Climate Scenario with SGMA Projects is provided in **Table 19**. Comparing the groundwater budget for WY2041 to WY2070 (**Table 18**) between the two 2030 Climate Scenarios, the total net aquifer inflows increase about 118,700 AFY due to increased managed aquifer recharge and deep percolation. The total net aquifer outflows decrease about 249,300 AFY due mostly to decreased groundwater pumping with agricultural demand reduction management actions.

The change in groundwater storage for the 2030 Climate Scenario with SGMA Projects improves by about 368,000 AFY. This change results in a net decline in groundwater in aquifer storage over WY2041 to WY2070 of about 12,900 AFY. A comparison of the annual change in groundwater storage over the 50-year hydrologic period is presented in **Figure 20**. The time series shows that change in groundwater storage has stabilized to slightly increasing over the period from WY2041 to WY2070, but at a level below the results for the Baseline Scenario with SGMA Projects.

A comparison of the average annual water budget components for the two 2030 Climate Scenarios is presented in **Figure 18**. Over this period, the average groundwater pumping of 1,444,000 AFY for the 2030 Climate Scenario with SGMA Projects, which includes agricultural pumping, urban pumping and exported water, is over 290,000 AFY less than in the 2030 Climate Scenario without SGMA Projects.

7.1.3 2070 Climate Change Water Budgets

The 2070 Scenarios simulate how the Kern County Subbasin aquifer would respond assuming hydrologic conditions representing a potentially very dry climate and are based on the DWR Climate Change Guidance (DWR, 2018A and 2018B). The 2070 DWR climate change factors were applied to the Baseline Scenario Conditions. Additional adjustments were made to the imported surface water supplies from the SWP, CVP and Kern River, and these accounted for an additional 6% decrease from the Baseline Conditions. The 2070 Climate Change Scenarios were run both with and without SGMA Projects.

The groundwater budget for the 2070 Climate Scenario without SGMA Projects over WY2041 to WY2070 (**Table 20**) is compared the same period for the Baseline Scenario without SGMA Projects to assess the relative change due to the climate change assumptions. The results show a net increase in aquifer inflows of about 66,100 AFY, however, the net aquifer outflows increase by about 231,600 AFY. This is mostly attributed to an even greater climate shift to earlier rainfall making more surface water available for managed aquifer recharge during the winter but less available for irrigation in the summer resulting in higher groundwater pumping. The net change in groundwater storage is an additional decline of about 165,500 AFY due to the climate change assumptions.

The 2070 Climate Scenario with SGMA Projects simulates the proposed SGMA projects and management actions (Section 5.2) applied to the 2070 climate change conditions. No other changes were made to this scenario. The groundwater budget for the 2070 Climate Scenario with SGMA Projects is provided in **Table 21**. Comparing the groundwater budget for WY2041 to WY2070 (**Table 20**) between the two 2070 Climate Scenarios, the total net aquifer inflows increase about 106,300 AFY due to increased managed aquifer recharge and deep percolation. The total net aquifer outflows decrease about 265,300 AFY due mostly to decreased groundwater pumping due to agricultural demand reduction management actions.

The change in groundwater storage for 2070 Climate Scenario with SGMA Projects improves by about 371,600 AFY. This change results in a net decline of groundwater in aquifer storage over WY2041 to WY2070 of about 118,300 AFY. A comparison of the annual change in groundwater storage over the 50-year hydrologic period is presented in **Figure 20**. The time series shows that change in groundwater storage has stabilized to slightly increasing over the period from WY2041 to WY2070, but at a level below the results for the Baseline and 2030 Scenarios with SGMA Projects.

A comparison of the average annual water budget components for the two different 2070 Climate Scenarios is presented in **Figure 19**. Over this period, the average groundwater pumping of 1,559,000 AFY for the 2070 Climate Scenario with SGMA Projects, which includes agricultural pumping, urban pumping and exported water, is over 307,000 AFY less than in the 2070 Climate Scenario without SGMA Projects.

7.2 Projected Future Sustainability Assessment

To assess the sustainability of the proposed GSP plans, the C2VSimFG-Kern model future scenario input files were modified to incorporate all the proposed SGMA projects and management actions.

7.2.1 Change in groundwater storage

Groundwater sustainability for the Kern County Subbasin was assessed using annual changes in groundwater storage. As discussed in Section 7.1, the decline in groundwater storage of the three future Baseline scenarios is significantly mitigated by the implementation of the proposed SGMA projects and management actions. An assessment of the projected future groundwater storage change for the six projected future scenarios is summarized in **Table 22**.

The Change in Groundwater Storage presented in **Table 22** provides the net difference in aquifer inflows and outflows without consideration of subsurface flow to and from adjacent groundwater basins. This provides a measure of the natural and managed water supply within the groundwater basin without being influenced either positively or negatively by the subsurface flow. For the Kern County Subbasin, the net operational flow differs from the change in groundwater storage by about 50,000 to 75,000 AFY for the scenarios without SGMA projects, indicating that most of the groundwater storage change is due to conditions within the basin.

The Adjustments to Groundwater (GW) Storage Change are made to account for limitations in either the underlying conceptual model of C2VSimFG-Kern or the setup of the projected future scenarios. The two adjustments made to the projected future water budgets include:

- **Adjustment for Excess Basin Outflows** is the difference in simulated basin outflow that is attributed to addition of SGMA projects in Kern County without comparable SGMA projects added to adjacent basins. Adjustment assumes that this difference is due to limitation of the simulation, and that this difference would remain in Kern County Subbasin when SGMA projects from adjacent basins are included in the simulation.
- **Adjustment for Excess Kern River Outflow** is the increase in simulated groundwater outflows to the Kern River relative to Baseline condition that are attributed to SGMA projects and climate change. The model is not optimized for river management. Because the Kern River is a highly managed system, the assumption is that in practice this water would be recovered for beneficial use and not allowed to flow from the basin.

These adjustments resulted in an overall improvement in the change in groundwater storage for the projected future water budgets. For the scenarios that include the SGMA Projects, the change in groundwater storage improves by 43,400 AFY (Baseline), 59,700 AFY (2030 Climate Change), and 72,300 AFY (2070 Climate Change). As a result of these adjustments, the adjusted change in groundwater storage for the three scenarios with SGMA Projects varied as follows:

- the Baseline Scenario with SGMA Projects changes from an increase of 42,100 AFY to an increase of 85,600 AFY.
- the 2030 Climate Scenario with SGMA Projects changes from a decline of 12,900 AFY to an increase of 46,800 AFY.
- the 2070 Climate Scenario with SGMA Projects changes from a decline of 118,000 AFY to a decline of 46,000 AFY.

These adjustments indicate areas of improvement for C2VSimFG-Kern. Future updates to the model will address how to better simulate these conditions directly to limit the use of post-simulation adjustments.

7.2.2 Sustainability Assessment

As defined by SGMA, the sustainable yield of a basin is the amount of groundwater that can be withdrawn annually without causing undesirable results. Although the SGMA regulations require that a single value of sustainable yield must be calculated basinwide, it should be noted that the sustainable yield can be changed with implementation of recharge projects, variations in climate, or changes in stream flow conditions. For the projected future scenarios, both the climate and the managed water supply operations are significantly affected which would lead to a change in the sustainable yield for the basin.

For the sustainability assessment, the sustainable yield was recalculated using the method described in Section 4.2, and the results are presented in **Table 23**. Without the SGMA projects and management actions, the percentage of the Average Annual Difference to the total groundwater pumping provides context to compare the significance of the level of groundwater pumping for the basin. For the scenarios without SGMA projects and management actions, the groundwater pumping exceeds the sustainable yield on the order of 25% to 34% (**Table 23**). However, with the proposed SGMA projects and management actions, the groundwater pumping is less than the sustainable yield of the Subbasin for the Baseline and 2030 climate scenarios and is within 3% of the sustainable yield for the 2070 climate scenario (**Table 23**). This assessment indicates that the proposed SGMA projects and management actions for the Kern County Subbasin are of sufficient magnitude that, if fully implemented, would lead to groundwater sustainability for the Kern County Subbasin after WY2040.

7.2.3 Minimum Thresholds and Measurable Objectives

Another requirement of SGMA is for groundwater levels not to cross their minimum thresholds to the extent that undesirable results would occur in the basin, and moreover, that proposed SGMA projects and management actions would lead to meeting the measurable objectives. The Kern County Subbasin GSAs have defined 186 representative monitoring well (RMW) locations spread across the Kern County Subbasin. A minimum threshold and measurable objective have been assigned each of the 186 locations, and the hydrographs for all 186 locations are provided in **Attachment A**. The RMW locations are shown on **Figure 21**.

The C2VSimFG-Kern results were used to assess whether the simulated groundwater levels would meet the minimum threshold and measurable objective for each monitoring well. Because C2VSimFG-Kern is

not fully calibrated, the results are presented as relative change (which does not require calibration) instead of simulated groundwater levels using the superposition method. Future change in groundwater level was determined for each of the 186 locations for each of the six projected future simulations. The change was calculated from the simulated March 2015 groundwater levels from the model. The change in groundwater level was then applied to the measured March 2015 groundwater level at the monitoring location. The result was to superimpose the simulated change in groundwater levels from the projected future C2VSimFG-Kern scenarios relative to the measured March 2015 groundwater level.

Figure 22 provides four representative examples of the simulated hydrographs using this method. Hydrographs of the simulated groundwater levels relative to the minimum thresholds and measurable objectives for all 186 locations were provided to the various GSAs and water districts for inclusion in their respective GSPs. In general, across most areas of the basin, groundwater levels fall near or below the minimum thresholds without the SGMA projects but are typically above the minimum threshold for the simulations that include the SGMA projects.

The groundwater hydrographs for some locations, especially along the eastern and western basin margins, show an unusual pattern that is likely influenced by issues with the hydrogeological conceptual model incorporated into C2VSimFG-Kern for these locations. The hydrographs for these areas are not considered to be representative of actual conditions that would physically occur. This is a limitation to the model. It is recommended that a more rigorous model update be conducted to revise the hydrogeological conceptual model to be consistent with that presented in the Kern County Subbasin GSPs. In addition, further calibration of C2VSimFG-Kern is recommended to update aquifer parameters in the Kern County Subbasin. The recommendations for revisions to the hydrogeological conceptual model and additional calibration are further discussed in Section 8.5.

8. VALIDATION OF C2VSIMFG-KERN PERFORMANCE

The C2VSimFG-Kern performs well within the central part the Kern County Subbasin. The model does not perform as well east of the Friant-Kern Canal or west of the California Aqueduct. The geologic and hydrogeologic conceptual models within the central part of the Kern County Subbasin appear to be generally realistic. The geologic and hydrogeologic conceptual models appear to be very poor in the areas where the model does not perform well.

8.1 C2VSimFG-Kern Validation

One of the concerns for the modeling is the overall calibration of C2VSimFG-Beta in Kern County. As discussed above, the assumption is that C2VSimFG-Beta was developed using reasonable care in developing the geologic framework and developing a consistent regional methodology for determining aquifer properties. An identified weakness of the C2VSimFG-Beta is the quality of data used in developing the overall water balance such as the extent of the groundwater banking operations in Kern County. The issues with the water balance are considered the primary contributing factor affecting the calibration of the C2VSimFG-Beta; the hydrogeologic conceptualization is reasonably accurate for a regional planning analysis.

To address these concerns, a validation analysis was performed for C2VSimFG-Kern by comparing simulations results to field measured groundwater level data collected during the Study Period and comparing those to a similar set of residuals from the C2VSimFG-Beta model. The statistical results of

this analysis should be comparable, if not better, for C2VSimFG-Kern compared to the C2VSimFG-Beta results.

The analysis used 42,058 groundwater levels measurements collected from 558 monitoring wells in the Kern County Subbasin. The data were collected by Kern County Water Agency, the Kern Fan Monitoring Committee, the DWR Water Data Library, and local agencies. For each location, the residual was calculated as the simulated groundwater level minus the measured groundwater level based on the well measurement data. A brief summary of the statistical measures used to evaluate the calibration results (shown on **Table 24**) is provided below:

- The residual mean is computed by dividing the sum of the residuals by the number of residual data values. The closer this value is to zero, the better the calibration especially as related to the water balance and estimating the change in aquifer storage. The residual mean of 17.3 feet for C2VSimFG-Kern is an improvement of 47% over the 32.6 feet from C2VSimFG-Beta.
- The absolute residual mean is the arithmetic average for the absolute value of the residual, so it provides a measure of the overall error in the model. The absolute residual mean of 37.4 feet for C2VSimFG-Kern is an improvement of 34% over the 56.8 feet from C2VSimFG-Beta.
- The residual standard deviation evaluates the scatter of the data. A lower standard deviation indicates a closer fit between the simulated and observed data. The standard deviation is 45.5 feet for C2VSimFG-Kern, which is an improvement of 16% over the 54.0 feet from C2VSimFG-Beta.
- The Root Mean Square (RMS) Error is the square root of the arithmetic mean of the squares of the residuals and provides another measure of the overall error in the model. The RMS Error is 50.0 feet for C2VSimFG-Kern, which is an improvement of 32% over the 73.5 feet from C2VSimFG-Beta.
- The correlation coefficient ranges from 0 to 1 and is a measure of the closeness of fit of the data to a 1 to 1 correlation. A correlation of 1 is a perfect correlation. The correlation coefficient of 0.76 for C2VSimFG-Kern is an improvement of 47% over the 0.52 from C2VSimFG-Beta.
- Another statistical measure is the ratio of the standard deviation of the mean error divided by the range of observed groundwater elevations. This ratio shows how the model error relates to the overall hydraulic gradient across the model. The ratio for C2VSimFG-Kern is 0.061 feet, which is an improvement of 34% over the 0.092 from C2VSimFG-Beta.

Considering these results in context with the overall range of measurements of 616 feet, the residual mean of 17.3 feet represents a relative percentage difference of less than 3%. For the absolute residual mean of 37.4 feet, the relative percentage difference is about 6%. Despite this improvement in model performance, the model is not considered fully calibrated. However, C2VSimFG-Kern is reasonably validated for assessing groundwater level changes on the subbasin scale for the purposes of SGMA planning.

8.2 Sensitivity Analysis

The C2VSimFG-Kern model was not formally calibrated. Some physical parameters were adjusted to improve model performance in specific areas. A sensitivity analysis was conducted on the adjusted model to understand how variations in model parameters affect model results. Eight physical parameter sets were systematically varied, and model results compared to the base model for a

selected group of groundwater hydrographs. C2VSimFG-Kern parameter sensitivities evaluated for Kern County Subbasin include:

- Horizontal hydraulic conductivity of aquifer (Kh)
- Vertical hydraulic conductivity of aquifer (Kv)
- Vertical hydraulic conductivity of Corcoran Clay aquitard (Kcorc)
- Streambed conductance of Kern River (Cstm)
- Specific storage of aquifer (Ss)
- Specific yield of aquifer (Sy)
- Soil hydraulic conductivity in root zone (Ksoil)
- Soil pore size distribution index in root zone (λ)

The Root Mean Squared Error between observed and simulated values was calculated for the original parameter set and after varying each parameter set upward and downward by a set factor. Results are presented in **Figure 23**. This sensitivity analysis shows that the hydrologic parameter values in the C2VSimFG-Kern model are generally within an acceptable range. A full model calibration would likely improve model performance.

8.3 Peer Review Process

Todd Groundwater worked with Woodard and Curran (W&C) throughout the model development process as W&C conducted an on-going peer review of model input files. W&C staff have developed several IWFM-based models and worked with DWR to develop C2VSimFG-Beta. Their reviews helped ensure that the model update used best practices when incorporating new data. The peer review process was documented in a series of meeting summaries to the KGA and KRGSA. The updated C2VSimFG-Kern input files for the Kern County Subbasin were shared with DWR for incorporation into future C2VSim public releases.

The more general assumptions in C2VSimFG-Beta were replaced with local data and knowledge that are regionally or locally significant for WY1995 to WY2015. This update employed a phased approach with regular peer reviews.

1) Phase 1 revisions address components of Regional Significance that require significant changes to the overall model input file structure. These include:
   a) Surface water delivery volumes, application areas and use by water district,
   b) Groundwater banking recharge, recovery and application of recovered water,
   c) Evapotranspiration rates and irrigation demand based on ITRC METRIC data (ITRC 2017),
   d) Urban population and per capita demand, including addition of an urban zone for Metropolitan Bakersfield, and
   e) Addition of groundwater extraction wells for groundwater banking projects.
2) Interim Review
   a) The Woodard & Curran Peer Review Team
   b) Kern County Subbasin water districts and purveyor's local data review
   c) Stakeholder input
3) Phase 2 revisions address components of Local Significance that generally require modifications of input data and parameters within the existing C2VSim model input file structure. These include:

a) Local water sources and demands of significance to individual Districts/GSAs,
b) District pumping for in-district delivery via surface water canals where significant,
c) District recharge operations utilizing canals, stream channels, and basins,
d) Wastewater disposal and land application, and
e) Review and limited adjustment of model parameters.

4) Interim Review by same reviewers listed in item 2

5) Phase 3 revisions include addressing comments and incorporating new data from the Interim Reviews

6) Interim Review by same reviewers listed in item 2

7) Tabulate model-derived water budgets for Peer-Review and GSP Use

In each update phase, historical and current water budgets for zones representing water agency service areas were produced with the revised C2VSimFG-Kern model incorporating corrected local data. These water budgets were shared with participating agencies for review, to ensure that C2VSimFG-Kern correctly represented local water balances. Where necessary, participating agencies provided additional data which was incorporated into C2VSimFG-Kern.

8.4 Internal Review Process

Todd Groundwater and Hydrolytics LLC worked collaboratively on this model revision, water budget development and the projected future scenarios. Throughout this work, efforts were applied to improve data management to develop a systematic process for generating model input files. Using this approach, internal review could be conducted with each firm reviewing the contributions from the other. The goal was to accurately represent the data provided by the Kern County agencies in the model.

Due to schedule constraints, a thorough internal review of the projected future model scenarios was not completed prior to the submission of the Public Review Draft of the model results in August 30, 2019. A thorough review of all input for the projected future scenarios was conducted in September and October 2019. During this review, several issues were identified and corrected. As a result, the results in this report vary from those provided in the August 2019 Public Review Draft. Although the numbers changed, the overall conclusions from the C2VSimFG-Kern simulations remained essentially the same.

8.5 Recommendations for Future Improvements to C2VSimFG-Kern

The C2VSimFG-Kern performs well in the Kern County Subbasin, producing simulated water budget components that generally match historical values compiled by local agencies. C2VSimFG-Kern simulated groundwater levels provide a reasonable approximation of observed groundwater levels in the central part of the Kern County Subbasin. The model is well suited for estimating the impacts of management actions on the Subbasin groundwater storage and is also well suited as a planning tool in meeting compliance of SGMA.

During the model update, several outstanding issues were identified that should be addressed in future updates to C2VSimFG-Kern. The following actions and model improvements are recommended:

- **Improve streamflow simulations of the Kern River and Poso Creek.** Flows in the Kern River channel, including local stream-groundwater interactions, are not well replicated and surface water diversions are not dynamically simulated. Some rejected recharge occurs in the Kern Fan

area in very wet years, with significant outflow of groundwater to the Kern River especially in the Kern Fan banking area (i.e., rejected recharge). This has been an ongoing issue and needs to be addressed for the projected future water budgets so that banking recharge volumes can be better matched in the model. It is recommended that future revisions to C2VSimFG-Kern further evaluate issues in simulating streamflow and seepage in the Kern River and Poso Creek (see Section 8.5). This may include incorporating more advanced streamflow simulation features that are available in IWFM but that have not been previously utilized in developing C2VSim models by DWR. Changing the stream simulation feature may require development of a local Kern County Subbasin model.

- **Improve the geologic and hydrogeologic conceptual model of the Kern County portion of the Central Valley.** A hydrogeologic conceptual model is a framework for understanding where groundwater exists, where it flows, and how groundwater interacts with surface water bodies and the land surface. A geologic conceptual model provides a framework for understanding the geologic features that control groundwater movement. Quantitative analysis of Kern County Subbasin groundwater flow is severely hampered by the lack of detailed geologic and hydrogeologic conceptual models of the areas outside the central alluvial basin. Geologic and hydrogeologic conceptual models will provide a foundation for the quantitative analysis of the groundwater flow system, and the framework for modeling the system. Key steps are:
    - Develop detailed geologic and hydrogeologic conceptual models of the Kern County Subbasin.
    - Differentiate the four Principal Aquifers that have been identified in the Kern County Subbasin based on definitions from local management area GSPs.
    - Identify the locations and characteristics of natural features that affect groundwater recharge and movement (faults, ridges, clays).
    - Understand water occurrence and movement in areas outside the central Kern County Subbasin.
    - Develop water quality maps (natural constituents and anthropogenic constituents).
    - Modify the Kern County Subbasin model to conform to the updated conceptual models.
- **Simulation of deep percolation and small watersheds.** Unreasonably high deep percolation (return flows) of the applied water in some areas has led to unreasonably elevated pumping rates to compensate. One problem is high root zone hydraulic parameter values in certain areas that were identified and corrected to better reflect local soil conditions. Because the excess pumping was returning to groundwater, the change has little effect on the basin change in storage, but the pumping and deep percolation are now more in line with local estimates. Root zone hydraulic parameters should be redeveloped throughout the subbasin to assure model values are representative of actual values.
- **Root Zone Parameters,** Areas of overly high root zone hydraulic parameters led to high volumes of deep percolation that required additional groundwater pumping to meet the overall water demand for irrigation. A review found areas of overlying high soil hydraulic conductivity and other soil parameters produced percolation rate that were too high. These areas were manually adjusted to be more in line with observed conditions. A more rigorous development of root zone parameters should be considered in the future as this issue demonstrates that it is a sensitive parameter.

- **Investigate development of a stand-alone Kern County Subbasin model.** The C2VSim model provided by DWR and updated with local data is adequate for GSP preparation. However, this model may not meet all of the groundwater modeling needs of Kern County Subbasin stakeholders. In addition, running a full Central Valley simulation model imposes longer model run times and reduces model flexibility. Stakeholders should undertake a comprehensive study to develop a list of their integrated (groundwater and surface water) modeling needs, and then decide whether further improving C2VSimFG-Kern or developing a new integrated hydrologic model is the best way to address the Subbasin modeling needs. This decision should be made before the end of 2020 to allow sufficient time to develop a new model or improve C2VSimFG-Kern in time for use in development of the 2025 GSP.
- **Adjust the finite element grid to honor water management boundaries.** The C2VSimFG-Kern model grid is a randomly generated grid that does not conform to any local features other than natural surface water channels. This limits the spatial accuracy of model inputs and the precision and flexibility of water budget outputs. Adjusting the grid to match district and agency boundaries, historical delivery areas, water management units within districts, and geologic and hydrologic features would greatly enhance model capabilities.
- **Quantify boundary flows.** Significant uncertainty exists regarding the rates and timing of groundwater flows into the Kern County Subbasin from surrounding watersheds, and groundwater flows from the Kern County Subbasin to Kings and Tulare counties to the north. Reliable estimates of boundary flows will improve model performance in boundary areas.
- **Kern County Subbasin Boundary.** The GSAs in the basin should consider when DWR updates the Bulletin 118 in 2020 to investigate the "actual" Kern County Subbasin and to remove those peripheral lands where aquifer connectivity does not exist.
- **Utilize more complex water management features of IWFM.** The Kern Update process modified information within the existing C2VSimFG-Beta model structure to improve model performance within the Kern County Subbasin. The IWFM application has several features that could be further utilized to improve model performance.
    - Adjust the agricultural crops to better match the Kern County crop mix (for example, create separate crop categories for carrots, young and mature almonds, young and mature pistachios, etc.).
    - Implement multi-cropping with semiannual or quarterly land use.
    - Some C2VSim data are organized by DWR subregions, which represent heterogeneous areas with homogeneous data. Developing Kern County Subbasin subregions and organizing model input data by these subregions may provide a better representation of local hydrologic conditions.
- **Calibrate the improved model for the Kern County Subbasin**. DWR did not fully calibrate the Kern County portion of the C2VSim model, owing to both poor historical input data and a lack of calibration data sets. The Kern Update process significantly improved the historical data in the model, developed some calibration data sets, and included limited adjustment of model parameters. The updated model performs adequately in the central part of the Kern County Subbasin and poorly in areas outside the central part of the basin. Once the above improvements are completed, the Kern County portion of the resulting model should be fully calibrated to ensure that it performs well throughout the Kern County Subbasin.

9. CONCLUSIONS

This brief summary provides an overview of the findings and conclusions of the modeling results for the Kern County Subbasin using C2VSimFG-Kern.

9.1 Findings of the C2VSimFG-Kern Application and Results

The subbasin-wide update of C2VSimFG-Kern incorporated data from many local agencies. Each participating agency provided data for their jurisdiction for use in improving the model. This included managed water supply data (e.g., surface water deliveries, land use, irrigation demand, return flows, and groundwater banking), stream and groundwater monitoring data, geologic data, and other relevant data. This information was compiled and used to improve C2VSimFG-Kern performance in the Kern County Subbasin.

The historical water budget analysis indicates that the Kern County Subbasin was in a state of overdraft equivalent to the long-term decline in groundwater storage from WY1995 to WY2014 of 277,144 AFY. Projected Future simulations indicate that the proposed SGMA projects and management actions in the Kern County GSPs are sufficient for the Kern County Subbasin to achieve sustainability under Baseline and 2030 Climate Change conditions.

C2VSimFG-Kern was used to evaluate the change in groundwater in storage for projected future conditions using a baseline condition that projects current water supply, water demand and land use over a 50-year period based on historical hydrology. The baseline was adapted following DWR climate change guidance to develop 2030 and 2070 climate change simulations. The proposed SGMA projects and management actions were compiled from all of the Kern County Subbasin GSAs and management areas. The total projects total about 421,000 AFY after implementation. This assessment indicates that the proposed SGMA projects and management actions for the Kern County Subbasin are of sufficient magnitude that, if fully implemented, would lead to groundwater sustainability for the Kern County Subbasin after WY2040.

The historical C2VSimFG-Kern performs well in the Kern County Subbasin, producing simulated water budget components and groundwater levels that generally match historical values compiled by local agencies. C2VSimFG-Kern simulated groundwater levels provide a reasonable statistical approximation of observed groundwater levels in the Kern County Subbasin that show significant improvement relative to C2VSimFG-Beta. Therefore, C2VSimFG-Kern is well suited as a planning tool to estimate the impacts of the proposed SGMA projects and management actions on groundwater conditions in the Kern County Subbasin.

The C2VSimFG-Kern model development and the water budget analysis were designed to fulfill the GSP requirement for a coordinated subbasin-wide water budget analysis, while also providing information required to fulfill other GSP requirements. The C2VSimFG-Kern was provided to DWR so the Kern County Subbasin revisions can be incorporated into their master version of the C2VSim model.

9.2 C2VSimFG-Kern Compliance with Coordination Agreement Requirements

Subbasin GSAs coordinated on the development and application of the C2VSimFG-Kern to ensure that the model was incorporating comparable data sets and the best available information; as such, the model meets numerous technical requirements for Subbasin-wide coordination, including for

Coordination Agreements in §357.4. As demonstrated throughout this memorandum, the C2VSimFG-Kern model documents the use of "the same data and methodologies" for water budget development.

Specifically, groundwater extraction data were coordinated through the use of ET METRIC data for all irrigated lands over the entire Subbasin to estimate private irrigation pumping. Monthly metered data from District, municipal, and banking pumping were incorporated as available. Surface water supply data were provided in similar units and formats using consistent templates for data collection and management in the model. Total water use and change in groundwater in storage were developed through consistent methodologies as applied in the C2VSimFG-Kern model. Calibration targets also incorporated consistent data sets for groundwater elevation data throughout the Subbasin as compiled in the DWR Water Data Library, KCWA water level database, and supplemented with local data, as needed. This memorandum documents coordination efforts in subsequent sections that demonstrates compliance with GSP requirements in §354.18, §357.4, and other portions of the regulations.

9.3 Limitations and Uncertainty of C2VSimFG-Kern

The C2VSimFG-Kern performs well in the Kern County Subbasin, producing simulated water budget components that generally match historical values compiled by local agencies. C2VSimFG-Kern simulated groundwater levels provide a reasonable approximation of observed groundwater levels in the central part of the Kern County Subbasin. The model is well suited to estimating the impacts of management actions on subbasin groundwater storage.

The C2VSimFG-Kern update was limited in scope, and some model components do not perform well. These components do not reduce model capabilities with respect to GSP development but limit the usefulness of the model for other types of studies. Flows in the Kern River channel, including local stream-groundwater interactions, are not well replicated and surface water diversions are not dynamically simulated. The Kern County Subbasin portion of the C2VSimFG-Kern is not calibrated, and although the land surface water budget components are generally accurate, groundwater conditions and stream flows are poorly simulated in much of the Subbasin. Some rejected recharge occurs in the Kern Fan area in very wet years, but this is not significant as it is a very small volume.

The C2VSimFG-Kern is a reliable and defensible tool to support planning future groundwater conditions and estimating the potential hydrological impacts of future climate conditions and management actions at the subbasin level. It is currently the best available quantitative tool for assessing projected future groundwater conditions under SGMA. DWR recommends updating and refining models used in GSPs to incorporate new data including that in annual GSP updates. Refining Kern County Subbasin hydrologic modelling tools to replicate district-level historical conditions will provide a reliable means of assessing future effects of management actions at the district level for future GSP development.

9.4 Applicability of C2VSimFG-Kern Simulation Results

Based on the model validation, C2VSimFG-Kern provides a useful planning tool to evaluate potential future trends in groundwater in the Kern County Subbasin. The model validation demonstrated the capability of C2VSimFG-Kern to reasonably simulate the groundwater elevations and trends during the period from WY1995 through WY2015 based on the comparison to measured data.

The ability to reasonably simulate historical conditions provides confidence that C2VSimFG-Kern can be used to simulate potential future conditions. The model has the capability to simulate the most beneficial application of water projects that would provide the long-term benefit to the area. For the

future case scenarios, the general practice is to evaluate model results with respect to long-term trends. Therefore, as a planning tool, it is most beneficial to run the model in relation to a base case and to evaluate the relative difference between the model scenario and the base case. The base case would assume a selected set of climatic, hydrologic and pumping conditions. Commonly, the calibration base period is assumed to repeat; however, any number of variations can be constructed.

It is important to note that in some cases the model results may vary from those measured in individual wells due to the geologic complexity of the Kern County Subbasin. However, the model is capable of evaluating the impacts of changes in pumping and water use practices in the Kern County Subbasin that are useful for SMGA planning purposes.

The conclusions and recommendations presented herein are professional opinions based on the C2VSimFG-Kern revisions and simulations as described herein. The findings and professional opinions presented in this letter are presented within the limits prescribed by the client contract, in accordance with generally accepted professional engineering, geologic and modeling practices, to support development of GSPs within the Kern County Subbasin. There is no other warranty, either expressed or implied, regarding the conclusions, recommendations, and opinions presented in this report.

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Water Year	Arvin-Edison WSD	Belridge WSD	Berrenda Mesa WSD	Buena Vista WSD	Cawelo WD	Kern River Canal Co.	Henry Miller WD	Kern Delta WD	Kern-Tulare WD	Lost Hills WD	North Kern WSD	Rosedale Rio Brave WSD	Semi-tropic WSD	Shafter-Wasco ID	So. San Joaquin MUD	Wheeler Ridge - Maricopa WSD	Olcese WD	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	144,722	106,293	90,909	162,444	78,084	14,994	43,242	183,471	27,131	103,268	198,865	0	74,487	149,252	112,888	177,348	1,493	1,668,891
1987	127,333	106,293	90,909	142,274	89,117	12,113	43,242	137,458	27,131	123,981	112,432	0	53,753	172,161	76,193	161,949	1,493	1,477,832
1988	114,321	106,293	90,909	141,152	77,106	4,203	43,242	135,078	27,131	111,872	81,580	0	47,071	164,192	71,243	154,030	1,417	1,370,840
1989	114,591	106,293	90,909	150,341	85,190	11,096	43,242	140,360	27,131	122,044	61,797	0	50,495	190,990	94,729	178,129	1,480	1,468,817
1990	70,816	106,293	90,909	124,845	67,867	14,757	43,242	114,531	27,131	88,963	51,926	0	34,381	49,992	73,000	170,693	1,480	1,130,826
1991	40,698	106,293	90,909	100,517	50,621	10,416	43,242	117,287	27,131	9,553	28,931	0	40,595	7,926	11,683	31,030	1,480	718,312
1992	52,839	106,293	90,909	108,874	54,406	9,909	43,242	118,190	27,131	52,853	34,291	0	45,851	94,467	65,310	96,514	1,480	1,002,559
1993	137,479	93,344	85,549	151,653	75,490	11,596	43,973	174,003	26,034	77,793	181,920	5,040	72,120	226,462	108,767	137,221	1,425	1,609,869
1994	171,856	110,017	93,092	125,084	62,968	13,862	53,471	132,865	28,017	87,636	117,580	2,362	47,111	110,951	83,680	151,368	1,685	1,393,606
1995	134,559	110,993	78,521	189,797	73,155	6,600	29,047	159,595	27,333	85,963	174,020	5,591	62,105	235,347	108,778	153,783	1,425	1,636,611
1996	166,288	112,412	115,132	184,597	90,229	11,591	39,539	179,052	28,749	145,349	202,199	5,722	72,231	313,420	128,865	189,454	1,987	1,986,816
1997	185,820	143,146	97,233	197,871	88,202	11,134	50,584	179,388	29,998	122,140	191,871	4,563	67,407	313,717	124,456	188,455	1,778	1,997,763
1998	120,808	79,387	85,885	152,455	69,758	4,959	30,260	124,464	24,422	80,845	153,662	4,756	53,064	240,072	89,373	148,174	849	1,463,194
1999	152,909	101,786	93,199	142,271	86,667	10,085	53,858	141,626	28,093	108,563	146,395	4,679	57,625	307,686	110,686	166,018	1,248	1,713,394
2000	158,008	111,057	87,200	135,689	87,894	12,833	44,302	152,338	29,948	119,828	133,872	3,920	61,358	315,833	119,597	179,278	1,382	1,754,337
2001	158,432	91,642	65,734	76,718	70,873	10,048	31,379	113,044	30,109	68,302	74,725	0	48,772	70,879	98,104	136,390	1,588	1,146,739
2002	158,197	107,617	63,705	78,735	75,042	9,058	31,724	116,181	25,443	67,574	62,006	0	55,121	165,448	103,849	133,652	1,702	1,255,054
2003	139,412	103,724	64,267	96,601	75,749	8,371	33,941	161,162	24,120	62,007	106,436	1,000	55,511	265,110	106,779	120,733	2,041	1,426,964
2004	155,531	118,543	68,902	86,119	78,558	9,383	39,101	138,664	25,541	67,607	99,610	1,739	58,351	174,605	106,537	138,771	1,637	1,369,199
2005	136,887	105,523	69,372	125,522	78,101	6,037	39,248	169,747	21,445	60,844	207,612	2,784	58,711	294,595	109,716	127,846	1,939	1,615,929
2006	140,411	115,146	84,869	149,851	96,249	5,317	46,538	172,882	22,525	73,422	199,626	0	68,468	332,115	120,106	150,416	2,048	1,779,988
2007	158,526	118,036	102,971	91,196	70,811	4,574	48,482	112,341	23,348	83,116	89,195	552	37,391	146,826	75,642	164,924	1,496	1,329,426
2008	157,604	114,525	86,217	70,032	62,437	4,380	18,156	145,633	22,788	74,554	86,051	0	47,623	29,675	87,776	168,211	1,700	1,177,361
2009	145,184	113,385	86,439	73,530	67,340	4,340	12,129	126,039	21,803	83,740	84,727	0	44,265	30,808	116,967	159,502	1,781	1,171,979
2010	132,462	117,589	88,556	102,109	76,351	3,604	29,694	166,787	19,272	88,191	171,744	1,543	65,238	168,870	120,394	159,162	1,756	1,513,322
2011	130,306	121,808	87,344	121,329	88,617	4,617	39,642	192,069	20,213	92,149	173,305	4,466	74,413	337,724	124,678	156,216	1,530	1,770,425
2012	148,146	130,559	87,953	96,407	89,745	3,988	41,553	195,763	21,682	91,720	81,584	1,329	35,369	227,901	81,602	168,753	1,783	1,505,837
2013	159,887	138,131	93,311	33,558	49,978	3,585	18,533	94,682	22,252	93,322	23,343	0	26,194	81,279	58,923	170,033	1,966	1,068,977
2014	144,605	123,390	82,731	410	41,223	2,645	2,246	70,367	14,067	82,546	11,290	0	8,303	5,748	14,249	152,372	1,238	757,429
2015	114,350	117,357	81,535	134	38,195	2,663	0	68,228	10,274	80,631	9,901	0	0	12,226	3,020	145,842	1,462	685,817

TABLE 2 - Summary of data input for surface water diversion from Kern River at different diversion and turnouts applied to C2VSimFG-Kern Historical Simulation

Water Year	Kern River to Beardsley Canal	Kern River to Carrier Canal at Rocky Point	Kern River to Carrier Canal at Calloway Weir	Kern River to CVC at Turnout #4	Kern River to River Canal	Kern River to Rio Vista at River Walk	Kern River to Rosedale Channel	Kern River to North Lake	Kern River to Pioneer Canal	Kern River to Berrenda Mesa WSD	Kern River to Pioneer Project	Kern River to Kern Water Bank	Kern River to Kern Water Bank Canal	Kern River to 2800 Acre Facility	Kern River to Buena Vista WSD BSA	Kern River to Aqueduct at Intertie	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	291,715	199,035	238,877	181,392	0	0	65,684	0	63,232	0	0	0	0	97,866	86,736	0	1,224,537
1987	190,539	76,888	179,876	58,811	0	0	19,893	0	756	0	0	0	0	21,592	86,736	0	635,091
1988	111,679	25,813	163,938	21,851	0	0	345	0	0	0	0	0	0	0	86,736	0	410,362
1989	98,796	28,696	168,926	23,291	0	0	0	0	0	0	0	0	0	0	86,736	0	406,445
1990	77,389	5,373	128,753	6,577	0	0	0	0	0	0	0	0	0	0	86,736	0	304,828
1991	69,736	180,189	56,331	13,944	0	0	5,869	0	0	0	0	0	0	0	86,736	0	412,805
1992	71,521	194,315	690	11,008	0	0	3,598	0	0	0	0	0	0	0	86,736	0	367,868
1993	213,099	241,104	43,555	59,099	50,897	0	54,936	0	27,803	0	0	0	0	64,852	64,488	0	819,833
1994	187,380	213,631	18,103	26,829	67	0	0	0	0	9,882	0	0	0	28,046	38,745	0	522,683
1995	256,234	248,113	65,360	144,230	136,516	0	91,721	0	40,366	23,822	45,284	0	0	60,476	103,429	11,850	1,227,401
1996	315,988	255,792	105,845	108,405	119,999	0	78,824	0	14,286	17,382	55,074	0	0	24,037	92,768	0	1,188,400
1997	288,746	280,471	123,771	130,336	123,333	0	62,841	0	23,271	14,977	45,600	0	0	27,212	134,320	52,848	1,307,726
1998	312,857	244,337	143,422	131,398	23,346	0	95,706	0	51,802	18,483	69,637	0	0	95,160	115,019	188,048	1,489,215
1999	214,847	180,856	71,974	46,274	58,082	0	33,938	0	839	6,915	21,343	0	0	17,891	77,220	0	730,179
2000	175,718	169,844	38,793	31,596	38,147	0	20,213	0	0	1,396	15,929	0	0	30,660	47,882	0	570,178
2001	130,052	188,404	23,762	14,050	4,631	0	3,177	0	2,179	0	0	0	0	0	32,686	0	398,941
2002	91,980	203,010	4,149	23,609	7,878	0	581	0	199	431	871	0	0	0	29,404	0	362,112
2003	164,112	206,448	15,893	14,088	31,451	0	12,306	0	0	1,045	0	0	0	0	38,307	0	483,650
2004	153,148	198,769	29,338	18,247	2,301	589	1,503	165	0	2,545	2,005	0	0	0	39,412	0	448,022
2005	236,776	228,885	73,215	62,146	60,019	0	141,022	1,442	1,942	39,702	102,111	21,548	23,125	77,127	72,865	0	1,141,925
2006	257,590	247,806	53,872	122,931	33,872	3,942	87,318	1,442	9,962	24,636	116,108	25,165	34,358	42,587	97,955	0	1,159,544
2007	135,525	189,169	1,049	10,483	7,752	2,746	0	0	0	13,099	17,809	7,507	0	4,568	47,914	0	437,621
2008	137,813	229,304	53,824	22,700	0	544	0	0	0	0	0	0	0	0	34,549	0	478,734
2009	139,246	238,103	31,342	28,635	115	712	109	0	0	0	0	0	0	0	18,418	0	456,680
2010	196,135	241,876	70,315	68,944	60,087	820	10,816	776	1,775	1,165	0	0	0	13,748	66,441	0	732,898
2011	298,003	266,684	75,784	160,243	90,048	1,752	101,209	787	20,479	26,223	121,857	23,951	47,187	84,876	98,416	0	1,417,499
2012	148,513	241,953	20,495	55,303	409	1,001	10,998	0	0	7,594	20,162	582	0	7,871	45,173	0	560,054
2013	45,141	153,474	706	25,758	0	247	0	0	0	3,529	0	0	0	155	0	0	229,010
2014	26,041	122,044	0	8,356	0	283	0	0	0	0	0	0	0	0	0	0	156,724
2015	16,883	104,841	0	0	0	195	0	0	0	0	0	0	0	0	0	0	121,919

TABLE 3 - Summary of data input for surface water diversions for various purposes applied to C2VSimFG-Kern Historical Simulation

Water Year	Metro Bakersfield Urban Surface Water Supply	Metro Bakersfield Wastewater Land Disposal	Kern Nat'l Wildlife Refuge SWP Supply	Kern Nat'l Wildlife Refuge Surface Water Inflows from Poso Creek	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	24,416	29,235	0	1,611	30,846
1987	25,298	30,832	0	247	31,079
1988	28,563	32,304	0	65	32,369
1989	27,818	33,785	0	136	33,921
1990	27,426	35,756	0	0	35,756
1991	20,959	36,837	0	123	36,960
1992	25,867	37,801	0	10	37,811
1993	30,261	38,774	120	852	39,746
1994	29,111	39,684	16,861	95	56,640
1995	27,248	40,709	12,097	896	53,702
1996	28,261	41,667	12,776	4,536	58,979
1997	19,216	40,832	7,964	13,811	62,607
1998	11,036	40,355	12,268	90,926	143,549
1999	26,996	39,629	14,827	1,876	56,332
2000	30,963	41,497	7,489	58	49,044
2001	28,611	41,559	13,179	0	54,738
2002	30,185	42,043	19,299	1	61,343
2003	32,206	42,962	20,945	22	63,929
2004	56,861	43,735	23,461	0	67,196
2005	43,727	44,021	23,310	9,025	76,356
2006	40,294	44,614	21,829	11,734	78,177
2007	55,334	44,643	21,607	2,440	68,690
2008	56,335	44,936	17,728	18	62,682
2009	58,834	45,416	19,494	9	64,919
2010	61,314	45,527	21,808	536	67,871
2011	64,388	46,429	26,599	7,691	80,719
2012	68,013	46,666	18,451	9	65,126
2013	66,998	45,513	23,701	0	69,214
2014	55,692	44,645	13,877	0	58,522
2015	44,981	43,256	9,203	0	52,459

TABLE 4 - Summary of data input for surface water diversion to groundwater banking and managed aquifer recharge for different facilities applied to C2VSimFG-Kern Historical Simulation

Water Year	Arvin-Edison WSD	Berrenda Mesa Project	Buena Vista WSD	Cawelo WD	Kern Delta WD	Kern River GSA	North Kern WSD	Rosedale-Rio Bravo WSD	Semi-tropic WSD	West Kern WD	City of Bakers-field	Pioneer Project	Kern Water Bank	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	63,708	0	28,948	0	0	107,936	115,498	103,384	0	25,559	164,861	0	0	609,894
1987	18,800	0	7,487	0	0	62,084	47,206	47,731	0	23,249	50,585	0	0	257,142
1988	1,434	0	227	0	0	49,926	11,171	19,026	0	24,594	18,294	0	0	124,672
1989	3,358	0	3,532	0	0	58,640	804	27,984	0	28,604	14,148	0	0	137,070
1990	4,660	0	0	0	0	35,825	0	11,530	0	22,368	9,564	0	0	83,947
1991	2,404	0	0	0	0	54,577	1,224	5,931	0	14,754	19,768	0	0	98,658
1992	3,886	0	799	0	0	48,497	10,236	11,880	0	10,368	23,482	0	0	109,148
1993	99,714	0	19,229	0	0	83,472	25,220	88,065	0	24,420	126,544	0	0	466,664
1994	28,968	0	11,485	0	0	60,217	12,333	26,016	0	29,233	67,418	0	0	235,670
1995	87,910	17,808	49,623	0	0	98,122	149,948	119,339	0	28,201	143,019	62,274	121,465	877,709
1996	69,472	23,398	18,253	0	0	102,034	103,277	116,704	0	37,351	75,468	51,330	232,355	829,642
1997	58,069	9,801	38,015	7,524	0	103,578	102,050	108,711	0	18,555	53,470	38,169	132,457	670,399
1998	97,098	9,493	63,868	9,136	0	90,233	196,469	136,250	0	23,133	149,426	57,357	236,320	1,068,783
1999	81,398	11,489	8,904	6,110	0	83,858	69,080	78,941	0	29,249	41,516	21,884	116,663	549,092
2000	95,786	1,027	238	3,446	0	74,926	163	44,501	0	23,082	51,444	22,032	36,551	353,196
2001	38,774	0	99	2,683	0	59,411	0	5,653	0	8,747	22,005	1,253	10,029	148,654
2002	4,437	0	1,065	2,596	0	63,427	0	1,404	0	19,467	11,840	0	13,439	117,675
2003	44,030	0	424	3,314	4,177	73,362	367	27,154	0	17,766	20,133	0	5,369	196,096
2004	7,160	3,172	0	5,172	1,380	65,335	3,039	9,626	0	3,513	22,480	10,768	53,070	184,715
2005	100,311	19,663	33,153	7,882	7,274	98,474	74,241	151,136	0	29,552	164,991	93,466	308,092	1,088,235
2006	90,722	28,268	22,966	4,219	1,224	95,246	138,698	174,051	0	14,385	113,166	64,388	308,877	1,056,210
2007	20,012	15,292	0	5,241	488	51,678	80,467	20,348	0	4,209	31,534	19,386	70,553	319,208
2008	4,409	0	0	5,069	0	53,118	0	0	92	0	8,787	0	0	71,475
2009	34,000	0	3,000	5,239	0	48,217	2,596	2,354	0	5,075	18,730	0	0	119,211
2010	101,606	323	19,127	6,252	11,038	97,829	18,377	76,399	0	10,419	40,113	0	8,272	389,755
2011	99,559	19,373	73,880	29,630	46,690	158,694	147,576	227,775	17,276	24,880	144,869	132,320	397,029	1,519,551
2012	27,799	20,055	0	7,162	54,573	83,460	60,613	88,019	1,865	30,166	37,046	27,293	83,991	522,042
2013	3,947	5,750	0	9,345	14,726	46,298	5,078	5,622	22	2,500	11,518	0	0	104,806
2014	3,518	0	0	2,102	0	46,654	0	0	0	0	9,176	0	0	61,450
2015	401	0	0	5,893	0	40,368	4,768	0	22	0	18,840	0	0	70,292

TABLE 5 - Summary of data input for groundwater recovery pumping for local water supply by water district applied to C2VSimFG-Kern Historical Simulation

Water Year	Arvin-Edison WSD	Berrenda Mesa Project	Buena Vista WSD	City of Bakers-field	Cawelo WD	KCWA ID4	Kern Delta WD	Kern Water Bank	Lost Hills UD	North Kern WSD	Olcese WD	Pioneer Project	Rosedale Rio Brave WSD	Semi-tropic WSD	West Kern WD	Wheeler Ridge - Maricopa WSD	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	1,955	0	0	0	0	0	0	0	274	0	101	0	0	0	12,073	0	14,403
1987	21,660	0	0	0	0	0	0	0	278	41,963	101	0	0	0	12,195	0	76,196
1988	27,486	0	960	0	0	0	0	0	281	67,609	138	0	0	0	12,316	0	108,790
1989	38,231	0	2,507	0	0	0	0	0	285	79,674	132	0	0	0	12,438	0	133,266
1990	78,769	0	2,605	0	957	0	0	0	292	73,635	132	0	0	0	12,560	0	168,949
1991	82,566	0	2,511	0	4,666	0	0	0	307	80,432	132	0	0	0	12,546	0	183,160
1992	94,444	0	4,146	0	7,124	0	0	0	306	72,926	132	0	0	0	12,533	5,419	197,029
1993	21,035	0	222	0	3,469	0	0	0	308	3,950	66	0	0	0	12,530	150	41,730
1994	67,679	0	1,732	0	7,805	0	0	0	321	37,251	123	0	0	0	12,078	2,705	129,693
1995	14,191	0	73	0	4,628	0	0	0	322	4,176	66	0	0	0	11,638	0	35,094
1996	1,095	0	175	0	2,475	0	0	0	322	4,726	143	0	0	2,373	13,642	0	24,950
1997	0	0	0	0	2,406	0	0	0	322	4,261	112	0	0	5,824	13,962	0	26,887
1998	245	0	0	0	1,008	0	0	0	307	318	232	0	0	1,499	13,404	76	17,089
1999	915	0	0	0	2,099	0	0	0	333	773	105	0	0	1,241	14,692	2,806	22,963
2000	2,119	0	855	0	6,406	0	0	0	336	15,864	81	0	0	689	17,125	0	43,475
2001	100,492	19,482	6,115	13,950	8,533	0	0	86,404	350	61,988	103	52,034	0	0	15,714	6,507	371,673
2002	86,809	3,436	4,453	13,972	10,047	0	0	24,664	360	70,804	94	9,578	0	2,082	16,247	0	242,545
2003	30,906	0	1,619	3,211	5,484	1,892	0	53,591	364	21,811	56	16,181	0	2,828	17,733	24	155,699
2004	75,399	0	3,848	7,147	8,920	3,345	0	27,736	393	49,888	120	1,985	0	2,879	20,809	41	202,510
2005	25,104	589	430	0	3,563	0	0	21,553	400	6,121	111	12,951	0	2,145	20,843	0	93,809
2006	174	0	228	0	4,202	0	0	0	416	2,645	77	0	0	156	22,108	0	30,007
2007	101,515	23,022	5,858	10,000	11,039	6,220	0	167,291	419	88,841	149	54,150	2,302	0	23,107	0	493,914
2008	141,081	27,850	6,066	13,400	12,222	9,478	9,744	246,249	423	100,465	115	77,533	7,470	0	22,340	0	674,436
2009	128,043	29,745	5,315	9,086	742	5,582	15,117	166,703	389	111,798	144	78,033	6,001	449	21,629	0	578,777
2010	37,081	15,117	841	3,896	2,078	1,886	4,466	97,576	362	20,897	112	41,021	0	375	21,334	0	247,041
2011	445	0	290	0	146	0	0	0	378	683	115	0	0	500	20,801	1,037	24,395
2012	43,589	6,362	1,835	3,960	2,058	1,319	3,148	94,381	393	103,236	107	14,257	0	0	21,107	14,579	310,330
2013	123,971	1,379	4,261	5,571	20,994	2,252	19,809	171,627	373	146,543	118	41,743	14,231	0	19,494	16,518	588,883
2014	146,319	23,891	3,269	7,997	18,120	30,884	34,160	183,235	359	133,769	472	78,603	21,604	0	33,129	16,020	731,830
2015	123,618	26,298	1,267	3,516	24,146	38,294	32,918	154,687	358	118,342	109	56,634	17,237	0	20,344	13,857	631,624

TABLE 6 - Summary of data input for groundwater pumping for basin export by water district applied to C2VSimFG-Kern Historical Simulation

Water Year	Arvin-Edison WSD to Aqueduct	DWR to Aqueduct	North Kern WSD to Friant-Kern Canal	Rosedale Rio Brave WSD to CVC	Semi-tropic WSD to Aqueduct	Wheeler Ridge - Maricopa WSD to Aqueduct	County of Kern to BVARA	TOTAL
	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1986	0	0	0	0	0	0	0	2,056
1987	0	0	0	0	0	0	673	63,724
1988	0	0	0	0	0	0	6,301	96,193
1989	0	0	0	0	0	0	5,879	120,544
1990	0	0	0	0	0	0	8,836	156,097
1991	0	0	0	0	0	0	22,114	170,307
1992	0	0	0	0	0	0	25,025	184,191
1993	0	0	0	0	0	0	7,521	28,892
1994	0	0	0	0	0	0		117,295
1995	0	2,319	0	0	0	0	4,748	23,134
1996	0	0	0	0	0	0	0	10,986
1997	0	0	0	0	0	0	0	12,603
1998	0	0	0	0	0	0	0	3,378
1999	0	0	0	0	0	0	0	7,938
2000	0	0	0	0	0	0	56	26,013
2001	0	0	0	0	1,457	638	10,024	355,608
2002	0	0	0	0	21,819	0	22,402	225,938
2003	12,380	0	0	0	0	0	9,886	137,602
2004	11,573	0	0	0	8,965	0	13,643	181,308
2005	13,939	0	0	0	19,103	0	6,071	72,567
2006	0	0	0		0	0	0	7,482
2007	7,609	0	7,276	0	6,282	0	10,437	470,388
2008	42,615	0	4,612	0	92,169	0	17,351	651,673
2009	43,080	0	5,880	0	86,194	7,243	7,786	556,758
2010	56,229	0	73	0	37,995	12,404	7,019	225,345
2011	16,065	0	0	0	0	0	369	3,217
2012	10,010	0	6,803	0	0	1,340	1,889	288,831
2013	15,111	0	7,471	12,116	5,610	3,815	9,786	569,016
2014	45,195	0	12,071	28,818	95,611	18,236	21,567	698,342
2015	67,142	0	9,752	26,314	89,453	26,943	23,330	610,923

TABLE 7 - Summary of population data input by urban zone applied to C2VSimFG-Kern Historical Simulation

Water Year	Urban Zone 97	Urban Zone 98	Urban Zone 99	Urban Zone 100	Urban Zone 102	Urban Zone 103	Urban Zone 104	Urban Zone 105	Urban Zone 106	Total	Annual Growth Rate
	Population	Population	Population	Population	Population	Population	Population	Population	Population	Population	percent
1985	18,266	4,545	54,766	199	11,589	1,845	15,756	443	229,085	336,493	
1986	18,506	4,565	56,021	184	11,631	1,868	16,127	443	245,095	354,441	5.3%
1987	18,747	4,586	57,277	170	11,673	1,892	16,498	443	261,105	372,389	5.1%
1988	18,987	4,607	58,532	155	11,715	1,915	16,869	442	277,114	390,337	4.8%
1989	19,227	4,627	59,788	141	11,758	1,939	17,240	442	293,124	408,285	4.6%
1990	19,467	4,648	61,043	126	11,800	1,962	17,611	442	309,134	426,233	4.4%
1991	19,808	4,662	64,110	132	12,190	2,023	17,570	475	316,532	437,502	2.6%
1992	20,150	4,676	67,178	138	12,581	2,084	17,528	507	323,930	448,771	2.6%
1993	20,491	4,690	70,245	144	12,971	2,145	17,487	540	331,328	460,041	2.5%
1994	20,832	4,704	73,313	150	13,362	2,206	17,445	572	338,726	471,310	2.4%
1995	21,174	4,718	76,380	156	13,752	2,268	17,404	605	346,124	482,579	2.4%
1996	21,515	4,732	79,447	161	14,142	2,329	17,363	637	353,522	493,848	2.3%
1997	21,856	4,746	82,515	167	14,533	2,390	17,321	670	360,920	505,117	2.3%
1998	22,197	4,760	85,582	173	14,923	2,451	17,280	702	368,318	516,387	2.2%
1999	22,539	4,774	88,650	179	15,314	2,512	17,238	735	375,716	527,656	2.2%
2000	22,880	4,788	91,717	185	15,704	2,573	17,197	767	383,114	538,925	2.1%
2001	23,154	4,887	94,141	193	16,313	2,601	17,609	742	395,409	555,047	3.0%
2002	23,429	4,985	96,564	200	16,922	2,628	18,020	717	407,703	571,169	2.9%
2003	23,703	5,084	98,988	208	17,532	2,656	18,432	692	419,998	587,291	2.8%
2004	23,977	5,182	101,412	215	18,141	2,683	18,844	667	432,292	603,413	2.7%
2005	24,252	5,281	103,836	223	18,750	2,711	19,256	643	444,587	619,536	2.7%
2006	24,526	5,379	106,259	230	19,359	2,738	19,667	618	456,882	635,658	2.6%
2007	24,800	5,478	108,683	238	19,968	2,766	20,079	593	469,176	651,780	2.5%
2008	25,074	5,576	111,107	245	20,578	2,793	20,491	568	481,471	667,902	2.5%
2009	25,349	5,675	113,530	253	21,187	2,821	20,902	543	493,765	684,024	2.4%
2010	25,623	5,773	115,954	260	21,796	2,848	21,314	518	506,060	700,146	2.4%
2011	25,815	5,802	117,403	261	21,959	2,862	21,474	519	512,386	708,482	1.2%
2012	26,009	5,831	118,871	261	22,124	2,877	21,635	521	518,791	716,919	1.2%
2013	26,204	5,860	120,357	262	22,290	2,891	21,797	522	525,275	725,458	1.2%
2014	26,400	5,889	121,861	263	22,457	2,905	21,961	523	531,841	734,102	1.2%
2015	26,598	5,919	123,385	263	22,626	2,920	22,125	525	538,489	742,850	1.2%

TABLE 8 - Summary of data input of per-capita water use by urban zone applied to C2VSimFG-Kern Historical simulation

Water Year	Urban Zone 97	Urban Zone 98	Urban Zone 99	Urban Zone 100	Urban Zone 102	Urban Zone 103	Urban Zone 104	Urban Zone 105	Urban Zone 106
	gdpc	gdpc	gdpc	gdpc	gdpc	gdpc	gdpc	gdpc	gdpc
1985	228	196	245	159	180	159	293	159	508
1986	228	196	245	159	180	159	293	159	480
1987	228	196	245	159	180	159	293	159	450
1988	228	196	245	159	180	159	293	159	439
1989	228	196	245	159	180	159	293	159	419
1990	228	196	245	159	180	159	293	159	438
1991	228	196	245	159	180	159	293	159	409
1992	228	196	245	159	180	159	293	159	417
1993	228	196	245	159	180	159	293	159	414
1994	228	196	245	159	180	159	293	159	421
1995	228	196	245	159	180	159	293	159	381
1996	228	196	245	159	180	159	293	159	401
1997	228	196	245	159	180	159	293	159	348
1998	228	196	245	159	180	159	293	159	304
1999	228	196	248	159	159	159	237	159	388
2000	228	196	248	159	159	159	237	159	367
2001	228	196	248	159	159	159	237	159	364
2002	228	196	248	159	159	159	237	159	362
2003	228	196	248	159	159	159	237	159	358
2004	228	196	248	159	159	159	237	159	386
2005	228	196	248	159	159	159	237	159	314
2006	228	196	248	159	159	159	237	159	338
2007	228	196	248	159	159	159	237	159	375
2008	228	196	248	159	159	159	237	159	367
2009	228	196	248	159	159	159	237	159	344
2010	228	196	248	159	159	159	237	159	328
2011	228	196	248	159	159	159	237	159	351
2012	228	196	248	159	159	159	237	159	378
2013	228	196	248	159	159	159	237	159	330
2014	228	196	248	159	159	159	237	159	314
2015	228	196	248	159	159	159	237	159	261

TABLE 9 - Summary of data input for crop evapotranspiration (ET) by crop type based on METRIC satellite data applied to C2VSimFG-Kern Historical Simulation

Water Year	Grain	Cotton	Sugar Beets	Cotton	Dry Beans	Saf-flower	Other Field Crops	Alfalfa	Pasture	Tomoto-Processed	Tomato-Fresh	Curcubits	Onions & Garlic	Potatoes	Other Truck	Almonds & Pistachios	Orchards	Citrus	Vineyards	Idle	Rice	Refuge	Urban	Native
Units	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr	in/yr
1985	30.0	31.6	34.6	35.4	30.8	28.0	27.9	38.9	35.8	28.8	27.3	24.9	28.7	27.6	29.3	31.6	29.7	36.5	25.0	27.4	35.8	31.6	28.1	27.5
1986	28.2	28.9	36.4	32.8	28.0	26.2	29.2	39.3	35.5	29.8	28.8	27.7	26.5	26.2	27.9	35.1	33.6	36.8	26.9	27.1	39.3	36.2	27.8	26.8
1987	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1988	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1989	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1990	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1991	30.0	31.6	34.6	35.4	30.8	28.0	27.9	38.9	35.8	28.8	27.3	24.9	28.7	27.6	29.3	31.6	29.7	36.5	25.0	27.4	35.8	31.6	28.1	27.5
1992	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
1993	28.2	28.9	36.4	32.8	28.0	26.2	29.2	39.3	35.5	29.8	28.8	27.7	26.5	26.2	27.9	35.1	33.6	36.8	26.9	27.1	39.3	36.2	27.8	26.8
1994	29.5	34.0	36.9	37.0	31.9	24.0	36.5	37.6	31.4	32.4	27.3	27.4	34.1	28.7	31.6	37.2	37.5	38.7	29.1	33.3	26.6	23.9	27.0	27.3
1995	30.1	32.4	35.8	34.4	30.7	26.6	30.7	36.6	32.6	29.4	29.0	28.1	33.1	27.4	30.2	35.8	35.5	35.8	28.7	32.2	31.6	36.3	27.5	29.6
1996	35.0	37.1	39.7	39.2	38.2	32.6	35.8	42.3	38.7	36.1	32.7	28.7	35.3	30.4	33.0	39.3	40.1	39.4	32.1	32.8	34.1	36.4	30.2	31.0
1997	31.3	35.5	39.1	37.7	33.9	29.3	37.2	43.5	36.0	33.2	28.1	28.8	29.7	28.8	30.1	33.7	34.0	38.1	26.1	30.6	34.1	34.0	28.1	31.1
1998	28.2	28.9	36.4	32.8	28.0	26.2	29.2	39.3	35.5	29.8	28.8	27.7	26.5	26.2	27.9	35.1	33.6	36.8	26.9	27.1	39.3	36.2	27.8	26.8
1999	30.0	31.6	34.6	35.4	30.8	28.0	27.9	38.9	35.8	28.8	27.3	24.9	28.7	27.6	29.3	31.6	29.7	36.5	25.0	27.4	35.8	31.6	28.1	27.5
2000	31.1	34.6	36.0	33.2	29.4	28.7	33.8	44.0	38.6	32.2	32.3	27.3	30.5	29.4	29.5	37.0	34.6	41.0	28.9	27.6	41.2	31.4	32.3	33.0
2001	31.9	33.4	36.3	32.0	29.3	27.2	32.1	44.5	33.8	30.2	29.9	26.5	28.8	28.1	28.8	39.9	36.0	40.7	29.7	28.0	41.7	30.8	30.5	31.6
2002	33.8	35.2	39.5	33.3	31.0	26.3	31.4	44.5	33.2	34.2	28.3	27.2	31.3	30.9	31.2	41.4	37.1	43.4	32.1	30.6	40.7	32.2	32.3	33.0
2003	33.0	35.5	35.6	33.2	33.5	28.0	31.7	42.9	30.6	31.0	26.2	27.8	29.7	27.2	28.4	39.6	32.8	38.8	30.4	29.7	37.0	32.1	28.5	30.4
2004	34.5	36.6	37.3	33.5	33.3	32.8	35.6	46.4	36.1	33.1	26.4	26.1	32.4	30.3	33.1	44.2	36.7	40.0	33.1	35.5	39.0	31.5	30.1	32.4
2005	31.8	35.4	40.6	30.5	31.8	27.8	33.0	40.7	32.3	28.4	23.7	26.8	29.6	28.4	28.0	35.1	30.2	34.8	28.0	29.6	37.3	34.1	28.2	30.0
2006	30.9	33.7	33.7	31.4	31.3	24.9	31.1	41.4	33.2	25.4	26.9	29.5	26.9	31.9	28.2	33.9	28.6	35.0	27.6	27.3	39.6	39.3	27.9	29.0
2007	34.3	36.5	33.9	36.1	31.6	28.9	35.3	44.1	35.3	29.4	24.4	26.7	29.1	27.8	32.5	34.5	29.6	37.6	29.6	29.7	38.0	34.0	27.7	31.5
2008	35.2	34.1	30.6	35.3	29.7	25.1	36.0	43.8	37.2	28.0	25.1	25.7	29.7	29.1	31.3	33.2	31.5	37.9	29.6	26.9	34.2	29.9	28.3	31.4
2009	35.3	34.1	25.1	34.2	32.4	32.6	33.9	42.2	30.9	26.5	24.4	24.9	27.1	29.3	29.6	34.5	31.9	37.8	30.4	28.9	35.8	30.5	27.9	32.0
2010	31.6	28.9	25.8	30.2	28.5	23.7	29.8	38.7	26.8	23.2	23.4	26.2	25.4	26.5	27.0	37.3	31.0	35.5	32.3	28.3	33.7	30.8	27.1	30.2
2011	30.1	28.2	23.9	28.3	27.0	21.8	29.6	36.0	25.1	22.6	27.0	24.4	25.5	25.8	25.2	36.2	32.0	33.6	30.9	26.6	38.1	33.6	26.9	32.7
2012	30.2	27.3	22.5	28.7	26.3	23.0	31.0	35.8	26.1	22.6	28.1	24.3	25.8	26.1	26.1	36.6	31.7	33.9	31.2	26.0	38.4	33.8	27.5	33.0
2013	35.7	35.5	28.0	34.7	32.7	33.2	36.4	44.0	33.1	27.2	30.7	29.1	32.4	30.1	30.1	43.6	35.5	39.9	38.6	29.5	36.3	36.8	29.1	35.2
2014	33.9	33.6	25.2	32.9	28.4	28.8	36.0	40.4	28.8	25.2	28.2	28.3	28.6	28.7	29.8	42.5	33.0	37.8	34.1	28.5	36.0	35.8	29.2	34.2
2015	33.4	34.2	28.3	36.3	31.9	33.9	37.0	43.2	29.0	24.0	26.4	27.1	34.8	27.5	30.7	38.8	31.8	38.3	31.0	28.1	29.6	32.2	27.9	32.4
Average	**32.4**	**33.4**	**33.0**	**33.4**	**30.9**	**27.8**	**32.9**	**41.5**	**33.0**	**28.8**	**27.5**	**26.9**	**29.3**	**28.5**	**29.5**	**37.3**	**33.3**	**37.7**	**30.3**	**29.1**	**37.1**	**33.6**	**28.8**	**31.3**
BETA	**21.6**	**39.8**	**39.2**	**32.3**	**31.1**	**34.9**	**36.4**	**48.0**	**50.4**	**31.6**	**40.6**	**32.0**	**36.5**	**35.4**	**31.6**	**48.1**	**45.9**	**42.5**	**42.0**	**57.1**	**50.2**	**76.1**	**52.0**	**57.1**
Difference	**10.8**	**-6.4**	**-6.3**	**1.1**	**-0.2**	**-7.2**	**-3.5**	**-6.5**	**-17.4**	**-2.8**	**-13.0**	**-5.0**	**-7.2**	**-6.9**	**-2.1**	**-10.9**	**-12.6**	**-4.8**	**-11.7**	**-28.0**	**-13.1**	**-42.6**	**-23.2**	**-25.8**

TABLE 10 - Summary of C2VSimFG-Beta modifications in the Kern County Revision applied to C2VSimFG-Kern by IWFM model input file

File Name	Change to Model Input File
C2VSimFG.in	
*	Change simulation starting time to 09/30/1985_24:00
C2VSimFG_Unsat.dat	
*	Replaced initial condition values with more representative values for revised starting
C2VSimFG_SWatersheds.dat	
*	Modified parameters to improve stream discharge match to historical values
C2VSimFG_Groundwater1985.dat	
*	Added hydrologic flow barrier at White Wolf Fault
*	Set Corcoran Clay thickness to 0 ft in areas where it is not present
*	New 10/1/1985 initial condition
*	Modified hydraulic conductivity and specific storage in Layer 1 in the Kern Water Bank
*	Kern County observation wells
C2VSimFG_ElemPump.dat	
*	FRACSK and DSTSK modified for Kern County elements with limited pumping
C2VSimFG_WellSpec.dat	
*	Added Kern County groundwater water bank recovery wells
*	Added Kern County In-District and Urban wells
C2VSimFG_PumpRates.dat	
*	Added Kern County groundwater water bank recovery pumping
*	Added Kern County In-District and Urban pumping
C2VSimFG_StreamInflow.dat	
*	Exteneded Poso Creek inflow through WY2015
C2VSimFG_DiverionSpec.dat	
*	Removed all Kern County diversions and renumbered remaining diversions to 1-371
*	Added Kern County diersions 372-484
C2VSimFG_Diverions.dat	
*	Removed all Kern County diversions and renumbered remaining diversions to 1-371
*	Added Kern County diersions 372-484
*	Updated diversion data for all diversions to Kern County
C2VSimFG_BypassSpecs.dat	
*	Removed bypass #17
C2VSimFG_RootZone.dat	
*	Native return flow is sent to either nearby stream nodes as runoff or out-of-model as ET
C2VSimFG_IrrPeriod.dat	
*	Adjusted Kern County irrigation periods
C2VSimFG_ReturnFlowFrac.dat	
*	Modified Kern County Ag return flow fraction
C2VSimFG_Urban.dat	
*	Added zone 106 for Metro Bakersfield and adjusted other Kern County zone areas
*	Applied estimated September 1985 initial condition

TABLE 10 - Summary of C2VSimFG-Beta modifications in the Kern County Revision applied to C2VSimFG-Kern by IWFM model input file

File Name	Change to Model Input File
C2VSimFG_Urban_Area.dat	
*	Changed Kern County oil fields from urban to native vegetation
C2VSimFG_Urban_PerCapWaterUse.dat	
*	Updated population for Kern County Urban Zones based on 1990, 2000, 2010 Census
*	Developed demands from historical data and water management plans
C2VSimFG_Urban_Population.dat	
*	Updated population for Kern County Urban Zones based on 1990, 2000, 2010 Census
C2VSimFG_Urban_WaterUseSpecs.dat	
*	Set fractions for SRs 19-21 based on local info
C2VSimFG_NonPondedCrop.dat	
*	Return flow = 0 for Kern County
C2VSimFG_NonPondedCrop_Area.dat	
*	Revided crop distributions to match historical distribution
C2VSimFG_PondedCrop_Area.dat	
*	Modified distribution of rice to be limited to areas in northwest Kern County with
C2VSimFG_NativeVeg_Area.dat	
*	Rebalanced native veg distribution after redistribution of non-ponded crop area to

Table 11A - Historical Groundwater Budget for the Kern County Subbasin for Water Years 1995 to 2014 based on the C2VSimFG-Kern Historical Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	GW Pumping	Small Watershed Inflow	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1995	880,480	944,800	185,777	-946,782	122,287	-75,299	1,111,263
1996	801,572	926,537	106,692	-1,247,471	41,190	-84,675	543,845
1997	766,667	771,510	126,405	-1,068,169	50,548	-87,372	559,587
1998	1,034,867	1,097,180	121,413	-884,593	155,312	-87,515	1,436,665
1999	755,674	633,676	39,704	-1,109,310	32,155	-85,211	266,692
2000	617,018	462,522	91,454	-1,375,733	25,956	-83,759	-262,541
2001	551,880	222,131	66,647	-1,839,000	24,633	-81,896	-1,055,605
2002	466,463	202,687	76,147	-1,760,186	18,882	-83,943	-1,079,950
2003	502,831	297,019	118,149	-1,492,816	34,003	-85,638	-626,452
2004	488,327	284,862	83,294	-1,860,344	27,959	-89,250	-1,065,153
2005	799,614	1,147,287	132,785	-1,108,382	93,557	-89,912	974,946
2006	839,390	1,125,277	44,657	-1,149,877	40,846	-96,591	803,702
2007	560,860	403,611	26,260	-2,099,953	17,882	-91,566	-1,182,908
2008	463,721	146,763	78,841	-2,341,780	36,058	-86,260	-1,702,659
2009	485,234	186,548	73,848	-2,206,377	21,586	-85,764	-1,524,923
2010	599,434	467,683	141,715	-1,470,205	58,145	-94,664	-297,892
2011	1,073,963	1,530,123	259,404	-984,968	118,303	-94,981	1,901,842
2012	713,826	580,590	88,581	-1,583,369	19,020	-93,041	-274,395
2013	538,356	156,704	59,483	-2,447,479	19,043	-83,619	-1,757,511
2014	447,782	84,456	50,857	-2,830,674	17,832	-81,081	-2,310,831
Total	**13,387,959**	**11,671,966**	**1,972,113**	**-31,807,470**	**975,198**	**-1,742,039**	**-5,542,280**
Average	**669,398**	**583,598**	**98,606**	**-1,590,373**	**48,760**	**-87,102**	**-277,114**

Table 11B - Current Groundwater Budget for the Kern County Subbasin for Water Year 2015 based on the C2VSimFG-Kern Historical Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	GW Pumping	Subsurface Flow within GW Basin	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
2015	429,983	89,744	46,344	-2,740,237	0	-51,201	-2,225,366

NOTES:

Deep Percolation	Precipitation and applied water that reaches the groundwater after simulated transport across the unsaturated zone
Managed Recharge and Canal Seepage	Combined groundwater recharge from managed aquifer recharge operations, groundwater banking, and seepage from canals and other conveyance
Net GW/SW Interactions	Net volumetric exchange of surface water and groundwater from streams: Positive represents a net groundwater recharge, and negative represents a net groundwater discharge to the stream
GW Pumping	Total groundwater pumping by wells. Groundwater banking recovery pumping is specified input whereas agricultural and municipal pumping is calculated by C2VSim based on demand
Subsurface Flow within GW Basin	Net subsurface groundwater flow into a neighboring water district or area within the Kern County Subbasin: negative is a net flow out of the district and positive is a net flow into the district
Subsurface Flow with Adjacent GW Basins	Net subsurface groundwater flow from the Kern County Subbasin with an adjoining groundwater basin: negative is a net flow out of the Basin and positive is a net flow into the Basin
Change in Groundwater Storage	Sum of the inflow components (positive numbers) plus the outflow components (negative numbers): positive is an increase in storage typified by a rise in GW levels whereas a negative is a decrease in storage typified by a decline in GW levels

TABLE 12: Estimated sustainable yield for Kern County Subbasin for WY1995 to WY2014 Base Period based on C2VSimFG-Kern Historical Simulation

Water Year	Total Average Annual Volume	Agricultural Average Annual Volume	Agricultural Average Annual Volume per Ag Acre	Urban Average Annual Volume
Units	Acre-ft	Acre-ft	ft/acre	Acre-ft
	Sustainable Yield from Groundwater Pumping			
Groundwater Pumping	1,590,373	1,239,931	1.59	176,146
Percentage of Pumping		78%		11%
Change in Groundwater in Storage	-277,114	-216,051	-0.28	-30,692
Percentage of Pumping		-17%		-17%
Sustainable Yield	**1,313,259**	**1,023,880**	**1.31**	**145,453**
Average Annual Difference	**-277,114**	**-216,051**	**-0.28**	**-30,693**
Percent Difference	**-21%**	**-21%**	**-21%**	**-21%**
	Sutainable Yield from Basin Recharge and Outflow			
Groundwater Recharge	1,400,362	1,091,789	1.40	155,101
Subsurface Outflow	-87,102	-67,909	-0.09	-9,647
Sustainable Yield	**1,313,260**	**1,023,880**	**1.31**	**145,453**
Average Annual Difference	**-277,114**	**-216,051**	**0**	**-30,692**
Percent Difference	**0**	**0**	**0**	**0**

NOTES:

Sustainable Yield from Groundwater Pumping Approach assumes that adjusting total groundwater pumping by the change in storage provides an reasonable approximation of the Basin Sustainable

Sutainable Yield from Basin Recharge and Outflow Approach assumes that the Basin Sustainable Yield can be reasonably approximated by adding up the different recharge components and non-

TABLE 13: Estimate of potential native yield for Kern County Subbasin for WY1995 to WY2014 based on C2VSimFG-Kern Historical Simulation

	Ag Precipitation Recharge			Other Area Precipitation Recharge			Small Watershed Inflows			
Water Year	Precipitation in Agricultural Area	Precipitation to ET Demand	Precipitation to Groundwater in Agricultural Area	Precipitation in Other Areas	Precipitation to ET Demand	Precipitation to Groundwater in Other Areas	Small Watershed Subsurface Inflow	Small Watershed Runoff Percolation	Small Watershed Recharge to Groundwater	Native Yield
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
1995	702,794	521,974	180,820	1,108,386	824,558	283,828	17,540	104,746	122,287	586,934
1996	381,496	351,540	29,956	526,809	422,541	104,268	17,512	23,679	41,190	175,414
1997	482,117	356,589	125,528	637,266	487,128	150,138	17,524	33,024	50,548	326,214
1998	966,485	663,632	302,853	1,492,576	1,024,918	467,658	17,840	137,472	155,312	925,823
1999	433,456	400,669	32,786	589,454	464,061	125,393	17,812	14,343	32,155	190,334
2000	384,158	357,496	26,661	476,308	398,994	77,315	17,757	8,200	25,956	129,933
2001	431,757	353,840	77,917	579,440	488,081	91,358	17,722	6,911	24,633	193,908
2002	255,111	227,877	27,234	382,463	317,069	65,394	17,679	1,203	18,882	111,510
2003	400,953	331,300	69,653	599,314	506,451	92,863	17,683	16,320	34,003	196,519
2004	301,023	275,258	25,765	422,514	339,652	82,862	17,661	10,298	27,959	136,586
2005	653,833	486,132	167,701	964,382	785,465	178,917	17,808	75,750	93,557	440,175
2006	499,756	447,319	52,437	657,647	546,950	110,697	17,783	23,063	40,846	203,981
2007	216,658	227,752	-11,095	292,814	241,483	51,331	17,725	157	17,882	58,119
2008	189,035	170,649	18,385	305,703	248,514	57,189	17,697	18,361	36,058	111,633
2009	268,010	221,348	46,663	405,160	336,116	69,044	17,674	3,913	21,586	137,293
2010	457,031	346,082	110,949	683,456	543,580	139,876	17,731	40,414	58,145	308,969
2011	649,878	441,717	208,161	1,023,701	692,781	330,919	17,932	100,370	118,303	657,382
2012	335,227	299,191	36,036	446,686	372,675	74,012	17,851	1,169	19,020	129,067
2013	214,951	203,005	11,946	303,560	246,644	56,916	17,787	1,257	19,043	87,906
2014	167,800	152,566	15,234	263,824	214,181	49,642	17,713	120	17,832	82,708
Total	**8,391,529**	**6,835,938**	**1,555,591**	**12,161,462**	**9,501,842**	**2,659,620**	**354,429**	**620,769**	**975,198**	**5,190,409**
Average	**419,576**	**341,797**	**77,780**	**608,073**	**475,092**	**132,981**	**17,721**	**31,038**	**48,760**	**259,520**
Use (ft/acre)	**0.54**	**0.44**	**0.10**	**0.59**	**0.46**	**0.13**	**0.01**	**0.02**	**0.03**	**0.144**

NOTES:

Simulation of Recharge	IWFM applies two processes to simulate the movement of water from the surface to the groundwater. The root zone simulates calculates the volume of water that will percolate below the root zone based on local soil properties. This water bases to the unsaturated zone that applies a 1-D vadose zone flow that simulates the rate that water will reach the groundwater based on subsurface properties and soil moisture content.
Percolation from Agricultural Area	Total volume of rainfall and applied water calculated to meet the total agricultural demand that percolates below the root zone in irrigated agricultural areas based on C2VSim simulation.
Percolation from Urban Area	Total volume of rainfall and applied water calculated to meet urban outdoor use that percolates below the root zone in urban areas based on C2VSim simulation.
Percolation from Native, Undeveloped or Fallow Areas	Total volume of rainfall and applied water that percolates below the root zone in native, undeveloped and fallow areas based on C2VSim simulation.
Percolation to Unsaturated Zone	Total volume of rainfall and applied water that percolates below the root zone from all areas based on C2VSim simulation.
GW Recharge from Unsaturated Zone	Volume of water going from the unsaturated zone to groundwater
GW Banking, Managed Recharge and Canal Seepage	Managed aquifer recharge and groundwater banking is simulated in C2VSim by applying a high recoverable loss factor for surface water diversions. For Kern County, these operations generally assumes that 88% to 94% of surface water deliveries physically recharge groundwater. This recharge is applied directly to the groundwater without passing through the unsaturated zone.
Net GW/SW Interactions	Net volumetric exchange between surface water in Kern River or Poso Creek and the groundwater. A positive number is surface water to groundwater, and a negative is groundwater discharge to the stream. This recharge is applied directly to the groundwater without passing through the unsaturated zone.
Total GW Recharge	Total volume to water reaching the groundwater as recharge

Table 14 - Hydrologic year correlation with relevant river indices for projected-future simulation period

Project Year	Hydrology Year	Annual Kern River Index	San Joaquin River Index
2021	**2003**	71	Below Normal
2022	**2004**	56	Dry
2023	**2005**	159	Wet
2024	**2006**	147	Wet
2025	**2007**	35	Critical
2026	**2008**	71	Critical
2027	**2009**	65	Below Normal
2028	**2010**	126	Above Normal
2029	**2011**	201	Wet
2030	**2012**	45	Dry
2031	**2013**	28	Critical
2032	**2014**	24	Critical
2033	**1995**	191	Wet
2034	**1996**	136	Wet
2035	**1997**	162	Wet
2036	**1998**	236	Wet
2037	**1999**	60	Above Normal
2038	**2000**	66	Above Normal
2039	**2001**	54	Dry
2040	**2002**	58	Dry
2041	**2003**	71	Below Normal
2042	**2004**	56	Dry
2043	**2005**	159	Wet
2044	**2006**	147	Wet
2045	**2007**	35	Critical
2046	**2008**	71	Critical
2047	**2009**	65	Below Normal
2048	**2010**	126	Above Normal
2049	**2011**	201	Wet
2050	**2012**	45	Dry
2051	**2013**	28	Critical
2052	**2014**	24	Critical
2053	**1995**	191	Wet
2054	**1996**	136	Wet
2055	**1997**	162	Wet
2056	**1998**	236	Wet
2057	**1999**	60	Above Normal
2058	**2000**	66	Above Normal
2059	**2001**	54	Dry
2060	**2002**	58	Dry
2061	**2003**	71	Below Normal
2062	**2004**	56	Dry
2063	**2005**	159	Wet
2064	**2006**	147	Wet
2065	**2007**	35	Critical
2066	**2008**	71	Critical
2067	**2009**	65	Below Normal
2068	**2010**	126	Above Normal
2069	**2011**	201	Wet
2070	**2012**	45	Dry

Table 16 - Projected Future Groundwater Budget for Kern County Subbasin under Baseline Conditions with NO SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net Stream GW/SW Interaction	Net Small Watershed Recharge	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	31,276,668	27,591,218	6,284,636	2,457,805	-80,359,227	-3,647,996	**-16,396,918**
Average	625,533	551,824	125,693	49,156	-1,607,185	-72,960	**-327,938**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	12,059,157	10,900,930	2,570,048	948,239	-31,618,403	-1,527,102	**-6,667,151**
Average	602,958	545,046	128,502	47,412	-1,580,920	-76,355	**-333,358**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	19,217,510	16,690,288	3,714,588	1,509,566	-48,740,823	-2,120,894	**-9,729,767**
Average	640,584	556,343	123,820	50,319	-1,624,694	-70,696	**-324,326**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	421,248	253,922	124,080	38,770	-1,605,058	-83,845	-850,883
2022	466,065	311,661	80,807	28,596	-1,881,001	-79,540	-1,073,415
2023	670,267	894,337	186,631	97,803	-1,082,942	-77,289	688,801
2024	782,933	971,636	250,700	67,141	-1,004,008	-81,747	986,650
2025	487,829	334,264	74,696	18,060	-1,956,094	-78,483	-1,119,730
2026	440,342	154,936	78,551	36,473	-2,258,997	-69,511	-1,618,207
2027	522,430	255,426	73,629	21,942	-1,995,091	-69,397	-1,191,063
2028	569,509	496,227	141,957	35,496	-1,490,383	-70,383	-317,575
2029	1,025,597	1,528,921	110,823	119,558	-891,968	-80,187	1,812,744
2030	692,430	587,522	63,468	19,157	-1,382,783	-79,634	-99,841
2031	550,146	164,041	109,295	19,161	-2,366,434	-73,780	-1,597,574
2032	459,496	111,528	66,581	18,134	-2,763,485	-65,268	-2,173,015
2033	742,600	875,129	188,075	126,420	-1,059,514	-71,675	801,034
2034	617,059	786,754	201,477	42,156	-1,422,316	-78,762	146,370
2035	691,055	727,363	294,732	52,652	-1,120,121	-82,586	563,094
2036	848,018	1,151,100	175,108	103,683	-890,760	-84,597	1,302,552
2037	617,636	539,499	102,463	32,114	-1,230,808	-82,549	-21,645
2038	517,060	379,550	106,226	26,241	-1,390,747	-77,398	-439,070
2039	495,144	190,829	65,868	25,370	-1,883,912	-72,405	-1,179,106
2040	442,293	186,285	74,884	19,311	-1,941,979	-68,067	-1,287,273
2041	466,980	254,002	124,912	34,980	-1,621,935	-66,834	-807,894
2042	519,154	311,722	81,095	28,467	-1,928,066	-66,378	-1,054,007
2043	723,193	894,377	183,602	100,835	-1,131,893	-66,724	703,389
2044	829,429	971,656	217,998	68,630	-1,055,212	-73,234	959,267
2045	520,072	334,263	67,722	18,136	-2,005,971	-71,742	-1,137,519
2046	465,742	154,936	78,954	36,599	-2,308,492	-64,094	-1,636,355
2047	542,433	255,426	73,991	22,117	-2,044,767	-65,020	-1,215,821
2048	587,534	496,227	142,442	35,645	-1,539,937	-66,665	-344,754
2049	1,038,285	1,528,924	111,871	121,871	-940,873	-77,190	1,782,886
2050	704,906	587,522	63,577	19,216	-1,430,758	-77,175	-132,713
2051	567,160	164,041	109,977	19,218	-2,411,967	-71,447	-1,623,019
2052	480,958	111,528	66,775	18,007	-2,776,754	-63,069	-2,162,556
2053	756,460	875,129	189,903	127,393	-1,105,182	-69,591	774,112
2054	629,422	786,754	203,667	42,236	-1,466,597	-76,937	118,546
2055	697,412	727,363	297,238	52,738	-1,163,909	-81,081	529,760
2056	955,260	1,151,202	186,248	169,221	-887,932	-83,323	1,490,676
2057	663,489	539,499	104,143	33,376	-1,272,005	-81,579	-13,077
2058	543,714	379,550	107,428	26,454	-1,432,264	-76,504	-451,623
2059	516,904	190,829	65,982	25,586	-1,924,204	-71,122	-1,196,025
2060	461,832	186,285	75,033	19,353	-1,923,734	-66,838	-1,248,069
2061	483,873	254,002	125,183	34,990	-1,662,322	-65,509	-829,782
2062	535,495	311,722	81,199	28,658	-1,968,451	-64,883	-1,076,261
2063	747,374	894,377	185,862	103,344	-1,173,248	-65,287	692,423
2064	797,596	971,656	227,478	42,092	-1,131,322	-72,135	835,365
2065	518,644	334,263	69,814	18,276	-2,046,917	-70,907	-1,176,825
2066	472,700	154,936	79,262	36,483	-2,350,004	-63,321	-1,669,944
2067	550,095	255,426	74,266	22,151	-2,087,215	-64,426	-1,249,703
2068	654,126	496,227	142,653	60,396	-1,488,744	-65,173	-200,515
2069	1,067,944	1,528,924	112,385	123,705	-984,856	-76,302	1,771,799
2070	719,324	587,522	63,930	19,394	-1,475,294	-76,404	-161,529

Table 17 - Projected Future Groundwater Budget for Kern County Subbasin under Baseline Conditions WITH SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	33,771,527	32,630,931	5,233,643	2,457,805	-69,157,708	-5,025,601	**-89,422**
Average	675,431	652,619	104,673	49,156	-1,383,154	-100,512	**-1,788**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	13,100,548	12,612,730	2,239,160	948,239	-28,535,055	-1,719,340	**-1,353,732**
Average	655,027	630,637	111,958	47,412	-1,426,753	-85,967	**-67,687**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	20,670,979	20,018,200	2,994,483	1,509,566	-40,622,653	-3,306,261	**1,264,311**
Average	689,033	667,273	99,816	50,319	-1,354,088	-110,209	**42,144**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	430,153	302,373	123,650	38,770	-1,594,606	-83,189	-782,849
2022	475,303	349,553	80,614	28,596	-1,862,120	-78,565	-1,006,617
2023	770,374	1,002,929	168,647	97,803	-1,009,264	-78,404	952,085
2024	855,058	1,086,448	198,849	67,141	-944,665	-84,319	1,178,512
2025	503,643	350,298	70,663	18,060	-1,861,303	-81,925	-1,000,565
2026	440,243	214,542	77,894	36,473	-2,187,564	-73,190	-1,491,603
2027	518,989	316,584	73,092	21,942	-1,919,158	-73,183	-1,061,733
2028	578,749	623,230	137,529	35,496	-1,407,567	-75,335	-107,901
2029	1,194,895	1,696,947	83,255	119,558	-744,743	-87,273	2,262,638
2030	750,668	608,048	58,365	19,157	-1,257,759	-87,531	90,947
2031	555,404	180,833	107,613	19,161	-2,187,295	-83,584	-1,407,869
2032	453,293	125,476	66,634	18,134	-2,567,449	-76,460	-1,980,378
2033	824,902	1,059,059	172,274	126,420	-840,738	-84,135	1,257,782
2034	653,828	917,135	178,991	42,156	-1,197,621	-93,181	501,309
2035	827,370	931,556	238,868	52,652	-872,560	-98,679	1,079,205
2036	1,116,969	1,381,739	113,563	103,683	-633,072	-102,650	1,980,231
2037	725,584	594,384	63,749	32,114	-1,023,020	-100,141	292,669
2038	511,919	433,966	84,887	26,241	-1,154,051	-95,834	-192,873
2039	489,540	224,450	65,153	25,370	-1,627,860	-92,035	-915,382
2040	423,665	213,184	74,871	19,311	-1,642,642	-89,729	-1,001,340
2041	445,485	305,376	122,807	34,980	-1,354,885	-89,185	-535,423
2042	498,858	354,364	80,832	28,467	-1,639,112	-89,772	-766,363
2043	812,155	1,090,304	140,266	100,835	-882,848	-92,437	1,168,274
2044	892,628	1,153,766	138,151	68,630	-836,920	-100,949	1,315,306
2045	524,833	355,672	49,525	18,136	-1,730,147	-100,070	-882,051
2046	454,216	218,616	78,021	36,599	-2,055,875	-92,126	-1,360,549
2047	532,454	320,562	73,425	22,117	-1,809,154	-93,438	-954,033
2048	593,653	668,774	137,874	35,645	-1,324,186	-97,255	14,505
2049	1,234,198	1,750,812	79,492	121,871	-710,054	-110,080	2,366,239
2050	768,780	619,092	54,500	19,216	-1,197,582	-110,438	153,567
2051	578,825	192,400	107,098	19,218	-2,110,155	-106,461	-1,319,074
2052	479,637	135,929	66,695	18,007	-2,470,952	-99,536	-1,870,221
2053	850,038	1,095,469	170,484	127,393	-813,603	-107,867	1,321,915
2054	682,383	948,274	168,655	42,236	-1,143,633	-117,748	580,168
2055	858,469	966,141	223,989	52,738	-849,900	-123,451	1,127,986
2056	1,291,577	1,415,721	105,108	169,221	-638,704	-126,824	2,216,098
2057	807,949	600,599	52,465	33,376	-1,027,113	-123,865	343,411
2058	541,774	439,164	78,391	26,454	-1,146,168	-119,115	-179,499
2059	503,264	229,194	64,724	25,586	-1,627,673	-114,273	-919,179
2060	435,869	217,320	75,042	19,353	-1,597,610	-111,590	-961,617
2061	449,783	308,906	122,761	34,990	-1,363,117	-110,530	-557,207
2062	501,922	357,723	80,757	28,658	-1,643,414	-110,538	-784,892
2063	820,754	1,111,099	135,039	103,344	-898,437	-113,406	1,158,393
2064	871,279	1,174,447	124,818	42,092	-868,913	-122,551	1,221,172
2065	511,277	358,753	43,942	18,276	-1,750,481	-120,972	-939,204
2066	454,845	222,078	77,969	36,483	-2,077,330	-112,479	-1,398,433
2067	531,138	323,961	73,264	22,151	-1,832,363	-113,339	-995,189
2068	672,372	689,792	138,150	60,396	-1,265,870	-116,258	178,583
2069	1,286,647	1,771,462	77,455	123,705	-733,283	-129,909	2,396,076
2070	783,917	622,428	52,784	19,394	-1,223,170	-129,799	125,553

Table 18 - Projected Future Groundwater Budget for Kern County Subbasin under 2030 Climate Conditions with NO SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	30,885,159	30,404,998	6,083,382	2,517,393	-85,792,996	-3,318,618	**-19,220,714**
Average	617,703	608,100	121,668	50,348	-1,715,860	-66,372	**-384,414**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	11,956,360	12,006,382	2,488,942	967,011	-33,772,959	-1,439,420	**-7,793,706**
Average	597,818	600,319	124,447	48,351	-1,688,648	-71,971	**-389,685**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	18,928,799	18,398,617	3,594,440	1,550,382	-52,020,037	-1,879,198	**-11,427,008**
Average	630,960	613,287	119,815	51,679	-1,734,001	-62,640	**-380,900**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	422,205	264,773	147,393	42,134	-1,686,375	-82,161	-892,031
2022	486,382	352,708	97,994	31,229	-1,966,104	-77,718	-1,075,519
2023	670,731	968,807	192,300	100,122	-1,194,263	-75,163	662,531
2024	724,438	1,015,022	177,313	64,551	-1,153,552	-78,823	748,944
2025	451,579	327,176	67,822	18,068	-2,002,002	-75,206	-1,212,569
2026	443,127	213,524	132,483	37,800	-2,325,127	-67,041	-1,565,234
2027	508,495	246,268	115,977	23,732	-2,151,549	-65,434	-1,322,507
2028	572,490	566,005	191,408	39,445	-1,651,430	-65,956	-348,038
2029	1,218,648	1,901,727	112,842	122,295	-1,104,305	-76,600	2,174,607
2030	553,673	532,639	51,185	19,641	-1,476,524	-74,857	-394,243
2031	521,194	199,452	76,829	18,143	-2,339,207	-68,717	-1,592,305
2032	453,699	143,631	46,557	17,968	-2,788,464	-60,558	-2,187,167
2033	743,629	915,198	182,822	122,210	-1,190,116	-67,058	706,686
2034	615,276	872,000	147,377	45,764	-1,543,359	-73,439	63,619
2035	736,533	843,258	281,587	55,297	-1,297,450	-77,197	542,029
2036	863,933	1,264,065	123,884	102,926	-1,044,324	-79,069	1,231,416
2037	542,139	510,531	72,919	32,384	-1,342,279	-75,848	-260,154
2038	507,189	428,732	81,591	27,413	-1,503,202	-70,781	-529,059
2039	482,914	213,280	87,387	26,084	-2,017,703	-65,709	-1,273,748
2040	438,087	227,586	101,273	19,804	-1,995,626	-62,086	-1,270,964
2041	462,417	263,946	147,623	39,151	-1,702,404	-60,765	-850,032
2042	532,326	354,460	98,221	31,228	-2,012,621	-59,960	-1,056,345
2043	717,292	967,381	179,212	103,193	-1,243,088	-59,869	664,119
2044	766,402	1,015,346	117,742	65,724	-1,204,632	-65,643	694,939
2045	477,463	326,770	51,863	18,138	-2,051,621	-63,896	-1,241,282
2046	465,642	213,337	132,843	37,870	-2,374,509	-57,074	-1,581,891
2047	526,192	246,482	116,132	23,946	-2,201,023	-56,606	-1,344,877
2048	584,963	564,936	191,656	39,636	-1,700,745	-57,895	-377,449
2049	1,218,687	1,904,385	99,805	124,949	-1,152,654	-69,447	2,125,726
2050	560,761	533,577	47,140	19,693	-1,524,426	-68,362	-431,617
2051	531,733	199,452	76,920	18,193	-2,385,216	-62,565	-1,621,483
2052	469,853	139,904	46,651	17,931	-2,807,543	-54,827	-2,188,030
2053	748,982	916,702	183,503	123,682	-1,235,658	-61,582	675,628
2054	618,472	870,588	145,806	45,880	-1,587,472	-68,329	24,946
2055	736,517	843,485	279,382	55,392	-1,341,090	-72,519	501,167
2056	954,438	1,263,249	134,078	169,164	-1,037,331	-74,710	1,408,888
2057	579,927	508,121	73,014	33,640	-1,384,414	-71,487	-261,199
2058	532,403	431,547	81,726	27,628	-1,544,662	-66,368	-537,727
2059	503,820	214,669	87,386	26,299	-2,057,978	-61,126	-1,286,930
2060	456,299	228,154	101,178	19,792	-1,984,645	-57,872	-1,237,094
2061	478,968	264,126	147,695	39,158	-1,742,970	-56,708	-869,739
2062	546,856	353,554	98,263	31,426	-2,052,889	-55,984	-1,078,775
2063	740,448	969,075	181,599	104,939	-1,284,313	-56,141	655,606
2064	735,683	1,013,851	124,774	41,649	-1,277,235	-62,203	576,518
2065	478,349	327,088	54,630	18,289	-2,092,701	-60,730	-1,275,076
2066	473,836	213,074	132,845	37,782	-2,406,519	-57,164	-1,606,144
2067	537,374	246,454	116,277	23,923	-2,231,035	-58,641	-1,365,648
2068	660,267	565,258	192,661	65,542	-1,647,974	-59,014	-223,263
2069	1,254,195	1,903,367	104,892	126,664	-1,191,285	-71,013	2,126,821
2070	578,235	536,275	48,924	19,883	-1,559,383	-70,699	-446,765

Table 19 - Projected Future Groundwater Budget for Kern County Subbasin under 2030 Climate Conditions WITH SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	32,838,979	35,447,299	4,941,607	2,517,393	-73,869,518	-4,735,936	**-2,860,202**
Average	656,780	708,946	98,832	50,348	-1,477,390	-94,719	**-57,204**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	12,873,160	13,719,306	2,153,021	967,011	-30,545,188	-1,641,666	**-2,474,378**
Average	643,658	685,965	107,651	48,351	-1,527,259	-82,083	**-123,719**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	19,965,818	21,727,994	2,788,586	1,550,382	-43,324,331	-3,094,271	**-385,823**
Average	665,527	724,266	92,953	51,679	-1,444,144	-103,142	**-12,861**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	436,607	313,191	146,335	42,134	-1,676,044	-81,420	-819,196
2022	495,680	391,450	97,863	31,229	-1,947,388	-76,701	-1,007,874
2023	777,040	1,077,709	179,601	100,122	-1,117,722	-76,444	940,302
2024	808,215	1,130,101	141,980	64,551	-1,088,738	-81,861	974,238
2025	462,701	343,315	61,517	18,068	-1,906,220	-78,953	-1,099,574
2026	439,400	273,084	131,767	37,800	-2,253,887	-70,713	-1,442,550
2027	504,308	306,757	115,891	23,732	-2,068,551	-69,760	-1,187,619
2028	576,402	692,833	189,187	39,445	-1,565,005	-71,313	-138,447
2029	1,371,389	2,070,178	67,647	122,295	-932,879	-84,094	2,614,536
2030	584,511	553,212	37,888	19,641	-1,345,295	-83,321	-233,371
2031	528,715	216,234	76,879	18,143	-2,159,236	-78,674	-1,397,939
2032	447,278	157,578	46,694	17,968	-2,586,970	-72,132	-1,989,585
2033	822,633	1,099,092	179,078	122,210	-954,120	-79,949	1,188,943
2034	642,235	1,002,883	120,224	45,764	-1,314,339	-88,379	408,386
2035	882,067	1,046,864	225,239	55,297	-1,036,291	-94,244	1,078,932
2036	1,079,981	1,496,375	67,732	102,926	-748,234	-98,400	1,900,379
2037	618,298	565,459	31,639	32,384	-1,137,009	-94,427	16,344
2038	503,029	481,733	53,082	27,413	-1,262,856	-89,986	-287,584
2039	473,864	246,867	81,296	26,084	-1,751,020	-86,330	-1,009,239
2040	418,807	254,393	101,481	19,804	-1,693,383	-84,564	-983,462
2041	444,811	315,197	147,563	39,151	-1,429,438	-83,810	-566,526
2042	514,255	397,576	97,317	31,228	-1,723,016	-83,907	-766,546
2043	816,698	1,163,940	134,478	103,193	-969,015	-86,356	1,162,938
2044	847,571	1,197,675	50,668	65,724	-949,162	-94,611	1,117,864
2045	471,125	348,281	32,446	18,138	-1,769,470	-93,309	-992,789
2046	446,314	276,979	132,424	37,870	-2,116,321	-86,037	-1,308,771
2047	507,943	310,952	116,190	23,946	-1,951,408	-86,246	-1,078,625
2048	570,746	737,315	190,434	39,636	-1,454,664	-89,846	-6,380
2049	1,365,299	2,126,760	34,358	124,949	-846,645	-103,976	2,700,745
2050	579,883	565,192	23,802	19,693	-1,287,166	-103,007	-201,604
2051	538,250	227,799	76,822	18,193	-2,083,539	-98,472	-1,320,948
2052	464,011	164,305	46,977	17,931	-2,493,990	-92,183	-1,892,949
2053	839,476	1,136,728	177,834	123,682	-921,588	-100,638	1,255,494
2054	659,537	1,032,674	98,253	45,880	-1,258,249	-110,065	468,030
2055	903,882	1,081,677	208,421	55,392	-1,002,340	-116,311	1,130,721
2056	1,216,310	1,529,332	56,914	169,164	-718,274	-120,237	2,133,209
2057	673,501	569,268	16,245	33,640	-1,122,622	-115,686	54,346
2058	522,020	489,739	44,186	27,628	-1,253,276	-110,474	-280,179
2059	481,112	252,996	77,161	26,299	-1,749,204	-105,946	-1,017,581
2060	429,670	259,054	101,488	19,792	-1,652,713	-103,828	-946,537
2061	447,419	318,905	147,790	39,158	-1,437,034	-102,731	-586,494
2062	515,397	400,090	96,110	31,426	-1,726,653	-102,439	-786,068
2063	822,203	1,186,122	125,545	104,939	-982,407	-105,263	1,151,138
2064	812,383	1,217,000	39,194	41,649	-986,296	-114,017	1,009,913
2065	461,447	351,690	27,964	18,289	-1,789,318	-112,105	-1,042,033
2066	449,867	280,211	132,607	37,782	-2,125,316	-106,826	-1,331,675
2067	511,035	314,307	116,486	23,923	-1,960,796	-107,878	-1,102,923
2068	651,081	758,626	191,836	65,542	-1,393,447	-109,878	163,759
2069	1,417,188	2,146,388	28,009	126,664	-861,456	-124,760	2,732,032
2070	585,382	571,217	19,064	19,883	-1,309,505	-123,427	-237,386

Table 20 - Projected Future Groundwater Budget for Kern County Subbasin under 2070 Climate Conditions with NO SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	30,266,907	32,824,218	5,541,096	2,495,122	-92,372,522	-3,271,463	**-24,516,680**
Average	605,338	656,484	110,822	49,902	-1,847,450	-65,429	**-490,334**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	11,792,918	12,994,527	2,263,192	960,586	-36,385,358	-1,447,672	**-9,821,843**
Average	589,646	649,726	113,160	48,029	-1,819,268	-72,384	**-491,092**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	18,473,988	19,829,691	3,277,904	1,534,536	-55,987,164	-1,823,791	**-14,694,837**
Average	615,800	660,990	109,263	51,151	-1,866,239	-60,793	**-489,828**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	408,652	250,550	140,163	38,275	-1,842,475	-83,663	-1,088,499
2022	472,102	369,832	95,673	30,903	-2,096,387	-78,608	-1,206,496
2023	673,989	1,058,910	189,890	97,206	-1,367,109	-76,560	576,325
2024	744,177	1,122,749	154,523	64,640	-1,269,966	-81,123	734,995
2025	434,940	339,216	62,383	18,095	-2,093,637	-77,242	-1,316,253
2026	469,752	316,670	142,130	42,165	-2,392,400	-68,542	-1,490,227
2027	468,805	219,342	111,136	22,713	-2,302,101	-66,245	-1,546,351
2028	565,266	622,490	194,932	37,491	-1,777,664	-66,172	-423,661
2029	1,232,895	2,021,954	94,628	120,391	-1,272,882	-75,969	2,121,016
2030	512,383	510,545	46,067	18,406	-1,606,048	-73,952	-592,602
2031	514,885	217,243	80,080	18,510	-2,404,879	-69,108	-1,643,271
2032	420,919	109,243	41,157	17,864	-2,961,316	-59,737	-2,431,871
2033	717,704	983,283	185,465	124,666	-1,366,638	-66,770	577,711
2034	636,472	1,011,310	124,135	48,403	-1,629,020	-73,691	117,609
2035	742,442	926,830	240,059	52,829	-1,506,120	-76,785	379,255
2036	840,589	1,369,821	66,325	95,355	-1,236,377	-78,889	1,056,824
2037	511,349	550,855	51,377	33,462	-1,460,435	-75,693	-389,084
2038	525,422	516,749	68,512	30,839	-1,615,455	-70,944	-544,878
2039	486,185	261,453	84,925	29,526	-2,078,540	-66,064	-1,282,515
2040	413,990	215,482	89,632	18,846	-2,105,907	-61,915	-1,429,871
2041	434,872	249,759	141,456	34,801	-1,861,023	-59,685	-1,059,819
2042	506,082	371,490	95,431	30,811	-2,143,228	-58,424	-1,197,837
2043	701,042	1,057,536	164,332	99,819	-1,415,545	-58,898	548,287
2044	765,882	1,123,035	84,872	65,709	-1,321,033	-65,596	652,868
2045	457,199	338,796	43,022	18,140	-2,143,265	-63,760	-1,349,868
2046	491,322	316,422	142,576	42,210	-2,441,728	-56,475	-1,505,673
2047	486,516	219,663	111,300	22,758	-2,350,989	-55,383	-1,566,136
2048	575,922	621,390	195,292	37,553	-1,826,869	-56,367	-453,078
2049	1,207,108	2,024,646	76,576	122,702	-1,321,171	-67,189	2,042,673
2050	516,604	511,479	41,647	18,437	-1,653,603	-66,049	-631,485
2051	524,249	217,243	80,184	18,541	-2,450,881	-61,709	-1,672,374
2052	436,390	105,521	41,256	17,846	-2,980,914	-52,973	-2,432,875
2053	721,385	984,833	185,983	125,947	-1,412,037	-60,560	545,551
2054	637,035	1,010,015	122,314	48,546	-1,673,215	-67,888	76,808
2055	739,029	926,775	240,837	53,236	-1,549,608	-71,550	338,718
2056	916,865	1,369,239	78,789	163,750	-1,223,884	-73,970	1,230,789
2057	542,683	548,446	53,332	34,610	-1,503,509	-70,686	-395,124
2058	550,193	519,512	70,081	31,051	-1,656,729	-65,944	-551,837
2059	506,313	262,783	85,481	29,722	-2,118,584	-60,956	-1,295,243
2060	434,143	216,084	89,721	18,987	-2,098,596	-57,233	-1,396,893
2061	453,048	249,994	141,478	34,761	-1,901,319	-55,229	-1,077,267
2062	522,814	370,621	95,685	30,984	-2,183,537	-54,157	-1,217,590
2063	725,002	1,059,135	169,499	100,139	-1,456,460	-54,936	542,379
2064	737,845	1,121,596	96,738	41,720	-1,390,161	-62,039	545,700
2065	456,525	339,078	47,370	18,277	-2,183,880	-60,597	-1,383,226
2066	498,361	316,005	142,585	41,907	-2,483,011	-53,520	-1,537,673
2067	496,804	219,419	111,431	22,808	-2,393,461	-52,693	-1,595,690
2068	655,939	621,712	196,418	66,128	-1,787,044	-52,309	-299,157
2069	1,243,827	2,023,476	87,110	124,017	-1,364,360	-64,030	2,050,039
2070	532,988	513,990	45,107	18,619	-1,697,522	-62,987	-649,805

Table 21 - Projected Future Groundwater Budget for Kern County Subbasin under 2070 Climate Conditions WITH SGMA Projects based on C2VSimFG-Kern Simulation

Water Year	Deep Percolation	Managed Recharge and Canal Seepage	Net GW/SW Interactions	Small Watershed Inflow	GW Pumping	Subsurface Flow with Adjacent GW Basins	Change in Groundwater Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
SUMMARY: WY2021 to WY2070 Simulatation Period							
Total	31,799,129	37,863,262	4,293,932	2,495,122	-79,755,674	-4,729,641	**-8,033,910**
Average	635,983	757,265	85,879	49,902	-1,595,113	-94,593	**-160,678**
SUMMARY: WY2021 to WY2040 Implementation Period							
Total	12,589,633	14,705,737	1,891,043	960,586	-32,975,395	-1,657,287	**-4,485,720**
Average	629,482	735,287	94,552	48,029	-1,648,770	-82,864	**-224,286**
SUMMARY: WY2041 to WY2070 Sustainability Period							
Total	19,209,496	23,157,525	2,402,889	1,534,536	-46,780,279	-3,072,354	**-3,548,190**
Average	640,317	771,917	80,096	51,151	-1,559,343	-102,412	**-118,273**
Annual Simulation Results for WY2021 to WY2070 Simulation Period							
2021	416,859	299,174	140,033	38,275	-1,829,917	-83,068	-1,018,646
2022	482,771	408,716	95,545	30,903	-2,075,055	-77,724	-1,134,857
2023	778,119	1,167,829	176,974	97,206	-1,283,726	-78,065	858,337
2024	824,224	1,237,834	116,452	64,640	-1,201,267	-84,296	957,582
2025	444,081	355,471	55,004	18,095	-1,995,258	-81,218	-1,203,834
2026	466,475	376,346	141,087	42,165	-2,313,156	-72,774	-1,359,861
2027	464,976	279,425	111,024	22,713	-2,213,764	-70,681	-1,406,307
2028	569,538	749,332	192,740	37,491	-1,685,558	-71,949	-208,410
2029	1,366,993	2,190,420	41,284	120,391	-1,077,423	-84,620	2,557,045
2030	534,178	531,150	29,555	18,406	-1,464,690	-82,917	-434,320
2031	519,704	234,003	79,675	18,510	-2,224,205	-79,250	-1,451,562
2032	415,122	123,188	41,020	17,864	-2,750,519	-71,829	-2,225,156
2033	783,412	1,166,531	179,799	124,666	-1,109,329	-80,416	1,064,663
2034	658,731	1,142,196	88,031	48,403	-1,395,221	-89,128	453,011
2035	863,103	1,130,070	184,994	52,829	-1,232,204	-94,328	904,464
2036	1,029,800	1,602,138	12,470	95,355	-917,373	-98,485	1,723,905
2037	570,198	605,678	8,505	33,462	-1,243,785	-94,402	-120,345
2038	523,835	569,446	34,689	30,839	-1,363,512	-90,407	-295,110
2039	479,164	294,676	72,792	29,526	-1,805,973	-86,949	-1,016,764
2040	398,352	242,115	89,372	18,846	-1,793,459	-84,780	-1,129,554
2041	414,818	301,192	141,646	34,801	-1,568,913	-83,592	-760,049
2042	491,990	414,742	93,845	30,811	-1,840,528	-83,323	-892,462
2043	790,613	1,254,107	115,429	99,819	-1,116,588	-86,323	1,057,057
2044	836,403	1,305,369	17,905	65,709	-1,045,824	-95,401	1,084,162
2045	449,154	360,429	22,817	18,140	-1,852,116	-93,998	-1,095,574
2046	471,989	380,169	142,402	42,210	-2,176,184	-86,568	-1,225,983
2047	471,984	283,737	111,550	22,758	-2,085,163	-85,737	-1,280,870
2048	554,428	793,776	194,145	37,553	-1,568,985	-88,857	-77,939
2049	1,321,092	2,246,987	3,572	122,702	-987,606	-102,881	2,603,867
2050	524,857	543,145	12,030	18,437	-1,398,511	-101,367	-401,409
2051	526,155	245,563	79,307	18,541	-2,147,741	-98,008	-1,376,184
2052	430,658	129,919	41,236	17,846	-2,649,533	-91,211	-2,121,085
2053	792,109	1,204,216	177,747	125,947	-1,064,253	-100,431	1,135,335
2054	668,348	1,172,104	66,220	48,546	-1,336,993	-110,282	507,943
2055	860,469	1,164,599	170,576	53,236	-1,194,626	-115,992	938,261
2056	1,144,616	1,635,346	2,390	163,750	-873,811	-120,178	1,952,112
2057	610,598	609,490	-6,003	34,610	-1,226,393	-115,425	-93,124
2058	546,965	577,365	26,400	31,051	-1,353,145	-110,712	-282,076
2059	486,798	300,706	68,354	29,722	-1,802,615	-106,347	-1,023,382
2060	409,456	246,809	89,277	18,987	-1,751,495	-103,792	-1,090,757
2061	418,628	304,951	141,821	34,761	-1,574,579	-102,407	-776,824
2062	495,173	417,295	92,534	30,984	-1,842,095	-101,824	-907,934
2063	793,354	1,276,196	108,214	100,139	-1,128,328	-105,241	1,044,334
2064	805,281	1,324,749	9,903	41,720	-1,082,528	-114,909	984,217
2065	440,536	363,793	19,730	18,277	-1,870,357	-113,021	-1,141,042
2066	471,618	383,251	141,837	41,907	-2,193,139	-104,993	-1,259,519
2067	473,770	286,942	111,773	22,808	-2,105,041	-103,867	-1,313,616
2068	625,100	815,113	195,615	66,128	-1,516,065	-105,894	79,999
2069	1,353,276	2,266,438	1,701	124,017	-1,005,088	-121,015	2,619,328
2070	529,258	549,028	8,916	18,619	-1,422,036	-118,758	-434,973

TABLE 22: Assessment of change in groundwater storage from C2VSimFG-Kern model results for historical and future scenarios for the Kern County Subbasin

Scenario	Model Results 2041-2070 Sustainability Period		Adjustments to GW Storage Change 2041-2070 Sustainability Period		
	Change in Groundwater Storage	Change in Net Operational Budget	Adjustment for Excess Basin Outflows	Adjustment for Excess Kern River Outflow	Adjusted Change in GW Storage
units	**AFY**	**AFY**	AFY	AFY	**AFY**
Historic	**-277,114**	**-190,012**	0	0	**-277,114**
Baseline	**-324,326**	**-253,629**	0	0	**-324,326**
Base Projects	**42,144**	**152,353**	26,327	17,108	**85,578**
2030 Climate	**-380,900**	**-318,260**	0	8,780	**-372,120**
2030 Projects	**-12,861**	**90,282**	27,056	32,634	**46,829**
2070 Climate	**-489,828**	**-429,035**	0	17,492	**-472,336**
2070 Projects	**-118,273**	**-15,861**	28,077	44,227	**-45,969**

NOTE:

"Change in *Groundwater Storage* " DOES include subsurface flow with adjacent basins

"*Operational Storage* " DOES NOT include subsurface flow with adjacent basins

"Adjustment for *Excess Basin Outflows* " is the difference in simulated basin outflow that is attributed to addition of SGMA projects in Kern County without comparable SGMA projects added to adjacent basins**.** Adjustment assumes that this difference is due to limitation of simulation, and that this difference would remain in Kern County when SGMA projects from adjacent basin are included in simulation.

"Adjustment for *Excess Kern River Outflow* " is the increase in simulated groundwater outflows to Kern River relative to Baseline condition that are attributed to SGMA Projects and Climate Change. Model is not optimized for river management. Since the Kern River is a highly managed system, the assumption is that in practice this water would be recovered for beneficial use rather than be a loss of water from the basin.

"*Adjusted Change in GW Storage* " Change in GW Storage plus modifications listed as adjustments to provide a more realistic Change in GW Storage estimate for the simulation.

TABLE 23: Evaluation of Sustainable Yield for Projected-Future scenarios based on C2VSimFG-Kern Model Results for Kern County Subbasin

Scenario	C2VSimFG-Kern Model Results 2041-2070 Sustainability Period					
	Groundwater Pumping	Change in Groundwater in Storage	GW Storage Adjustments	Sustainable Yield	Average Annual Difference of Pumping to Yield	Percent Difference of Pumping to Sustainable Yield
units	AFY	AFY	AFY	AFY	AFY	AFY
Historic	**1,590,373**	**-277,114**	**0**	**1,313,259**	**-277,114**	**-21%**
Baseline	**1,624,694**	**-324,326**	**0**	**1,300,369**	**-324,326**	**-25%**
Baseline Projects	**1,354,088**	**42,144**	**43,434**	**1,439,666**	**85,578**	**6%**
2030 Climate	**1,734,001**	**-380,900**	**8,780**	**1,361,881**	**-372,120**	**-27%**
2030 Projects	**1,444,144**	**-12,861**	**59,690**	**1,490,974**	**46,829**	**3%**
2070 Climate	**1,866,239**	**-489,828**	**17,492**	**1,393,902**	**-472,336**	**-34%**
2070 Projects	**1,559,343**	**-118,273**	**72,304**	**1,513,373**	**-45,969**	**-3%**

NOTES:

Groundwater Pumping	Total groundwater pumping by wells. Groundwater banking recovery pumping is specified input whereas agricultural and municipal pumping is calculated by C2VSim based on demand
Change in Groundwater in Storage	Sum of the inflow components (positive numbers) plus the outflow components (negative numbers): positive is an increase in storage typified by a rise in GW levels whereas a negative is a decrease in storage typified by a decline in GW levels
Adjusted Banking	Adjustment that assumes that recharge operations are affected by reductions in imported water sources, but
GW Storage Adjustments	Adjustment to GW Storage that reflect artifacts of the simulation. For Kern County, adjustments made to reflect no SGMA projects simulated north of Kern County, and that Kern River operations are not optimized to
Sutainable Yield	Sustainable yield is defined is the amount of pumping that can be sustained in the groundwater basin without the undesirable effect of a decline in groundwater storage that serves as a proxy for other undesirable effects
Average Annual Difference	The difference between the sustainable yield and the simulated groundwater pumping. A negative value is pumping in excess of the sustainable yield
Percent Difference	The percentage of the Average Annual Difference to the total groundwater pumping to provide context and a method to compare the significance of the difference in the pumping copmared to the sustainable yield.

TABLE 24: Summary of Statistical Analysis for Validation of C2VSimFG-Kern Historical Simulation

Validation Measure	C2VSimFG-Kern	C2VSimFG-Beta	Percent Change
Units	Feet	Feet	Percent
Residual Mean	17.3 ft	32.6 ft	47%
Residual Standard Deviation	45.5 ft	54.0 ft	16%
Absolute Residual Mean	37.4 ft	56.8 ft	34%
Root Mean Square (RMS) Error	50 ft	73.5 ft	32%
Scaled Absolute Residual Mean	0.061	0.092	34%
Correlation Coefficient	0.76	0.52	47%
Number of Monitor Wells	558	558	same
Number of Observations	42,075	42,075	same

Notes

Observation Point	Location in the model where measured data from well is compared to simulated model results
Residual	Difference between measured and simulated groundwater elevations at an observation point
Residual Mean	Statistical measure of fit of simulated to measured data using sum of the residuals divided by the number of residual data values
Residual Standard Deviation	Statistical evaluation of the scatter of the data by calculating standard deviation of residuals
Absolute Residual Mean	Statistical measure of fit of simulated to measured data using sum of the absolute value residuals divided by the number of residual data values
Root Mean Square (RMS) Error	Statistical measure of fit of simulated to measured data using square root of the quotient of sum of squares of residuals by the number of observations
Scaled Absolute Residual Mean	Statisical measure to provide scale of validation using ratio of the absolute residual mean divided by the range of observed groundwater elevations
Correlation Coefficient	Scaled measure of the closeness of fit of simulated to measured data from -1 to 1 correlation with 1.0 a perfect correlation
Number of Monitor Wells	Number of wells where measured groundwater level data was compared to C2VSimFG-Kern simulation results for model validation
Number of Observations	Number of groundwater level measurements that were compared to C2VSimFG-Kern simulation results for model validation

FIGURES

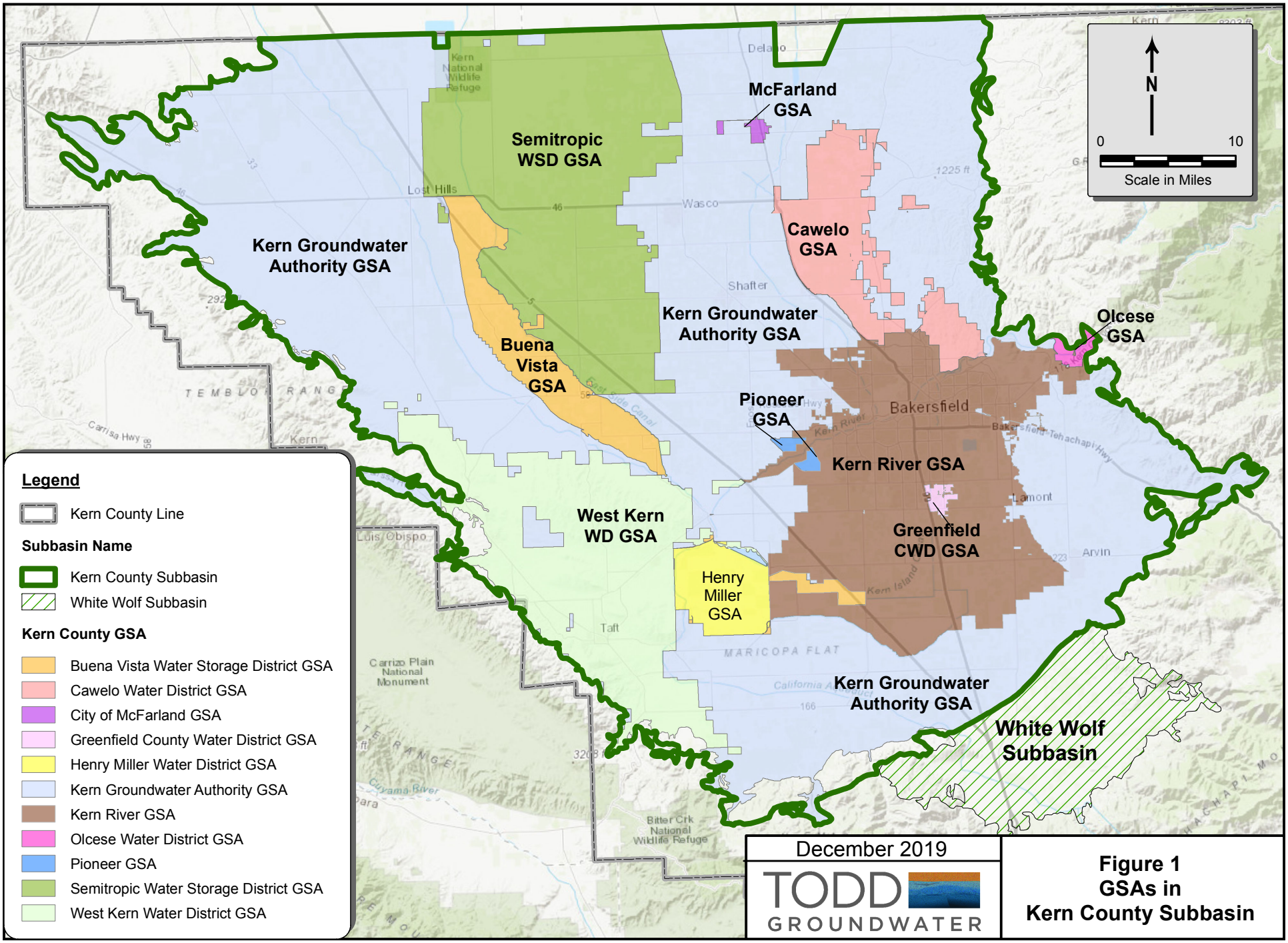
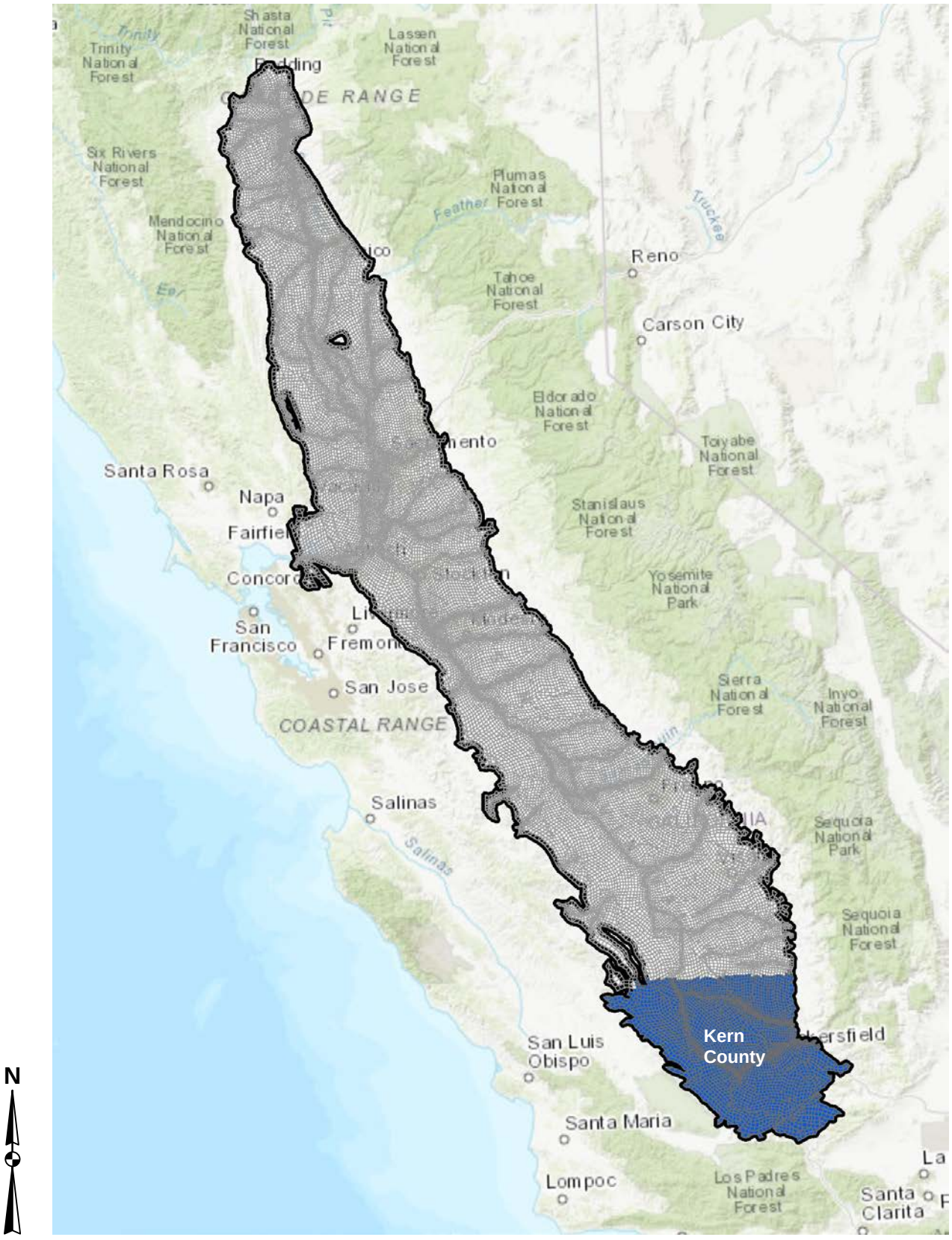
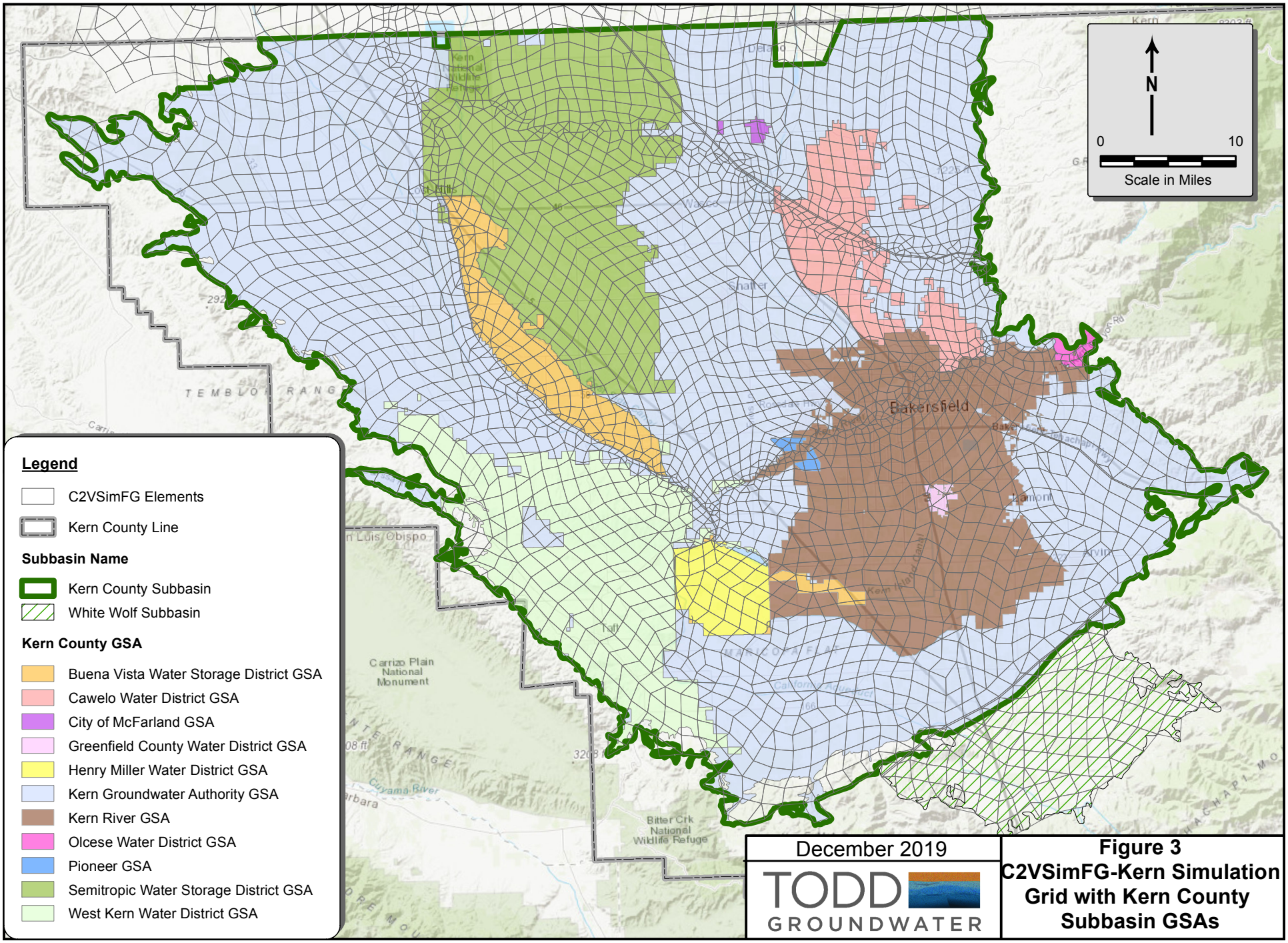


Figure 1
GSAs in
Kern County Subbasin



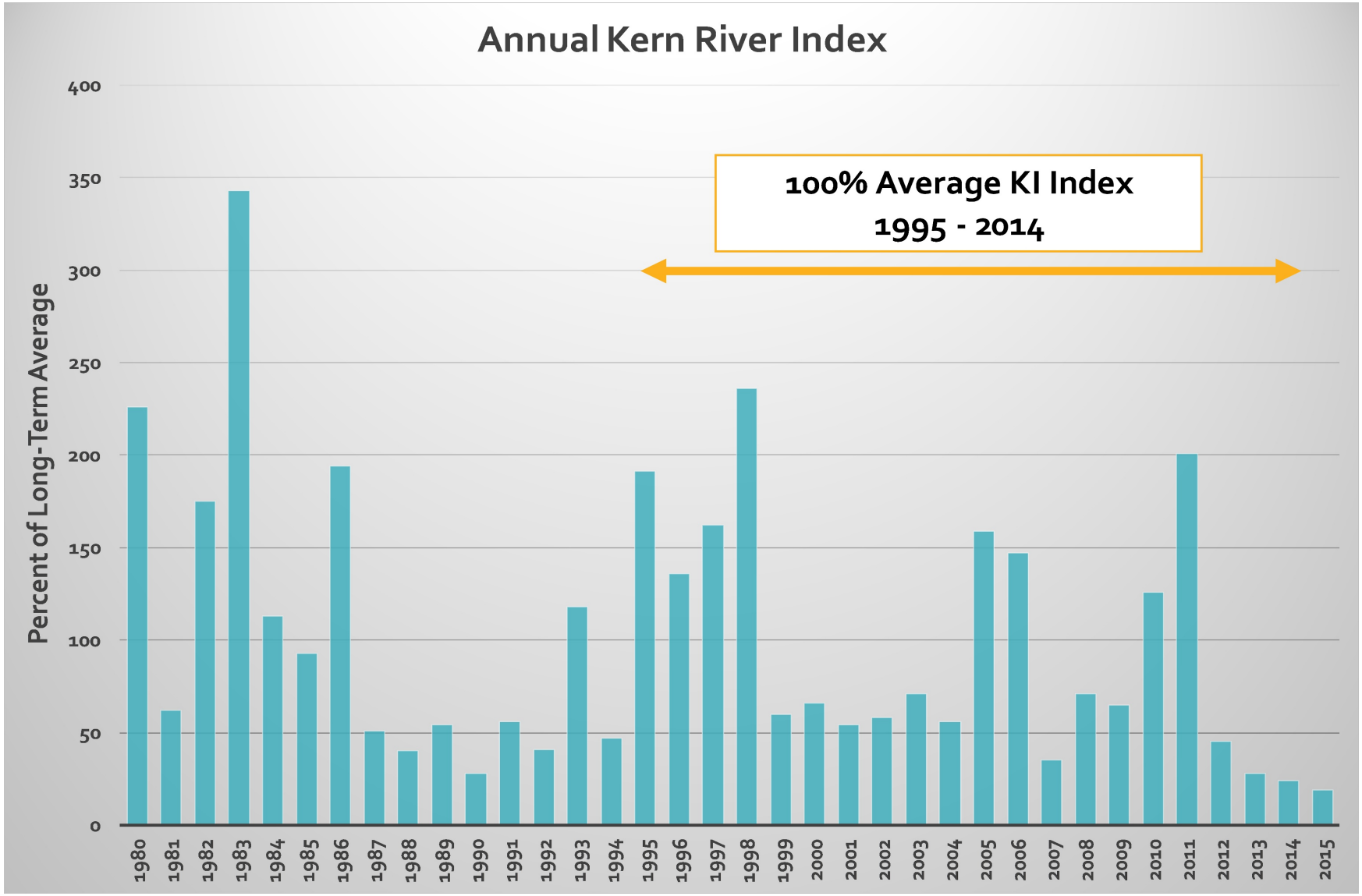
December 2019	Figure 2 C2VSimFG Simulation Grid for Central Valley Showing Kern County Subbasin
TODD GROUNDWATER	



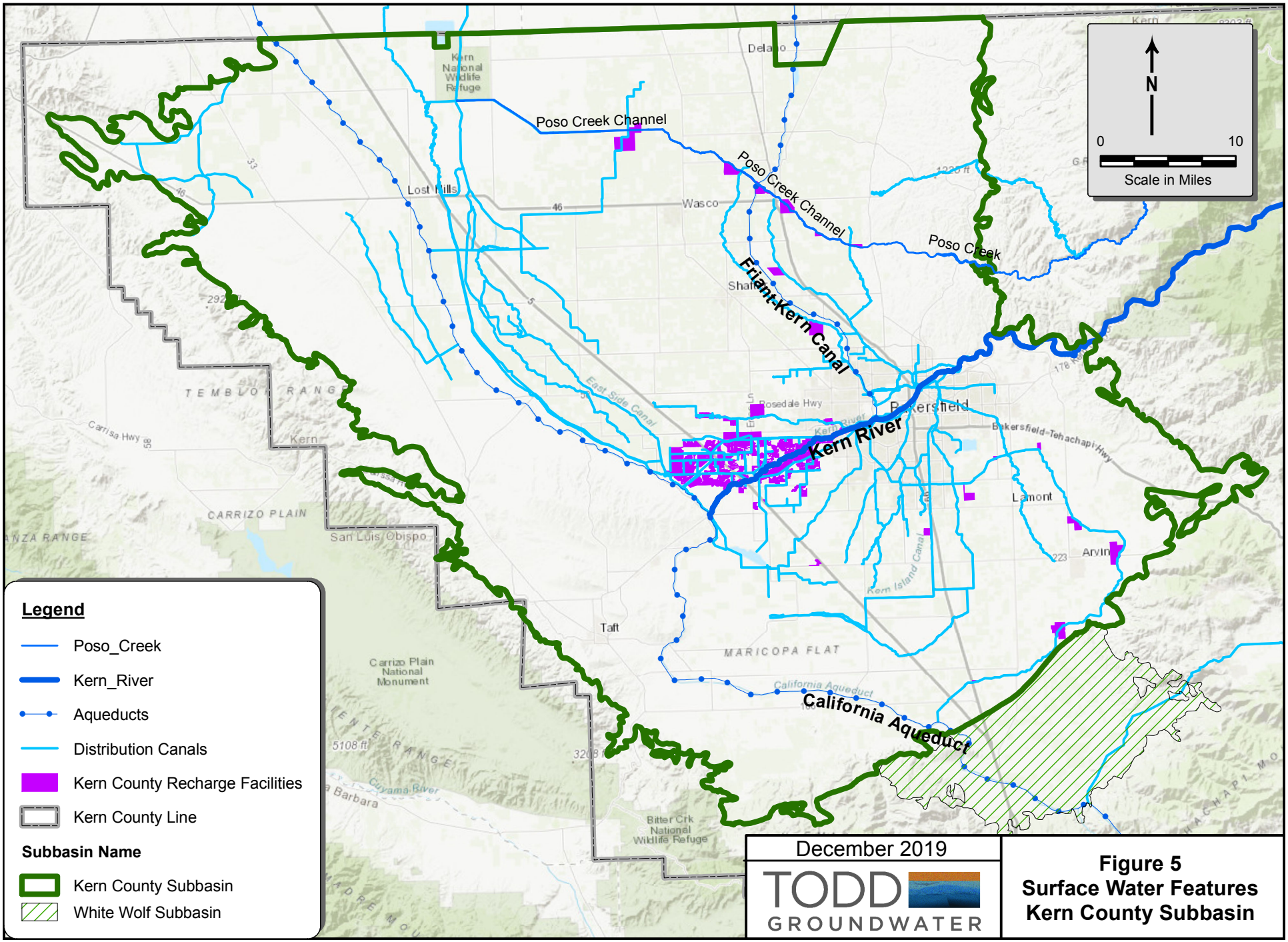
December 2019

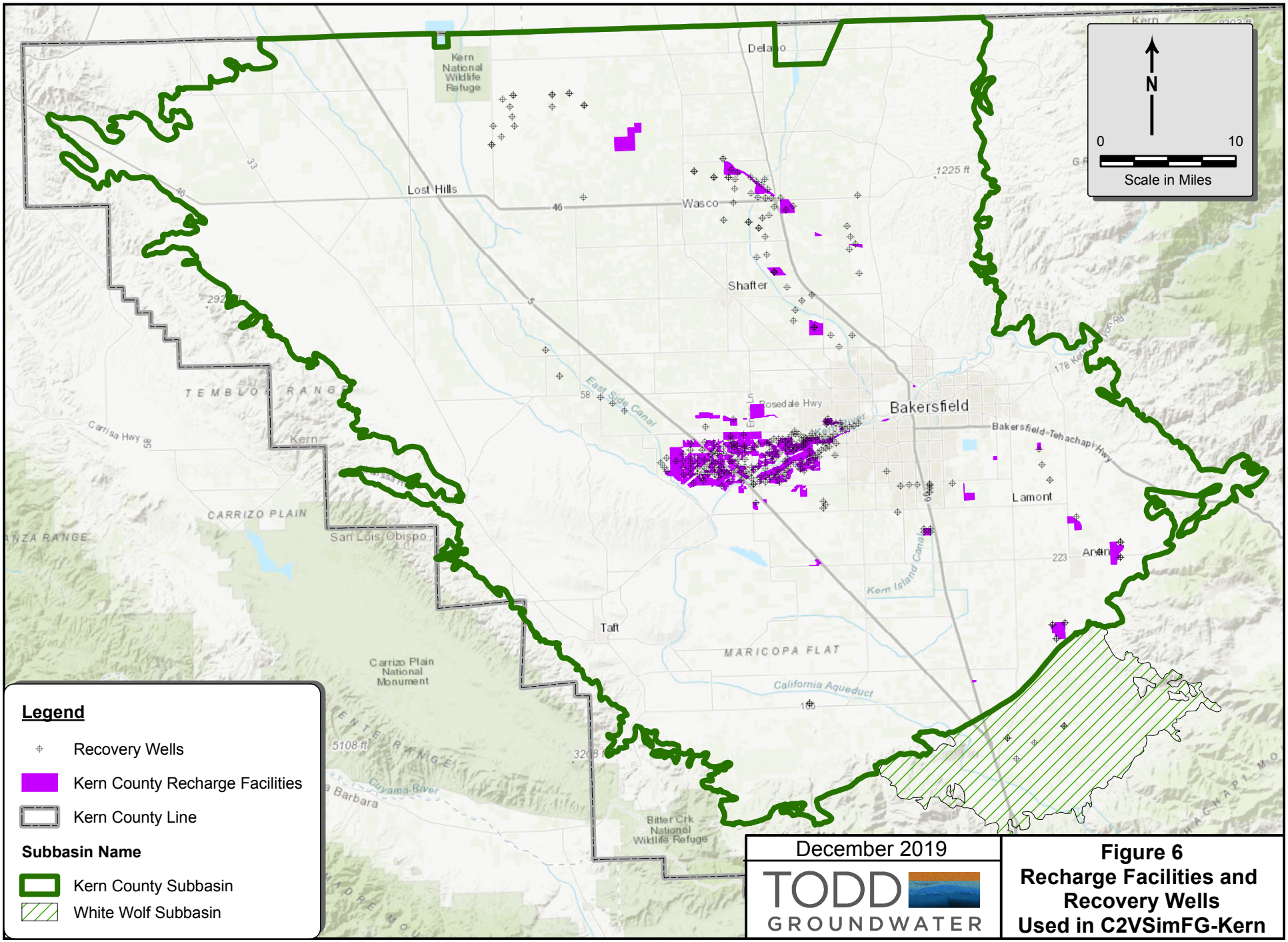
TODD GROUNDWATER

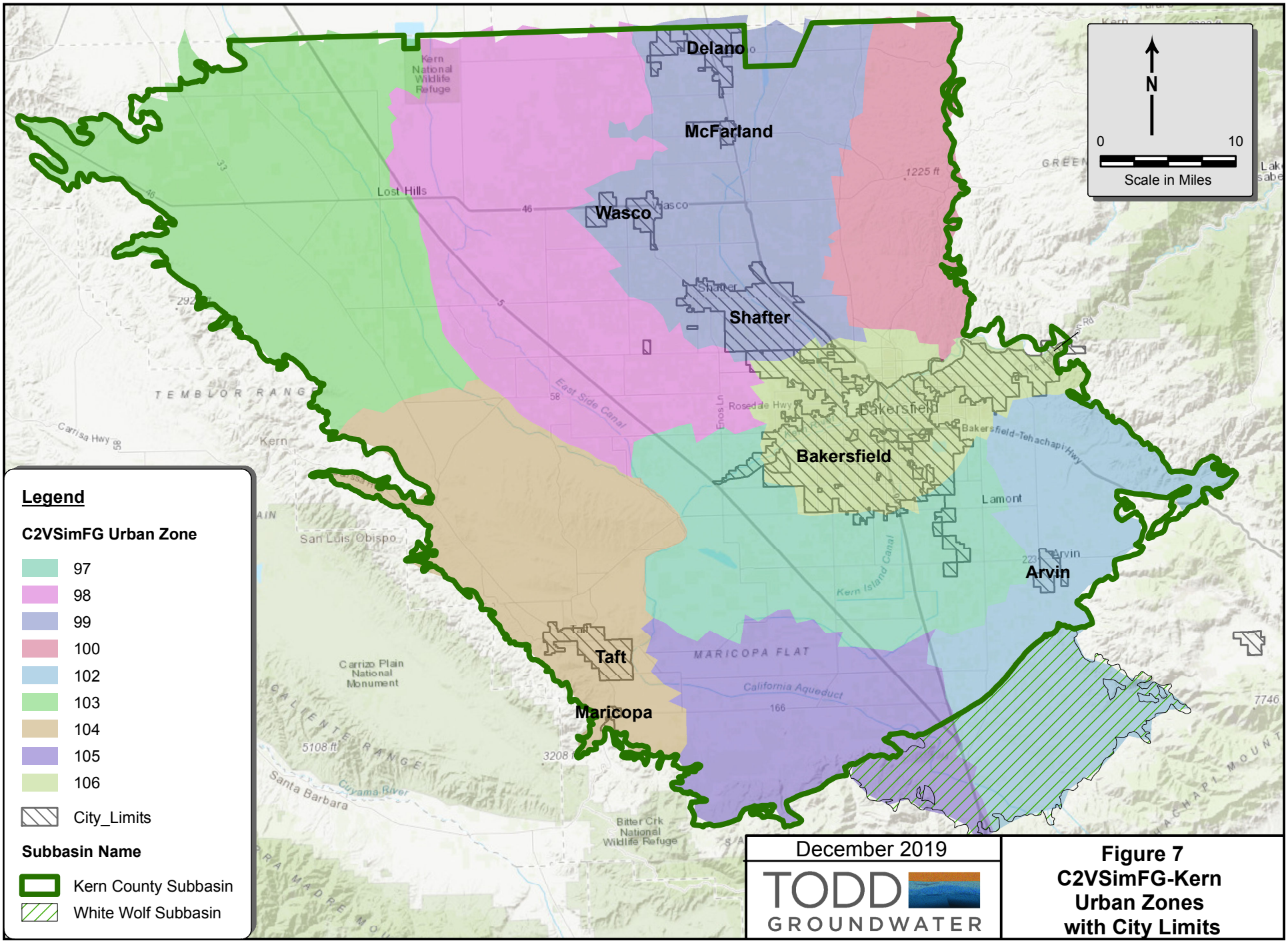
Figure 3
C2VSimFG-Kern Simulation Grid with Kern County Subbasin GSAs



December 2019	Figure 4 Annual Kern River Index used to Define 20-Year Historical Study Period
TODD GROUNDWATER	


Poso Creek Channel
Poso Creek Channel
Poso Creek
Friant-Kern Canal
Kern River
California Aqueduct
Kern National Wildlife Refuge
Lost Hills
Wasco
Delano
Shafter
Bakersfield
Rosedale Hwy
Bakersfield-Tehachapi Hwy
Lamont
Arvin
Taft
Kern
San Luis Obispo
CARRIZO PLAIN
TEMBLOR RANGE
MARICOPA FLAT
Carrizo Plain National Monument
Bitter Crk National Wildlife Refuge
East Side Canal
Kern Island Canal
Carrisa Hwy
N
0
10
Scale in Miles
Legend
Poso_Creek
Kern_River
Aqueducts
Distribution Canals
Kern County Recharge Facilities
Kern County Line
Subbasin Name
Kern County Subbasin
White Wolf Subbasin
December 2019
TODD GROUNDWATER
Figure 5
Surface Water Features
Kern County Subbasin


N
0
10
Scale in Miles
Kern National Wildlife Refuge
Delano
Lost Hills
Wasco
Shafter
Bakersfield
Lamont
Arvin
Taft
Kern
San Luis Obispo
CARRIZO PLAIN
MARICOPA FLAT
TEMBLOR RANGE
Carrizo Plain National Monument
Bitter Crk National Wildlife Refuge
East Side Canal
Kern Island Canal
California Aqueduct
Rosedale Hwy
Bakersfield-Tehachapi Hwy
Carrisa Hwy
Legend
Recovery Wells
Kern County Recharge Facilities
Kern County Line
Subbasin Name
Kern County Subbasin
White Wolf Subbasin
December 2019
TODD GROUNDWATER
Figure 6
Recharge Facilities and Recovery Wells Used in C2VSimFG-Kern


Delano
McFarland
Wasco
Shafter
Bakersfield
Lamont
Arvin
Taft
Maricopa
Lost Hills
Kern National Wildlife Refuge
Carrizo Plain National Monument
Bitter Crk National Wildlife Refuge
TEMBLOR RANGE
MARICOPA FLAT
East Side Canal
Kern Island Canal
California Aqueduct
Rosedale Hwy
Bakersfield-Tehachapi Hwy
Carrisa Hwy
San Luis Obispo
Santa Barbara
Kern
N
0
10
Scale in Miles
Legend
C2VSimFG Urban Zone
97
98
99
100
102
103
104
105
106
City_Limits
Subbasin Name
Kern County Subbasin
White Wolf Subbasin
December 2019
TODD GROUNDWATER
Figure 7
C2VSimFG-Kern
Urban Zones
with City Limits

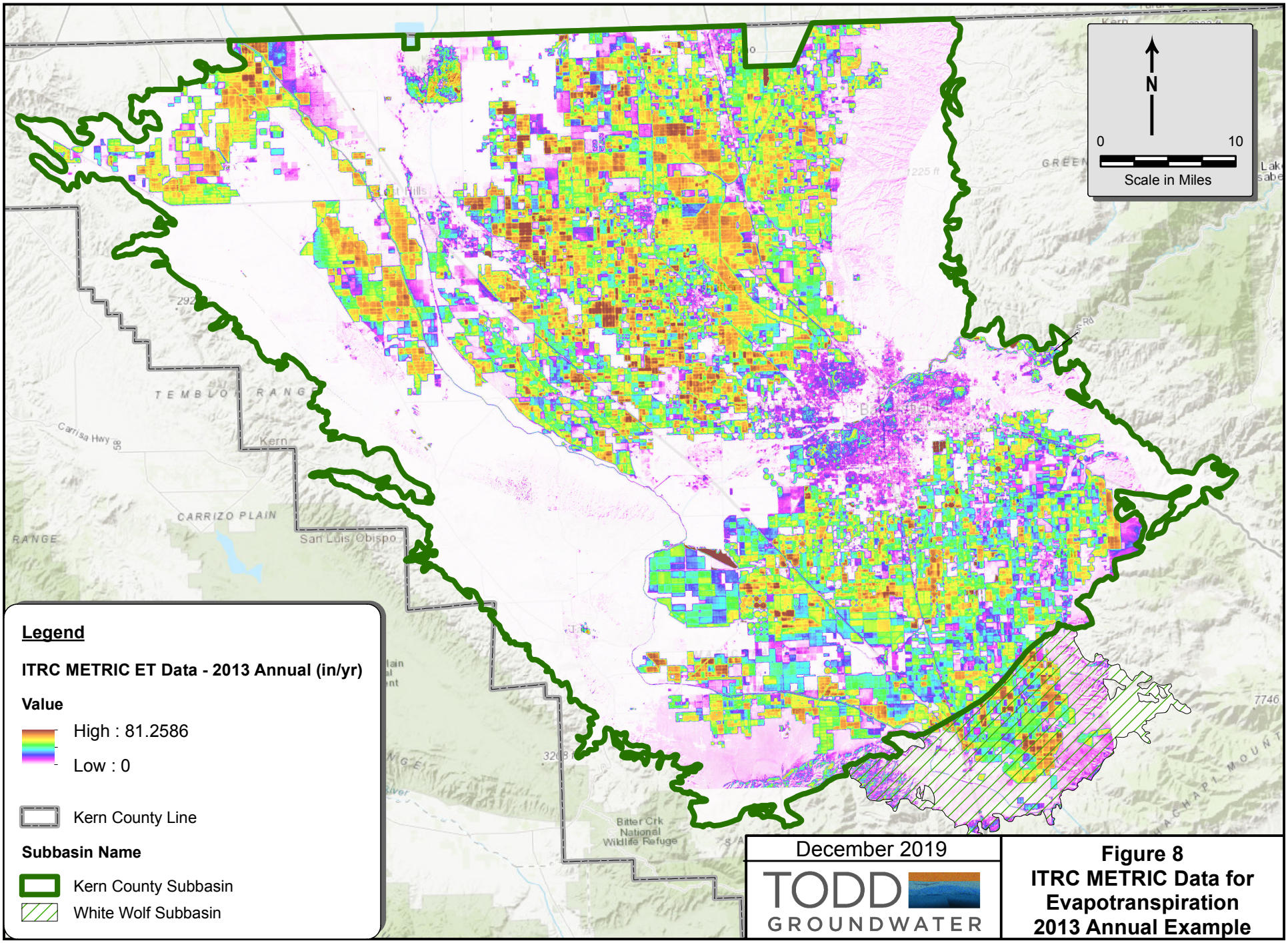
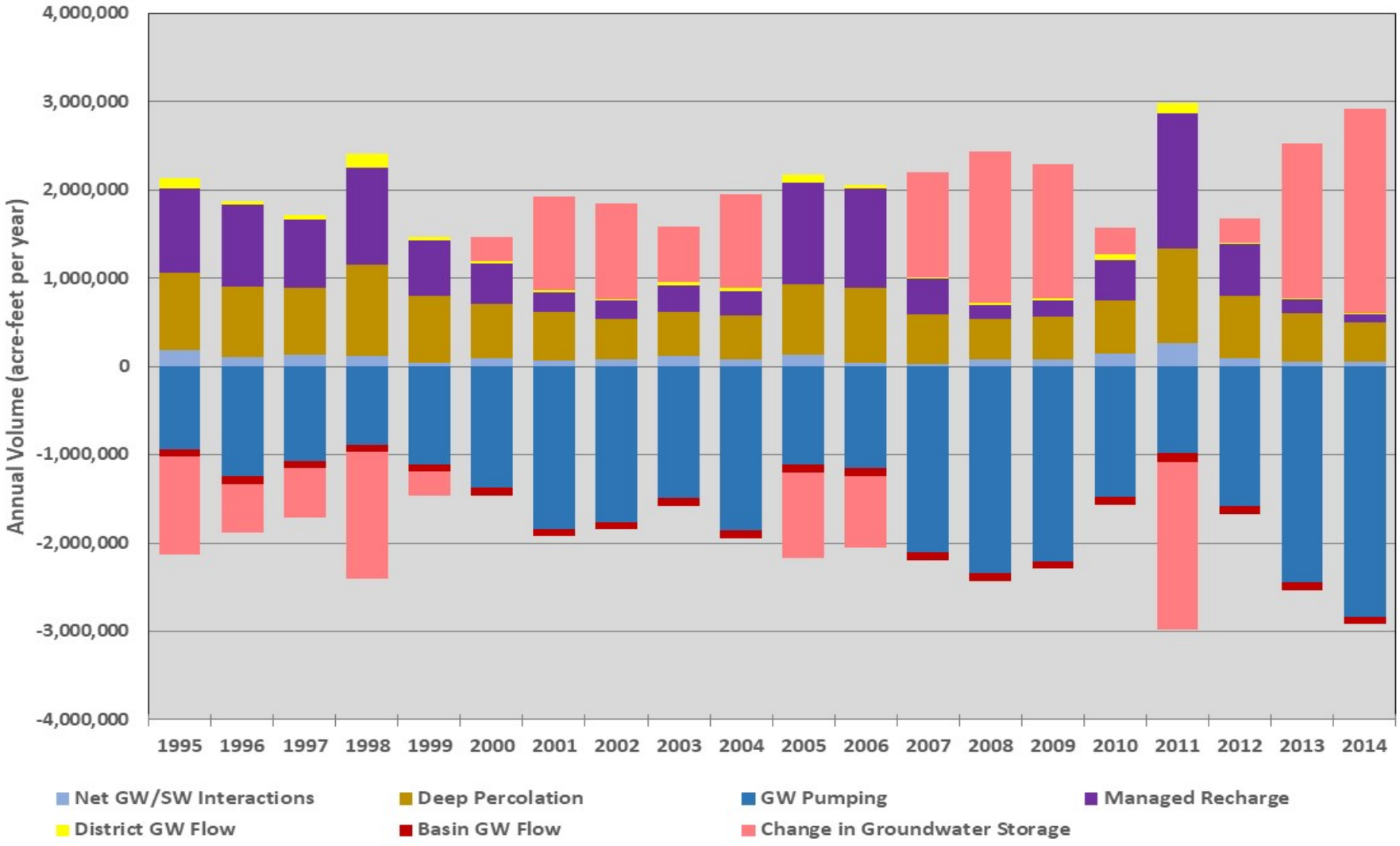
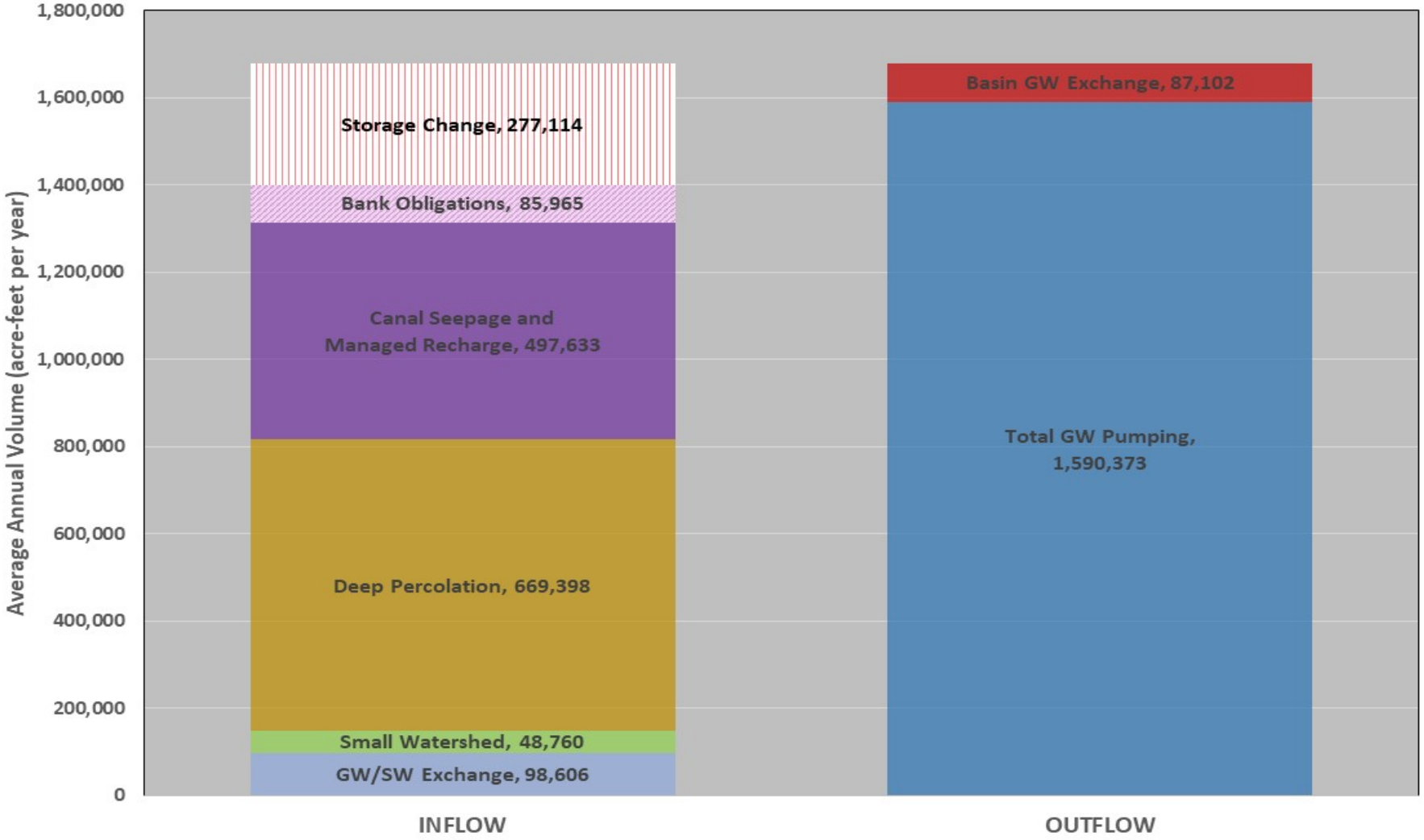


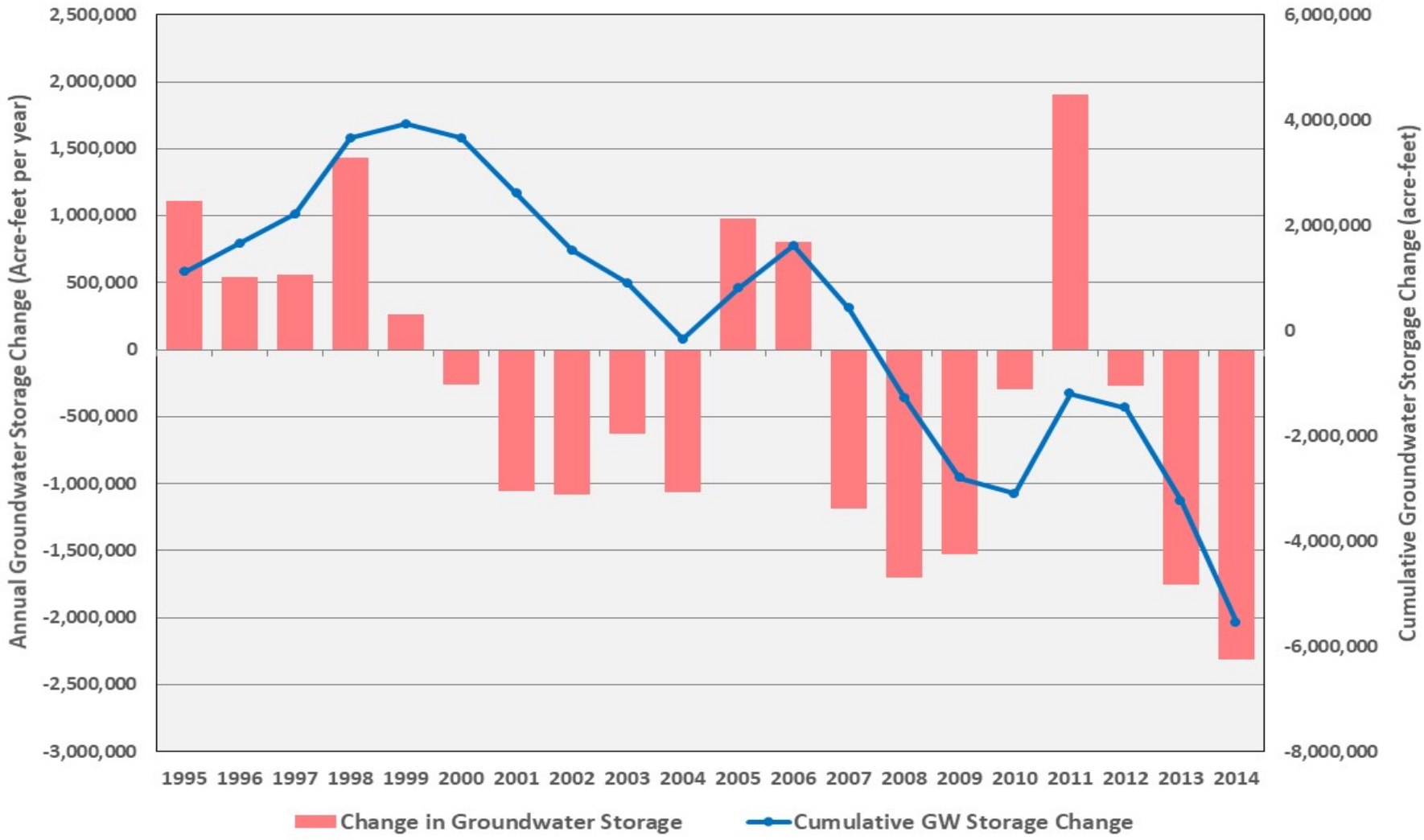
Figure 8
ITRC METRIC Data for Evapotranspiration 2013 Annual Example



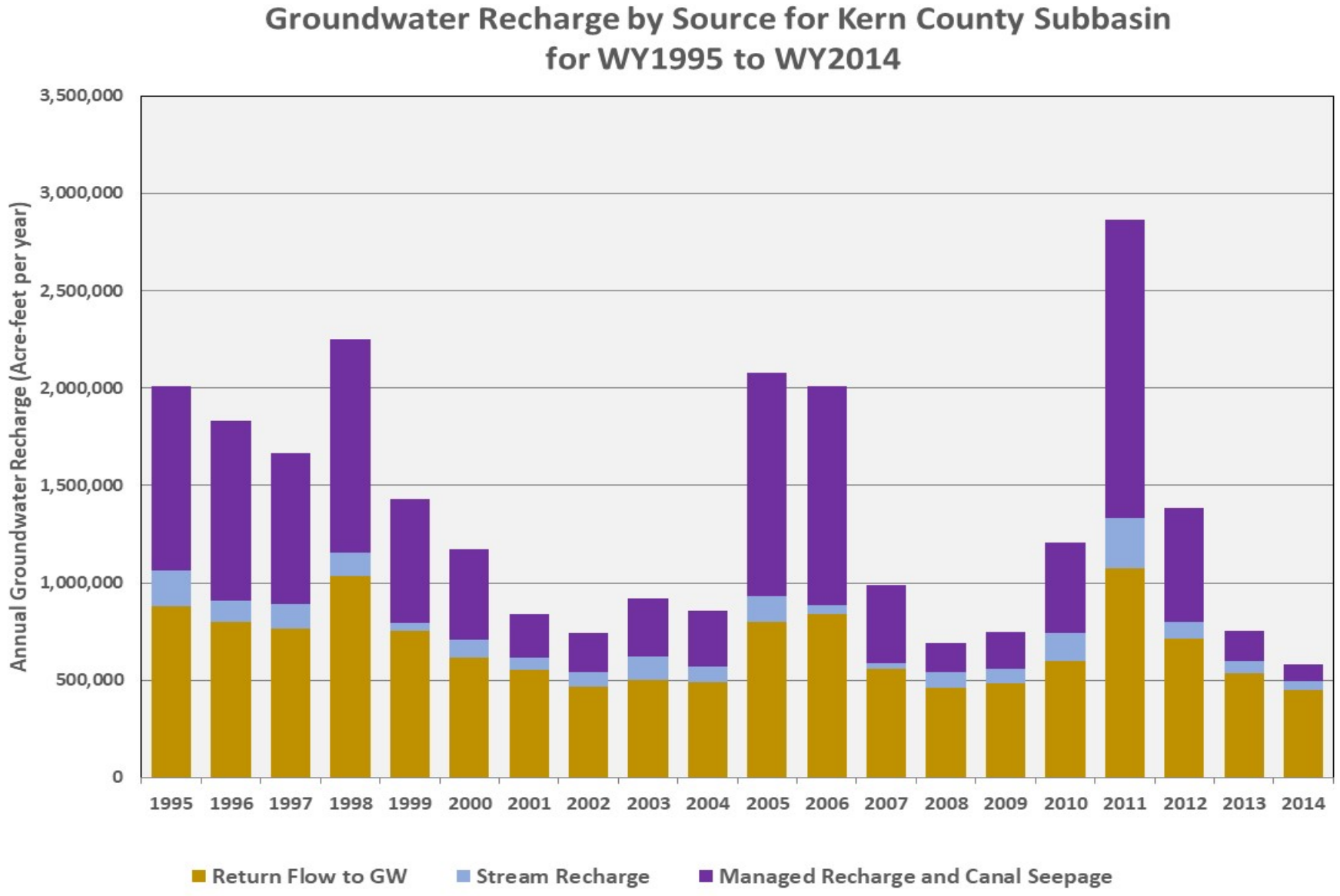
December 2019	Figure 9 C2VSimFG-Kern Historical Groundwater Budget for Kern County Subbasin
TODD GROUNDWATER	



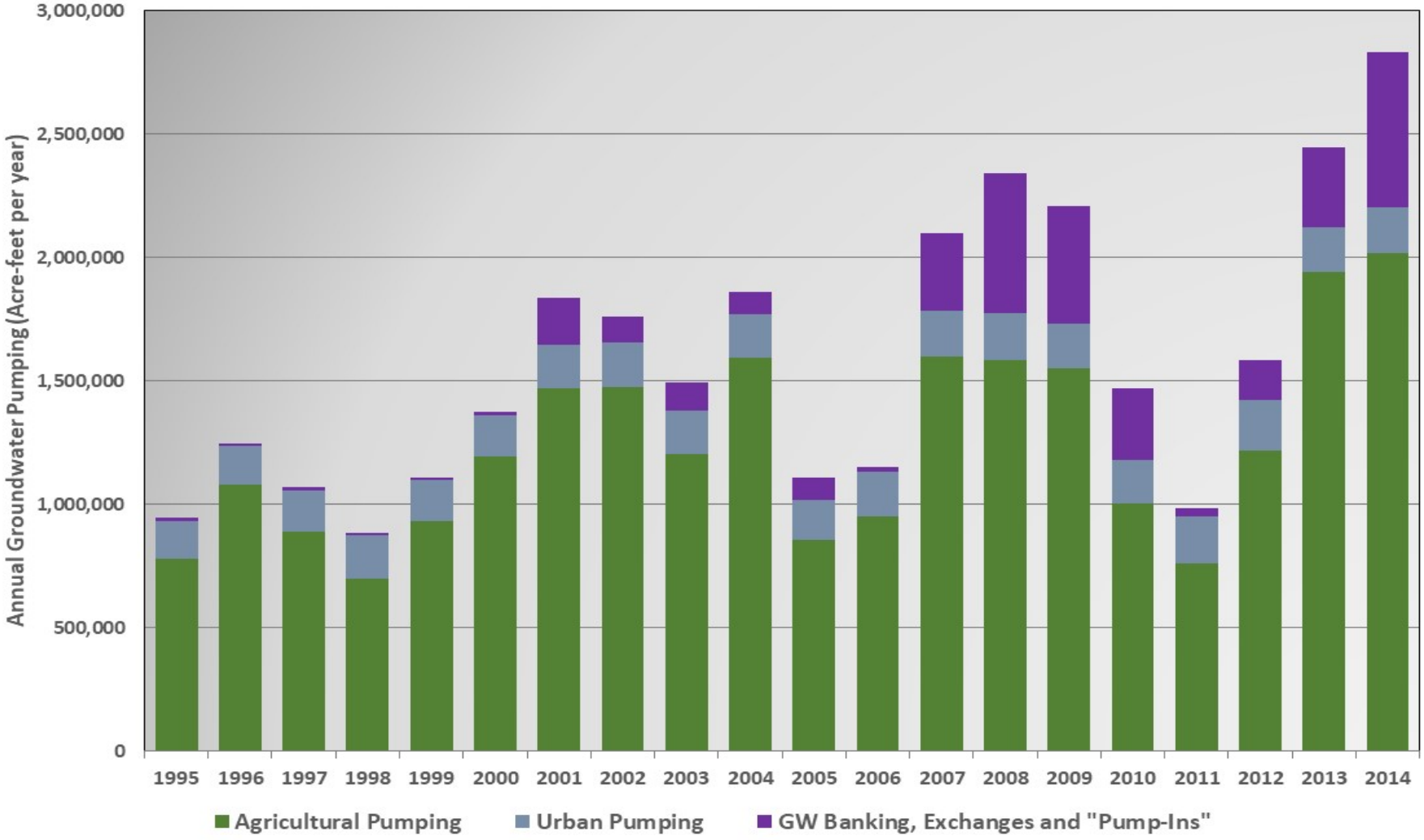
December 2019	Figure 10 C2VSimFG-Kern Average Annual Water Budget for Kern County Subbasin
TODD GROUNDWATER	



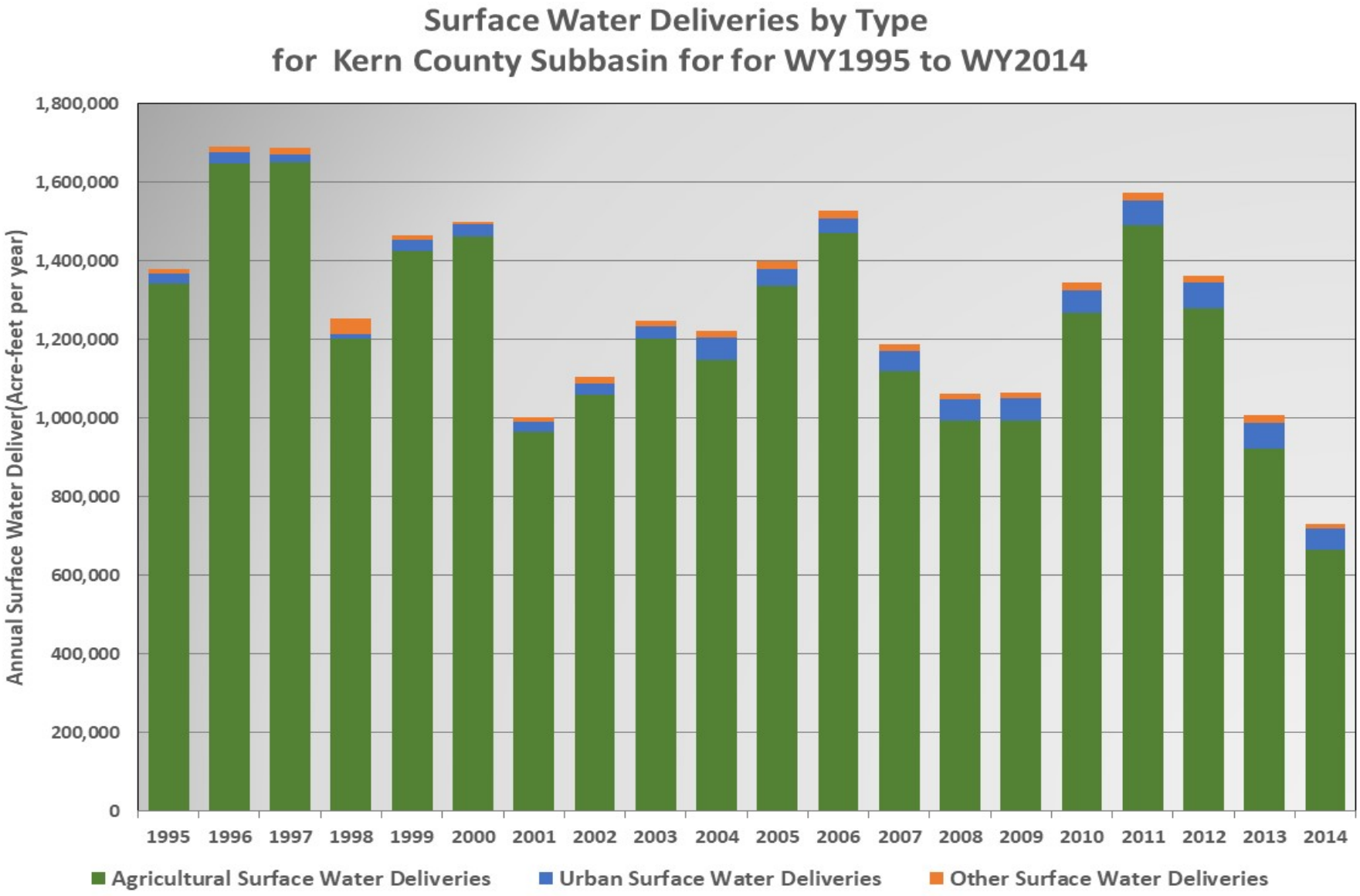
December 2019	Figure 11 Simulated Historical Change in Groundwater Storage for Kern County Subbasin
TODD GROUNDWATER	



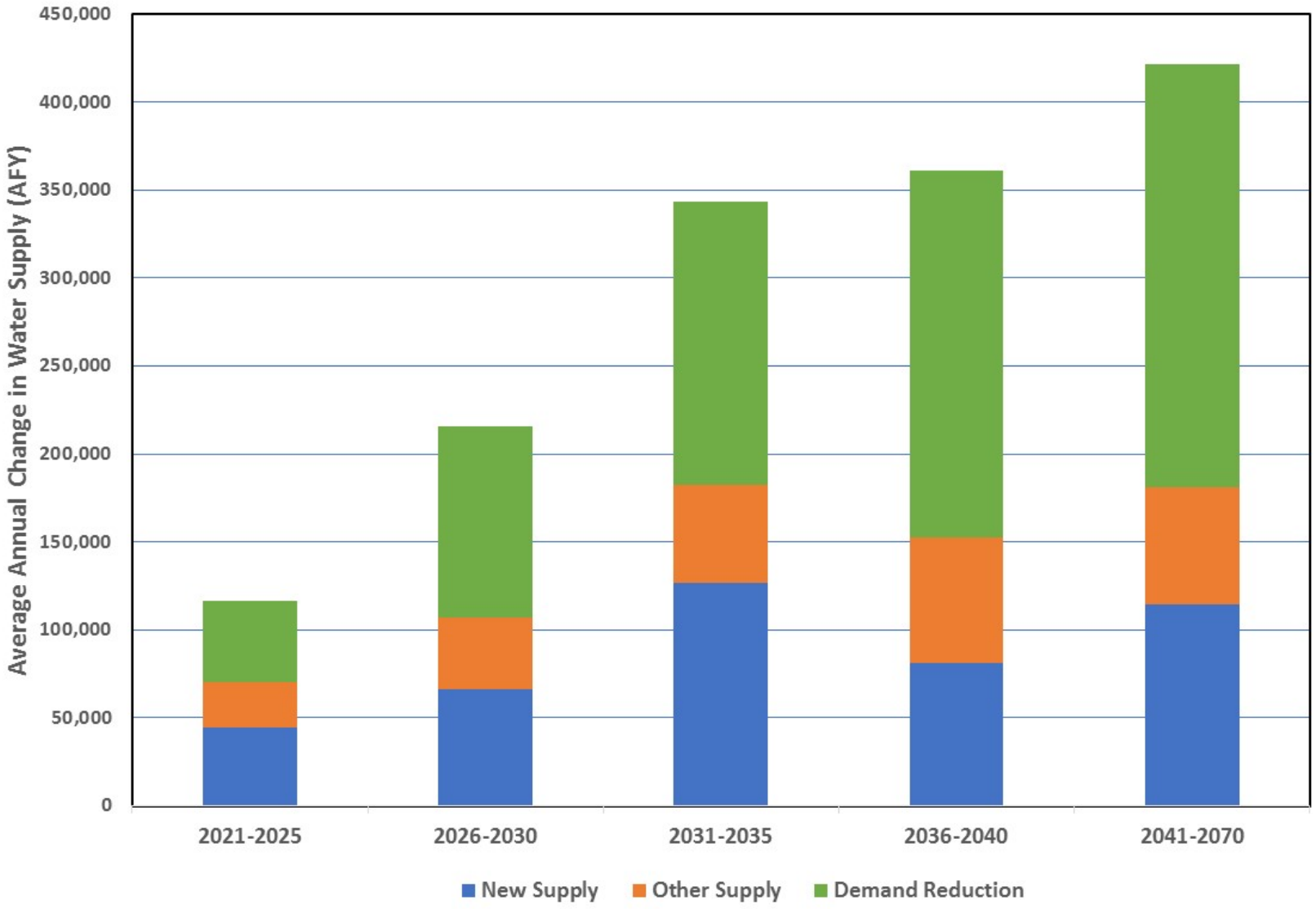
December 2019	Figure 12 Simulated Historical Recharge Operations for Kern County Subbasin
TODD GROUNDWATER	



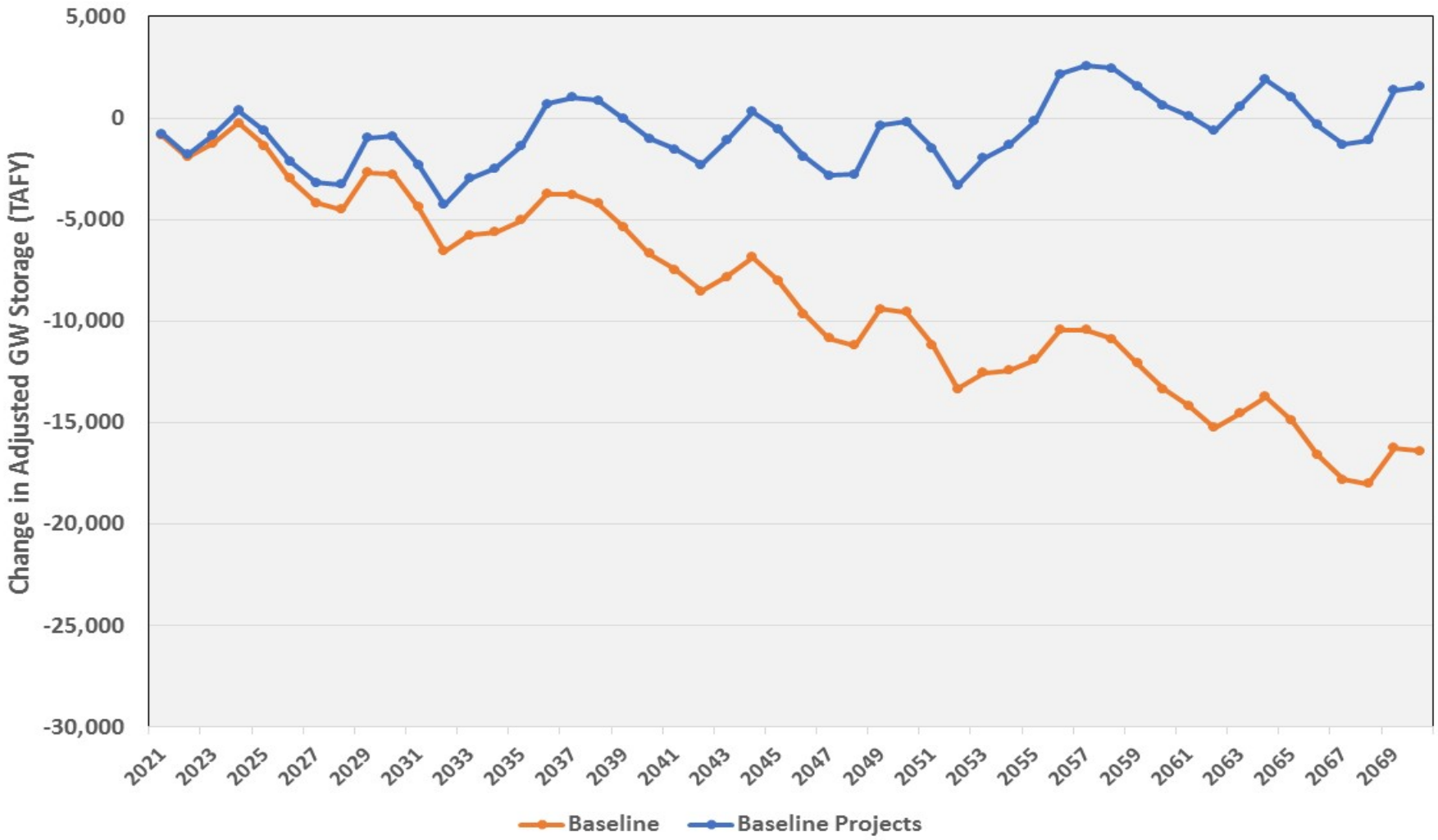
December 2019	Figure 13 Simulated Historical Groundwater Pumping for Kern County Subbasin
TODD GROUNDWATER	



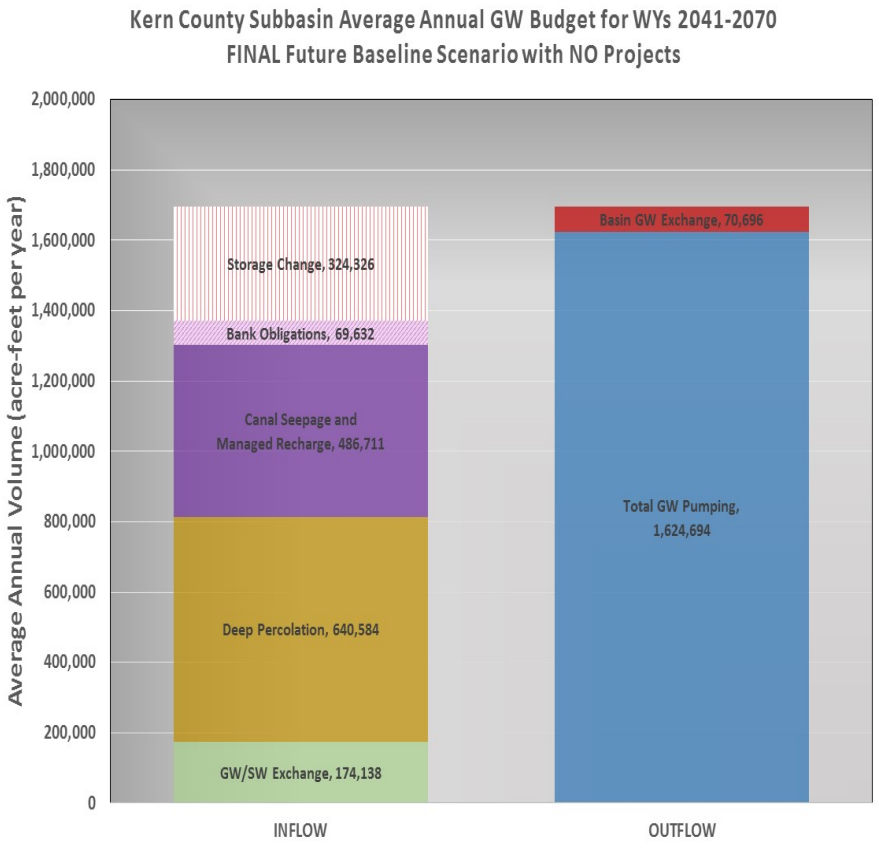
December 2019	Figure 14 Simulated Historical Surface Water Deliveries for Kern County Subbasin
TODD GROUNDWATER	

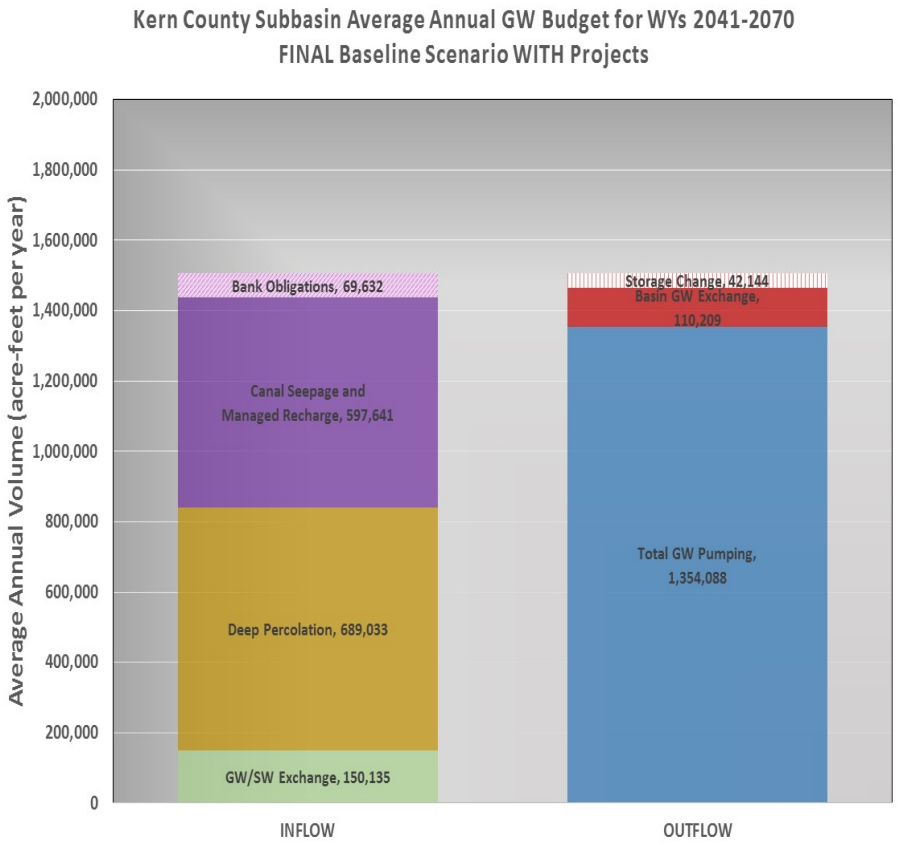


December 2019	Figure 15 Average Annual Benefit of Proposed SGMA Projects and Management Actions
TODD GROUNDWATER	

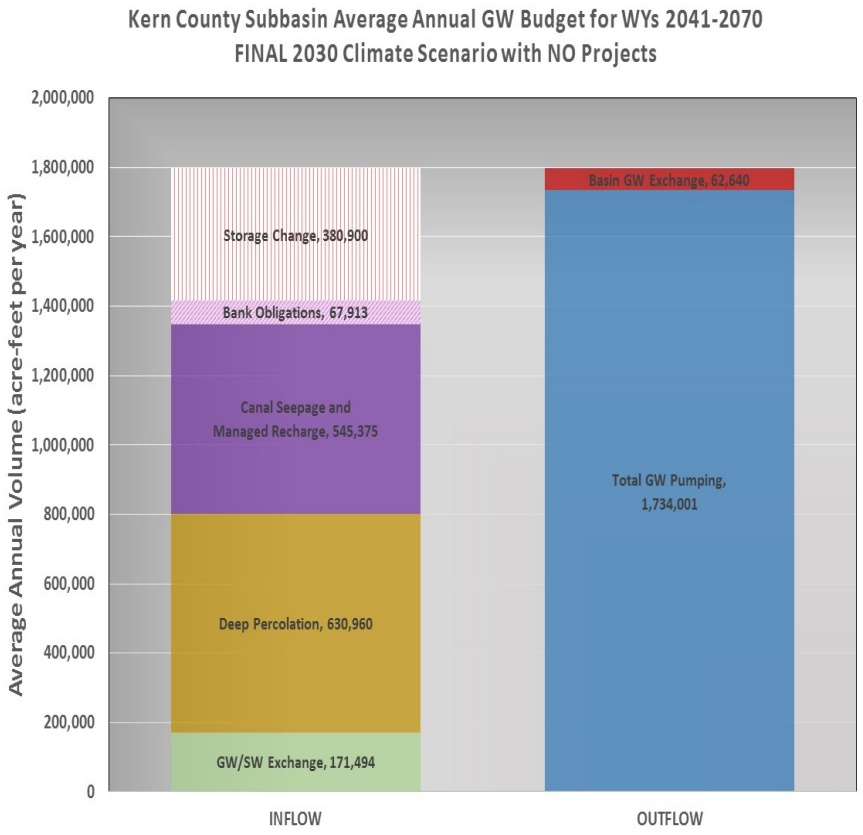


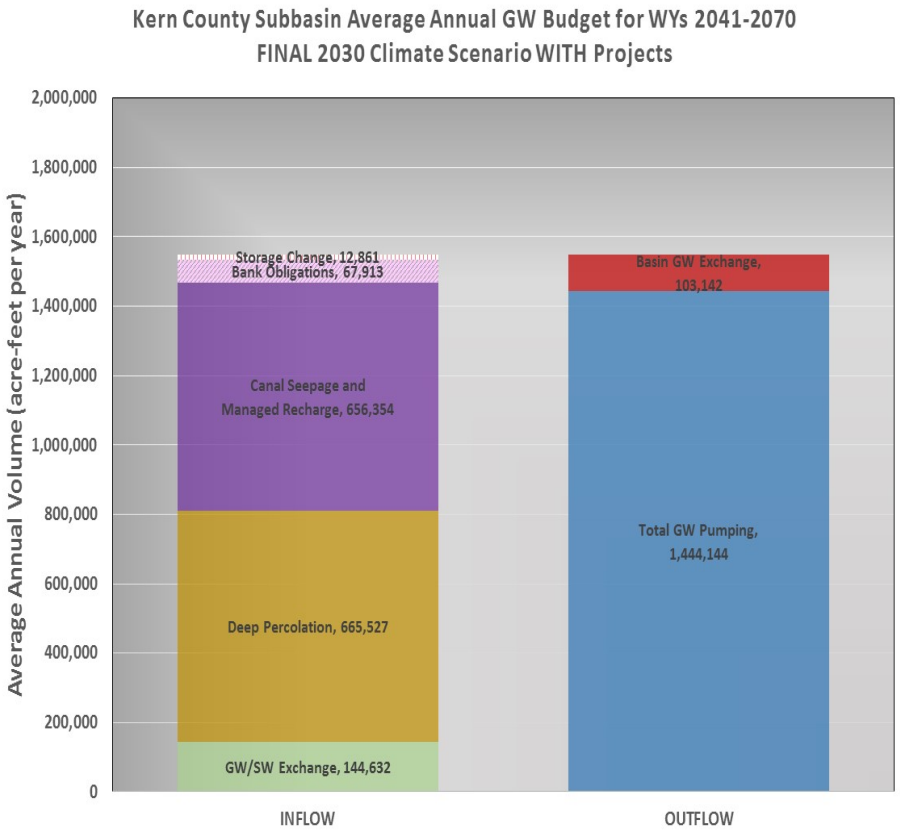
December 2019	Figure 16 Projected Future Change in Groundwater Storage for Baseline Conditions
TODD GROUNDWATER	



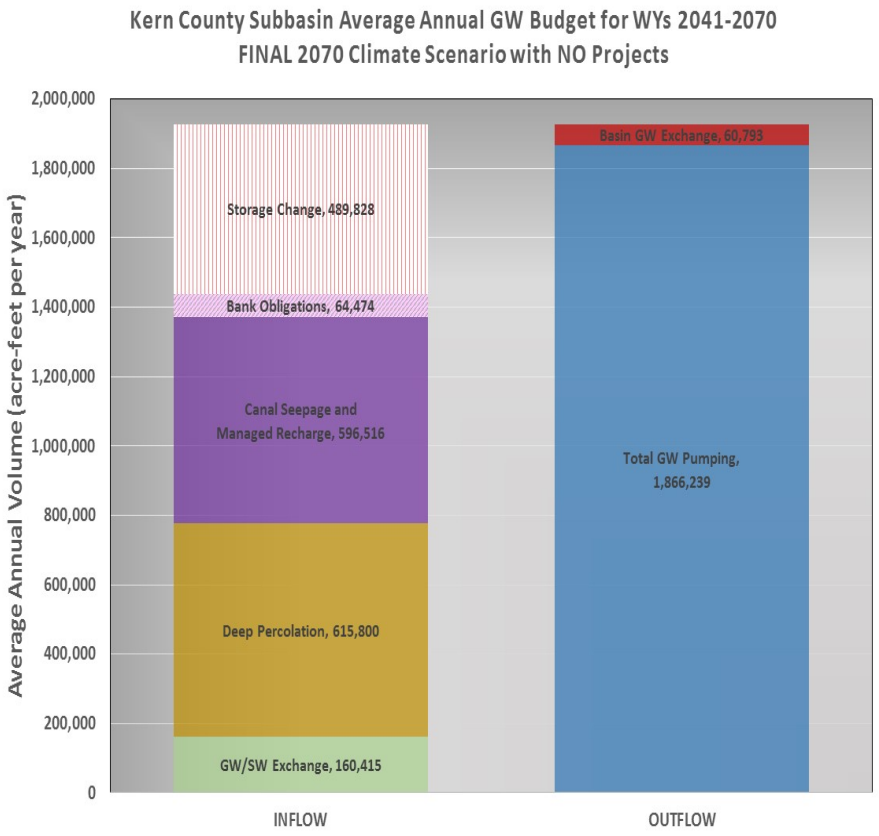


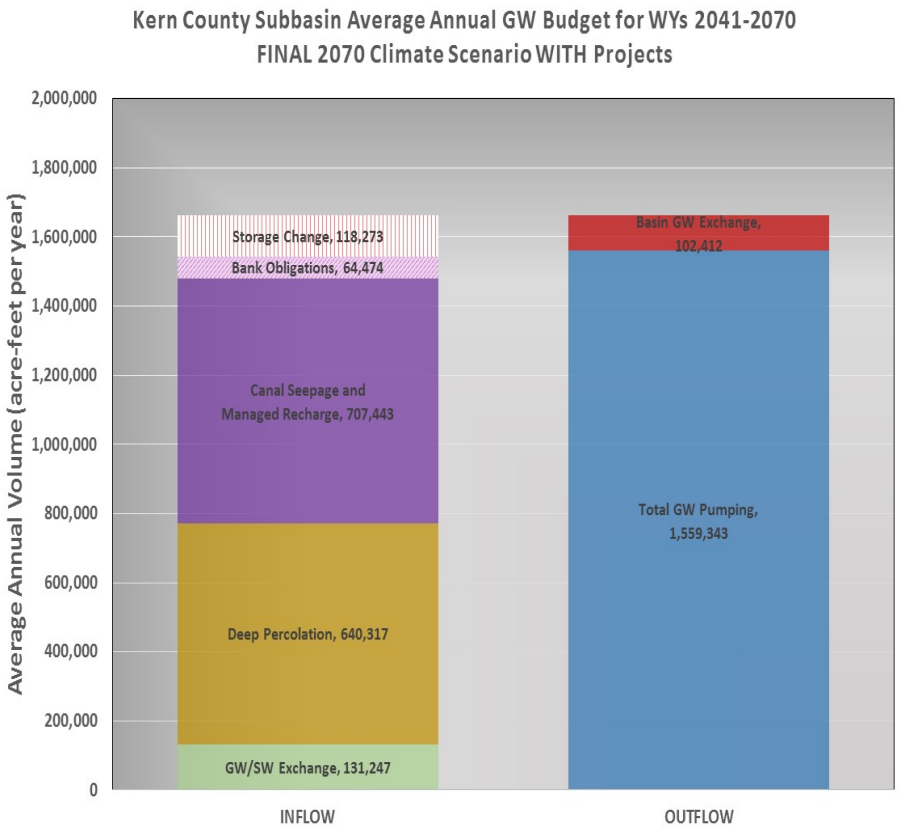
December 2019	Figure 17 Baseline Projected Future Average Annual Groundwater Budget for WY2041-2070
TODD GROUNDWATER	



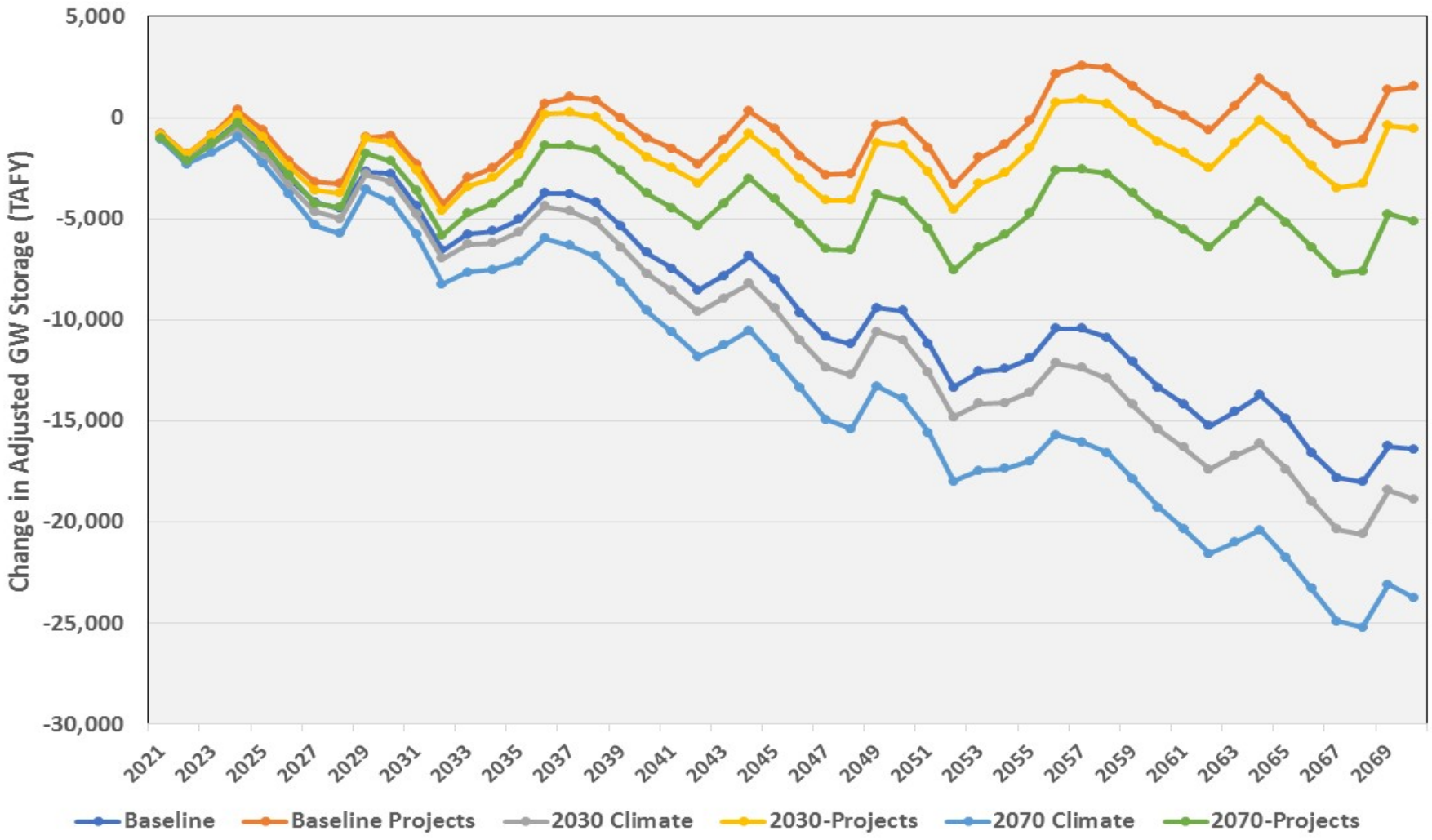


December 2019	Figure 18 2030 Climate Projected Future Average Annual Groundwater Budget for WY2041-2070
TODD GROUNDWATER	

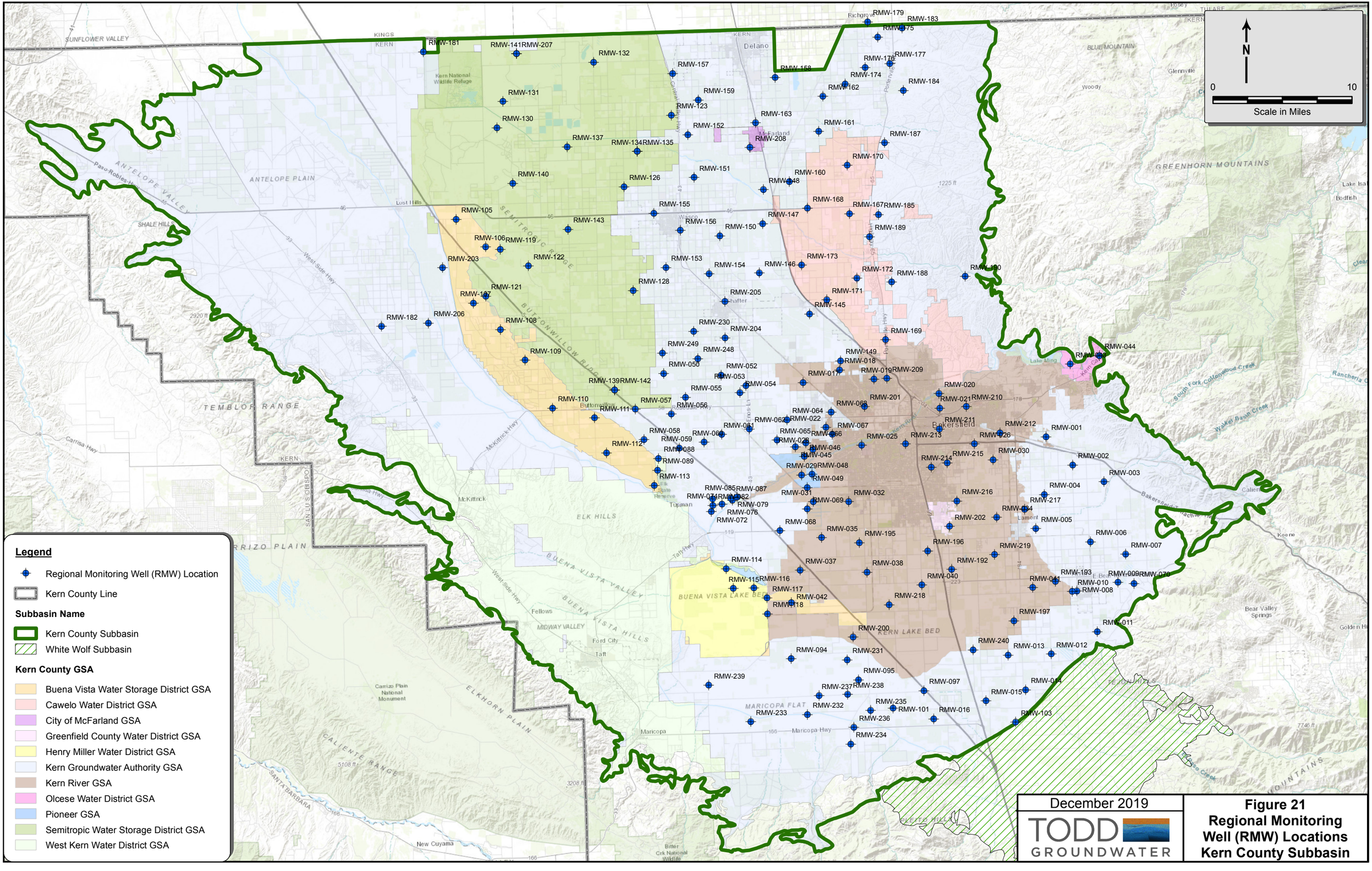


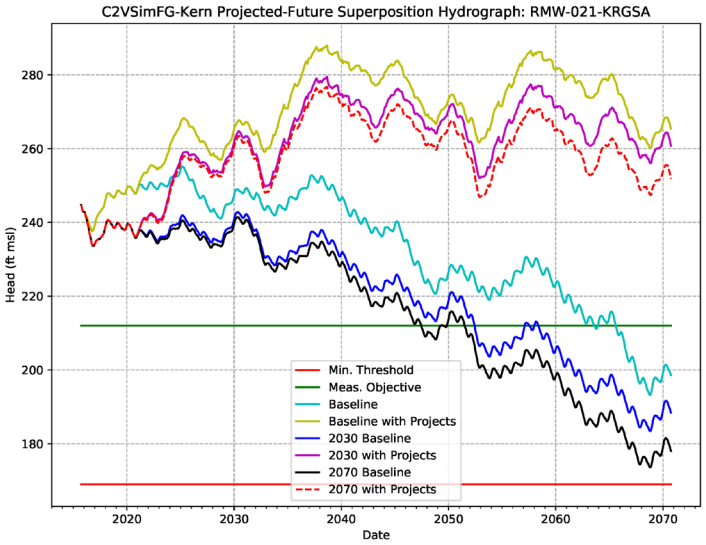


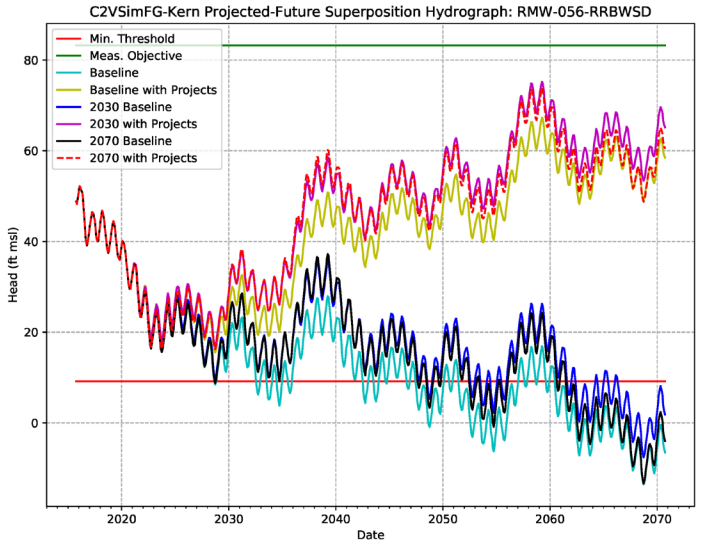
December 2019	Figure 19 2070 Climate Projected Future Average Annual Groundwater Budget for WY2041-2070
TODD GROUNDWATER	

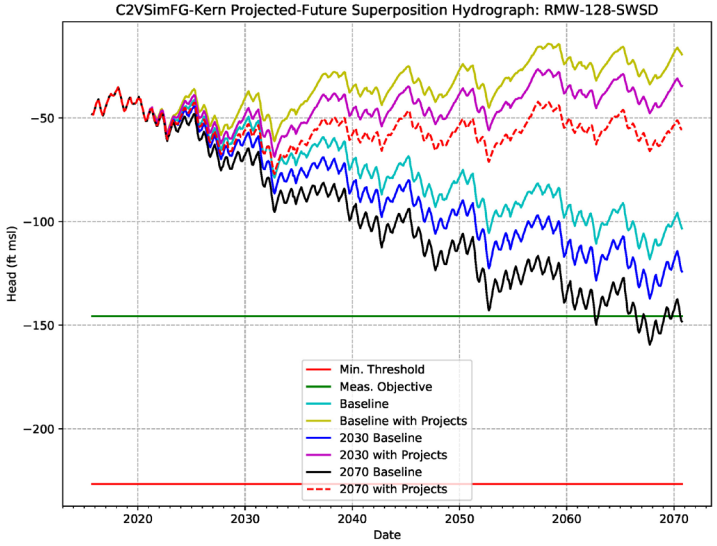


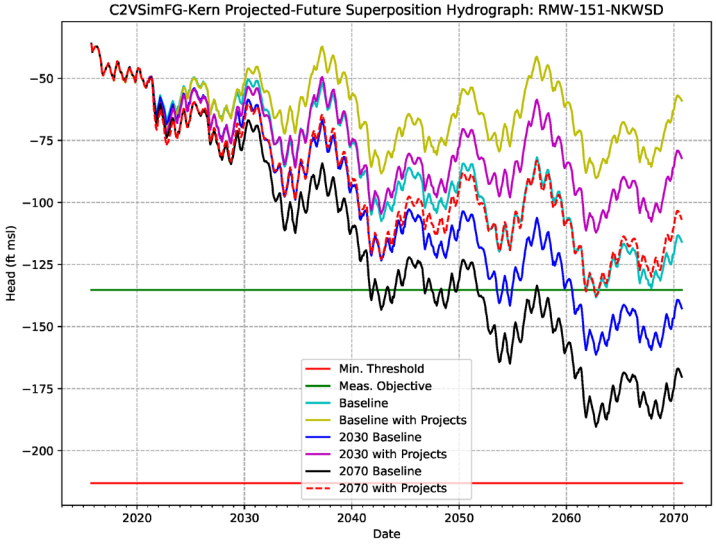
December 2019	Figure 20 Projected Future Change in Groundwater Storage for All Conditions
TODD GROUNDWATER	


N
0
10
Scale in Miles
Legend
Regional Monitoring Well (RMW) Location
Kern County Line
Subbasin Name
Kern County Subbasin
White Wolf Subbasin
Kern County GSA
Buena Vista Water Storage District GSA
Cawelo Water District GSA
City of McFarland GSA
Greenfield County Water District GSA
Henry Miller Water District GSA
Kern Groundwater Authority GSA
Kern River GSA
Olcese Water District GSA
Pioneer GSA
Semitropic Water Storage District GSA
West Kern Water District GSA
December 2019
TODD GROUNDWATER
Figure 21
Regional Monitoring Well (RMW) Locations
Kern County Subbasin





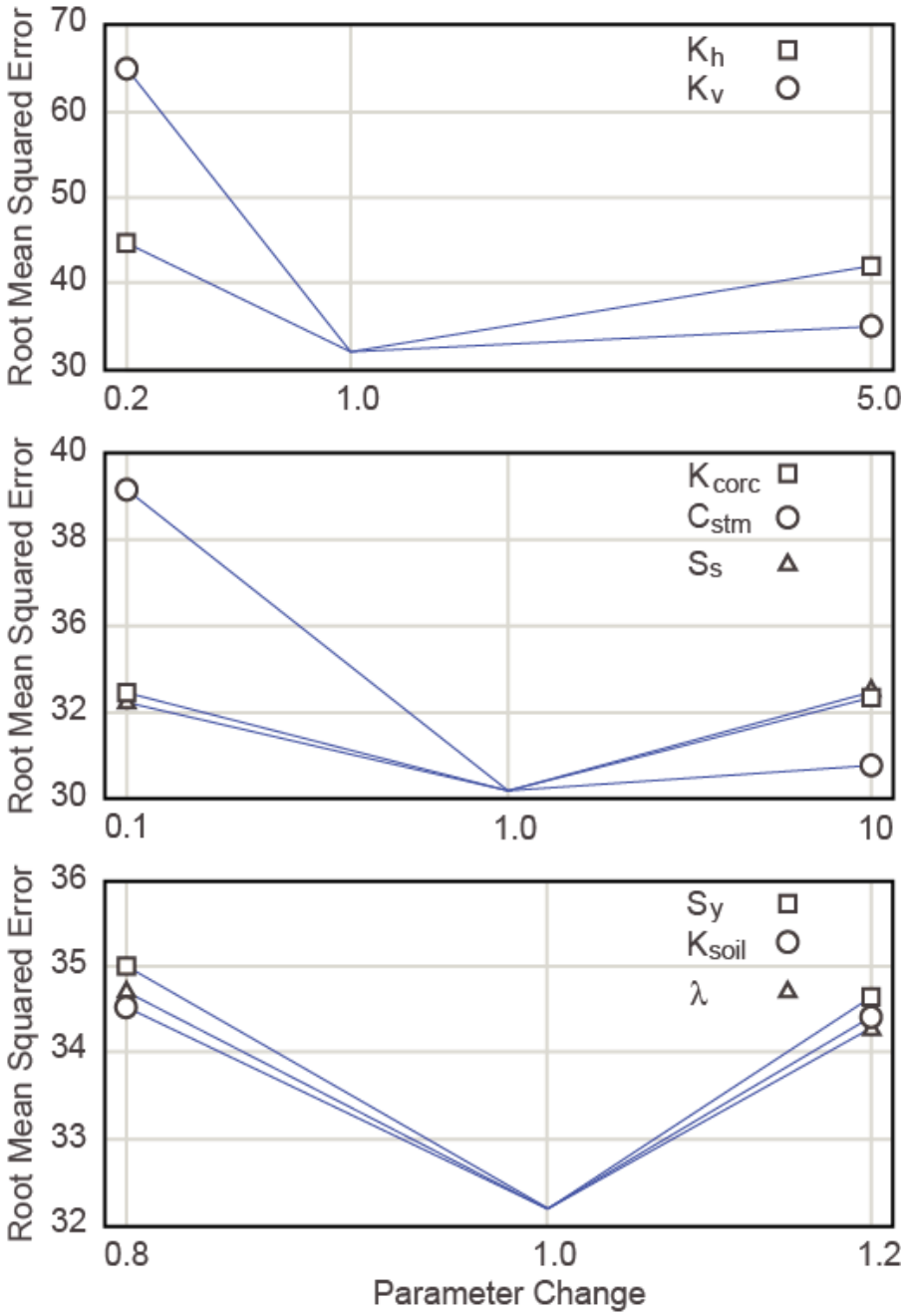




December 2019

TODD GROUNDWATER

Figure 22
Hydrographs for all Projected Future Conditions with SGMA Sustainability Criteria



Notes:
Sensitivity parameters modified and evaluated for Kern County Subbasin
Kh – horizontal hydraulic conductivity of aquifer
Kv – vertical hydraulic conductivity of aquifer

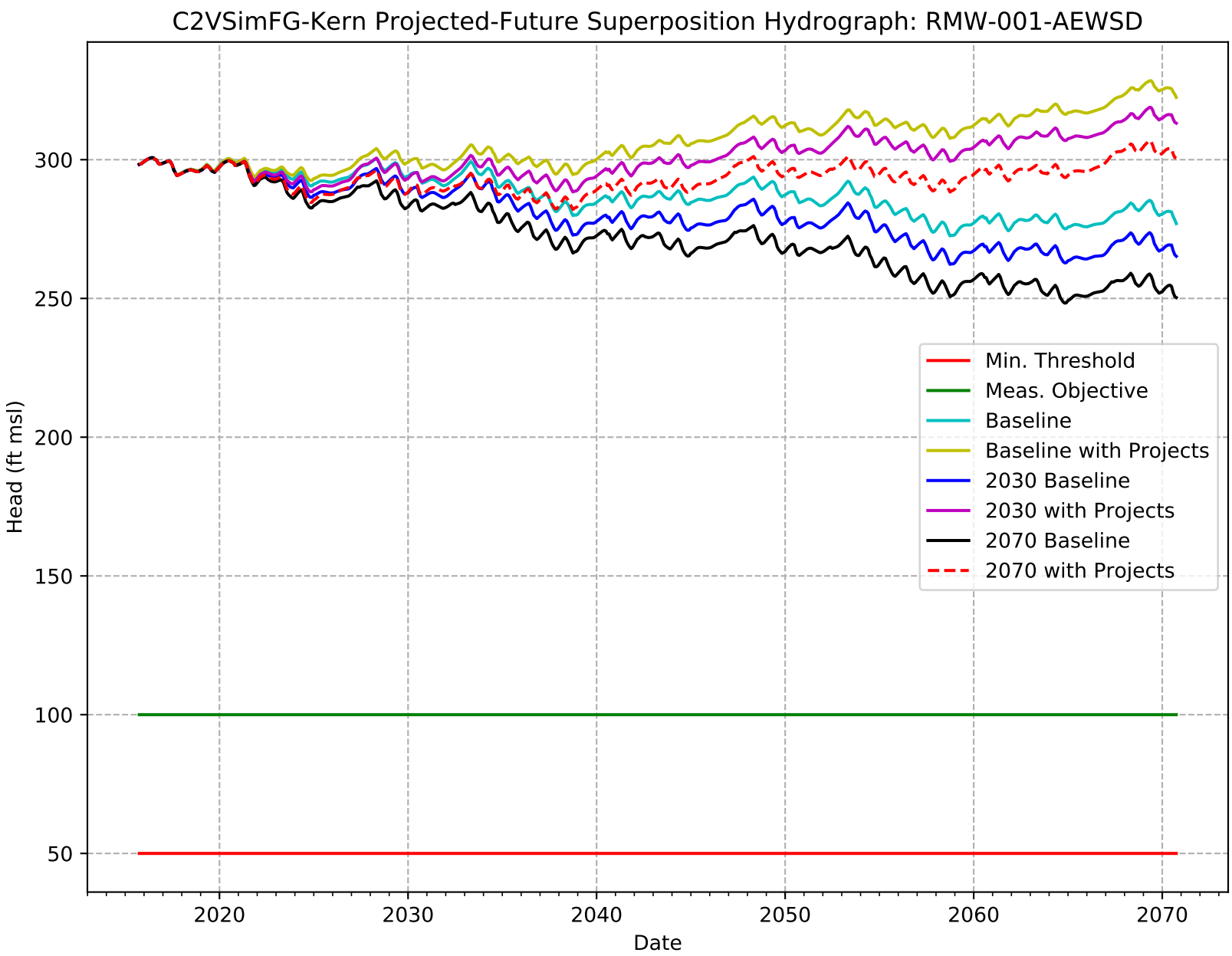
Kcorc - horizontal hydraulic conductivity of Corcoran Clay aquitard or equivalent
Cstm – streambed conductance of Kern River and Poso Creek
Ss – specific storage of aquifer

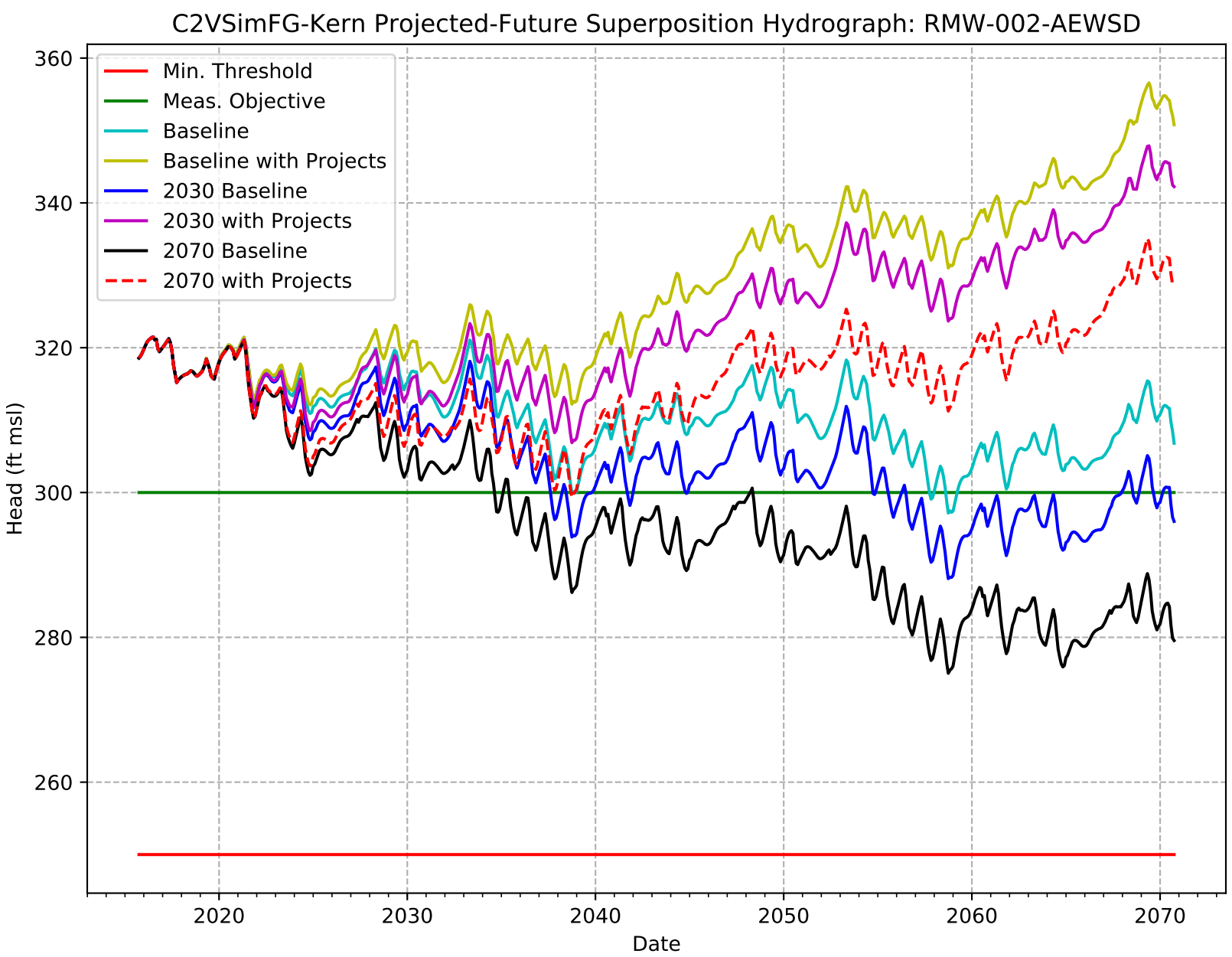
Sy – specific yield of aquifer
Ksoil –soil hydraulic conductivity in root zone
Λ –soil pore size distribution index in root zone

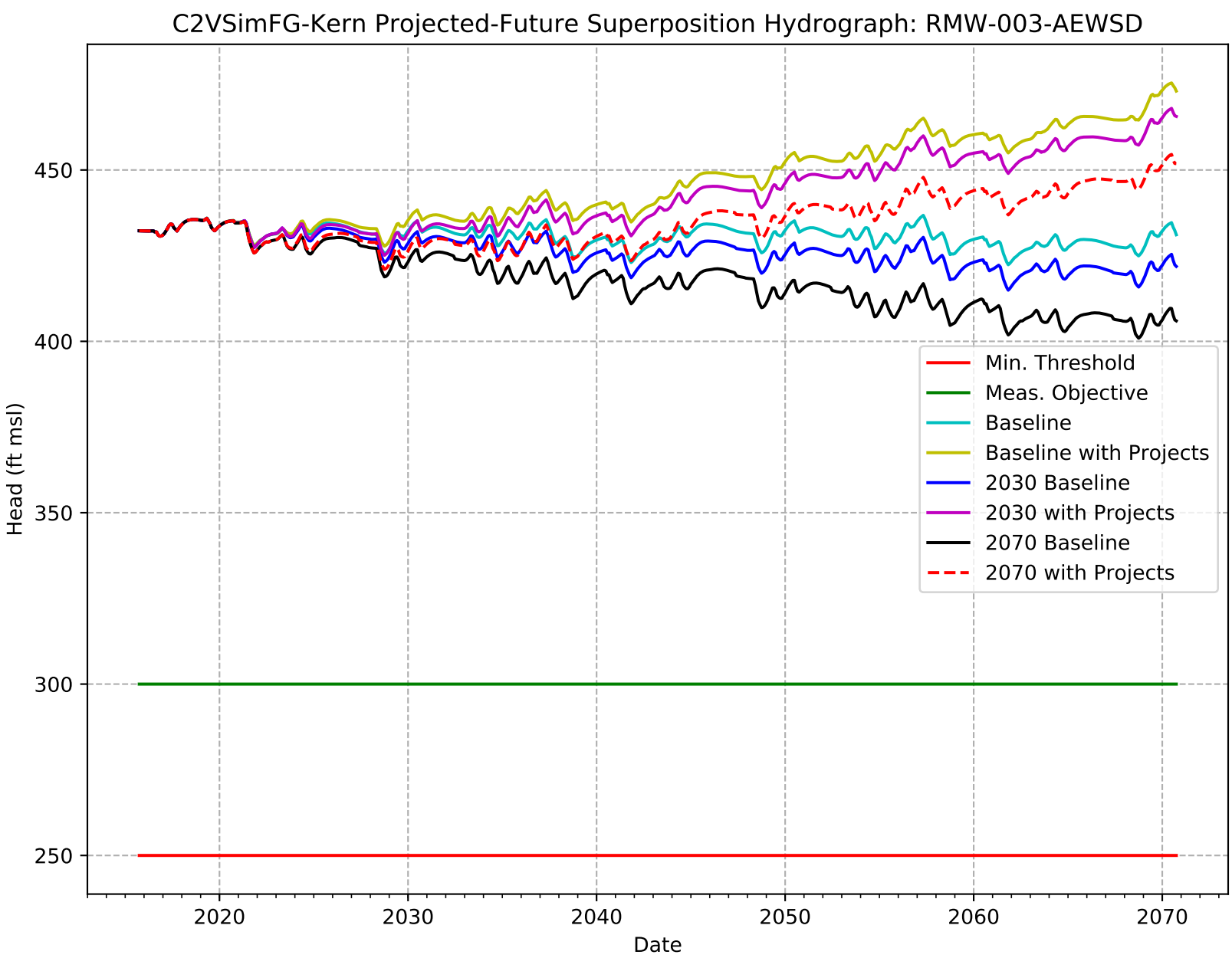
December 2019	Figure 23 C2VSimFG-Kern Sensitivity Analysis Results
TODD GROUNDWATER	

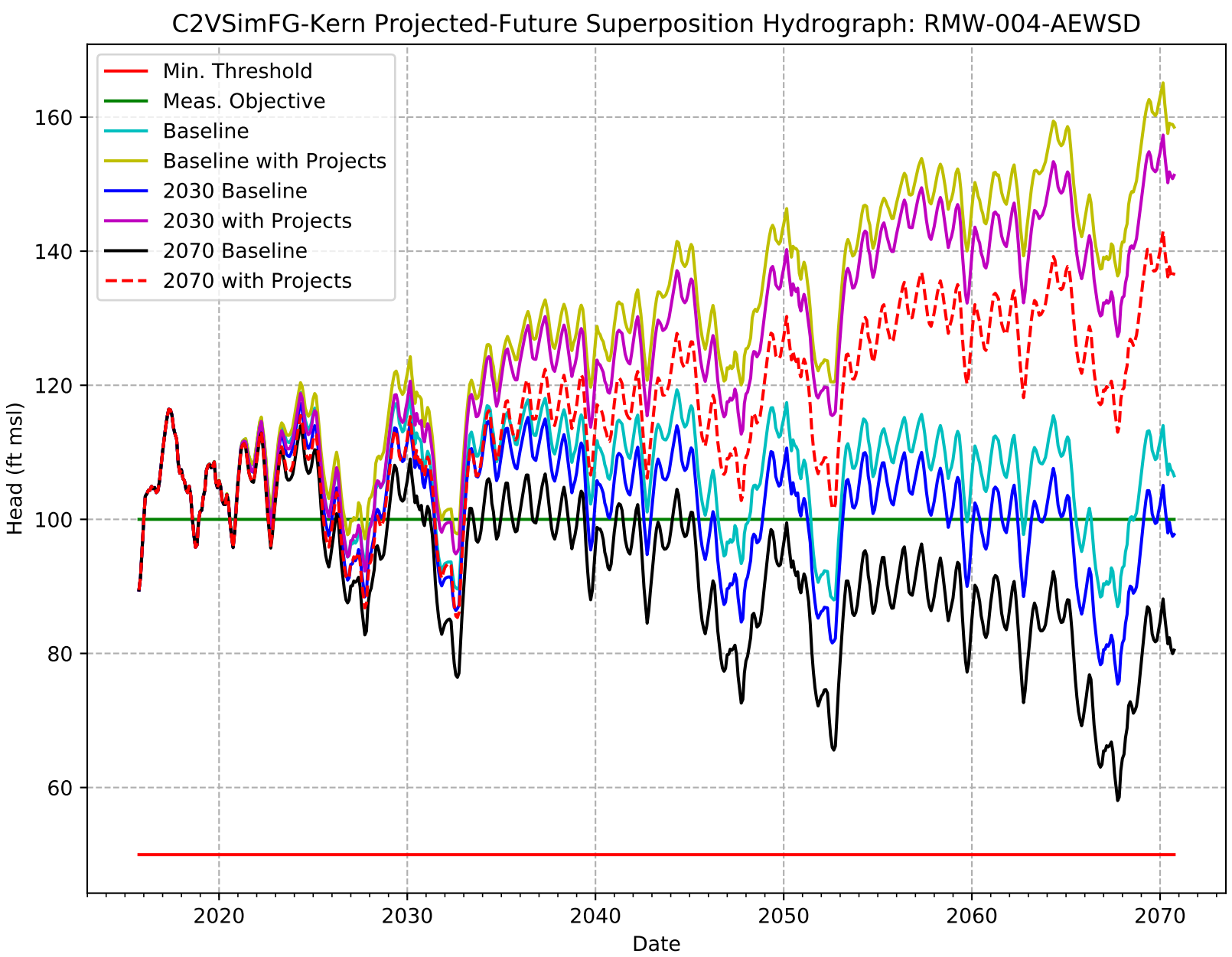
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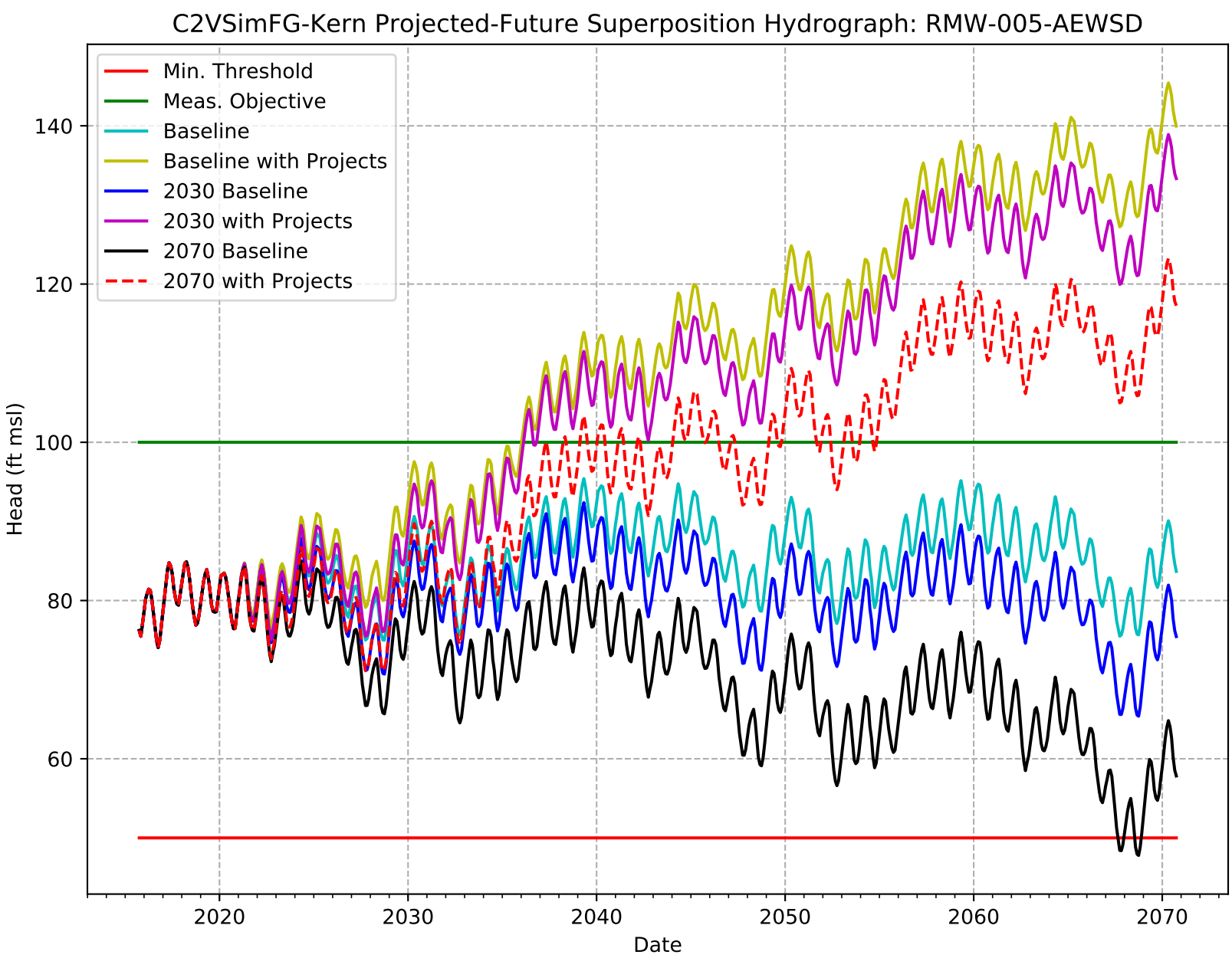
C2VSimFG-Kern Hydrographs at Regional Monitoring Wells in Kern County Subbasin for Projected Future Water Budget Simulations

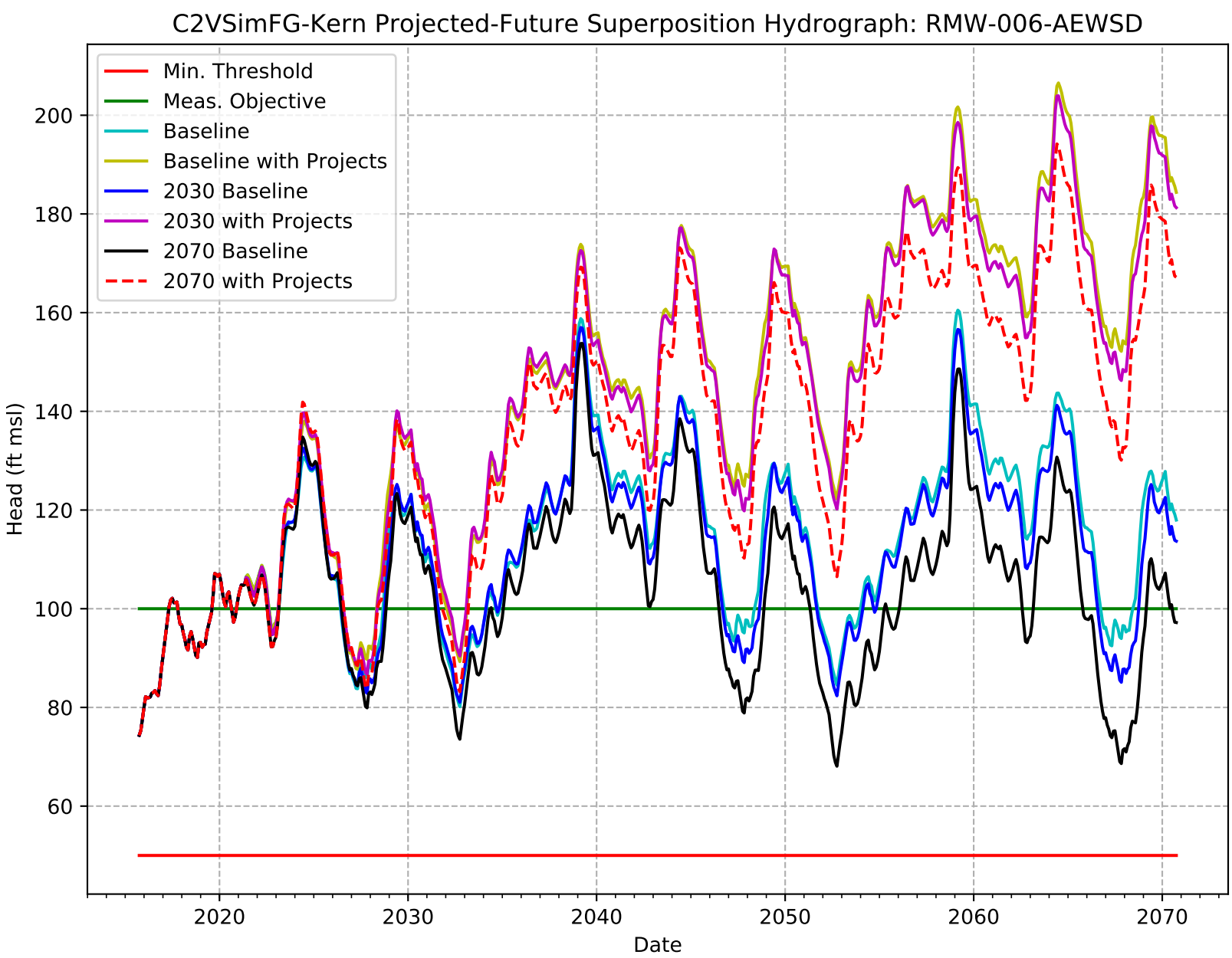

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-001-AEWSD
Head (ft msl)
300
250
200
150
100
50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

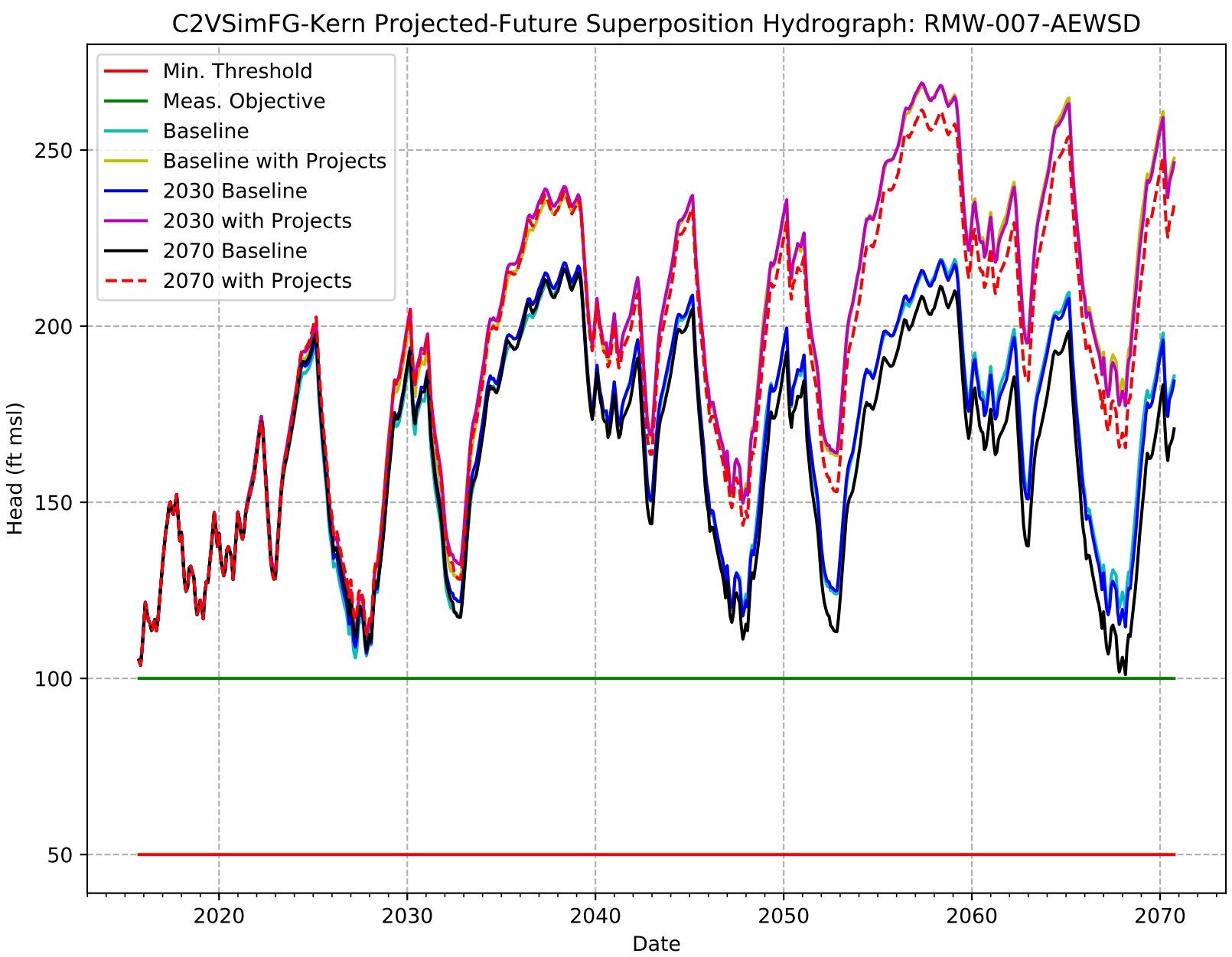

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-002-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
360
340
320
300
280
260
2020
2030
2040
2050
2060
2070
Date

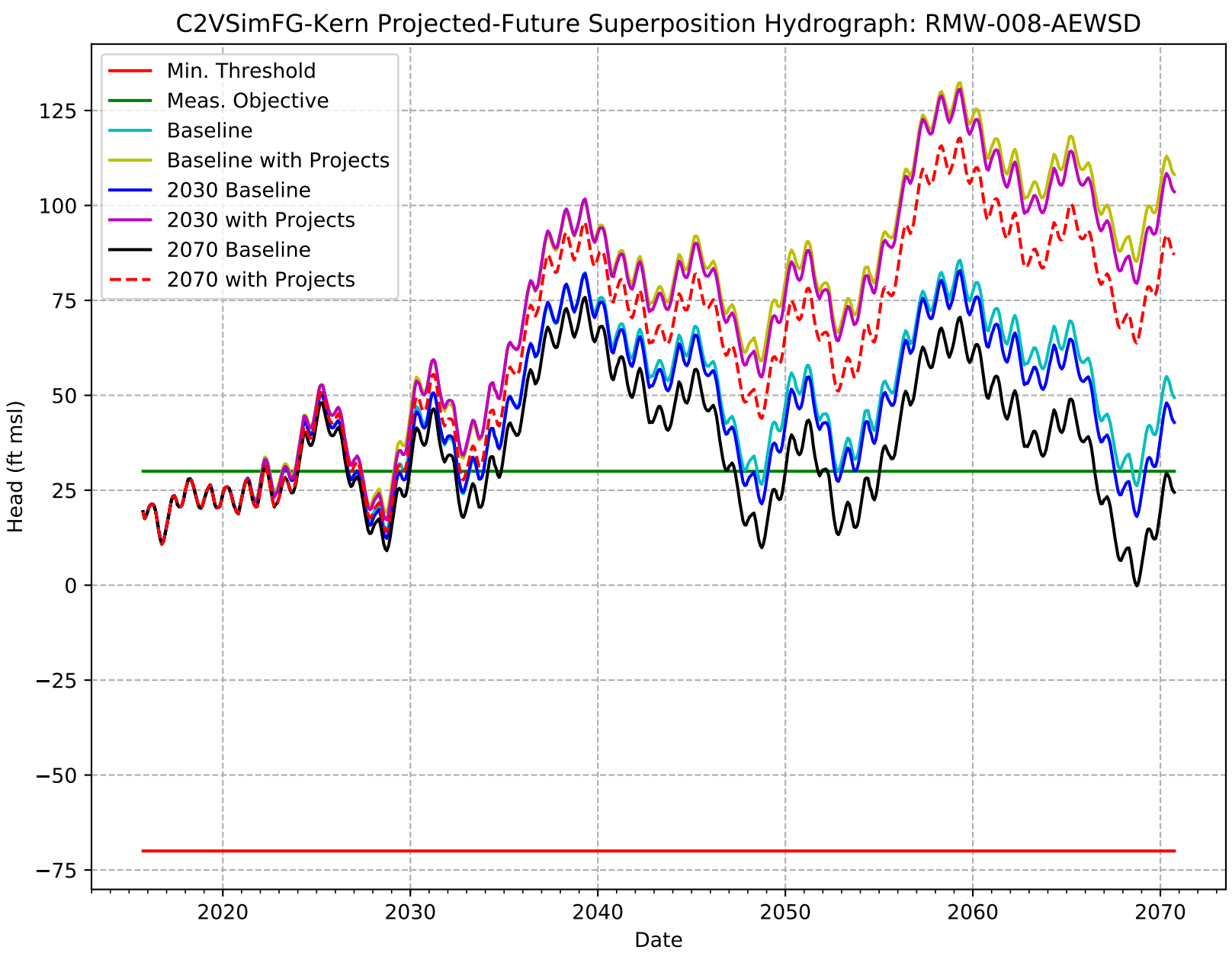

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-003-AEWSD
Head (ft msl)
450
400
350
300
250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

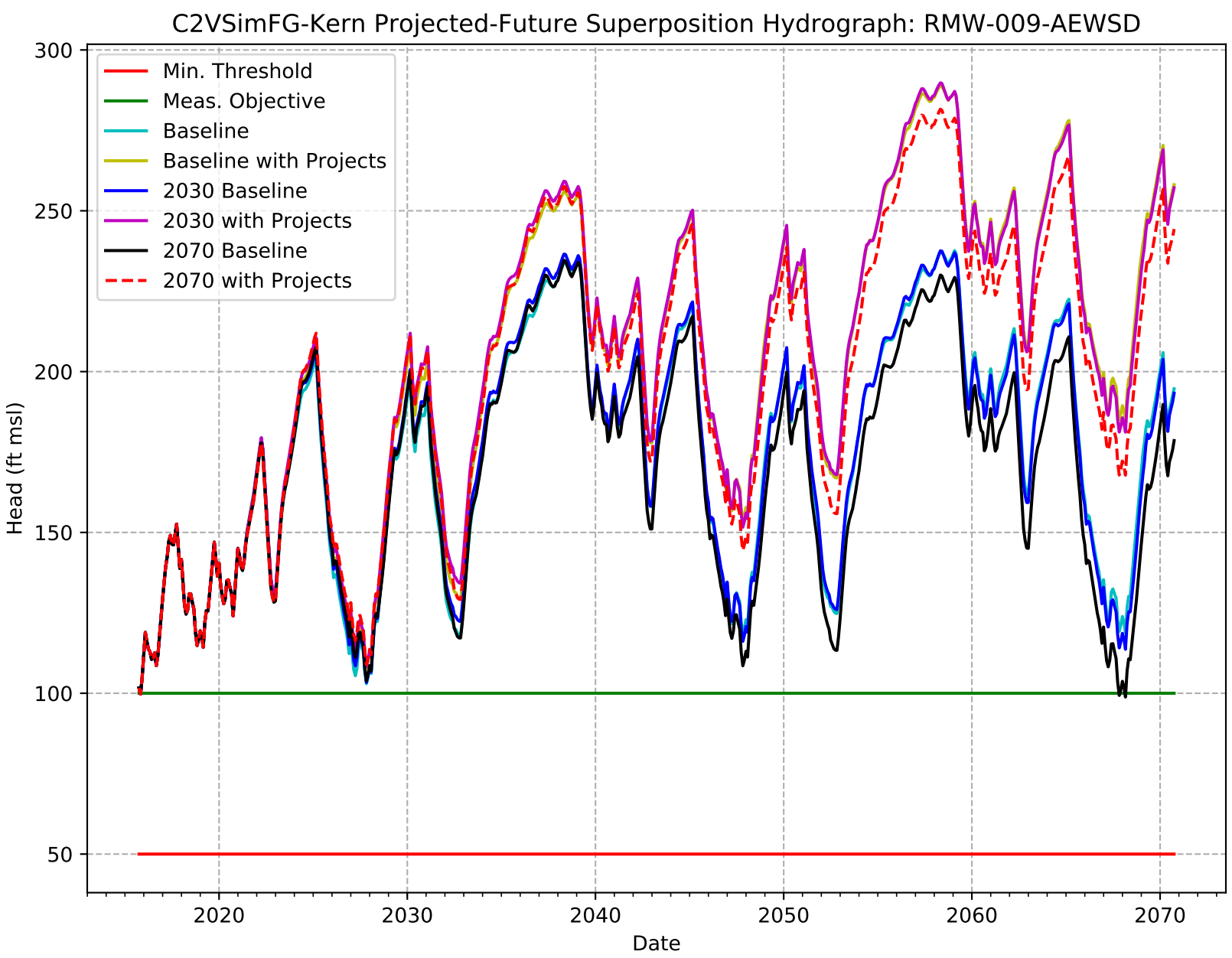

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-004-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

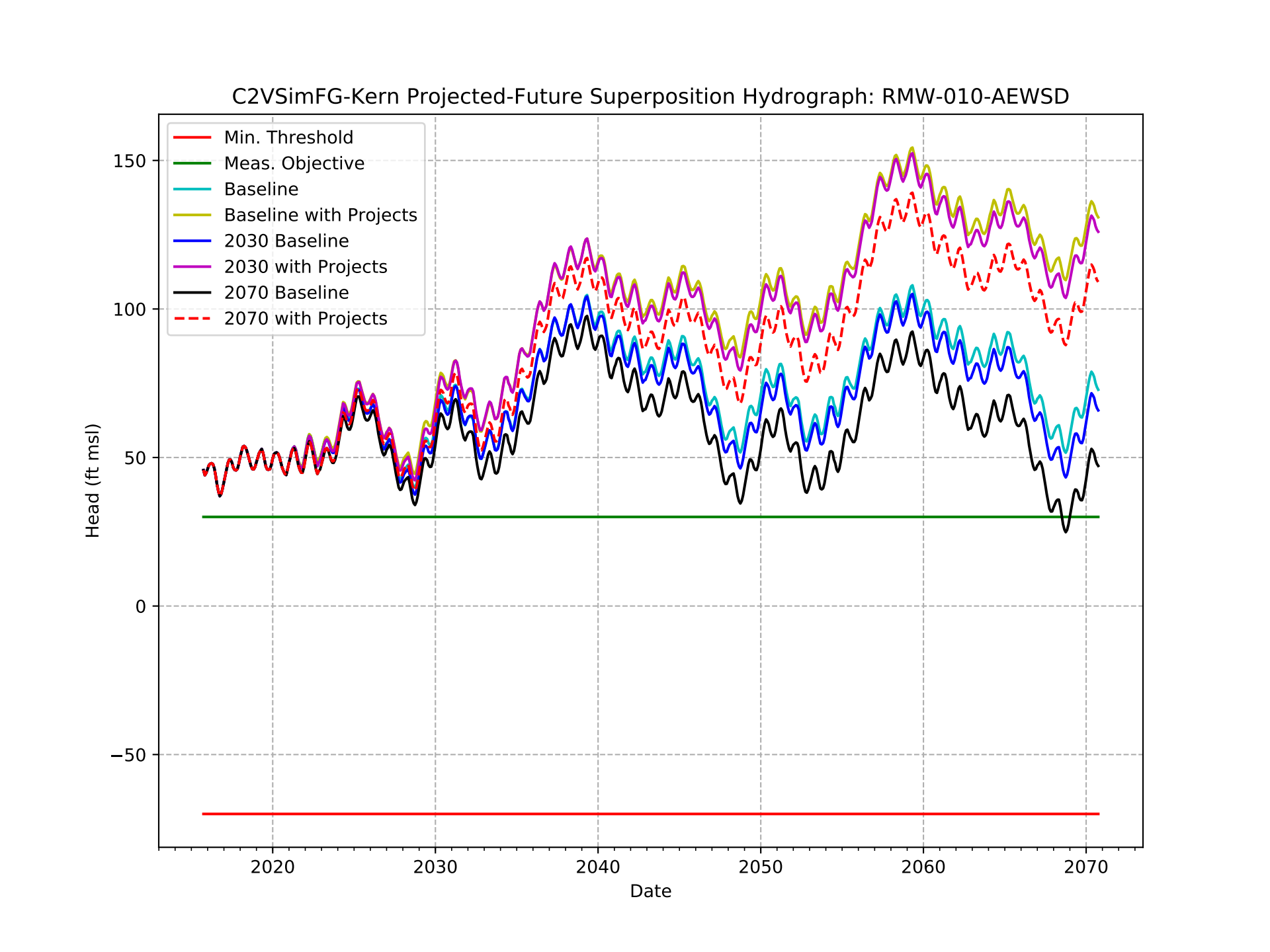

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-005-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

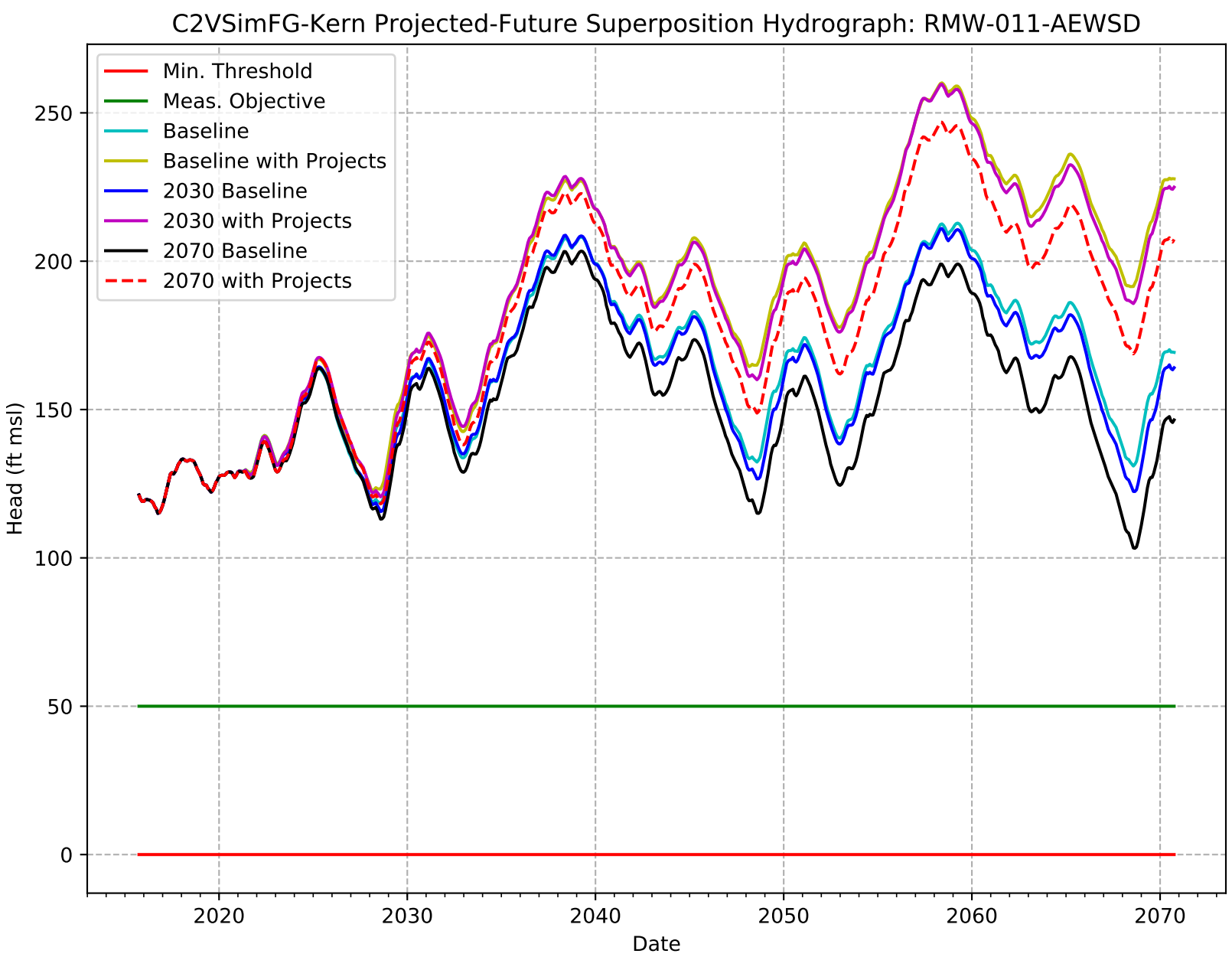

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-006-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

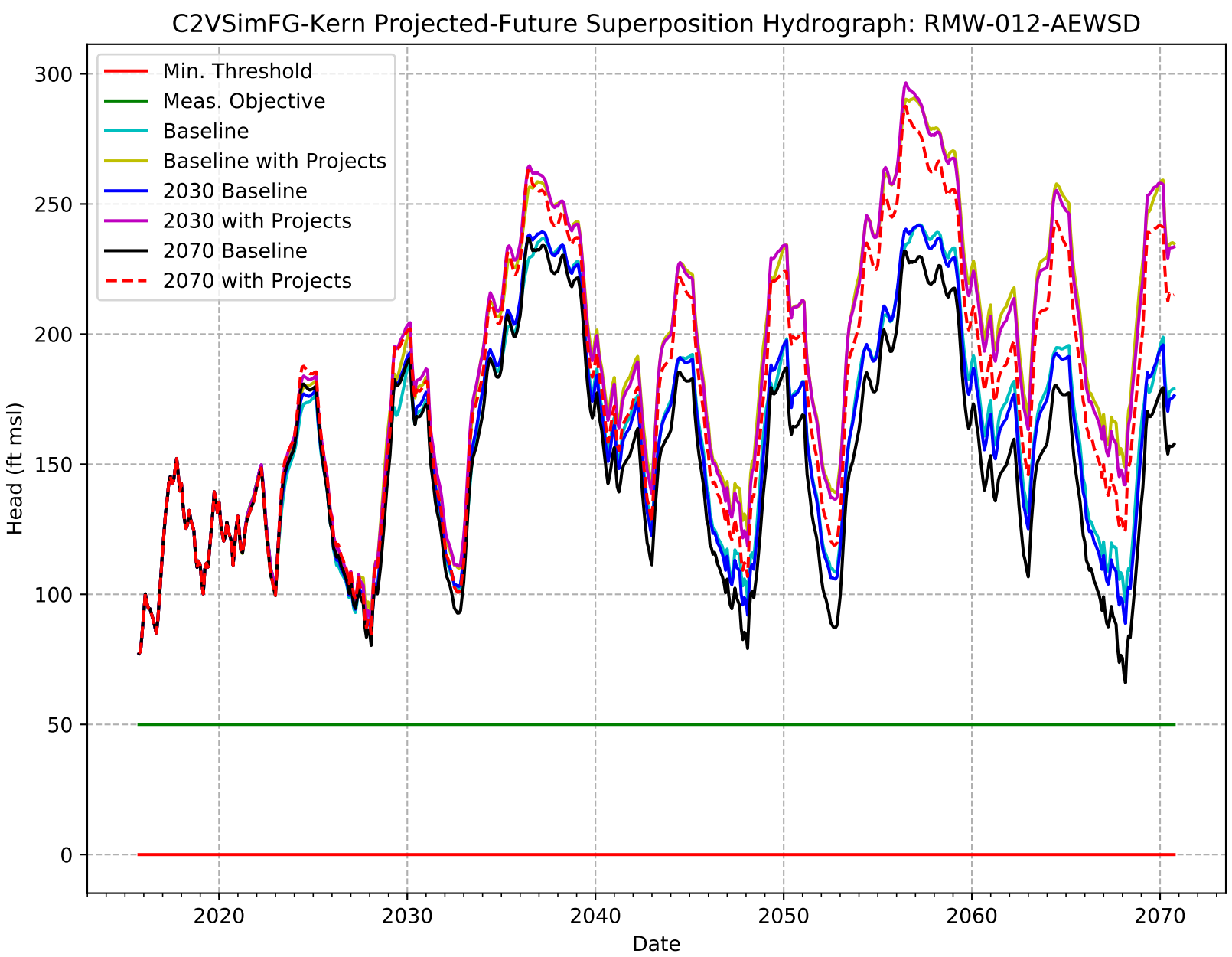

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-007-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
200
150
100
50
2020
2030
2040
2050
2060
2070
Date

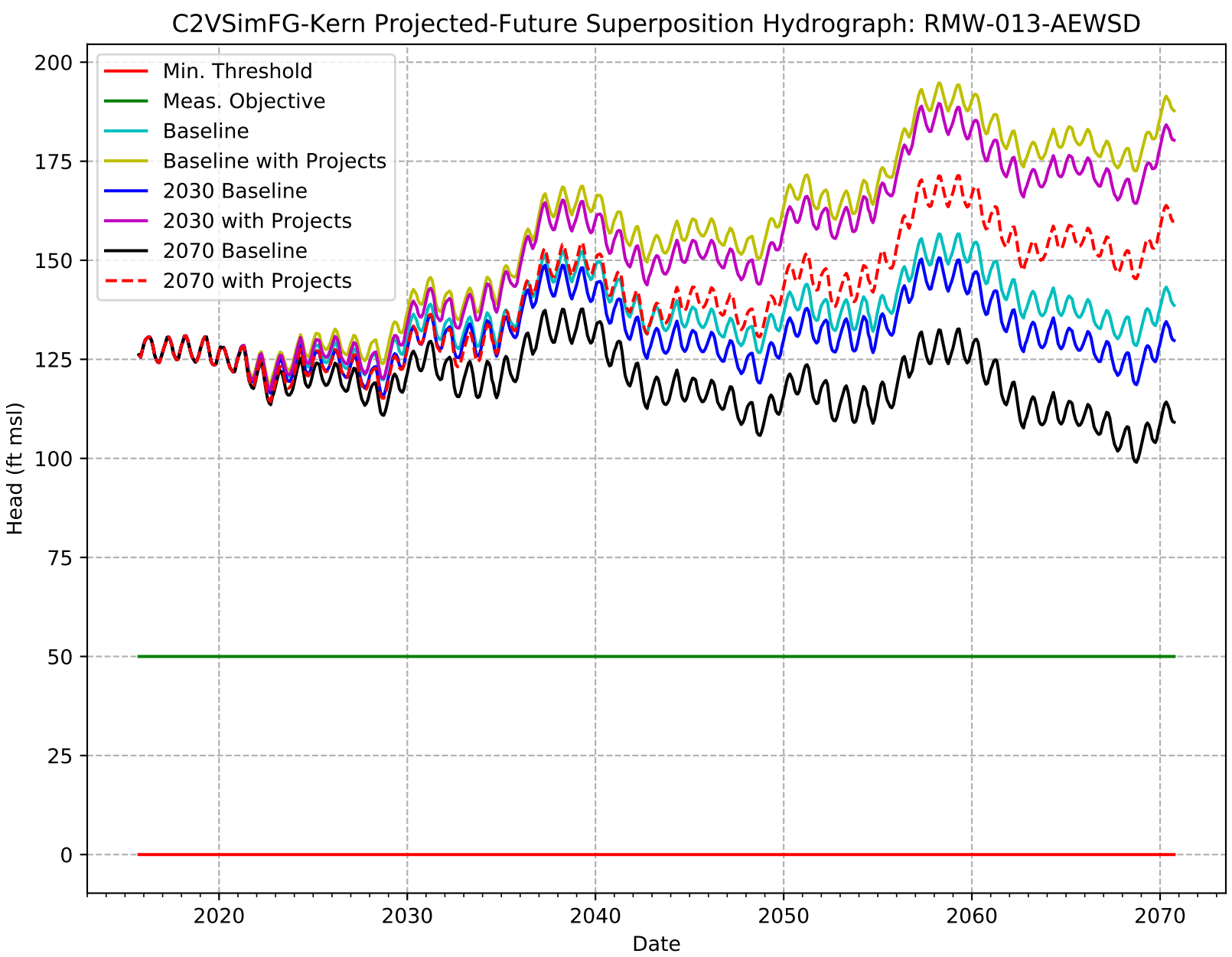

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-008-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
125
100
75
50
25
0
−25
−50
−75
2020
2030
2040
2050
2060
2070
Date

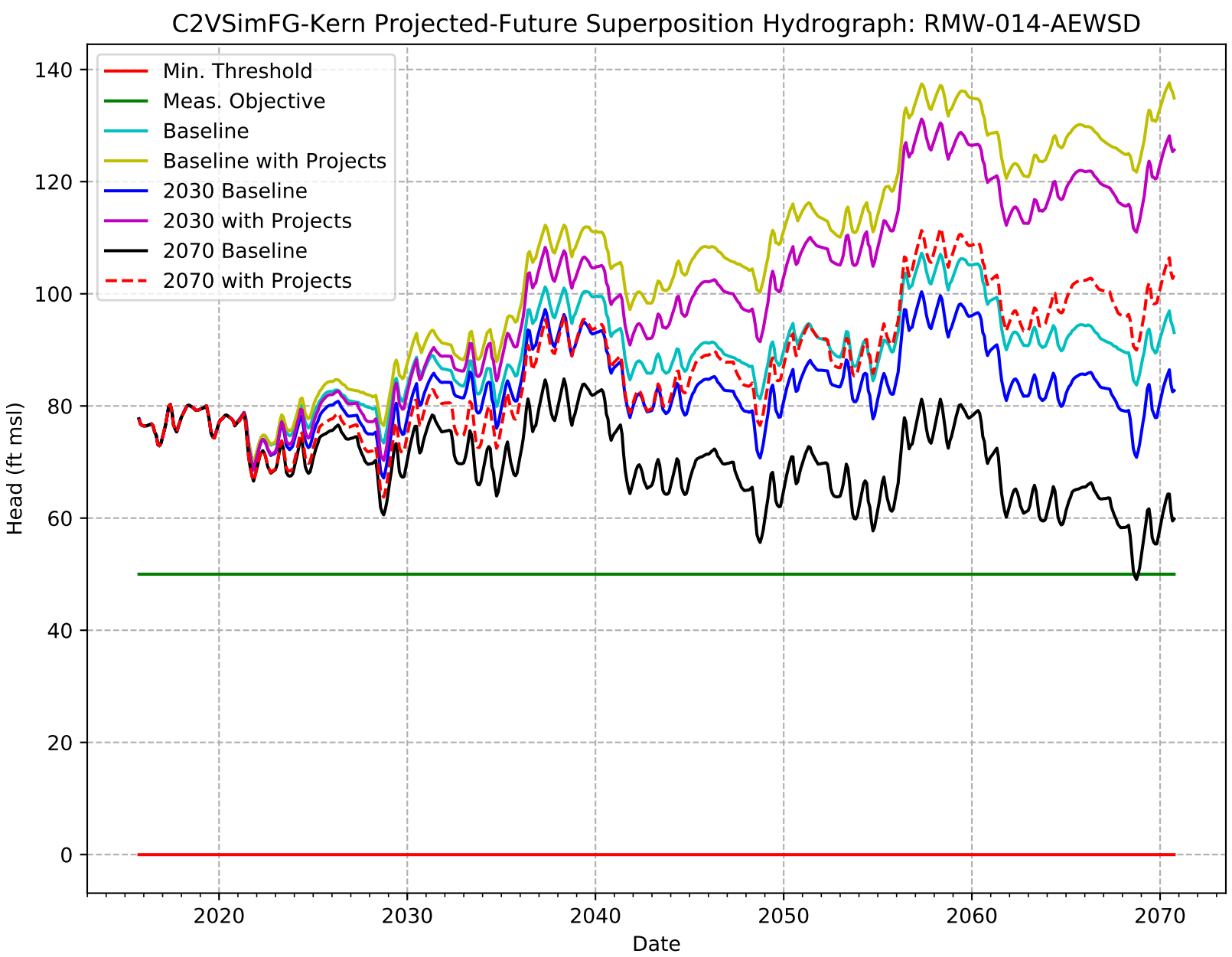

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-009-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
300
250
200
150
100
50
2020
2030
2040
2050
2060
2070
Date

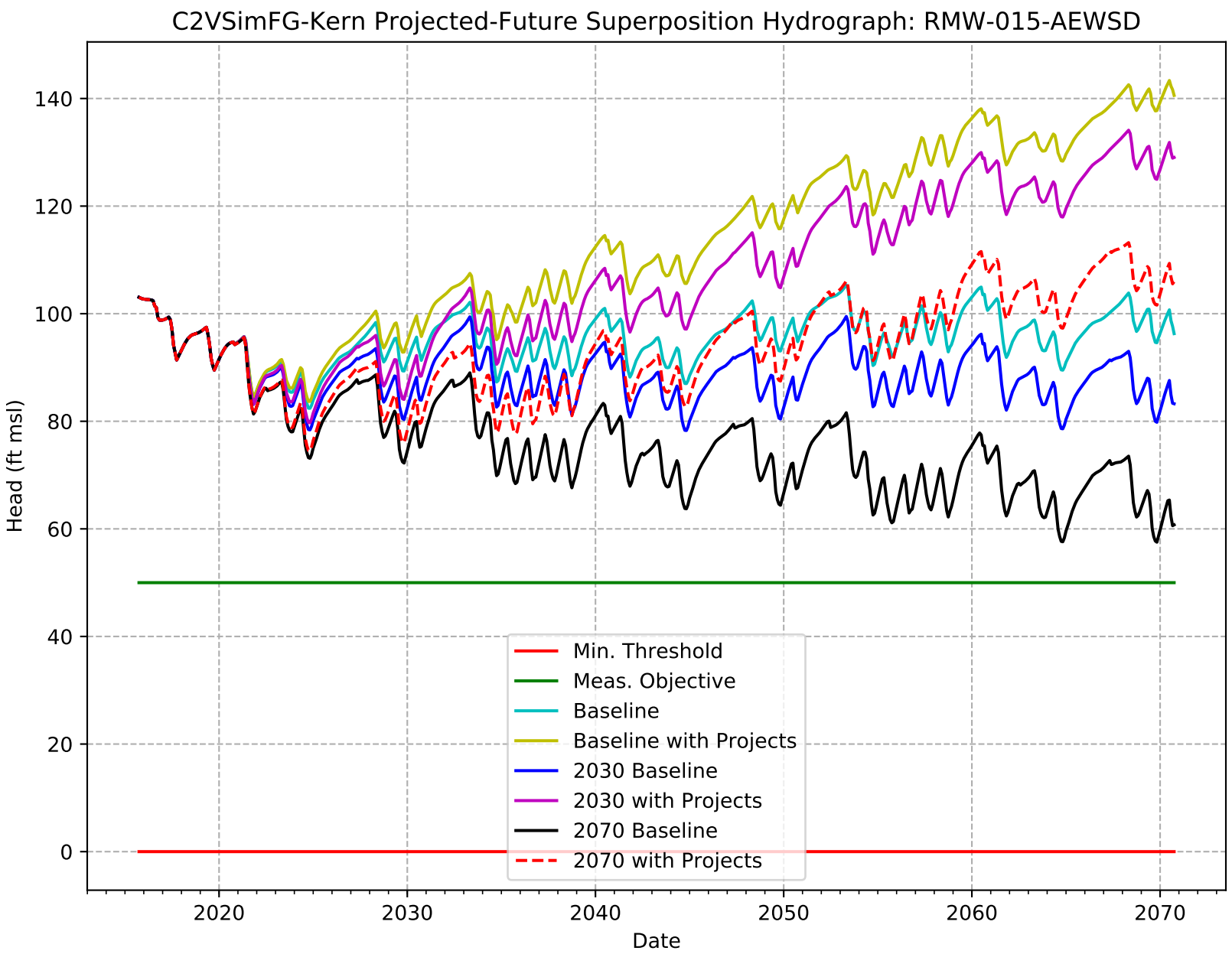

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-010-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
150
100
50
0
−50
Head (ft msl)
2020
2030
2040
2050
2060
2070
Date

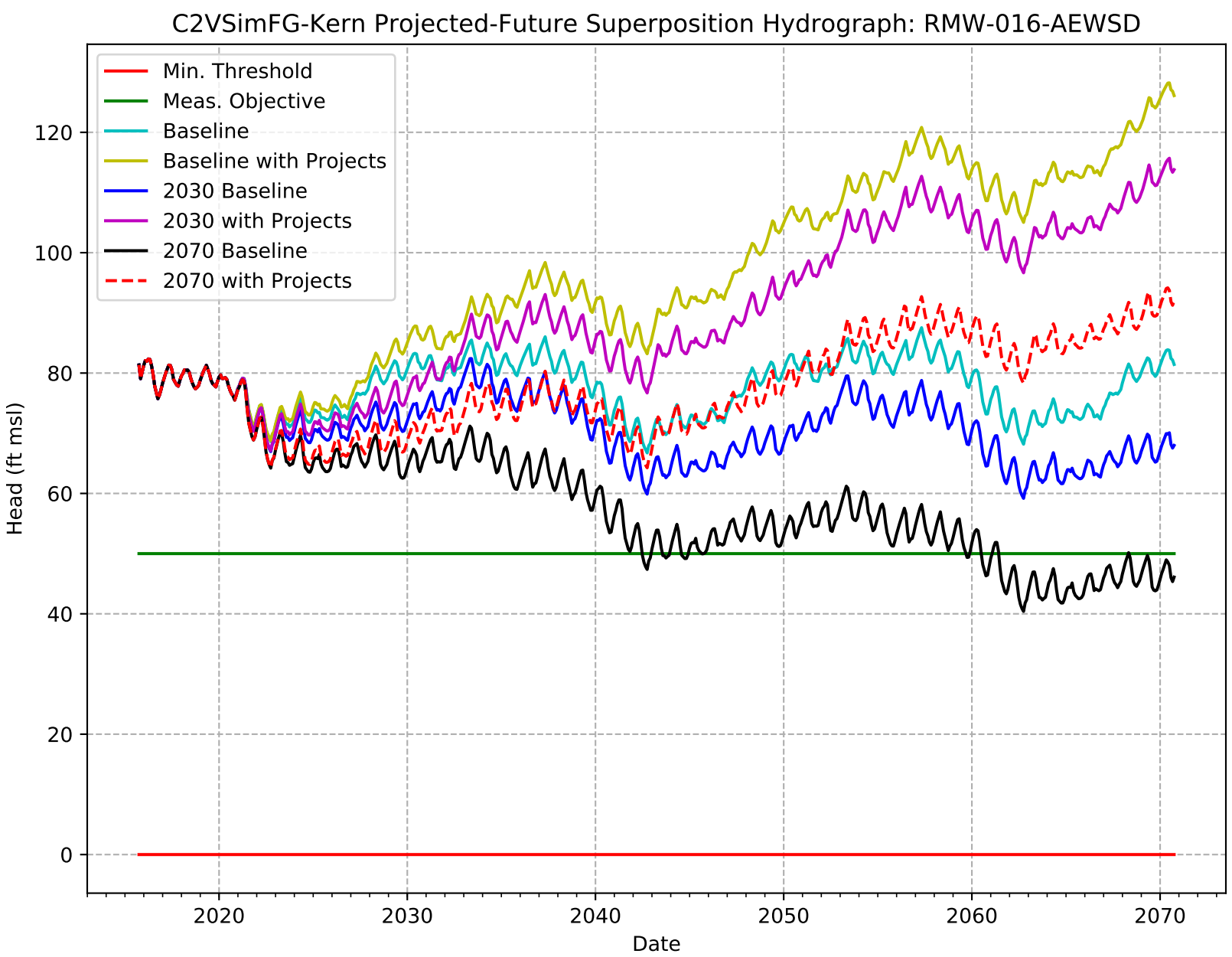

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-011-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date

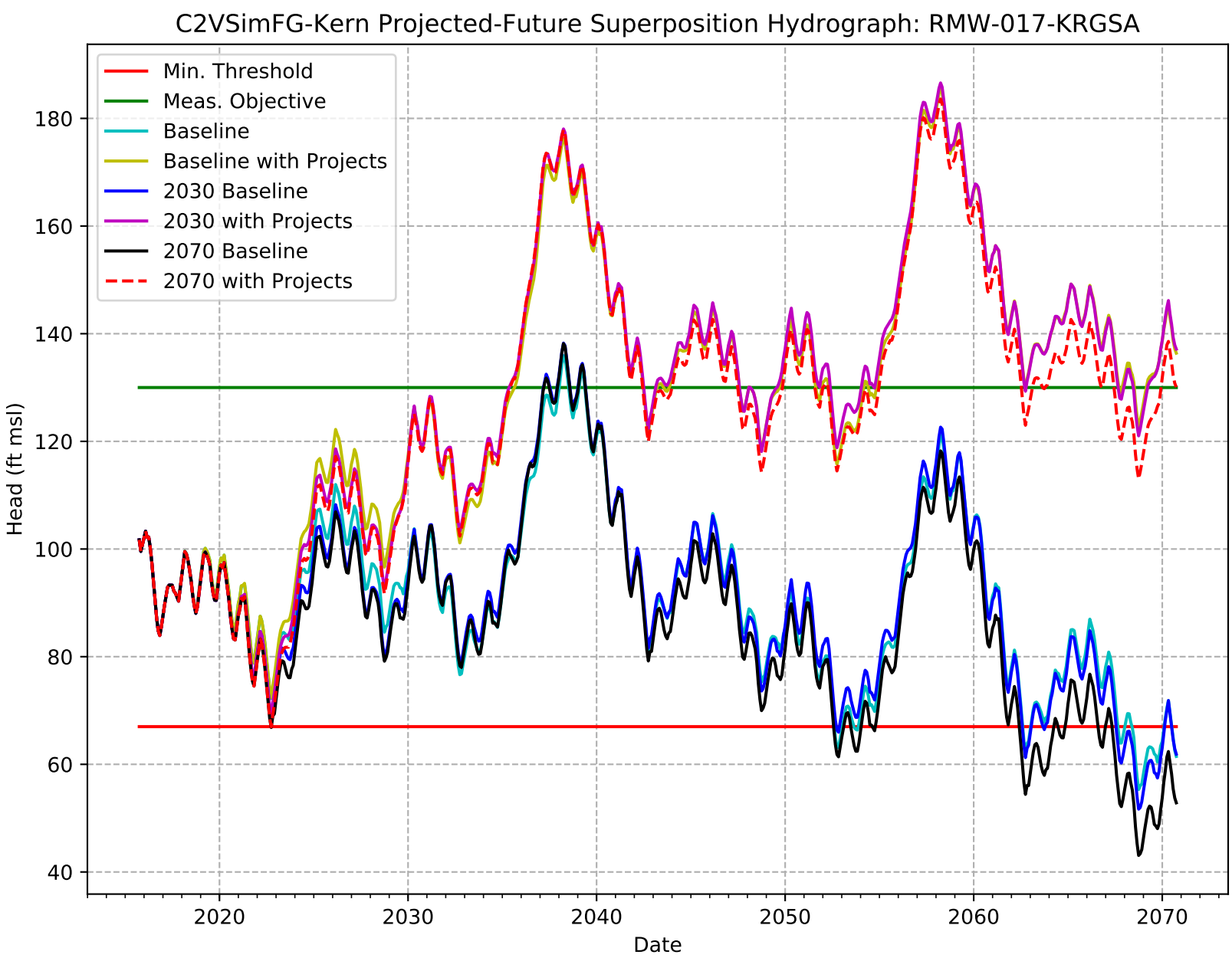

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-012-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
300
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date

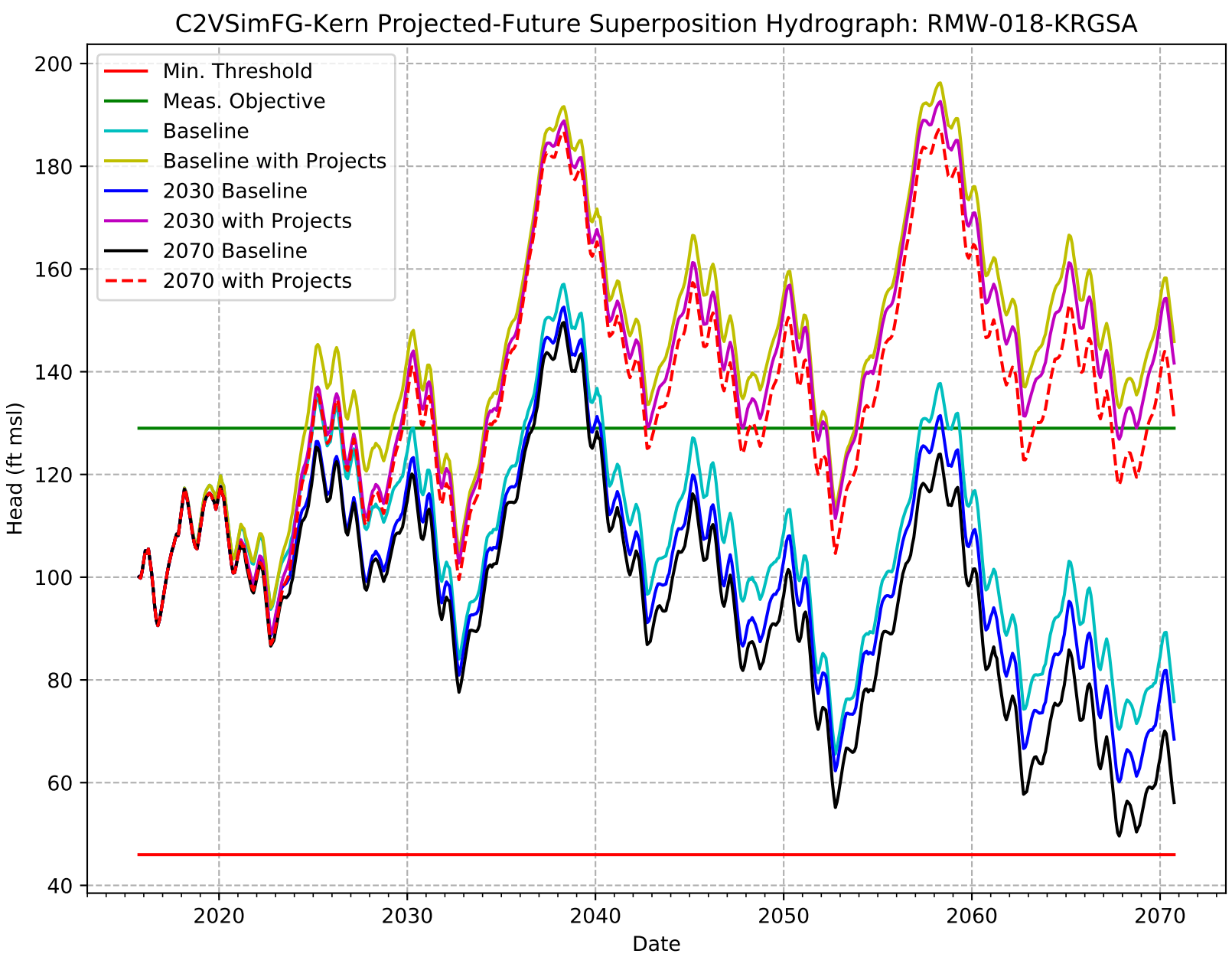

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-013-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
175
150
125
100
75
50
25
0
2020
2030
2040
2050
2060
2070
Date

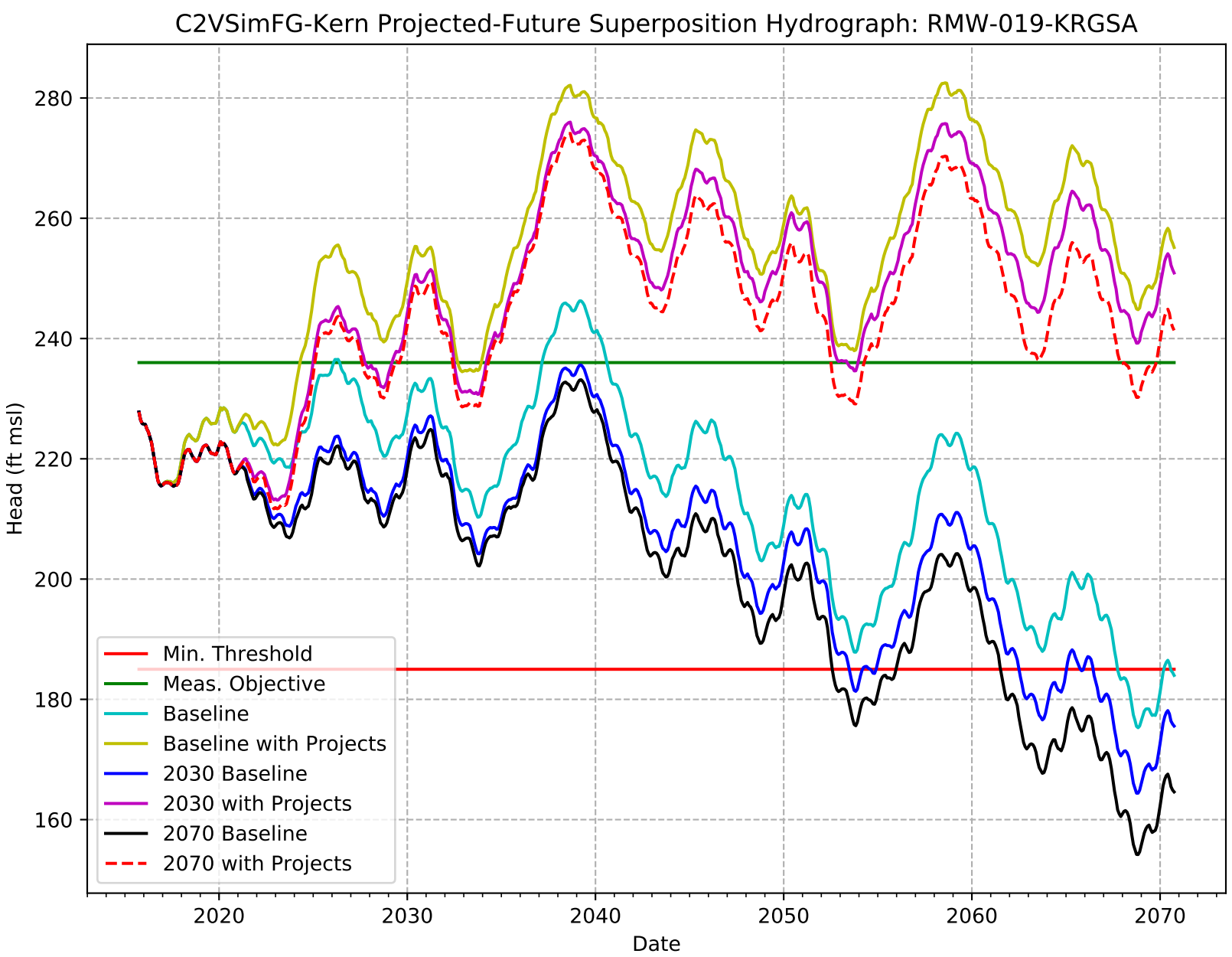

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-014-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
140
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

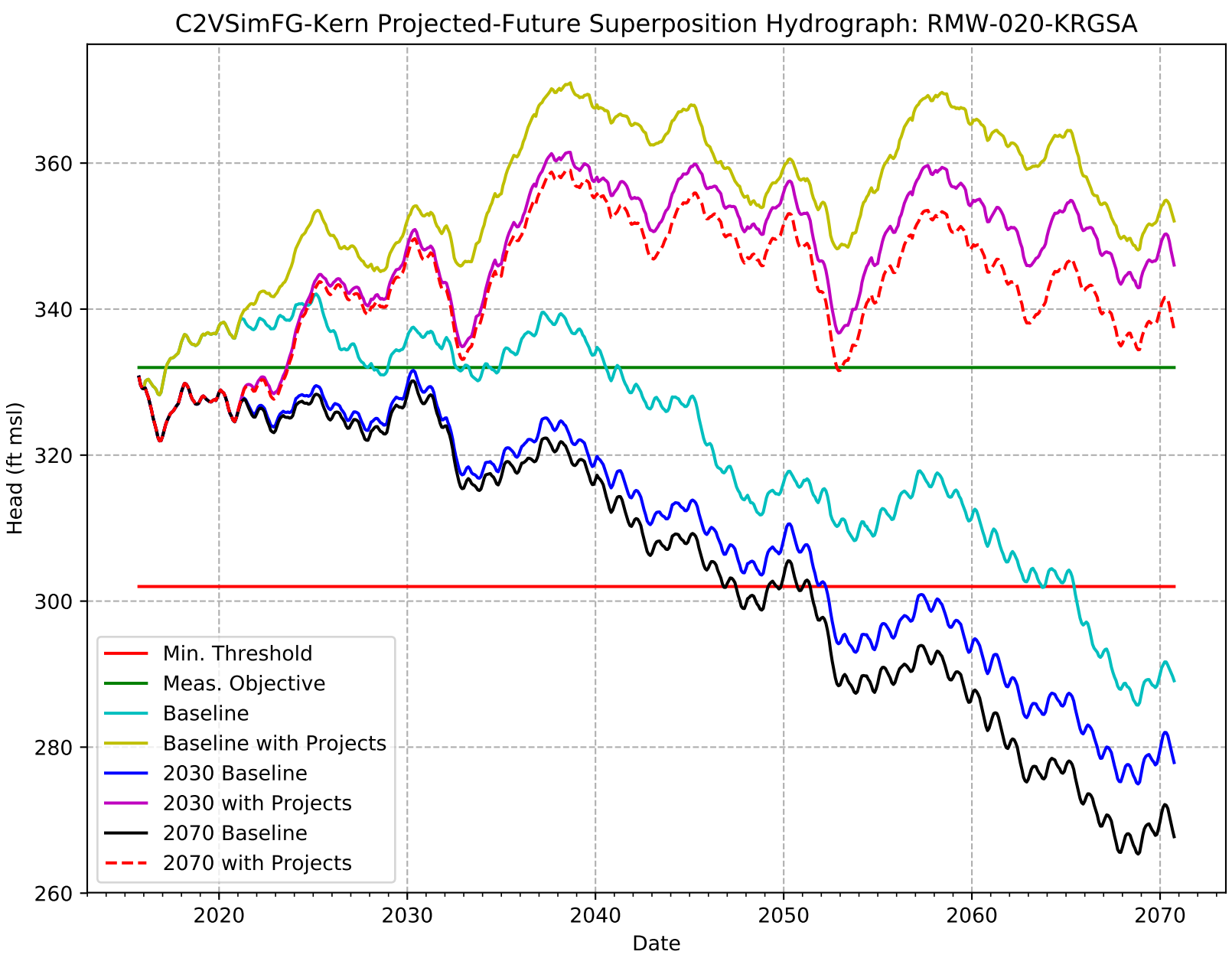

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-015-AEWSD
Head (ft msl)
Date
0
20
40
60
80
100
120
140
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

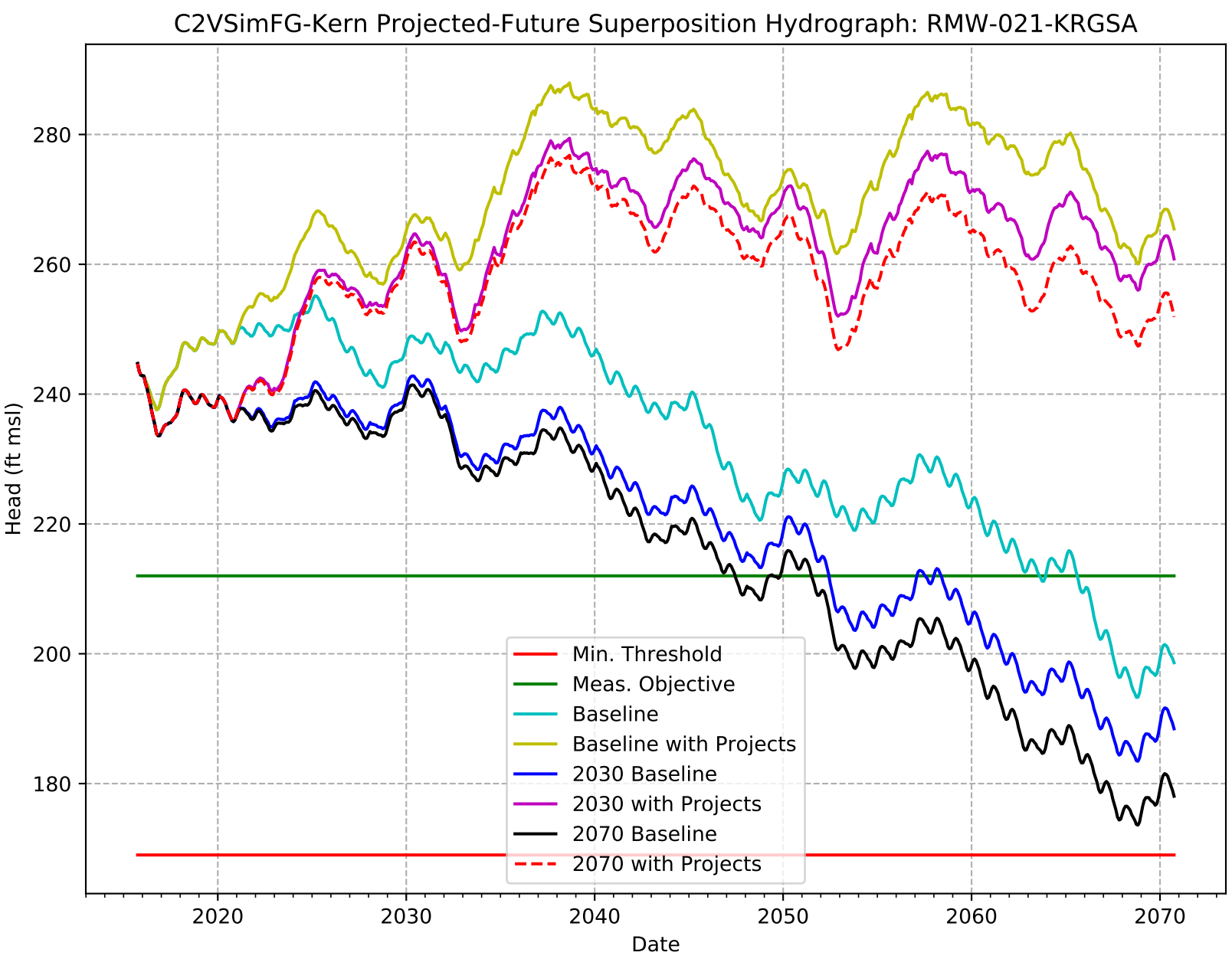

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-016-AEWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

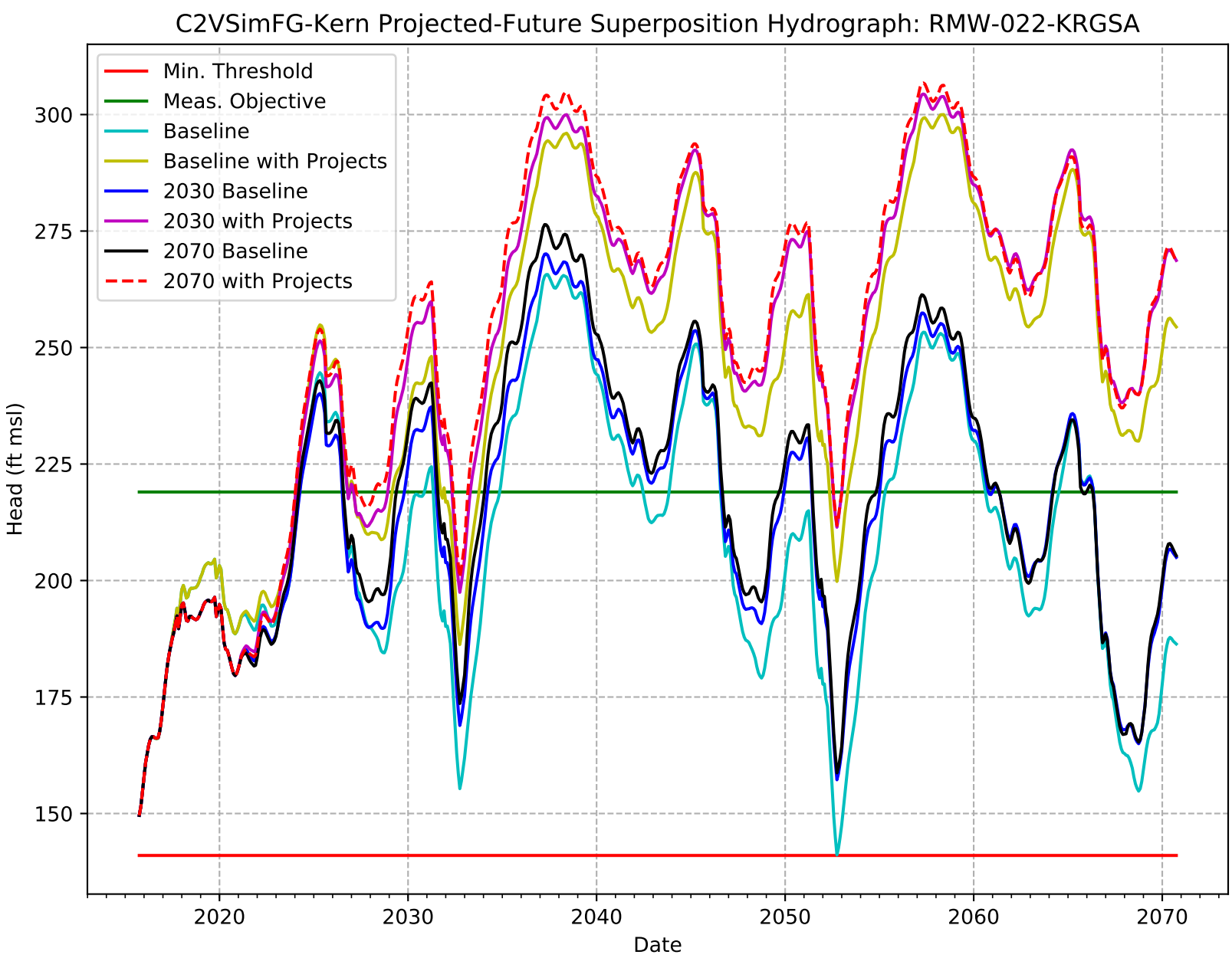

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-017-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date

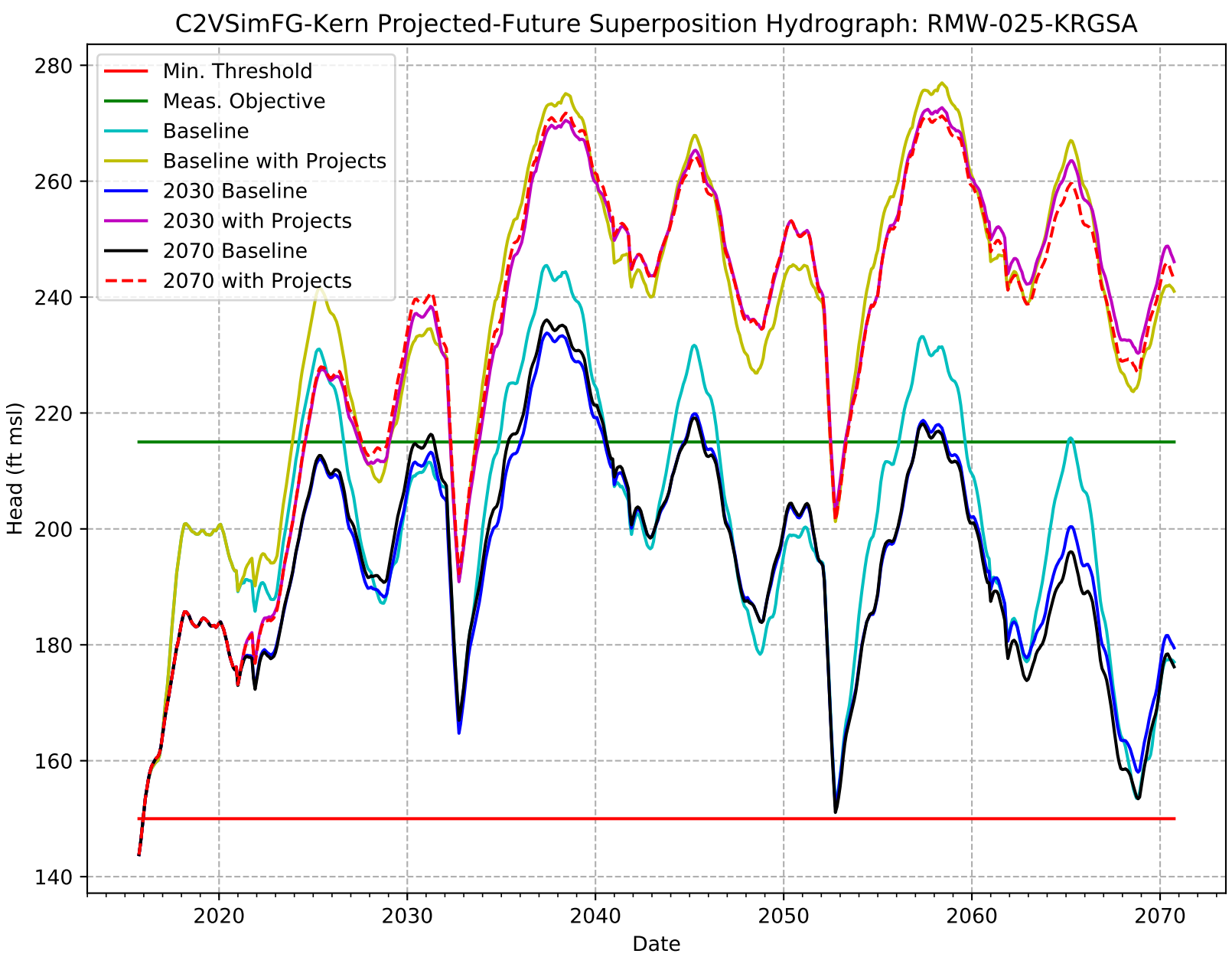

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-018-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date

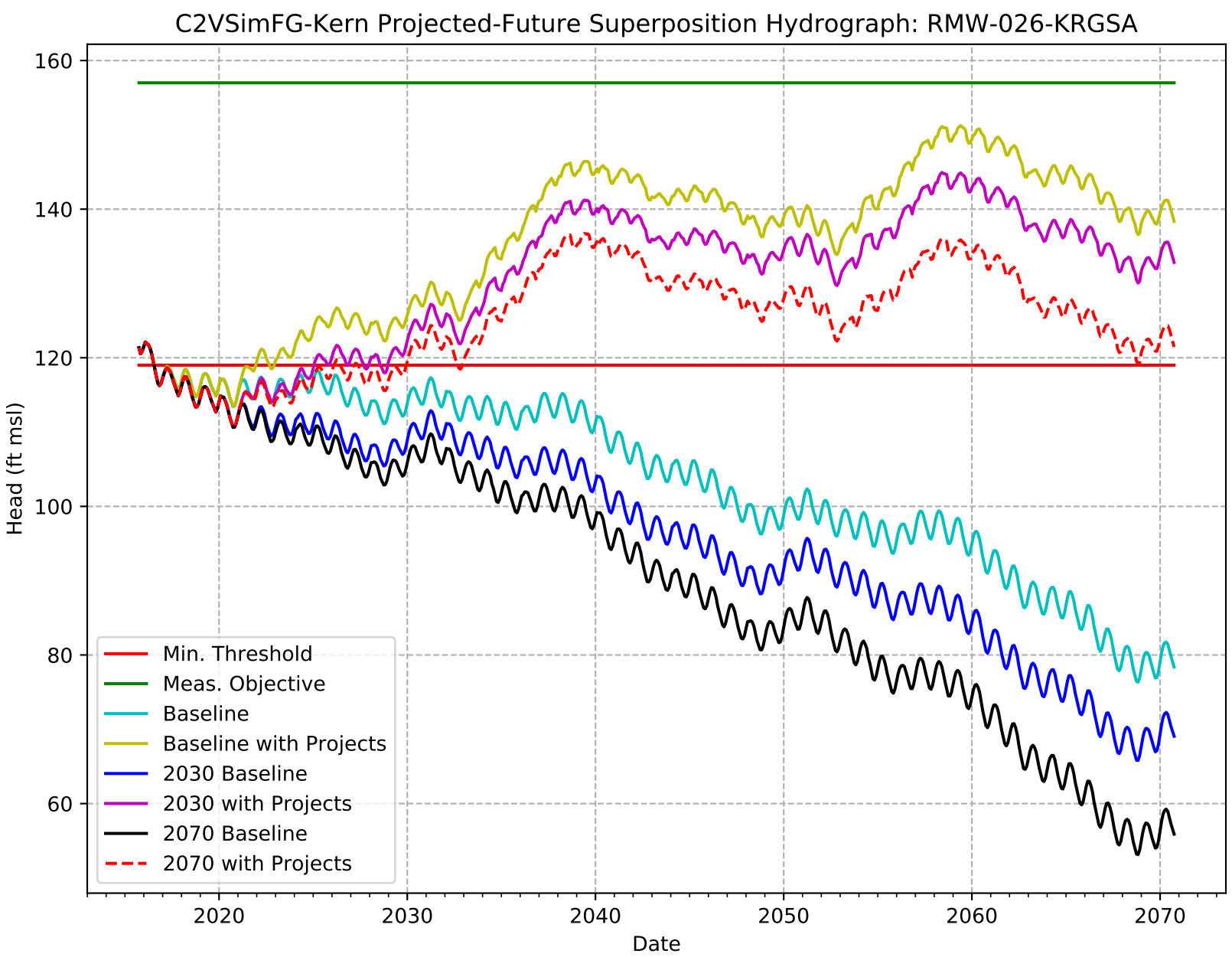

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-019-KRGSA
Head (ft msl)
280
260
240
220
200
180
160
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

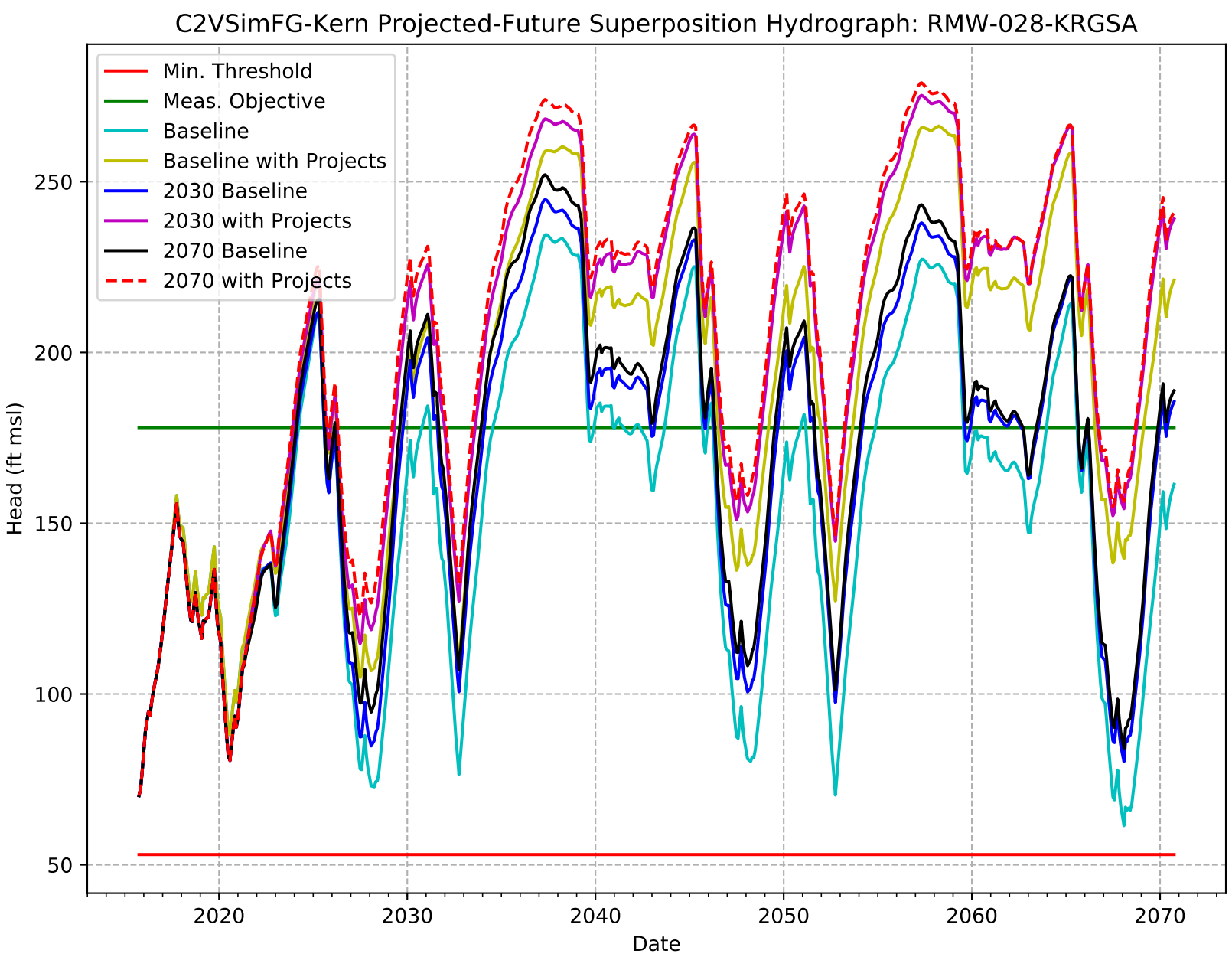

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-020-KRGSA
Head (ft msl)
360
340
320
300
280
260
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

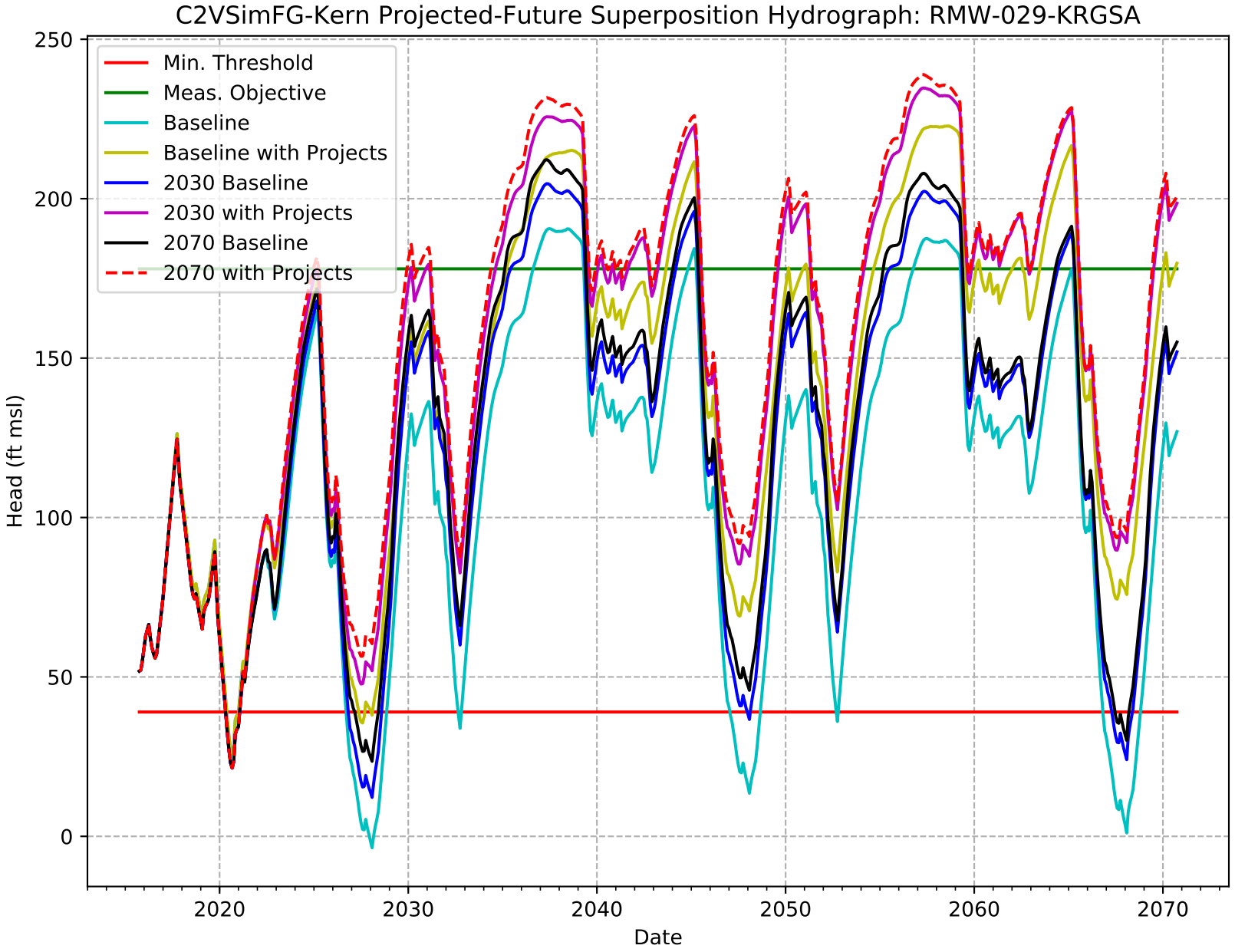

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-021-KRGSA
Head (ft msl)
280
260
240
220
200
180
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

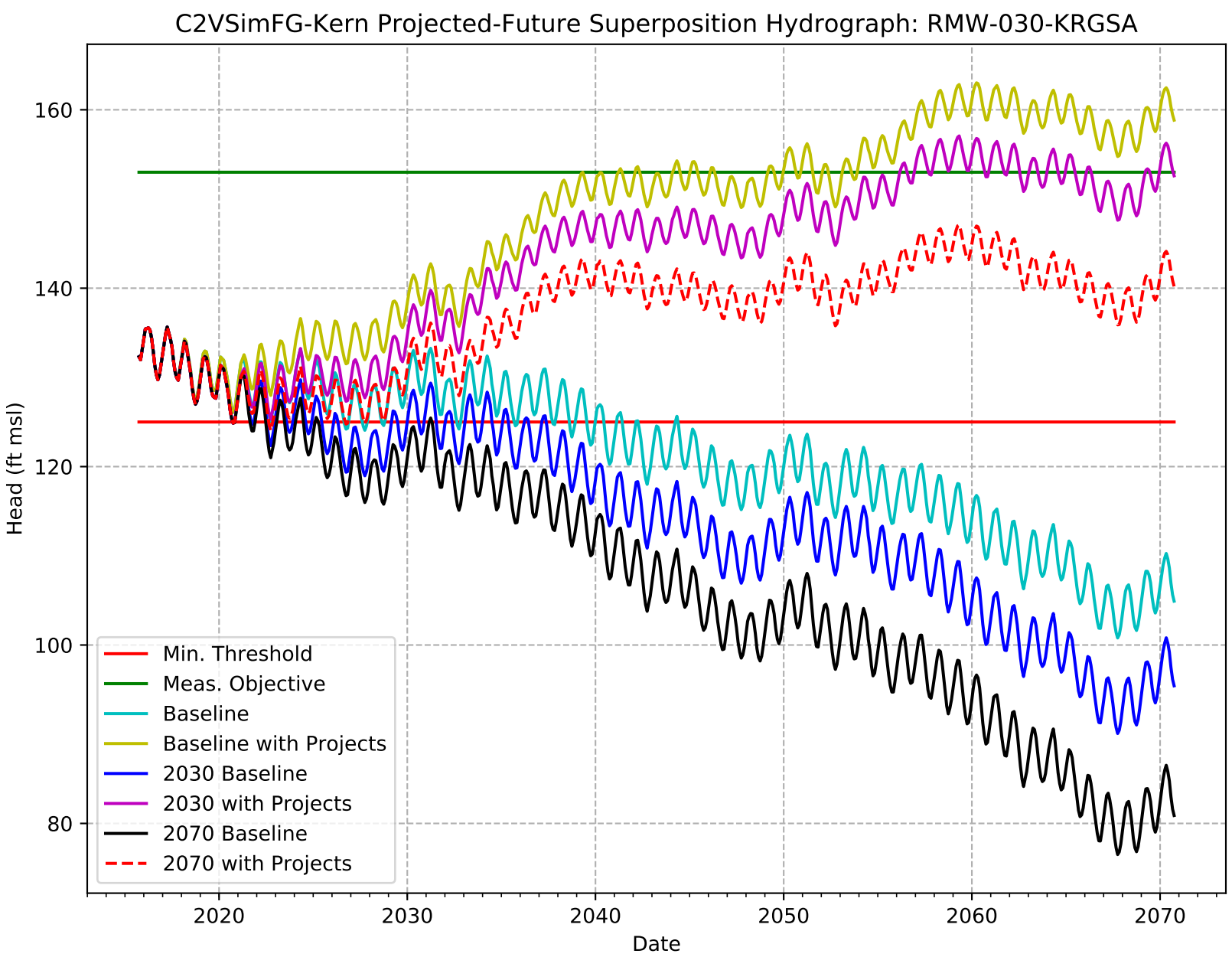

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-022-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
300
275
250
225
200
175
150
2020
2030
2040
2050
2060
2070
Date

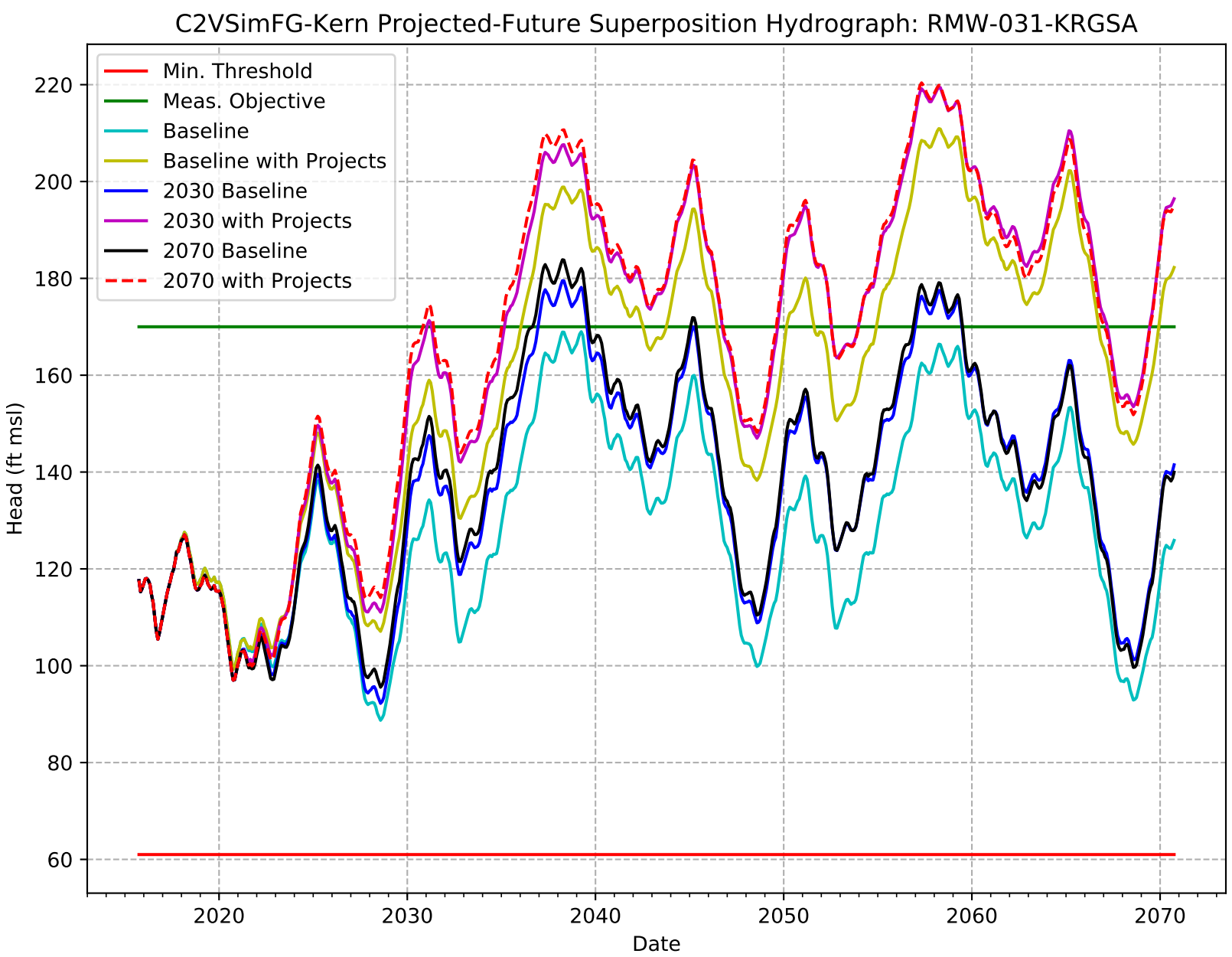

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-025-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
280
260
240
220
200
180
160
140
2020
2030
2040
2050
2060
2070
Date

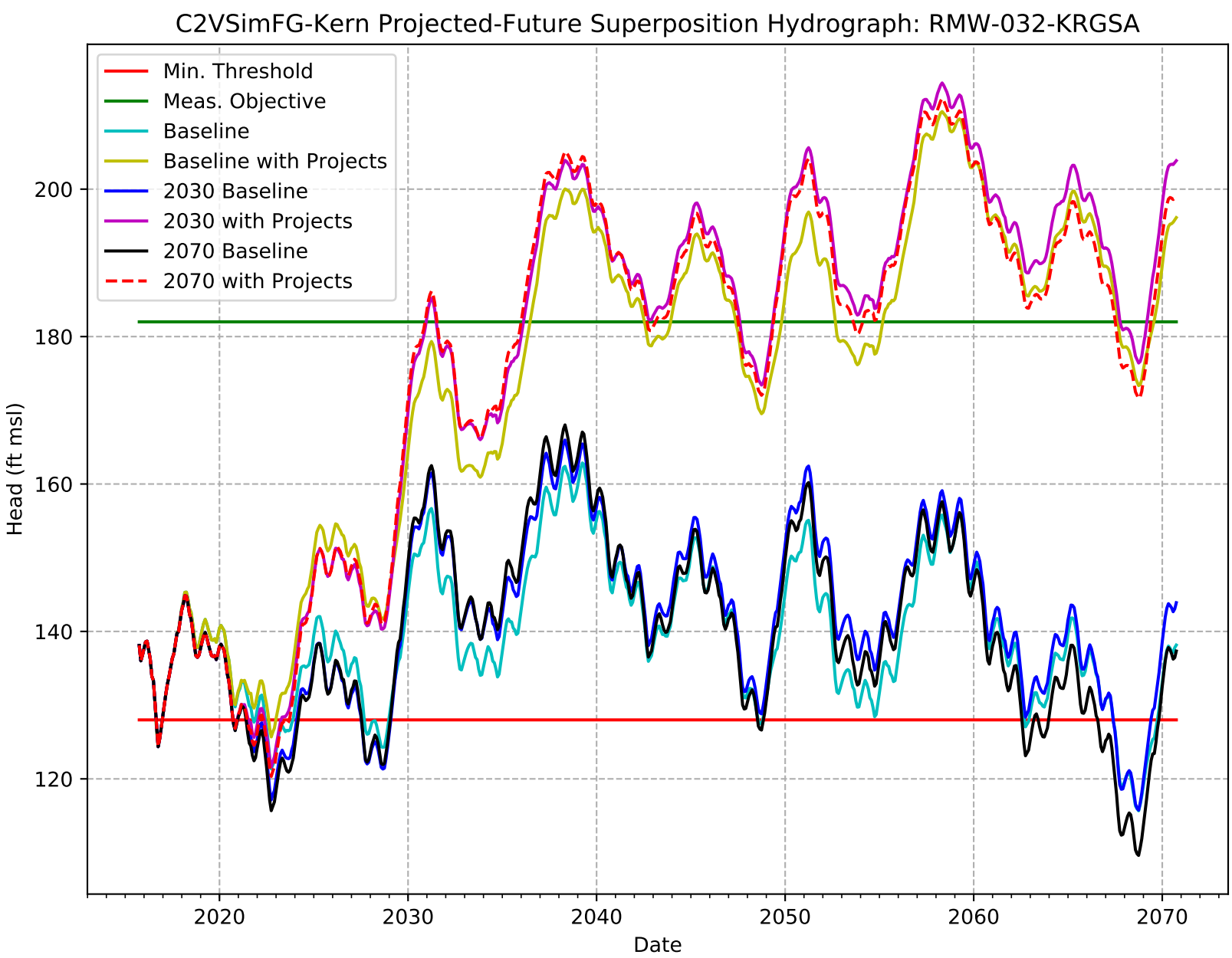

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-026-KRGSA
Head (ft msl)
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

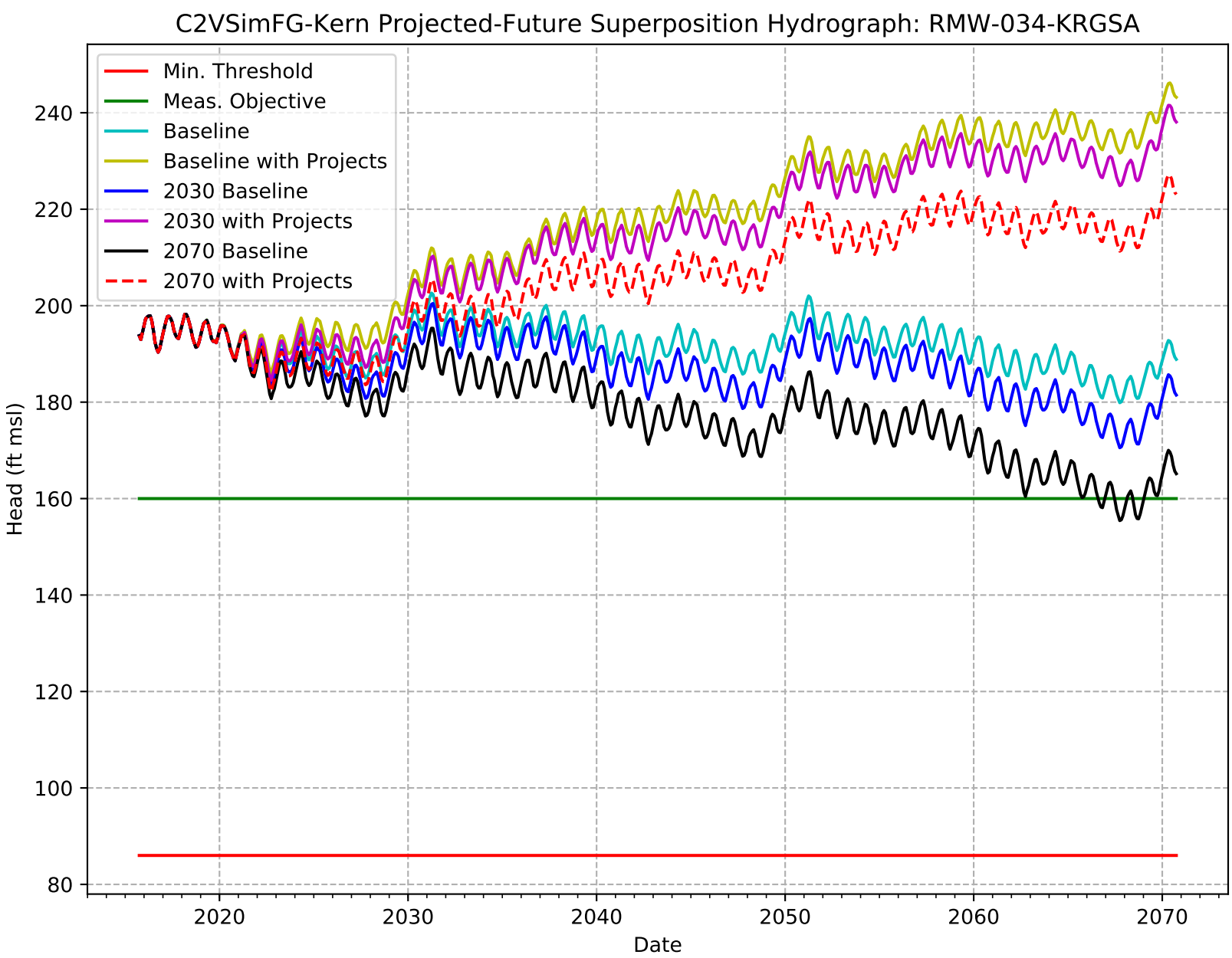

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-028-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
200
150
100
50
2020
2030
2040
2050
2060
2070
Date

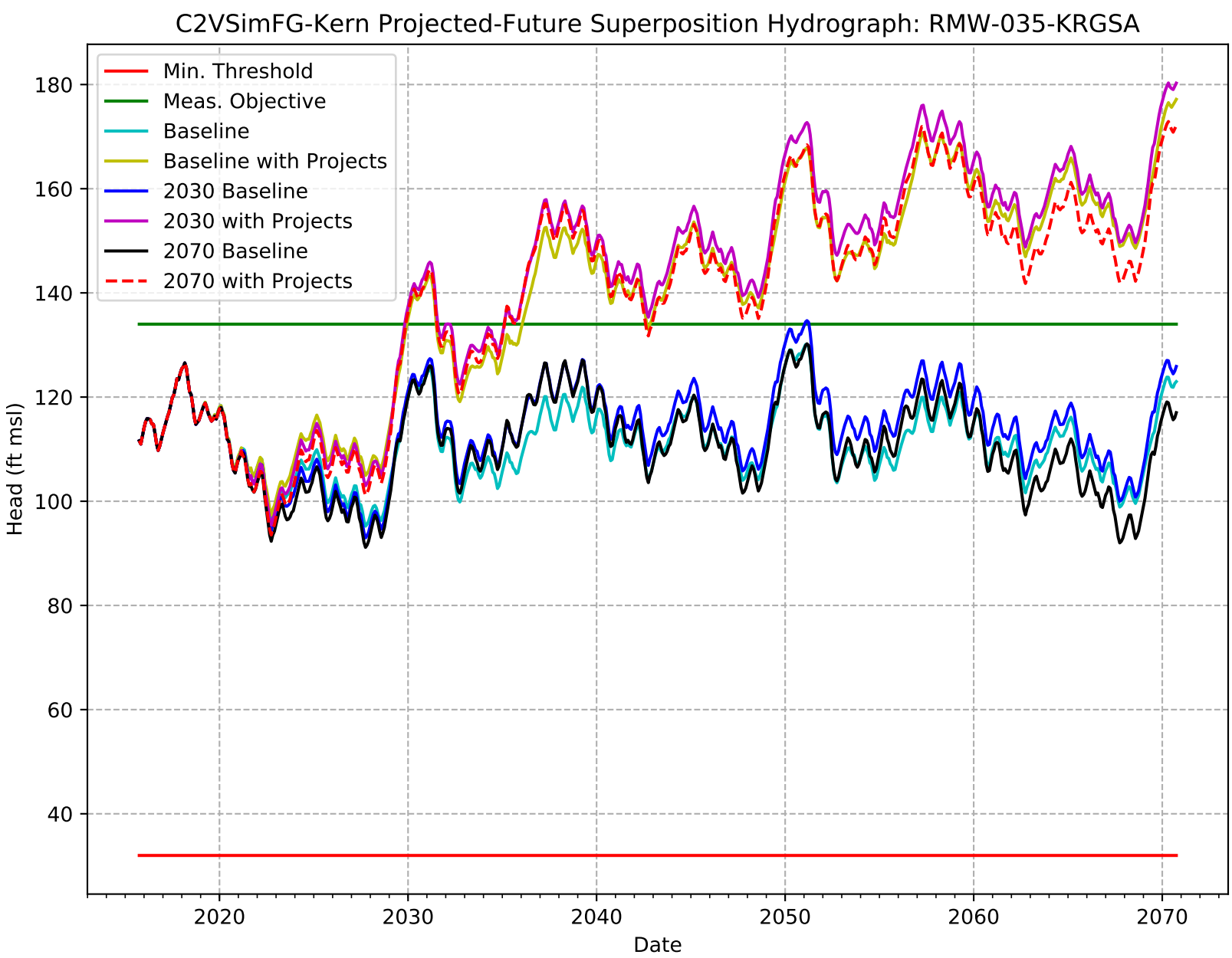

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-029-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date

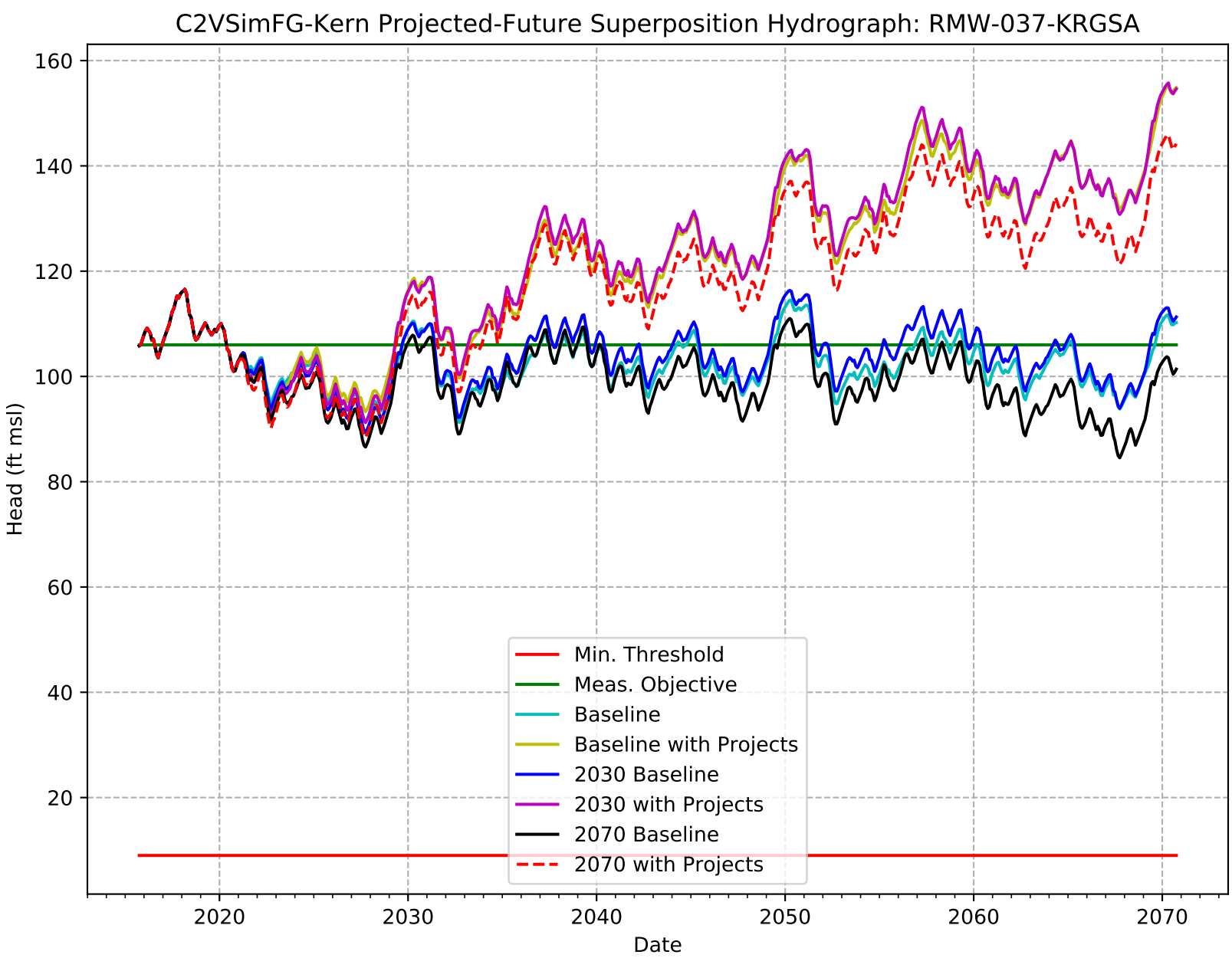

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-030-KRGSA
Head (ft msl)
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

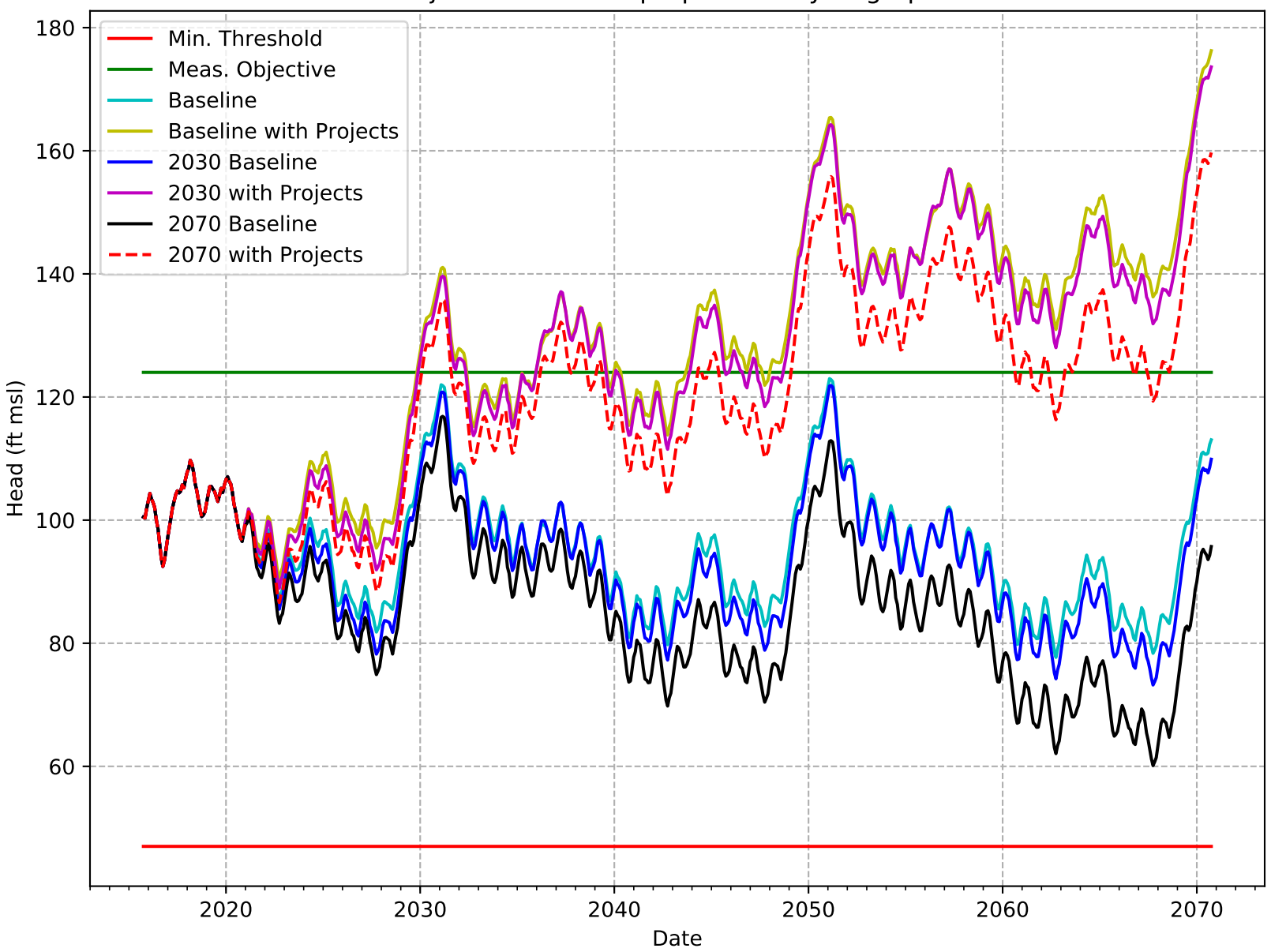

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-031-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
220
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

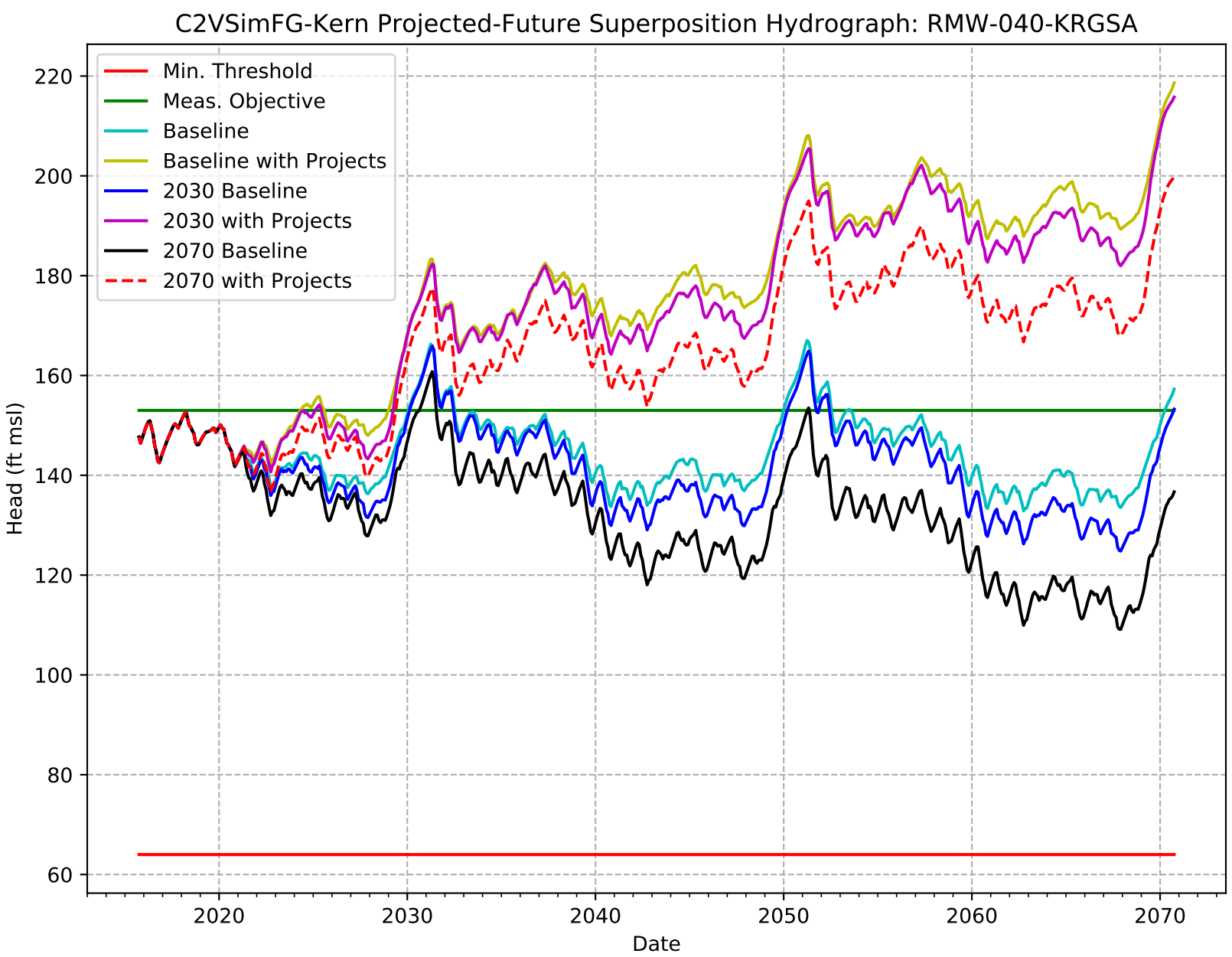

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-032-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date

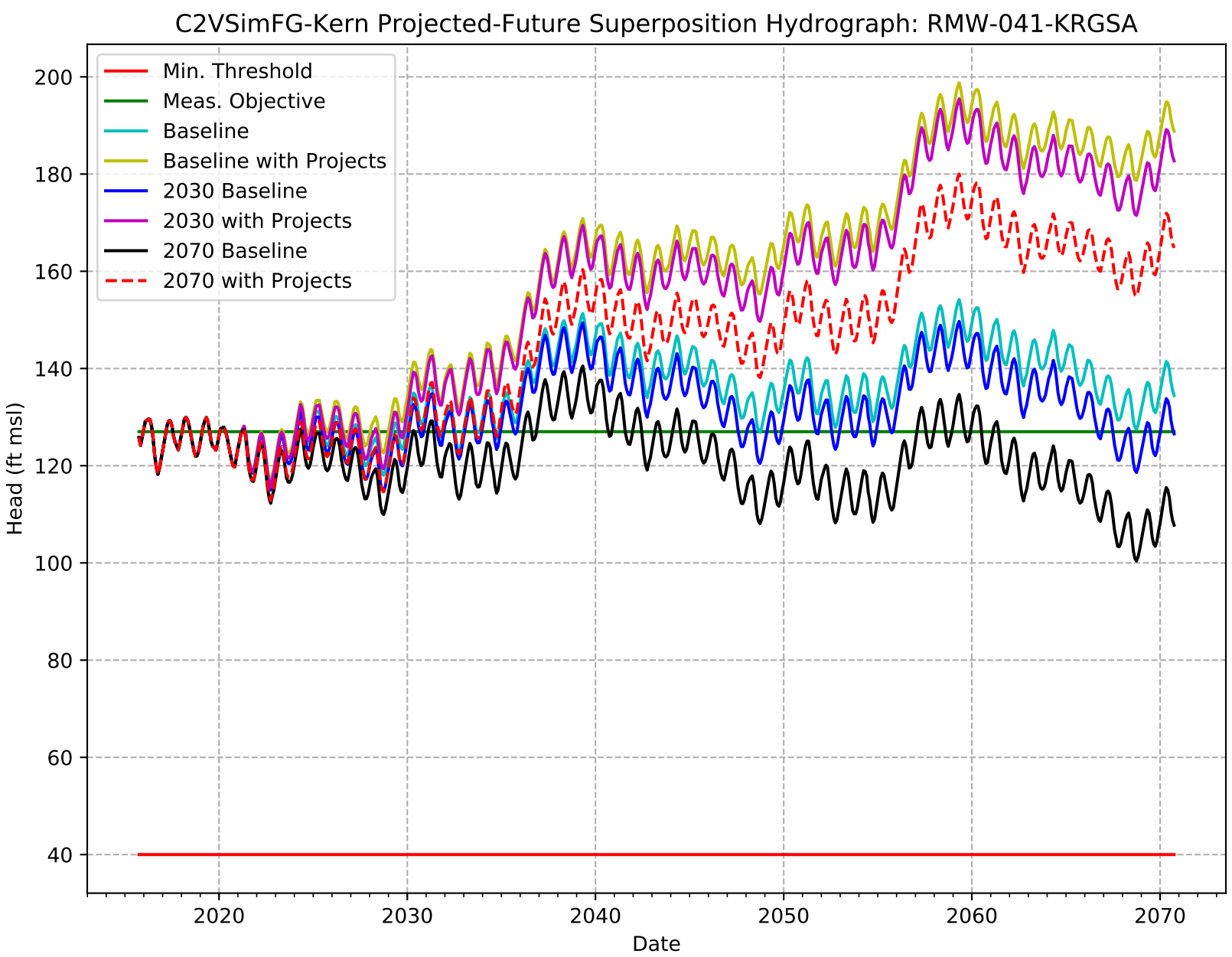

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-034-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
240
220
200
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date

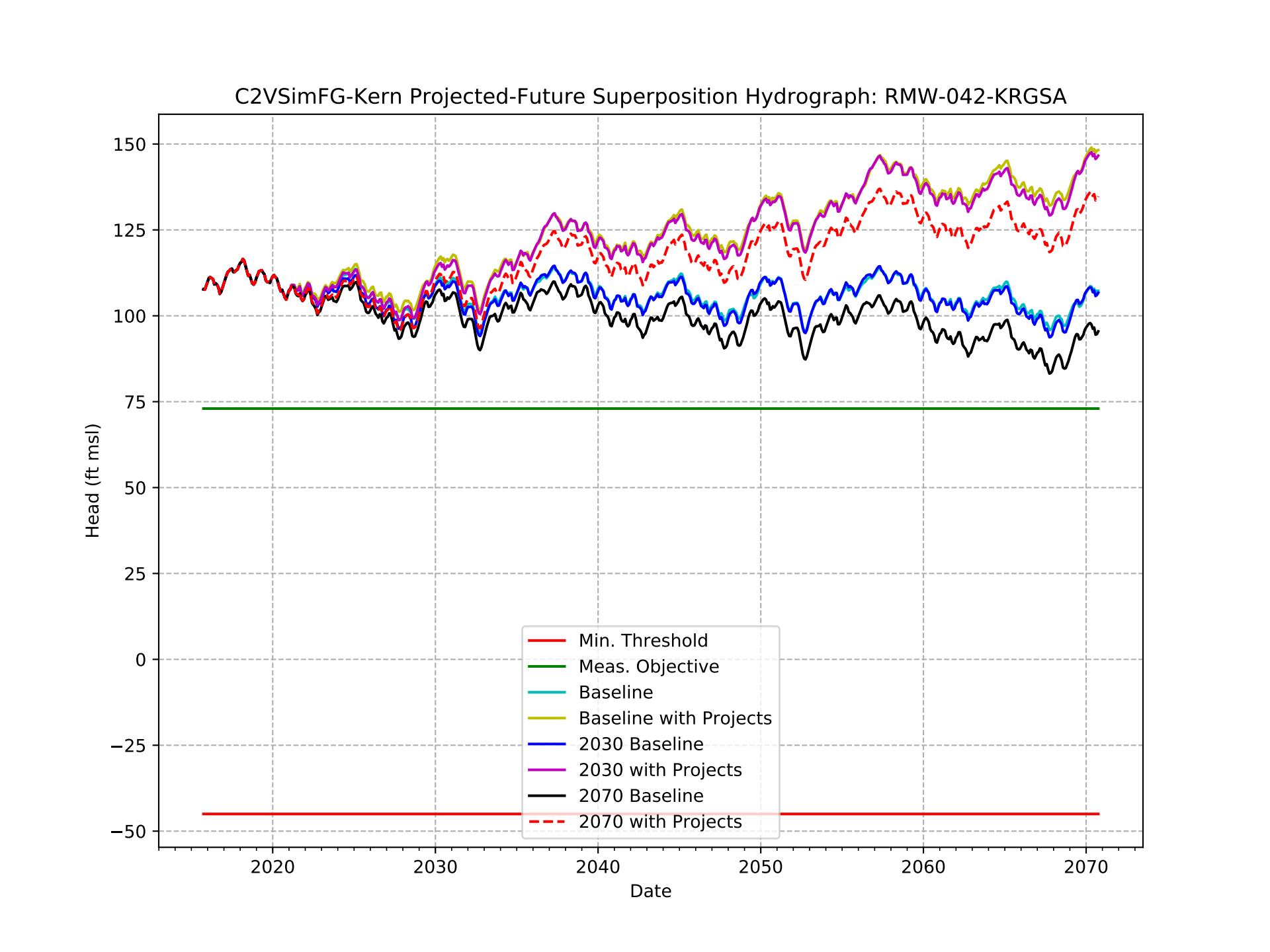

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-035-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date

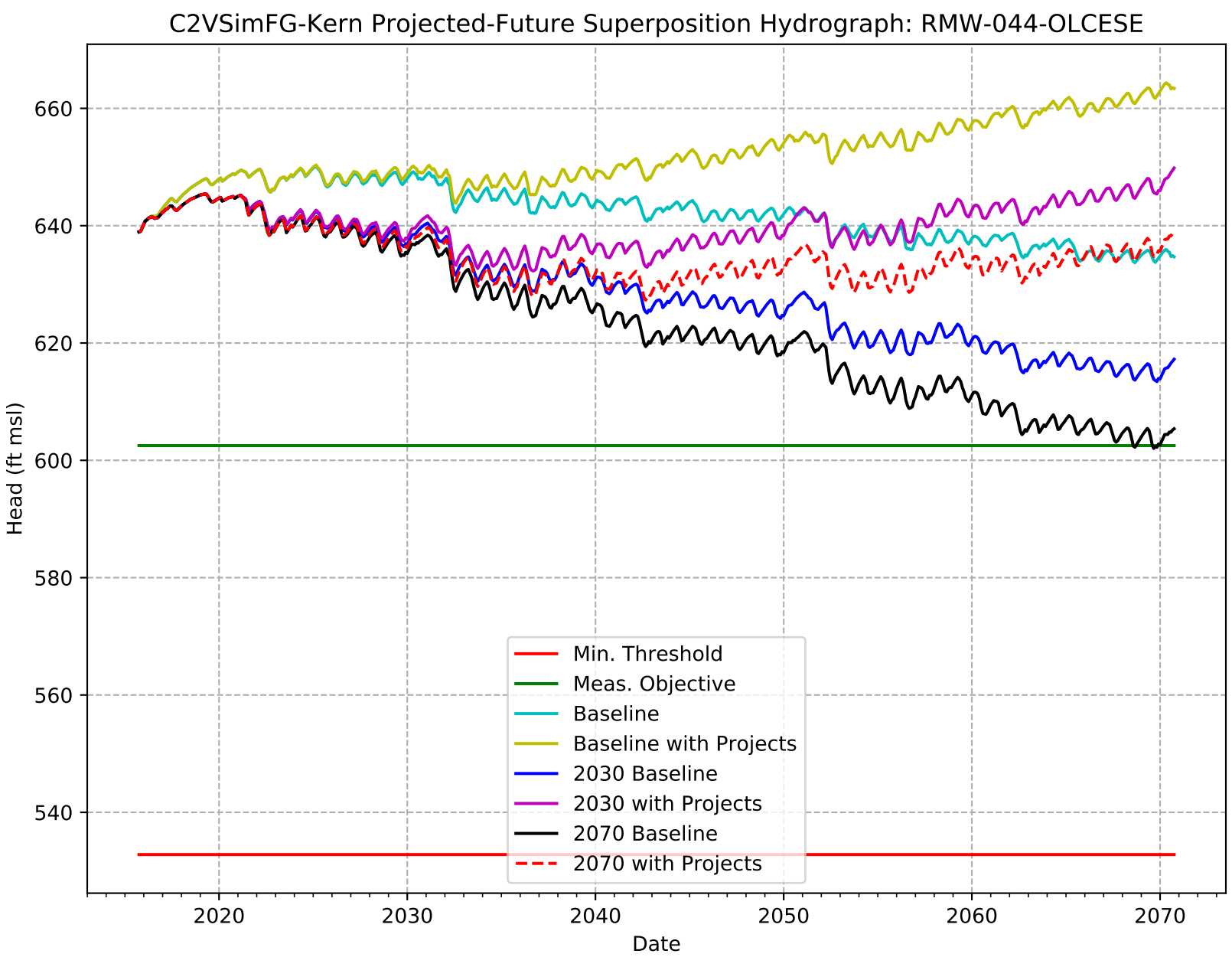

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-037-KRGSA
Head (ft msl)
160
140
120
100
80
60
40
20
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

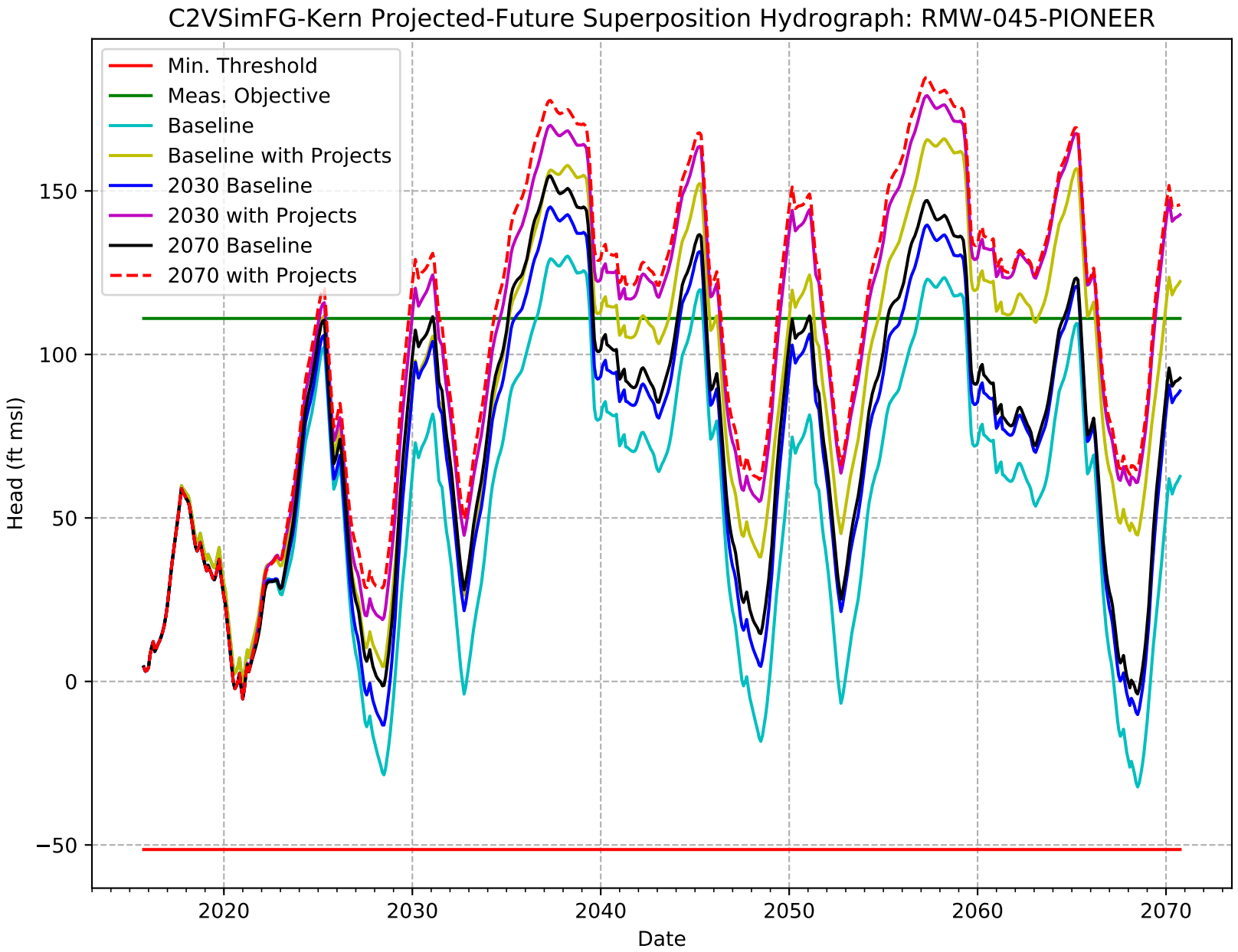

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-038-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

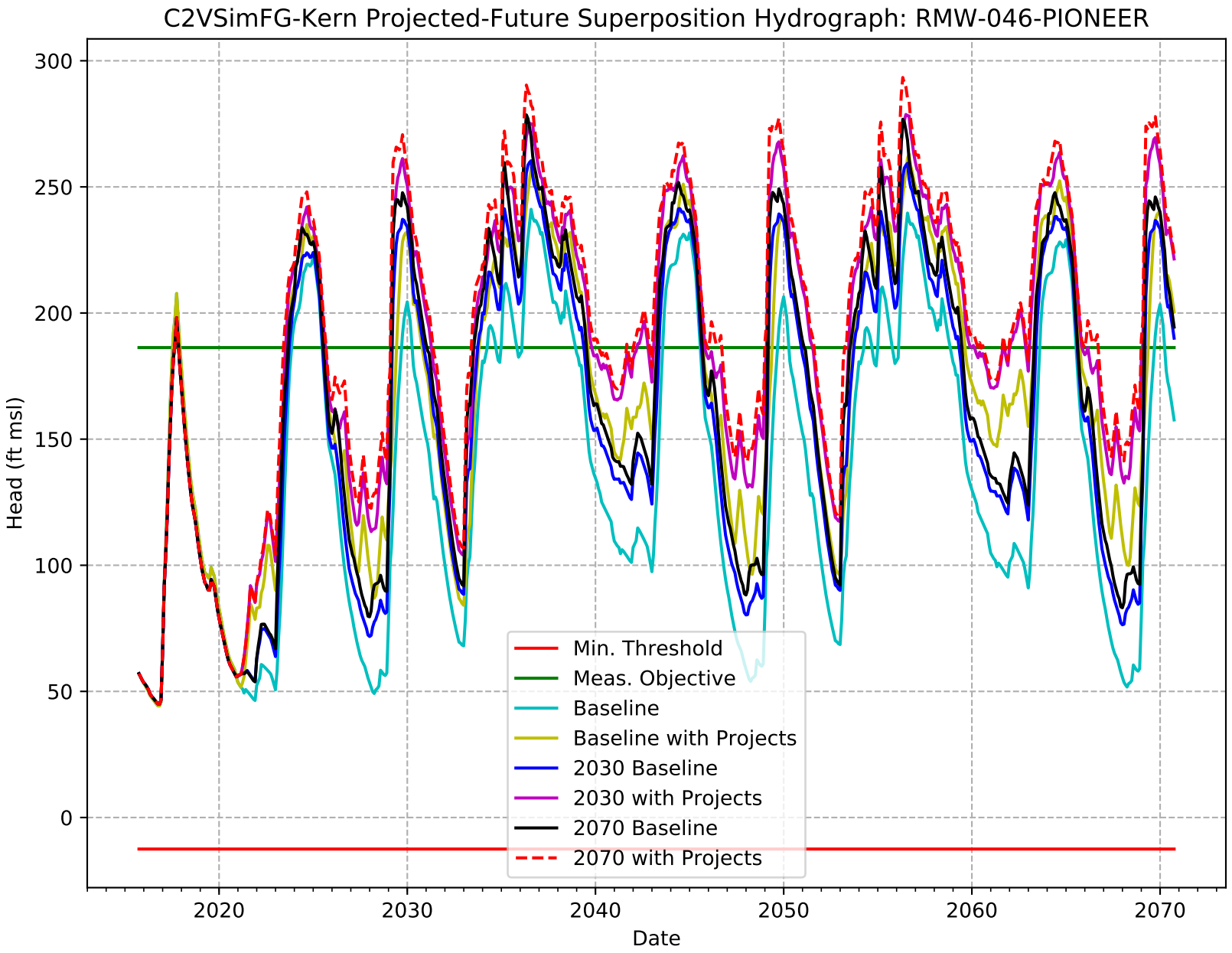

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-040-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
220
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

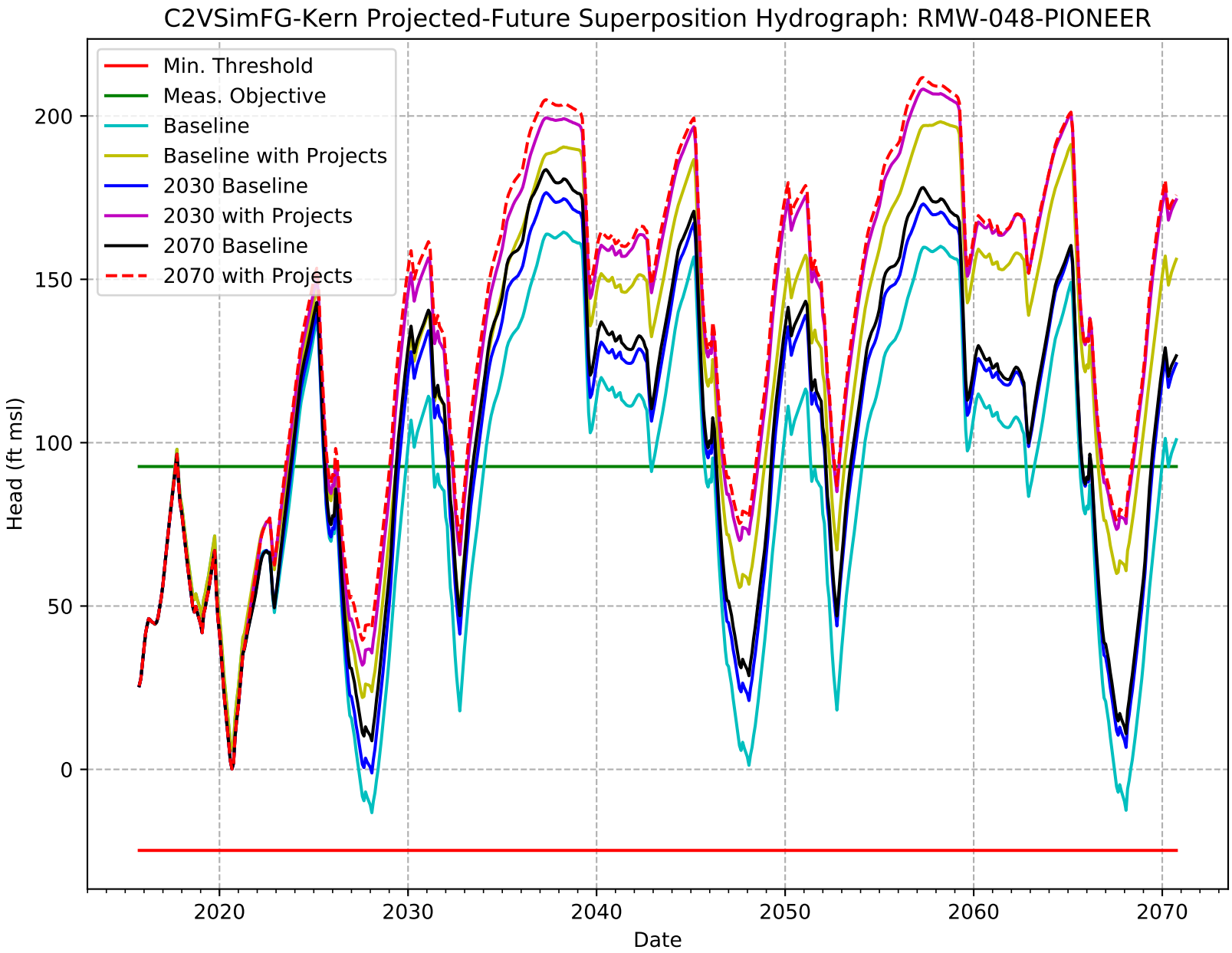

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-041-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date

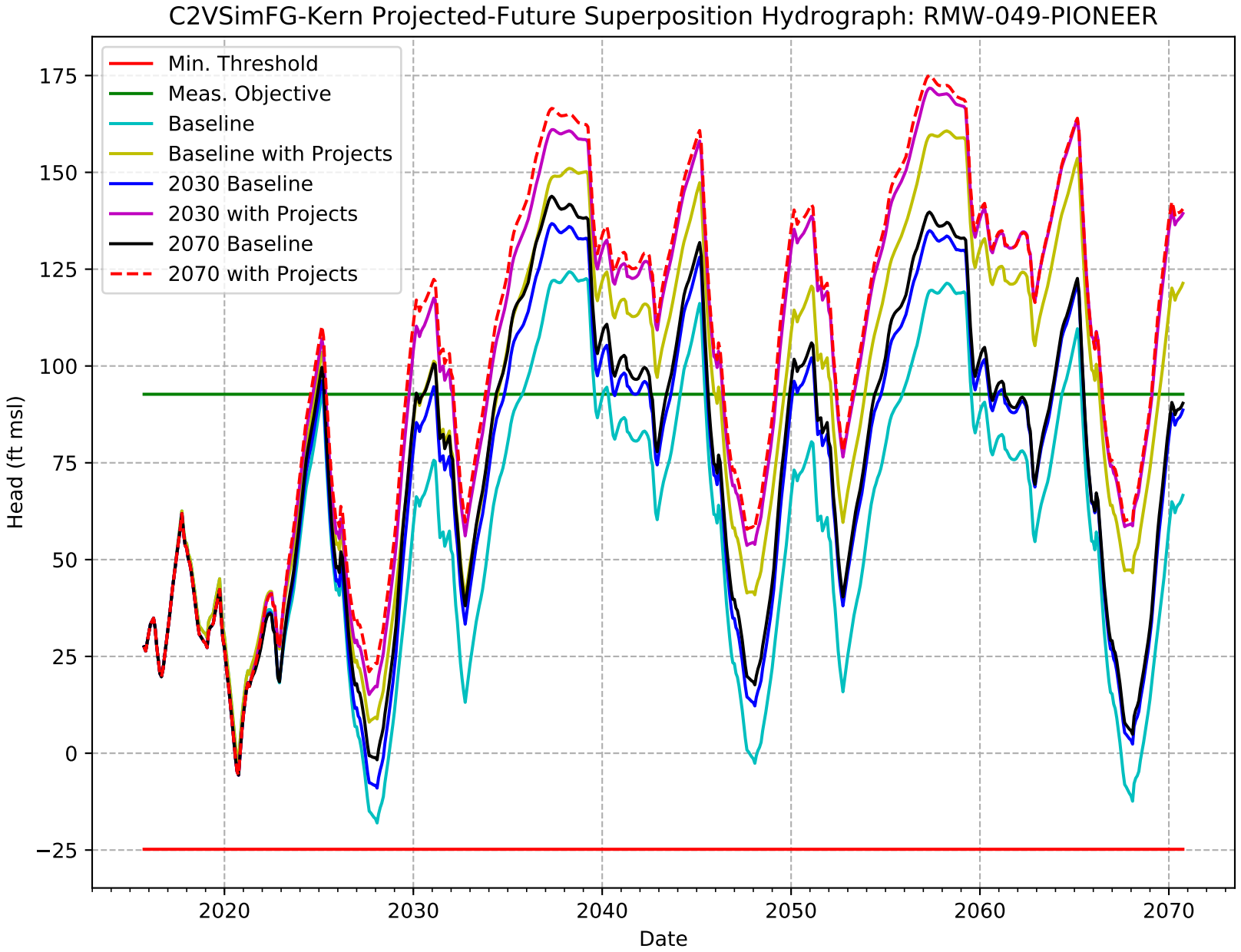

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-042-KRGSA
Head (ft msl)
150
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

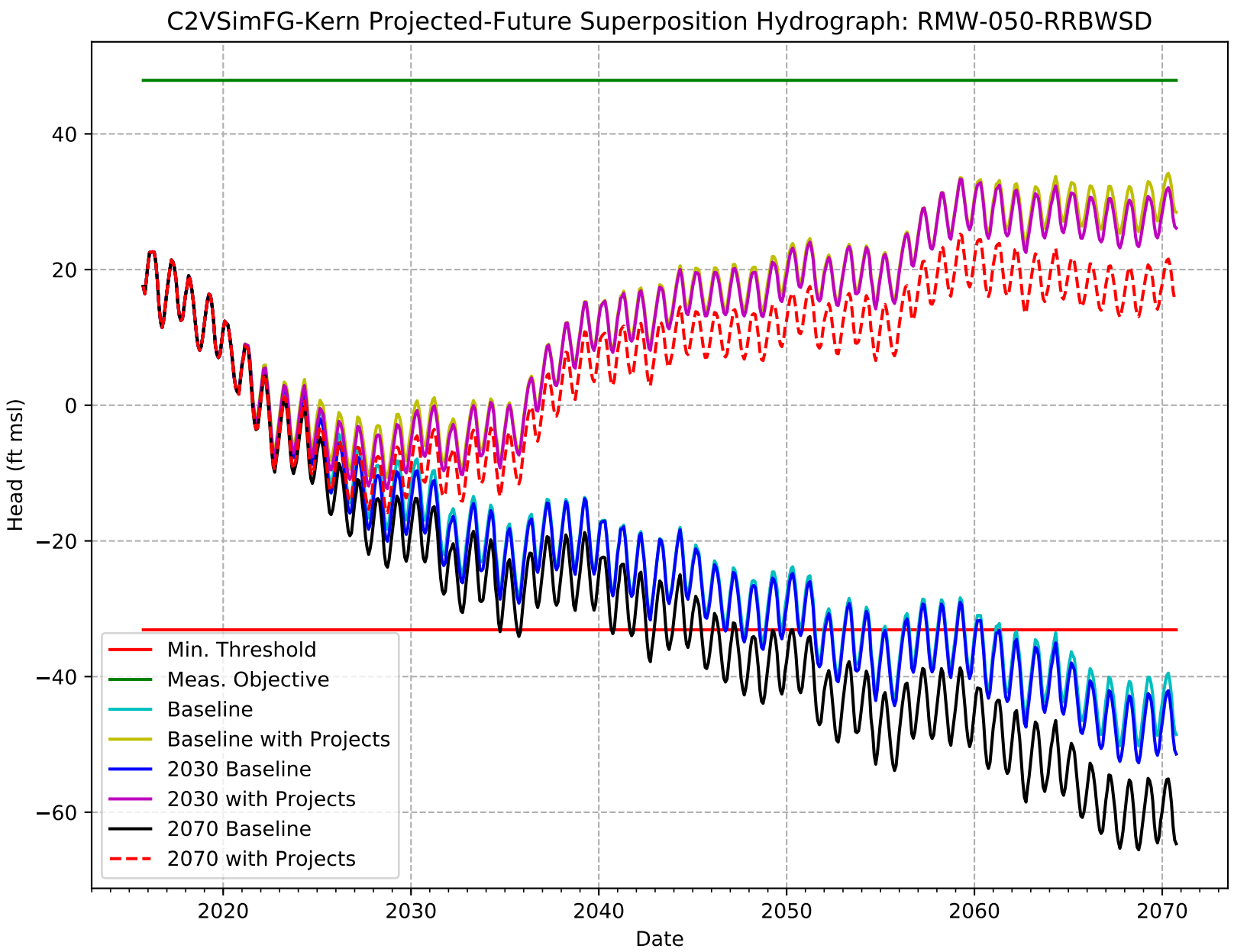

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-044-OLCESE
Head (ft msl)
660
640
620
600
580
560
540
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

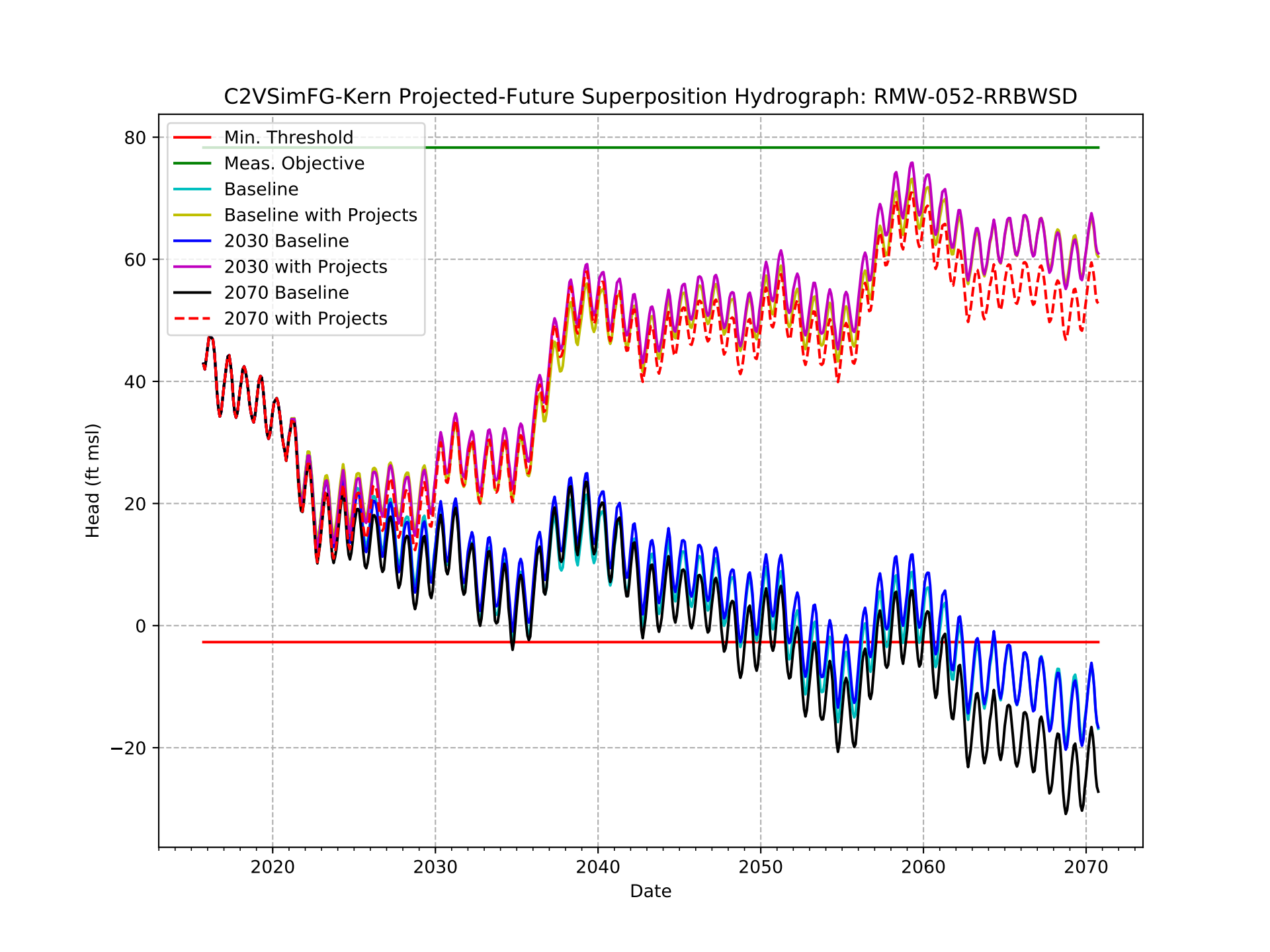

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-045-PIONEER
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date

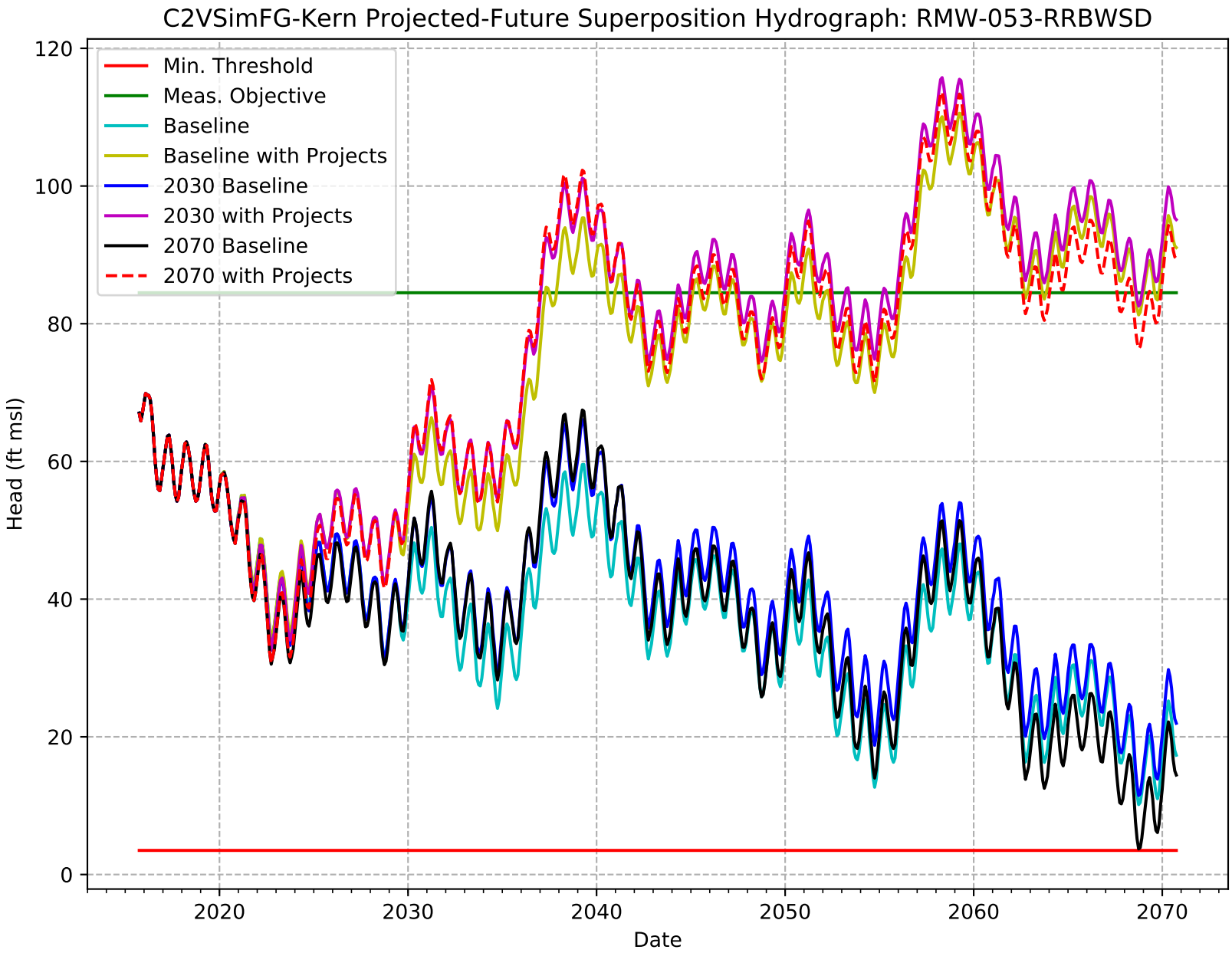

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-046-PIONEER
Head (ft msl)
300
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

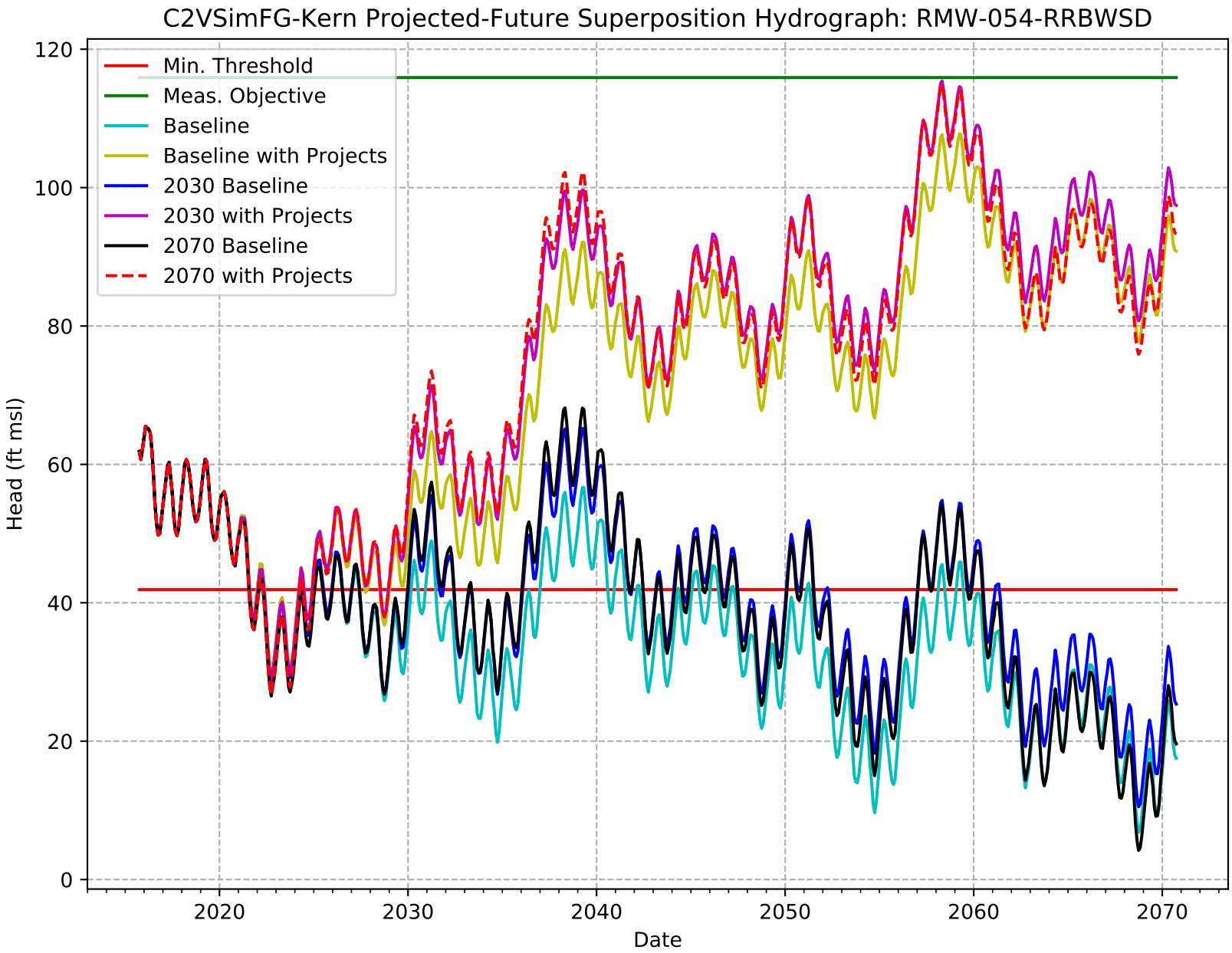

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-048-PIONEER
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date

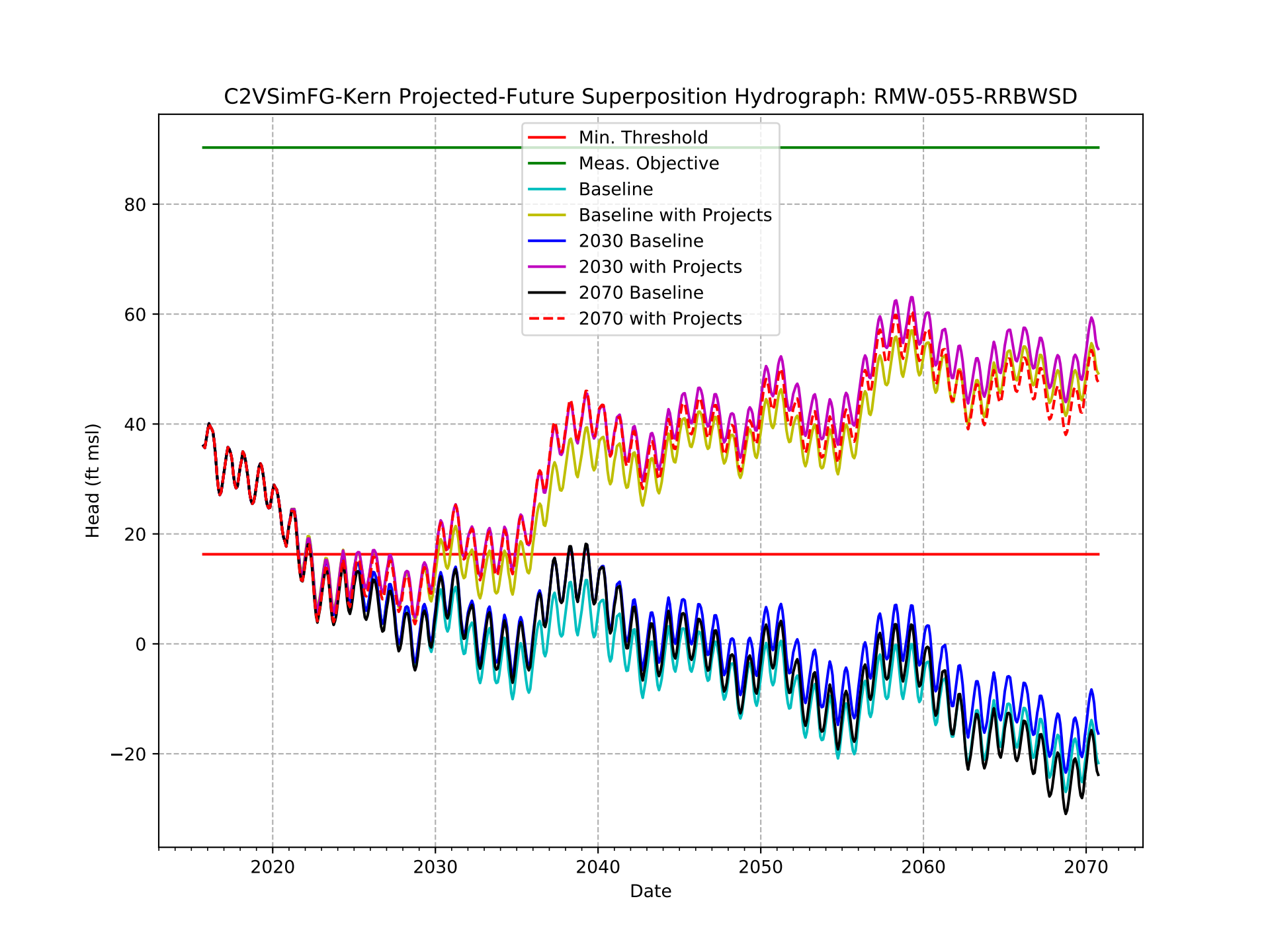

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-049-PIONEER
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
175
150
125
100
75
50
25
0
−25
2020
2030
2040
2050
2060
2070
Date

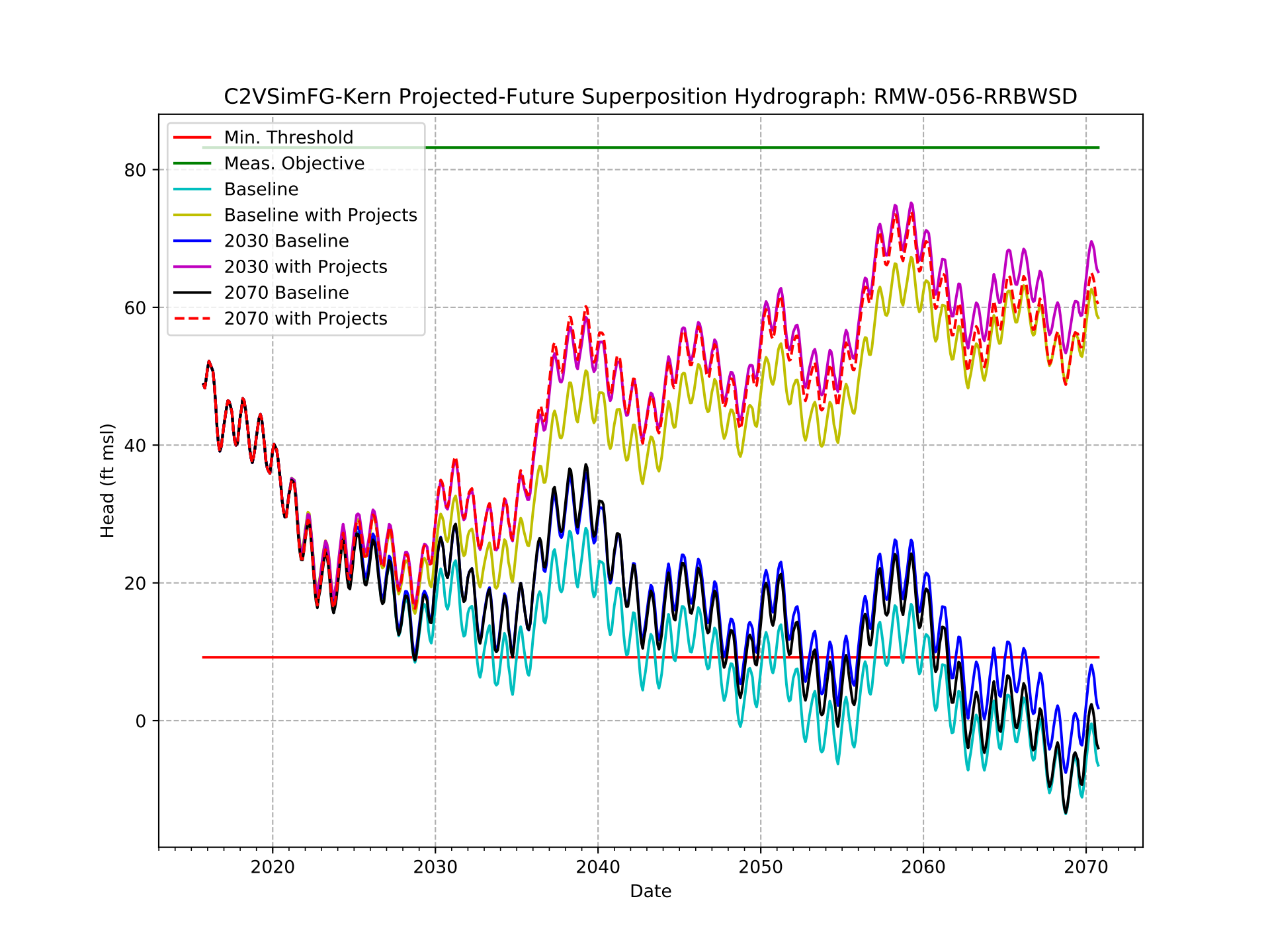

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-050-RRBWSD
Head (ft msl)
40
20
0
−20
−40
−60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

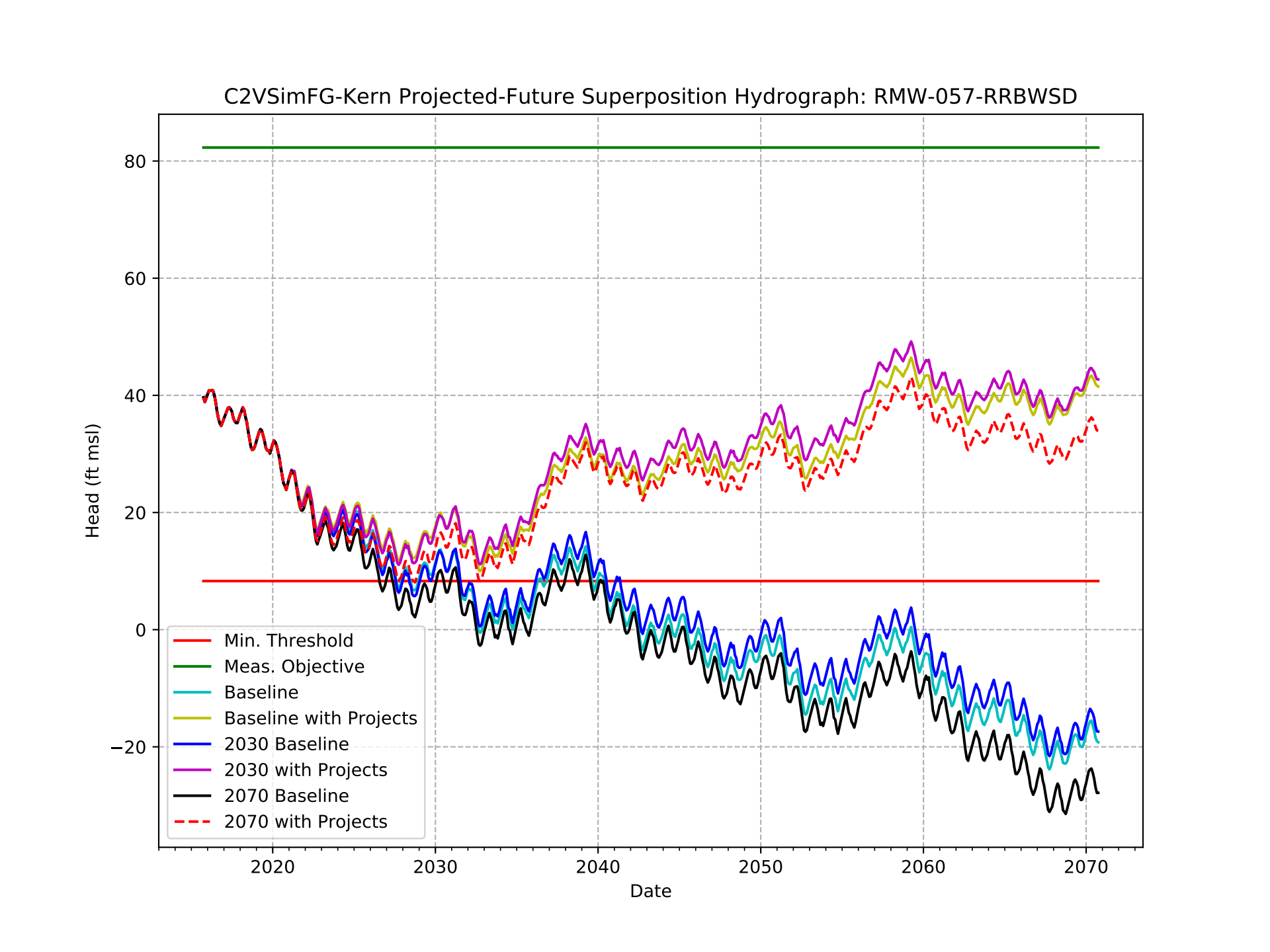

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-052-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
80
60
40
20
0
−20
2020
2030
2040
2050
2060
2070
Date

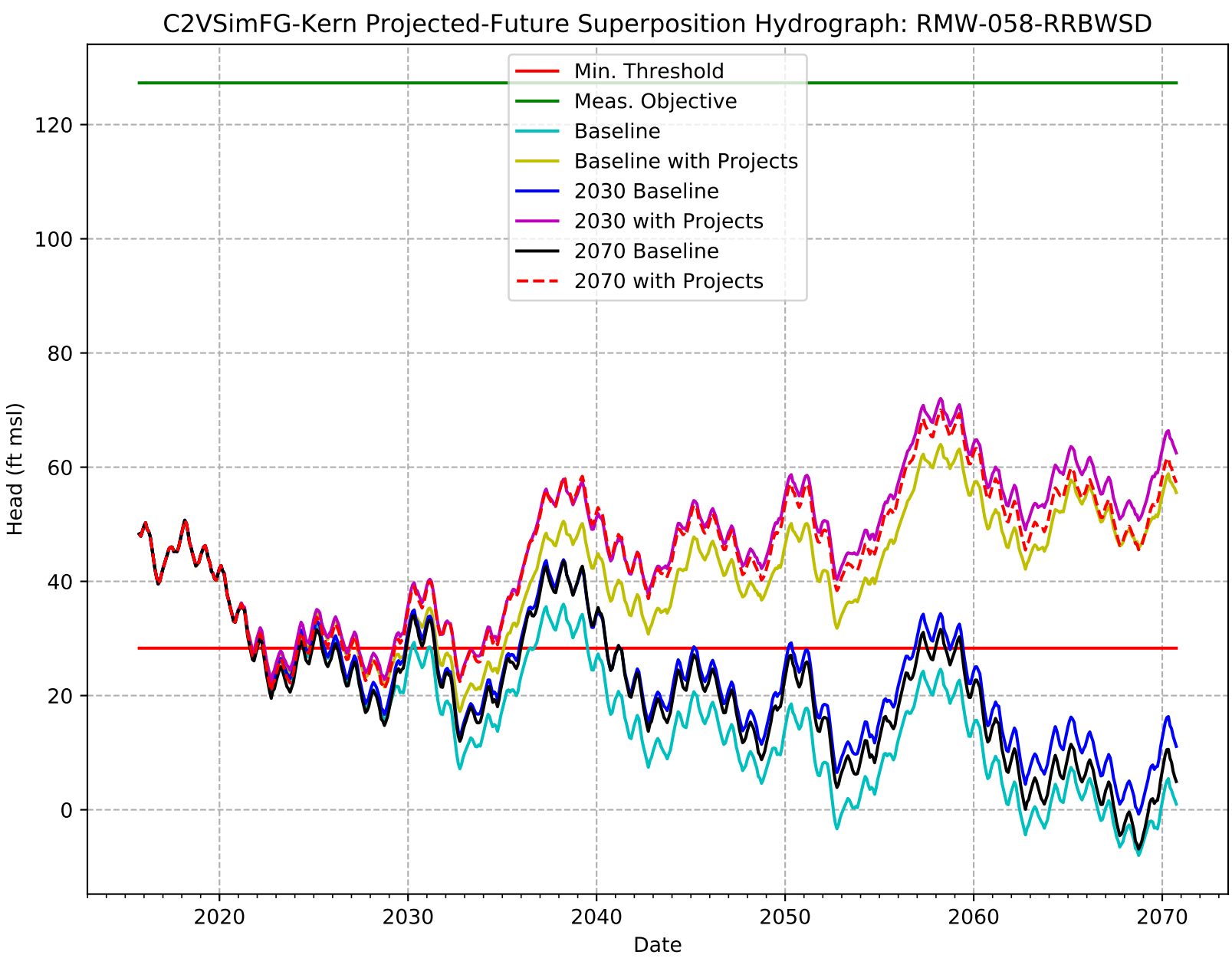

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-053-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
Date
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070

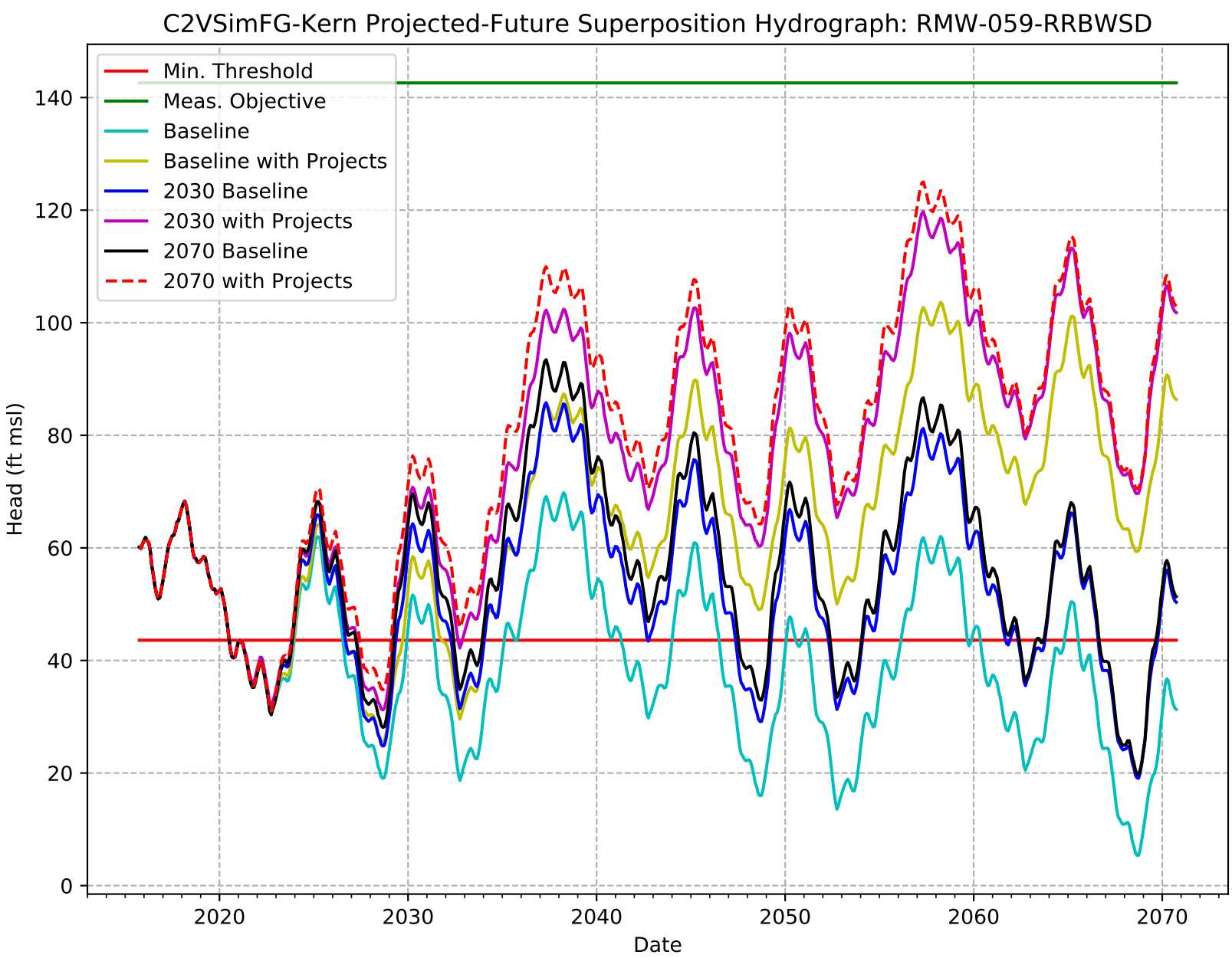

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-054-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
Date
0
20
40
60
80
100
120
2020
2030
2040
2050
2060
2070

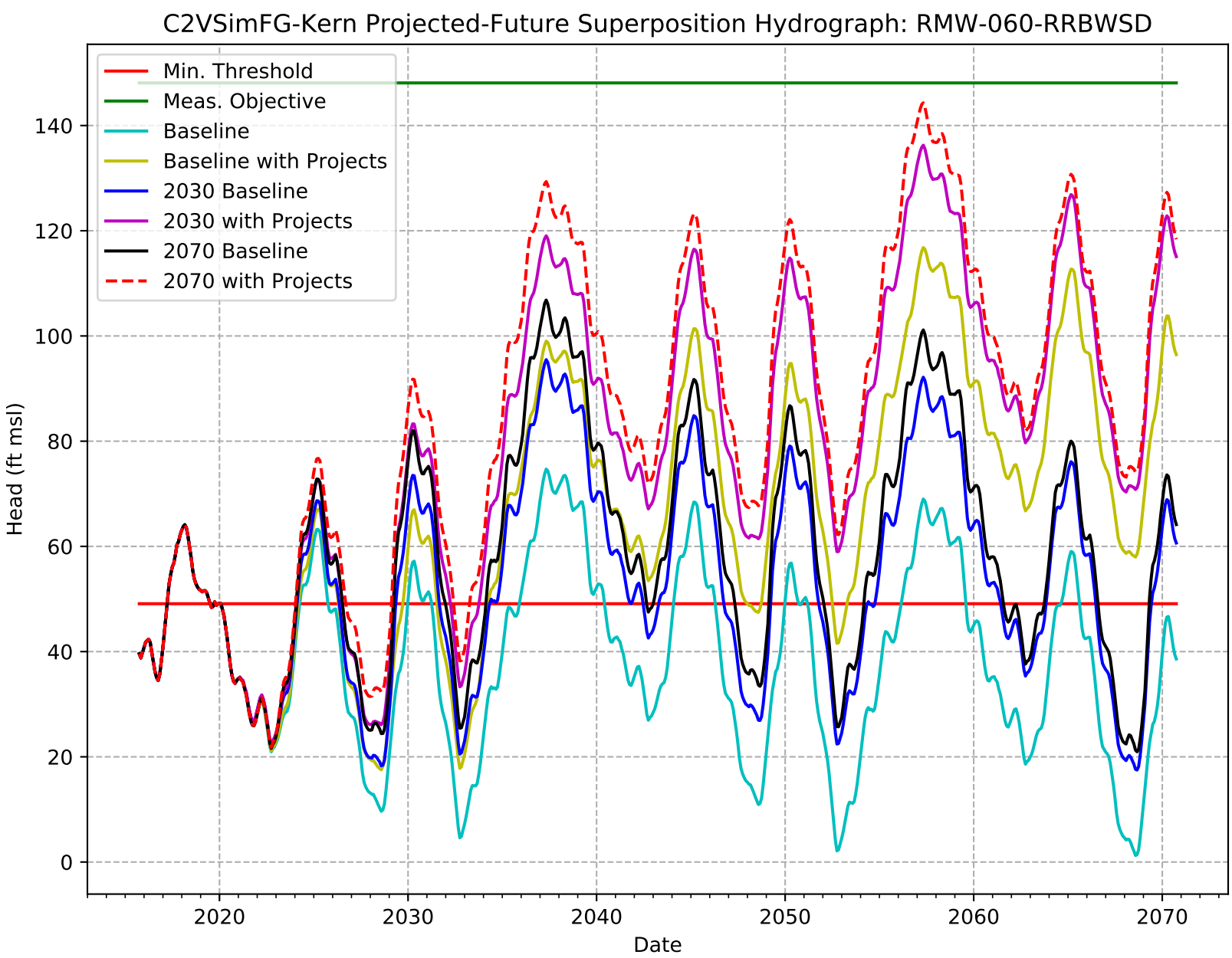

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-055-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
80
60
40
20
0
−20
2020
2030
2040
2050
2060
2070
Date

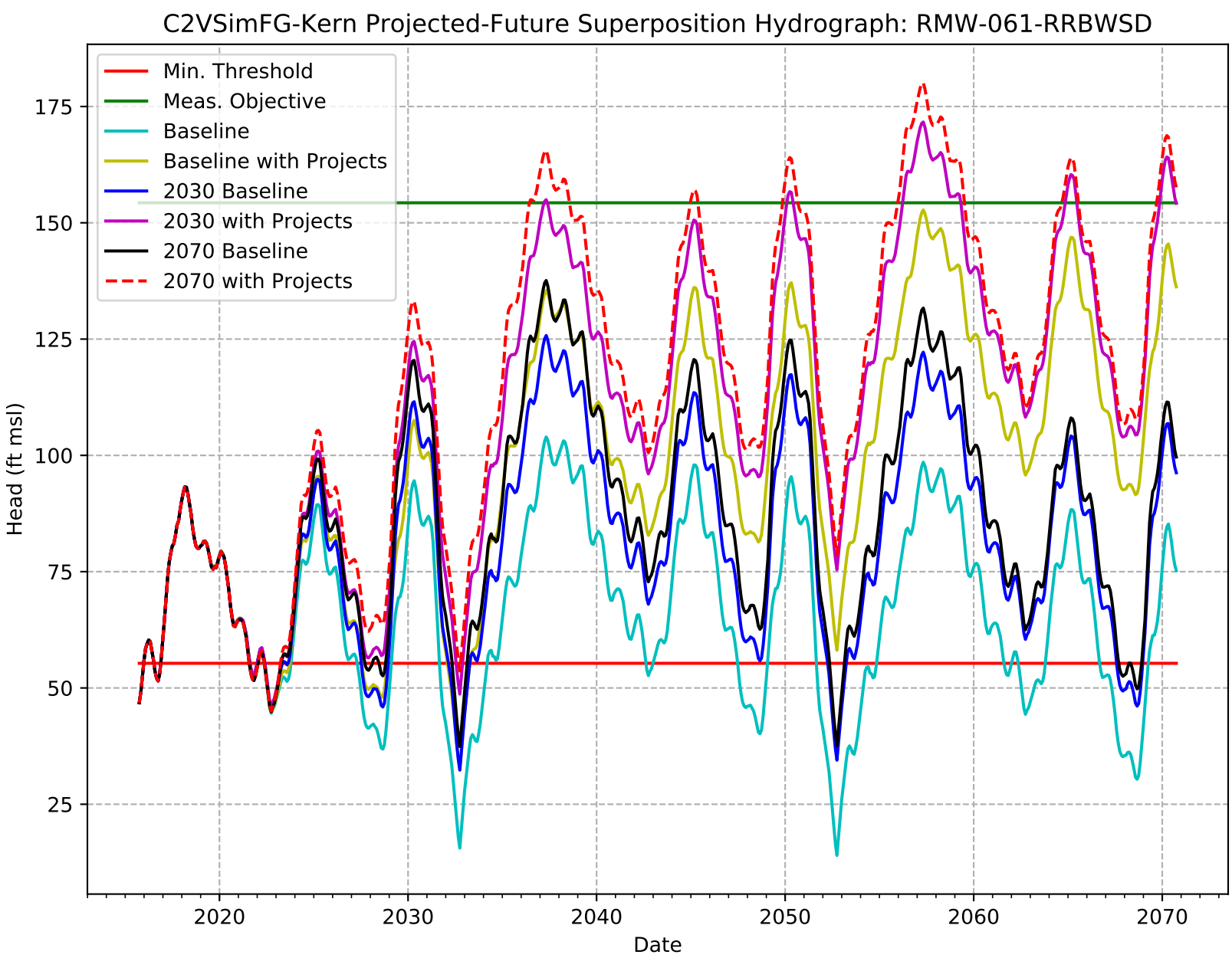

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-056-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

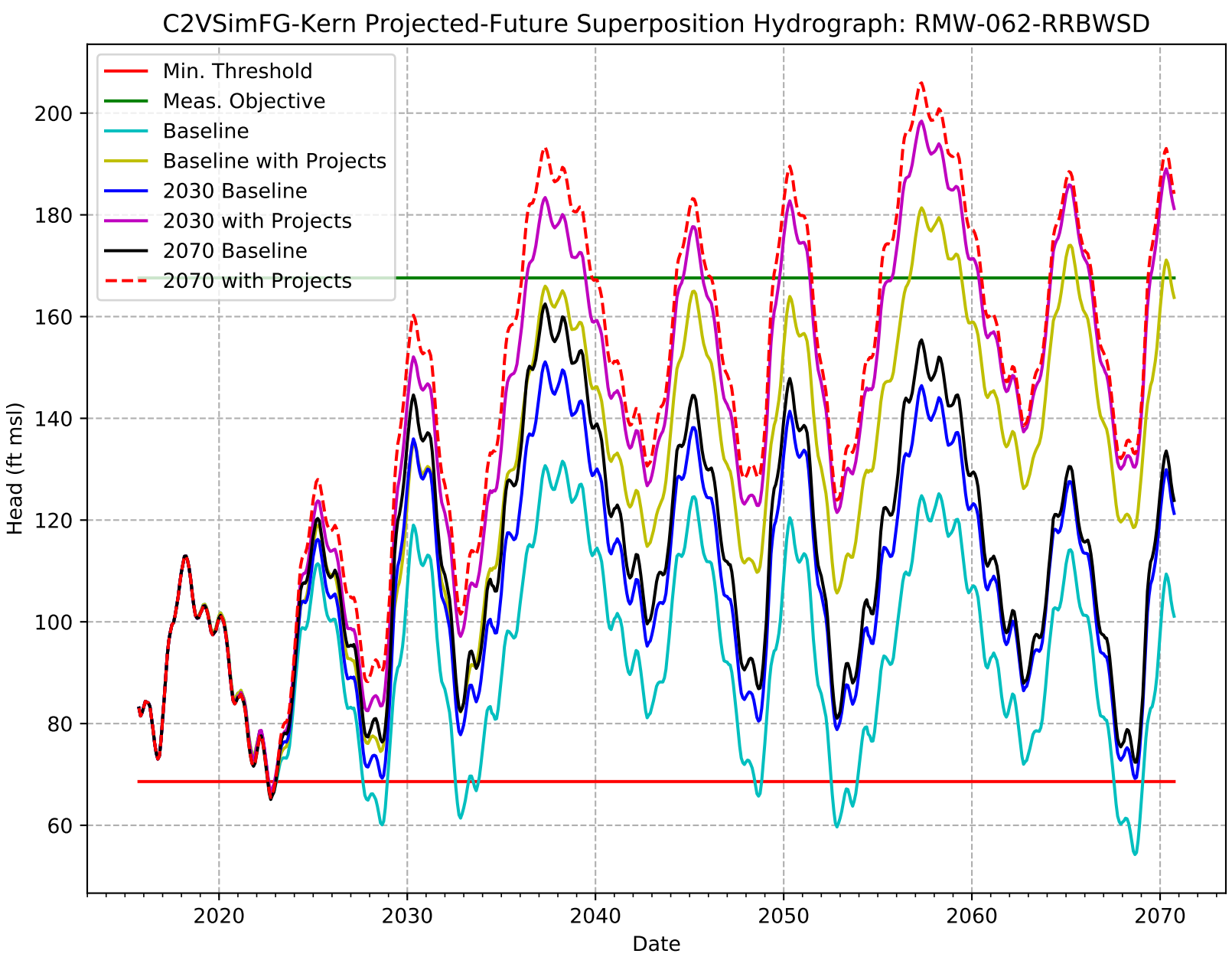

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-057-RRBWSD
Head (ft msl)
80
60
40
20
0
−20
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

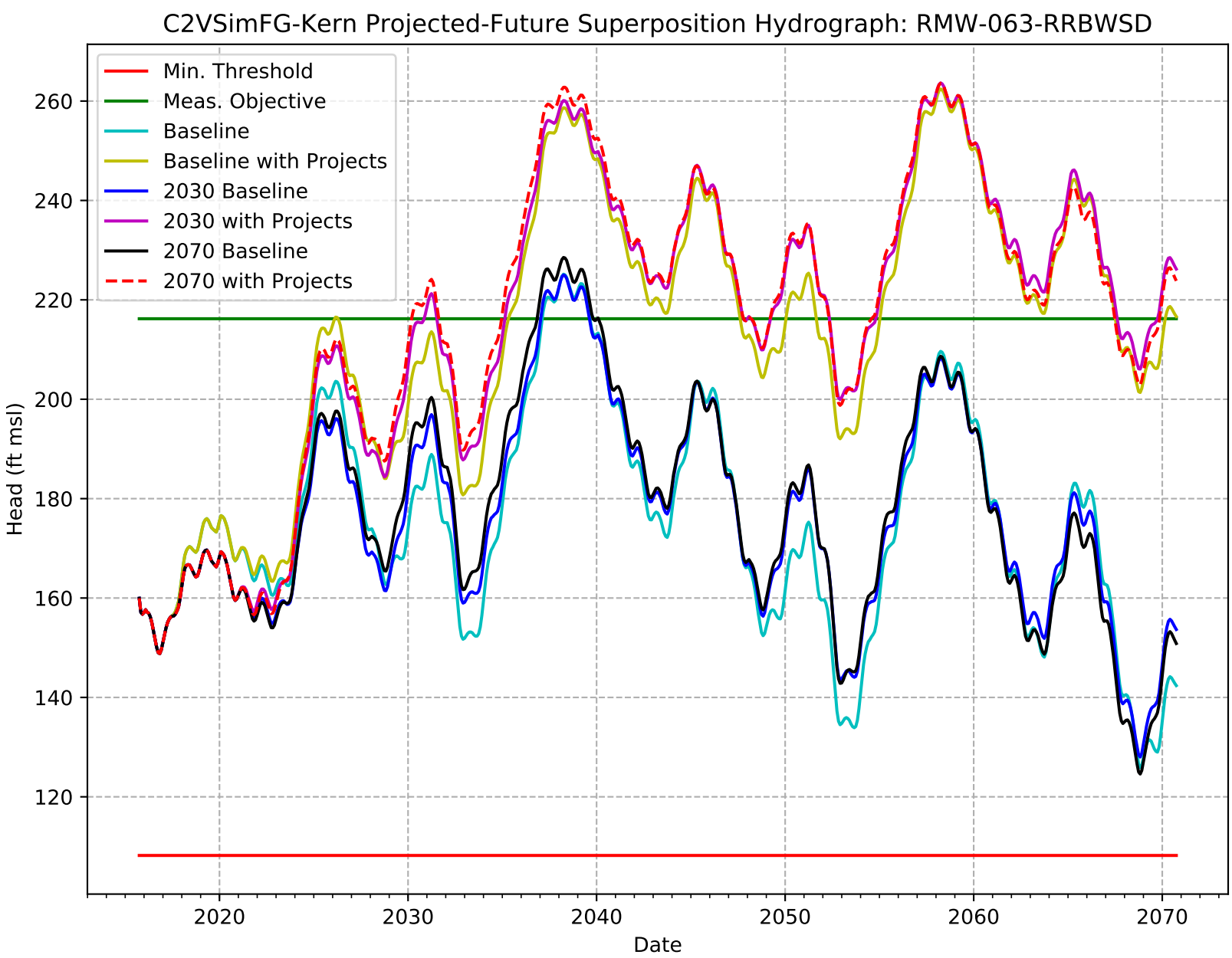

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-058-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
120
100
80
60
40
20
0
2020
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2040
2050
2060
2070
Date

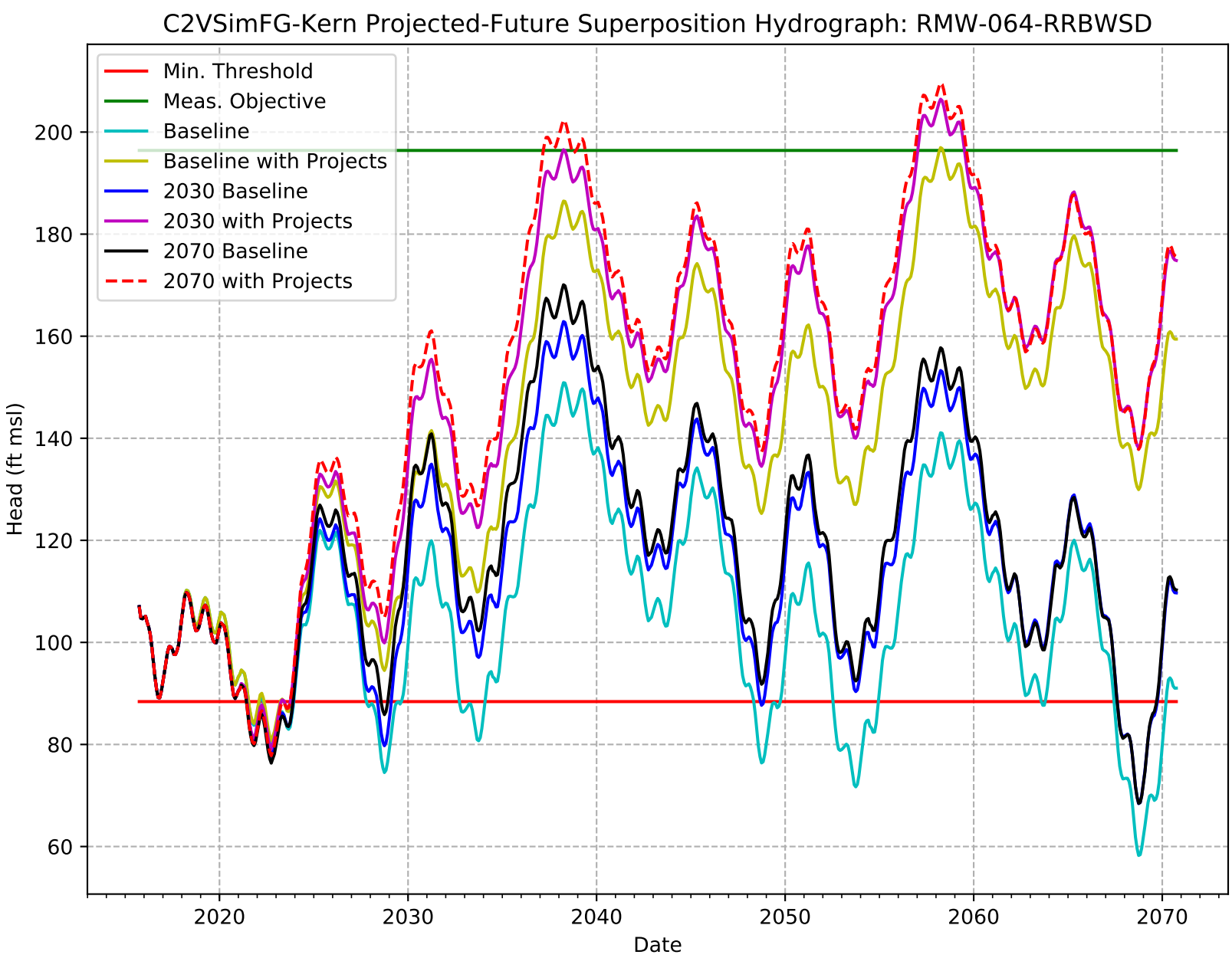

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-059-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
0
20
40
60
80
100
120
140
2020
2030
2040
2050
2060
2070
Date

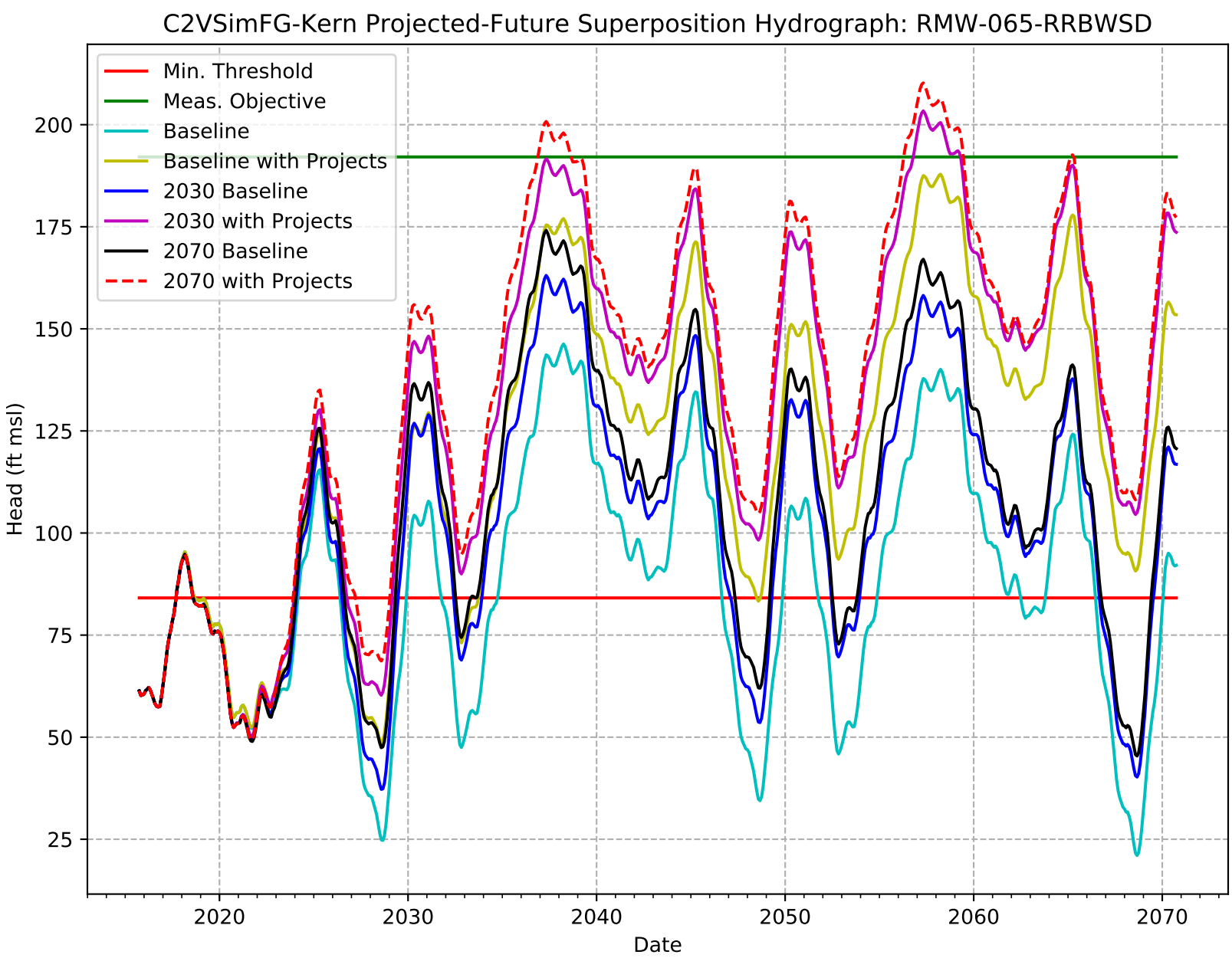

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-060-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
0
20
40
60
80
100
120
140
2020
2030
2040
2050
2060
2070
Date

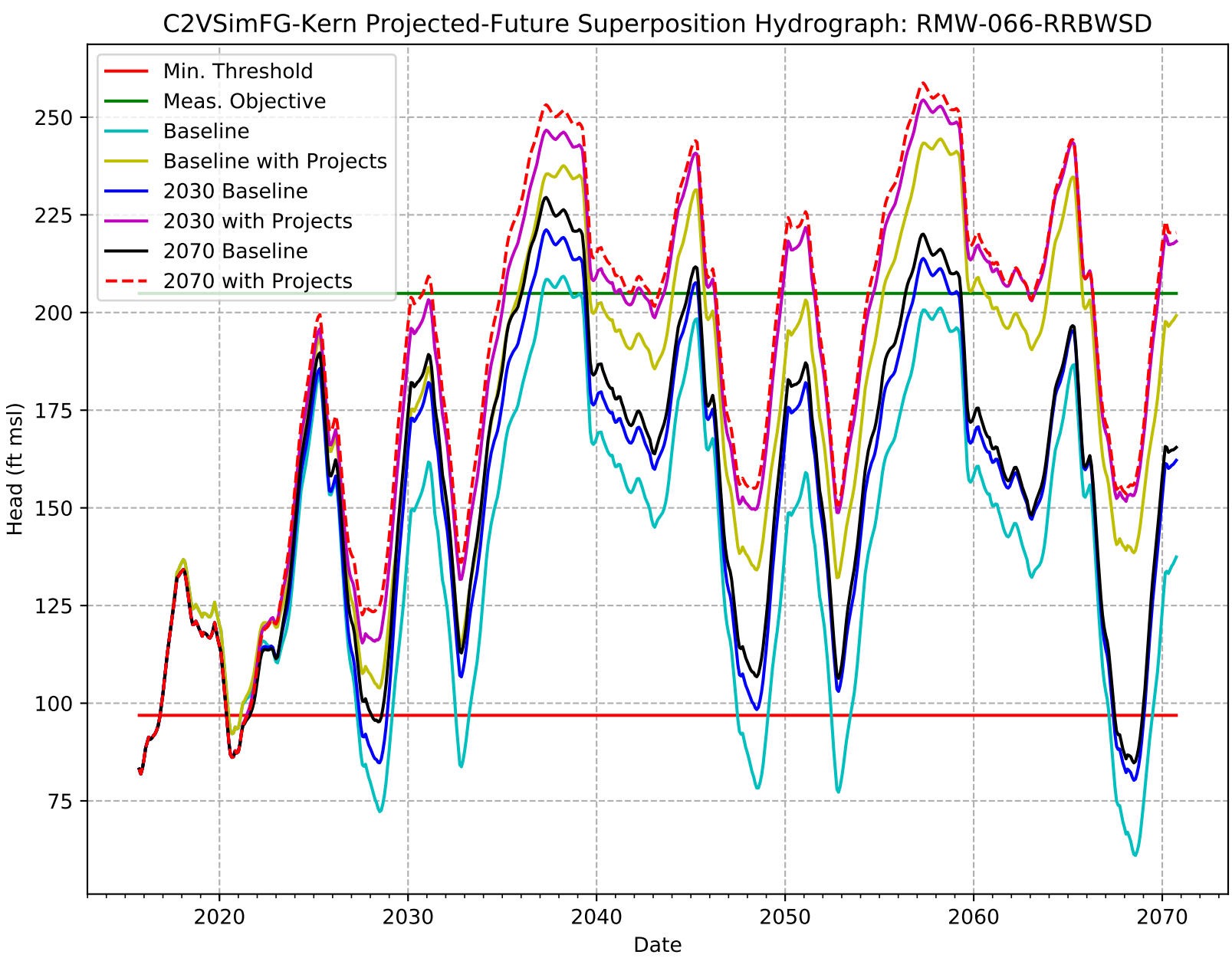

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-061-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
175
150
125
100
75
50
25
2020
2030
2040
2050
2060
2070
Date

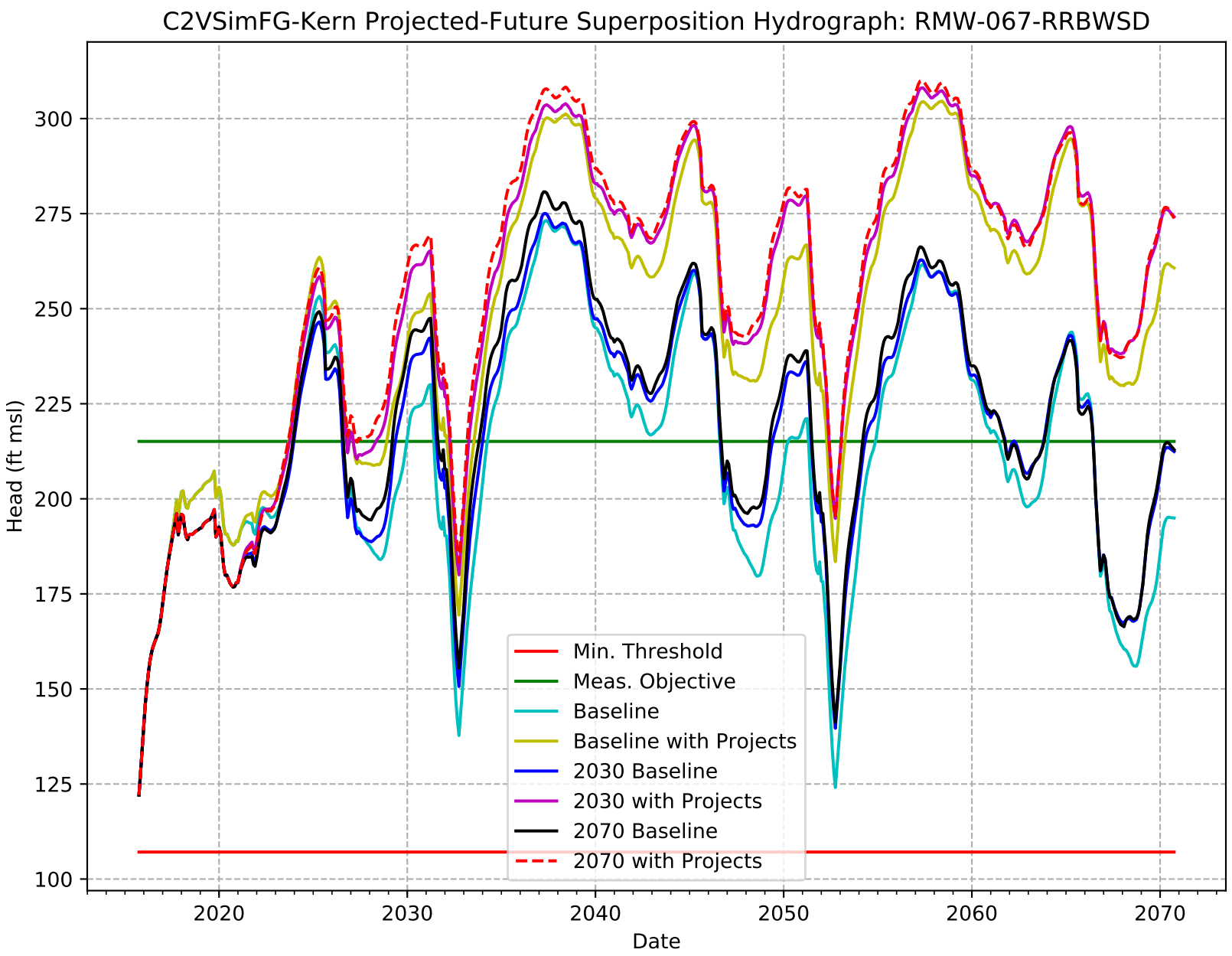

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-062-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

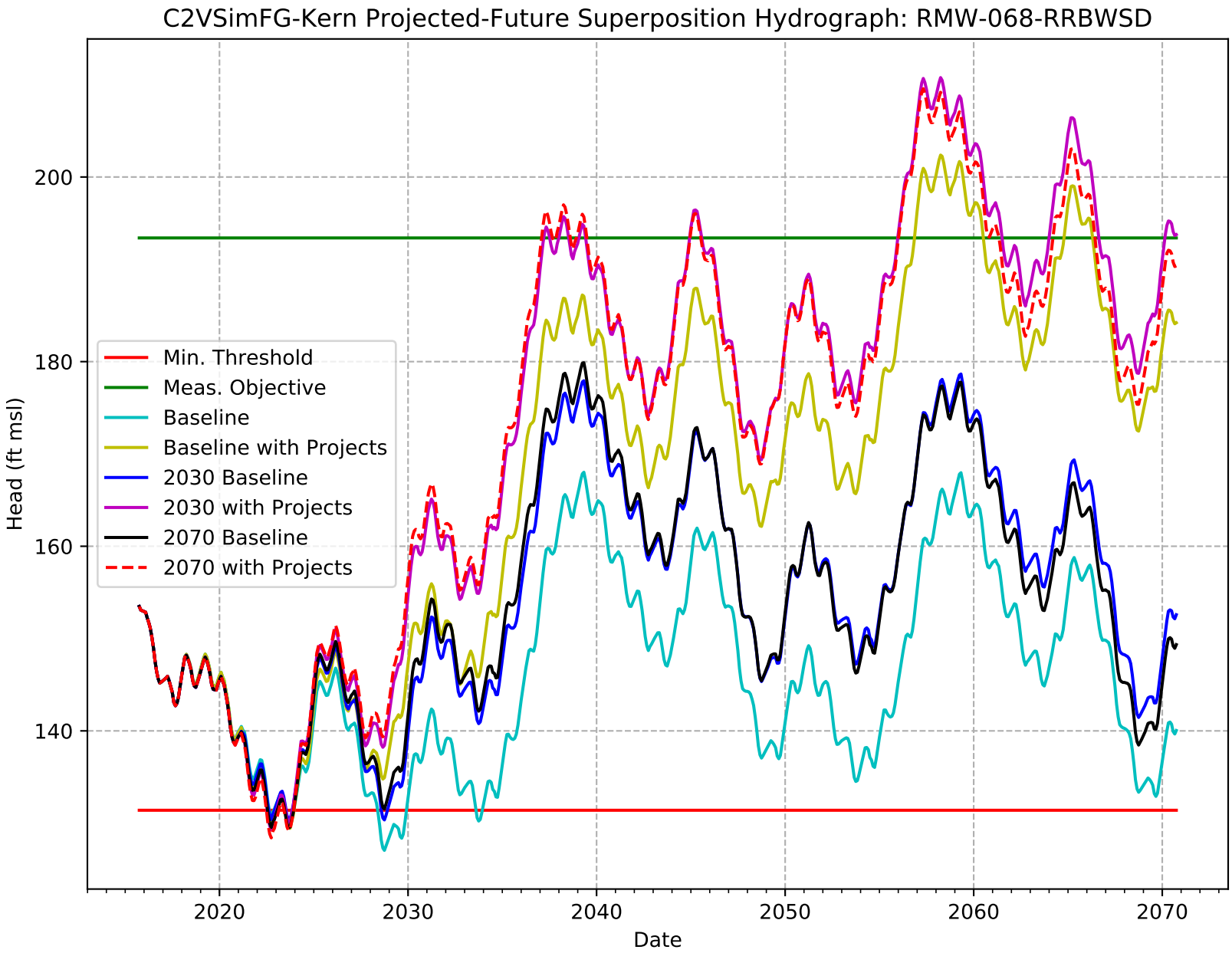

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-063-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
260
240
220
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date

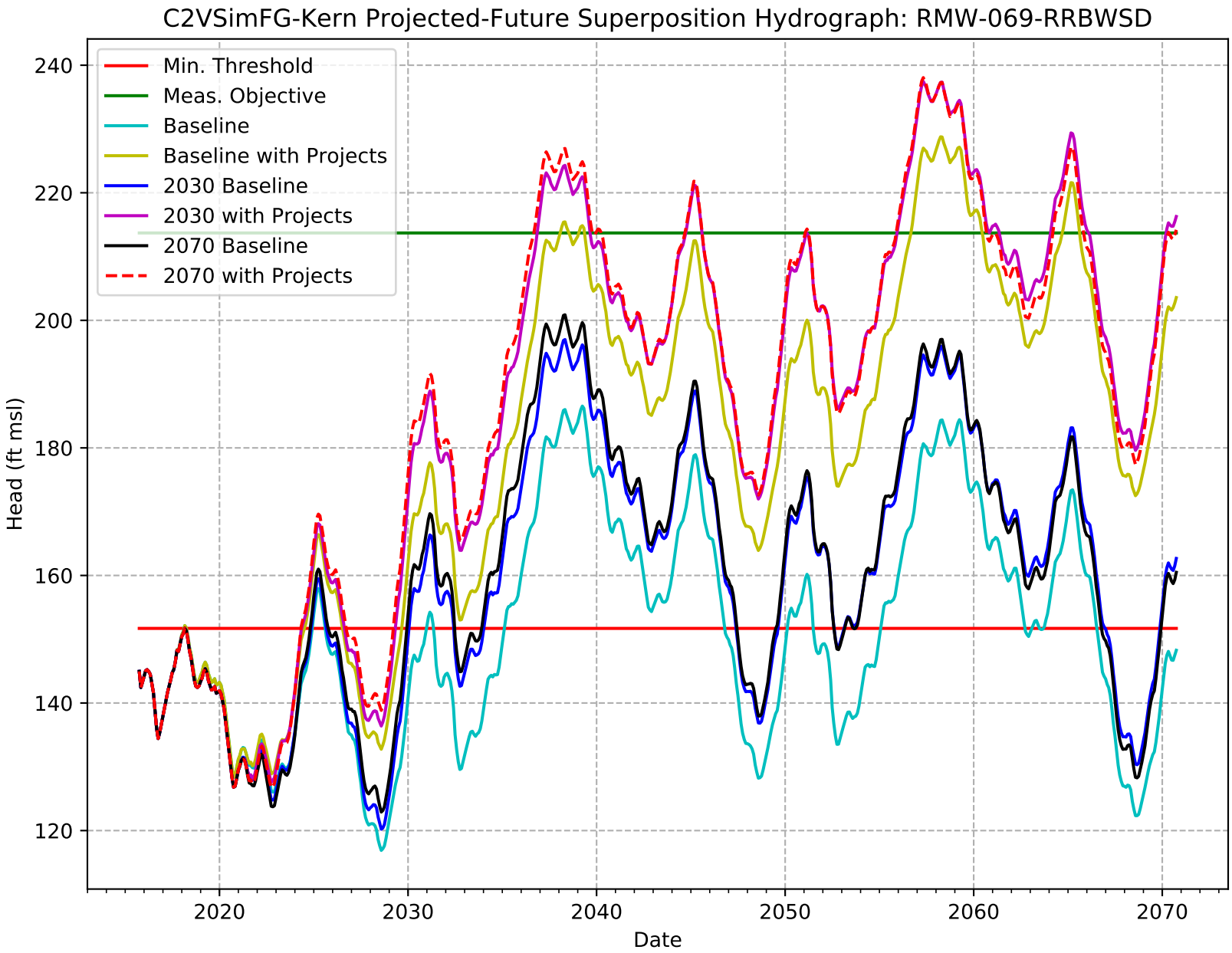

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-064-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

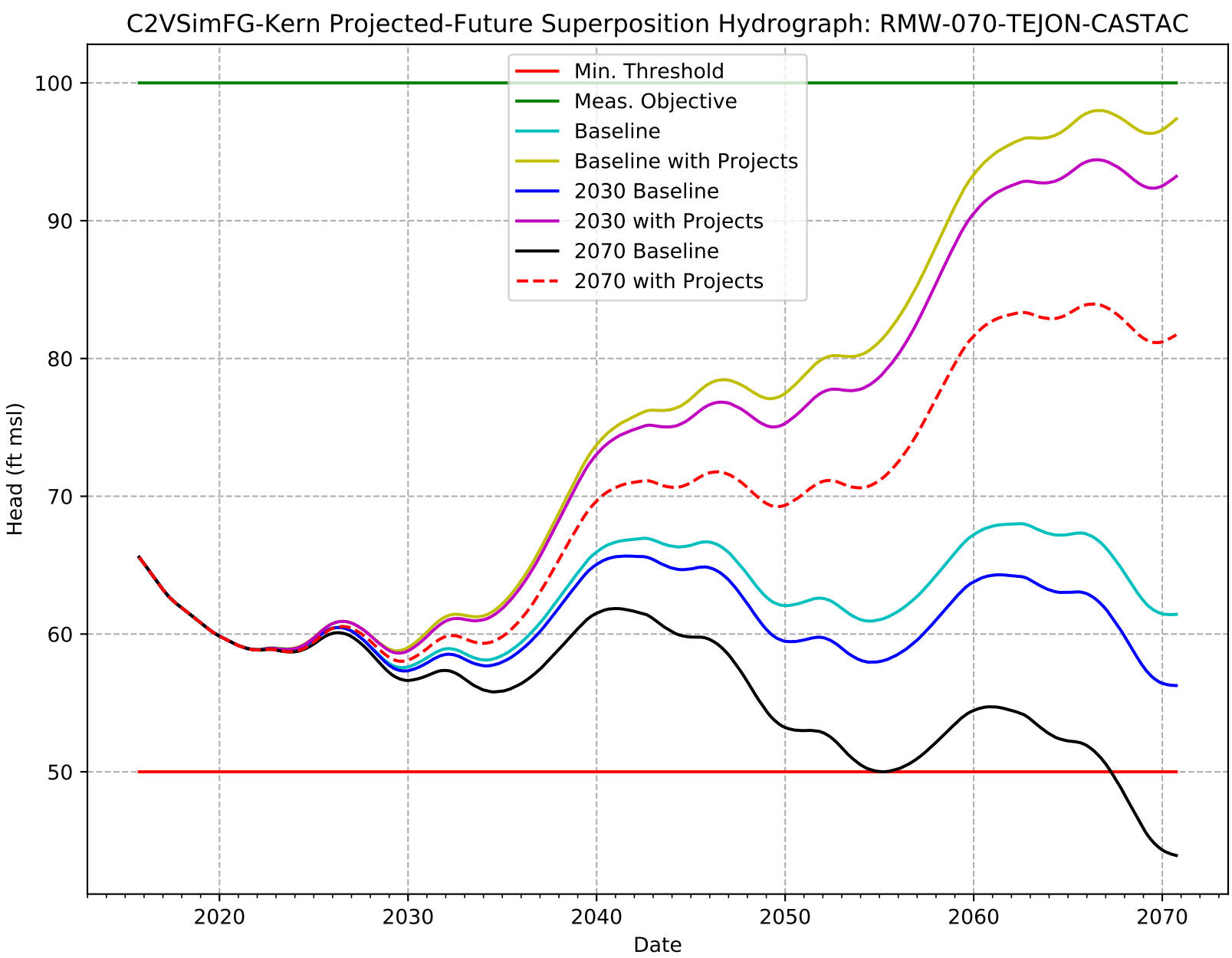

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-065-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
175
150
125
100
75
50
25
2020
2030
2040
2050
2060
2070
Date

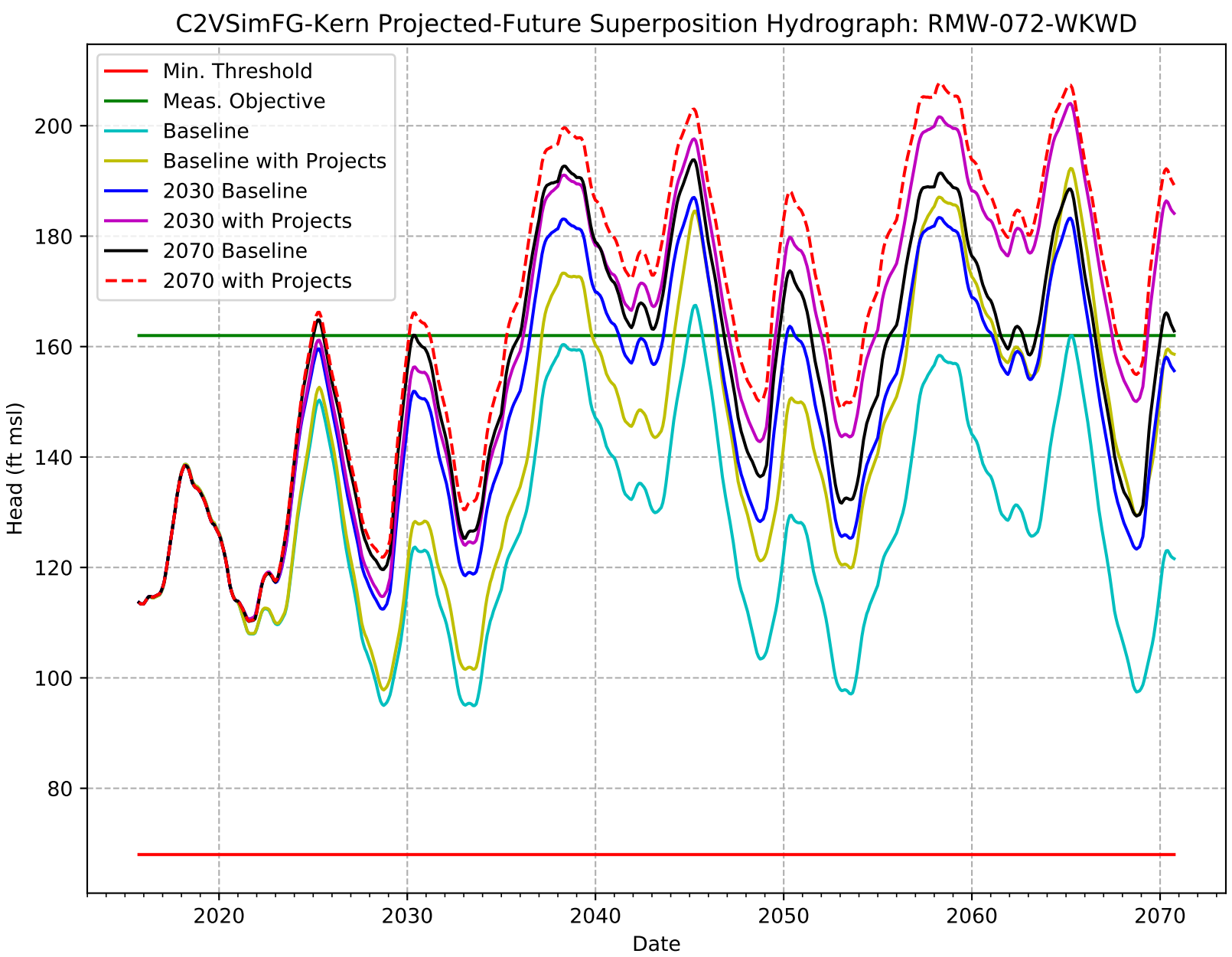

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-066-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
225
200
175
150
125
100
75
2020
2030
2040
2050
2060
2070
Date

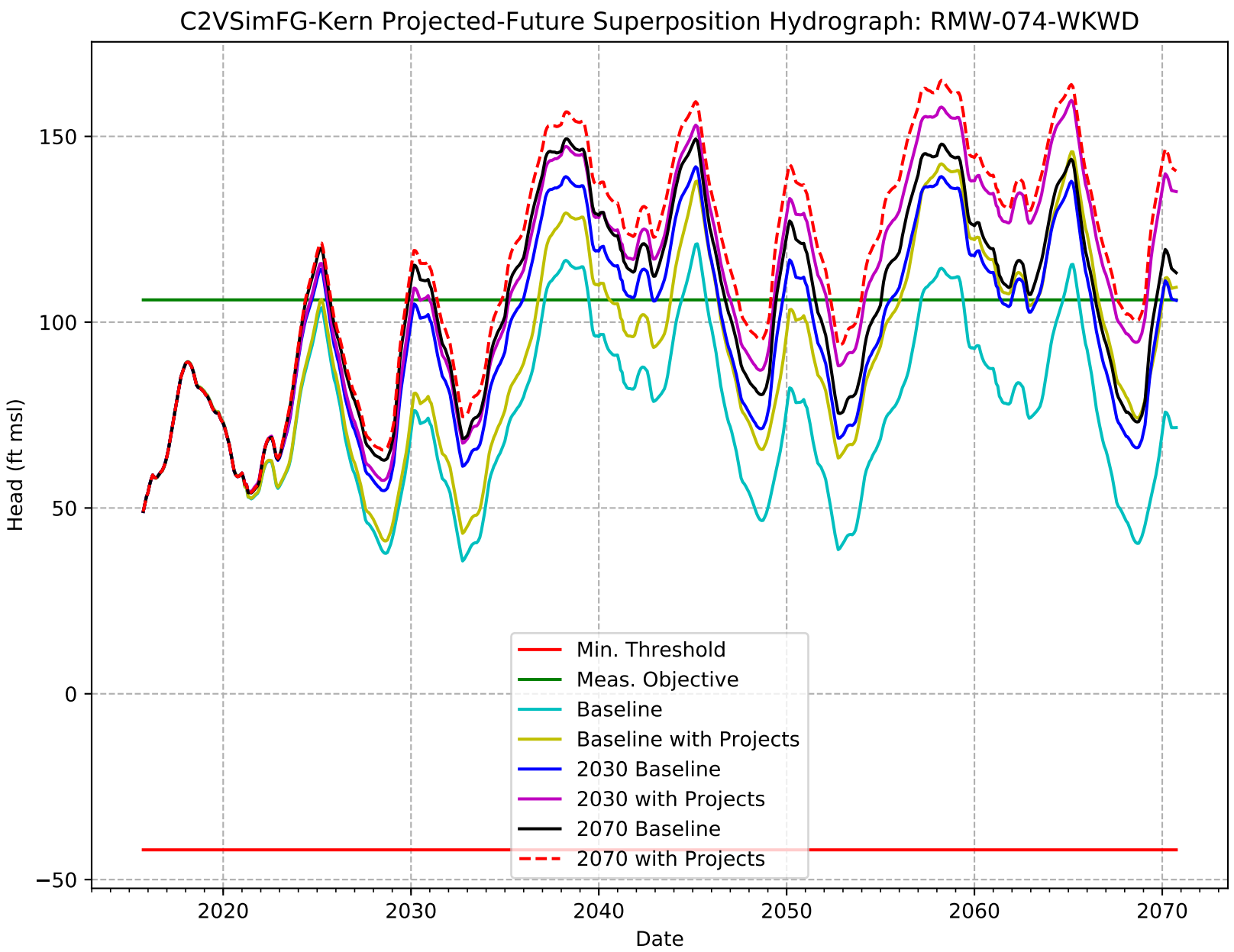

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-067-RRBWSD
Head (ft msl)
300
275
250
225
200
175
150
125
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

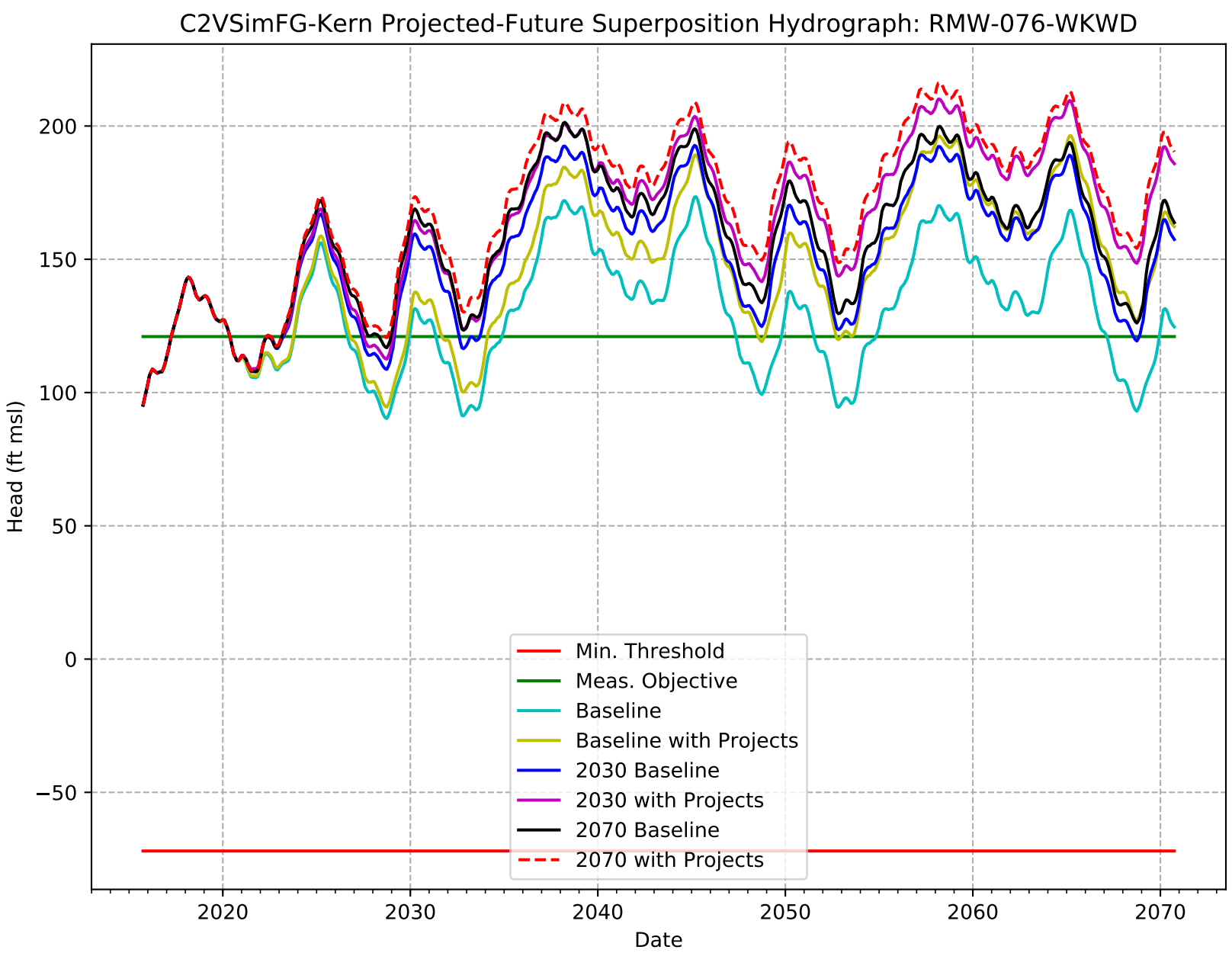

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-068-RRBWSD
Head (ft msl)
200
180
160
140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

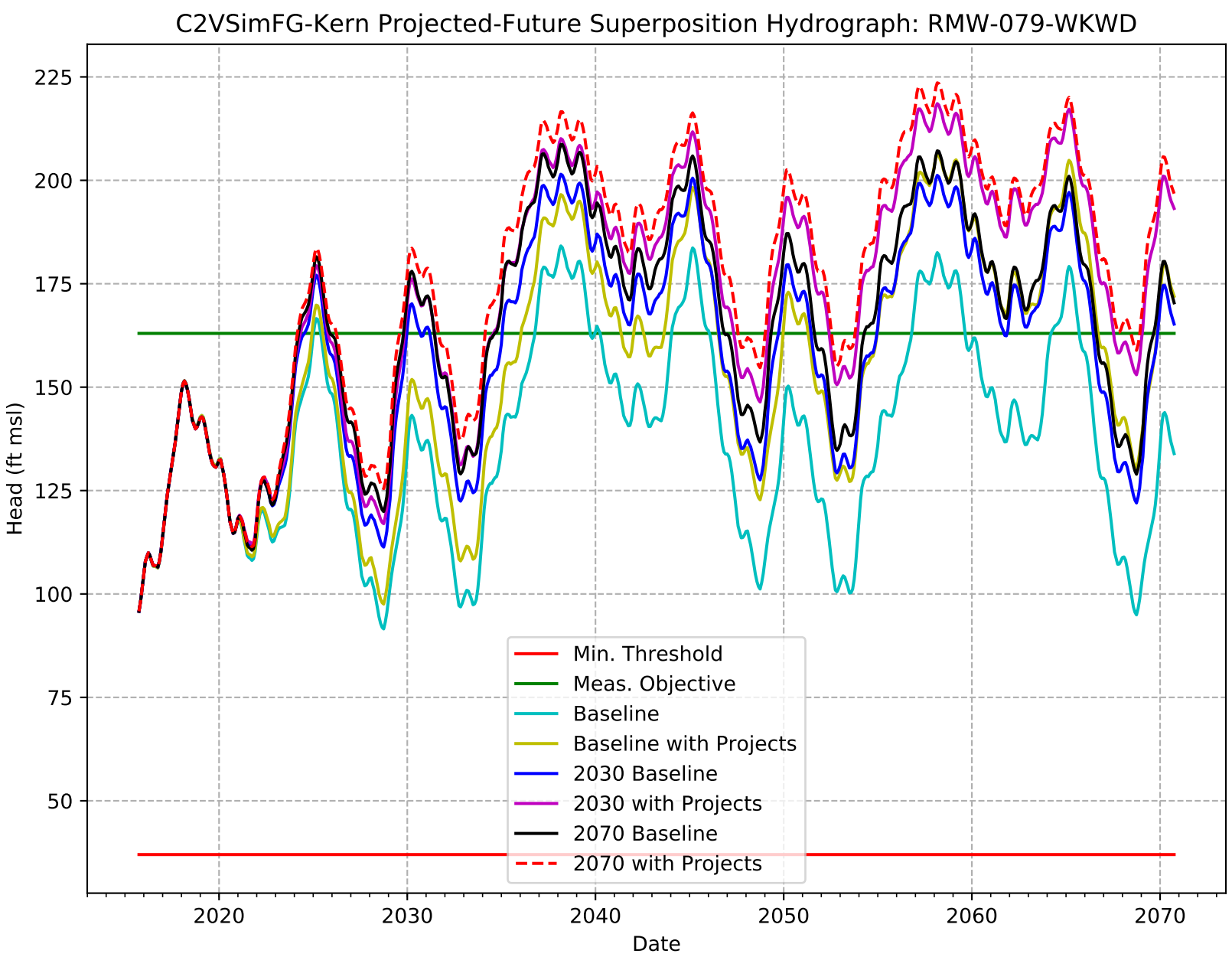

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-069-RRBWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
240
220
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date

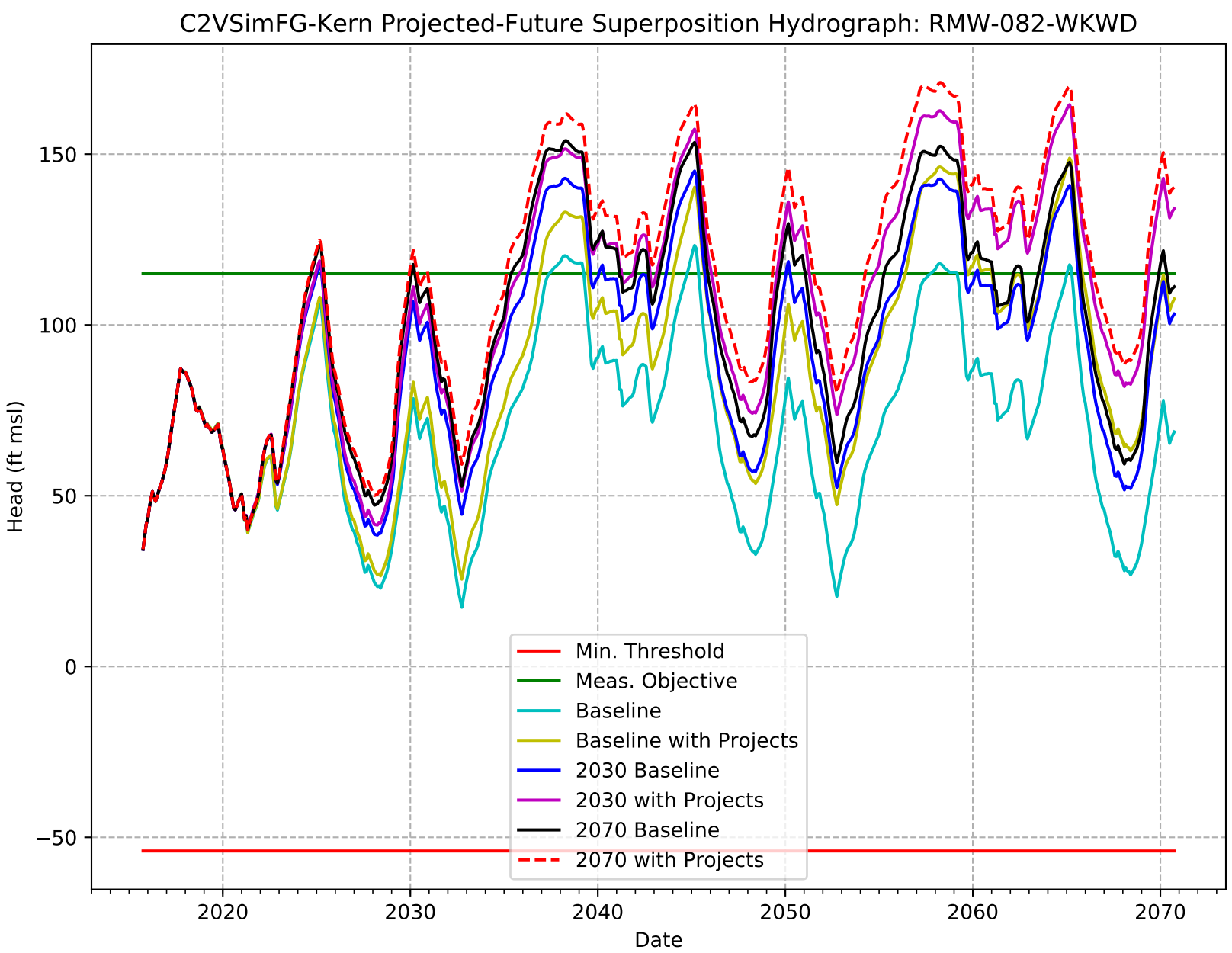

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-070-TEJON-CASTAC
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
90
80
70
60
50
2020
2030
2040
2050
2060
2070
Date

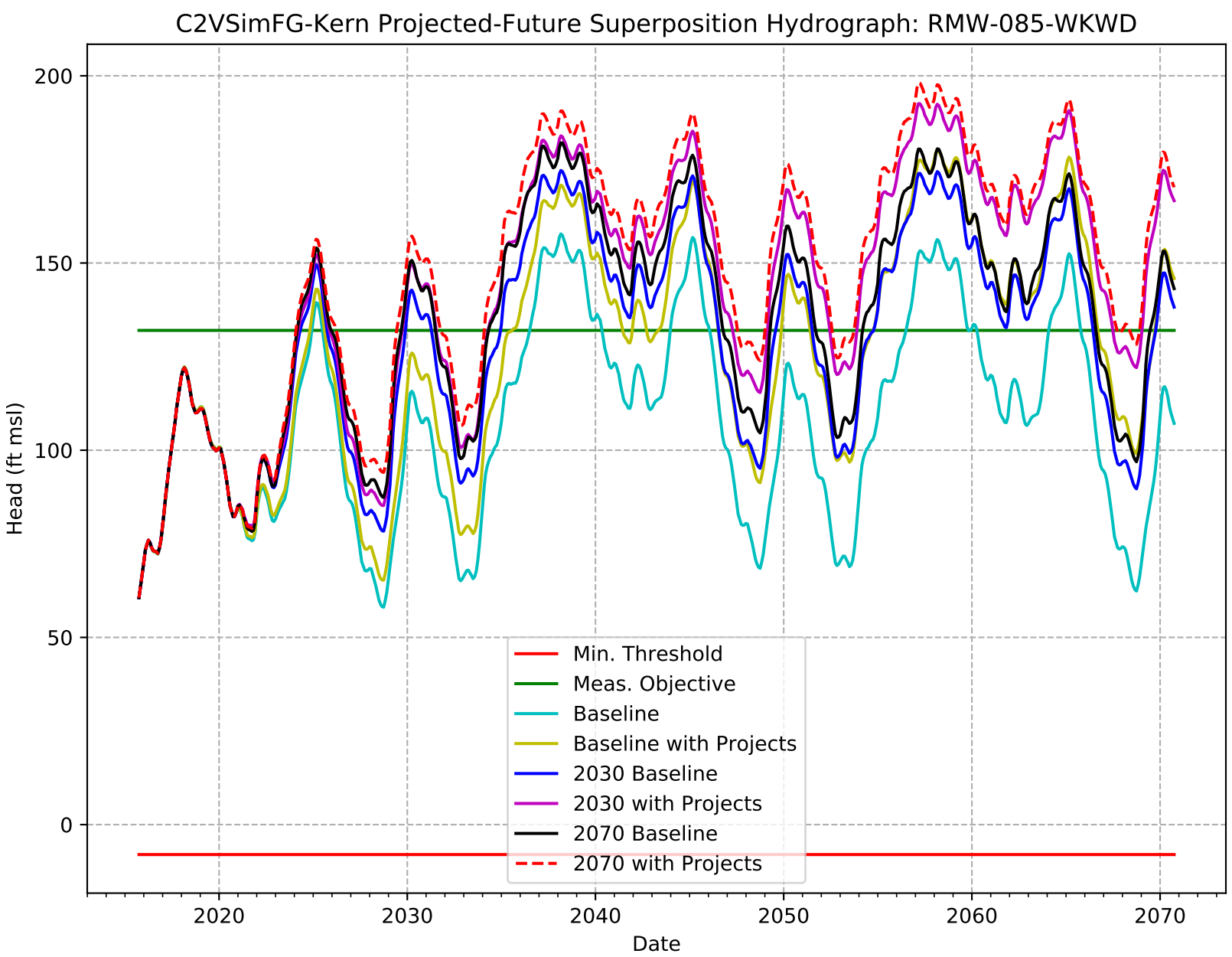

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-072-WKWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date

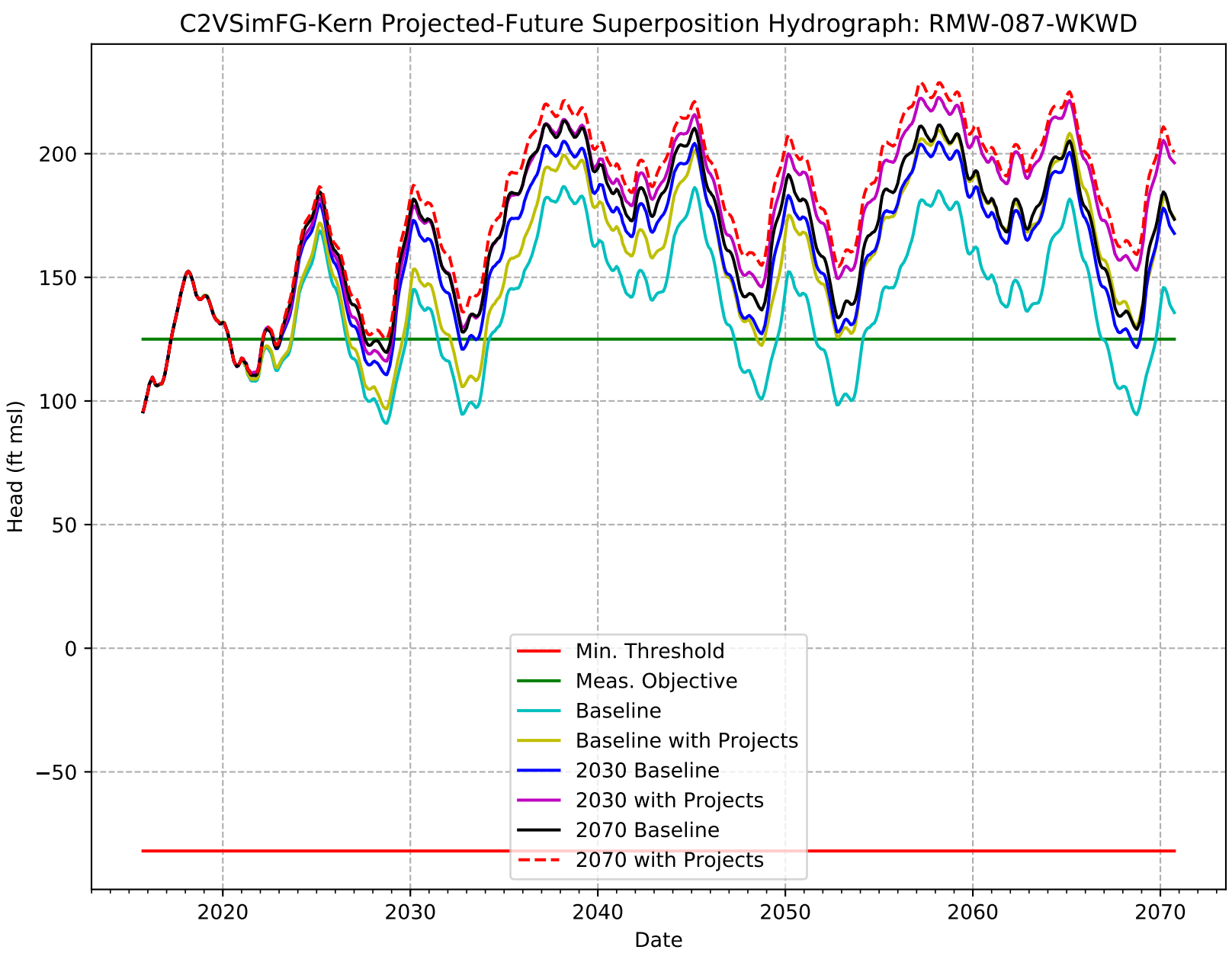

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-074-WKWD
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

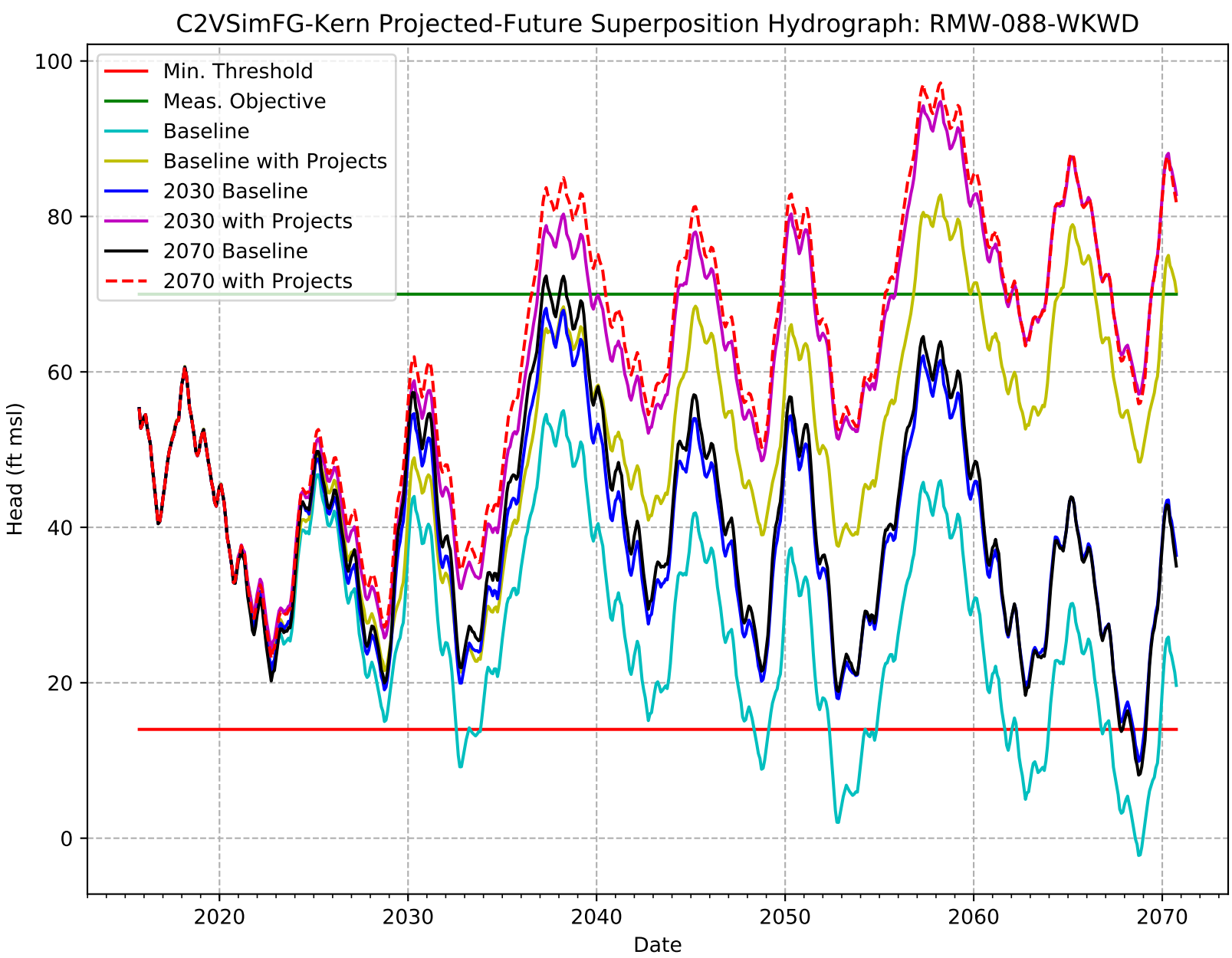

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-076-WKWD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

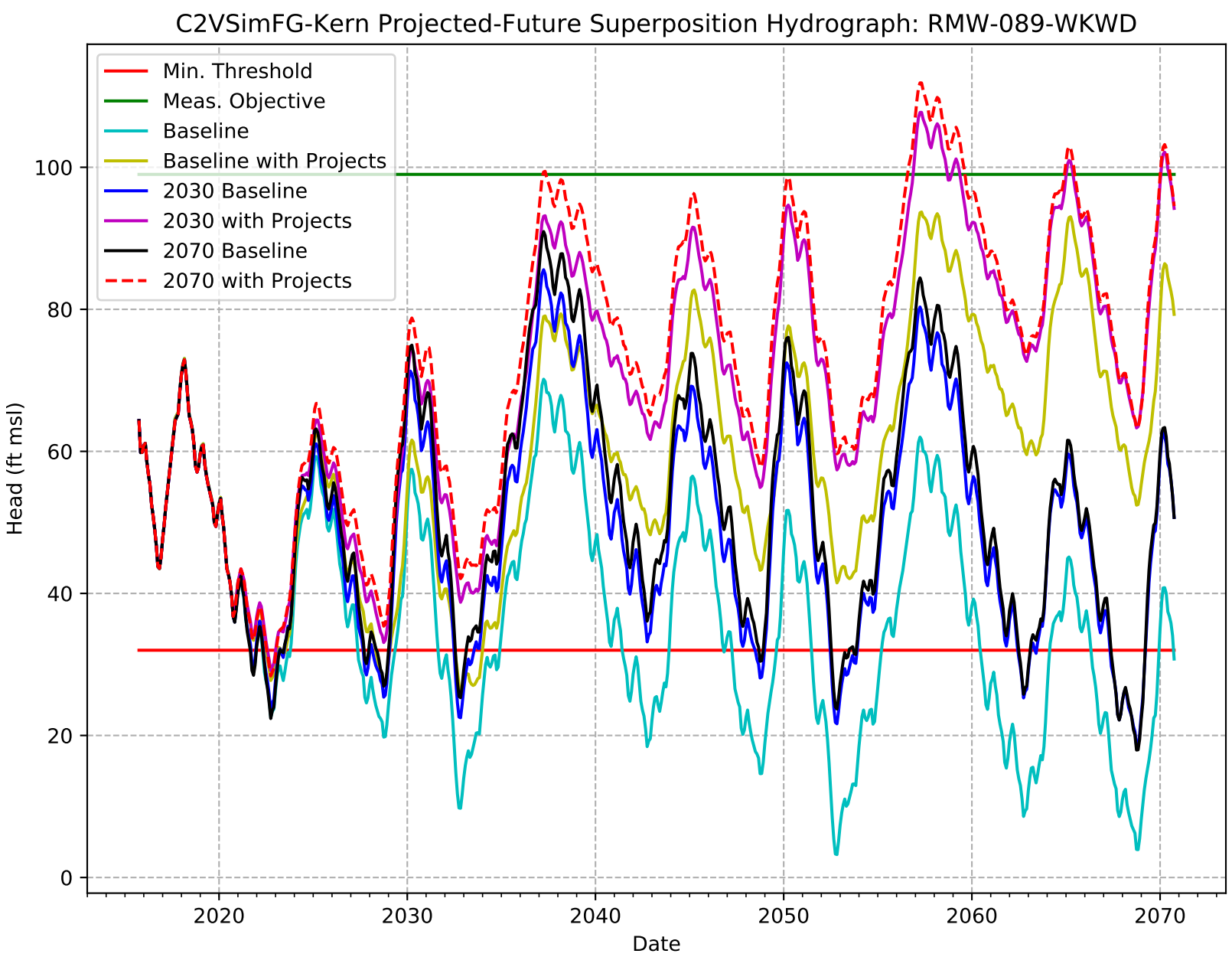

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-079-WKWD
Head (ft msl)
225
200
175
150
125
100
75
50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

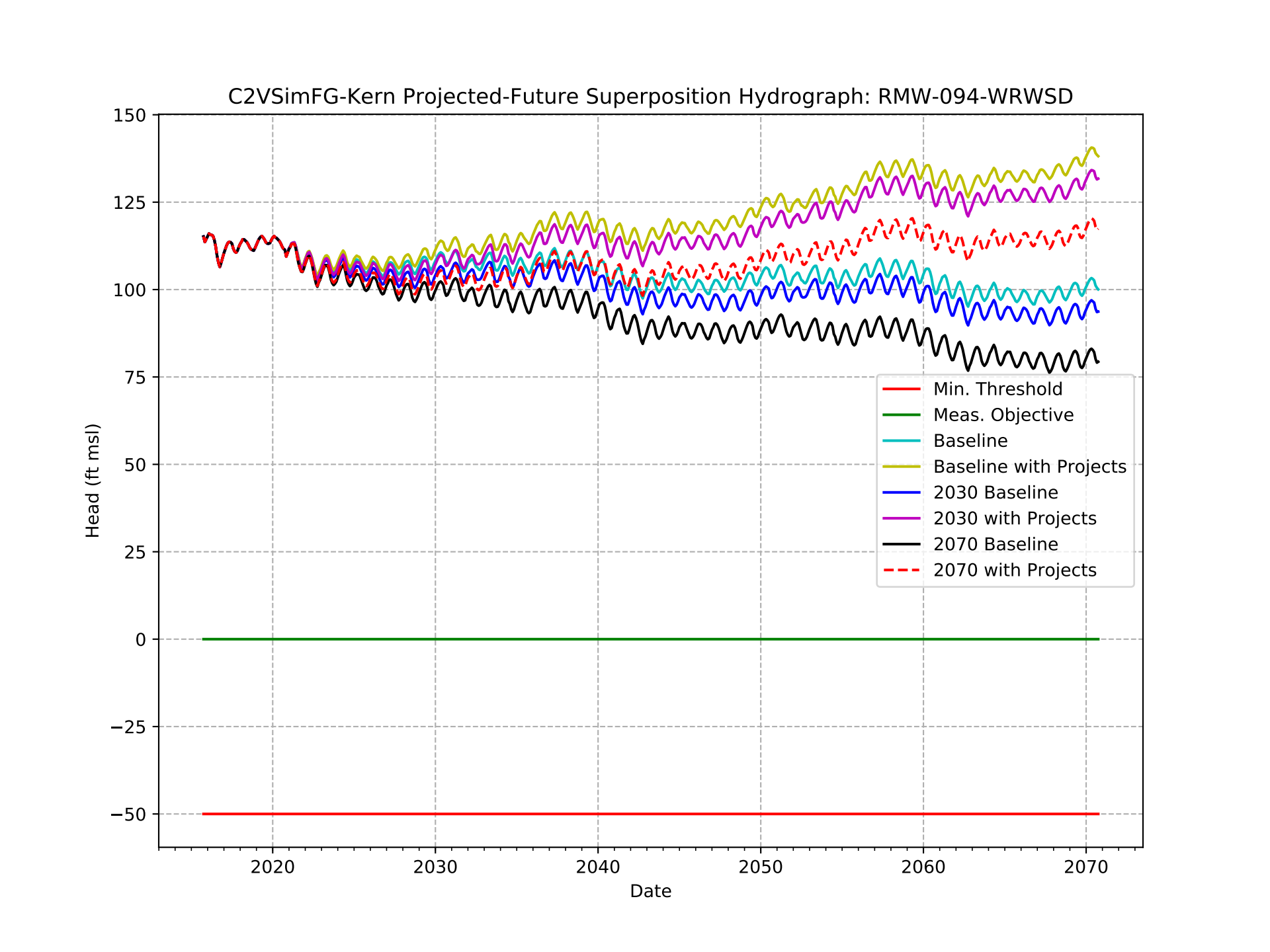

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-082-WKWD
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

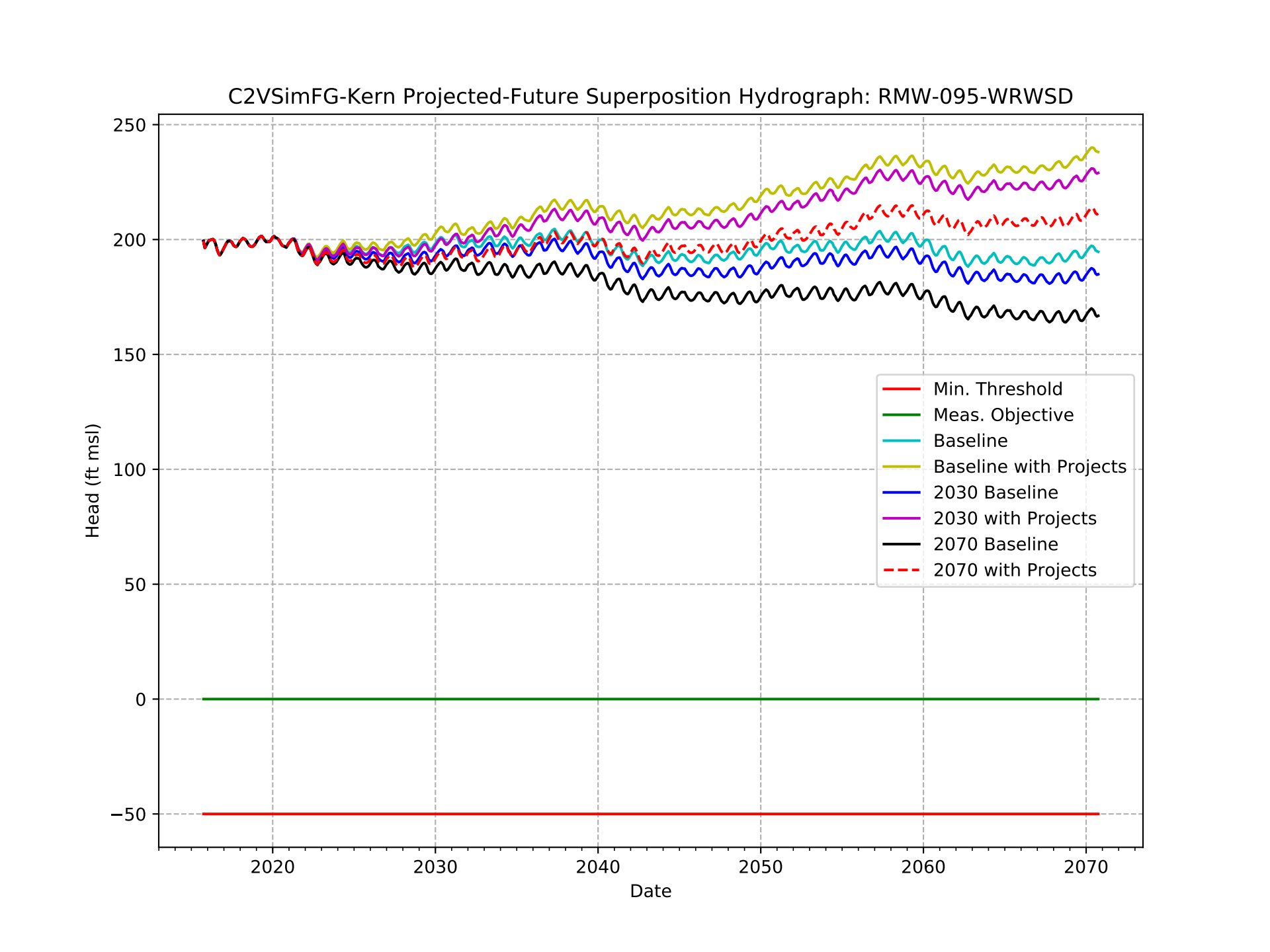

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-085-WKWD
Head (ft msl)
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

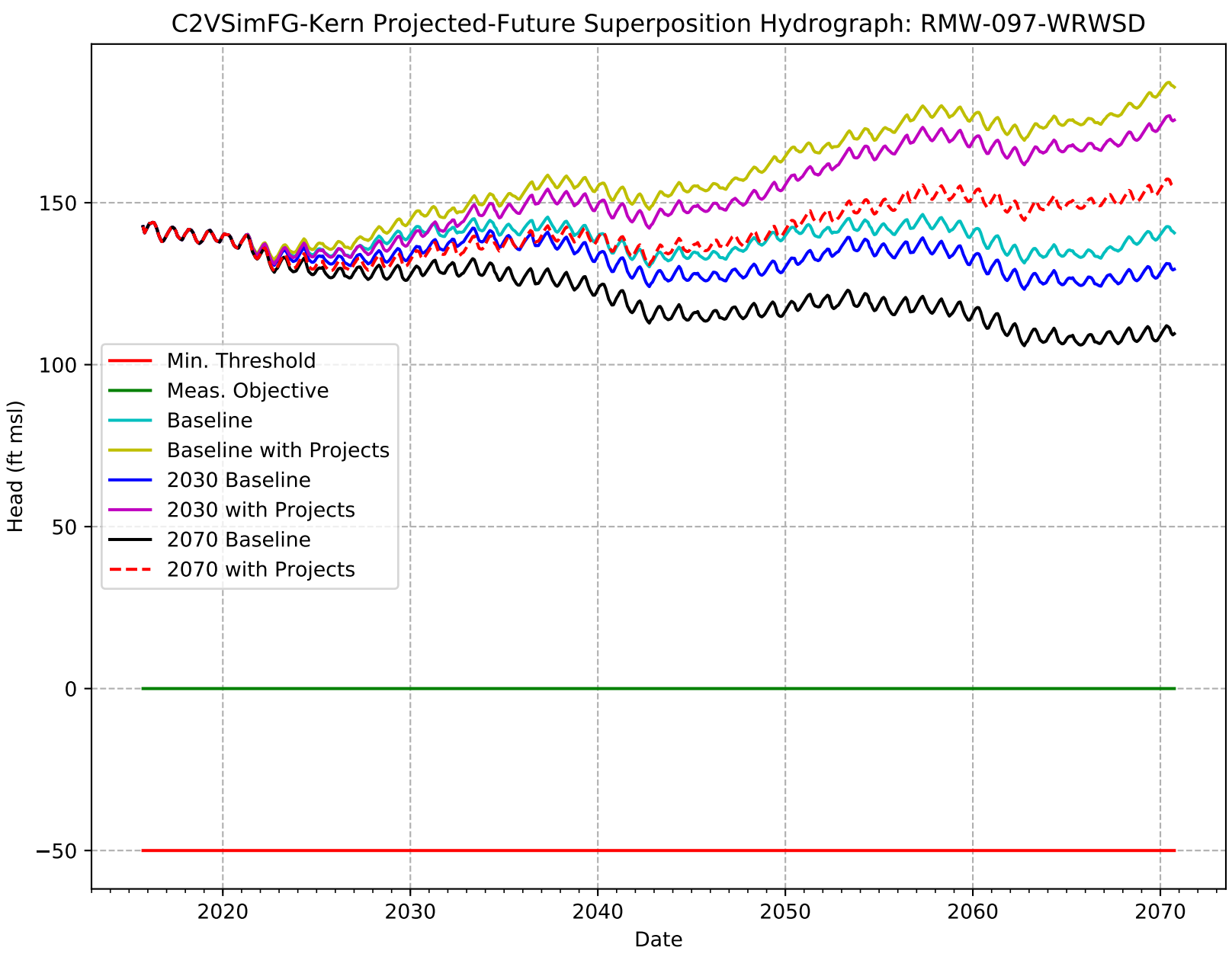

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-087-WKWD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

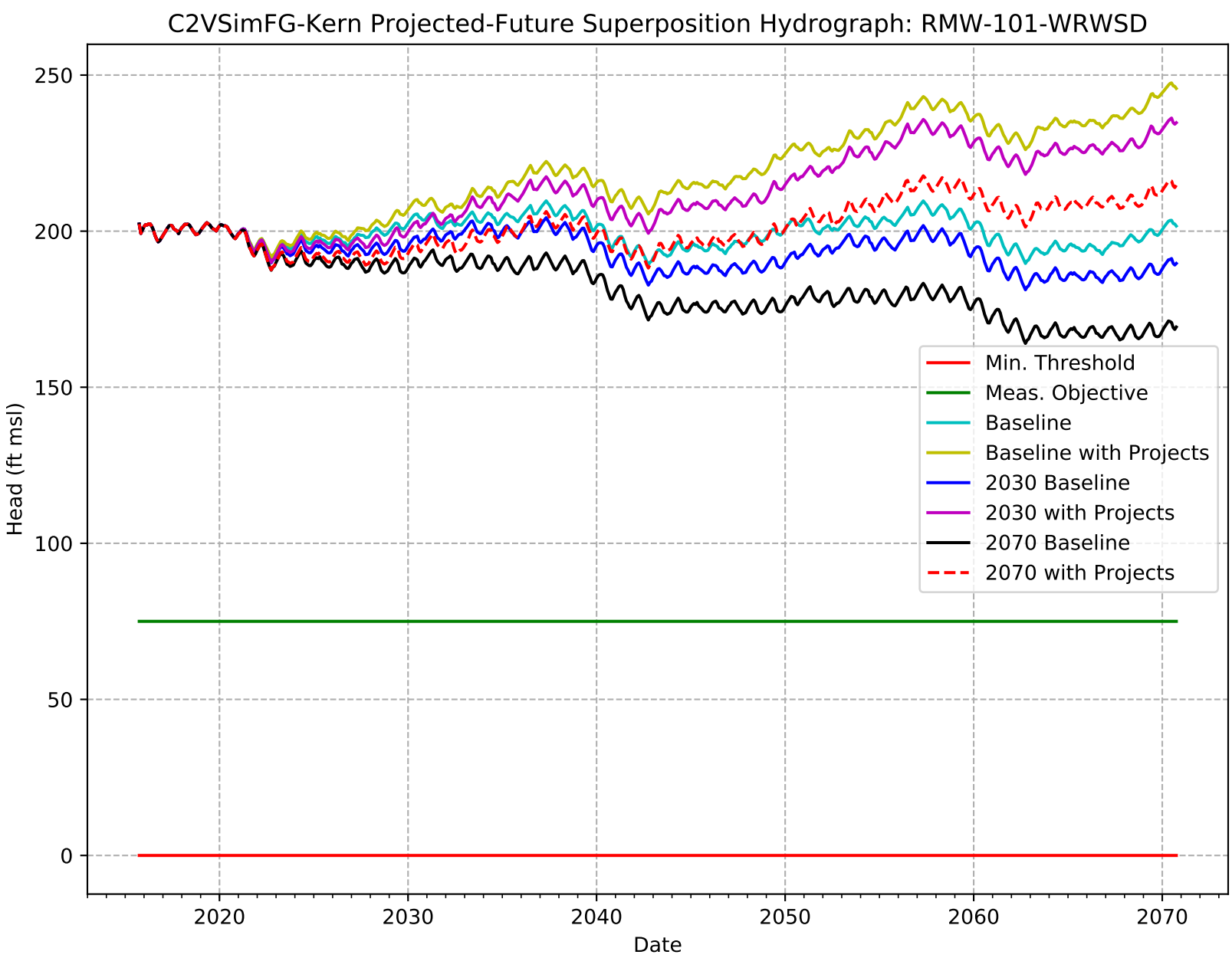

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-088-WKWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

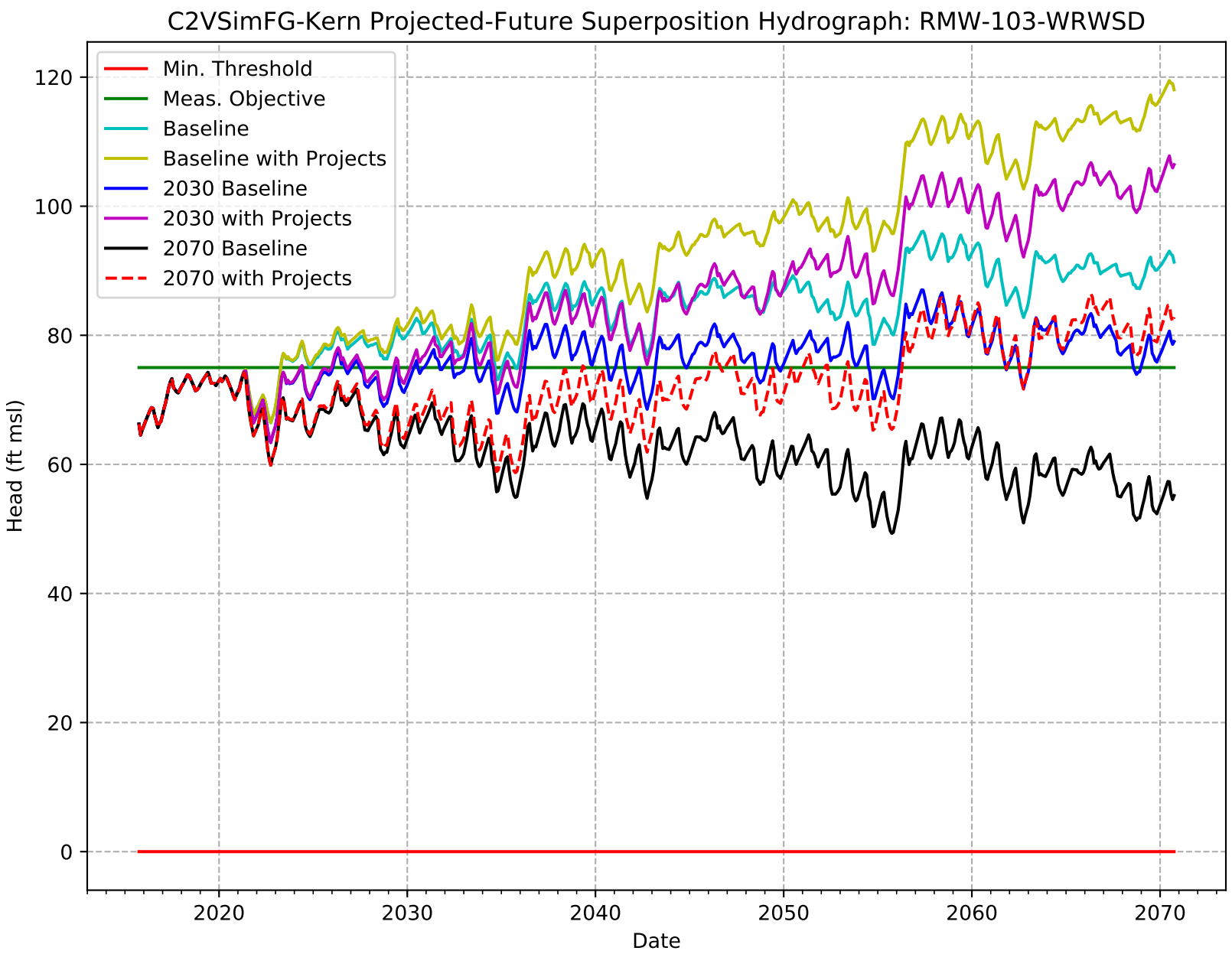

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-089-WKWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
0
20
40
60
80
100
2020
2030
2040
2050
2060
2070
Date

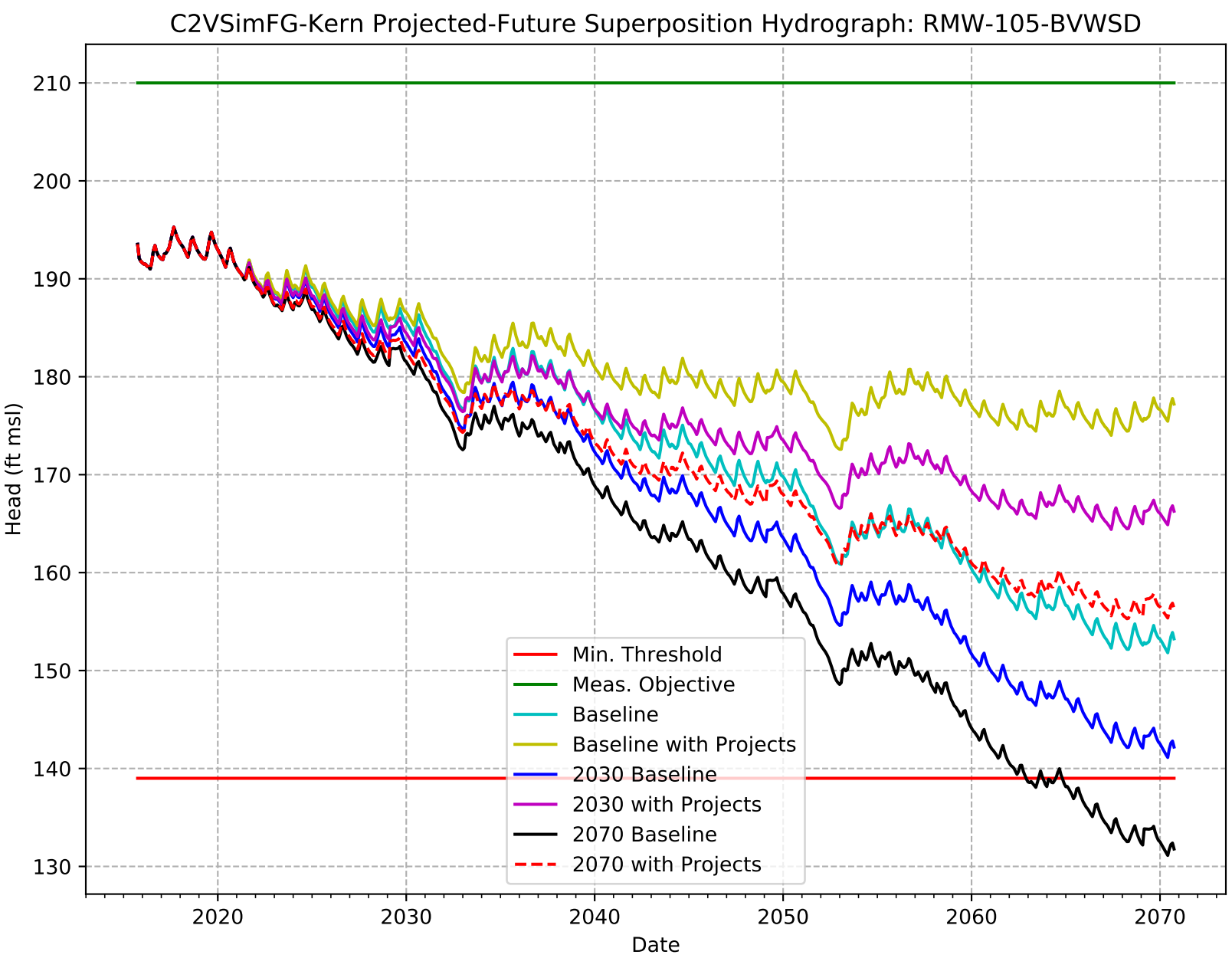

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-094-WRWSD
Head (ft msl)
Date
150
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

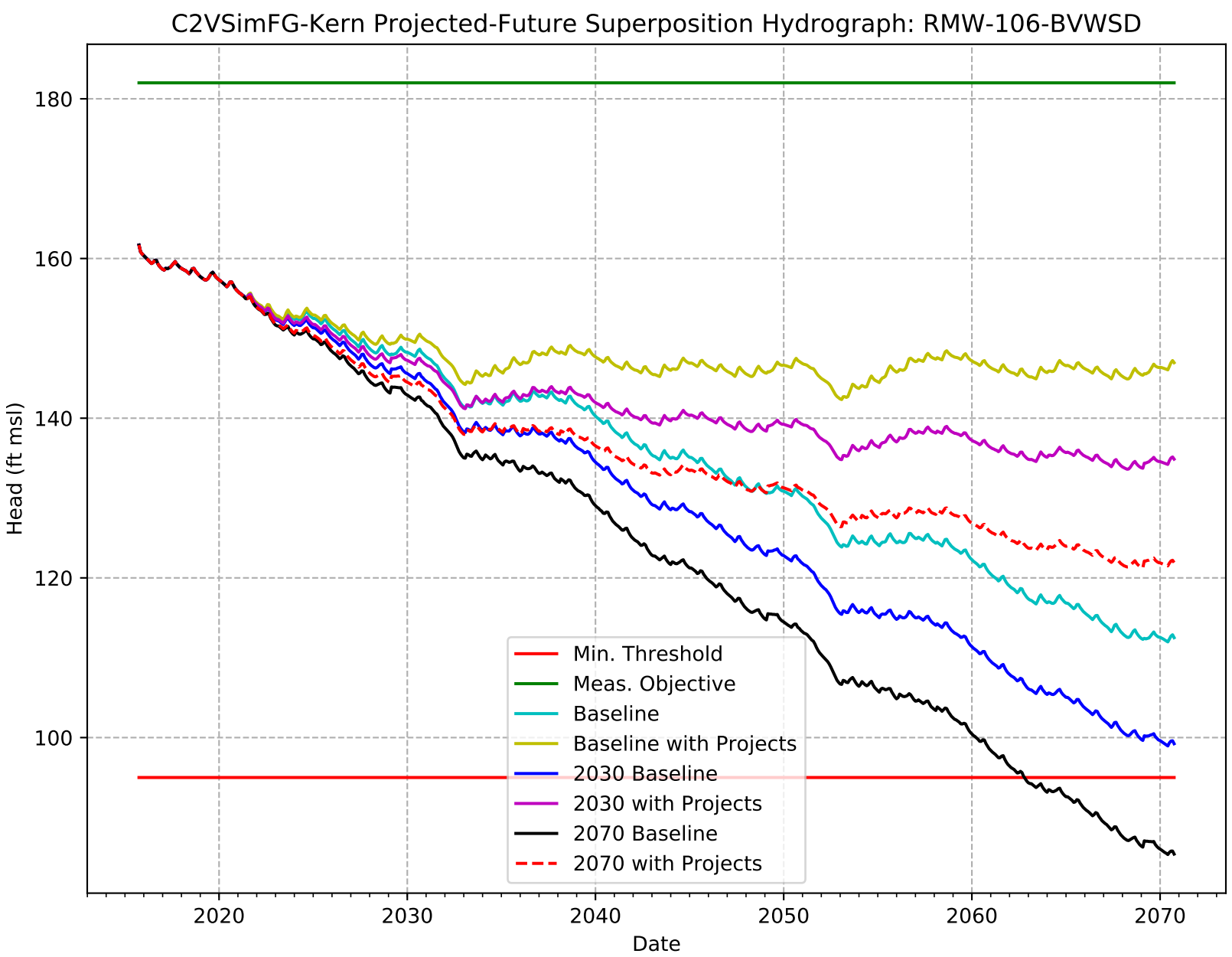

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-095-WRWSD
Head (ft msl)
250
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

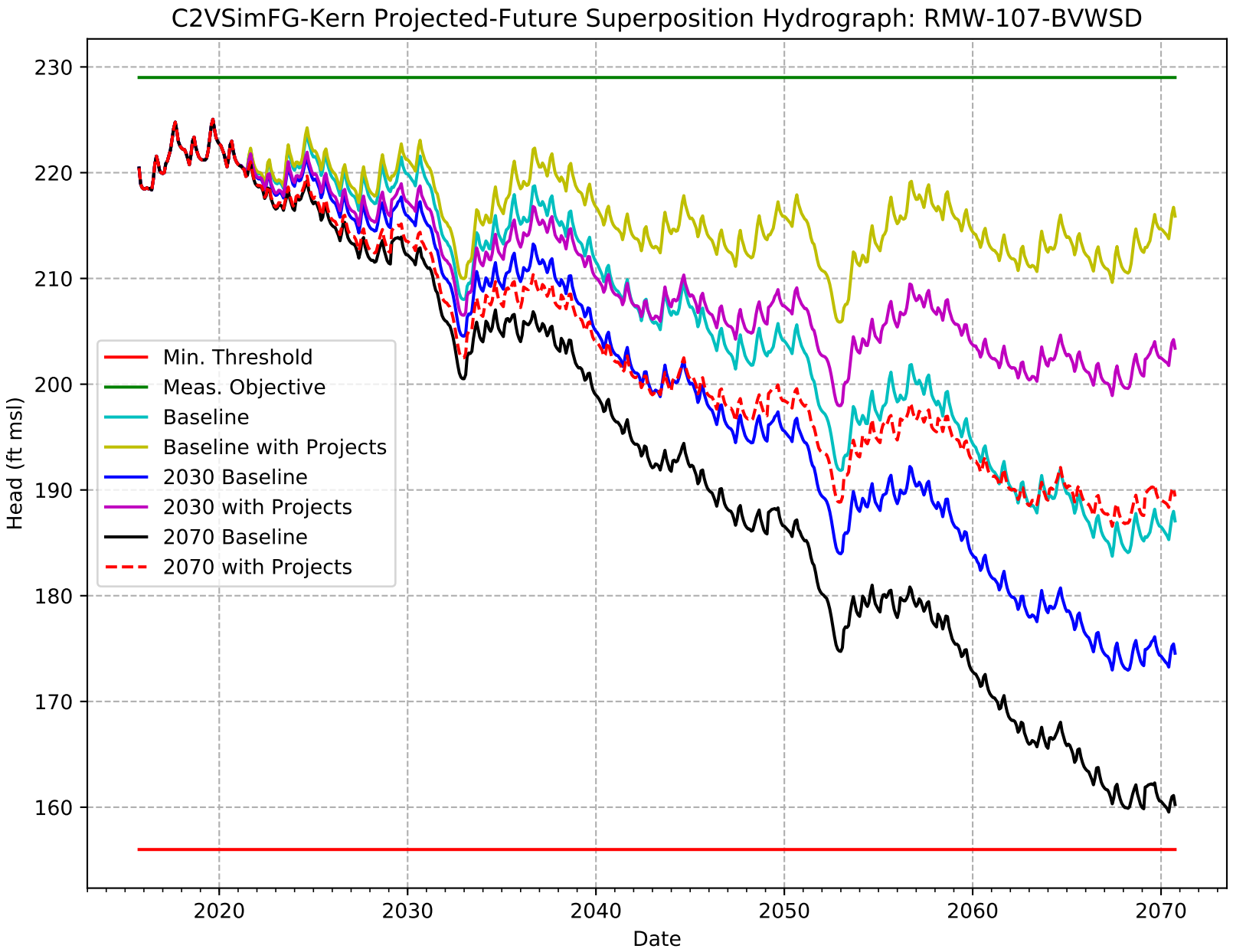

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-097-WRWSD
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

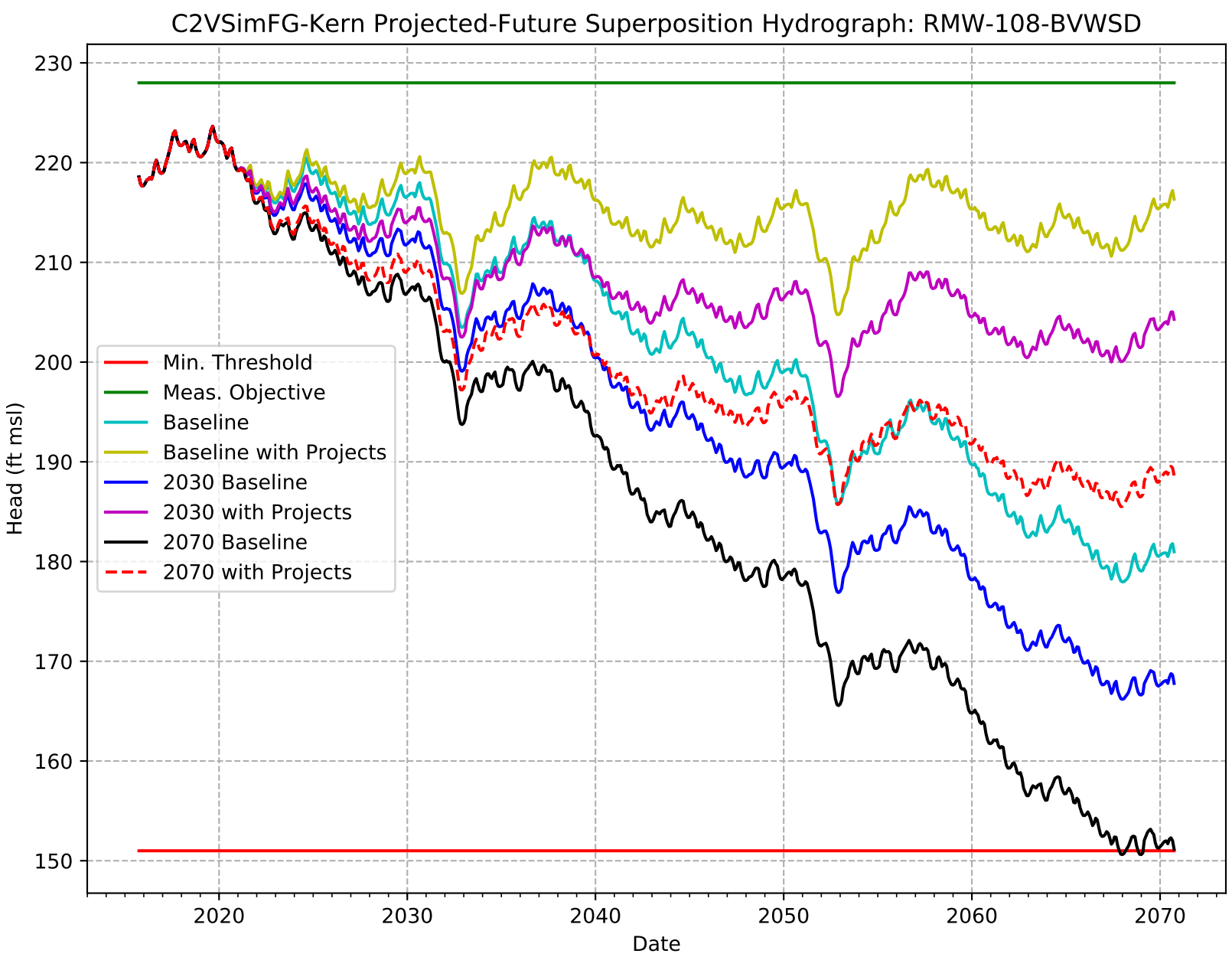

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-101-WRWSD
Head (ft msl)
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

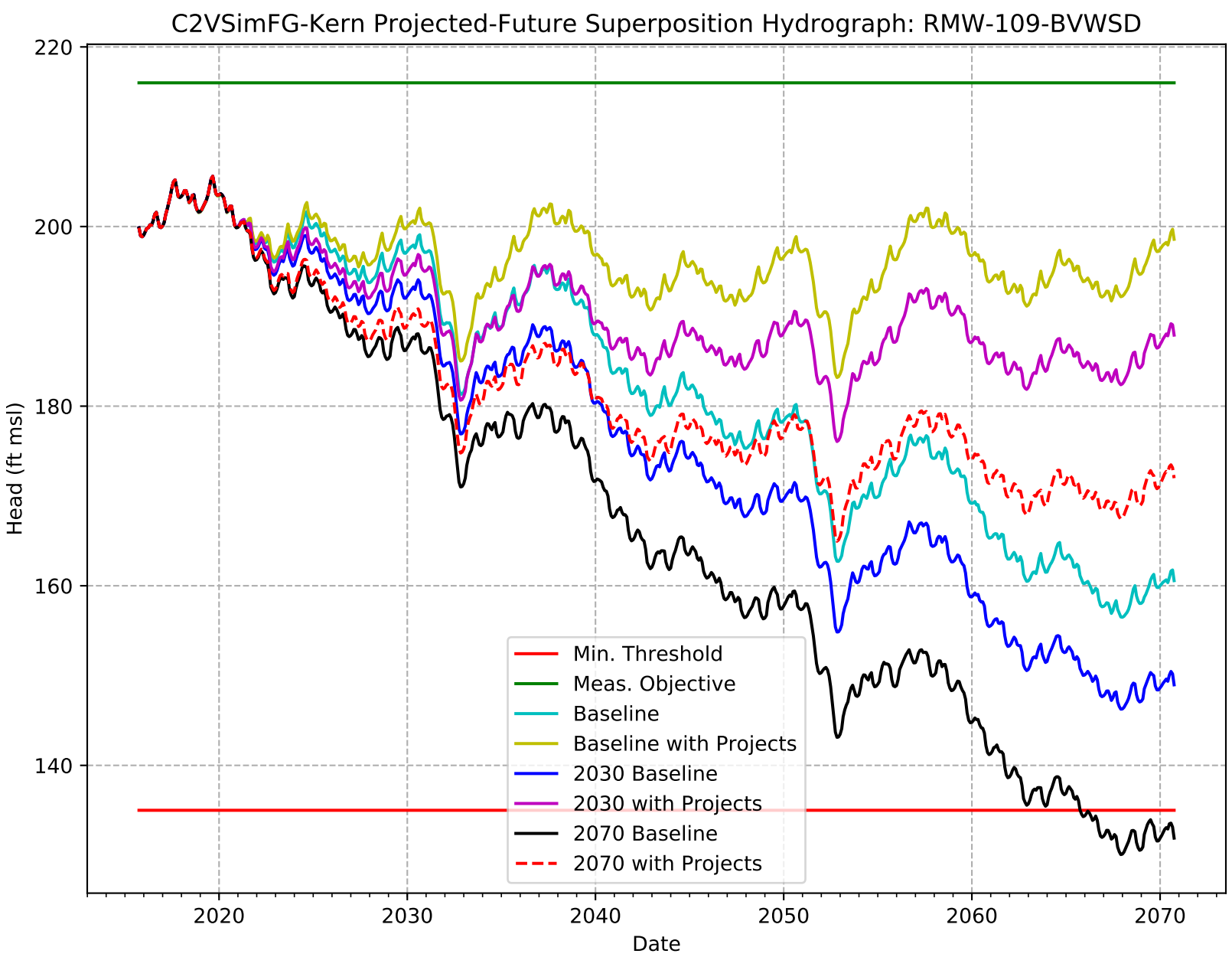

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-103-WRWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

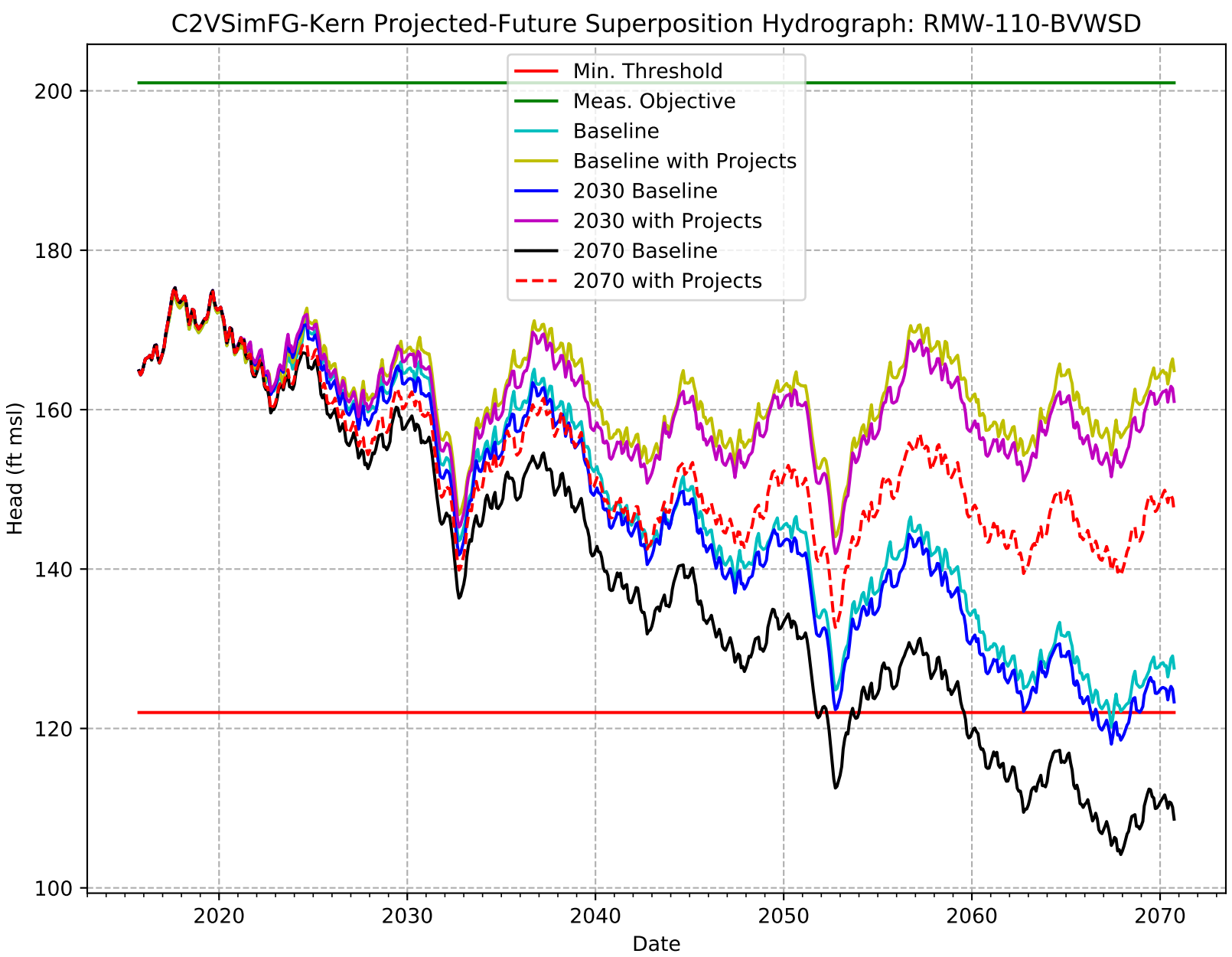

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-105-BVWSD
Head (ft msl)
210
200
190
180
170
160
150
140
130
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

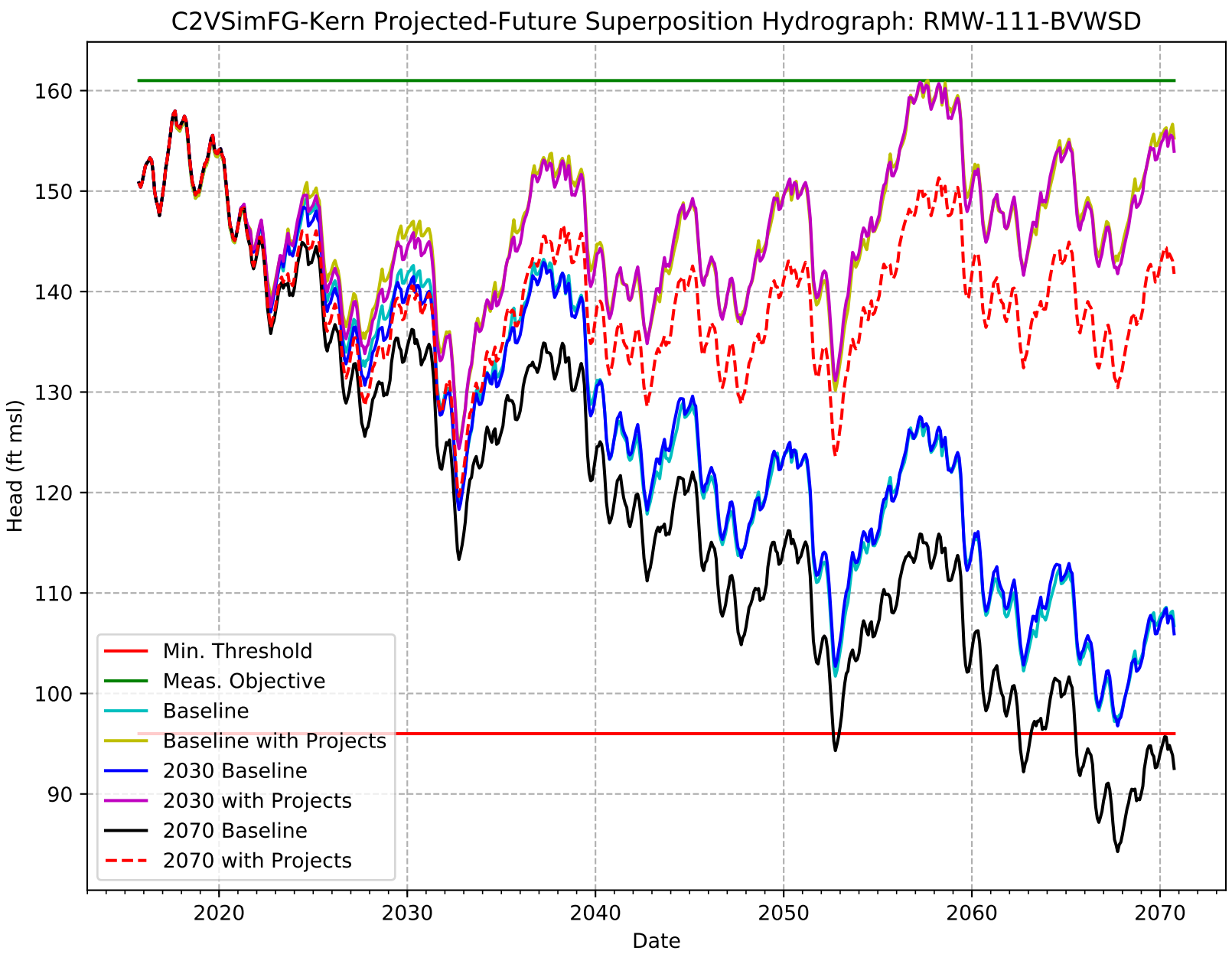

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-106-BVWSD
Head (ft msl)
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

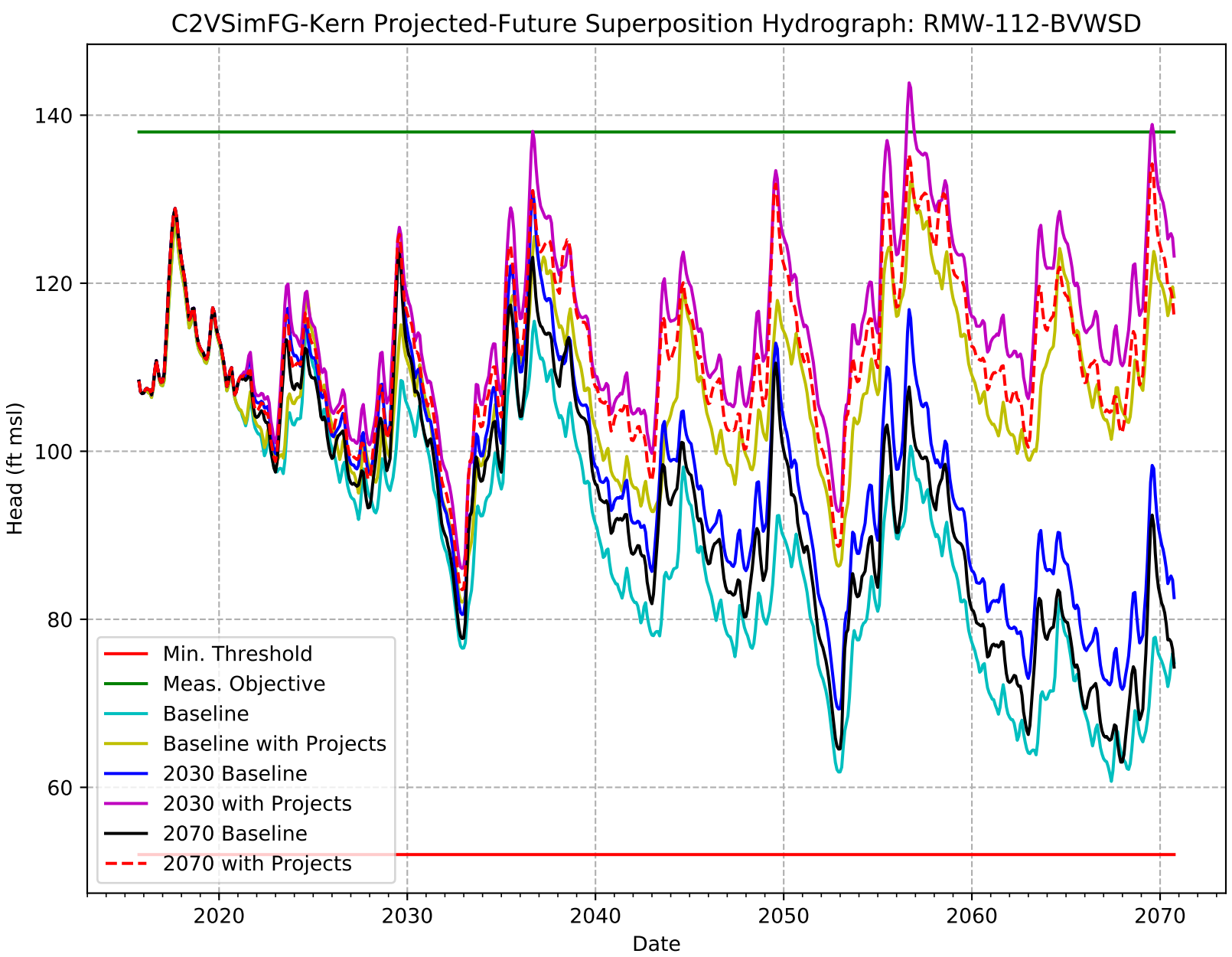

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-107-BVWSD
Head (ft msl)
Date
230
220
210
200
190
180
170
160
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

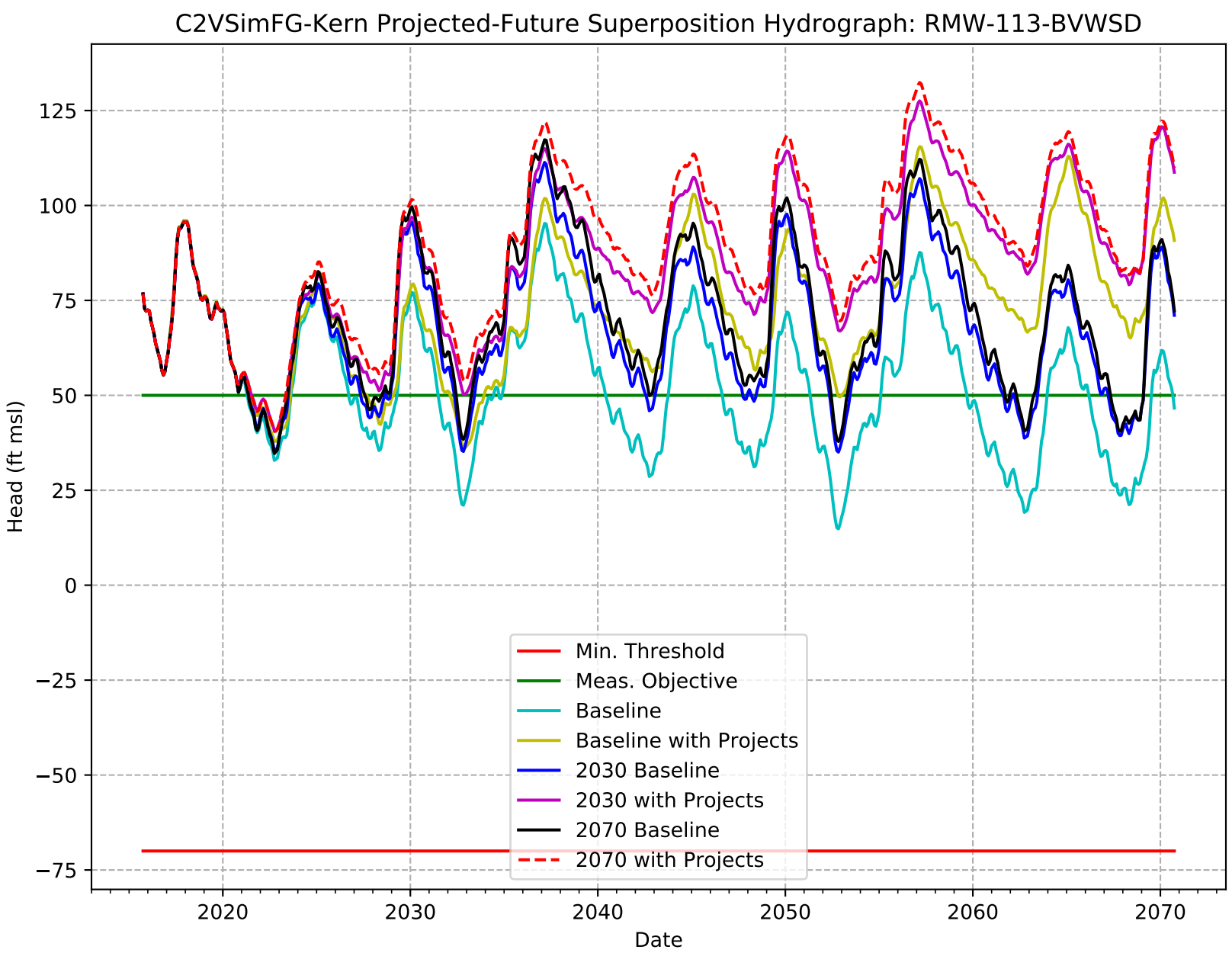

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-108-BVWSD
Head (ft msl)
Date
230
220
210
200
190
180
170
160
150
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

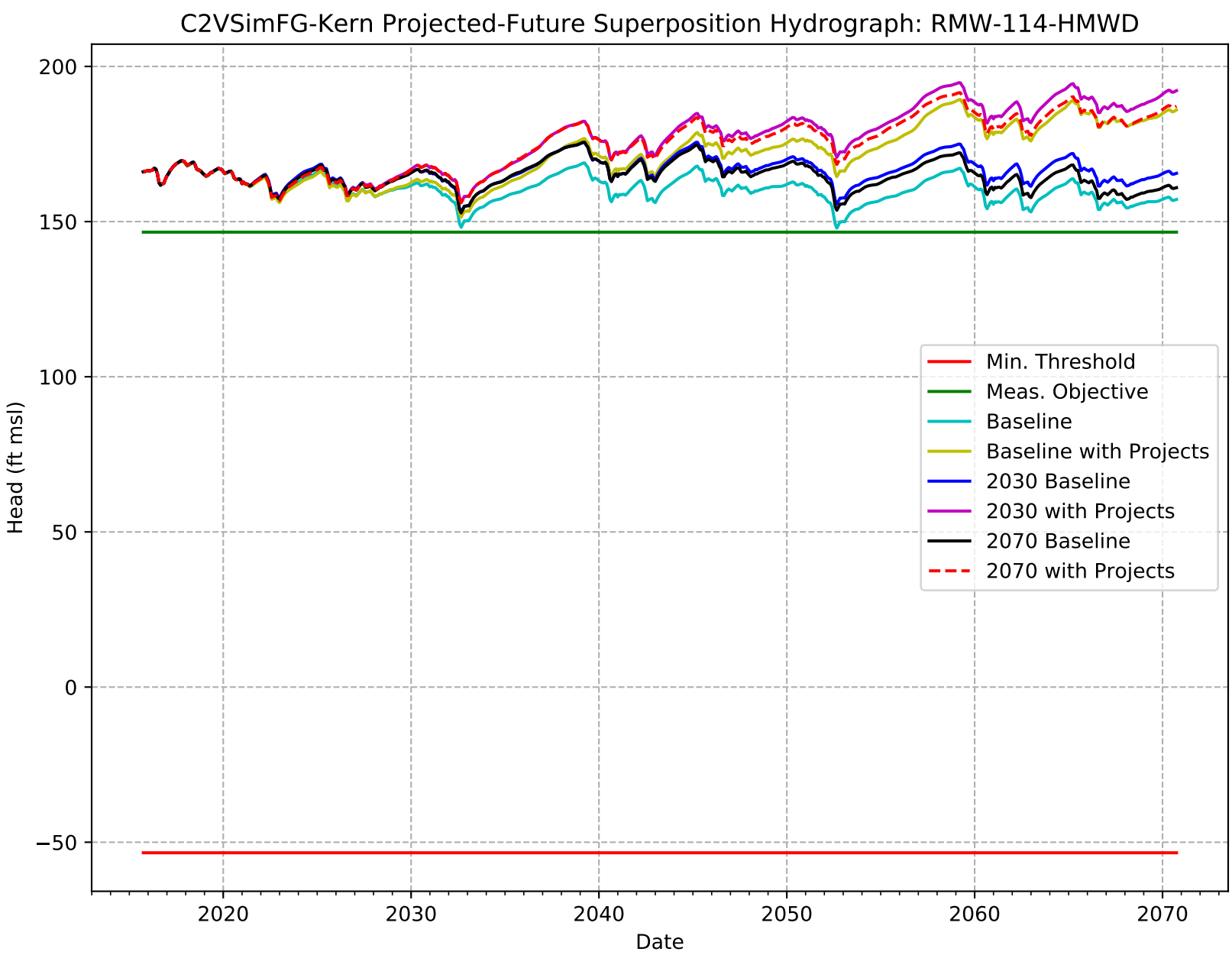

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-109-BVWSD
Head (ft msl)
220
200
180
160
140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

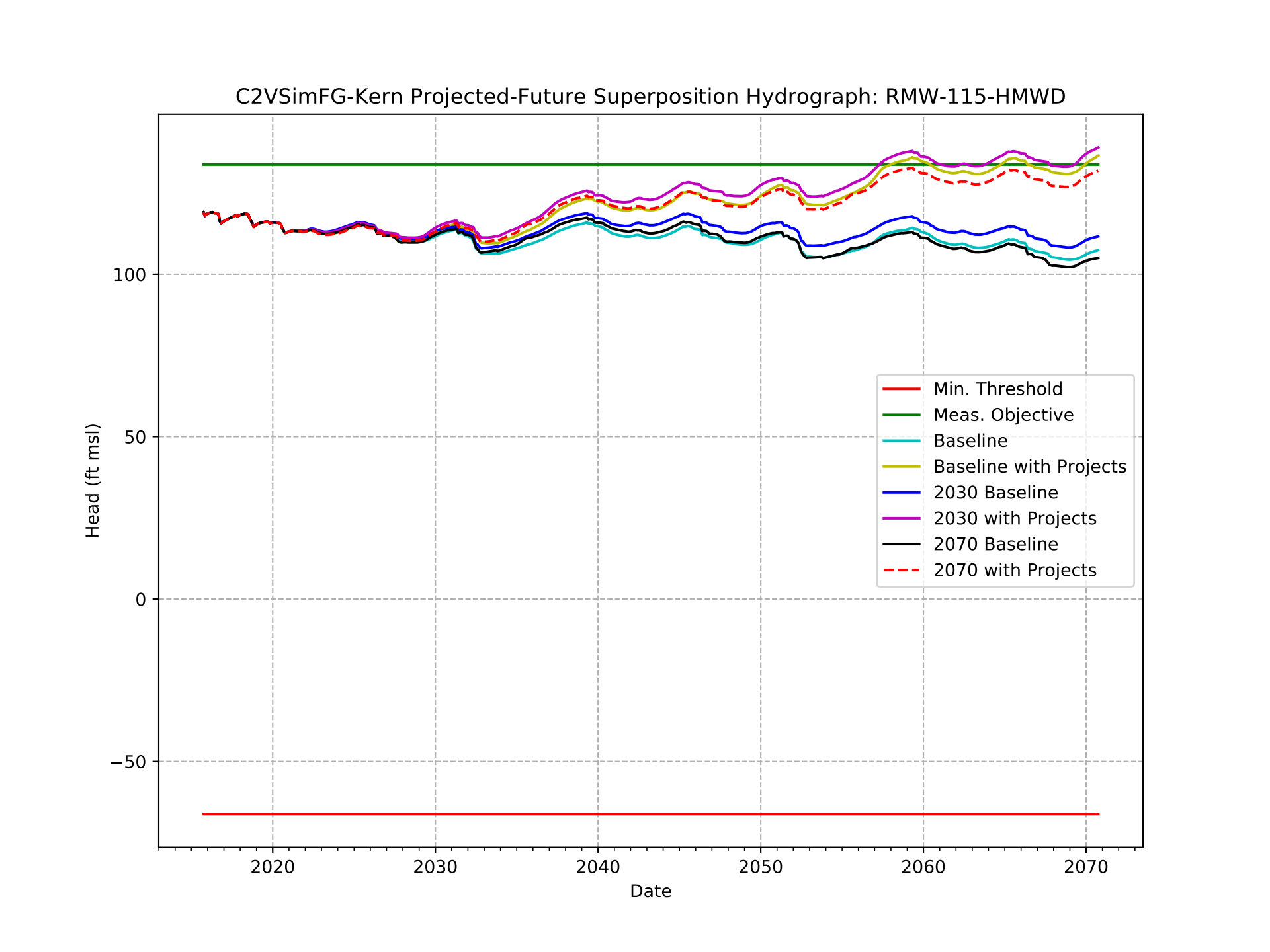

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-110-BVWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
Date
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070

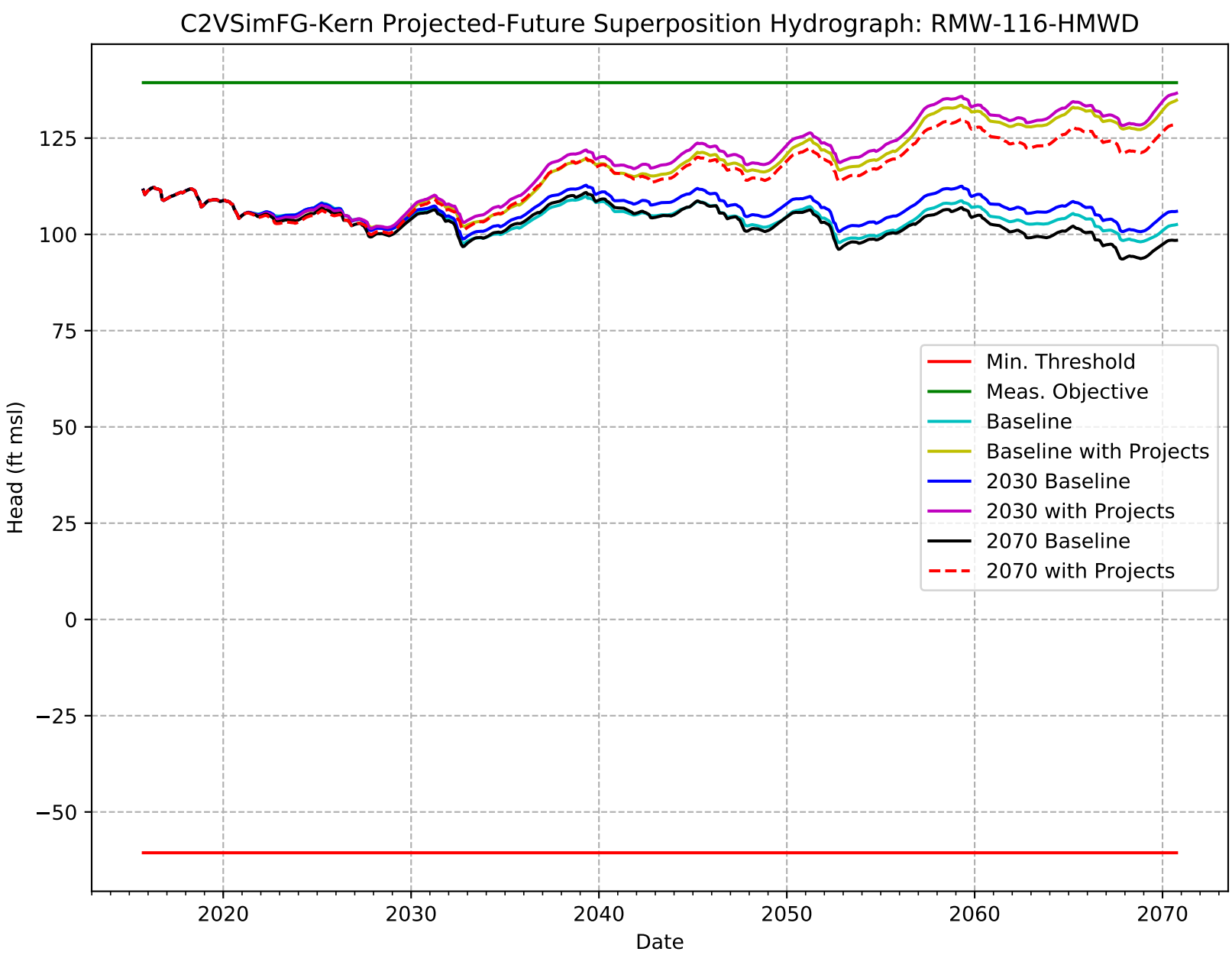

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-111-BVWSD
Head (ft msl)
160
150
140
130
120
110
100
90
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

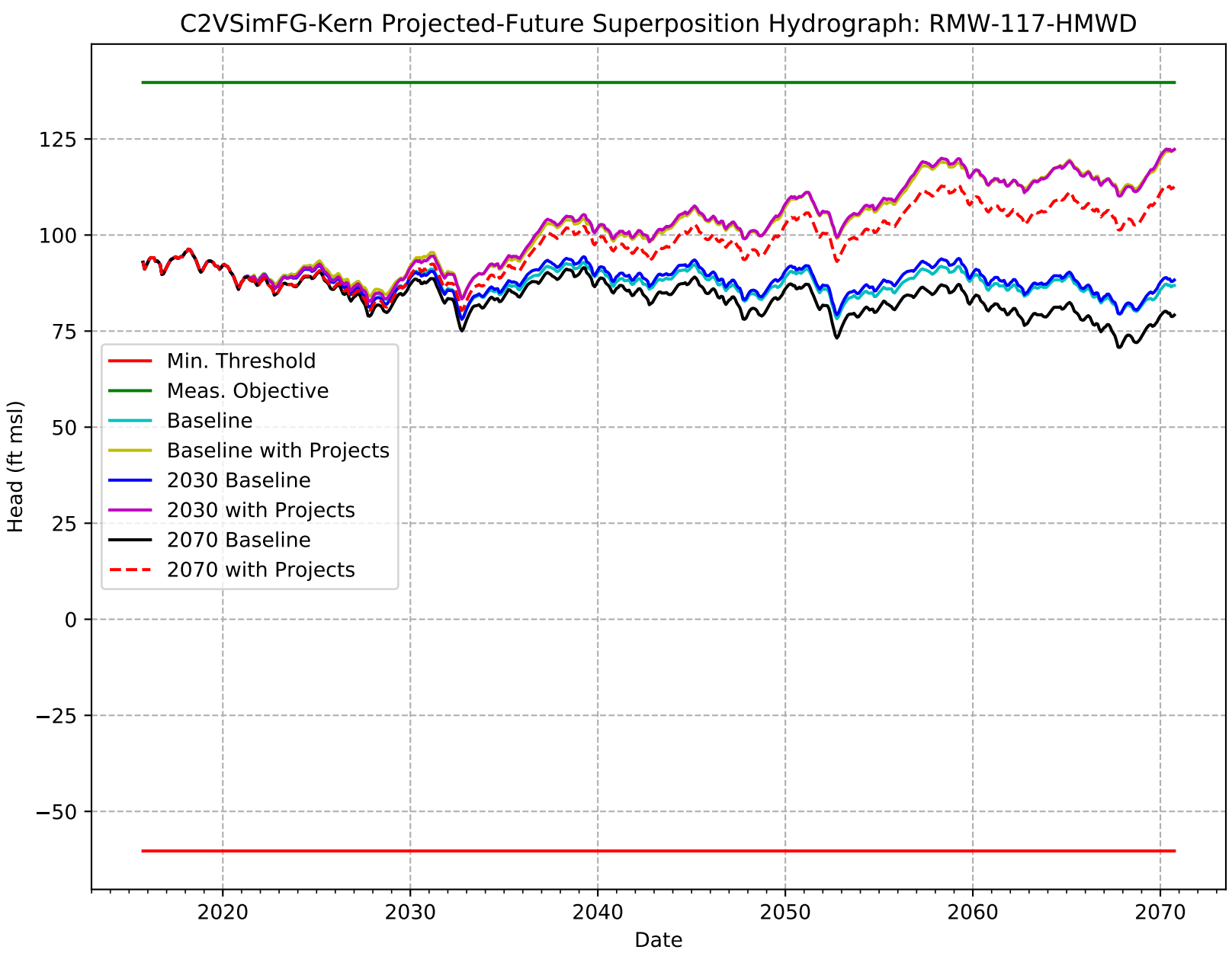

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-112-BVWSD
Head (ft msl)
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

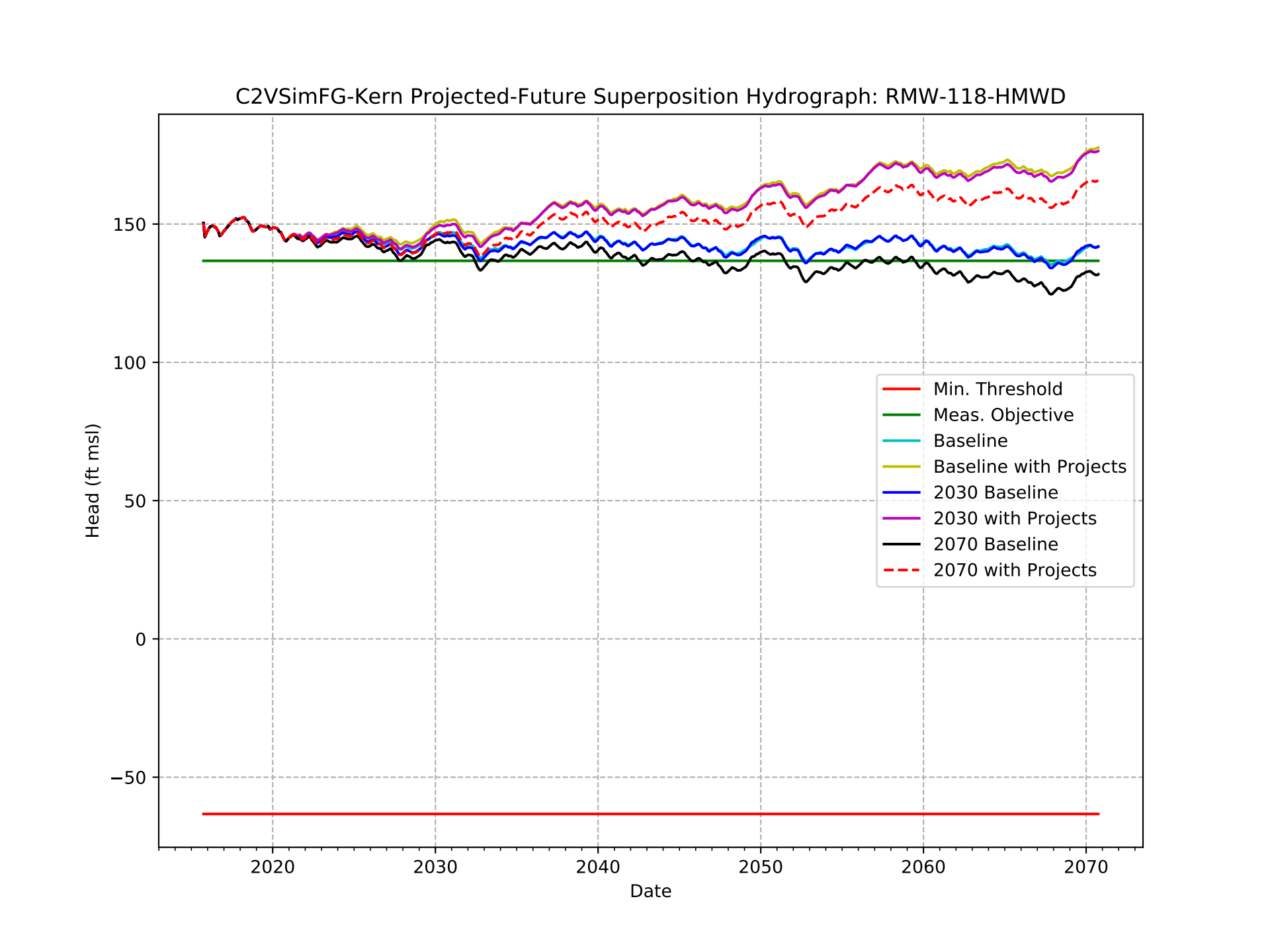

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-113-BVWSD
Head (ft msl)
125
100
75
50
25
0
−25
−50
−75
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

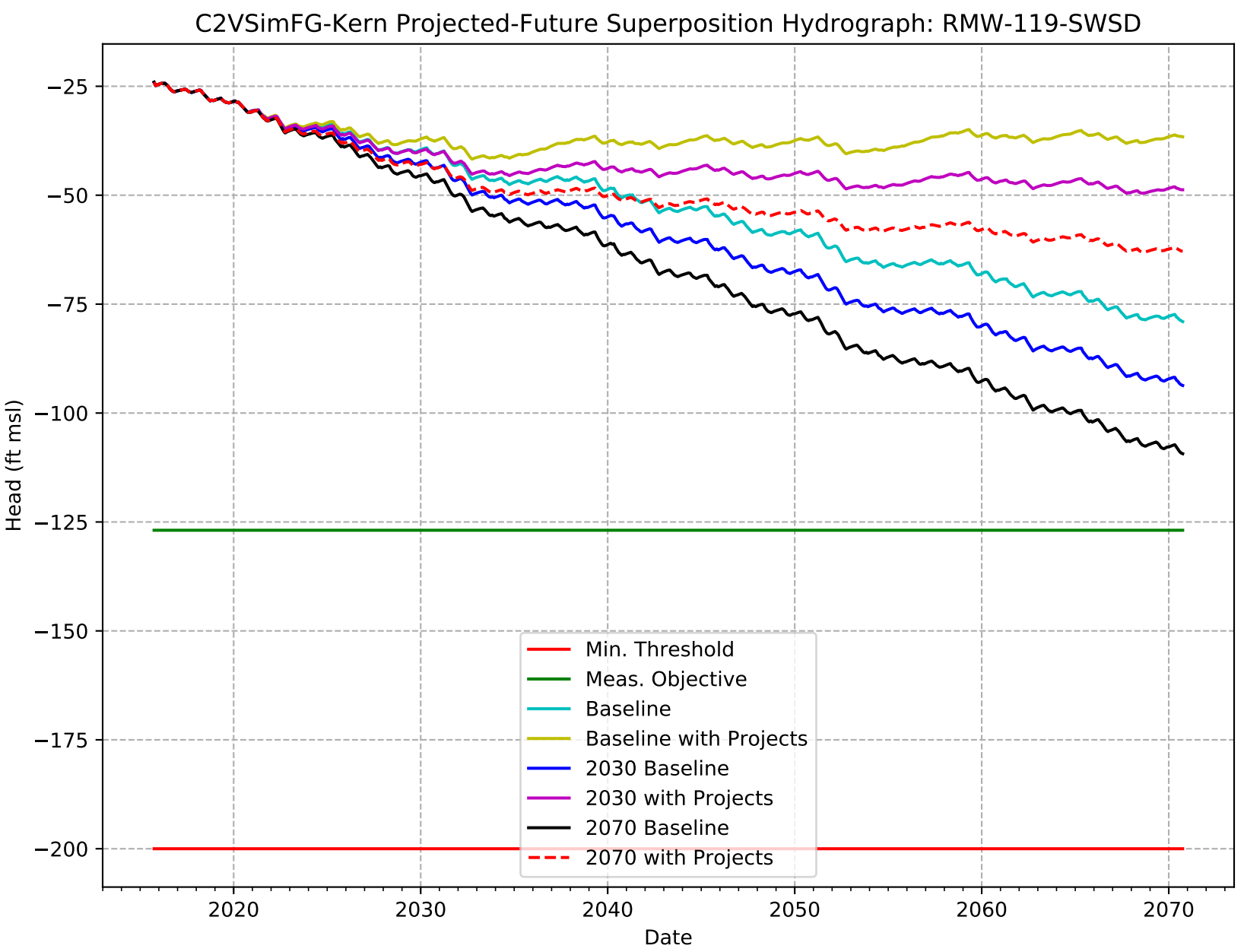

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-114-HMWD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

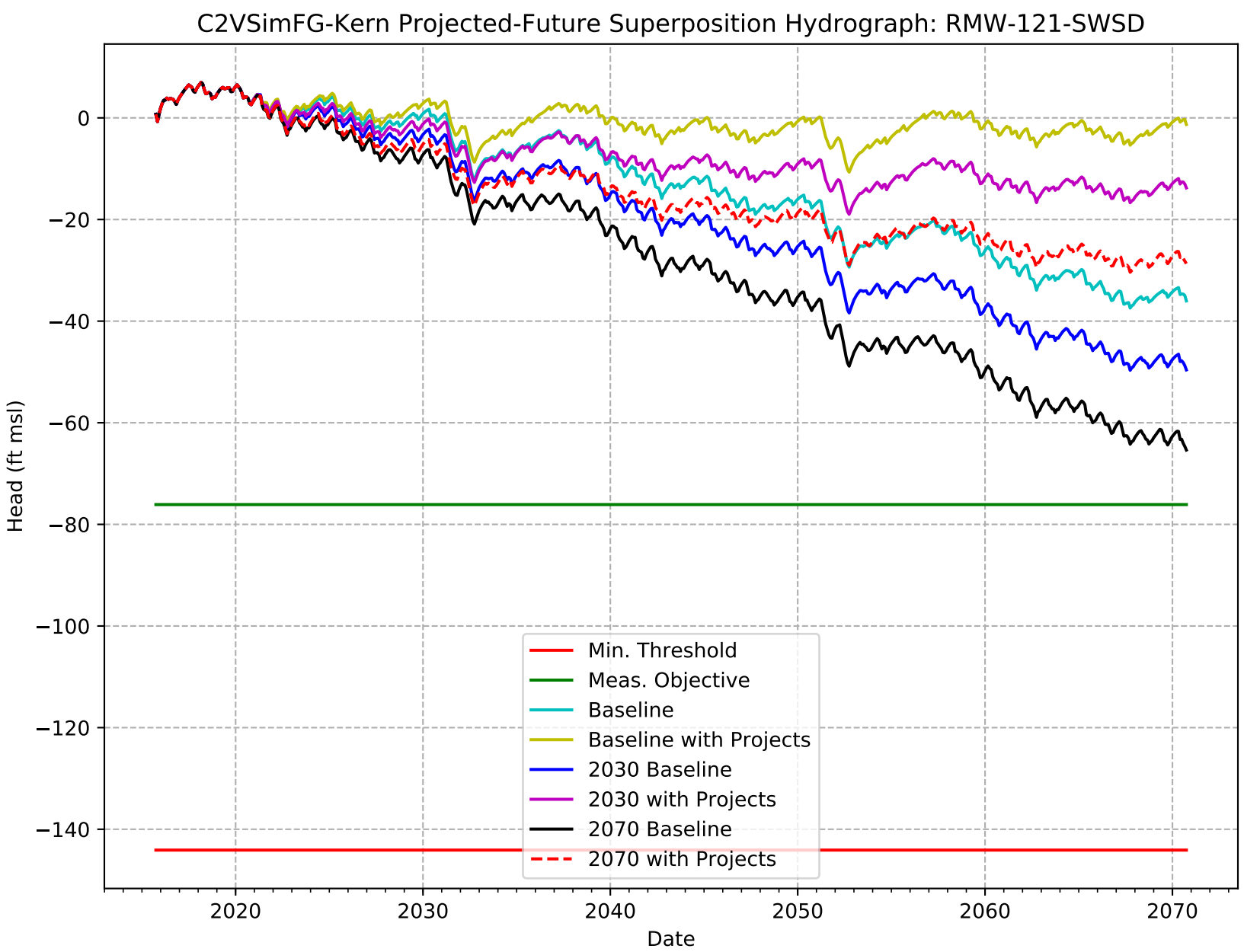

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-115-HMWD
Head (ft msl)
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

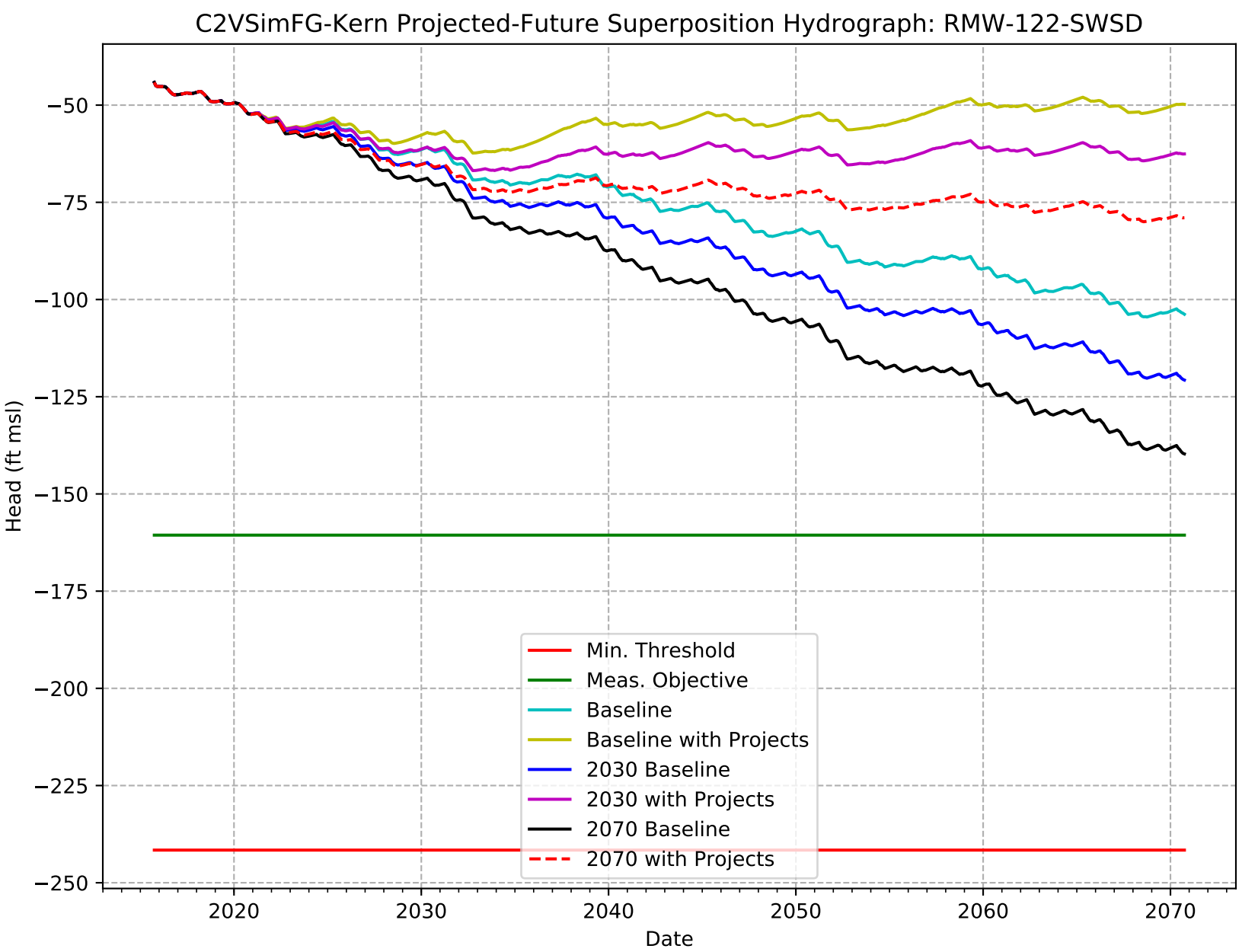

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-116-HMWD
Head (ft msl)
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

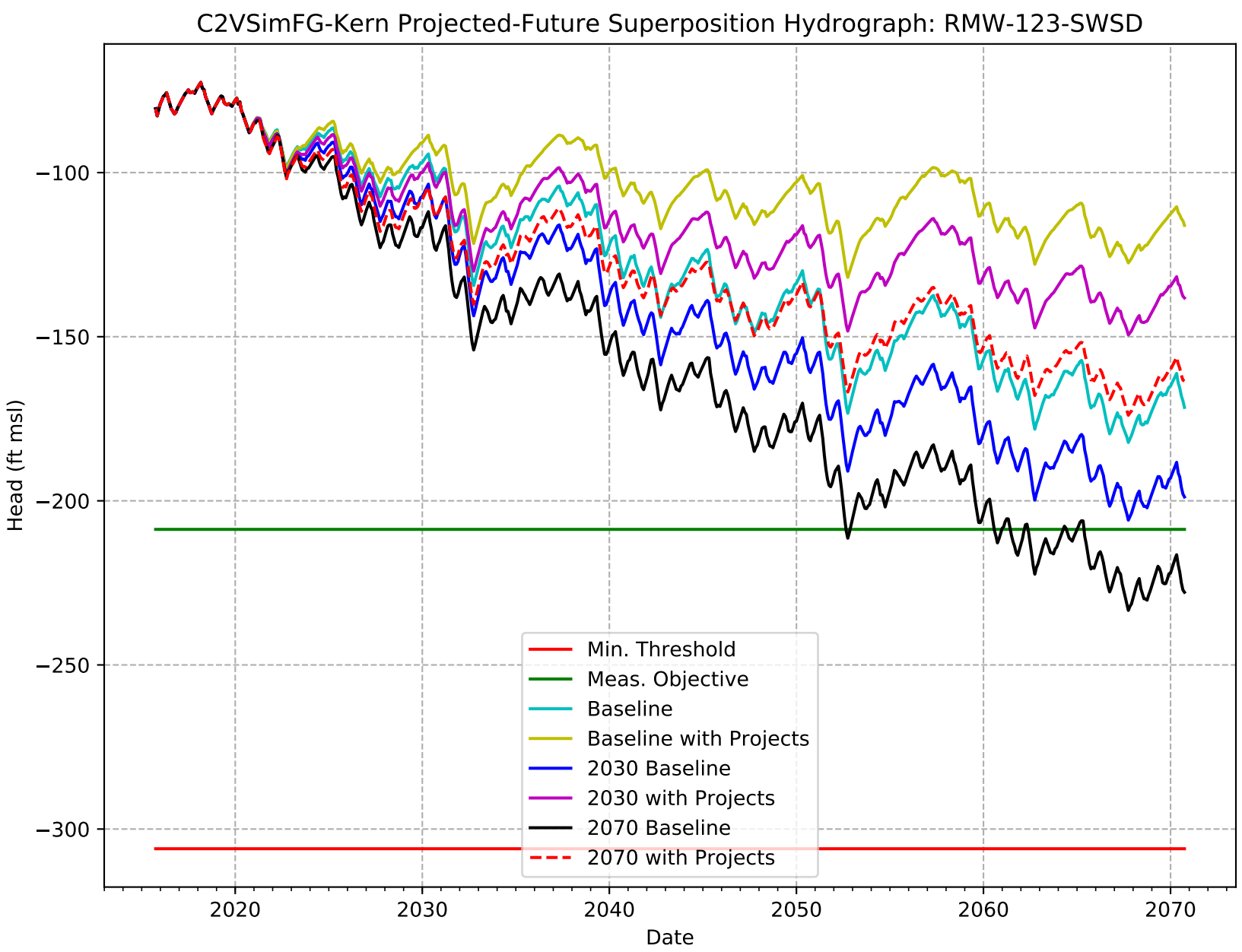

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-117-HMWD
Head (ft msl)
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

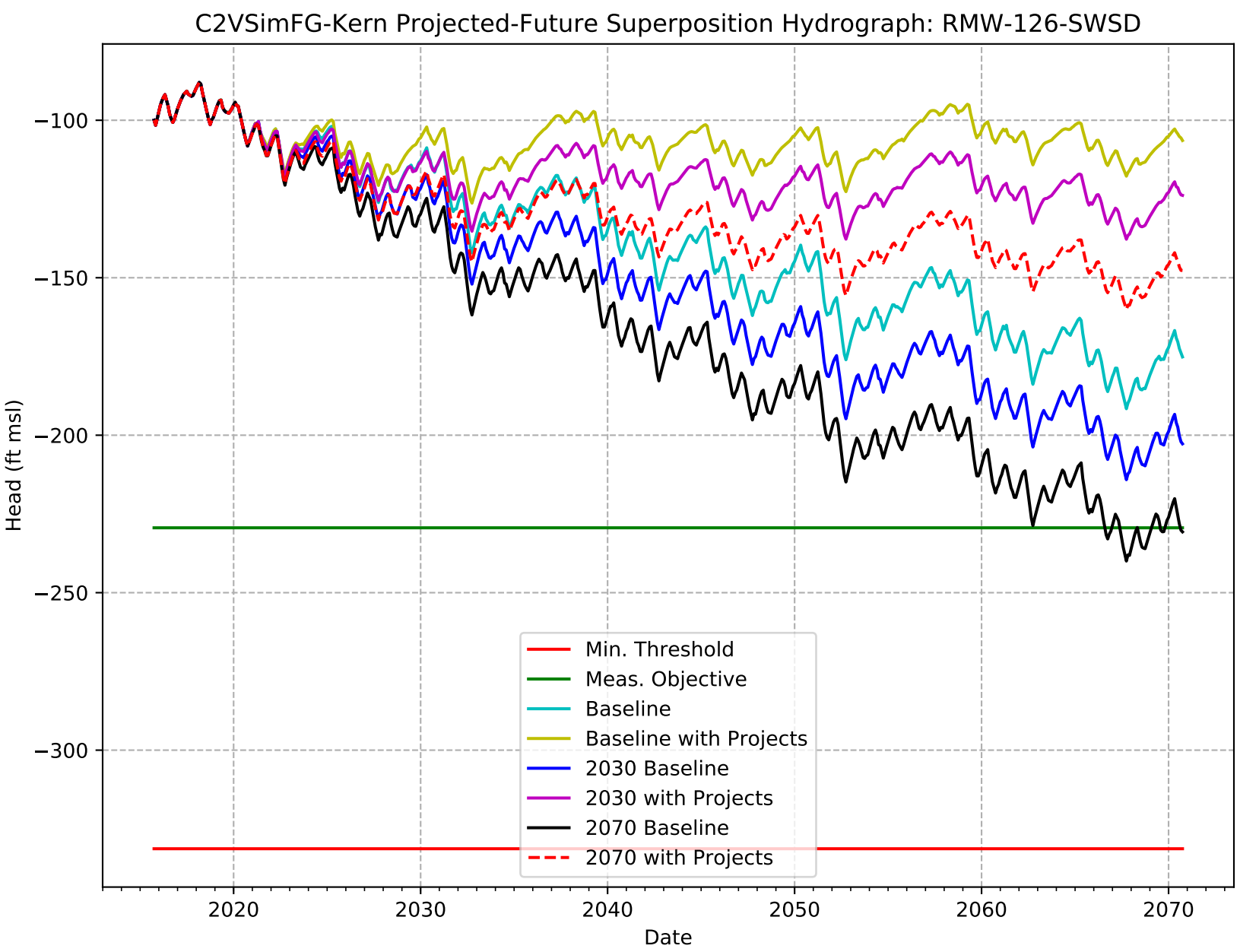

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-118-HMWD
Head (ft msl)
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

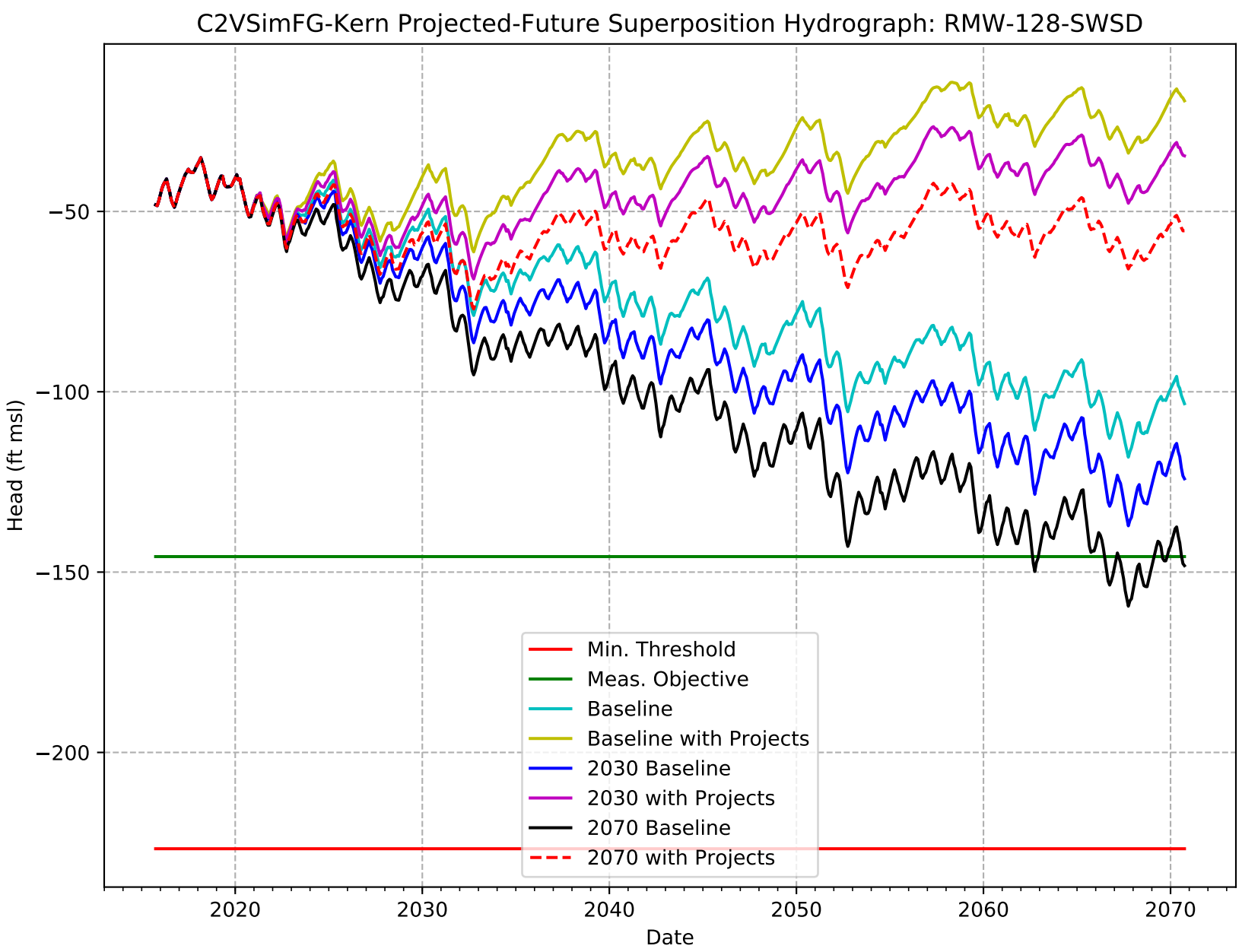

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-119-SWSD
Head (ft msl)
−25
−50
−75
−100
−125
−150
−175
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

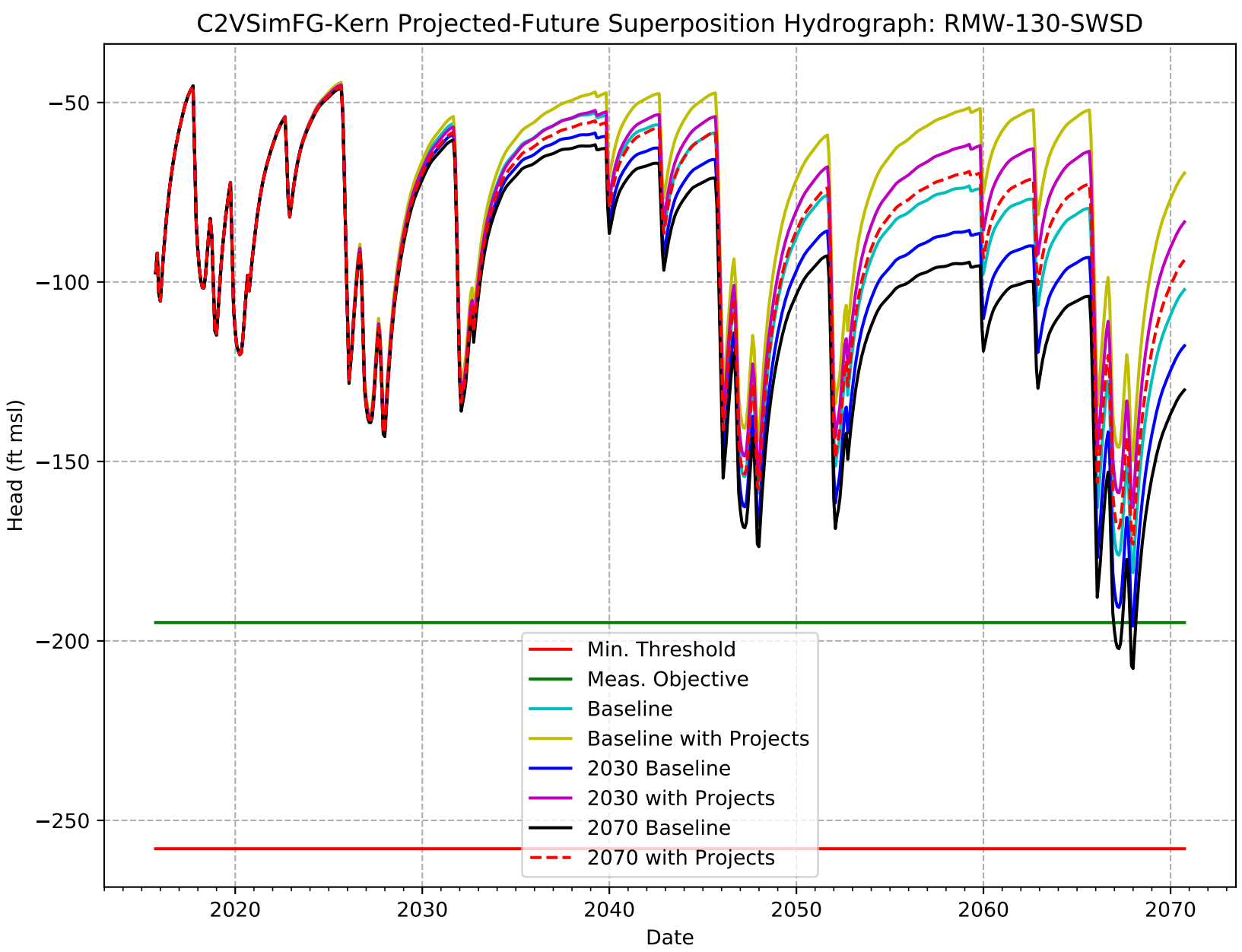

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-121-SWSD
Head (ft msl)
0
−20
−40
−60
−80
−100
−120
−140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

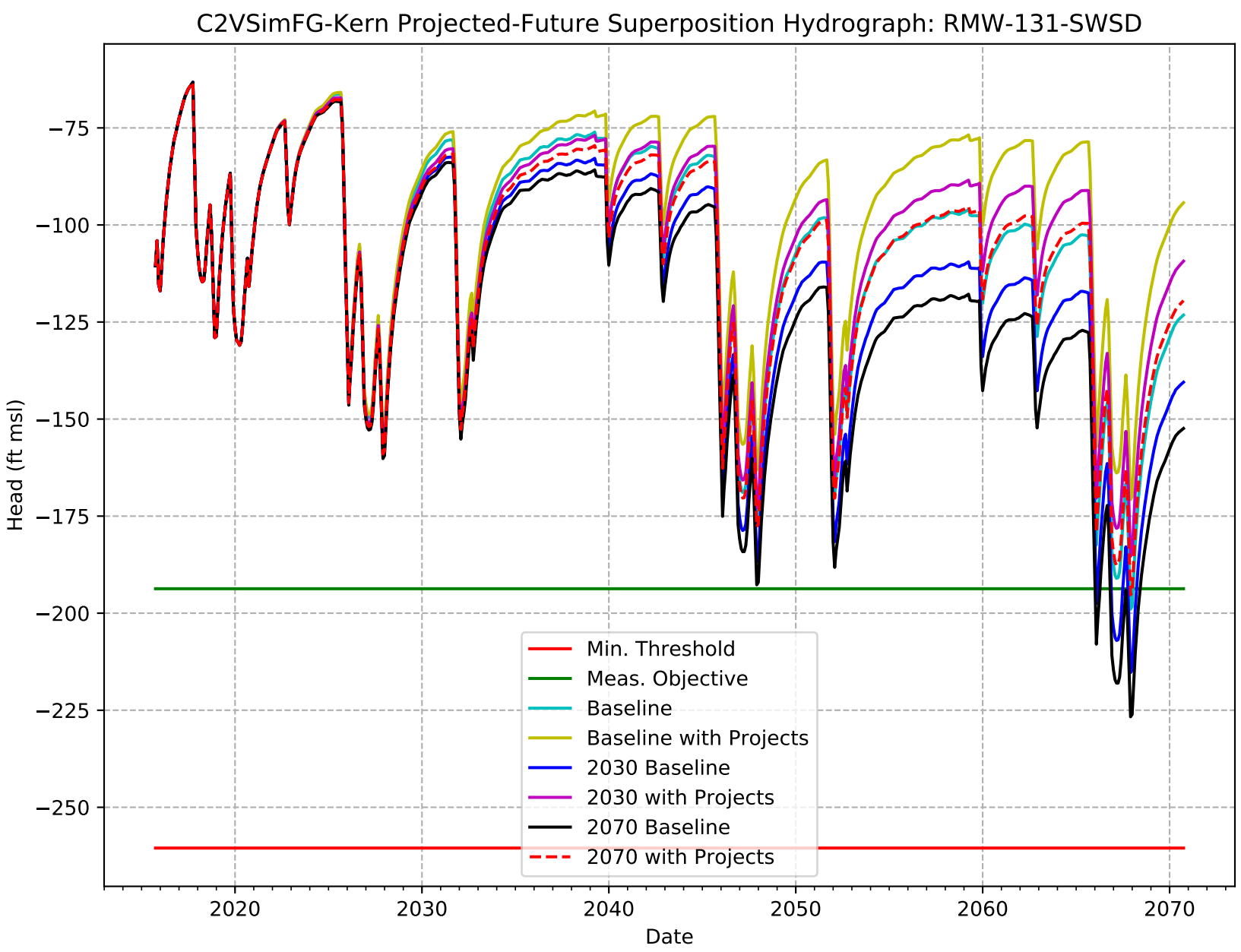

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-122-SWSD
Head (ft msl)
−50
−75
−100
−125
−150
−175
−200
−225
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

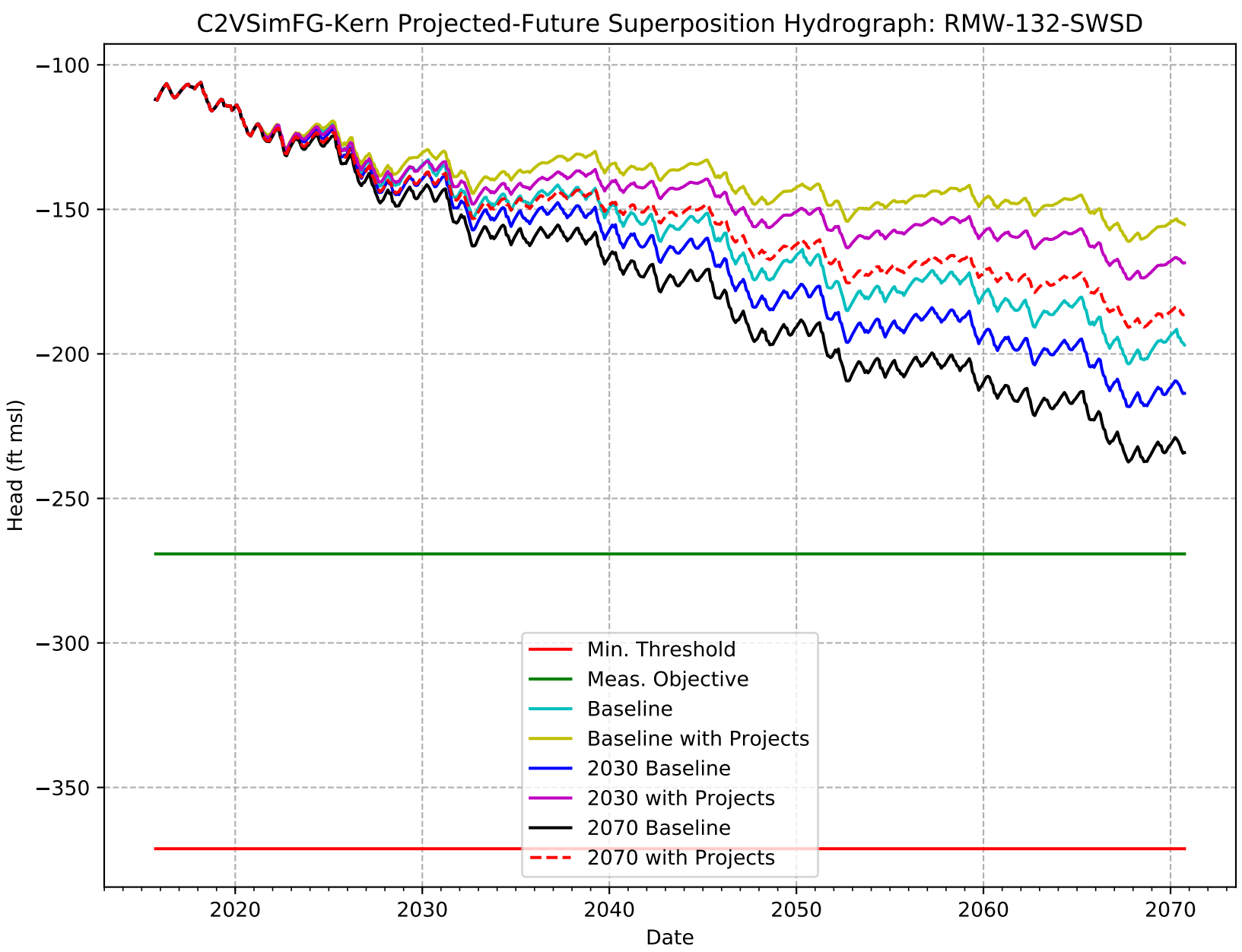

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-123-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

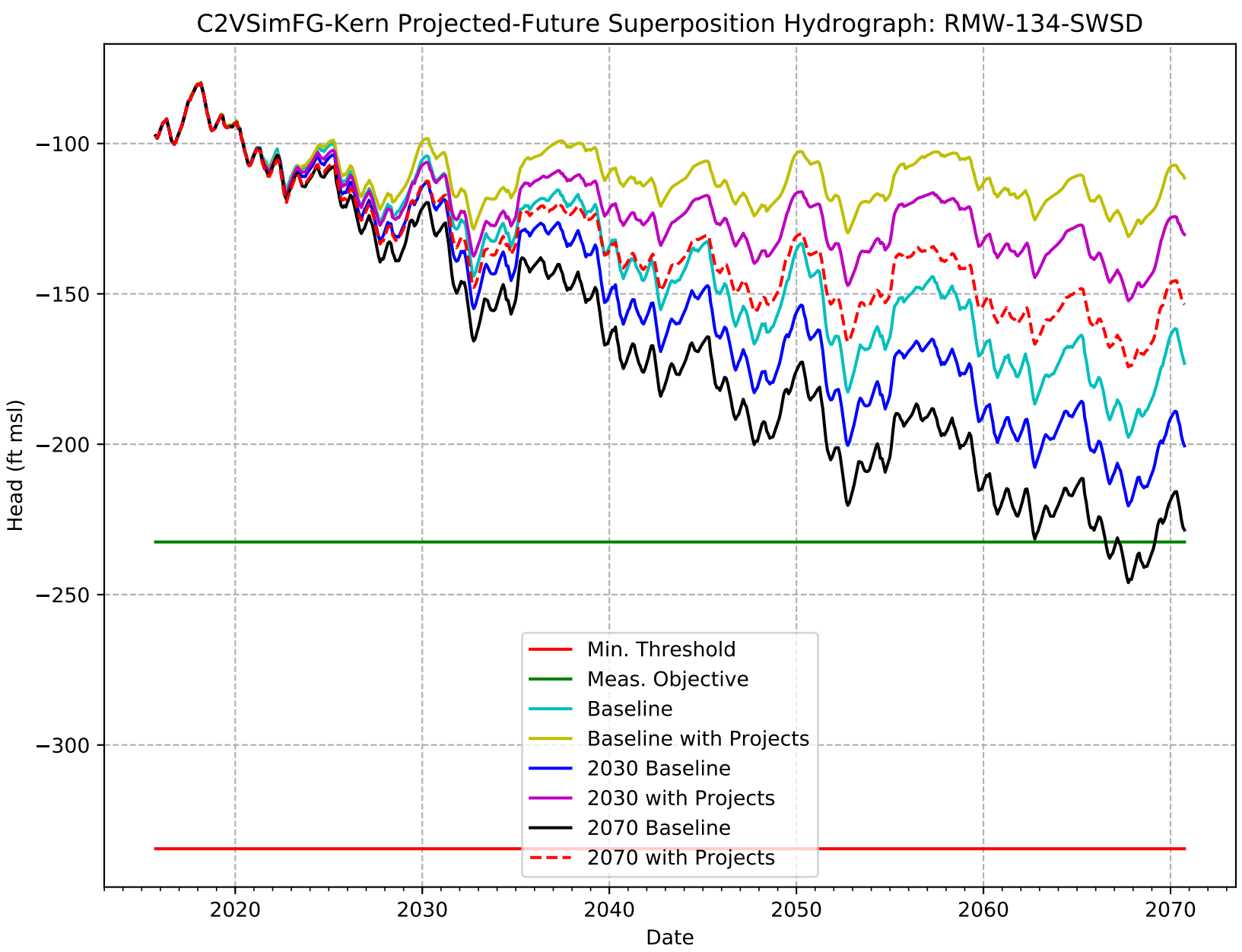

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-126-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

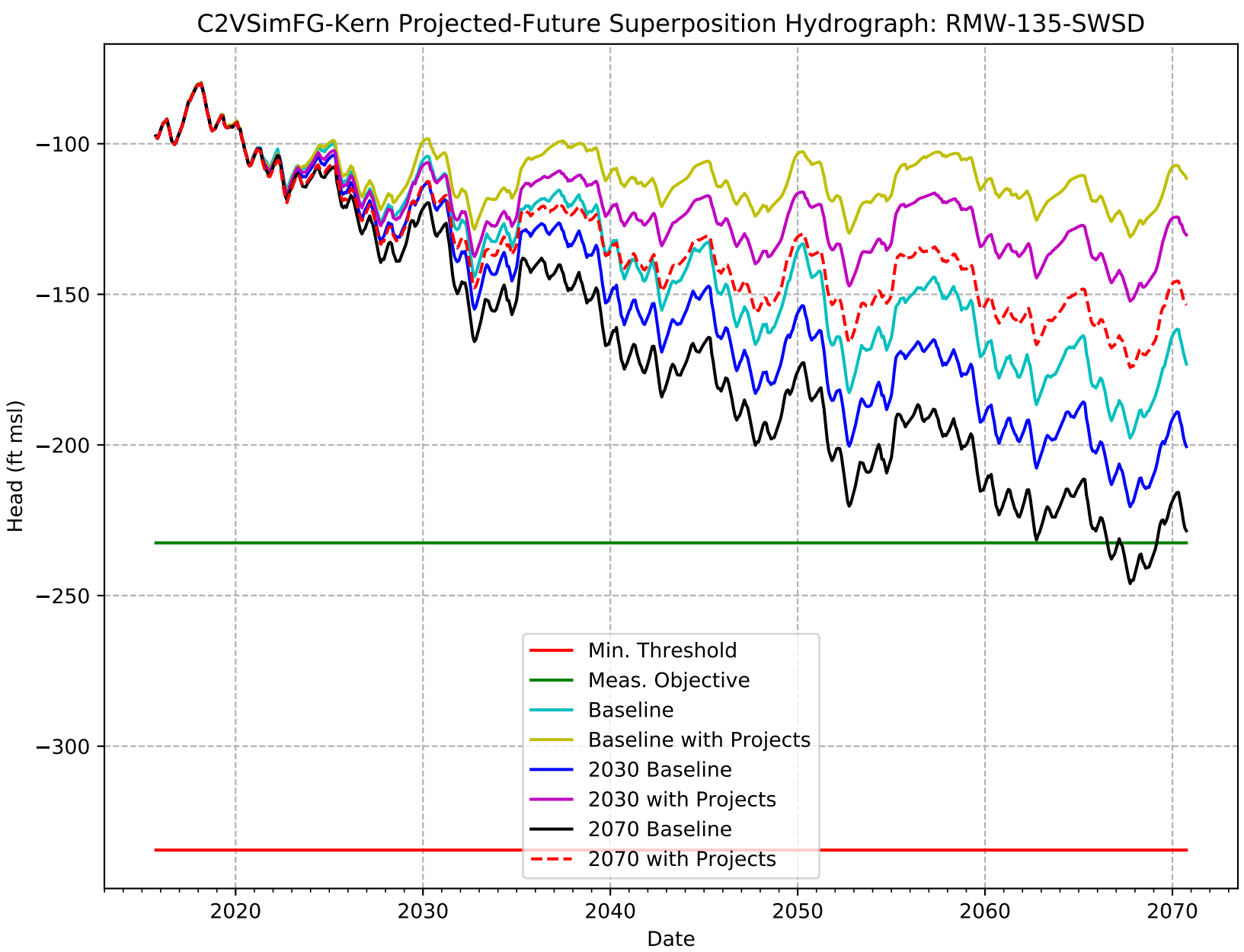

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-128-SWSD
Head (ft msl)
−50
−100
−150
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

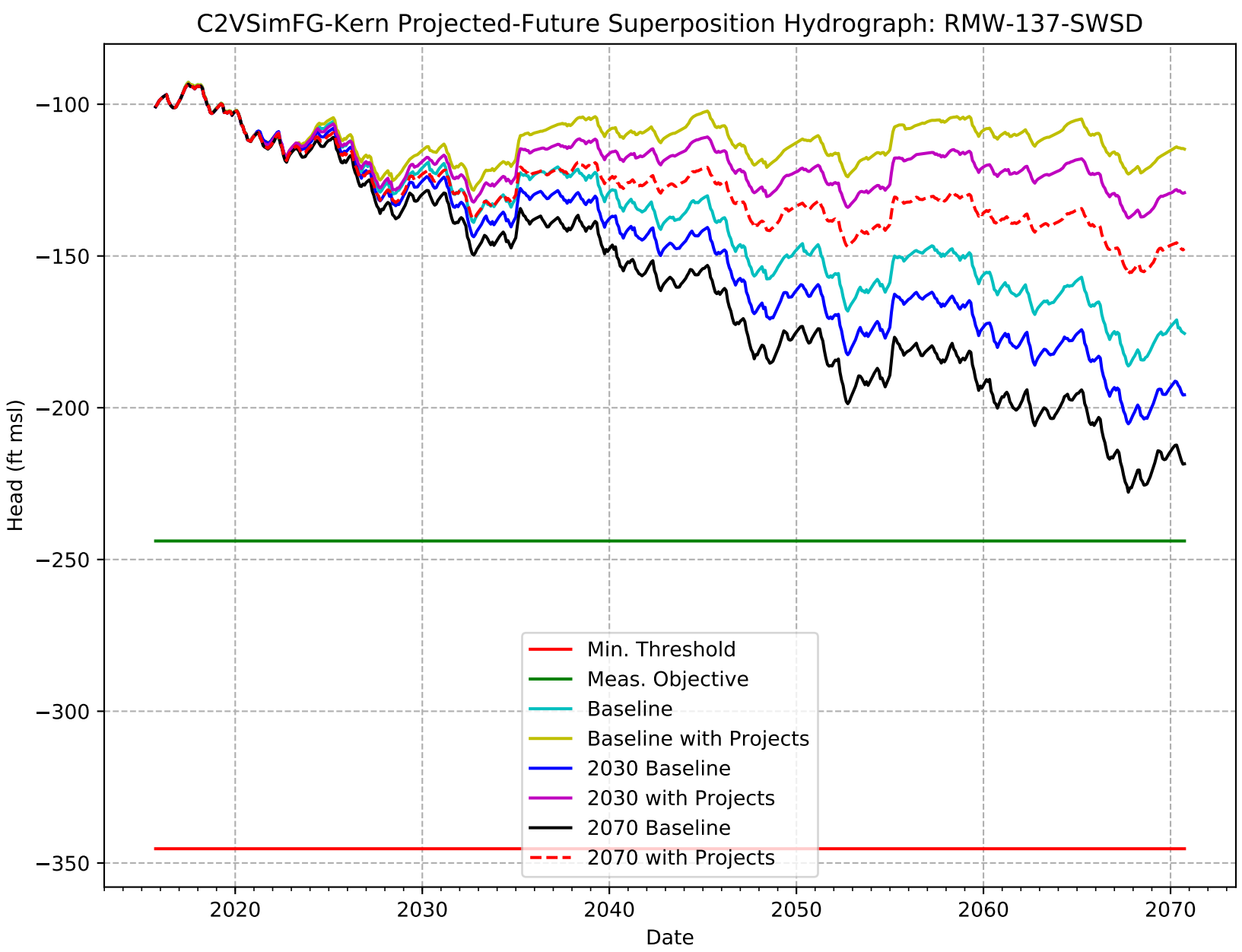

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-130-SWSD
Head (ft msl)
−50
−100
−150
−200
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

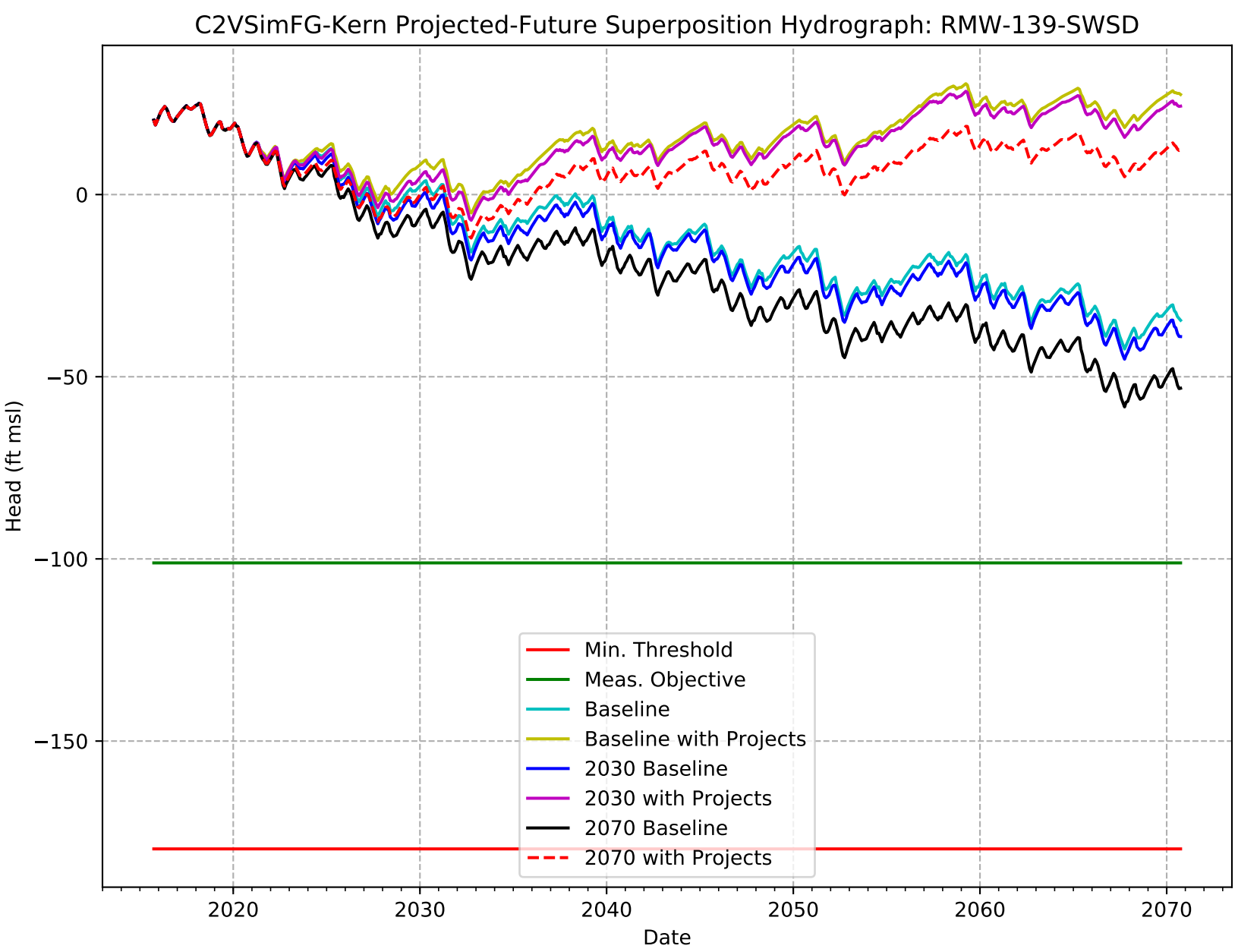

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-131-SWSD
Head (ft msl)
−75
−100
−125
−150
−175
−200
−225
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

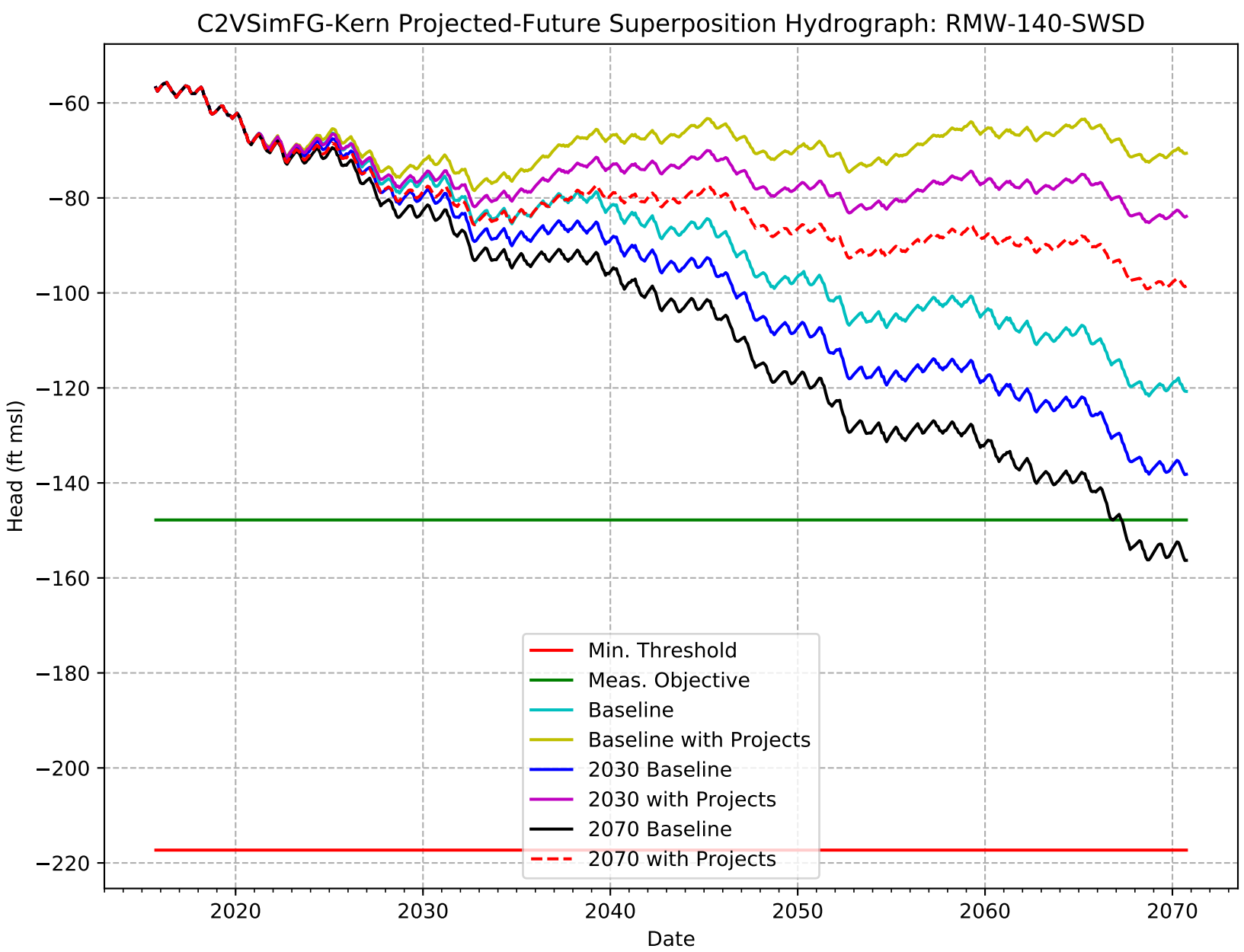

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-132-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
−350
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

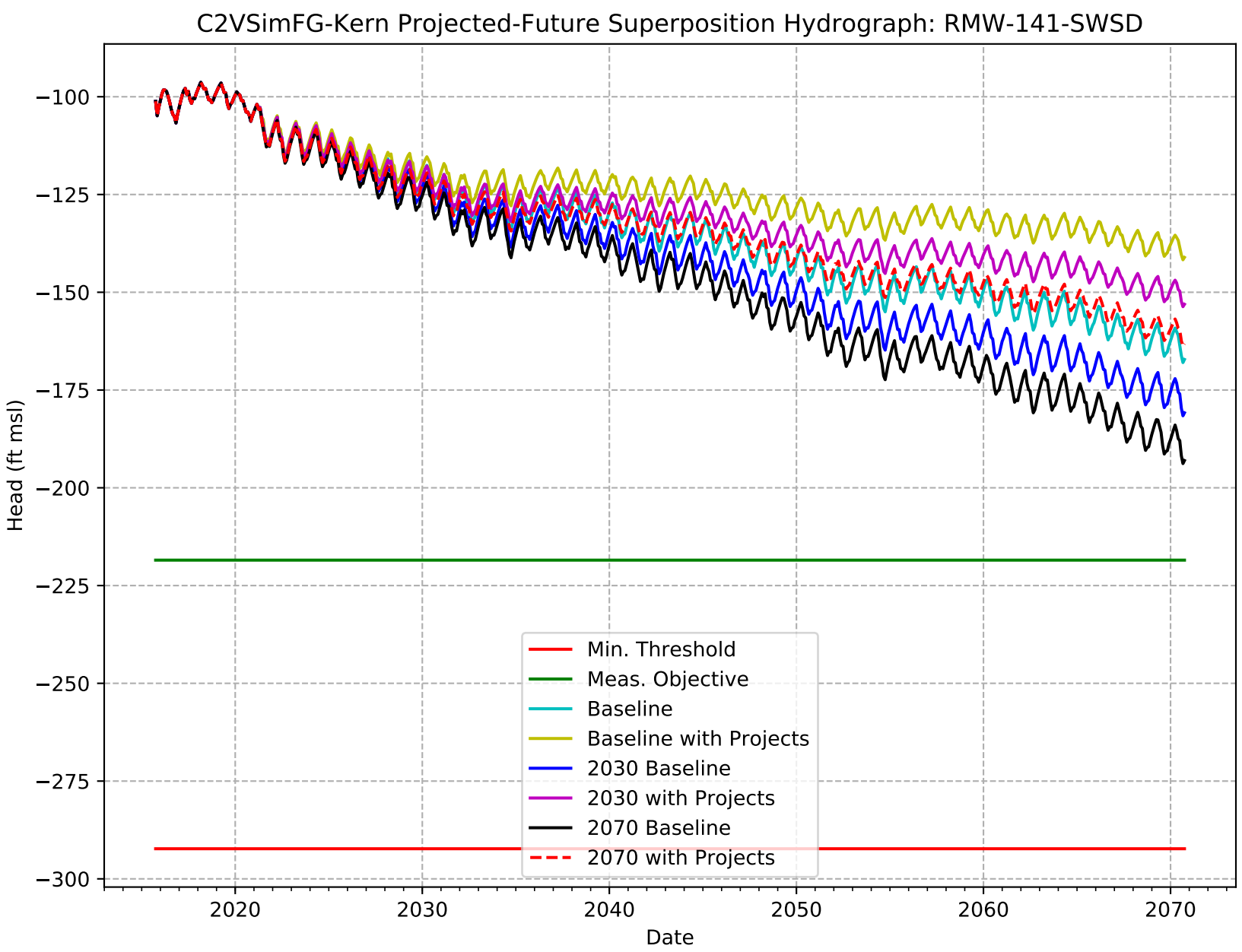

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-134-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

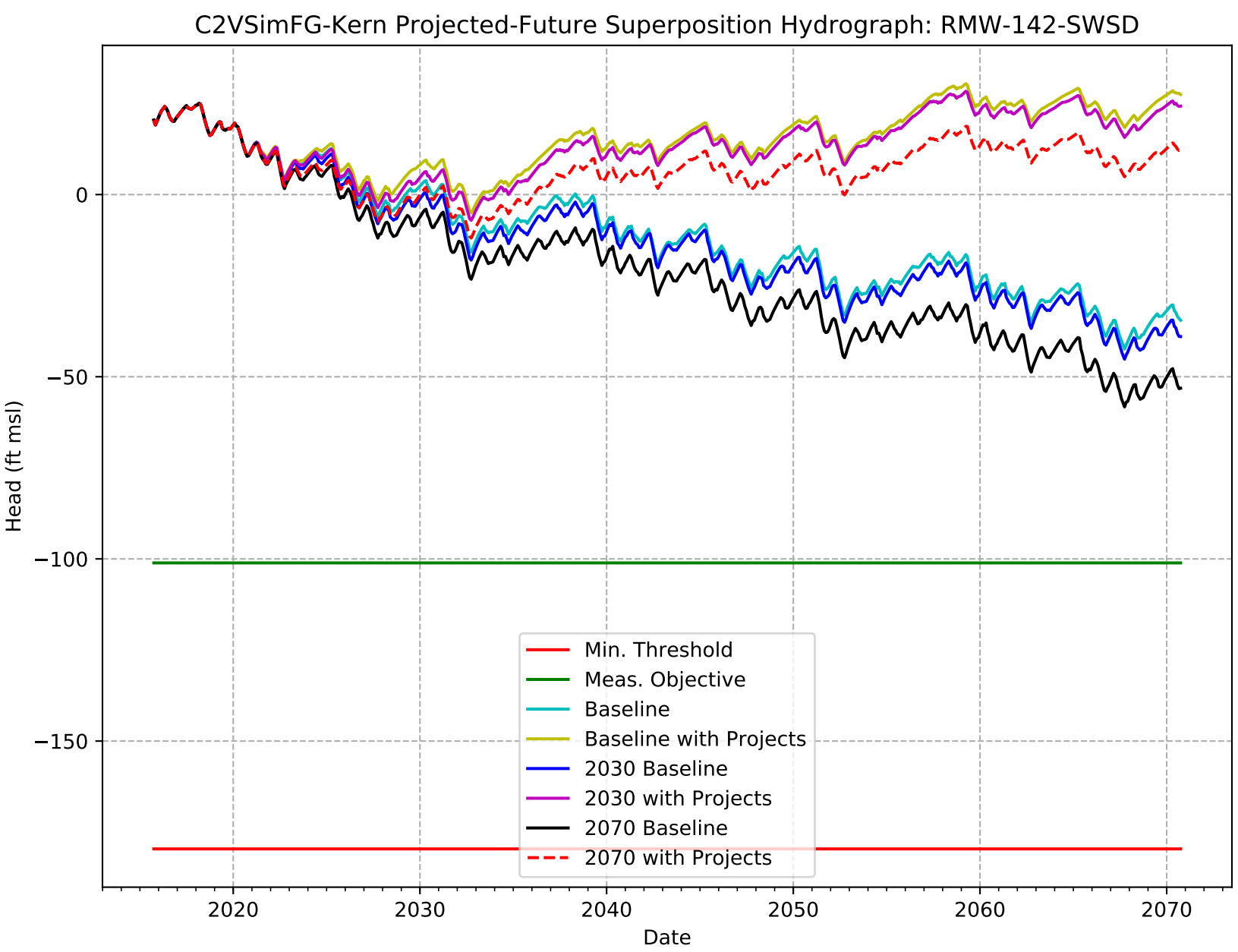

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-135-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

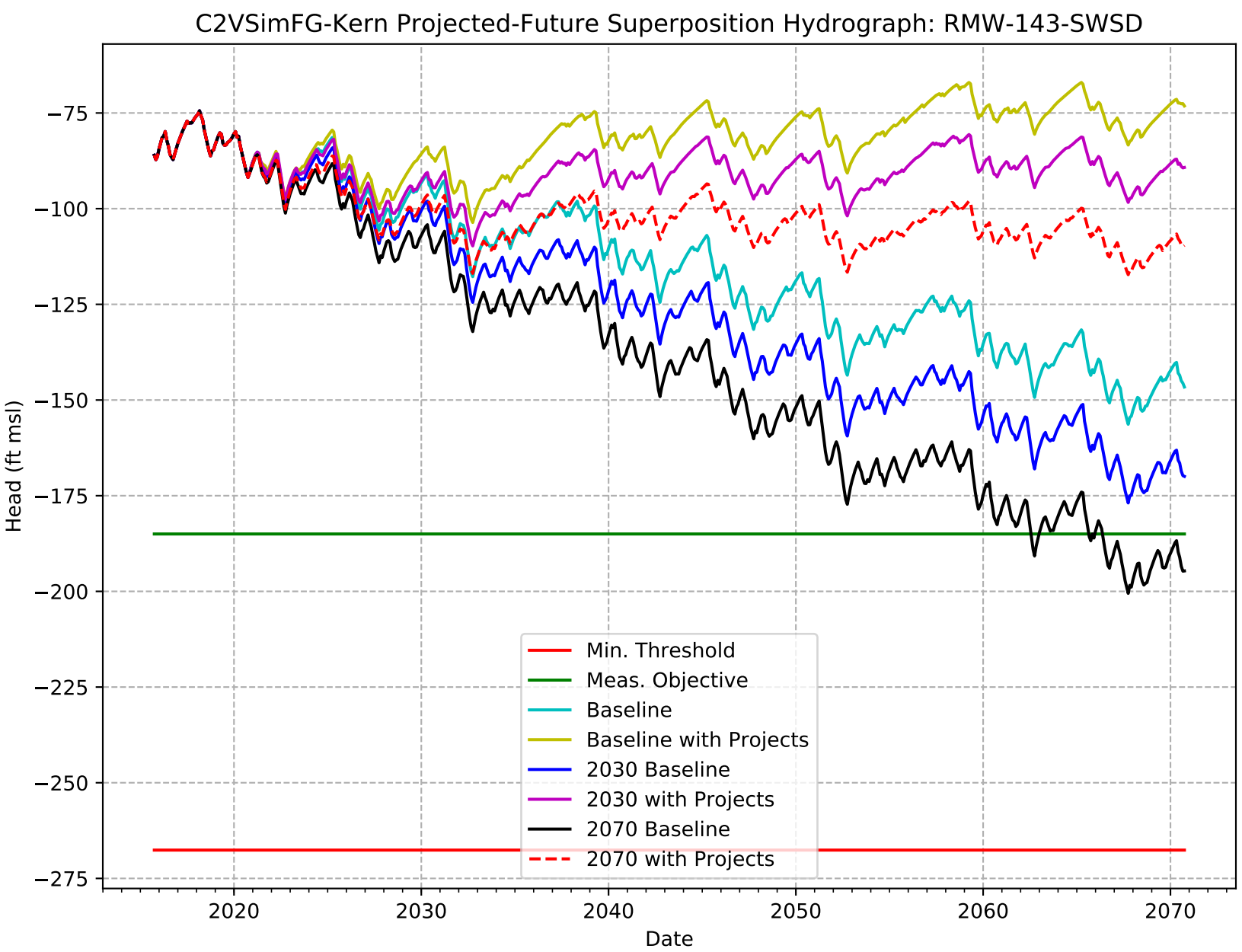

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-137-SWSD
Head (ft msl)
−100
−150
−200
−250
−300
−350
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

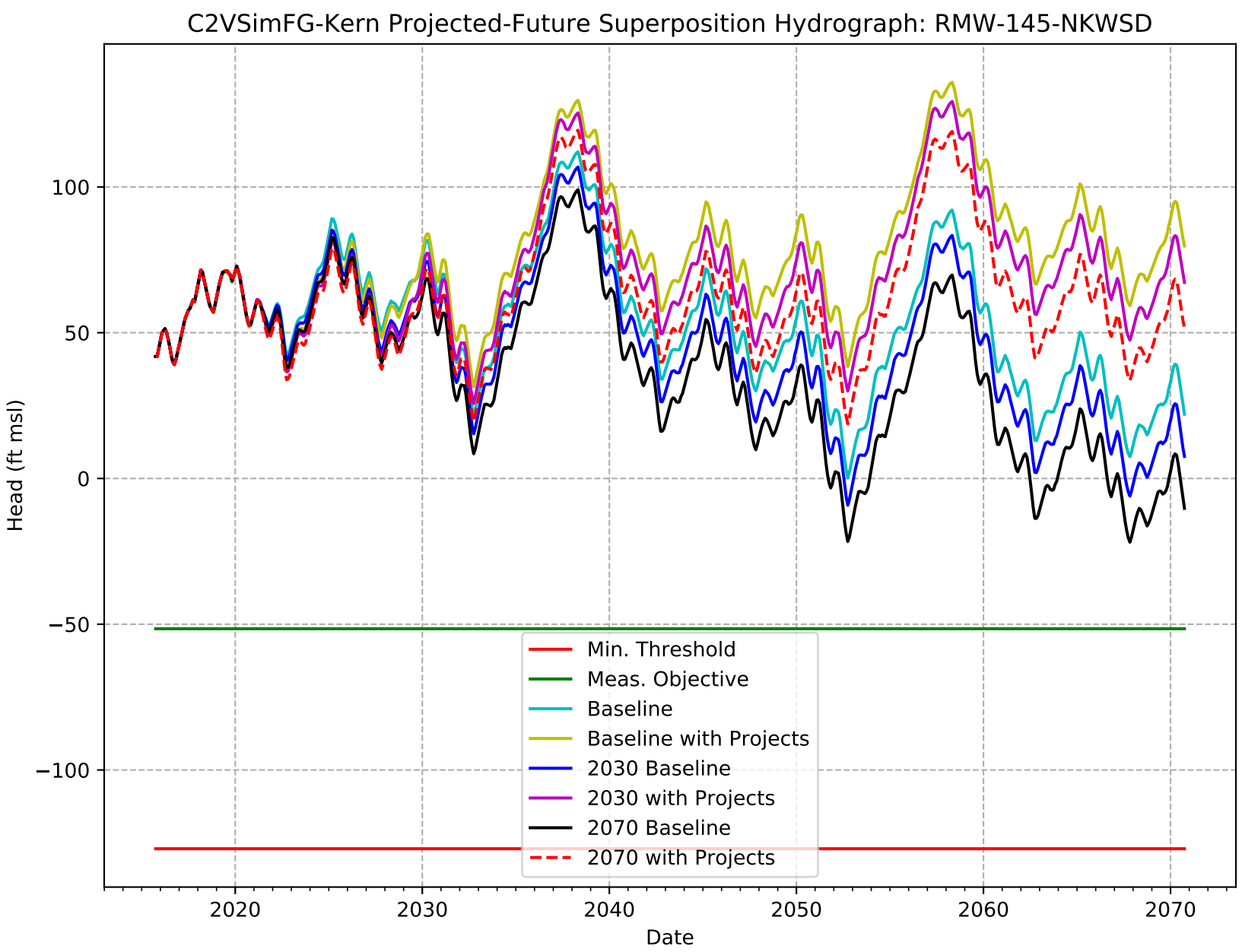

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-139-SWSD
Head (ft msl)
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

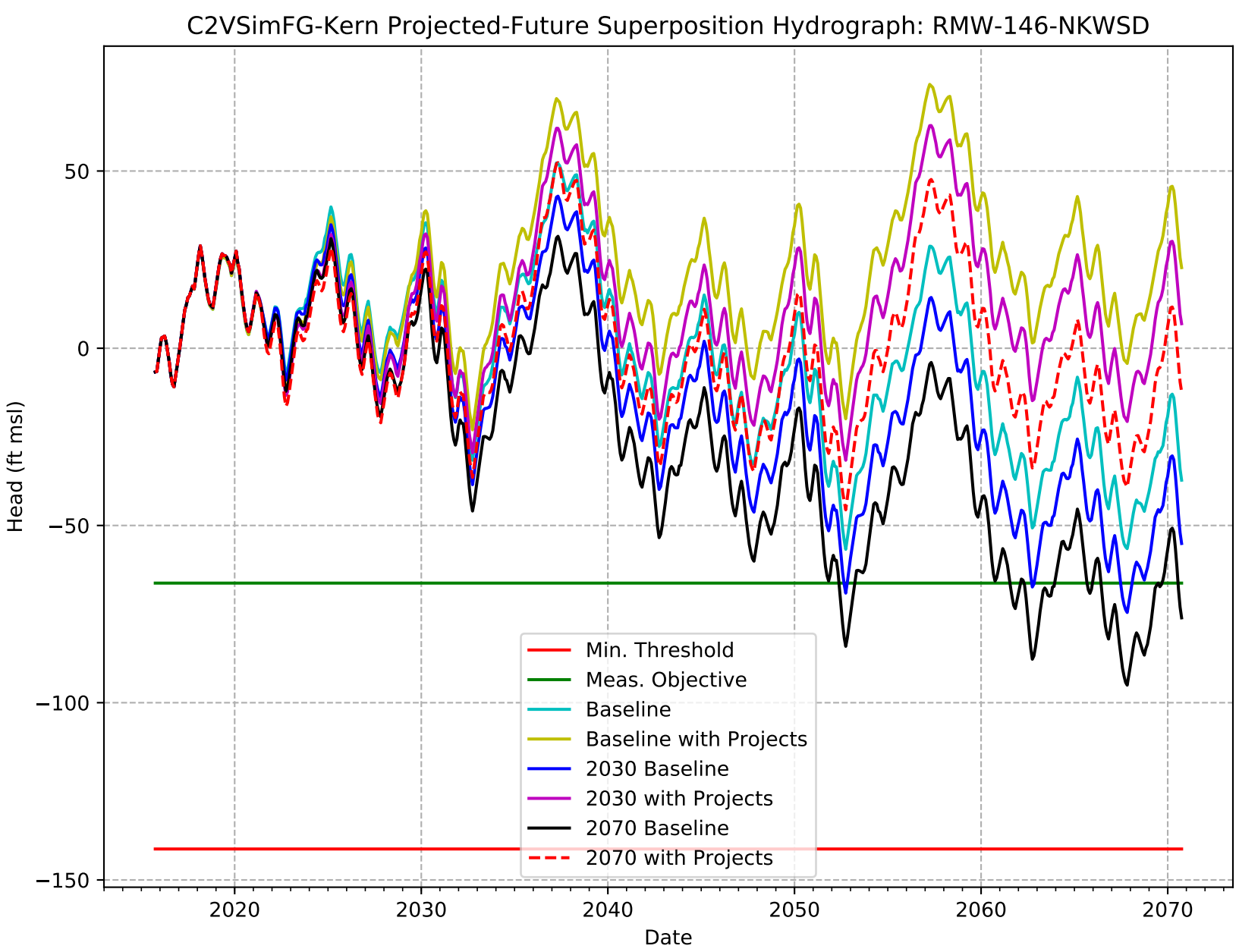

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-140-SWSD
Head (ft msl)
−60
−80
−100
−120
−140
−160
−180
−200
−220
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

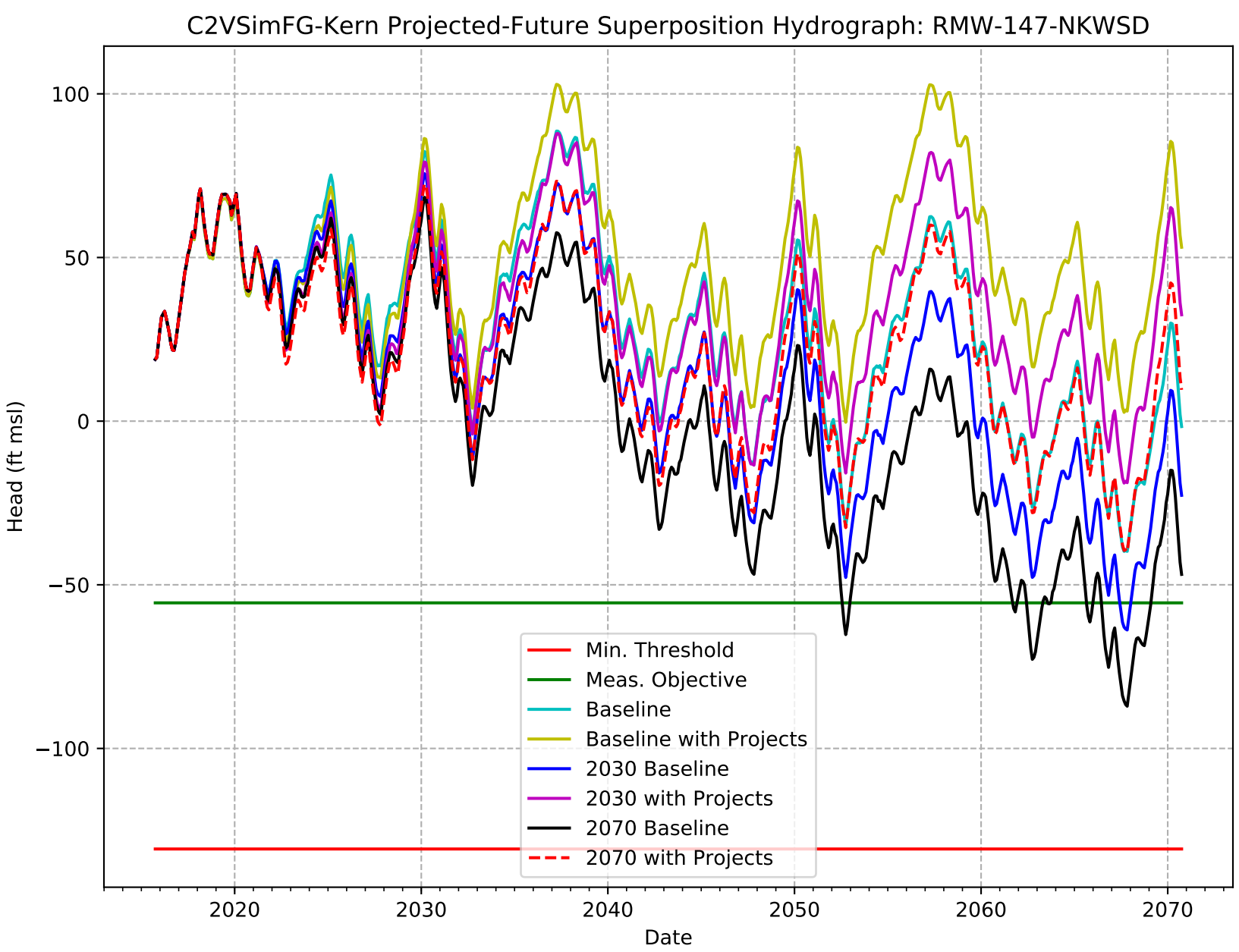

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-141-SWSD
Head (ft msl)
−100
−125
−150
−175
−200
−225
−250
−275
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

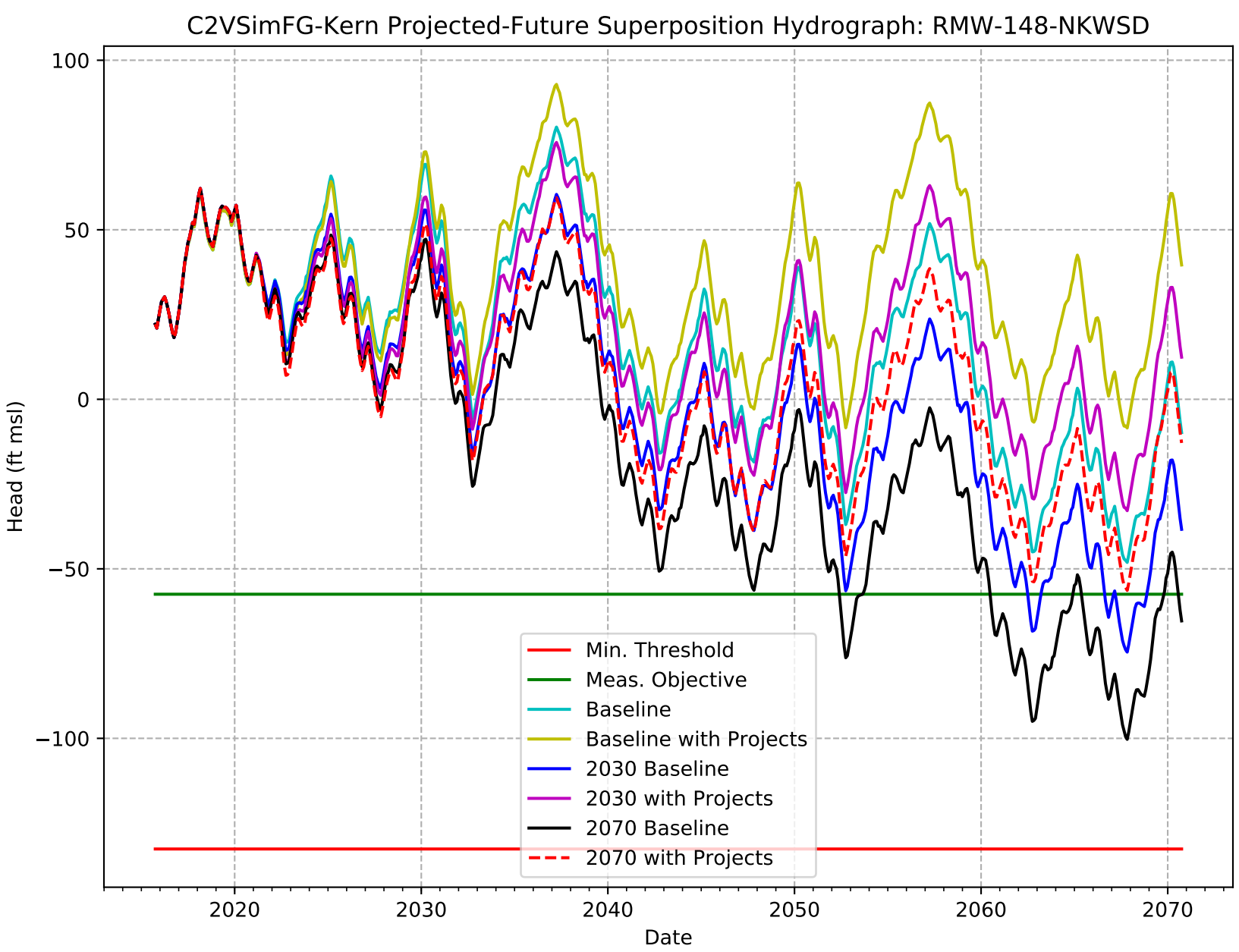

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-142-SWSD
Head (ft msl)
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

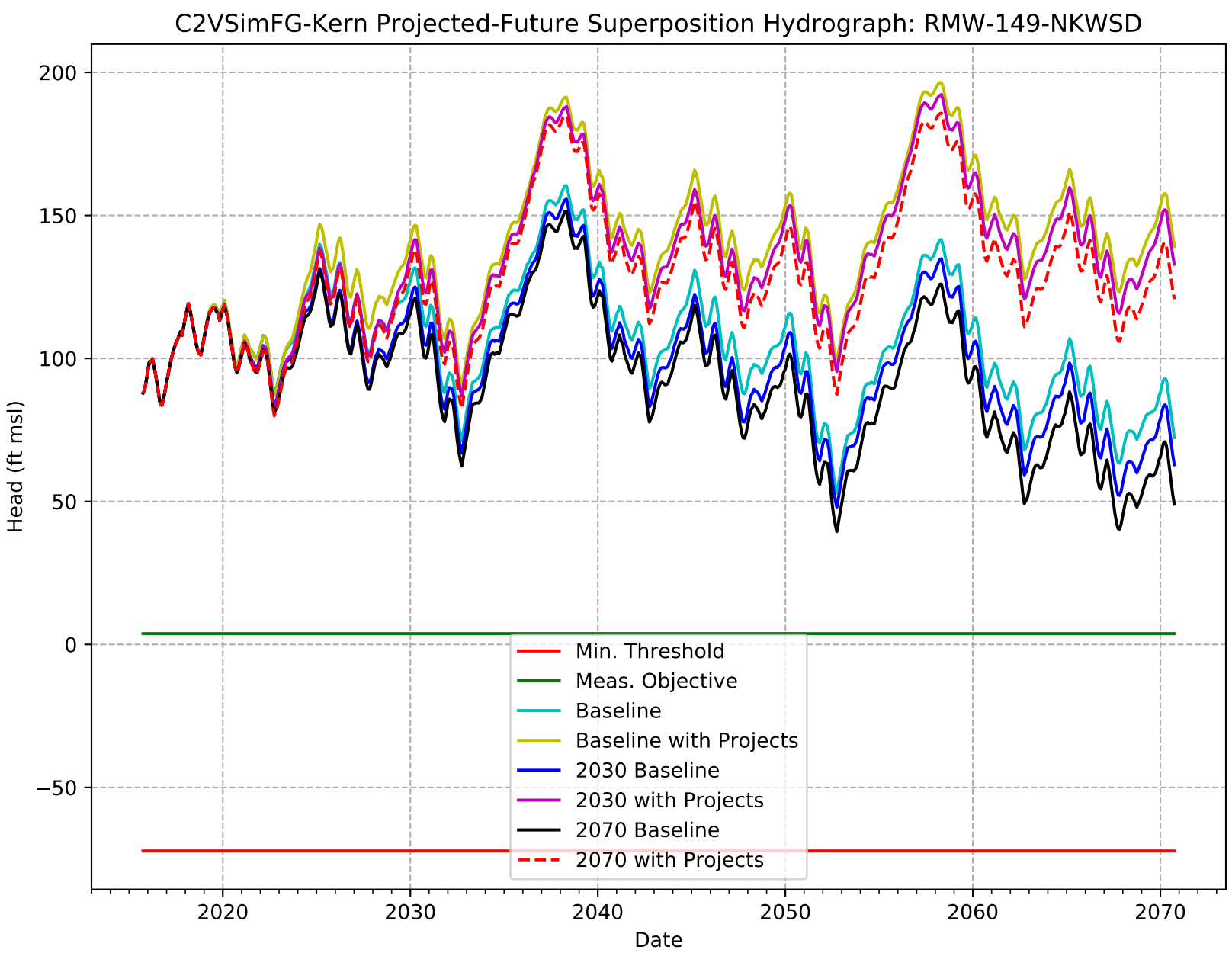

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-143-SWSD
Head (ft msl)
−75
−100
−125
−150
−175
−200
−225
−250
−275
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

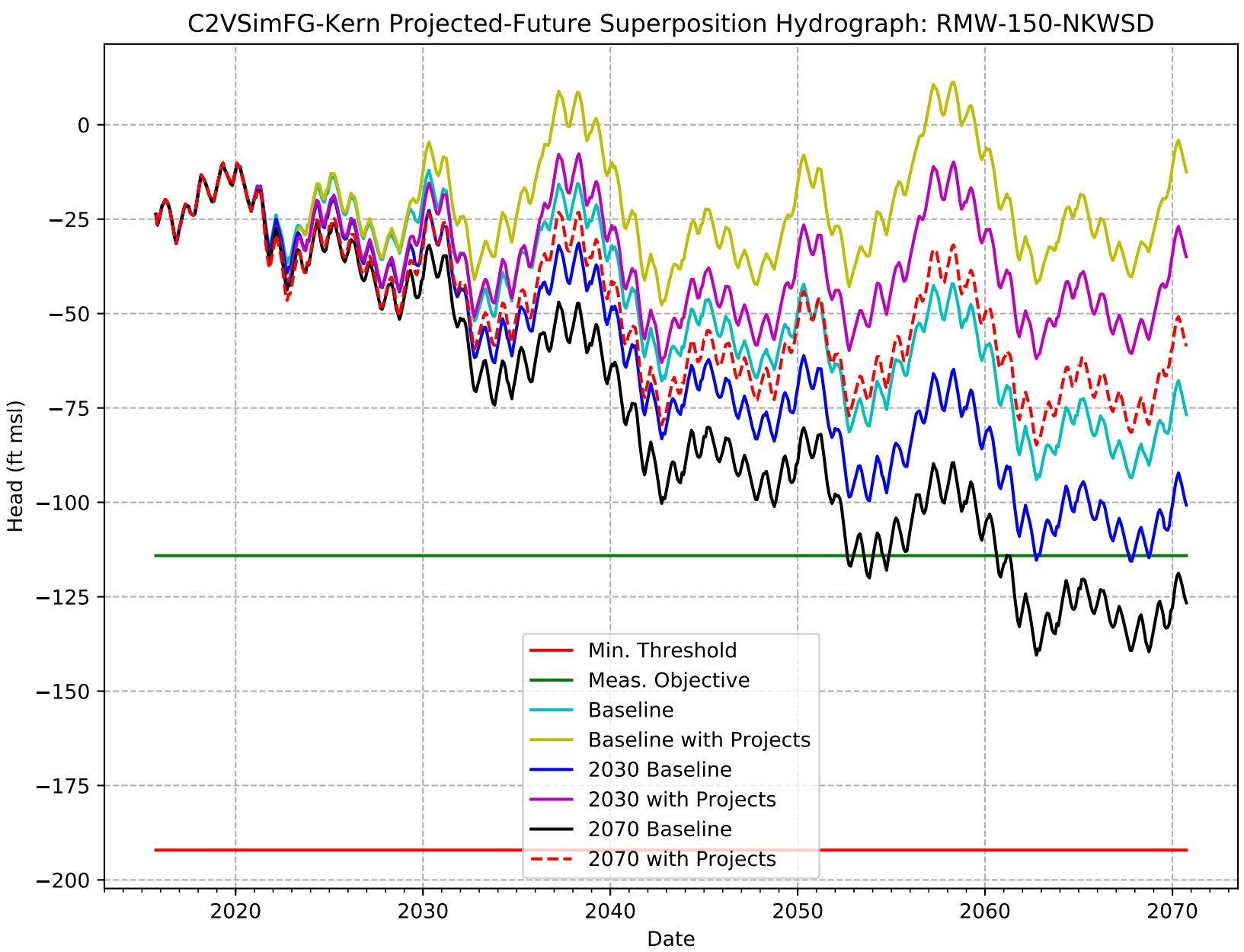

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-145-NKWSD
Head (ft msl)
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

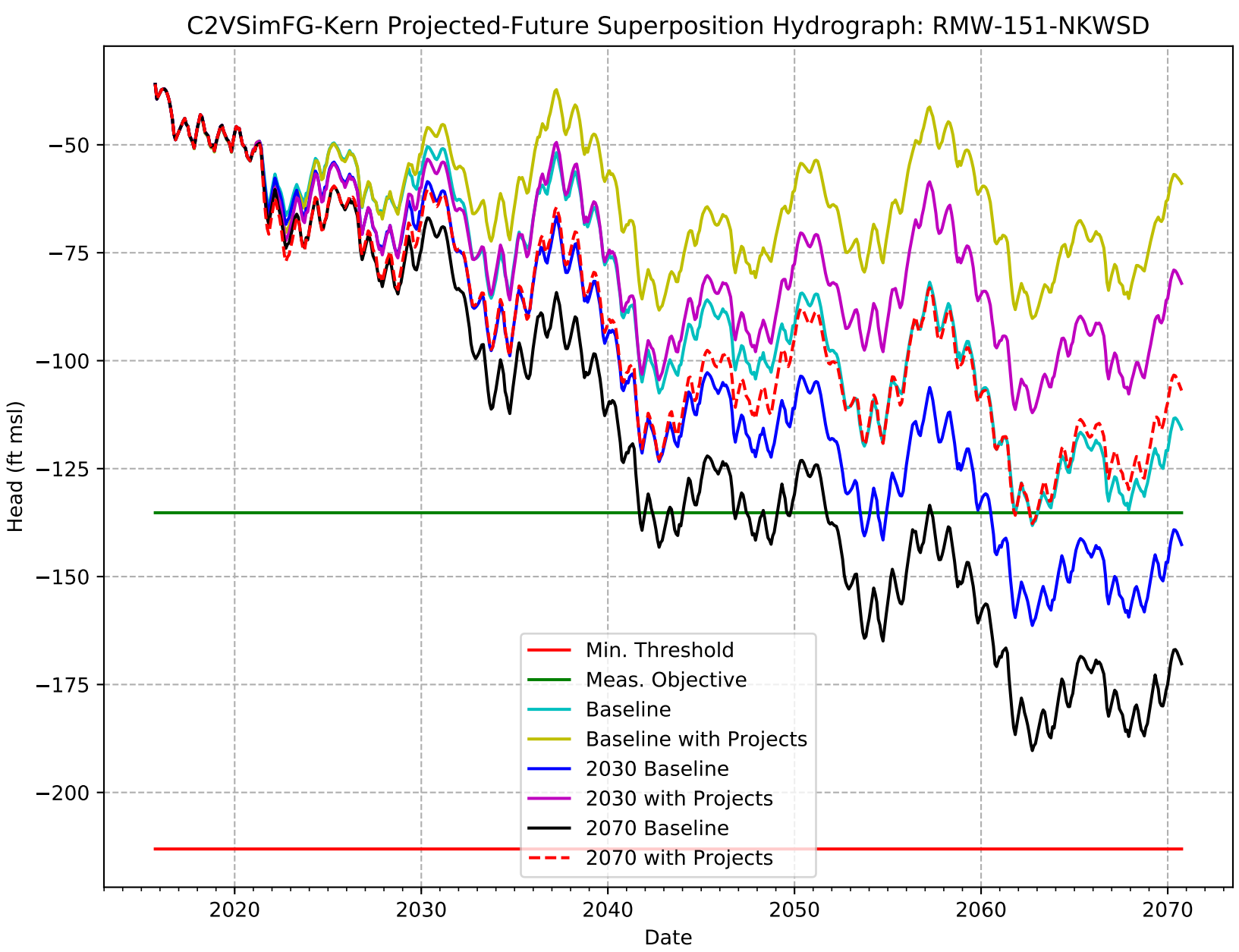

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-146-NKWSD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

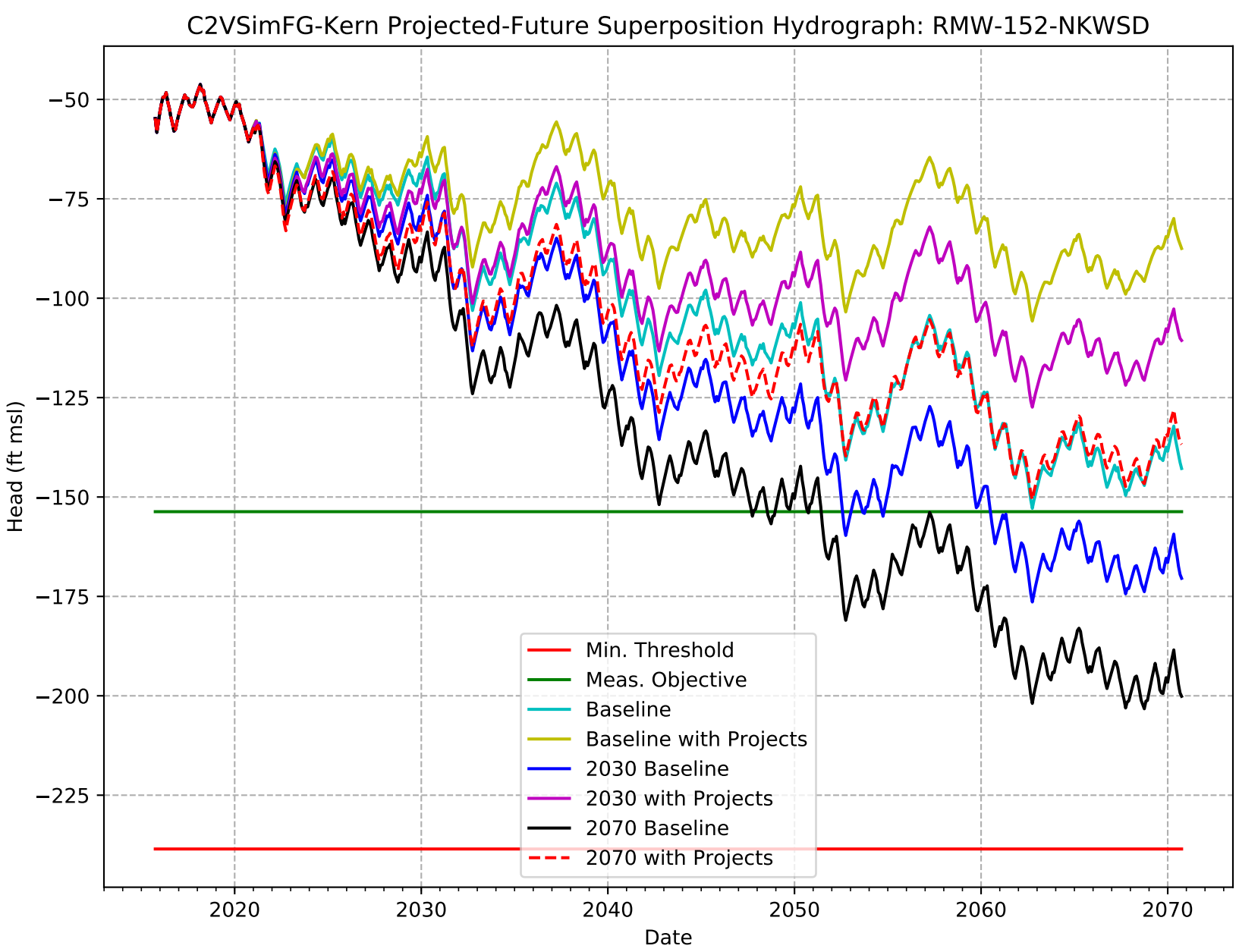

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-147-NKWSD
Head (ft msl)
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

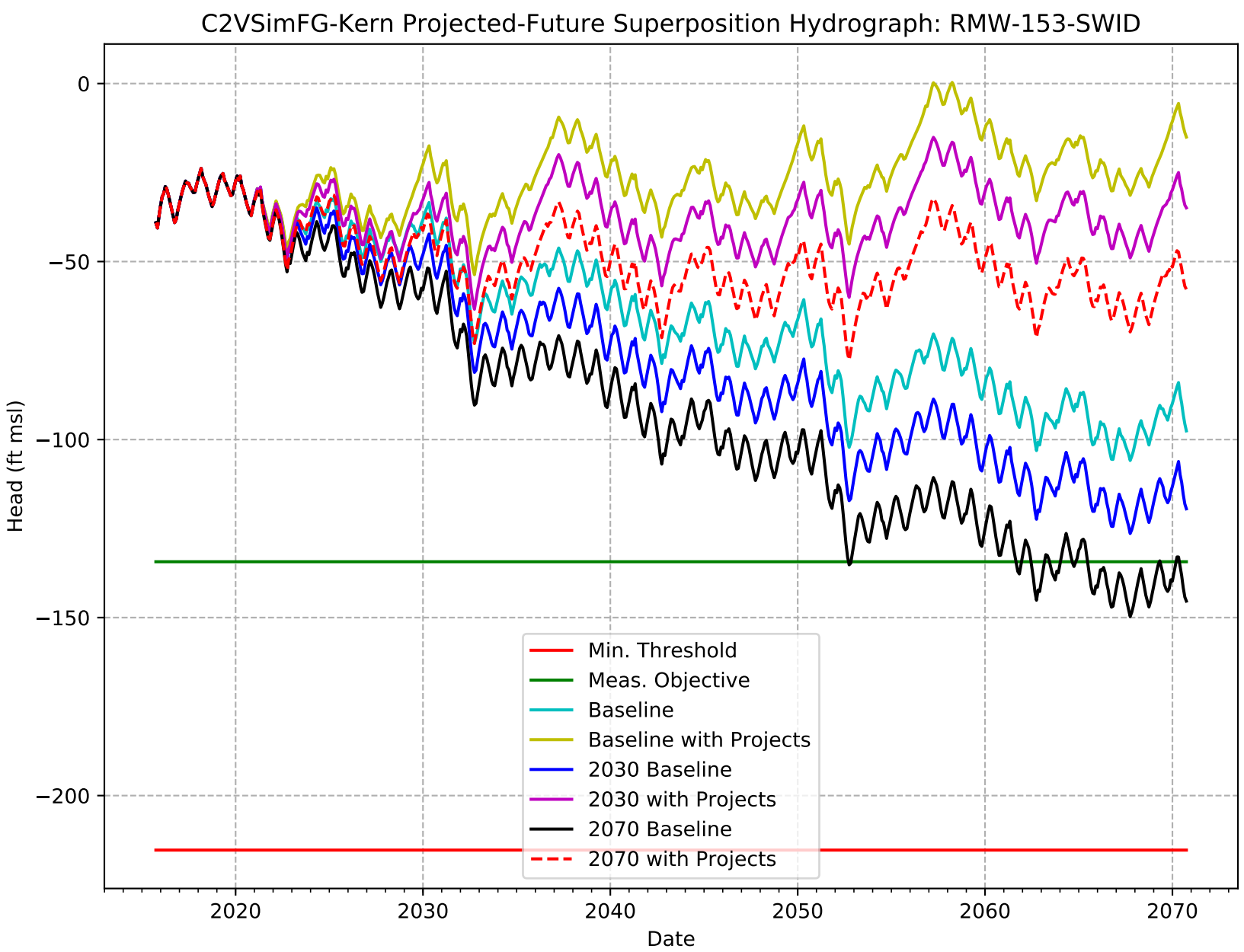

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-148-NKWSD
Head (ft msl)
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

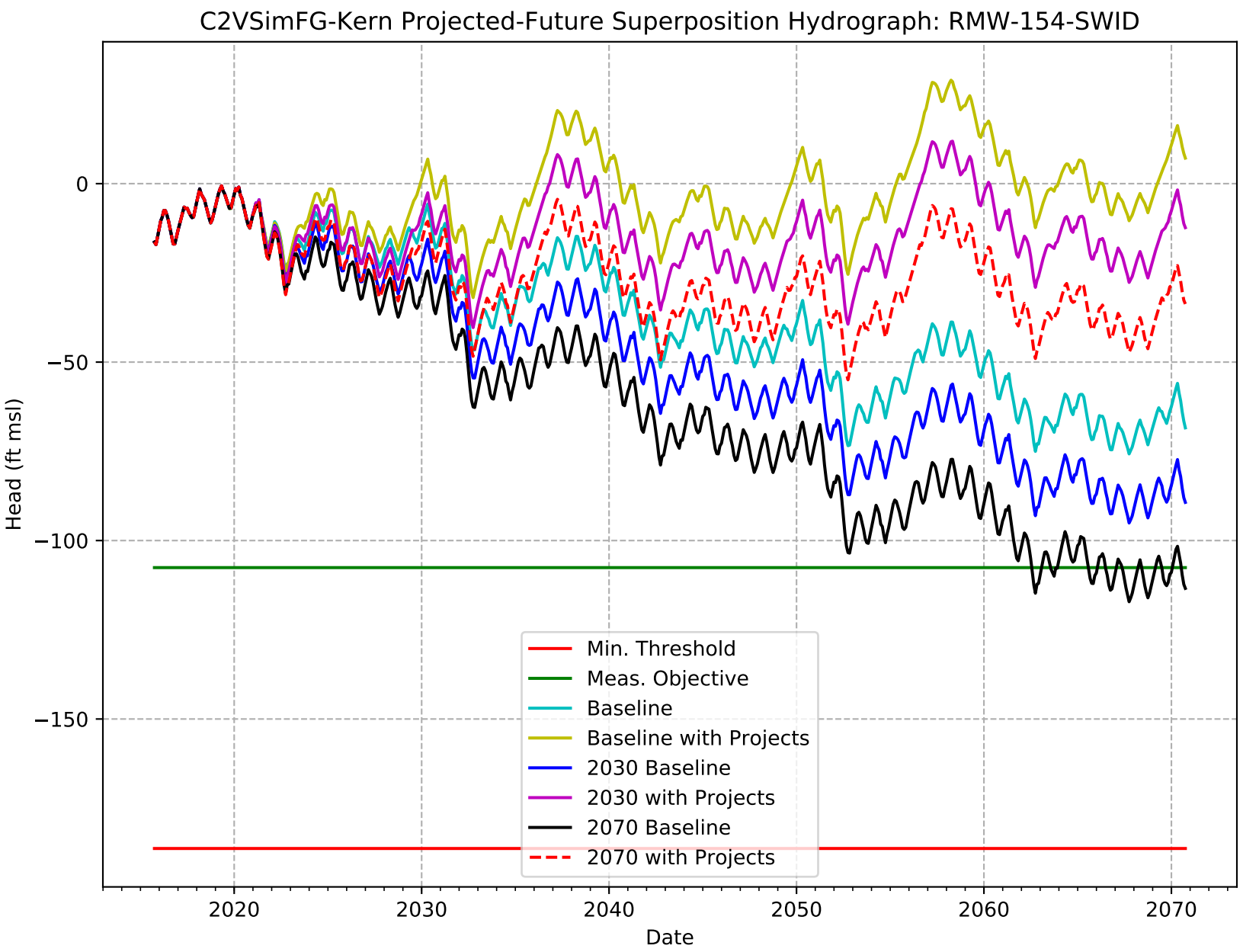

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-149-NKWSD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

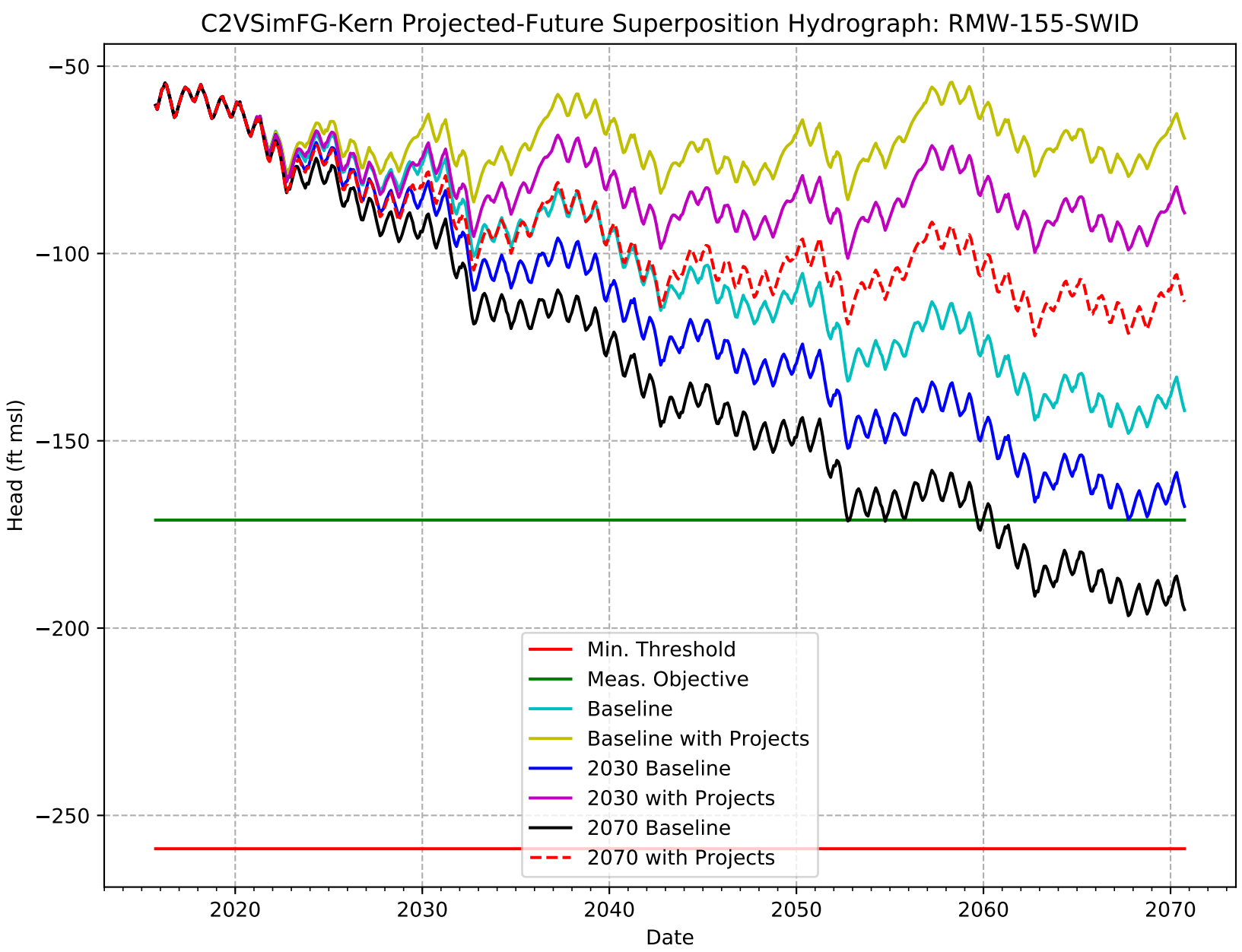

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-150-NKWSD
Head (ft msl)
0
−25
−50
−75
−100
−125
−150
−175
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

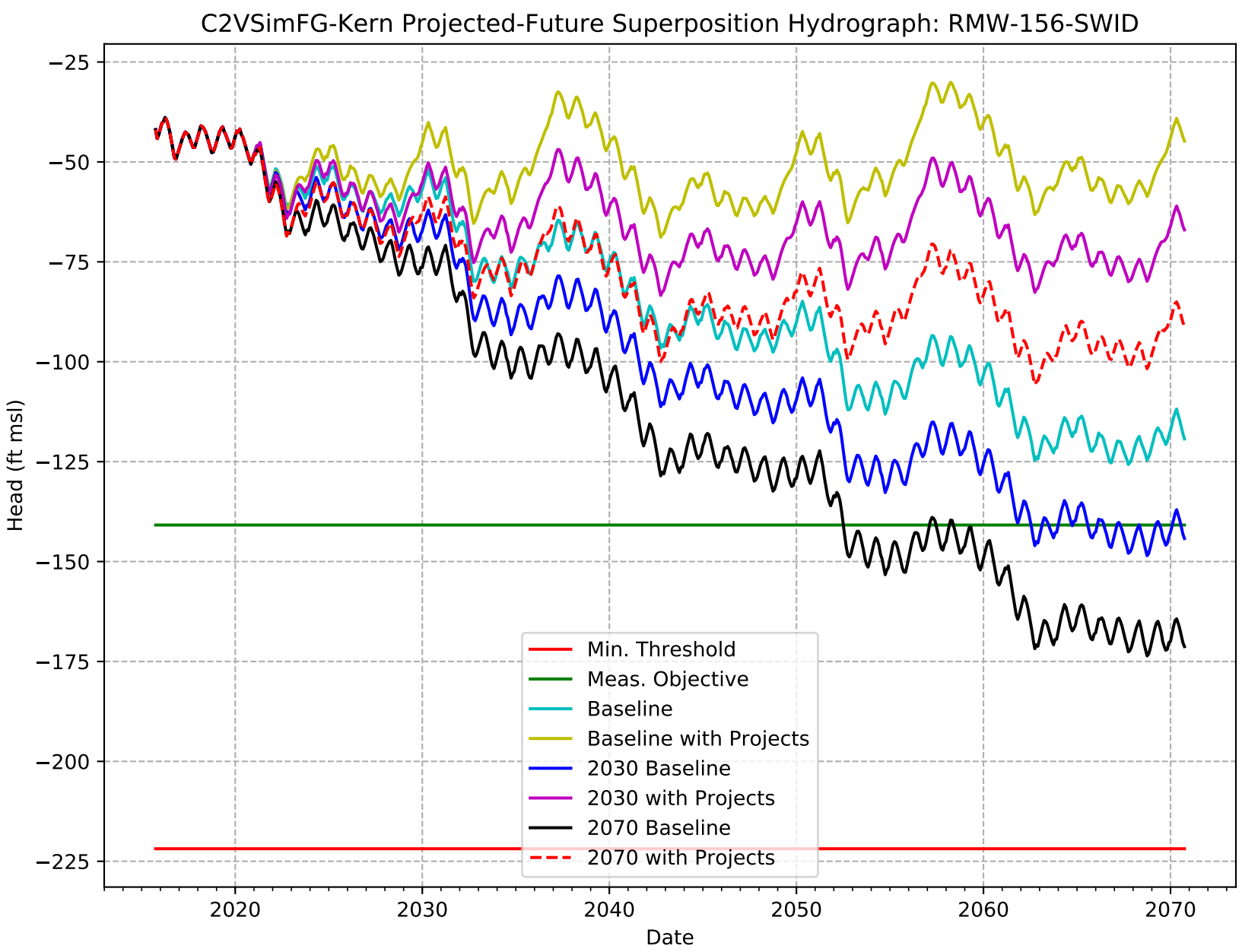

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-151-NKWSD
Head (ft msl)
−50
−75
−100
−125
−150
−175
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

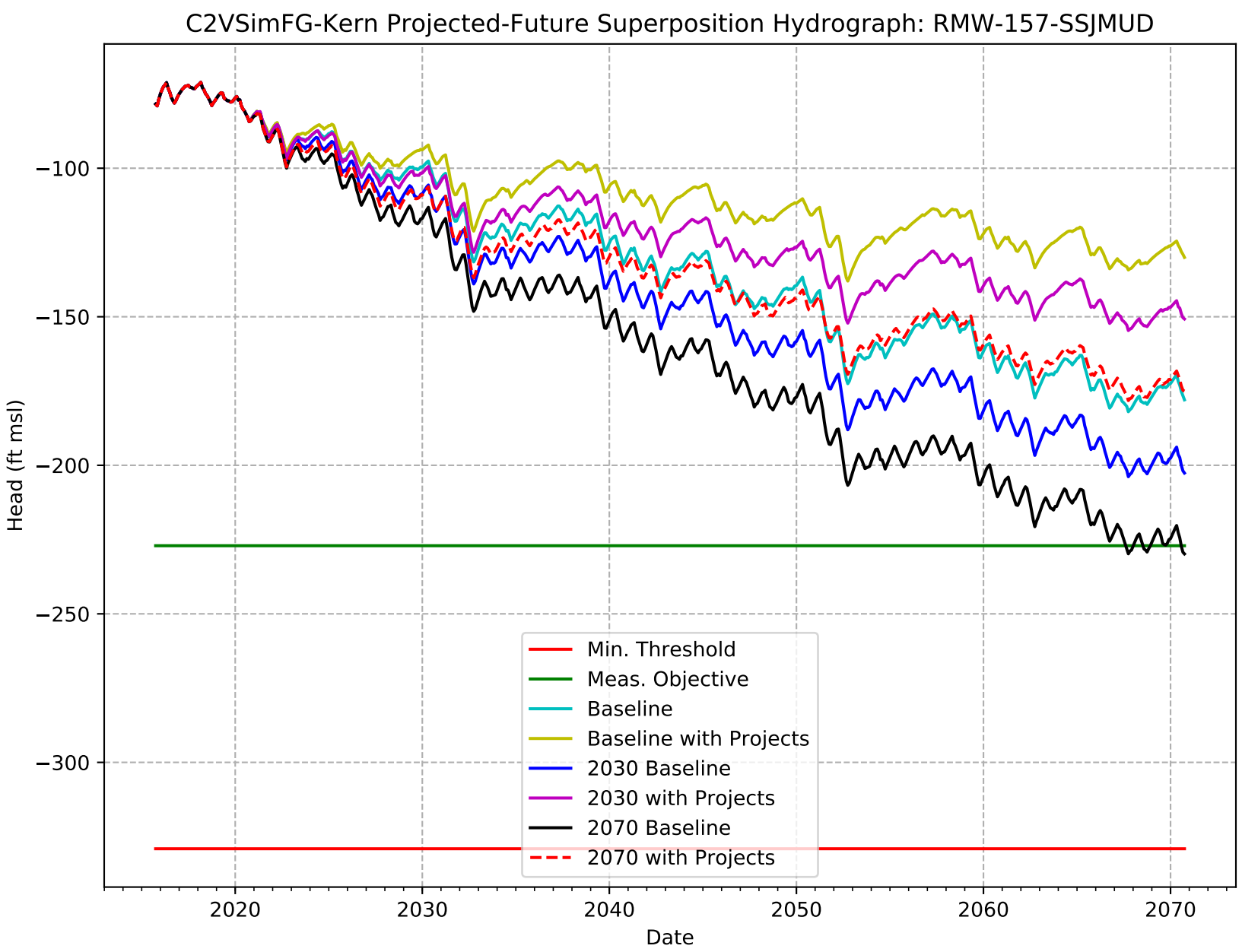

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-152-NKWSD
Head (ft msl)
−50
−75
−100
−125
−150
−175
−200
−225
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

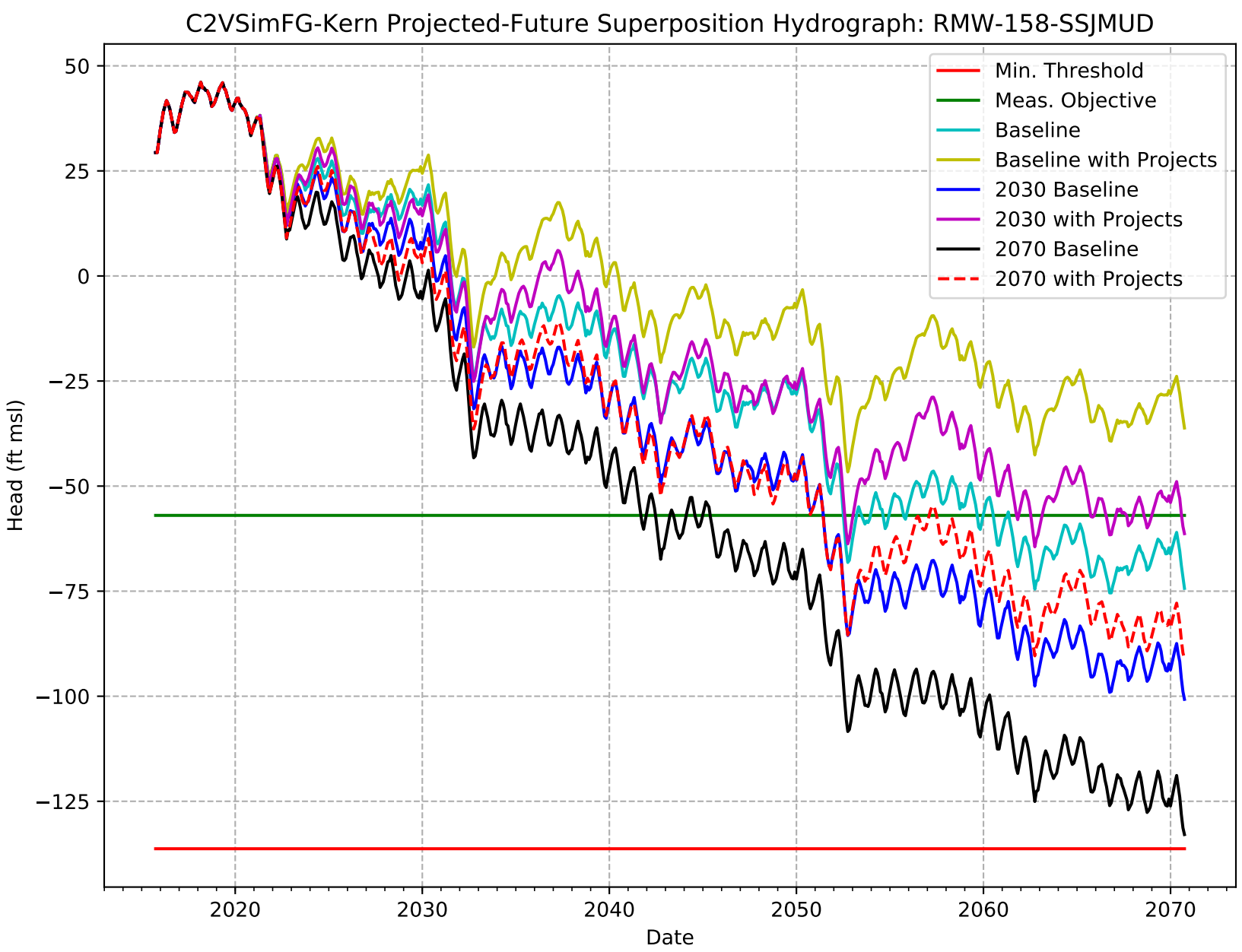

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-153-SWID
Head (ft msl)
0
−50
−100
−150
−200
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

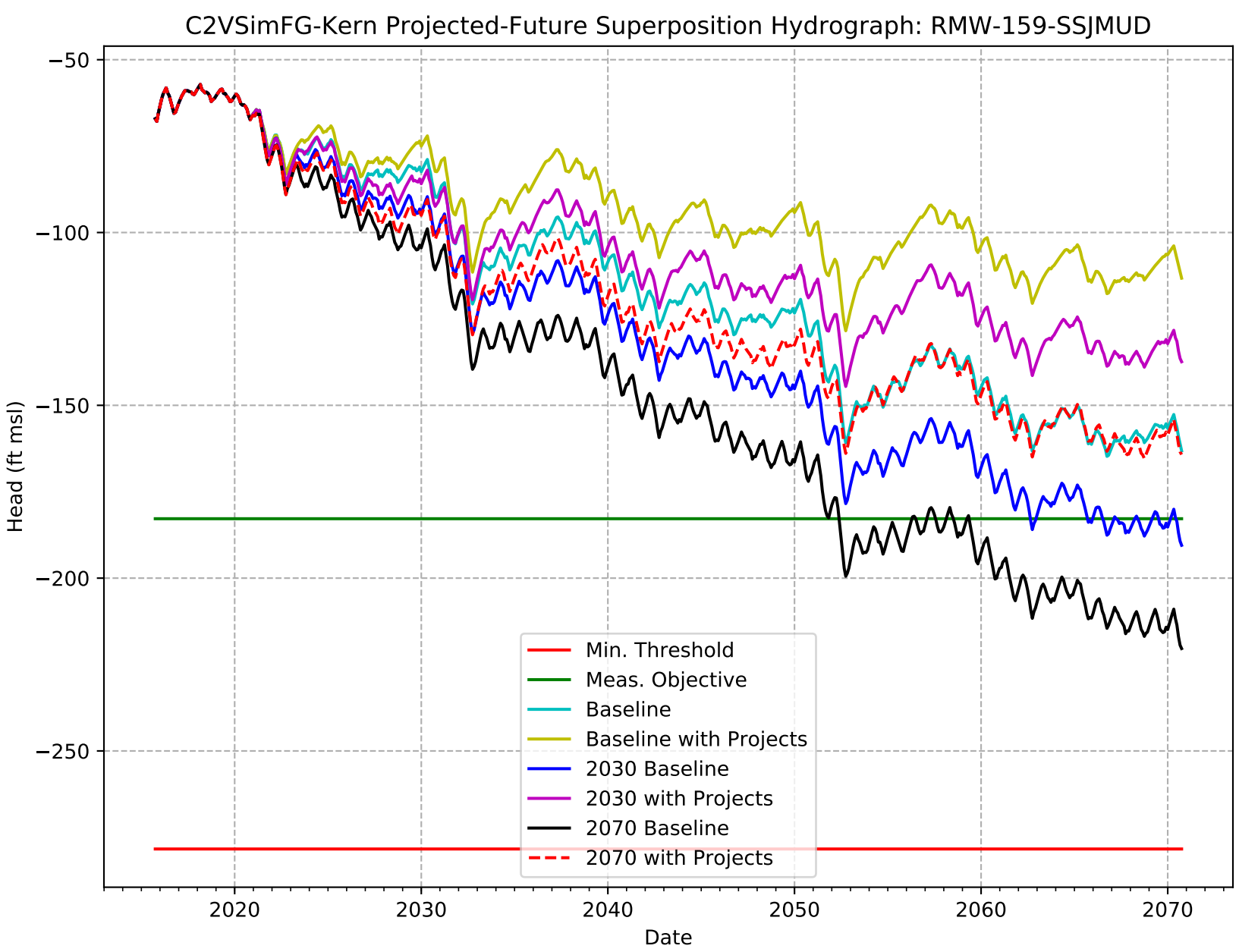

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-154-SWID
Head (ft msl)
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

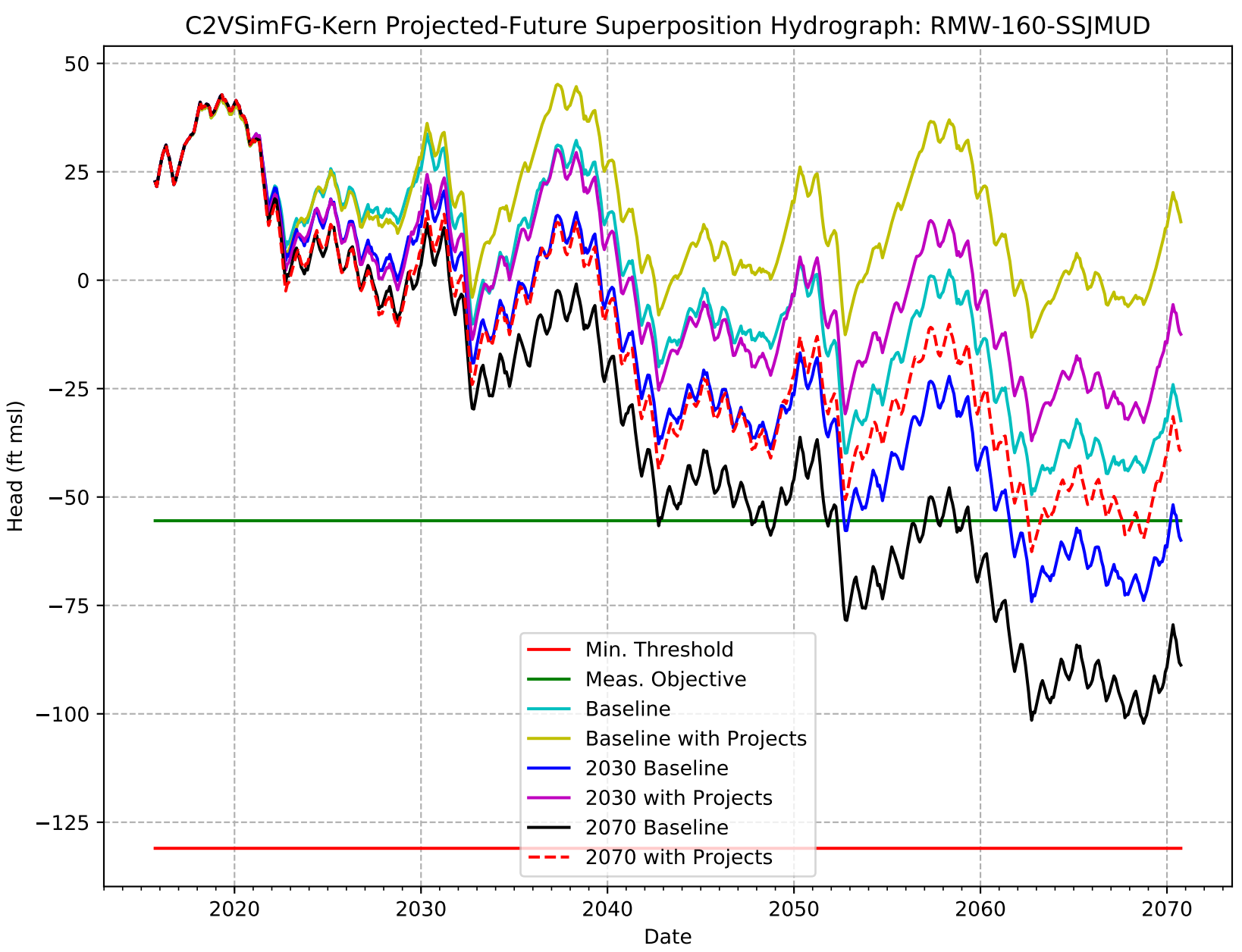

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-155-SWID
Head (ft msl)
−50
−100
−150
−200
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

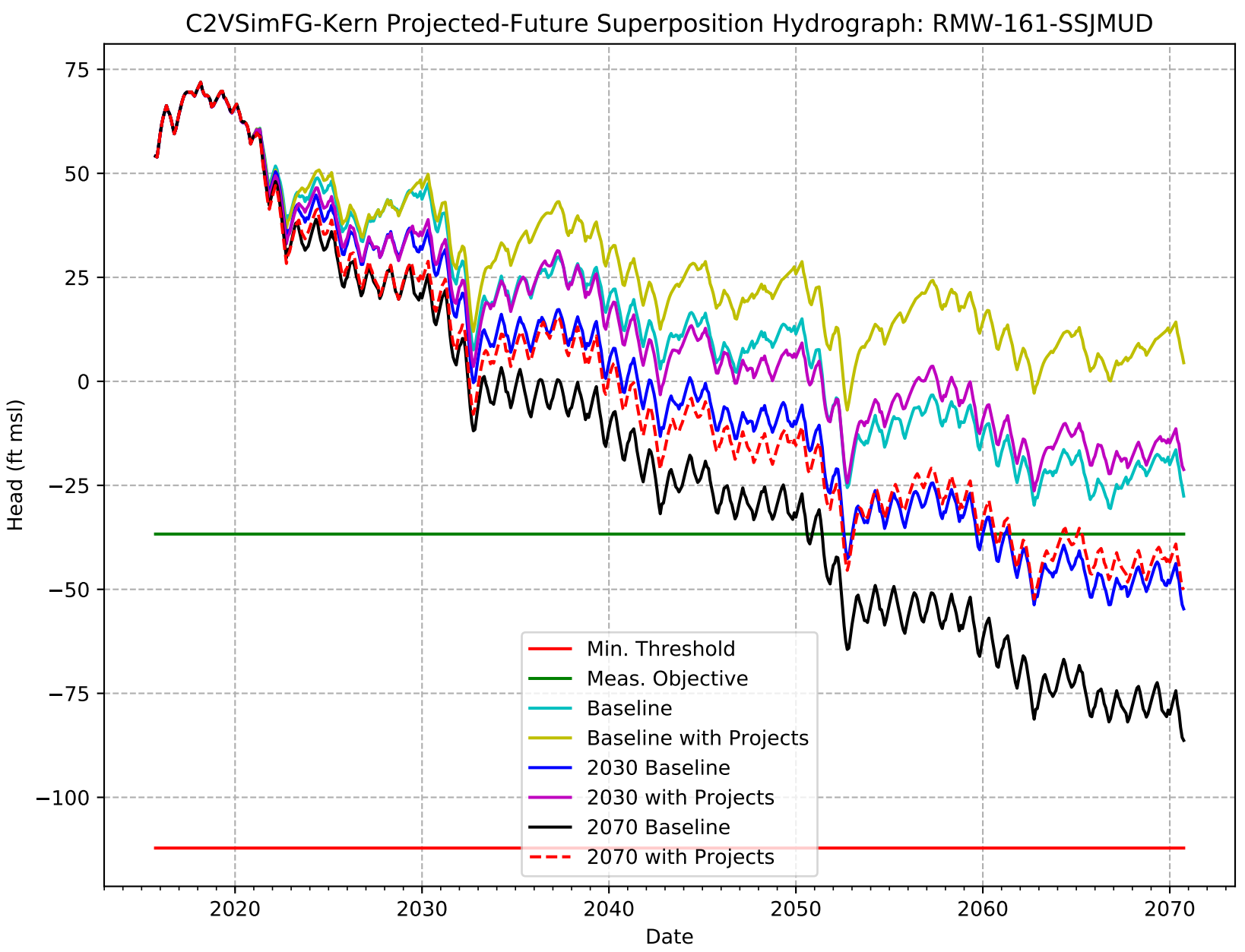

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-156-SWID
Head (ft msl)
−25
−50
−75
−100
−125
−150
−175
−200
−225
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

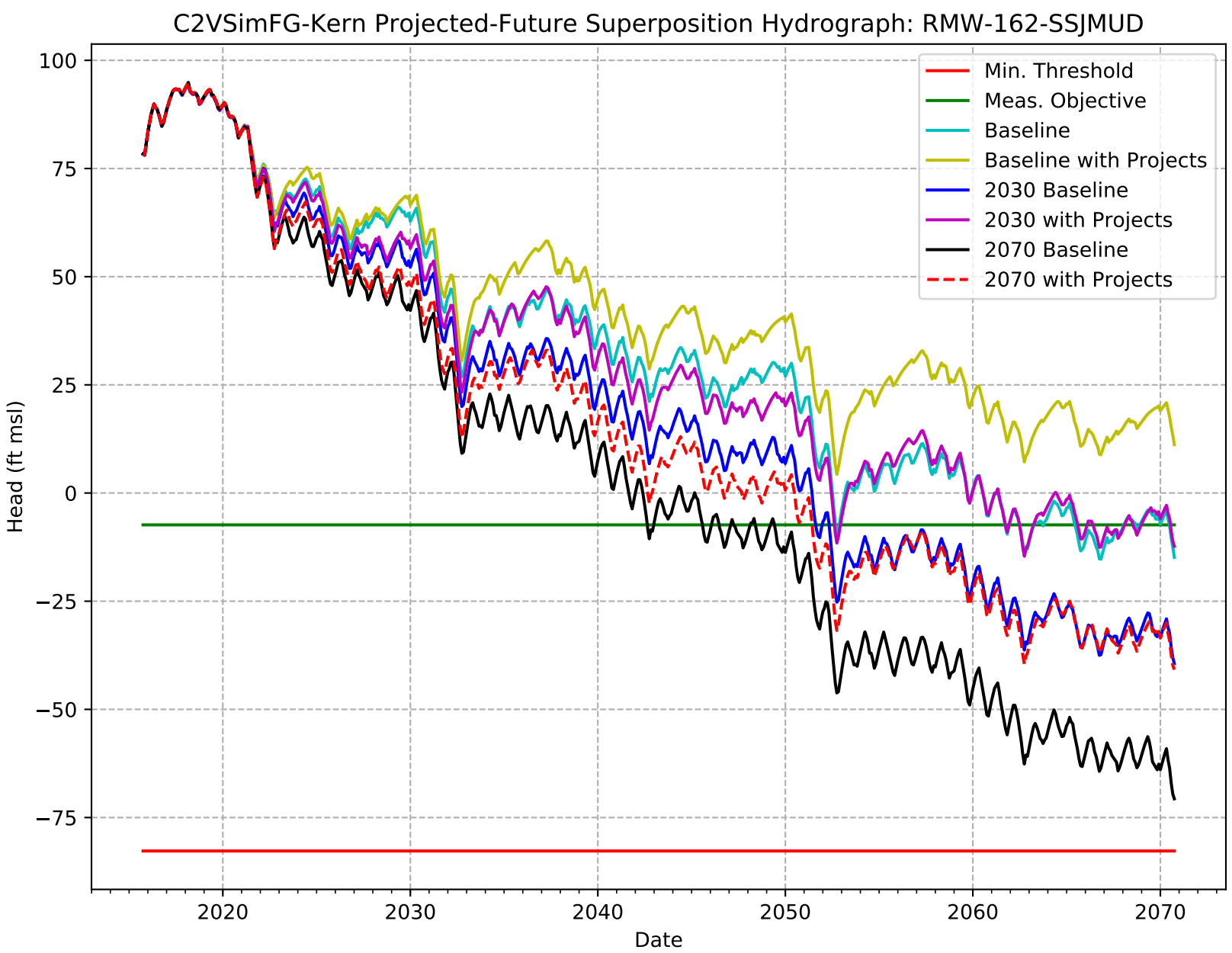

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-157-SSJMUD
Head (ft msl)
−100
−150
−200
−250
−300
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

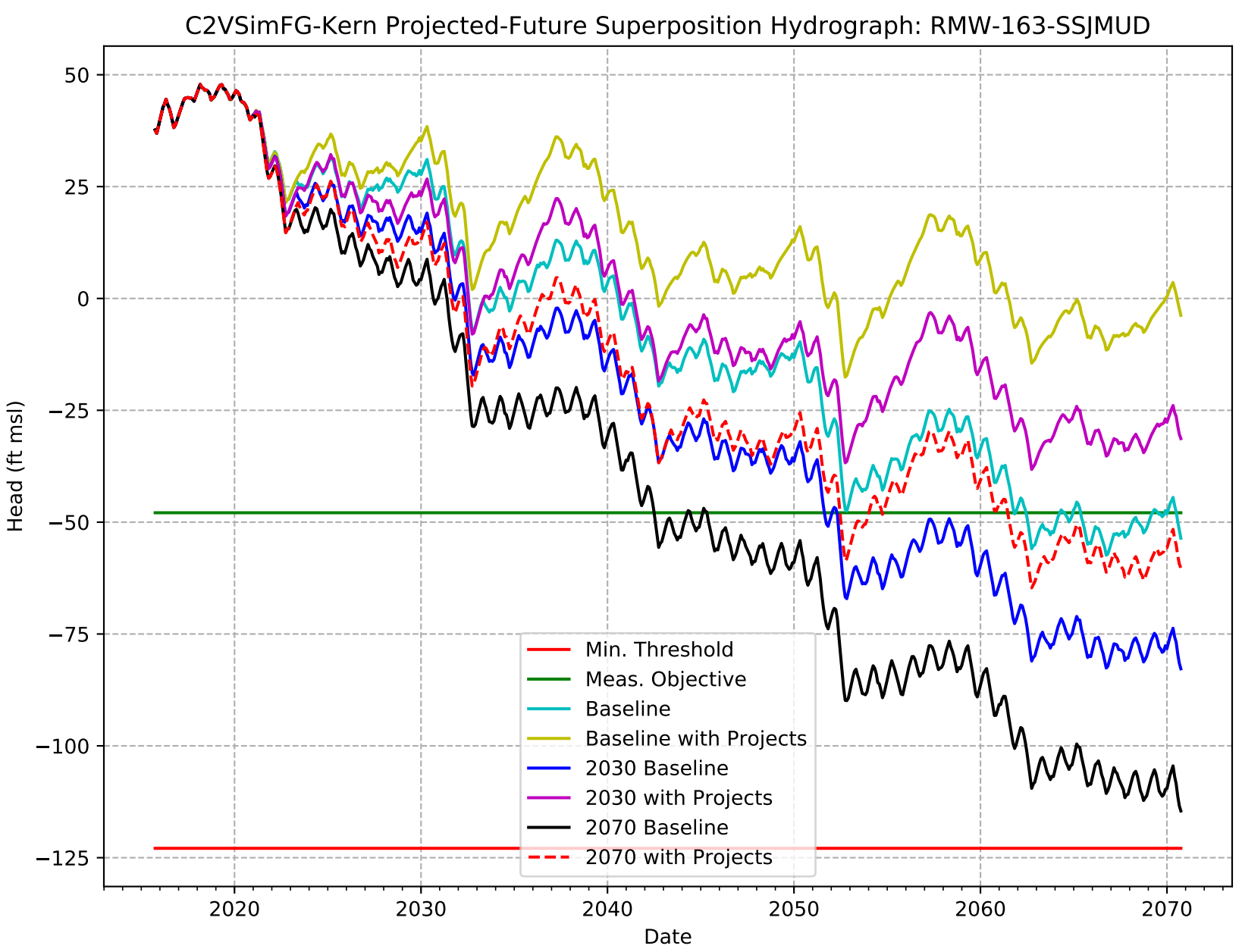

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-158-SSJMUD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date

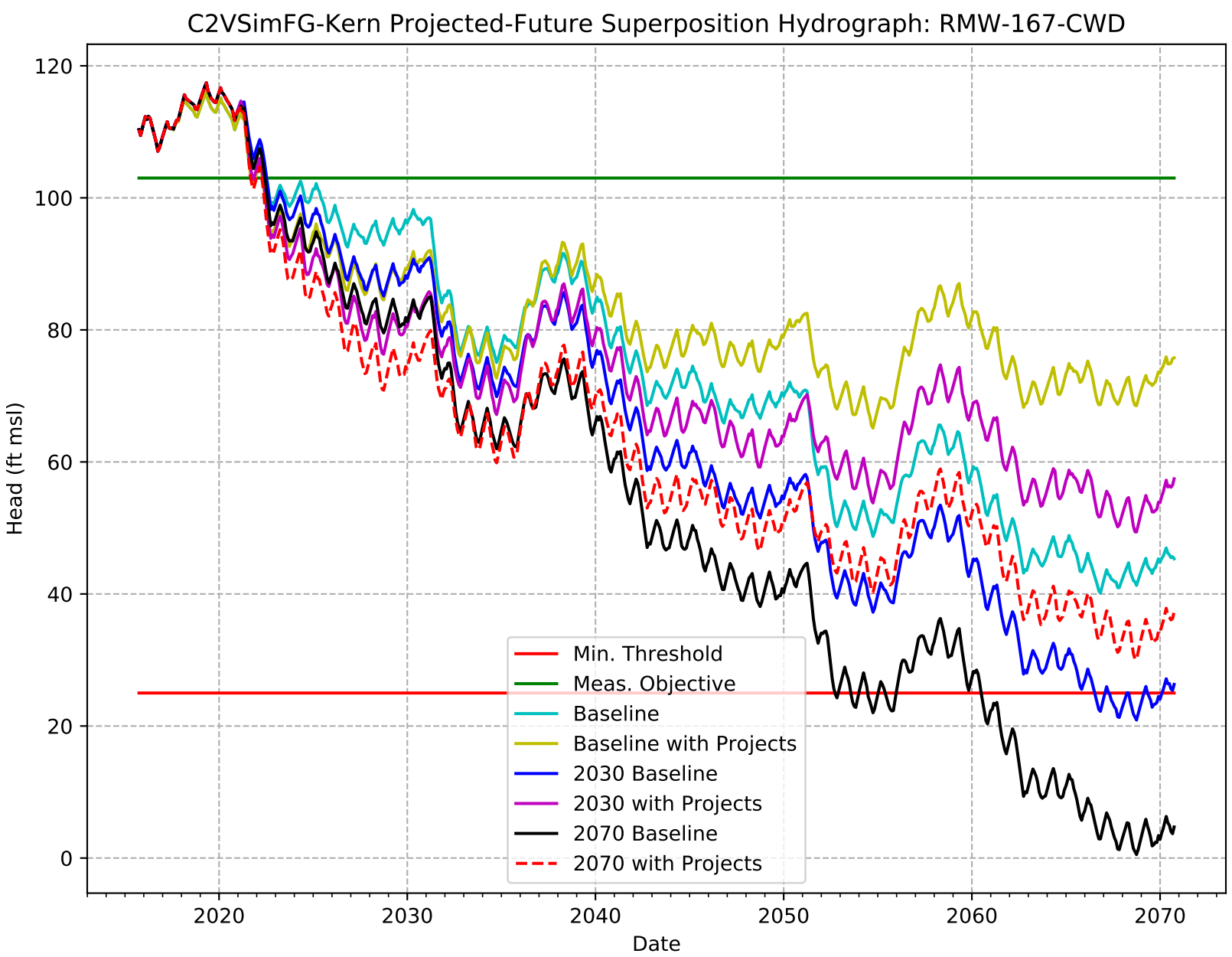

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-159-SSJMUD
Head (ft msl)
−50
−100
−150
−200
−250
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

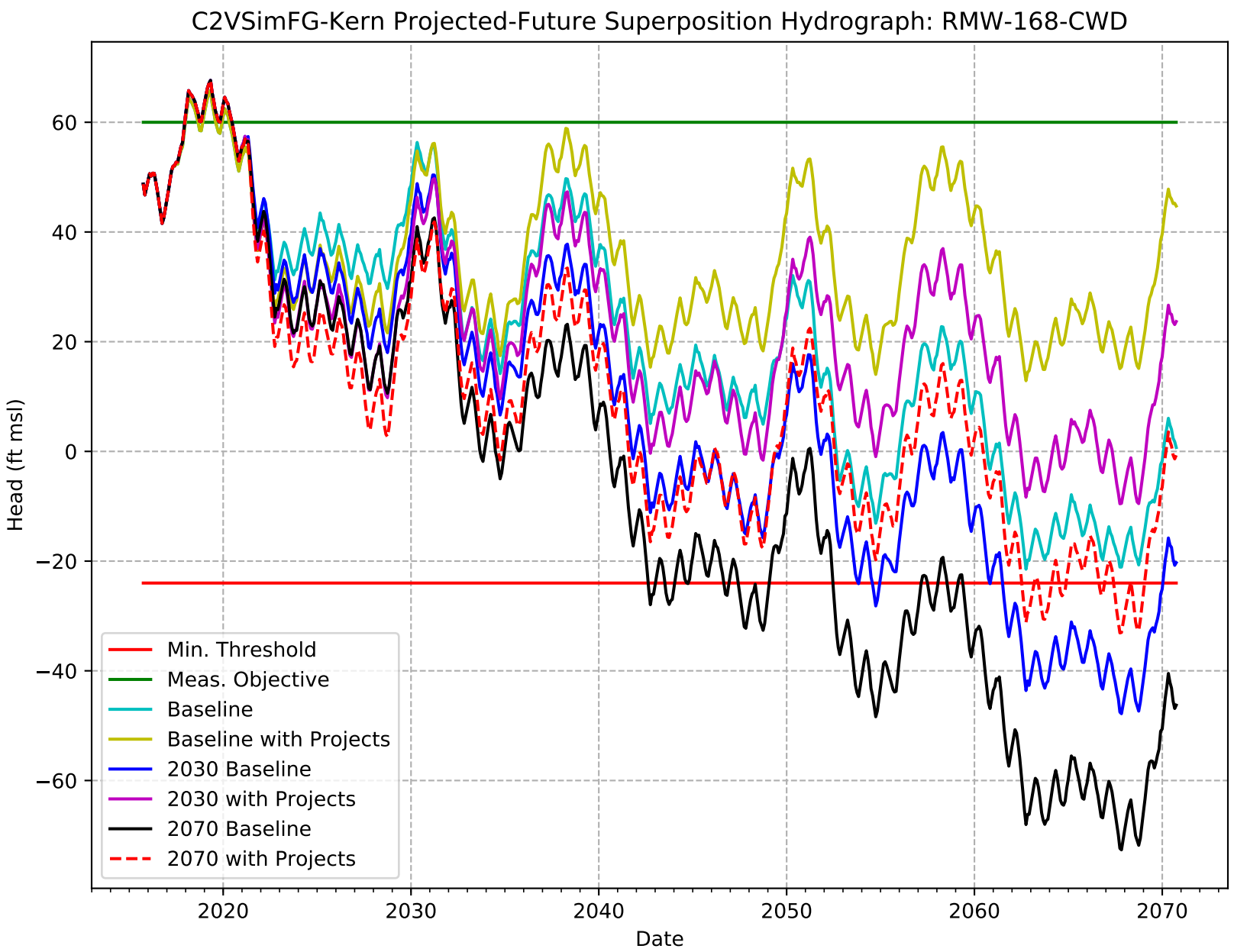

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-160-SSJMUD
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

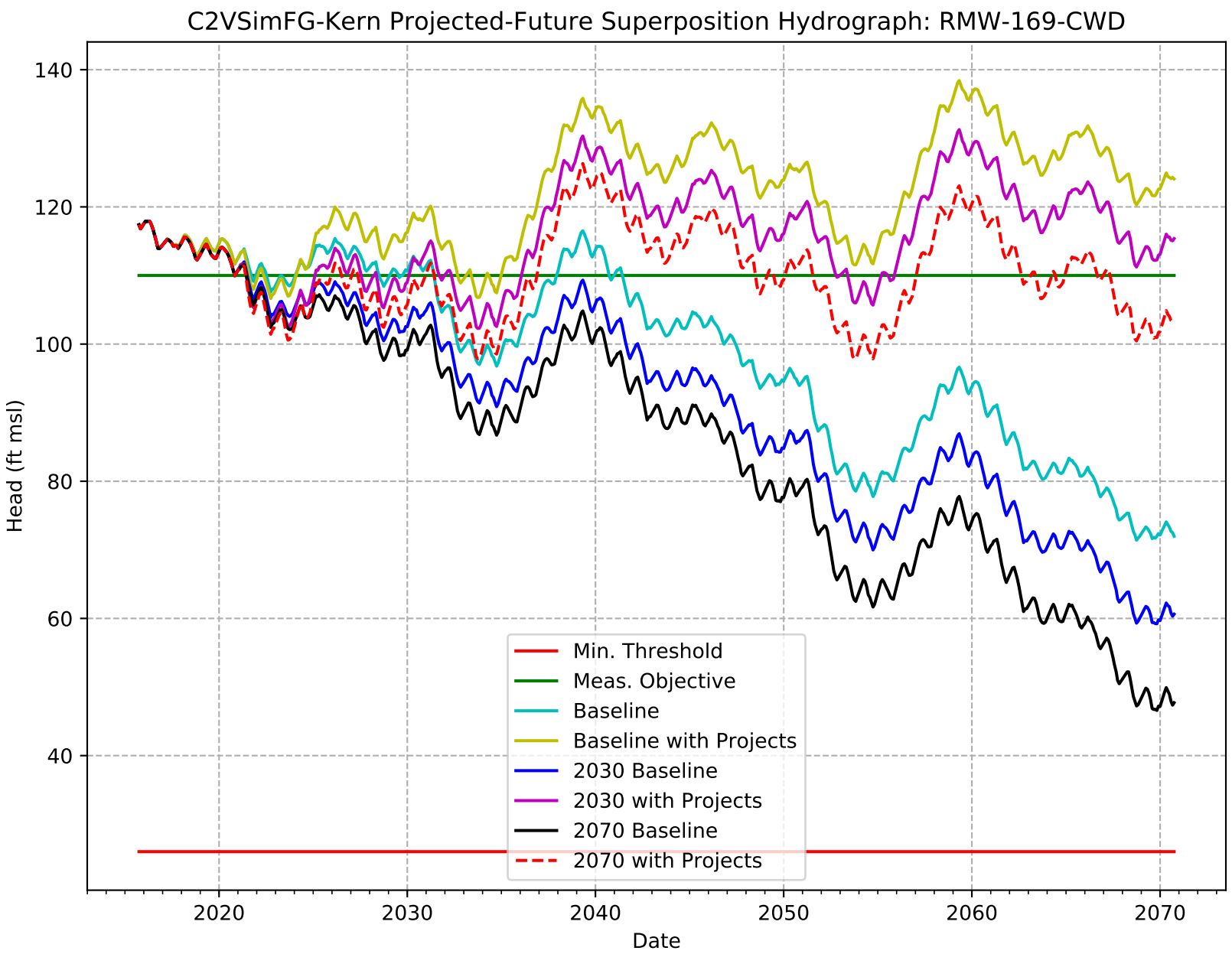

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-161-SSJMUD
Head (ft msl)
75
50
25
0
−25
−50
−75
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

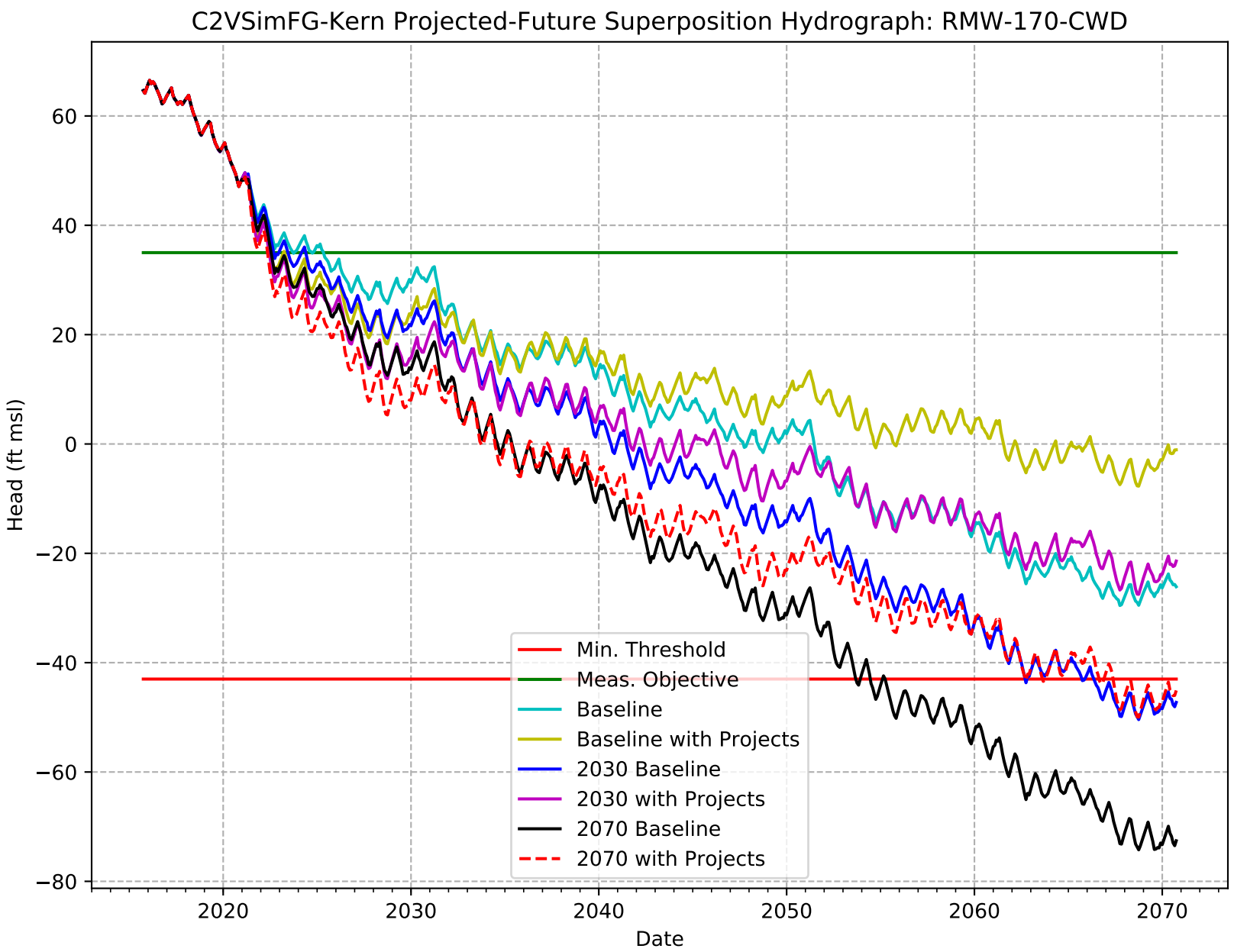

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-162-SSJMUD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
75
50
25
0
−25
−50
−75
2020
2030
2040
2050
2060
2070
Date

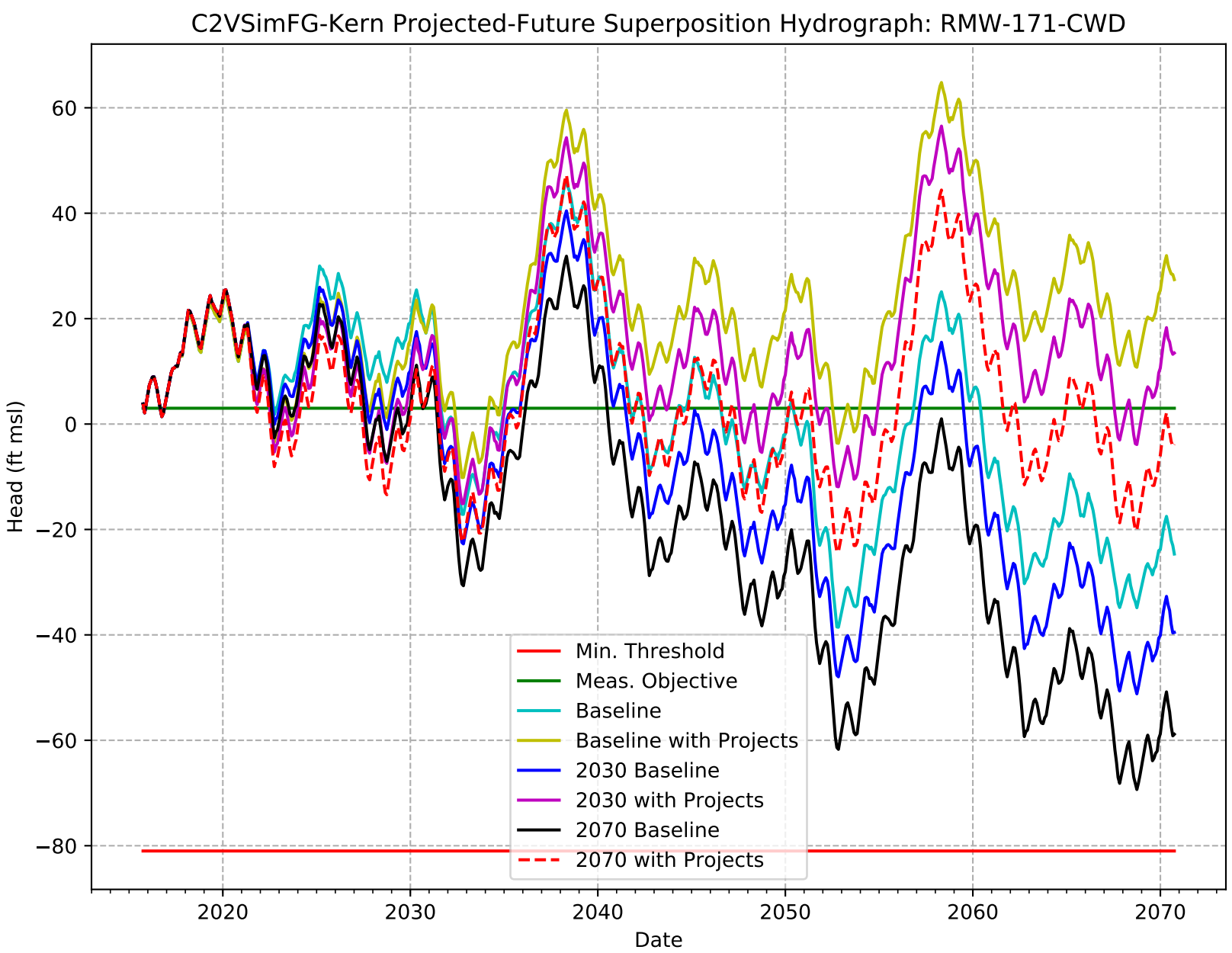

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-163-SSJMUD
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

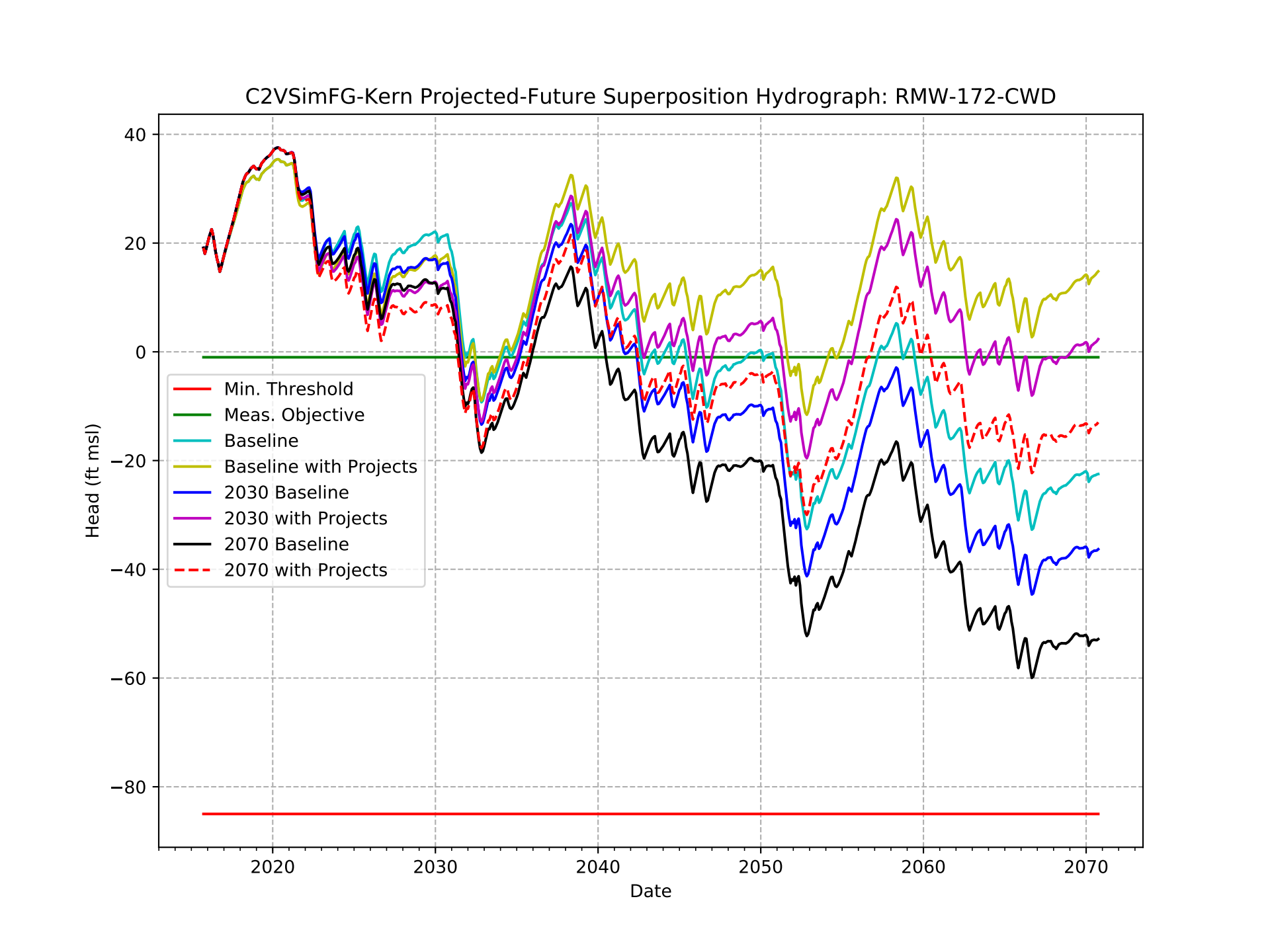

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-167-CWD
Head (ft msl)
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

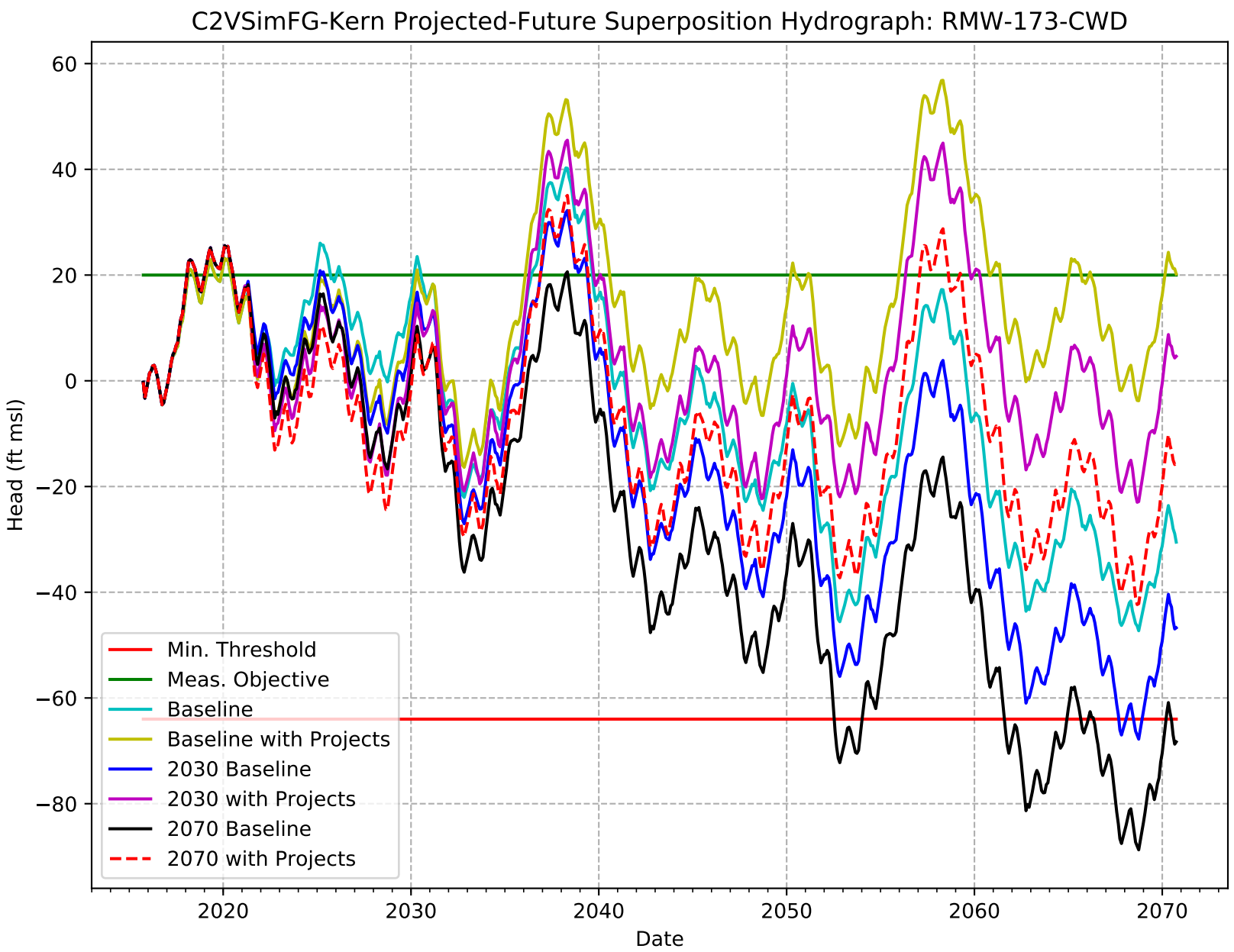

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-168-CWD
Head (ft msl)
60
40
20
0
−20
−40
−60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

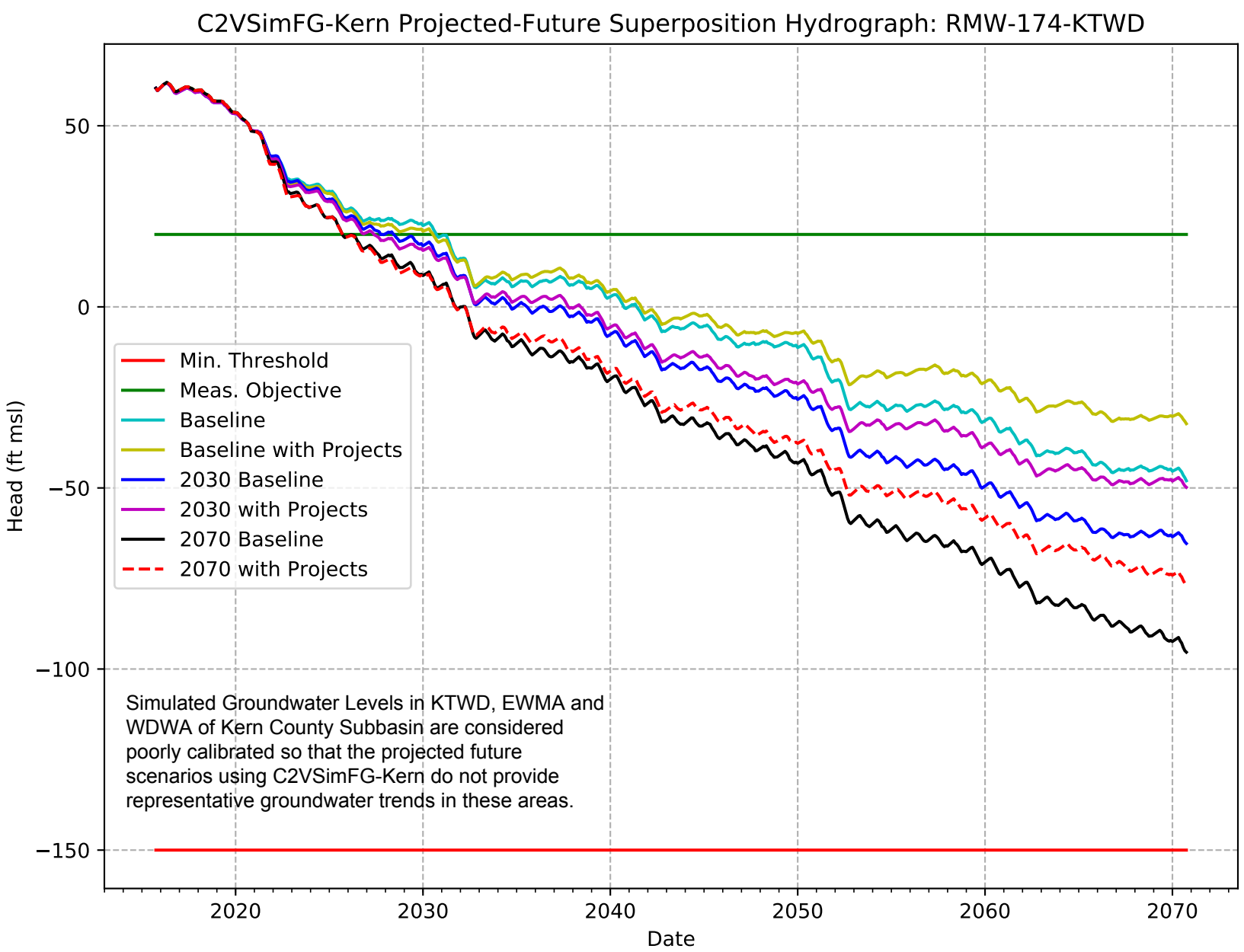

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-169-CWD
Head (ft msl)
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

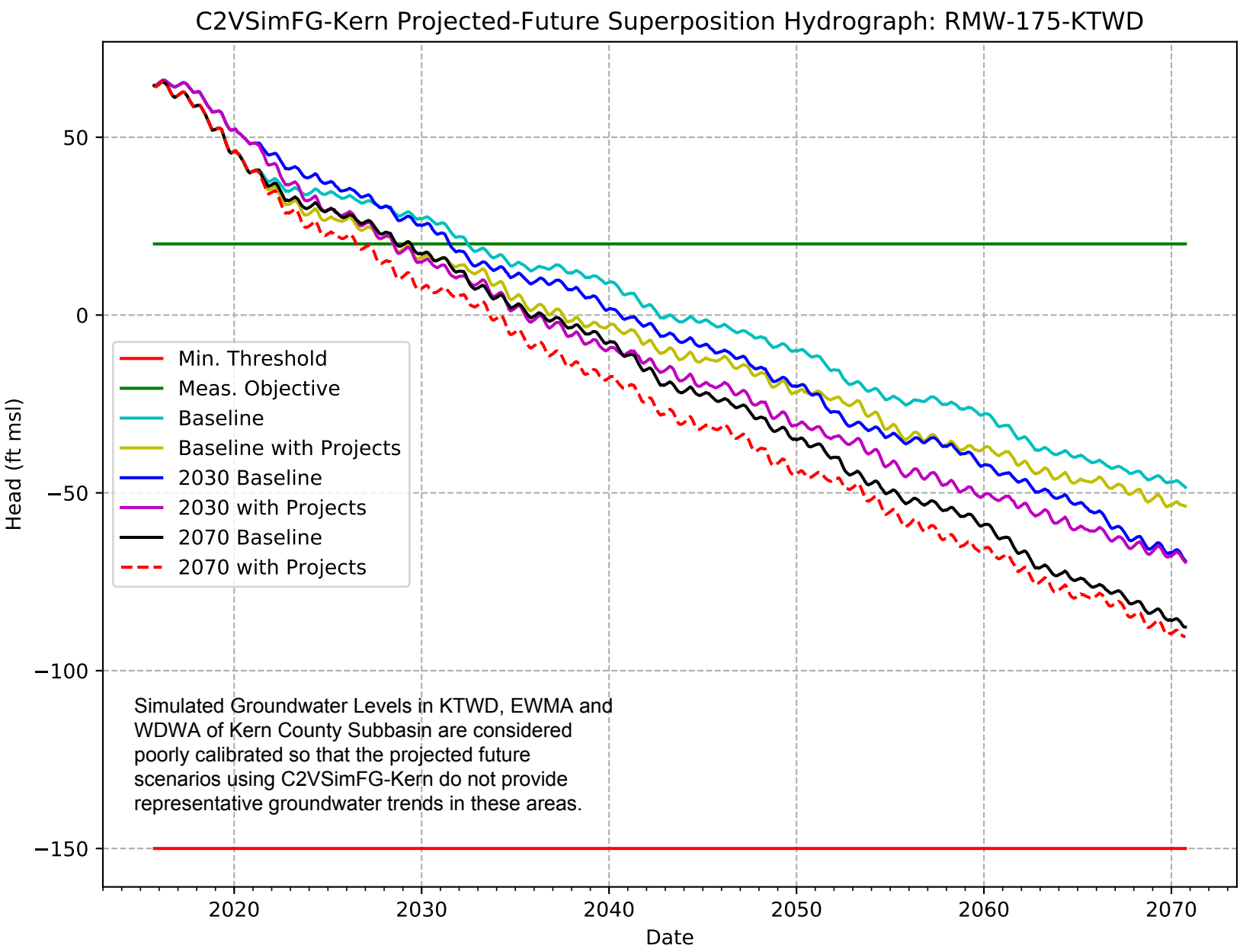

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-170-CWD
Head (ft msl)
60
40
20
0
−20
−40
−60
−80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

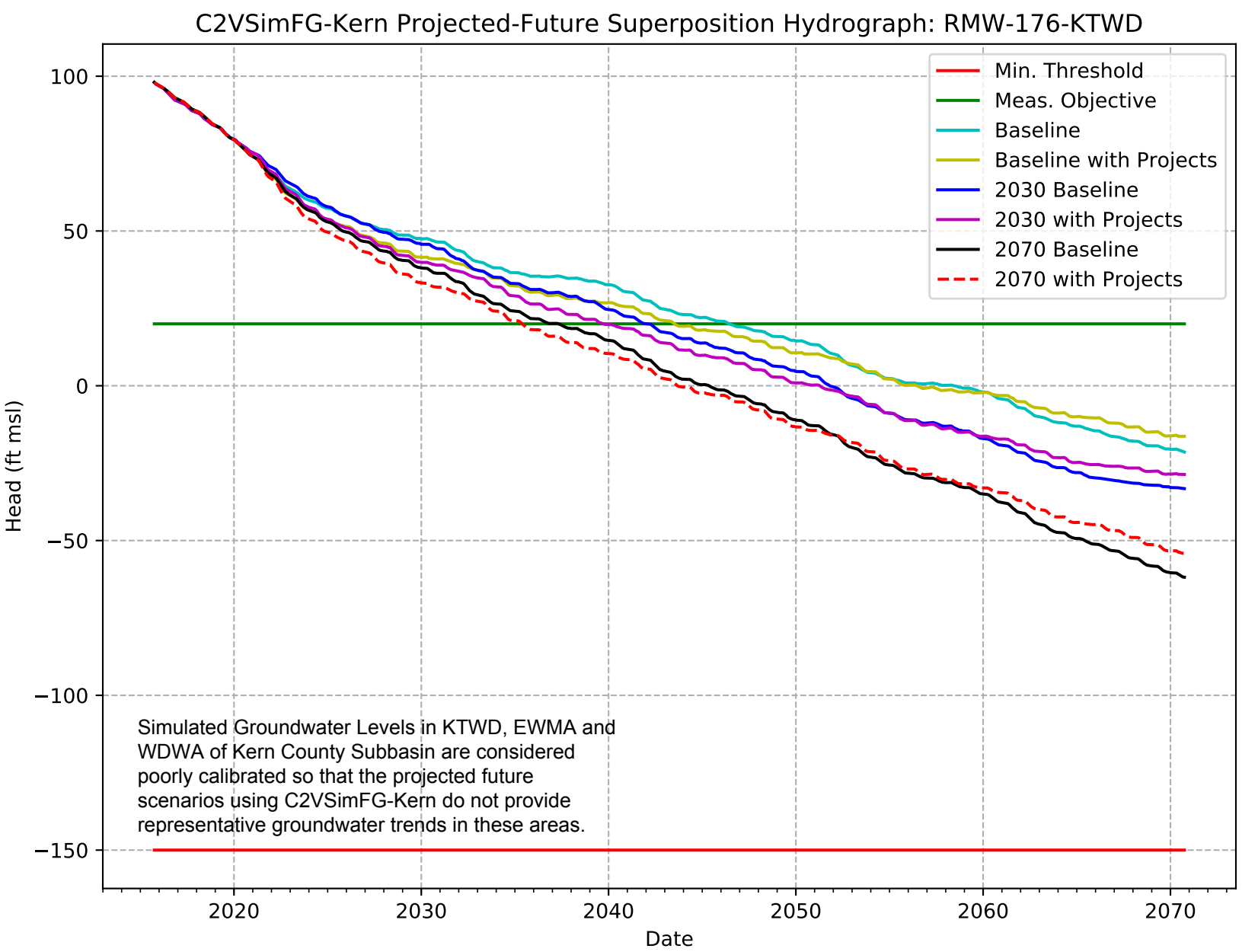

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-171-CWD
Head (ft msl)
60
40
20
0
−20
−40
−60
−80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

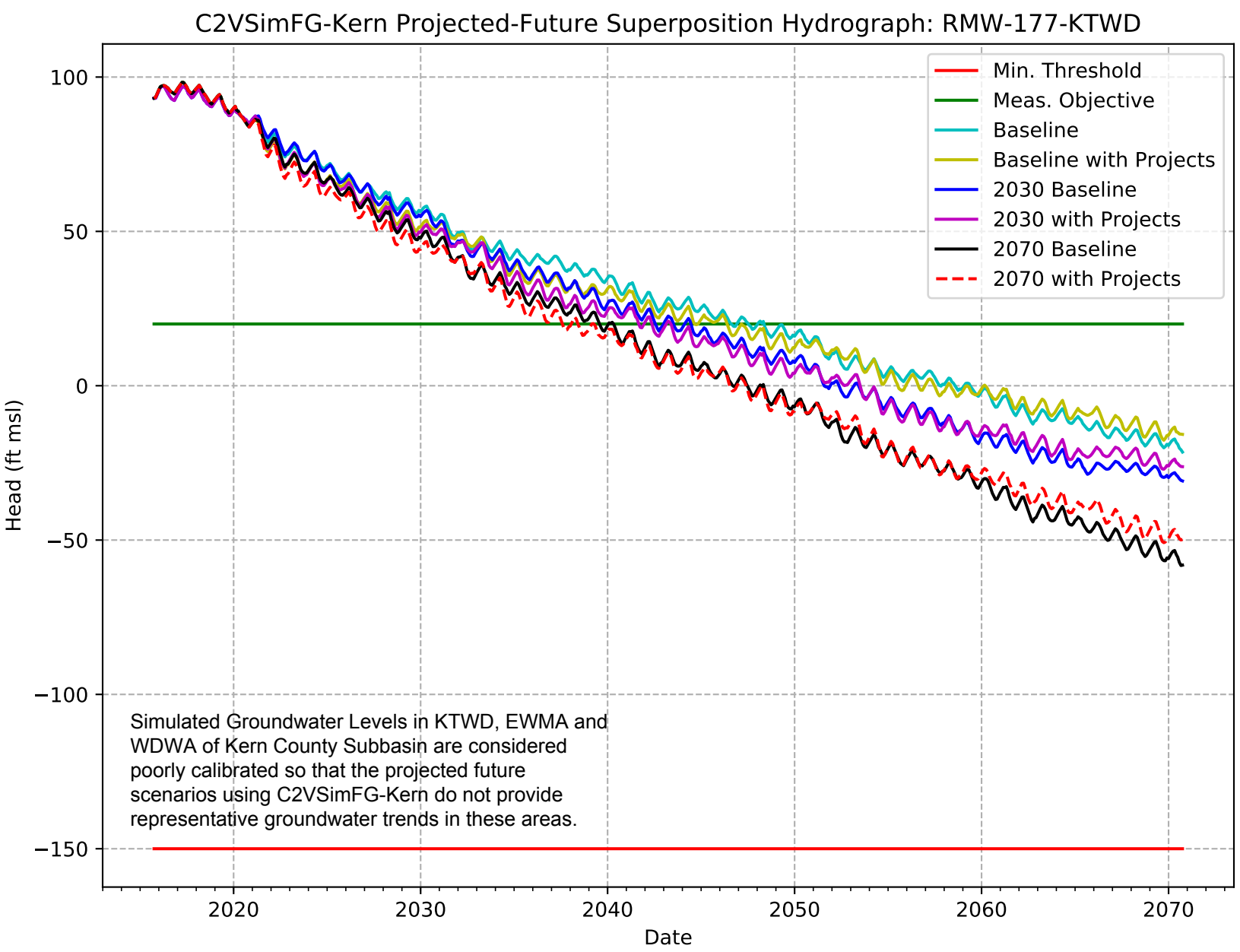

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-172-CWD
Head (ft msl)
Date
40
20
0
−20
−40
−60
−80
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

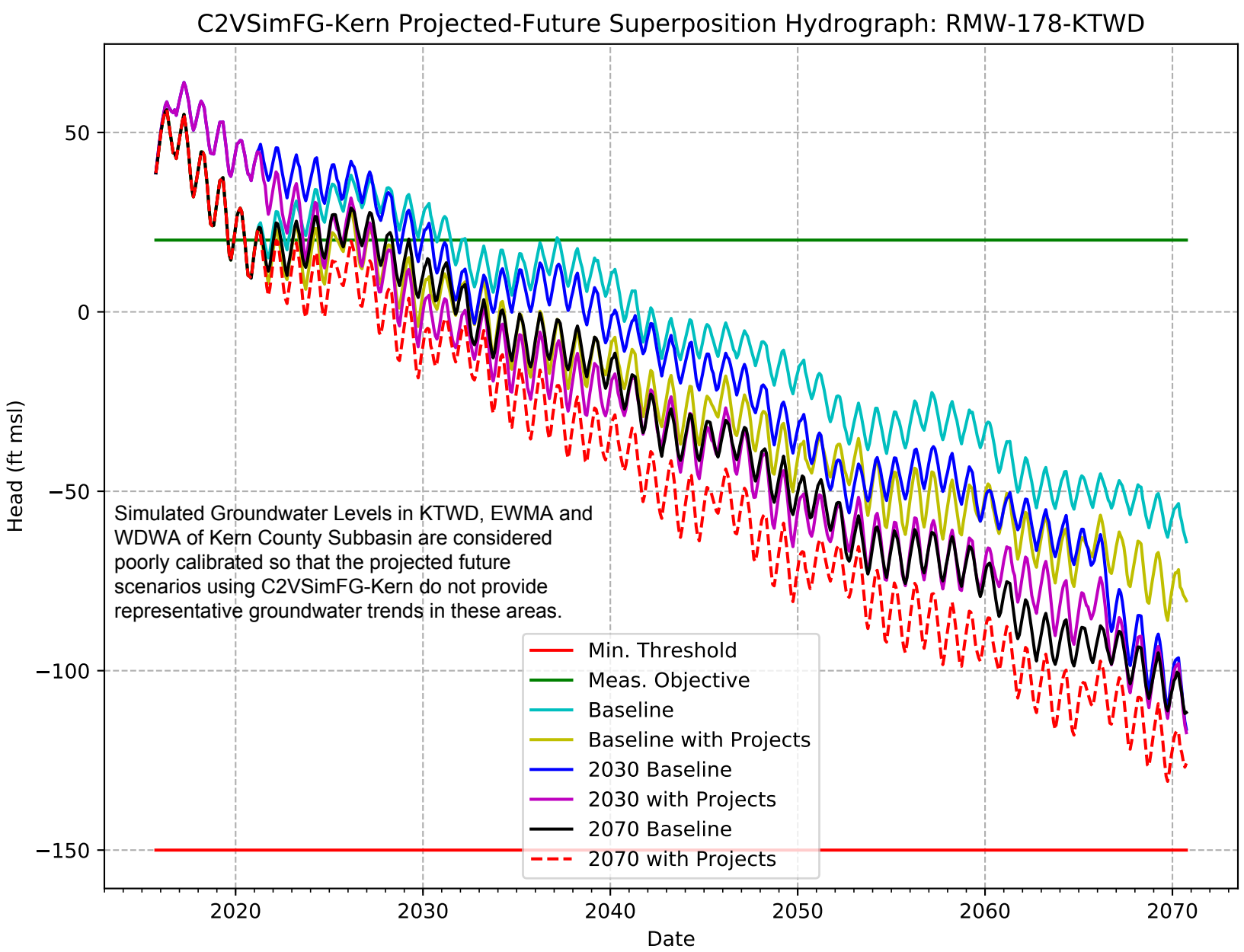

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-173-CWD
Head (ft msl)
60
40
20
0
−20
−40
−60
−80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

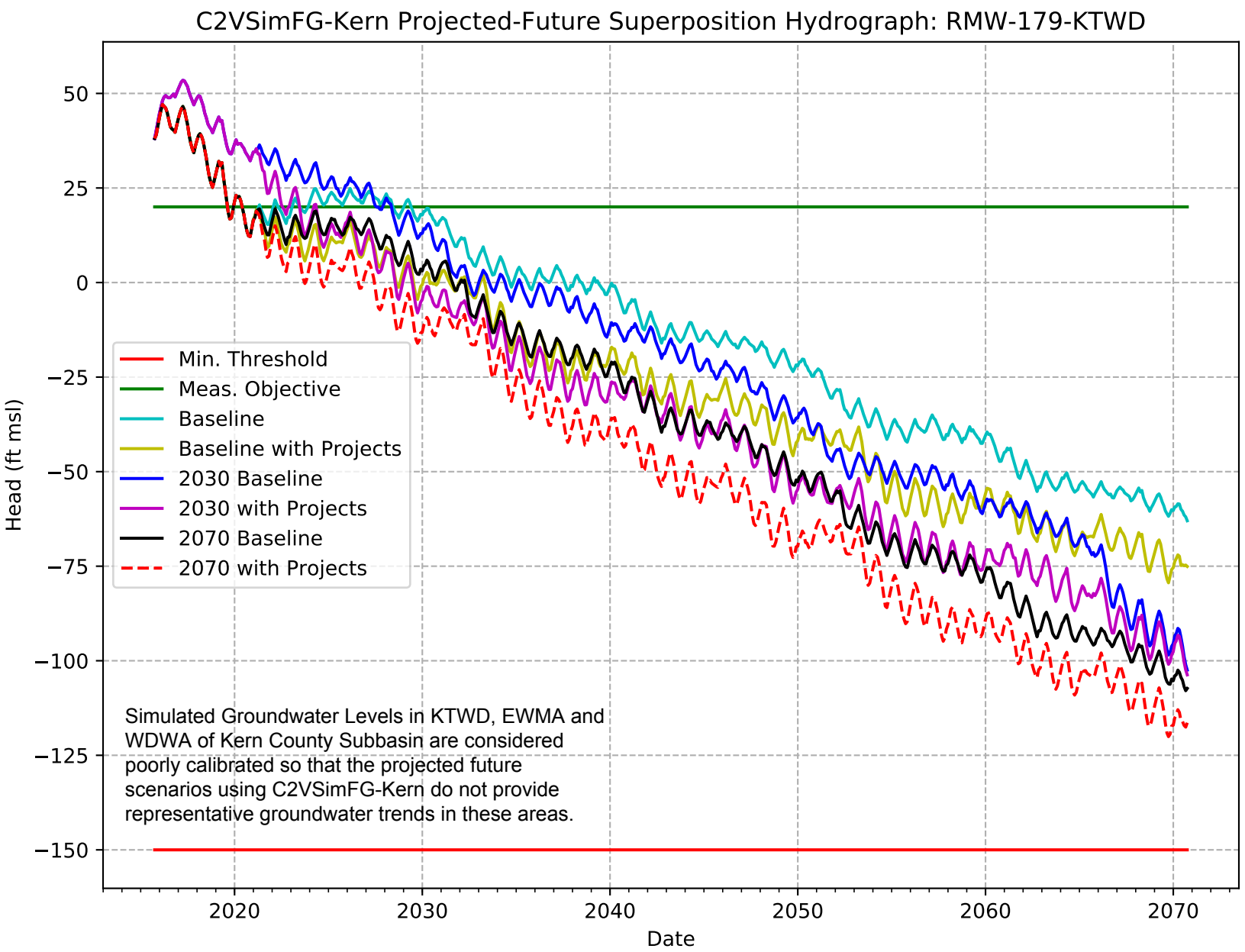

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-174-KTWD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

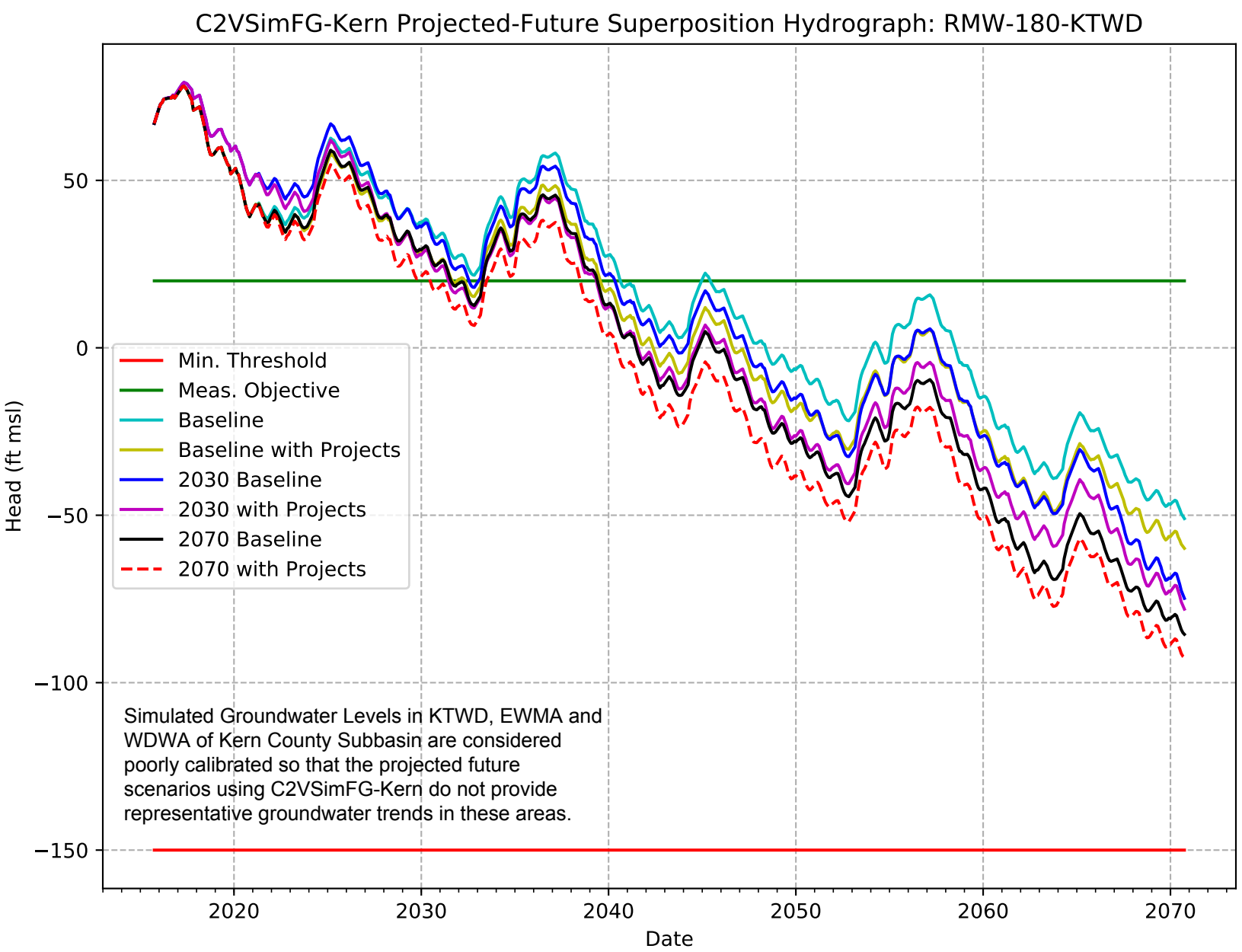

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-175-KTWD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

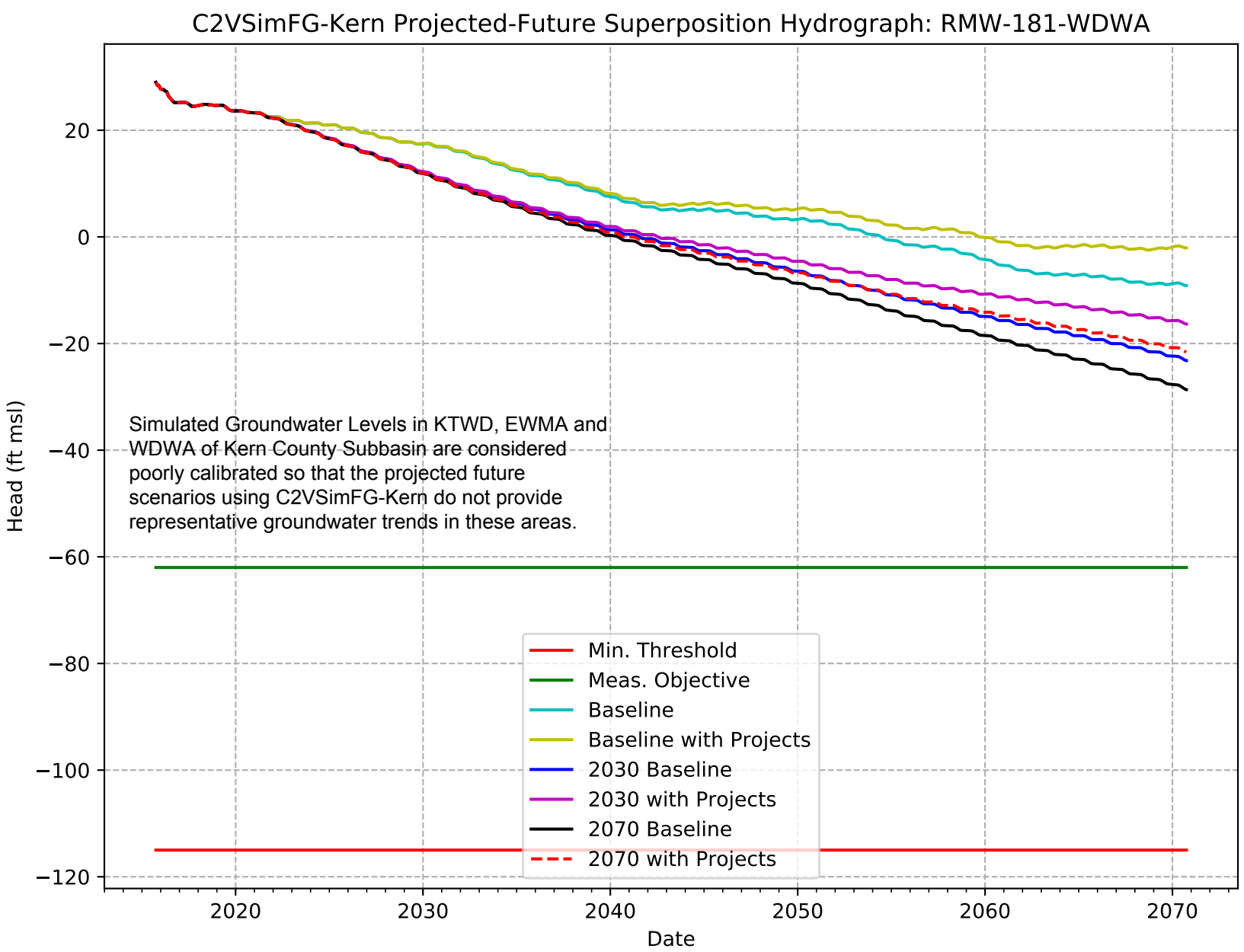

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-176-KTWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

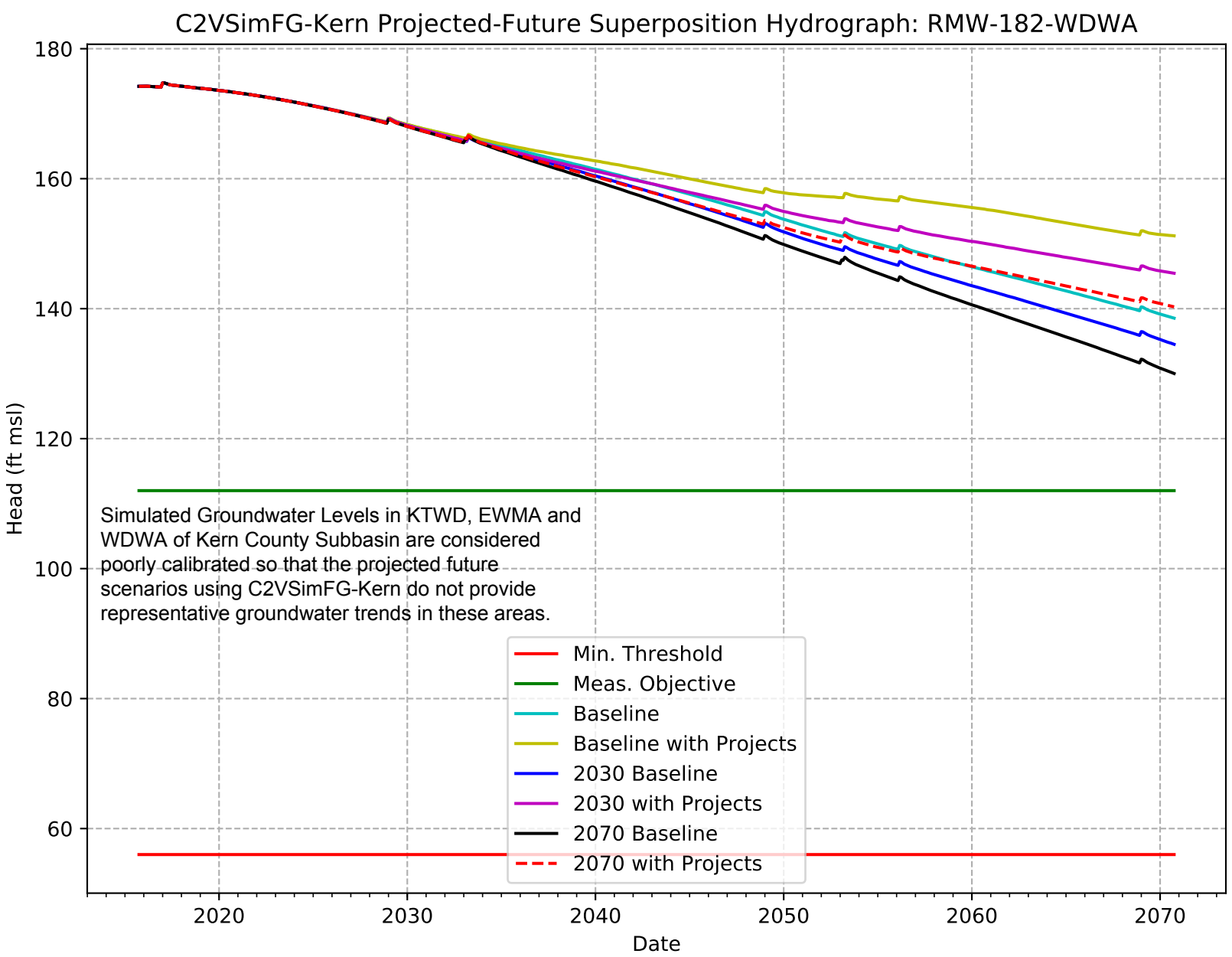

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-177-KTWD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
100
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

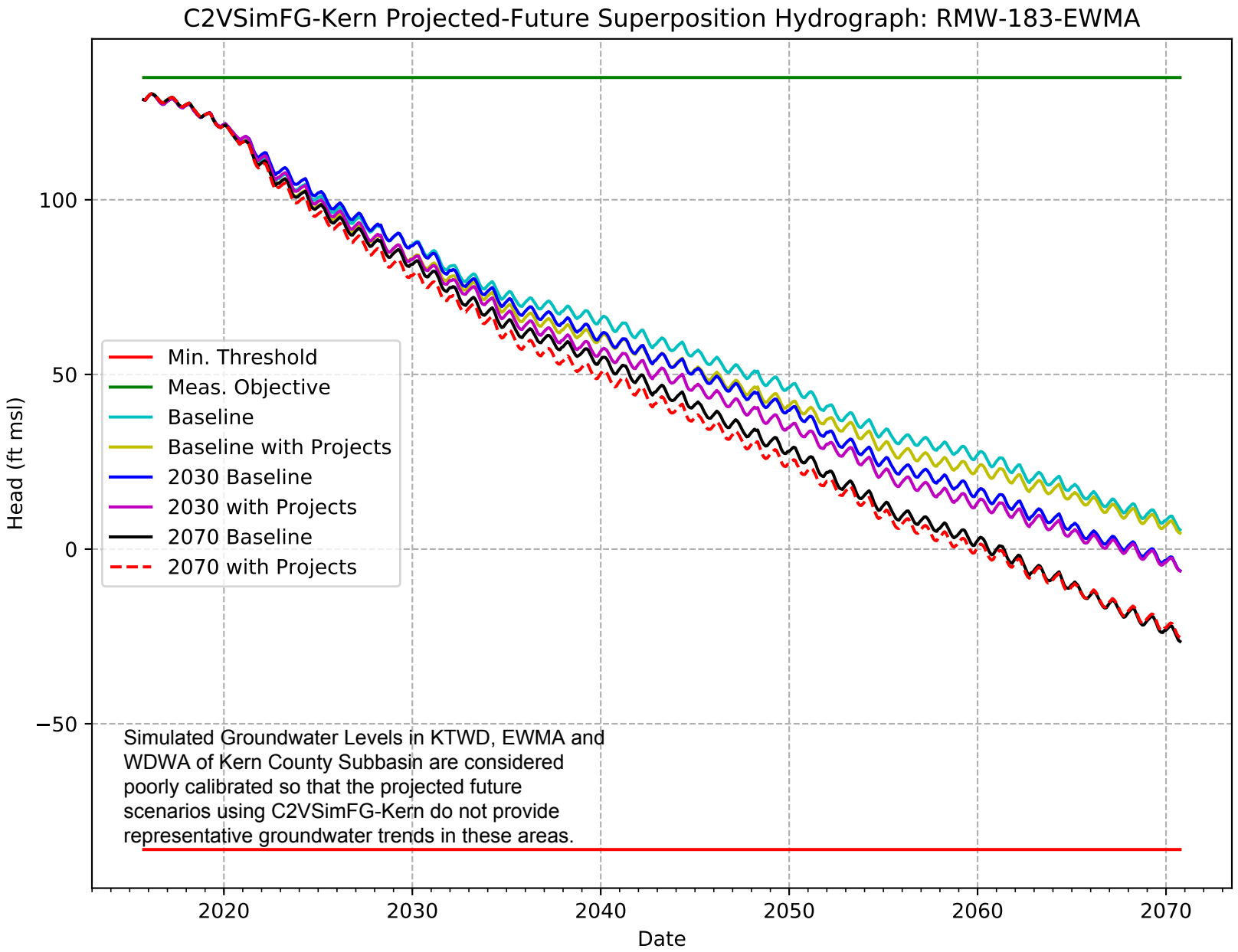

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-178-KTWD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

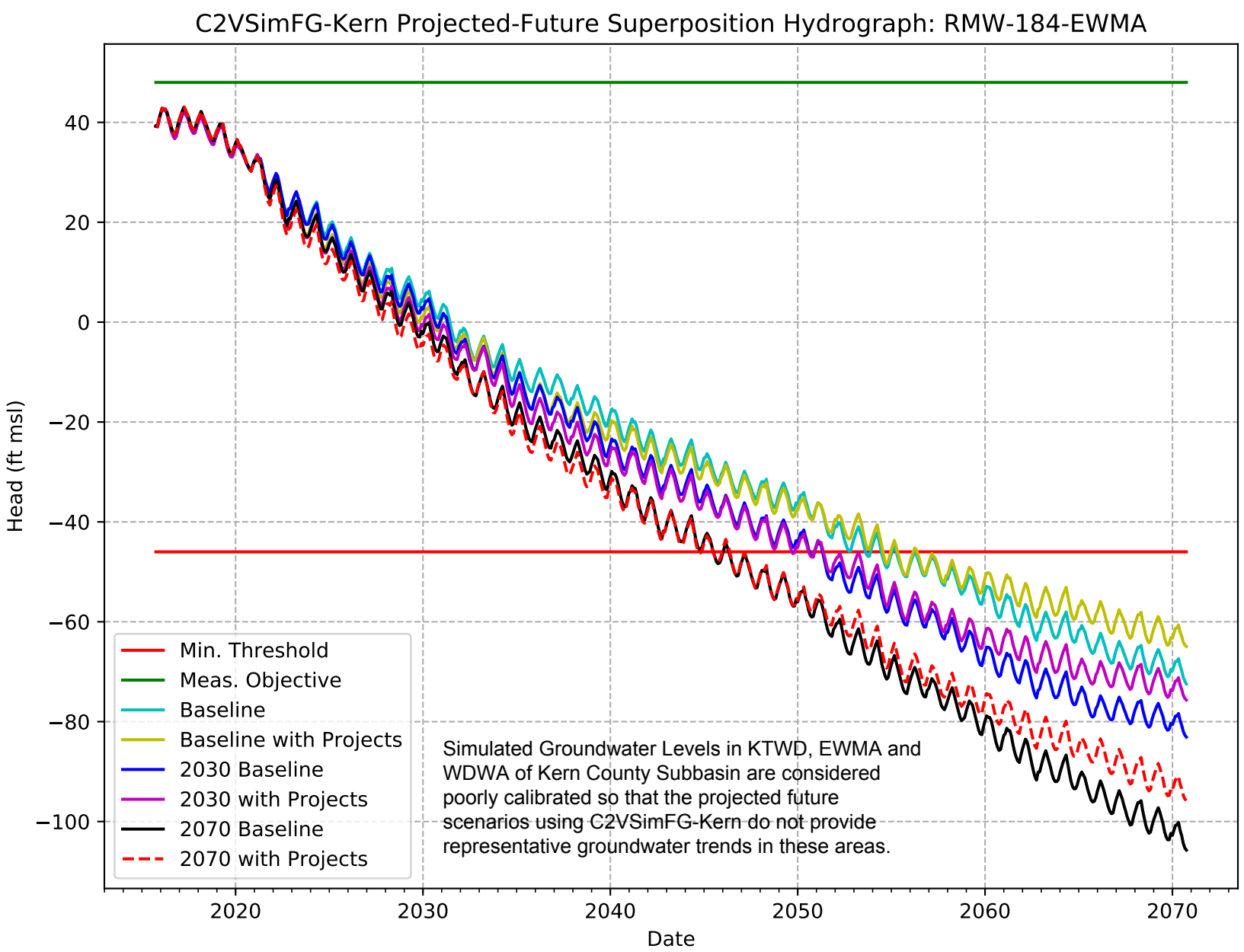

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-179-KTWD
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and
WDWA of Kern County Subbasin are considered
poorly calibrated so that the projected future
scenarios using C2VSimFG-Kern do not provide
representative groundwater trends in these areas.

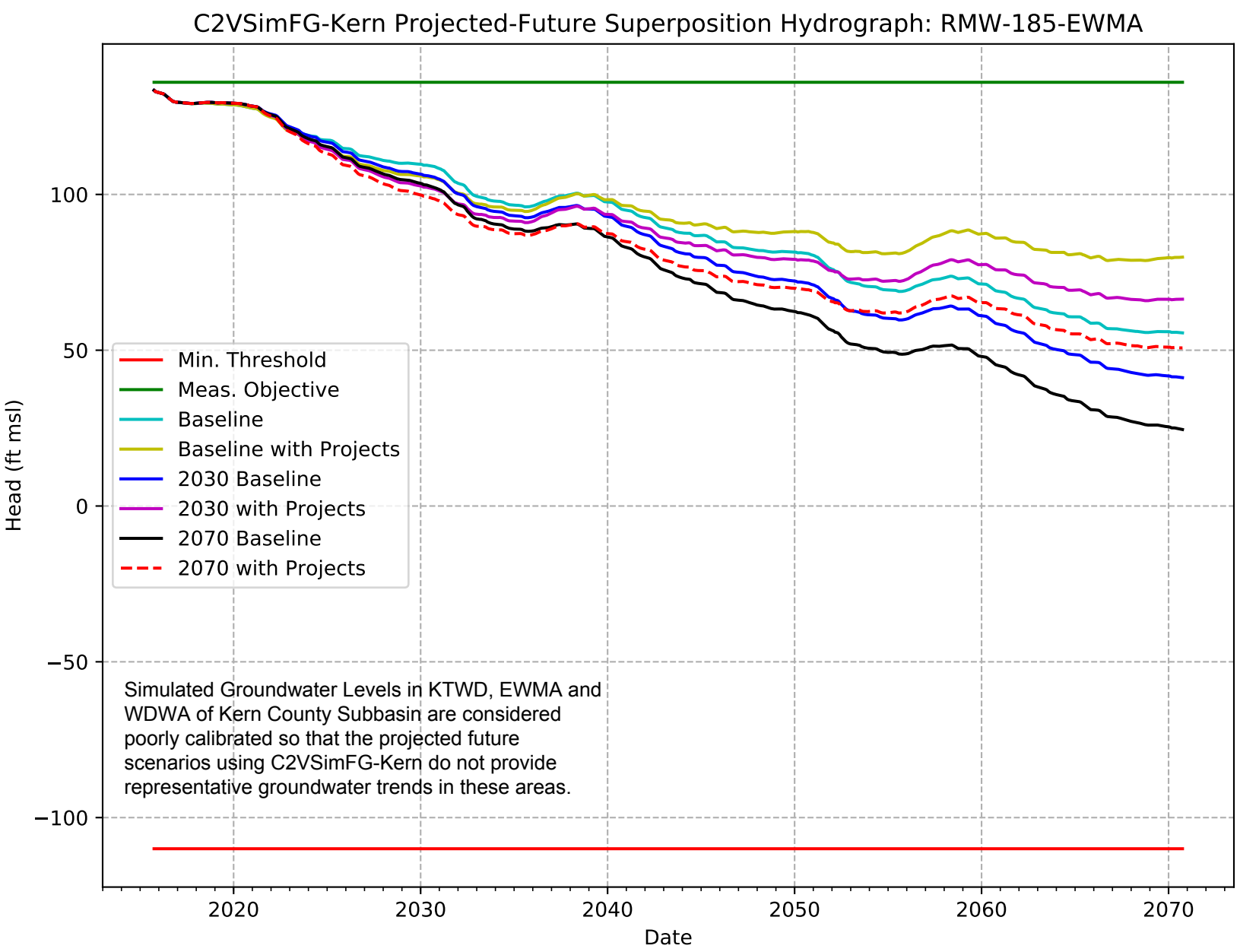

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-180-KTWD
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

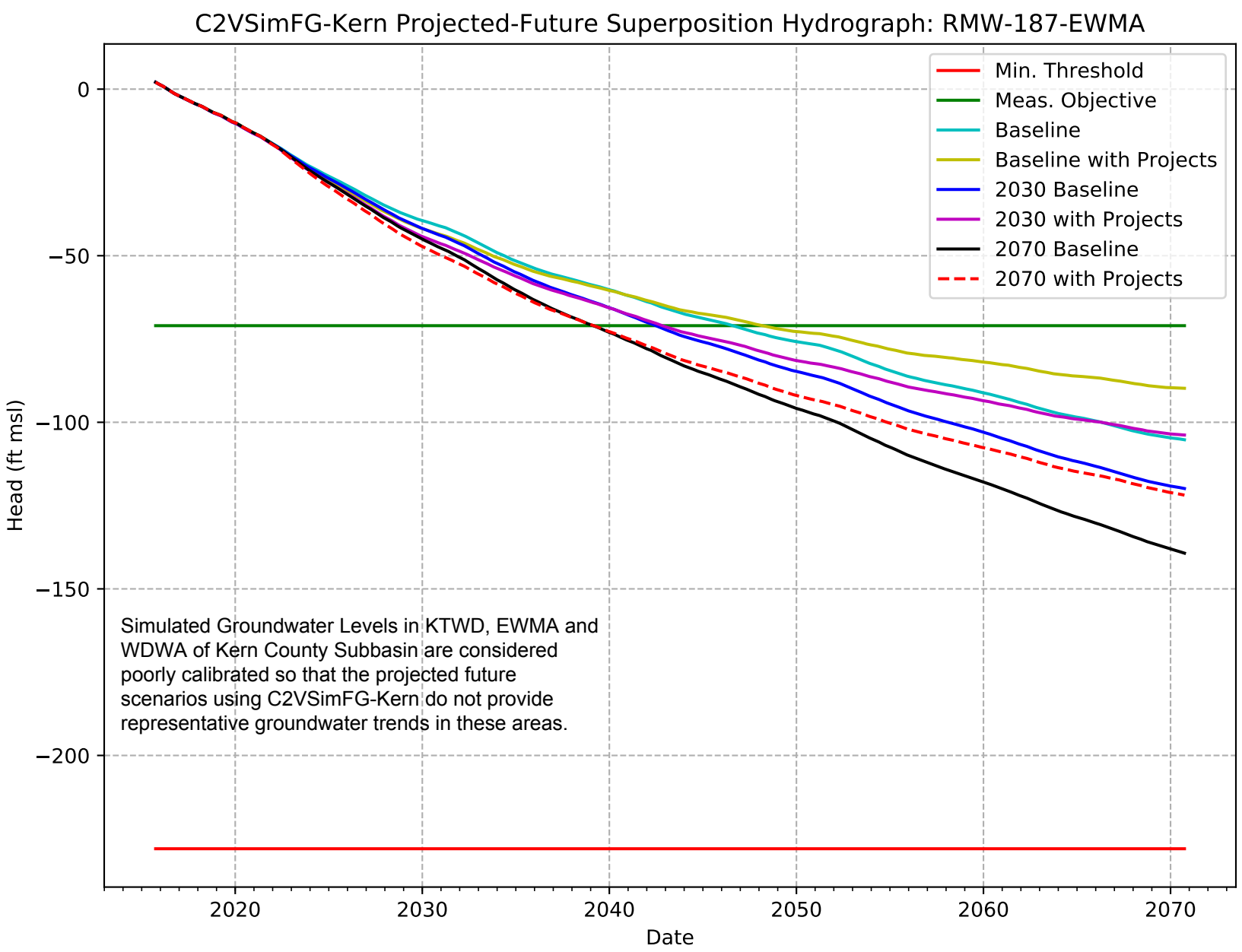

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-181-WDWA
Head (ft msl)
20
0
−20
−40
−60
−80
−100
−120
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

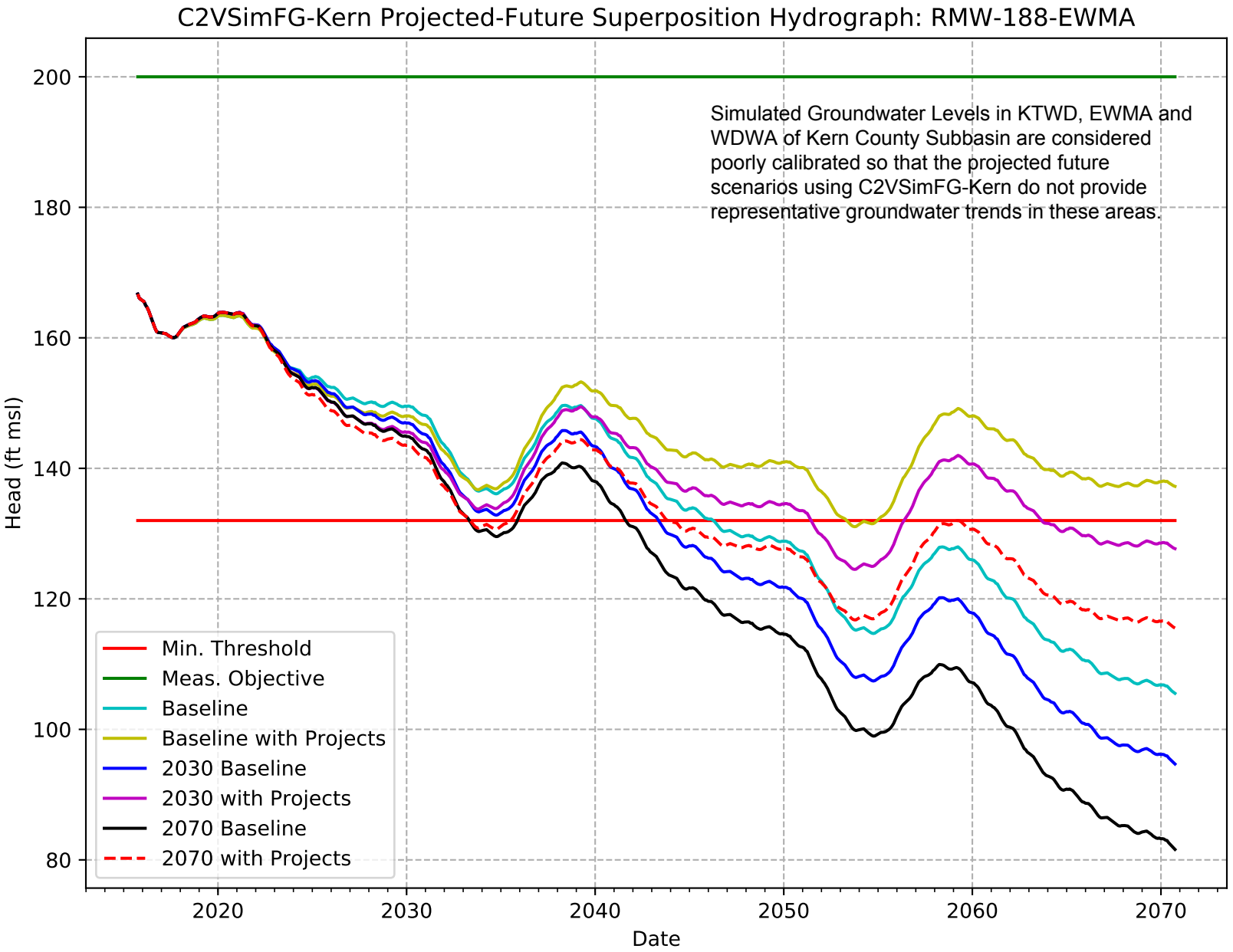

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-182-WDWA
Head (ft msl)
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

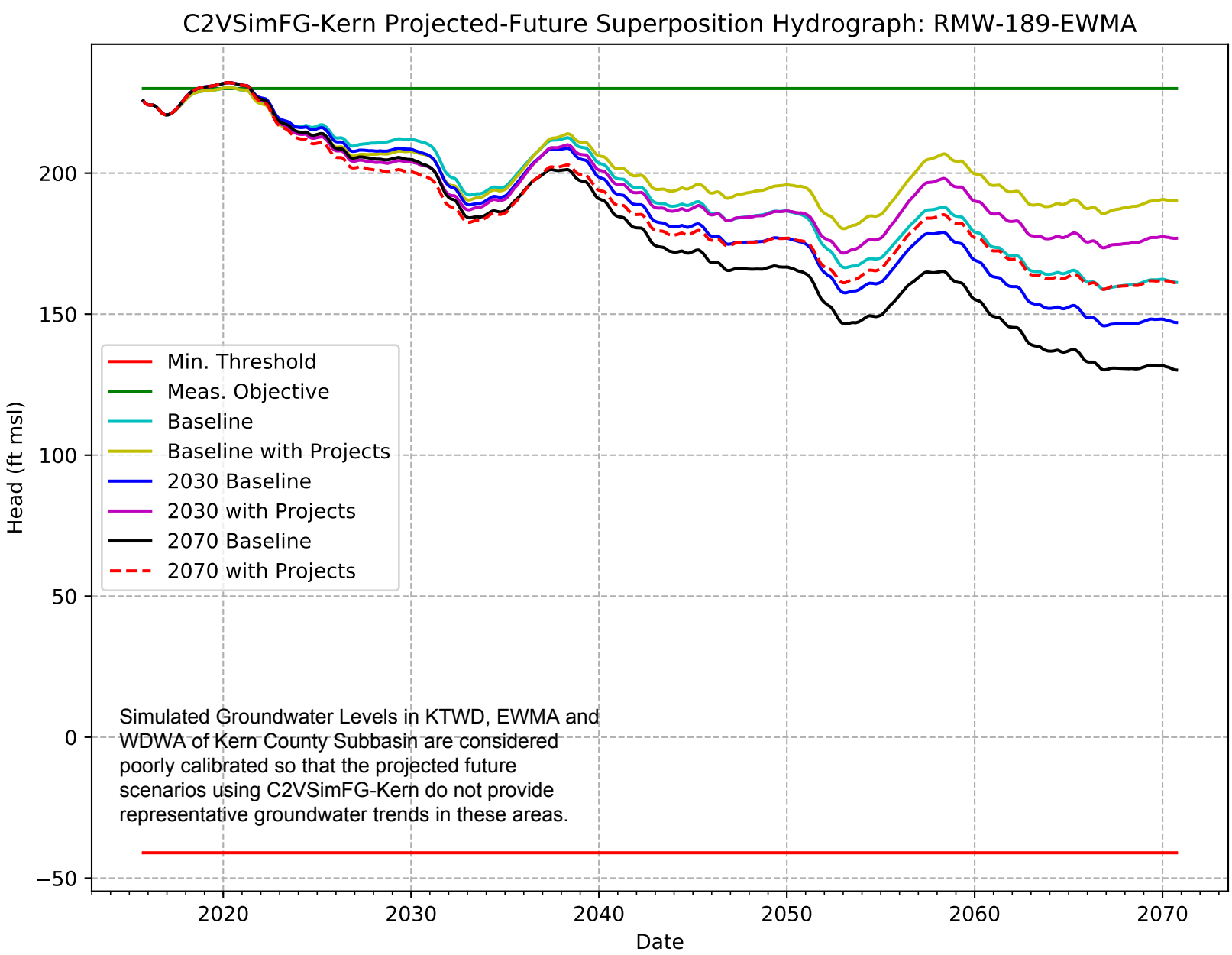

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-183-EWMA
Head (ft msl)
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

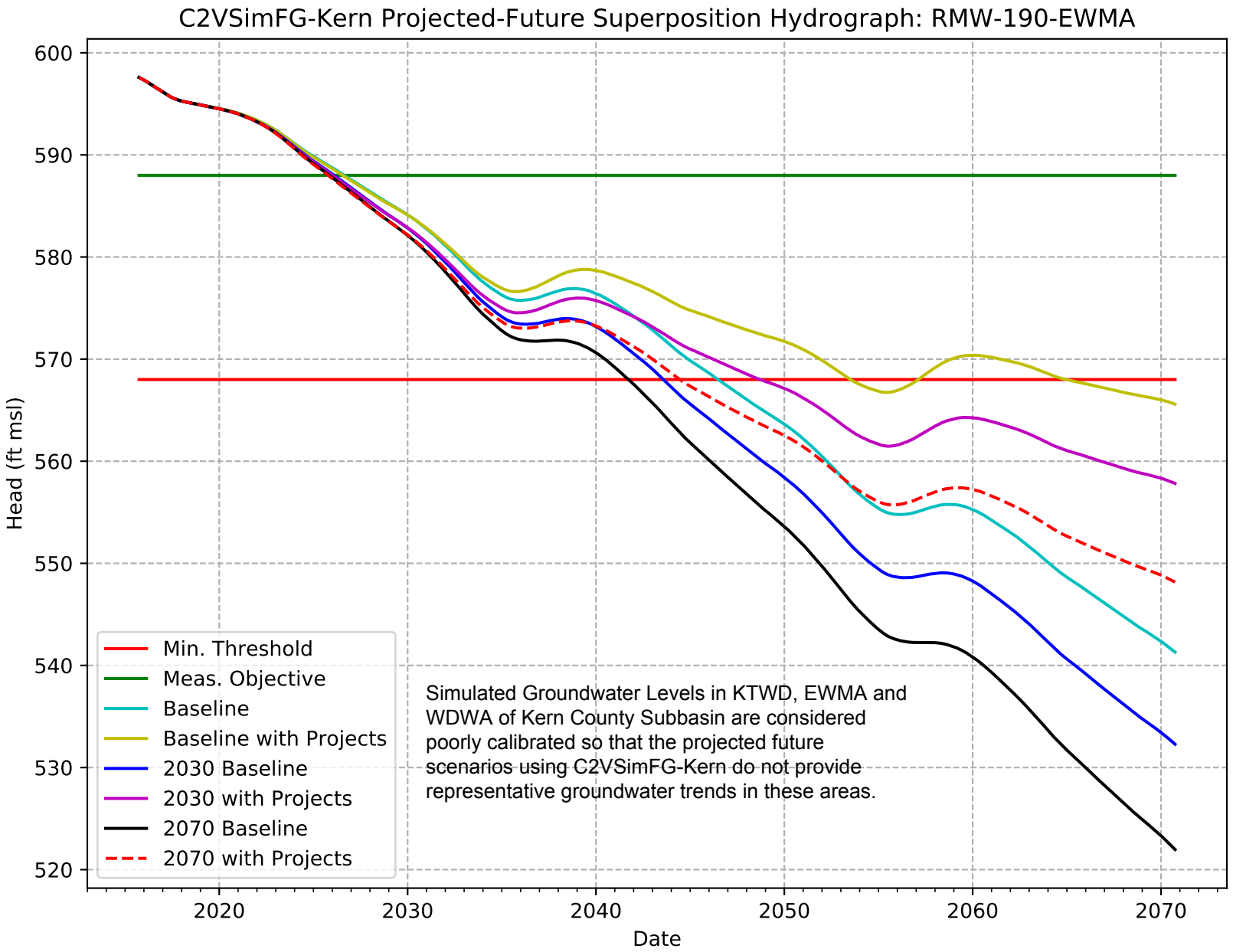

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-184-EWMA
Head (ft msl)
40
20
0
−20
−40
−60
−80
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

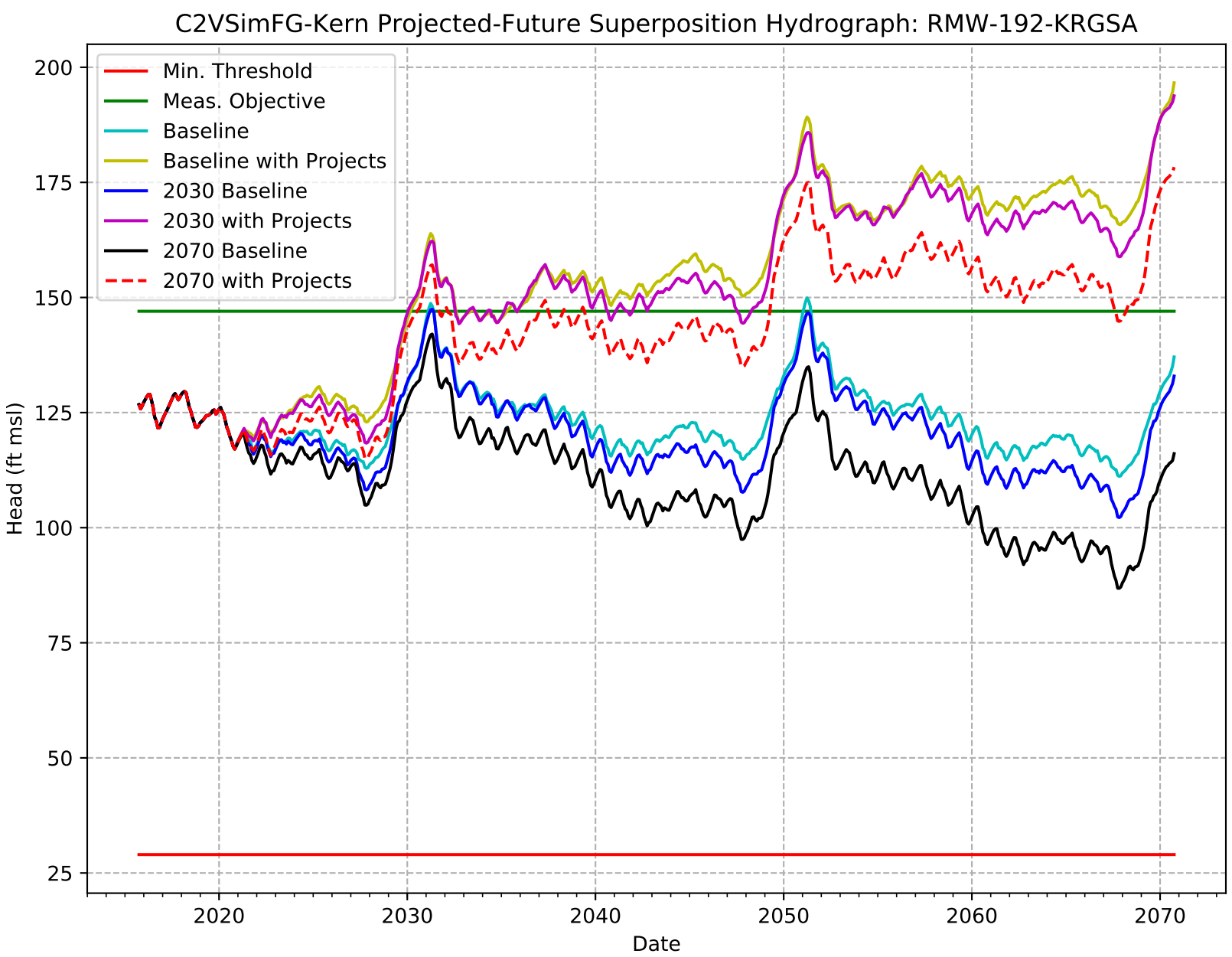

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-185-EWMA
Head (ft msl)
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

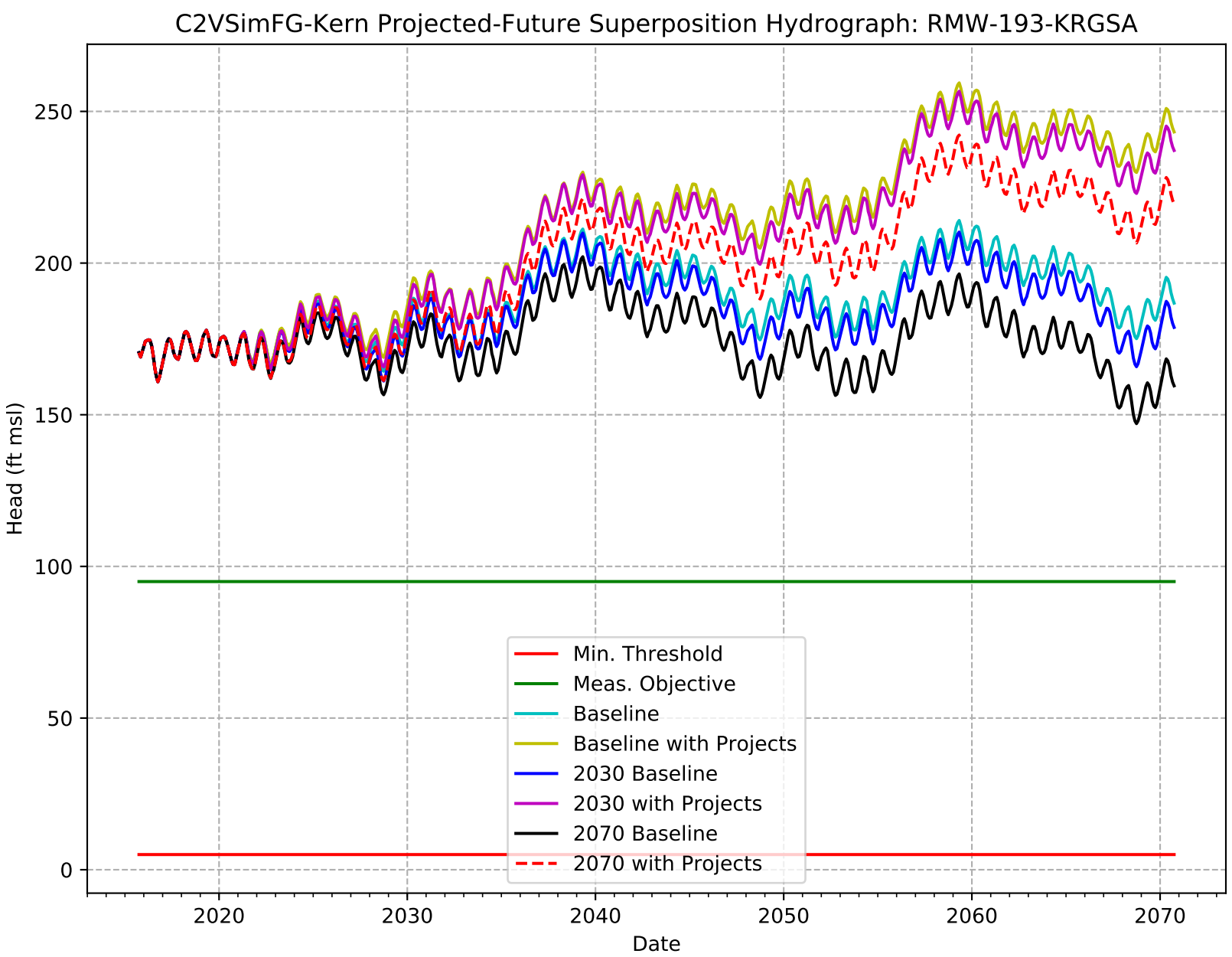

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-187-EWMA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
0
−50
−100
−150
−200
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

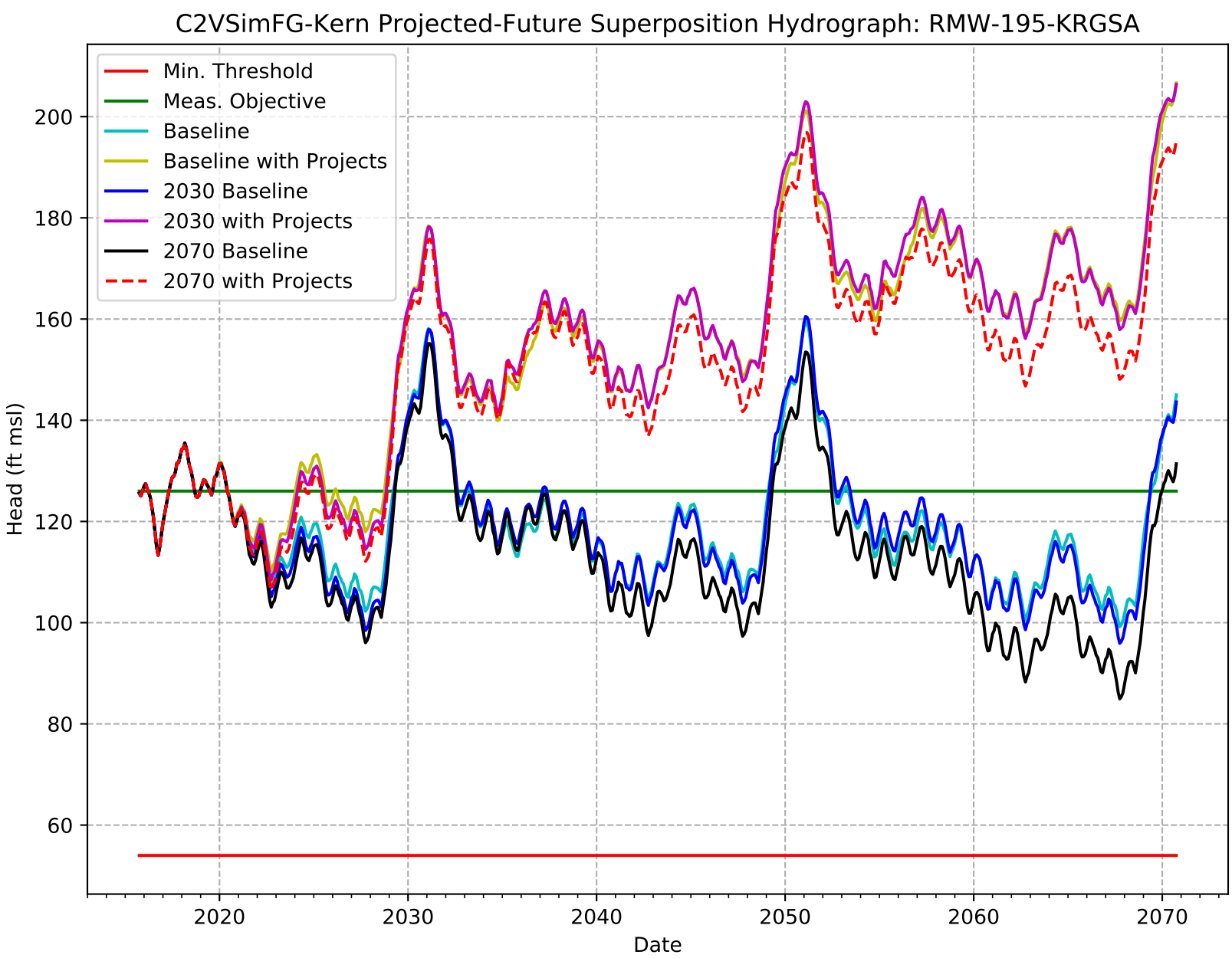

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-188-EWMA
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Head (ft msl)
Date
200
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

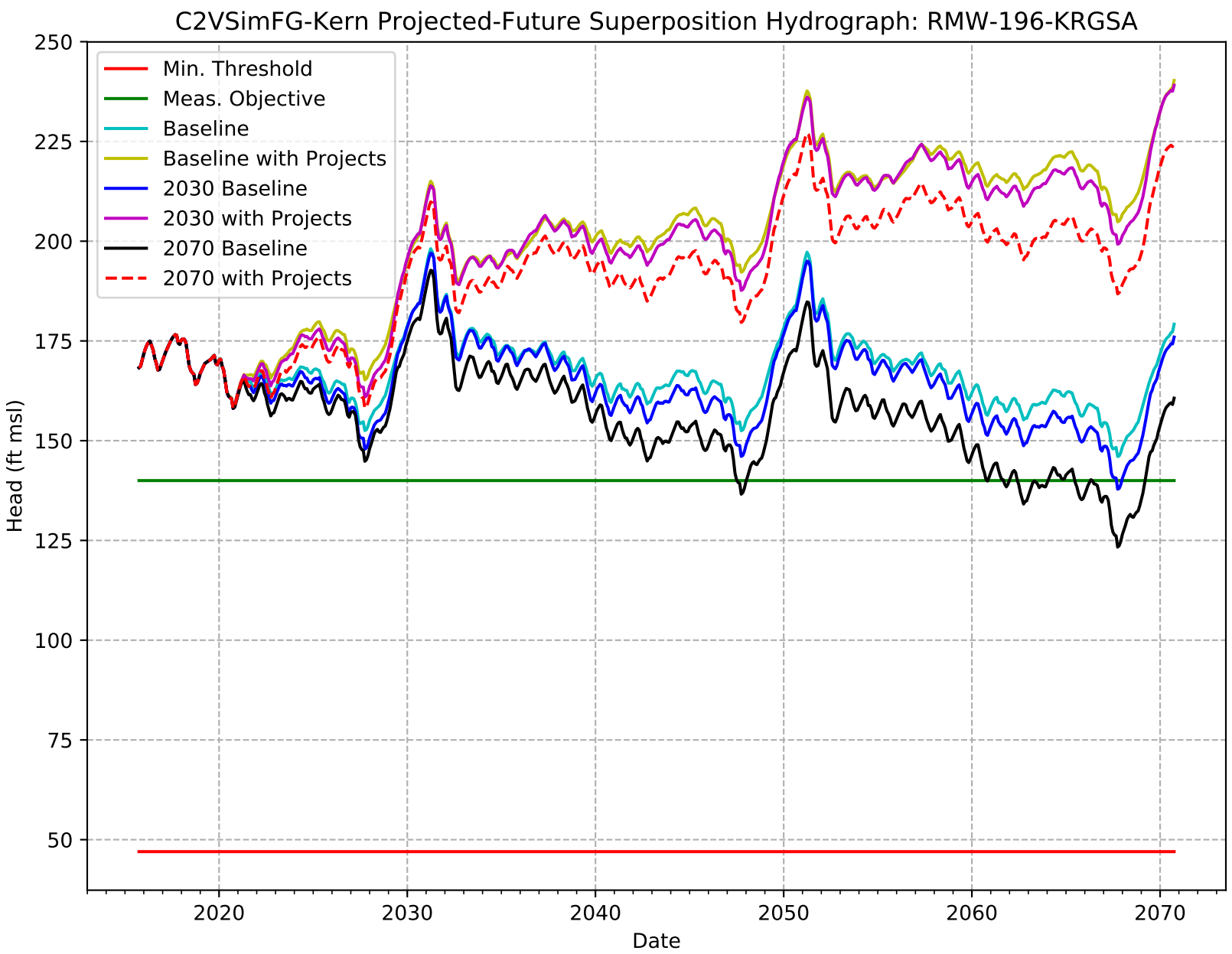

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-189-EWMA
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

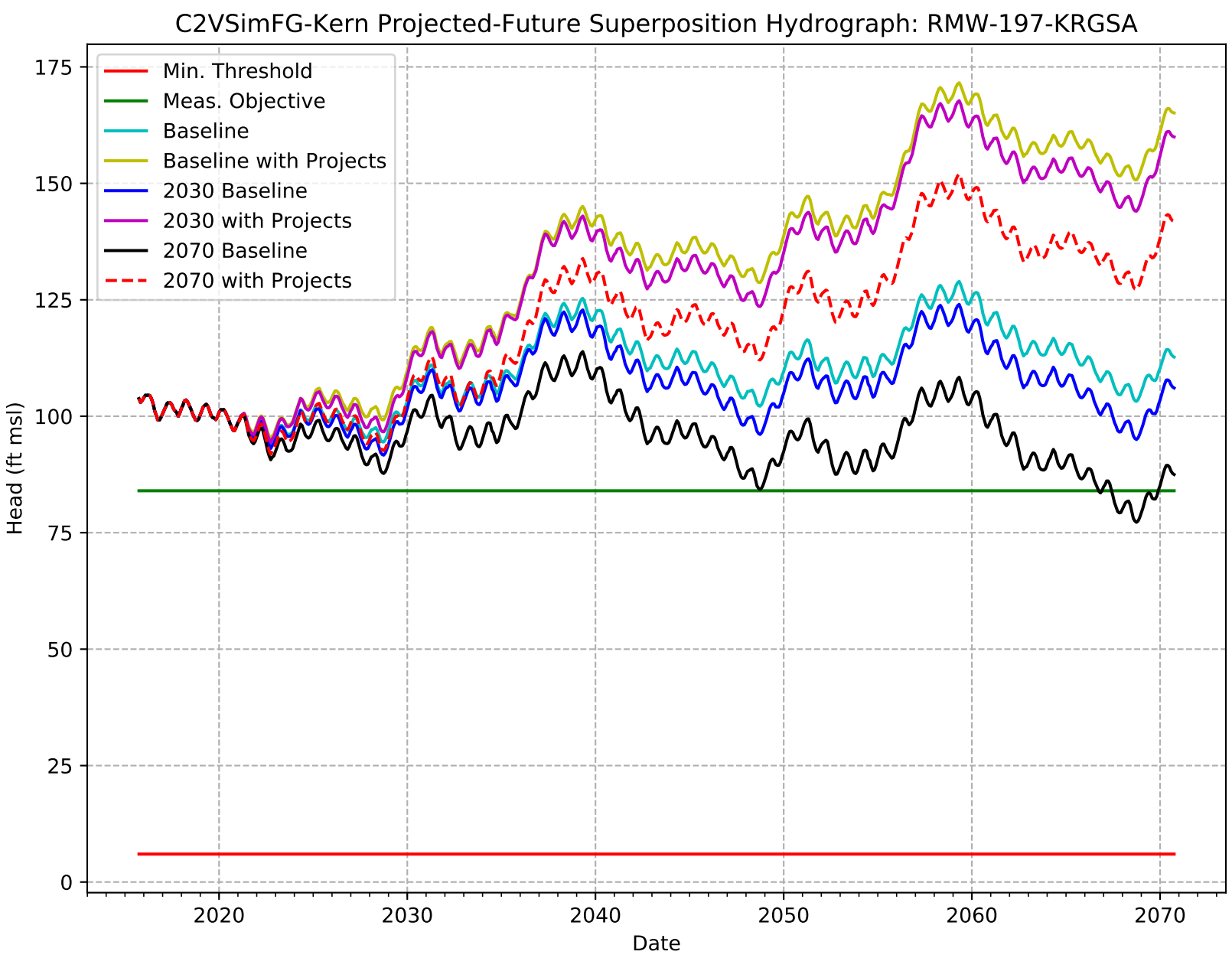

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-190-EWMA
Head (ft msl)
600
590
580
570
560
550
540
530
520
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.

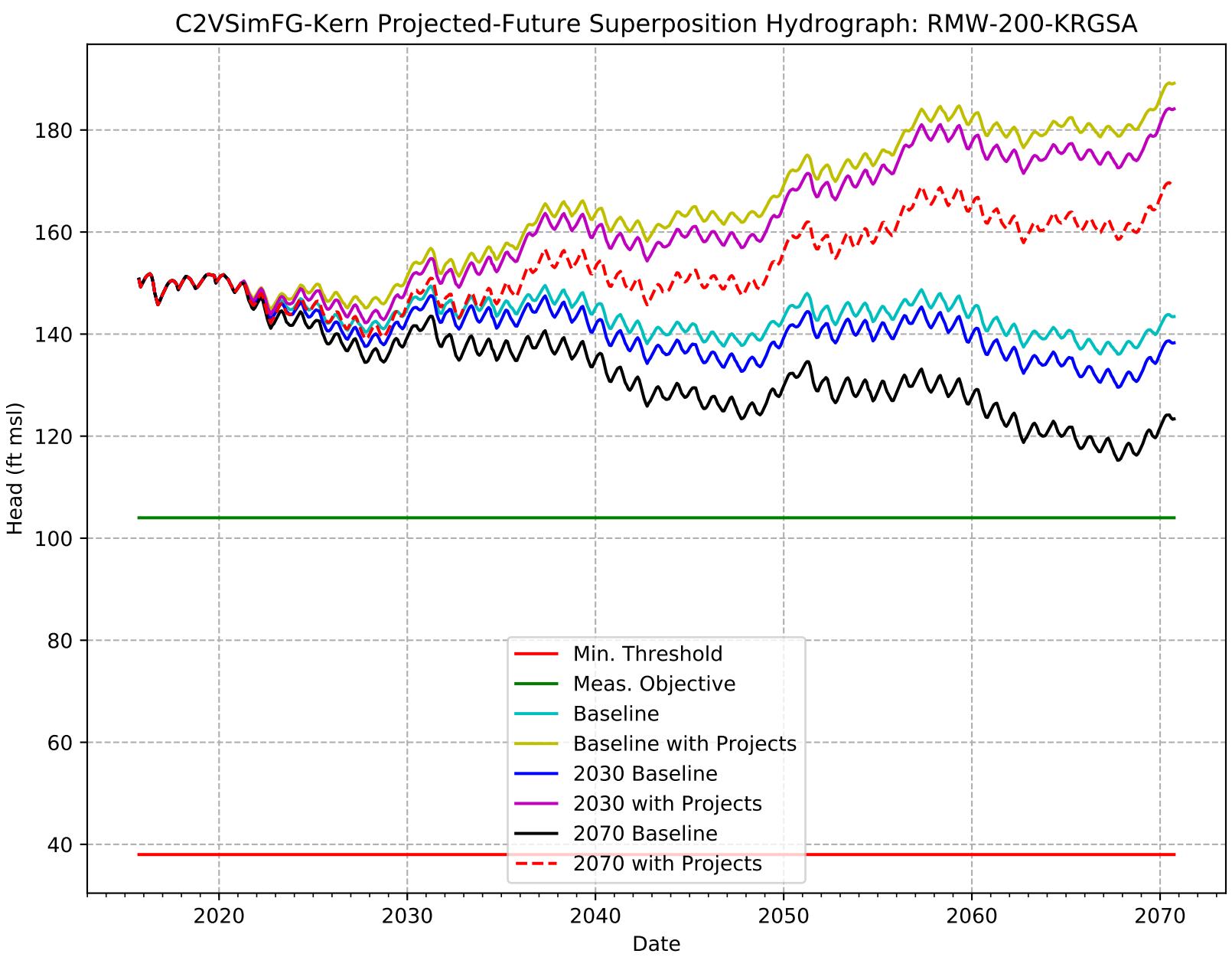

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-192-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
175
150
125
100
75
50
25
2020
2030
2040
2050
2060
2070
Date

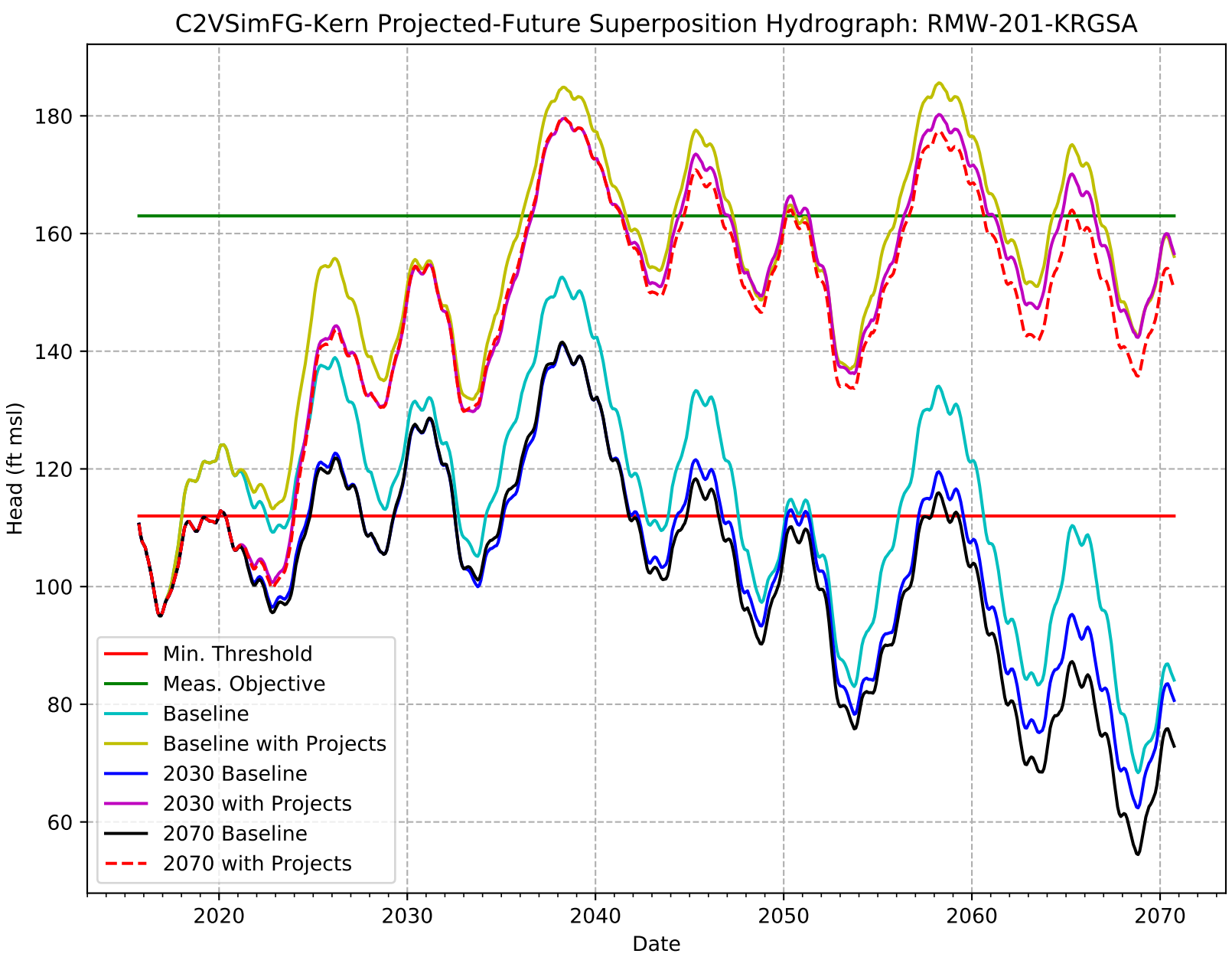

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-193-KRGSA
Head (ft msl)
250
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

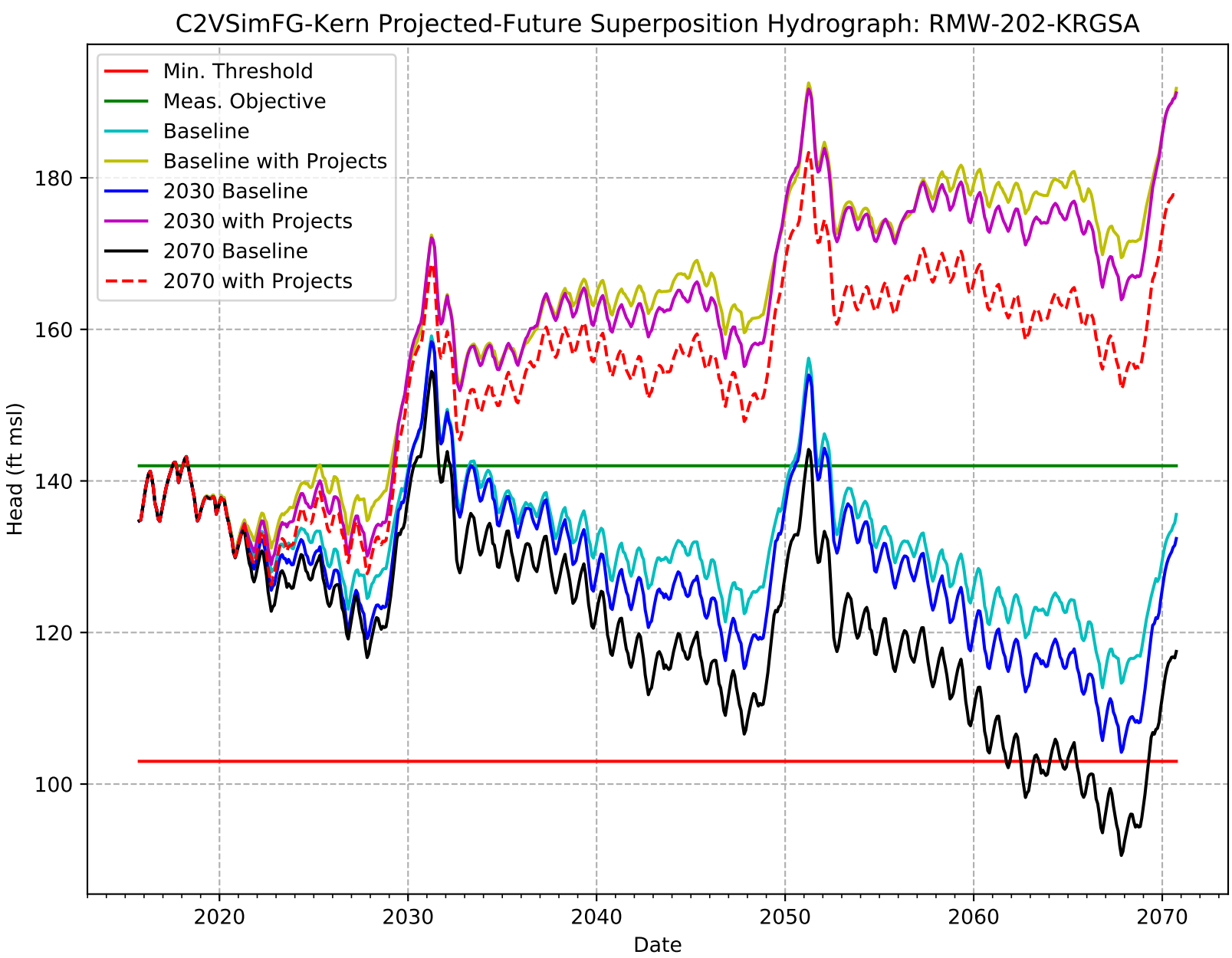

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-195-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
200
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

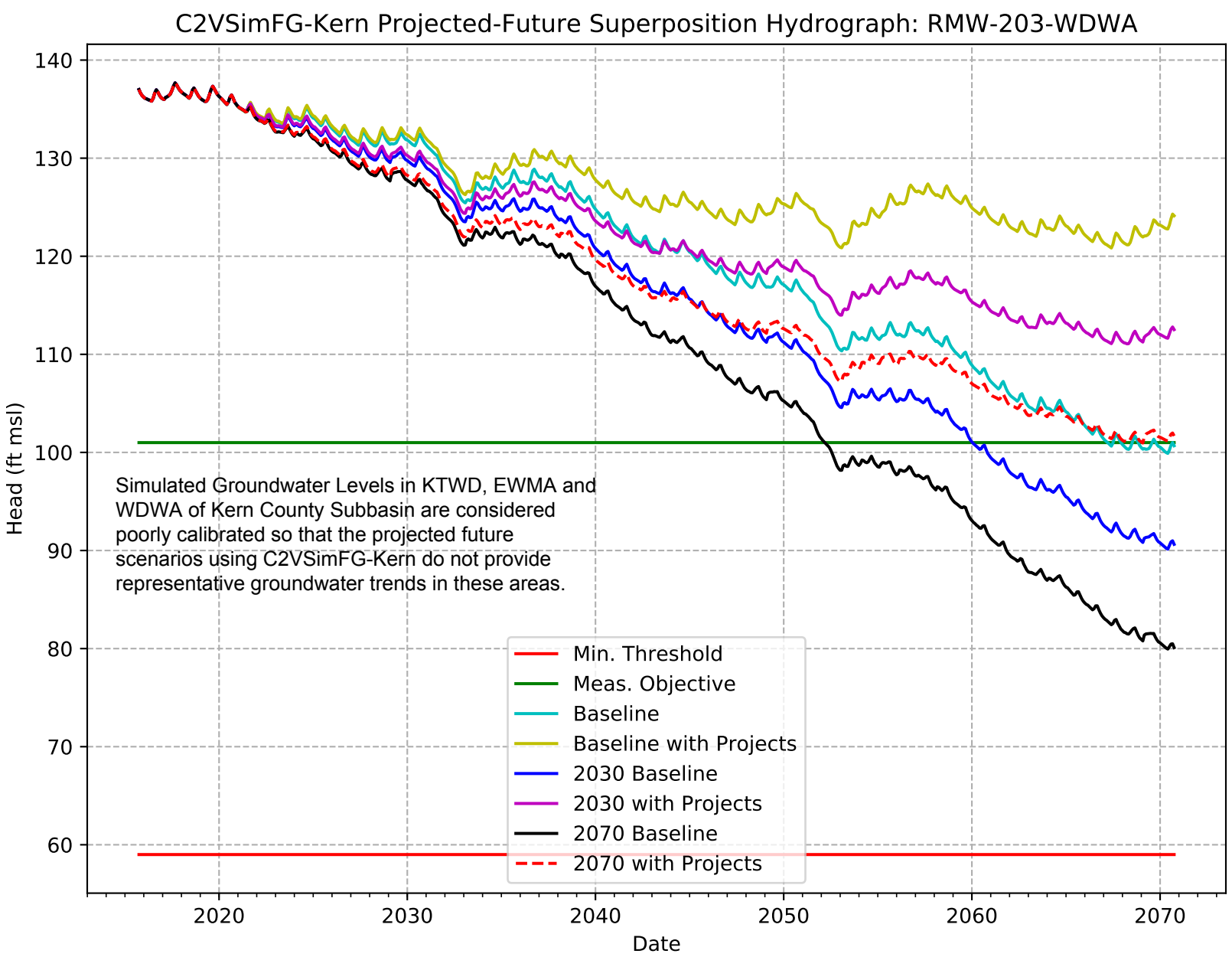

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-196-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
250
225
200
175
150
125
100
75
50
2020
2030
2040
2050
2060
2070
Date

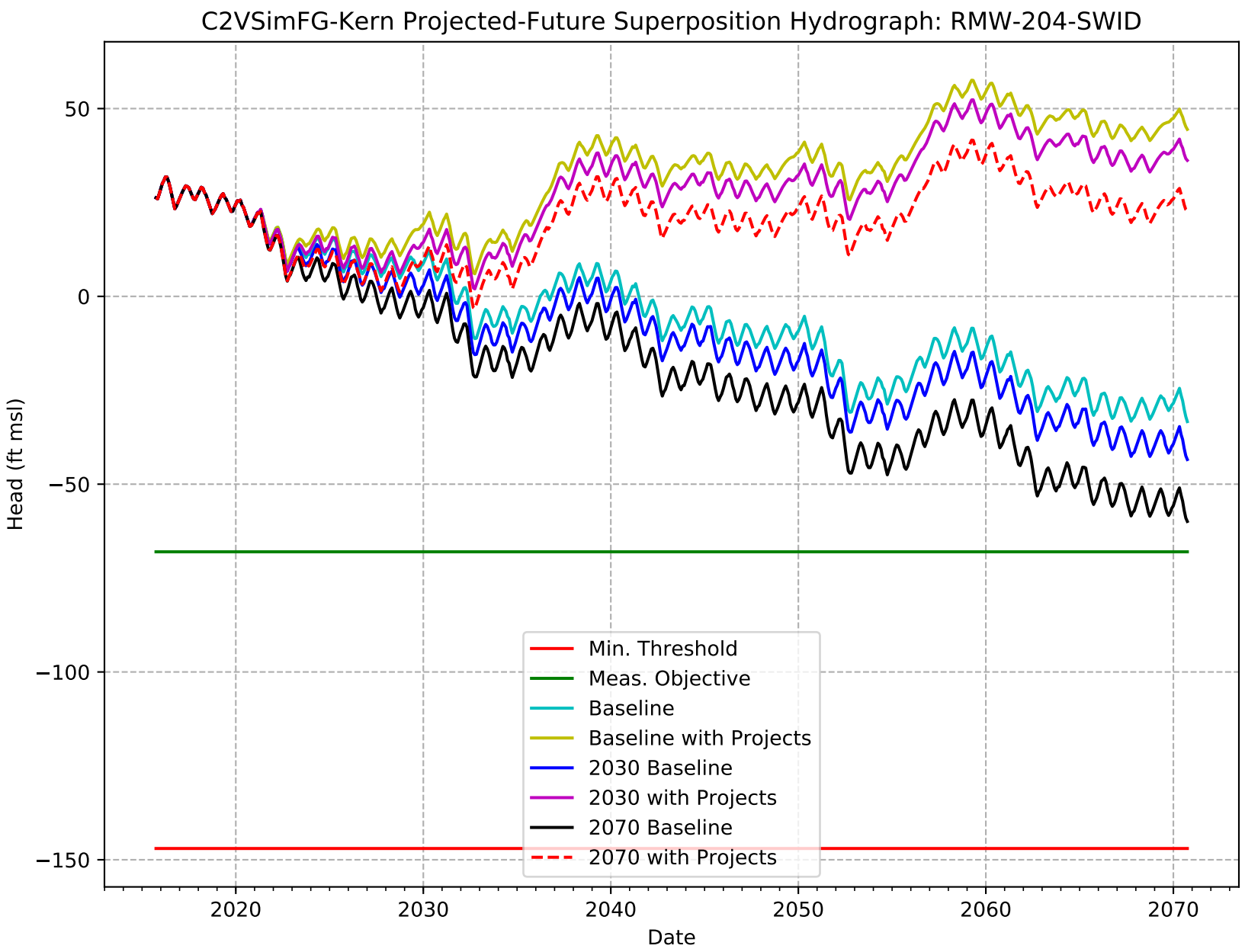

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-197-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
175
150
125
100
75
50
25
0
2020
2030
2040
2050
2060
2070
Date

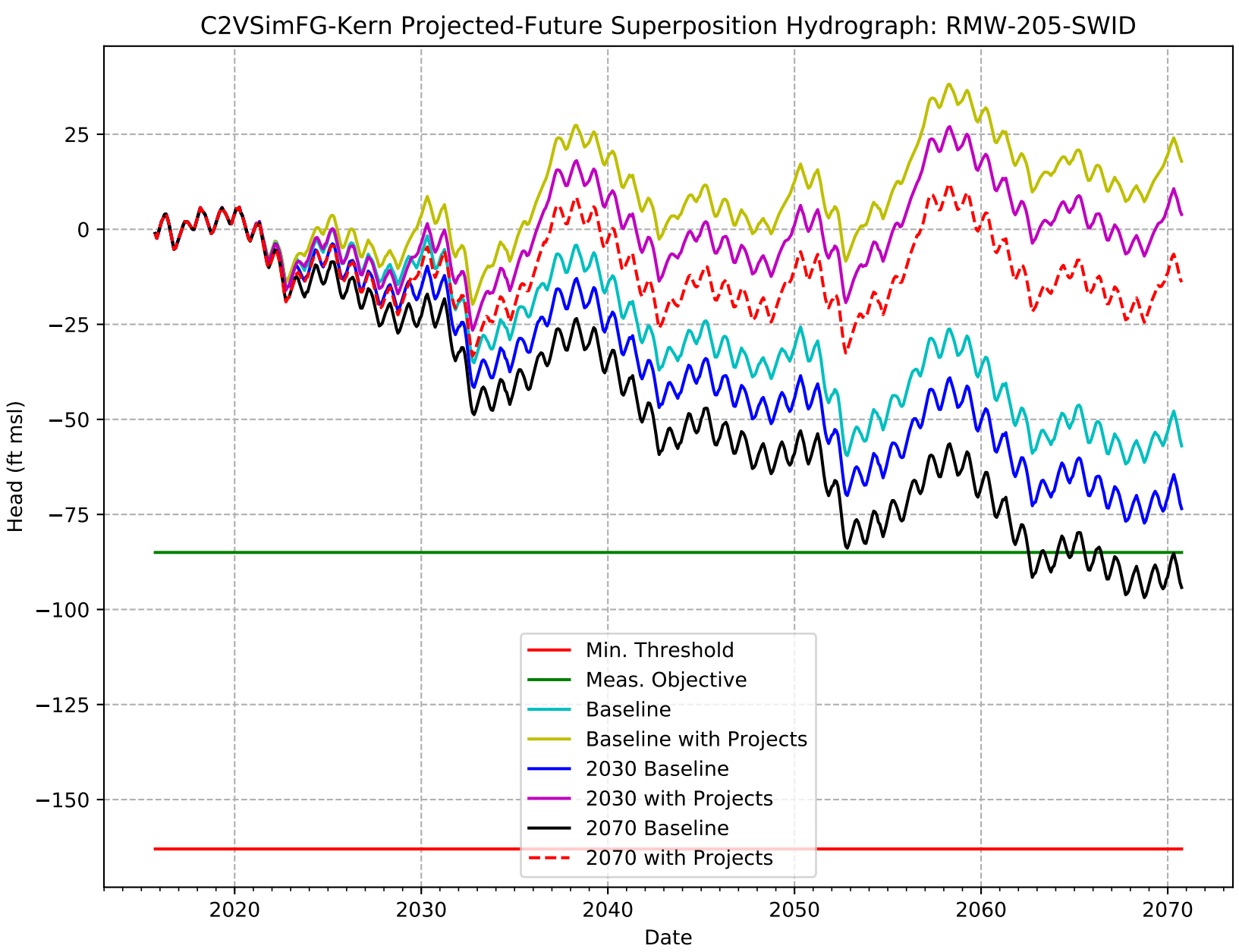

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-200-KRGSA
Head (ft msl)
180
160
140
120
100
80
60
40
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

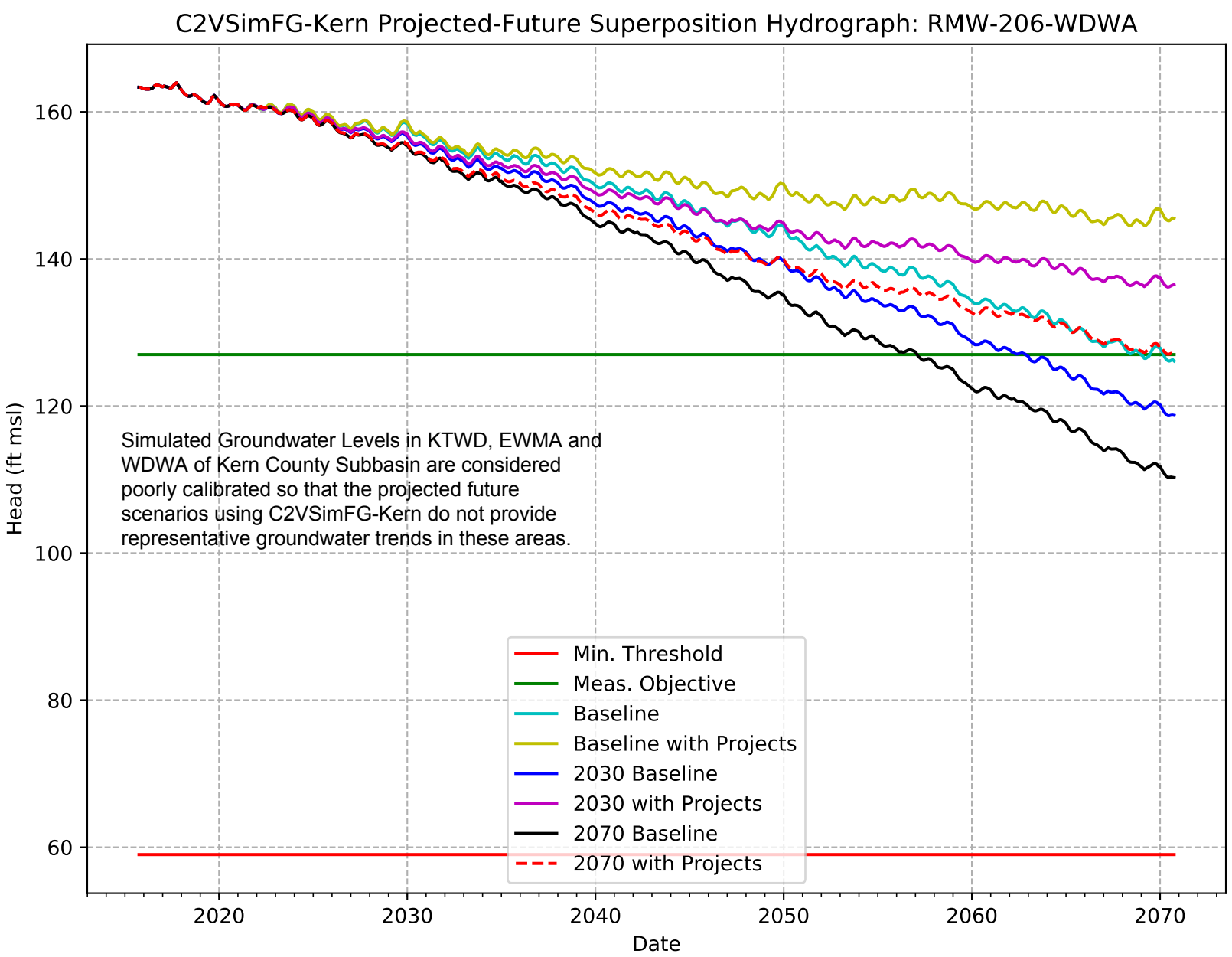

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-201-KRGSA
Head (ft msl)
180
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

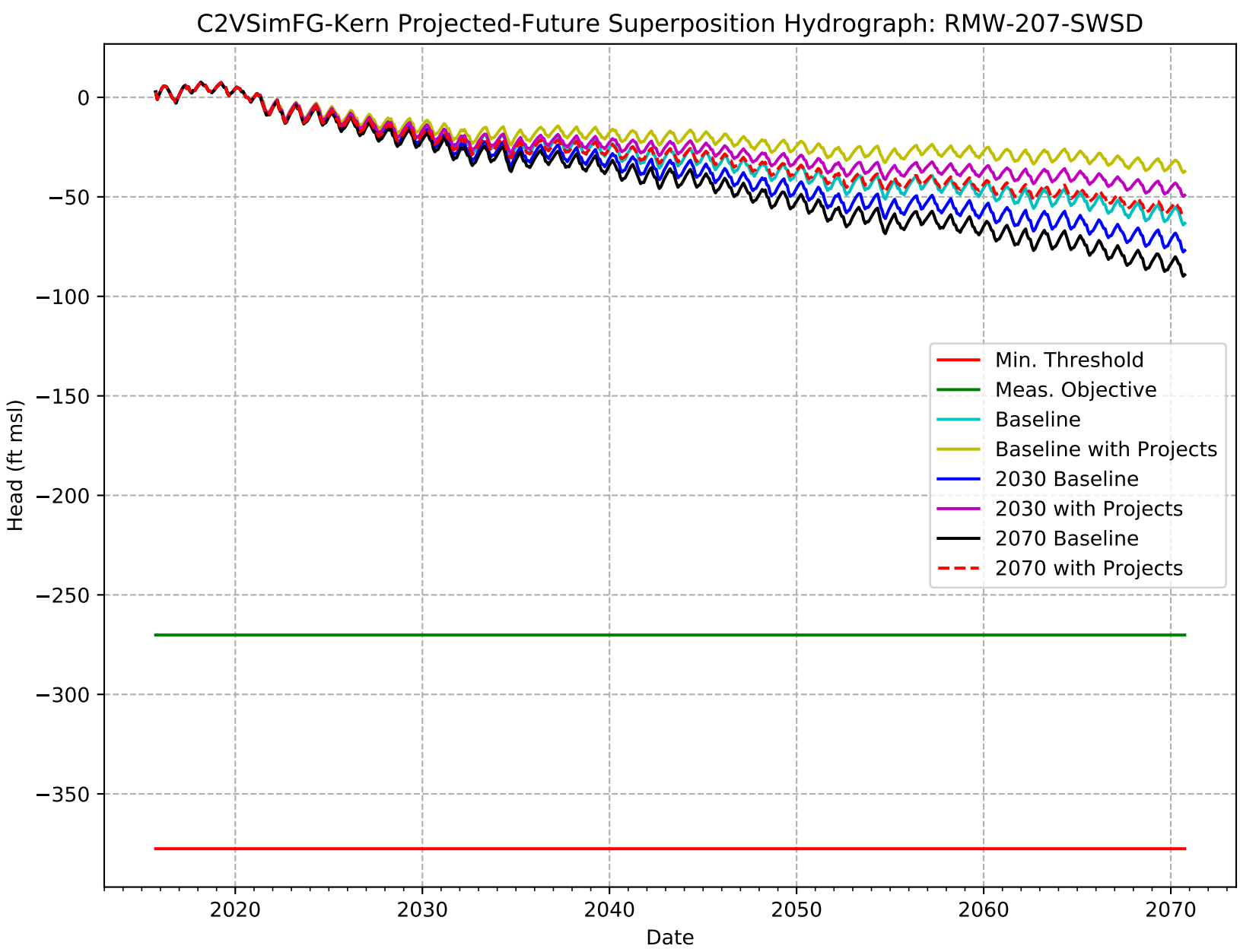

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-202-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date

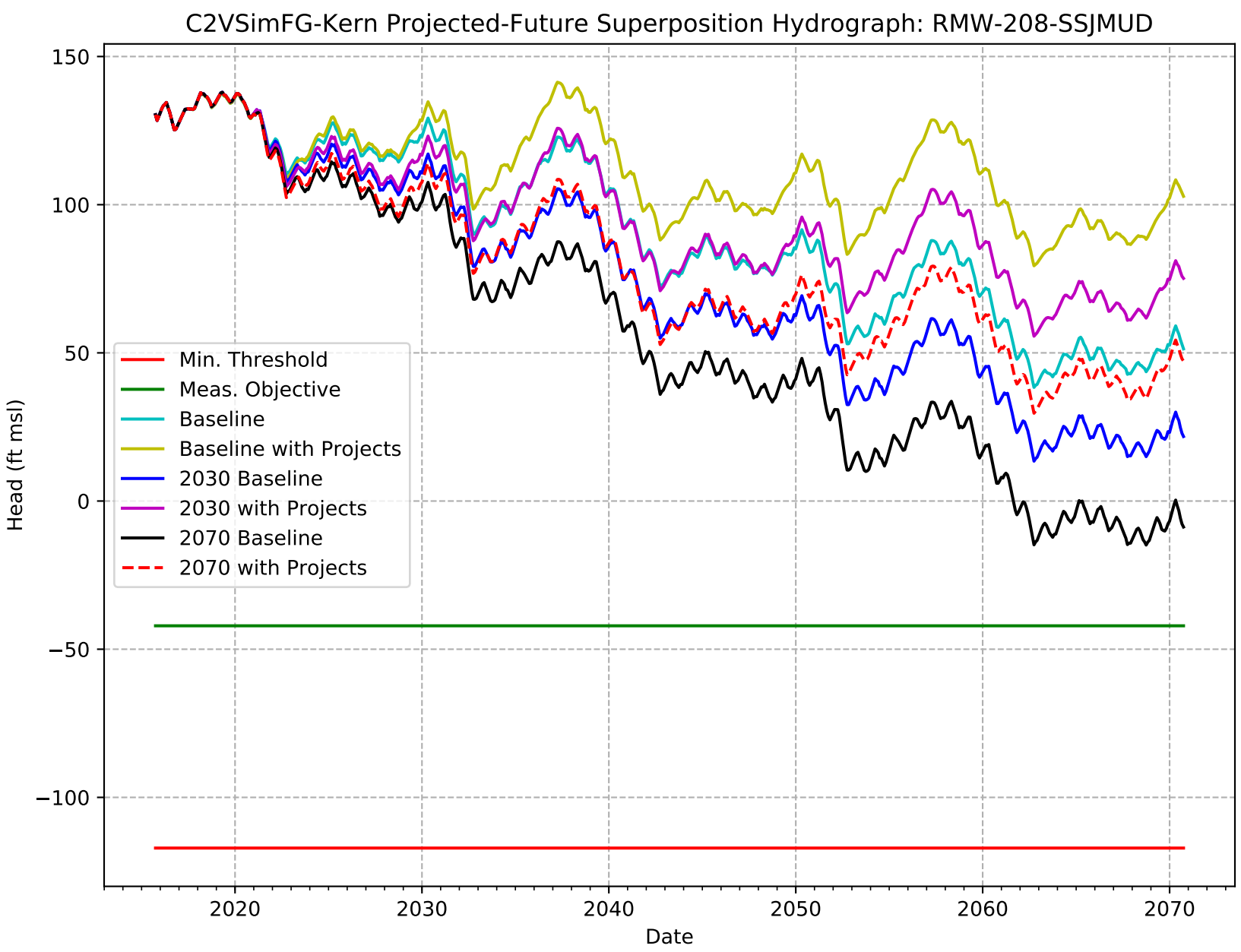

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-203-WDWA
Head (ft msl)
Date
140
130
120
110
100
90
80
70
60
2020
2030
2040
2050
2060
2070
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

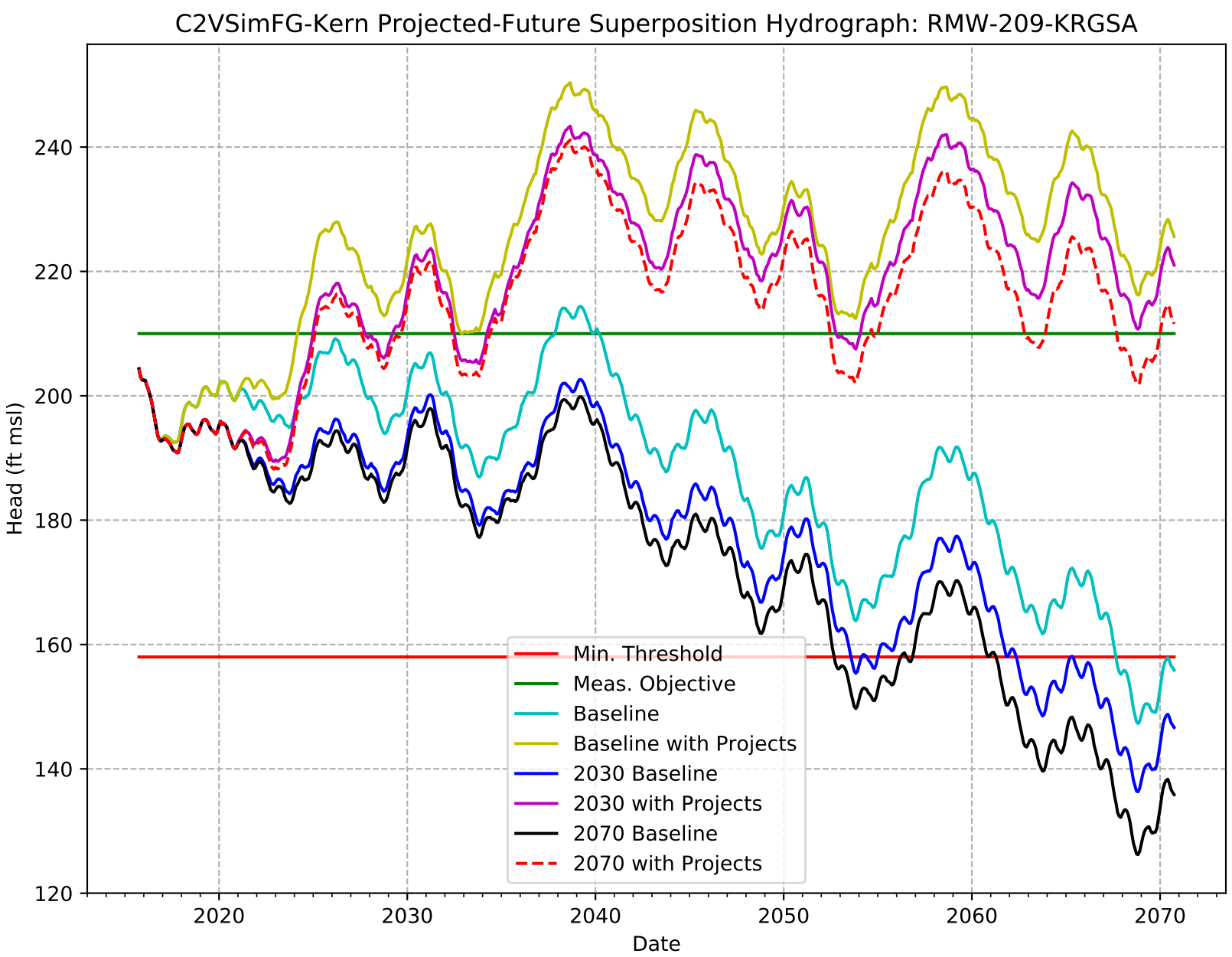

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-204-SWID
Head (ft msl)
50
0
−50
−100
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

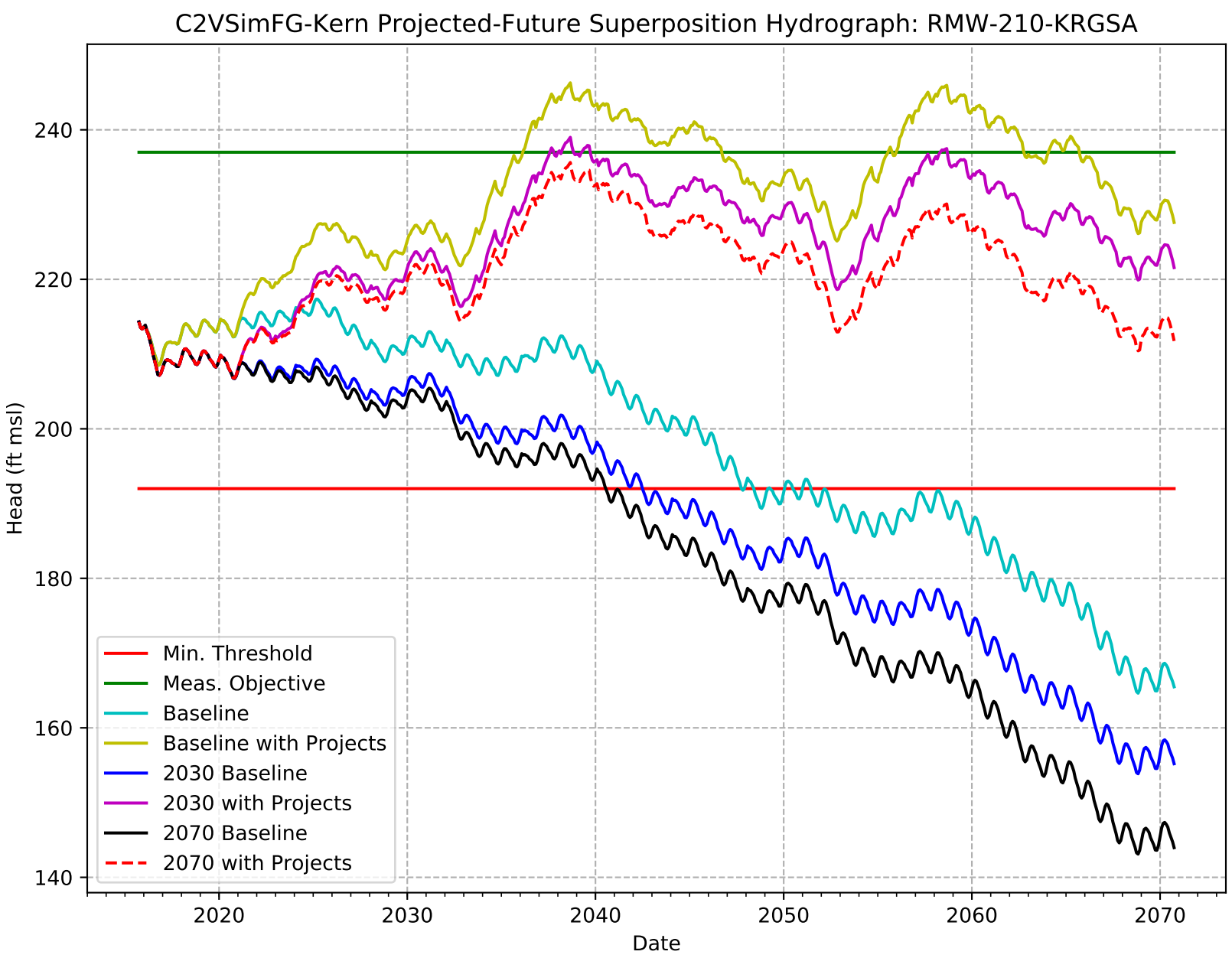

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-205-SWID
Head (ft msl)
25
0
−25
−50
−75
−100
−125
−150
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

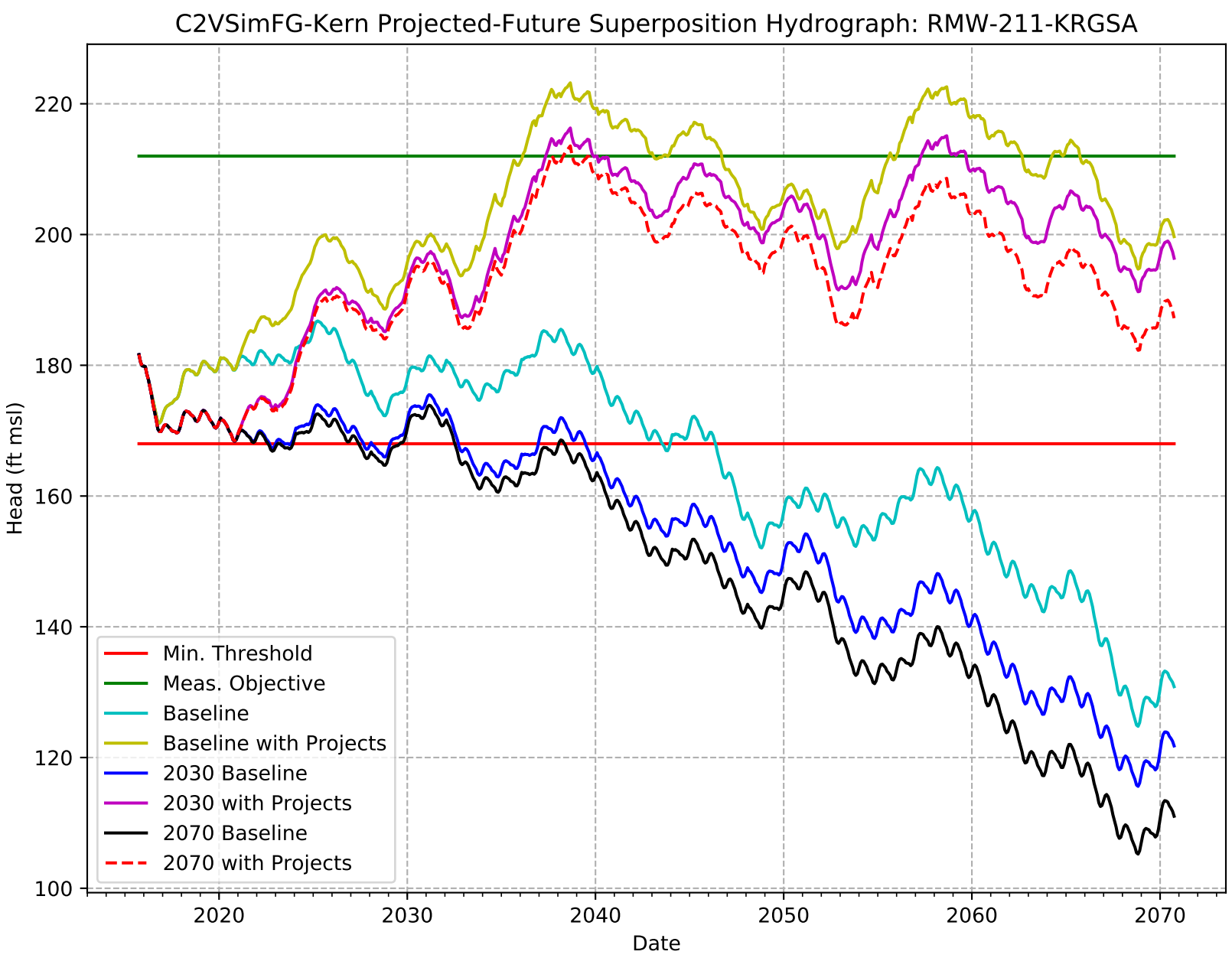

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-206-WDWA
Head (ft msl)
160
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date
Simulated Groundwater Levels in KTWD, EWMA and WDWA of Kern County Subbasin are considered poorly calibrated so that the projected future scenarios using C2VSimFG-Kern do not provide representative groundwater trends in these areas.
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

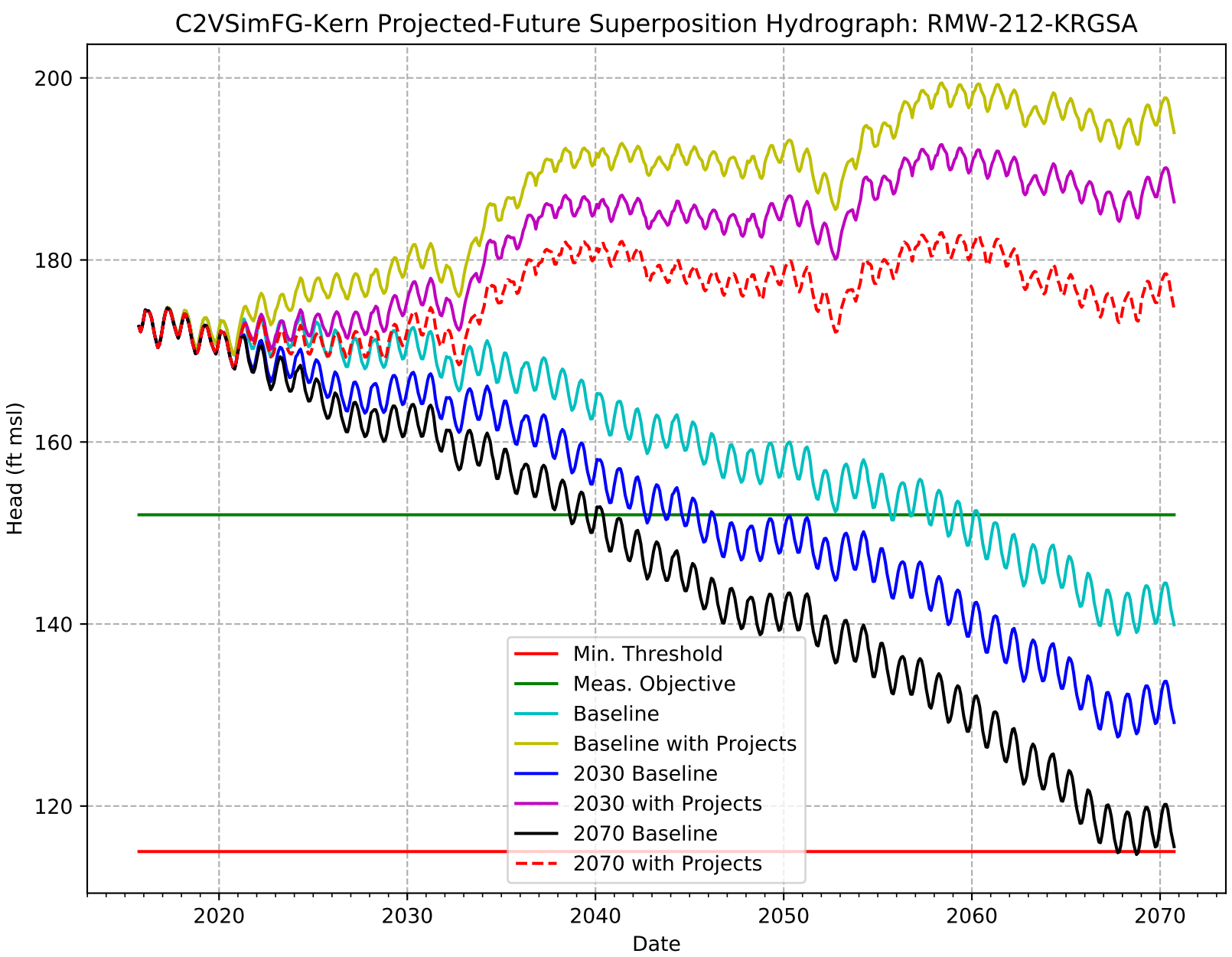

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-207-SWSD
Head (ft msl)
0
−50
−100
−150
−200
−250
−300
−350
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

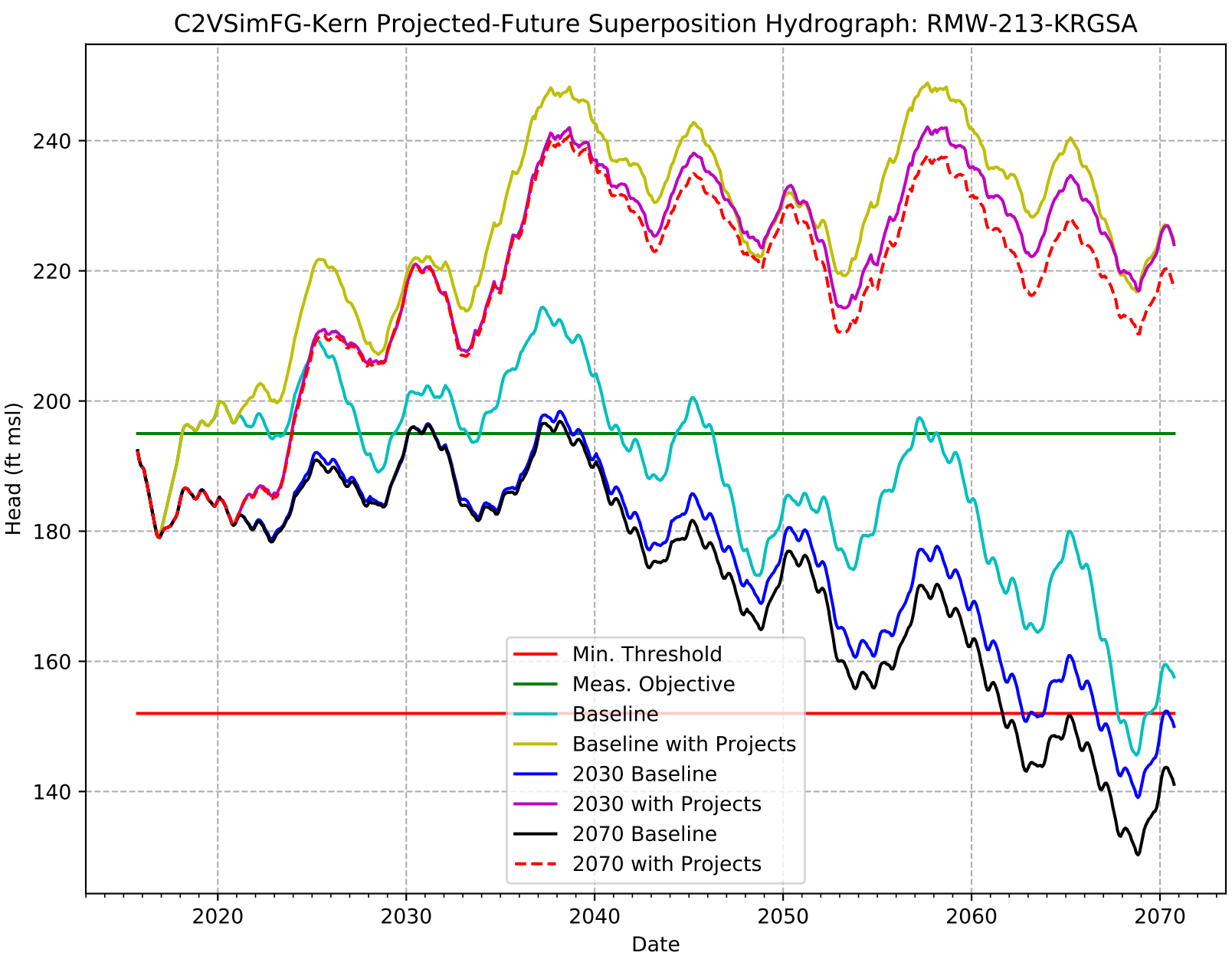

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-208-SSJMUD
Head (ft msl)
Date
150
100
50
0
−50
−100
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

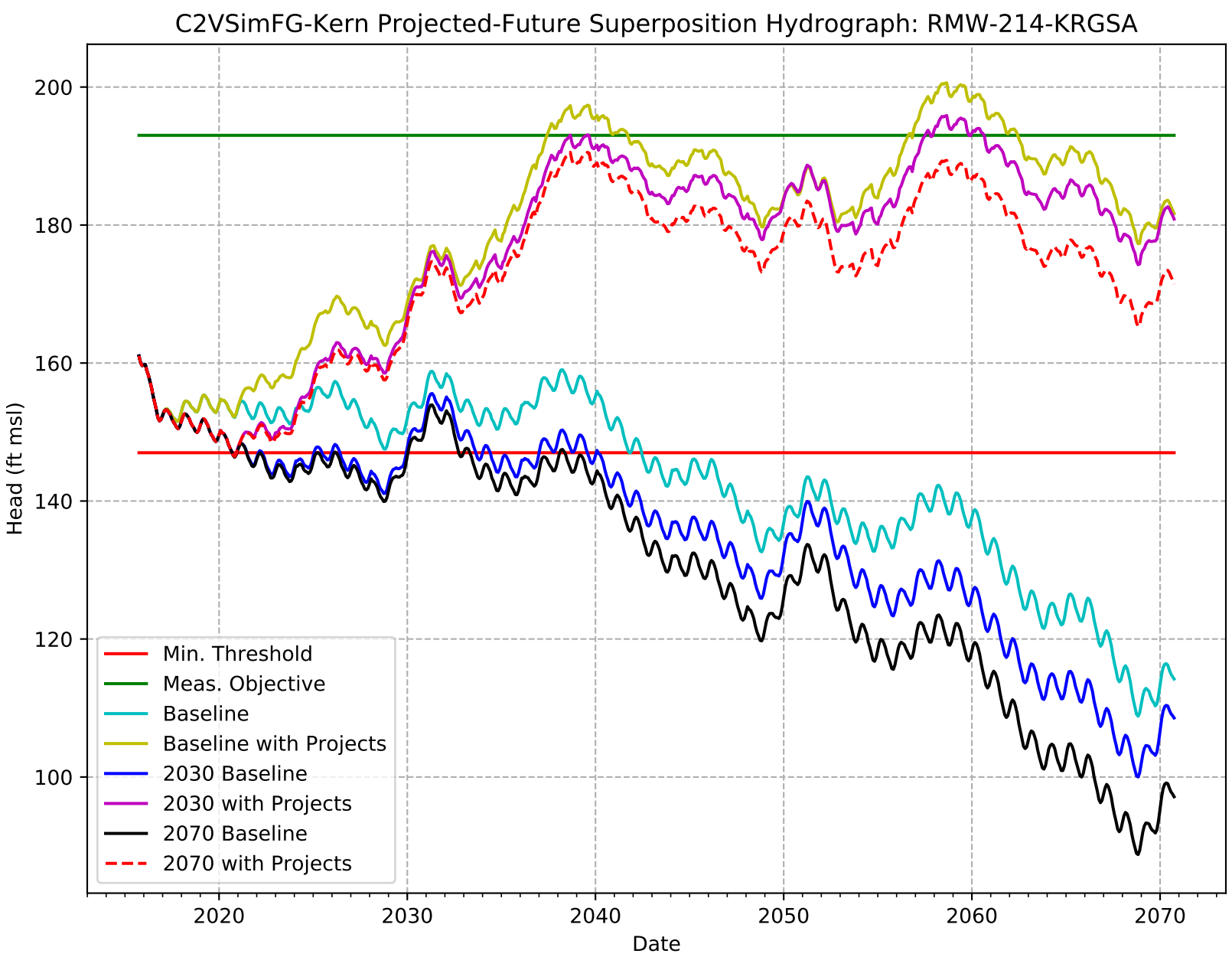

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-209-KRGSA
Head (ft msl)
240
220
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

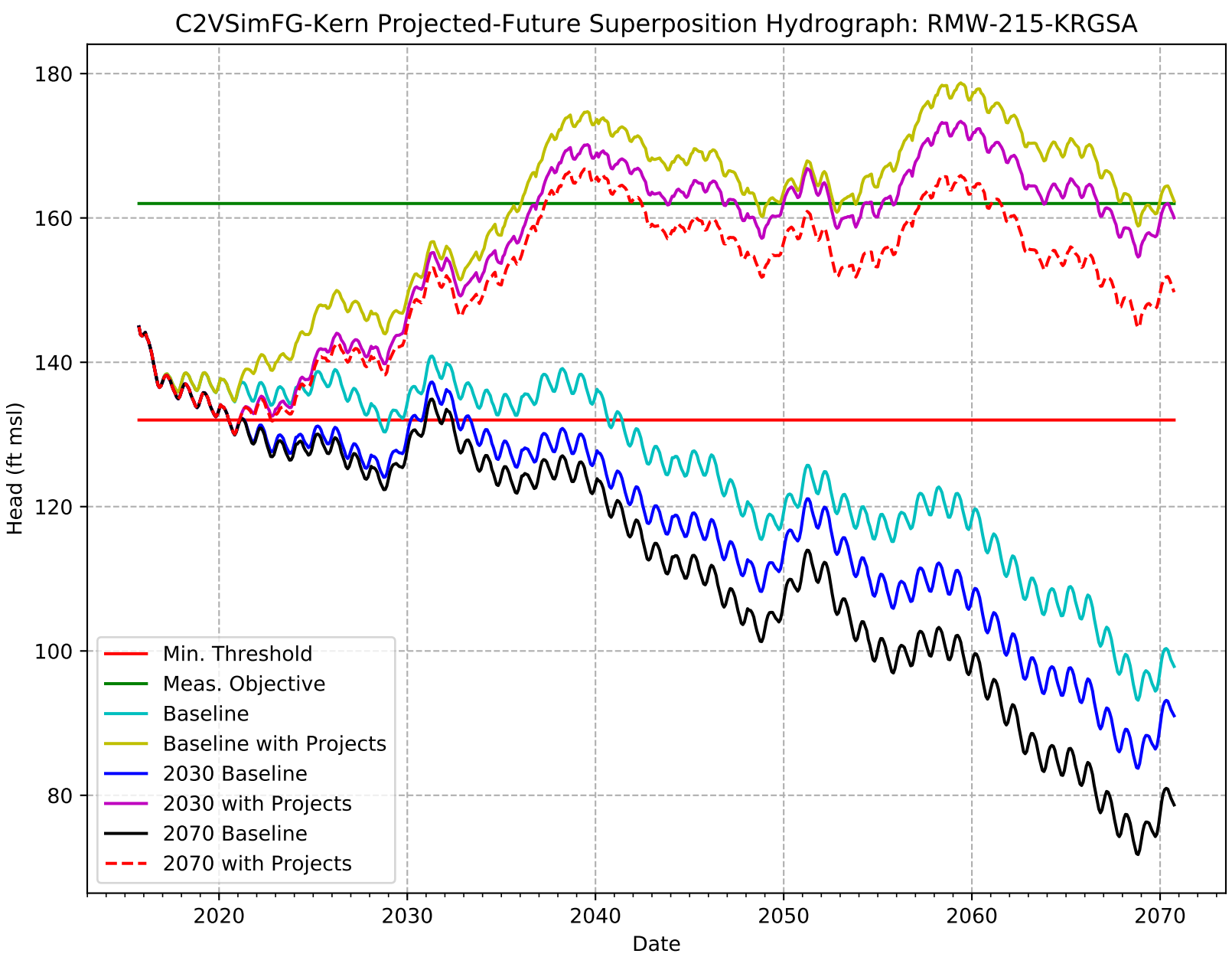

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-210-KRGSA
Head (ft msl)
240
220
200
180
160
140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

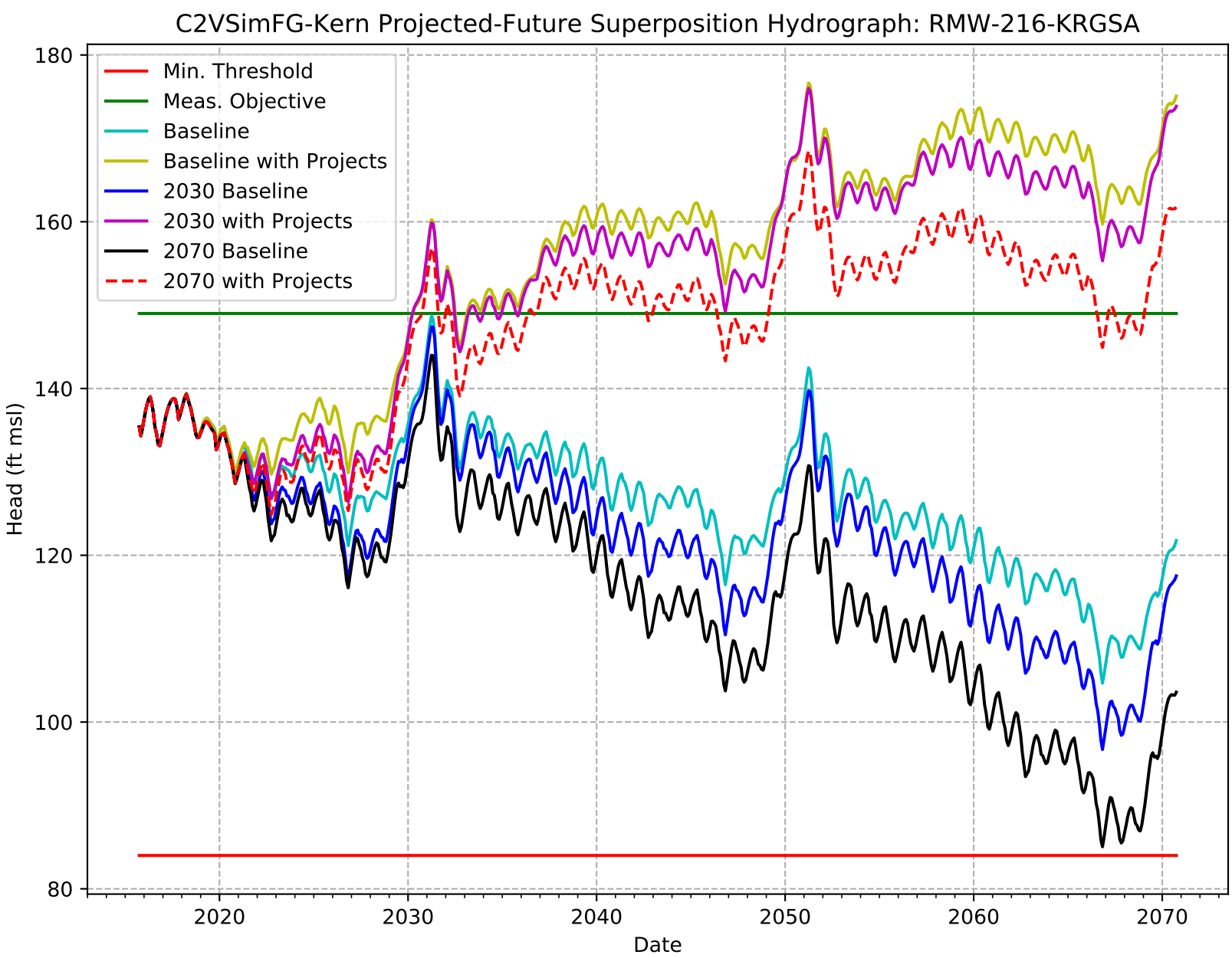

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-211-KRGSA
Head (ft msl)
Date
220
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

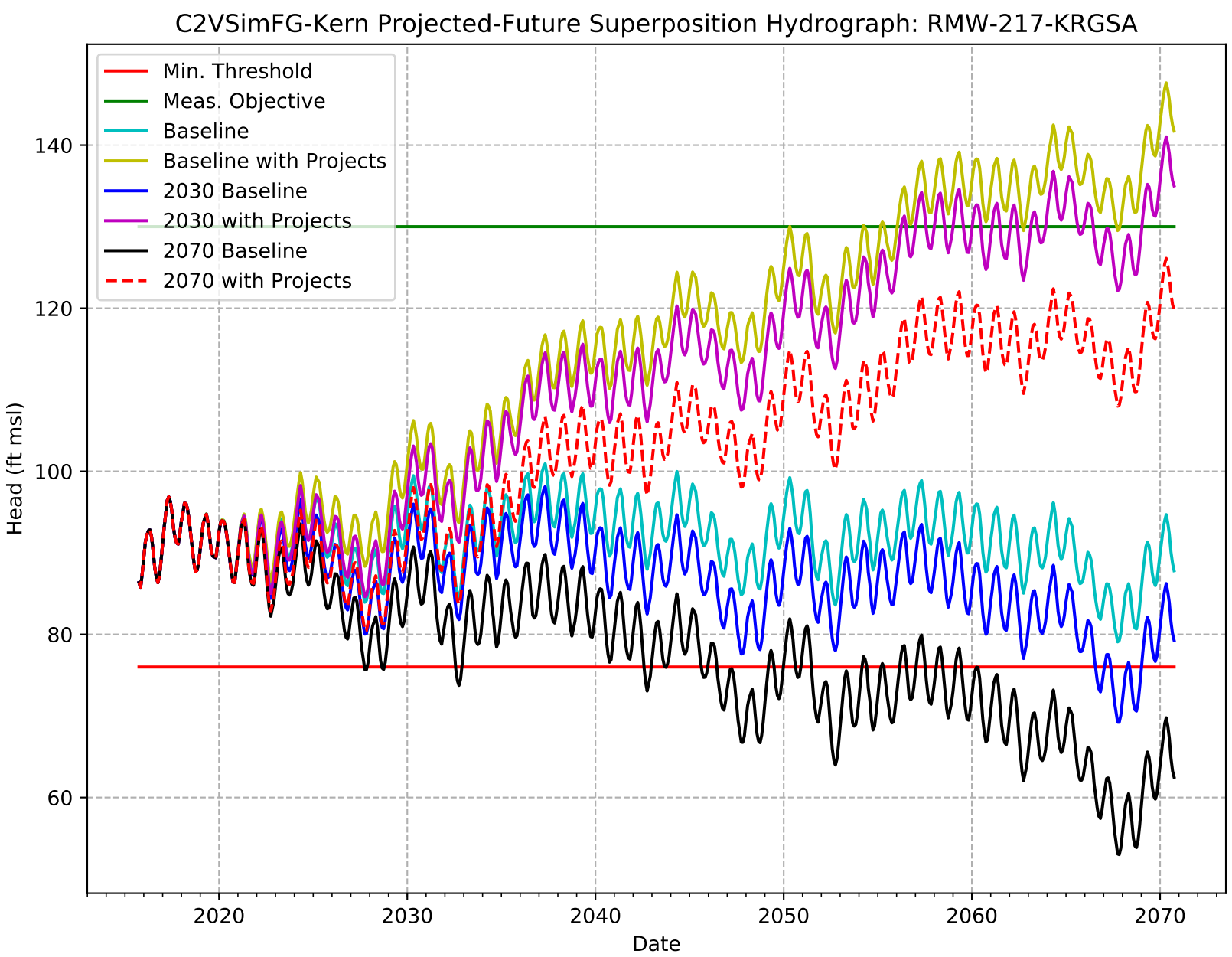

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-212-KRGSA
Head (ft msl)
200
180
160
140
120
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

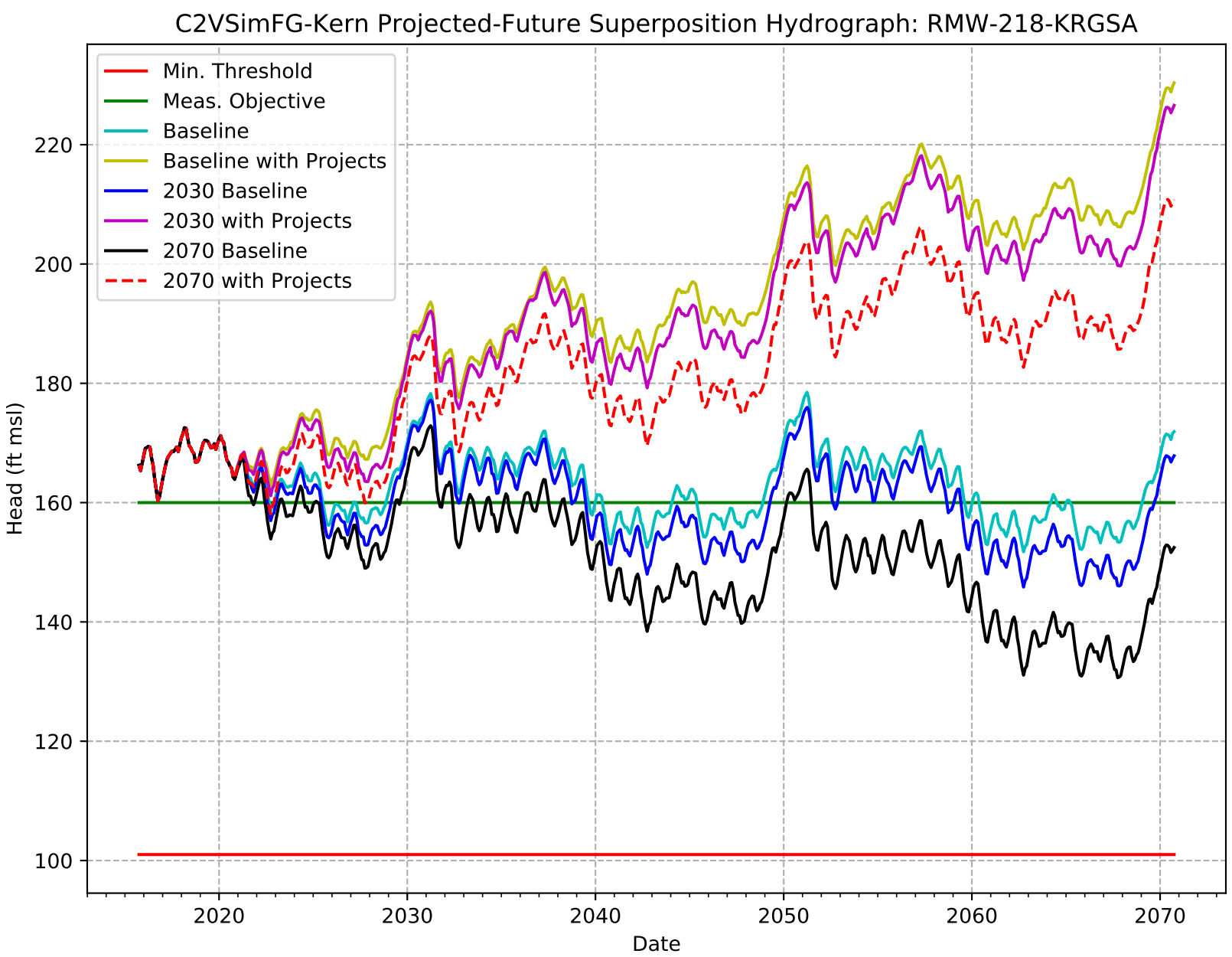

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-213-KRGSA
Head (ft msl)
240
220
200
180
160
140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

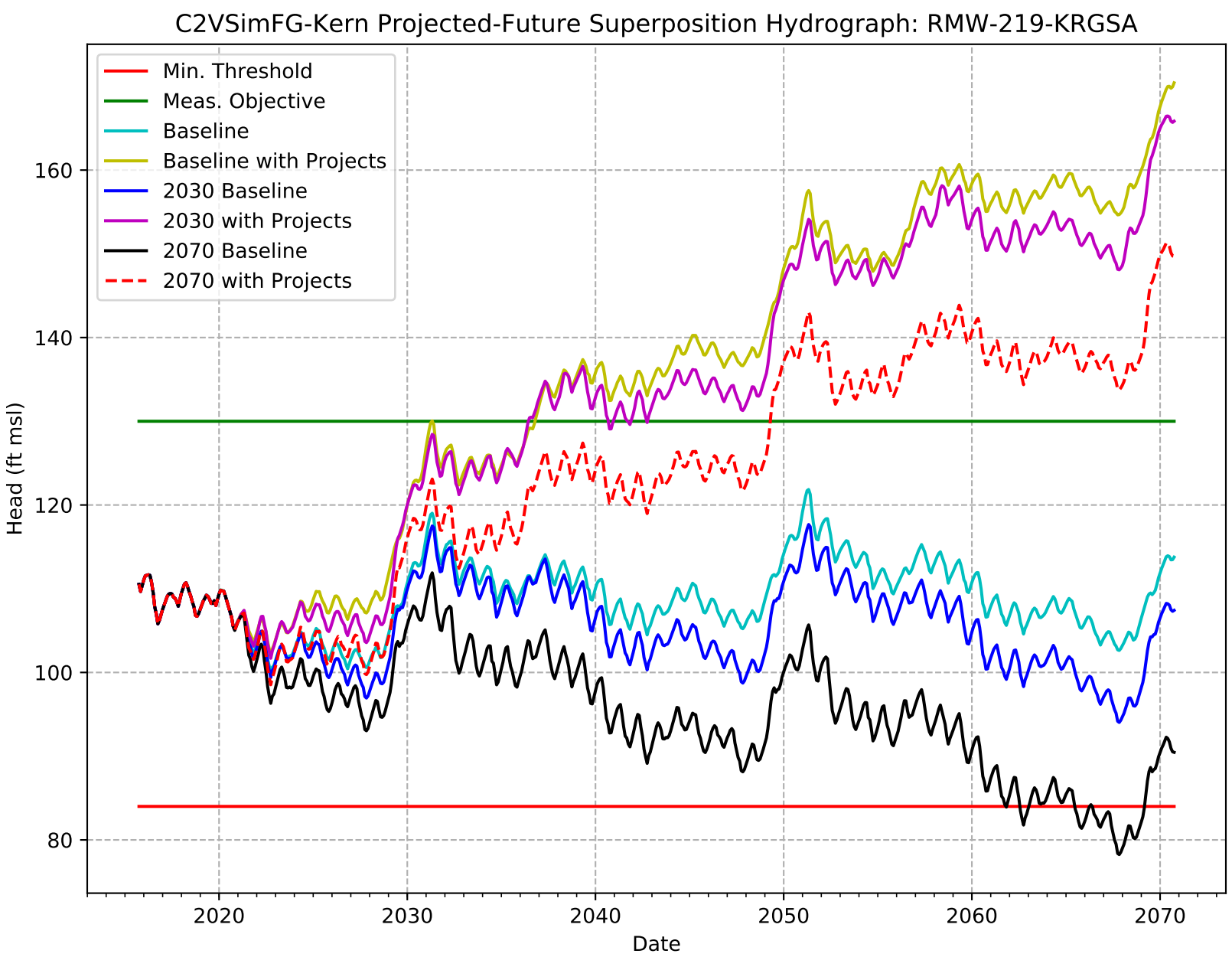

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-214-KRGSA
Head (ft msl)
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

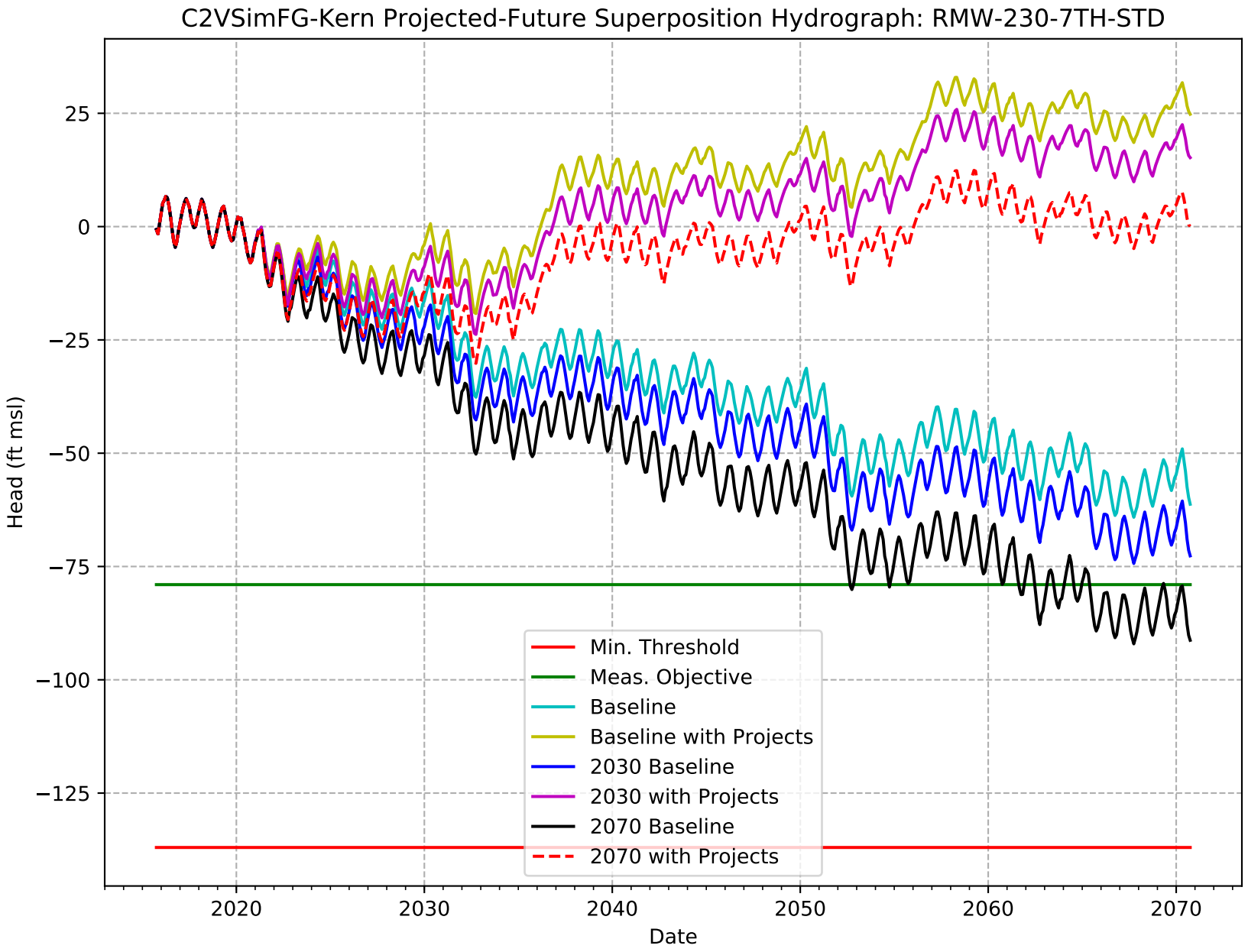

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-215-KRGSA
Head (ft msl)
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

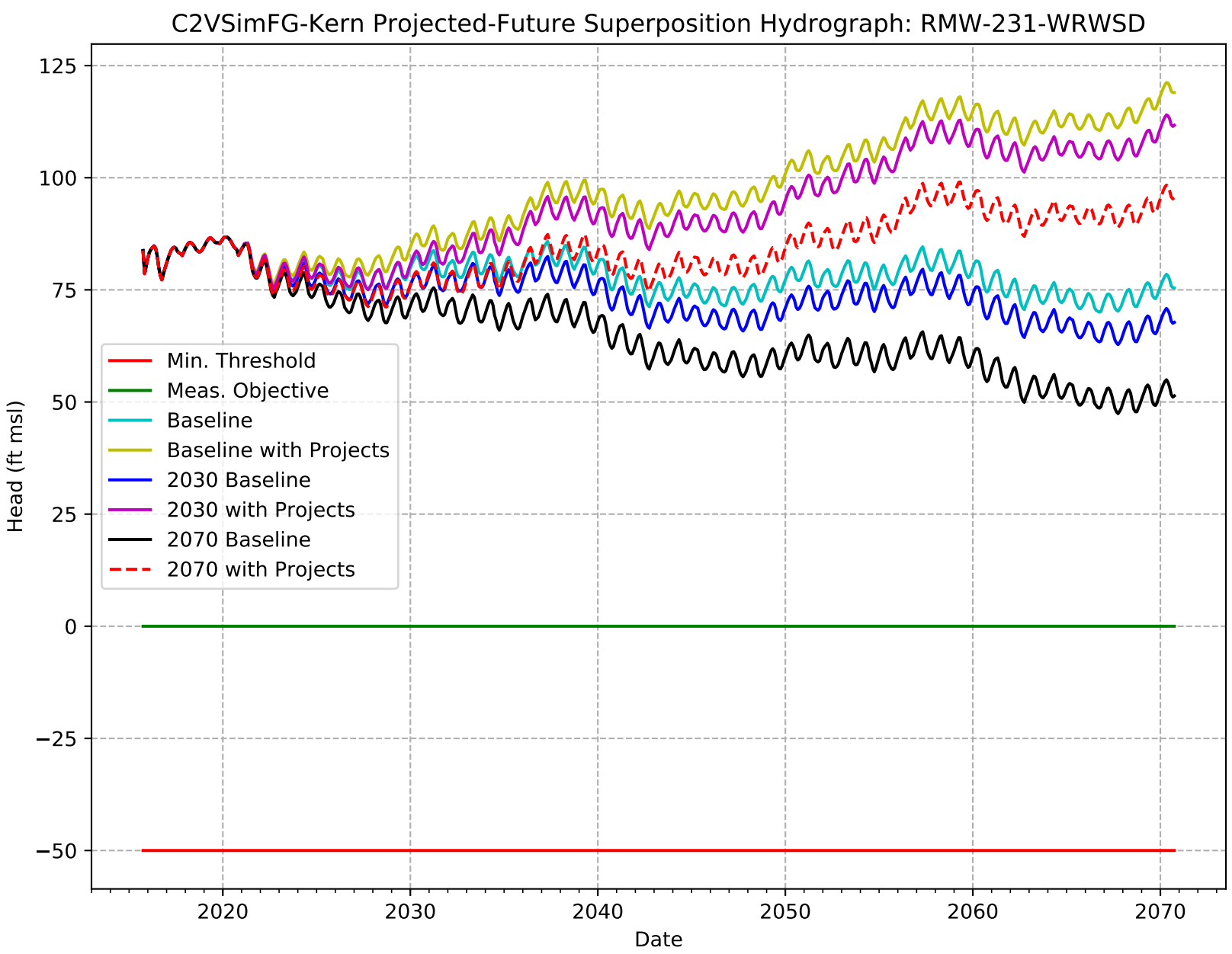

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-216-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
180
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date

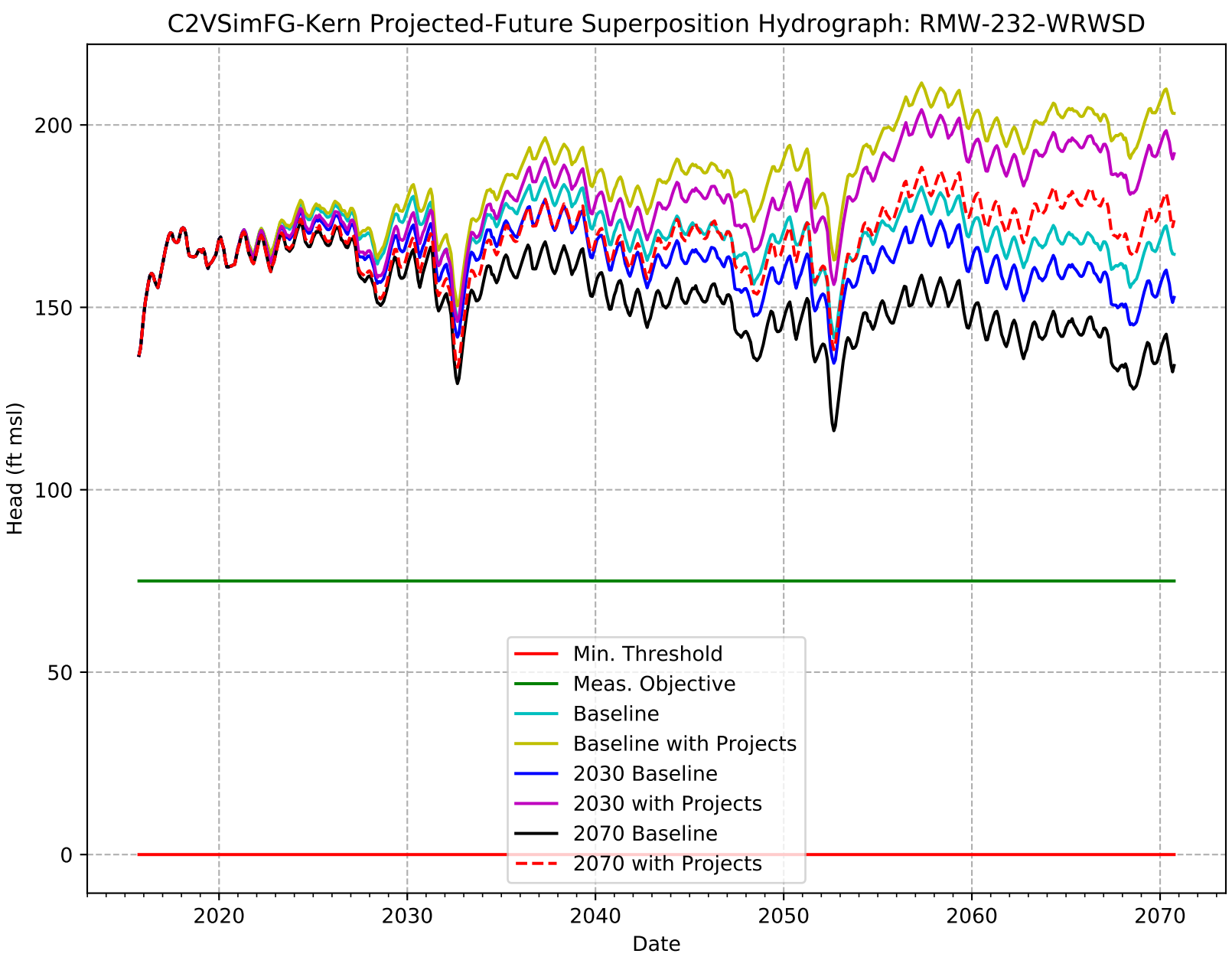

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-217-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
140
120
100
80
60
2020
2030
2040
2050
2060
2070
Date

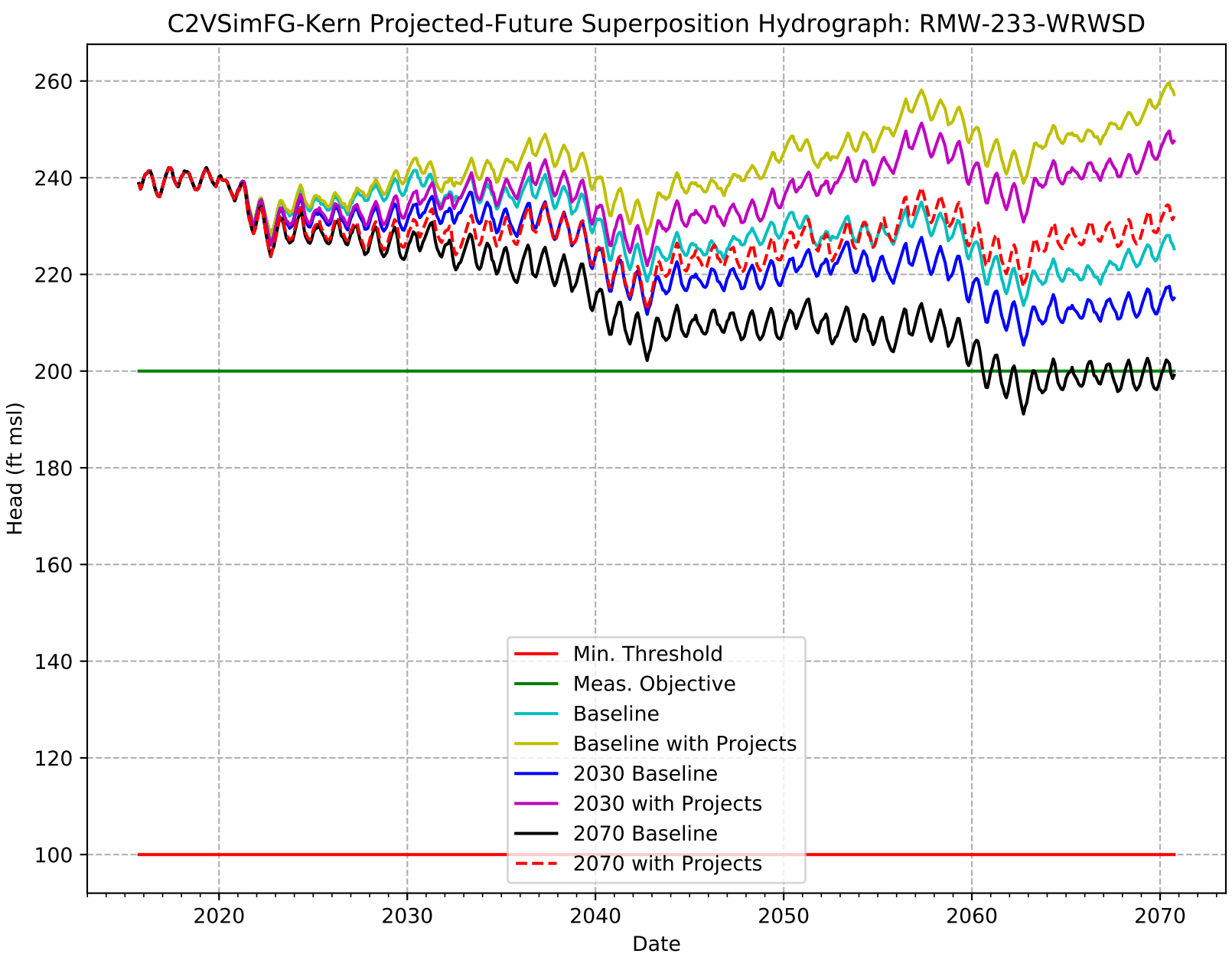

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-218-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
220
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date

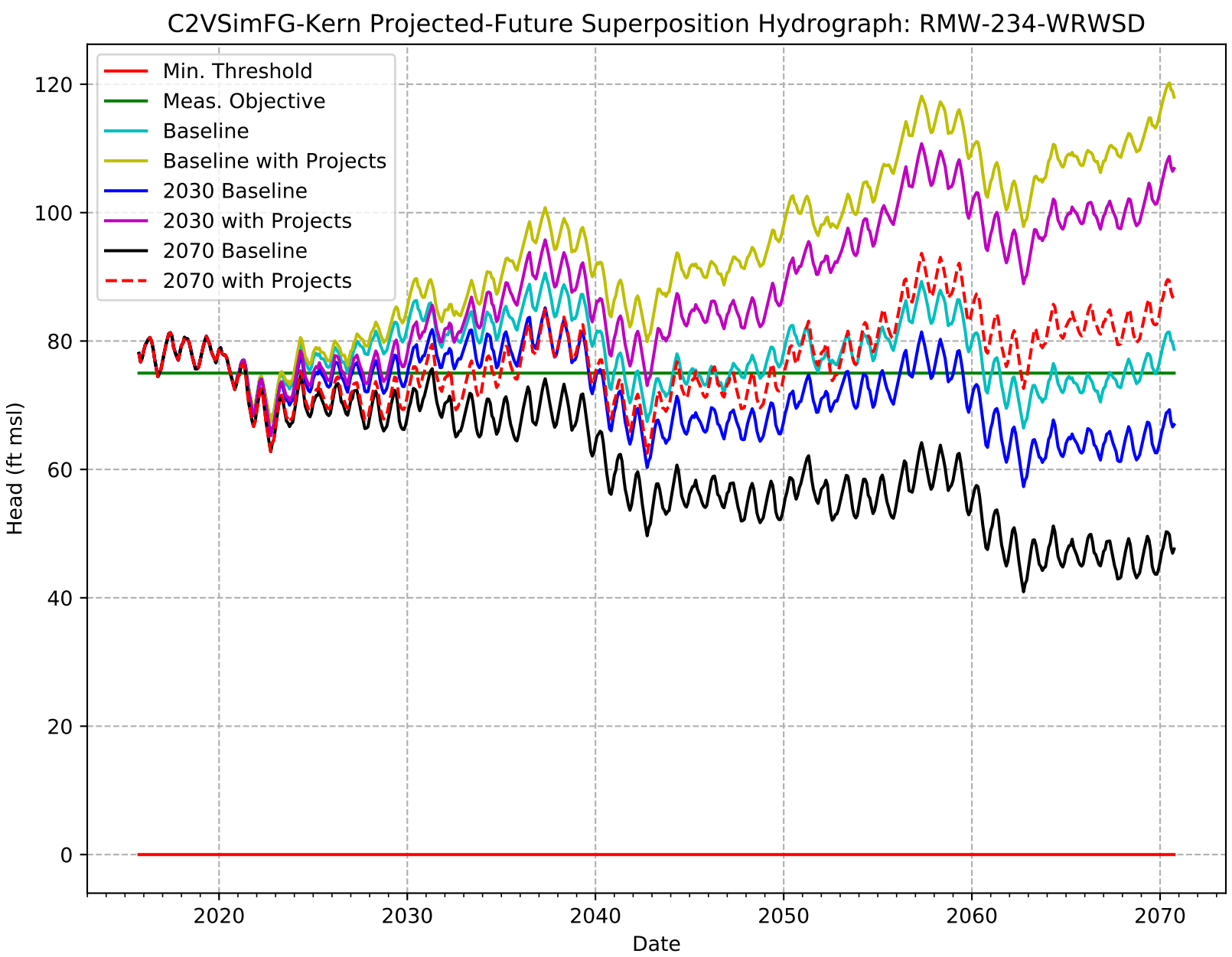

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-219-KRGSA
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
160
140
120
100
80
2020
2030
2040
2050
2060
2070
Date

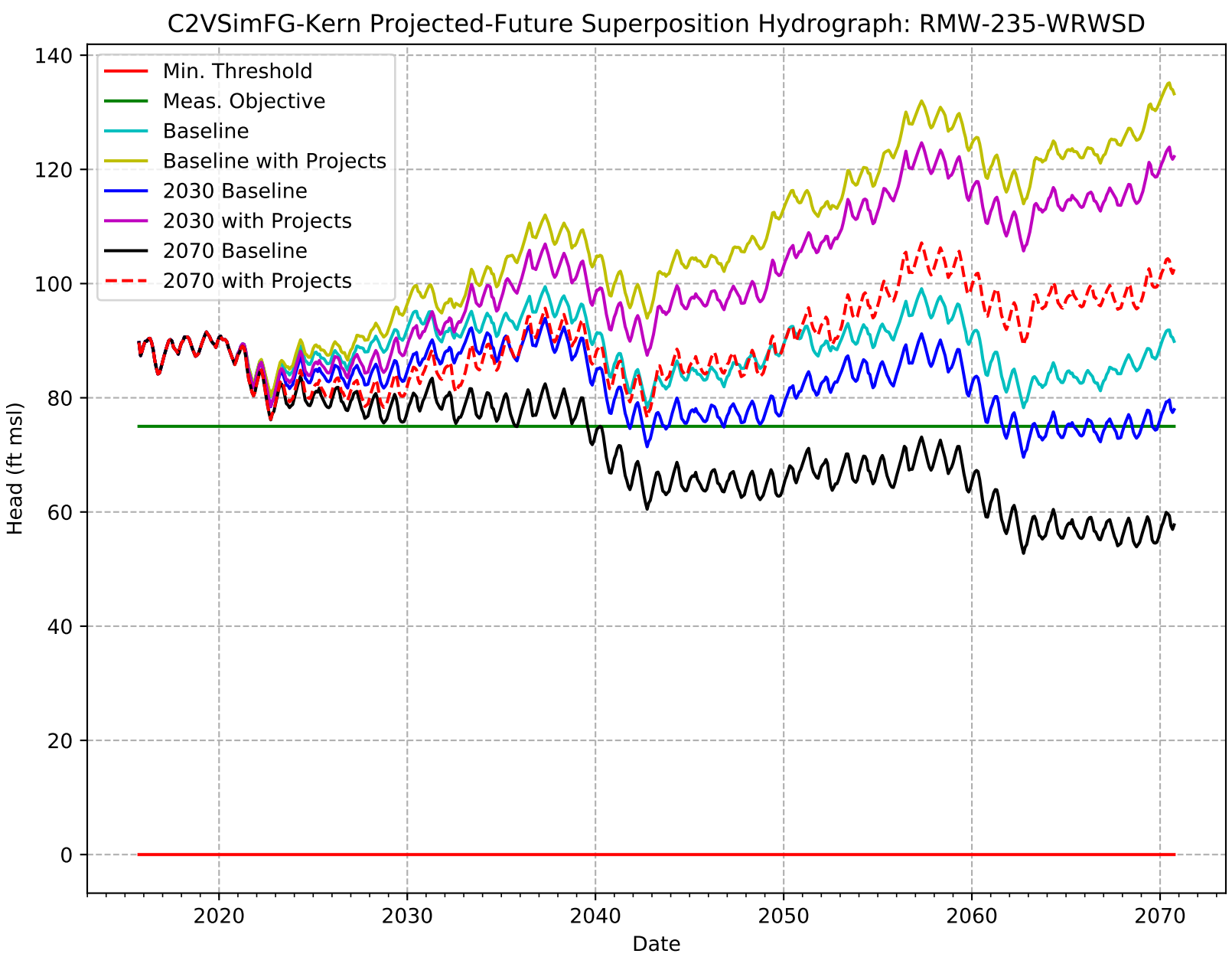

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-230-7TH-STD
Head (ft msl)
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

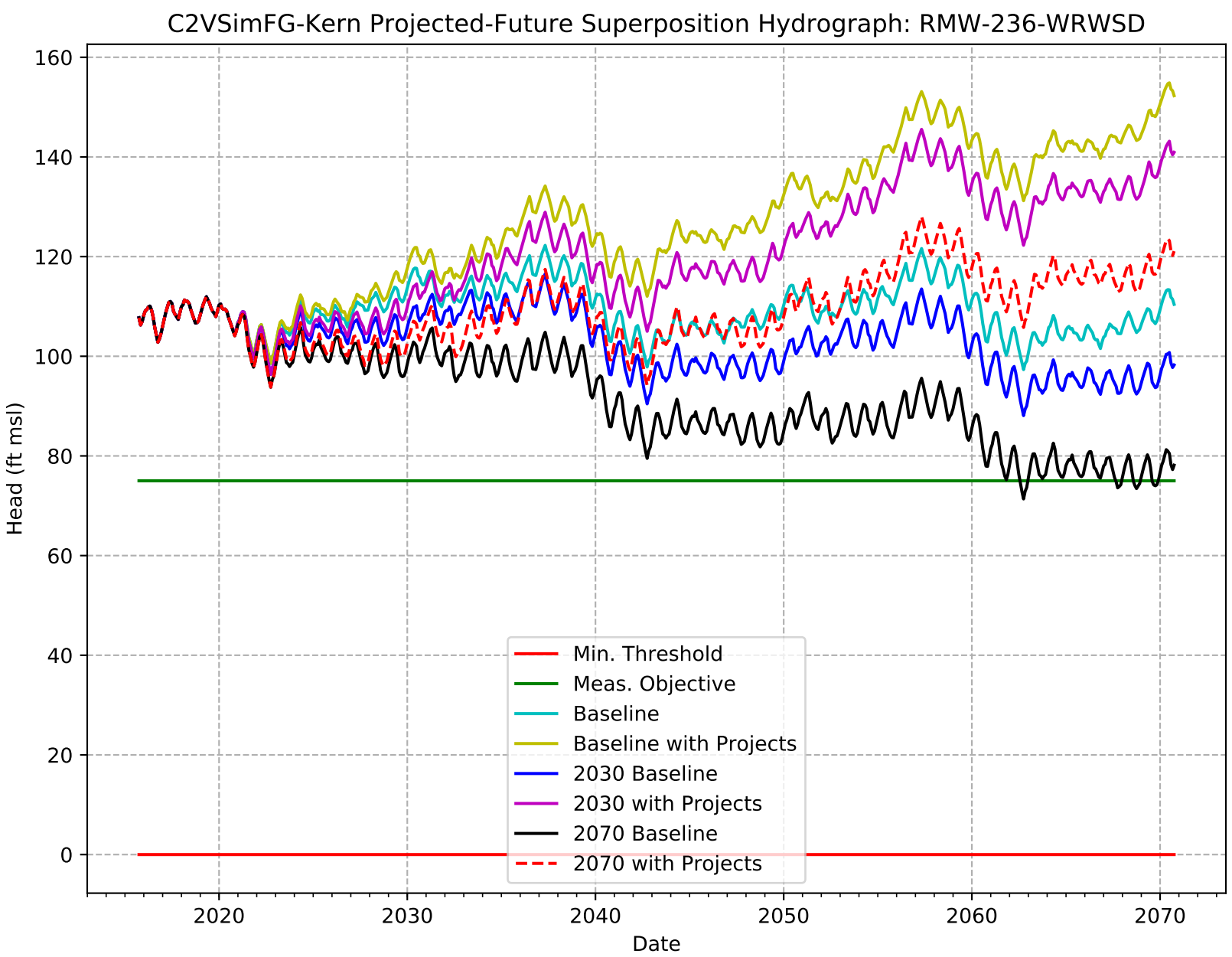

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-231-WRWSD
Head (ft msl)
125
100
75
50
25
0
−25
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

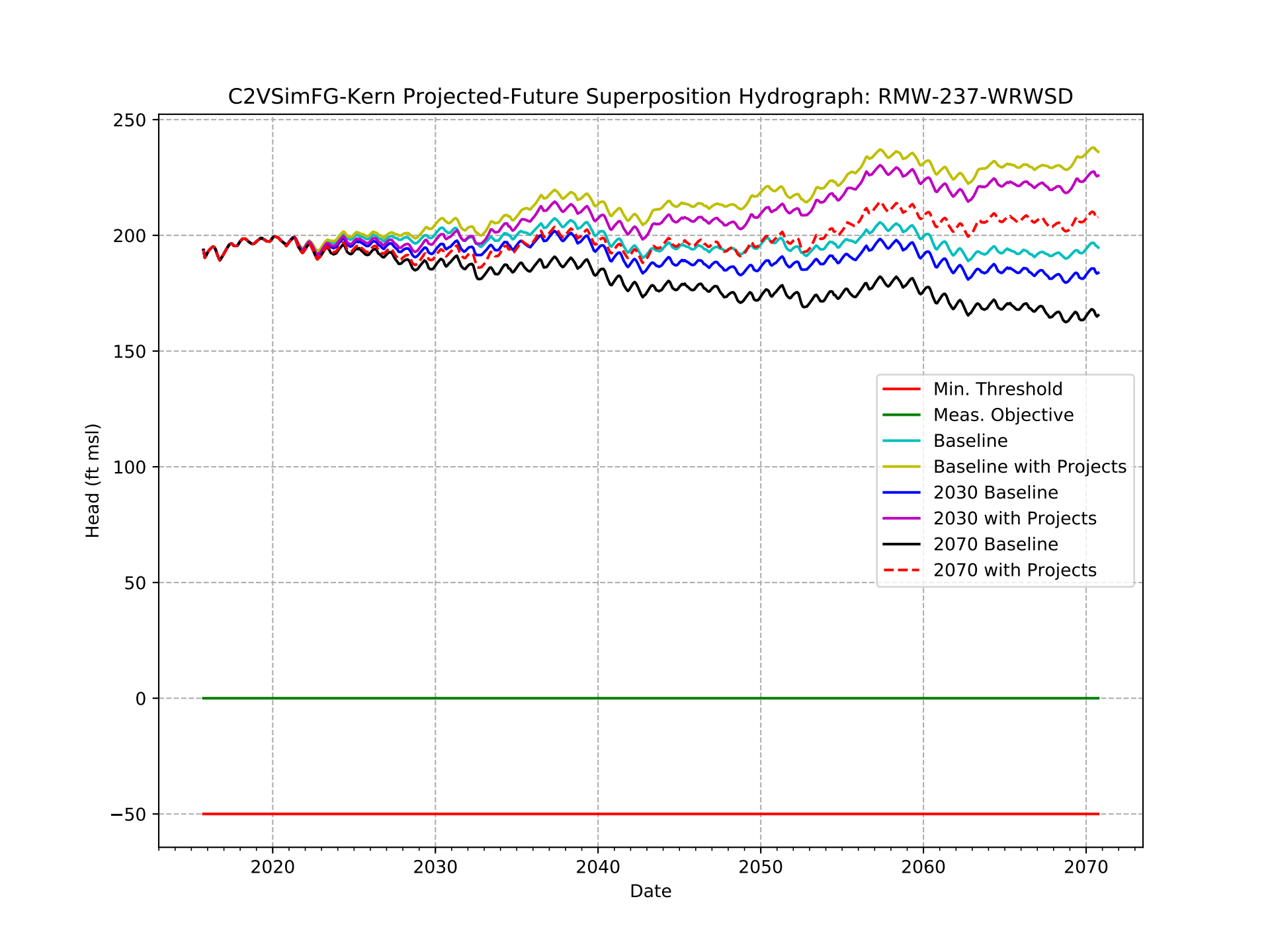

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-232-WRWSD
Head (ft msl)
200
150
100
50
0
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

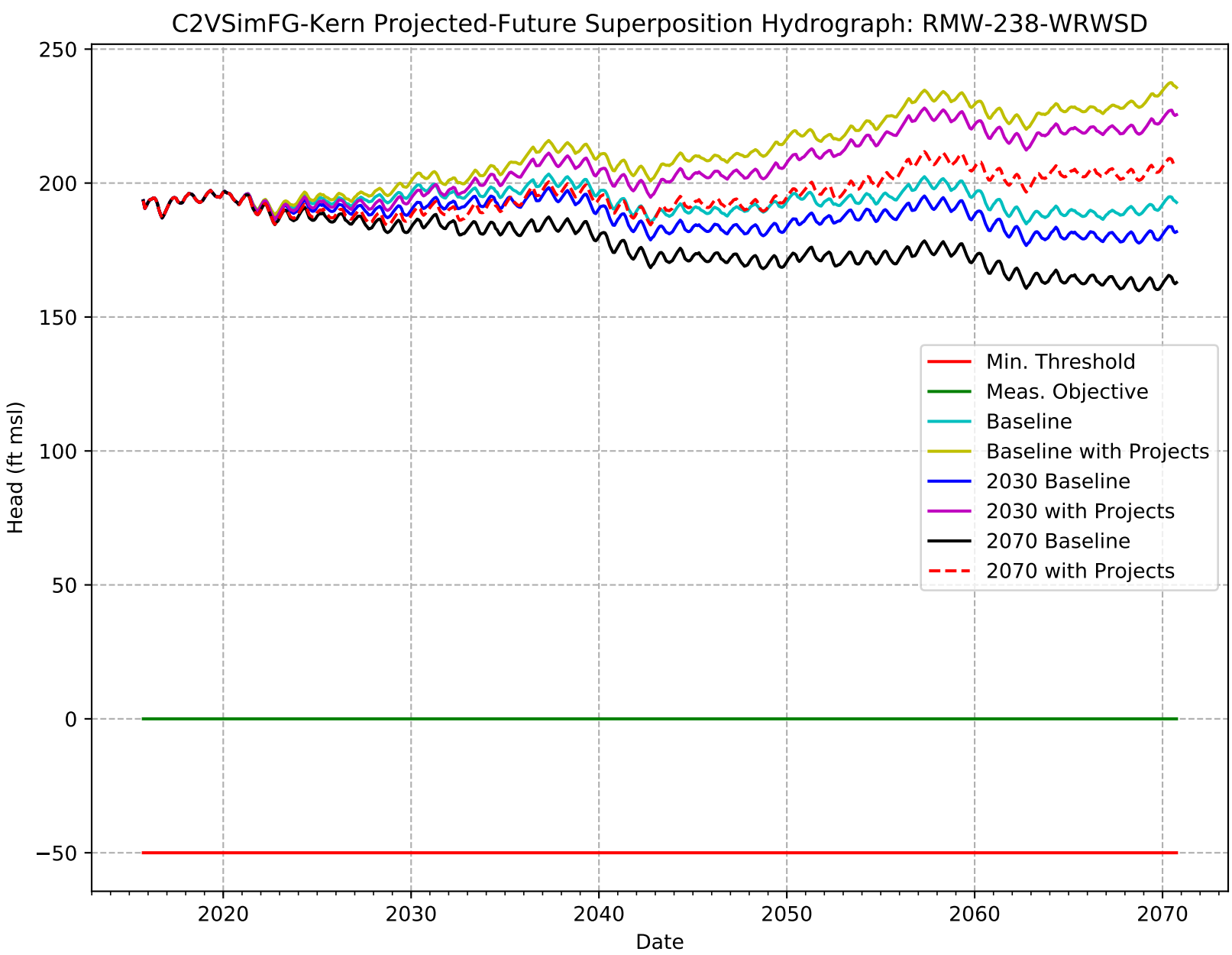

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-233-WRWSD
Head (ft msl)
260
240
220
200
180
160
140
120
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

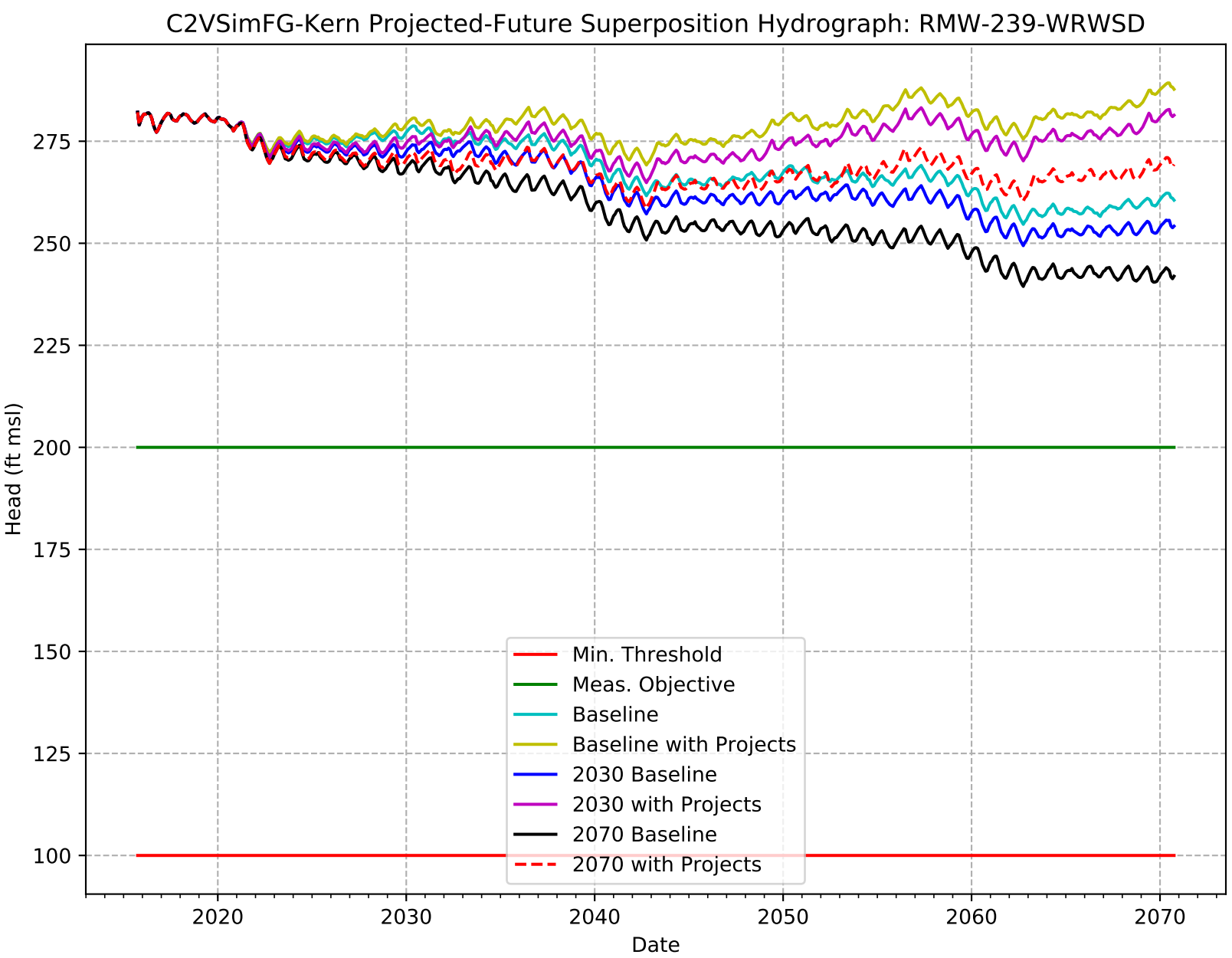

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-234-WRWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Date

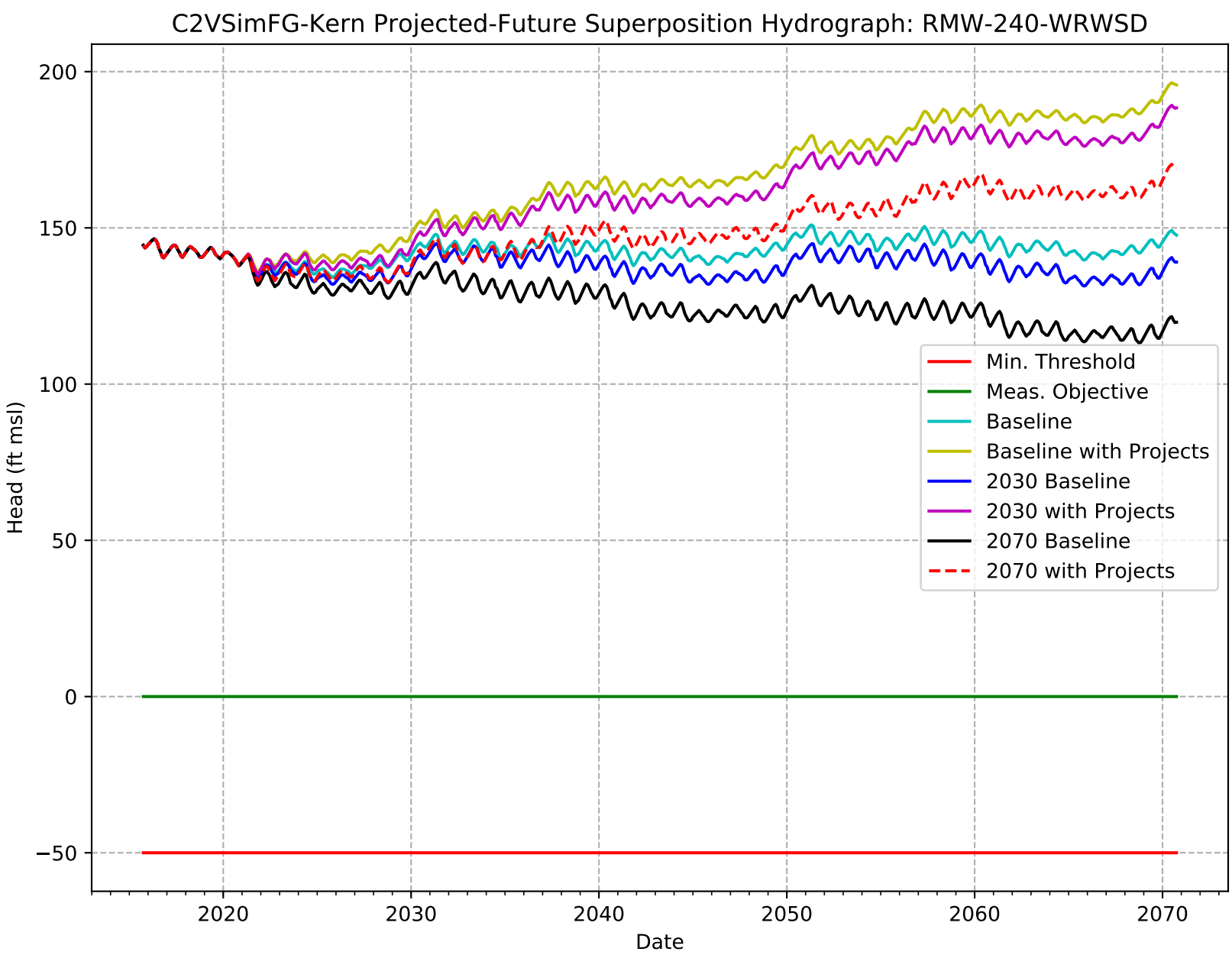

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-235-WRWSD
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects
Head (ft msl)
Date
140
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070

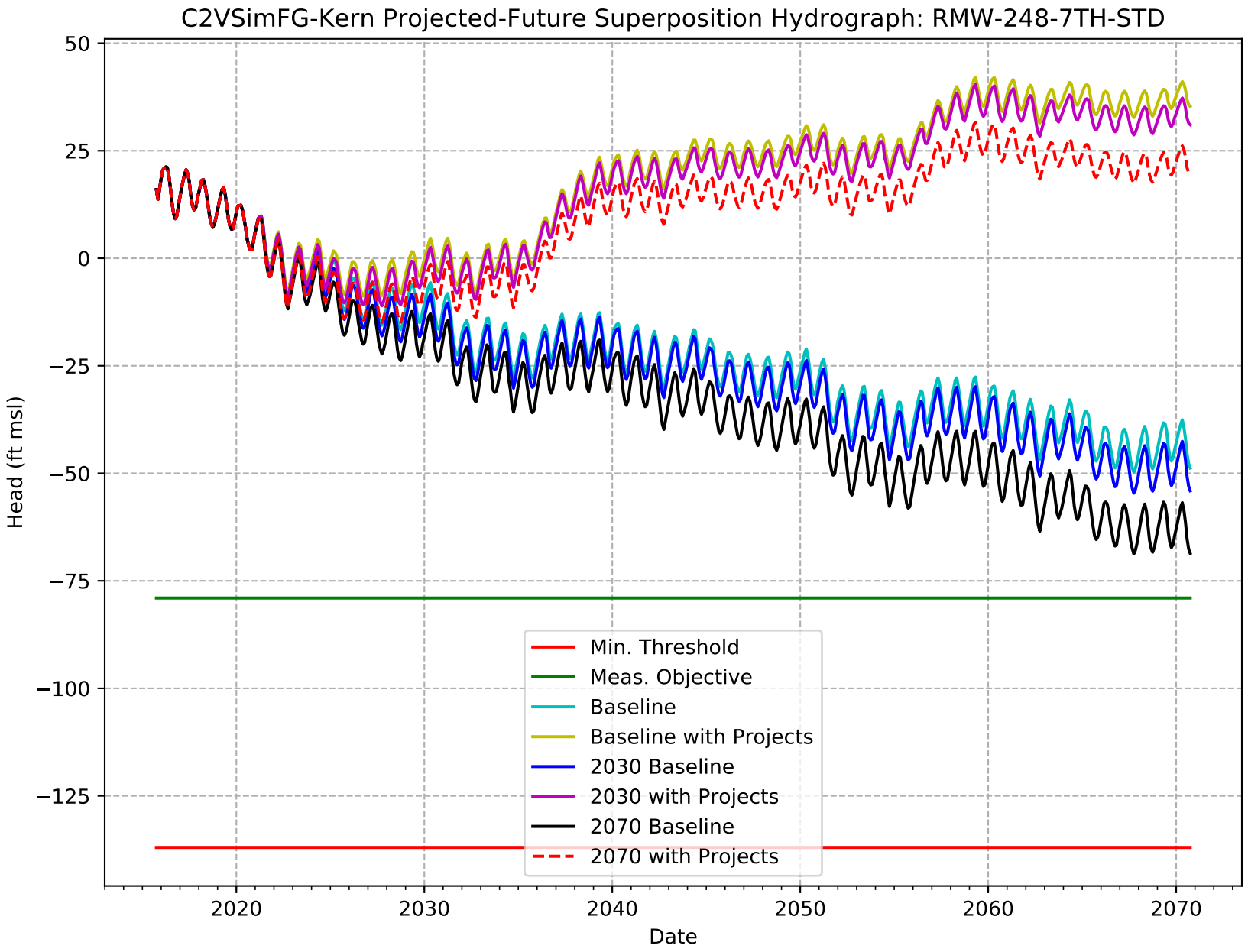

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-236-WRWSD
Head (ft msl)
Date
160
140
120
100
80
60
40
20
0
2020
2030
2040
2050
2060
2070
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

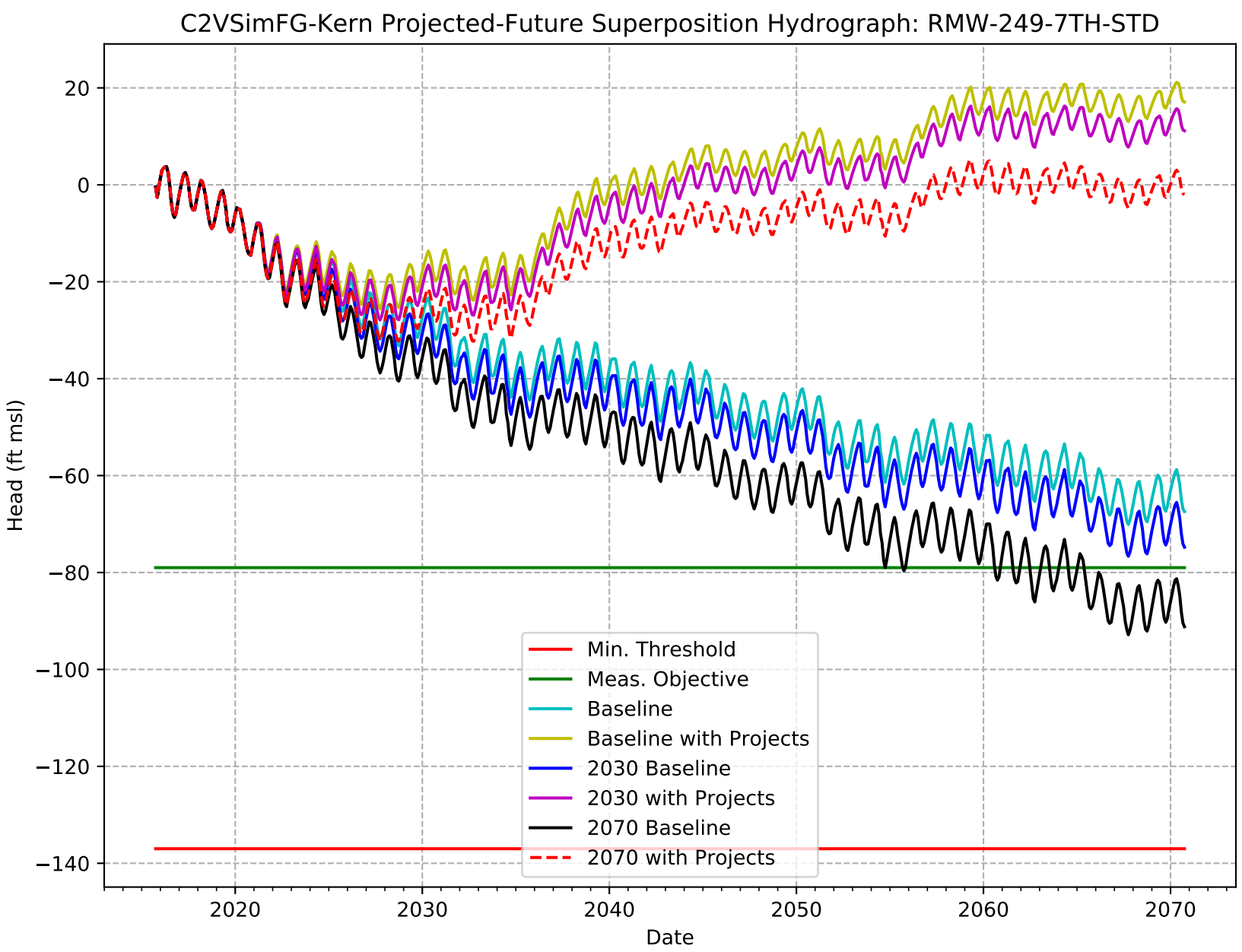

C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-237-WRWSD
Head (ft msl)
250
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-238-WRWSD
Head (ft msl)
250
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-239-WRWSD
Head (ft msl)
275
250
225
200
175
150
125
100
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-240-WRWSD
Head (ft msl)
200
150
100
50
0
−50
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-248-7TH-STD
Head (ft msl)
50
25
0
−25
−50
−75
−100
−125
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects


C2VSimFG-Kern Projected-Future Superposition Hydrograph: RMW-249-7TH-STD
Head (ft msl)
20
0
−20
−40
−60
−80
−100
−120
−140
2020
2030
2040
2050
2060
2070
Date
Min. Threshold
Meas. Objective
Baseline
Baseline with Projects
2030 Baseline
2030 with Projects
2070 Baseline
2070 with Projects

KERN COUNTY
OIL AND GAS PERMITTING PROGRAM
ANNUAL PROGRESS REPORT
(December 9, 2015 to November 30, 2016)

Kern County Planning and
Natural Resources Department
2700 'M' Street, Suite 100
Bakersfield, CA 93301
(661) 862-8600

Lorelei Oviatt, AICP, Director

December 2016

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1.0 Introduction

On November 9, 2015, the Kern County Board of Supervisors approved revisions to the Kern County Zoning Ordinance – 2015 (C), focused on Oil and Gas Local Permitting and certified an Environmental Impact Report (SCH #2013081079). Staff was directed to provide an annual update to the Board regarding the process.

1.1 Reporting Period

This report marks the first year of Oil and Gas processing under the new revisions to the Zoning Ordinance. The reporting Period began on December 9, 2015, the first day after the Ordinance was enacted, and goes through November 30, 2016.

1.2 Topics to be Discussed

Staff has proposed the following topics to be discussed in this and each subsequent Report to your Board:

Accounting of Annual Permits

- Oil and Gas Conformity Review
- Minor Activity Review

Accounting of Annual CEQA Mitigation Fees Collected

- Roads Mitigation
- Fire equipment Mitigation
- Rural Crimes Task Force Mitigation
- Biological Habitat Replacement Mitigation
- Air Quality Emission Reduction Agreement Mitigation
- Agricultural Land Replacement Mitigation
- Paleontological Mitigation
- Notice of Exemption Clerk Posting Fee

County Produced Permit Assistance

- Accela Automation
- Oil and Gas Handbook
- Small Producers Handbook

Continued Coordination

- Online Permitting System
- Other County Departmental Reporting
- Emission Reduction Agreement Reporting
- Re-use of Produced Water

2.0 Accounting

2.1 Annual Permits

During the reporting period, the Planning and Natural Resources Department received and processed the following number of permits:

Permit Type	Applied	Issued	Closed
Oil and Gas Conformity Review	1202	1122	125
Minor Activity Review	77	72	20

In the first year of the new program, County Staff has successfully reviewed 100% of applications within the mandated 7-day and 3-day review time frames. With an average 7-day review being completed within 5 days.

2.2 Annual CEQA Mitigation Fees Collected

During the reporting period, the Planning and Natural Resources Department collected the following CEQA mitigation fees:

Mitigation Measure	FEE CODE	AMOUNT
4.16-1	POG050 - Roadway Maintenance/Improvements	$388,700.00
4.14-1	POG051 - Firefighting Equipment	$162,450.00
4.5-3	POG052 - Paleontological Resource	$10,300.00
4.14-2	POG053 - Rural Crimes Unit	$432,225.00
4.2-1	POG054 - Mitigation of Agricultural Land Replacement	$30,996.00
4.3-8	POG055 - Air Quality Impacts	$3,329,332.87
4.3-8	POG057 – SJVAPCD Fee	$138,722.20
4.4-16	POG056 - Biological Resources Mitigation	$60,502.50

3.0 County Produced Permit Assistance

3.1 Accela Automation

Beginning shortly after the project was approved by your Board, Staff began working to create a new permitting process. This process entailed the development of computer aided permitting software, designed to assist in meeting the review periods set out by the adoption of the revisions to the Zoning Ordinance. Accela Automation, the program currently used by the County for processing of grading and building permits by the Public Works Department was selected as the most compatible. Staff worked to design a module capable of handling oil and gas permits. The program was successfully launched at the start of the permitting process and has allowed Staff to input each oil and gas review permit into a database. Benefits of this program include: consistent processing times, accurate fee and mitigation estimates, and has allowed for reporting of permitting types for production of annual reports.

3.2 Oil and Gas Handbook

In January 2016, Staff released the Oil and Gas Handbook. This handbook is designed as an introduction to oil and gas permitting. The handbook can be utilized by oil and gas companies or

by citizens in Kern County to help with understanding the rules and regulations of the local permitting process. A copy of the handbook can be found on the Kern County Website, located: http://www.co.kern.ca.us/planning/pdfs/oil_gas/kern_oil_gas_permitting_handbook.pdf

3.3 Small Producers Handbook and Permitting Software

County Staff released the first version of the Small Producers Handbook in November. This handbook differs from the Oil and Gas handbook, in that it provides a step-by-step tutorial for any company to begin the permitting process. Along with the handbook, Staff worked with a private consultant to create an online permitting tool. This wizard driven program can be used by any company wishing to create a detailed site plan and checklist for mitigation monitoring and reporting. The program, along with the handbook, allows companies to walk through each of the requirements of the Zoning Ordinance and produce a package that can be submitted to County Staff for review.

4.0 Continued Coordination

4.1 Online Permit Submission

Staff is currently developing tools to allow for the online submission of oil and gas permits through the Accela Automation program, known as Citizen Access. Applicants will be able to submit the application package, including site plans, mitigation compliance, and fees completely from their office. They will also have the ability to check the status of their permit and print the necessary permit documents, once a permit has been issued. Staff believes this process will dramatically increase the efficiency of the permitting process and save applicants time and money. Another feature of Citizen Access will be the ability for any member of the public to view past and current permits online. Staff estimates this online feature will be available in January 2017.

4.2 Other County Departmental Reporting

Two mitigation measures approved with the revisions to the Ordinance require other County Departments to file annual reports with your Board. These Mitigation Measures are MM 4.14-2 (Rural Crimes) and MM 4.16-1 (Roads). The Sheriff's Department provided the Board of Supervisors during budget hearings in July and august the staffing levels for the Rural Crimes Unit and is utilizing these funds to keep the unit operational. The Roads Commissioner has determined that the amount of the funding should increase through the first quarter next year before expenditures begin. Projects eligible for the funding were identified in the Final EIR and Public Works is beginning an evaluation of priorities.

4.3 Emission Reduction Agreement Reporting

On August 18th, 2016, the San Joaquin Air Pollution Control (APCD) Board approved the final Emission Reduction Agreement (ERA) between the APCD and the County for mitigation of air impacts as outlined in the Final EIR. County Staff is currently working with the APCD to setup processing for coordination of review with respect to the project selection and approval process and transfer of funds.

4.4 Re-use of Produced Water

Mitigation Measure 4.17-2 states the following:

> Applicant shall increase the re-use of produced water, and reduce its use of municipal and industrial-quality ground or surface water use to the extent feasible. By the end of 2016, the Applicants shall work with the County to review water use data submitted to Division of Oil Gas and Geothermal Resources under Senate Bill 1281 and identify the five biggest oil industry users of municipal and industrial water by volume. The five biggest oil industry users of municipal and industrial water shall work together to develop and implement a plan identifying new measures to reduce municipal and industrial water use by 2020. The plan shall address the following activities, as appropriate: steam generation; drilling and completions (including hydraulic fracturing); dust control; compaction activities related to construction; and landscaping. Through the KernFLOWS initiative or other efforts (e.g., Groundwater Sustainability Agency), the five biggest oil industry users of municipal-and-industrial water shall also work with local agricultural producers and water districts to identify new opportunities to increase the use of produced water for agricultural irrigation and other activities, as appropriate. Any produced water treated and used for agricultural irrigation or other activities shall be tested and monitored to assure compliance with applicable standards for such agricultural irrigation or other uses.

Industry representatives have submitted a memorandum identifying the five biggest industry users of municipal and industrial water by volume. These companies are: Chevron, Freeport-McMoRan Oil & Gas, Aera Energy, LINN Energy, and California Resources Corporation. The estimated amount of combined M&I water injected was 8,000 acre-feet/year. The industry has committed to working together to identify new measures to reduce M&I water by 2020. Staff will continue to update the report as necessary.

KERN COUNTY
OIL AND GAS PERMITTING PROGRAM
ANNUAL PROGRESS REPORT
(December 1, 2016 to November 30, 2017)

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1.0 Introduction

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1.1 Reporting Period

This report marks the second full year of Oil and Gas processing under the revisions to the Zoning Ordinance. The reporting Period began on December 1, 2016, the first day after last year's annual report, and goes through November 30, 2017.

1.2 Topics to be Discussed

Staff has proposed the following topics to be discussed in this and each subsequent Report to your Board:

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- Oil and Gas Conformity Review
- Minor Activity Review

Accounting of Annual CEQA Mitigation Fees Collected

- Roads Mitigation
- Fire equipment Mitigation
- Rural Crimes Task Force Mitigation
- Biological Habitat Replacement Mitigation
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County Produced Permit Assistance

- Accela Automation
- Oil and Gas Handbook
- Small Producers Handbook

Continued Coordination

- Online Permitting System
- Other County Departmental Reporting
- Emission Reduction Agreement Reporting
- Re-use of Produced Water

2.0 Accounting

2.1 Annual Permits

During the reporting period, the Planning and Natural Resources Department received and processed the following number of permits:

Permit Type	Applied		Issued		Closed	
	2016	2017	2016	2017	2016	2017
Oil and Gas Conformity Review	1202	1943	1122	1891	125	252
Minor Reworks *	N/A	424	N/A	399	N/A	4
Minor Activity Review	77	118	72	105	20	38

* Permitting initiated in May 2017

In the second year of the program, County Staff has successfully reviewed 100% of applications within the mandated 7-business day and 3-business day review time frames. With an average 7-business day review being completed within 5-business days.

2.2 Annual CEQA Mitigation Fees Collected

During the reporting period, the Planning and Natural Resources Department collected the following CEQA mitigation fees:

Mitigation Measure	FEE CODE	AMOUNT	
		2016	2017
4.16-1	POG050 - Roadway Maintenance/Improvements	$388,700.00	$1,444,500.00
4.14-1	POG051 - Firefighting Equipment	$162,450.00	$380,700.00
4.5-3	POG052 - Paleontological Resource	$10,300.00	$37,950.00
4.14-2	POG053 - Rural Crimes Unit	$432,225.00	$1,065,050.00
4.2-1	POG054 - Mitigation of Agricultural Land Replacement	$30,996.00	$20,817.00
4.3-8	POG055 - Air Quality Impacts	$3,329332.87	$14,443,711.93
4.3-8	POG057 – SJVAPCD Fee	$138,722.20	$584,744.32
4.4-16	POG056 - Biological Resources Mitigation	$60,502.50	$349,985.29

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3.1 Accela Automation

Beginning shortly after the project was approved by your Board, Staff began working to create a new automated permitting process. This process entailed the development of computer aided permitting software, designed to assist in meeting the review periods set out by the adoption of the revisions to the Zoning Ordinance. Accela Automation, the program currently used by the County for processing of grading and building permits by the Public Works Department was selected as the most compatible. Staff

worked to design a module capable of handling oil and gas permits. The program was successfully launched at the start of the permitting process and has allowed Staff to input each oil and gas review permit into a database. Benefits of this program include: consistent processing times, accurate fee and mitigation estimates, and has allowed for reporting of permitting types for production of annual reports.

3.2 Oil and Gas Handbook

In January 2016, Staff released the Oil and Gas Handbook. This handbook was designed as an introduction to oil and gas permitting. The handbook can be utilized by oil and gas companies or by citizens in Kern County to help with understanding the rules and regulations of the local permitting process. A copy of the handbook can be found on the Kern County Website, located:
http://www.co.kern.ca.us/planning/pdfs/oil_gas/kern_oil_gas_permitting_handbook.pdf

3.3 Small Producers Handbook and Permitting Software

County Staff released a Small Producers Handbook in November of 2016. This handbook differs from the Oil and Gas handbook, in that it provides a step-by-step tutorial for any company to begin the permitting process. Along with the handbook, Staff worked with a private consultant to create an online permitting tool. This wizard driven program can be used by any company wishing to create a detailed site plan and checklist for mitigation monitoring and reporting. The program, along with the handbook, allows companies to walk through each of the requirements of the Zoning Ordinance and produce a package that can be submitted to County Staff for review.

4.0 Continued Coordination

4.1 Online Permit Submission

In January of 2017 Staff completed development of a tool to allow for the online submission of oil and gas permits through the Accela Automation program, known as Citizen Access. Applicants now are able to submit an application package, including site plans, mitigation compliance, and fees completely from their office. They also have the ability to check the status of their permit and print the necessary permit documents, once a permit has been issued. This process has dramatically increased the efficiency of the permitting process and saved applicants time and money. Another feature of Citizen Access is the ability for any member of the public to view past and current permits online.

4.2 Other County Departmental Reporting

Two mitigation measures approved with the revisions to the Ordinance require other County Departments to file annual reports with your Board. These Mitigation Measures are MM 4.14-2 (Rural Crimes) and MM 4.16-1 (Roads). The Sheriff's Department provided the Board of Supervisors during budget hearings in July and August the staffing levels for the Rural Crimes Unit and is utilizing these funds to keep the unit operational. The Roads Commissioner has determined that the amount of the funding should increase through the first quarter next year before expenditures begin. Projects eligible for the funding were identified in the Final EIR and Public Works is beginning an evaluation of priorities.

4.3 Emission Reduction Agreement Reporting

On August 18th, 2016, the San Joaquin Air Pollution Control (APCD) Board approved the final Emission Reduction Agreement (ERA) between the APCD and the County for mitigation of air impacts as outlined

in the Final EIR. County Staff continues to work with the APCD on the coordinated review of projects to facilitate their consideration and the subsequent transfer of funds upon approval.

4.4 Re-use of Produced Water

Mitigation Measure 4.17-2 states the following:

> Applicant shall increase the re-use of produced water, and reduce its use of municipal and industrial-quality ground or surface water use to the extent feasible. By the end of 2016, the Applicants shall work with the County to review water use data submitted to Division of Oil Gas and Geothermal Resources under Senate Bill 1281 and identify the five biggest oil industry users of municipal and industrial water by volume. The five biggest oil industry users of municipal and industrial water shall work together to develop and implement a plan identifying new measures to reduce municipal and industrial water use by 2020. The plan shall address the following activities, as appropriate: steam generation; drilling and completions (including hydraulic fracturing); dust control; compaction activities related to construction; and landscaping. Through the KernFLOWS initiative or other efforts (e.g., Groundwater Sustainability Agency), the five biggest oil industry users of municipal-and-industrial water shall also work with local agricultural producers and water districts to identify new opportunities to increase the use of produced water for agricultural irrigation and other activities, as appropriate. Any produced water treated and used for agricultural irrigation or other activities shall be tested and monitored to assure compliance with applicable standards for such agricultural irrigation or other uses.

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1.0 Introduction

On November 9, 2015, the Kern County Board of Supervisors approved revisions to the Kern County Zoning Ordinance – (2015C), focused on Oil and Gas Local Permitting and certified an Environmental Impact Report (SCH #2013081079). Staff was directed to provide an annual update to the Board regarding the process.

History of Oil and Gas Zoning Amendment

On January 22, 2013, your Board directed Staff to proceed with identifying changes to the Zoning Ordinance that would provide streamlined permitting for oil and gas operations with full California Environmental Quality Act (CEQA) coverage and address surface owners concerns in split estate (surface and minerals owned by different entities) situations. The costs were directed to be fully funded by the oil industry, but as with other development applications, managed by Staff as an objective review and proposal that balanced the needs of business with critical environmental protection and quality of life issues for all of Kern County. The revisions to Title 19 of the Kern County Zoning Ordinance included updated procedures, implementation standards, and conditions for future oil and gas exploration, development, and production activities in unincorporated Kern County. The project required consideration of environmental impacts under the California Environmental Quality Act (CEQA) with an Environmental Impact Report (EIR), which was certified by your Board.

Specifically, the Zoning Ordinance revisions addressed oil and gas exploration and operation activities by:

- Establishing updated implementation standards, conditions and mitigation measures to address environmental impacts of pre-drilling exploration, well drilling, and the operation of wells and other oil and gas production-related equipment and facilities, including exploration, production, completion, stimulation, reworking, injection, monitoring, and plugging and abandonment; and by,

- Establishing new "Oil and Gas Conformity Review" and "Minor Activity Review" ministerial permit (7 day review time) procedures for future well drilling and operations to ensure compliance with the updated implementation standards, mitigation measures, and conditions and provide for ongoing tracking and compliance monitoring.

- Incorporating a 120 day pathway and additional notice and monitoring requirements for projects on split estate that do not have surface owner signature on the site plan application for Oil and Gas Conformity Review in some areas to encourage surface and mineral owner dialogue and resolution of issues.

- Implementing a Mitigation Measure Monitoring Program in compliance with the California Environmental Quality Act, which includes all mitigation measures included in a comprehensive Environmental Impact Report prepared for the project.

The unincorporated valley portion of Kern County was broken up into five Tiers. Tier 1 consisting of land primarily used for oil and gas exploration. Tier 2 consisting of property zoned for agricultural use. Tier 3 consisting of industrial zoned lands. Tier 4 consisting of residential and commercial zones and Tier 5 consisting of Special Planning Areas.

Two types of permits are now required for oil and gas exploration. An Oil and Gas Conformity Review is required for all new wells (exploration, production, observation and injection), re-works of existing wells, and SB4 – regulated activities. A Minor Activity Review is required for other new ground disturbing

activities such as: pipelines, tanks, and treatment facilities that are not associated with an Oil and Gas Conformity Review.

Departmental Structure

On December 9, 2015, oil and gas companies began submitting applications for oil and gas permits. Your Board authorized Staff to develop a system for receiving and processing these permits under a new Departmental Division known as: Energy/Permitting. Currently, the Division is managed by one Division Chief (filled), and one Supervising Planner (filled), three Planners (2 vacant), three Permit Specialists (filled), one Oil Compliance Officer (vacant), and one Office Services Technician (vacant). As permitting levels were low at the beginning of the process Staff has held positions open to ensure adequate processing fees are collected prior to filling vacant positions. Staff has identified the need for a fiscal support position to manage aspects of the reconciliation required by the Auditor. Staff will continue to monitor permitting levels and processing times, as well as process improvement, prior to consultation with the CAO to request and fill vacant positions.

1.1 Reporting Period

This report marks the third full year of Oil and Gas processing under the revisions to the Zoning Ordinance. The reporting Period began on December 1, 2017, the first day after last year's annual report, and goes through November 30, 2018.

During this reporting year, several parties filed lawsuits challenging the adequacy of the certified EIR, and the cases were consolidated before Judge Eric Bradshaw of the Kern County Superior Court (Vaquero Energy, Inc. et al. v. County of Kern et al., King 7 Gardiner Farms LLC v. County of Kern en al., and Committee for a Better Arvin et al. v. County of Kern et al., Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679). On April 20, 2018, the Court issued a judgment (Judgment) that upheld the EIR in its entirety except for requiring supplemental analysis under the California Environmental Quality Act (CEQA) for two (2) issues: (i) impacts to rangeland/grazing land, and (ii) impacts from road paving as a potential future means of mitigation to reduce designated air emissions. The Judgement did not vacate any portion of the Ordinance or the EIR. Pursuant to the Judgment, the Court issued a writ of mandate (Writ) to the County.

In response to the Court's ruling Staff prepared a Supplemental Environmental Impact Report (SEIR) and revisions to the Kern County Zoning Ordinance to address the potential impacts from oil and gas operations to rangeland/grazing land. The Kern County Planning Commission on November 8, 2018 considered and recommended the Board of Supervisors to certify the Supplemental Environmental Impact Report (SEIR) and adopt an ordinance amending various chapters of the Kern County Zoning Ordinance, relating to site development standards and permitting procedures for oil and gas exploration, extraction, operation, and production activities in unincorporated Kern County. The Kern County Board of Supervisors considered the SEIR and project on December 11, 2019 and approved the SEIR and related ordinance. The SEIR and approvals will be submitted back to the Superior Court for review in January, 2019. An appeal to the State of California Appeals Court is pending for consideration sometime in 2019 -2020.

1.2 Topics to be Discussed

Staff has proposed the following topics to be discussed in this and each subsequent Report to your Board:

Accounting of Annual Permits

- Oil and Gas Conformity Review
- Minor Activity Review

Accounting of Annual CEQA Mitigation Fees Collected

- Roads Mitigation
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- Accela Automation
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Continued Coordination

- Online Permitting System
- Other County Departmental Reporting
- Emission Reduction Agreement Reporting
- Re-use of Produced Water

2.0 Accounting

This topic discusses the details of the permitting process in terms of permits processed and mitigation fees collected.

2.1 Annual Permits

During the reporting period, the Planning and Natural Resources Department received and processed the following number of permits:

Permit Type	Applied			Issued			Closed		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Oil and Gas Conformity Review	1,202	1,943	1,114	1,122	1,891	1,055	125	252	42
Minor Reworks *	N/A	424	925	N/A	399	903	N/A	4	93
Minor Activity Review	77	118	159	72	105	151	20	38	26

* Permitting initiated in May 2017
Source: Accela

In the third year of the program, County Staff has successfully reviewed 100% of applications within the mandated 7-business day and 3-business day review time frames. With an average 7-business day review being completed within 5-business days. Staff notes that the Division of Oil Gas and Geothermal Resources (DOGGR) will not issue the necessary permits unless the applicant has obtained a Kern County permit.

Section 19.98.100 of the Zoning Ordinance has provisions for the processing of an Oil and Gas Conformity Review when there is split mineral and surface ownership. When the applicant cannot obtain a signature from the surface owner, the 120 day permit process is activated. During this reporting period, the

Department has processed and approved three (3) permits under this pathway which include video surveillance, but none have yet to be finaled.

2.2 Annual CEQA Mitigation Fees Collected

The following CEQA mitigation fees were collected during the reporting period. The requirements for the expenditure of each collected amount is detailed in the individual mitigation measures and where appropriate, funds are managed by the County Administrative Office (CAO) to be expended by the responsible entity for specific uses.

Mitigation Measure	FEE CODE	AMOUNT		
		2016	2017	2018
4.16-1	POG050 - Roadway Maintenance/Improvements	$388,700.00	$1,444,500.00	$2,805,000.00
4.14-1	POG051 - Firefighting Equipment	$162,450.00	$380,700.00	$299,550.00
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4.3-8	POG057 – SJVAPCD Fee	$138,722.20	$584,744.32	$1,301,032.45
4.4-16	POG056 - Biological Resources Mitigation	$60,502.50	$349,985.29	$431,815.40

Source: Accela

The Public Service Mitigation Measure (MM 4.14-1) established a total funding goal in the amount of $850,000.00 for acquisition of industrial firefighting and rescue equipment. Each applicant for an Oil and Gas Conformity Review permit is required to contribute $150.00 per each well for this Special Revenue Fund until the funding goal of $850,000.00 has been met. As of the date of this report the balance of this account has reached $846,925.00. The entire $850,000.00 will be collected by the end of 2018. The Fire Department has ordered the construction of the Combination Walk in/Non-Walk-in Industrial Firefighting Vehicle which will take a year to build.

3.0 County Produced Permit Assistance

3.1 Accela Automation

Subsequent to when the project was approved by your Board, Staff began working to create a new automated permitting process. This process entailed the development of computer aided permitting software, designed to assist in meeting the review periods set out by the adoption of the revisions to the Zoning Ordinance. Accela Automation, the program currently used by the County for processing of grading and building permits by the Public Works Department was selected as the most compatible. Staff worked to design a module capable of handling oil and gas permits. The program was successfully launched at the start of the permitting process and has allowed Staff to input each oil and gas review permit into a database. Benefits of this program include: consistent processing times, accurate fee and mitigation estimates, and has allowed for reporting of permitting types for production of annual reports.

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County Staff released a Small Producers Handbook in November of 2016. This handbook differs from the Oil and Gas handbook, in that it provides a step-by-step tutorial for any company to begin the permitting process. Along with the handbook, Staff worked with a private consultant to create an online permitting tool. This wizard driven program can be used by any company wishing to create a detailed site plan and checklist for mitigation monitoring and reporting. The program, along with the handbook, allows companies to walk through each of the requirements of the Zoning Ordinance and produce a package that can be submitted to County Staff for review. A copy of the handbook can be found on the Kern County Website, located:
https://psbweb.co.kern.ca.us/planning/pdfs/oil_gas/kern_oil_gas_small_producers_handbook.pdf

4.0 Continued Coordination

The success of the permitting program continues to be based on close coordination with State agencies including: DOGGR (Division of Oil, Gas, and Geothermal Resources), State Water Board, RWQCB (Regional Water Quality Control Board), SJVAPCD (San Joaquin Valley Air Pollution control Board), CDFW (California Department of Fish and Wildlife). Every week, a CD with all permits issued and materials submitted are sent so that these agencies, who can then utilize Kern County's enforcement of the permit requirements and EIR as a basis for the issuance of their permits.

Working proactively with the private sector, Staff identified areas for support in the permit process.

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For 2019 the District has established the emission reductions cost effectiveness fee at $9,090 per ton of emissions reduced. The Kern County Planning and Natural Resources Department Fee Well Emissions and Related Fee Schedule for the year 2019 to take effect January 1, 2019.

4.4 Re-use of Produced Water

Mitigation Measure 4.17-2 states the following:

> Applicant shall increase the re-use of produced water, and reduce its use of municipal and industrial-quality ground or surface water use to the extent feasible. By the end of 2016, the Applicants shall work with the County to review water use data submitted to Division of Oil Gas and Geothermal Resources under Senate Bill 1281 and identify the five biggest oil industry users of municipal and industrial water by volume. The five biggest oil industry users of municipal and industrial water shall work together to develop and implement a plan identifying new measures to reduce municipal and industrial water use by 2020. The plan shall address the following activities, as appropriate: steam generation; drilling and completions (including hydraulic fracturing); dust control; compaction activities related to construction; and landscaping. Through the KernFLOWS initiative or other efforts (e.g., Groundwater Sustainability Agency), the five biggest oil industry users of municipal-and-industrial water shall also work with local agricultural producers and water districts to identify new opportunities to increase the use of produced water for agricultural irrigation and other activities, as appropriate. Any produced water treated and used for agricultural irrigation or other activities shall be tested and monitored to assure compliance with applicable standards for such agricultural irrigation or other uses.

Industry representatives have submitted a memorandum identifying the five biggest industry users of municipal and industrial water by volume. These companies are: Chevron, Freeport-McMoRan Oil & Gas, Aera Energy, LINN Energy, and California Resources Corporation. The estimated amount of combined M&I water injected was 8,000 acre-feet/year. The industry has committed to working together to identify new measures to reduce M&I water by 2020. Staff will continue to update the report as necessary.

KERN COUNTY
OIL AND GAS PERMITTING PROGRAM
ANNUAL PROGRESS REPORT
(December 1, 2018 to November 30, 2019)

Kern County Planning and
Natural Resources Department
2700 'M' Street, Suite 100
Bakersfield, CA 93301
(661) 862-8600

Lorelei H. Oviatt, AICP, Director

December 2019

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1.0 Introduction

On November 9, 2015, the Kern County Board of Supervisors approved revisions to the Kern County Zoning Ordinance – (2015C), focused on Oil and Gas Local Permitting and certified an Environmental Impact Report (SCH #2013081079). Staff was directed to provide an annual update to the Board regarding the process.

History of Oil and Gas Zoning Amendment

On January 22, 2013, your Board directed Staff to proceed with identifying changes to the Zoning Ordinance that would provide streamlined permitting for oil and gas operations with full California Environmental Quality Act (CEQA) coverage and address surface owners concerns in split estate (surface and minerals owned by different entities) situations. The costs were directed to be fully funded by the oil industry, but as with other development applications, managed by Staff as an objective review and proposal that balanced the needs of business with critical environmental protection and quality of life issues for all of Kern County. The revisions to Title 19 of the Kern County Zoning Ordinance included updated procedures, implementation standards, and conditions for future oil and gas exploration, development, and production activities in unincorporated Kern County. The project required consideration of environmental impacts under the California Environmental Quality Act (CEQA) with an Environmental Impact Report (EIR), which was certified by your Board.

Specifically, the Zoning Ordinance revisions addressed oil and gas exploration and operation activities by:

- Establishing updated implementation standards, conditions and mitigation measures to address environmental impacts of pre-drilling exploration, well drilling, and the operation of wells and other oil and gas production-related equipment and facilities, including exploration, production, completion, stimulation, reworking, injection, monitoring, and plugging and abandonment; and by,

- Establishing new "Oil and Gas Conformity Review" and "Minor Activity Review" ministerial permit (7 day review time) procedures for future well drilling and operations to ensure compliance with the updated implementation standards, mitigation measures, and conditions and provide for ongoing tracking and compliance monitoring.

- Incorporating a 120 day pathway and additional notice and monitoring requirements for projects on split estate that do not have surface owner signature on the site plan application for Oil and Gas Conformity Review in some areas to encourage surface and mineral owner dialogue and resolution of issues.

- Implementing a Mitigation Measure Monitoring Program in compliance with the California Environmental Quality Act, which includes all mitigation measures included in a comprehensive Environmental Impact Report prepared for the project.

The unincorporated valley portion of Kern County was broken up into five Tiers. Tier 1 consisting of land primarily used for oil and gas exploration. Tier 2 consisting of property zoned for agricultural use. Tier 3 consisting of industrial zoned lands. Tier 4 consisting of residential and commercial zones and Tier 5 consisting of Special Planning Areas.

Two types of permits are now required for oil and gas exploration. An Oil and Gas Conformity Review is required for all new wells (exploration, production, observation and injection), re-works of existing wells, and SB4 – regulated activities. A Minor Activity Review is required for other new ground disturbing

activities such as: pipelines, tanks, and treatment facilities that are not associated with an Oil and Gas Conformity Review.

Departmental Structure

On December 9, 2015, oil and gas companies began submitting applications for oil and gas permits. Your Board authorized Staff to develop a system for receiving and processing these permits under a new Departmental Division known as: Energy/Permitting. Currently, the Division is managed by one Division Chief (filled), and one Supervising Planner (filled), one Planner (filled), three Permit Specialists (filled), one Oil Compliance Officer (vacant), and one Office Services Technician (vacant). As permitting levels were low at the beginning of the process Staff has held positions open to ensure adequate processing fees are collected prior to filling vacant positions. A fiscal support technician has been assigned to the Energy/Permitting Division to manage aspects of the reconciliation required by the Auditor. Staff will continue to monitor permitting levels and processing times, as well as process improvement, prior to consultation with the CAO to request and fill vacant positions.

1.1 Reporting Period

This report marks the third full year of Oil and Gas processing under the revisions to the Zoning Ordinance. The reporting Period began on December 1, 2018, the first day after last year's annual report, and goes through November 30, 2019.

During the previous reporting year there were several parties that filed lawsuits challenging the adequacy of the certified EIR, and the cases were consolidated before Judge Eric Bradshaw of the Kern County Superior Court (Vaquero Energy, Inc. et al. v. County of Kern et al., King 7 Gardiner Farms LLC v. County of Kern en al., and Committee for a Better Arvin et al. v. County of Kern et al., Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679). On April 20, 2018, the Court issued a judgment (Judgment) that upheld the EIR in its entirety except for requiring supplemental analysis under the California Environmental Quality Act (CEQA) for two (2) issues: (i) impacts to rangeland/grazing land, and (ii) impacts from road paving as a potential future means of mitigation to reduce designated air emissions. The Judgement did not vacate any portion of the Ordinance or the EIR. Pursuant to the Judgment, the Court issued a writ of mandate (Writ) to the County.

In response to the Court's ruling Staff prepared a Supplemental Environmental Impact Report (SEIR) and revisions to the Kern County Zoning Ordinance to address the potential impacts from oil and gas operations to rangeland/grazing land. The Kern County Planning Commission on November 8, 2018 considered and recommended the Board of Supervisors to certify the Supplemental Environmental Impact Report (SEIR) and adopt an ordinance amending various chapters of the Kern County Zoning Ordinance, relating to site development standards and permitting procedures for oil and gas exploration, extraction, operation, and production activities in unincorporated Kern County. The Kern County Board of Supervisors considered the SEIR and project on December 11, 2018 and approved the SEIR and related ordinance. The SEIR and approvals were submitted back to the Superior Court and the SEIR was certified as valid. No challenges remain to the Final EIR in Superior Court. An appeal to the State of California Appeals Court is pending for consideration as three cases. The first case heard in the State Appeals Fifth Appellate District was Vaquero Energy, Inc. v County of Kern (BCV-15-101645) which was decided in favor of the county and applicants on November 19,2019 as a published opinion. The remaining cases are scheduled for oral briefing in January 2020.

1.2 Topics to be Discussed

Staff has proposed the following topics to be discussed in this and each subsequent Report to your Board:

Accounting of Annual Permits

- Oil and Gas Conformity Review
- Minor Activity Review

Accounting of Annual CEQA Mitigation Fees Collected

- Roads Mitigation
- Fire equipment Mitigation
- Rural Crimes Task Force Mitigation
- Biological Habitat Replacement Mitigation
- Air Quality Emission Reduction Agreement Mitigation
- Agricultural Land Replacement Mitigation
- Paleontological Mitigation
- Notice of Exemption Clerk Posting Fee

County Produced Permit Assistance

- Accela Automation
- Oil and Gas Handbook
- Small Producers Handbook

Continued Coordination

- Online Permitting System
- Other County Departmental Reporting
- Emission Reduction Agreement Reporting
- Re-use of Produced Water

2.0 Accounting

This topic discusses the details of the permitting process in terms of permits processed and mitigation fees collected.

2.1 Annual Permits

During the reporting period, the Planning and Natural Resources Department received and processed 2,483 permits and since the inception of the Ordinance 7,166 have been processed (See Table 1 for a breakdown of permit types).

In the fourth year of the program, County Staff has successfully reviewed 100% of applications within the mandated 7-business day and 3-business day review time frames. With an average 7-business day review being completed within 5-business days. Staff notes that the Division of Oil Gas and Geothermal Resources (DOGGR) will not issue the necessary permits unless the applicant has obtained a Kern County permit.

Section 19.98.100 of the Zoning Ordinance has provisions for the processing of an Oil and Gas Conformity Review when there is split mineral and surface ownership. When the applicant cannot obtain a signature from the surface owner, the 120 day permit process is activated. During this reporting period, the Department has processed thirteen (13), approved four (4) and finaled one (1) permit(s) under this pathway which include video surveillance.

Table 1 Permit Issuance

Permit Type	Applied				Issued				Closed			
	2016	2017	2018	2019	2016	2017	2018	2019	2016	2017	2018	2019
Oil and Gas Conformity Review	1,202	1,943	1,114	1,323	1,122	1,891	1,055	1,208	125	1,090	276	49
Minor Reworks *	N/A	424	925	952	N/A	399	903	880	N/A	322	306	50
Minor Activity Review	77	118	159	208	72	105	151	177	20	64	70	20

*Permitting initiated in May 2015
Source: Accela

2.2 Annual CEQA Mitigation Fees Collected

The following CEQA mitigation fees were collected during the reporting period. The requirements for the expenditure of each collected amount is detailed in the individual mitigation measures and where appropriate, funds are managed by the County Administrative Office (CAO) to be expended by the responsible entity for specific uses.

Mitigation Measure	FEE CODE	AMOUNT				
		2016	2017	2018	2019	Totals
4.16-1	POG050 - Roadway Maintenance/Improvements	$388,700.00	$1,444,500.00	$2,805,000.00	$2,769,000.00	$7,407,200.00
4.14-1	POG051 - Firefighting Equipment	$162,450.00	$380,700.00	$299,550.00	$47,026.00	$889,726.00
4.5-3	POG052 - Paleontological Resource	$10,300.00	$37,950.00	$61,800.00	$59,200.00	$169,250.00
4.14-2	POG053 - Rural Crimes Unit	$432,225.00	$1,065,050.00	$1,427,575.00	$1,312,975.00	$4,237,825.00
4.2-1	POG054 - Mitigation of Agricultural Land Replacement	$30,996.00	$20,817.00	$66,247.67	$28,242.00	$146,302.67
4.3-8	POG055 - Air Quality Impacts	$3,329332.87	$14,443,711.93	$32,268,388.27	$38,896,506.00	$88,937,939.07
4.3-8	POG057 – SJVAPCD Fee	$138,722.20	$584,744.32	$1,301,032.45	$1,554,270.00	$3,578,768.97
4.4-16	POG056 - Biological Resources Mitigation	$60,502.50	$349,985.29	$431,815.40	$505,495.00	$1,347,798.19

Source: Accela

The Public Service Mitigation Measure (MM 4.14-1) established a total funding goal in the amount of $850,000.00 for acquisition of industrial firefighting and rescue equipment. Each applicant for an Oil and Gas Conformity Review permit is required to contribute $150.00 per each well for this Special Revenue Fund until the funding goal of $850,000.00 has been met. The total fee of $850,000.00 has been received and the firefighting equipment has been purchased, therefore this fee is no longer collected.

3.0 County Produced Permit Assistance

3.1 Accela Automation

Subsequent to when the project was approved by your Board, Staff began working to create a new automated permitting process. This process entailed the development of computer aided permitting software, designed to assist in meeting the review periods set out by the adoption of the revisions to the Zoning Ordinance. Accela Automation, the program currently used by the County for processing of grading and building permits by the Public Works Department was selected as the most compatible. Staff worked to design a module capable of handling oil and gas permits. The program was successfully launched at the start of the permitting process and has allowed Staff to input each oil and gas review permit into a database. Benefits of this program include: consistent processing times, accurate fee and mitigation estimates, and has allowed for reporting of permitting types for production of annual reports.

3.2 Oil and Gas Handbook

In January 2016, Staff released the Oil and Gas Handbook. This handbook was designed as an introduction to oil and gas permitting. The handbook can be utilized by oil and gas companies or by citizens in Kern

County to help with understanding the rules and regulations of the local permitting process. A copy of the handbook can be found on the Kern County Website, located:
https://psbweb.co.kern.ca.us/planning/pdfs/oil_gas/kern_oil_gas_permitting_handbook.pdf

3.3 Small Producers Handbook and Permitting Software

County Staff released a Small Producers Handbook in November of 2016. This handbook differs from the Oil and Gas handbook, in that it provides a step-by-step tutorial for any company to begin the permitting process. Along with the handbook, Staff worked with a private consultant to create an online permitting tool. This wizard driven program can be used by any company wishing to create a detailed site plan and checklist for mitigation monitoring and reporting. The program, along with the handbook, allows companies to walk through each of the requirements of the Zoning Ordinance and produce a package that can be submitted to County Staff for review. A copy of the handbook can be found on the Kern County Website, located:
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Southern San Joaquin Municipal Utility District Management Area Plan

Kern County, CA

Submitted to:
Southern San Joaquin Municipal
11281 Garzoli Ave.
Delano, CA 93215

Submitted by:
GEI Consultants, Inc.
5001 California Ave., Suite 120
Bakersfield, CA 93309
661.327.7601

December 2019

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List of Acronyms

AF	Acre-feet
AFY	Acre-feet per year
AWMP	Agricultural Water Management Plan
BMP	Best Management Practices
BVWSD	Buena Vista Water Storage District
CASGEM	California Statewide Groundwater Elevation Monitoring Program
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CGPS	Continuous Global Positioning System
CGS	California Geological Survey
CUP	Conditional Use Permit
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CWD	Cawelo Water District
CV-SALTS	Central Valley Salinity Alternatives for Long-term Sustainability
DAC	Disadvantaged Community
DBCP	Dibromochloropropane
DEID	Delano-Earlimart Irrigation District
DMS	Data Management System
DTSC	Department of Toxic Substance Control
DWR	Department of Water Resources
EIR	Environmental Impact Report
ESA	European Space Agency
ET	Evapotranspiration
FKC	Friant-Kern Canal
ft msl	Feet Mean See Level
GAMA	Groundwater Ambient Monitoring and Assessment Program
GDE	Groundwater Dependent Ecosystem
GEI	GEI Consultants, Inc.
GIS	Geographic Information System
GMP	Groundwater Management Plan
GPS	Global Positioning System
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	Hydrogeologic conceptual model
HZ	Hydrogeologic Zone
ILRP	Irrigated Lands Regulatory Program
InSAR	Interferometric Synthetic Aperture Radar
IRWM	Integrated Regional Water Management

IRWMP	Integrated Regional Water Management Plan
ITRC	Irrigation Training and Research Center
JPA	Joint Powers Agreement
JPL	Jet Propulsion Laboratory
KCPHSD	Kern County Public Health Services Department
KCWA	Kern County Water Agency
KFMC	Kern Fan Monitoring Committee
KGA	Kern Groundwater Authority
KRWCA	Kern River Water Coalition Authority
KTWD	Kern-Tulare Water District
LADWP	Los Angeles Department of Water and Power
MCL	Maximum Contaminant Limit
mg/L	milligram per liter
MMU	Minimum map unit
NAIP	National Agricultural Imagery Program
NASA	National Aeronautics and Space Administration
NCCAG	Natural Communities Commonly Associated with Groundwater
NEPA	National Environmental Policy Act
NGS	National Geodetic Survey
NHD	National Hydrography Dataset
NKWSD	North Kern Water Storage District
NPDES	National Pollution Discharge Elimination System
NRCS	National Resource Conservation Service
NTNC	Non-Transient Non-Community
NWI	National Wetland Inventory
PBO	Plate Boundary Observation
PCE	Tetrachloroethylene
PGA	Pacific Geotechnical Associates
ppm	parts per million
ppt	parts per trillion
PWS	Public Water System
RWQCB	Regional Water Quality Control Board
SAGBI	Soil Agricultural Groundwater Banking Index
SCV	Survey of California Vegetation
SDWIS	Safe Drinking Water Information System
SGMA	Sustainable Groundwater Management Act
SJVAPCD	San Joaquin Valley Air Pollution Control District
SMC	Sustainable Management Criteria
SOPAC	Scripps Orbit and Permanent Array Center
SSJMUD	Southern San Joaquin Municipal Utility District
SSURGO	Soil Survey Geographical Database

Subbasin	Kern County Subbasin
SWP	State Water Project
SWSD	Semitropic Water Storage District
TAF	Thousand Acre-Feet
TCP	1,2,3-trichloropropane
TDS	Total Dissolved Solids
TNC	Transient Non-Community
UAVSAR	Unmanned Aerial Vehicle Synthetic Aperture Radar
UIC	Underground Injection Control
UC Davis	University of California, Davis
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USDW	Underground Source of Water
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UWMP	Urban Water Management Plan
VegCAMP	Vegetation Classification and Mapping Program
WWTP	Waste Water Treatment Plant

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Executive Summary

This management area plan was written to represent the efforts of Southern San Joaquin Municipal Utility District (SSJMUD) to comply with the California state regulated Sustainable Groundwater Management Act (SGMA) of 2014. According to SGMA, groundwater basins in California that have been classified as high or medium priority must correct current overdraft conditions in order to reset the balance of groundwater input/output as an effort to reach sustainability by the year 2040. This plan was written in conjunction with and in support of a basin-wide Groundwater Sustainability Plan (GSP) drafted on behalf of the Kern Groundwater Authority (KGA). The KGA represents 16 member agencies within the boundary of the Kern County Subbasin (Subbasin) which are joined together by the adoption of a Joint Powers Agreement (JPA). While the District will be coordinating with the KGA to comply with SGMA, it will write its own management area plan. This management area plan follows the California Code of Regulations and discusses background information of the District and its corresponding management area; current practices and existing plans; management structure and actions; and current groundwater conditions and future sustainability management practices required to comply with SGMA.

SSJMUD is located within the Tulare Lake Region of the Central Valley. Beneficial users serviced within the District boundaries consist of agricultural; municipal and domestic; and industrial. Groundwater is used in this region to support agricultural production and industrial practices that support the economic viability of local communities. This management area plan includes a detailed overview of the Districts' historical, current, and projected groundwater conditions, including groundwater storage, water quality, and land subsidence.

This plan provides the required elements of a GSP and identifies an initial path for sustainable management in the Districts' portions of the Subbasin. As documented in this management area plan, the goal for the District is to balance the average inflow and outflows of water in the District so that a negative change in groundwater storage does not occur; thus, preventing the lowering of average groundwater levels beyond 2040 through the actions of the District. This goal is expected to maintain groundwater levels as well as prevent water quality degradation and land subsidence. To reach the sustainability goal by 2040, the District will implement projects and management actions over time by increasing supply or reducing demand. Once fully implemented, project and management actions are expected to reduce the groundwater pumping for the District to avoid undesirable results

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1. Introduction

1.1 General Information

1.1.1 *Purpose of Management Area Plan*

To comply with the requirements of SGMA, SSJMUD has contracted with GEI Consultants, Inc. (GEI) for the preparation of this management area plan for inclusion in the KGA GSP. This management area plan serves to do the following:

- Define and describe the geographic and geologic conditions of the SSJMUD area in the Subbasin.
- Identify and describe the sustainability goal for the Subbasin and the SSJMUD jurisdictional area.
- Identify and describe the six undesirable results set forth in SGMA, as they pertain to the Subbasin and the SSJMUD jurisdictional area.
- Identify and describe the specific minimum thresholds and measurable objectives required for SSJMUD to achieve the sustainability goal of the Subbasin.
- Define and identify projects and management actions proposed by SSJMUD to achieve the sustainability goal.

1.2 Agency Information

Agency's Name:	Southern San Joaquin Municipal Utility District
Agency's Address:	11281 Garzoli Ave, Delano CA 93215
Agency's Phone Number:	(661) 725-0610
Agency's Website:	http://www.ssjmud.org/
Contact Person:	Roland Gross
Contact Person's Title:	General Manager, SSJMUD

SSJMUD was formed in 1935, under the Municipal Utility District Act of the Public Utility Code of California, with the purpose to obtain and provide a supply of water for lands located within the boundaries of the District. Although the District includes the cities of Delano and McFarland, the District only provides agriculture water services. SSJMUD first entered into a 9(e) Water Services Contract with United States Bureau of Reclamation (USBR) in 1945. In 2011, this Water Service Contract was converted to a permanent 9(d) Repayment Contract with the USBR, which now has the benefit of being a perpetual contract for the existing amounts of contracted water supply, thus securing the District's water supply from the Central Valley Project (CVP).

1.2.1 *Legal Authority of Agencies*

On May 27, 2014 the agencies and districts listed in Table 1-1 below and the County of Kern entered into a JPA agreement to form the KGA. To facilitate the implementation of the KGA GSP, the Agency's jurisdictional area is divided into management areas formed by the portion of the Subbasin that underlies the boundaries of each general member agency. Under this JPA agreement, the KGA was granted the authority to serve as the Groundwater Sustainability Agency (GSA) for all of its member agencies. This JPA Agreement was amended and restated on March 22, 2017. The amended and restated JPA agreement is included in Appendix A of the KGA GSP.

Table 1-1: Kern Groundwater Authority Member Agencies

Arvin Community Services District	Rosedale-Rio Bravo Water Storage District
Arvin-Edison Water Storage District	Semitropic Water Storage District
Cawelo Water District	Shafter-Wasco Irrigation District
City of Shafter	Southern San Joaquin Municipal Utility District
Kern County Water Agency – Pioneer Project	Tejon-Castaic Water District
Kern-Tulare Water District	West Kern Water District
Kern Water Bank Authority	Westside District Water Authority
North Kern Water Storage District	Wheeler Ridge-Maricopa Water Storage District

SSJMUD entered into a cooperative agreement with the City of Delano and the City of McFarland for the purposes of coordinating SGMA compliance and the development and implementation of a management area plan under the KGA. Per the terms of the KGA's JPA agreement, the Districts maintain authority over their own internal matters, including but not limited to, their respective surface water supplies, their respective groundwater supplies, facilities, operations, water management, and water supply matters.

Nothing in this Management Chapter or in the related Groundwater Sustainability Plan determines or alters surface water rights or groundwater rights under common law, any provision of law that determines or grants surface water rights, or otherwise. (See, California Water Code section 10720.5(b)). This Management Chapter and the related Groundwater Sustainability Plan shall be construed consistent with Section 2 of Article X of the California Constitution and nothing provided in this Chapter modifies rights or priorities to use or store groundwater except as expressly stated in California Water Code section 10720.5(a). SSJMUD reserves and retains all rights to the use of water to the extent provided by law.

1.3 Management Area Plan Implementation Costs

SSJMUD, on behalf of its customers and landowners, will incur costs to implement its management area plan and maintain the plan via five-year updates, both on their own and as members of the KGA. These costs and sources of funding are described below.

1.3.1 *Costs Generated by Management Area Plan Implementation*

Table 1-2 presents a description and an estimate of the costs associated with the implementation of the SSJMUD management area plan and measures associated with SGMA compliance.

Table 1-2: Estimated Costs for Management Area Plan Implementation

Item	Description	Estimated Cost
Monitoring	Improvement of in-district monitoring network for SGMA compliance. Coordination of groundwater level, groundwater quality, and land subsidence monitoring activities for annual reporting and Five-Year Updates	$400,000 for the first 5 years
Projects	Implementation of projects that have been identified in this plan. This estimate is for the duration of the 20-year SGMA implementation period.	$70,000,000
Management	Administration of management actions and SGMA implementation measures.	$65,000 per year
Annual Report	Reporting of data collected in-district for inclusion in the Subbasin's Annual Report to DWR.	$25,000 per year
5-Year Management Area Plan Update and Report	Development of plan updates, based upon the ongoing evaluation of groundwater conditions, changes to monitoring network, and developments of new projects and management actions for SGMA implementation.	$500,000 every 5 years

These costs are an estimate based on known requirements for SGMA compliance and on projects that have been identified at this time. They are subject to change as SGMA is implemented both at the district-level and throughout the Subbasin.

1.3.2 *Management Area Plan Implementation Funding*

Under the JPA Agreement, the KGA may impose reasonable fees, charges, assessments, and other levies to implement its management area plan. However, the KGA shall have no authority to impose any such fees, charges, assessments, or other levies on any of its members or within a management area without the express consent and approval of the affected member(s). SSJMUD

retains its own authority, within its own jurisdiction, to impose fees, changes, assessments, or other levies as defined in their respective Rules and Regulations, pursuant to the Water Code.

1.4 Description of Plan Area

The KGA's jurisdictional area is entirely within the Subbasin, as defined in the California Department of Water Resources (DWR) Bulletin 118, South of the Tulare Lake hydrologic region of the San Joaquin Valley groundwater basin. The Subbasin is bound by the Kern County – Tulare County line to the north, the Sierra Nevada Mountains to the east, the Tehachapi Mountains to the south, and the Temblor range to the west. The Kern River flows from the Sierra Nevada Mountains, to the southwest, thence north, to its terminus at the Tulare Lakebed.

SSJMUD is bound by the northern Subbasin boundary between the Tule Subbasin and Kern County Subbasin (coincidental with the Kern-Tulare County line), and Semitropic Water Storage District (SWSD) to the west, North Kern Water Storage District (NKWSD) and the Cawelo Water District (CWD) to the south, and Kern-Tulare Water District (KTWD) and undistricted lands within Kern County to the east. California State Highway 99 roughly bisects the areas covered by SSJMUD's jurisdictional area. The Friant-Kern Canal (FKC, CVP) flows through SSJMUD, from Millerton Dam on the San Joaquin River, running south and terminating at the Kern River, east of Highway 99.

1.4.1 *Geographic Areas Covered*

As shown in Figure 1-1, this management area plan covers SSJMUD's jurisdictional area and the cities of Delano and McFarland. This area represents approximately 3% of the area within the Subbasin. The boundaries are coincidental with the boundaries of the Subbasin, SWSD, NKWSD, CWD, KTWD, and undistricted lands in the unincorporated portion of Kern County. The district is located entirely within the Subbasin. There are no adjudicated areas within SSJMUD.

The incorporated cities of Delano and McFarland lay almost entirely within SSJMUD's jurisdictional area, with the exception of the land annexed into the City of McFarland for its wastewater treatment plant (which is located in the NKWSD's jurisdictional area), as shown in Figure 1-1. There are also several *de minimis* domestic water users and multi-parcel water systems located within the SSJMUD jurisdictional area, which will be covered by this management area plan.

1.4.2 *Plan Area Setting*

The total service area of SSJMUD is approximately 66,000 acres, with an irrigated acreage of approximately 51,000 acres. While the total irrigated acreage remains consistent, the actual parcels receiving water from each of the districts varies from year to year, based on decisions made by the landowners for which properties are to be irrigated and which crops are being grown. Land use mainly consists of vineyards, deciduous fruits and nut crops, and citrus, as

Jurisdictional Area of SSJMUD Management Area

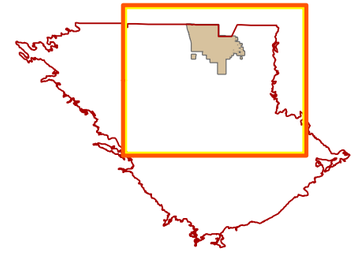
Adjacent Jurisdiction

- Cawelo GSA
- Semitropic WSD GSA
- McFarland GSA
- North Kern Water Storage District
- Shafter - Wasco Irrigation District
- Kern - Tulare Water District
- Delano - Earlimart Irrigation District
- Eastside Water Management Area
- City of Delano

Management Plan Area

- Southern San Joaquin MUD

- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Miles

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Southern San Joaquin Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 1-1

SOURCE: DWR, Kern County, Stakeholder Input.

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shown in Figure 1-2. Field crops, pasture, and grain and hay crops are located mainly in the western portion of the district, west of Highway 99. The majority of land within the limits of the cities of Delano and McFarland is classified as urban, with some land in deciduous crops or idle.

Figure 1-3 shows the areas of SSJMUD that currently receive surface water and the areas that are dependent on groundwater only. The cities of Delano and McFarland are groundwater dependent, while the service area covered by SSJMUD has access to both groundwater and surface water supplies.

Based on the data available from DWR, the jurisdictional area of SSJMUD has domestic water supply well density ranging from 1 to 22 wells per sq. mi., as shown in Figure 1-4. The area outside the City of Delano has a domestic well density of 15 to 22 wells per sq. mi.

The density of water production wells for agricultural use generally range from 0 to 6 wells per sq. mi., as shown in Figure 1-5. Most of the areas with higher well densities are in the western portion of the District. The density of water production wells for municipal use is generally 0 to 2 sq. mi. for areas around the cities of Delano and McFarland as shown in Figure 1-6.

There are scattered multi-parcel and state small water systems throughout the western portion of the District in proximity to the cities of Delano and McFarland. As shown in Figure 1-3, these include the two incorporated cities, the unincorporated communities, and the state small systems owned and operated by Cal Water. The *de minimis* domestic water users and multi-parcel water systems located within the SSJMUD's jurisdictional area are also groundwater dependent.

1.4.3 *Existing Plans in Plan Area*

There are existing groundwater management plans (GMP) within the Plan Area: the 2007 Poso Creek Integrated Water Management Plan (IRWMP) and the SSJMUD 2015 Agricultural Water Management Plan (AWMP), which is discussed in further detail in the basin setting section (Section 2) of this management area plan. A copy of the SSJMUD AWMP is included in Appendix B.

Adopted in July 2007, the Poso Creek IRWMP was created to address short and long-term water supply challenges at a regional scale. The IRWMP was developed by the Poso Creek Regional Management group comprised of seven agricultural districts, of which the SWSD was the lead agency. Groundwater goals within the IRWMP included:

- Maintain groundwater levels at economically viable pumping lifts
- Protect the quality of groundwater and enhance where practical
- Enhance monitoring activities to meet groundwater levels and water quality goals

Of the highest priority to the IRWMP was facilitating proper groundwater management. In addition to the requirements of the Districts' water management plans and the Poso Creek IRWMP, there are other federal, state, local, and regional programs that monitor groundwater

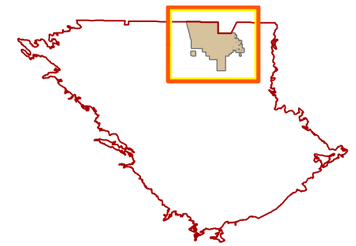
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LAND USE WITHIN SSJMUD MANAGEMENT AREA

Agriculture
- Citrus And Subtropical
- Deciduous Fruits And Nuts
- Field Crops
- Grain And Hay Crops
- Pasture
- Truck Nursery And Berry Crops
- Vineyard
- Young Perennial
- Idle; Vacant

Urban
- Commercial
- Industrial
- Semiagricultural & Incidental to Agriculture
- Residential
- Urban
- Urban Landscape

Management Plan Area
- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 1-2

SOURCE: Land IQ, 2014; Kern County, 2016; DWR, 2006.

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GROUNDWATER DEPENDENT COMMUNITIES

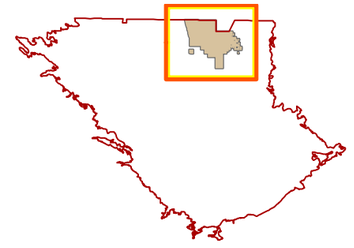
Groundwater Dependent Communities

- Agbayani Village WS
- City of Delano
- City of Mcfarland
- Kern Co P&R-Lake Woollomes WS
- Kern Valley State Prison
- Pond MWC

Management Plan Area

- Southern San Joaquin MUD

- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Miles

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Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 1-3

R23E R24E R25E R26E R27E

T24S T25S T26S T27S

White River
Tulare County
Kern County
Delano
City of Delano (CA1510005)
Garces Hwy
Kern Valley State Prison (CA1510802)
Agbayani Village WS (CA1500518)
Rag Gulch
155
Friant-Kern Canal
Kern Co P&R-Lake Woollomes WS (CA1502319)
Famoso Porterville Hwy
Pond MWC (CA1502620)
99
Poso Creek Flood Channel
Sherwood Ave
43
McFarland
City of Mcfarland (CA1510013)
65
Pond Poso Canal
Poso Creek
Calloway Canal
Lerdo Canal
Wasco
46

SOURCE: CA DHS SDWIS (2019)

16-Aug-2019 Z:\Projects\1610693_SSJMUD_SGMASSJ005_GWdependentCommunities.mxd SI

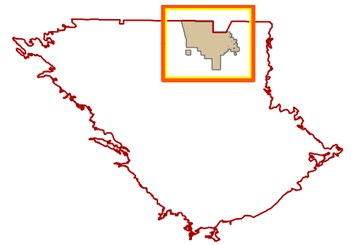
WELL DENSITY BY SECTION (DOMESTIC WELLS)

Domestic Well Count by Section

- 1 - 2
- 3 - 4
- 5 - 8
- 9 - 12
- 13 - 22

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

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AUGUST 2019 FIGURE 1-4

SOURCE: DWR WCR (2019)

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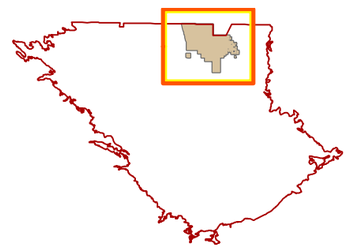
WELL DENSITY BY SECTION (PRODUCTION WELLS)

Production Well Count by Section

- 1 - 2
- 3 - 4
- 5 - 8
- 9 - 12
- 13 - 22

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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AUGUST 2019 FIGURE 1-5

SOURCE: DWR WCR (2019)

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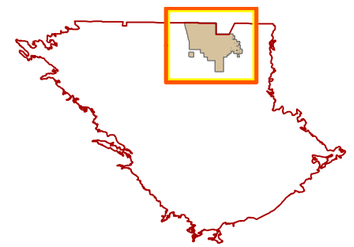
WELL DENSITY BY SECTION (PUBLIC WELLS)

Public Well Count by Section

- 1 - 2
- 3 - 4
- 5 - 8
- 9 - 12
- 13 - 22

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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AUGUST 2019 FIGURE 1-6

SOURCE: DWR WCR (2019)

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levels, groundwater and surface water quality, surface water inflow, weather and precipitation, and land subsidence. A description of these existing monitoring programs is provided in the basin setting and monitoring network sections of this management area plan.

In addition to these regional and district plans, the City of Delano has adopted an Urban Water Management Plan (UWMP); the City of McFarland is exempt from the requirement for an UWMP because its annual groundwater usage is less than 3,000 acre-feet per year (AFY). In addition to the required GMP, both Delano and McFarland have adopted General Plans. For the areas not within the limits of the incorporated cities, the Kern County General Plan applies. The General Plans for the cities and the General Plan for the County each have land use elements which address water usage. These elements are to be considered in this management area plans.

1.4.3.1 City of Delano General Plan

The City of Delano's General Plan (adopted in December 2005) includes an open space and conservation element. This element of the General Plan describes that groundwater is the primary source of domestic water supply for the city, as well as the sources of groundwater recharge. One of the objectives stated in the General Plan is "to protect natural resources including groundwater, soils, and air quality, to meet the needs of present and future generations."

The policies and standards adopted in the General Plan which deal specifically with groundwater are:

Policy #1: Protect areas of natural groundwater recharge from land uses and disposal methods, which would degrade groundwater quality. Promote activities, which combine stormwater control, and water recharges.

Policy #2: Expand programs that enhance groundwater recharge in order to maintain the groundwater supply, including the installation of detention ponds in new growth areas.

1.4.3.2 City of McFarland General Plan

The City of McFarland's General Plan (adopted in September 1991, updated in December 2015) includes an open space, conservation, and recreation element, which contains a description of the sources of the city's water supply. The current version of the open space, conservation, and recreation element does not address groundwater objectives, nor does it currently provide the policies or measures to meet those objectives.

1.4.3.3 Kern County General Plan

The Kern County General Plan contains provisions within the Land Use, Open Space and Conservation Element that relate specifically to groundwater resource management. These provisions, found in the Resource Policies of the Land Use, Open Space, and Conservation Element, are:

Policy #10: To encourage effective groundwater resource management for the long-term economic benefit of the County the following shall be considered:

a. Promote groundwater recharge activities in various zone districts
b. Support for the development of Urban Water Management Plans and promote Department of Water Resources grant funding for all water providers
c. Support the development of GMPs
d. Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water and groundwater and desalination

Under the General Provisions of the General Plan, there is a section which deals specifically with surface and groundwater. This section includes a policy statement which states that the County will "encourage the development of the County's groundwater supply to sustain and ensure water quality and quantity for existing users, planned growth, and maintenance of the natural environment" and that "new high consumptive water uses, such as lakes and golf courses, should require evidence of additional verified sources of water other than local groundwater. Other sources may include recycled stormwater or wastewater."

The implementation measures listed in the General Provisions which are directly related to groundwater are:

Measure U: The Kern County Environmental Health Services Department will develop guidelines for the protection of groundwater quality which will include comprehensive well construction standards and the promotion of groundwater protection for identified degraded watersheds.

Measure X: Encourage effective groundwater resource management for the long-term benefit of the County through the following:

i. Promote groundwater recharge activities in various zone districts
ii. Support for the development of Urban Water Management Plans and promote Department of Water Resources grant funding for all water providers
iii. Support the development of GMPs
iv. Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water and groundwater and desalination

Measure Z: General Plan Amendments subject to environmental review and not otherwise subject to California Water Code Section 10910 shall demonstrate through a water supply assessment that a long-term water supply for a 20-year timeframe is available. The water assessment shall include, but not limited to, the following:

i. Source and quantity of historical water use on the site.

ii. Estimated water consumption of the proposed development.

iii. Estimated storage, if any, in meeting the projected need.

iv. Recommendations for additional sources of water to address demand shortage. Such measures may include, but not limited to, development of future sources of additional surface water and groundwater, including water transfers, conjunctive use, recycled water, conservation, and additional storage of surface water, groundwater, and desalination.

Written acknowledgement that water will be provided by a community or public water system with an adopted Urban Water Management Plan shall constitute compliance with this requirement.

1.4.4 *Plan Elements from CWC Section 10727.4*

A. Control of Saline Water Intrusion

Seawater intrusion is not considered an issue in the Subbasin. The coastal range provides a barrier, preventing seawater from coming into contact with groundwater flow in the Subbasin.

B. Wellhead Protection Areas and Recharge Areas

Permits are issued by the Kern County Public Health Services Department (KCPHSD) Water Well Program to construct, reconstruct, and destroy water wells. The Districts assist their landowners through this process to comply with the wellhead protection area program. This program was implemented through the Safe Drinking Water Act and aims to prevent contamination in public water systems. The Districts also manage recharge areas throughout their jurisdictional boundaries and with adjacent water district recharge programs such as for the Kern Water Bank and Pioneer Project.

C. Migration of Contaminated Groundwater

There is one identified contamination plume of concern within SSJMUD's boundaries. Refer to Section 2.3.4 for further details.

D. Well Abandonment and Well Destruction Program

The KCPHSD issues permits to destroy water wells. The process consists of completing a water well permit through the county. All state and county regulations must be followed during the destruction process. According to the Kern County Ordinance Code 14.08, any wells that are abandoned or wells with inadequate water supply must be destroyed. Furthermore, any abandoned wells on the site of an active new well construction permit must be destroyed prior to construction.

E. Replenishment of Groundwater Extractions

To manage the groundwater basin within its boundaries, the Districts actively participate in conjunctive use or underground storage programs (see Section 2.7.2). In addition to these efforts, the Districts will work to implement additional projects to bring more water into the basin to maintain sustainable groundwater conditions.

F. Conjunctive Use or Underground Storage

The Districts actively participate in conjunctive use and underground storage programs to manage the groundwater basin within its boundaries. These projects aim to reduce demand on local groundwater resources. Projects include land fallowing, expansion of recharge facilities, and water banking on behalf of the Districts (see Section 2.7.2).

G. Well Construction Policies

The KCPHSD, Environmental Health Division, issues permit to construct, deepen, or replace water wells. The permitting process consists of a county water well permit and the SGMA implemented Overdraft Supplemental Well Application accompanied by detailed site maps.

H. Groundwater contamination cleanup, groundwater recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects

Regarding groundwater contamination cleanup, there are five contamination plumes in Pond and Delano. Potential contaminants at the sites include gasoline, tetrachloroethylene (PCE), pesticides, fumigants, and herbicides. Since there are no nearby impacted wells or municipal wells (within 1,500 feet of the sites), these sites are not impacting groundwater quality. SSJMUD is not taking an active role in the remediation effort that is managed by the Department of Toxic Substance Control (DTSC).

Through its water management practices, the District is constantly pursuing water conservation. Efficient water management practices are described in each District's GMP. For information regarding in-lieu use, water recycling, and extraction projects, see Section 2.7.2.

I. Efficient Water Management Practices

The existing GMPs the Districts currently follow are their own GMP's as well as the Poso Creek IRWMP. These plans were implemented to approach short and long-term water supply challenges throughout the region. These challenges were combatted with increased recharge capacities, improved conveyance, and coordinated operation of the water management programs.

J. Relationships with State and Federal Regulatory Agencies

The District coordinates with other state and federal agencies as needed to manage its water supplies; construct and implement water management projects; monitor and report local water conditions; and coordinate and provide input to local, regional and state water policy matters.

K. Land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity

Documents pertaining to land use plans and coordination between planning agencies are included in Section 1.4.3 of this management area plan. The Districts will continue to coordinate with the KGA and other GSAs in the Subbasin as the SGMA implementation process proceeds.

L. Impacts on Groundwater Dependent Ecosystems

The presence of GDE's has not been identified. Section 2.3.7 of this management area plan provides an overview of the available information regarding GDEs in the Districts.

1.5 Notice and Communication

Per Section 354.10 of the GSP emergency regulations, the following sections discuss the notice and communication processes conducted by the Districts with other agencies and interested parties. A list public outreach meetings and workshops for the Districts' beneficial users and other interested parties are provided along with a brief overview of their respective purpose.

1.5.1 *Participating Agencies*

The following agencies were engaged in the public outreach activities related to the development of this management area plan:

- City of Delano
- City of McFarland
- Kern Groundwater Authority

1.5.2 *Beneficial Uses and Users*

As required by Section 354.10(a) of the GSP emergency regulations, beneficial use and users in the Districts' portions of the Subbasin have been identified. The beneficial uses of groundwater in the management area plan, consistent with the uses identified in DWR Bulletin 118, are:

- Agricultural;
- Municipal and Domestic;
- And Industrial.

Users of groundwater have been identified as landowners, agricultural operations (including farms, dairies, and food processors), businesses, rural residents, and urban residents of

incorporated communities and unincorporated communities. These beneficial users of groundwater have been identified as stakeholders for public outreach activities in the plan area.

1.5.3 *Public Meetings*

Throughout the development of this management area plan, SSJMUD has conducted a series of public meetings to educate and engage the beneficial users within the District boundaries regarding the planning and implementation of SGMA. The Districts have also encouraged its beneficial users to participate in public meetings held by the KGA. A list of all meetings conducted by the Districts are provided in Table 1-3.

Following the enactment of SGMA in 2014, the Districts began conducting public outreach meetings and workshops to educate its beneficial users on SGMA implementation and to open the lines of communication for the development of this management area plan. Active participation was encouraged for all beneficial users in order to accurately reflect the diverse social, cultural, and economic elements of the beneficial users represented in this management area plan.

In addition to their regularly scheduled board meetings, which are publicly noticed on the District website (see Section 1.2), SSJMUD facilitated a publicly-noticed stakeholder outreach meeting on April 29, 2019 to discuss the Districts' joint efforts to develop a management area plan under the KGA. This meeting was then followed-up with smaller, landowner-focused meetings on May 2, 2019. SSJMUD also held publicly-noticed quarterly landowner meetings.

The sign-in sheets, agendas, and minutes from these meetings are included in Appendix C. Feedback received was taken under consideration and used in the development of this management area plan. The GSA Board, along with the General Manager and Consultant, considered feedback to formulate a plan that accurately captures all beneficial use/users and their interests with a goal to achieve groundwater sustainability by 2040.

Table 1-3: SSJMUD Public Meetings and Workshops

Date	Meeting	Purpose
Monthly	KGA Stakeholder Coordination Meetings	Review development of SGMA management area plan with KGA member agencies and coordinate on efforts for development.
Monthly	Board Meetings	Review development of SGMA management area plan.
August 21, 2018	Management Area Plan Development Meeting	Meeting with growers in the district and representatives from Wonderful Orchards, Westchester Group, and Yurosek Farms to discuss plan progress and development of Sustainable Management Criteria and Projects and Management Actions to be included in the management area plan.
February 21, 2019	Management Area Plan Development Meeting	Overview of SGMA plan development and coordination with the cities of Delano and McFarland and the district managers.
April 29, 2019	Stakeholder Outreach Meeting	Review presentation of SGMA; participants; and overview of Plan development and sustainable management criteria.
May 2, 2019	Stakeholder Outreach Meeting	Review and follow up to discuss April 29 meeting materials.
May 14, 2019	KGA Open House	Presentation of member agencies' GSPs/plans development with representatives from state agencies in attendance.
June 12, 2019	Management Area Plan Development Meeting	Discussion of Plan administrative draft with representatives from the cities of Delano and McFarland.
September 24, 2019	Management Area Plan Review	Meeting with representatives from the cities of Delano and McFarland to provide them an opportunity to ask questions or make comments on the Public Draft of the District's Management Area Plan.
September 26, 2019	KGA Open House	Presentation of member agencies' GSPs/plans development with representatives from state agencies in attendance.
October 8, 2019	Stakeholder Outreach Meeting	Presentation to review the contents of the District's management area plan, including the water budget, Sustainable Management Criteria, Projects, and Management Actions.

1.5.4 Comments Received

In addition to the district-level and GSA-level outreach efforts, SSJMUD provided an opportunity for the public to review and comment on its management area plan during the 90-day Public Comment period facilitated by KGA. This management area plan was made available

to the public on the KGA's website and SSJMUD's website during the comment period. During the comment period, which commenced on August 30, 2019 and ended on November 29, 2019, SSJMUD received three letters pertaining to its management area plan and two letters via the KGA with comments pertinent to SSJMUD's management area plan. These comment letters and a summary table responding to the comments in these letters has been included in Appendix D of this plan.

The SSJMUD Board of Directors met on December 11, 2019 to review the revisions made to the Public Draft of the District's Management Area Plan. Upon review and approval of the revisions made, the Board adopted Resolution 19-14 to adopt and implement the SSJMUD Management Area Plan. A copy of this resolution is included in Appendix E of this plan.

1.5.5 Management Area Plan Organization

This management area plan includes the following information, pertinent to SSJMUD's jurisdictional area:

- Basin Setting elements, pertaining to the groundwater conditions and sustainability indicators of the portions of the Subbasin located within the jurisdictional area of SSJMUD (Section 2),
- The sustainability goal and undesirable results, adopted at the Subbasin, and applied to the management areas within SSJMUD, along with the sustainable management criteria for all sustainability indicators within SSJMUD that have been identified as applicable to the Subbasin (Section 3),
- The identification of existing monitoring networks for the evaluation of sustainable management criteria and monitoring of sustainability indicators identified in the management area plan (Section 4), and
- The identification of projects and management actions proposed by the District to reach the sustainability goals identified in this management area plan (Section 5).

2. Basin Setting

The Basin Setting is made up of the hydrogeologic conceptual model (HCM), the current and historical groundwater conditions, the water budget components of the Subbasin, and the description of Subbasin management areas. This section provides the local and regional details of the HCM and groundwater conditions as context for defining and assessing sustainable management criteria and projects and management actions for SSJMUD.

2.1 Introduction

Regional details for the entire Subbasin basin setting are included in the KGA GSP basin setting chapter; whereas, most of the discussion provided in this section focuses on the extent of SSJMUD boundaries and the immediate vicinity. Pertinent details related to the entire Subbasin that apply to SSJMUD, such as the definition of the vertical and lateral extents of the groundwater Subbasin and the regional geology, regional structural setting, and aquifer hydrostratigraphy are presented in this section.

Details of this study come from SSJMUD's 2012 *Agricultural Water Management Plan* (SSJMUD, 2012), and the *Geologic Study of the Southern San Joaquin Municipal Utility District* (USBR, 1948). These studies are referenced herein. Figure 2-1 presents the current extent of SSJMUD's jurisdictional area and its proximity to other agencies within the Subbasin.

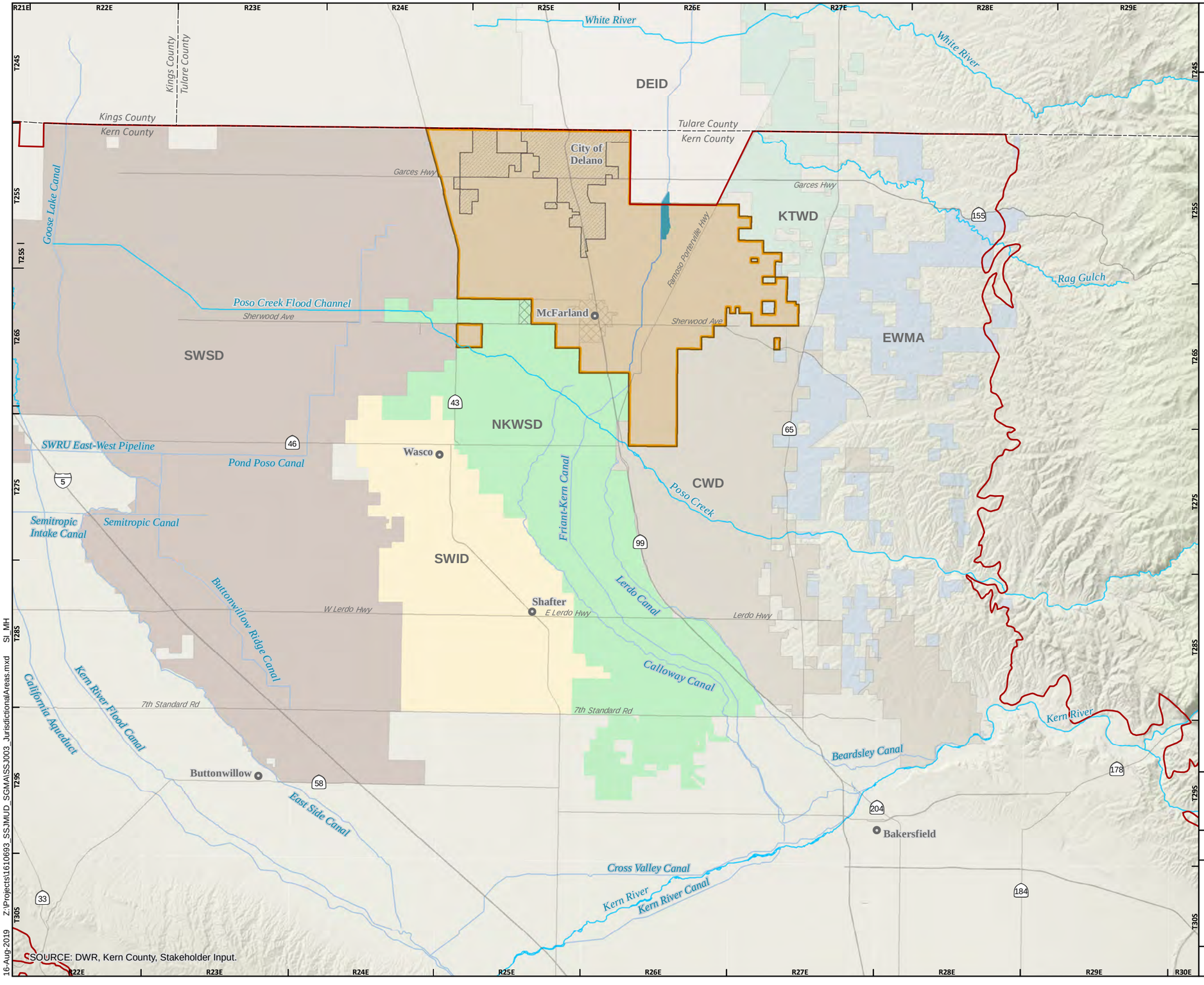
2.2 Hydrogeologic Conceptual Model

The hydrogeologic conceptual model characterizes the physical components and interaction of the surface water and groundwater systems in the study area. A brief description of the regional geology and structural setting of the area in and around SSJMUD, including the vertical and lateral extents of the groundwater Subbasin, groundwater flow, aquifer characteristics, and other physical characteristics are presented in this section.

2.2.1 *Subbasin Regional Setting*

As described in the KGA GSP basin setting, the Kern County Subbasin is located in the southern San Joaquin Valley, known as the Tulare Lake Region of the Central Valley. The Tulare Lake Region encompasses the Central Valley subbasins from just north of Fresno to the Tehachapi Mountains and San Emigdio Mountains at the southern end of the valley; with the Sierra Nevada Mountains (Sierra Nevada) to the east, and the Coast Ranges to the west (Figure 2-2). SSJMUD is situated in the north eastern portion of the Subbasin. For additional information on the regional geologic and structural setting for the entire Subbasin, please refer to Section 2 of the KGA GSP Basin Setting chapter (Chapter 2 of the KGA GSP).

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SOURCE: DWR, Kern County, Stakeholder Input.

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SSJMUD PLAN AREA

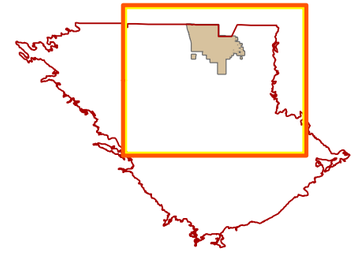
Adjacent Jurisdiction

- Cawelo GSA
- Semitropic WSD GSA
- McFarland GSA
- North Kern Water Storage District
- Shafter - Wasco Irrigation District
- Kern - Tulare Water District
- Delano - Earlimart Irrigation District
- Eastside Water Management Area
- City of Delano

Management Plan Area

- Southern San Joaquin MUD

- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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FIGURE 2-1

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Figure 2-2: Central Valley Hydrologic Regions - Tulare Lake Region

2.2.1.1 Sediment Deposition

The southern San Joaquin Valley (and most of the Central Valley), was a large basin with marine deposition occurring from Late Jurassic and Cretaceous Periods into the Tertiary Period. Thereafter, continental deposition of alluvial, fluvial, and lacustrine sediments occurred along the margins and into the center of the valley. These younger sediments were derived from the surrounding mountain ranges (Planert and Williams, 1995). Sand, silt, and clay deposits were deposited in the study areas in a complex sequence by the Kern River and Poso Creek (Kern River Formation), flowing from the Sierra Nevada Mountains to the east, and to a lesser extent, by streams along the Coast Range to the west. The terminus for these flows in the geologic past was Tulare Lake (Tulare Formation) (NKWSD, 2012).

A conceptual block diagram below (Figure 2-3) is provided as a general example of the sequence of deposition in the valley and shows the source of most fresh water into the basin originates from the Sierra Nevada mountains.

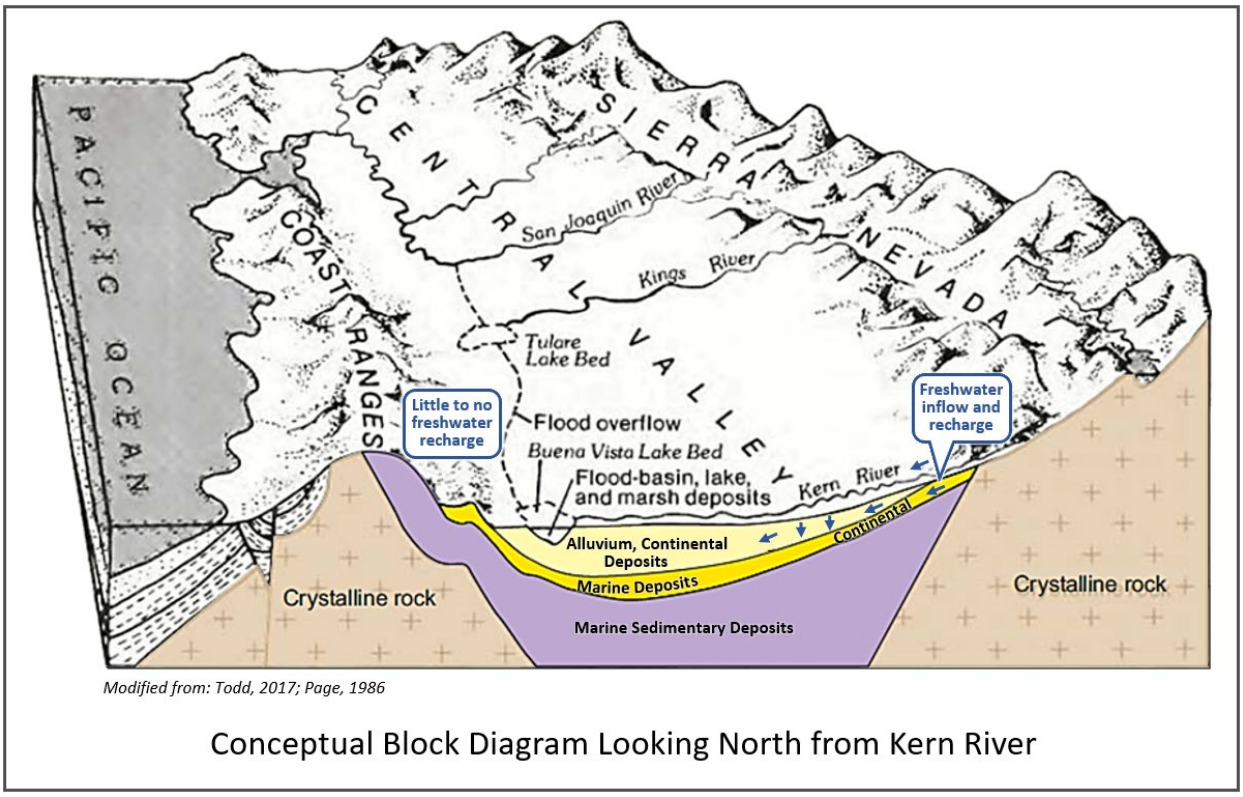


Figure 2-3: Conceptual Block Diagram from Kern River (Looking North)

2.2.2 *Groundwater Subbasin Lateral and Vertical Boundaries*

Within SSJMUD, jurisdictional boundaries limit the lateral extent of groundwater pumping, while natural boundaries delineate the vertical extent of groundwater with beneficial use. The KGA GSP provides context for the discussion of lateral and vertical extents of groundwater in the Subbasin. By applying California Water Code §10723.2, the bottom of the groundwater Subbasin includes groundwater that can be applied to beneficial use. The KGA GSP basin setting references criteria from the state and federal code for defining the extent of groundwater with beneficial use in the Subbasin. For details on these criteria, refer to the KGA GSP. In general, the groundwater Subbasin extent, where no exemptions or commercially producible hydrocarbons or minerals exist, likely ranges between 3,000 mg/l and 10,000 mg/l total dissolved solids (TDS) depending on the feasibility of treatment and recovery of the groundwater for beneficial use. The definition below provides context for the groundwater boundaries discussion in the Subbasin.

2.2.2.1 Datasets with Lateral and Vertical Distribution of Groundwater in the Subbasin

As described above, the KGA GSP basin setting discusses criteria for defining the bottom of the groundwater Subbasin. This section and subsections present datasets with general vertical distribution of groundwater ranging from 2,000 to 10,000 mg/l TDS.

Page's 1973 depth to fresh groundwater with a TDS of 2,000 mg/l is presented on Figure 2-4. There are other definitions for fresh groundwater (Heath, 1983), but for this discussion, Page's dataset is used because it is a commonly known and is a published dataset in the Central Valley. Page's (1973) base of fresh water is not however, the defined bottom of the groundwater Subbasin.

The depth to groundwater with a TDS of 10,000 mg/l (one of the criteria for the definition of an Underground Source of Drinking Water, or USDW), is presented on Figure 2-5. This dataset was recently developed by research in the Subbasin based on geochemical analysis of water samples and geophysical log analysis (Gillespie et al., 2017), and provides further insight of the distribution of groundwater that may be within the range for potential beneficial use.

Both the lateral and bottom boundaries of the groundwater in the Subbasin are constrained by the primacy productive limits with depths to hydrocarbons, and aquifer exemptions with corresponding depths. However, within SSJMUD's management area, there are no aquifer exemptions or active oil fields within the District. The oil field depths to hydrocarbons are below the base of 10,000 mg/l TDS. The base of 10,000 mg/l TDS may underlie the depth to hydrocarbons of the oil fields in proximity to the District; where applicable, the shallowest of the two is considered the bottom of the Subbasin.

2.2.2.2 Conceptual profile of the Groundwater Basin underlying SSJMUD

Figure 2-6 is a conceptual profile of the groundwater basin in SSJMUD, the groundwater basin is laterally continuous until reaching structural highs at the margins where a lot of the sediments begin to pinch out. The vertical extents are defined by the base of fresh water and the USDW. Both the base of fresh water and the base of USDW dip to the east. At about the middle of NKWSD, the base of freshwater levels out and decreases in depth toward CWD and SSJMUD. Although the conceptual profile does not illustrate the oil fields, as stated above, there are no primacy limits or aquifer exemptions within the vertical groundwater Subbasin boundaries of SSJMUD.

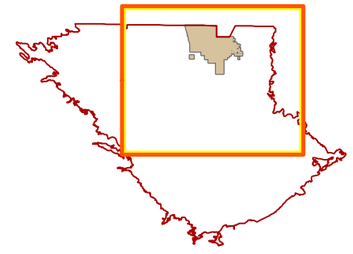
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BASE OF FRESHWATER BY PAGE (1973) AND NON-USDWS

- Elevation Contour of Specific Conductance 3,000 micromhos per centimeter (Page-1973)
- Elev — Primacy Productive Limits (Hydrocarbon max Elevation)
- Elev — Aquifer Exemption (max Elevation)

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Southern San Joaquin Municipal Utility District Management Area Plan

Kern County, California

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AUGUST 2019 FIGURE 2-4

NOTES:

(Approximate) Elevation of base of fresh water (Specific conductance generally less than 3,000 micomhos per centimeter) or ~2,000 mg/L TDS.

Hydrocarbon elevations from primacy productive limits represent difference between average surface elevation and minimum depth of productive limit.

Elevation to hydrocarbons and the top of exempted aquifers are generalized. Refer to the report table for details. Exemptions are subject to change as applications are approved.

Per 40 CFR §144.3, exempted aquifers are not USDWs. Based on criteria of 40 CFR §146.4, primacy productive limits are not suitable USDWs.

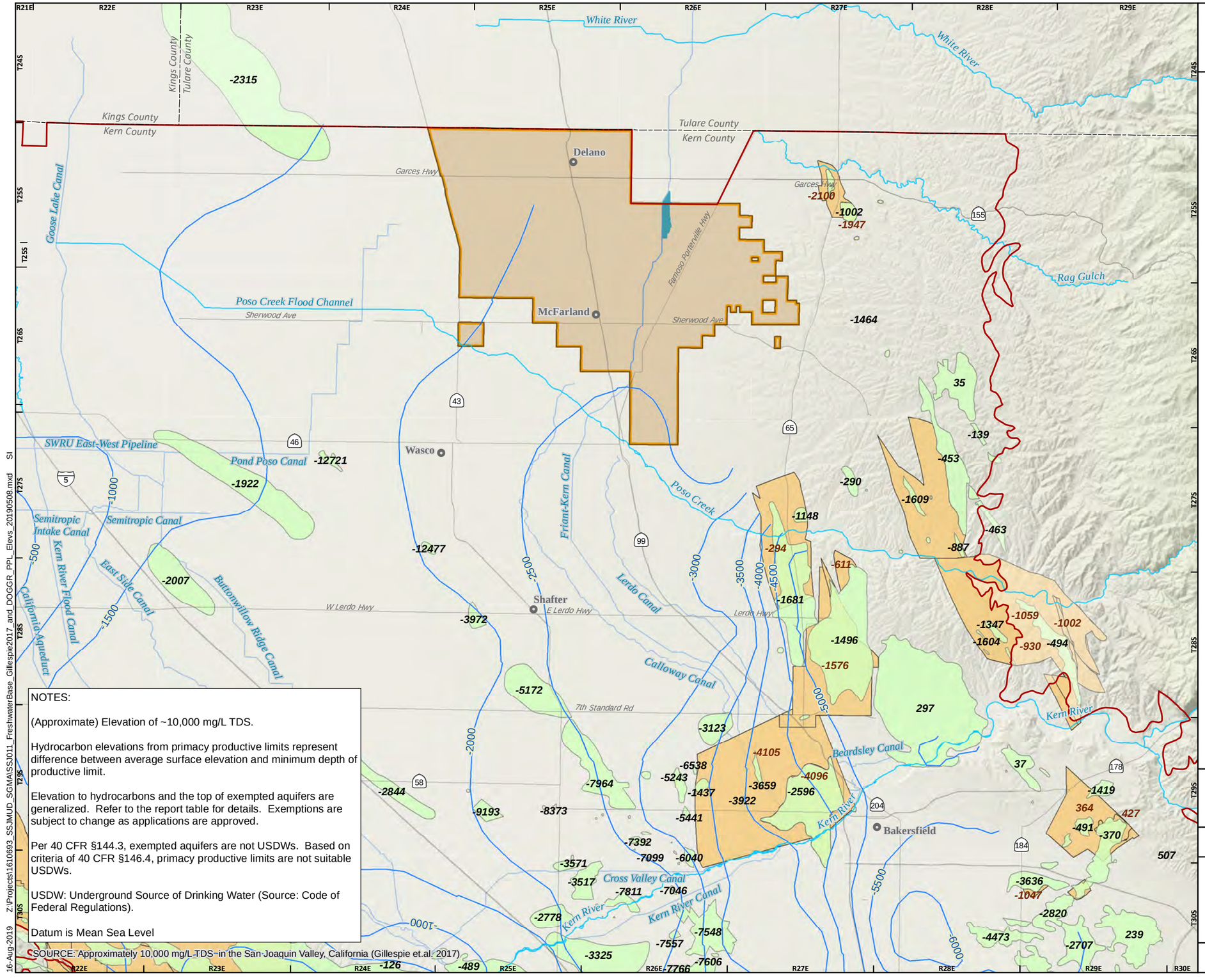
USDW: Underground Source of Drinking Water (Source: Code of Federal Regulations).

Datum is Mean Sea Level

SOURCE: Base of Fresh Groundwater (Approximately 3,000 micromhos) in the San Joaquin Valley, California (R.W. Page 1973)

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ELEVATION CONTOURS OF 10,000 MG/L TDS WITH NON-USDWS



NOTES:

(Approximate) Elevation of ~10,000 mg/L TDS.

Hydrocarbon elevations from primacy productive limits represent difference between average surface elevation and minimum depth of productive limit.

Elevation to hydrocarbons and the top of exempted aquifers are generalized. Refer to the report table for details. Exemptions are subject to change as applications are approved.

Per 40 CFR §144.3, exempted aquifers are not USDWs. Based on criteria of 40 CFR §146.4, primacy productive limits are not suitable USDWs.

USDW: Underground Source of Drinking Water (Source: Code of Federal Regulations).

Datum is Mean Sea Level

SOURCE: Approximately 10,000 mg/L TDS in the San Joaquin Valley, California (Gillespie et.al. 2017)

Elevation Contour of 10,000 mg/L TDS (Gillespie et.al. 2017)

Elev Primacy Productive Limits (Hydrocarbon max Elevation)

Elev Aquifer Exemption (max Elevation)

Management Plan Area

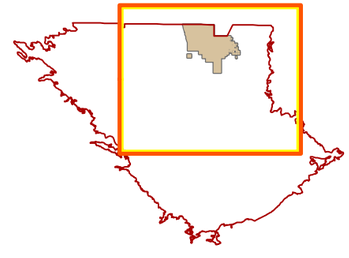
Southern San Joaquin MUD

Kern County Subbasin Boundary

Highway

Waterway

Major Conveyance



0 2 4 8
Miles

N

Southern San Joaquin Municipal Utility District Management Area Plan

Kern County, California

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FIGURE 2-5

16-Aug-2019 Z:\Projects\16\10693_SSJMUD_SGMA\SSJ011_FreshwaterBase_Gillespie2017_and_DOGGR_PPL_Elevs_20190508.mxd SI

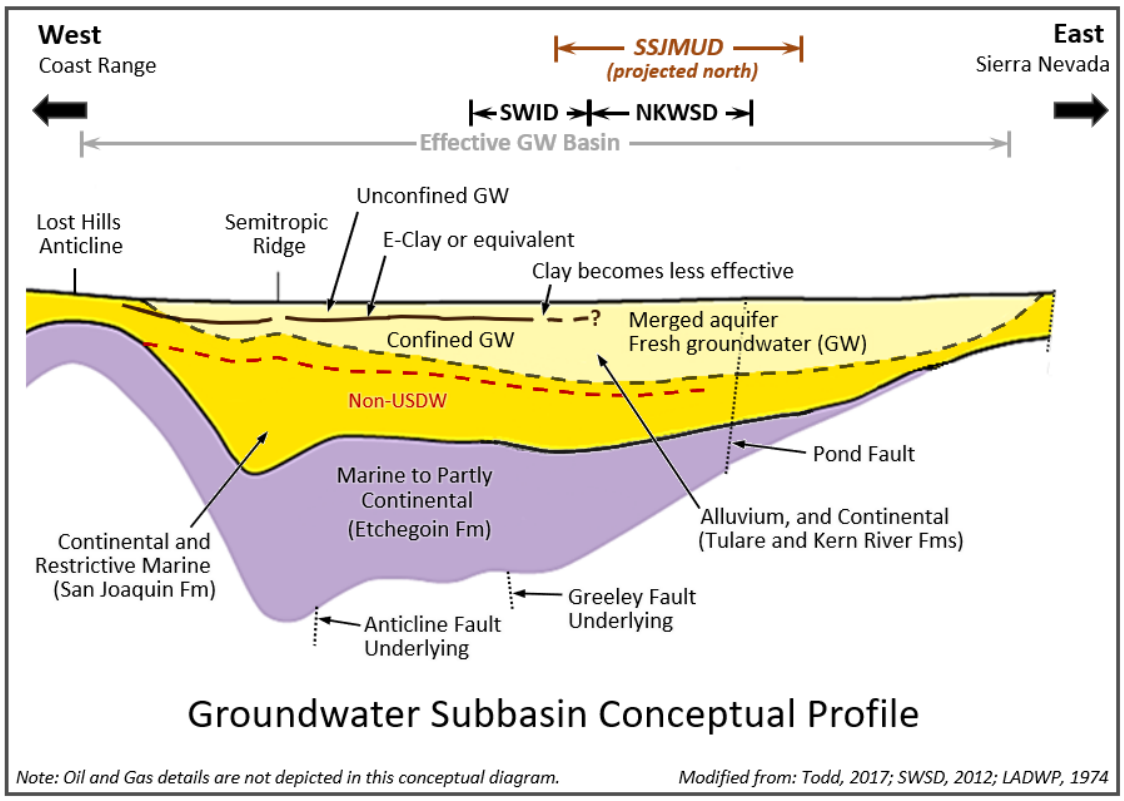


Figure 2-6: Conceptual Profile of Subbasin

2.2.2.3 SSJMUD Setting and Lateral Boundaries

SSJMUD's jurisdictional area lies in the north central portion of the Subbasin and encompasses a surface area of approximately 64,700 acres (101 square miles), plus an additional 320 acres of undistricted lands adjacent to SSJMUD's eastern boundary. The lateral boundaries of SSJMUD's jurisdictional area, shown in Figure 2-1, also include the incorporated cities of Delano and McFarland and the unincorporated community of Pond, and both the North Kern and Kern Valley State Prisons. As described above, SSJMUD is bordered by Delano-Earlimart Irrigation District (DEID) and Tulare County to the north, Kern-Tulare Water District (KTWD) undistricted lands to the east, Cawelo Water District (CWD) and North Kern Water Storage District (NKWSD) to the south, and Semitropic Water Storage District (SWSD) to the west.

2.2.2.4 SSJMUD Subbasin Vertical Boundaries

From Page's data (Figure 2-4), the base of 2,000 mg/l TDS "fresh water" ranges in SSJMUD from approximately -1,600 ft msl (~1,850 ft bgs) in the western portion of the District near T25SR25E and -2,000 ft msl (~2,400 ft bgs) in the southern central portion of SSJMUD near T26SR26E. The base of 2,000 mg/l TDS water is approximately -1,200 ft msl (~1,650 ft bgs) in the eastern portion of the District near T25SR27E.

While the data from Gillespie et al. (2017) (Figure 2-5), does not cover the entire District, the base of 10,000 mg/l TDS is estimated to range from -1,750 ft msl (~2,100 ft bgs) in the western portion of the District near T25SR25E and -2,500 ft msl (~2,800 ft bgs) in the southeastern portion of the District, near T27SR26E.

2.2.2.5 General Observations of Base of Fresh Water

Just south of SSJMUD is the Pond-Poso Fault, which marks the northern end of the deep northwest-trending trough of fresh groundwater between Bakersfield and Wasco. This trough of fresh groundwater (-2400 ft msl) lies between the concealed Poso Creek fault to the northeast and the concealed, pre-Quaternary Greeley fault system on the southwest. Historical displacement on the Greeley Fault and historical and recent displacement on the Pond Fault may have led to this depression of Quaternary sediments that accommodate this trough of fresh groundwater. Slightly trending more northerly than the Pond Fault, is a trough to the east of SSJMUD underlying KTWD (-2800 ft msl). This trough represents the depth to fresh groundwater in the Santa Margarita and Olcese Formations and does not represent a structural and lithologic low in continental deposits as observed in the trough to the south of Pond Fault. Cross sections from KTWD confirm the depths to the Santa Margarita and Olcese Formation and Page's Base of Freshwater (KTWD, 2016). Additionally, the shallowing of the base of fresh water to -1200 ft msl underlying some parts of SSJMUD, is the transition of water quality at the base of continental deposits approaching Pliocene Marine deposits.

2.2.3 *Principal Aquifers and Aquitards*

Groundwater underlying SSJMUD is a part of a regional alluvial aquifer system that is heterogeneous in texture and occurs under a variety of conditions, including upper unconfined zone and lower confined zone in the western half of the district. On the eastern half of the district, the Corcoran Clay thins and loses confinement to the east, where the aquifer is unconfined to semiconfined with depth. Water quality further differentiates the alluvial groundwater system of the Subbasin with lower concentrations of TDS on the eastern side and higher TDS in the upper zone on the western side.

The production horizons (confined unconfined zones in the eastern half) of the Subbasin aquifer are generally thick and consist of interbedded layers of gravel, sand, silt, and clay of the continental deposits of the Kern River (USBR, 1948). Much of the district is underlain by alluvium of the coalesced Poso Creek Fan and Rage Gulch Alluvial Fan Below this is the Kern River Formation which interbeds with fluvio-lacustrine deposits in the western half of the district, characterized by finer grained deposits. Groundwater wells extend to depths of greater than 1,200 feet (Page, 1986; Lofgren and Klausing, 1969), and the maximum thickness of freshwater deposits ranges from roughly 1,700 ft to 2,100 ft on the east side, gradually deepening to the south and west side of SSJMUD.

2.2.3.1 Formation Names and Descriptions within Aquifers

The aquifers underlying the study area are made up of alluvium, the Kern River Formation, and clay beds associated with lakebed deposits. For more details throughout the Subbasin, including the Santa Margarita and Olcese formations to the east of SSJMUD, refer to the KGA GSP Basin Setting chapter.

USBR (1948) describes the aquifer of SSJMUD to be made up of the "Kern River series" which overlies older marine deposits. The Kern River series is made up of a lower blue bed which is rich in silt, diatoms, and fine-grained sediment likely representative of fluvio-lacustrine conditions, and the intermediate Kern River Formation and upper "Delano Beds" or older alluvium, which are essentially identical and were deposited by coalescing alluvium derived from the weathering of the nearby highlands and Sierra to the east. USBR (1948) describes the process of deposition as "beds of sand, sandy clay, and clay [that were] laid down in a complex assemblage of discontinuous lenses, stringers, and pockets. The streams (flowing westward from the Sierra) swept back and forth across the valley floor building great alluvial fans, which grew until they coalesced and reached farther and farther out into the valley". This coalescing of discontinuous and lensoidal alluvium is what forms most of the aquifer system underlying SSJMUD. Grain sizes fine westward as the distal edges of these fans are approached.

The Kern River Formation is between 300 and 550 feet thick underlying SSJMUD (USBR, 1948). This formation consists mostly of poorly sorted fluvial sandstone and conglomerate with interbeds of siltstone or mudstone that becomes finer grained northward and westward (Bartow and Pittman, 1983). Some of the thicker siltstone or mudstone interbeds may represent deposits of small ephemeral lakes or ponds (Bartow and Pittman, 1983). The Kern River Formation is coarsest in its easternmost exposures, generally the area south of the Kern River, where the composition includes a cobble conglomerate with boulders near the base and pebbly sandstone (Bartow and Pittman, 1983).

The modified E-clay of the Corcoran Clay member has been mapped by Page (1986) in the western half of the district. Below is a brief description of the Tulare Formation for which likely only the Corcoran Clay Member is present in SSJMUD. In general, the Tulare Formation is located west of SSJMUD, near the western half of SWSD.

The Tulare Formation is Plio-Pleistocene in age, and in conjunction with the Kern River Formation (Mio-Pliocene to possibly early Pleistocene), represents west-east facies change across the Subbasin. The Tulare and Kern river formations are moderately to highly permeable and are major freshwater sources within the Subbasin (Page, 1986; SWSD, 2012).

The Tulare Formation (western Subbasin) contains up to 2,200 feet of interbedded, oxidized to reduced sands, gypsiferous clays, and gravels derived primarily from Coast Range sources. The permeable deposits of the Tulare Formation are divided into upper and lower units, separated by the Corcoran Clay member of the formation. Groundwater beneath the Corcoran Clay is typically

confined to semiconfined (Page, 1986; SWSD, 2012). In addition to its confining properties, laboratory tests indicate that the clay is highly susceptible to compaction (Faunt, et al., 2009).

The Corcoran Clay occurs laterally in the north Subbasin (~34 miles wide in extent) from Delano to Lost Hills (Figure 2-7) and narrows to the south just to the west of the Kern River banking facilities to about 3.5 miles wide. Within the central area of the Subbasin between the Kern River and Highway 46, the depth to the Corcoran Clay varies from 300 to 450 feet. Further north to the county line, the depth varies from 200 feet to the east and 750 feet to the west. The Corcoran Clay, most notably the modified E-clay (Page, 1986) is generally very fine grained; however, isolated, coarser zones are possible, particularly where the clay is less than 20 feet thick. The thickness of the clay is as much as 100 feet in a small area of the southern Subbasin but typically varies between 20 and 40 feet. In the northern Subbasin, the clay might be as thick as 60 to 80 feet in isolated areas, but the thickness typically varies between 10 and 30 feet. The Corcoran Clay is also not present in the eastern/northeastern part of the Subbasin from the cities of McFarland and Bakersfield, to Edison (Faunt et al., 2009).

Older alluvium or the "Delano Beds" overly the Tulare and Kern River formations. These deposits also make up a portion of SSJMUD's aquifer. They are composed from 150 to 300 feet of Pleistocene-age lenticular deposits of clay, silt, sand, and gravel that are loosely consolidated to cemented (USBR, 1948 and DWR, 2006). These deposits are moderately to highly permeable and yield sufficient water to wells. They are often indistinguishable from the underlying Tulare and Kern River formations (DWR, 2006).

The Holocene-age younger alluvium is not saturated underlying the district (USBR, 1948). According to USBR, the younger alluvium differs from older alluvium in that the former is not oxidized or cemented and is usually loose.

2.2.3.2 Physical Properties of Each Aquifer and Aquitard

Aquifer parameters within the Subbasin are available for both well pumping tests and calibrated groundwater models. For details on aquifer parameters estimated for the Subbasin-level, refer to the KGA GSP Basin Setting. Aquifer properties reported herein include hydraulic conductivity which is a function of an aquifer's ability to move or transmit water (transmissivity) through an aquifer of a given saturated thickness, and the specific yield (unconfined systems) and storage coefficient (confined systems), which are functions of an aquifer's ability to store and release water from storage (storativity).

Table 2-1: Aquifer Parameters for Kern County Subbasin

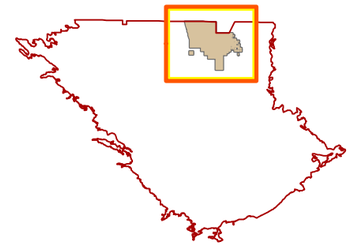
Township Range	Estimated Specific Capacity (gpd/ft)	Source
T25S-R25E	35,000	Davis et. al. 1964
T25S-R26E	36,000	Davis et. al. 1964
T26S-R25E	85,000	Davis et. al. 1964
T26S-R26E	68,000	Davis et. al. 1964

APPROXIMATE THICKNESS AND EXTENT OF E-MODIFIED CORCORAN CLAY

- Corcoran Clay Thickness Contour *(from model)*
- Approximate Extent of Corcoran Clay *(USGS)*

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

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AUGUST 2019 FIGURE 2-7

SOURCE: C2VSIM Corcoran Clay layer top and bottom elevations, DWR (2018); Corcoran Clay extent, Faunt, USGS (2009) - http://pubs.usgs.gov/pp/1766/PP_1766.pdf

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Pumping test data within SSJMUD were not available at a district-level; however, aquifer test data derived from pumping tests in the Subbasin, some of which are in proximity to SSJMUD, are briefly described below. Pumping test data were taken from two sources: 1) relatively short (1.5- to 5-hour) pumping tests by the USGS at irrigation wells during the late 1950s and 1960 (McClelland, 1962), and 2) from constant rate pumping tests from engineering consultants in the 2000's (Todd, 2018). The depth of these test wells varied from 98 to 1,500 feet below ground surface (bgs) (median: 650 ft bgs), and pumping rates varied from 44 to 4,480 gpm (median: 2,500 gpm). The analysis included the use of water level recovery data from pumping wells and water levels from observation wells. From these tests, the hydraulic conductivity was estimated at ranges from 3 to 250 feet per day (ft/d; median: 60 ft/d), which is consistent with published ranges for clean, medium- to coarse-grained sand (Heath, 1983), or for a fine sand to coarse gravel (Schwartz & Zhang, 2003). These values also fall within the range of the groundwater models that were partially calibrated with these data (C2VSim; CVHM; Todd, 2018; Todd, 2017).

Estimates of specific capacities observed from pumping in SSJMUD have been reported by USGS (McClelland et. al., 1962), and are included in Table 2-2 below. These data have been used for various Transmissivity estimates in the past and may prove useful for future work.

Table 2-2: SSJMUD Specific Capacity

SSJMUD Specific Capacity	
Township Range	Estimated Specific Capacity (gpd/ft)
T25R25	35,000
T25R26	36,000
T26R25	85,000
T26R26	68,000
Source: McClelland et al, 1962	

Corcoran Clay

The Corcoran Clay Member of the Tulare Formation is most commonly known for its fine-grained beds; however, lithology does vary from fine (clay and silt) to coarse (sand) texture (Page, 1986; Faunt et al., 2009). Faunt et al., (2009) compiled and estimated horizontal hydraulic conductivities within the range of 0.0024 to 33 ft/d, which is within the range of silt to fine/medium sand (Heath, 1983). A range of vertical hydraulic conductivity was estimated from permeameters and field tests between 6.6 x 10-6 ft/d to 1.5 x 10-3 ft/d (Faunt et al., 2009), representing a potential vertical anisotropy range of 3.6 x 102 to 2.2 x 104. As noted by Faunt et

al., (2009) laboratory permeameter tests may have underestimated the hydraulic conductivity while field testing may have overestimated hydraulic conductivity due to potential for intra-borehole flow across the clay. Additionally, recent inelastic compaction of the Corcoran Clay in areas of subsidence may have further reduced vertical hydraulic conductivity (Faunt et al., 2009).

Specific Yield and Storage

Storage of an aquifer is primarily described and quantified by the storativity or the volume of water released from storage per unit surface area of the aquifer per unit decline in hydraulic head. It is important to note that while storativity applies to both confined and unconfined systems, it can be further simplified for these two systems. Storativity accounts for aquifer compression and water expansion (specific storage components), which are the primary factors for estimating storage in confined systems; thus, for confined systems, the specific storage or storage coefficient is most often reported. In contrast, for unconfined systems, the specific yield or effective porosity (gravity-driven dewatering of an aquifer) better represents storativity because aquifer compressibility and water expansion are somewhat negligible in unconfined systems. For unconfined systems, specific yield is most often reported, and is a function of porosity and specific retention.

For confined systems, the aquifer compressibility of the storage coefficient can be further defined as elastic and inelastic skeletal specific storage, where inelastic storage will be lost once compression and dewatering occur. It is estimated that in the Central Valley, the inelastic specific storage typically is 30 to several hundred times larger than the elastic skeletal specific storage (Faunt et al., 2009; Ireland et al., 1984). Where fine-grained deposits with inelastic storage are thick in the aquifer system, water released could be a major source of water, but could also result in a permanent loss in storage capacity of fine-grained sediments.

Specific yield underlying SSJMUD was estimated by USBR (1948). The estimates were only meant to be a preliminary characterization; nonetheless, they are presented herein. They were evaluated based on soil type from well logs at or just below the water table at the time of the study. The average estimated specific yield in SSJMUD (from the Kern County line to Poso Creek) is roughly 7.6 percent (USBR, 1948). The yield is as high as 13 percent along Poso Creek. Just north of SSJMUD in the Rag Gulch channel, the yield was estimated at 14 percent (USBR, 1948). Underlying the western half of the district, the yield was estimated as low as 5 percent (USBR, 1948). USBR's mapped specific yield data is included in Appendix F.

2.2.3.3 Geologic Features that Significantly Affect Groundwater Flow

The large, asymmetrical, northwestward-trending trough of the Central Valley, and consequently the southern Tulare Lake Basin, is the principal structure controlling the occurrence and movement of groundwater in the area. Groundwater within the Subbasin is laterally bounded to east, south, southwest, and west by the surrounding highlands (Sierra Nevada, Tehachapi, and San Emigdio Mountains, and Coast Ranges, respectively) and crystalline basement rock. Groundwater flows from higher elevation recharge areas of the highlands from tributary rivers

and streams toward the center axis/trough of the valley and then northward outside of the Subbasin (Page, 1986), except where fault barriers and extensive recharge zones cause local variation in groundwater flow changes such as in the center of the Subbasin along the Kern River. Sediments are several thousand feet thick in the central portions and western side of the basin but considerably thinner where deposited on and draped over the Bakersfield Arch which extends from the southeast of Edison to the northwest of Shafter (Figure 2-8) (Bartow, 1991). In general, most of the confinement of ground water occurs near the axis of the valley because of more extensive confining beds of the Tulare Formation, such as the Corcoran Clay (Page 1986). Figure 2-7 presents the extent, depth, and approximate thickness of the Corcoran Clay as estimated by the USGS (Page, 1986).

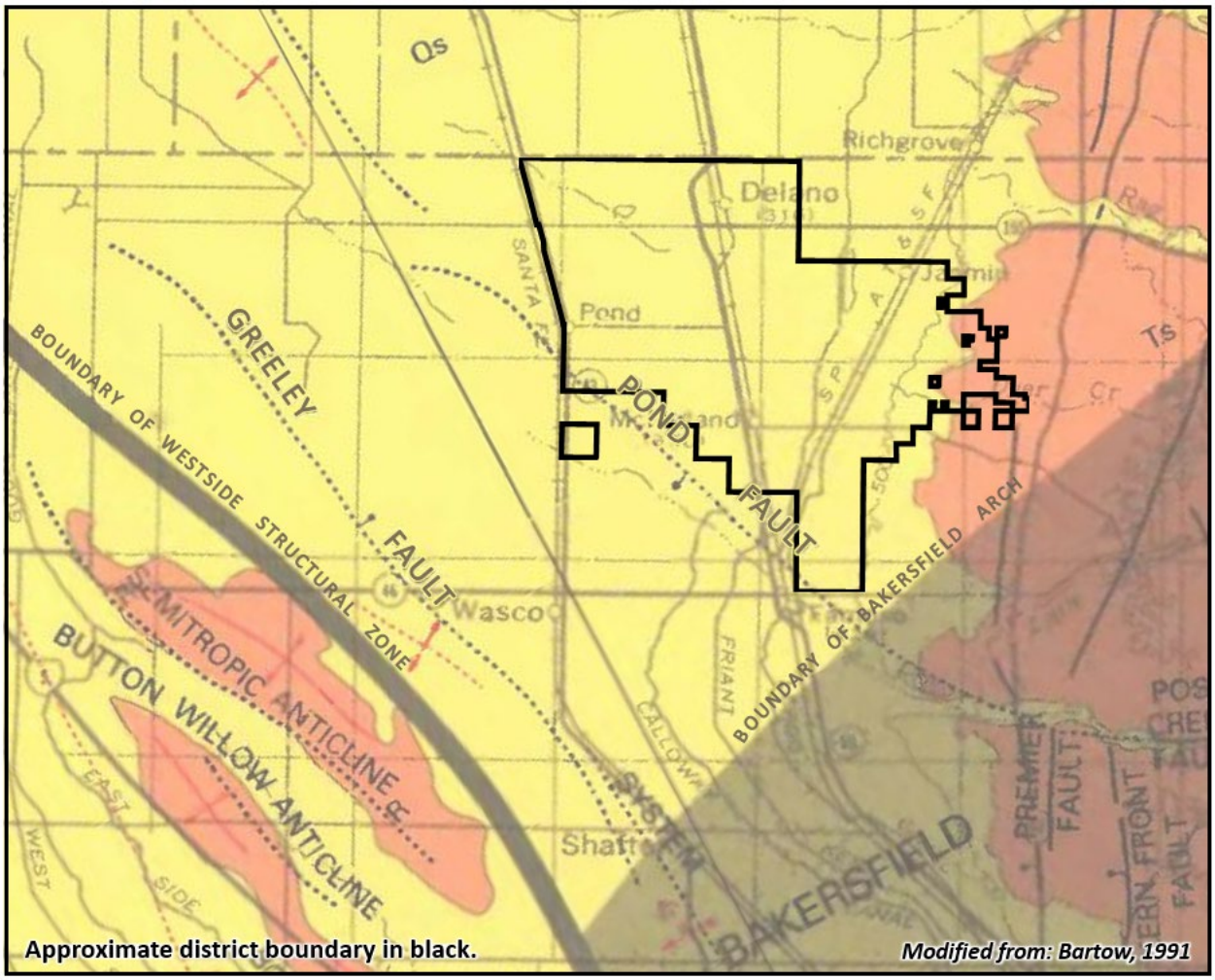


Figure 2-8: Geologic Map (Bartow, 1991)

Faults

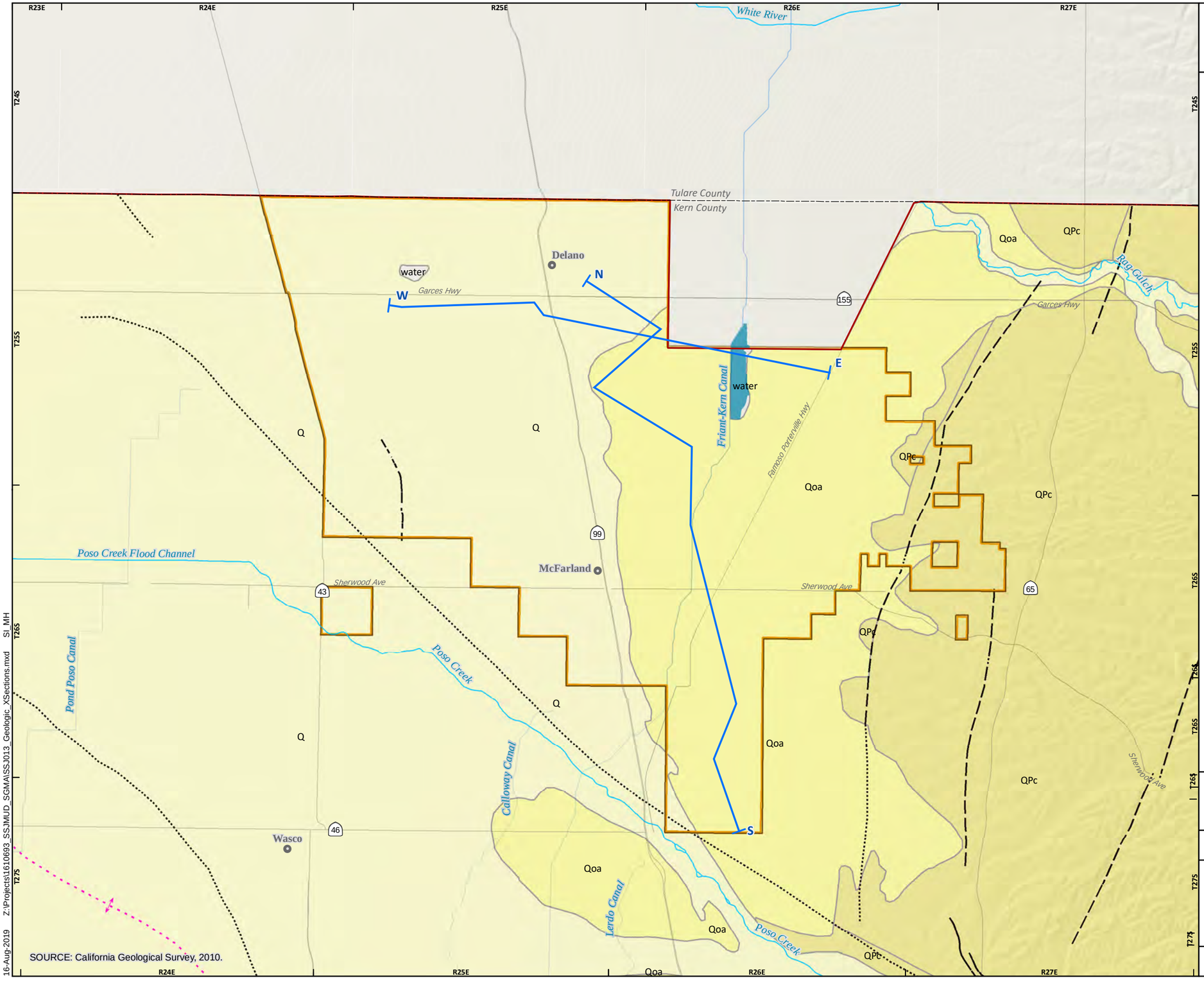
Numerous faults are mapped within the Subbasin and have been grouped by age of displacement (Figure 2-9, CGS, 2010a; and Figure 2-8). Most of the active faults within the Subbasin are located on the east, south, and southeastern sides of the Subbasin. Many of the faults are oriented

toward the northwest, parallel to the San Andreas Fault, while several faults are oriented northeasterly. The Pond-Poso Fault reportedly alters groundwater flow in the valley (DWR, 2006). Existing literature is not clear about the number of the faults in the Subbasin that are barriers to groundwater flow, although Faunt et al., (2009) included four northwest-trending "potential horizontal flow barriers" in the groundwater Central Valley Hydrologic Model (CVHM) near Semitropic Ridge and Buttonwillow Ridge and east toward Pond-Poso Fault. Although these faults are reported in regional datasets, LADWP (1974), indicates that Semitropic anticline fault system and Greeley fault system do not show displacement in sediments shallower than 10,000 feet (well below the base of USDW); therefore, they are not directly impactful to groundwater flow in the Subbasin.

The Pond-Poso Fault System reportedly affects groundwater flow. This system is a zone of four subparallel breaks/faults 2/3 mile in width, which extends from just east of Trico anticline (T25S-R24E) southeasterly approximately 48 miles through the Poso Creek oil field to the base of the Sierra Nevada (LADWP, 1974). Based on seismic reflection lines and vibratory seismic profile lines, the Pond-Poso Fault dips southwesterly at 50 to 70 degrees. LADWP (1974) and Holzer (1980) documented approximately 30 to 65 feet of difference in water levels across the fault zone, respectively from 1974 and 1978 studies. Holzer (1980) observed that fault offset of groundwater levels was greater during dry years when the lowest seasonal water level low occurred. The Pond-Poso Fault System is also documented to offset sediment in the subsurface. This vertical offset of sediment ranges from approximately 20 to 80 feet in the upper 1,000 feet of the subsurface (LADWP, 1974 and PGA, 1991), and the displacement decreases northwesterly along the fault system (LADWP, 1974). Exploratory trenches documented offset of 9 inches at 10 feet depth, and slickensides in the trenches show near vertical, oblique slip movement (LADWP, 1974). Coincidentally, Holzer (1980) concluded that 9 inches of offset had occurred along the Pond-Poso Fault System since the 1950s. Holzer (1980) observed fault movement from February 1977 to March 1979 during seasons of water level decline.

2.2.3.4 Cross Sections with Structures that Affect Groundwater Flow in SSJMUD

The purpose of developing cross sections for this management area plan was to identify prevailing conditions that affect groundwater flow and groundwater quality in the study area, and not to focus on correlating detailed stratigraphy. Furthermore, sediments underlying the study area are highly lenticular and, although some locally continuous clays are present, the eastern extent of the E-clay or other equivalent confining beds is debatable (Logan, 1992); thereby making accurate correlations difficult. However, to provide context for groundwater flow within the study area, a brief discussion of correlated stratigraphy in the literature is provided below, with the understanding that developed cross sections for this management area plan do not fully attempt to correlate stratigraphy across the study area.



GEOLOGIC MAP INDEX *(CGS, 2010)*

Regional Cross Section

Geologic Features

- Fault, certain
- Fault, approx. located
- Fault, concealed
- Anticline, concealed

Geologic Units

- **Q** - Pleisto-Holocene: alluvium, lake, playa and terrace deposits; unconsolidated and semi-consolidated
- **Qoa** - Quaternary: older alluvium, lake, playa and terrace deposits
- **QPc** - Plio-Pleistocene: sandstone, shale and gravel deposits; mostly loosely

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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FIGURE 2-9

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Historical Cross Sections

Historical cross sections are included in Appendix G. A few observations from the historical cross sections are provided below:

- Lofgren and Klausing (1969; B-B' Hydrologic Section and Geologic Section) provide some detail on the transition from an upper and lower aquifer zone in western SSJMUD to one aquifer zone with the absence of the Corcoran E-Clay in the southern and eastern portion of the district. The upper zone is likely unconfined to semiconfined while the lower zone is confined. In the south and east the aquifer system is semiconfined to confined with depth.

- Few wells are installed in the upper zone where water quality is poorer than below the Corcoran (C-C' Hilton et al, 1963; and H-H' Davis et al, 1959).

- The base of freshwater deepens eastward from SWSD and reaches an elevation of -1700 ft msl west of Delano at which point it begins to shallow eastward likely due to the proximity of the contact with Pliocene marine strata. The San Joaquin Formation is present under the westside of the district and likely becomes thin to nonexistent on the eastern side of the district, where the Etchegoin Formation is the upper contact of Pliocene marine deposits (Schierer et al, 2007). East of SSJMUD, the base of fresh water may be mixed into the Pliocene marine strata, due to proximity to recharge areas in foothills and prominent aquifers underlying the marine strata, such as the Santa Margarita and Olcese Formations (B-B'; Lofgren and Klausing, 1969).

- The trough of fresh water in central SSJMUD deepens southward into NKWSD (H-H' Croft, 1972); likewise, oxidized deposits associated with alluvial fans are thicker in the central portion of SSJMUD and progressively toward the south (Croft, 1972; B-B' geologic section of Lofgren and Klausing, 1969).

- PGA (1991; C-C') documented the displacement of bedding across the Pond Fault as observed in seismic and down hole geophysics. PGA's magnitude of displacement across the fault is consistent with LADWP (1974) (20 to 80 of displacement), except that LADWP reported the fault zone dipping to the southwest.

- Additional historical cross sections of lithology are included in Appendix G from the USBR (1948) investigation.

Current Cross Sections

Cross sections for SSJMUD are provided as Figure 2-10 and Figure 2-11 of this management area plan (north to south and east to west trending). The cross sections include general lithology from well drilling logs (DWR, 2017a), surficial geology along with folds and faults by the California Geological Survey (CGS, 2010a, b), the base of fresh groundwater (Page, 1973), the E-Clay confining layer (DWR, 2018a), groundwater elevations for the upper and lower aquifer

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North

South

ELEVATION (FT MSL)

600
400
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400
-1,600
-1,800
-2,000

-- City of Delano
25S-26E-07
-- SR 99
-- City of Delano
25/26-18
25S-26E-18 H/J
-- City of Delano
Delano Well 25
25S-25E-24
25S-26E-32
26S-26E-05
-- Friant-Kern Canal
26S-26E-28
F001M
26S-26E-32
27S-26E-04

Alluvium

Kern River Formation

Spring 2015 Groundwater Levels

Alluvium

Kern River Formation

Etchegoin Formation (Pliocene Marine)

Approximate Base of Fresh Water (Page, 1973)

Etchegoin Formation (Pliocene Marine)

NOTE: Geology taken from Bartow (1984) and Croft (1972). Exact contacts not available for this cross section.

Miles
0 0.5 1.1
Vertical Exaggeration = 17x

Perforated Interval
Sand
Gravel with Sand
Sand with Clay
Gravel, Sand, and Clay
Clay
Gravel

Southern San Joaquin Municipal Utility District Management Area Plan

Kern County, CA

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NORTH TO SOUTH CROSS SECTION

August 2019

FIGURE 2-10

FENCE GEI; SAC FROM DWR - GEI GW MODS.GLB; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\SSJMUD N-S.GDW; 8/16/2019

West

East

ELEVATION (FT MSL)

600
400
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400
-1,600
-1,800
-2,000

25S-25E-17

-- City Of Delano

25S-25E-22

-- City of Delano

25S-25E-14
25/25-14

-- SR-99

25S-25E-24
Delano Well 25

-- City of Delano

25S-26E-18 H/J

25S-26E-20

-- Friant-Kern Canal

25S-26E-22

25S-26E-23

Alluvium

Alluvium

Alluvium

Upper Zone overlying confining clay

Lower Zone underlying confining clay

Approximate Extent of Corcoran Clay

Spring 2015 Groundwater Levels

Kern River Formation

Kern River Formation

Kern River Formation

Approximate Base of Fresh Water (by Page 1973, USGS)

Etchegoin Formation (Pliocene Marine)

Etchegoin Formation (Pliocene Marine)

Etchegoin Formation (Pliocene Marine)

NOTE: Geology taken from Bartow (1984) and Croft (1972). Exact contacts not available for this cross section.

Miles
0 0.4 0.8
Vertical Exaggeration = 13x

Perforated Interval

2015 Groundwater Elevation

Sand

Gravel, Sand, and Clay

Gravel

Sand with Clay

Clay

Gravel with Sand

Clay with Gravel

Southern San Joaquin Municipal Utility District Management Area Plan

Kern County, CA

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WEST TO EAST CROSS SECTION

August 2019

FIGURE 2-11

FENCE GEI; SAC FROM DWR - GEI GW MODS.GLB; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\SSJMUD W-E.GDW; 8/16/2019

zones, and general interpretations of faults and folds underlying SWSD. The E-Clay data on the cross sections represent the C2VSim Corcoran model layer. The C2VSim Corcoran model layer was compared with the CVHM model layer (USGS, 2018a) and mapped Page (1986) modified "E" clay extent and was found to be in general agreement. The C2VSim Corcoran layer was chosen because C2VSim fine-grid model is the basis for the Subbasin's groundwater model. The cross sections also include a representation of general well construction across the study area. Logged fine-grained deposits in well logs are depicted to provide an interpretation of dipped bedding in the subsurface, as observed from seismic data correlations from PGA (1991), and cross sections by B-E (1968).

2.2.3.5 General Water Quality of Principal Aquifers

A general summary of water quality variation both laterally (from west to east across the Subbasin) and vertically (shallow–deep within the Subbasin) is provided in the table at the beginning of Section 2.2.2. In general, water quality is poor in the western third of the Subbasin and in shallow perched zones, generally above shallow beds of the Corcoran Clay. Groundwater is progressively fresher below the Corcoran Clay, toward the center of the basin, and eastern half of the Subbasin. Water quality within the Subbasin is described in more detail in Section 2.3.4 herein.

2.2.3.6 Primary Use of Each Principal Aquifer

The unconfined zone to the east of the Corcoran Clay and the production zone beneath and outside the extent of the Corcoran Clay are the key zones within the Subbasin aquifer system that provide the bulk of water production for beneficial use. The primary uses of the Subbasin's aquifer system include agricultural, municipal, domestic, and storage for the banking of surface water.

2.2.3.7 Summary of Beneficial Uses and Users of Groundwater

Land use in SSJMUD is 70 percent agriculture, 9 percent urban/industrial/residential, and 21 percent open space. According to the 2014 SGMA legislation, beneficial users of groundwater and property interests potentially affected by the use of groundwater include:

- Agricultural Users
- Domestic Users
- Municipal Well Operators
- Public water systems
- Local Land Use Planning Agencies, and
- Environmental Users

According to DWR well completion reporting and the CASGEM program, groundwater wells are constructed for a variety of uses including:

- Domestic / Residential
- Irrigation
- Stock
- Municipal / Public
- Monitoring / Observation
- Industrial
- Cathodic Protection
- Other / Unknown

2.2.4 *Data Gaps and Uncertainty in the Hydrogeologic Conceptual Model*

The primary data gaps in the hydrogeologic conceptual model include:

- Groundwater characterization on the eastern and western flanks of the Subbasin as further presented in Section 2.3 Groundwater Conditions, and

- Groundwater quality of the primary aquifer zones and confined zones on the eastern and western flanks of the Subbasin, from wells screened solely in a single aquifer zone.

2.2.5 *Mapped Physical Characteristics*

2.2.5.1 Topographic Information

Figure 2-12 presents a topographic map of SSJMUD's administrative area and local proximity. The east side of the district is rolling upland with steep-sided gulches due to natural drainage and topographic relief (USBR, 1948). The central portion of the district is marked by a belt of westerly slopes 30 to 40 feet per mile with recent alluvial fans (Poso and Rag Gulch fans) that have coalesced to the west. Elevation ranges from 700 feet msl on the eastern edge to 250 feet msl on the very northwestern edge of the district. Poso creek is located just south of the district. The FKC cuts through the center of the district, with the cities of Delano and McFarland along Highway 99 running west of FKC. North Kern State Prison and Kern Valley State Prison are located west of Delano.

2.2.5.2 Surficial Geology (Including Location of Geologic Sections)

Surficial geology of the Subbasin has been documented in a variety of previous investigations and is presented on Figure 2-8 and Figure 2-9 (Bartow, 1991 and CGS, 2010). According to the CGS (2010b), the western part of the district consists mainly of Pleistocene to Recent unconsolidated and semi-consolidated alluvial (Q of Figure 2-9) lake, playa, and terrace deposits. USBR (1948) reports that groundwater does not occur in the young alluvium underlying the district. Older Pleistocene alluvium (Qao) is present in the eastern portion of the district on top of

Pliocene-Pleistocene deposits (QPc) of sandstone, shale and gravel deposits, including the Kern River Formation.

As described by USBR (1948), the surficial geology does control some of the topographic features of the district. The rolling upland topographic area on the east is developed by erosion in Pliocene to Pleistocene alluvial fan and flood plain sediments. The broad west-sloping valley floor is situated on the medial and distal portions of the alluvial fans.

Bartow (1991) provides a similar map (Figure 2-8) as the CGS map but refers to Quaternary alluvial and lacustrine sediments (Qs) on the valley floor and Tertiary sedimentary rocks (TS) in the very eastern edge of the district. The map shows the location of the Bakersfield Arch to the southeast as well as the boundary of the westside structural zone to the southwest of the district and the Pond Fault trending along the southeast border of the district. As mentioned in the previous sections, the Pond Fault displaces bedding and has been documented to affect horizontal groundwater flow, although it is not considered a significant barrier to flow.

Page (1986) provides a somewhat different interpretation of the surficial geology, as discussed in the KGA GSP Basin Setting. Most of the valley is made up of Miocene to recent continental deposits (QTc) – a heterogenous mixture of gravel, sand, silt, and clay with some layers of conglomerate, sandstone, siltstone, and claystone. The western half of the district is made up of Recent flood basin deposits (Qb) – clay, silt, and some sand.

2.2.5.3 Soil Characteristics

Soils within the Subbasin have two general origins that are approximately delineated by the trough of the valley, which also mirror depositional patterns as mapped in surficial geology. The eastern alluvial fans were deposited primarily by runoff from the Sierra Nevada, Tehachapi, and Transverse mountain ranges. These soils are of igneous and metamorphic origin; are typically well drained, very low in salinity, and ideal quality for agriculture. The northwestern alluvial fans originated from Coast Range sedimentary rock formed on the sea bottom. This northwest region tends to have more areas with poorly drained soils of relatively marginal quality (Provost & Pritchard, et al., 2015).

Figure 2-13 and Figure 2-14 present the soil distribution within the Subbasin as defined by U.S. Dept. of Agriculture (USDA), National Resources Conservation Service, Soil Survey Geographical Database (SSURGO) as obtained from the DWR SGMA Data Viewer website (DWR, 2018b). More detailed soil survey data can be found in four USDA reports on various portions of the Subbasin: Soil Survey of Kern County, California (USDA, 1981, 1988, 2007, and 2009), including recent online updates.

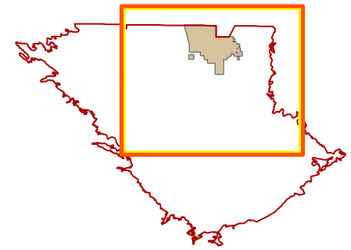
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REGIONAL TOPOGRAPHY

- Airport
- State Prison
- Elevation Contour (NAVD88)
- Wildlife Refuge

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

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AUGUST 2019

FIGURE 2-12

SOURCE: USGS, FWS

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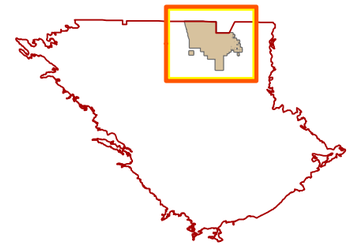
NRCS
HYDROLOGIC SOIL GROUPS

Hydrologic Group - Dominant Condition

- A - HIgh Infiltration *(Sands or Gravels)*
- B - Moderate Infiltration *(Fine to coarse Soils)*
- C - Slow Infiltration *(Moderately Fine to Fine Soils)*
- D - Very Slow Infiltration
- No Data

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Kern County, California

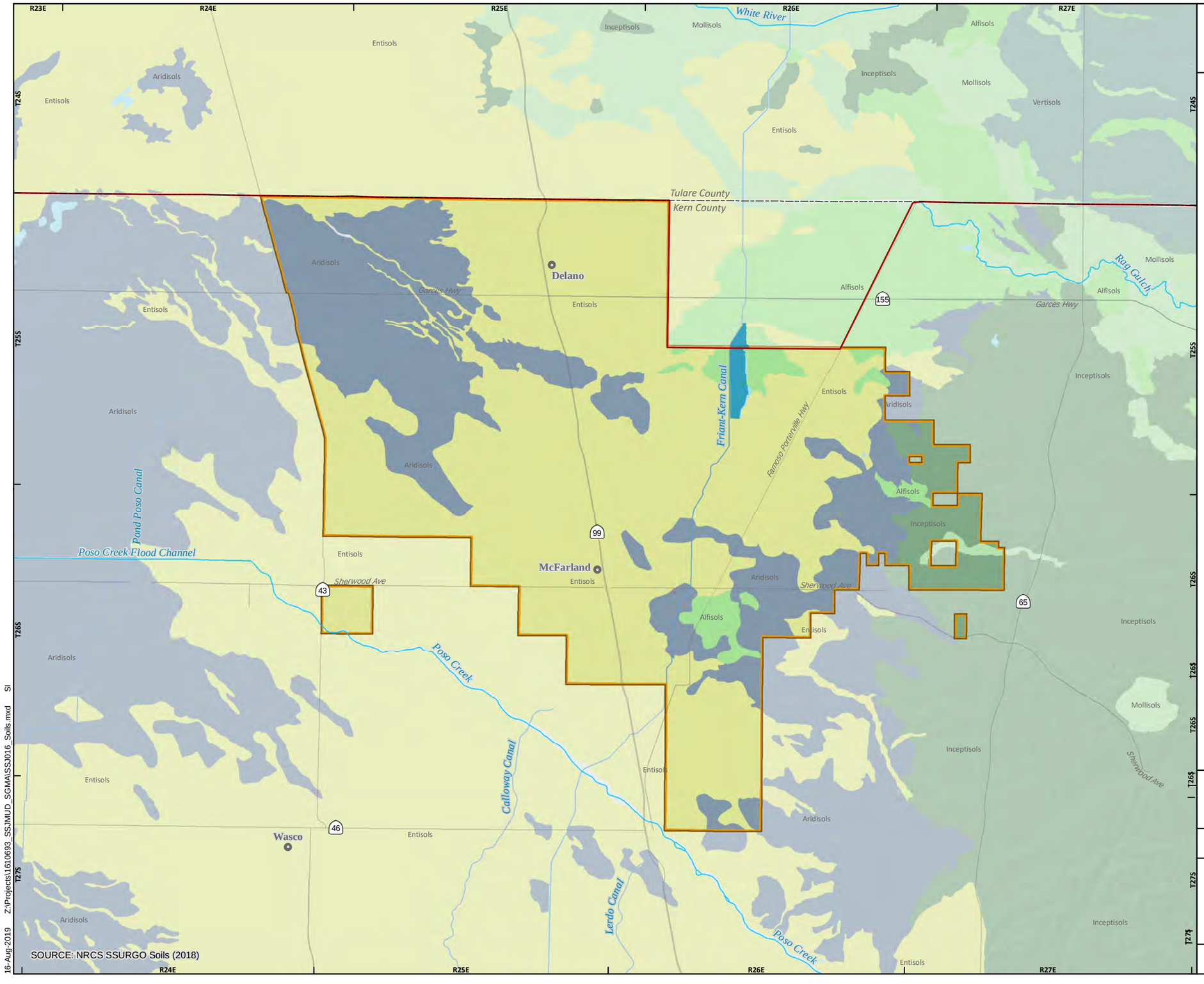
GEI Consultants

AUGUST 2019 FIGURE 2-13

SOURCE: NRCS SSURGO Soils (2018)

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TAXONOMIC SOIL ORDERS (USDA SSURGO)

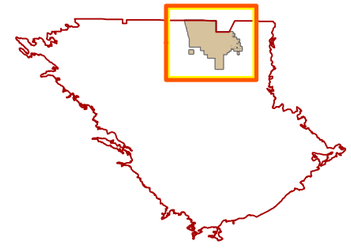


Taxonomic Soil Order

- Alfisols
- Aridisols
- Entisols
- Inceptisols
- Mollisols
- Vertisols
- Bodies of Water
- No Data

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Kern County, California

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AUGUST 2019 FIGURE 2-14

SOURCE: NRCS SSURGO Soils (2018)

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2.2.5.4 Hydrologic Soils Groups

For the purposes of SGMA, a useful index of a soil's capacity to infiltrate precipitation and applied irrigation water is the NRCS Hydrologic Soils Group classification. Hydrologic Soils Groups typical of the Study area are defined below and are displayed on Figure 2-13 was developed using data from the NRCS' Soil Survey Geographic Database (SSURGO).

- Hydrologic Group A – "Soils in this group have low runoff potential when thoroughly wet. Water transmitted freely" (NRCS, 2009). Group A soils have a high infiltration rate due to well drained sands or gravelly sands giving the group the highest potential for contributing to groundwater recharge.

- Hydrologic Group B – "Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission is unimpeded" (NRCS, 2009). Group B soils are moderately well drained due to moderately fine to coarse textures and have the second highest potential permeability and potential for contributing to groundwater recharge. These soils are present on the east, west, and south sides of the valley floor.
- Hydrologic Group C – "Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission is somewhat restricted" (NRCS, 2009). This group has limited potential to contribute to groundwater recharge. Group C soils have a low infiltration rate due to their fine texture or because of a layer that impedes downward movement of water. These soils are present along the valley floor, along the eastern highlands, and at various locations along the northwestern side of the Study area.

- Hydrologic Group D – "Soils in this group have high runoff potential when thoroughly wet. Water transmission is very restricted" (NRCS 2009). This group has a very limited capacity to contribute to groundwater recharge. These soils have a very slow infiltration rate due to the presence of clay and are located primarily along the northern boundary of the Study area.

2.2.5.5 Taxonomic Soil Orders

Figure 2-14 displays taxonomic soil orders for the study area north of the Kern River, as defined by the Soil Survey Geographic Database (SSURGO) mapping obtained from the DWR SGMA Data Viewer website (NRCS, 2018). This figure shows six soil orders with the most prominent being Aridisols and Entisols and Inceptisols along the eastern highland mixed with Alfisoils, Mollisols, and Vertisols. Based on the NRCS publication Keys to Soil Taxonomy (NRCS, 12th edition, 2014), the following characteristics are associated with each of these soil types:

- Ardisols are dry soils characterized by a low humus, light colored surface horizon with a subsurface accumulation of soluble salts, silicate clays, and possibly a cemented layer of calcium carbonate, calcium sulfate (gypsum) or silica.

- Entisols are characterized by the absence of soil horizons due to recent deposition or active erosion under extreme wet or dry conditions.

- Inceptisols exhibit a weak appearance of soil horizons overlying a weathering-resistant parent material.

- Alfisols are characterized by well-developed soil horizons enriched with aluminum- and iron-bearing (Al/Fe) minerals but depleted of calcium carbonate. Translocated clays typically form a layer with relatively high amounts of mineral nutrients (calcium, magnesium, sodium, and potassium).

- Mollisols are characterized by a thick, dark surface horizon of humus, which typically originates from native grass vegetation with mineral nutrients present in most horizons.

- Vertisols are clay-rich soils (>30%) with significant cracking during the dry season due to the shrink-swell response of the clay minerals during the dry and wet seasons. The shrink-swell action produces significant vertical mixing of the soil.

2.2.5.6 Natural Recharge, Direct Recharge Areas, and Potential Recharge Areas

Direct recharge, potential recharge, and in-lieu recharge are differentiated in this section from natural recharge.

- Natural recharge occurs by groundwater underflow from adjacent sources, precipitation exceeding evapotranspiration to allow deep percolation in a subbasin, or from deep percolation of natural surface waters flowing into the Subbasin.

- Direct recharge is either planned or unplanned deep percolation of surface water from unlined conveyance, field application, managed recharge, and spreading operations.

- In-lieu recharge refers to instances where surface water is applied to lands that otherwise would have been irrigated using groundwater. Imported surface water for in-lieu recharge to the study area is conveyed through the same pipelines and canals as contracted imported water. These conveyances are described in the surface water bodies section of this management area plan. In-lieu recharge will be further discussed in the water budget section of this management area plan because it is an accounting aspect of water input to the basin. It represents the application of surface water for use to meet water demands and does not represent direct recharge to the subsurface for the purposes of replenishing aquifers, although it benefits the aquifer system by alleviating groundwater pumping demand.

2.2.5.7 Natural Recharge

As discussed in the KGA GSP Basin Setting, natural recharge to the Subbasin occurs mainly by underflow or surface recharge from the eastern and southern highlands (Sierra Nevada and

Tehachapi Mountains). The surface water bodies as a source of recharge are discussed in the next section.

Fresh water primarily recharges the aquifer underlying the district, from the east and southeast where the E-Clay or other beds are not effective confining units. These areas of recharge extend from the Kern River and Poso Creek through the fans of alluvium spreading out from these tributaries.

In general, natural recharge by precipitation is minimal in the study area, and may only occur in extreme wet years, because typically evapotranspiration exceeds the amount of natural precipitation to the Subbasin (Provost and Pritchard et. al., 2015).

2.2.5.8 Direct Recharge

In SSJMUD, direct recharge to groundwater occurs from infiltration through unlined canals and application of irrigation water more than the total ET of farmland that migrates below the root zone. Direct recharge is planned in the future for SSJMUD via spreading grounds.

2.2.5.9 Potential Recharge Areas

As described in the KGA GSP Basin Setting, the Soil Agricultural Groundwater Banking Index (SAGBI), may further estimate groundwater recharge suitability; however, the dataset may be limited to the shallow subsurface at or just below the root zone (O'Geen et al, 2015). The California Soil Resource Lab at University of California Davis has developed an online application (https://casoilresource.lawr.ucdavis.edu/sagbi/) to present the SAGBI, which estimates groundwater recharge suitability based on five major factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. Areas of Natural and Direct Recharge are shown on Figure 2-15.

UC Davis mapping coverage of the SAGBI indicates a moderately good to excellent rating for the Poso Creek alluvial fan area near SSJMUD. SAGBI ratings are moderately poor to very poor along the western portions of the district. In addition to the areas identified in the KGA GSP Basin Setting, SSJMUD commissioned its own groundwater recharge feasibility study in 2018 to identify the locations of potential direct recharge projects.

2.2.5.10 Surface Water Bodies and Supplies

Figure 2-16 shows the location of surface water bodies near SSJMUD according to the National Hydrography Dataset (NHD). The federal FKC, as well as Poso Creek, and other significant ephemeral streams that flow from the mountains. Although the Kern River doesn't flow through the District, it is the most important local source of surface water to Kern County and to NKWSD, which is to the south of SSJMUD. The Kern River has been regulated by the Isabella Dam and Reservoir since 1954. The dam and reservoir are operated by the U.S. Army Corps of Engineers and the distribution of water is administered by the Kern River Watermaster. Poso Creek and the Kern River provide local surface water during the wet season and during above

normal and wet water years. Irregularly occurring flows are captured, to the degree possible, by spreading grounds and recharge facilities as described above in each district.

2.2.5.11 Source and Point of Delivery for Imported Water Supplies

SSJMUD uses both groundwater and surface water from local and imported sources. In the Subbasin, the Kern River is the primary source of local supply. However, Poso Creek and other minor streams contribute occasionally.

Imported water is supplied to SSJMUD by the CVP from the Friant Division. The FKC is a feature of the CVP. The canal diverts water from Millerton Reservoir, created by Friant Dam on the San Joaquin River, and extends southward a distance of 152 miles through Fresno, Tulare, and Kern counties to its terminus at the Kern River near Bakersfield. Water districts along the east side of the San Joaquin Valley entered into long-term water supply contracts with the Bureau of Reclamation, which provide for the delivery of three types of water; Class 1, Class 2, and Section 215. SSJMUD holds a contract for Friant Division for both Class 1 and Class 2 water. Figure 2-17 shows the FKC and indicates where water from this canal is delivered to SSJMUD.

Section 215 Water

Section 215 Water is available in exceptionally large water supply years and in infrequent and otherwise unmanaged flood flows of short duration. This category of water is not storable for project purposes (i.e., for meeting contract obligations for Class 1 and Class 2 water). Section 215 water can be made available under temporary contracts to districts who are not long-term Friant contractors, a mechanism some districts in the North of the River area that are not Friant contractors have exercised. The historical allocation priorities for section 215 water are as follows:

1. Long-term contractors;
2. Cross
3. Other parties within the Friant Division service area with direct delivery capabilities;
4. CVP contractors outside of the Friant Division service area; and
5. Other parties.

SSJMUD has purchased Section 215 water in the past when it has been available, and the District has the ability to either bring it in-district with available capacity in the FKC or the ability to bank the water through agreements with entities in the Subbasin (e.g. NKWSD) or outside of the Subbasin (e.g. Kaweah Delta Water Storage District).

AREAS OF NATURAL AND DIRECT RECHARGE

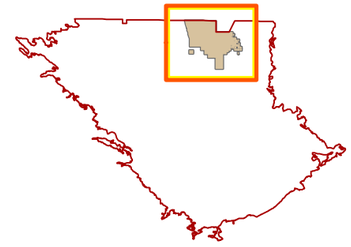
- SSJMUD Reservoir Location
- SSJMUD Lateral *(Pipeline)*

Major Canal

- *Lined*
- *Unlined*
- Minor Canal
- Spreading Grounds

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway



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Kern County, California

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AUGUST 2019 FIGURE 2-15

SOURCE: SSJMUD, USGS NHD, Kern County

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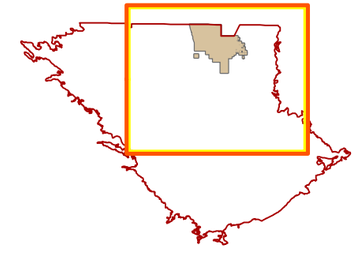
SURFACE WATER FEATURES FROM NATIONAL HYDROGRAPHY DATASET

NHD Hydrology

- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Major Canal
- Minor Canal
- Lake/Pond
- Swamp/Marsh

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway



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AUGUST 2019 FIGURE 2-16

SOURCE: USGS NHD, Kern County

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LOCATION OF TURNOUTS SERVING SOUTHERN SAN JOAQUIN MUD

- SSJMUD Friant-Kern Turnout
- SSJMUD Lateral *(Pipeline)*

Major Conveyance

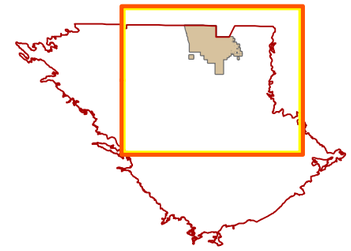
- *Lined (or Pipeline)*
- *Unlined*

Source of Imported Water

- Central Valley Project *(CVP)*
- State Water Project *(SWP)*
- SWP & Kern River
- Kern River

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway



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Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 2-17

SOURCE: USGS NHD, Kern County

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2.3 Current and Historical Groundwater Conditions (Reg. § 354.16)

2.3.1 *Groundwater Trends*

Annual groundwater elevation contour maps covering much of SSJMUD have been prepared by KCWA in Water Supply Reports since before the 1990s. These maps provide seasonal high groundwater level conditions from spring water level data prior to most of the active groundwater pumping during peak evapotranspiration (ET) and growing season conditions.

Below is a generalized diagram of groundwater flow in the Subbasin (Figure 2-18). In the absence of pumping or significant barriers, groundwater naturally flows from high elevation points of recharge to lower elevation points with less recharge. Based on a review of the 1995 to 2017 Schmidt and Associates maps and historical groundwater data from USGS and KCWA (Page, 1986; and KCWA, 2018), groundwater generally flows westward from the Sierra Nevada and Kern River. Groundwater flows from natural and managed recharge points along the Kern River, which is situated on the Bakersfield Arch and has a broad topographical rise that gradually dips to the north and south of the river; thus, the rough alignment of the river effectively splits the Subbasin into Northern and Southern groundwater flow regimes. To the North of the river, groundwater flows from the uplands along the east margins of the Subbasin toward the west and northwest until it leaves the Subbasin as subsurface underflow or is captured by pumping wells for irrigation or potable consumption. Figure 2-18 below presents the approximate location of the San Joaquin Valley (Buttonwillow) Syncline. The syncline likely negates the potential flow of saline connate water of the westside from significantly impacting groundwater in the main production zone of the Subbasin.

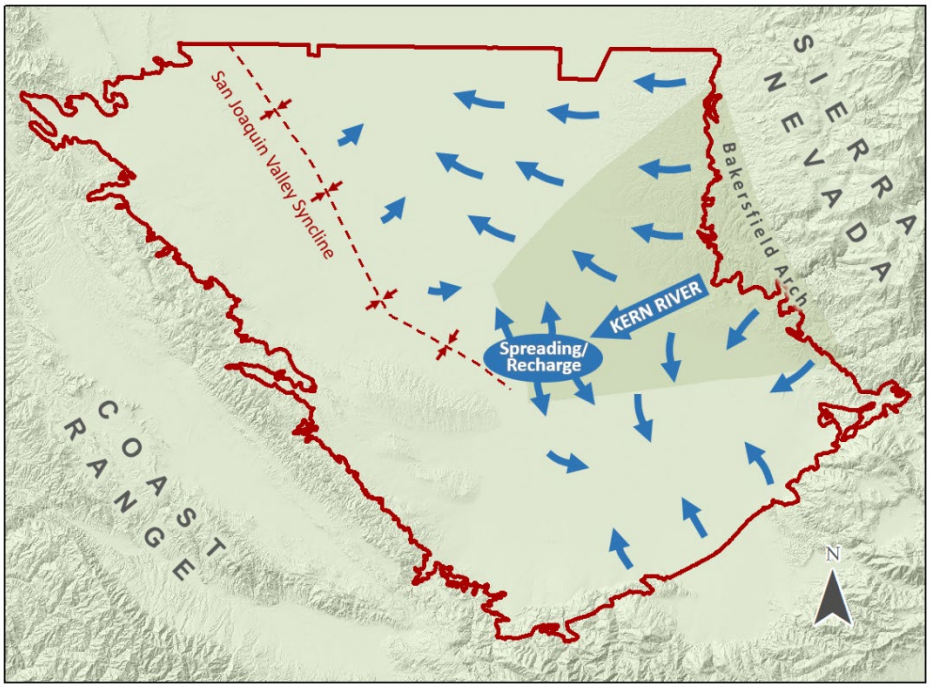


Figure 2-18: Generalized Groundwater Flow in Kern County Subbasin

As observed in cross sections Figure 2-10 and Figure 2-11, the seismic form correlations confirm the general flow direction of groundwater and the general topographic high of the Bakersfield Arch with bedding gradually dipping northerly on the northside of the Arch, and southerly on the south side of the Arch. Cross sections also depict some of the highs of the anticlines and the low of the Buttonwillow Syncline. In general, groundwater elevations near the river tend to respond to flow in the river channel and the management of groundwater banking projects located near the river, whereas, groundwater elevations further away from the river show more pronounced seasonal responses from pumping and recharge.

The following sections include the discussion of groundwater elevation contours, hydrographs, and other details to present the historical and current groundwater conditions within SSJMUD.

2.3.1.1 Elevation and Flow Directions (Groundwater Contour Map for Each Principal Aquifer)

Groundwater elevation contour maps were prepared for Spring 2015 (seasonal high) (Figure 2-19) as well as Fall 2015 (seasonal low) (Figure 2-20) to provide relatively current groundwater flow trends across the Subbasin since the inception of SGMA. Groundwater contour maps were prepared for the main production zone. In general, flows were consistent with historical trends, with groundwater flowing from the uplands on the east and around Poso Fan, and from the south along Kern River Fan along the natural flow direction to the northwest and toward pumping well discharge points. Groundwater elevations during Spring 2015 from less than minus 100 ft msl on the west to greater than 150 ft msl on the southeast. Groundwater elevation data for the Fall 2015 were limited in availability due to the high demand for pumping; therefore, the data range is incomplete and represents only a partial dataset; however, general groundwater flow trends are consistent with historical trends. Groundwater elevation data for the Fall 2015 in the main production zone of the aquifer system ranged from less than minus 150 ft msl to greater than 100 ft msl. In addition to recent mapping, the KCWA historical maps are provided in Appendix G.

2.3.1.2 Hydrographs

Hydrographs provided in Appendix I present groundwater elevations versus time with corresponding water years. In general, groundwater levels decline during dry years and increase during wet years based on the availability of imported surface water supplies. As a reference for recent surface supply water years, the below Table 2-3 presents the water year indexes from 1995 to 2017 for both the Sacramento Valley Index (typically representative of the State Water Project (SWP) allocations), and the San Joaquin Valley Index (typically representative of the FKC allocations). The 23-year period (1995-2017) started with six years of wet to above-normal years followed by 12 of the final 17 years as below normal to critically dry years. The implementation of SGMA (2015) began with critically-dry and dry years midway through a historic 5-year drought period.

SPRING 2015 GROUNDWATER ELEVATION CONTOURS

Spring 2015 Groundwater Surface Elevation
(ft MSL)

Management Plan Area

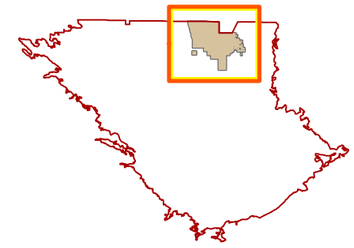
Southern San Joaquin MUD

Kern County Subbasin Boundary

Highway

Waterway

Major Conveyance



Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-19

SOURCE: GEI (2019)

16-Aug-2019 Z:\Projects\16\10693_SSJMUD_SGMASSJ020_Spring2015_GWE_Contours.mxd SI

FALL 2015 GROUNDWATER ELEVATION CONTOURS

Fall 2015 Groundwater Surface Elevation *(ft MSL)*

Management Plan Area

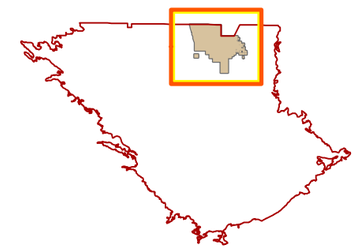
Southern San Joaquin MUD

Kern County Subbasin Boundary

Highway

Waterway

Major Conveyance



Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 2-20

SOURCE: GEI (2019)

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Table 2-3: Water Year Types

Water Year	Sacramento Valley	San Joaquin Valley
1995	Wet	Wet
1996	Wet	Wet
1997	Wet	Wet
1998	Wet	Wet
1999	Wet	Above Normal
2000	Above Normal	Above Normal
2001	Dry	Dry
2002	Dry	Dry
2003	Above Normal	Below Normal
2004	Below Normal	Dry
2005	Above Normal	Wet
2006	Wet	Wet
2007	Dry	Critical
2008	Critical	Critical
2009	Dry	Below Normal
2010	Below Normal	Above Normal
2011	Wet	Wet
2012	Below Normal	Dry
2013	Dry	Critical
2014	Critical	Critical
2015	Critical	Critical
2016	Below Normal	Dry
2017	Wet	Wet

Source: http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST

A complete set of hydrographs for data in the data management system (DMS) is contained in Appendix I. A select group of representative hydrographs with a summary table of well data are included in the Appendix I and are discussed below. These representative hydrographs were selected from CASGEM, neighboring district-owned supply wells, and private wells that are made available for SSJMUD water level monitoring.

Group 1. T26S-R26E and T27S-R26E:

Hydrographs represent wells in the southern portion of the study area just northwest of Poso Creek. The magnitude in seasonal drawdown and rise and fall of water levels between wet and dry years indicate is fairly small compared with Group 2. Potentially indicating that Group 1 wells are closer to natural recharge along the Kern and Poso Fans.

Group 2. T25S-R24E to T26S-R26E:

Hydrographs represent wells in central SSJMUD. The magnitude in seasonal drawdown and rise and fall of water levels is larger than Group 1, because it is further downgradient from natural recharge, appears to exhibit more semi-confinement which is consistent with the presence of the Corcoran Clay near these wells and possibly due to greater amounts of fine-grained units in the subsurface as indicated in historical cross sections from USBR, 1948).

Group 3. T24S-R26E and T25S-R26E:

Hydrographs in the north-central area of SSJMUD exhibit less seasonal drawdown in some wells and a smaller response in water level change between dry years and wet years. These trends may indicate more unconfined conditions. Water level elevations are higher in Group 3 than in Groups 1 and 2.

Overall, for all areas of SSJMUD, water levels are declining in dry years, and stabilizing or increasing in wet years.

2.3.2 *Change in Groundwater Storage*

Change in groundwater storage is estimated in the KGA GSP Basin Setting. Included with the description are graphs of the change in groundwater storage over the study period of 1995 through 2015.

Historical changes in groundwater elevation maps for SSJMUD are documented in Appendix G. As observed with the change in elevation maps and hydrographs, groundwater storage is reduced during "dry" water years when imported surface water deliveries are limited, resulting in greater reliance on pumping groundwater to meet water demands.

2.3.3 *Seawater Intrusion*

Seawater intrusion is not applicable to Subbasin. The Coast Range are a barrier to groundwater flow that separates seawater from the Subbasin.

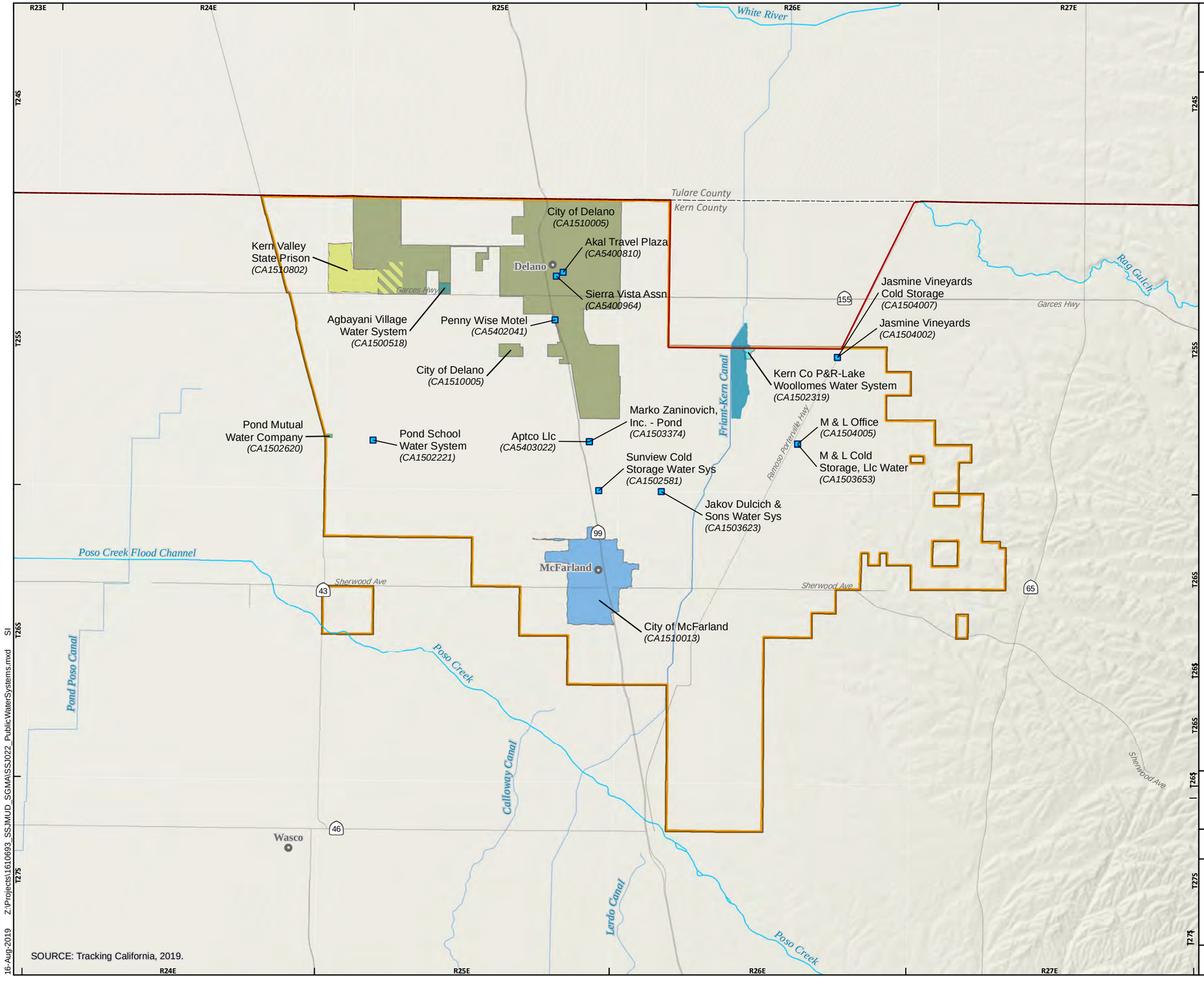
2.3.4 *Groundwater Quality*

The purpose of this groundwater quality section is to discuss groundwater quality issues that may affect the supply and beneficial uses of groundwater as stated under CCR §354.16. This section includes a discussion of water quality standards used and information relevant to capturing the groundwater quality in SSJMUD boundaries.

Public Water Systems

While land use within SSJMUD is predominately agricultural, there are 18 public water systems that are located within the District's service area identified through the Groundwater Ambient Monitoring and Assessment Program (GAMA). Six of these water systems are classified as community water systems, meaning that there are at least 15 service connections, or 25 year-round residents are served. The remaining public water systems are either Non-Transient Non-Community (NTNC) or Transient Non-Community water systems (TNC). These classifications are generally designated for businesses who supply water to their employees, or a transient (pass through) population. Table 2-4 lists the public water systems with a brief description, classification and estimated population served. Figure 2-21 shows where they are located within SSJMUD boundaries.

Water quality data from regulated drinking water systems is available through the State Drinking Water Information System (SDWIS). NTNC water systems are required to test for most



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PUBLIC WATER SYSTEMS

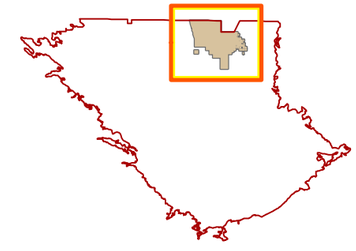
- Public Water Service Area (generalized location)

Public Water Service Area

- Agbayani Village Water System
- City of Delano
- Kern Co. P&R Lake Woollomes Water System
- Kern Valley State Prison
- City of McFarland
- Pond Mutual Water Company

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 2-21

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regulated constituents at least once every 3 years. TNC have reduced monitoring requirements and typically only test for nitrate and bacteria on a regular basis.

Table 2-4: Public Water Systems within SSJMUD

Water System #	Water System Name	Type	Population Served	Service Area	Number of Wells
1500518	Agbayani Village Water System	C	NT=12; R=26	Residential	1
5400810	Akal Travel Plaza	TNC	200	Restaurant	1
5403022	Aptco, LLC	NTNC	150	Industrial/ Agricultural	1
1510013	City of McFarland	C	15,105	Residential	3
1510005	City of Delano	C	56,623	Residential	13
1503623	Jakov Dulcich & Sons Water System	TNC	40	Industrial/ Agricultural	1
1504002	Jasmine Vineyards	TNC	NT=6; T=75	Other Transient	1
1504007	Jasmine Vineyards Cold Storage	NTNC	27	Other Transient	1
1502319	Kern Co P&R – Lake Woollomes Water System	TNC	R=1; T=400	Recreation	1
1510802	Kern Valley State Prison	C	5,300	Institution	2
1503653	M & L Cold Storage, LLC	NTNC	50	Industrial/ Agricultural	1
1504005	M & L Office	NTNC	113	Other Non-Transient	1
1503374	Marko Zaninovich, Inc – Pond	NTNC	30	Industrial/ Agricultural	1
5402041	Penny Wise Motel	TNC	27	Hotel	1
1502620	Pond Mutual	C	48	Residential	1
1502221	Pond School Water System	NTNC	250	School	1
5400964	Sierra Vista Assn	C	44	Residential	1
1502581	Sunview Cold Storage Water System	NTNC	130	Industrial/ Agricultural	1

C = Community water system
NTNC = Nontransient non-community water system
TNC = Transient non-community water system
NT = Nontransient
T = Transient
R = Residential

Existing Water Quality Monitoring Programs

SSJMUD does not own any wells within their district. Therefore, there is no direct monitoring of groundwater quality within their service area. This evaluation was conducted using public water system data.

Domestic Wells

Domestic wells are used exclusively to supply general household needs of the property owner and are typically constructed to a shallower depth than municipal or agricultural wells. Therefore, domestic wells are more commonly impacted by surface contaminants leaching into the groundwater.

Currently, information about domestic wells is limited. There is an effort being led by the SWRCB, as well as multiple other agencies, to explore the best sources of information and conduct a Needs Assessment of domestic wells in contaminated groundwater basins. An effort that is specific to SSJMUD is being conducted by the Tulare Kern Funding Area Disadvantaged Community Involvement Program that anticipates its study will be completed by the end of 2019. This study is seeking to quantify the number of domestic wells in the funding area. These studies will also gather information on the disadvantaged communities (DAC) and domestic well owners and explore potential remedies for contaminated wells.

Water Quality Standards

Federal and State Drinking Water Standards are predominantly referenced when discussing water quality standards. However, the predominant use of land in SSJMUD is for agricultural purposes and drinking water salinity limits are not protective enough for agriculture. For this reason, the SWRCB's Agricultural Water Quality Goals (Ag Goals) is also referenced for evaluation of groundwater quality in this area. The most applicable standard, Drinking Water Standard or Ag goals will be used as a reference point when discussing each constituent.

Water quality constituents that have the potential to impact the groundwater quality of SSJMUD are: arsenic, hexavalent chromium, nitrate, chloride, sodium, boron, 1,2,3-trichloropropane (TCP) and dibromochloropropane (DBCP). The list of these constituents along with their corresponding standards are listed in Table 2-5. In the Subbasin, arsenic, hexavalent chromium, and boron are predominately naturally occurring. Constituents related to salinity - chloride and sodium - are also naturally occurring but concentrated by surface activities. Nitrate is predominately anthropogenic. DBCP and TCP are manmade chemicals and are completely anthropogenic.

Table 2-5: List of Constituents and Standards

Constituent	Units*	Drinking Water Standard	Agricultural Water Quality Goal
Arsenic	ppb	10	100
Boron	ppb	1,000	700
Chloride	ppm	250	106
Dibromochloropropane (DBCP)	ppt	2	n/a
Hexavalent Chromium	ppb	n/a	n/a
Nitrate	ppm	10	n/a
Sodium	ppm	n/a	69
1,2,3-Trichloropropane (TCP)	ppt	5	n/a

*ppt = parts per trillion
ppb = parts per billion
ppm = parts per million

Land Use

Multiple sources were used to determine the land and crop land uses within SSJMUD. Ideally one single source would be used; however, none of the single sources cover the entire extent of Kern County. Using the combination of sources, land use for the entire county is accounted for.

The sources that were used in priority order are: 2014 data from Land IQ, 2016 Kern County Data from Department of Agriculture and Measurement Standards, and 2006 data from Department of Water Resources (DWR).

Land IQ was contracted by DWR to assist in obtaining land use data. In addition, Land IQ works in partnership with many other water districts within Kern County and uses satellite data to obtain the land and crop records. Given that water districts have worked closely with Land IQ to develop the data, this dataset was given the highest priority of the three sources to develop the land and crop land uses within SSJMUD.

Data from Land IQ also covers much of the crop land in the county and it was determined that crop patterns have been consistent within the last ten years. 2016 Kern County data was then used to fill in any spatial gaps of missing data from Land IQ. The last source, 2006 DWR data, was used to fill in any missing gaps from the two other sources. Despite DWR data being older than Land IQ and Kern County data, much of the missing land data filled by DWR are generally riparian and native vegetation land. Geographic Information System software (GIS) was used to merge shapefiles from all three data sources together.

When evaluating water quality, it is important to know what the land uses are in the area. Often, the land use activities may impact the groundwater quality. SSJMUD has a combined land acreage of 64,711.66. Of the total land within SSJMUD, about 81 percent is dedicated to agricultural land. From the agricultural land data, about 91 percent of it was determined from the use of Land IQ data, 4 percent from Kern County data, and 5 percent from DWR data. The next largest percentage of land use within both districts is urban at about 8 percent. Urban land use is predominately located in the central and north central portions of the District. Table 2-6 provides a breakdown of these land uses within SSJMUD. Figure 2-22 shows the land use distribution.

Table 2-6: Land Uses within SSJMUD

Land Use	Acres	Percentage (%)
Agriculture	52,527.02	81.17
Industrial	516.71	0.80
Commercial	665.16	1.03
Native Vegetation	3,612.65	5.58
Urban	5,388.70	8.33
Urban Landscape	19.80	0.03
Residential	282.65	0.44
Vacant	818.58	1.26
Surface Water	880.39	1.36
Total	64,711.66	100

Data Used

Public Water System Wells

Public water systems were identified through GAMA and water quality data was extracted from SDWIS. Since most of the water systems identified are businesses, monitoring requirements are sometimes less extensive than municipalities serving residential communities. Consequently,

there are some water systems with no data or only one result available for the identified constituents of concern in this region. Since SSJMUD does not own any groundwater wells and water quality data was not available, municipal well data was used for representation. Of the 18 public water systems identified, 33 wells were evaluated, and water quality data was trended from 2008 to current. In addition to the water quality data, the cities of Delano and McFarland provided well construction details.

Water level data and well construction details were not available for public supply wells, which has been challenging in determining where wells are perforated within the aquifer. This information is helpful for understanding what the water quality trends mean in relation to the aquifer. Water level data is also of value to determine if water quality trends are related to fluctuation in wet and dry water years. When examining the data, depths where constituents are more prevalent in the aquifer should be considered. Knowing this can help determine if water levels and well construction have an impact on water quality conditions.

Water Quality Evaluation

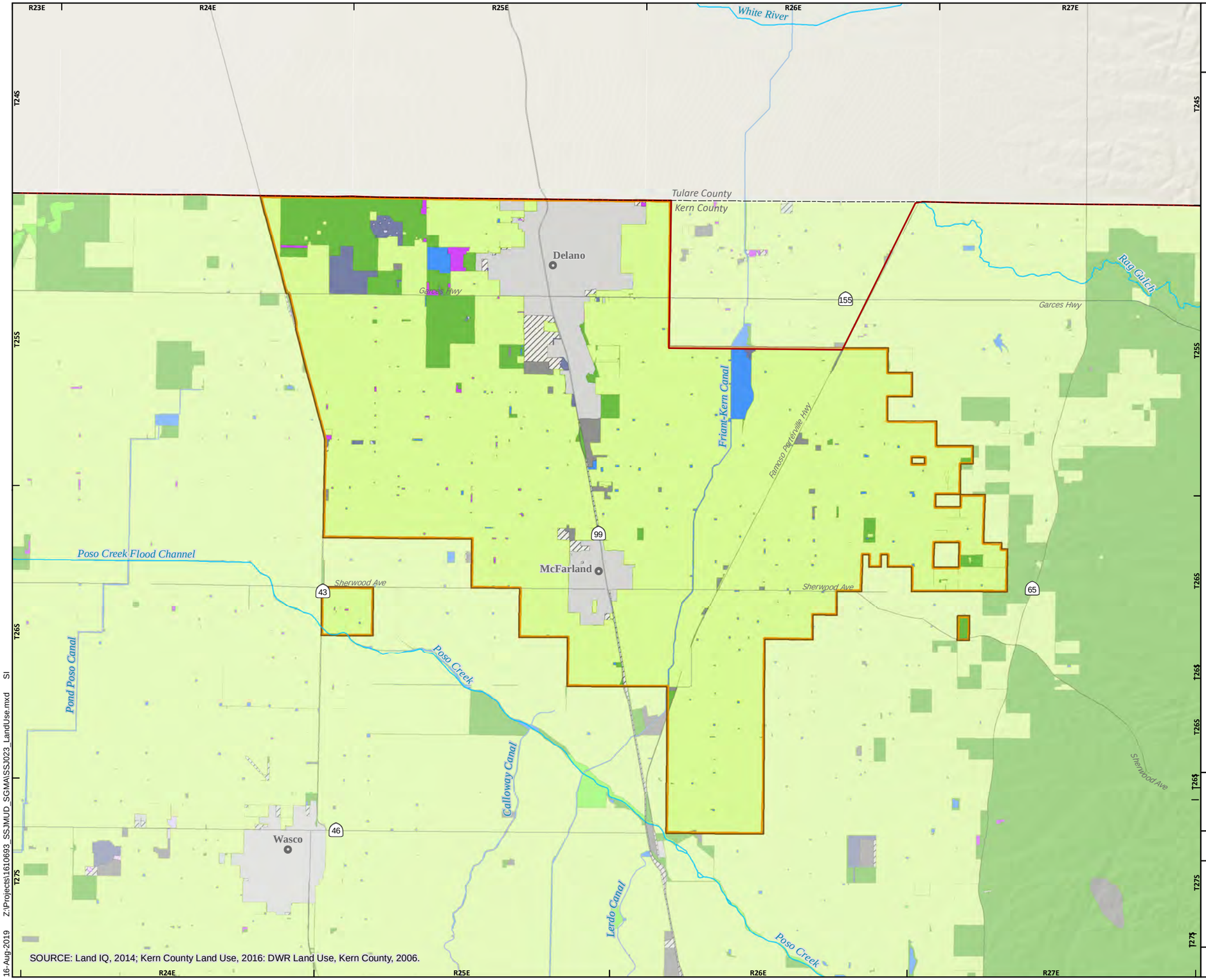
Groundwater conditions in SSJMUD was conducting using public water system data. All available water quality data was evaluated to identify constituents of concern, as identified in Table 2-5. Not all constituents that are commonly found in the Subbasin are found at concerning concentrations in SSJMUD. Therefore, only TCP, arsenic, chloride, and sodium are addressed as constituents of concern.

Sodium and Chloride

Since land use within SSJMUD is predominately agricultural, the SWRCB's Ag goals are referenced as the appropriate value rather than drinking water standards. Sodium and chloride have an Ag goal of 69 and 106 ppm, respectively. Drinking water does not apply a limit for sodium. The recommended limit for chloride is 250 ppm and the upper limit is 500 ppm.

Ag goals were published by the Food and Agriculture Organization of the United Nations in 1985. The criteria are protective of various agricultural uses of water, including irrigation of various types of crops and stock watering. At or below the thresholds presented in the Water Quality Goals database, agricultural uses of water should not be limited.

Both sodium and chloride show similar trends in the wells evaluated; therefore, for this discussion, they will be collectively referred to as salinity levels. Since sodium concentrations is an important measurement to crop yield, the focus of salinity level discussion will be on sodium. Table 2-7 summarizes sodium concentrations for the public water systems included in this analysis.



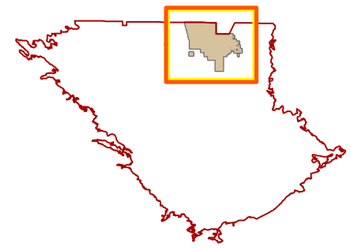
LAND USE

Land Use

- Agriculture
- Riparian Vegetation
- Native Vegetation
- Commercial
- Industrial
- Residential
- Urban Landscape
- Urban
- Surface Water
- Vacant

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Kern County, California

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FIGURE 2-22

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Table 2-7: Summary of Sodium Prevalence among Public Water Systems

	Sodium Concentrations		
Water System	0-34 ppm	35-69 ppm	>70 ppm
Agbayani Village Water System			1
Akal Travel Plaza			1
Aptco, LLC			1
City of Delano	1	5	7
City of McFarland		2	1
Jakov Dulcich & Sons Water System			1
Jasmine Vineyards		1	
Jasmine Vineyards Cold Storage			1
Kern Co P&R-Lake Woolomes Water System	1		
Kern Valley State Prison			2
M & L Cold Storage, LLC Water			1
M & L Office			1
Marko Zaninovich, Inc. – Pond			1
Penny Wise Motel			1
Pond Mutual		1	
Pond School Water System		1	
Sierra Vista Assn			1
Sunview Cold Storage Water System			1
Total Wells	2	10	21

When compared against Ag goals, data indicates that there are 12 wells with no trends available. Only one sodium result was available for those wells. For the remaining wells, no discernable trends were observed. Wells with elevated sodium levels were located throughout the District's service area. More data such as well construction information will be necessary to determine if elevated sodium areas are in a certain part of the aquifer. If sodium levels continue to increase, this will cause an adverse effect on the Ag industry due to sodium hazard concern to crops mentioned earlier.

TCP

TCP is a newly regulated synthetic organic chemical. The SWRCB reports that contamination in the Central Valley is predominately from legacy pesticide applications of certain soil fumigants. The drinking water MCL is 5 ppt; there is no Ag goal.

While TCP contamination is widespread throughout the Subbasin, there appears to be less occurrence where the Corcoran Clay is present. Detections in SSJMUD are relatively intermittent and appear to only occur above the 5 ppt detections limit when wells are perforated in the upper aquifer, or when a nearby wells is serving as a conduit between the upper and lower aquifers.

Of the public supply wells tested, 36 percent of the wells have detections above the MCL of 5 ppt. Table 2-8 shows the water systems and the number of wells that are impacted by TCP. Noncommunity water systems are not required to monitor for TCP. There are four of these water systems, which are identified in Table 2-8 with no data. The table confirms that TCP is a

contaminant of concern for SSJMUD given that 36 percent of the wells in the region exceed the MCL.

Table 2-8: Summary of TCP Prevalence among Public Water Systems

	TCP Concentrations		
Water System	Non-Detect	>5 ppt	No Data
Agbayani Village Water System	1		
Akal Travel Plaza			1
Aptco, LLC	1		
City of Delano	7	6	
City of McFarland	1	2	
Jakov Dulcich & Sons Water System		1	
Jasmine Vineyards			1
Jasmine Vineyards Cold Storage	1		
Kern Co P&R-Lake Woolomes Water System			1
Kern Valley State Prison	2		
M & L Cold Storage, LLC Water		1	
M & L Office	1		
Marko Zaninovich, Inc. – Pond	1		
Penny Wise Motel			1
Pond Mutual	1		
Pond School Water System	1		
Sierra Vista Assn		1	
Sunview Cold Storage Water System		1	
Total Wells	17	12	4

Arsenic

In terms of drinking water quality, arsenic is the primary contaminant of concern in SSJMUD. There is a primary drinking water standard of 10 ppb for arsenic. The Ag goal is 100 ppb. All water quality data in SSJMUD indicates that arsenic is below the Ag goal.

The most common source of arsenic is from natural geochemical processes that leach metals from the sediments, particularly in the lakebed areas and where dark clay deposits occur. Studies conducted by USGS found that arsenic is in an easily exchangeable state where oxidizing geochemical conditions, caused by groundwater containing higher oxygen content, dissolve the pyrite (a mineral which can contain arsenic) and release arsenic into the groundwater. Smith et. al. (2018) found that over-pumping in the San Joaquin Valley has led to land subsidence due to compaction of the lakebed deposits (clay layers) that then releases the high arsenic pore water from the clay layers into the groundwater. In SSJMUD, the Corcoran Clay is in the northwest portion of the District.

About 33 percent of the wells evaluated exceed the drinking water limit. Elevated arsenic levels are predominately located in the confined aquifer, which is in the north east portion of the District. Tables 2-9 shows the number of municipal wells within the District and their respective arsenic concentration levels.

Table 2-9:Summary of Arsenic Prevalence among Public Water Systems

	Arsenic Concentrations			
Water System	<5 ppb	6-10 ppb	>11 ppb	No Data
Agbayani Village Water System		1		
Akal Travel Plaza	1			
Aptco, LLC	1			
City of Delano	3	5	5	
City of McFarland	1	2		
Jakov Dulcich & Sons Water System				1
Jasmine Vineyards	1			
Jasmine Vineyards Cold Storage		1		
Kern Co P&R-Lake Woolomes Water System	1			
Kern Valley State Prison			2	
M & L Cold Storage, LLC Water		1		
M & L Office			1	
Marko Zaninovich, Inc. – Pond	1			
Penny Wise Motel				1
Pond Mutual			1	
Pond School Water System			1	
Sierra Vista Assn			1	
Sunview Cold Storage Water System	1			
Total Wells	11	9	11	2

Because arsenic is believed to be naturally occurring in the Subbasin and leaching from dark clay deposits is the local sources of contamination, arsenic concentrations greater than 10 ppb are most commonly found in wells that are screened across pyrite sediments. Higher concentrations are generally found in very deep wells.

When comparing arsenic levels to a well's depth, there was an observed trend. For wells in the City of Delano, which are within the Corcoran Clay, wells at 1,200 feet or greater are above the arsenic MCL compared to shallower wells. Figure 2-23 shows this observation, which coincides with studies conducted in the Subbasin that arsenic concentrations tend to be elevated in the deeper part of the aquifer.

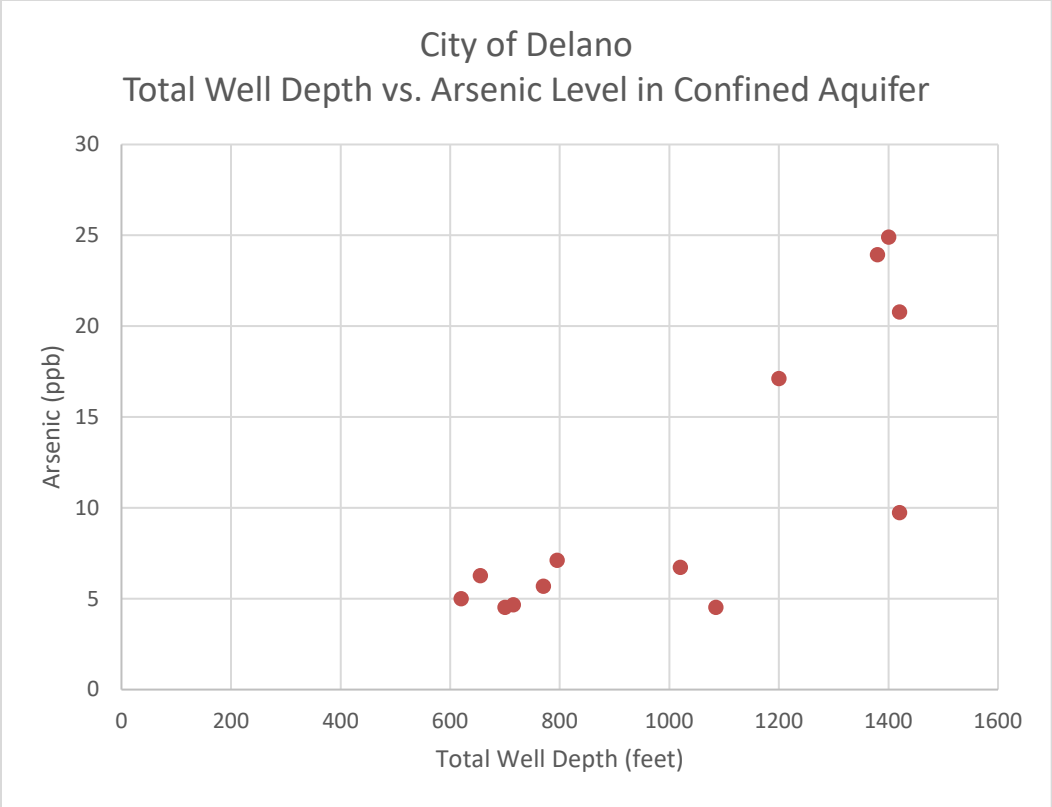


Figure 2-1: City of Delano - Relationship between Total Well Depth and Arsenic Levels

Even though a similar trend of deeper wells having elevated arsenic levels is seen outside of the Corcoran Clay, there was not enough data at the time of evaluation to conclude that arsenic is not generally found in the shallow aquifer. Well construction details are necessary to make this determination. This similar trend of elevated arsenic levels in deeper wells was noted in City of McFarland wells, which are east of the Corcoran Clay. Figure 2-24 shows that with deeper wells, arsenic levels are elevated. Even though the arsenic levels do not exceed the MCL like the wells within the Corcoran Clay, it is observed that the arsenic levels in the deeper wells are higher compared to shallower wells. The deeper wells also have lower screened intervals, therefore are drawing water from the deeper part of the aquifer where there is less dilution. For the wells within the City of McFarland, wells deeper than 1,200 feet have higher arsenic levels compared to shallower wells, which is similar to City of Delano.

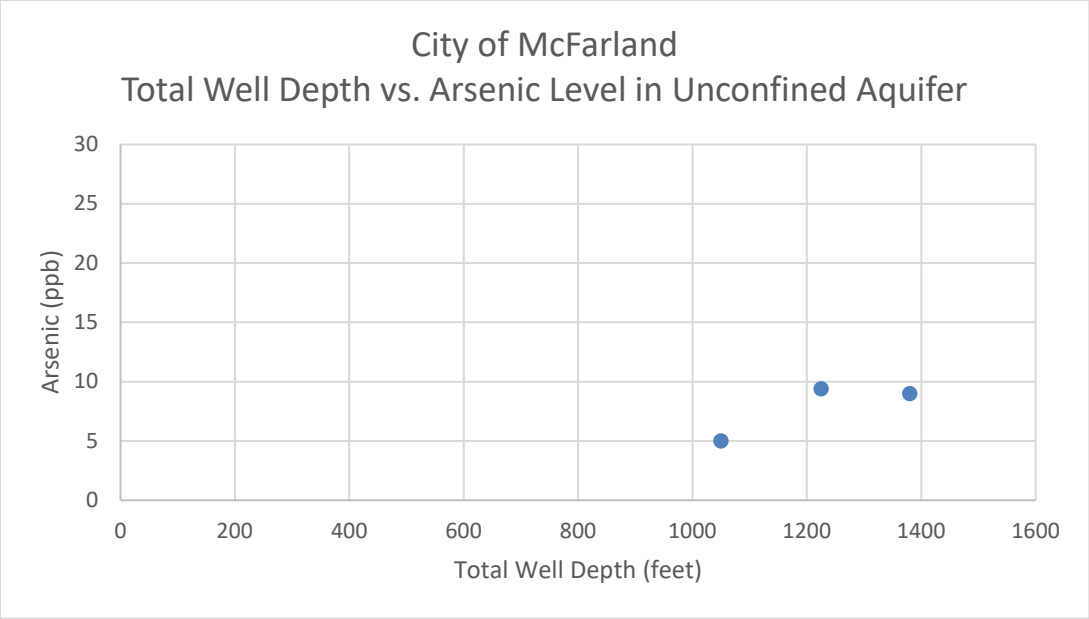


Figure 2-2: City of McFarland - Relationship between Total Well Depth and Arsenic Levels

No discernable trends were observed when comparing arsenic levels to water levels. When analyzing the wells together, there was no clear relationship. However, when looking at some wells individually, certain relationships were observed. Since the correlation was not consistent for most of the wells, no discernable trend can be stated.

Nitrate

Nitrate contamination is a significant concern in rural communities, particularly where agriculture is the predominant land use. However, a significant source of nitrate also comes from septic systems that are used in these rural communities. Since municipal services (drinking water or wastewater collection systems) are not available in rural communities, all domestic and public wastewater disposal is through onsite septic systems.

Even though nitrate is not a concern in terms of the percentage of wells with elevated levels, more data is necessary to determine if there are observable trends. Nitrate can be naturally present at low concentrations in groundwater, typically less than 2 ppm. Moderate and high concentrations generally occur because of human activities. Septic systems typically contribute moderate concentrations between 5 and 15 ppm of nitrate as nitrogen. Typically, higher concentrations (greater than 20 ppm) are associated with applying fertilizers to crops. Nitrate contamination is a significant public health concern because it has acute health effects. High concentrations of nitrate are typically found in shallow groundwater, such as those in the unconfined aquifer. About 24 percent of the municipal wells exceed the drinking water MCL for nitrate. Table 2-10 shows the number of wells at different concentration levels.

Table 2-10: Summary of Nitrate Prevalence among Public Water Systems

	Nitrate Concentrations		
Water System	0-5 ppm	6-10 ppm	>11 ppm
Agbayani Village Water System		1	
Akal Travel Plaza			1
Aptco LLC			1
City of Delano	8	4	1
City of McFarland	2	1	
Jakov Dulcich & Sons Water System			1
Jasmine Vineyards	1		
Jasmine Vineyards Cold Storage	1		
Kern Co P&R-Lake Woolomes Water System	1		
Kern Valley State Prison	2		
M & L Cold Storage, LLC Water			1
M & L Office	1		
Marko Zaninovich, Inc. – Pond		1	
Penny Wise Motel			1
Pond Mutual	1		
Pond School Water System	1		
Sierra Vista Assn			1
Sunview Cold Storage Water System			1
Total Wells	18	7	8

The location of elevated nitrate concentrations tends to be in rural areas where municipal services are not available. Despite most of the land use being agricultural, there are rural communities as well. As previously mentioned, since there are no municipal services, these communities rely on septic systems to manage their wastewater. Septic tanks are known to have failures such as leakage and are not as well maintained as a municipal sewer system. The failing septic tanks leak contaminants, such as nitrate, which eventually enter the groundwater. This is especially concerning if there is a groundwater well downgradient of the septic tank. Elevated nitrate levels in a groundwater well is typically due to surface contamination and have been more prevalent in shallower wells or in areas where a confined aquifer is not present. To better understand the nitrate trends, more data such as well construction information would be beneficial.

Contamination Plumes

A search of contamination plumes within SSJMUD was conducted using both GeoTracker and EnviroStor databases. The criteria outlined in the KGA GSP Basin Setting was applied during this review. Based on the criteria, five facilities in Pond and Delano, were identified and are being overseen by the Central Valley Regional Water Quality Control Board and Department of Toxic Substances. Table 2-11 identifies the facilities and the potential contaminants of concern. Other sites were acknowledged, but no nearby impacted wells or municipal wells within 1,500 feet of those sites were identified. Since there are no nearby affected wells and remediation efforts have begun, those sites are not impacting the groundwater quality, therefore not presented in Table 2-11.

Table 2-11: Contamination Sites within SSJMUD

Global ID#	Potential Contaminants of Concern	Status
T0602900113	Gasoline	Open – Remediation as of 7/6/16
SL185724257	Pesticides, other chlorinated hydrocarbons, TCP, synthetic organic carbons, other solvent, Nitrate+Nitrite as N	Open – Verification monitoring as of 4/20/10
60001327	Tetrachloroethylene (PCE)	Active as of 8/4/10
60002270	Tetrachloroethylene (PCE)	Associated with 60001327
60002268	Tetrachloroethylene (PCE)	Associated with 60001327
60002269	Tetrachloroethylene (PCE)	Associated with 60001327

The main contamination plume to be concerned with is the city-wide PCE plume in Delano. There are three dry cleaners that have been identified so far. Three City of Delano wells were within 225 feet of the plume and were destroyed in July 1995. City of Delano Well 22 is the closest active well to the plume; however, none of the city's wells have had any PCE detections so far. It is unknown if there are any other domestic wells within the plume. PCE has been detected as high as 420 ppb in one of the monitoring wells near the site. Groundwater samples have been collected between 105 to 250 feet below ground surface and levels have generally decreased with depth, except for one sample. Studies conducted so far at this site show that PCE is generally not detected above reporting limits at depths greater than 230 feet below ground surface or in samples collected more than a quarter mile downgradient of the potential source area. A Geosyntec report dated August 8, 2018 indicates that the Corcoran Clay is approximately 250 feet below ground at the site and believes that PCE, if present in a dense non-aqueous phase, would sink in groundwater but not below the clay. This still needs to be confirmed since a lower confining unit has not been encountered yet. Investigative work is still in progress and includes further groundwater investigation work and more monitoring well installations to better define the lateral and vertical limits of the plume. Figure 2-25 shows the locations of these contamination sites.

Groundwater Quality Findings

Based on data evaluated in this groundwater characterization, sodium is the primary constituent of concern for SSJMUD. Salinity is strictly an agricultural concern and arsenic is strictly a drinking water concern. All other constituents that were evaluated are not as great of concern since the concentrations and overall impact to this region are low.

Overall, sodium is of great concern for the District. 64 percent of the municipal wells are over the sodium Ag limit. Since the land use in SSJMUD is about 81 percent agricultural, the focus of the water quality evaluation for salinity, was sodium due to its impact the agricultural industry. High sodium levels pose a sodium hazard to crops. Sodium levels were observed to be elevated throughout the District. Management actions will need to be established to limit the impact to the agricultural industry from increasing sodium levels.

Following sodium, TCP and arsenic are of concern. TCP was elevated in about 36 percent of the municipal wells within the District. Elevated TCP wells are located throughout the District's

service area. Arsenic was elevated in about 33 percent of the wells. High arsenic wells are predominately located in the northwestern portion of the District's service area where the Corcoran Clay is present. For wells within the Corcoran Clay, it was observed that wells deeper than 1,200' had arsenic levels at or above the MCL. This same trend was observed for wells outside the clay.

Overall, nitrate was not seen as a concern. About 24 percent of the wells exceeded the MCL. Since nitrate is a surface contaminant, it is expected for wells with shallow screened intervals or annular seals to typically show the highest levels of contamination. More data, such as well construction information will be valuable to determine if there are any trends observed. To comply with the Human Right to Water, nitrate levels will need to be closely monitored and management actions will need to be in place to comply with the nitrate drinking water standard.

Contamination plumes were identified using the GeoTracker and EnviroStor databases. Of the plumes identified, the main one of concern to the District is the city-wide plume in Delano. So far, no drinking water wells have been impacted. However, much work still needs to be completed to determine the extent of the plume, both laterally and vertically.

From this water quality evaluation, sodium, TCP, and arsenic are the constituents of concern for SSJMUD's service area. These constituents will impact both the agriculture industry and public health. More information such as well construction information and water level data are necessary to determine if there are any relationships with constituent levels. All other constituents that were evaluated are not as great of a concern since the concentrations and overall impact to this region are low. Public health related constituents, TCP and arsenic already has an impact to public water systems that are already exceeding the respective MCLs but unable to provide treatment for the wells. There are disadvantaged communities among the District and it is anticipated that the Needs Assessment study will capture the domestic wells within Kern County to better understand the water quality impacts to these communities. If sodium levels continue to elevate or become more prominent in the area, it will become detrimental to the agricultural industry. This can greatly impact this industry since it is one of the primary economic livelihoods for the county.

2.3.5 *Land Subsidence*

As described in the KGA GSP Basin Setting, inelastic (irrecoverable) land subsidence (subsidence) is a potential concern in areas of active groundwater extraction with underlying fine-grained sediment, such as in the study area. Increased potential for Undesirable Results may occur due to subsidence. Undesirable Results of subsidence may include, but are not limited to, flood risk in low lying areas; well casing damage or collapse; canal and infrastructure damage or collapse; and reduced groundwater storage (LSCE, 2014).

According to DWR (2014), the Kern County Subbasin was rated at a high potential for future subsidence, due to 1) most of the wells monitored with water levels at or below historical lows; 2) documented historical subsidence; and 3) documented current subsidence. Moreover, greater

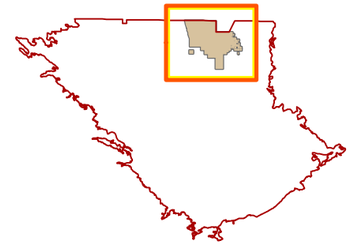
CONTAMINATION SITES WITHIN SSJMUD

Site Types from Envirostor and Geotracker Databases

- Cleanup Program Site (Open)
- LUST Cleanup Site
- DTSC Site Cleanup Program (Active)
- Other Evaluation (Current or Inactive)

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Kern County, California

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AUGUST 2019 FIGURE 2-25

SOURCE: DTSC EnviroStor/SWRCB GeoTracker (2019)

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amounts of subsidence are occurring to the north of Kern County boundaries in the Tulare Subbasin. The amount of future subsidence will depend on whether future water levels decline below previous low levels and remain low for a considerable amount of time. Maintaining water levels above the previous low water levels may limit the risk of future subsidence.

Several processes contribute to subsidence in the Subbasin and include, in order of decreasing magnitude: aquifer compaction by overdraft, hydro compaction (shallow or near-surface subsidence) of moisture deficient deposits above the water table that are wetted for the first time since deposition, petroleum reservoir compaction due to oil and gas withdrawal, and subsidence caused by tectonic forces (Ireland et al., 1984).

Inelastic compaction (subsidence) typically occurs in the fine-grained beds of aquifers and in the aquitards. The fine-grained beds contain water in the pore spaces between the clay particles at the time of deposition and this water supports the clay particles which contributes to the thickness of the fine-grained bed. During dry conditions when surface water supplies are diminished, over-pumping of groundwater may cause a one-time release of water from the clay (dewatering). This one-time release is also referred to as the inelastic skeletal specific storage of clay. Once the clays dewater, the volume released from inelastic storage results in permanent realignment of the clay particles and the collapse of the clay layer structure, or permanent land subsidence. Although space within the overall aquifer is reduced by an amount equivalent to subsidence of the land surface (due to reduced thickness of the clay layers), this storage reduction does not substantially decrease usable storage for groundwater in the aquifer because the clay layers do not typically store significant amounts of recoverable, usable groundwater (LSCE, 2014). However, Ojha et. al. (2019), references recent studies suggesting that subsidence between 2007-2015 in the Central Valley (primarily San Joaquin Valley) resulted in losses of 0.4% to 5.25% storage capacity in the aquifer system. Although much this capacity mostly represents fine grained layers, this loss may impact the overall aquifer system by increasing the replenishment time of the aquifer which could pose further challenges to water management (Ojha et. al., 2019).

The one-time release of water compaction has been substantial in some areas of the Central Valley; and it is estimated that by the mid-1970s, about one-third of the volume of water pumped from storage in areas such as Los Banos-Kettleman City, came from compaction of fine-grained beds (Poland et al, 1975; Faunt et al, 2009); therefore, water budget projections may need to consider the one-time release of water from compaction as an irrecoverable water source for future projections. Although the largest body of fine-grained beds is the Corcoran Clay, a relatively insignificant volume of water has been released from storage in the Corcoran Clay (Faunt et al, 2009). However, aquifer water quality could be impacted by poor quality water released from the dewatering of clays, as postulated for an increase in arsenic (Smith et. al, 2018). The surface displacement of subsidence represents the reduced thickness of the impacted clay layers and this vertical displacement, if significant enough, may cause damage to wells and structures.

Groundwater overdraft is considered to be the primary driver of historical land subsidence in the Central Valley (Faunt et. al., 2009). USGS estimates that about 75 percent of the subsidence occurred in the 1950s and 1960s, corresponding to extensive groundwater development (Galloway, et al., 1999), prior to implementation of the SWP, CVP, and other development of surface water resources.

2.3.5.1 Subsidence Results and Methodology in the Study Area.

Results of subsidence estimates are summarized in the Table 2-12 below and on Figure 2-26 through Figure 2-30. In addition, time-series charts of subsidence are provided in Appendix J. Results were compiled from historical leveling surveys, recent GPS data, extensometer data, and satellite- and aircraft-based remote sensing.

Historical Results

Within the study area, historical subsidence has been documented from leveling surveys by the National Geodetic Survey at up to 6.5 feet from 1926 to 1970 (Ireland et al., 1984). Compaction data by the extensometers were plotted against the DWR water year indices. Greater rates of compaction generally correlated with low water year indices (critical, dry, or below normal) while compaction rates were lower during high water year indices (wet, and above normal).

In general, Figure 2-26 shows that centers of historical subsidence occurred northeast of SSJMUD and propagated outward to the south into SSJMUD.

CGPS

Recent subsidence studies of the Central Valley, and the Kern County Subbasin have utilized continuous GPS (CGPS) station data. The following CGPS stations are located in or near the study area: P544 (Twisselman Road), P545 (Lerdo Highway), P563 (Buttonwillow Rest Area), P564 (Wasco), and P565 (Delano), respectively located west of SWSD along I-5 and Twisselman Road, southwest of SWSD (along I-5 just north of Lerdo Highway), south of SWSD along I-5 at the Buttonwillow Rest Area, within SWID at Wasco Airport, and to the north of NKWSD at Delano Municipal Airport. These CGPS stations are monitored as a part of Unmanned Aerial Vehicle Synthetic Aperture Radar's (UNAVCO) Plate Boundary Observation (PBO). Day-to-day CGPS height solutions vary by as much as about 35 mm, likely due to variable atmospheric conditions, random walk noise, and other effects not directly related to land-surface-elevation change (Zerbini and others, 2001; Williams and others, 2004; Langbein, 2008) and, for this reason, short-term day-to-day comparisons of CGPS data to characterize land subsidence in the Central Valley is not ideal. Based on the time-series charts in Appendix J, CGPS data are more meaningful in characterizing land subsidence when looking at quarterly and annual trends. Therefore, cumulative subsidence and rates of subsidence were calculated by taking averages of the dataset for each water year. Note: For CGPS data plotted with InSAR data (Figure 2-27 through Figure 2-30), cumulative subsidence and rates were by daily averages.

In general, CGPS data show subsidence in the SSJMUD region with relatively modest declines (P544, P545, P563) and much higher decline (P564 and P565) in Wasco and Delano.

HISTORICAL LAND SUBSIDENCE

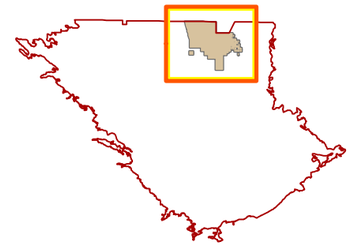
- Line of Equal Subsidence (ft)
- Approximate Extent of Corcoran Clay

Subsidence 1926 to 1970

- More than 12 ft
- 10 to 12 ft
- 8 to 10 ft
- 6 to 8 ft
- 4 to 6 ft
- 2 to 4 ft
- 1 to 2 ft
- 0 to 1 ft

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

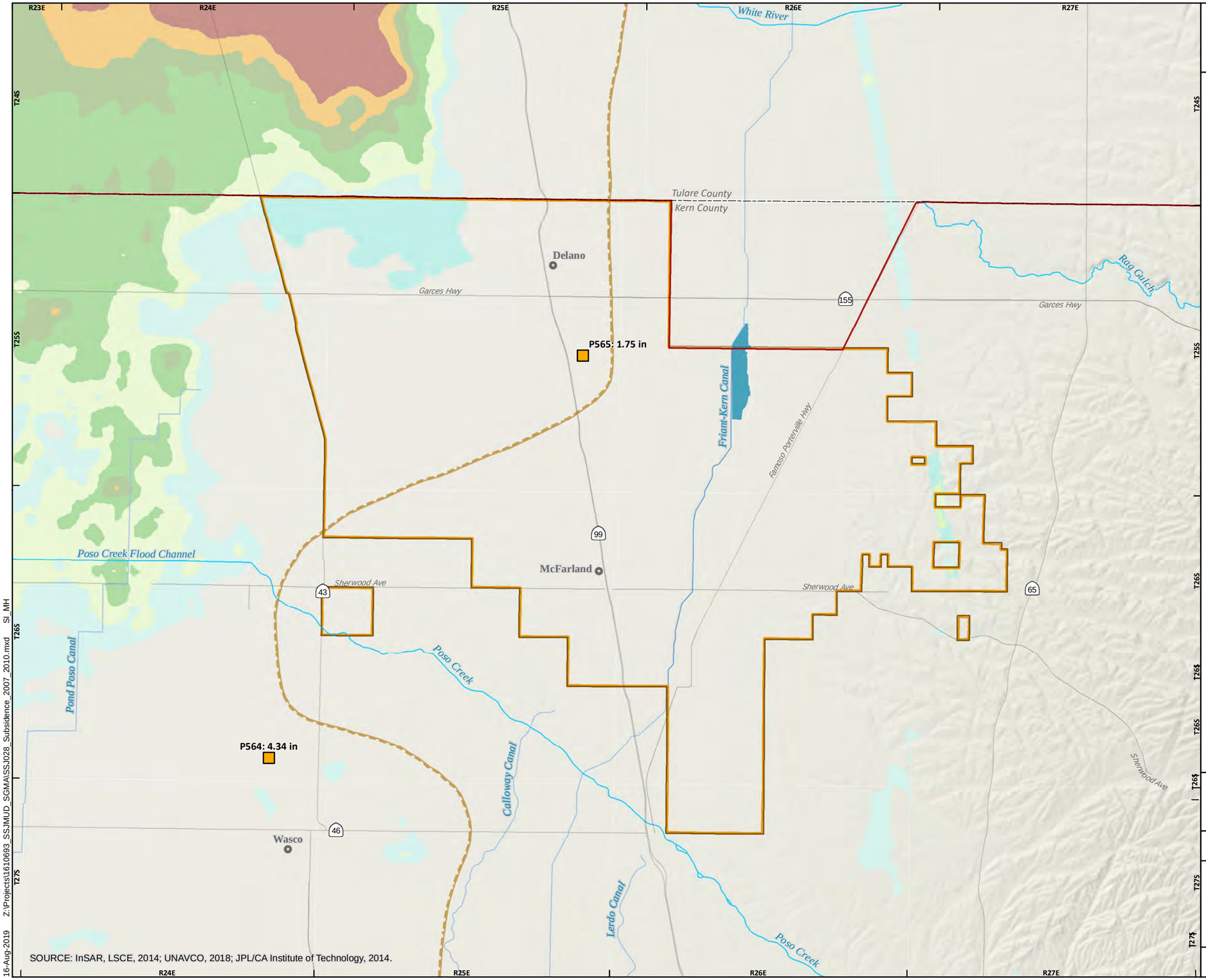
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FIGURE 2-26

SOURCE: Subsidence Contours by Geodetic Leveling (1926 - 1970), Ireland, 1984.

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LAND SUBSIDENCE 2007-2010

SOPAC Continuous GPS Monitoring Location

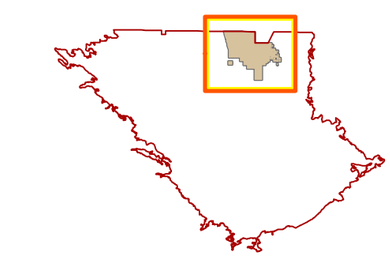
Approximate Extent of Corcoran Clay

Subsidence 2007 through 2010 (LSCE InSAR, 2014)

- 5 to 10 in
- 4 to 5 in
- 3 to 4 in
- 2 to 3 in
- 1 to 2 in
- 0 to 1 in

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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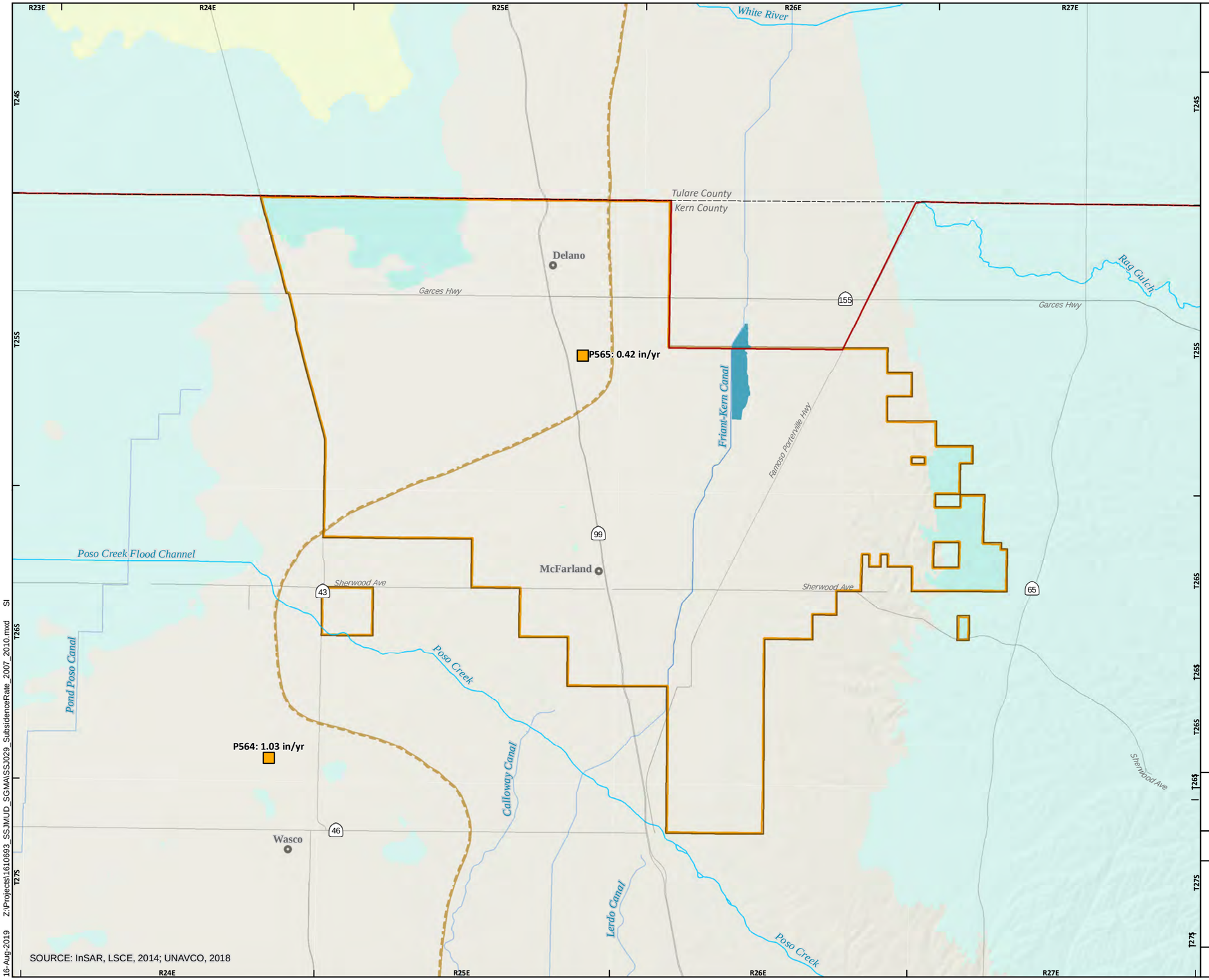
Southern San Joaquin
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Management Area Plan

Kern County, California

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AUGUST 2019 FIGURE 2-27

LAND SUBSIDENCE RATE 2007 - 2010



SOPAC Continuous GPS Monitoring Location

Approximate Extent of Corcoran Clay

Subsidence Rate 2007 to 2010

1 to 2 in/yr

0 to 1 in/yr

Management Plan Area

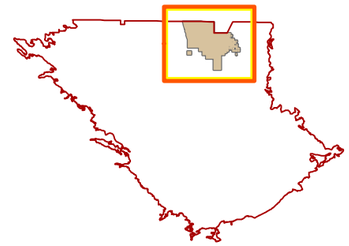
Southern San Joaquin MUD

Kern County Subbasin Boundary

Highway

Waterway

Major Conveyance



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Southern San Joaquin
Municipal Utility District
Management Area Plan

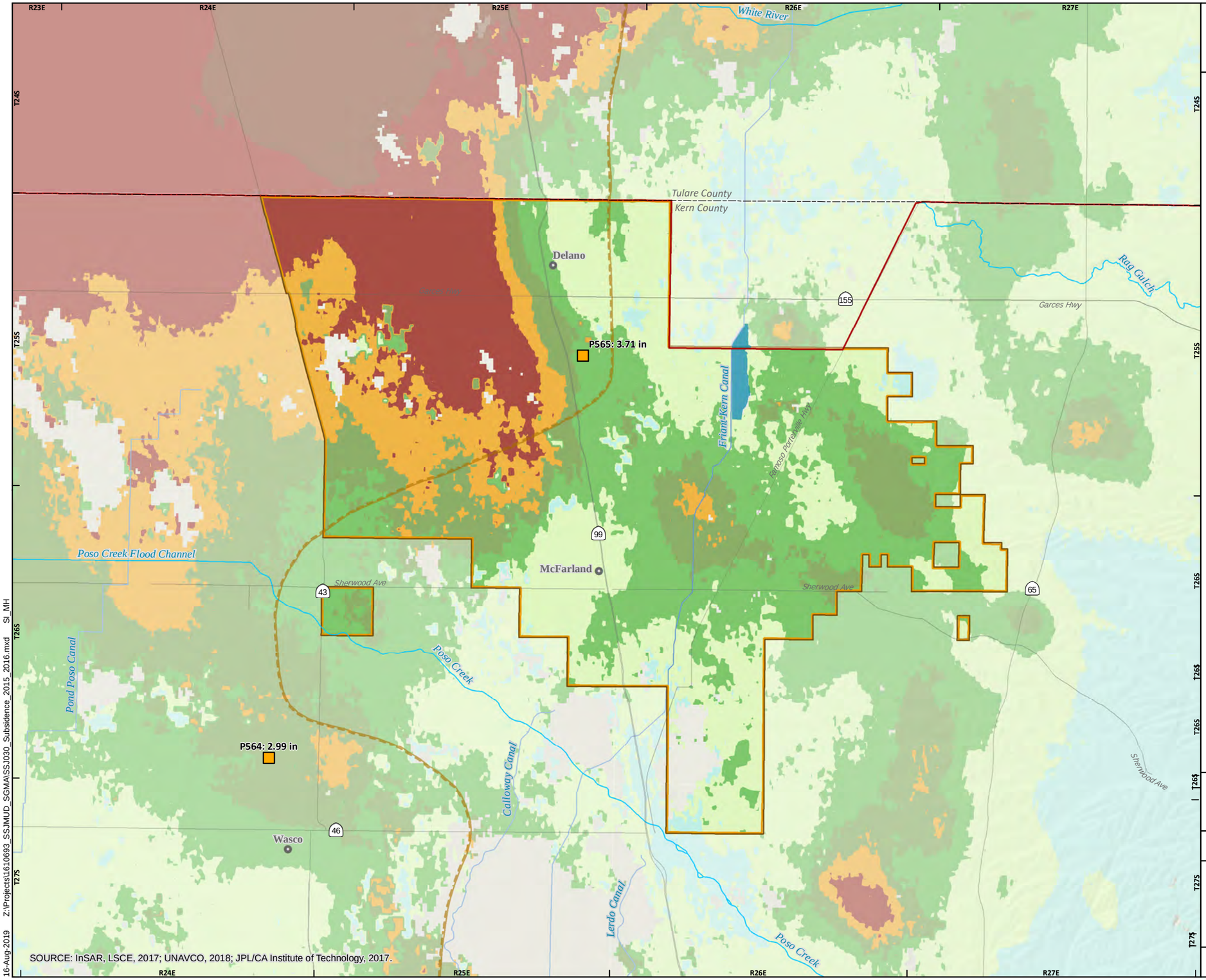
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FIGURE 2-28

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LAND SUBSIDENCE 2015 - 2017

SOPAC Continuous GPS Monitoring Location

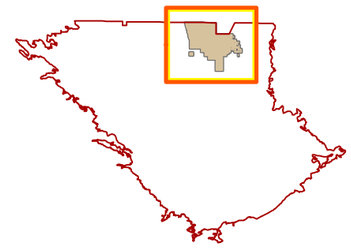
Approximate Extent of Corcoran Clay

Subsidence 2015 through 2016 (LSCE InSAR, 2017)

- 15 to 20 in
- 10 to 15 in
- 5 to 10 in
- 4 to 5 in
- 3 to 4 in
- 2 to 3 in
- 1 to 2 in
- 0 to 1 in

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Miles

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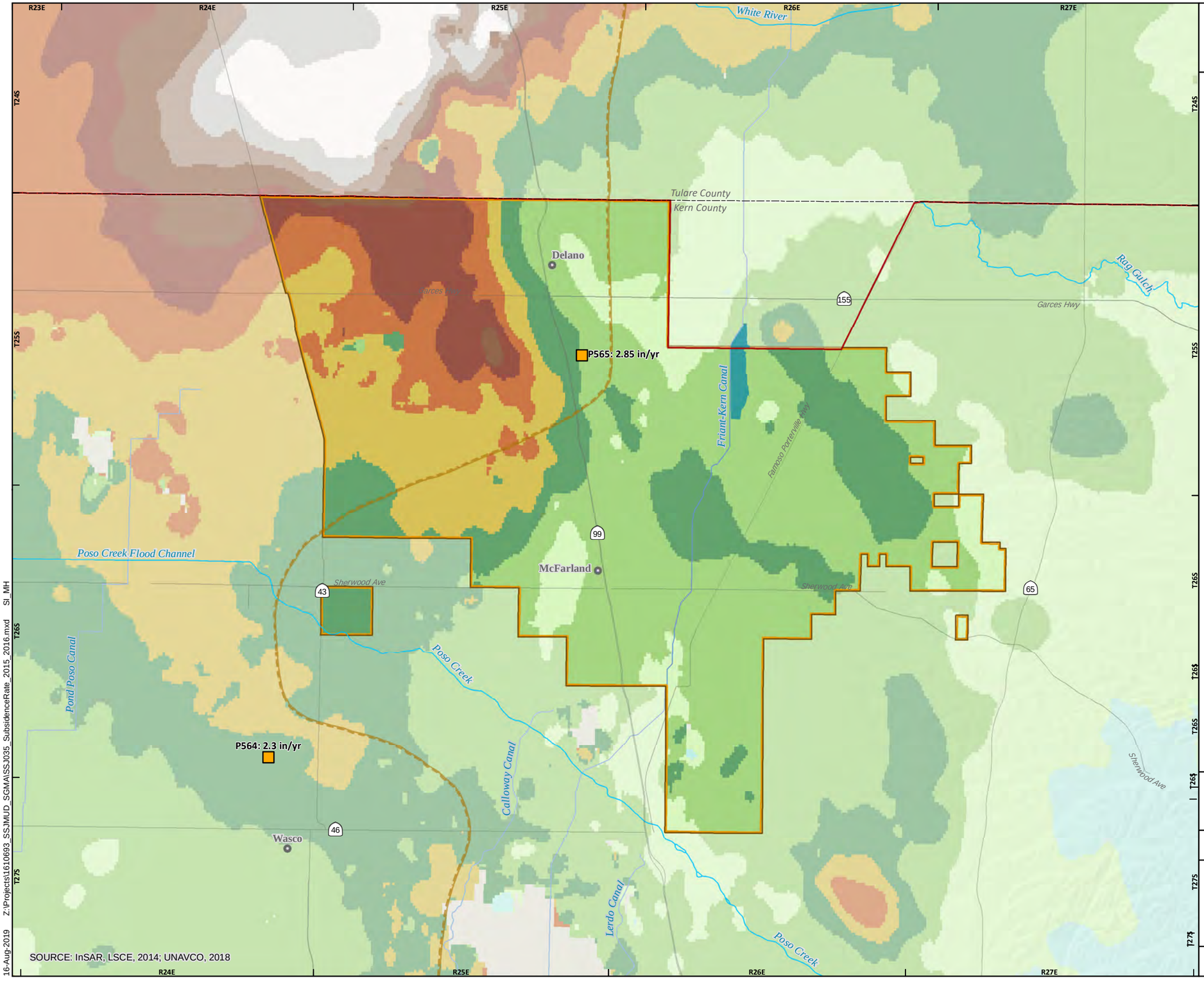
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Management Area Plan

Kern County, California

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FIGURE 2-29



LAND SUBSIDENCE RATE 2015 - 2017

SOPAC Continuous GPS Monitoring Location

Approximate Extent of Corcoran Clay

Subsidence Rate 2015 to 2016

- More than 10 in/yr
- 9 to 10 in/yr
- 8 to 9 in/yr
- 7 to 8 in/yr
- 6 to 7 in/yr
- 5 to 6 in/yr
- 4 to 5 in/yr
- 3 to 4 in/yr
- 2 to 3 in/yr
- 1 to 2 in/yr
- 0 to 1 in/yr

Management Plan Area

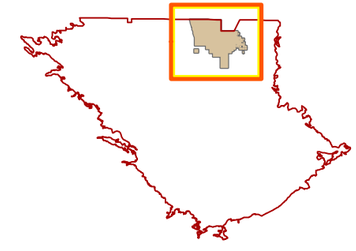
Southern San Joaquin MUD

Kern County Subbasin Boundary

Highway

Waterway

Major Conveyance



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Southern San Joaquin Municipal Utility District Management Area Plan

Kern County, California

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FIGURE 2-30

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Ojha et. al. (2019) incorporated many of these CGPS points in a regional Central Valley-wide study of subsidence and were able to estimate skeletal storage of the aquifer system at CGPS points in the Valley. This skeletal storage could then be used to estimate the loss in storage of the aquifer based on CGPS subsidence estimates. Ojha et. al (2019) found that elastic subsidence recovered after 10 to 20 months from when groundwater levels begin to recover.

Extensometer

SSJMUD does not currently have any subsidence monitoring points with its plan area. However, it is appropriate to consider monitoring on a basin-wide level because subsidence occurs on a regional scale. This would include the use of monitoring points in neighboring management areas. Semitropic currently maintains an extensometer (25S/22E-35B001) for monitoring compaction in the subsurface. This extensometer was completed to a depth of 900 feet below ground surface in 2006. The benefit of an extensometer over other datasets such as CGPS or Interferometric Synthetic Aperture Radar (InSAR), is that an extensometer measures a discrete subsurface interval, or typically the interval of the ground surface to the total depth of the extensometer. On the other hand, CGPS and InSAR monitor overall change in ground surface relative to a datum such as sea level, regardless of the depth interval. Moreover, InSAR provides information over a wide area.

Ideally, an extensometer should be installed below the base of the compacting aquifer system (Galloway et. al, 1999), to monitor the entire compaction zone. Although Page's base of freshwater and nearby supply wells to the southeast suggest the lower aquifer zone extends below the extensometer, the upper 900 feet that the extensometer monitors is a very active depth interval of groundwater production.

Extensometer data have been collected over time, and a consistent dataset from December 2013 to present is provided in the table below. Time-series (Appendix J) data show that between December 2013 and October 2016, the rate of subsidence recorded by 25S/22E-35B001 extensometer was nearly 1.0 inch per year. This rate is within the range of rates reported for CGPS points in the area (0.1 to 2.8 inches per year) and is consistent with the interpretation that higher rates of subsidence are northeast of SWSD and inside the northeast boundary of SWSD, while lower rates are observed in central SWSD, to the south and to the west.

Time-Series Data

Time-series data (Appendix J) present cumulative subsidence from approximately 2006 to 2017 with corresponding water level elevation hydrographs observed from nearby wells. Below normal to "critical dry" water years are shaded in yellow, while above normal to "wet" water years are shaded in gray. All wells are within the lower zone or main production groundwater zone unless noted with "upper zone".

Variation in subsidence on the time-series is a function of:

- elastic subsidence to inelastic subsidence as well as the lag time of subsidence after the main pumping season,

- the distribution of fine-grained sediments in the subsurface,
- the amount of water pumped from fine-grained units, and
- potential near-surface factors such as shrinking and swelling of some soil types due to precipitation or other factors.

All the factors mentioned above may introduce additional signals or noise to the CGPS data; however, general broad trends are discernible when plotting data with water year type and nearby water levels. In the future, more water level monitoring and pumping data in areas near these CGPS stations may provide finer resolution of data to interpret lag times, elastic changes, and other short-term signals.

Based on the attached time-series, residual subsidence persists after each pumping season (especially in dry years) for relatively long periods of time (several months to over a year). Researchers note that delayed or residual subsidence response may occur in the Central Valley for years after pumping (USGS, 2018b).

The following observations were derived from the time-series data:

- P544 (Twisselman Road) shows increasing subsidence associated with dry years. Subsidence may lag up to 6 months after pumping season, while long-term residual subsidence and elastic rebound is observed from 6 to 18 months. No water level data in nearby pumping zones were available. Only water levels from shallow monitoring piezometers are plotted on this chart.

- P545 (Lerdo Highway) shows increasing subsidence associated with dry years and water level decline in the lower zone. Water levels and some elastic subsidence may recover/rebound within a month of the beginning of a wet water year; however, both elastic and inelastic subsidence lags for at least 6 to 18 months or longer after a dry year. Subsidence rates trend more with lower zone water levels than upper zone water levels. The included upper zone well is located in Buena Vista Water Storage District (BVWSD), is in the upper zone above the "E" Clay or equivalent and may vary over time because of groundwater production in the upper zone that occurs in BVWSD.

- P563 (Buttonwillow Rest Area) data are similar to P545, with subsidence associated with dry years and the rebound from elastic subsidence due to wet year conditions and stabilization of water levels. The subsidence time lag is evident in the elastic recovery from April 2011 to summer 2012. Similar to P545, changes in subsidence rates do not correlate significantly with upper zone water levels. Subsidence rates are associated with decline in water level from the lower zone.

- Data for SWSD Extensometer 25S22E35B001M are collected monthly to quarterly rather than daily, so any small-scale noise, rebound, or recovery aren't seen in the data. Consequently, subsidence may be more apparent in the extensometer data while water levels are variable during each year. Continued monitoring may confirm the

consequences of residual drawdown during sequential wet years. In general, subsidence or compaction occurs during dry years, and a decrease in the rate of subsidence is observed during wet years.

- P564 (Wasco) within SWID. In general, rates of subsidence increase during dry years and decrease during wet years. Between 2009 to 2011, elastic rebound (recovery) appears to outgain inelastic subsidence. On the other hand, between the wet year 2016 to 2017, subsidence continued but at a low rate even after some recovery of water levels. Note: P564 subsidence data are plotted on a smaller vertical scale (from -2 to 18 inches) than P545 and P563. As a result, smaller monthly changes in subsidence observed in the latter, aren't as apparent in P564

- P565 (Delano) within SSJMUD, also plots subsidence on a smaller vertical scale. P565 shows a lesser rate of subsidence between 2006 and 2009 in comparison to P564 but shows a similar rate of decline between 2011 and 2016. Overall, subsidence at P565 increases during dry years and decreases in wet years. A slight elastic rebound is observed in wet years. This plot is consistent with overall regional trends of declining water levels during the drought.

Remote Sensing

Recent investigations of land surface subsidence include Satellite-based Interferometric Synthetic Aperture Radar (InSAR), aircraft-based L-band SAR or Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR). The data from these remote sensing techniques have been processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL). Reported data have been published in a subsidence study commissioned by the California Water Foundation (LSCE, 2014), and by JPL via the DWR SGMA Data Viewer (DWR, 2018b) and the DWR website (Farr et al, 2015, Farr et al, 2016). The InSAR data were processed from a group of satellites including but not limited to: Japanese PALSAR, Canadian Radarsat-2, and European Space Agency's (ESA) satellite-borne Sentinel-1A. Data reported herein are from 2006 to 2017 with a gap from 2011 to 2014 when satellite outage occurred before the launch of the ESA's Sentinel satellites in 2014.

Ojha et. al. 2019, compared InSAR vertical displacement time series against CGPS and extensometer data by averaging the value of InSAR pixels within 200 m of each GPS and extensometer station. They found a good agreement between InSAR measurements and CGPS and extensometer data. The average standard deviation of the difference between InSAR and GPS was 0.9 inch, and between InSAR and extensometer data was 0.6 inch (Ojha et. al, 2019). The agreement of InSAR with extensometer measurements indicates that the majority of the compaction measured by InSAR occurs in the same depth intervals as extensometers and that any change or compaction in the subsurface below the average extensometer depth (1300 feet) is negligible.

DWR is currently evaluating the remote sensing data with in-field measurements, such as from CGPS stations, as a means of "ground truthing" the remote sensing data (Mardock, 2018). This plan does not intend to validate the InSAR data, but only to present it as best available regional data. Data gaps are undoubtedly present, and therefore, the discussion below is a qualitative interpretation of the data. Nonetheless, cumulative subsidence and rates of subsidence, based on InSAR data, are also provided in the table below and in the attached figures.

Along with InSAR data, the CGPS data for P564 and P565 are plotted as cumulative subsidence on Figure 2-27 and Figure 2-28. Evaluating spatial distribution of land subsidence. Data from 2007 to 2011 show subsidence of 1.7 inches in CGPS points within SSJMUD and 0 to ~1.2 inches for InSAR data within SSJMUD. Data from 2015 to 2016 show subsidence of 3.7 inches in CGPS points within SSJMUD, and 0 to ~8 inches for InSAR data within SSJMUD.

Discussion of Results

Overall, the subsidence data indicate that centers of greatest decline, both historically and recently, occur north of the study area in the adjacent subbasin and propagate outward to the south, west, and southwest into Kern. As a qualitative observation, the CGPS, extensometer, and InSAR data agree with the trends as stated above. From a quantitative standpoint, the magnitude of subsidence reported from InSAR from 2015 to 2016 is much higher than surrounding CGPS and extensometer data points. In the future, additional monitoring points would be beneficial to corroborate the highest subsidence rates detected by InSAR in northwest SSJMUD.

Based on time-series data, subsidence appears generally to trend with water levels from lower zone wells – deeper wells with screens below confining clays ("E" clay or equivalent), which are more likely to dewater fine-grained beds below the confining units. Consequently, recent subsidence does not trend as closely with upper zone water levels.

Continued monitoring of water levels, pumping, and subsidence, as well as more detailed subsurface lithologic characterization may provide a better dataset for future projection of subsidence. At this time, the calculated rates of subsidence have been posted on the results table and the time-series charts. These historical rates present an estimate of possible future subsidence rates if groundwater extraction continues at the current rate.

Table 2-12: Subsidence Results

District Area	Date Range	Approximate Cumulative Subsidence (inches)	Approximate Annual Rate of Subsidence (inches/year)	Source
North of SSJMUD boundary (Historical)	1926 to 1970	0 to 150	0 to 3.4	Ireland, 1984. Topographic Maps and Leveling Data
North of SSJMUD boundary	2007 to 2011	4 to 12	1.0 to 2.9	LSCE, 2014. JPL InSAR
West, South, SW SSJMUD (Historical)	1926 to 1970	0 to 48	0 to 1.1	Ireland, 1984. Topographic Maps and Leveling Data.
NE SSJMUD	1926 to 1970	48 to 120	1.1 to 2.7	Ireland, 1984.
West SSJMUD	1926 to 1970	12 to 48	0.3 to 1.1	Ireland, 1984.
Central SSJMUD	1926 to 1970	12 to 48	0.3 to 1.1	Ireland, 1984.
	1962 to 1970	12	1.5	Poland et al, 1975.
SWID. Wasco Proximity	Oct-06 to Oct-09 Jan-07 to Mar-11 Oct-11 to Oct-16 Spring-12 to Jul-17 May-15 to Sep-16 Dec-13 to Oct-16	5.5 4.3 10.3 10.7 3.0 6.8	1.8 1.0 2.1 2.0 2.3 2.4	CGPS PBO (P564).
SSJMUD. Delano proximity	Oct-06 to Oct-09 Jan-07 to Mar-11 Oct-11 to Oct-16 Spring-12 to Jul-17 May-15 to Sep-16 Dec-13 to Oct-16	2.0 1.7 10.7 11.0 3.7 8.0	0.7 0.4 2.1 5.3 3.0 2.8	CGPS PBO (P565).
SSJMUD extent	Jan. 2007 to Mar. 2011	-2.7 to 4	0.6 to 1	LSCE, 2014. Compiled from InSAR (negative values are potential uplift in land surface).
North of SSJMUD boundary		4 to 12	1.0 to 2.9	
SSJMUD extent	May 2015 to Sept. 2016	0.4 to 10.4	0.3 to 7.8	InSAR ESA Sentinel-1A (Farr et al., 2016)
North of SSJMUD boundary		1.1 to 16	0.8 to 12.3	

Future Data Availability and Subsidence

According to USGS, the ESA's Sentinel satellites collect InSAR data at an approximate weekly rate, and data are available for download and interpretation (personal communication, USGS). These InSAR data are available but will require users support for the interpretation and distribution of the information. Likewise, CGPS data will likely to be available for future use. DWR is currently evaluating the remote sensing data with in-field measurements such as from CGPS stations, as a means of "ground truthing" the data (Mardock, 2018). Continued improvements in data interpretation and processing will benefit remote subsidence monitoring along with continued collection of CGPS and extensometer data. Figure 2-31 shows the locations

of CGPS locations and FKC Benchmark survey locations within SSJMUD that will be used for future subsidence monitoring. Further discussion of subsidence monitoring will be addressed in the Monitoring Networks section of this report.

2.3.6 *Interconnected Surface Water Systems*

Interconnected surface water systems are surface waters that are hydraulically connected by a continuous saturated zone to an underlying aquifer. There are no known natural interconnected surface water systems near SSJMUD since the subsequent impoundment and regulation of flow of the Kern River and groundwater pumping.

Apart from managed surface water to natural drainages in the study area, Poso Creek channel is the only channel that experiences natural recharge from the surrounding highlands. However, Poso Creek is ephemeral and only flows during limited "wet" months of some "wet" years.

2.3.7 *Potential Groundwater Dependent Ecosystems*

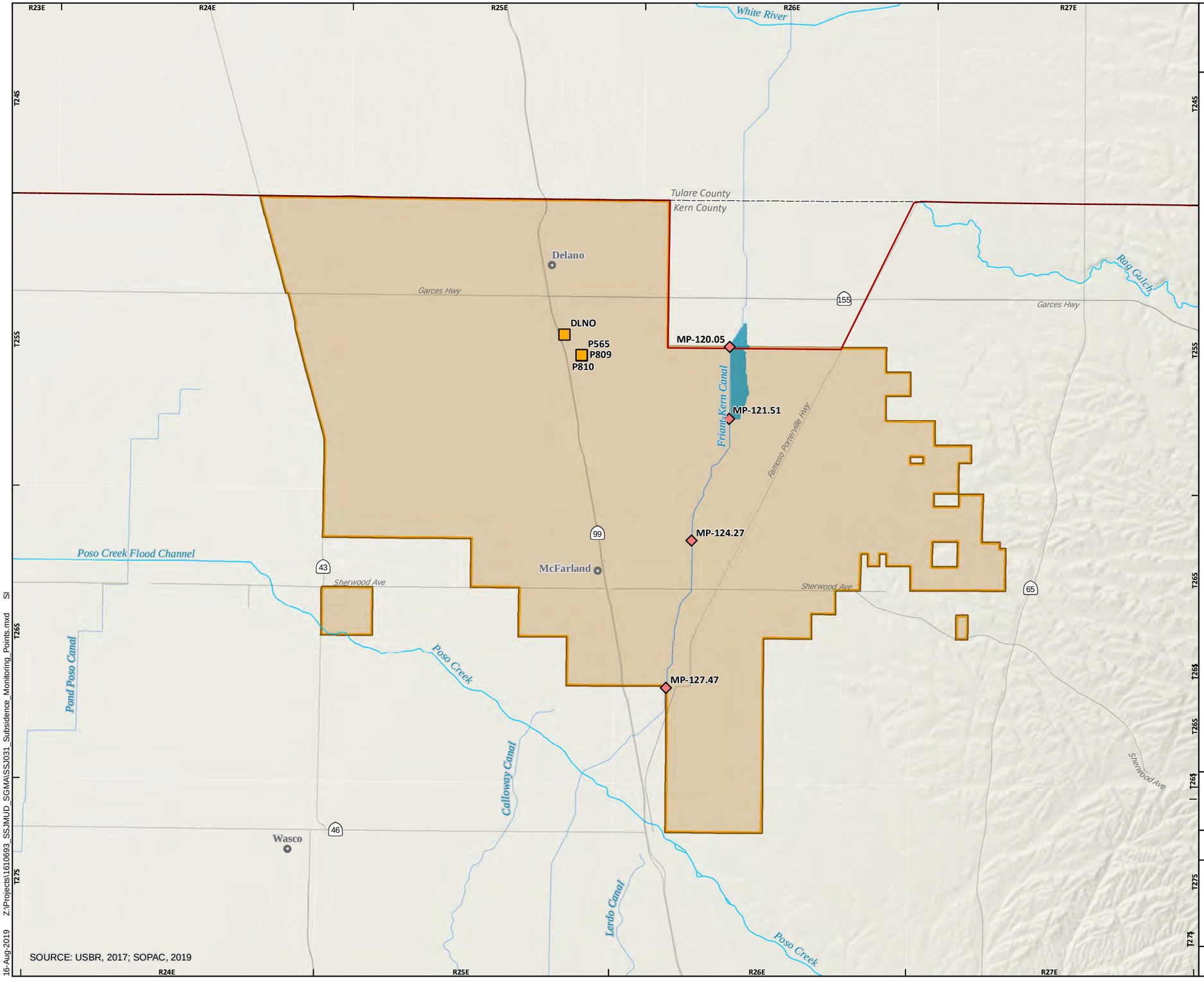
SGMA defines a Groundwater Dependent Ecosystem (GDE) as ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. SGMA states that a GSP shall include impacts on GDEs but does not explicitly state the requirements that warrant a GDE to be eligible for protection.

The first step in evaluating a potential GDE is to identify vegetation communities that are typically associated with groundwater, and secondly, to confirm the presence of shallow groundwater that could support potential GDEs. Lastly, is to evaluate any active groundwater pumping that could lead to shallow groundwater level change in the vicinity of potential GDEs.

In SSJMUD, there are no known GDEs. Many of the vegetation communities that could be potential GDEs are likely to be associated with managed wetlands and riparian areas that are supported by a combination of groundwater and imported surface water. In addition, other potential habitats include ephemeral wetlands covered by water seasonally but supported by irrigation deliveries and precipitation, and groundwater recharge basins that are artificially flooded with surface water.

Currently, the best available dataset for evaluating the occurrence of vegetation communities that are typically associated with groundwater is the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset (DWR, 2018c). DWR has stated that use of the NCCAG dataset is not mandatory and does not represent DWR's determination of a GDE. Rather, NCCAG can provide a starting point for the identification of GDEs within a groundwater basin (DWR, 2018c).

The NCCAG dataset maps vegetation in the northwest part of SSJMUD. There are no known natural or surface water features that support shallow groundwater in SSJMUD. KCWA has not mapped shallow groundwater in SSJMUD. Therefore, further investigation may be warranted to understand the NCCAG dataset mapped in the district.

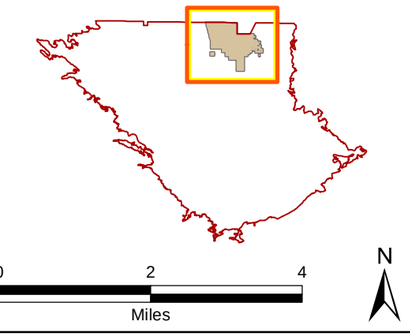


SUBSIDENCE MONITORING POINTS

- USBR Friant-Kern Benchmark Subsidence Survey
- SOPAC Continuous GPS Monitoring Location

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

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AUGUST 2019 FIGURE 2-31

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Below is a discussion of the NCCAG dataset. For reference, the NCCAG vegetation and wetlands data are presented in Figures 2-32 and 2-33, respectively. Distribution of mapped NCCAG vegetation occurs in the natural lowlands along Poso Creek.

2.3.7.1 Review of NCCAG Dataset Components

The NCCAG dataset was compiled based on 48 layers of publicly available data sets developed by state or federal agencies that map vegetation, wetlands, springs, and seeps in California (DWR 2019). A technical working group with representatives from DWR, California Department of Fish and Wildlife (CDFW), and TNC reviewed the datasets compiled to assemble the NCCAG. This dataset attempts to extract mapped vegetation and wetland features that have indicators suggesting dependence on groundwater. The data presented in NCCAG display vegetation polygons that have indicators of GDEs based on published and/or field observations of phreatophytic vegetation characteristics in California, flooding frequency, or areas classified as perennial hydrologic features. A phreatophyte is defined as a "deep-rooted plant that obtains water that it needs from the phreatic zone (zone of saturation) or the capillary fringe above the phreatic zone" (TNC 2018). The dominance of phreatophytic plant species in a mapped vegetation type is a primary indicator of GDEs. A list of plant species considered to be phreatophytes based on review of peer-reviewed scientific literature on rooting depths, published lists of phreatophytes, expert field observations, and vegetation alliance descriptions is publicly available (Klausmeyer et al. 2018, TNC 2018).

While developing the NCCAG dataset of areas with indicators of GDEs, the technical working group attempted to exclude vegetation and wetland types and polygons that are less likely to be associated with groundwater (Klausmeyer et al. 2018). For example, riparian vegetation along perennial mountain streams is generally not in the NCCAG dataset, because although these communities contain species that can act as phreatophytes, vegetation at those sites is generally sustained by surface waters that are not locally interconnected with shallow groundwater aquifers. The working group also attempted to remove any polygons that are not likely to be GDEs where they occurred in areas where they are more likely supported by alternate artificial water sources (e.g. local seepage from agricultural irrigation canals), or where appropriate available data indicated the shallow groundwater depth is located well below the rooting zone (Klausmeyer et al. 2018).

The Vegetation Classification and Mapping Program (VegCAMP) and National Wetland Inventory (NWI) are the vegetation mapping datasets that cover the water districts of interest and a discussion of each dataset follows below.

The VegCAMP dataset is the primary vegetation base layer used for the NCCAG dataset. Fish and Game code Section 1940 directed CDFW to develop and maintain a standardized vegetation dataset for the state of California, which conforms to the U.S. National Vegetation Classification Standards, and to produce a hierarchical classification of vegetation types. VegCAMP is the product of the Survey of California Vegetation (SCV). Vegetation polygon attributes are assigned to the alliance taxon level in the hierarchical classification system, when possible. An

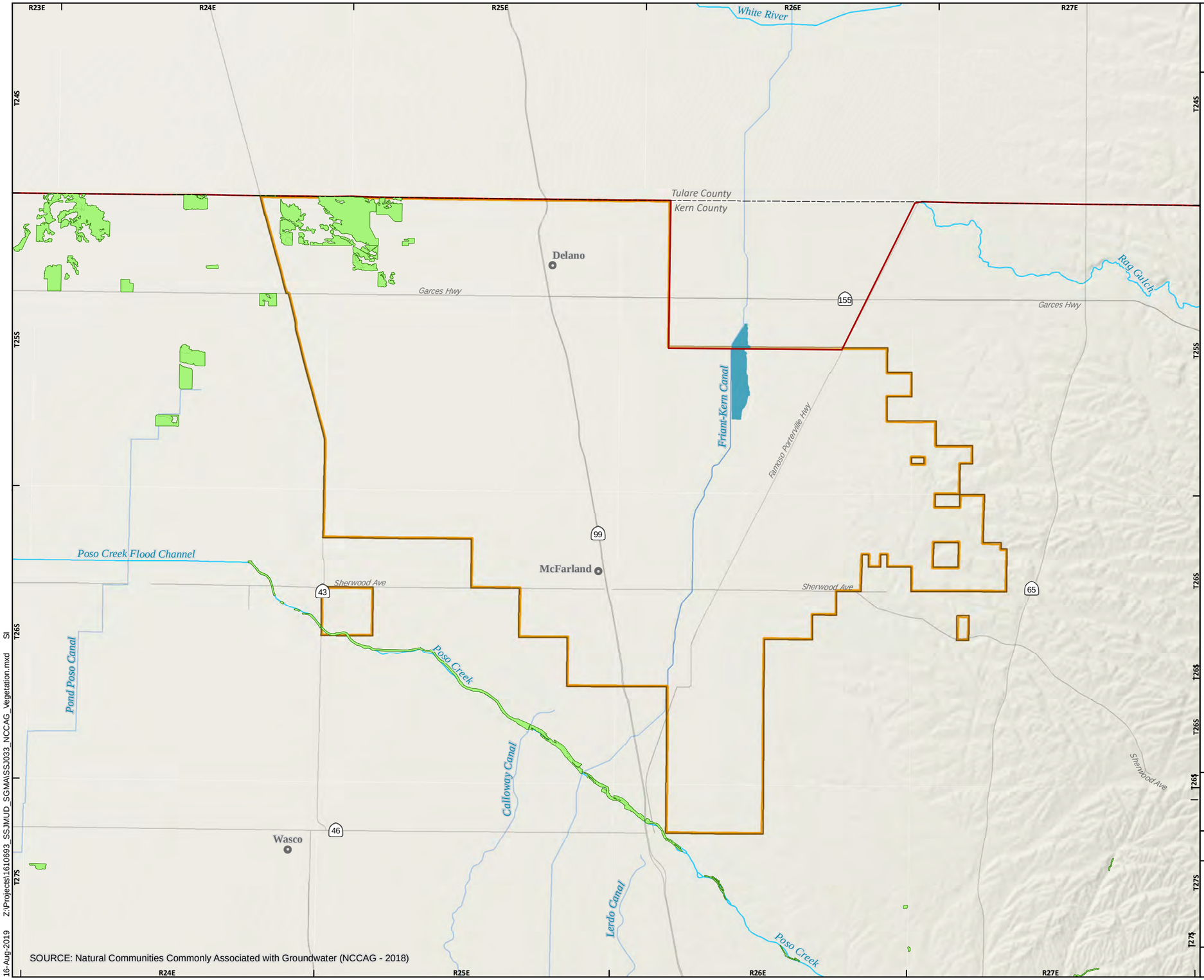
"alliance" is a lower taxonomic rank that is based on plant species composition as compared to higher taxon levels that more broadly define the life form (tree, shrub, or herbaceous) and ecological drivers (e.g., climate, regionalism). The alliance-level taxon is a group of diagnostic plant species that repeat across a landscape reflecting regional to sub-regional climate, substrate, hydrology, moisture/nutrient factors, and disturbance regimes. The VegCAMP data also includes polygons of group-level, which are higher level and less specific than alliance level descriptions. Alliances are defined and described in detail by A Manual of California Vegetation (Sawyer et al. 2009).

The VegCAMP vegetation maps are geospatially registered polygons that are digitized on base imagery that meets or exceeds the National Agricultural Imagery Program (NAIP) resolution standards of 1-meter ground sample distance. VegCAMP is considered the highest resolution data source for California vegetation mapping and is therefore used as the basis of the NCCAG dataset. The minimum map unit (MMU) of VegCAMP data is typically 1–2 acres, with a maximum of 10 acres; wetlands identified in VegCAMP have an MMU of 0.25 acre with the minimum polygon width of at least 10 meters (DWR 2018c). Accuracy Assessments are conducted in-field as a form of quality control, to correct any specific and systematic errors prior to map finalization and release. SCV requires every map to be verified and to meet a standard of at least 80 percent overall accuracy between map units and spot checks, and the maps typically exceed this standard. Data gaps and overlaps are ideally eliminated through geodatabase quality checking of each map (CDFW 2018).

The National Wetland Inventory (NWI) created by the U.S. Fish and Wildlife Service (USFWS) is a mapping tool that identifies wetlands by type, based on the Cowardin classification (Cowardin et al. 1979), and distribution throughout the United States. NWI relies on trained image analysts to digitize wetland habitats, which are identified based on vegetation, visible hydrology and geography. Mapping is completed at 1:24,000 scale (1-inch equals 2000 feet). A margin of error is inherent in the identification of wetlands on imagery; thus, detailed on-the-ground inspection of any site may result in revision of the wetland boundaries or classification established through image analysis (USFWS 2018). In the continental United States, NWI uses a target MMU of 0.5 acre (USFWS 2015). Certain types of "farmed wetlands" and submerged aquatic vegetation found in intertidal and subtidal zones of estuaries are specifically excluded from the NWI dataset.

2.3.7.2 Conclusions

As state in the introduction of this section, there are no known GDEs in SSJMUD. Although NCCAG data are mapped within the Poso Creek channel and in the northwest corner of the District, persistent shallow groundwater has not been documented in either location. Poso Creek is ephemeral and rarely flows west of SR-99. Based on the data gaps discussed in the above description, a field survey may be warranted to identify some of the NCCAG species listed in the Poso Creek area and in the northwestern portion of the District. In addition, field investigation of any potential shallow water table within the Poso Creek channel may be informative.



NCCAG VEGETATION

Vegetation (NCCAG)

Management Plan Area

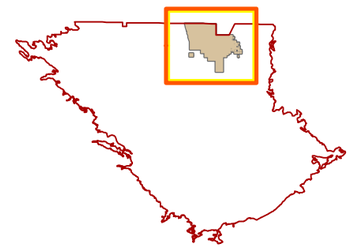
Southern San Joaquin MUD

Kern County Subbasin Boundary

Highway

Waterway

Major Conveyance



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Southern San Joaquin
Municipal Utility District
Management Area Plan

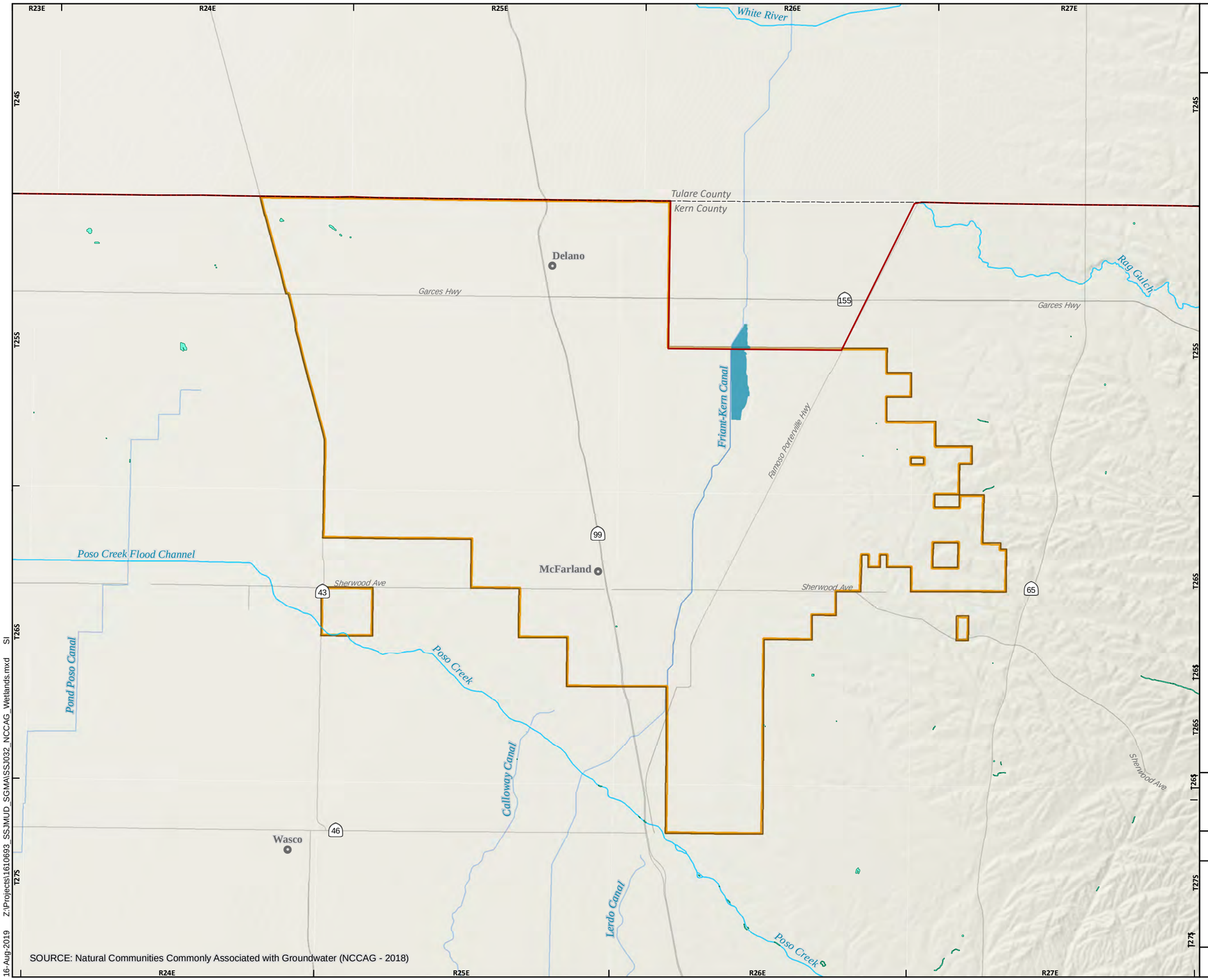
Kern County, California

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AUGUST 2019

FIGURE 2-32

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NCCAG WETLANDS

Wetlands (NCCAG)

Management Plan Area

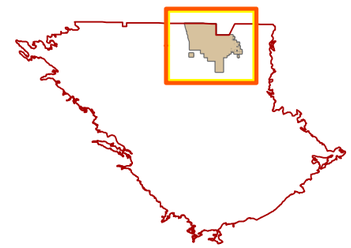
Southern San Joaquin MUD

Kern County Subbasin Boundary

Highway

Waterway

Major Conveyance



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Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

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AUGUST 2019

FIGURE 2-33

2.4 Management Areas within SSJMUD

This management area plan covers the jurisdiction of SSJMUD as shown in Figure 2-34. Management areas for the districts described in this management area plan are defined as follows:

2.4.1 *SSJMUD District Management Area*

The "District" management area consists of the land located within the boundaries of SSJMUD, including those undistricted "islands" that are entirely within SSJMUD and lands within the limits of the cities of Delano and McFarland. These areas are subject to the sustainable management criteria, projects, and management actions defined by SSJMUD in this plan.

2.4.2 *SSJMUD Undistricted Management Area*

The "Undistricted" management area consists of the land located adjacent to SSJMUD's boundaries which are to be covered for SGMA compliance with the District's management area plan. In 2019, Kern County withdrew from membership in the KGA, which resulted in undistricted lands of the Subbasin no longer being covered under the KGA's GSP. In order to give landowners a method by which they could comply with SGMA, the Member Agencies of the KGA engaged with landowners to establish agreements by which the landowner would be covered by the sustainable management criteria, projects, and management actions of a district without annexation into that district. SSJMUD has entered into agreements with landowners who represent 320 acres of undistricted land.

2.5 District Water Budget

All GSAs in the Kern County Subbasin coordinated and collaborated on the development of a groundwater model (Model) to evaluate historical, baseline and projected groundwater conditions. The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop the Model on behalf of the Subbasin. The contract required that Todd Groundwater use the C2VSim model provided by DWR. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (see Attachment H in Umbrella GSP). Basin-wide water budget results from the Model are provided in Attachment H and show the Subbasin has a total storage deficit of approximately 277,100 AFY over the baseline period.

The Subbasin's dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a GSA level water accounting system (Checkbook) using Subbasin specific values for supply, demand and net results. The Model results reflect Subbasin-wide conditions and do not allocate water shortages/surpluses, nor do the results allocate the "ownership" of water. As a result, the GSAs, through a coordinated effort, developed the Checkbook that estimates current conditions for each GSA that are generally

consistent with the Model results under baseline condition. The Checkbook and Model budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability in the interest of developing a Subbasin coordinated approach.

To ensure the individual water budgets reflected actual conditions, the KGA members developed the Checkbook budget and coordinated water accounting methodology. The result of that effort indicates a current baseline shortage/deficit for KGA members of approximately 256,300 AFY. This reflects the difference between a total demand for KGA members of 1,939,400 AFY and a total supply of 1,683,100 AFY. Of the shortage/deficit of the KGA, SSJMUD's portion of the KGA deficit is 16,557 AFY, which represents a difference in demand of 149,835 AFY and a water supply of 133,278 AFY.

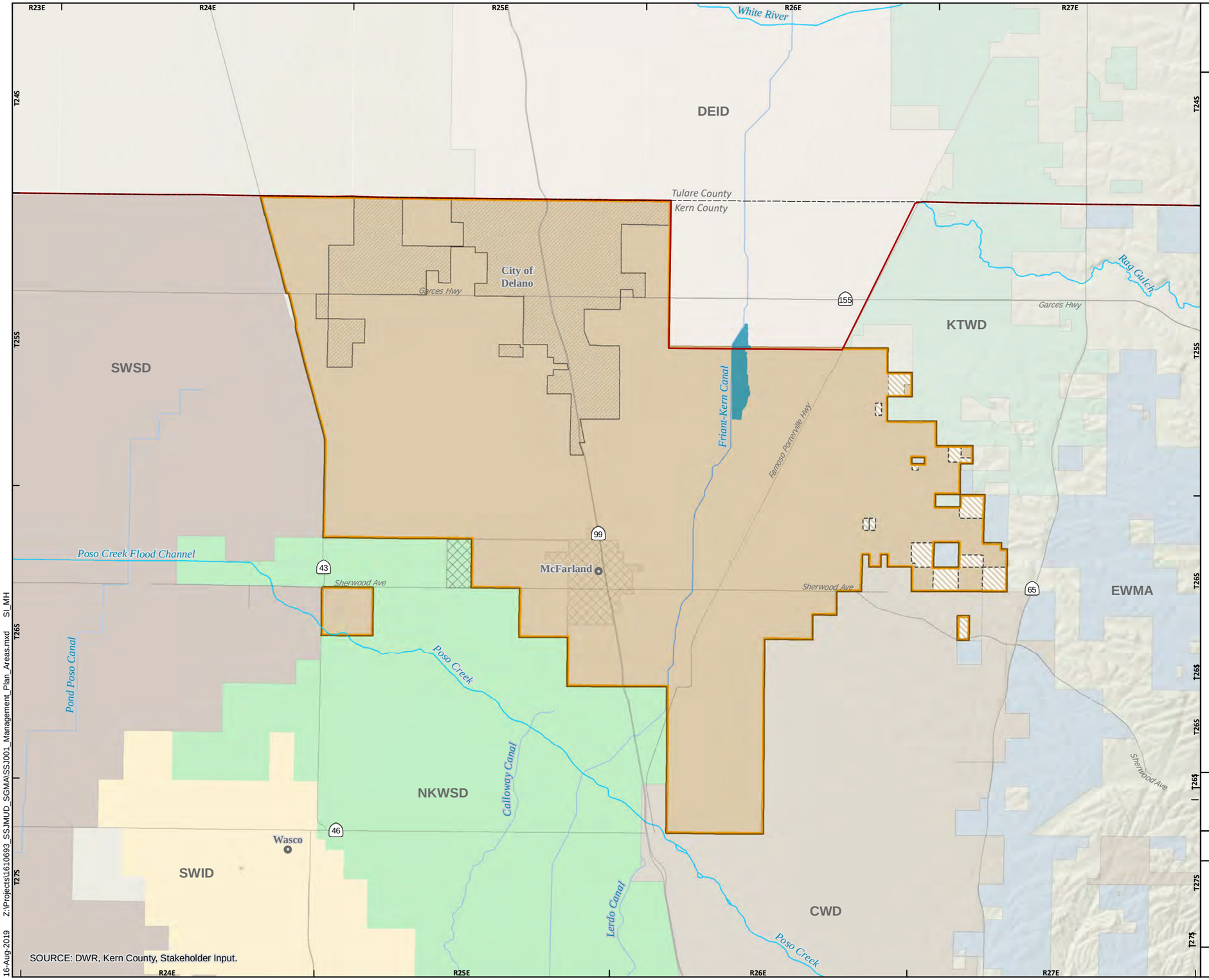
The water supplies available to each KGA member from the Pioneer and Kern Water Bank banking programs are incorporated into the listed total available supplies in the KGA's Checkbook water budget. Both programs only store surface supplies, and do not have consumptive demands that contribute to the shortages identified in the Checkbook water budget. For more detail on these banking programs, please see their respective management area plans.

As is mentioned above, each estimate includes data gaps and has varying degrees of accuracy and/or reliability. The Checkbook water budget is complimentary to the Model and reflects the allocation of water supply benefits and obligations independent of geographic constraints within the Subbasin only for the purposes of developing this management area plan and the KGA's GSP. As stated previously in this management area plan, this is not an allocation of water rights. This was important to recognize and ensure the coordination of the various groundwater banking projects and water management programs amongst the various GSA's within the groundwater basin.

2.5.1 *Planning Budgets*

In addition to the KGA Checkbook water budget, SSJMUD has developed a district-level historical water budget, as well as current and future projection water budgets for their use in implementing SGMA to meet the Sustainability Goal of the Subbasin. The following section describes, in detail, the estimation of the planning water budgets for the SSJMUD management area. These water budgets were developed to quantify the inflows and outflows within the District, based on water supply availability, water demand, and land use information for a historical, current, and future time periods.

Historical water budget was estimated for the time period between water year 1993 and 2015, consistent with the hydrologic base period selected for the Subbasin Model. This time period was selected as it includes varying conditions of water years affected by changes in water supply availability and changes to water demand. This period was also selected as reliable data is available for the district and includes enough variability to quantify and evaluate district responses.



SSJMUD
MANAGEMENT AREA

Management Plan Area

- Southern San Joaquin MUD

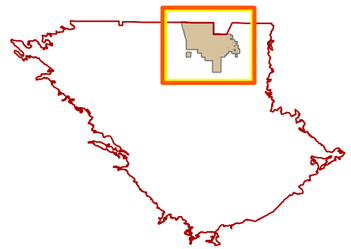
Management Area

- SSJMUD-1 *(District Land)*
- SSJMUD-2 *(Undistricted Land)*

Adjacent Jurisdiction

- Cawelo GSA
- Semitropic WSD GSA
- McFarland GSA
- North Kern Water Storage District
- Shafter - Wasco Irrigation District
- Kern - Tulare Water District
- Delano - Earlimart Irrigation District
- Eastside Water Management Area
- City of Delano

- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 2-34

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The current conditions water budget uses the historical period averages as a baseline and adds the projects and management actions that have been implemented in the years from 2015 to 2019.The projected water budget uses a representative period of 1970 to 2009 to project the SSJMUD CVP contract supply to determine the average long-term hydrology. Other supply and demand components are determined from components of the historical budget.

Sections 2.5.1 and 2.5.2 outline data for the historical water budget for 1993 to 2015, relying on the inflow into the districts and the outflow out of the districts to determine the representative change in storage. The data is summarized in yearly format with approximations made to some data sources based on best judgement.

2.5.2 *Water Budget Components*

The following section describes in detail various components of the water budget, methodology and data sources used in estimation of these water budget components.

2.5.2.1 Demand

Total demand for the District's management area is estimated as the sum of -

- Evapotranspiration (ET) of irrigated acreage,
- surface water outflow, and
- subsurface outflow.

ET was estimated for the total irrigated acres within the District. Urban areas were excluded in this demand estimation as urban water demand was included in the cities' pumping data in Section 2.5.2.11. Land use outside of the irrigated acres and urban areas rely on water supplies other than groundwater pumping and were therefore not considered in this demand estimation.

2.5.2.2 Evapotranspiration

Irrigated acres were estimated based on the 2014 land use data developed by Land IQ, on behalf of DWR. SSJMUD's management areas comprise of approximately 65,000 acres. Land use data collected by SSJMUD indicated that irrigated acreage remained relatively constant over the years ranging from 51,639 acres in 1993 to 42,572 acres in 2016. The irrigated acreage estimated by Land IQ in 2014 was estimated as 44,787 acres, which falls in this range. This land use distribution for SSJMUD's jurisdictional area is shown in Figure 2-22.

ET data is used to estimate the districts historical groundwater pumping requirements. ET for agricultural lands was estimated based on the Irrigation Training and Research Center (ITRC) ET data from 1993 to 2015 based on the corresponding Land IQ irrigated land use data. ITRC estimates ET data based on satellite imagery. As explained previously, irrigated acreage remained relatively constant over the years. However, ET data varied due to the changing crop patterns.

Table 2-13 shows the estimated ET for SSJMUD based on the corresponding irrigated acreages from 1993 to 2015. SSJMUD's ET varied from 101.2 thousand acre-feet (TAF) in 2015 to 141.5 TAF in 2013 with an average ET of 121.6 TAF.

Table 2-13: SSJMUD Historical ET Data, in TAF

Year	Total ET (ITRC)
1993	124.5
1994	130.2
1995	127.0
1996	140.6
1997	122.3
1998	116.4
1999	108.5
2000	114.9
2001	128.4
2002	126.5
2003	124.5
2004	137.8
2005	113.7
2006	109.3
2007	121.2
2008	117.5
2009	117.4
2010	111.8
2011	113.7
2012	127.6
2013	141.5
2014	119.5
2015	101.2
Minimum	**101.2**
Maximum	**141.5**
Average 1993-2015:	**121.6**

ET for non-agricultural lands such as riparian vegetation is not included in this estimation as it was assumed that the precipitation over the non-agricultural land will result in a net zero demand. ET in urban areas is also excluded, as it is accounted for in the cities' pumpage estimation.

2.5.2.3 Surface Outflows

In addition to participating in transfer and exchange programs, SSJMUD also periodically participates in banking services and return water to other agencies. In the period of 1993 to 2015, SSJMUD participated in such a groundwater bank with KTWD. A summary of SSJMUD's historical outflows to KTWD is shown in Table 2-14. These outflows range from zero to a maximum of 2.17 TAF in 2000. The average outflow to KTWD was 0.5 TAF over the hydrologic base period of 1993 to 2015.

The deliveries made to districts in the Subbasin participating in the transfer and exchange programs, over a long period of time, is expected to net zero change in groundwater storage. This is reflected in the surface outflow components in the projected future water budget for SSJMUD.

2.5.2.4 Subsurface Outflows

At this time, there is insufficient data to determine the exact volume of subsurface outflow from SSJMUD. Therefore, for the purposes of this management area plan, it is assumed that subsurface outflows into the Kern County Subbasin net zero change in groundwater storage. This has been identified as a data gap and will be addressed in future plan updates.

Table 2-14: SSJMUD Surface Outflows, in AF

Year	Total Outflow from District
1993	0
1994	0
1995	0
1996	0
1997	0
1998	0
1999	2,081
2000	2,168
2001	40
2002	0
2003	1,898
2004	0
2005	1,969
2006	1,541
2007	188
2008	0
2009	1,879
2010	0
2011	0
2012	0
2013	0
2014	0
2015	0
Minimum	**0**
Maximum	**2,168**
Average 1993-2015:	**511**

2.5.2.5 Sustainable Yield

The sustainable yield is the expected amount of water each district is allowed to pump from the Subbasin without seeing significant impacts or undesirable results. The sustainable yield can be used as a way for each district to manage its performance in reaching groundwater sustainability. While the thresholds, objectives, and milestones of each sustainability indicator are the metric by which the Subbasin will be evaluated, the districts may use the sustainable yield as one way to ensure that they maintain their objectives as described in this plan.

There are two components to sustainable yield: native yield and surface water supply. Native yield is the sum of subsurface flow, runoff, and precipitation. For the purposes of this management area plan, subsurface flow and runoff are assumed to be between 0.15 AF per acre and 0.30 AF per acre in the Subbasin. With the implementation of SGMA and further refinement of the Kern County Subbasin Model, this range is subject to change in future management area plan updates. An assumed precipitation volume of 0.42 AF/acre for irrigated lands is also a component of sustainable yield for the Subbasin. The summation of these components provides a native yield range of 0.57 AF per acre to 0.72 AF per acre for irrigated lands. Because precipitation is only accounted for over irrigated acreage, the native yield assigned to other land uses for the purposes of this plan ranges from 0.15 AF per acre to 0.30 AF per acre. The sustainable yield for land with access to surface water supply is the native yield, plus whatever surface water is available.

2.5.2.6 Water Supply

SSJMUD primarily receives water through supplemental water sources. Native sources such as streambed infiltration are considered minimal. Supplemental water sources for SSJMUD include water received from the CVP contract and surplus water, when it is available.

Native sources are available from precipitation, subsurface flow, and runoff. Precipitation over non-agricultural lands is estimated as a net zero change in groundwater storage as it was assumed that the ET for these non-agricultural lands balances out the precipitation. As a result, only precipitation over agricultural lands is used to estimate water supply into the District. For the purposes of developing these water budget components for SGMA planning, an assumed precipitation value of 0.42 AF per irrigated acre is used.

Subsurface flow and runoff are components of native yield that are estimated to be in the range of 0.15 AF per acre to 0.30 AF per acre and is attributed to all lands within the Subbasin. The summary of SSJMUD's water supply is presented in Table 2-15.

2.5.2.7 CVP Water

The CVP is the primary source of surface water available to SSJMUD and provides water via the Friant-Kern Canal from Millerton Lake (Friant Reservoir). SSJMUD, through its contract with the USBR, receives 97 TAF of Class 1 and 45 TAF of Class 2 water per year. This water is used to supplement ET demand. In addition, the District receives recaptured Class 1 and Class 2, 16B, and other water when available from the CVP. The non-Class 1 and non-Class 2 water are typically "surplus water" made available during periods of forecasted spill on the Friant Dam. On average, SSJMUD receives 96.0 TAF of deliveries via the Friant-Kern Canal (1993-2015) as shown in Table 2-15.

2.5.2.8 Precipitation

Precipitation is a source of inflow into the District. However, precipitation is only considered for the irrigated acreage. Areas outside irrigated acreage such as native vegetation is assumed to net

zero in the water budget analysis as it was assumed that the demand is met by the precipitation. Similarly, rural areas were also estimated to net zero in the water budget and were estimated to be of minimal use.

Through the coordination with all the member agencies of KGA, it was estimated that the average precipitation for the area is 0.42 AF per acre per year. This value is applied as an annual value to the irrigated acreage and is observed in Table 2-15.

2.5.2.9 Inflow to the Groundwater System

For the purposes of developing the water budgets for this plan, an assumed zero net change in groundwater storage is used. This assumption is made in the absence of reliable data. This has been identified as a data gap and will be addressed in subsequent plan updates.

2.5.2.10 Agricultural Pumping

Groundwater pumping in the District is estimated as the volume of water required to supplement surface water supplies to cover the total ET for the irrigated lands. Agricultural pumping is estimated as:

$$AP = CD - SWc - Pr$$

where: AP = Agricultural Pumping

CD = Agricultural Crop Demand

SWc = Surface Water Crop Delivery

Pr = Total Precipitation

Total pumping is dependent on the amount of surface water available to the District which varies annually. During wet years, the District requires less pumping due to excess surface water imports; similarly, during dry years the District would require more pumping due to decreased surface water imports.

The volume of groundwater pumping (change in storage) within the SSJMUD from 1993 to 2015 are shown in Table 2-16. It was observed that SSJMUD has an average change in storage ranging from 2.5 TAF per year to 12.3 TAF per year of net surplus based on the 0.15 AF per acre to 0.30 AF per acre of native inflow range. The negative values in the change in storage columns represent the years in which the District had to pump groundwater in order to meet the ET demand of irrigated acreage.

Using the native inflow range over the period of 1993 to 2015, it is estimated that the largest volume that the District had to pump was 85.2 TAF in 2014. The largest surplus of water in the District over this same period, using the native yield range, is an estimated 50.5 TAF in 2011. While the District shows an average surplus condition, operational conditions during drought (as observed in the 2012 – 2015 period) severely limit the amount of surface water delivered into SSJMUD. As a result, the District had to rely heavily on groundwater to meet ET demand.

Table 2-15. Summary of SSJMUD Water Supply

Year	Friant-Kern Canal Deliveries[1]	Avg Rainfall[2]	Native Inflow (0.15 AF/acre)[3]	Native Inflow (0.30 AF/acre)[4]	Total Water Supply (0.15 AF/acre)[5]	Total Water Supply (0.30 AF/acre)[6]
1993	111.1	18.8	9.8	19.5	139.7	149.5
1994	79.0	18.8	9.8	19.5	107.5	117.3
1995	116.1	18.8	9.8	19.5	144.6	154.4
1996	125.5	18.8	9.8	19.5	154.1	163.8
1997	124.0	18.8	9.8	19.5	152.5	162.3
1998	89.7	18.8	9.8	19.5	118.2	128.0
1999	114.5	18.8	9.8	19.5	143.1	152.8
2000	122.0	18.8	9.8	19.5	150.6	160.3
2001	96.5	18.8	9.8	19.5	125.1	134.8
2002	103.3	18.8	9.8	19.5	131.8	141.6
2003	111.4	18.8	9.8	19.5	140.0	149.7
2004	101.2	18.8	9.8	19.5	129.7	139.5
2005	121.0	18.8	9.8	19.5	149.6	159.3
2006	118.2	18.8	9.8	19.5	146.7	156.5
2007	71.4	18.8	9.8	19.5	100.0	109.7
2008	92.5	18.8	9.8	19.5	121.0	130.8
2009	121.3	18.8	9.8	19.5	149.8	159.6
2010	117.7	18.8	9.8	19.5	146.3	156.0
2011	125.9	18.8	9.8	19.5	154.4	164.2
2012	76.5	18.8	9.8	19.5	105.1	114.8
2013	61.0	18.8	9.8	19.5	89.5	99.3
2014	5.8	18.8	9.8	19.5	34.3	44.1
2015	3.3	18.8	9.8	19.5	31.9	41.6
Minimum	3.3	18.8	9.8	19.5	**31.9**	**41.6**
Maximum	125.9	18.8	9.8	19.5	**154.4**	**164.2**
Average 1993-2015:	96.0	18.8	9.8	19.5	**124.6**	**134.3**

(1) All Surface Water Deliveries, which supplement irrigated acreage, Includes FKC water Delivered to Kern Tulare WD

(2) Estimated Rainfall 0.42 feet per irrigated acre

(3) Native Inflow of 0.15 AF/acre for gross acreage

(4) Native Inflow of 0.30 AF/acre for gross acreage

(5) Total Water Supply (0.15 AF/acre Native Inflow)

(6) Total Water Supply (0.30 AF/acre Native Inflow)

Table 2-16: SSJMUD Estimated Ag Pumpage, in TAF

Year	Friant-Kern Canal Deliveries	To Other Districts	Avg Rainfall	ET (ITRC)	Native Inflow (0.15 AF/acre)	Native Inflow (0.30 AF/acre)	Δ Storage (0.15 AF/acre)	Δ Storage (0.30 AF/acre)
1993	111.1	0.0	18.8	124.5	9.8	19.5	15.3	25.0
1994	79.0	0.0	18.8	130.2	9.8	19.5	(22.7)	(12.9)
1995	116.1	0.0	18.8	127.0	9.8	19.5	17.7	27.4
1996	125.5	0.0	18.8	140.6	9.8	19.5	13.4	23.2
1997	124.0	0.0	18.8	122.3	9.8	19.5	30.3	40.0
1998	89.7	0.0	18.8	116.4	9.8	19.5	1.9	11.6
1999	114.5	2.1	18.8	108.5	9.8	19.5	32.5	42.2
2000	122.0	2.2	18.8	114.9	9.8	19.5	33.5	43.2
2001	96.5	0.0	18.8	128.4	9.8	19.5	(3.4)	6.4
2002	103.3	0.0	18.8	126.5	9.8	19.5	5.3	15.0
2003	111.4	1.9	18.8	124.5	9.8	19.5	13.5	23.3
2004	101.2	0.0	18.8	137.8	9.8	19.5	(8.1)	1.7
2005	121.0	2.0	18.8	113.7	9.8	19.5	33.9	43.6
2006	118.2	1.5	18.8	109.3	9.8	19.5	35.9	45.6
2007	71.4	0.2	18.8	121.2	9.8	19.5	(21.4)	(11.6)
2008	92.5	0.0	18.8	117.5	9.8	19.5	3.5	13.3
2009	121.3	1.9	18.8	117.4	9.8	19.5	30.6	40.3
2010	117.7	0.0	18.8	111.8	9.8	19.5	34.4	44.2
2011	125.9	0.0	18.8	113.7	9.8	19.5	40.8	50.5
2012	76.5	0.0	18.8	127.6	9.8	19.5	(22.5)	(12.8)
2013	61.0	0.0	18.8	141.5	9.8	19.5	(52.0)	(42.3)
2014	5.8	0.0	18.8	119.5	9.8	19.5	(85.2)	(75.5)
2015	3.3	0.0	18.8	101.2	9.8	19.5	(69.3)	(59.5)
Minimum	3.3	0.0	18.8	101.2	9.8	19.5	(85.2)	(75.5)
Maximum	125.9	2.2	18.8	141.5	9.8	19.5	40.8	50.5
Average 1993-2015:	96.0	0.5	18.8	121.6	9.8	19.5	**2.5**	**12.3**

2.5.2.11 Urban Pumping

City of Delano and City of McFarland do not have detailed urban pumping data available at this time for the entire hydrologic base period of 1993 to 2015. Groundwater pumping for the cities was estimated for 2005, 2010 and 2015 in the City of Delano's 2015 Urban Water Management Plan (UWMP) and in City of McFarland's 2015 General Plan Amendment Environmental Impact Report (EIR). This data does not include the demand from either of the prisons in SSJMUD's jurisdictional area as neither of the cities provide water to the prisons. The cities of Delano and McFarland have provided actual groundwater pumping volumes for use in the historical water budget for SSJMUD and to develop projected water budgets for this management area plan.

This combination of estimated and actual data was used to estimate the 2005, 2010 and 2015 urban pumping for SSJMUD. Table 2-17 provides a summary of City of Delano and City of McFarland urban pumping for 2005, 2010, and 2015, which represents the urban pumping for SSJMUD's management area. As shown in the below table, it was observed that urban pumping decreased in 2015 when compared to 2005 and 2010. This decrease in demand can be attributed to the historical drought the State of California experienced between 2011 and 2015 which enacted water restrictions on urban users and promoted conservation of urban water.

Table 2-16: SSJMUD Estimated Urban Pumpage, in TAF

City	2005	2010*	2015*
Delano	9.8	9.3	8.1
McFarland	1.6	1.7	1.8
Total	11.4	11.0	9.9

* Values in UWMP updated to actual Production values

2.5.2.12 Urban Recovery

The City of Delano has a wastewater treatment plant (WWTP) located in SSJMUD. The effluent from the WWTP is applied to agricultural land for beneficial reuse as irrigation water for permanent tree crops or pasture and hay crops in proximity to the WWTP. The historic wastewater flows are shown in Table 2-18. The effluent provided for beneficial reuse ranging from 3.7 TAF to 4.9 TAF, with an average of 4.5 TAF and an average recovery rate of 49.2%.

The McFarland WWTP is located outside of SSJMUD's jurisdictional area, in NKWSD. Like Delano's WWTP, the effluent from the McFarland WWTP is provided for beneficial reuse in irrigation of tree crops, pasture, or for groundwater recharge. At this time, the effluent from McFarland's WWTP is credited to NKWSD's water budget because it is used outside of SSJMUD.

Table 2-18: Delano WWTP Effluent Volumes, in TAF

	2005	2010 [1]	2015 [1]	Average
Groundwater Pumped	9.8	9.3	8.1	**9.0**
% of Supply	50%	52%	45%	**49.2%**
Recycled	4.9	4.8	3.7	**4.5**

(1) Values updated to reflect actual city effluent volumes.

2.5.3 *Historical Water Budget*

The historical water budget for SSJMUD's jurisdictional area, presented in Table 2-19, represents the average conditions for the hydrologic base period of 1993 to 2015. This water budget includes the average change in groundwater storage to do agricultural groundwater pumping, imported water supplies, and urban groundwater pumping. The coordinated subsurface inflow range of 0.15 AF per acre to 0.30 AF per acre and the assumed precipitation of 0.42 AF per irrigated acre is included in Table 2-19. Over this assumed range, the average change in groundwater storage for SSJMUD's jurisdictional area ranges from 4.0 TAF overdraft to 5.7 TAF surplus.

Table 2-19: SSJMUD Historical Water Budget (1993-2015), in TAF

Data Type, Water Year and Hydrologic Condition (1)	Total Surface Inflow + (2)	Total Surface Outflow - (3)	Total Rainfall + (4)	Total ET (ITRC) - (5)	Δ Storage (Irrigated Lands) = (6)	City of Delano Demand - (7)	City of McFarland Demand - (8)	City of Delano Recycled Water + (9)	Native Inflow (0.15 AF/acre) + (10)	Native Inflow (0.30 AF/acre) + (11)	Δ Storage w/NY and City Data (0.15 AF/acre) = (12)	Δ Storage w/NY and City Data (0.30 AF/acre) = (13)
Historical Data												
Average												
1993 to 2015	96.0	0.5	18.8	121.6	**(7.2)**	9.3	1.7	4.5	9.8	19.5	**(4.0)**	**5.7**

Notes:

(1) Data presented as historical (1993-2015) average conditions.

(2) Historical Data includes Deliveries brought in through FKC. CVP Model Data includes Sum of: Class 1, Class 2, Other, 16B, Recapture Class 1, Recapture Class 2

(3) Delivery to Kern Tulare

(4) Estimated 0.42 AF per acre over irrigated acreage (44,787 acres) (Rainfall over non-irrigated acreage assumed balanced by total ET)

(5) Historical is average 1993 to 2015 value. CVP Model Data uses Average of 2013 to 2015 over irrigated acreage (Rainfall over non-irrigated acreage assumed net zero with total ET)

(6) Determined by (6) = (2)+(4)-(3)-(5)

(7) Average Consumptive Demand of City of Delano based on 2015 Urban Water Management Plan with updated 2015 consumptive use data

(8) Average Consumptive Demand of City of McFarland based on its EIR for the 2015 General Plan Amendment with updated 2015 consumptive use data

(9) Recycled water from WWTF in Delano applied to Agricultural Fields. Projections determined from UWMP and Adjusted 2010 and 2015 Demand and actual effluent volume data

(10) Native yield (0.15 AF/acre) over total acreage

(11) Native yield (0.30 AF/acre) over total acreage

(12) Storage Change determined by (12) = (6)+(9)+(10)-(7)-(8)

(13) Storage Change determined by (13) = (6)+(9)+(11)-(7)-(8)

Source: Historical Data KGA Water Supply Accounting, Rainfall Estimated, ITRC ET. Projected Data CVP Projection Model ".c" condition. City Data from Delano UWMP (2015), and City of McFarland General Plan Amendment EIR (2015)

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2.5.4 *Current Water Budget*

While the historical base period used in the previous section is consistent with the base period selected for the Subbasin groundwater model, it does not capture the current conditions within the District. Since 2015, projects and management actions have been implemented as part of the District's response to the 2006-2016 drought. The following section will describe the water budget components used to determine the water budget for SSJMUD under current conditions. Some of the water budget components developed in the historical water budgets are used in the current water budget.

2.5.4.1 Agricultural Demand

The average historical ET data from 2013 to 2015 (described in the previous section) is used in the "current conditions" water budget for SSJMUD. This shortened historical period is most representative of the current land use and crop types in the District's management areas. As with the historical water budget, ET for undeveloped land is assumed to net zero change in groundwater storage because it is assumed that the ET is balanced with precipitation. ET from urban land is also not counted in the calculation of agricultural demand because those lands are supplied by the urban groundwater pumping. The average of 2013 through 2015 ET is 120.7 TAF and is used in Table 2-20.

2.5.4.2 Urban Demand

Groundwater pumping data from 2009 to present for the cities of Delano and McFarland, were used to develop the current conditions water budget, as it closely reflects the current urban water use. The City of Delano currently pumps 8.1 TAF to meet its urban demand; the City of McFarland pumps 1.8 TAF.

2.5.4.3 Water Supply

The average current water supply conditions are based on the long-term average supply for the CVP. As with the historical water budgets, exchanges and transfers between SSJMUD and other districts are expected to be a net zero change in groundwater storage for the districts. Water that is "banked" is recognized as the 10% of leave behind water, the remainder of the water is considered temporary storage which is not included in the water accounting for the current conditions.

To account for subsurface inflow and runoff, SSJMUD is using the KGA range of 0.15 AF per acre to 0.30 AF per acre for the gross acreage of its jurisdictional area. In addition to the subsurface inflow and runoff and precipitation, the effluent from the Delano WWTP averages 3.7 TAF for beneficial reuse under current conditions.

As shown in Table 2-20, SSJMUD received an average surplus flow of 2.8 TAF under current conditions. The district has also taken advantage of available surplus supply made available to

Friant contractors, bring this supply into the District or banking it in NKWSD for in-district delivery during dry periods. This has led to the current conditions water budget reflecting an average change in groundwater storage for SSJMUD that is net positive 6.3 TAF to 16.1 TAF over the assumed native inflow range of 0.15 AF per acre to 0.30 AF per acre. The addition of the City of Delano Spreading Grounds (in pilot phase), SSJMUD added 500 AFY of recharge capacity. This, in addition to the adoption of emergency drought measures by the cities, has led to the current conditions with projects in SSJMUD having a net positive change in groundwater storage of 6.9 TAF per year to 16.6 TAF per year over the assumed native inflow range.

Table 2-20: SSJMUD Current Water Budget, in TAF

Data Type, Water Year and Hydrologic Condition (1)	Total Surface Inflow + (2)	Total Surface Outflow - (3)	Total Rainfall + (4)	Total ET (ITRC) - (5)	Δ Storage (Irrigated Lands) = (6)	City of Delano Demand - (7)	City of McFarland Demand - (8)	City of Delano Recycled Water + (9)	Native Inflow (0.15 AF/acre) + (10)	Native Inflow (0.30 AF/acre) + (11)	Δ Storage w/NY and City Data (0.15 AF/acre) = (12)	Δ Storage w/NY and City Data (0.30 AF/acre) = (13)
CVP Model Data Long-Term Average												
2015.c (Current)	104.8	-	18.8	120.7	**2.8**	8.1	1.8	3.7	9.8	19.5	**6.3**	**16.1**
2015.c (Current with Current Projects)	105.3	-	18.8	120.7	**3.4**	8.1	1.8	3.7	9.8	19.5	**6.9**	**16.6**

Notes:

(1) Data presented as average conditions based on CVP model data (1922-2003) as represented by a historical average condition by water year type

(2) Historical Data includes Deliveries brought in through FKC. CVP Model Data includes Sum of: Class 1, Class 2, Other, 16B, Recapture Class 1, Recapture Class 2

(3) Delivery to Kern Tulare

(4) Estimated 0.42 AF per acre over irrigated acreage (44,787 acres) (Rainfall over non-irrigated acreage assumed balanced by total ET)

(5) Historical is average 1993 to 2015 value. CVP Model Data uses Average of 2013 to 2015 over irrigated acreage (Rainfall over non-irrigated acreage assumed net zero with total ET)

(6) Determined by (6) = (2)+(4)-(3)-(5)

(7) Average Consumptive Demand of City of Delano based on actual consumptive use data

(8) Average Consumptive Demand of City of McFarland based on actual consumptive use data

(9) Recycled water from WWTF in Delano applied to Agricultural Fields, based on actual effluent volumes

(10) Native yield (0.15 AF/acre) over total acreage

(11) Native yield (0.30 AF/acre) over total acreage

(12) Storage Change determined by (12) = (6)+(9)+(10)-(7)-(8)

(13) Storage Change determined by (13) = (6)+(9)+(11)-(7)-(8)

Source: Historical Data KGA Water Supply Accounting, Rainfall Estimated, ITRC ET. Projected Data CVP Projection Model ".c" condition. City Data from Delano UWMP (2015), and City of McFarland General Plan Amendment EIR (2015)

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2.5.5 *Projected Water Budget*

A projected water budget is prepared to estimate a baseline condition of supply, demand, and plan implementations. This projected water budget accounts for conditions for 2030 and 2070, using data on projected available supplies, projected changes in demand due to changes in land use. The projected water budget, consistent with the Subbasin groundwater model, also accounts for climate change factors that affect the water budget inflow and outflow components. Projects and management actions, which are described in Section 5, are not accounted for in this baseline projected water budget.

2.5.5.1 Agricultural Demand

As shown in Section 2.2.3.7, land use has not varied greatly historically, as a result it was assumed that the crop demand will remain similar in the future. However, overall irrigated acreage will decrease as urban land use increases within the cities' limits and spheres of influence. For the purposes of this projected water budget, crop types within the District are assumed to remain the same. Current water demands for agriculture are based off the most recent crop demand (2013 to 2015 ITRC based ET) and have been adjusted to account for the climate change factors used in the Subbasin groundwater model.

The projected agricultural demand for average 2030 conditions is estimated to be 119.2 TAF. The projected agricultural demand for average 2070 conditions is estimated to be 125.0 TAF. The increase in ET is due to the irrigated acreage and crop types in the District remaining the mostly unchanged from 2030 to 2070. Agricultural to urban land use conversion is anticipated to be relatively small from 2030 to 2070.

2.5.5.2 Urban Demand

Urban water demand is expected to increase as shown in Table 2-21. These volumes are subject to further reduction, due to mandatory indoor water use reductions (described further in Section 5 of this plan).

Table 2-21: SSJMUD Projected Urban Demand, in TAF

City	2015*	2030	2070
Delano	8.1	11.5	21.5
McFarland	1.8	2.3	3.6
Total	9.9	14.8	25.1

* Current Average Production values

2.5.5.3 Water Supply

WWTP Effluent

As identified in the historical and current water budgets, the City of Delano's WWTP is anticipated to continue providing effluent for beneficial reuse. The estimated volumes are based on the population growth projections in each city's respective General Plans. The Delano WWTP

is anticipated to provide 11.5 TAF of effluent for beneficial reuse in 2030; that volume is projected to increase to 21.5 TAF by 2070.

Table 2-22: Projected Effluent Volumes from Delano WWTP, in TAF

	2015 [1]	2030	2070
Groundwater Pumped	8.1	11.5	21.5
% of Supply	46%	43%	59%
Recycled	3.7	4.9	12.6

(1) Values updated to reflect actual city effluent volumes.

Precipitation

As described during the historical water budget estimation, precipitation for project water budget is also estimated as 0.42 AF per irrigated acre, with adjustments to account for the climate change factors used in the Subbasin groundwater model. These adjusted volumes are shown in Table 2-23.

CVP Water

Projected water supply from the CVP for SSJMUD is based on "Future Friant Supplies Model". This model estimated SSJMUD supplies from CVP based on Class 1, Class 2, Other, 16B, Recapture Class 1, and Recapture Class 2 categories. It is expected due to restriction, regulations, and climate change the Districts will receive a lower than historical amount of water from the CVP. City recycled water is expected to increase as shown in Table 2-23.

SSJMUD's other surface water supplies are assumed to net zero with the District demand over long term periods and are left out of the projected water budgets. SSJMUD, at its current baseline conditions, shows a positive storage in 2030 for the assumed native inflow range, adjusting for climate change factors used in the Subbasin groundwater model and accounting for reduction of irrigated acreage due to urban use conversion. At 0.15 AF per acre for 2030 conditions, SSJMUD has an estimated surplus of 400 AF. The District has an estimated surplus of 10.2 TAF for 2030 conditions at 0.30 AF per acre.

For 2070 conditions, SSJMUD shows a baseline of 8.6 TAF to 18.4 TAF net overdraft, when accounting for climate change factors used in the Subbasin groundwater model, CVP model data for Friant, and the cities' projected increase in urban demand. These volumes reflect a baseline condition which does not account for the proposed projects and management actions that are conceptual and yet to be implemented by the District.

The projects and management actions to be implemented to reach sustainability by 2040 are outlined in Section 5. The District will implement projects and management actions to reach sustainability and the projected impact of the projects and management actions are summarized in Section 5.

Table 2-23: SSJMUD Projected Baseline Water Budget for 2030 and 2070, in TAF

Data Type, Water Year and Hydrologic Condition (1)	Total Surface Inflow + (2)	Total Surface Outflow - (3)	Total Rainfall + (4)	Total ET (ITRC) - (5)	Δ Storage (Irrigated Lands) = (6)	City of Delano Demand - (7)	City of McFarland Demand - (8)	City of Delano Recycled Water + (9)	Native Inflow (0.15 AF/acre) + (10)	Native Inflow (0.30 AF/acre) + (11)	Δ Storage w/NY and City Data (0.15 AF/acre) = (12)	Δ Storage w/NY and City Data (0.30 AF/acre) = (13)
CVP Model Data Long-Term Average												
2015.c (Current)	104.8	-	18.8	120.7	**2.8**	8.1	1.8	3.7	9.8	19.5	**6.3**	**16.1**
2015.c (Current with Current Projects)	105.3	-	18.8	120.7	**3.4**	8.1	1.8	3.7	9.8	19.5	**6.9**	**16.6**
2030.c	100.0	-	18.8	119.2	**(0.4)**	11.5	2.3	4.9	9.8	19.5	**0.4**	**10.2**
2070.c	90.8	-	18.6	125.0	**(15.6)**	21.5	3.6	12.6	9.8	19.5	**(18.4)**	**(8.6)**

Notes:

(1) Data presented average conditions along with projected future conditions based on CVP model data (1922-2003) as represented by a historical average condition, also by water year type, and 2030 and 2070 conditions

(2) Historical Data includes Deliveries brought in through FKC. CVP Model Data includes Sum of: Class 1, Class 2, Other, 16B, Recapture Class 1, Recapture Class 2

(3) Delivery to Kern Tulare

(4) Estimated 0.42 AF per acre over irrigated acreage (44,787 acres) (Rainfall over non-irrigated acreage assumed balanced by total ET)

(5) Historical is average 1993 to 2015 value. CVP Model Data uses Average of 2013 to 2015 over irrigated acreage (Rainfall over non-irrigated acreage assumed net zero with total ET)

(6) Determined by (6) = (2)+(4)-(3)-(5)

(7) Average Consumptive Demand of City of Delano based on 2015 General Plan population growth projections with actual consumptive use data

(8) Average Consumptive Demand of City of McFarland based on its EIR for the 2015 General Plan population growth projections with actual consumptive use data

(9) Recycled water from WWTF in Delano applied to Agricultural Fields. Projections determined from 2015 General Plan population growth and actual effluent data

(10) Native yield (0.15 AF/acre) over total acreage

(11) Native yield (0.30 AF/acre) over total acreage

(12) Storage Change determined by (12) = (6)+(9)+(10)-(7)-(8)

(13) Storage Change determined by (13) = (6)+(9)+(11)-(7)-(8)

Source: Historical Data KGA Water Supply Accounting, Rainfall Estimated, ITRC ET. Projected Data CVP Projection Model ".c" condition. City Data from Delano UWMP (2015), and City of McFarland General Plan Amendment EIR (2015)

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2.6 Existing Monitoring Programs

The purpose of this section is to identify and discuss existing water resource monitoring programs as required under §354.8(c). This section specifically focuses on water level and groundwater quality monitoring within the District's boundaries.

2.6.1 *Existing Water Level Monitoring*

The umbrella level GSP describes existing water level monitoring networks at a generalized regional scale. These networks include the Kern Fan Monitoring Committee (KFMC), Kern County Water Agency (KCWA) groundwater monitoring, and water level data reported to CASGEM. These regional networks benefit data collection and inform SSJMUD on water level changes occurring in the Subbasin. The umbrella level GSP provides details on the KFMC, KCWA, CASGEM networks, and an approximate number of wells and locations of monitoring throughout the Subbasin. This section focuses on groundwater monitoring at the local-level, and provides a brief description of the monitoring network, well types, well construction, participants in local monitoring, and figures with locations.

2.6.1.1 Groundwater Level Monitoring

SSJMUD uses water level monitoring data from supply wells in the district to report on local and regional groundwater level conditions. Historically, water levels in supply wells have been measured twice a year, in both the "spring" and "fall", with the timing of these measurements intended to coincide with the annual water level high and low, respectively.

The district uses 66 supply wells for monitoring purposes. These locations of these wells are shown on Figure 1 of Appendix J. The district coordinates with the private well landowners for well access.

The wells are classified as interim monitoring wells for SGMA purposes because they are actively used as water supply wells for domestic and agricultural use. As such, there are limitations on the ability to collect data when they are in operation, the wells are not designed for monitoring, and well construction data are limited.

In the future, improvements to the District's infrastructure will likely include completion of dedicated monitoring wells to replace interim wells in the monitoring network. The locations of these wells are to be determined as part of the development of the District's management area plan.

2.6.1.2 Semitropic Water Storage District Water Banking Project Monitoring Committee

In addition to local monitoring, SSJMUD also participated in the monitoring committee for the Semitropic Water Storage District Water Banking Project. The Semitropic Water Banking Monitoring Committee is made up of Semitropic Water Storage District, Southern San Joaquin Municipal Utility District, Cawelo Water District, Shafter-Wasco Irrigation District, North Kern

Water Storage District, Rosedale-Rio Bravo Water Storage District, and Buena Vista Water Storage District, with KCWA and Department of Water Resources working alongside the monitoring committee. The committee submits biennial monitoring reports which first began in 1995 and have continued to the present. The reports include groundwater elevation maps, discussion of groundwater flow trends, groundwater quality, land subsidence, and time series data on hydrographs. A summary is presented in Table 2-24 below.

Table 2-24: Summary of Monitoring Committee

Monitoring Network	Number of Wells Monitored	Date Range	Source
SWSD Water Banking Monitoring Committee	29 SWSD monitoring wells ~ 65 supply wells SWSD, ~53 wells NKWSD, ~8 wells in BVWSD, ~ 11 wells in SWID, a few wells RRBWSD, and a few in SSJMUD	1995 to present	Biennial Groundwater Monitoring Report for the Semitropic Water Storage District Water Banking Project.

Locations of wells in the monitoring network are included in the figure in Appendix K.

The benefit of the monitoring committee is in coordination of water level data collection and reporting, which provides more understanding of water levels at the boundaries between SSJMUD and neighboring districts. Data that are a result of this coordination, including groundwater contour maps, hydrographs, and subsidence data, are presented in the Groundwater Conditions section of this report.

Many of the wells in the committee's monitoring network are included in the future monitoring network for this Groundwater Sustainability Plan.

2.6.2 *Existing Land Subsidence Monitoring*

The umbrella level GSP describes existing land subsidence monitoring networks at a generalized regional scale. These networks include Borehole Extensometers, Continuous GPS (CGPS), Leveling Surveys, and Remote Sensing. These regional networks benefit data collection and inform SWSD on land subsidence changes occurring in the Subbasin. The KGA GSP and the Groundwater Conditions section of this report provide details on these networks and status of data usability and collection. This section focuses on land subsidence monitoring at the local-level. Details on data availability and locations are provided below.

2.6.2.1 Local Land Subsidence Monitoring

As a part of the Semitropic Water Banking Monitoring Committee, land subsidence has been monitored and data reported in the biennial reports prepared by Schmidt and Associates. The monitoring network includes SWSD's borehole extensometer, as well as nearby continuous GPS points P545, P563, and P564 (Table 2-18). In addition, P565 near the Delano Airport is also monitored through UNAVCO and Scripps Orbit and Permanent Array Center (SOPAC) (Table 2-18). All of these GPS stations are maintained, and data are processed and reported, by affiliates of UNAVCO (https://www.unavco.org/instrumentation/networks/status/pbo) and SOPAC (http://sopac-csrc.ucsd.edu/index.php/sopac/). A location map of the existing land subsidence monitoring network is included in Appendix K.



Figure 2-35: Monument Survey by GPS Methods

Details including data for the CGPS points and extensometer, and benefits and frequency of the data, are further discussed in the Groundwater Conditions of this report. In general, CGPS points record daily to sub-daily frequency, while the extensometer is currently set up for manual measurements that require periodic visits to record data values. While CGPS points record near continuous data, their limitations are in that they measure land surface deformation referenced to a datum but cannot measure discrete intervals in the subsurface. On the other hand, the borehole extensometer can measure a discrete interval from the bottom of the extensometer to ground surface, thus providing a more accurate approximation of compaction in the intervals subject to groundwater pumping.

Details of the data collected from these monuments is included in the Groundwater Conditions section of this report.

2.6.2.2 USBR Friant-Kern Canal

Recently USBR and Friant Water Authority have worked together to collect elevation survey data along the Friant-Kern Canal from Tulare County to Kern County.

Surveys were taken at construction benchmark points that were measured during construction in the 1940s and 1950s. SSJMUD is coordinating with USBR to consider future monitoring at these points along the canal within the district. These points are listed as mile postings along the canal (Table 2-18).

2.6.2.3 Remote Sensing Land Subsidence Monitoring

In addition to CGPS and level surveying along infrastructure such as the Friant-Kern Canal, NASA and DWR have collected remote sensing data (INSAR and UAVSAR) on a regional scale to better understand the lateral and temporal extent of subsidence within the study area. The

methodology and approach for collecting and processing the data has varied over the last decade as refinements have been made. NASA and DWR are working together to field calibrate these remote sensing data with CGPS points to better understand the quantitative estimates of land subsidence that have been reported.

The existing monitoring data are available for some date ranges and therefore are discussed further in the Groundwater Conditions of this report. In addition, the umbrella level GSP also provides details on INSAR and UAVSAR reporting and availability. As remote sensing data continue to be available, it will be used for the monitoring network of this management area plan.

2.6.2.4 Summary Land Subsidence Monitoring

Table 2-25 below shows the current available land subsidence monitoring for the study area.

Table 2-25: Summary of Land Subsidence Monitoring in Study Area

Type	Stations	Range of Available Data	Source
Continuous GPS Stations	P544, P545, P563, P564, P565	Varies. 2000 to present 2005 to present	UNAVCO PBS www.unavco.org Access data from: Instrumentation > Network Monitoring > Plate Boundary Observatory (PBO).
InSAR / UAVSAR	Remote Satellite Imagery	Recent. Range of freely accessible data: 2007 to 2011 2014 to present	Areal extent varies depending on dataset. Not always extensive across the Subbasin. Post-processed data available from (Farr, et. al., 2016), JPL, and USGS.
Survey Monuments	MP-116.94, MP-120, MP-124, MP-127,	1959-2017, 2017-present	USBR, Friant-Kern Canal. (Coverage: SSJMUD and Tulare).

2.6.3 *Existing Groundwater Quality Monitoring*

SSJMUD does not directly monitor groundwater quality in its management area. However, it uses the data collected by the Public Water systems (PWS) within its District boundary to monitor the groundwater quality. A summary of each of the Districts' local and regional efforts programs are discussed in this section.

Groundwater quality in the District is currently monitored by a network of domestic wells. Table 2-26 summarizes the types of monitoring program implemented within the District.

Table 2-26: Types of Monitoring Program Implemented within the District

Well Type	Number of Wells	Monitoring Program	
		AB 3030	Title 22
Public Water system Wells	24		X

The monitoring programs previously described are implemented through sampling a combination of the District's network of wells. This network is described in detail below.

2.6.3.1 SSJMUD's Water Quality Monitoring Program

As discussed earlier, SSJMUD does not directly monitor groundwater quality in its management area. However, it uses the data collected by the municipalities within its District boundary to monitor the groundwater quality. The public water systems within SSJMUD are included in Table 2-27 below.

2.6.3.2 Kern County Subbasin Water Quality Monitoring Efforts

SSJMUD, with the objective of identifying and implementing specific programs as needed to reflect changing conditions in the basin, established a Groundwater Monitoring Committee that includes Semitropic W.S.D (as the lead agency), and five other neighboring water districts. The KCWA and DWR are interested parties and periodically participate in the Committee activities. One of the committee's key objectives is to control degradation of groundwater quality and enhance quality where practicable. Since its inception in 1994, this committee has been preparing a biennial monitoring report that provides a comprehensive study of the underlying groundwater with the objective of identifying and implementing specific programs as needed to reflect changing conditions in the basin. The biennial report characterizes the groundwater quality based on the collected data from Semitropic's monitoring network, and the five neighboring water districts.

Additionally, the District is an active member of multiple regional groundwater quality monitoring programs. These programs are briefly described below. Groundwater quality data from these programs will be used by the District for SGMA monitoring purposes.

2.6.3.3 Irrigated Lands Regulatory Program

The Irrigated Lands Regulatory Program (ILRP) was initiated in 2003 with a focus on protecting surface waters; groundwater regulations were added in 2012. The Kern River Watershed Coalition Authority (KRWCA) implements the ILRP program in the Subbasin. Data collected and reported as a part of ILRP are provided to the SWRCB and are available in the GeoTracker database for download and use. The KRWCA's primary group is made up of 10-member agencies representing approximately 1.5M acres of irrigated land, out of which 4% of the irrigated acreage is under the district's jurisdiction.

2.6.3.4 California Drinking Water Information System Database (SDWIS)

Routine water quality monitoring data is also available from the eight Public Water Systems (PWS) within SSJMUD boundaries. These systems are required to routinely sample for Title 22 regulated constituents. These water systems were identified through the Groundwater Ambient Monitoring and Assessment (GAMA) database. Water quality data is available through SDWIS. This program provides data for an additional 12 wells. Table 2-27 summarizes the public water systems identified within SSJMUD boundaries.

Table 2-17: Public Water Systems within SSJMUD

Water System Number	Water System Name	District	Type	# Connections	Population Served	Service Area	# Wells
CA1500518	Agbayani Village Water System	SSJMUD	C	5	NT=12; R=26	Residential	1 well
CA5400810	Akal Travel Plaza	SSJMUD	NC	3	200	Restaurant	1 Well
CA5403022	Aptco Llc	SSJMUD	NTNC	6	150	Industrial/Agricultural	1 Well
CA1510013	City of McFarland	SSJMUD	C	2804	15105	Residential	3 Wells
CA1510005	City of Delano	SSJMUD	C	9544	56623	Residential	13 wells
CA1503623	Jakov Dulcich and Sons	SSJMUD	NC	1	40	Industrial/Agricultural	1 well
CA1504002	Jasmine Vineyards	SSJMUD	NC	1	NT=6; T=75	Other	1 Well
CA1504007	Jasmine Vineyards Cold Storage	SSJMUD	NTNC	1	27	Transient Area	1 well
CA1502319	Kern Co P&R-Lake Woollomes Water System	SSJMUD	NC	4	R=1; T=400	Recreation Area	1 Well
CA1510802	Kern Valley State Prison	SSJMUD	C	2249	5300	Institution	2 wells
CA1503653	M & L Cold Storage, LLC	SSJMUD	NTNC	1	50	Industrial/Agricultural	1 well
CA1504005	M & L OFFICE	SSJMUD	NTNC	1	113	Other Non-Transient Area	1 well
CA1503374	Marko Zaninovich, Inc - Pond	SSJMUD	NTNC	12	30	Industrial/Agricultural	1 well
CA5402041	Penny Wise Motel	SSJMUD	NC	3	27	Hotel	1 Well
CA1502620	Pond Mutual	SSJMUD	C	18	48	Residential	1 Well
CA1502221	Pond School Water System	SSJMUD	NTNC	1	250	School	1 Well
CA5400964	Sierra Vista Assn	SSJMUD	C	13	44	Residential	1 Well
CA1502581	Sunview Cold Storage Water System	SSJMUD	NTNC	4	130	Industrial/Agricultural	1 well

*C = Community water system
NTNC = Nontransient non-community water system
TNC = Transient non-community water system
NT = Nontransient
T = Transient
R = Residential

2.7 Existing Water Resource Programs

This section identifies and discusses current water resources programs the District participates in. Expanding off Section 1.4.3, this section provides an in-depth overview of each program and District involvement.

2.7.1 *Management Plans*

The State of California has pre-SGMA programs for the management of groundwater supply and quality. These programs are managed at various levels of government by existing public agencies, either individually or collaboratively with neighboring agencies within the same groundwater basin. The following section provides an overview of these programs and the elements addressed in each.

2.7.1.1 Groundwater Management Plans

In 1992, the State of California passed the Groundwater Management Act (AB 3030). This legislation provided guidelines for the agencies and districts to provide planned and coordinated monitoring, operation, and administration of groundwater basins with the goal of long-term sustainability. There are several types of GMPs.

Pre-SB 1938 Plans:

These plans, typically adopted before 2002, could be prepared by a local agency in a Bulletin 118-desginated basin on a voluntary basis. The voluntary components of these plans include:

- The control of saline water intrusion.
- Identification and management of wellhead protection areas and recharge areas.
- Regulation of the migration of contaminated groundwater.
- The administration of a well abandonment and well destruction program.
- Mitigation of conditions of overdraft.
- Replenishment of groundwater extracted by water producers.
- Monitoring of groundwater levels and storage.
- Facilitating conjunctive use operations.
- Identification of well construction policies.
- The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.
- The development of relationships with state and federal regulatory agencies.
- The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

SB 1938 Plans:

These plans were generally adopted during or after 2002, incorporating the elements of the Pre-SB 1938 Plans. With the passage of SB 1938, the following components were required as part of any GMP:

- Basin Management Objectives: The GMP shall include Basin Management Objectives relating to the monitoring and management of groundwater levels within the groundwater basin, groundwater quality degradation, inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin.
- Agency Cooperation: The local agency shall prepare a plan to involve other agencies that enables the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin.
- Mapping: The local agency shall prepare a map that details the area of the groundwater basin, as defined in DWR's Bulletin 118, and the area of the local agency, that will be subject to the GMP, as well as the boundaries of other local agencies that overlie the basin in which the agency is developing a GMP.
- Monitoring Protocols: The local agency shall adopt monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence (in basins for which subsidence has been identified as a potential problem), and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin.
- Located outside Bulletin 118 Groundwater Basins: Plans located outside DWR Bulletin 118 alluvial groundwater basins will incorporate the above components and shall use geologic and hydrologic principles appropriate to those areas.

AB 359 Plans:

When AB 359 was enacted in 2013, it required additional technical components related to groundwater recharge areas and modification to several of the existing GMP adoption procedures in place as part of SB 1938. The additional technical components are as follows:

- The groundwater projects to which these requirements apply include projects that are part of an integrated regional water management program or plan.
- Groundwater projects require a description of how recharge areas identified in the plan substantially contribute to the replenishment of the groundwater basin and a map identifying the recharge areas, as defined, for the groundwater basin to be included in a GMP for purposes of the state funding requirements.
- Require the local agency to provide the map of the recharge areas to local planning agencies and notify the department and other interested persons when a map is submitted to those local planning agencies.

SSJMUD adopted a Pre-SB 1938 GMP in 1993. This GMP was also included in SSJMUD's Agricultural Water Management Plan in 2012.

2.7.1.2 Agricultural Water Management Plans

The Water Conservation Act of 2009 (SB X7-7) requires that agricultural water suppliers serving more than 25,000 irrigated acres adopt and submit to DWR an Agricultural Water Management Plan (AWMP). These plans include reporting on implementation status of Efficient Water Management Practices (EWMPs) within the supplier's service area. Areas which are served by recycled water deliveries only are excluded from the total amount of irrigated acreage. In the Emergency Drought Measures enacted by the State of California in 2015, agricultural water suppliers serving 10,000 irrigated acres or more were required to prepare and submit an AWMP to DWR. The Emergency Drought Measures also included requirements for information beyond the requirements of SB X7-7. SSJMUD prepared its first draft of its AWMP in 2010; the final draft was submitted to the US Bureau of Reclamation and approved in May 2012.

2.7.1.3 Urban Water Management Plans

The Urban Water Management Planning Act requires that urban water suppliers with a usage of over 3,000 AFY or that serve more than 3,000 urban connections must adopt an Urban Water Management Plan (UWMP). This plan is to ensure that the urban water supplier adequate addresses water supplies for existing and future demands. These plans were first required in 2005, with updates to be prepared and submitted by urban water suppliers every five (5) years. Based upon its historic and current water usage of less than 3,000 AFY, the City of McFarland is not required to prepare and implement a UWMP. The City of Delano, however, prepared and submitted its 2010 UWMP in 2011, with a subsequent update prepared in 2015.

2.7.1.4 Integrated Regional Water Management Plans

In 2002, the Regional Water Management Planning Act (SB 1672) created the Integrated Regional Water Management (IRWM) Program. The IRWM Program is used as a collaborative effort to identify and implement water management solutions on a regional scale that increase regional self-reliance, reduce conflict between agencies and users, and manage water to concurrently achieve social, environmental, and economic objectives. By collaborating on projects, participants in the IRWM Program can provide these benefits and meet their water supply and quality goals. In the Kern County Subbasin, there are two IRWM Plans: the Poso Creek IRWM Plan and the Kern County IRWM Plan. SSJMUD is a participant in the Poso Creek IRWM Plan, which was adopted in 2007.

2.7.1.5 Irrigated Lands Regulatory Program

The Tulare Lake Basin General Order (Order R5-2013-0120) was passed by the RWQCB in 2006. This order requires that any irrigated land having the potential to discharge to surface water or groundwater must comply with the requirements set by the RWQCB. Compliance

includes membership in a Coalition or obtaining coverage through an Individual Order from the RWQCB. SSJMUD is a member of the Kern River Watershed Coalition Authority, which was formed in 2011.

2.7.1.6 Groundwater Export Ordinance

Kern County adopted a groundwater export ordinance in 1998, which requires a Conditional Use Permit (CUP) for export of water to areas both outside the County and within watershed areas of underlying aquifers in the County. The ordinance applies only to the southeastern drainage of the Sierra Nevada and Tehachapi mountains in the South Lahonten Hydrologic Region in eastern Kern County.

2.7.1.7 Title 22 Drinking Water Program

The Division of Drinking Water regulates public drinking water systems, which include municipal and state small water systems. In addition to the cities of Delano and McFarland, there are several state small systems and multi-parcel/multi-connection systems in SSJMUD's jurisdiction. These systems are required to comply with the standards set forth in Title 22 of the California Code of Regulations. For single parcel/single-connection systems, Kern County Environmental Health Services provides regulation and oversight to meet the requirements of Title 22.

2.7.2 *Conjunctive Use Programs*

Conjunctive use or "the coordinated use of surface water and groundwater" has been used for many years in Kern County, for the benefit of water users, to allow for flexibility in the way water is delivered, whether climatic conditions allow for imported surface water, or if groundwater is needed in any given year. Conjunctive use is further described by the Water Education Foundation with the following: "In its passive form, also called in-lieu conjunctive use, surface water is used in wet years and groundwater is used in dry years. In active conjunctive use, surface water is directly injected into aquifers and wells to be used as needed as part of groundwater banking" (Water Education Foundation, 2019).

SSJMUD has participated in conjunctive use programs, for both in-lieu and direct recharge banking activities to enhance the flexibility of water supplies to meet the water demands of SSJMUD stakeholders.

3. Sustainable Management Criteria

3.1 Sustainability Goals

SGMA requires that a sustainability goal be defined for the basin (CWC §10727(a)) and the GSP emergency regulations further clarify that the sustainability goal be defined on a basin-wide basis. SSJMUD, working with the KGA and other GSAs in the Subbasin have developed the following sustainability goals for the Subbasin:

> *Sustainable management in the Kern County Subbasin will result from the implementation of projects and management actions at the member agency level of each GSA to maintain its groundwater use to the sustainable yield of the basin, operate at or above established measurable objectives, and above established minimum thresholds. The sustainable yield, measurable objectives, and minimum thresholds in the Subbasin have been established based on the technical information presented in the Basin Setting of this KGA GSP and the technical information developed by each member agency and presented in their management area plans.*
>
> *The projects and management actions proposed by the member agencies of the KGA include a variety of water supply development and demand management actions that collectively will bring the Subbasin sustainability over the 20-year implementation period.*
>
> *The Subbasin will continuously monitor groundwater conditions, as required by SGMA, and will continue coordination among the KGA member agencies and all other GSA's in the Subbasin to identify the potential for or presence of undesirable results. The coordination process established in the development of the this GSP and memorialized in the coordination agreement will ensure that the Subbasin is managed as a unit and that the districts within the Subbasin work collaboratively towards sustainability.*

3.2 Undesirable Results

Undesirable results for each sustainability indictor have been developed through a collaborative process with all GSAs in the Subbasin, compliant with GSP emergency regulations, which states that undesirable results are to be defined consistently throughout the basin (23-CCR § 354.20). The definitions of undesirable results provide flexibility for each management area within the Subbasin to define minimum thresholds that constitute significant and unreasonable impacts to the beneficial uses and users of groundwater within the specific management areas.

The definitions of undesirable results for the Subbasin are described in the KGA GSP and are repeated here with additional information regarding causes and effects of each sustainability indicator for the SSJMUD management area.

3.2.1 Undesirable Results for Chronic Lowering of Groundwater Levels

The basin-wide definition of undesirable results for chronic lowering of groundwater levels is as follows:

> *The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.*
>
> *This is determined when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area). Minimum thresholds shall be set by each of the management areas through their respective management area plans and Groundwater Sustainability Plans.*

Within the Subbasin, a management area will be considered an undesirable results watch area for lowering of groundwater levels when it exceeds its minimum threshold criteria, as determined by each management area. The SSJMUD management area will be considered an undesirable results watch area when 51% of the representative monitoring sites in a management area violate their minimum threshold for groundwater levels. If multiple undesirable results watch areas meet the criteria for a Subbasin undesirable result, as defined above, the Subbasin would be considered to be experiencing an undesirable result.

3.2.1.1 Potential Cause of Undesirable Results

A potential cause of the undesirable result of chronic lowering of groundwater levels in the SSJMUD management area is a continued or increased reliance on groundwater pumping due to the reduction of imported water supplies. As the primary use of groundwater in SSJMUD is for agriculture, increased groundwater pumping could also occur if new land is put into agricultural production or if water use per acre on existing irrigated land increases. Volume of water pumped by municipal and industrial users is relatively minimal when compared to the volume of water used for agricultural production. No significant development is anticipated in SSJMUD based on the review of the current General Plans.

3.2.1.2 Potential Effects of Undesirable Results

The primary potential effect of the chronic lowering of groundwater levels on the beneficial uses and users of groundwater in SSJMUD may include groundwater well dewatering and increased pumping lift. Well dewatering is detrimental to wells as it can lead to increased maintenance costs (e.g., well rehabilitation/redevelopment and pump lowering) and reduced well lifespan due to corrosion of well casings and screens. Increased pumping lift results in more energy use necessary per unit volume of groundwater pumped and corresponding higher pumping costs, as well as increased wear and tear on well pump motors, and reduced well efficiency.

3.2.2 Undesirable Results for Reduction of Groundwater Storage

The basin-wide definition of undesirable results for reduction of groundwater storage is as follows:

> *The point at which significant and unreasonable impacts, as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended 10-year drought period.*
>
> *This is determined when the volume of storage (above the groundwater level minimum thresholds) is depleted to an elevation lower than the groundwater level minimum threshold in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by the acreage of each management area). Minimum thresholds shall be set by each of the management areas through their respective management area plans and Groundwater Sustainability Plans.*

Within the Subbasin, a management area will be considered an undesirable results watch area for reduction in storage when it exceeds its minimum threshold criteria, as determined by each management area. The SSJMUD management area will be considered an undesirable results watch area for reduction in groundwater storage when 51% of the representative monitoring sites in a management area violate their minimum threshold for groundwater levels, since water elevations serve as a proxy for reduction of groundwater storage. If multiple undesirable results watch areas meet the criteria for a Subbasin undesirable result, as defined above, the Subbasin would be considered to be experiencing an undesirable result.

3.2.2.1 Potential Cause of Undesirable Results

Reduction of groundwater storage is generally correlated to chronic lowering of groundwater levels. Therefore, the potential causes of undesirable results due to reduction in groundwater storage are generally the same as the potential causes listed above for the undesirable results due to chronic lowering of groundwater levels.

3.2.2.2 Potential Effects of Undesirable Results

SSJMUD has defined the undesirable result of reduction of groundwater storage as the reduction of available groundwater volumes needed to support a 10-year drought period, similar to that experienced over the 2006 to 2016 period. The volume of groundwater storage needed to support a 10-year drought is above the minimum threshold for chronic lowering of groundwater levels, therefore groundwater elevations below this minimum threshold would have the same effects on beneficial uses and users in SSJMUD as chronic lowering of groundwater levels.

3.2.3 Undesirable Results for Degraded Water Quality

The basin-wide definition of undesirable results for degraded water quality is as follows:

The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

This is determined when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the designated monitoring points within the basin. Minimum thresholds shall be set by each of the management areas through their respective management area plans and Groundwater Sustainability Plans.

Within the Subbasin, a management area will be considered an undesirable results watch area for degraded water quality when it exceeds its minimum threshold criteria, as determined by each management area. The SSJMUD management area will be considered an undesirable results watch area for degraded water quality when 51% of the representative monitoring sites in a management area violate their minimum threshold for groundwater levels, since groundwater levels serve as a proxy for degraded water quality. If multiple undesirable results watch areas meet the criteria for a Subbasin undesirable result, as defined above, the Subbasin would be considered to be experiencing an undesirable result.

3.2.3.1 Potential Cause of Undesirable Results

As described in Section 2.3.4, groundwater within the SSJMUD management area plan's boundaries is high quality that meets nearly all existing standards, including the SWRCB's Water Quality Goals. Based on the available data and trend analysis, TCP, arsenic and salinity are the primary constituents of concern. Potential cause of undesirable results for these constituents are:

- **TCP:** no undesirable results related to groundwater levels or management. TCP is a chlorinated hydrocarbon that is highly soluble in water with a low soil sorption coefficient, meaning that it easily migrates in groundwater. The half-life of TCP in groundwater is reported from one to two hundred years (reference: State Water Board, Groundwater Information Sheet, TCP https://www.waterboards.ca.gov/gama/docs/coc_tcp123.pdf). Additionally, the California Water Boards reports that drinking water sources impacted with TCP in the Central Valley are attributed to past application of soil fumigants containing TCP (1,3-D soil fumigants), which were applied between 1950 and the late 1970's. By the early 80's these fumigants were believed to be completely out of the market. Because of the nature and source of TCP contamination, water management activities do not influence groundwater contamination from TCP.
- **Arsenic:** potential causes of undesirable results related to arsenic and lowered water levels are unknown at this time because arsenic is naturally occurring in the groundwater. Where the Corcoran clay is present, arsenic leaches into the groundwater from the pyrite sediments contained within the clay deposits. Consequently, arsenic occurrence is a

function of contact with these deposits. If lowered water levels minimize contact with the clay deposits, less arsenic will be present in the groundwater.

Outside of the Corcoran clay, arsenic is also found in very deep portions of the basin. Data analysis shows that elevated arsenic levels are predominately located in the confined aquifer, which is in the north east portion of the District. Trends were observed with very deep wells showing higher arsenic concentrations. There were clear trends indicating that lowered water levels contributed to increased arsenic levels.

- **Salinity:** potential causes of undesirable results related to salts and lower water levels are unknown at this time. No discernable trends were observed. Wells with elevated sodium levels are located throughout the District's service area. Studies and management plans conducted through CV-SALTS are expected to have a greater impact on salt loading/management than groundwater levels.

The extent and impact that groundwater levels have had historically, and may have in the future, should continue to be analyzed and addressed in future updates of this plan. It is proposed to monitor the interaction of water management actions with groundwater levels, and in turn the interaction of groundwater levels with water quality, over the next five years to determine if a correlation exists. With respect to point source contamination issues, GeoTracker and EnviroStor databases should be routinely monitored for any updates or new contamination sites.

3.2.3.2 Potential Effects of Undesirable Results

Potential effects of an undesirable result for sodium depends on the beneficial users. Salinity levels are unlikely to increase to levels that exceed the drinking water limits. Therefore, agricultural users are the most impacted. Effects of levels above the SWRCB Ag goals could potentially reduce crop yield.

While it is important for SSJMUD and KGA to closely monitor the correlation between groundwater levels and contaminant concentrations, other water quality regulatory programs are expected to have a greater impact. The ILRP and the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) program both focus on managing the increasing salinity and nitrate levels in the Central Valley. ILRP is contributing to reducing nitrate loading through its nitrate management plans. By 2022, CV-SALTS will require waste discharge permittees to establish and participate in management zones that are focused on supporting the Human Right to Water and provide replacement drinking water where nitrate exceeds the MCL of 10 ppm.

Because degraded water quality could potentially reduce the amount of usable supply delivered to groundwater users or require the need for treatment systems, which could potentially have a negative economic effect, SSJMUD and KGA intend to cooperate with regulatory programs focused on studying, mitigating, and managing nitrates and salts in the groundwater.

3.2.4 Undesirable Results for Land Subsidence

The basin-wide definition of undesirable results for land subsidence is as follows:

> *The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure.*
>
> *This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.*

It is generally recognized that land subsidence is occurring within the Subbasin and also within SSJMUD. However, within SSJMUD management area described in this management area plan, no impacts to critical infrastructure have been identified. The lowering of groundwater levels within the SSJMUD area could potentially contribute to subsidence, as can the groundwater pumping from neighboring areas. As no impacts to critical infrastructure have been identified and because it is not clearly understood how groundwater pumping in different areas of the basin affects subsidence, SSJMUD has identified land subsidence as a data gap. As a result, no minimum thresholds are established for land subsidence at this time. SSJMUD will work cooperatively with the KGA and other GSAs in the Subbasin to collect additional data and develop a better understanding of the causes (amount and locations of groundwater pumping) and impacts to critical infrastructure. Minimum thresholds will be adopted by SSJMUD at such time that a clear understanding of the causes and effects can be developed.

3.2.4.1 Potential Cause of Undesirable Results

Land subsidence can be caused by several mechanisms, but the mechanism most relevant to sustainable groundwater management is the depressurization of aquifers and aquitards due to lowering of groundwater levels, which can lead to compaction of compressible strata and lowering of the ground surface. Therefore, the potential causes of the undesirable results of land subsidence are generally the same as the potential causes listed above for undesirable results due to chronic lowering of groundwater levels.

3.2.4.2 Potential Effects of Undesirable Results

Potential effects of land subsidence include damage to critical infrastructure including pipelines, roads, building, water conveyance systems, and flood control facilities. Damage to these systems could impact water delivery to surface water, resulting in increased groundwater use. Of primary concern to the District, is the impact of subsidence to the FKC. Subsidence affecting the canal is from groundwater pumping to the north of the Subbasin.

3.2.5 Undesirable Results for Seawater Intrusion

The location of the Subbasin, as it is described in the KGA GSP's basin setting and the basin setting of this management area plan demonstrates that seawater intrusion is not under

consideration for this management area or for the Subbasin at large because the Kern County Subbasin is located more than 60 miles from the nearest body of seawater. This separation precludes the possibility of seawater intrusion.

3.2.6 Undesirable Results for Interconnected Surface Streams

Due to the historic groundwater pumping in the Subbasin and the Tulare Lake Basin, in general, the groundwater elevations have lowered such that interconnected surface streams no longer exist in the KGA portions of the Subbasin. This information is presented in the KGA GSP basin setting and the basin setting in this management area plan.

3.3 Minimum Threshold

The following section sets the minimum threshold for each of the sustainability indicators applicable to the SSJMUD management area. Thresholds are discussed as a proposed minimum groundwater elevation that would exhibit undesirable results if groundwater elevations fall below the proposed thresholds for any sustainability indicator. Of the six sustainability indicators, seawater intrusion and interconnected surface water are not issues within the District, as indicated in the Basin Setting.

In accordance to §354.28 (d), the District thresholds with respect to groundwater elevations are used as a proxy for identifying undesirable results in groundwater storage, groundwater water quality, and land subsidence. Although groundwater storage in the basin is plentiful, it becomes uneconomical to obtain groundwater at certain depths. Therefore, SSJMUD has elected to maintain approximately 10-years of groundwater storage (by volume) above the minimum threshold for groundwater elevation to manage a 10-year operational drought, similar to the 2006-2016 historical period. With respect to water quality, water levels cause changes in concentration of constituents at different depths of water level per location. Subsidence is known to be caused by the dewatering clay layers (from water level decline) and can be represented by groundwater levels.

The minimum threshold values are determined by separating the basin underlying the SSJMUD management area into different hydrogeologic zones (HZs), areas with similar hydrologic and geologic conditions. The creation of the HZs was closely coordinated with those districts adjacent to the SSJMUD management area. Figures in Appendix H shows the distribution of HZs across the District and its neighboring management areas. Spring water level data spatially representative of individual HZs were plotted together and a linear trend was projected from 2006 to 2016 (historic 10-year drought period). Within the District's, all HZ groundwater elevation plots show a declining groundwater slope during the 2006-2016 period. This 10-year period was then projected to 2040 with a unique equal slope for each HZ to estimate the resulting groundwater level if the 2006-2016 conditions persisted for the 20-year implementation period from 2020 through 2040. This methodology was chosen as it would represent a worst-case condition and present a case which could be evaluated by the District's stakeholders to

understand what level of impact would be considered significant and unreasonable to individual stakeholder within each HZ. As previously stated, this methodology represents a worst-case scenario in terms of imported water supply deliveries and local hydrology. Figure 3-1 shows the change in groundwater elevation from 2015 to 2040 for North of the Kern River.

The 2040 conditions are set as the minimum threshold value. Figure 3-2 shows the estimated minimum thresholds in the SSJMUD management area. The projected 2040 water levels indicate the expected change to groundwater level with hydrology maintaining the 2006 to 2016 trend through 2040. This trend represents a worst-case scenario in which the District does not implement any management actions, or projects to mitigate pumping beyond what currently exists and is the case landowners/stakeholders were presented to determine which impacts would be significant and unreasonable. Through a series of workshops and individual meetings between the District's staff and landowners, the results of this projected future condition were reviewed with District's stakeholders. Based on the review and feedback from landowners and stakeholders, the District adopted the minimum thresholds and measurable objectives described in the following section.

3.3.1 The Chronic Lowering of Groundwater Levels

Minimum threshold values for chronic lowering of groundwater levels in SSJMUD are shown on Table 3-1. The minimum threshold values vary within the management area (and throughout the Subbasin) due to hydrology and the projected decreases in water levels, determined in each HZ. The management area contains multiple minimum thresholds depending on the hydrologic gradients and spatial distribution of the representative monitoring sites as shown in the table below.

NORTH OF RIVER GROUNDWATER PROJECTED ELEVATIONS CHANGE 2015 - 2040

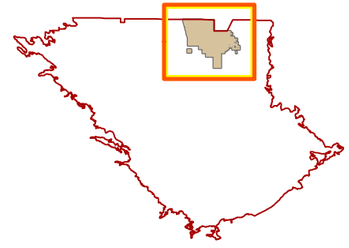
- Projected 2040 Groundwater Elevation Contour (MSL)
- Hydrogeologic Zone

GW Drop 2015-2040

- -228 to -159
- -259 to -229
- -315 to -260
- -343 to -316

Management Plan Area

- Southern San Joaquin MUD
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



0 2 4 Miles

N

Southern San Joaquin Municipal Utility District Management Area Plan

Kern County, California

GEI Consultants

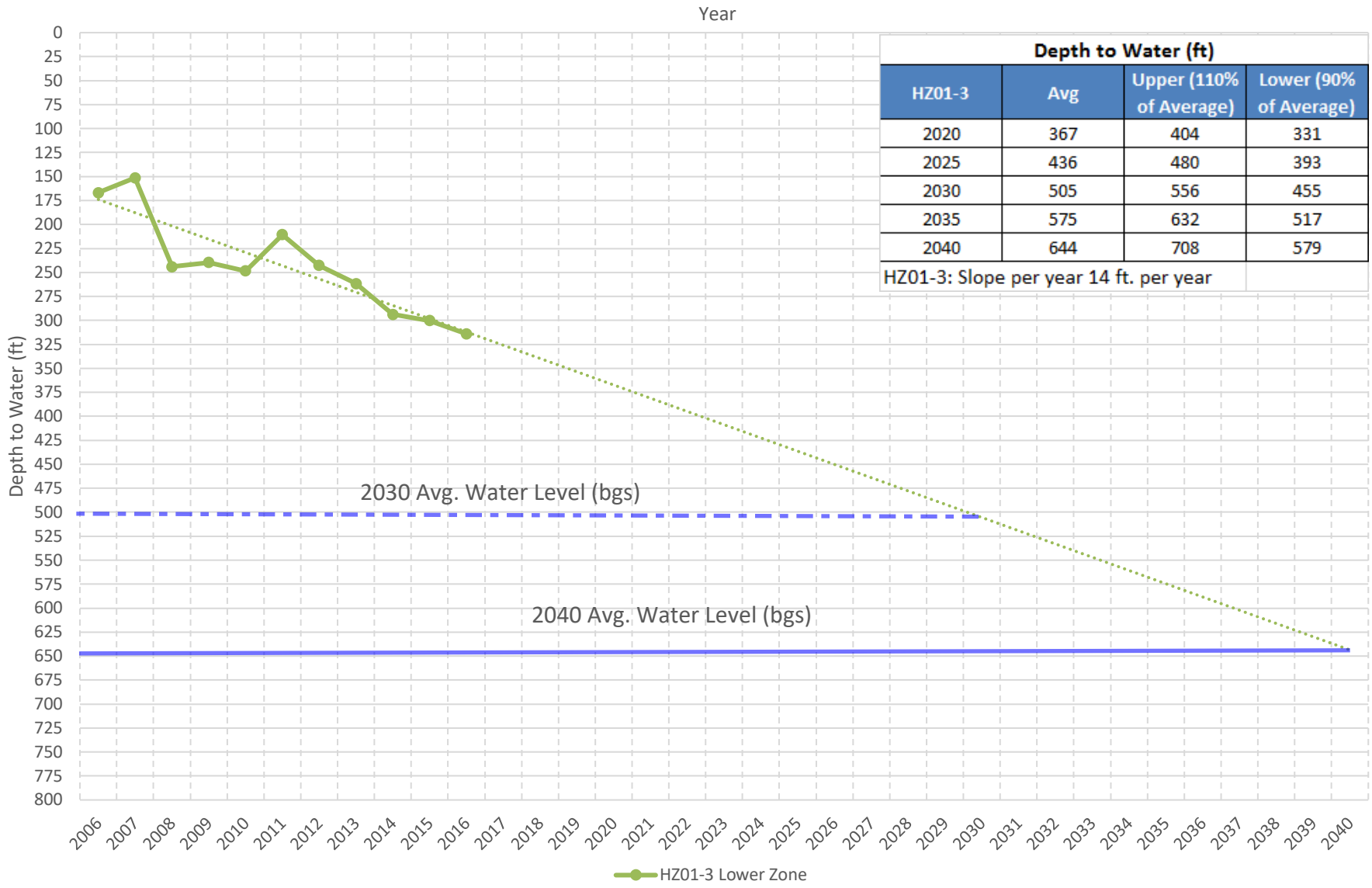
AUGUST 2019 FIGURE 3-1

SOURCE: GEI (2019)

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HZ 01-3



Depth to Water (ft)			
HZ01-3	Avg	Upper (110% of Average)	Lower (90% of Average)
2020	367	404	331
2025	436	480	393
2030	505	556	455
2035	575	632	517
2040	644	708	579
HZ01-3: Slope per year 14 ft. per year			

Figure 3-2

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Table 3-1: Minimum Thresholds for SSJMUD Monitoring Points

Well ID	Latitude	Longitude	Minimum Threshold
City of Delano			
Well 14	35.742	-119.242	-197
Well 23	35.790	-119.303	-215
Well 30	35.790	-119.231	-101
City of McFarland			
Taylor Ave. Well	35.667	-119.240	-117
SSJMUD 66 Wells			
8	35.747	-119.336	-329
14	35.739	-119.205	-136
23	35.719	-119.304	-278
42	35.693	-119.232	-123
53	35.631	-119.191	-131
59	35.682	-119.152	-112
62	35.718	-119.145	-83

SSJMUD believes that the proposed minimum groundwater elevation will not cause undesirable results in the basin. The District will reevaluate the threshold based upon the District's ability to implement projects and management actions and, if necessary, will adjust the minimum threshold if they are able, to prevent causing an undesirable result in the basin.

In determining the minimum threshold, the impact of lowering water levels to the proposed minimum threshold was analyzed by using available well construction data for agriculture, municipal, and domestic wells. The well impact analysis of the equivalent minimum threshold average values (represented as depth to water values) for each HZ was used to determine that a portion of the existing wells are impacted to varying extents. Most wells are expected to be operational (even with a decrease in efficiency) as the bottom of the screens remain in the water. This can be observed in Figure 3-3 for agricultural wells, Figure 3-4 for domestic wells, and Figure 3-5 for municipal wells.

Although the data presented is a subset of the total wells in the Districts' management areas, it is reasonable to assume that many wells will maintain operation even at the proposed minimum threshold values. The projected minimum threshold depths to water were reviewed with landowners within SSJMUD, along with the well impact analysis, to determine if it would be economical to mitigate the impacts of agricultural, domestic, and municipal wells.

It was determined that at the average 2040 water levels, impacts to agricultural wells could and would be mitigated by landowner to the extent that declining groundwater levels was created by localized actions by those landowners. It was determined that none of the identified agricultural

water wells within the SSJMUD management area would be dewatered, however in many instances water levels near the minimum threshold would require lowering of pump bowls.

It was also identified that if water levels were to fall to levels near the minimum threshold then mitigation would be necessary to address the impacts to the few impacted domestic wells in the area. Any further decrease in water level below the established minimum threshold would create a significant and unreasonable impact to overlying groundwater users and would cause an undesirable result. In normal operating conditions, the extent of impact to wells is expected to be less as water levels are expected to be at higher elevations than the minimum threshold. However, the analysis determined it is possible for the District to drop water levels to the established minimum threshold values and not have undesirable results that cannot be mitigated.

3.3.2 Groundwater Storage

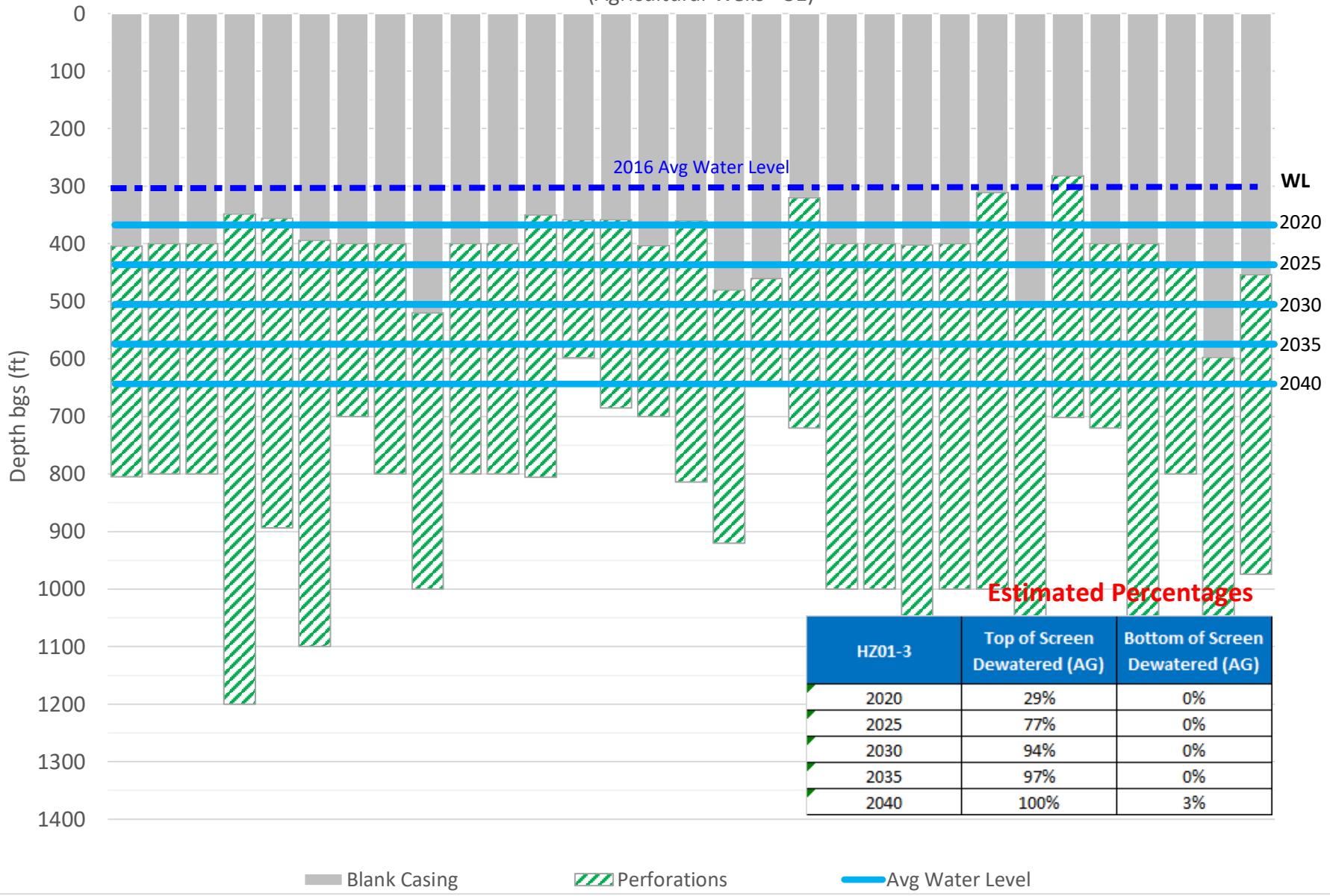
The minimum threshold for groundwater storage was set in conjunction with the minimum threshold for the groundwater level. In this Subbasin groundwater storage is not a significant issue regarding water supply since there is enough storage in the Subbasin to use beyond the set minimum threshold, but access is reduced based on what is economical to currently extract. The minimum thresholds impact to groundwater users for reduction of groundwater storage are the same as those for the chronic lowering of groundwater based on the ability to economically access the water and the proposed water levels are not expected to cause an undesirable result.

3.3.3 Degraded Water Quality

Minimum thresholds are not set for degraded water quality because the data analysis conducted does not indicate that water quality is degraded by lowered water levels. Data trending was performed on several representative wells in the management area plan's boundaries to evaluate contaminant concentration changes and identify correlations to groundwater levels. This trending indicated that no discernable trends can be stated since the correlation between groundwater levels and arsenic levels was not consistent for most of the wells. TCP trending indicates that contaminant concentrations also did not correlate to water level changes. Sodium levels also could not be correlated with water levels due to lack of data.

Based on these findings, groundwater levels will be used as a proxy for degraded water quality as the District, in coordination with the other members of the KGA, continues to analyze groundwater level and water quality trends. Even though SGMA does not require a GSA to comply with Federal and state drinking water standards, the various monitoring programs overseen by regulatory agencies (as discussed in Section 2.6.3.3) were incorporated into this management area plan by reference. Existing regulatory programs include Title 22 (Regulations Related to Drinking Water), ILRP, and CV-SALTS. While managing groundwater levels, the District and KGA will work cooperatively with entities implementing these regulatory programs to share facilities, data, and (when applicable) management actions to protect all users and beneficial uses of groundwater.

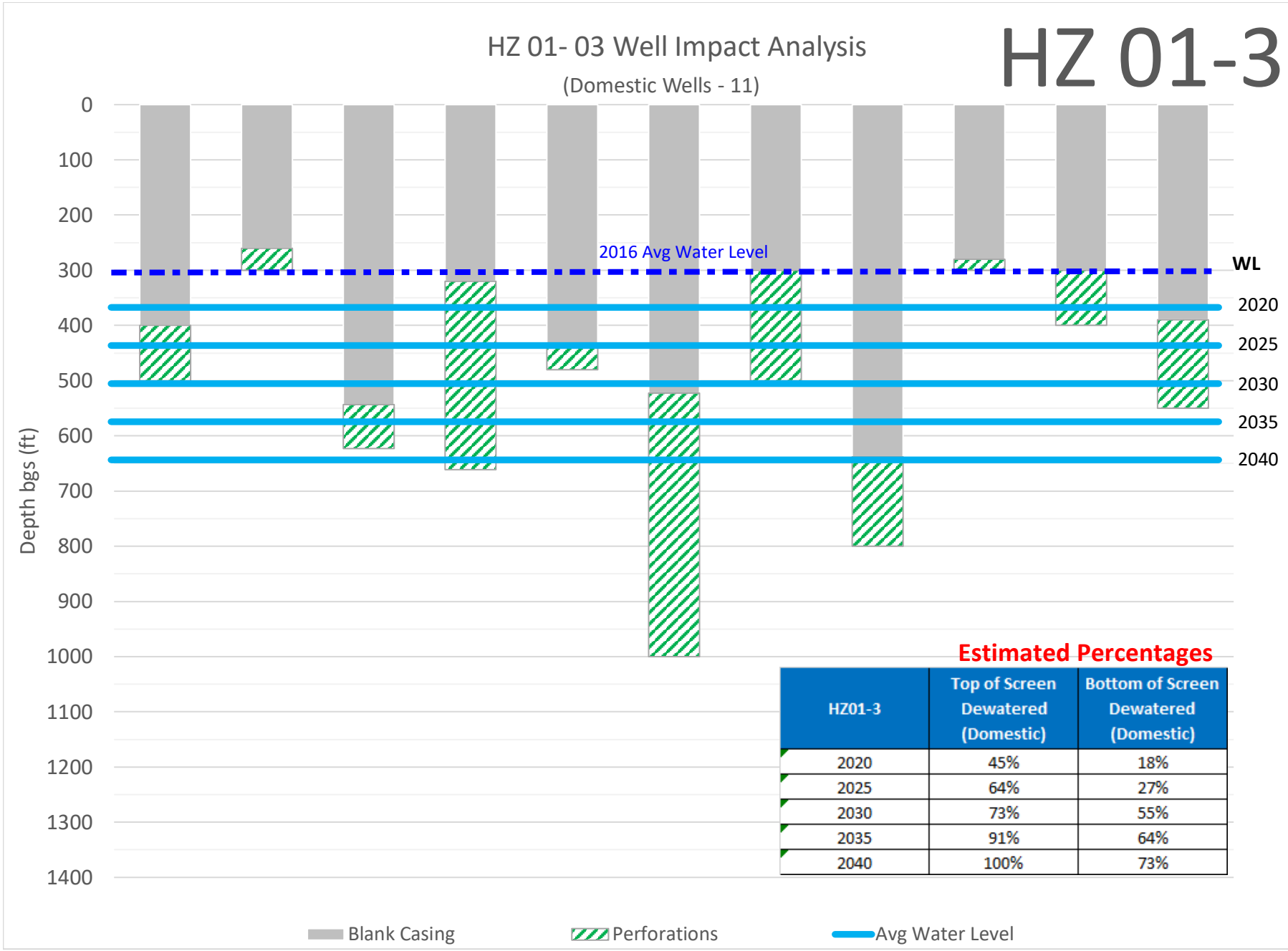
HZ 01-3



Estimated Percentages

HZ01-3	Top of Screen Dewatered (AG)	Bottom of Screen Dewatered (AG)
2020	29%	0%
2025	77%	0%
2030	94%	0%
2035	97%	0%
2040	100%	3%

Figure 3-3



Estimated Percentages

HZ01-3	Top of Screen Dewatered (Domestic)	Bottom of Screen Dewatered (Domestic)
2020	45%	18%
2025	64%	27%
2030	73%	55%
2035	91%	64%
2040	100%	73%

Figure 3-4

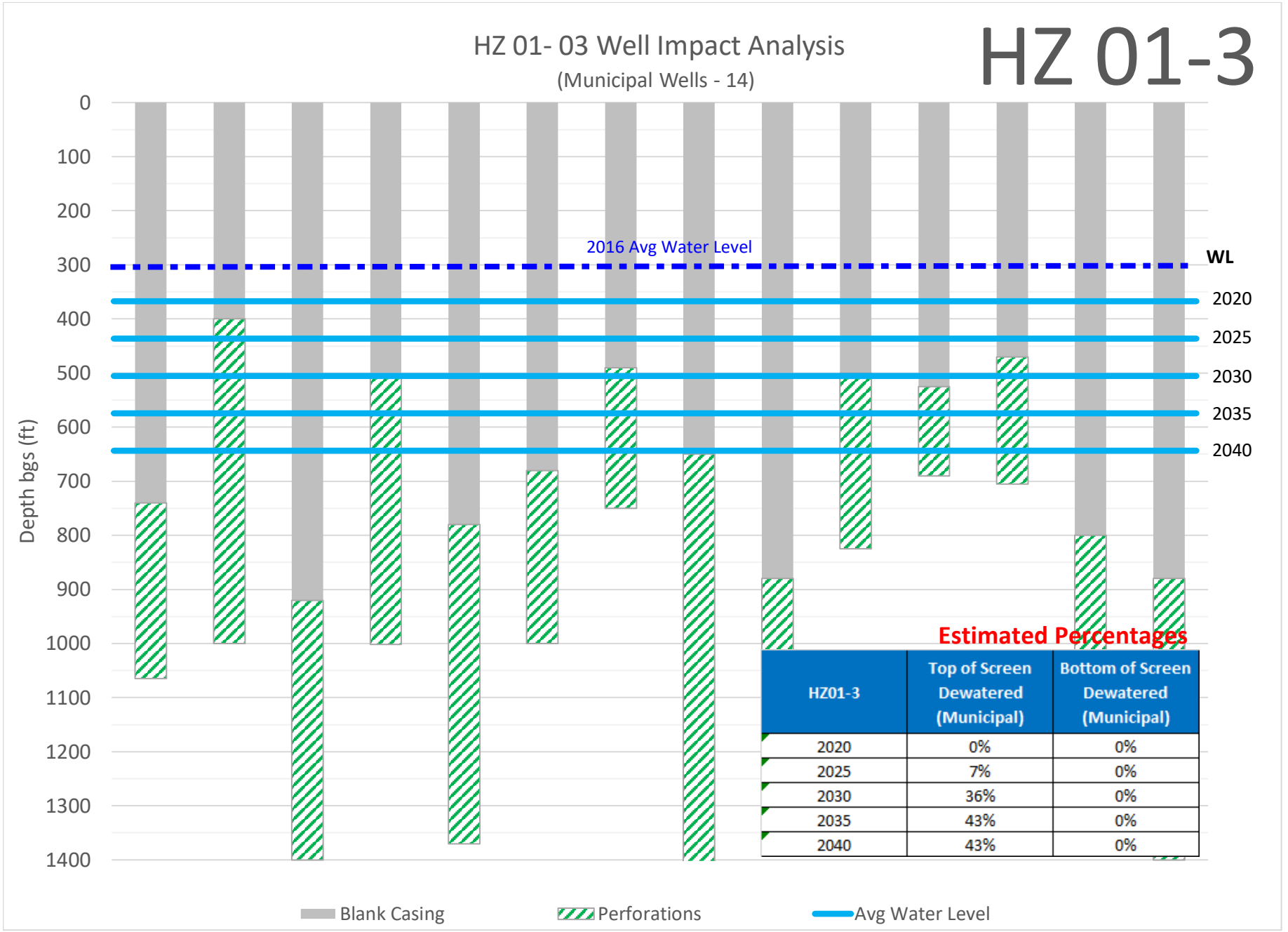

HZ 01- 03 Well Impact Analysis
(Municipal Wells - 14)
HZ 01-3
Depth bgs (ft)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
2016 Avg Water Level
WL
2020
2025
2030
2035
2040
Estimated Percentages
HZ01-3
Top of Screen Dewatered (Municipal)
Bottom of Screen Dewatered (Municipal)
2020 0% 0%
2025 7% 0%
2030 36% 0%
2035 43% 0%
2040 43% 0%
Blank Casing
Perforations
Avg Water Level

Figure 3-5

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As defined in Section 4: Monitoring Network, water quality sampling coincides with groundwater levels. This approach is expected to provide clear correlations between water quality and groundwater levels. Monitoring sites and parameters were strategically selected to inform on future degradation of water quality.

3.3.4 Subsidence

The minimum threshold for land subsidence is set equivalent to the chronic lowering of groundwater levels minimum threshold. Land subsidence currently occurs and is expected to continue with lowering of groundwater levels. The proposed water levels are unknown to cause an undesirable result regarding subsidence. In the future, when more consistent and better calibrated data is available, it may be necessary to adjust the minimum threshold dependent on what new information is available. Information needed are specifically the magnitude of subsidence around facilities and infrastructure, which are areas that may cause a significant economic problem affecting water users and others. In the future, minimum thresholds will be derived from monitoring programs implemented to increase the available data in suspected critical areas and to calibrate spatial data available.

Current data available for the Subbasin indicates that subsidence varies throughout the Subbasin. Within the jurisdictional area of SSJMUD, higher rates of subsidence occur in the northwestern portion of SSJMUD increasing North towards the Tule Basin and West to SWSD. While these rates of subsidence are higher than the rest of the area covered in this management area plan, they have not been identified as significant or unreasonable.

3.4 Measurable Objectives and Interim Milestones

The measurable objective is established in accordance to regulation §354.30 (d), groundwater elevations can serve as the value for multiple sustainability indicators where the representative value is a reasonable indicator for multiple measurable objective. As with the minimum threshold, measurable objective values were not established for depletion of interconnected surface water and sea water intrusion as these are not applicable to the basin.

The measurable objective values are determined in the same manner as explained in Section 3.3 for the minimum threshold with the exception that the measurable objective is set at 2030 water levels per the methodology described above. For the SSJMUD management area, the measurable objective is the adopted goal to maintain groundwater levels at or above the interpolated 2030 water levels. The measurable objective is a ten-year rolling average of the groundwater elevation at any given monitoring site, that represents the proposed groundwater elevation at which SSJMUD plans to maintain for sustainability.

Figure 3-6 shows the change in groundwater elevations from 2015 to 2030 for North of the Kern River. Setting the measurable objective at the 2030 water level was determined based on the margin of safety giving the District's an approximate storage of 10-years (may vary

significantly) of water supply in the instance the District is faced with a similar water supply situation as experienced during the 2006 to 2016 drought.

The interim milestones are the points at which the District plans to set their water level to reach the sustainability goal at the district level within 20 years of the plan implementation. The milestones are set every five years and are based on a linear trend to reach the measurable objective values by 2040, as shown in Figure 3-7 for the SSJMUD management area. The District will implement projects and management actions to maintain a path along the interim milestones and to meet the measurable objectives. The time frame for implementation of management actions and projects are discussed in this section.

3.4.1 The Chronic Lowering of Groundwater Levels

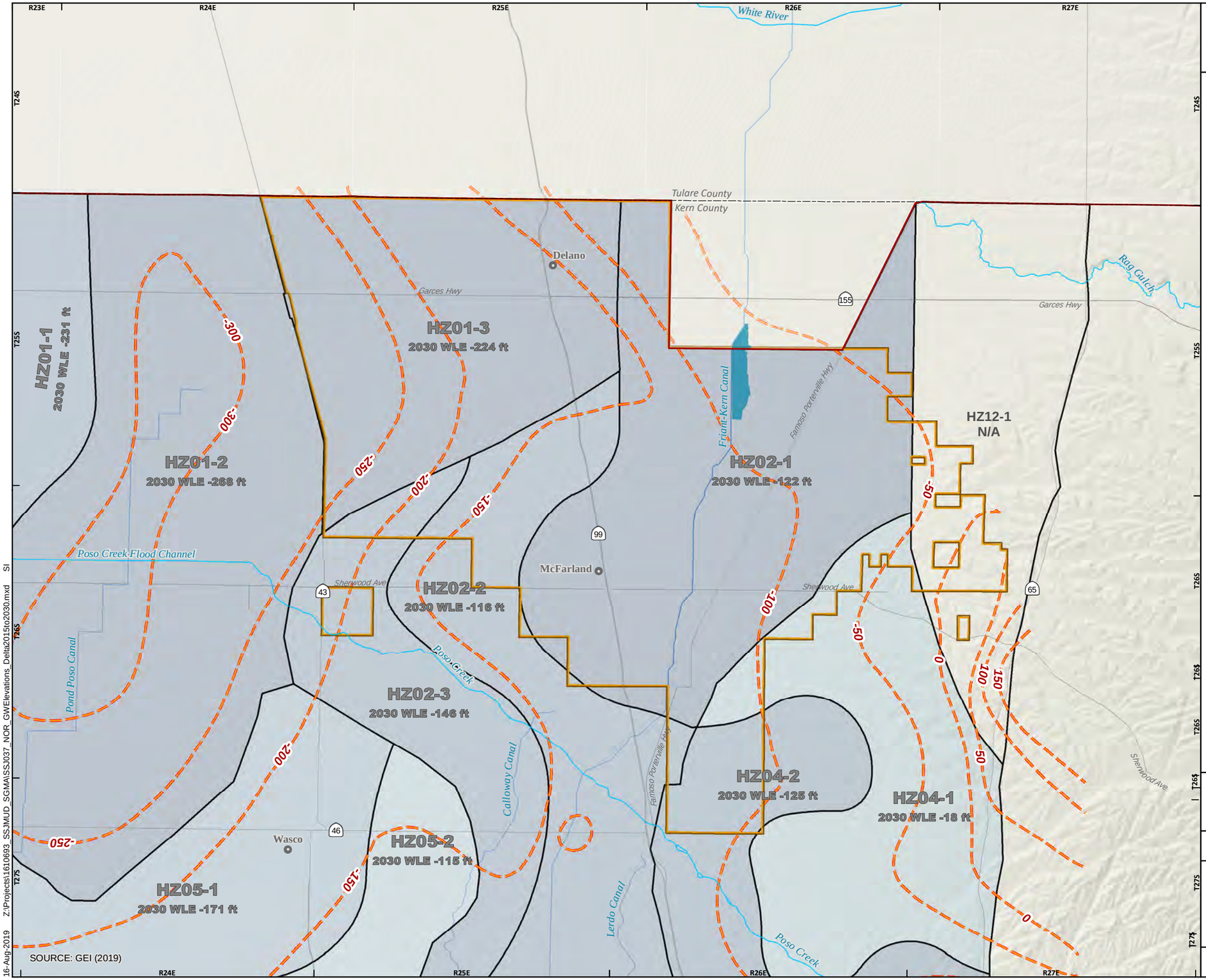
The measurable objective for the chronic lowering of groundwater levels is set at projected 2030 water levels and are monitored at the specific monitoring points. The measurable objective in each management area are monitored at various location. The established measurable objective values are determined from the 2030 water level contours and are shown for each representative monitoring point as shown in Table 3-2 for the SSJMUD management area. Figure 3-7 shows the measurable objectives along with minimum thresholds in the SSJMUD management area.

The proposed measurable objective will allow the District to operate in a worst-case scenario drought condition (2006 to 2016 conditions) and maintain operation before approaching the minimum threshold for an approximated 10 years. Prior to 10 years, the District would have the ability to implement projects or perform emergency actions to reduce pumping.

The measurable objective, like the minimum threshold values vary within the management area (and the basin) due to hydrology and the projected decrease in water level determined in each HZ subzone. The Management area contains multiple measurable objectives dependent on hydrologic gradients and spatial distribution.

The interim milestones were determined trending a linear trend to reach the measurable objective by 2040. The steps to reach the measurable objectives will be set by the interim milestones which are checked every five years during the plan's implementation. At these points, projects and management actions will be taken to reduce the reliance on groundwater supply. Section 5 contains details of the projects and management actions which will be used to achieve the interim milestones every five- years. A linear interpolation between the 2015 spring groundwater levels and the measurable objective (2030 water level projections) are used in setting the interim milestones.

NORTH OF RIVER GROUNDWATER PROJECTED ELEVATIONS CHANGE 2015 - 2030



Projected 2030 Groundwater Elevation Contour (MSL)

Hydrogeologic Zone

GW drop 2015-2030

- -136 to -95
- -155 to -137
- -189 to -156
- -206 to -190

Management Plan Area

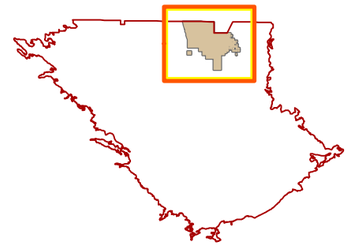
Southern San Joaquin MUD

Kern County Subbasin Boundary

Highway

Waterway

Major Conveyance



0 2 4
Miles

N

Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 3-6

16-Aug-2019 Z:\Projects\16\10693_SSJMUD_SGMA\SSJ037_NOR_GWElevations_Delta2015to2030.mxd SI

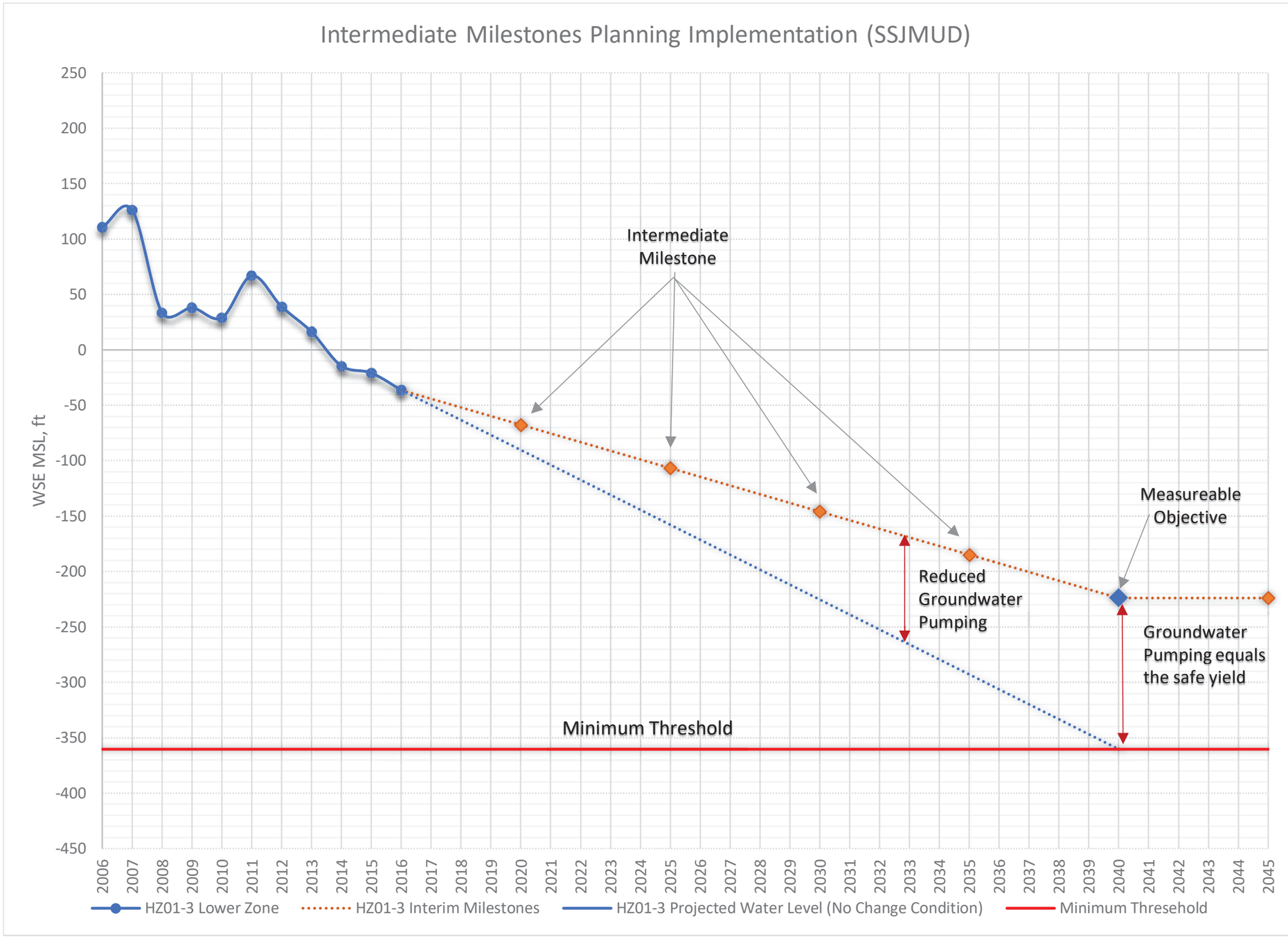

Intermediate Milestones Planning Implementation (SSJMUD)
WSE MSL, ft
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
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2041
2042
2043
2044
2045
Intermediate Milestone
Measureable Objective
Reduced Groundwater Pumping
Groundwater Pumping equals the safe yield
Minimum Threshold
HZ01-3 Lower Zone
HZ01-3 Interim Milestones
HZ01-3 Projected Water Level (No Change Condition)
Minimum Thresehold

Figure 3-7

Table 3-2: Measurable Objectives for SSJMUD Monitoring Points

Well ID	Latitude	Longitude	Measurable Objective
City of Delano			
Well 14	35.742	-119.242	-105
Well 23	35.790	-119.303	-113
Well 30	35.790	-119.231	-8
City of McFarland			
Taylor Ave. Well	35.667	-119.240	-42
SSJMUD 66 Wells			
8	35.747	-119.336	-227
14	35.739	-119.205	-57
23	35.719	-119.304	-183
42	35.693	-119.232	-48
53	35.631	-119.191	-55
59	35.682	-119.152	-37
62	35.718	-119.145	-7

3.4.2 Groundwater Storage

The measurable objective for the reduction in groundwater storage is based on the measurable objective for the chronic lowering of groundwater levels. In setting the measurable objective at the 2030 projection and the minimum threshold at the 2040 water level projection (based on the historical drought), approximately 10 years of storage is available to the District before reaching the minimum threshold, this was set as a factor of safety. A linear interpolation between the 2015 spring groundwater levels and the measurable objective (2030 water level projections) are used in setting the interim milestones.

3.4.3 Degraded Water Quality

For similar reasons as defined in Section 3.3.3 (Minimum Threshold for Degraded Water Quality), the measurable objective for the lowering groundwater levels will be used as a proxy for the measurable objective for degraded water quality. A linear interpolation between the 2015 spring groundwater levels and the measurable objective (2030 water level projections) are used in setting the interim milestones. As defined in Section 4: Monitoring Network, water quality sampling coincides with groundwater levels. This approach is expected to provide clear correlations between water quality and groundwater levels.

3.4.4 Land Subsidence

The measurable objective for land subsidence at this time is based on the measurable objective of chronic lowering of groundwater levels. As mentioned in Section 2.3.5,3.3.4 the magnitude and severity of subsidence is unknown, and data is needed to be collected to ensure the set reasonable

measurable objective and minimum threshold. The data will be reviewed at the five-year intervals. A linear interpolation between the 2015 spring groundwater levels and the measurable objective (2030 water level projections) are used in setting the interim milestones.

3.5 Margin of Operational Flexibility

The margin of operational flexibility between the measurable objectives and the minimum thresholds is a designated 10-year drought water supply. The flexibility in the system is the amount of time to implement projects to bring in additional surface water supply or to reduce groundwater demand to maintain groundwater levels above the minimum thresholds. Table 3-3 shows example of the District's operational flexibility to maintain above the minimum thresholds through voluntary management actions, such as a fallowing or land retirement program.

Table 3-3: Example District Operational Flexibility

Sustainability Component	Categories of Projects & Management Actions
Water Demand	Incentives of pumping reduction
	Fees for landowner excess pumping
	Water Market Response
	Buy Back Program
Water Supply	Import Water Supply
	Recharge Projects
	Surface Water Capture
	Other Projects

In instances where voluntary programs are not being utilized or are proven to be ineffective in the reduction of groundwater demand, more drastic measures will be taken. These measures may include mandatory pumping reduction and land fallowing. In instances where neighboring management areas differ on their sustainable management criteria, having a greater difference between the measurable objective and the minimum threshold will allow for more operational flexibility within the District so they may take action prior to reaching the minimum threshold and/or potentially negatively affecting adjacent management areas. In addition, neighboring management areas which approach their minimum thresholds may have less impact on the Districts' management area due to the larger range between the measurable objective and the minimum threshold for a given representative monitoring site, which allows for approximately 10-years of water level decline.

3.6 Potential Effects beyond Management Area

The setting of the minimum thresholds and measurable objectives described in this management area plan is coordinated with neighboring Districts to maintain a similar water level gradient as

2015 conditions. It is not expected to severely affect areas outside of the District in terms of significantly changing the surrounding water levels either lower, or higher, than conditions of neighboring Districts' plans. Also, the change in groundwater storage is correlated with the change in groundwater levels and is not expected to cause severe impact to neighboring Districts or GSAs.

Subsidence is a potential impact to neighboring Districts, GSAs, and subbasins. This extent is currently unknown, and more data needs to be collected to determine where the impacts may occur and what is contributing to these impacts.

Water quality data used to characterize groundwater conditions does not indicate that water quality degrades when groundwater levels decline. Regardless, a sampling program has been established to monitor changes in water quality related to water levels. No minimum threshold or measurable objective is set because degradation has not been observed.

Degraded water quality within SSJMUD is defined as an increasing trend in salinity (sodium and chloride) that potentially threatens agriculture viability within the district; or concentrations of nitrate, arsenic or hexavalent chromium exceeding the respective drinking water standard, because of declining water levels. While these constituents are present throughout the district, the overall trends indicate lower concentrations with lower water levels. In contrast, higher concentrations are typically observed with higher water levels.

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4. Monitoring Networks

This chapter describes the objectives, design, rationale, monitoring protocols, and data reporting requirements of the monitoring network to be implemented. This chapter discusses any data gaps, and a plan for assessment and future improvement to the monitoring network to fill data gaps.

The monitoring network and protocols are designed to collect data of sufficient quality, frequency, and distribution to characterize the groundwater and change in storage of the District, along with water budget components in SSJMUD, and to evaluate changing conditions due to water management actions and future water supply projects.

4.1 Monitoring Network Objectives

The monitoring network in the District is designed to meet the following monitoring objectives of this plan:

- Monitor impacts of groundwater pumping on beneficial uses and users of groundwater,
- Monitor progress toward measurable objectives of this plan relative to minimum thresholds,
- Collect data to quantify annual changes in water budget components of the study area, and
- Monitor changes in groundwater conditions relative to the pertinent sustainability indicators:
    - Groundwater Potentiometric Surfaces, or Groundwater Levels,
    - Groundwater Storage,
    - Groundwater Quality, and
    - Land Subsidence

4.1.1 *Water Level Monitoring as a Key Sustainability Indicator*

As described in the Section 3 of this management area plan, groundwater elevation is the key sustainability indicator for undesirable results in the Subbasin because lowering of groundwater levels leads to:

- Increased groundwater well pumping costs,
- decrease in groundwater storage,
- increased land surface subsidence most notably where fine-grained units and active groundwater overdraft are present, and

- potential changes in groundwater quality.

The groundwater level monitoring network is key to informing the progress of the management area plan's objectives for all sustainability indicators. While water levels are the key sustainability indicator for which minimum thresholds have been established, the monitoring network continues to include data collection stations for water quality, land subsidence, and other water budget components such as water demand and water supply inputs. The following sustainability indicators are not pertinent to this management area plan: seawater intrusion and depletions of interconnected surface water. Seawater intrusion is anticipated to not be a problem since the District is several miles from the ocean. For details on depletions of interconnected surface water, please refer to Section 2.3.6.

4.1.2 *Monitoring Progress toward Measurable Objectives*

The monitoring network will inform progress of sustainable management to reach interim milestones and measurable objectives. As described in Section 3.3 of this management area plan, groundwater levels are the primary indicator for which minimum thresholds have been set, and for which interim milestones and measurable objectives will be compared. However, all sustainability indicators identified in this management area plan and in the KGA Umbrella GSP are included in the monitoring network. As groundwater level monitoring progresses, effects on other indicators can be evaluated. Tracking the progress of water levels as well as other indicators will inform the effectiveness of water management actions and implemented projects. The details for how the measurable objectives and minimum thresholds were developed for groundwater levels are described in Section 3 of this Plan.

Monitoring the progress toward reaching interim milestones and measurable objectives will provide information needed to evaluate whether adjustments to management actions and the monitoring networks are required. Tables 3-1 and 3-2 show the minimum threshold and measurable objective for each monitoring site included as part of this Management Area Plan's network. As stated in §354.34(g)(3), minimum thresholds, measurable objectives, and interim milestones will be established at each monitoring site or representative monitoring site. Where needed, interim milestones for groundwater levels or other sustainability indicators may be adjusted in the five-year updates in order to maintain the objectives of this management area plan.

4.1.3 *Potential Impacts to Beneficial Uses and Users of Groundwater*

The monitoring network to be implemented will provide data to monitor the impacts of sustainable groundwater management on beneficial uses and users of groundwater, as well as secondary impacts such as land subsidence. A summary of potential impacts is included below in Table 4-1.

Table 4-1. Potential Impacts of Overdraft with Corresponding Monitoring

User Group	Potential Impacts	Monitoring and Data Collection
Irrigated Agriculture	• Increased pumping costs and maintenance • Decrease in groundwater storage	• Water level monitoring • Incorporate data into the Subbasin model to monitor storage outlooks with interim milestones
	Increased salinity in the upper and migration into the lower zone	Water quality monitoring
Industrial, Commercial, and Residential Wells	• Increased pumping costs and maintenance • Well Dewatering • Decrease in groundwater storage	• Water level monitoring • Incorporate data into the Subbasin model to monitor storage outlooks with interim milestones
	Increased Arsenic	Water quality monitoring
	Increased TCP and Nitrates	Water quality monitoring in lower aquifer zone
Public Facilities	Damaged infrastructure	Land subsidence monitoring
Groundwater Dependent Ecosystems (Preliminary NCCAG mapped dataset).	• Decline in shallow groundwater levels • Reductions in shallow groundwater storage due to groundwater pumping	• Water level monitoring • Confirm NCCAG mapped areas by field survey and evaluation • If applicable, compare pumping in the upper and lower zone with water levels in the shallow zone

4.1.4 *Monitoring Network for Water Budget Components*

One of the objectives of the monitoring network is to monitor the water budget components in order to quantify the change in water budget over time. This aspect of the network will rely on local monitoring stations for water levels, but also regional weather stations and remote sensing methods for consumptive use. In addition, water supply and exports accounting are required to monitor the water budget components. These aspects of the network are briefly described below.

4.1.4.1 Water Inflow to the Subbasin

As described in the water budget section of the report, water inflow to the Subbasin within the Districts includes:

- Surface water supplies (both imported and natural), that satisfies consumptive use, or becomes managed or unmanaged direct recharge to the Subbasin
- Precipitation
- Subsurface inflow

Surface Water Supplies

SSJMUD monitors all water received via the Friant-Kern Canal, and neighboring districts, at conveyance interties. The District performs monitoring using metering, or other gauging methods.

All imported surface water into the Districts, whether it is contracted and will be used for direct consumptive use, other exchanges, in-lieu banking, oil produced water, or direct recharge counts as water inflow to the Subbasin. Surface water diversions and imports are monitored by the Districts and are available annually to be incorporated in data evaluation.

Precipitation

Depending on the water year, precipitation may account for recharge as well as consumptive use in the Subbasin. It is a component of water budget accounting that is monitored by weather stations. The following weather stations (Table 4-2**Error! Reference source not found.**) may be used for monitoring purposes in or near the Subbasin. Online weather station data are updated daily to monthly.

Table 4-2. Weather Stations within the Vicinity.

Station Name	ID	Latitude	Longitude	Elevation (feet msl)	Other
Shafter	CIMIS 5	35.532556	-119.281790	360	
Delano	CIMIS 182	35.8330	-119.255960	300	Just north of Subbasin.

Source: https://cimis.water.ca.gov/Stations.aspx

Subsurface Inflow

Historical quantities of groundwater inflow to the Subbasin underlying the study area have been estimated in various regional models, calculated in local studies by Darcian Law, and may be estimated in the future by water budget accounting.

As a model of the study area is refined, groundwater inflow calculations may become more accurate. In addition, annual water budget accounting as well as semiannual water elevation monitoring, contouring and gradient estimating, will continue to provide data to support estimates of groundwater inflow.

4.1.4.2 Water Out of the Subbasin

As described in the water budget section of the report, water outflow or removal from the Subbasin within the District includes:

- Consumptive use from crop demand, other vegetation, evaporation, and other beneficial use such as water recreation, domestic use, municipal or industrial use, etc.

- Exported water or “Pump Back”
- Subsurface outflow

Consumptive Use

Sources of water for consumptive use include diverted surface water, precipitation, and groundwater. As described in the water budget section of this plan, consumptive use from crop demand, other vegetation, and evaporation has been calculated from remote sensing techniques (GEI, 2017; ITRC-METRIC) with periodic ground truthing. The District continues to use remote sensing methodology to further quantify consumptive use within the study area for monitoring (Land IQ, 2019). The Subbasin will continue to coordinate techniques and methodology for monitoring consumptive use to update water budget components for the Subbasin.

Exported Water, “Pump back” Water

The District monitors water that leaves the study area for banking partners or exchanges by metering or other gauging methods. These data are included in annual accounting of the water budget and will continue to be available in the future.

Subsurface Outflow

Historical quantities of groundwater outflow to the Subbasin underlying the study area have been estimated in various regional models, calculated in local studies by Darcian Law, and estimated by water budget accounting.

As the model of the study area is refined, groundwater outflow calculations may become more accurate. In addition, annual water budget accounting as well as semiannual water elevation monitoring, contouring and gradient estimating, will continue to provide data to support estimates of groundwater outflow.

4.2 Monitoring Network Design

The monitoring network design considers the use of existing monitoring networks, and the coverage required to monitor areas within the District with current and projected groundwater use. The network to be implemented is also designed to have new locations installed for data collection to fill pertinent data gaps in groundwater conditions.

The monitoring network is designed to collect data with respect to the applicable sustainability indicators in the study area: groundwater levels and reduction of groundwater storage, degraded water quality, and land subsidence. Seawater intrusion and interconnected surface waters are not applicable sustainability indicators in the study area, as described in the basin setting of this report, and are therefore, not included in the design of this monitoring network. A brief summary of the network design is introduced below. Details are provided in the sections on the monitoring of sustainability indicators.

4.2.1 *Monitoring Frequency Design*

The monitoring frequency is outlined in the protocols for monitoring sustainability indicators. In general, monitoring will occur semiannually for groundwater and monthly for land subsidence with co-located groundwater gauging. This frequency provides sufficient short-term, seasonal, and long-term data to evaluate the effectiveness of management actions.

4.2.2 *Spatial Density Design*

The spatial density of the monitoring network design accounts for general representative distribution in the district. The District's management area includes agricultural land, as well as the Cities of Delano and McFarland.

The spatial distribution of the water level monitoring sites is presented on Figure 4-1. For additional details on the spatial density for each of the monitoring sites, refer to the sections below on the monitoring of sustainability indicators.

4.2.3 *Rationale for Design*

Rationale regarding the design of the monitoring network is provided in the sections below dedicated to each sustainability indicator. In general, monitoring stations were chosen based on the following scientific rationale:

- Aquifer representation – Per DWR guidelines §354.34, monitoring wells were chosen to represent each underlying aquifer under the jurisdiction of the District
- Potential impacts to beneficial users of groundwater
- Availability of site-specific historical data and technical information
- Spatial and vertical representation
- Site accessibility

Additionally, monitoring stations were chosen based on providing suitable spatial density and representation of both agricultural and urban areas. Groundwater contour maps, hydrographs, land subsidence, and groundwater quality maps in the basin setting provide the background for current hydrogeologic conditions and where data gaps are located. Further discussion of data gaps is provided in the sections on sustainability indicators below.

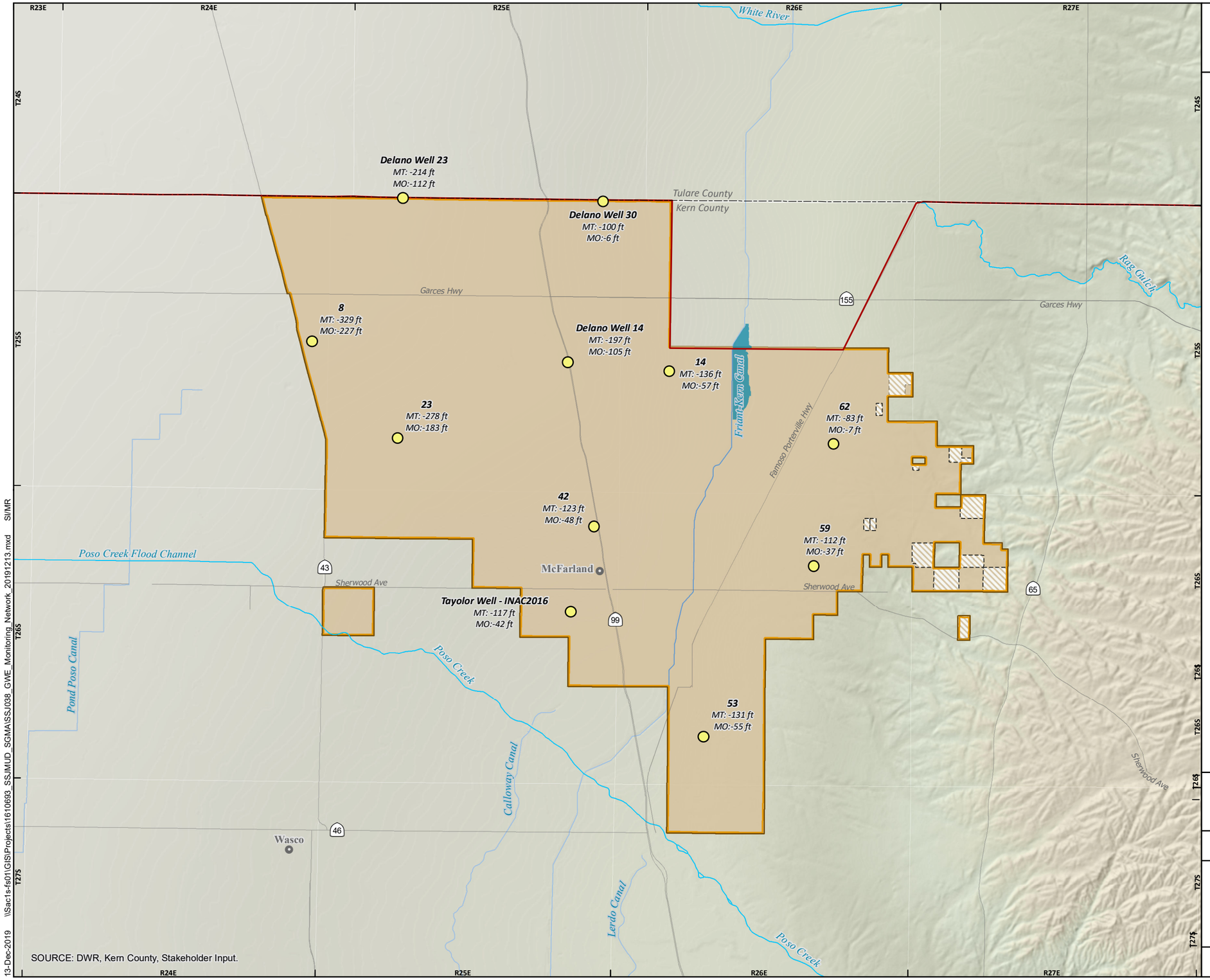
4.3 Monitoring Network

4.3.1 *Chronic Lowering of Groundwater Levels and Reduction of Groundwater Storage*

SSJMUD network of wells for monitoring water levels, water quality, and groundwater storage changes are included on Table 4-3**Error! Reference source not found.** and Figure 4-1. Table 4-

3 provides about the well type, reference point elevation, etc. The wells selected are predominately CASGEM wells which will

SPATIAL DISTRIBUTION OF THE WATER LEVEL MONITORING SITES



SOURCE: DWR, Kern County, Stakeholder Input.

Monitoring Well

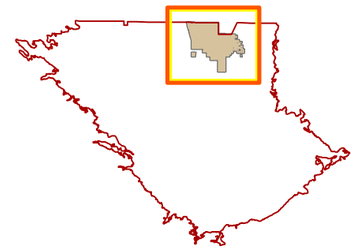
- Southern San Joaquin M.U.D.

Management Plan Area

- Southern San Joaquin MUD

Management Area

- SSJMUD-1 *(District Land)*
- SSJMUD-2 *(Undistricted Land)*
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



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Miles

N

Southern San Joaquin
Municipal Utility District
Management Area Plan

Kern County, California

GEI Consultants

DECEMBER 2019 **DRAFT** FIGURE 4-1

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Table 4-3. SSJMUD Water Level and Water Quality Monitoring Network

Well No.	DMS ID	T-R-S	Latitude	Longitude	GSE (ft MSL)	RP Elev. (ft MSL)	Coord Source	Monitoring Type	Owner	Management Area Plan Well Monitoring Status	To be replaced	Management Area Plan Parameters Type	Year Constructed	Borehole Depth (ft)	Well Depth (ft)	Perforated Interval (ft)	Annular Seal (ft)	Casing Diameter (in)	Aquifer Zone
Delano Well 14	--	25S-25E-23H	35.742	-119.242	308		City of Delano	Supply Well	Municipal	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
Delano Well 23	--	25S-25E-05C	35.790	-119.303	264		City of Delano	Supply Well	Municipal	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
Delano Well 30	--	25S-25E-01B	35.790	-119.231	338		City of Delano	Supply Well	Municipal	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
McFarland Taylor Ave. Well	--	26S-25E-13E	35.667	-119.240	359		City of McFarland	Supply Well	Municipal	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
SSJMUD Well 8	--	25S-24E-13P2	35.74702	-119.336	265	259	District	Supply Well	Private	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
SSJMUD Well 14	--	25S-26E-19J1	35.73948	-119.205	354	351	District	Supply Well	Private	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
SSJMUD Well 23	--	25S-25E-29R2	35.7185	-119.304	294	292	District	Supply Well	Private	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
SSJMUD Well 42	--	25S-26E-01P2	35.69295	-119.232	342	338	District	Supply Well	Private	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
SSJMUD Well 53	--	26S-26E-32	35.63068	-119.191	433	430	District	Supply Well	Private	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
SSJMUD Well 59	--	26S-26E-10	35.682	-119.152	513	512	District	Supply Well	Private	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production
SSJMUD Well 62	--	25S-26E-26	35.71837	-119.145	474	472	District	Supply Well	Private	Interim	Yes	WL and WQ	--	--	--	--	--	--	Main Production

be used as interim well sites for monitoring which will be gauged at a minimum frequency of two times per year (Spring and Fall). This frequency will capture the seasonal high and seasonal low conditions, per §354.34.

4.3.1.1 Rationale

The District's monitoring network design and site selection for monitoring the groundwater levels was based on the same rationale outlined in section 4.3.1 of this chapter. Since the District owns both agricultural production wells, and monitoring wells, an additional column has been added in the table to indicate the level of compliance with the DWR Best Management Practices guidelines for monitoring networks (DWR, 2016). The level of compliance has been categorized as Interim wells.

Interim wells (originally designed and constructed as agricultural production wells) were selected for the network to provide adequate spatial distribution until a permanent dedicated monitoring well can be installed. These interim wells generally have water level gauging data reported historically; however, not all of them have available well construction data. Interim wells selected were chosen based on spatial location to fill gaps in the monitoring network.

The monitoring network for each respective aquifer zone was considered where active groundwater production occurs and where aquifer zones are present. For example, as described in the basin setting of this chapter, no pumping for beneficial uses occurs in the upper zone and is therefore classified as de minimis; consequently, the monitoring network does not include any monitoring of this zone (refer to the basin setting of this chapter for details on extent of the Corcoran clay). Therefore, congruous to the pumping occurring in the aquifer zones, all wells included in this monitoring network will monitor the lower zone.

4.3.1.2 Monitoring Frequency

The monitoring network will be capable of collecting sufficient data to demonstrate seasonal, short-term (1 to 5 years) and long-term (5 to 10 years) trends in groundwater and related surface conditions and yield representative information about groundwater conditions as necessary to evaluate plan implementation. In general, water level monitoring will be seasonal to evaluate groundwater elevations during spring time (seasonal high prior to summer irrigation demands) and fall (seasonal low after the summer irrigation demands).

4.3.1.3 Spatial Density

In general, the monitoring network well density follows the recommendation of 4 to 10 wells per 100 square miles (DWR, 2016), in active groundwater production zones. Table 4-4 below lists the well density for the network with interim wells and with future installation of monitoring wells. The well density is listed in relation to the three management areas.

Table 4-4. Monitoring Network Well Density per Management Area (approximate)

Management Area	Area (Sq. miles)	Corresponding minimum number of wells recommended in DWR BMP	Monitoring wells included as part of the network
SSJMUD	101	4	11

4.3.1.4 Data Gaps

While the monitoring network provides a good spatial coverage of the entire District, the interim wells identified lack well construction details and require confirmation of perforation intervals. As referenced in § 352.4 of the regulations, *"If an Agency relies on wells that lack casing perforations, borehole depth, or total well depth information to monitor groundwater conditions as part of a Plan, the Agency shall describe a schedule for acquiring monitoring wells with the necessary information, or demonstrate to the Department that such information is not necessary to understand and manage groundwater in the basin."*

All supply wells included in the monitoring network lack well construction details and require confirmation of perforation intervals and annular seal details. The extents of the Corcoran clay (shown in the Basin Setting) was primarily used to determine where upper and lower aquifers exist and does not indicate with absolute certainty that a shallower aquifer does not exist in the central and east portions of SSJMUD. The description of steps to fill this data gap has been identified in section 4.5 below.

4.3.2 *Degraded Water Quality*

The District proposes to utilize the same network of wells that were identified as part of the groundwater level monitoring network.

4.3.2.1 Rationale

Since the District's monitoring network comprises wells for both water quality and water level monitoring, the same rationale elaborated in Section 4.3.1.1 applies here.

4.3.2.2 Spatial Density

As described in section 4.3.1.3 and evidenced in Table 4-4, the monitoring network well density follows DWR's BMP recommendation of 4 to 10 wells per 100 square miles, in active groundwater production zones.

4.3.2.3 Data Gaps

The data gaps identified in section 4.3.4.3 are also applicable here.

4.3.3 *Seawater Intrusion*

Seawater intrusion is not applicable to this management area plan.

4.3.4 *Land Subsidence*

The network of land subsidence monitoring is included on Table 4-5. The monitoring stations include those from the existing regional subsidence network, as discussed in the existing monitoring of the basin setting and umbrella section of the KGA GSP.

Table 4-5. Land Subsidence Monitoring

Type	Stations	Well Pair	Frequency	Source
Continuous GPS Stations	P564 Wasco P565 Delano Airport	26S-24E-36P 25S-25E-23	Daily to Monthly	UNAVCO PBS www.unavco.org Access data from: Instrumentation > Network Monitoring > Plate Boundary Observatory (PBO).
InSAR / UAVSAR	Remote Satellite Imagery		Monthly to Annually	Areal extent varies depending on dataset. Not always extensive across the Subbasin. Post-processing is required to use the data.
Survey Monuments	MP-116.94, MP-120, MP-124, MP-127		Event-specific	USBR, Friant-Kern Canal. (Coverage: SSJMUD and Tulare).

4.3.4.1 **Rationale**

Discrete monitoring stations are paired with water level monitoring points to record changes in land subsidence over time with respect to groundwater. The monitoring network is designed to take advantage of available data from CGPS and remote sensing sources. Most importantly, as the network consistently collects data for several years, an understanding of the long-term effects of groundwater extraction on local land subsidence will improve.

4.3.4.2 **Land Subsidence Spatial Density**

The District currently utilizes for monitoring, one CGPS station near Delano (P565), and one CGPS station located ~4 miles southwest of the District near Wasco (P564).

In addition, InSAR data has been used to evaluate land subsidence in between these monitoring points. However, the InSAR data historically has had large gaps over the District during certain time periods (example seen in the Basin Setting Figure 2-22).

In addition to the CGPS and InSAR data, benchmark locations along the Friant-Kern Canal exist in the northern, central and southeastern portions of the District where the Friant-Kern Canal and Poso creek intersect.

Future coordination with other Subbasin stakeholders will be critical to provide input on regional basin-wide remote sensing surveys to continue to provide coverage between subsidence monitoring points.

4.3.4.3 Data Gaps

The western and eastern portions of the District do not have discrete point stations for monitoring subsidence, rather InSAR regional data has been used. Based on InSAR data, these areas appear to experience greater subsidence relative to adjacent portions of the District where subsidence point stations are located. If deemed appropriate, in the future, installation of discrete point stations such as National Geodetic Survey (NGS) type concrete survey monuments or CGPS stations, may be useful control points to compare with InSAR data in the District.

4.3.5 *Depletion of Interconnected Surface Water*

Depletion of interconnected surface water is not applicable to the basin.

4.4 Monitoring Protocols and Reporting Standards

The District monitoring protocols for collection of groundwater levels and water quality samples will generally follow the Groundwater Monitoring Protocols, Standards, and Sites BMP produced by DWR (DWR, 2016a). The protocols and standards for monitoring and reporting requirements are provided below. For detailed description of monitoring protocols and reporting standards, please refer to the KGA GSP.

4.5 Monitoring Network Improvement Plan

A monitoring network improvement plan with an assessment of improvements is required every five years. This improvement plan contains areas of data gaps in the initial monitoring network, in which additional data or monitoring sites are needed.

The network assessment conforms with § 354.38 and is required for every five-year update. It includes:

- An evaluation of uncertainty of the data and whether there are data gaps including in the number of monitoring sites, the frequency of monitoring, and whether the monitoring stations comply with the minimum standards of a monitoring network.
- A description of the location and reason for data gaps in the network, and any local issues and circumstances that limit or prevent monitoring.
- A description of how data gaps will be filled before the next five-year assessment, including the location and purpose of newly added or installed monitoring sites.

- Plans for network revisions to adjust the monitoring frequency and density of monitoring sites to better assess the effectiveness of management actions, if there are:
    - Minimum threshold exceedances,
    - Highly variable spatial or temporal conditions,
    - Adverse impacts to beneficial uses and users of groundwater, or
    - The potential to adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of sustainability goals in an adjacent basin.

4.5.1 *Assessment of Network Improvements*

An assessment of the monitoring network is provided below to discuss future improvements.

4.5.1.1 Water Level, Groundwater Storage, and Water Quality Monitoring Network Assessment Plan

As indicated previously in the data gaps section, construction details of the interim wells need to be determined to improve on the monitoring network. This will be mitigated by conducting downhole well surveys and desktop surveys to fill in the well construction details gap.

Within the next 5 years, the plan to fill data gaps in the water level monitoring network include:

- Coordinate with cities for access to use wells in monitoring network.
- Assess if interim wells are compliant with monitoring well standards.
- Assess the feasibility of a future permanent well installation to fill the data gaps in the management area coverage.
- Rank or prioritize future installation sites and reject any redundant monitoring sites if any.
- Assess the need to increase coverage of the future monitoring network, further than currently recommended.
- Finalize future monitoring network and develop a schedule for station installation.
- Continue evaluating the monitoring network for data gaps.

4.5.1.2 Land Subsidence Network Assessment Plan

As described in the data gaps section of the land subsidence network, the western portion of the District does not currently have discrete point stations for monitoring subsidence. Rather, InSAR regional data has been used to provide coverage between discrete monitoring stations. Additional monitoring of subsidence in the west is needed to better evaluate land subsidence as a sustainability indicator.

Based on InSAR data, the data near the CGPS point appears relatively similar for an analysis of one time period and is missing data for another, seen in Basin Setting. If deemed appropriate, in

the future, installation of discrete point stations such as NGS-type concrete survey monuments or CGPS stations, may be useful control points to compare with InSAR data in the west and east parts of the District.

Alternatively, as described in the Basin Setting, various groups have or are comparing InSAR data with monitoring point stations (CGPS and extensometer) to evaluate the effectiveness of using InSAR in lieu of monitoring stations. A better understanding and continued monitoring of subsidence by remote sensing such as InSAR and point station data are needed to further this evaluation.

It is anticipated that the Friant-Kern Canal benchmarks may also be useable as interim monitoring stations with coordination between the District, Friant Water Authority, and USBR.

As described in the Basin Setting, reduction in storage as potentially an undesirable result, has been documented from land subsidence in the San Joaquin Valley. In order to evaluate potential changes in storage, water level data with subsidence data from stations such as CGPS are needed. This evaluation requires reliable co-located groundwater monitoring stations within the vicinity of the subsidence stations.

Plan to fill Data Gaps

Within the next 5 years, the plan to fill data gaps in the subsidence monitoring network include:

- Coordinate with Friant Water Authority and USBR on the use of the Friant-Kern Canal benchmarks as interim monitoring sites.
- Evaluate future benchmark monitoring sites co-located with the future well monitoring network, especially in the western portion of the District, where monitoring stations are not currently present.
- Assess the adequacy of nearby interim wells and future monitoring wells as co-located water level monitoring stations with CGPS, to better evaluate water levels with subsidence monitoring data. Collect data and evaluate the need for installing a well closer to CGPS station.
- Continue to collect data to evaluate InSAR data in relation to discrete point stations, to assess the feasibility of using InSAR or other remote sensing data as a supplement for data gaps in the monitoring station network.

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5. Projects, Management Actions, and Adaptive Management

5.1 Sustainability Goal

The sustainability goal of the District is to balance the average annual inflow and outflow of water in the district so that a negative change in groundwater storage does not occur; thus, preventing the lowering of groundwater levels beyond 2040. This section describes projects and management actions to meet this sustainability goal for SSJMUD in a manner that can be maintained over the planning and implementation horizon. The projects and management actions presented here represent the best available engineering and analysis completed to-date. This list will be updated throughout the planning and implementation period to reflect analyses and new emerging opportunities.

5.2 Projects and Management Actions Processes

The following sections describe the processes required for projects and management actions to be implemented, the sustainability indicator(s) addressed and an overview of the expected benefits. A summary list of the projects and management actions considered by SSJMUD are provided in Table 5-1 at the end of this Section.

5.2.1 *Goals and Objectives*

Per Section 354.44 of the GSP emergency regulations, plans are to include projects and management actions to address any existing or potential undesirable result for the identified relevant sustainability indicators. SSJMUD plans to implement projects and management actions that will meet the measurable objectives of the following sustainability indicators: (1) chronic lowering of groundwater levels, (2) reduction of groundwater storage, (3) degraded water quality, and (4) land subsidence.

Implementation of each project and management action will address the chronic lowering of groundwater levels. Since groundwater levels are used as proxy for identifying undesirable results in groundwater storage, groundwater quality, and land subsidence, each project and management action may also address the other three sustainability indicators. Tables 5-1 provides an indication of the sustainability indicators that may be addressed by the proposed management action.

5.2.2 *Circumstances for Implementation*

Given the circumstances of conditions described in the basin setting of this management area plan, SSJMUD has already begun implementation of certain projects and management actions. Projects and management actions will be implemented as seen fit by the District and certain

management actions will be implemented as early as 2020 following the adoption of this management area plan. Other management actions will be implemented following the development of the appropriate plans to be approved by the SSJMUD Board of Directors.

When feasible, the District will construct projects to bring in supplemental water to the Subbasin and implement management actions to reduce pumping of groundwater. Table 5-1 provides a timeline for each management action's implementation and the circumstances for which each will be implemented.

5.2.3 *Public Notice*

The public notice and outreach processes for the District consist of notified public board meetings, discussion with landowners within the District's boundaries, and the CEQA process each project and management action may undergo before implementation. SSJMUD provides public noticing by posting all board meeting notices, agendas, and minutes on its website (see Section 1.2) according to the Brown Act.

5.2.4 *Permitting and Regulatory Processes*

Permitting and regulatory requirements vary for the different projects and management actions SSJMUD plans to implement. While these requirements are similar for the District's project and management actions, specific requirements will depend on the type of project, which could be recharge and infrastructure projects as well as administrative actions that incentivize reduced groundwater pumping. The following is a list of the types of permitting at the federal, state, and county level that could apply, but not necessarily, to all management actions:

- Federal
    - If federal grants are used, National Environmental Policy Act (NEPA) documentation is required
    - National Pollution Discharge Elimination System (NPDES) stormwater program permit
- State
    - California Environmental Quality Act (CEQA) documentation is required for all project and management actions.
        - These documents include one or more of the following: Initial Study, Categorical Exemption, Negative Declaration, Mitigated Negative Declaration, and Environmental Impact Report;
- Regional
    - San Joaquin Valley Air Pollution Control District (SJVAPCD) permit and regulations

Table 5-1
Proposed list of Projects and Management Actions for Southern San Joaquin MUD

P/MA Number	P/MA Name	Summary Description	Relevant Sustainability Indicators Affected			Cirumstance for Implementation	Public Noticing Process	Permitting and Regulatory Process Requirements	Status	Timetable / Circumstances for Initiation	Timetable for Completion	Timetable for Accural of Expected Benefits	Expected Benefits				Source(s) of Water, if Applicable	Legal Authority Required	Estimated Costs		
													Primary		Secondary						
			Goundwater Levels and Storage	Goundwater Quality	Land Subsidence								Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency			One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
1	City of Delano Spreading Grounds	Improvements to existing 16-acre stormwater retention basin for use as a spreading basin. Improvement to adjacent 32-acre site for expansion of spreading grounds.	•		•	Pilot phase operation underway. Permanent implementation upon completion of CEQA.	SSJMUD Meetings & Webiste	NPDES, Dust Control Plan, CEQA	Initiated	2020	2021	Through 2040	500 AFY		TBD	TBD	CVP Contract Water and Surplus Water	District / SGMA authorities	$ 450,000	TBD	Grant/ District/ City of Delano
2	In-District Spreading and Recovery Facility	80-acre spreading ponds and 2 recovery wells	•		•	Implementation upon Acquisition of Land and completion of CEQA	SSJMUD Meetings & Webiste	NPDES, Dust Control Plan, CEQA	Initiated	2020	2022	Through 2040	2,800 AFY				CVP Contract Water	District / SGMA authorities	$ 1,664,491	TBD	Grant/ District
3	Schuster Intertie	Construction of pipeline between Semitropic and SSJMUD to proivide operational flexibility and allow SSJMUD to import more supplies to the Subbasin.	•		•	Upon completion of development	SSJMUD Meetings & Webiste	CEQA, County LUP, Road Encroachments, NEPA (if federal	Conceptual	2020	2022	Through 2040	1,811 AFY		TBD	TBD	CVP Contract Water	District / SGMA authorities	$ 2,500,000	TBD	Grant/ District
4	SSJMUD & Cawelo WD Intertie	Construction of pipeline between Cawelo and SSJMUD to proivide operational flexibility and allow SSJMUD to import more supplies to the Subbasin.	•		•	Upon completion of development	SSJMUD Meetings & Webiste	CEQA, County LUP, Road Encroachments	Conceptual	2022	2025	Through 2040	500 AFY		TBD	TBD	CVP Contract Water	District / SGMA authorities	$ 5,000,000	None	Grant/ District
5	SSJMUD & NKWSD 9-28 Intertie	Construction of pipeline to connect SSJMUD's existing system to NKWSD to provide opertational flexibility to absorb delivered surface water	•		•	Upon completion of development	SSJMUD Meetings & Webiste	CEQA, County LUP, Road Encroachments	Conceptual	2022	2025	Through 2040	4,284 AFY		TBD	TBD	CVP Contract Water and Surplus Water	District / SGMA authorities	$ 2,000,000	TBD	Grant/ District
6	Souteast Delano Spreading Grounds	Conversion of land to permanent spreading grounds, up to 320 acres, to facilitate groundwater recharge in proximity to the City of Delano to the benefit of both the district and the city.	•		•	Implementation upon Acquisition of Land and completion of CEQA	SSJMUD Meetings & Webiste	NPDES, Dust Control Plan, CEQA	Initiated	2020	2022	Through 2040	2,640 AFY		TBD	TBD	CVP Contract Water and Surplus Water	District / SGMA authorities	$ 8,000,000	TBD	Grant/ District/ City of Delano
7	Pond Road Spreading Grounds	Conversion of land to permanent spreading grounds, up to 220 acres in proximity to the FKC, to capture and utilize excess surface water deliveries.	•		•	Implementation upon Acquisition of Land and completion of CEQA	SSJMUD Meetings & Webiste	NPDES, Dust Control Plan, CEQA	Conceptual	2020	2025	Through 2040	1,840 AFY		TBD	TBD	CVP Contract Water and Surplus Water	District / SGMA authorities	$ 6,000,000	TBD	Grant/ District
8	In-District Spreading Grounds	Conversion of land to permanent spreading grounds, up to 800 acres, to facilitate groundwater recharge. This project would consist of multiple locations throughout SSJMUD identified as potential recharge sites.	•		•	Implementation upon Acquisition of Land and completion of CEQA	SSJMUD Meetings & Webiste	NPDES, Dust Control Plan, CEQA	Conceptual	2020	2030	Through 2040	9,600 AFY		TBD	TBD	CVP Contract Water and Surplus Water	District / SGMA authorities	$ 44,000,000	TBD	Grant/ District
9	Conversion of Dairy to Recharge Facility	Conversion of land previously used for dairy operations into permanent recharge facilities.	•		•	Implementation upon Completion of Feasibilty Study, Acquisition of Land and completion of CEQA	SSJMUD Meetings & Webiste	NPDES, Dust Control Plan, CEQA	Conceptual	2020	2030	Through 2040	TBD		TBD	TBD	CVP Contract Water and Surplus Water	District / SGMA authorities	TBD	TBD	Grant/ District
10	"Surface Water First" Incentive Program	Implementation of fees for groundwater use when surface water is available.	•		•	Upon adoption of this plan and development of District program	SSJMUD Meetings & Webiste	Board Approval	Conceptual	2020	2020	Through 2040	None	1,800 AFY	TBD	TBD	Existing surface water supply	District / SGMA authorities	None	None	None
11	On-Farm Efficiency/Deficit Irrigation Practices Incentive Program	Improvements to individual farming operations that address water use efficiency and/or groundwater protection through incentive programs.	•		•	Upon adoption of this plan	SSJMUD Meetings & Webiste	SB 7, AB 1668, and SB 606	Conceptual	2020	2025	Through 2040	None	TBD	None	None	No additional supply required	District / SGMA authorities	TBD	TBD	District
12	Refinement of Water Budget Components	Improvement of monitoring and measurements to refine the accuracy of measurement or calculation of inflow and outflow components of district-level water budget. Will also refine Subbasin Model and water budget.	•			Ongoing	SSJMUD Meetings & Webiste	None	Ongoing	Ongoing	TBD	Through 2040	TBD	TBD	TBD	TBD	No additional supply required	District / SGMA authorities	TBD	TBD	District
13	Conversion of Agricultural Land to Urban Use	Conversion of agricultural land to urban use within the limits of each city to reduce groundwater use due to the decreased demand.	•		•	Ongoing	SSJMUD Meetings & Webiste	County zone change, CEQA	Ongoing	Ongoing	TBD	Through 2030	None	1750 AFY	TBD	TBD	No additional supply required	District / SGMA authorities	TBD	TBD	Landowners and Cities

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- Local/County
    - Encroachment permits;
    - Kern County grading permit;
    - Kern County well permit;
    - Kern County supplemental well permit.

5.2.5 *Implementation and Timetable Status*

The current status of each project and management action is included in Table 5-1. Since most projects and management actions are in the conceptual phase of development, timeline for implementation is estimated and subject to change depending on project need and supplemental water availability. SSJMUD will begin to implement management actions to reduce groundwater extractions as soon as 2020 and will continue to implement based on their estimated timeline.

The status of each project and management action is also provided in Table 5-1. Each project and management action are designated as follows:

Conceptual: The project or management action is identified but has not undergone significant planning, engineer or feasibility analyses.

Not yet started: This project or management action as undergone some initial evaluations but has advanced to an implementation phase. The management action will likely require additional feasibility analyses.

Initiated: The project or management action has undergone initial planning and feasibility assessments and being advanced to implementation.

Ongoing: The project or management action is part of an ongoing effort by the District and will continue to be implemented to meet the sustainability goals of the District.

5.2.6 *Expected Benefits*

Table 5-1 provide the estimated benefits for each project and management action the Districts plan to implement. As previously stated, most of the proposed actions are in their conceptual phase of development; therefore, a range has been provided for the estimated benefits each action is expected to yield.

5.2.7 *Source and Reliability of Water Outside of SSJMUD*

SSJMUD will bring in supplemental water from outside the District to support projects and management actions. While not all projects and management actions require source water from outside the district, there are several that do. As discussed in Section 2 of this management area plan, SSJMUD's primary source of water is supplied by the CVP which will help support existing and future projects and management actions in the District. In addition, the District will be seeking other sources of water and will continue to participate in various surface water

transfer and exchange programs as well as explore purchasing markets in the Central Valley to support their effort to achieve groundwater sustainability by 2040.

5.2.8 *Legal Authority Required*

SSJMUD is a member agency under the KGA GSA. Under the JPA with KGA, each district maintains its authority over in-district services and projects. Thus, SSJMUD has the legal authority to implement projects and management actions in order to achieve groundwater sustainability.

5.2.9 *Estimated Costs and Funding*

As previously stated, most of the projects and management actions are in their conceptual phase of development; therefore, costs may not be available. Where costs have been estimated, they are subject to change as the project or management action undergoes more detailed analysis.

With regard to funding, the District has been successful in securing grants through various government agencies for past projects. The District will continue these efforts and apply for various funding sources at all levels of government in order to implement project and management actions.

5.3 SSJMUD Projects Planned Regardless of Conditions

Given the circumstances of conditions described in the basin setting, the District may implement projects as early as 2020. SSJMUD has identified the following projects to accomplish groundwater sustainability:

- In-District Spreading and Recovery Facility
- SSJMUD and Semitropic Schuster Intertie
- SSJMUD and CWD Intertie Pipeline
- SSJMUD and North Kern WSD 9-28 Intertie Pipeline
- Southeast Delano Spreading Grounds
- City of Delano Spreading Grounds
- Pond Road Spreading Grounds
- In District Spreading Grounds
- Conversion of Dairy to Recharge Facility

5.3.1 *City of Delano Spreading Grounds*

SSJMUD proposes identifying and evaluating potential land suitable for developing recharge basins, with possible purchase with private and/or public partnering agencies within the City of Delano. The purpose of this project is to capture surface water deliveries that are delivered

through the FKC. Excess available surface supply, or those flows beyond the quantity of water that satisfies immediate water demand within a service area, typically occurs in wet years when precipitation in contributing watersheds is large enough to induce surface water available above Friant Class 1 contract supplies. Potential flows to capture consists of water which is currently discharged during wet years, during flood conditions and for water that needs to be delivered due to changes in timing to meet environmental water management goals for the San Joaquin River Restoration.

Any purchased land holdings under this project would be converted to dedicated spreading ponds, used to hold recharge delivered water into the groundwater basin. To that extent, conveyance from the Friant-Kern Canal to any spreading ponds will be constructed using pipe and/or canal systems, as well as conveyance pumping stations.

5.3.2 *In-District Spreading and Recovery Facility*

This project will include construction of 80-acres of spreading ponds and the installation of two recovery wells within district boundaries. The proposed recharge ponds have an anticipated annual capacity of 3,240 AFY. SSJMUD will realize an estimated recoverable volume of 2,800 AFY from this project. Prior to this project, the district has not had any in-district direct recharge facilities. Implementation of this project will allow SSJMUD the opportunity to capitalize on wet period storage of CVP supplies and allow them to bypass less favorable out-of-district banking agreements to store water that would increase the District's and the Subbasins water reliability and drought resiliency.

5.3.3 *SSJMUD and Semitropic Schuster Intertie*

The proposed project is to construct an intertie in coordination with SWSD. This pipeline will allow for SSJMUD to bank or return water to SWSD previously delivered to SWSD's groundwater banking program. SSJMUD would be able to deliver wet period water from the FKC for groundwater banking to SWSD and able to return water to SSJMUD for irrigation purposes during dry years.

This Project removes the need to involve a third-party in an agreement with SWSD for banking since it establishes a direct connection to return water to SSJMUD from SWSD, thereby increasing operational flexibility and reliability to deliver previously stored water from groundwater storage at times of drought. If federal funding is secured for this project, NEPA will also need to be considered as part of the permitting and regulatory process.

5.3.4 *SSJMUD and CWD Intertie Pipeline*

SSJMUD and CWD propose to construct a bidirectional intertie connecting their respective water conveyance systems. This pipeline is a regional opportunity to improve flexibility, reliability, and conjunctive use of water supplies.

A primary benefit is the improved access each District will have to each other's contract supply. The pipeline will allow SSJMUD, a CVP water contractor, and CWD, a Kern River and SWP water contractor, to more easily exchange contract surface supplies to meet their immediate agricultural demand. With the increasing uncertainty of surface supplies, the ability to efficiently exchange and obtain supplies from different sources has also become increasingly important. Benefits provided by the intertie are further shared with nearby districts, as other water management strategies occur such as multi-district water transfers and groundwater banking. If federal funding is secured for this project, NEPA will also need to be considered as part of the regulatory and permitting process.

5.3.5 *SSJMUD and North Kern WSD 9-28 Intertie Pipeline*

Project proposal includes the construction of the 9-28 Intertie pipeline with NKWSD. This pipeline will allow for the return of CVP Class I, Class II, and surplus floodwater that was previously delivered to the District's groundwater banking partner (NKWSD) from the FKC for groundwater banking or irrigation purposes during wet years. The pipeline is the conveyance mechanism for return of previously stored water to the District during dry years.

This project removes the need to involve a third-party in an agreement with North Kern for banking since it established a direct connection to return water to SSJMUD from NKWSD, thereby increasing operational flexibility and reliability to deliver previously stored water from groundwater storage during times of drought. If federal funding is secured for this project, NEPA will also need to be considered as part of the regulatory and permitting process.

5.3.6 *Southeast Delano Spreading Grounds*

SSJMUD proposes the purchasing of land holdings, with possible partnering agencies (to be identified later), in and around the eastern most portion of the District. The District is currently exploring the potential for capturing excess surface water deliveries in the FKC. Excess surface supply, or those flows beyond the quantity of water that satisfies immediate water demand, typically occur in wet years where precipitation in applicable watersheds is large enough to induce surface water available above Class I contract supplies. Potential captured flows consist of water which is currently discharged during wet year and flood conditions.

Any purchased land holdings under this project would be converted to dedicated spreading ponds, used to hold recharge delivered water into the groundwater basin. To that extent, conveyance from the FKC to any spreading ponds will be constructed using pipe and/or canal systems, as well as conveyance pumping stations.

Implementation of this project has the potential for contributing water supplies to SSJMUD, the City of Delano (which qualifies as a DAC), and Poso Creek IRWM water users. Specifically, SSJMUD will use a portion of these captured flows to offset their groundwater use in dry years by moving the surplus water to this banking facility using either the FKC or other existing infrastructure. Wet year water supplies captured in the spreading grounds and storage locations

will be utilized by SSJMUD, City of Delano, and potentially other Poso Creek stakeholders, during years where other water supplies are limited. Depending upon the scale of the project, the anticipated benefits range from 247 AFY for a 30-acre site to 2,640 AFY for a 320-acre site.

5.3.7 *Pond Road Spreading Grounds*

SSJMUD proposes identifying and evaluating potential land holdings to be purchased, with possible private and/or public partnering agencies. The District is currently exploring the potential for capturing excess surface water deliveries in the Friant-Kern Canal. Excess surface supply, or those flows beyond the quantity of water that satisfies immediate water demand, typically occur in wet years where precipitation in applicable watersheds is large enough to induce surface water available above Class 1 contract supplies. Potential captured flows consist of water which is currently discharged during wet year and flood conditions.

Any purchased land holdings under this project would be converted to dedicated spreading ponds, used to hold recharge delivered water into the groundwater basin. To that extent, conveyance from the FKC to any spreading ponds will be constructed using pipe and/or canal systems, as well as conveyance pumping stations.

5.3.8 *In-District Spreading Grounds*

SSJMUD proposes identifying and evaluating potential land holdings to be purchased, with possible private and/or public partnering agencies. The District is currently exploring the potential for capturing excess surface water deliveries in the FKC. Excess surface supply, or those flows beyond the quantity of water that satisfies immediate water demand, typically occur in wet years where precipitation in applicable watersheds is large enough to induce surface water available above Class 1 contract supplies. Potential captured flows consist of water which is currently discharged during wet year and flood conditions.

Any purchased land holdings under this project would be converted to dedicated spreading ponds, used to hold recharge delivered water into the groundwater basin. To that extent, conveyance from the FKC to any spreading ponds will be constructed using pipe and/or canal systems, as well as conveyance pumping stations.

5.3.9 *Conversion of Dairy to Recharge Facility*

SSJMUD proposes identifying and evaluating potential purchase of a dairy, with possible private and/or public partnering agencies. The District is currently exploring the potential for capturing excess surface water deliveries in the FKC. Excess surface supply, or those flows beyond the quantity of water that satisfies immediate water demand, typically occur in wet years where precipitation in applicable watersheds is large enough to induce surface water available above Class 1 contract supplies. Potential captured flows consist of water which is currently discharged during wet year and flood conditions.

Any purchased land holdings under this project would be converted to dedicated spreading ponds, used to hold recharge delivered water into the groundwater basin. To that extent, conveyance from the FKC to any spreading ponds will be constructed using pipe and/or canal systems, as well as conveyance pumping stations. Before eventual conversion to spreading grounds, the dairy facility will be replaced by alfalfa fields, with the view of removing nitrates from the soil and improving infiltration with the alfalfa root system.

In addition to the development of the a CEQA document, the use of former dairy waste discharge ponds may require review and approval by the Central Valley RWQCB to ensure that degradation of groundwater quality in the proposed project area does not occur. A soils and groundwater sampling plan, report of findings and analysis, and a remediation plan and report may be required prior to the use of the former dairy site for groundwater recharge.

5.4 Management Actions Planned for Groundwater Sustainability

Per Section 354.4 of the GSP emergency regulations, the following sections details the managements actions SSJMUD will take to achieve groundwater sustainability by 2040. The district has identified the following management actions:

- In-Lieu Recharge Incentive Program
- On-Farm Efficiency/Deficit Irrigation Practices Incentive Program
- On-Farm Recharge Activities Incentive Program
- Conversion of Agricultural Land to Urban Use
- Urban Water Conservation Program
- In-District Allocation Structure
- Voluntary Land Fallowing
- Pumping Restrictions

5.4.1 *In-Lieu Recharge Incentive Program*

SSJMUD has access to imported surface water to supply its jurisdictional area. However, there are instances in which growers have historically opted to pump groundwater, rather than receiving deliveries of surface water from the district which services their properties. When this occurs, the district must either use that water for groundwater recharge or enter into exchanges with other districts (either in this Subbasin or in another basin).

While this may be an economic decision for the grower, it has the potential to cause local impacts to groundwater in the district over the long-term. To prevent local impacts to groundwater due to the use of groundwater over available surface water, the districts may explore a fee structure in which growers with access to surface water may be assessed for the use

of groundwater when surface water is available for use. The fees collected for such activities would be applied to the expansion of existing recharge projects or the development of new recharge projects to accommodate the additional surface water that would be brought into the district to replace the additional groundwater pumped.

The adoption of an incentive program would require approval of a district's Board of Directors. No additional permitting would be required for this management action because it does not change existing uses of land or infrastructure within the district.

5.4.2 *On-Farm Efficiency/Deficit Irrigation Practices Incentive Program*

As an agricultural water service provider, SSJMUD complies with all provisions of SB 7 (amending Division 6, Part 2.55 of the Water Code) passed into law in November 2009 regarding agricultural water conservation and management. Efficient management practices in the law, related to SGMA objectives, include volumetric water pricing, incentives for conjunctive use and increased groundwater recharge, and development of an overall water budget. AB 1668 and SB 606 passed in 2018 did not materially add to these objectives, save for those districts serving between 10,000 and 25,000 acres who must now prepare water management plans under the newer laws.

While these new laws do not require water use objectives or savings thresholds, they do encourage more efficient use of water by the agricultural sector and its suppliers. SSJMUD will encourage improvements to individual farming operations that address water use efficiency and/or groundwater protection through incentive programs.

5.4.3 *Refinement of Water Budget Components*

In addition to the implementation of this management area plan, and the monitoring and measurement described herein, the districts may consider additional improvements to refine the accuracy of the measurement or calculation of inflow and outflow components of their water budgets. The scope of these improvements is yet to be determined, but it may include improved ET measurement to further refine the calculation of consumptive water use, improved weather data to provide more accurate precipitation volumes, refinement of subsurface flow volumes using groundwater level data and local hydrogeologic data, and improved estimation of surface runoff. These efforts would culminate in the improvement of the Kern County Subbasin Model, which is used as a coordinated subbasin-wide water budget. This management action is conceptual; a volume of water associated with this management action has not been calculated.

5.4.4 *Land Conversion from Agricultural Use to Urban Use*

As described in the General Plans for the cities of Delano and McFarland, anticipated population growth is expected to lead to changes in land use within the limits of each city and in the Sphere of Influence for each city. The conversion of land use from agricultural to urban use generally leads to an overall reduction in groundwater use due to the decreased demand, in terms of

volume per unit area. The City of Delano and the surrounding areas have a projected increase of 2,100 acres in urban use; the City of McFarland and its surrounding areas have a projected increase of 1,100 acres.

While these areas are described as part of each city's Sphere of Influence in their respective General Plans, the lands which are anticipated to convert from irrigated agricultural use to urban use are still zoned for Agricultural use in either the city or county zoning. In order to develop these lands for urban use, the land would have to be re-zoned for the proposed, non-agricultural use.

The conversion of land use from agricultural to urban is an ongoing process, the pace of which is determined by external factors such as the demand for land based on each city's growth and need for additional housing and/or property to support business, industrial, or municipal use. The projected growth for each city is based upon the current General Plans and may be subject to change when the cities update their respective plans.

5.4.5 *Urban Water Conservation Program*

As referenced in the Umbrella Basin Setting (Chapter 2), urban water usage in the future is expected to comply with the conservation mandates contained in SB 606 and AB 1668, both bills signed into law in May 2018. Based on that legislation, indoor residential use is to be capped at 55 gpcd in 2019 and ramp down to 50 gpcd by 2030, and outdoor residential use is to be capped in the future based on local climate and size of landscaped areas. Standards for outdoor usage are to be defined in a SWRCB rule-making process to be completed by June 2022.

Urban water conservation compliance currently derives from SB 7X-7 passed in 2009 (Water Conservation Act of 2009), and the UWMP for Delano, along with associated ordinances, reflect that Act's mandates of a 20% reduction in urban per capita water usage by 2020. While McFarland is not currently required to prepare a UWMP, projected population growth and expansion of its service area will require the preparation and implementation of an SB 7X-7 compliant plan. Future achievements in urban conservation will be as derived from the passage of AB 1668 and SB 606 in 2018. Future amendments to UWMPs and modified ordinances of both cities will eventually embody these recent laws.

5.4.6 *Mitigation Program for Potential Impacts to Domestic Wells*

In the use of projected groundwater elevation contours to establish SMCs based on recent hydrologic conditions, the districts using this method observed that there are potential impacts to shallow domestic wells resulting from the establishment of SMCs which allow for groundwater levels to fall below the historically lowest elevations. To mitigate these impacts the Districts, in coordination with other KGA members, will develop a mitigation program to offer financial assistance for the replacement of domestic wells which are impacted by groundwater management to the proposed SMCs. The KGA members will also develop eligibility criteria for the proposed mitigation program which would help determine if the impacts are a result of the

plan's implementation or have some other cause. Since this management action is conceptual, a volume of water associated with this management action has not been calculated. The implementation of this management action is dependent upon the coordination of the elements of the program, including the funding mechanism, and the approval of the districts' respective boards.

5.4.7 *In-District Allocation Structure*

At the time of this draft of the District's management area plan, SSJMUD does not have an established allocation structure and fee schedule for groundwater extraction. As SGMA is implemented throughout the Subbasin, the districts are required to manage to the sustainable management criteria established in Section 3 of this management area plan. One of the ways to manage for the sustainable management criteria (SMC) is to allocate the Sustainable Yield for their respective districts to the landowners within their districts. The allocation structure would allow for the transfer of groundwater pumping credits within each district's jurisdiction, provided that it does not lead to localized impacts to at the representative monitoring sites defined in Sections 4 of this management area plan.

While the specifics of such an allocation structure may vary between the districts, a baseline groundwater extraction volume would be allocated to each parcel based on its size and the Sustainable Yield for the district. If a landowner were to extract more water than the baseline volume for that parcel or for the aggregate of all of their parcels within the district, they would be required to pay an extraction fee which would be applied toward projects and programs implemented by the district to reach and/or maintain sustainability.

5.4.8 *Voluntary Land Fallowing*

In the event of a drought, the District may not be able to entirely meet in-district demand by increasing the volume of imported water. The combination of decreased availability in surface water to supply to the district and decreased recharge from other sources in the Subbasin has the potential to lead to violations of sustainable management criteria at the representative monitoring sites, in the absence of decreased demand. To facilitate the district's ability to maintain sustainability at its monitoring sites, the district will develop and implement a voluntary land fallowing program.

The District will be required to develop the guidelines for eligibility and the terms of the program, prior to submitting them to the board for adoption. This will also include the determination of funding and for the program and in-district outreach.

5.4.9 *Pumping Restrictions*

In the event that the districts or the entire Subbasin are nearing a condition where they are at risk of triggering an undesirable result, even with the implementation of the projects and management actions described in this Plan, it may be necessary for the district to limit groundwater pumping.

The volume of groundwater extraction permitted under this Management Action would be determined by the district based on the Sustainable Yield for the district and the SMC at the Representative Monitoring Sites.

5.5 Summary

A summary list of the projects and management actions considered by SSJMUD is provided in Table 5-1.

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Appendix A

Joint Powers Authority Agreement

KERN GROUNDWATER AUTHORITY
FOR THE TULARE LAKE BASIN PORTIONS OF KERN COUNTY
AMENDED AND RESTATED JOINT POWERS AGREEMENT

THIS AMENDED AND RESTATED AGREEMENT ("Agreement") is made and effective as of March 22, 2017, pursuant to the Joint Exercise of Powers Act (Government Code Sections 6500, *et seq.*) by and between the public agencies listed on the attached Exhibit A.

This Agreement is made with reference to the following facts and understandings.

A. Each of the parties to this Agreement (the "Members") provides water service to landowners and/or residents and/or provides water to retail water entities within its respective service area and the County of Kern has various oversight and active roles relative to water resources within the County, including, but not limited to, flood control, police powers, and water service.

B. Pursuant to a Joint Powers Agreement dated as of May 27, 2014 (the "Original Agreement"), the Kern Groundwater Authority (the "Authority") was created to carry out the purposes of Part 2.75 of Division 6 (commencing at Section 10750 of the California Water Code) and develop, adopt and implement a groundwater management plan that would be available to those lands within the boundaries of the Authority's members and within the Tulare Lake Groundwater Basin.

C. On August 29, 2014, the California Legislature passed comprehensive groundwater legislation contained in SB 1168, SB 1319 and AB 1739. Collectively, those bills, as subsequently amended, enacted the "Sustainable Groundwater Management Act" ("SGMA"). Governor Brown signed the legislation on September 16, 2014 and it became effective on January 1, 2015. In adopting SGMA, the Legislature intended "[t]o provide local groundwater agencies with the authority and technical and financial assistance necessary to sustainably manage groundwater." (California Water Code Section 10720(d).)

D. SGMA anticipates that each affected groundwater basin or subbasin will be regulated separately by one or more Groundwater Sustainable Agencies (each, a "GSA"). A local agency or combination of local agencies may elect to be the GSA for a basin or sub-basin. SGMA generally provides that a combination of local agencies may form a GSA through a joint powers agreement, memorandum of understanding or other legal agreement. (California Water Code Section 10723.6)

E. Groundwater sustainability under SGMA is to be achieved through Groundwater Sustainability Plans ("GSPs"). Under SGMA, a GSP can be a single plan developed by one or more GSAs, or multiple coordinated plans within a basin or subbasin by multiple GSAs (California Water Code Section 10727).

F. The Members, individually and collectively, have the goal of cost-effective, sustainable groundwater management in the Kern County Subbasin that considers the interests and concerns of the Members and other stakeholders.

G. As used in this Agreement "Kern County Subbasin" means such basin as defined in Department of Water Resources Bulletin 118, as its boundaries may be modified from time to time through the procedures described in California Water Code Section 10722.2.

H. The intent of the Members under this Agreement is to provide each Member with the sole right and responsibility to implement SGMA within its respective boundaries and/or Management Areas, as defined herein, in a manner determined by the Member, whether through the Authority or as a GSA. To facilitate coordination within the Kern County Subbasin, the Members desire for the Authority to have the authority to serve as a GSA for some or all of the Members within the Kern County Subbasin in a manner that allows the Members (individually or collectively) to directly implement SGMA and a GSP within their respective Management Areas as defined herein, while the Authority serves primarily a coordinating and administrative role in order to provide for sustainable groundwater management through the subbasin. The Members expressly intend that the Authority will not have the authority to limit or interfere with the respective Members' rights and authorities over their own internal matters, including, but not limited to, a Member's surface water supplies, groundwater supplies, facilities, operations, water management, and Water Supply Matters, as defined herein. Nothing in this Agreement is intended to modify or limit Members' police powers.

I. The Members expressly intend that neither SGMA, nor this Agreement, nor any GSP adopted by the Authority shall be construed as authorizing the Authority, or any dispute resolution process contained herein, to:

(i) determine or alter surface water rights or groundwater rights (California Water Code Section 10720.5 (b));

(ii) make binding determinations of the water rights of any person or entity (California Water Code Section 10726.8 (b)); or

(iii) supersede the existing land use authority of cities or counties, including the city or county general plan, within the overlying basin (California Water Code Section 10726.8 (f)).

J. In light of the enactment of SGMA together with the goals and intent described above, the Members wish to amend and restate the Original Agreement in its entirety as provided herein.

THEREFORE, in consideration of the mutual promises, covenants and conditions herein set forth, it is agreed by and among the Members that the Original Agreement is hereby amended and restated to read in its entirety as follows:

Article I: Definitions

As used in this Agreement, unless the context requires otherwise, the meaning of the terms hereinafter set forth shall be as follows:

(a) "Associate Members" shall mean those Members of the Authority admitted in accordance with the terms and provisions of this Agreement that are not General Members. The Board of Directors may from time to time admit Associate Members on terms and conditions

consistent with SGMA and as determined by the Board. Representatives of Associate Members may not serve on the Board and/or Board Committees. Likewise, while the Board of Directors welcomes their input, the representatives of Associate Members shall be non-voting, their presence shall not be counted in determining whether a quorum is present, and they shall not be permitted in closed sessions of the Board of Directors.

(b) "Authority" shall mean the Kern Groundwater Authority, being the separate entity created pursuant to the provisions of Government Code sections 6500 *et seq.* by this Agreement.

(c) "Board of Directors" or "Board" shall mean the governing body of the Authority as established by Section 3.01 of this Agreement.

(d) "Committee" shall mean any committee established pursuant to Section 3.03 of this Agreement.

(e) "Fiscal Year" shall mean that period of 12 months established as the Fiscal Year of the Authority pursuant to Section 4.01 of this Agreement.

(f) "General Members" shall mean those Members of the Authority more particularly identified as General Members on Exhibit A, and any parties which shall hereafter become General Members in accordance with the terms and provisions of this Agreement. A local agency as defined by SGMA may participate as a General Member on its own behalf or join with one or more agencies as a single General Member. Multiple agencies which elect to coordinate their representation as one General Member shall, for purposes of this Agreement, be treated as one General Member.

(g) "GSA" shall mean Groundwater Sustainability Agency as defined in SGMA.

(h) "GSA Notice Date" shall mean March 1, 2017.

(i) "Kern County Subbasin" means the groundwater subbasin described in Recital G of this Agreement.

(j) "GSP" shall mean Groundwater Sustainability Plan as defined in SGMA.

(k) "Management Area" shall mean the area within the boundaries of a Member or group of Members to be managed by that Member or group of Members under any GSP adopted by the Authority.

(l) "Members" shall mean the General Members and Associate Members.

(m) "SGMA" shall mean the Sustainable Groundwater Management Act.

(n) "Special Activities" shall mean activities that are consistent with the purpose of this Agreement, but which are undertaken by fewer than all the Members in the name of the Authority pursuant to Section 3.07.

(o) "Water Supply Matters" shall mean a Member's surface water supplies, groundwater supplies, facilities, operations, water management, water supply projects and financial affairs.

Article II: Creation of Authority

Section 2.01 – Creation.

The Members hereby reaffirm that, pursuant to their joint exercise of powers under the provisions of Government Code sections 6500 *et seq*., they have created a public entity to be known as the "Kern Groundwater Authority."

Section 2.02 – Term.

This Agreement is an amendment of the Original Agreement and shall therefore become effective, including without limitation on General Members not executing it, upon its execution by at least 75% of the General Members and will remain in effect until terminated by agreement of a majority of then participating General Members. Notwithstanding the above, once the Authority has adopted and approved a GSP for some or all of the Kern County Subbasin, this Agreement shall not be terminated except by agreement of 75% of the General Members (as described in Section 3.05 below). Unless it is terminated, this Agreement shall remain in effect and be binding upon the Members and upon all future Members for such a period as the Authority engages in any activities under this Agreement, except as to any party which withdraws or is terminated from its participation in the Authority in accordance with this Agreement. This Agreement shall supersede the Original Agreement and the Interim Funding Agreement effective 2013. Any monies collected pursuant to the Interim Funding Agreement which have not been expended as of the date of this Agreement shall be credited towards each Member's financial commitment as identified herein.

Section 2.03 – Purpose.

(a) The purposes of this Agreement are to:

(i) provide for the joint exercise of powers common to each of the Members and powers granted pursuant to SGMA (subject to the restrictions contained in this Agreement), through the Authority, to cooperatively carry out the purposes of SGMA and develop, adopt and implement a legally sufficient GSP covering those portions of the Kern County Subbasin that are within the jurisdictional boundaries of the Members, subject to the limitations set forth herein; and

(ii) provide a mechanism for the coordination of groundwater management activities by and among the Members, in accordance with SGMA.

(b) Each of the General Members (or group of General Members) shall have the sole and absolute right, in its sole discretion, to:

(i) become a GSA individually or collectively within the General Member's boundaries or the Management Area managed in whole or in part by such General Member;

(ii) approve the portion, section or chapter of the GSP adopted by the Authority as applicable within the General Member's boundaries or the Management Area managed in whole or in part by such General Member, as provided for in Section 7.01 of this Agreement; and

(iii) implement SGMA and the GSP adopted by the Authority within the General Member's boundaries or the Management Area managed in whole or in part by such General Member.

(c) Except to the extent requested by a General Member with respect to the lands within its boundaries, the Authority shall serve primarily a coordinating and administrative role in order to provide for sustainable groundwater management of the Kern County Subbasin in a manner that does not limit any Member's rights or authority over its own water supply matters, including, but not limited to, a Member's Water Supply Matters. Subject to the provisions, limitations and restrictions contained in this Agreement, activities unrelated to coordinating and administrative tasks necessary for groundwater management and sustainability shall not be undertaken by the Authority.

(d) Notwithstanding any other provision of this Agreement, the Authority shall not seek status as a GSA or approve a GSP prior to the GSA Notice Date.

(e) Not later than the GSA Notice Date, or such later date as determined by the Board of Directors, each Member shall provide the Authority with written notice that such Member will:

(i) continue as a Member and request the Authority to act as the GSA within such Member's boundaries or for the Management Area managed in whole or in part by such Member pursuant to a separate agreement between the Authority and the Member setting forth the terms and conditions of the Authority's role as the GSA within such Member's boundaries or for the Management Area managed in whole or in part by such Member;

(ii) continue as a Member and confirm that it will implement the GSP adopted by the Authority within such Member's boundaries or for the Management Area managed in whole or in part by such Member continue as a Member;

(iii) continue as a Member but seek GSA status within its boundaries or within the Management Area managed in whole or in part by such Member in order to implement SGMA and the GSP adopted by the Authority therein; or

(iv) seek GSA status within its boundaries or within the Management Area managed in whole or in part by such Member and adopt its own GSP, in which case such Member shall be deemed to have withdrawn from the Authority pursuant to Article VI but will endeavor in good faith to develop and execute a coordination agreement with the Authority in accordance with SGMA. Such Member may still be eligible to become an Associate Member pursuant to Section 6.02 (a).

The County of Kern may form a separate GSA or be part of a GSA for areas not within the boundaries of other Members and also be a GSA or participate in a GSA formed pursuant to this Agreement.

Section 2.04 – Powers.

(a) Subject to the limitations and restrictions contained within this Agreement, the Authority shall have the power to take any action, for the benefit of its Members, to carry out the purposes of this Agreement, including, but not limited to, applying for loans and grants, becoming a GSA for any or all of the Kern County Subbasin except the portions thereof for which Members become the GSA, and developing, adopting and implementing a GSP, subject to the paramount right of Members to become GSAs as specified in Section 2.03. The Authority shall have the power to sue and be sued. Notwithstanding the foregoing, the Authority shall not have the power to control, limit or empower a Member's rights and authorities over its own Water Supply Matters. Likewise, unless a Member requests it, the Authority shall have no power to interfere with (i) the Member's rights, use or management of the Member's water or water supply or (ii) the rights of individual landowners within the Member's boundaries to utilize, apply, store, or otherwise use surface or groundwater. Subject to the limitations and restrictions contained in this Agreement, the Authority is authorized, in its own name, to do all acts necessary for the exercise of said powers provided that said acts are duly adopted by the then seated Board of Directors and are consistent with this Agreement. Except as provided in Section 4.05, the Authority may not levy assessments on its Members. In accordance with California Government Code Section 6509, the foregoing powers shall be subject to the restrictions upon the manner of exercising such powers pertaining to the Cawelo Water District.

(b) Notwithstanding anything to the contrary in this Agreement, the Authority shall not (i) undertake any activities within any Member's boundaries, or within a Management Area managed in whole or in part by such Member, unless the Member formally and expressly requests, consents to and agrees, in writing, to the activity proposed in accordance with Section 7.4 or (ii) acquire or seek to acquire by eminent domain any property of a Member. Nothing in this Agreement shall modify or limit the police powers of Members, if any.

Article III: Internal Organization

Section 3.01 – Governing Body.

(a) The Authority shall be governed by a Board of Directors which is hereby established and which shall be initially composed of representatives of the General Members, as shown on Exhibit A. Without amending this Agreement, the Board of Directors composition shall be altered from time to time to reflect the termination and/or admission of any new General Members.

(b) Each General Member's governing board shall select a representative from its governing body or the governing body of one of the agencies within the General Member to serve as their Board member. A General Member may designate from its governing body or the governing body of one of the agencies within the General Member to serve as its alternative Director. The role of each alternate Director shall be to assume the duties of the Director appointed by his/her Member entity in case of the absence or unavailability of such Director, including without limitation such Director's duties as a member of any Committee established pursuant to Section 3.03. The Directors and alternates so named shall continue to serve until their respective successors are appointed.

(c) Nothing in this Agreement shall preclude a future amendment of this Agreement to reconfigure the Board of Directors into a smaller body comprised of representatives of General Members or other individuals, all as defined in such amendment.

Section 3.02 – Officers.

The Board shall select a Chair from among the Board of Directors who shall be the presiding officer of the Board meetings. The Board shall select a Vice Chair from among the Board of Directors who shall serve as the presiding officer in the absence of the Chair. The Board shall also select a Secretary, who need not be a member of the Board of Directors. The terms of such Officers shall be established by the Board of Directors from time to time and as necessary.

Section 3.03 – Committees.

There shall be established such Committees as the Board of Directors shall determine from time to time. Each such Committee shall be comprised of representatives of General Members, shall exist for the term specified in the action establishing the Committee, shall meet as directed by the Board of Directors, and shall make recommendations to the Board of Directors on the various activities of the Authority. The Board of Directors may delegate authority to the Committee to administer and implement the various activities of the Authority, subject at all times to the limitations on the Authority set forth in this Agreement; provided, that no power to enforce any aspect of SGMA or the GSP adopted by the Authority shall be delegated to a Committee.

Members shall be give reasonable advance notice of all Committee meetings, including without limitation ad hoc Committee meetings, all of which meetings shall be open to Members and their representatives.

Section 3.04 – Seal; Bylaws.

The Board may (but need not) adopt an official seal for the Authority and adopt such bylaws as it may deem necessary to regulate the affairs of the Authority in accordance with this Agreement. The bylaws may be amended from time to time by a majority vote of the Board of Directors as it may deem necessary.

Section 3.05 – Voting; Quorum.

(a) Subject to Section 3.05(c), each member of the Board of Directors shall be entitled to a vote determined as follows:

(i) Each member of the Board shall have one (1) vote on matters with respect to which such member is entitled to vote.

(ii) Voting on actions related to Special Activities shall be weighted as determined by each Special Activity agreement.

(b) Directors holding two-thirds of the voting power on the entire Board of Directors on a matter shall constitute a quorum for the transaction of Authority business. Any Board member abstaining from a vote shall be counted for purposes of determining the existence of a quorum, but shall not be deemed to be voting.

(c) A Director (including a Director serving as a member of a Committee) shall be entitled to vote on any matter or action (i) that would affect the General Member represented by such Director, (ii) relating to the general business or administration of the Authority, or (iii) that would impact any land or landowners within the boundaries of the General Member represented by such Director or the Management Area managed in whole or in part by such General Member.

(d) Examples of matters and actions on which a Director shall be entitled to vote include without limitation matters or actions relating to the implementation of SGMA within the boundaries of the General Member represented by such Director, amounts to be paid by the General Member represented by such Director to the Authority, the imposition of fees or charges within the boundaries of the General Member represented by such Director, the adoption or amendment of the Authority's GSP.

(e) In the event of a disagreement as to whether a Director is entitled to vote on a matter or action coming before the Board or a Committee, such Director shall be entitled to vote on the matter or action unless 75% of the Directors present at the meeting determine that such Director is not so entitled.

(f) Except as otherwise provided in this Agreement, any action by the Board of Directors shall require a two-thirds vote of the Directors entitled to vote thereon that are present at the meeting. Any amendment of this Agreement shall be governed by Section 8.01.

(g) Two-thirds of the members of a Committee entitled to vote thereon shall constitute a quorum for a matter or action before the Committee. All questions and matters of any nature whatsoever coming before any Committee shall be determined, provided a quorum is present, by the concurrence of 75% of the members of such Committee entitled to vote thereon present and voting on such matter. Any Committee member entitled to vote thereon abstaining from a vote shall be counted for purposes of determining the existence of a quorum, but shall not be deemed to be voting.

(h) This Section 3.05 shall not apply to matters affecting implementation of SGMA within a particular Management Area. Such matters shall be governed by the Member or

Members implementing SGMA within that Management Area, except to the extent otherwise agreed upon by such Member(s) pursuant to 2.04(b) or in a Special Activity agreement.

Section 3.06 – Meetings.

Meetings of the Board of Directors and any Committee (to the extent applicable) shall be conducted in accordance with the Ralph M. Brown Act, California Government Code Sections 54950, *et seq.*

Section 3.07 - Special Activities.

With the prior approval of the entire Board of Directors, Members may undertake Special Activities in the name of the Authority. All Members shall be given the opportunity to participate in each Special Activity of the Authority unless the Special Activity is an action described in Section 7.04. Prior to undertaking a Special Activity, the Members electing to participate in the Special Activity shall enter into an activity agreement. Such activity agreement shall provide that (i) no Special Activity undertaken pursuant to such agreement shall conflict with the terms of this Agreement and (ii) the Members to the activity agreement shall indemnify, defend and hold the Authority, and the Authority's other Members, harmless from and against any liabilities, costs or expenses of any kind arising as a result of the Special Activity described in the activity agreement. All assets, rights, benefits, debts, liabilities and obligations attributable to a Special Activity shall be assets, rights, benefits debts, liabilities and obligations solely of the Members that have entered into the activity agreement for that Special Activity, in accordance with the terms of the activity agreement, and shall not be the assets, rights, benefits, debts, liabilities and obligations of those Members that have not executed the activity agreement. Members not electing to participate in the Special Activity shall have no rights, benefits, debts, liabilities or obligations attributable to such Special Activity.

Article IV: Financial Provisions

Section 4.01 – Fiscal Year.

The Fiscal Year of the Authority shall be from January 1 through December 31 of each year.

Section 4.02 – Funds; Accounts.

(a) The North Kern Water Storage District shall serve as the Fiscal Agent and Treasurer for the Authority unless otherwise determined by the entire Board. The Fiscal Agent shall be responsible for all money of the Authority from whatever source. The Board may compensate the fiscal agent for services rendered.

(b) All funds of the Authority shall be strictly and separately accounted for and regular reports shall be rendered of all receipts and disbursements at least quarterly during the Fiscal Year. The books and records of the Authority shall be open to inspection by the Members.

(c) The Authority shall contract with a certified public accountant to make an audit or review of the accounts and records of the Authority which shall be conducted in compliance with Section 6505 of the California Government Code. The Fiscal Agent shall have the right to reject

any proposed certified public accountant. All costs associated with this Audit will be the full responsibility of the Authority.

Section 4.03 – Property; Bonds.

The Board of Directors shall from time to time designate the officers and persons, in addition to those specified in Section 4.02 above, who shall have charge of, handle, or have access to any property of the Authority. Each such officer and person shall file a bond in an amount designated by the Board of Directors.

Section 4.04 – Budget.

By a date set by the Board of Directors each Fiscal Year, the Board of Directors shall adopt a budget for the Authority for the ensuing Fiscal Year; provided, that except as provided in Section 4.05, the Authority shall not impose assessments or other charges on Members. Notwithstanding the foregoing, by its execution of this Agreement, each Member confirms that it has authorized its Director and Alternate Director to approve actions and expenditures by the Authority over and above the approved annual budget of the Authority for a Fiscal Year that do not create a fiscal obligation greater than $5,000 on such Member without further action of such Member.

Section 4.05 – Payments To The Authority.

(a) Except as otherwise provided, all fees, costs and expenses incurred by the Authority for general administrative services, such as legal, preparation of audits, and other general administrative functions shall be funded (i) from permissible contributions from third parties and (ii) assessments on the General Members, levied from time to time by the Board of Directors to carry out the activities of the Authority generally applicable to all General Members, which shall be equal per General Member, as initially shown on Exhibit A.

(b) No Member shall be bound, financially or otherwise, by any obligation, contract or activity undertaken by the Authority unless and except to the extent agreed upon by the Member, except that each Member shall be obligated to fund its then current annual share of the general basic budget of the Authority, provided such budgets are otherwise approved as provided herein. Funding of other matters shall be through Special Activity agreements or as otherwise agreed to by the Members in writing.

Section 4.06 – GSP Fees.

The Authority may impose reasonable fees, charges, assessments and other levies to implement its GSP and/or SGMA; provided, that the Authority shall have no authority to impose any such fees, charges, assessments or other levies on any of its Members or within a Management Area without the express consent and approval of the affected Member(s), or the Member or Member implementing the Authority's GSP and SGMA within such Management Area.

Article V: Management

Section 5.01 – Management.

In addition to, or in lieu of, hiring employees, the Authority may engage one or more General Member(s) or third party(ies) to manage any or all of the business of the Authority on terms and conditions acceptable to the Board of Directors. Any General Member or third party so engaged shall have such responsibilities as are set forth in the contract for such General Member's or third party's services.

Article VI: Relationship of Authority And Its Members

Section 6.01 – Separate Entity; Property.

In accordance with California Government Code Sections 6506 and 6507, the Authority shall be a public entity separate and apart from the parties to this Agreement. Unless, and to the extent otherwise agreed herein, the debts, liabilities and obligations of the Authority shall not be debts, liabilities or obligations of the Member entities. The Authority shall own and hold title to all funds, property and works acquired by it during the term of this Agreement.

Section 6.02 – Admission, Withdrawal and Termination of Members.

(a) Additional qualified parties may join in this Agreement and become General Members upon the approval of the entire Board of Directors, subject to terms and conditions as may be established by the Board of Directors. Associate Members may be admitted on terms and conditions established by the entire Board of Directors. Prior to being admitted as a new Member, an entity shall execute an agreement to be bound by the terms of this Agreement and any other terms and conditions established by the Board of Directors.

(b) Notwithstanding anything herein to the contrary, any Member may withdraw from this Agreement by giving 30 days written notice of its election to do so, which notice shall be given to the Board of Directors and to each of the other parties.

(c) Upon withdrawal, the Member shall not be relieved of all obligations for assessments to pay costs or liabilities of the Authority which were incurred prior to the date of the withdrawing Member's notice of withdrawal, but shall remain responsible for all obligations for assessments to pay costs or liabilities of the Authority which were incurred prior to the date of the withdrawing Member's notice of withdrawal.

(d) Subject to any contrary provisions of SGMA, a Member may be terminated by a three-fourths vote of the Directors representing Members not subject to the termination vote if such Member is then in breach of this Agreement and the breach is identified in the vote of the Board of Directors. Upon termination, the breaching Member shall no longer be a Member of the Authority; provided, that such termination shall become effective no earlier than 90 days after such vote of the Board of Directors and shall only be effective if the breach identified in the vote of the Board of Directors has not be cured by the effective date for the termination.

(e) Upon termination, the Member shall be entitled to a reimbursement for all assessments collected within 12 months prior to the termination vote and they shall be relieved

of all ongoing obligations for assessments to pay costs or liabilities of the Authority which were incurred prior to the date of the termination.

(f) Upon withdrawal or termination as a Member, the provisions of Section 2.04(b) shall remain applicable to any such withdrawing or terminated Member. The withdrawing or terminated Member will also be entitled to copies of all documents, information, and material developed by the Authority and paid for in whole or in part by the Member prior to the Member's withdrawal or termination.

(g) Upon withdrawal or termination as a Member, whether occurring before or after the GSA Notice Date and/or the date the Authority becomes a GSA as provided for in SGMA, or whether occurring before or after June 30, 2017, it is contemplated the withdrawing or terminated Member would concurrently become (or designate) a GSA for the lands within its boundaries (or a Management Area managed in whole or in part by such Member), so that such lands of the withdrawing or terminated Member would continue to be subject to a GSA and if applicable a GSP and the powers of such withdrawing Member within its boundaries would not be limited by this Agreement. In such event the Authority and its remaining Members shall (i) not object to or interfere with the lands in the withdrawing or terminated Member's boundaries (or a Management Area managed in whole or in part by such Member) being in a GSA, as designated by such withdrawing or terminated Member, (ii) facilitate such transition to the extent reasonably necessary, and (iii) in cooperation with the withdrawing or terminated Member, withdraw from managing the Kern County Subbasin as a GSA (if it has already elected to be a GSA) for that portion of the Basin within the boundaries of the withdrawing or terminated Member and so notify the Department of Water Resources..

Section 6.03 – Disposition Of Property Upon Termination Or Determination By Board Of Directors Of Surplus.

(a) Upon termination of this Agreement or upon determination by the Board of Directors that any surplus money is on hand, such surplus money shall be returned to the Members of the Authority. The distribution of said surplus shall be proportionate to the current year percentages as shown in Exhibit A, or as modified after the inclusion of new Members.

(b) The Board of Directors shall first offer any surplus properties, works, rights and interests of the Authority for sale to the Members and the sale shall be at the Authority's actual cost unless otherwise required by law. If no such sale is consummated, then the Board of Directors shall offer the surplus properties, works, rights and interests of the Authority for sale in accordance with applicable law to any governmental agency, private entity or persons for good and adequate consideration.

Section 6.04 –Liability For Debts.

The Members do not intend hereby to be obligated either jointly or severally for the debts, liabilities or obligations of the Authority, except as may be specifically provided for in California Government Code Section 895.2 as amended or supplemented. Provided, however, if any General Member(s) of the Authority are, under such applicable law, held liable for the acts or omissions of the Authority caused by negligent or wrongful act or omission occurring in the performance of this Agreement, such parties shall be entitled to contribution from the other Members so that after said contributions each General Member shall bear an equal share of such liability, as shown on the then-current Exhibit A. This Section 6.04 does not apply to acts or omissions of a Member in implementing the GSP adopted by the Authority within such

Member's boundaries or a Management Area managed in whole or in part by such Member.

Section 6.05 – SGMA-Related Expenses Incurred by Members.

Expenses incurred by a Member, or group of Members, for the implementation of the SGMA within a Management Area shall be borne solely by that Member or group of Members. Neither the Authority nor its other Members shall be liable for such expenses.

Article VII – Implementation of SGMA

Section 7.01 – Development of GSP.

Any Member or group of Members may create its or their own chapter or provisions governing SGMA implementation within their respective boundaries or a Management Area managed in whole or in part by such Member(s) for inclusion by the Authority into the Authority's GSP. The Authority shall promptly review the proposed chapter or provisions for consistency with the Authority's GSP and to determine that it meets the requirements of SGMA. If the Authority determines by a vote of 75% of the Directors that a Member's proposed chapter or provisions is/are consistent with SGMA and the Authority's GSP, it shall incorporate such chapter or provisions into the Authority's GSP. Such chapter or provisions may include operating conditions and criteria for groundwater banking projects that have previously been negotiated with other Members or agencies within the Basin and/or are contained within approved environmental documents, and in reviewing a Member's chapter the Authority shall not reject or fail to approve a Member's chapter based solely upon such operating conditions and criteria. The Authority shall not adopt a GSP that will be implemented within any Member's boundaries or Management Area without the prior approval of the Member.

Section 7.02 – Authorization to Carry Out the Terms of the GSP.

The Authority is authorized to carry out any of the following powers for the benefit of its Members that are included in the GSP adopted by the Authority without any further approval of the Board of Directors, subject at all times to the limitations and restrictions contained within this Agreement:

(a) Collection and maintenance of water extraction information and other technical data.

(b) Coordination of actions within, and reporting by, a Management Area.

(c) Carrying out studies and other technical investigations.

(d) Establishment and administration of conjunctive use and land fallowing programs.

(e) Requiring permitting of water extraction facilities.

(f) Requiring installation of meters.

(g) Buy, sell, exchange, recharge, and/or store water if the benefits thereof are made available to all General Members.

(h) Fix and collect rates for replenishment and other activities as a regulatory or service fee provided for at Water Code Sections 10730 through 10731.

Section 7.03 – Actions Requiring Additional Approval.

Subject to the limitations of this Agreement, the Authority shall not do any of the following without the approval of 75% of the voting power of the Board of Directors:

(a) Restrict or otherwise limit extraction of native groundwater other than through economic incentives and disincentives.

(b) Fund capital construction projects.

Notwithstanding any other provision of this Agreement, the Authority shall not restrict or otherwise limit the extraction of water stored (whether through direct recharge or in lieu deliveries) in the Kern County Subbasin as a part of any banking or recharge project or program, or otherwise seek to regulate the operation any such project or program.

Section 7.04 – Management Areas.

Any General Member (or group of General Members) may request that the Authority directly assume the responsibility of implementing SGMA and the Authority's GSP within its Management Area by giving written notice to the Authority, which notice may be given at any time. Where the service areas of multiple Members overlap a Management Area, the Members within the Management Area shall unanimously join the request. The Board of Directors shall take action to accept or reject such request. If the Authority accepts such request, the Authority and the requesting General Member(s) shall develop a mutually acceptable agreement describing the respective roles and responsibilities of the Authority and the requesting General Member(s) with respect to such implementation.

Except as otherwise expressly provided, the Authority's role within a Management Area, unless otherwise unanimously requested by the Member(s) managing such Management Area, shall be primarily coordinating and administrative. In particular, the roles and responsibilities for implementing SGMA and the GSP within a Management Area shall be the subject of a Special Activity agreement between the Member(s) and the Authority.

Article VIII: Miscellaneous Provisions

Section 8.01 – Amendment.

This Agreement may be amended from time to time by the concurrence of 75% of the General Members. To provide non-concurring parties an opportunity to withdraw from the Authority as provided herein, an amendment shall be binding on all parties 60 days after the required concurrence has been obtained.

Section 8.02 – Severability And Validity Of Agreement.

Should the participation of any party to this Agreement, or any part, term or provision of this Agreement be decided by a courts or the Legislature to be illegal, in excess of that party's authority, in conflict with any law of the State of California, or otherwise rendered unenforceable or ineffectual, the validity of the remaining portions, terms or provisions of this Agreement shall

not be affected thereby and each party hereby agrees it would have entered into this Agreement upon the remaining terms and provisions.

Section 8.03 – Assignment.

Except as otherwise provided in this Agreement, the rights and duties of the parties to this Agreement may not be assigned or delegated without the advance written consent of the Authority (as evidenced by a majority vote of the Board of Directors), and any attempt to assign or delegate such rights or duties in contravention of this section shall be null and void. Any assignment or delegation permitted under the terms of this Agreement shall be consistent with the terms of any contracts, resolutions or indentures of the Authority then in effect, including without any Special Activity agreement to which the assigning or delegating Member is a party. This Agreement shall inure to the benefit of and be binding upon the successors and assigns of the parties hereto. This section does not prohibit a party from entering into an independent agreement with another agency regarding the financing of that party's contributions to the Authority or the disposition of proceeds which that party receives under this Agreement so long as such independent agreement does not affect, or purport to affect, the rights and duties of the Authority or the parties under this Agreement.

Section 8.04 – Execution In Parts Or Counterparts.

This Agreement may be executed in parts or counterparts, each part or counterpart being an exact duplicate of all other parts or counterparts, and all parts or counterparts shall be considered as constituting one complete original and may be attached together when executed by the parties hereto. Facsimile or electronic signatures shall be binding.

Section 8.05 – Notices.

Notices authorized or required to be given pursuant to this Agreement shall be in writing and shall be deemed to have been given when mailed, postage prepaid, or delivered during working hours to the addresses set forth for each of the parties hereto on Exhibit "A" of this Agreement, or to such other changed addresses communicated to the Authority and the Member entities in writing, and to such other entities that become Members.

Section 8.06 – Dispute Resolution.

(a) A dispute resolution group shall be established by the Board of Directors to resolve disputes and/or controversies through mediation relating to the interpretation, construction, performance, termination, breach of, or withdrawal from this Agreement (the "Dispute Resolution Group"). The Dispute Resolution Group shall meet with the parties involved no later than 30 days following notification of the dispute or controversy. Thereafter, the Dispute Resolution Group will have 90 days to endeavor to resolve the dispute.

(b) Following conclusion of the dispute resolution process as herein provided, any Member may pursue any judicial or administrative remedies otherwise available. Notwithstanding this Section 8.06, a Member may seek a preliminary injunction or other interlocutory judicial relief if necessary to avoid irreparable damages or to preserve the status quo.

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Arvin Community Services District
Name of Member

By: Raul Barraza Jr.

Print Name: Raul Barraza, Jr.

Title: General Manager

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

ARVIN EDISON WATER STORAGE DISTRICT
Name of Member

By: _____

Print Name: KEVIN PASCOE

Title: BOARD MEMBER

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Camelo WD

Name of Member

By: _____

Print Name: David Fenn

Title: Board member

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

City of Shafter
Name of Member

By: _____

Print Name: Michael James

Title: Public Works Director

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Kern County
Name of Member

By: _____

Print Name: ZACK SCRIVNER

Title: Chairman, Board of Supervisors, ~~County of Kern~~

APPROVED AS TO FORM
Office of County Counsel
Kern County
By _____

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Kern County Water Agency
Name of Member

By: _____

Print Name: Curtis Creel

Title: General Manager

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Kern - Tulare Water District
Name of Member

By: [signature]

Print Name: Steven C. Dalke

Title: General Manager

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

NORTH KERN
Name of Member

By: _____

Print Name: KEVIN ANDREW

Title: PRESIDENT

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

OLCESE WATER DISTRICT
Name of Member

By: _____

Print Name: JEFF SIEMENS

Title: _____

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Rosedale-Rio Bravo Water Storage District
Name of Member

By: Gary Vark

Print Name: Gary Vark

Title: Director

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Semitropic Water Storage District
Name of Member

By: _____

Print Name: Rick Wegis

Title: Board member

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Shafter - Wasco
Name of Member

By: _____

Print Name: D Mark Franz

Title: Director

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

SSTMUD

Name of Member

By: James R. Ragan

Print Name: James R. Ragan

Title: member

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Tejon - Castaic Water District
Name of Member

By: _____

Print Name: Dennis Atkinson

Title: President

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

WEST KERN WATER DISTRICT
Name of Member

By: Gary J. Morris

Print Name: GARY MORRIS

Title: BOARD MEMBER

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

WESTSIDE WATER DISTRICT AUTH.
Name of Member

By: _____

Print Name: Joseph MacIlvaine

Title: President

IN WITNESS WHEREOF, the parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or governing board, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

Wheeler Ridge-Maricopa Water Storage District

Name of Member

By: _____

Print Name: George R. Cappello

Title: Board President

By: _____

Print Name: Jose Marin

Title: Board Secretary

EXHIBIT A

GENERAL MEMBERS

Arvin Community Services District

Arvin-Edison Water Storage District

Cawelo Water District

City of Shafter

Kern County Water Agency

Kern County

Kern-Tulare Water District

North Kern Water Storage District

Olcese Water District

Rosedale-Rio Bravo Water Storage District

Semitropic Water Storage District

Shafter-Wasco Irrigation District

Southern San Joaquin Municipal Utility District

Tejon-Castaic Water District

West Kern Water District

Westside District Water Authority

Wheeler Ridge-Maricopa Water Storage District

Appendix B

SSJMUD Agricultural Water Management Plan

FIVE YEAR UPDATE

AGRICULTURAL WATER MANAGEMENT PLAN

SOUTHERN SAN JOAQUIN
MUNICIPAL UTILITY DISTRICT



MAY 2012

BEFORE THE BOARD OF DIRECTORS OF THE
SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

IN THE MATTER OF: **RESOLUTION NO. 12-09**

ADOPTING A FIVE YEAR UPDATE
OF THE DISTRICT'S WATER MANAGEMENT PLAN

WHEREAS, a five year update to the Southern San Joaquin Municipal Utility District's WATER MANAGEMENT PLAN, has been prepared, presented to and discussed by the Board of Directors of the Southern San Joaquin Municipal Utility District which defines water management, control and policies of the Southern San Joaquin Municipal Utility District:

THEREFORE, BE IT RESOLVED that the WATER MANAGEMENT PLAN prepared by the staff of the Southern San Joaquin Municipal Utility District is adopted as presented and discussed at a noticed meeting scheduled for this date, is deemed acceptable and the Board of Directors finds that adoption of the same is in the best interest of the Southern San Joaquin Municipal Utility District and its landowners.

RESOLVED FURTHER, that William R. Carlisle, Manager-Secretary, is hereby authorized and directed to file said WATER MANAGEMENT PLAN on behalf of the Southern San Joaquin Municipal Utility District with the U. S. Bureau of Reclamation as deemed acceptable to this Board of Directors and to execute such other documents as may be necessary to carry out the intent of the above resolution.

The foregoing Resolution was adopted at a regular meeting of the Board of Directors of Southern San Joaquin Municipal Utility District held at the District Office on the 14th day of May, 2012, upon a motion of Director Regan and seconded by Director Morris, was authorized by the following vote:

AYES: Fisher, Dulcich, Regan, Zaninovich and Morris

NOES: None

ABSENT: None

I HEREBY CERTIFY that I am the duly appointed Secretary of the SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT and that the foregoing resolution was adopted by the Board of Directors of said District at a meeting held on the 14th day of May 2012, at which meeting a quorum was present at all times and acting.

IN WITNESS WHEREOF, I have set my hand this 14th day of May, 2012.

William R. Carlisle
WILLIAM R. CARLISLE, Secretary

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT
2010 Water Management Plan

Date of first draft – DECEMBER 27, 2010
Date of final – MAY 14, 2012

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Section 3:	Best Management Practices (BMPs) for Agricultural Contractors	3-1
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Plate 1 District Location Map

Plate 2 District Vicinity Map

Attachment A District Facilities Map

Attachment B District Soils Map

Attachment C District Rules and Regulations

Attachment D District Sample Bills

Attachment E District Water Shortage Plan

Attachment F District Map of Groundwater Facilities

Attachment G Groundwater Management Plan

Attachment H Notices of District Education Programs and Services Available to Customers

Section 1: Description of the District

District Name: *Southern San Joaquin Municipal Utility District*

Contact Name: William R. Carlisle

Title: Secretary/General Manager

Telephone: (661) 725-0610

E-mail: gm@ssjmud.org

Web Address

A. History

1. Date district formed: 1935 *Date of first Reclamation contract*: 10/18/1945
Original size (acres): 61,000 *Current year (last complete calendar year)*: 2009

The Southern San Joaquin Municipal Utility District (District) under its present name was organized in 1935, in accordance with the provisions of California laws pertaining to the formation and operation of municipal utility districts. The District was formed for the purpose of entering into a contract for purchase and distribution of water from the Central Valley Project (CVP). Portions of the area now included in the District formerly were part of the Poso Irrigation District, formed in 1888 and of the Kern and Tulare Irrigation District, formed in 1890. These early districts were short lived because of financial difficulties and lack of water. Prior to completion of the Southern Pacific Railroad through the vicinity in 1873, land in the area was used principally for livestock grazing.

With improved transportation facilities and development of large capacity water wells, irrigated agriculture superseded livestock production in the area. In subsequent years, intensive pumping had resulted in a serious lowering of the groundwater table underlying the District. This had necessitated drilling deeper wells with large increases in costs for installation and operation. At present, the District's only source of irrigation water is their surface supply from the Central Valley Project.

2. Current size, population, and irrigated acres

	(2009)
Size (acres)	64,000
Population served	48,442
Irrigated acres	44,627

The Cities of Delano and McFarland are located entirely within the District's service area boundary. The District does not, however, make any direct deliveries to either cities and is therefore not an urban water provider. The cities, however, do rely on the local groundwater supply, which is naturally recharged. The District provides a small amount of recharge to the groundwater reservoir supply through on-farm, in-lieu recharge efforts and recharge efforts through District reservoirs. A portion of this recharge would accrue to the benefit of the urbanized areas.

3. Water supplies received in current year

Water Source	*AF*
Federal urban water (Tbl 1)	
Federal agricultural water (Tbl 1)	121,259
State water (Tbl 1)	
Other Wholesaler (define) (Tbl 1)	
Local surface water (Tbl 1)	
Upslope drain water (Tbl 1)	
District ground water (Tbl 2)	
Banked water (Tbl 1)	
Transferred water (Tbl 6)	
Recycled water (Tbl 3)	
Other (define) (Tbl 1)	
Total	121,259

"Other" District water is defined as delivered non-Project water made available through exchanges between the District and other Friant-Division CVP contractors that have local water sources in addition to their CVP supply.

4. Annual entitlement under each right and/or contract

	AF	*Source*	*Contract #*	*Availability period(s)*
Reclamation Urban AF/Y				
Reclamation Agriculture AF/Y	97,000	Friant Division CVP – Class 1	Ir1-1460D	All year
Reclamation Agriculture AF/Y	50,000	Friant Division CVP – Class 2	Ir1-1460D	All year
Other AF/Y				

5. Anticipated land-use changes

There are no anticipated land-use changes.

6. Cropping patterns (Agricultural only)

List of current crops (crops with 5% or less of total acreage) can be combined in the 'Other' category.

Original Plan (1998)		*Previous Plan (2004)*		*Current Plan*	
Crop Name	*Acres*	*Crop Name*	*Acres*	*Crop Name*	*Acres*
Almonds	13,344	Alfalfa	3,536.5	Almonds	13,170
Grapes	10,656	Almonds	11,885	Table, Grapes	10,992
Cotton	10,080	Citrus	4,647	Navel Oranges	4,250
Alfalfa	5,664	Table Grapes	12,901	Pistachios	4,130
Citrus	2,928			Alfalfa	2,796
				Grapes	2,740
Other (<5%)	5,328	*Other (<5%)*	10,923.5	*Other (<5%)*	6,549
Total	48,000	*Total*	43,893	*Total*	44,627

(See Planner, Chapter 2, Appendix A for list of crop names)

The total acreage of 44,627, listed in the table above, is the current cropped portion of the total irrigated acres (45,765) listed in Section 1.A.2. and in Section 5, Table 5. The remaining 1,138 acres were idle/fallow during the current year.

7. Major irrigation methods (by acreage) (Agricultural only)

Original Plan (1998)		*Previous Plan (2004)*		*Current Plan*	
Irrigation Method	*Acres*	*Irrigation Method*	*Acres*	*Irrigation Method*	*Acres*
Row	17,897	Row	16,724	Flood	18,453
Flood	15,501	Flood	14,485	Drip	16,265
Drip	5,355	Drip	5,004	Micro Sprinkler	4,849
Sprinkler	5,261	Sprinkler	4,916	Fan Jet	3,243
Misters	2,959			Furrow	1,409
				Sprinkler	408
Other		*Other*	2,764	*Other*	0
Total	46,973	*Total*	43,893	*Total*	44,627

(See Planner, Chapter 2, Appendix A for list of irrigation system types)

The total acreage of 44,627, listed in the table above, is the current cropped portion of the total irrigated acres (45,765) listed in Section 1.A.2. and in Section 5, Table 5. The remaining 1,138 acres were idle/fallow during the current year.

B. Location and Facilities

See **Attachment A** for points of delivery, turnouts (internal flow) and outflow (spill) points, measurement locations, conveyance system, storage facilities, operational loss recovery system, wells and water quality monitoring locations.

The Southern San Joaquin Municipal Utility District (District) is located in Kern County, California, approximately 75 miles southeast of Fresno and 30 miles northwest of Bakersfield. The District includes lands in the southeastern San Joaquin Valley and the adjacent low foothills of the Sierra Nevada mountains. Its northern boundary is the Kern-Tulare Counties line, from which it extends southward about 13 miles. Its greatest width east and west is also about 13 miles. The general location of the District is shown on Plate 1. The principal town and location of the District's headquarters is Delano, located in the north-central part of the District. The community of McFarland is also in the District and is located about six miles south of Delano.

The distribution system is designed for a capacity of one (1) cubic foot per second for each 80 acres, with a delivery pressure of 10 feet of head available at the highest point in each 160 acres. The portion of the District lying below the Friant-Kern Canal is served by a

combination gravity and pumping system, with the pumping being confined to the first sub-lateral. The portion of the District lying above the canal is served by pumping through three (3) pumping stations on the canal and two re-lift plants on each of the three (3) laterals. The District has eleven (11) regulating reservoirs in total. Each has an area of approximately two (2) acres. Their locations within the distribution system are shown in **Attachment A**.

The District's system consists of 158 miles of pipelines. The original pipelines, completed in the early 1950's, were made of concrete. Portions of the pipelines were of non-reinforced pipe with mortar joints, while portions were of reinforced concrete pipe with rubber gasketed joints.

The District has 539 active deliveries at the present time and approximately 30 that are not currently in use. All deliveries are metered. Older meters are being replaced by a propeller type meter that indicates the flow and records the total flow that is supplied to the user.

The District does not own any groundwater production facilities. Landowners in the District continue to own and operate groundwater production facilities aside from the District.

1. Incoming flow locations and measurement methods

Location Name	*Physical Location*	*Type of Measurement Device*	*Accuracy*
Friant-Kern Canal & Lateral 1	FKC Mile Post 119.6	Propeller Meter	±2%
Friant-Kern Canal & Lateral 2	FKC Mile Post 122.5	Propeller Meter	±2%
Friant-Kern Canal & Lateral 3	FKC Mile Post 124.5	Propeller Meter	±2%
Friant-Kern Canal & Lateral 4	FKC Mile Post 126.7	Propeller Meter	±2%
Friant-Kern Canal & Lateral 5	FKC Mile Post 128.3	Propeller Meter	±2%
Friant-Kern Canal & Lateral 6	FKC Mile Post 129.8	Propeller Meter	±2%
Friant-Kern Canal & Lateral 7	FKC Mile Post 124.5 E	Propeller Meter	±2%
Friant-Kern Canal & Lateral 8	FKC Mile Post 127.7 E	Propeller Meter	±2%
Friant-Kern Canal & Lateral 9	FKC Mile Post 130.4 E	Propeller Meter	±2%

2. Current year Agricultural Conveyance System

Miles Unlined - Canal	*Miles Lined - Canal*	*Miles Piped*	*Miles - Other*
None	None	175	None

3. Current year Urban Distribution System

Miles AC Pipe	*Miles Steel Pipe*	*Miles Cast Iron Pipe*	*Miles - Other*
N/A	N/A	N/A	N/A

4. Storage facilities (tanks, reservoirs, regulating reservoirs)

Name	*Type*	*Capacity (AF)*	*Distribution or Spill*
Lateral 1 – Bassett	Regulating	1	Distribution
Lateral 2 – Airport	Regulating	1	Distribution
Lateral 3 – Elmo	Regulating	1	Distribution
Lateral 7 – S2	Regulating	1	Distribution
Lateral 7 – S3	Regulating	1	Distribution
Lateral 7 – S4	Regulating	1	Distribution
Lateral 7 – S5	Regulating	1	Distribution
Lateral 7-1 – S6	Regulating	0.5	Distribution
Lateral 8 – S10	Regulating	1	Distribution
Lateral 8 – S11	Regulating	1	Distribution
Lateral 8 – S12	Regulating	1	Distribution
Lateral 8 – Reynolds S14	Regulating	14	Distribution
Lateral 9 – S16	Regulating	1	Distribution
Lateral 9 – S17	Regulating	1	Distribution
Lateral 9 – S18	Terminal Reservoir	1	Distribution

5. Outflow locations and measurement methods (Agricultural only)
Provide this information in Section 2 F.

6. Description of the agricultural spill recovery system

There are no operational spill losses experienced by the District. All water conveyed within the District's distribution system remains within the system until utilized. On-farm tailwater return systems have been constructed by those District landowners not utilizing permanent on-farm distribution systems. All deep percolation losses return to usable groundwater source and no water leaves the service area in the form of surface runoff.

7. Agricultural delivery system operation (check all that apply)

On-demand	*Scheduled*	*Rotation*	*Other (describe)*
	✓		

8. Restrictions on water source(s)

Source	*Restriction*	*Cause of Restriction*	*Effect on Operations*
USBR	Declaration	Quantity of Snowfall	Reduced Deliveries
FKC	Capacity	Subsidence/Siphons	Reduced Deliveries

9. Proposed changes or additions to facilities and operations for the next 5 years

Since the District is fully developed, the only anticipated changes to the District's distribution system are continued efforts to replacing older pipelines. The District is also scheduled to build Reservoir S-21 along Lateral 8 in 2010, and plans to expand the Lateral 8 – Reynolds S14 reservoir in 2012.

C. Topography and Soils

1. Topography of the district and its impact on water operations and management

The general relief of the District gently slopes predominantly from the southeast to the northwest, with the topography becoming smoother and more level to the west. The topography of lands varies in elevation from a high of 650 feet on the eastern boundaries to a low of 240 feet at the western boundaries. The average slope is about 21 feet per mile and the average elevation is about 310 feet above sea level.

The District may be divided topographically into three types of terrain: (1) low foothills on the eastern boundary of the District, (2) an intermediate belt averaging 6 miles wide, sloping 30 to 40 feet per mile westerly with small isolated areas of poor drainage and (3), in the western portion, a zone with relatively flat slopes that originate from a series of alluvial fans, of which those of Poso Creek and Rag Gulch are pre-eminent. Farther west these fans merge into an area of very flat slopes marked by saline soils.

2. District soil association map (Agricultural only)

See **Attachment B**, District Soils Map

Soils of the District can be divided into three (3) different major categories. The foothill area is distinguished by hardpan and other compact subsoil layers which allow for limited

development into vineyards and truck crop areas. The transition zone and the majority of the valley floor area consists of deep permeable soils. The soil in this area is extremely productive and well suited for any crop that fits the existing weather conditions. On the western limits of the District, the soil contains areas of saline type material which require specific reclamation actions to become productive.

In February of 1948, the United States Bureau of Reclamation made a semi-detailed land classification of the District, as detailed in Land Use Study of the Southern San Joaquin Municipal Irrigation District. The land classes assigned to District lands represent varying degrees of suitability for irrigation and were determined by evaluation of the factors of soil, topography and drainage in relationship to adapted crops, productivity and land management.

The first soil region contains soils mainly on alluvial fans, alluvial plains, basin rims and flood plains in the eastern part of the San Joaquin Valley. The Garces soil series is deep, nearly level, saline-alkali, well-drained silt loam and clay loams soils. With the Garces soils, typically, the surface layer is silt loam. The subsoil is clay loam and loam. The substratum is loam and fine sandy loam. In some areas, the substratum is stratified and contains a brittle layer of weakly to moderately cemented material. These soils are moderately to strongly saline-alkali.

The Kimberlina soil series is deep, nearly level, well drained fine sandy loam and sandy loam soils. Also present, to a minor extent, are Cajon soils which are deep and somewhat excessively drained. The surface soil of the Kimberlina soils is fine sandy loam. The upper part of the underlying material is fine sandy loam, and the lower part is silt loam.

The McFarland soil series is a deep, nearly level, well drained loam soil. These soils are formed in alluvium and derived from granite rock. The surface layer and underlying material are loam.

The second soil region included within the District contains soils on terraces in the eastern part of the San Joaquin Valley. The Delano soil series is deep, nearly level to hilly, well

drained sandy loam and clay loam soils. These soils are formed in alluvium and derived from granite rock. The surface layer of Delano soils is sandy loam. The subsoil is clay loam, sandy clay loam and sandy loam. The substratum is sandy loam.

3. Agricultural limitations resulting from soil problems (Agricultural only)

Soil Problem	*Estimated Acres*	*Effect on Water Operations and Management*
Salinity	None	None
High-water table	None	None
High or low infiltration rates	None	None
Other (define)	None	None

D. Climate

1. General climate of the district service area

The climate of the District is typical of the San Joaquin Valley, being semiarid and characterized by mild winters and hot, dry summers. Mean annual temperature at Delano is 62.9 degrees Fahrenheit. The average annual minimum and maximum temperatures are 48.4 and 78.5 degrees, respectively.

The average yearly rainfall for the District area is 6.97 inches, based on records published for the California Irrigation Management Information System (CIMIS) station number 182 at Delano, for the 8-year period of 2002-2010, inclusive. Rain falls principally during the period November to April.

Many of the crops in this area are crops that are particularly sensitive to frost. The most favored areas for citrus and other frost-sensitive crops are the tops and slopes of some of the foothills where there is better air drainage. The area is in a thermal belt, but there are cold areas in some of the low lands and depressions.

The climatological normals for the District area presented in the preceding tables were obtained from the CIMIS station number 182 at Delano, for the 8-year period of 2002-2009,

inclusive. The climatological extremes for the District area were obtained from the CIMIS station number 182 at Delano, for the period of 2002-2009, inclusive.

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Annual*
Avg Precip.	1.05	1.11	0.86	0.86	0.38	0.01	0.00	0.00	0.00	0.76	1.02	0.91	6.97
Avg Temp.	45.7	50.4	56.8	60.5	69.8	76.0	81.8	81.0	73.5	61.9	52.0	45.5	62.9
Max. Temp.	57.4	64.1	71.8	75.5	86.2	93.0	99.2	97.5	92.2	79.5	67.3	58.0	78.5
Min. Temp	36.7	39.1	43.2	46.4	53.1	58.3	63.7	62.1	55.9	46.9	40.2	35.5	48.4
ETo	1.13	1.93	3.53	5.05	7.14	7.91	8.09	7.3	5.33	3.28	1.67	1.12	4.46

Weather station ID CIMIS #182 *Data period: Year* 2002 *to Year* 2009

Average wind velocity 3.2 mph *Average annual frost-free days:* 280

2. Impact of microclimates on water management within the service area

Demand exists for water during the winter months for frost protection purposes. This demand is independent of the evapotranspiration demand.

E. Natural and Cultural Resources

1. Natural resource areas within the service area

Name	*Estimated Acres*	*Description*
N/A	None	N/A

2. Description of district management of these resources in the past or present

Not Applicable

3. Recreational and/or cultural resources areas within the service area

Name	*Estimated Acres*	*Description*
N/A	None	N/A

F. Operating Rules and Regulations

1. Operating rules and regulations

See **Attachment C**, District Rules and Regulations (water related)

2. Water allocation policy (Agricultural only)

See **Attachment C**, Section C, Page C-5

General: Any Water User of lands within the District designated non-excess (or otherwise made eligible to receive water) who has otherwise complied with these Rules and Regulations and policies of the Board, including having timely submitted an application for water service, is entitled to water service made available to the District under the Contract with the Bureau. Provided, however, no Schedule B lands shall be eligible to receive any share of the District's contract entitlement until all applications for Schedule A lands are fulfilled.

3. Official and actual lead times necessary for water orders and shut-off (Agricultural only)

See **Attachment C**, Section B (9), Page C-4

Water delivery changes are made six (6) days a week with no changes on Sundays. Water Users desiring water shall place their water orders a minimum of 24-hours in advance. Water orders are taken between the hours of 7:00 A.M. to 3:30 P.M. Monday through Friday and 7:00 A.M. to 9:00 A.M. on Saturday. No orders are taken on Sunday and orders for Monday changes must be in by 9:00 A.M. Saturday. All orders are compiled by the Dispatcher in order to place the District water order for the next day deliveries.

4. Policies regarding return flows (surface and subsurface drainage from farms) and outflow (Agricultural only)

See **Attachment C**, Section B (11), Page C-4

The District reserves the right to turn off Water deliveries in those instances of a Water User not taking care of his water and flooding roads or neighboring lands.

5. Policies on water transfers by the district and its customers

See **Attachment C**, Section B (5), Page C-3

Water may be transferred from one parcel to another parcel provided the parcels are owned or leased by the same person(s) or company. No landholder or Water User can transfer or exchange water outside the District service area.

Exchanges of water with other Friant-Division, CVP contractors are permitted with Board approval.

G. Water Measurement, Pricing, and Billing

1. Agricultural Customers

a. Number of farms 225

b. Number of delivery points (turnouts and connections) 640

c. Number of delivery points serving more than one farm 4

District delivery points serving more than one farm exist when an individual landowner divides a parcel and sells off the divided portion of his/her land to another party. When this occurs, water conveyed to each parcel is accomplished through the existing turnout and meter. When payment for the water is due to the District, the original landowner, whose name is on the District account, pays the District water bill. The original landowner then receives payment from the secondary landowner based on his share of the delivery.

In order to comply with the current Guidelines, all farm deliveries must be provided with measurement capability meeting the established minimum accuracy requirements. For the referenced (4) deliveries, the District will design, construct and place into operation, new metered turnouts with appropriate rating capabilities and sized to meet the requirements of each delivery. The installations will be completed during Fall 2012. The budget estimate to complete all four (4) installations is $12,000.

d. Number of measured delivery points (meters and measurement devices) 640

e. Percentage of delivered water that was measured at a delivery point 100

f. Delivery point measurement device table (Agricultural only)

Measurement Type	*Number*	*Accuracy (+/- %)*	*Reading Frequency (Days)*	*Calibration Frequency (Months)*	*Maintenance Frequency (Months)*
Orifices					
Propeller meter	640	±6%	Daily	Upon Request	As needed
Weirs					
Flumes					
Venturi					
Metered gates					
Acoustic doppler					
Other (define)					
Total					

The District's water tracking software performs a day by day comparison of what is ordered versus the amount recorded as delivered through each individual meter. When a consistent difference occurs, the District installs a temporary clock mechanism within the meter and proceeds to repair, recalibrate and reinstall the existing clock. In the case where the clock is not repairable, the District installs a new clock. As it relates to District underground line meters, which can no longer be repaired, the District replaces the entire meter. In the event that the District receives a complaint from a water user, the District automatically installs a temporary clock and repairs, recalibrates and reinstalls the clock in question, unless a new clock is warranted. This program is performed on an on-going basis.

2. Urban Customers

This section was intentionally left blank because the District does not have urban customers.

a. *Total number of connections* N/A

b. Total number of metered connections N/A

c. Total number of connections not billed by quantity N/A

d. Percentage of water that was measured at delivery point N/A

e. Percentage of delivered water that was billed by quantity N/A

f. Measurement device table

Meter Size and Type	*Number*	*Accuracy (+/-percentage)*	*Reading Frequency (Days)*	*Calibration Frequency (Months)*	*Maintenance Frequency (Months)*
5/8-3/4"					
1"					
1 ½"					
2"					
3"					
4"					
6"					
8"					
10"					
Compound					
Turbo					
Other (define)					
Total					

3. Agriculture and Urban Customers

a. Current year agriculture and /or urban water charges - including rate structures and billing frequency

The current-year water rate is $49.93 per acre foot. Water users are billed on a monthly basis with payments due on or before the 20th of each month for water used the prior month.

b. Annual charges collected from customers (current year data)

Fixed Charges			
Charges ($ unit)	*Charge units ($/acre), ($/customer) etc.*	*Units billed during year (acres, customer) etc.*	*$ collected ($ times units)*
$44.70	$/Acre	49,900 Acres	$2,230,530

Volumetric Charges			
Charges ($ unit)	*Charge units ($/AF), ($/HCF), etc.*	*Units billed during year (AF, HCF) etc.*	*$ collected ($ times units)*
$49.93	$/Acre Foot	115,323 AF	$5,758,077

Lift Charges			
Charges ($ unit)	*Charge units ($/AF), ($/HCF), etc.*	*Units billed during year (AF, HCF) etc.*	*$ collected ($ times units)*
$11.00	$/lifts per account	117,848 Lifts	$1,296,330

See **Attachment D**, District Sample Bill

c. Water-use data accounting procedures

The District record management system is kept on a Dell Server Computer System. The District utilizes True Point Solutions Software for water accounting which interfaces with Sage Software for invoicing and financial accounting. More than forty years of records are archived at the District office and available to customers for their reference.

H. Water Shortage Allocation Policies

1. Current year water shortage policies or shortage response plan - specifying how reduced water supplies are allocated

See **Attachment C**, Section C (2), Page C-5

The District's annual entitlement of Class 1 and Class 2 water shall be distributed according to requests taken from water applications. During dry years, requests may be allocated proportionately to all applicants on the basis of the acreage entitled to receive water.

2. Current year policies that address wasteful use of water and enforcement methods

See **Attachment C**, Section B (11), Page C-4

The District reserves the right to turn off water deliveries in those instances of a Water User not taking care of his water allocation and flooding roads or neighboring lands. Prior to turning off such a delivery, an attempt will be made to reach by phone the responsible party causing the wasting of water.

Section 2: Inventory of Water Resources

A. Surface Water Supply

1. Acre-foot amounts of surface water delivered to the water purveyor by each of the purveyor's sources

2009 Month	Federal Ag Water (acre-feet)	Federal non-Ag Water. (acre-feet)	State Water (acre-feet)	Local Water (acre-feet)	Other Water (Non-Proj) (acre-feet)	Upslope Drain Water (acre-feet)	Total (acre-feet)
Method							
January	1664	0	0	0	0	0	1,664
February	5659	0	0	0	0	0	5,659
March	2613	0	0	0	0	0	2,613
April	7006	0	0	0	0	0	7,006
May	17165	0	0	0	0	0	17,165
June	19853	0	0	0	0	0	19,853
July	23566	0	0	0	0	0	23,566
August	18227	0	0	0	0	0	18,227
September	12234	0	0	0	0	0	12,234
October	8511	0	0	0	0	0	8,511
November	4094	0	0	0	0	0	4,094
December	667	0	0	0	0	0	667
TOTAL	121,259	0	0	0	0	0	121,259

2. Amount of water delivered to the district by each of the district sources for the last 10 years

Year	Federal Ag Water (acre-feet)	Federal non-Ag Water. (acre-feet)	State Water (acre-feet)	Local Water (acre-feet)	Other Water (Non-Proj) (acre-feet)	Upslope Drain Water (acre-feet)	Total (acre-feet)
2000	121,461	0	0	0	700	0	122,161
2001	95,669	0	0	0	857	0	96,526
2002	105,889	0	0	0	300	0	106,189
2003	106,157	0	0	0	1,500	0	107,657
2004	100,328	0	0	0	850	0	101,178
2005	114,754	0	0	0	850	0	115,604
2006	118,151	0	0	0	0	0	118,151
2007	71,431	0	0	0	0	0	71,431
2008	92,458	0	0	0	0	0	92,458
2009	121,259	0	0	0	0	0	121,259
Total	1,047,557	0	0	0	5,057	0	1,052,614
Average	104,756	0	0	0	506	0	105,261

B. Ground Water Supply

1. Acre-foot amounts of ground water pumped and delivered by the district

2009 Month	District Groundwater (acre-feet)	Private Groundwater *(acre-feet)
Method		
January	0	0
February	0	0
March	0	1,507
April	0	0
May	0	5,255
June	0	8,946
July	0	13,965
August	0	4,809
September	0	0
October	0	0
November	0	0
December	0	0
TOTAL	0	34,482

*normally estimated

2. Ground water basin(s) that underlies the service area

Name	*Size (Square Miles)*	*Usable Capacity (AF)*	*Safe Yield (AF/Y)*
Kern County Basin (5-22.14)	3,040	11,200,000	37,000[(1)]
SSJMUD	100	59,000[(2)]	15,800[(3)]

[(1)] *Bureau of Reclamation Water Needs Analysis Summary, March, 1988.*
[(2)] *Groundwater pumping quantity based on continued delivery of contract supply leading to a period of stable groundwater levels. Ref. USBR Needs Assessment, February 14, 2000.*
[(3)] *Safe yield. Quantity independent of imported water deliveries. Ref. USBR Water Supply Study, February, 1948.*

3. Map of district-operated wells and managed ground water recharge areas

See **Attachment F**, District Map of Ground Water Facilities

As stated previously, the District does not own or operate any groundwater extraction wells. A map indicating the District's groundwater facilities (limited to regulation reservoirs) and its proximity to Poso Creek is included as **Attachment F**.

4. Description of conjunctive use of surface and ground water

The main contributions to the recharge of the groundwater reservoir underlying the District are from any percolation from the 12 regulating reservoirs, Poso Creek runoff and other smaller adjacent foothill drainage areas to the east. Historically, the District has primarily achieved its groundwater recharge goals through an in-lieu surface water delivery program. When surface water supplies are available and can be delivered to the District, the surface water supplies are utilized "in lieu" of groundwater pumping. The District will continue this program whenever surface supplies are available and will augment deliveries whenever supplemental supplies can be purchased at a reasonable cost and ordered for delivery by growers. The District continues to evaluate available and developing banking programs.

5. Ground Water Management Plan

See **Attachment G**, Groundwater Management Plan

The District, through its Groundwater Management Plan, entitled *Groundwater Management Program, Under California Water Code, Sections 10750 Et Seq.*, dated May 12, 1993, meets the AB 3030 requirements for management of groundwater related resources.

6. Ground Water Banking Plan

The District does not participate in any groundwater banking projects.

C. Other Water Supplies

1. "Other" water used as part of the water supply

2009 Month	Federal Ag Water (acre-feet)	Federal non-Ag Water. (acre-feet)	State Water (acre-feet)	Local Water (acre-feet)	Other Water (Non-Proj) (acre-feet)	Upslope Drain Water (acre-feet)	Total (acre-feet)
Method							
January	1664	0	0	0	0	0	1,664
February	5659	0	0	0	0	0	5,659
March	2613	0	0	0	0	0	2,613
April	7006	0	0	0	0	0	7,006
May	17165	0	0	0	0	0	17,165
June	19853	0	0	0	0	0	19,853
July	23566	0	0	0	0	0	23,566
August	18227	0	0	0	0	0	18,227
September	12234	0	0	0	0	0	12,234
October	8511	0	0	0	0	0	8,511
November	4094	0	0	0	0	0	4,094
December	667	0	0	0	0	0	667
TOTAL	121,259	0	0	0	0	0	121,259

As stated previously in Section 1.A.3, "Other" District water is defined as delivered non-Project water made available through exchanges between the District and other Friant-Division CVP contractors that have local water sources in addition to their CVP supply.

D. Source Water Quality Monitoring Practices

1. Potable Water Quality (Urban only)

Not Applicable

2. Agricultural water quality concerns: *Yes* _____ *No* ✓
(If yes, describe)

3. Description of the agricultural water quality testing program and the role of each participant, including the district, in the program

Individual landowners are signator to the Kern Sub-watershed of the Southern San Joaquin Valley Water Quality Coalition. The District is not a participant as it has no agricultural related discharges.

4. *Current water quality monitoring programs for surface water by source (Agricultural only)*

There are currently two (2) water quality sampling and monitoring programs conducted on waters related to the District. The first of these is a four-entity program conducted on waters in the Friant-Kern Canal. A sample is taken monthly, year-round, on which tests are run to determine suitability and treatability. The second program is run by Reclamation District No. 770 on waters of the Kaweah River and the Tule River. Tests are run at least annually to provide a base related to pumping into the Friant-Kern Canal for flood water management purposes. The tests are designed to insure that any waters pumped into the canal meet Title 22, CAC, standards.

Current water quality monitoring programs for groundwater by source (Agricultural only)

Water quality monitoring programs on groundwater are conducted by the cities of Delano and McFarland based on criteria established by the State Department of Health Services.

E. Water Uses within the District

1. Agricultural

See Water Inventory Tables, Table 5 - Crop Water Needs

2009 Crop Name	Area (crop acres)	Crop ET (AF/Ac)	Leaching Requireme (AF/Ac)	Cultural Practices (AF/Ac)	Effective Precipitation (AF/Ac)	Appl. Crop Water Use (acre-feet)
Alfalfa	2,796	3.50	0.022	-	0.20	9,288
Almonds	13,170	2.60	0.022	-	0.15	32,556
Apples	122	3.20	0.023	-	0.20	369
Beans	45	3.00	0.018	-	0.20	127
Berries, except Straw	61	3.00	0.018	-	0.20	172
Blackeyes	116	3.00	0.018	-	0.20	327
Cherries	339	3.20	0.023	-	0.20	1,025
Corn	39	2.00	0.016	-	-	79
Grapefruit	20	2.60	0.012	0.25	0.35	50
Grapes	2,740	2.30	0.020	-	0.10	6,083
Hay - Other	1,243	3.70	0.022	-	0.20	4,378
Kiwi	89	2.30	0.020	-	0.10	198
Lemons and Limes	10	2.60	0.012	0.25	0.35	25
Milo	78	1.50	0.002	-	0.25	98
Multiple	272	3.00	0.018	-	0.20	766
Naval Oranges	4,250	2.60	0.012	0.25	0.35	10,676
Oats	105	1.50	0.002	-	0.25	131
Pasture	89	3.70	0.008	-	0.15	317
Pecans	394	2.60	0.022	-	0.20	954
Persimmons	15	3.20	0.023	-	0.20	45
Pistachios	4,130	2.60	0.022	-	0.20	10,003
Raisin Grapes	463	2.30	0.020	-	0.10	1,028
Roses	391	1.50	0.012	-	0.10	552
Silage	951	2.00	0.016	-	-	1,917
Table, Grapes	10,992	2.30	0.020	-	0.10	24,402
Valencia Oranges	420	2.60	0.012	0.25	0.35	1,055
Vegetables, other	109	3.00	0.018	-	0.20	307
Walnuts	688	2.60	0.022	-	0.20	1,666
Watermelon	9	3.00	0.018	-	0.20	25
Wheat	194	1.50	0.002	-	0.25	243
Wine Grapes	287	2.30	0.020	-	0.10	637
Fallow	1,138	-	-	-	-	0
Crop Acres	45,765					109,500

Total Irrig. Acres 44,627 (If this number is larger than your known total, it may be due to double cropping)

2. Types of irrigation systems used for each crop in current year

Crop name	*Total Acres*	*Flood - acres*	*Furrow (Row) - acres*	*Sprinkler - acres*	*Low Volume - acres*	*Multiple methods -acres*
Alfalfa	2,796	2,213	20	37	526	0
Almonds	13,170	4,795	430	89	7,501	355
Apples	122	122	0	0	0	0
Beans	45	0	45	0	0	0
Berries, except Straw	61	0	61	0	0	0
Blackeyes	116	0	0	0	116	0
Cherries	339	159	0	0	180	0
Corn	39	0	0	39	0	0
Grapefruit	20	0	0	0	20	0
Grapes	2,740	1,718	59	0	879	84
Hay – Other	1,243	419	465	78	281	0
Kiwi	89	0	89	0	0	0
Lemons and Limes	10	0	0	0	10	0
Milo	78	0	0	0	78	0
Multiple	272	117	78	0	77	0
Naval Oranges	4,250	2,607	115	9	1500	19
Oats	105	105	0	0	0	0
Pasture	89	68	0	0	21	0
Pecans	394	394	0	0	0	0
Persimmons	15	15	0	0	0	0
Pistachios	4,130	2,510	0	0	1,580	40
Raisin Grapes	463	275	0	0	188	0
Roses	391	0	0	0	391	0
Silage	951	323	0	0	628	0
Table, Grapes	10,992	2,509	47	156	8,193	87
Valencia Oranges	420	0	0	0	420	0
Vegetables, other	109	0	0	0	109	0
Walnuts	688	95	0	0	593	0
Watermelon	9	9	0	0	0	0
Wheat	194	0	0	0	194	0
Wine Grapes	287	0	0	0	287	0

3. *Urban use by customer type in current year*

Not Applicable.

4. *Urban Wastewater Collection/Treatment Systems serving the service area – current year*

Not Applicable.

5. *Ground water recharge/management in current year (Table 6)*

None.

6. *Transfers and exchanges into or out of the service area in current year (Table 6)*

The District did not participate in any transfers and/or exchanges with other entities during the current year.

7. *Trades, wheeling, wet/dry year exchanges, banking or other transactions in current year (Table 6)*

None.

8. *Other uses of water in current year*

None.

F. Outflow from the District (Agricultural only)

Districts included in the drainage problem area, as identified in "A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley (September 1990)," should also complete Water Inventory Table 7 and Appendix B (include in plan as Attachment L)

See Facilities Map, **Attachment A**, for the location of surface and subsurface outflow points, outflow measurement points, outflow water-quality testing locations

1. *Surface and subsurface drain/outflow in current year*

The District did not have any surface and/or subsurface drainage/outflow during 2009.

2. *Description of the Outflow (surface and subsurface) water quality testing program and the role of each participant in the program*

Not Applicable.

3. *Outflow (surface drainage & spill) Quality Testing Program*

Not Applicable.

Outflow (subsurface drainage) Quality Testing Program

Not Applicable.

4. *Provide a brief discussion of the District's involvement in Central Valley Regional Water Quality Control Board programs or requirements for remediating or monitoring any contaminants that would significantly degrade water quality in the receiving surface waters.*

Individual landowners are signator to the Kern Sub-watershed of the Southern San Joaquin Valley Water Quality Coalition. The District does not participate in the ILRP as it has no irrigated lands based discharges.

G. Water Accounting (Inventory)

1. *Water Supplies Quantified*

   a. *Surface water supplies, imported and originating within the service area, by month (Table 1)*

   See Section 5, Table 1.

   b. *Ground water extracted by the district, by month (Table 2)*

   See Section 5, Table 2.

   c. *Effective precipitation by crop (Table 5)*

   See Section 5, Table 5.

   d. *Estimated annual ground water extracted by non-district parties (Table 2)*

   See Section 5, Table 2.

   e. *Recycled urban wastewater, by month (Table 3)*

   See Section 5, Table 3.

   f. *Other supplies, by month (Table 1)*

   See Section 5, Table 1.

2. *Water Used Quantified*

   a. *Agricultural conveyance losses, including seepage, evaporation, and operational spills in canal systems (Table 4) or Urban leaks, breaks and flushing/fire uses in piped systems (Table 4)*

   See Section 5, Table 4.

   b. *Consumptive use by riparian vegetation or environmental use (Table 6)*

   See Section 5, Table 6.

   c. *Applied irrigation water - crop ET, water used for leaching/cultural practices (e.g., frost protection, soil reclamation, etc.) (Table 5)*

   See Section 5, Table 5.

   d. *Urban water use (Table 6)*

   See Section 5, Table 6.

   e. *Ground water recharge (Table 6)*

   See Section 5, Table 6.

   f. *Water exchanges and transfers and out-of-district banking (Table 6)*

   See Section 5, Table 6.

   g. *Estimated deep percolation within the service area (Table 6)*

   See Section 5, Table 6.

   h. *Flows to perched water table or saline sink (Table 7)*

   See Section 5, Table 7.

   i. *Outflow water leaving the district (Table 6)*

   See Section 5, Table 6.

   j. *Other* - None

3. Overall Water Inventory
a. Table 6

See Section 5, Table 6.

H. Assess Quantifiable Objectives:

Identify the Quantifiable Objectives that apply to the District (Planner, chapter 10) and provide a short narrative describing past, present and future plans that address the CALFED Water Use Efficiency Program goals identified for the District.

The District has been identified as having lands within its boundary that are subject to quantifiable objectives. The identified quantifiable objectives address increasing the water supply for beneficial uses by providing long-term diversion flexibility to benefit Pixley National Wildlife Refuge, to provide improved long-term diversion flexibility to increase the water supply for beneficial uses and to decrease flows to salt sinks to increase the water supply for beneficial uses.

The District currently has no plans in place that would make water available to the Pixley National Wildlife Refuge. The District does not have any habitat preservation or restoration sites which could be the candidate areas for conserved water supply diversions. District growers have improved on-farm irrigation systems to the extent that in excess of 55 percent of these systems are permanent, low volume systems. This has resulted in reduced losses to the soil mantle outside of the root zone. Resultant water savings have first been dedicated to improving crop yields with the periodic residual being the negotiating tool to allow the District to deal with reduced water supplies resulting from settlement of the San Joaquin River litigation.

Section 3: Best Management Practices (BMPs) for Agricultural Contractors

A. Critical Agricultural BMPs

1. *Measure the volume of water delivered by the district to each turnout with devices that are operated and maintained to a reasonable degree of accuracy, under most conditions, to +/- 6%*

Number of turnouts that are unmeasured or do not meet the standards listed above: 4

Number of measurement devices installed last year: 0

Number of measurement devices installed this year: 2

Number of measurement devices to be installed next year: 4

In order to comply with the current Guidelines, all farm deliveries must be provided with measurement capability meeting the established minimum accuracy requirements. For the referenced (4) deliveries to be installed next year, the District will design, construct and place into operation, new metered turnouts with appropriate rating capabilities and sized to meet the requirements of each delivery. The installations will be completed during Fall 2012 and reported in the subsequent annual report to this Plan. The budget estimate to complete all four (4) installations is $12,000.

Types of Measurement Devices Being Installed	*Accuracy*	*Total Installed During Current Year*
Propeller meter	±6%	2

2. *Designate a water conservation coordinator to develop and implement the Plan and develop progress reports*

Name: Bill Carlisle *Title:* Secretary/General Manager

Address: P.O. Box 279 or 11281 Garzoli Avenue, Delano, CA 93216

Telephone: (661) 725-0610 *E-mail:* gm@ssjmud.org

3. Provide or support the availability of water management services to water users

See **Attachment H**, Notices of District Education Programs and Services Available to Customers.

a. On-Farm Evaluations

1) On farm irrigation and drainage system evaluations using a mobile lab type assessment

	Total in district	*# surveyed last year*	*# surveyed in current year*	*# projected for next year*	*# projected 2nd yr in future*
Irrigated acres	44,627	80	240	2,232	2,232
Number of farms	225	2	3	12	12

The District is supplied with color brochures from the North West Kern Resource Conservation District, which are sent out to each landowner at the beginning of each water year. These brochures supply information as it pertains to these evaluations.

2) Timely field and crop-specific water delivery information to the water user

See **Attachment H**, Notices of District Education Programs and Services Available to Customers.

Each week, the Friant Water Authority issues a reproduction of crop coefficients to all of its contractors which are compiled by the Kings River Conservation District and made available by the District to its growers. The table lists the daily average for the previous seven (7) days and estimate of the average for the subsequent seven (7) days of crop coefficients. District water delivery information is provided to each water user, each month in which delivery to a water user is made. This information can then be used by a water user to manage water used by field and crop.

b. Real-time and normal irrigation scheduling and crop ET information

See **Attachment H**, Notices of District Education Programs and Services Available to Customers.

Each week, the Friant Water Authority issues a reproduction of crop coefficients and CIMIS evapotranspiration rates to all of its contractors which are compiled by the Kings River Conservation District and made available by the District to its growers. The crop coefficients table lists the daily, average for the previous seven (7) days and an estimate of the average for the subsequent seven (7) days, while the CIMIS evapotranspiration rates table lists data for twelve (12) CIMIS stations located within the Friant Division, CVP service area and details daily, total for the previous seven (7) days, normal previous seven (7) days, variance percentage from normal and normal next seven (7) days, evapotranspiration rates.

Most normal year information pertaining to irrigation scheduling and crop evapotranspiration (ET), such as CIMIS data and crop coefficients, is available to the landowner/grower through many agencies or services. The following are examples of services and information that are available to growers:

- The office of Water Use Efficiency (OWUE), through the Department of Water Resources (DWR) provides CIMIS data free of charge to the public for the use in estimating crop water use for irrigation scheduling. This information can be found through the OWUE's CIMIS website at www.cimis.water.ca.gov;
- During the growing season, crop ET information is published in the local newspapers and broadcast daily over the radio for reference and use by any water user;
- The U.S. Weather Service currently provides real-time CIMIS ET data and forecasts on their local weather channels and on the NOAA website.

The examples listed above provide crop specific ET data that is based on real-time. In an effort to assist District landowners in the understanding of crop coefficient and evapotranspiration rates, and how to develop water use for a specific crop, calculated examples will be published within the on-farm water conservation tools and strategies found in the Water Conservation Information Bulletins, as described in Section 3.3.d. of this report.

c. Surface, ground, and drainage water quantity and quality data provided to water users

The District, upon request, will provide surface water quality data, which is provided to the District by the Friant Water Authority, to District landowners/growers. The District, however, does not participate in in-district water quality testing. As per the District's Rules and Regulations for Water Service; "The District's water supply is in a raw, untreated condition, and as a result is considered to be unfit for human consumption without treatment. The District does not warrant the quality of water delivered and is under no obligation to construct or furnish water treatment facilities or maintain or better the quality of water."

d. Agricultural water management educational programs and materials for farmers, staff, and the public

Program	*Co-Funders (If Any)*	*Yearly Targets*
Water Conservation Information Bulletins	Keller/Wegley Consulting Engineers Client Group Provost & Pritchard Consulting Group	Quarterly Publications.Mailings
Friant Water Authority	Friant Division Contractors	Monthly Publications

See **Attachment H** for samples of provided materials and notices

The Water Conservation Information Bulletins will be provided to the District to inform both the District and its growers of on-farm water conservation tools and strategies. This educational program is being sponsored by both Keller/Wegley Consulting Engineers and Provost & Pritchard Consulting Group. The program is scheduled to release its first publication in late Spring/early Summer 2012.

e. other

None

4. Pricing structure - based at least in part on quantity delivered
Describe the quantity-based water pricing structure, the cost per acre-foot, and when it became effective.

The District's pricing structure is that of three (3) forms, all which are values set on an annual basis. Fixed charges are based on a per acre basis and applied to all eligible lands at a value of $44.70. Volumetric charges are based on a per acre-foot basis and can be adjusted as water supply allocations from Reclamation change. The cost per acre-foot for 2009 was $49.93. The Friant-Kern Canal bifurcates the District. The lands that are supplied surface water via the District's gravity system are west of the Friant-Kern Canal. All lands located east of the Friant-Kern Canal are supplied surface water through a pressurized system. Water delivered through this system is charged the third form of pricing, known as lift charges. Lift charges are based on a per lift basis at a cost of $11.00.

5. Evaluate and describe the need for changes in policies of the institutions to which the district is subject.

The District is currently looking into water quality issues and policies as they relate to pump-back and pump-in capability involving the Friant-Kern Canal.

6. Evaluate and improve efficiencies of district pumps
Describe the program to evaluate and improve the efficiencies of the contractor's pumps.

As stated previously, the District does not own or operate any groundwater pumping facilities. The District does operate distribution system lift stations and includes those facilities in the District preventative maintenance program including efficiency performance tests.

B. Exemptible BMPs for Agricultural Contractors

(See Planner, Chapter 2, Appendix C for examples of exemptible conditions)

1. Facilitate alternative land use

Drainage Characteristic	*Acreage*	*Potential Alternate Uses*
High water table (<5 feet)	0	Not Applicable[1]
Poor drainage	0	Not Applicable[1]
Ground water Selenium concentration > 50 ppb	0	Not Applicable[1]
Poor productivity	0	Not Applicable[1]

[1]Not applicable as all lands are put to beneficial use.

Describe how the contractor encourages customers to participate in these programs.

2. Facilitate use of available recycled urban wastewater that otherwise would not be used beneficially, meets all health and safety criteria, and does not cause harm to crops or soils

Sources of Recycled Urban Waste Water	*AF/Y Available*	*AF/Y Currently Used in District*
No non-recycled sources of urban wastewater exist within the District	N/A	N/A

3. Facilitate the financing of capital improvements for on-farm irrigation systems

The District maintains a listing of potential funding sources and has an established policy to provide assistance in completing funding application documents. The District is a member of the Farm Service Agency (FSA), formerly known as the Agricultural Stabilization and Conservation Service, which is part of the United States Department of Agriculture. The FSA administers programs concerning on farm conservation and grants loans to farms, through a 50 percent cost-share program for conservation related improvements. The District also financially participates in on-farm efficiency evaluations.

4. Incentive pricing

Structure of incentive pricing	*Related goal*
Off-Peak water usage	Energy Savings
Discounted weekend water rates (program has been discontinued due to no noticeable change in delivery pattern).	Water Availability/Energy Savings were the program goals

5. a) Line or pipe ditches and canals

Not applicable. The District's distribution system is a closed pipeline system.

b) Construct regulatory reservoirs

Regulatory reservoirs required for proper system operation have previously been constructed. No additional facilities are currently required for efficient operation. Funds are budgeted to maintain existing reservoir facilities.

6. Increase flexibility in water ordering by, and delivery to, water users

The District has, over the past few years, been replacing several miles of its distribution system, which was clay mortar joint pipe, which severely leaked, causing a loss in potential delivered supply to the growers. By replacing the old clay mortar joint pipe with new, more efficient and modern pipe, the District has been able to increase its percentage of supply delivered to approximately 98 percent.

The District's water tracking software, which performs a day-by-day comparison of what is ordered versus the recorded delivered volume through each individual meter, allows the District to manage, at high accuracy, the amount of water delivered at each turnout. This level of tracking allows the District to maximize flexibility in water ordering and water accounting based on available system characteristics.

The District does not have a 'water order form.' Water orders are currently submitted to the District by landowners on their own template, via fax, email or in-person at the District office.

7. Construct and operate district spill and tailwater recovery systems

None. There are no District spills.

8. Plan to measure outflow.

This is not applicable to the District, due to the District not having any outflow other than a shallow leaching fraction from applied water.

Total # of outflow (surface) locations/points 0
Total # of outflow (subsurface) locations/points 0
Total # of measured outflow points 0
Percentage of total outflow (volume) measured during report year Not Applicable

Identify locations, prioritize, determine best measurement method/cost, submit funding proposal

Location & Priority	*Estimated cost (in $1,000s)*				
	2009	*2010*	*2011*	*2012*	*2013*
Not Applicable					

9. Optimize conjunctive use of surface and ground water

Historically, the District has primarily achieved its groundwater recharge goals through an in-lieu surface water delivery program. When surface water supplies are available and can be delivered to the District, the surface water supplies are utilized "in lieu" of groundwater pumping. The District will continue this program whenever surface supplies are available and will augment deliveries whenever supplemental supplies can be purchased at a reasonable cost

and ordered for delivery by growers. The District continues to evaluate available and developing banking programs.

10. Automate canal structures

The District utilizes a closed piped system. Automation of structures is currently limited to the District delivery points from the Friant-Kern Canal, which are automated and controlled by the Friant Water Authority. The District has taken the first steps toward total system automation by replacing all main gate control devices and constructing low volume bypass piping and valves at each large diameter system control location. A trial SCADA element is currently in-place, the success or failure of which will be published during this Plan's annual updates.

11. Facilitate or promote water customer pump testing and evaluation

See **Attachment H**, Notices of District Education Programs and Services Available to Customers.

The District has and will continue to provide information to the growers relative to the availability of pump testing and efficiency services provided by the serving utility or local pump companies. The involvement of the District with private pump efficiencies is related to water conservation and overall resource management. The fact that a farmer may apply a given amount of water to a field with a pump which is operating at a less than optimum efficiency does affect the application time and the total quantity of water which is being demanded by the crop. In May, 2012, the District has plans to initially distribute and continuously make available a memorandum informing landowners of the Center for Irrigation Technology's Agricultural Pumping Efficiency Program and a listing of local participating pump test companies.

12. Mapping

GIS maps	*Estimated cost (in $1,000s)*				
	2009	*2010*	*2011*	*2012*	*2013*
Layer 1 – Distribution system	0	0	0	0	0
Layer 2 – Drainage system	N/A	N/A	N/A	N/A	N/A
Suggested layers:					
Layer 3 – Ground water information	0	0	0	0	0
Layer 4 – Soils map	0	0	1	0	0
Layer 5 – Natural & cultural resources	N/A	N/A	N/A	N/A	N/A
Layer 6 – Problem areas	N/A	N/A	N/A	N/A	N/A

C. Provide a 3-Year Budget for Implementing BMPs

1. Amount actually spent during current year.

BMP #		*BMP Name*	*Actual Expenditure (not including staff time)*	*Staff Hours*
A	*1*	*Measurement*	*$0*	*0*
	2	*Conservation staff*	*0*	*0*
	3	*On-farm evaluation /water delivery info*	*3,000*	*0*
		Irrigation Scheduling	*0*	*0*
		Water quality	*0*	*0*
		Agricultural Education Program	*0*	*0*
	4	*Quantity pricing*	*0*	*0*
	5	*Policy changes*	*0*	*0*
	6	*Contractor's pumps*	*0*	*0*
B	*1*	*Alternative land use*	*$0*	*0*
	2	*Urban recycled water use*	*0*	*0*
	3	*Financing of on-farm improvements*	*0*	*0*
	4	*Incentive pricing*	*0*	*0*
	5	*Line or pipe canals/install reservoirs*	*0*	*0*
	6	*Increase delivery flexibility*	*0*	*0*
	7	*District spill/tailwater recovery systems*	*0*	*0*
	8	*Measure outflow*	*0*	*0*
	9	*Optimize conjunctive use*	*0*	*0*
	10	*Automate canal structures*	*0*	*0*
	11	*Customer pump testing*	*0*	*0*
	12	*Mapping*	*0*	*0*
		Total	*$3,000*	*0*

2. Projected budget summary for the next year.

BMP #		BMP Name	Budgeted Expenditure (not including staff time)	Staff Hours
A	*1*	*Measurement*	*$0*	*0*
	2	*Conservation staff*	*0*	*0*
	3	*On-farm evaluations/water delivery info*	*3,000*	*0*
		Irrigation Scheduling	*0*	*0*
		Water quality	*0*	*0*
		Agricultural Education Program	*0*	*0*
	4	*Quantity pricing*	*0*	*0*
	5	*Policy changes*	*0*	*0*
	6	*Contractor's pumps*	*1,000*	*8*
B	*1*	*Alternative land use*	*$0*	*0*
	2	*Urban recycled water use*	*0*	*0*
	3	*Financing of on-farm improvements*	*7,000*	*4*
	4	*Incentive pricing*	*0*	*0*
	5	*Line or pipe canals/install reservoirs*	*0*	*0*
	6	*Increase delivery flexibility*	*0*	*0*
	7	*District spill/tailwater recovery systems*	*0*	*0*
	8	*Measure outflow*	*1,000*	*8*
	9	*Optimize conjunctive use*	*2,500*	*16*
	10	*Automate canal structures*	*2,000*	*50*
	11	*Customer pump testing*	*0*	*8*
	12	*Mapping*	*1,000*	*8*
		Total	*$17,500*	*102*

3. Projected budget summary for 3rd year.

BMP #		BMP Name	Budgeted Expenditure (not including staff time)	Staff Hours
A	*1*	*Measurement*	*$0*	*0*
	2	*Conservation staff*	*0*	*0*
	3	*On-farm evaluations/water delivery info*	*3,000*	*0*
		Irrigation Scheduling	*0*	*0*
		Water quality	*0*	*0*
		Agricultural Education Program	*0*	*0*
	4	*Quantity pricing*	*0*	*0*
	5	*Policy changes*	*0*	*0*
	6	*Contractor's pumps*	*1,000*	*8*

(continued)

BMP #		BMP Name	Budgeted Expenditure (not including staff time)	Staff Hours
B	*1*	*Alternative land use*	*$0*	*0*
	2	*Urban recycled water use*	*0*	*0*
	3	*Financing of on-farm improvements*	*7,000*	*4*
	4	*Incentive pricing*	*0*	*0*
	5	*Line or pipe canals/install reservoirs*	*0*	*0*
	6	*Increase delivery flexibility*	*0*	*0*
	7	*District spill/tailwater recovery systems*	*0*	*0*
	8	*Measure outflow*	*1,000*	*8*
	9	*Optimize conjunctive use*	*2,500*	*16*
	10	*Automate canal structures*	*30,000*	*16*
	11	*Customer pump testing*	*0*	*8*
	12	*Mapping*	*2,500*	*8*
		Total	*$47,000*	*68*

Section 4: Best Management Practices for Urban Contractors

(Due to the adoption of revised BMPs in December 2008, this section will be updated in Spring 2009.)

Not Applicable

A. Urban BMPs

1. *Utilities Operations*
   - *1.1 Operations Practices*
   - *1.2 Pricing*
   - *1.3 Metering*
   - *1.4 Water Loss Control*

2. *Education*
   - *2.1 Public Information Programs*
   - *2.2 School Education*
3. *Residential*

4. *CII*
5. *Landscape*

B. Provide a 3-Year Budget for Expenditures and Staff Effort for BMPs

1. Amount actually spent during current year.

Year 2010		*Projected Expenditures*	
BMP #	*BMP Name*	*(not including staff hours)*	*Staff Hours*
1. Utilities Operations			
	1.1 Operations Practices	*$0*	*0*
	1.2 Pricing	*0*	*0*
	1.3 Metering	*0*	*0*
	1.4 Water Loss Control	*0*	*0*
2. Education			
	2.1 Public Information Programs	*$0*	*0*
	2.2 School Education	*0*	*0*
3. Residential		*0*	*0*
4. CII		*0*	*0*
5. Landscape		*0*	*0*
	Total	*$0*	*0*

2. Projected budget summary for 2nd year.

Year 2011		*Projected Expenditures*	
BMP #	*BMP Name*	*(not including staff hours)*	*Staff Hours*
1. Utilities Operations			
	1.1 Operations Practices	*$0*	*0*
	1.2 Pricing	*0*	*0*
	1.3 Metering	*0*	*0*
	1.4 Water Loss Control	*0*	*0*
2. Education			
	2.1 Public Information Programs	*$0*	*0*
	2.2 School Education	*0*	*0*
3. Residential		*0*	*0*
4. CII		*0*	*0*
5. Landscape		*0*	*0*
	Total	*$0*	*0*

3. Projected budget summary for 3rd year.

Year 2012		*Projected Expenditures*	
BMP #	*BMP Name*	*(not including staff hours)*	*Staff Hours*
1. Utilities Operations			
	1.1 Operations Practices	*$0*	*0*
	1.2 Pricing	*0*	*0*
	1.3 Metering	*0*	*0*
	1.4 Water Loss Control	*0*	*0*
2. Education			
	2.1 Public Information Programs	*$0*	*0*
	2.2 School Education	*0*	*0*
3. Residential		*0*	*0*
4. CII		*0*	*0*
5. Landscape		*0*	*0*
	Total	*$0*	*0*

Section 5: District Water Inventory Tables

Table 1

Surface Water Supply

2009 Month	Federal Ag Water (acre-feet)	Federal non-Ag Water. (acre-feet)	State Water (acre-feet)	Local Water (acre-feet)	Other Water (Non-Proj) (acre-feet)	Upslope Drain Water (acre-feet)	Total (acre-feet)
Method							
January	1664	0	0	0	0	0	1,664
February	5659	0	0	0	0	0	5,659
March	2613	0	0	0	0	0	2,613
April	7006	0	0	0	0	0	7,006
May	17165	0	0	0	0	0	17,165
June	19853	0	0	0	0	0	19,853
July	23566	0	0	0	0	0	23,566
August	18227	0	0	0	0	0	18,227
September	12234	0	0	0	0	0	12,234
October	8511	0	0	0	0	0	8,511
November	4094	0	0	0	0	0	4,094
December	667	0	0	0	0	0	667
TOTAL	121,259	0	0	0	0	0	121,259

Table 2

Ground Water Supply

2009 Month	District Groundwater (acre-feet)	Private Groundwater *(acre-feet)
Method		
January	0	0
February	0	0
March	0	1,507
April	0	0
May	0	5,255
June	0	8,946
July	0	13,965
August	0	4,809
September	0	0
October	0	0
November	0	0
December	0	0
TOTAL	0	34,482

*normally estimated

Table 3

Total Water Supply

2009 Month	Surface Water Total (acre-feet)	District Groundwater (acre-feet)	Recycled M&I (acre-feet)	Total District Water (acre-feet)
Method				
January	1,664	0	0	1,664
February	5,659	0	0	5,659
March	2,613	0	0	2,613
April	7,006	0	0	7,006
May	17,165	0	0	17,165
June	19,853	0	0	19,853
July	23,566	0	0	23,566
August	18,227	0	0	18,227
September	12,234	0	0	12,234
October	8,511	0	0	8,511
November	4,094	0	0	4,094
December	667	0	0	667
TOTAL	121,259	0	0	121,259

*Recycled M&I Wastewater is treated urban wastewater that is used for agriculture.

Table 4

Distribution System

2009 Canal, Pipeline, Lateral, Reservoir	Length (feet)	Width (feet)	Surface Area (square feet)	Precipitation (acre-feet)	Evaporation (acre-feet)	Spillage (acre-feet)	Seepage (acre-feet)	Total (acre-feet)
Lateral 1	33,500	0	0	0	0	0	0	0
Lateral 2	43,800	0	0	0	0	0	0	0
Lateral 3	40,900	0	0	0	0	0	0	0
Lateral 4	37,000	0	0	0	0	0	0	0
Lateral 5	25,300	0	0	0	0	0	0	0
Lateral 6	19,300	0	0	0	0	0	0	0
Lateral 7	19,500	0	0	0	0	0	0	0
Lateral 8	31,700	0	0	0	0	0	0	0
Lateral 9	23,800	0	0	0	0	0	0	0
Sub-Laterals	783,150	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
TOTAL			0	0	0	0	0	0

Note: Seepage from the distribution system is acknowledged to occur. The seepage, however, is the source for the groundwater which is pumped by landowners to replace the supply lost to seepage.

Table 5

Crop Water Needs

2009 Crop Name	Area (crop acres)	Crop ET (AF/Ac)	Leaching Requireme (AF/Ac)	Cultural Practices (AF/Ac)	Effective Precipitation (AF/Ac)	Appl. Crop Water Use (acre-feet)
Alfalfa	2,796	3.50	0.022	-	0.20	9,288
Almonds	13,170	2.60	0.022	-	0.15	32,556
Apples	122	3.20	0.023	-	0.20	369
Beans	45	3.00	0.018	-	0.20	127
Berries, except Straw	61	3.00	0.018	-	0.20	172
Blackeyes	116	3.00	0.018	-	0.20	327
Cherries	339	3.20	0.023	-	0.20	1,025
Corn	39	2.00	0.016	-	-	79
Grapefruit	20	2.60	0.012	0.25	0.35	50
Grapes	2,740	2.30	0.020	-	0.10	6,083
Hay - Other	1,243	3.70	0.022	-	0.20	4,378
Kiwi	89	2.30	0.020	-	0.10	198
Lemons and Limes	10	2.60	0.012	0.25	0.35	25
Milo	78	1.50	0.002	-	0.25	98
Multiple	272	3.00	0.018	-	0.20	766
Naval Oranges	4,250	2.60	0.012	0.25	0.35	10,676
Oats	105	1.50	0.002	-	0.25	131
Pasture	89	3.70	0.008	-	0.15	317
Pecans	394	2.60	0.022	-	0.20	954
Persimmons	15	3.20	0.023	-	0.20	45
Pistachios	4,130	2.60	0.022	-	0.20	10,003
Raisin Grapes	463	2.30	0.020	-	0.10	1,028
Roses	391	1.50	0.012	-	0.10	552
Silage	951	2.00	0.016	-	-	1,917
Table, Grapes	10,992	2.30	0.020	-	0.10	24,402
Valencia Oranges	420	2.60	0.012	0.25	0.35	1,055
Vegetables, other	109	3.00	0.018	-	0.20	307
Walnuts	688	2.60	0.022	-	0.20	1,666
Watermelon	9	3.00	0.018	-	0.20	25
Wheat	194	1.50	0.002	-	0.25	243
Wine Grapes	287	2.30	0.020	-	0.10	637
Fallow	1,138	-	-	-	-	0
Crop Acres	45,765					109,500

Total Irrig. Acres 44,627 (If this number is larger than your known total, it may be due to double cropping)

Table 6

2009 District Water Inventory

Water Supply	Table 3		121,259
Riparian ET	(Distribution and Drain)	minus	0
Groundwater recharge	(intentional - ponds, injection)	minus	0
Seepage	Table 4	minus	0
Evaporation - Precipitation	Table 4	minus	0
Spillage	Table 4	minus	0
Transfers/exchanges/trades/wheeling	(into or out of the district)	plus/minus	0
Non-Agri deliveries	(delivered to non-ag customers)	minus	0
Water Available for sale to agricultural customers			121,259
Compare the above line with the next line to help find data gaps			
2005 Actual Agricultural Water Sales	From District Sales Records		121,259
Private Groundwater	Table 2	plus	34,482
Crop Water Needs	Table 5	minus	109,500
Drainwater outflow	(tail and tile not recycled)	minus	0
Percolation from Agricultural Land	(calculated)		46,241

Note: Actual Agricultural Water Sales are for 2009. That portion of the USBR table is unable to be modified.

Table 7

Influence on Groundwater and Saline Sink

2009

Agric Land Deep Perc + Seepage + Recharge - Groundwater Pumping = District Influence on	0
Estimated actual change in ground water storage, including natural recharge)	0
Irrigated Acres (from Table 5)	45,765
Irrigated acres over a perched water table	0
Irrigated acres draining to a saline sink	0
Portion of percolation from agri seeping to a perched water table	0
Portion of percolation from agri seeping to a saline sink	0
Portion of On-Farm Drain water flowing to a perched water table/saline sink	0
Portion of Dist. Sys. seep/leaks/spills to perched water table/saline sink	0
Total (AF) flowing to a perched water table and saline sink	0

Table 8

Annual Water Quantities Delivered Under Each Right or Contract

Year	Federal Ag Water (acre-feet)	Federal non-Ag Water. (acre-feet)	State Water (acre-feet)	Local Water (acre-feet)	Other Water (Non-Proj) (acre-feet)	Upslope Drain Water (acre-feet)	Total (acre-feet)
2000	121,461	0	0	0	700	0	122,161
2001	95,669	0	0	0	857	0	96,526
2002	105,889	0	0	0	300	0	106,189
2003	106,157	0	0	0	1,500	0	107,657
2004	100,328	0	0	0	850	0	101,178
2005	114,754	0	0	0	850	0	115,604
2006	118,151	0	0	0	0	0	118,151
2007	71,431	0	0	0	0	0	71,431
2008	92,458	0	0	0	0	0	92,458
2009	121,259	0	0	0	0	0	121,259
Total	1,047,557	0	0	0	5,057	0	1,052,614
Average	104,756	0	0	0	506	0	105,261

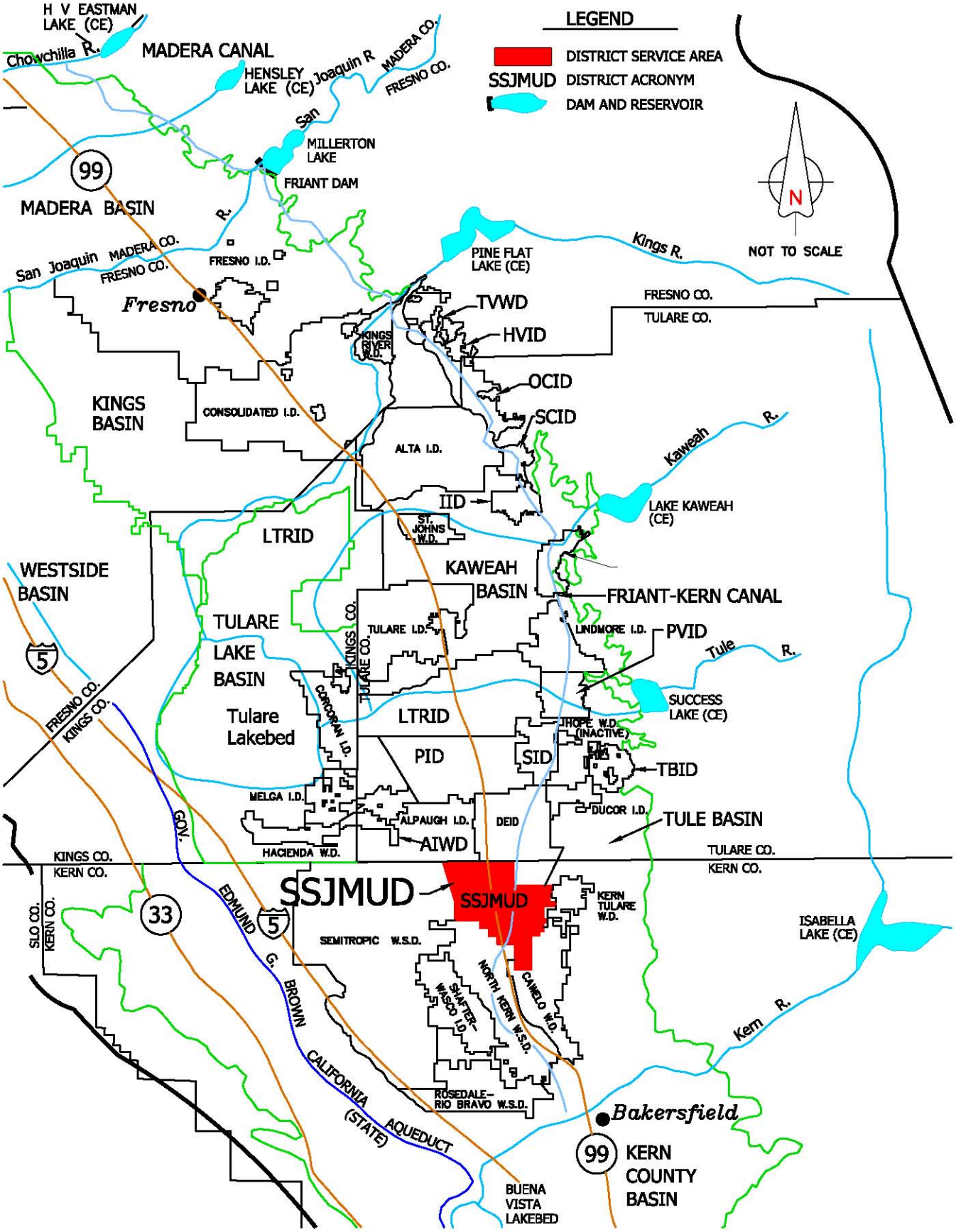
PLATES

FIVE YEAR UPDATE

WATER MANAGEMENT PLAN

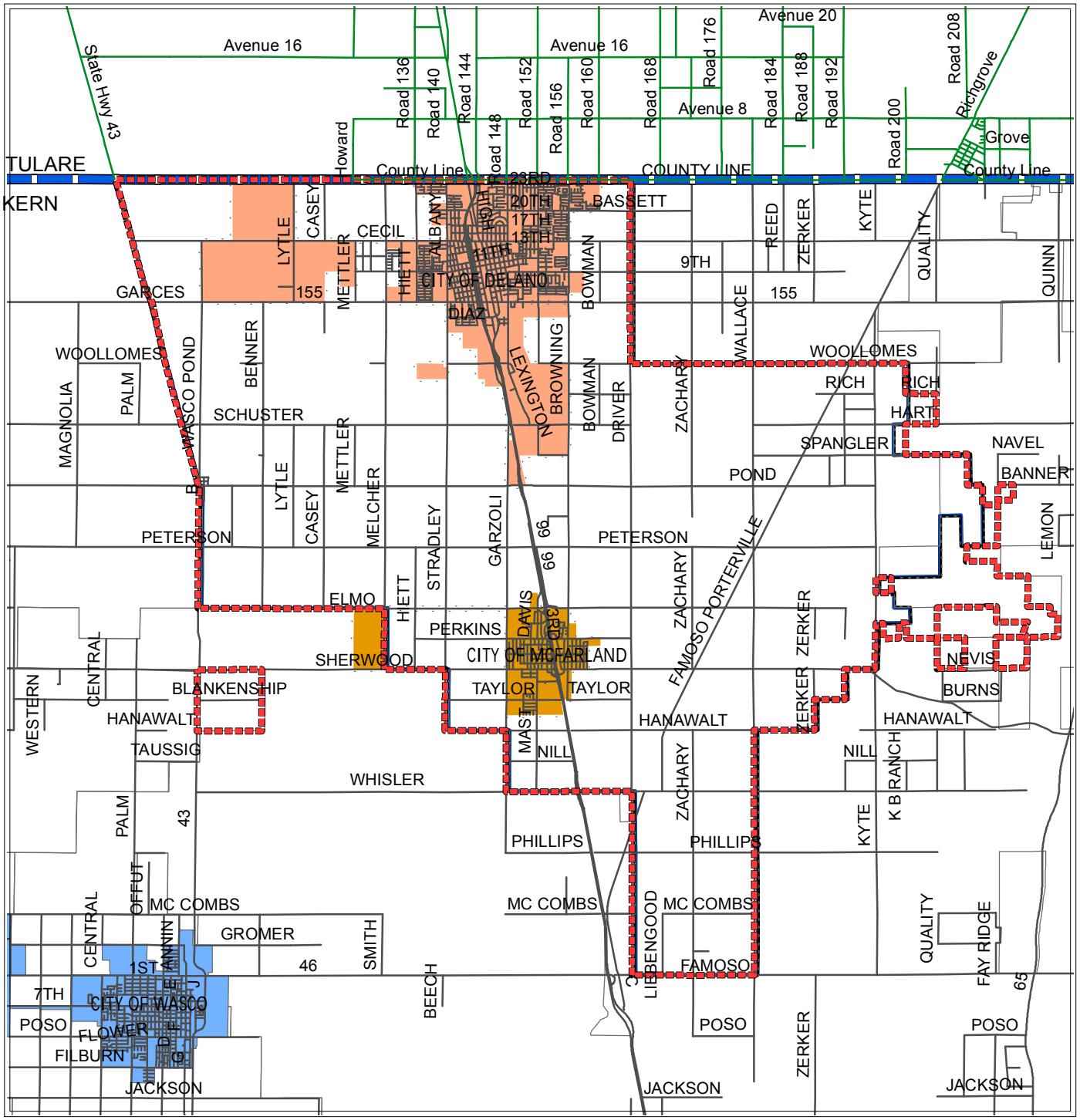
SOUTHERN SAN JOAQUIN

MUNICIPAL UTILITY DISTRICT



LOCATION MAP
AGRICULTURAL WATER MANAGEMENT PLAN
SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

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ATTACHMENT A

DISTRICT FACILITIES MAP

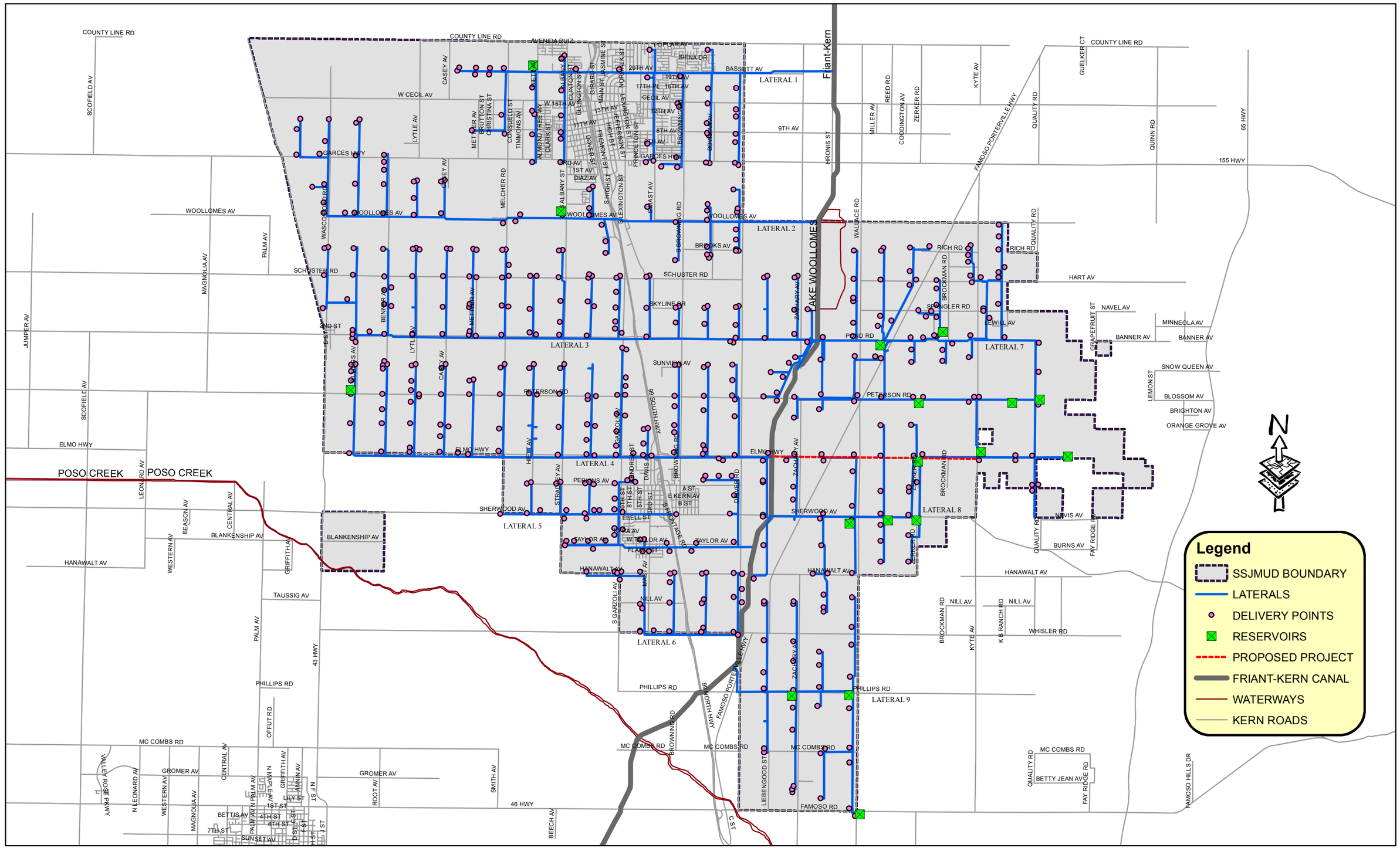
FIVE YEAR UPDATE

WATER MANAGEMENT PLAN

SOUTHERN SAN JOAQUIN

MUNICIPAL UTILITY DISTRICT

ATTACHMENT A



DISTRIBUTION SYSTEM
SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

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KELLER/WEGLEY

ATTACHMENT B

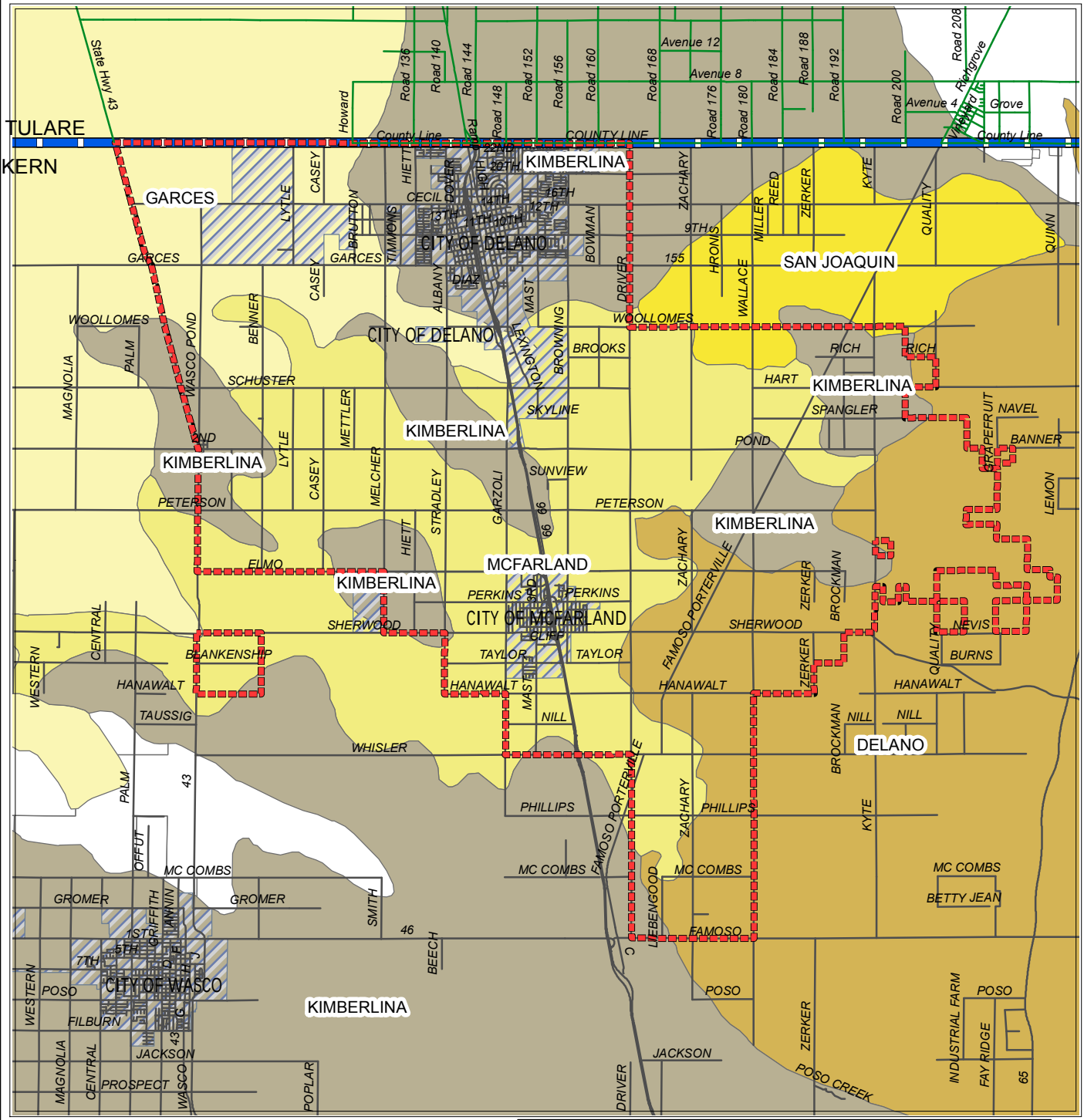
DISTRICT SOILS MAP

FIVE YEAR UPDATE

WATER MANAGEMENT PLAN

SOUTHERN SAN JOAQUIN

MUNICIPAL UTILITY DISTRICT



Legend

- streets
- SSJMUD Boundary 2011
- County_Kern

CityLimits_update

- <all other values>

Munici_ID

- CITY OF DELANO
- CITY OF MCFARLAND
- CITY OF WASCO

NOTE:
SOIL CLASSIFICATIONS, SUCH AS KIMBERLINA, DERIVED FROM KERN COUNTY GIS SHAPEFILE, casoila_kern_intersect.shp

0 0.5 1 2 3 4 Miles

N

SOIL CLASSIFICATIONS

WATER MANAGEMENT PLAN - UPDATE 2011

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

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ATTACHMENT C

DISTRICT RULES AND REGULATIONS

FIVE YEAR UPDATE

WATER MANAGEMENT PLAN

SOUTHERN SAN JOAQUIN

MUNICIPAL UTILITY DISTRICT

SSJMUD

Southern San Joaquin Municipal Utility District

RULES AND REGULATIONS

FOR WATER SERVICE

Effective March 1, 2002

Board of Directors

John N. Fisher, President
Peter Dulcich, Vice President
George Zaninovich
Donnie Morris
James Regan

William R. Carlisle, General Manager/Secretary
Phylliss Sims, Office Manager/Treasurer
Roland Gross, Field Superintendent
Larry Green, Dispatcher/Asst. Water Master

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RULES AND REGULATIONS
FOR WATER SERVICE
SOUTHERN SAN JOAQUIN
MUNICIPAL UTILITY DISTRICT

Adopted January 11, 1989, Revised September 13, 1989, February 13, 1991, February 10, 1993, January 12, 1994, March 1, 1994; Effective March 1, 2002.

A. GENERAL

(1) Authority:

Article 4, Section 11885 of the Municipal Utility District Act states as follows:

The Board shall supervise and regulate every utility owned and operated by the District including the fixing of rates, rentals, charges, and classification, and the making of rules, regulations, contracts, practices, and schedules for or in connection with any service product or commodity owned or controlled by the District.

(2) Applicable Contracts with United States of America:

The District receives its surface water supply by Contract I1r-1460-LTR1, with the United States from the Central Valley Project and delivers its supply through a pipeline distribution system constructed by the United States under Contracts 175r-1434 and Supplementary Contract 14-06-200-6660.

(3) Definitions:

The following definitions shall be applicable to these Rules and Regulations:

Board: The Board of Directors of the Southern San Joaquin Municipal Utility District.

Bureau: Bureau of Reclamation of the United States Department of Interior.

District: Southern San Joaquin Municipal Utility District

Schedule A Lands: Those lands within the District's boundaries, as of March 1, 2001 which are presently connected to the District's distribution system and which either (a) have received a surface water supply from the District during the five (5) years immediately preceding March 1, 2001, or (b) which were designated excess land according to Federal Reclamation Law in effect prior to October 12, 1982, but which have become eligible prior to March 1, 2002.

Schedule B Lands: Those lands within the District's boundaries as of March 1, 2001, or as subsequently annexed to the District, not defined as Schedule A lands.

Water User: The individual or entity who either owns, leases or in a wholesale capacity distributes water to property within the District and makes application with the District for water service, and is responsible for ordering, controlling, using and paying for water received from the District.

Water Year or Year: March 1 through the last day of February.

B. DELIVERY OF WATER

1) District Water Supply – General: The District sells water as a commodity only and not as a guaranteed service and will not be liable for defective quality of water, shortage of water, either temporary or permanent, or for failure to deliver water or delay in doing so. The District assumes no liability for damages to persons or property occasioned through defective works.

The District's water supply is in a raw, untreated condition, and as a result is considered to be unfit for human consumption without treatment. The District does not warrant the quality of water delivered and is under no obligation to construct or furnish water treatment facilities or maintain or better the quality of water.

(2) Applications: Each year prior to February 15, Water Users shall file on a form provided by the District, an "Application for Water" for the forthcoming Water Year. Said application shall contain the following:

(a) Name and address of the Water User.

(b) Telephone number of the Water User and telephone number of the local individual who manages or irrigates the farm or distributes water.

(c) Farm or operation delivery numbers, with legal descriptions, Assessor's parcel numbers, assessed acreage, ownership and Schedule A or B land designation, crop, type of irrigation method and requested quantity of water, for each delivery.

(d) If the Water Application is for leased land, the Landowner must also sign the Water Application along with the Lessee.

Unless previously paid, the Water Application shall be accompanied with a deposit of 18.00 per irrigable acre. However, if in the judgement of the General Manager, the applicant for water is a poor risk, an additional sum may be required to guarantee payment of water bills. The deposit does not represent any particular quantity of water and will be returned when the Landholder ceases to operate the lands served by the outlet. Existing deposits held by the District are considered grandfathered until the land is either sold or assessed per D(2)(a). All deposits paid after March 1, 2002 shall be made in the amount of $18.00 per irrigable acre.

The water year begins on March 1. Applications received after the above deadline may result in a delay of water service while the application is reviewed. In any case, water deliveries will be delayed a minimum of 48 hours after the forms are received.

(3) Bureau Forms: The Water Application must also be accompanied by the proper Bureau Certification or Verification forms for the forthcoming Water Year (unless previously submitted). Such forms must be completed by the Landowner, and where the property is leased, by the lessee. No water will be delivered until the forms, properly completed, are in the District office. Forms may be obtained in the District office.

District staff will review the forms for completeness but are not responsible for errors not found. The District is not responsible for deliveries made to landholders filing forms with incorrect information or if no forms have been filed. The landholder is responsible for filing timely and correct forms.

(4) Land Sales: If, during a year in which water is allocated, a parcel of land is sold, the remaining water, if any, allocated to that land will be assigned to the new owners. However, if the seller has used all of the water allocated to the land, the new owner will not have a water allocation until the next Water Year.

Upon sale of the land, change in a lease or other operating arrangement, both parties must notify the District within 15 days (verbally or by letter) and file new Certification forms within 30 days. However, no water will be delivered to newly acquired land until the proper forms are filed with the District. Landholders not notifying the District of a change in status will be responsible for any charges incurred until such notification is given.

If the proper forms are not filed within 30 days, any water that may have been delivered may be charged at "Full Cost" from the date of the change of status until the forms are filed.

(5) Excess Supplies/Pools: A Water User who retains his allocation with the intent to use in the current Water Year will pay for such water. A Water User who releases his remaining allocation prior to August 15 will not be charged for the water. Water released on or after said deadline, will be charged to the landholder except for the water which can be disposed of by the District.

Prior to February 15 each year, Water Users must apply on the Application for Water form provided by the District for water allocated to the District by the United States Bureau of Reclamation. In the event

requests exceeds allocation, Water Users requests shall be pro-rated to each eligible acre of land within the District proportionally based on the total eligible acreage within the District.

Unused requested and/or pro-rated water will be billed after the last day of February of the same Bureau water year. Unused water will be billed and not eligible to be carried over. Water may be transferred from one parcel to another parcel provided the parcels are owned or leased by the same person(s) or company. No landholder or Water User can transfer or exchange water outside the District service area.

Prior to but not later than August 15 each year, Water Users having reserved water greater than they can use on eligible land owned or leased by them will be allowed to assign their excess water to a common pool. Pool water will be made available on a first come, first served basis to other Water Users for use on eligible lands in the District. Either Board policy or the General Manager, depending on existing circumstances, will determine the disposition of water remaining in the common pool at the end of the irrigation season.

(6) M & I Deliveries: No Water User is eligible to be delivered water for municipal or industrial uses, as defined in the District's contract with the Bureau, until it has complied with the District's M&I water policy and procedures.

(7) Excess Lands: Water received through District delivery outlets shall not be used to irrigate or provide water to excess lands as determined by the Bureau. Violators are subject to a cut off of water delivery until the situation is rectified and may be assessed the full-cost rate, plus interest, for any such water delivered.

(8) Place of Use: Water received under the District contracts with the United States shall not be used to irrigate or provide water to lands outside of District boundaries, except in certain circumstances as determined by the Bureau and the Board. Violators are subject to cut off of water delivery and other penalties which may be prescribed by law.

(9) Turn Ons and Turn Offs: All adjustments and turning on and off of water deliveries, gates and pumps are performed by District personnel. Unauthorized individuals tampering with District facilities are subject to a Misdemeanor charge as prescribed by the California Penal Code.

Water delivery changes are made six (6) days a week with no changes on Sundays. Water Users desiring water shall place their water orders a minimum of 24-hours in advance. For example, to have water turned on or off on Tuesday morning, the water order must be placed with the District Dispatcher (phone 725-0610) by 9:00 A.M. Monday morning. Water orders can also be faxed to 725-2110 or emailed. Water orders are taken between the hours of 7:00 A.M. to 3:30 P.M. Monday through Friday and 7:00 A.M. to 9:00 A.M. on Saturday. No orders are taken on Sunday and orders for Monday changes must be in by 9:00 A.M. Saturday. All orders are compiled by the Dispatcher in order to place the District water order for the next day deliveries. Water orders should not be called into the Ditchrider's homes as those orders may not be accepted by the Dispatcher the following morning.

The District has an employee designated for standby to handle emergencies during off-duty hours. During holidays and off-duty hours, Water Users must call 725-0610 and choose option 5 to report an emergency. Please do not use this emergency service for a non-emergency use. An emergency is a broken pot, ruptured pipeline or similar failure, not an error in scheduling water. Excessive use of emergency service may result in a service charge of up to $50.00 per call.

(10) Access: To operate the system, it is necessary to have access to valves, meters, etc. No delivery of water will be made to a Water User who blocks access to his delivery or provides an unsafe condition for District personnel.

(11) Runoff Prohibited: In addition to the reasons stated above, the District reserves the right to turn off Water deliveries in those instances of a Water User not taking care of his water and flooding roads or neighboring lands. Prior to turning off such a delivery an attempt will be made to reach by phone the responsible party causing the flooding.

(12) Carryover/Preuse: To the extent permitted by the Bureau in administering the water supply contract between the District and Bureau, the District may carryover water allocated or acquired from the prior Water Year or to preuse water to be allocated the next Water Year, as the case may be, but carryover or preuse will not be permitted for individual water users.

(13) Responsibility After Delivery: The District assumes no responsibility for water after it passes through its meter and into a Water User's pipeline or ditch. As a condition for water service, Water User shall indemnify and shall assume the defense of and hold harmless the District and its officers, agents and employees for any and all loss, damage, liability, claims or cause of action of every nature whatsoever, for damage to or destruction of property, including the District's property or for injury to or death of persons, in any manner arising out of or incidental to the control, carriage, handling, use, disposal or distribution of water once it has passed the District's meter.

(14) Subdivided Parcels – Additional Turnouts: Water Services shall only be provided to a single parcel through a turnout designated to serve that parcel only, the water user of which is eligible to receive water upon such lands. After April 13, 1994, the District shall not provide water service to any parcel which does not have a turnout designated to serve that single parcel, unless, and only so long as, the Manager determines that multiple parcels served by a single turnout are under common ownership and/or control. Accordingly, for any land after such date which is further sub-divided, the owners of such land must make arrangements at their sole cost and expense for the District to install additional turnout(s), such that each sub-divided parcel has its own turnout, together with any necessary easements across other landowner's land so that water service can be provided for from a turnout located within the District's existing right-of-way. Notwithstanding the foregoing, the General Manager may, at District expense, provide for the District installing additional turnouts such that multiple parcels being served by a single turnout prior to April 13, 1994, are thereafter served by separate turnouts.

C. ALLOCATION OF WATER

(1) General: Any Water User of lands within the District designated nonexcess (or otherwise made eligible to receive water) who has otherwise complied with these Rules and Regulations and policies of the Board, including having timely submitted an application for water service, is entitled to water service made available to the District under the Contract with the Bureau. Provided, however, no Schedule B lands shall be eligible to receive any share of the District's contract entitlement until all applications for Schedule A lands are fulfilled.

(2) Allocation of Class I and Class II Water: The District's annual entitlement of Class I and Class II water shall be distributed according to requests taken from water applications. During dry years, requests may be allocated proportionately to all applicants on the basis of the acreage entitled to receive water (i.e. designated nonexcess or otherwise entitled to service under reclamation law). Provided, however, no Schedule B lands shall be eligible to receive any share of the District's Class I entitlement until all applications for Schedule A lands are fulfilled.

In any year in which the District's water supply under its contract with the Bureau is adequate to supply all applications for Schedule A lands, but not all Schedule B lands, the Schedule B lands shall share in such a shortage on a proportionate acreage basis.

(3) Allocation of Other Water from Bureau: Notwithstanding the foregoing, water made available by the Bureau beyond the District's contract providing for Class I and Class II water will be allocated to meet the demands of any Schedule A lands within the district, and secondly shall be allocated equally on a per acre basis to owners or operators of Schedule B lands within the District requesting service. Such water shall include, but not be limited to, water which is unstorable or flood flows.

(4) Allocation of Water Other than from the Bureau: In spite of the foregoing, water which the District acquires from sources other than the Bureau shall be marketed within the District to Water Users at a price which reflects the cost of acquiring such additional supplies, and shall be allocated on a "first come, first served" basis.

(5) Allocations of System Capacity: At times that there is inadequate capacity upon a particular lateral to meet the request of all Water Users requesting water service at that particular time, the District shall first reduce the quantity of water provided to each Water User's turnout to the capacity for which the system was originally designed, which was 3.74 acre-feet per day per 160-acre parcel (approximately 5.29 gallons per minute per acre), and then in the event that there is still inadequate capacity upon a particular lateral, the District shall prorate the quantity provided to each Water User requesting service at that particular time on an equal basis per acre. The Board may provide specific exceptions to the foregoing where landowners in a particular service area have funded enhancements of the system to provide a greater level of service, such as the East System Improvement Project.

D. PAYMENT

(1) Tolls and Charges: Payments required to be paid in order for a Water User to be eligible to receive water from the District include the following:

(a) Standby charges, annually fixed by the Board on a per acre basis for the availability of water and/or groundwater benefits, assessed to all "irrigated lands," regardless of whether eligible or capable of receiving water from the District, and collected by the County of Kern along with property taxes.

(b) Water tolls, annually fixed by the Board on a per acre-foot basis, and paid for by Water Users in the manner set forth following. The Board shall fix a basic Water Toll to cover District costs attributable to providing water service to all Water Users, including, but not limited to, the following costs: Water, District operation and maintenance, administration, debt service (to the extent not covered by the standby charge) and reserve accounts. In addition thereto, Water Toll surcharges shall be charged for each lift through a District pumping plant based on the estimated power cost to pump an acre-foot of water through each plant.

(c) Bureau charges, including cost of service charges, Friant surcharge, restoration fund payments, and full-cost charges where applicable, fixed by the Bureau and added to water tolls as applicable, and paid by Water Users in the manner set forth following. The District may impose an administrative charge in addition to such Bureau charges.

(d) Non-contract water, such as water purchased from outside the District or groundwater put into the District's distribution system, will not be charged the charges in (b) and (c) above. However, a service charge will be fixed to cover District costs attributable to delivering such water, including, but not limited to, the following costs: District operation and maintenance, administration, debt service, Bureau of Reclamation charges for use of federal facilities and surcharges for each lift through District pumping plant based on the estimated power cost to pump an acre-foot of water through each plant. The District reserves the right to deny any request for delivery of such water if it may create capacity, water quality problems, endangering public safety or during a bona fide emergency event.

(2) Payment Schedule: The water service contract with the Bureau requires the District to prepay for all water prior to delivery to the District and, therefore, the following regulations will apply:

(a) Payments of monthly water bills are due and payable on or before the 20th of each month for water used the prior month. Payments not received on or before the 20th will be assessed a 10% penalty plus interest at 1-1/2% per month, and if not paid by 8:30 A.M. on the 26th of the month, the water will be shut off on the 27th of the month, and no water orders will be accepted until payment is made in full. An additional deposit totaling $28.00 per assessed acre will be required before water service is resumed if a bill is delinquent sixty (60) days after date of penalty. If the aforementioned steps have been imposed on a Water User and the General Manager believes noncompliance will persist, that Water User may, at the discretion of the General Manager, be required to submit a monthly schedule for water delivery and pay for said water by cash or cashier's check thirty (30) days in advance of delivery.

(b) Lands or parties which are in arrears in payment to the District of any assessments, standby charges, water tolls, penalties or interest, will not receive District water until payment in full is made as set forth above. Water will be delivered in accordance with Contract I1r-1460-LTR1 with the United States… "The Contractor shall not furnish water made available pursuant to this contract for lands or parties which are in arrears in the advance payment of water rates levied or established by the Contractor." (Art. 22(b))

(3) Means of Payment: For payment of bills by check, other than those signed by the Water User and applicant, the District requires the name of the account being paid. Checks which do not identify the account being paid will be returned. When paying two or more accounts, the District requires a separate check for each account being paid in order that a true and exact audit trail can be made. Checks received paying for more than one account will be returned. Penalties and interest will be assessed if the account becomes delinquent.

(4) NSF Checks: Checks returned for non-sufficient funds will be charged an additional $50.00 service charge. All accounts paid by such check will be delinquent and assessed penalties as above.

(5) Delinquencies: As prescribed by California Public Utilities Code Section 12811.1, any fees, tolls, rates or other charges which become delinquent, together with interest and penalties thereon, shall become a lien on the real property within the District for which the services were provided upon the District filing a certificate with the County Recorder, which lien shall have the same force, effect and priority as a judgment lien. This remedy is in addition to other remedies provided by law. In order to partially recover the District's costs incurred in processing said lien, added to said lien will be a service charge of $100.00.

E. ENFORCEMENT OF RULES AND REGULATIONS – APPEALS – AMENDMENTS

(1) The General Manager of the District is authorized to perform all acts necessary and proper to enforce these Rules and Regulations. Failure of a Water User to comply with any of these Rules and Regulations shall be sufficient cause for the termination of water service, and water service will not again be furnished to such Water User until full compliance has been made with all the requirements as herein set forth; PROVIDED, HOWEVER, that Water User in no way be relieved of any responsibility for payment of any charge or obligations by reason of such termination of water service. When it is practicable to do so, advance notice of any such termination of water service will be furnished to Water User. In no event shall any liability accrue against the District or any of its officers, agents or employees, for damage, direct or indirect, arising from such terminations of water service. Non-enforcement of any provision of these Rules and Regulations does not constitute a waiver of the District's right of enforcement at any time.

(2) In the event a Water User disagrees with a decision made by the General Manager in carrying out the enforcement of these Rules and Regulations, he/she shall have the right of appeal to the Board. Appeals should be submitted in writing no less than five (5) days prior to a regular meeting of the Board in order to be considered at that meeting, and shall specifically set forth the decision being appealed and shall give the reasons for said appeal.

(3) These Rules and Regulations shall become effective March 1, 2002, and may be added to, amended or repealed at any time by resolution of the Board of the District.

HELPFUL INFORMATION

- Water Applications and RRA Forms are due in the Office by February 15 each year. (pages 3 & 4)
- Return of excess water is due by August 15 each year. (pages 4 & 5)
- Payments are due by the 20th of each month. (Page 10)
- To place an order for water. (page 6)
    - By Phone: 725-0610 between 7 a.m. & 3:30 p.m. Monday through Saturday.
    - By Fax: 725-2110
    - By email.
    - In person.
- To report an emergency, call 725-0610, choose option 5. (page 6)

ATTACHMENT D

DISTRICT SAMPLE BILL

FIVE YEAR UPDATE

WATER MANAGEMENT PLAN

SOUTHERN SAN JOAQUIN

MUNICIPAL UTILITY DISTRICT

SSJMUD

Southern San Joaquin Municipal Utility District
P. O. Box 279 Delano, California 93216
Phone: (661) 725 - 0610 FAX: (661) 725 - 2110

Invoice Date: 9/30/2011
Account Number: 101
Invoice Number: 8446
Due Date: *20th of Month*

Meter Number: 090202 ***Meter Entitlement:*** 304.00 ***YTD Used:*** 100.00 ***Remaining Entitlement:*** 204.00

Bureau of Reclamation Water Charge	$12.58	X	18.00 A.F. =	$226.44
Capital Repayment	$14.00	X	18.00 A.F. =	$252.00
Environmental Restoration Fee	$9.29	X	18.00 A.F. =	$167.22
Friant Surcharge	$7.00	X	18.00 A.F. =	$126.00
Power/Pumping Surcharge	$22.00	X	18.00 A.F. =	$396.00
Variable Cost Recovery & Trinity PUD	$7.57	X	18.00 A.F. =	$136.26
Total Charges for Meter No: 090202				$1,303.92

Meter Number: 090208 ***Meter Entitlement:*** 620.00 ***YTD Used:*** 394.99 ***Remaining Entitlement:*** 225.01

Bureau of Reclamation Water Charge	$12.58	X	56.00 A.F. =	$704.48
Capital Repayment	$14.00	X	56.00 A.F. =	$784.00
Environmental Restoration Fee	$9.29	X	56.00 A.F. =	$520.24
Friant Surcharge	$7.00	X	56.00 A.F. =	$392.00
Power/Pumping Surcharge	$22.00	X	56.00 A.F. =	$1,232.00
Variable Cost Recovery & Trinity PUD	$7.57	X	56.00 A.F. =	$423.92
Total Charges for Meter No: 090208				$4,056.64

NOTE: A PENALTY of 10% will be assessed on all balances, if payment for all water tolls including penalties and interest is not received in the office on or before 3:30 PM on the 20th of the month. District water will be shut off on the 27th of the month if payment for all water tolls is not received on or before 8:30 AM on the 26th of the month.

SSJMUD

Southern San Joaquin Municipal Utility District
P. O. Box 279 Delano, California 93216
Phone: (661) 725 - 0610 FAX: (661) 725 - 2110

Total Entitlement:	**1,656 A.F.**	***Total Charges for All Meters:***	**$8,134.16**
YTD Used:	**985 A.F.**	***Balance Forward:***	**$.00**
Remaining Balance:	**671 A.F.**	***Total Due:***	**$8,134.16**

NOTE: A PENALTY of 10% will be assessed on all balances, if payment for all water tolls including penalties and interest is not received in the office on or before 3:30 PM on the 20th of the month. District water will be shut off on the 27th of the month if payment for all water tolls is not received on or before 8:30 AM on the 26th of the month.

ATTACHMENT E

DISTRICT WATER SHORTAGE PLAN

FIVE YEAR UPDATE

WATER MANAGEMENT PLAN

SOUTHERN SAN JOAQUIN

MUNICIPAL UTILITY DISTRICT

Attachment E is not applicable to the District. As per Section 1.H.1, the District's entitlement of Class 1 and Class 2 water shall be distributed according to requests taken from water applications. During dry years, requests may be allocated proportionately to all applicants on the basis of the acreage entitled to receive water.

ATTACHMENT F

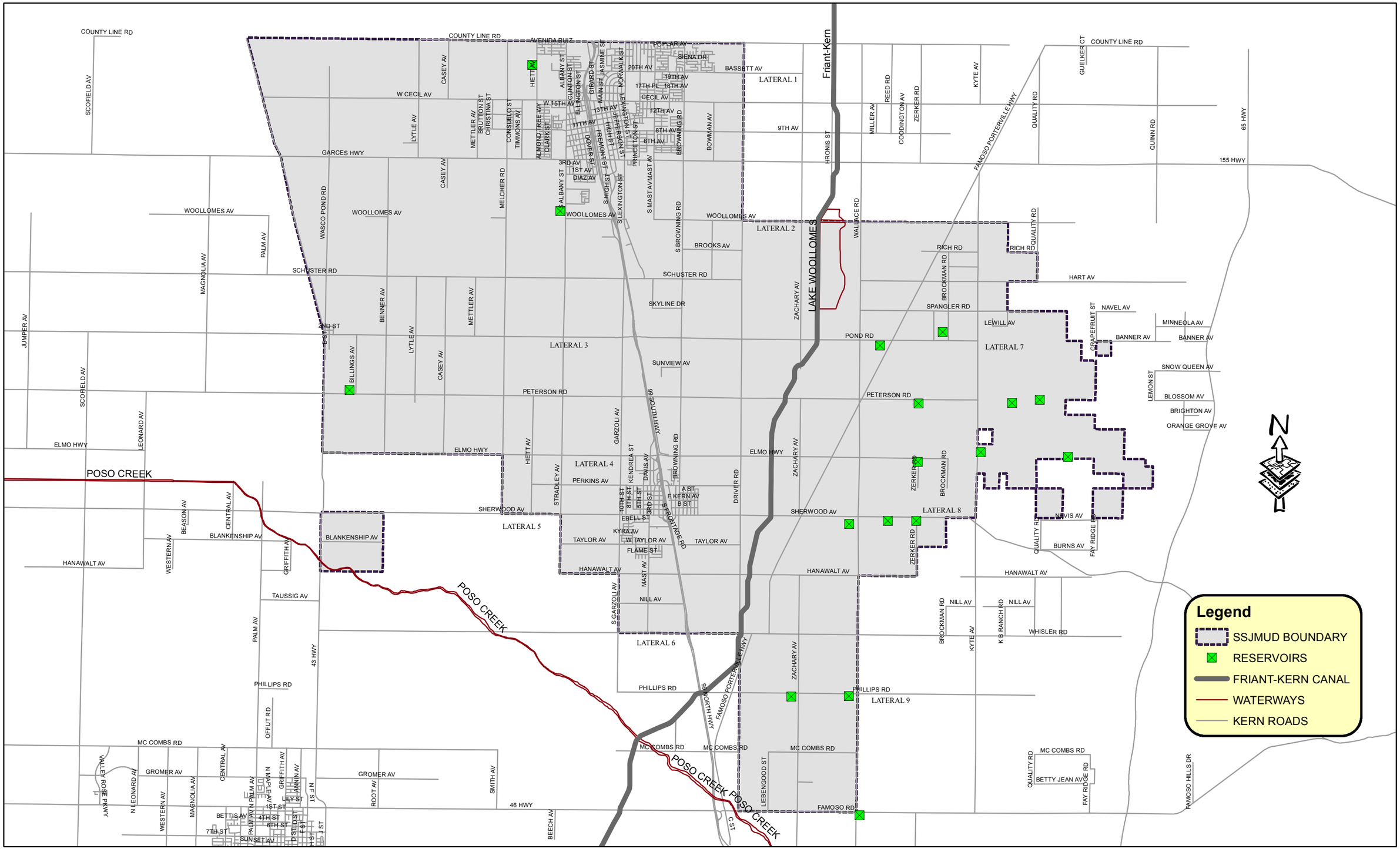
DISTRICT MAP OF GROUNDWATER FACILITIES

FIVE YEAR UPDATE

WATER MANAGEMENT PLAN

SOUTHERN SAN JOAQUIN

MUNICIPAL UTILITY DISTRICT



S:\SSJMUD\DISTRICT_GROUNDWATER_FACILITIES.mxd

DISTRICT GROUNDWATER FACILITIES
SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

KELLER/WEGLEY

ATTACHMENT G

GROUNDWATER MANAGEMENT PLAN

FIVE YEAR UPDATE

WATER MANAGEMENT PLAN

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

February 26, 2001

Project No. 201104.0
SSJMUD
Groundwater Management Plan

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT
P.O. Box 279
Delano, CA 93216
ATT.: Mr. Bill Carlisle

Re: Groundwater Management Plan Update

Dear Bill,

As requested, Cornerstone Engineering has reviewed the current groundwater management plan and compared it against applicable provisions in the California Water Code as revised by AB 3030. This report summarizes AB 3030 requirements for groundwater plans, the condition of SSJMUD's existing groundwater plan and the provisions of the plan requiring action.

AB 3030 requirements

As stated on the Department of Water Resources groundwater web page,

The Groundwater Management Act, commonly referred to as AB 3030, was signed into law on September 26, 1992, and became effective on January 1, 1993. The legislation is designed to provide local public agencies with increased management authority over groundwater resources in addition to those existing groundwater management capabilities. AB 3030 was developed in response to Environmental Protection Agency's Comprehensive State Groundwater Protection Programs...Action is voluntary not mandatory.

Attached is a copy of the applicable Water Code Sections 10750-10756.

The purpose of the legislation was to encourage local agencies to work cooperatively to manage groundwater resources within their jurisdictions to ensure the safe production and quality of groundwater.

The water code states groundwater management plans may include elements relating to all of the following:

1. The control of saline water intrusion.

2. Identification and management of wellhead protection areas and recharge areas.
3. Regulation of the migration of contaminated groundwater.
4. The administration of a well abandonment and well destruction program.
5. Mitigation of conditions of overdraft.
6. Replenishment of groundwater extracted by water producers.
7. Monitoring of groundwater levels and storage.
8. Facilitating conjunctive use operations.
9. Identification of well construction policies.
10. The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.
11. The development of relationships with state and federal regulatory agencies.
12. The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

As stated by the Department of Water Resources,

Each component would play some role in evaluating or operating a ground water basin so that ground water can be managed to maximize the total water supply while protecting ground water quality.

Department of Water Resources' Bulletin 118-80 (page 9) defines ground water basin management as including planned use of the ground water basin yield, storage space, transmission capability, and water in storage. Ground water basin management includes:

1. *Protection of natural recharge and use of intentional recharge;*
2. *Planned variation in amount and location of pumping over time;*
3. *Use of ground water storage conjunctively with surface water from local and imported sources; and,*
4. *Protection and planned maintenance of ground water quality.*

The 12 components listed in Section 10753.7 of the Ground Water Management Act (AB 3030) form a basic list of data collection and operation of facilities that may be undertaken by an agency operating under this act.

Data collection will provide information to evaluate the water resources in the basin within the boundaries of the district. The construction of facilities will allow operation of the basin to protect ground water quality and to maximize the water supply by means of recharge of surface water and extraction of ground water at appropriate times and locations."

Included in the attachments are details of applicable elements from the Department of Water Resources that may be of use to SSJMUD.

Additionally, the legislation as defined in the water code contains provisions with regard to adoption of rules and regulations to implement and enforce the plan including the imposition of

fees and assessments, land annexation into the district, and coordination of the plan with adjacent districts.

Existing Groundwater Management Plan

The following summarizes the action points of the existing plan:

- Meet and coordinate groundwater plans with other agencies who share the San Joaquin Valley basin such as North Kern Water Storage District and Delano-Earlimart Irrigation District
- Preserve water rights and contracts respecting surface water supplies
- Integrating the conjunctive use of surface and groundwater supplies to achieve the optimal use of each by surface delivery in lieu of groundwater pumping, transfers and exchanges with neighboring areas, and groundwater banking
- Pricing surface water at rates which induce water users to buy surface water when available, rather than pumping groundwater
- Groundwater data collection and monitoring for the purpose of documenting accomplishments of the Management Program and to identify and implement specific programs to reflect changing conditions of the basin. This includes for example, continuance of spring and fall collection of water level data, utilization of water quality monitoring wells to sample and test water quality, and hydrologic data collection.
- Monitoring of the districts financial ability to implement the groundwater plan and if necessary, implementing groundwater replenishment assessments as well as water extraction fees

Recommended Action

The Department of Water Resources has no formal Groundwater Management Plan review procedure. Details of groundwater management plan elements are discretionary, as applicable to the specific needs of each managing district.

The existing SSJMUD Groundwater Management Plan appears to meet the basic intent of AB 3030 even though it was enacted pursuant to AB-255, which has been superseded by AB 3030. At this juncture, the recommended course of action is to apply district groundwater management policies already in place. An evaluation and prioritization should be made of the twelve AB 3030 suggested plan elements mentioned above. This information will be helpful in executing the action points of the existing groundwater plan.

For clarification purposes, it is recommended the existing plan basis be changed from the current AB 255 basis to an AB 3030 reference. All other provisions in the plan appear satisfactory.

Despite the fact AB 3030 is more advisory rather than regulatory, a well-monitored groundwater management plan will greatly benefit SSJMUD and help to preserve this vital resource.

It should be noted Mr. Carl Hauge of the Department of Water Resources was very helpful in providing assistance in our research. He can be reached at (916) 327-8861 or chauge@water.ca.gov.

If you have any questions, please contact Mark Dawson at this office at (661) 325-9474.

Respectfully,

CORNERSTONE ENGINEERING, INC.

Mark Dawson, Project Engineer
RCE C44513, Expires 3/31/02

MKD: mkd
Enclosures
J:\Projects\2001\201104\Docs\Groundwater Management Plan 2001 Update.doc

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[i] California Department of Water Resources, May 22, 1998
[ii] Ibid., December 29, 1999

BEFORE THE BOARD OF DIRECTORS OF
THE SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

IN THE MATTER OF: RESOLUTION NO. 93-11

RESOLUTION OF THE BOARD OF DIRECTORS OF THE
SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT
TO ADOPT A GROUNDWATER MANAGEMENT PROGRAM PURSUANT
TO PART 2.5 OF DIVISION 6 OF THE CALIFORNIA WATER CODE

WHEREAS, pursuant to Resolution No. 92-10, adopted December 9, 1992, this Board set the date of a public hearing pursuant to Water Code section 10753 to consider a proposed groundwater management program;

WHEREAS, as prescribed by Water Code section 10753, the Board provided notice of that hearing on the question of adopting a groundwater management program; and

WHEREAS, on July 14, 1993, as prescribed by the above-referenced notice, this Board of Directors conducted hearings on the proposed groundwater management program; and

WHEREAS, no written protest to adoption of the plan has been filed; and

WHEREAS, having fully considered all testimony received at the hearing, this Board finds that it is in the best interest of the District and its landowners to adopt a resolution to implement the District Groundwater Management Program attached hereto.

NOW, THEREFORE, BE IT RESOLVED, by this Board of Directors that said Board declares the adoption of the attached District Groundwater Management Program attached hereto;

BE IT FURTHER RESOLVED, that the secretary-manager is directed to provide copies of the adopted District Groundwater Management Program to any interested persons who may request a copy of said program.

ALL THE FOREGOING, being on motion of Director Shick, and seconded by Director Peck, was authorized by the following vote:

AYES: Directors Antonell, Hiett, Clement, Peck & Shick

NOES: None

ABSENT: None

ABSTAIN: None

I HEREBY CERTIFY that the foregoing is the resolution of said District as duly passed and adopted by said Board of Directors on this 10th day of August 1993.

WITNESS my hand and seal of said Board of Directors this 10th day of August 1993.

Secretary of the Board of Directors

(SEAL)

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT
PHONE DELANO 725-0610
P.O. BOX 279 DELANO, CALIF. 93216

June 16, 1993

To All Water Users and Landowners:

Enclosed for your information is a copy of a proposed Groundwater Management Plan which is being considered by the District. The Board of Directors will hold a public hearing on the Plan at 2:00 P. M. on July 14, 1993 in the District office.

This plan is being proposed pursuant to Part 2.5 of Division 6 of the Water Code. The District Board of Directors believes that it is in the best interest of the District and its landowners to adopt such a plan and thereby reduce the opportunity for the State or others to attempt to impose groundwater management in the future.

Your attention is called to page 7 of the plan which explains the procedure for adopting a plan.

The powers of the District under the plan are explained on page 6. Under any plan adopted, the District would have the authority to levy and collect groundwater replenishment fees and extraction fees. However, we do not intend to do so at this time. Furthermore, any fees would have to be approved by the District voters.

If you have any questions, please call.

Sincerely yours,

STANLEY T. NELSON, JR.
General Manager

STN:sb

Enclosures

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT
KERN COUNTY, CALIFORNIA

GROUNDWATER MANAGEMENT PROGRAM UNDER CALIFORNIA WATER CODE SECTIONS 10750 ET SEQ.

MAY 12, 1993

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SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT
GROUNDWATER MANAGEMENT PROGRAM
MAY 12, 1993

The Southern San Joaquin Municipal Utility District (District) desires to formalize its existing Groundwater Management Program to provide for the continuance of local management, and to enhance existing monitoring activities so as to position itself to identify and implement modifications to its ongoing program that may be required to preserve and enhance the groundwater resource. Accordingly, the District is proposing to organize its existing Groundwater Management Program under provisions of California Water Code 10750 et seq., which were added through enactment of AB-255 and became effective January 1, 1992. With adoption of Resolution 92-10 on December 9, 1992, the District commenced procedures to enact a Groundwater Management Plan pursuant to AB-255.

Preservation and enhancement of the groundwater resource is vital to sustaining the local economies which have been built up in reliance, in whole or in part, on this resource. Physically, the District's objective is to preserve the utility of the groundwater resource, both in terms of quantity and quality. Further, enhancement or augmentation of the resource is necessary to mitigate the present level of overdraft in the overall groundwater basin and the attendant long-term decline in groundwater levels. Economically, the District's objective is to accomplish the stated physical objectives at least cost to minimize or reduce any duplication of agencies by establishing a local management program.

MANAGEMENT AREA

The previously cited provisions of the California Water Code provide for the development of a management program within the boundaries of the District. The District's underlying groundwater basin is part of the larger basin which is part of the south San Joaquin Valley basin. It is proposed that the management area for the District's Program may include agreements with adjacent areas which would encompass the area of influence of groundwater activities. The adjacent areas would include lands in the North-Kern Water Storage District, and Delano-Earlimart Irrigation District.

PROGRAM ELEMENTS

The objective of the Groundwater Management Program is to preserve and maximize the utility of the groundwater resource through conjunctive use with available surface water, all with the view of obtaining an adequate water supply of satisfactory quality and quantity at the least possible cost to sustain the agriculture production in the District and an adequate supply for towns and cities within the District. Elements have been formulated to achieve the objectives and are presented in the sections which follow. Necessarily, the subsequent discussion includes a description of management activities which are presently in place.

SURFACE WATER SUPPLY

Groundwater management in California is rooted in the conjunctive us of surface and groundwater resources. Simply, water supplies from the two sources are integrated to accomplish the optimum utilization of each. In this regard, the District's primary source of surface water supply is imported Central Valley Project water (originating i Millerton Lake on the San Joaquin) under long-term contract with the United States. Also, the District makes short-term and year-to-year arrangements to secure additional Central Valley Project (CVP) and other supplies. The District has conjunctively utilized CVP waters and groundwater since 1951. The District has in place and operates an extensive system of conveyance and distribution facilities throughout its service area to make use of the surface supplies as available.

Under the subject Program, the District will seek to preserve the water rights and contracts respecting its surface water supplies. Further, the District will pursue opportunities to supplement these supplies. Additional opportunities could include the purchase of additional CVP or ''Section 215 water'' and any other water which may be available in the future at reasonable cost.

GROUNDWATER BASIN CHARACTERISTICS

The physical characteristics of the groundwater basin substantially shape the Groundwater Management Program. In particular, the manner in which groundwater is replenished is directly affected by surface and subsurface characteristics, such as the permeability of the overlying and subsurface soils. Replenishment of the groundwater resource is more particularly discussed in the section following.

GROUNDWATER REPLENISHMENT

The replenishment of groundwater underlying the District occurs naturally and through deliberate, controlled means (artificial). The District's groundwater replenishment is achieved indirectly through the delivery of surface water, when available, to lands otherwise relying on the groundwater resource (also referred to as in-lieu recharge, i.e., delivery of surface water in lieu of groundwater pumping). The importation of CVP water has totaled over 4.3 million acre-feet over the last 42 years for both surface delivery and groundwater replenishment activities. Additionally, irrigation water not consumed by evapotranspiration of cropped lands returns to the underlying groundwater system.

Under the Management Program, the District will make every effort to preserve the presently available in-lieu recharge capabilities, and will consider enhancement of these capabilities as well as the development of additional facilities. Delivery of surface water in lieu of groundwater pumping will continue, limited only by the availability of surface water and distribution facilities.

CONJUNCTIVE USE OF SURFACE AND GROUNDWATER

As discussed previously, groundwater management is the conjunctive use of surface water and groundwater supplies where conjunctive use refers to integrating the two sources of supply to achieve the optimal use of each. The District's conjunctive use program reflects available facilities, groundwater basin characteristics, and the nature of the surface water supplies respecting availability and institutional considerations. In particular, the District's conjunctive use program includes surface delivery in lieu of groundwater pumping, transfers and exchanges with neighboring areas. Further, it depends on available groundwater storage capacity and, conversely, it depends on groundwater in storage when needed to supplement available surface supplies.

Surface delivery in lieu of groundwater pumping motivated the District to enter into a long-term contract with the United States in 1945 for the importation of a supplemental surface water supply from the Friant Unit of the CVP. This aspect of the District's program relies on its extensive system of irrigation distribution facilities.

Water transfers and exchanges, in various forms, are also a part of the District's conjunctive use program. Under the Management Program, the District will seek to preserve and enhance its conjunctive use activities. Enhancement of conjunctive use activities could include the development of groundwater banking arrangements with other agencies utilizing their storage capacity or the groundwater storage capacity within this District.

MANAGEMENT OF GROUNDWATER EXTRACTIONS

Effective groundwater replenishment necessarily involves both the management of water supply to the basin and the management of the extractions from the basin. Extractions within the management area are by private wells and those wells owned and operated by the City of Delano and Mcfarland Mutual Water Company for municipal and industrial purposes. It is expected that management of groundwater extractions in the District can be achieved through economic inducement rather than regulating extractions. This has been achieved and would continue to be implemented by pricing surface water at rates which induce water users to buy surface water when available, rather than pumping groundwater. The District also attempts to assist water users to qualify for delivery of surface water, but Federal Reclamation Law and Regulations as to eligibility and pricing often inhibit these efforts.

MONITORING

Optimal use of the groundwater resource is dependent on obtaining good basic data respecting both geology and hydrology. The purpose of this element of the Program is to characterize the conditions within the groundwater basin, both to document the accomplishments o the Management Program and to identify and implement specific programs, as needed, to reflect changing conditions in the basin. Monitoring includes gathering the basic data and analyzing these dat to characterize the basin and would be subject to modification, as needed, to reflect changes or additions in the programs implemented under the Management Program. Monitoring is considered critical to future management decisions. Accordingly, the District's present activities in this regard may be expanded.

WATER LEVELS

Data respecting water levels are used to evaluate groundwater flow and storage conditions. Maps showing contours of equal water level elevation indicate the direction of groundwater movement and can be used to quantify estimates of groundwater under flow entering and leaving the management area. Maps of depth to groundwater can provide insight into the distribution of pumping lifts (and so assist in estimating pumping cost). Maps showing changes in groundwater levels (when used in conjunction with data on specific yield) can be used to estimate changes in groundwater storage. In addition to these water level maps, hydrographs of water levels in selected wells provide information on seasonal and long-term variations in water levels.

The District routinely measures water levels in both the spring and fall. The present monitoring network will be reviewed in order to provide sufficient areal coverage to prepare representative water level evaluation and depth contour maps. Measurement of water levels will continue to be performed in both spring and fall in order to show seasonal variations in water levels. Using the same wells for monitoring over a long-term period will facilitate the preparation of meaningful water level change maps and hydrographs.

WATER QUALITY

Water quality monitoring, including water sampling and testing, will identify the suitability of groundwater for various uses. A network of water quality monitoring wells has been established to provide sufficient data to allow preparation of water quality contour maps. The same wells can be sampled each year, allowing long-term water quality trends to be identified. It is envisioned that supplemental water quality sampling would also be performed at other wells, as needed to better define localized areas of impaired water quality. Water quality testing may typically include standard agricultural-type analyses, but may also include additional testing (e.g., Title 22) as required.

WATER SUPPLY AND WATER SUPPLY USE

Data related to the hydrologic inventory of the basin will be collected annually. These data will allow quantification of the various elements of the hydrologic inventory, and will support further analysis of the impact of various elements of the Program. Principal components of the inventory to be considered include amounts of water replenished and quantities of groundwater pumped.

ANALYSIS

Documentation, in the form of a monitoring report, will be prepared as required to present the results of the monitoring element of the District's Program. The contents of the monitoring report could include:

1. Maps showing spring and fall water elevations;

2. Maps showing spring and fall depths to water;

3. Map showing change in water levels from spring to the current year to spring of previous year;

4. Estimate of change in groundwater storage computed using specific yield data and maps of change in groundwater levels;

5. Assess effectiveness of management activities.

INSTITUTIONAL CONSIDERATIONS

The Groundwater Management Program requires a public body, endowed with appropriate powers, to carry out the Program. California Water Code Sections 10750 et seq. provide the necessary powers. Prior to enactment of these provisions of the Water Code, the vehicle best suited to the management of groundwater was the water replenishment district. Many of the powers granted a Water Replenishment District are granted to the agency organizing its program under the cited provisions of the Water Code.

The District would (upon adoption of the Program) have the authority to levy and collect general groundwater replenishment assessments, as well as water extraction fees based on the amount of groundwater extracted from the aquifier. However, these fees must be ''ratified'' by a majority vote in an election governed by the election rules applicable to the District. At the present time the Board does not intend to invoke such powers, intending instead to rely on water charges and standby charges to pay for district costs. However, changing Federal and State regulatory actions and water conditions may cause the District's entire financial program to be reassessed in the future.

Powers granted to a district which adopts a Groundwater Management Program include the powers of a Water Replenishment District (Part 4, of Division 18, of the Water Code), to the extent not already possessed by a district, including, but not limited to the following:

a. Acquire and operate facilities, waters and rights needed to replenish the groundwater supplies;

b. Store water in groundwater basins, acquire water rights, import water into the District, and conserve water;

c. Participate in legal proceedings as required to protect and defend water rights, and water supplies, and to prevent unlawful exportation of water from the District;

d. Under certain conditions to exercise the right of eminent domain;

e. Act jointly with other entities in order to economically perform required activities;

f. Carry out investigations required to implement the program;

g. Fix rates for water for replenishment purposes; and

h. Fix the terms and conditions of contracts for use of surface water in-lieu of groundwater.

PROCEDURE FOR ADOPTION OF PROGRAM

At the conclusion of the May 12, 1993 public hearing, the Board of Directors approved a draft of the Groundwater Management Program and adopted the Resolution of Intention to Adopt and Implement the Program. Copies of the Groundwater Management Plan will be sent to each owner of a water extraction, storage, or distribution facility within the District, and upon written request, to any other interested person. The Board of Directors also fixed the time, date and place for a second hearing to be held by the Board of Directors for the purpose of considering protests to the implementation of the Groundwater Management Program (a notice of the second hearing will be appended to the Groundwater Management Program). Furthermore, notice of said public hearing shall also be published in accordance with the provisions of California Government Code Section 6066.

At any time prior to the conclusion of the second public hearing, any landowner within the District may file a written protest or withdraw a protest previously filed. A protest by a landowner shall include the landowner's signature and description of the land owned sufficient to identify the land. A public agency owning land is deemed to be a landowner for the purpose of making a written protest.

If at the conclusion of the second public hearing the Board of Directors finds that a ''majority protest'' exists, the Groundwater Management Program shall be abandoned and no new program shall be considered by the Board for a period of one (1) year. If a ''majority protest'' have not been filed, the Board of Directors, within thirty-five (35) days after the conclusion of the hearing, may adopt a resolution to implement the Groundwater Management Program. A ''majority protest'' shall be determined to exist if the Board of Directors of the District finds that protests filed and not withdrawn prior to the conclusion of the second public hearing represent more than fifty percent (50%) of the assessed value of the land within the Southern San Joaquin Municipal Utility District. (Water Code Section 10757).

As part of the Groundwater Management Program, the Board of Directors reserves the right to subsequently amend the program or adopt another type of groundwater management program after following procedures required by law in order to repond to changing conditions.

ATTACHMENT H

NOTICES OF DISTRICT EDUCATION PROGRAMS AND SERVICES AVAILABLE TO CUSTOMERS

FIVE YEAR UPDATE

WATER MANAGEMENT PLAN

SOUTHERN SAN JOAQUIN

MUNICIPAL UTILITY DISTRICT

SSJMUD

Southern San Joaquin Municipal Utility District

An Independent CVP Friant Division Water Contractor

BOARD OF DIRECTORS

John N. Fisher
President

Peter Dulcich
Vice President

Donnie Morris
Director

James A. Regan
Director

George Zaninovich
Director

STAFF

William Carlisle
General Manager/ Secretary

Connie Rising
Office Supervisor/ Treasurer

Roland Gross
Field Superintendent

Rick Notley
Maintenance Supervisor

Mail:
P. O. Box 279
Delano, CA 93216

Shipping:
11281 Garzoli Ave.
Delano, CA 93215

Phone:
(661) 725-0610

Facsimile:
(661) 725-2110

Email:
water@ssjmud.org

May 9, 2012

TO: DISTRICT LANDOWNERS

FROM: SSJMUD BOARD OF DIRECTORS

RE: AGRICULTURAL PUMP EFFICIENCY TESTING

This memorandum is being distributed to inform Landowners within the Southern San Joaquin Municipal Utility District (SSJMUD) of the Center for Irrigation Technology's Agricultural Pumping Efficiency Program (Program) funded by the Pacific Gas and Electric Company's (PG&E) Advanced Pumping Efficiency Program through 2012 using the Public Purpose Programs Fund under the auspices of the California Public Utilities Commission. The program offers 2,300 subsidized pump efficiency tests per year and cash incentives for 300 pump retrofit projects per year. Below is a listing of local participating pump test companies and other local companies that can provide pump testing services. For more information on the Program and a full complete listing of all participating pump testing companies, please visit the Center for Irrigation Technology's website at http://www.pumpefficiency.org.

This memorandum contains information on a program that is supplemental to the normal pump efficiency service information provided by the District. That information is provided on the memorandum which is attached.

Farm Pump & Irrigation Co., Inc.
535 N. Shafter Avenue
Shafter, CA 93263
Office: (661) 746-3376

Irrigation Concepts
32151 Elmo Highway
McFarland, CA 93250
Office: (661) 792-1886

Pacific Irrigation, Inc.
11845 School Street
Bakersfield, CA 93307
Office: (661) 366-5555

Provost & Pritchard Consulting Group
1800 30th Street, Suite 280
Bakersfield, CA 93301
Office: (661) 616-5900

SA Camp Pump Company
17876 Zerker Road
Bakersfield, CA 93308
Office: (661) 399-2976

SSJMUD

Southern San Joaquin Municipal Utility District

An Independent CVP Friant Division Water Contractor

BOARD OF DIRECTORS

John N. Fisher
President

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Vice President

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Mail:
P. O. Box 279
Delano, CA 93216

Shipping:
11281 Garzoli Ave.
Delano, CA 93215

Phone:
(661) 725-0610

Facsimile:
(661) 725-2110

Email:
water@ssjmud.org

May 9, 2012

TO: DISTRICT LANDOWNERS

FROM: SSJMUD BOARD OF DIRECTORS

RE: AGRICULTURAL PUMP EFFICIENCY TESTING COMPANIES

This memorandum is being distributed to inform Landowners within the Southern San Joaquin Municipal Utility District (SSJMUD) of local companies which provide services related to pump efficiency testing. It should be noted that some of these companies are eligible for reimbursement through various programs or may conduct this service free of charge.

Allied Energy & Field Services, Inc.
P.O. Box 2606
Visalia, CA 93279
Office: (559) 622-9082

Farm Pump & Irrigation Co., Inc.
535 N. Shafter Avenue
Shafter, CA 93263
Office: (661) 746-3376

Irrigation Concepts
32151 Elmo Highway
McFarland, CA 93250
Office: (661) 792-1886

Kaweah Pump
15499 Avenue 280
Visalia, CA 93292
Office: (559) 747-0755

Kemble Hydro Tech
1111 Norboe Avenue
Corcoran, CA 93212
Office: (559) 992-3166

Mid Valley Pump Testing
P.O. Box 1751
Tulare, CA 93275
Office: (559) 684-7867

Pacific Irrigation, Inc.
11845 School Street
Bakersfield, CA 93307
Office: (661) 366-5555

Pacific Gas & Electric Company
1918 H Street
Bakersfield, CA 93301
Office: (800) 743-5000

Provost & Pritchard Consulting Group
1800 30th Street, Suite 280
Bakersfield, CA 93301
Office: (661) 616-5900

SA Camp Pump Company
17876 Zerker Road
Bakersfield, CA 93308
Office: (661) 399-2976

Southern California Edison Company
www.sce.com/forms/RequestPumpTest.aspx

Valley Pump and Dairy Systems
2280 South "K" Street
Tulare, CA 93274
Office: (559) 686-2000

FRIANT WATER AUTHORITY

April 2011

Volume 23, No. 206

FRIANT Waterline

Big Runoff Begins But Is Under Control

Bureau's Restoration Water Decision Boosts Friant Use

Peak snowmelt and runoff have begun with remaining snowpack water content within the San Joaquin River watershed double what it should normally be on May 1.

U.S. Bureau of Reclamation and Friant Water Authority water managers, however, are not particularly worried. A well-planned strategy of aggressive Friant Dam releases, coupled with cooler than average spring temperatures to date, has carved out a great deal of welcomed storage space in Millerton Lake.

STORAGE CUT IN HALF

As of May 2, the reservoir behind Friant Dam contained 223,674 acre-feet of water, less than half of what was in storage on March 26 during a late winter and early spring stretch of potent storms.

With the San Joaquin River's full natural flow and actual Millerton inflow remaining at least a few thousand cubic feet per second less than releases on each

Please see **Runoff**, Page 3



Arvin-Edison Water Storage District

Accident victim John Collins, former Bakersfield College President, is reached on his partially submerged car in the Arvin-Edison Canal April 13 by a Bakersfield emergency staff member suspended from a helicopter following a harrowing accident.

Arvin, Friant Staffs Help Save Driver

Friant Water Authority and Arvin-Edison Water Storage District canal operations staff members assisted with quick and effective emergency water management actions during a dramatic April 13 rescue of former Bakersfield College President John Collins, driver of a car that veered into the Arvin-Edison Canal in Bakersfield.

The car driven by the 93-year-old Collins drifted across Truxton Avenue, through a fence and into the canal not far below its headworks from the Friant-Kern Canal.

SNAGGED BY CABLE

By good fortune, the car landed backwards in the canal, its trunk sprung open. Although the rushing current rapidly pushed the car nearly a half mile downstream, the trunk lid jammed into a safety cable where the vehicle wedged in place.

Had the vehicle not been snagged, the car might have been swept further down the

Please see **Rescue**, Page 3



Restoration Leader

Alicia (Ali) Forsythe, the new San Joaquin River Management Program Manager, and her colleagues will be kept busy with the draft environmental study. *(For more on her appointment, please see Page 3.)*

Friant Water Authority / J. Randall McFarland

SAN JOAQUIN RIVER RESTORATION PROGRAM

Draft Environmental Study Issued

An 8,000-page environmental blueprint that is to guide San Joaquin River Restoration Program (SJRRP) planners and designers has been released for public review and comment.

The long-awaited series of documents – a draft federal program environmental impact statement and state environmental impact report (PEIS/R) was released April 22 by the U.S. Bureau of Reclamation and the California Department of Water Resources (DWR).

'UNAVOIDABLY' DELAYED

For the first time in so public a manner, the Bureau acknowledged that the program that is to restore flows and a salmon fishery to all San Joaquin River reaches between Friant Dam and the Merced River has run into delays.

"Reclamation recognizes that some actions required by the Settlement are unavoidably behind schedule," the Bureau stated in a news release. "This includes certain channel and structural improvement projects that may be beneficial for

Please see **Study**, back page

New Deputy Resources Chief Meral Meets Friant Leaders

Jerry Meral, Governor Brown's new State Resources Agency Deputy Director, has had a first-hand look at key San Joaquin River Restoration Program locations and has received a primer on Friant Division water issues, needs, programs and hopes explained by numerous Friant water leaders.

Meral's April 7 view of the central San Joaquin Valley was marked by heavy rain and flood releases that swelled the San Joaquin River's flows and obscured evidence of critically dry conditions which had prevailed until this winter's big storm events.

VIEWS SWOLLEN RIVER

Friant Water Authority leaders conducted a tour of portions of west valley reaches of the San Joaquin River and its associated flood control bypass channels.

"We had planned to show some of the in-channel challenges being faced by the

Please see **Meral**, back page



Deputy Resources Secretary Jerry Meral (left) with Tulare Irrigation District General Manager J. Paul Hendrix

Friant Water Authority

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Volume 23, No. 206
Published by the Friant Water Authority, as a review of issues and developments to inform those interested in water supplies along the East Side of the southern San Joaquin Valley. To comment or ask any questions, please write or call us at (559) 562-6305, visit our web site at *www.Friantwater.org* or contact your local irrigation district. This issue was printed May 3.

854 Harvard Avenue • Lindsay, California 93247-1715
Telephone: *(559) 562-6305* • Facsimile: *(559) 562-3496*
Website: *www.friantwater.org*

- **Harvey Bailey**, *Chairman of the Board*
- **Nick Canata**, *Vice Chairman*
- **Tom Runyon**, *Secretary-Treasurer*

- **Ronald D. Jacobsma**, *General Manager*
- **Mario Santoyo**, *Assistant General Manager*
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Arvin-Edison Water Storage District
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Exeter Irrigation District
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Kaweah Delta Water Conservation District
Kern-Tulare Water District
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Saucelito Irrigation District
Shafter-Wasco Irrigation District
Stone Corral Irrigation District
Tea Pot Dome Water District
Terra Bella Irrigation District
Tulare Irrigation District

HOUSE WATER AND POWER SUBCOMMITTEE

Hearing In Fresno Airs Valley Water Frustration

San Joaquin Valley water supply frustrations were the focus of an April 11 House Water and Power Subcommittee field hearing at Fresno City Hall.

The hearing's published theme – "Creating Jobs by Overcoming Man-Made Drought: Time for Congress to Listen and Act" – set the tone that one speaker after another followed.

One Friant Water Authority board member, Kaweah-Delta Water Conservation District Vice President Mark Watte, testified during the well-attended hearing.

Those attending armed themselves with signs linking water supply curtailments – such as those that plagued the valley in the years before the current above-average precipitation – with job losses, economic woes, social problems, higher food costs and environmental difficulties.

FEDS BLAMED

The overwhelming mood was one of placing blame on federal government agencies, bureaucrats, regulations and court decisions for the grief caused in cutting Central Valley Project water supplies in the west valley to as low as 5% in 2009. That resulted in thousands of job losses, hundreds of thousands of idle acres and millions of dollars in economic damage.

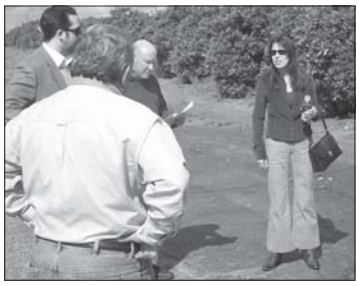
Water and Power Subcommittee Chairman Tom McClintock (*R-Elk Grove*) blamed the political left for advocating what he termed "politically motivated junk science."

"The House and Senate must act now," said a valley Congressman, Rep. Devin Nunes (*R-Visalia*) in commenting on the valley's water crisis and Delta pumping restraints. "The time for studying and talking is over."

Rep. Jim Costa (*D-Fresno*) told an interviewer after the hearing, "I think anytime you can continue to find greater awareness to the problems we're facing here. That's helpful."

One of the few dissenting voices was that of Larry Collins, Pacific Coast Federation of Fishermen's Associations Vice President, who defended

Please see **Hearing**, Page 3


Friant Water Authority

Assembly Member Makes Friant Visit

Assembly member Linda Halderman listens to a presentation by Orange Cove Irrigation District Manager Fergus Morrissey during an April 8 Friant Division tour. Also listening (left) is Assembly Republican Caucus Chief Consultant Doug Haaland and Friant Water Authority Assistant General Manager Mario Santoyo.

AROUND FRIANT

TULE RIVER

Corps Says No To Testing Higher Storage In Lake Success

Lake Success on the Tule River will remain less than half full in the wake of a U.S. Army Corps of Engineers decision to scrap a data gathering test this spring that would have increased permitted storage .

Had the plan been approved, the lake's maximum water surface elevation would have been increased 10 feet.

Storage in Lake Success has been restricted by the Corps since 2004 due to seismic safety concerns.

The surface level now is normally allowed no higher than 630 feet above sea level, or 40,000 acre-feet. That is 10 feet higher than the initial restriction.

The reservoir's as-built capacity is 82,300 acre-feet.

Corps officials for several years have been working on a solution to concerns that the dam's foundation and structure might be susceptible to failure in a major earthquake. The test had been intended to help the Corps find the highest safe level for water storage.

The Corps felt the risk was too high to undertake such a test..

Increased storage would have been beneficial to Tule River water users, and would have enhanced recreation.

Favoring the test were the Porterville Irrigation District, Tulare County, City of Porterville, Lower Tule River Irrigation District and Vandalia Irrigation District.

President Obama's 2012 budget includes funds to begin purchasing land below the dam, including a mobile home park. No funding is in place for replacing Success Dam. Published reports indicate the project cost is now estimated to be more than $450 million.

KERN RIVER

Isabella Dam Plans Expected

The U.S. Army Corps of Engineers is expected to conduct public meetings during May to explain how it believes problems with Isabella Dam can best be resolved.

The facility is now ranked among the Corps' most at-risk dams.

Seepage below the auxiliary dam, concerns over an earthquake fault running through the site and fears of insufficient spillway size have dogged the facility and led to restrictions on water storage.

A bigger auxiliary spillway will be proposed to be part of the solution so a greater spill could be handled without overtopping the earth-fill dams.

Lawsuit Will Challenge New Take Limits

State's Salmon Fishermen Are Gleeful Over 2011 Prospects, Long Season

While commercial salmon fishermen are ecstatic over prospects for what they believe could be their best season in years, a lawsuit is being prepared against two agencies over this season's expanded take limits.

A complaint was expected to be filed in early May (after WATERLINE press time) on behalf of the San Joaquin River Group Authority, of which the Friant Water Authority is a member, against the National Marine Fisheries Service (NMFS) and Pacific Fishery Management Council (PFMC).

The San Joaquin River Group Authority (SJRGA) is a joint powers authority that includes irrigation and water districts in the San Joaquin River Basin.

TAKE LIMITS QUESTIONED

The lawsuit, expected to be filed in a U.S. District Court, will seek a court determination that the agencies were arbitrary in their permitting of this season's salmon take limits, and requiring that the agencies start over.

At the heart of the suit is an allegation that the large amount of ocean take of salmon to be allowed by the new limits will cause species recovery programs in California rivers to suffer, resulting in even fewer fish in the future.

With the salmon season opening, the lawsuit is not expected to be of much help to the SJRGA this year.

"There is nothing we can do to put a stop to the current fishing season. Federal law does not allow that," a SJRGA statement said. "The best we can do is hope that over harvesting salmon is not permitted again in the future."

The lawsuit will reportedly seek to show that the PFMC's forecasting model is flawed and that hatcheries are having too much harmful influence. The plaintiff believes hatchery fish are increasing in the proportion of the fall-run Chinook salmon stock, leading to progressively less genetic diversity, less species resilience, and greater vulnerability to catastrophic occurrences such as poor ocean conditions that existed from 2007-09.

SALMON RECOVERY

Ronald D. Jacobsma, Friant Water Authority General Manager, said the SJRGA, as well as many other state and federal agencies, is working hard to promote recovery of fall-run Chinook and spring-run Chinook salmon in the San Joaquin basin.

Spring-run is a "threatened" species under the Endangered Species Act. It was extirpated from the basin, but there are substantial on-going efforts now to reintroduce spring-run.

A major part of that effort is to be the San Joaquin River Restoration Program in which Friant Division contractors of Central Valley Project water are involved deeply. The SJRGA's Vernalis Adaptive Management Program is also aimed in restoring salmon in the San Joaquin River Basin.

Fall-run salmon are not listed, but are an ESA candidate species.

AGENCIES TARGETED

SJRGA officials point out that the same state agency – the Department of Fish and Game (DFG) – and federal agencies (NMFS and U.S. Fish and Wildlife Service [USFWS]) authorizing a substantial commercial harvest of salmon this year have acted in past years to stop or critically reduce Delta water export pumping from the Delta to, in part, protect spring and winter-run salmon.

"The amount of fishing those agencies are allowing this year will kill many, many times more salmon than the Delta pumps ever did," the SJRGA said in a statement. The same state and federal agencies continually demand higher flows and more water released from reser-

Please see **Lawsuit**, Page 3



Arvin-Edison Water Storage District

Even with lower post-rescue flows, water still poured over the car.

Rescue: Water Cut To Help Victim Escape From Canal

Continued from front page

canal to where its cold and rushing waters fall into a siphon that carries Arvin-Edison's water under the Kern River.

Collins was also able to open the car's sunroof and stand on a seat as the car filled with cold water.

Four Arvin-Edison Water Storage District staff members responded immediately as did Bakersfield police and fire rescuers, who initially reported having trouble locating the car in the high rushing water.

FWA STAFF CUTS FLOWS

Once at the scene, rescuers got a life vest to Collins that he put on but could not secure. With the water moving too fast to put a swimmer in the water, Arvin-Edison asked the Friant Water Authority staff for an emergency cutoff of flows from the Friant-Kern Canal.

Friant's staff was able to quickly reduce the diversion by 485 cubic feet per second to greatly ease the rescue effort.

A helicopter was used to lift Collins out of the vehicle and onto a gurney. He was rushed to a Bakersfield hospital. Collins was cold but not injured. The car was then lifted by crane from the canal.

Eric Quinley, Friant Water Authority Maintenance Manager, said the Authority coordinated with the City of Bakersfield and river operators but no spill into the Kern River from the Friant-Kern Canal's Terminal Check was necessary during the 45 minutes that water was cut off from the Arvin-Edison Canal.

Hearing: Fresno Frustration

Continued from Page 2

the government's role in salmon protection by saying, "The more water you take out of [the Delta], the more you guarantee the death spiral of my industry." Collins blamed "corporate billionaire agribusinesses" for the troubles of fishermen, an assertion that was aggressively challenged by Nunes.

BAKERSFIELD MEETING

Meanwhile, a Bakersfield meeting was held April 27 by Kern County farmers, the Kern County Water Agency and Rep. Kevin McCarthy to seek solutions to the water supply crisis, including easing Endangered Species Act restrictions to curtail water deliveries.

Means of resolving Delta problems, including new water conveyance facilities such as a user-financed canal or tunnel, were discussed.

"We are not asking the government to pay for it, we are just asking to find common sense regulations so we can get it into the ground and get it moving," said McCarthy.

Frustration was also expressed over difficulties in separately meeting similar state and federal regulations.

Delta Bypass Study Hits A Snag In Court

A San Joaquin County judge has thrown a monkey wrench into state plans to drill and take soil samples for a water conveyance bypass tunnel or canal through or around the Delta.

The court ruled access to private lands proposed by the state Department of Water Resources under the Bay Delta Conservation Plan is a taking of land.

The ruling is a major problem for the facility's planners but was cheered around Stockton where a modern-day version of the Peripheral Canal is strongly opposed.

State officials said they may appeal but will work toward obtaining access by using eminent domain.

The state wants to take core samples at hundreds of locations for facility planning and design.

Lawsuit: Salmon Actions Targeted

Continued from Page 2

voirs to preserve and enhance the salmon fishery.

A state and federal goal of doubling natural production of Chinook salmon "will not be achieved if high levels of salmon fishing are allowed to continue," the SJRGA said.

SALMON RETURNS UP

Meanwhile, it is estimated this year's Chinook salmon run will be the best since 2007, with an estimated 730,000 Chinook now expected to return to the Sacramento River.

In 2009, a record-low 39,500 Chinook returned to the river to spawn. The commercial salmon season is to last through September. California's salmon fishing season in recent years has been cancelled or greatly curtailed.

SAN JOAQUIN RIVER RESTORATION

Reclamation Names New Program Manager

The San Joaquin River Restoration Program has a new U.S. Bureau of Reclamation manager.

Alicia (Ali) Forsythe, who has been the Acting Program Manager since January 2011, was named earlier this spring to head the complex planning and implantation effort.

"Ali is a great selection to head the Restoration Program," said Friant Water Authority General Manager Ronald D. Jacobsma. "She is uniquely qualified and experienced to deal with the multi-faceted challenges the program is already facing. We look forward to working with her as the Program Manager."

IMPLEMENTATION

The Restoration Program is being implemented as a result of the San Joaquin River litigation Settlement agreed to nearly five years ago by the lawsuit's environmental plaintiffs, led by the Natural Resources Defense Council (NRDC); Friant Division water agencies; and the U.S. government.

Restoration of flows and fishery habitat, with an objective of restoring a salmon fishery between Friant Dam and the Merced River, are program objectives along with a co-equal Water Management Goal. Under the Settlement, the Settling Parties agreed to strive to return all or much of the water given up by Friant districts for river restoration.

The Bureau's Regional Director, Donald Glaser, said Forsythe "has been involved with San Joaquin River issues for many years and has gained the respect of the organizations and individuals who are working together to implement this important restoration program."

COORDINATION

Forsythe is to coordinate with:

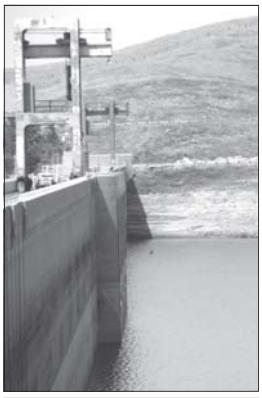
- The other SJRRP Implementing Agencies (U.S. Fish and Wildlife Service, National Marine Fisheries Service, California Department of Water Resources, California Department of Fish and Game).
- The Settling Parties (NRDC and Friant Water Authority).
- The Restoration Administrator (selected jointly by NRDC and FWA to provide recommendations regarding specific elements of the Settlement).
- Downstream landowners and water districts, and many other entities.

BACKGROUND

Forsythe has managed various National Environmental Policy Act, California Environmental Quality Act, water rights and restoration projects in both the public and private sectors.

She began her federal career with Reclamation in 2009 on the SJRRP staff. Forsythe led the program's interim flow activities and three on-going site-specific channel and structural improvements projects, oversaw the program's budget and schedule, and helped establish and implement SJRRP policies and direction. Prior to joining the Mid-Pacific Region, she was a project manager with CH_2M Hill.

Forsythe holds Bachelor of Science degrees in Environmental Studies and Hydrologic Sciences from the University of California, Santa Barbara.



Friant Water Authority

Millerton Lake's level, which looked low in mid-April, has dropped even more since then.

Runoff: Millerton Storage Makes Room For Snowmelt

Continued from front page

day for well over a month, reservoir storage has continued to decline. Flood releases into the river, which briefly were near the channel capacity of 8,000 c.f.s., have been reduced as demands have increased and reservoir storage has dropped. Nearly all of that flood release water has flowed to the ocean.

Friant districts were slow to step up water orders, for irrigation or groundwater recharge purposes, because all local streams have also been handling flood release flows. Until recently, spring rains had made many fields too wet for cultural work or irrigation.

RECOVERED WATER

A help in creating demand in early April was a decision by the U.S. Bureau of Reclamation to make available 460,000 acre-feet of Recovered Water Account (RWA) water credits for Friant Division long-term contractors under the San Joaquin River Restoration Program's Water Management Goal.

RWA water is available at a cost of $10 per acre-foot to all Friant Division long-term contractors who experience a reduction in water deliveries due to the flows called for in the Settlement to restore the San Joaquin River.

"These advanced RWA water credits are being made available to take advantage of this year's unusually wet hydrologic conditions for the purpose of reducing or avoiding future water supply impacts," a Bureau statement said. "The additional 460,000 acre-feet of RWA water credits is based on projections of anticipated future water supply impacts as a direct result of the flows called for in the Settlement."

FULL SUPPLY FOR NOW

In addition, the current Friant "uncontrolled season" water supply conditions – featuring full supplies of Class 1 and Class 2 water – are to continue throughout May and possible into June, according to Michael Jackson, Reclamation's Area Director in Fresno.

Deliveries of "Section 215" (unstorable) water to non-Central Valley Project contractors will continue until demands fill the Madera and Friant-Kern canals, Bureau staff member Ed Salazar said. He explained that even with the big storage reduction, a huge snowpack remains and more water needs to be moved out of fairly small Millerton Lake.

The May 1 snow surveys of nine San Joaquin River watershed courses show snowpack water content that is 199% of the May 1 average, and 163% of what is considered normal for April 1, the date upon which snow conditions are assumed to peak.

San Joaquin River runoff is currently expected to be 164% of average in the April-through-July peak period, or 2,060,000 acre-feet.

Corps Faces Lawsuit Over Rules For Levees

At a time when one federal agency after another is striving for improved riparian and fishery habitats along and in California rivers, another agency is demanding that vegetation vanish from Central Valley levees.

The U.S. Army Corps of Engineers in 2007 began imposing a clear-off-the-levees policy across the nation.

Now, two environmental organizations have served notice they will sue the Corps for violating the Endangered Species Act (ESA).

The Sacramento *Bee* reported that the Corps' rules do not state implicitly that all trees and vegetation – except for grass – must be eliminated but such is the practical effect.

Should levee operators not comply and a damaging flood were to occur, federal aid would not be forthcoming.

The Corps has suspended the rules from taking effect within the Central Valley until 2012.

ALLEGATIONS

Friends of the River and Defenders of Wildlife plan to sue against the rules. They allege the Corps failed to consult as required with other federal agencies to ensure the rules would not cause environmental harm. Nor did the Corps study environmental consequences, as required by the ESA, the organizations say.



Friant Water Authority / J. Randall McFarland

As the flood release-swollen San Joaquin River flows by at Sand Slough, north of Dos Palos, Friant Water Authority Water Resources Manager Stephen Ottemoeller points to a map to show state Deputy Resources Secretary Jerry Meral key locations in the San Joaquin River Restoration Program between Friant Dam and Merced River.

Study: Restoration's Impacts

Continued from front page

successful reintroduction of salmon." The latter is currently scheduled to occur by the end of 2012.

The schedule and projects were included in the Settlement of 18-year litigation reached several years ago by the plaintiffs – an environmental coalition led by the Natural Resources Defense Council – on one hand and the U.S. government along with the FWA and many of its member Friant Division districts on the other.

The Bureau says it "will promptly initiate consultation with the parties to the [San Joaquin River] Settlement to develop a new schedule based upon the PEIS/R that assures implementation of the Restoration Program in a manner that addresses the requirements of the Settlement for expeditious action while meeting the requirements of the legislation to minimize impacts on third party interests."

FOUR HEARINGS IN MAY

Four public hearings and open houses of 2½ hours each have been scheduled in valley locations during May to explain the PEIS/R, which took three years to compile, as part of a 60-day public comment period. (*Please see story, lower left.*)

Federal and state officials say the joint document describes direct, indirect and cumulative impacts of implementing the SJRRP. Agencies involved include Reclamation, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the California Department of Fish and Game and DWR.

General Manager Ronald D. Jacobsma said the Friant Water Authority's first task is to coordinate review and comment responsibilities among Authority and member district staff members. Comments on the massive document are due June 21.

The PEIS/R is required under federal and state laws, and is considered crucial to implementing the comprehensive, long-term effort to restore flows to the San Joaquin River below Friant Dam to restore a self-sustaining Chinook salmon fishery in the river. The SJRRP is also to reduce or avoid adverse water supply impacts from restoration flows.

Four Hearings Set On Restoration's Environmental Plan

Four public hearings will be held from May 24-26 around the Central Valley as the U.S. Bureau of Reclamation and California Department of Water Resources solicit input on the San Joaquin River Restoration Program's newly released draft program environmental impact statement and environmental impact report.

Each public hearing will include an open house portion during which the Restoration Program staff will be available to talk with public. Formal public hearings will follow to gather comments.

The meetings will be held:

In Visalia

- Tuesday, May 24, 10 a.m. - 12:30 p.m., Lampliter Inn, 3300 West Mineral King Avenue.

In Fresno

- Tuesday, May 24, 6 p.m. - 8:30 p.m., Piccadilly Inn-University, 4961 North Cedar Avenue.

In Los Banos

- Wednesday, May 25, 6 p.m. - 8:30 p.m., Merced County Fairgrounds, 403 F Street.

In Sacramento

- Thursday, May 26, 1:30 p.m. - 4 p.m., Holiday Inn-Capitol Plaza, 300 J Street.

Meral: Visits River, Friant

Continued from front page

Bureau of Reclamation and Department of Water Resources in implementing river restoration, but most of what we'd hoped to see was under water from the flood releases," said Ronald D. Jacobsma, Friant Water Authority General Manager.

STORAGE NEED

The extremely soggy condition had an upside, Jacobsma added, including an opportunity to view local West Side seepage under levees and resulting field-flooding problems, caused by high groundwater, of the sort that have occurred during early San Joaquin River Restoration Program interim flows.

"It also gave us a great opportunity to show the need for more storage – on the surface and underground – to capture high runoff flows when they are occurring, reduce flooding threats and gain longer-lasting water supply benefits for the environment and Friant users who are providing the river restoration flows," he said.

Meral in the past has expressed reservations on the need for new surface water storage projects.

The San Joaquin River has one proposed new reservoir project – Temperance Flat in the upper end of the CVP's Millerton Lake, northeast of Fresno.

'MUCH IN TOUCH'

Jacobsma noted that Meral, who served as Department of Water Resources Deputy Director during Brown's first administration from 1975-83, is well known for his support and involvement in the environment and its issues.

"Jerry Meral is also very much in touch with the practical problems and real needs that California water providers have to deal with for their customers," Jacobsma said.

> **'He was keenly interested in everything we showed him and points of view we presented'**
> —RONALD D. JACOBSMA

"He was keenly interested in everything we showed him and points of view we presented on surface water storage development, infrastructure needs, Delta solutions and conveyance, groundwater issues and river restoration."

TULARE MEETING

During a luncheon meeting later in Tulare hosted by the Friant Water Authority and Tulare Irrigation District, Meral listened intently as directors and managers from several Friant Division contractors of Central Valley Project water spoke.

They outlined past and present programs, along with future plans and desires.

All of the projects they discussed have been aimed at further improving beneficial water delivery and on-farm use efficiency, and the region's already extensive system of groundwater storage and water banking.

DELTA OVERSIGHT

Meral is in charge of the Bay-Delta Conservation Program, which is charged with finding solutions to the Delta's many infrastructure, environmental, water quality and water supply problems.

Meral, former Planning and Conservation League Executive Director, is again on the front line in debate over whether to build alternative water conveyance through or around the Delta. Even while many in the environmental community were opposing such a plan, Meral pushed for the construction of a controversial Peripheral Canal that was ultimately defeated by California voters in November 1982.

A renewed plan is now focusing increasingly on development of a large tunnel to bypass the fragile Delta in order to move north state water to the CVP and state Water Project pumps near Tracy.



Friant Water Authority / J. Randall McFarland

Harvey Bailey, Friant Water Authority Chairman and Orange Cove Irrigation District President, explains the importance of San Joaquin River water delivered to Orange Cove growers and city residents through the Friant-Kern Canal (background). Fifty-five participants in the Water Education Foundation's San Joaquin Valley tour also visited Friant Dam, the San Joaquin River and many other valley water features April 12-15.

FRIANT WATER AUTHORITY
SAN JOAQUIN RIVER AND ASSOCIATED WATER DATA

		THIS YEAR 07/27/11	LAST WEEK	LAST YEAR 07/28/10
RESERVOIR STORAGE (A.F.)	CAPACITY		STORAGE	
Southern California Edison:				
Vermillion (Edison)	125,000	122,485	123,001	122,126
Florence	64,400	63,750	61,717	58,539
Huntington	89,000	87,177	87,162	87,421
Shaver	135,300	134,260	131,614	122,624
Sub-total (Big Creek)	413,700	407,672	403,494	390,710
Mammoth Pool	122,000	120,892	120,981	116,420
Redinger	26,100	24,168	24,235	24,270
Sub-total Southern California Edison	561,800	552,732	548,710	531,400
Pacific Gas & Electric:				
Crane Valley (Bass Lake)	45,400	34,557	34,620	34,370
Kerckhoff	4,200	4,157	3,621	3,630
Sub-total P G & E	49,600	38,714	38,241	38,000
TOTAL UPSTREAM STORAGE	611,400	591,446	586,951	569,400
MILLERTON LAKE	520,500	498,774	515,245	440,617
TOTAL STORAGE	1,131,900	1,090,220	1,102,196	1,010,017
INFLOW & RELEASE DATA (C.F.S.)				
Millerton Releases:				
Madera Canal		1,149	1,048	894
Friant-Kern Canal		4,195	4,111	3,608
San Joaquin River		347	349	349
Spillway		0	0	0
Total Millerton Releases		5,691	5,508	4,851
Actual Millerton Inflow		5,252	4,698	2,330
Computed Natural River (@Friant)		4,626	5,233	1,377
SAN JOAQUIN RIVER (A.F.)				
This Month:				
Actual to-date		434,059	366,678	228,648
Forecasted		840,000	840,000	300,000
April/July Period:				
Actual to-date		2,199,963	2,132,582	1,520,936
Forecasted		2,240,000	2,240,000	1,550,000
Last Year Actual				1,535,227
Water Year:				
Actual to-date		3,081,730	3,014,349	1,951,497
Forecasted		3,313,000	3,313,000	2,081,000
Last Year Actual				2,028,707
ESTIMATED WATER YET TO BE DELIVERED (A.F.)				
Contract Year Ending February 28		921,397*	1,046,245*	599,202

*Figure is based on 100% Class I, 20% Class II, plus estimated carry over of 63,390 AF, minus District usage and SJR releases.

Not included in estimated water to be delivered is the current uncontrolled season water now available.

FRIANT WATER AUTHORITY
SAN JOAQUIN RIVER AND ASSOCIATED WATER DATA

PRECIPITATION DATA

REPORTING STATIONS:	AVERAGE (INCHES)	THIS YEAR 07/27/11 ACCUMULATIVE TO DATE (INCHES/PERCENT AVG)	LAST YEAR 07/28/10 ACCUMULATIVE TO DATE (INCHES/PERCENT AVG)
HUNTINGTON			
This Month	0.32	0.20 / 63	0.04 / 13
Seasonal Average*	0.32	0.20 / 63	0.04 / 13
Annual Average	42.73	0.20 / 0	0.04 / 0
CRANE VALLEY			
This Month	0.06	0.00 / 0	0.00 / 0
Seasonal Average*	0.06	0.00 / 0	0.00 / 0
Annual Average	40.62	0.00 / 0	0.00 / 0
FRIANT			
This Month	0.01	0.00 / 0	0.00 / 0
Seasonal Average*	0.01	0.00 / 0	0.00 / 0
Annual Average	14.33	0.00 / 0	0.00 / 0

* Seasonal Average (July - June) is through the current month

MISC RIVER/RESERVOI	CAPACITY (A.F.)	STORAGE (A.F.)	RELEASE (C.F.S.)	INFLOW (C.F.S.)
Chowchilla/Buchanan	150,000	136,746	170	37
Fresno/Hidden	90,000	49,798	285	0
Kings/Pine Flat	1,000,000	938,709	7,141	4,561
Kaweah/Terminus	185,000	149,942	2,225	859
Tule/Success	82,314	40,255	117	89
Kern/Isabella	570,000	339,597	2,464	1,848

FRIANT WATER AUTHORITY
SAN JOAQUIN RIVER AND ASSOCIATED WATER DATA

CVP/SWP SAN LUIS OPERATIONS

PUMPING INSTANTANEOUS	MAX. FLOWRATE (C.F.S.)	THIS YEAR 07/27/11	LAST WEEK FLOWRATE (C.F.S.)	LAST YEAR 07/28/10 Average
Tracy P.P.	4,600	4,191	4,067	4,248
Banks P.P.	10,000	7,095	7,112	6,010
MONTH TO DATE				
Tracy P.P.		215,157	157,173	220,421
Banks P.P.		362,659	263,267	281,208
SEASON TO DATE (Since October 1)				
Tracy P.P.		1,996,117	1,938,133	1,585,260
Banks P.P.		3,049,675	2,950,283	1,638,198
SAN LUIS RESERVOIR	CAPACITY (A.F.)		(A.F.)	
Federal	980,000	793,658	833,952	421,040
State	1,060,000	930,693	930,439	517,125
Total	2,040,000	1,724,351	1,764,391	938,165
SAN LUIS RESERVOIR		NET DAILY STORAGE CHANGE		
Federal		(8,556)	(4,697)	(8,114)
State		261	94	(1,701)

SACRAMENTO-SAN JOAQUIN DELTA FLOW INDICES

	FLOWRATE (C.F.S.)
Delta Outflow Index	8,598
Sacramento River @ Freeport	16,455
San Joaquin River @ Vernalis	5,449
Total Delta Inflow	24,476

FRIANT WATER AUTHORITY
SAN JOAQUIN RIVER AND ASSOCIATED WATER DATA

CIMIS EVAPOTRANSPIRATION RATES

REPORTING STATION #	REPORTING STATION	YESTERDAY 7/26/2011 (Inches)	TOTAL PAST 7 DAYS (Inches)	NORMAL PAST 7 DAYS (Inches)	VARIANCE FROM NORMAL (%)	NORMAL NEXT 7 DAYS* (Inches)
5	Shafter/USDA	0.26	1.81	1.82	-1	1.78
15	Stratford	0.30	2.08	1.93	8	1.88
39	Parlier	0.25	1.78	1.77	1	1.71
80	Fresno State	0.28	2.01	1.91	5	1.87
86	Lindcove	0.26	1.83	1.80	2	1.75
125	Arvin-Edison	0.30	2.09	1.93	8	1.89
138	Famoso	0.26	1.83	1.94	-6	1.89
142	Orange Cove	0.29	2.10	1.93	9	1.88
145	Madera	0.28	1.99	2.14	-7	2.08
148	Merced	0.26	1.86	1.76	6	1.73
169	Porterville	0.25	1.83	1.86	-2	1.82
182	Delano	0.26	1.83	1.94	-6	1.89

FRIANT WATER AUTHORITY
SAN JOAQUIN RIVER AND ASSOCIATED WATER DATA

CROP COEFFICIENTS 27-Jul-11

Crop (Description)	Today	Avg. Prev. 7 Days	Avg. Next 7 Days
Alfalfa (average)	0.95	0.95	0.95
Almonds (Feb. 20 leafout, Nov. 15 leafdrop)	0.96	0.97	0.95
Almonds (Mar. 1 leafout, Nov. 15 leafdrop)	0.97	0.97	0.96
Beans (Apr. 1 plant date, Aug. 1 harvest)	0.42	0.53	0.25
Beans (May 1 plant date, Aug. 15 harvest)	0.90	1.03	0.77
Beans (Jun. 1 plant date, Sep. 15 harvest)	1.09	1.08	1.09
Citrus (year round)	0.65	0.65	0.65
Corn (Apr. 15 plant date, Sep. 15 harvest)	1.10	1.10	1.10
Cotton (Apr. 1 plant date, Sep. 20 defoliate)	1.25	1.25	1.24
Cotton (Apr. 15 plant date, Oct. 1 defoliate)	1.27	1.28	1.26
Cotton (May 1 plant date, Oct. 1 defoliate)	1.28	1.29	1.27
Wheat, Oats, Barley (Dec. 1 plant date, Jun. 1 harvest)	0.00	0.00	0.00
Grapes, Raisin (Mar. 15 leafout, Oct. 15 leafdrop)	0.63	0.63	0.63
Grapes, Table (Mar. 15 leafout, Oct. 15 leafdrop)	0.80	0.80	0.80
Kiwi (Mar. 15 leafout, Nov. 1 leafdrop)	1.00	1.00	1.00
Melons (Apr. 1 plant date, Jul. 15 harvest)	0.00	0.00	0.00
Melons (May 1 plant date, Aug. 15 harvest)	0.90	0.90	0.73
Melons (Jun. 1 plant date, Sep. 20 harvest)	0.56	0.47	0.66
Melons (Jul. 1 plant date, Oct. 10 harvest)	0.16	0.16	0.16
Olives (year round)	0.75	0.75	0.75
Pasture Grass	0.84	0.83	0.85
Pistachio (Apr. 1 leafout, Nov. 15 leafdrop)	1.19	1.19	1.19
Safflower (Mar. 1 plant date, Aug. 1 harvest)	0.34	0.58	0.11
Low Chilling Stone Fruit (Feb. 15 leafout, Dec. 1 leafdrop)	0.95	0.95	0.95
Stone Fruit (Mar.1 leafout, Nov. 15 leafdrop)			
[Peach, Nectarine, Plum, Apricot]	0.95	0.95	0.95
Late Stone Fruit (Mar. 16 leafout, Nov. 1 leafdrop)	0.95	0.95	0.95
Soft Fruit (Apr. 1 leafout, Nov. 15 leafdrop)			
[Apple, Pear]	0.96	0.96	0.96
Tomato (Mar. 1 plant date, Jul. 20 harvest)	0.00	0.10	0.00
Tomato (Apr. 1 plant date, July 30 harvest)	0.76	0.88	0.20
Walnut, Early (Mar. 15 leafout, Nov. 1 leafdrop)	1.15	1.15	1.15
Walnut, Late (Apr. 1 leafout, Nov. 1 leafdrop)	1.15	1.15	1.15

NOTE: *This information is a reproduction of information compiled by Kings River Conservation District. This information is provided as a general guideline and may not exactly be reflective of all locations or varieties.*

Appendix C

Outreach and Communication

SSJMUD

Southern San Joaquin Municipal Utility District

BOARD OF DIRECTORS

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Vice President

James Regan

George Zaninovich

Brandon Morris

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Roland Gross
Manager/Secretary

Samia Shamrouhk
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John Bonkosky
Field Superintendent

ADDRESS

P. O. Box 279
Delano, CA 93216

PH: 661-725-0610
Fax: 661-725-2110

Email
Roland@ssjmud.org

October 2, 2019

Sustainable Groundwater Management Act Stakeholder Workshop

Topic: SGMA – SSJMUD Management Area Plan under the Kern Groundwater Authority's (KGA) Groundwater Sustainability Plan (GSP)

When: Tuesday, October 8, 2019 @ 10:00 am – 12:00 pm

Where: Hyatt Place Delano, 1200 Garzoli Ave, Delano CA 93215

You are invited by the Southern San Joaquin Municipal Utility District (SSJMUD) to attend a SGMA workshop at the Hyatt Place Delano (1200 Garzoli Ave, Delano CA 93215) on Tuesday, October 8, 2019 from 10:00 am to 12:00 pm.

We will provide an update on the district's development of a Management Area Plan under the KGA's GSP, including the development of Sustainability Management Criteria for groundwater conditions and proposed Projects and Management Actions to be undertaken by the District during the implementation of SGMA.

If you are planning to attend this workshop, please RSVP to Grace Martin (GEI Consultants) at 661.716.3010 or gemartin@geiconsultants.com by Friday October 4, 2019 so we can get a head count to ensure adequate seating.

Thank you and we look forward to seeing you at the workshop.

Regards,

Roland Gross
Southern San Joaquin M.U.D.

SSJMUD SGMA Stakeholder Workshop

Oct. 8, 2019 10:00 - 12:00

Name : Company	Phone Number	E-Mail
Bert Fugate Farming.	805-922-6646	Bert@fugateco.com
Robert Quinn / Ronald B. Quinn & Co	559-799-3701	RQuinnco@yahoo.com
Steve Spurlock C.V.C Ranches	555-798-1100	Tulare Butte Kern
Ari Cimenthal Ag-Wise	661-325-1567	ariadne@ag-wiseinc.com
John LEBOEUF Mulder Farms	661-204-6262	John.Leboeuf@mulderfarms.com
Bill Mueller Wildcat Dist, LLC	559-217-5565	BILL@WILDCAT84.com
Francisco Parra Malley Farms	559-288-9597	fparra@malleyfarms.com
Joe Bresson Hronis, Inc.	661-378-0880	joe.bresson@hronis.net
Christian Curtis Legal	661 979-0779	christian@curtislegalgroup.com
Josh Newfield Newfield Ag	661 201-9218	josh@newfieldag.com
Jeff Looker / Sunview	661 792-3151	jlooker@sunviewvineyards.com
Brian Huens / Anderson Farms	661-805-4244	bhuens@outlook.com
Ella Kelsey / Kingsburg Citrus	661-792-3604	kcc@atg.internet.com
Erin Kendall	978-8613	

Southern San Joaquin Municipal Utility District Management Area Plan

Kern Groundwater Authority
Groundwater Sustainability Plan

Tuesday, October 8, 2019

GEI Consultants

Management Area Plan

- The District's Plan incorporates the cities of Delano and McFarland
- Includes undistricted lands adjacent to the District that signed agreements for coverage under the Plan
- Part of Kern Groundwater Authority Groundwater Sustainability Plan (KGA GSP)

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Management Area Plan

- Includes:
  - Introduction
  - Basin Setting
  - Sustainable Management Criteria
  - Monitoring Network
  - Projects and Management Actions

GEI Consultants

Introduction

- Section includes:
  - Contact Info
  - General Description of the Plan Area
    - Existing land use
    - Sources of water
  - Existing Plans
    - Agricultural Water Management Plan
    - Urban Water Management Plan for Delano
    - General Plans for the Cities and Kern County

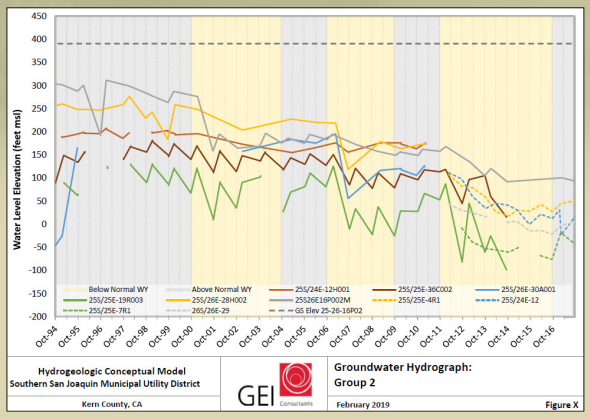
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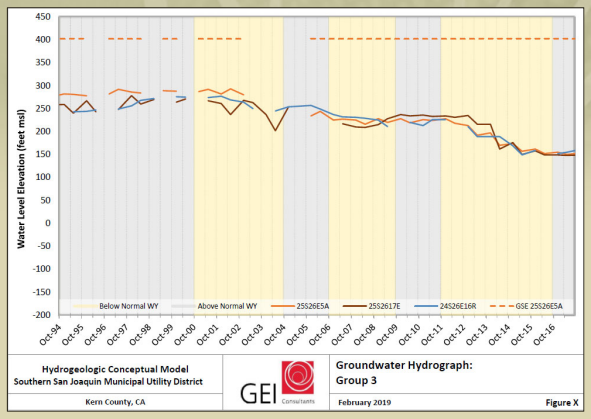
Basin Setting

- Consistent with KGA GSP Basin Setting Chapter
- Includes:
  - Hydrogeologic Conceptual Model
    - Hydrogeologic conditions of the Plan area
  - Existing conditions in the Plan area
    - Sustainability Indicators
  - Water Budget
    - Historical Budget
      - average conditions from 1993-2015
    - Current Water Budget
      - changes within the district post-2015
    - Projected Water Budget
      - estimated changes in demand and supply for 2030 and 2070 conditions

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Existing Conditions





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Historical Water Budget

- Demand
  - Agricultural Demand
    - Based on ITRC ET data from 1993 through 2015
    - ET for undeveloped land and land in urban use not considered part of ag demand
  - Urban Demand
    - Based on a combination of data from the cities General Plans, Delano's UWMP, and actual pumping data available from the cities of Delano and McFarland
- Supply
  - CVP Supply, Delano WWTP Effluent, Precipitation, and Native Inflow
  - Through coordination with KGA agreed upon the following assumptions:
    - 0.42 AF/irrigated acre for precipitation
    - Range of Native Inflow of 0.15 AF/acre to 0.30 AF/acre for the gross acreage of the district

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Current Water Budget

- Demand
  - Agricultural Demand
    - Based on 2013 to 2015 data for irrigated lands
  - Urban Demand
    - Based on actual pumping data from 2013 to 2015 (no ET demand)
- Supply
  - CVP Supply, Delano WWTP Effluent, Precipitation, and Native Inflow
  - Through coordination with KGA agreed upon the following assumptions:
    - 0.42 AF/irrigated acre for precipitation
    - Range of Native Inflow of 0.15 AF/acre to 0.30 AF/acre for the gross acreage of the district

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Historical and Current Water Budget TAF

Water Year and Hydrologic Condition	Total Surface Inflow	Total Surface Outflow	Total Rainfall*	Total ET (ITRC)	Δ Storage (Irrigated Lands)	City of Delano Demand	City of McFarland Demand	City of Delano Recycled Water	Δ Storage (Irrigated Lands and City)	Native Inflow Range (0.15 AF/acre to 0.30 AF/acre)	Δ Storage with City and Native Inflow Range
Historical Data											
1993 to 2015	96.0	0.5	18.8	121.6	(7.2)	9.3	1.7	4.5	(13.7)	9.8 to 19.5	(4.0) to 5.7
Projected CVP											
2015.c (Current)	104.8	0	18.8	120.7	2.8	8.1	1.8	3.7	(3.4)	9.8 to 19.5	6.3 to 16.1

* Precipitation assumed to be 0.42 AF/irrigated acre

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Projected Water Budgets

- Represents estimated conditions at 2030 and 2070
- Components are adjusted to account for:
  - Projected CVP Supply
  - Land conversion from agricultural to urban use (through 2030)
  - Climate Change Factors used in the Subbasin groundwater model

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Projected Water Budget*
TAF

Water Year and Hydrologic Condition	Total Surface Inflow	Total Surface Outflow	Total Rainfall**	Total ET (ITRC)	Δ Storage (Irrigated Lands)	City of Delano Demand	City of McFarland Demand	City of Delano Recycled Water	Δ Storage (Irrigated Lands and City)	Native Inflow Range (0.15 AF/acre to 0.30 AF/acre)	Δ Storage with City and Native Inflow Range
Projected Kern River Supply											
2030.c	100.0	0	18.8	119.2	**(0.4)**	11.5	2.3	4.9	(11.9)	9.8 to 19.5	0.4 to 10.2
2070.c	90.8	0	18.6	125.0	**(15.6)**	21.5	3.6	12.6	(28.1)	9.8 to 19.5	(18.4) to (8.6)

*This is a BASELINE budget (no projects or management actions)
**Reflects assumed precipitation at 0.42 AF/irrigated acre, adjusted with climate change factors used in Subbasin model

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Sustainable Management Criteria

- Sustainability Goal and Undesirable Results
  - Defined at the Subbasin level
  - Adopted by KGA and the other GSAs in the Subbasin
  - Consistent with the Umbrella KGA GSP

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Sustainability Indicators

- Kern County Subbasin Sustainability Indicators :
  - Chronic lowering of groundwater levels
  - Reduction of groundwater storage
  - Degradation of groundwater quality
  - Land Subsidence
- Sustainability Indicators not of concern:
  - Seawater Intrusion
  - Depletion of interconnected surface water

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Sustainable Management Criteria

- Addresses four Sustainability Indicators
- Defines Undesirable Results
- Provide
  - Minimum Thresholds
  - Measurable Objectives
  - Interim Milestones

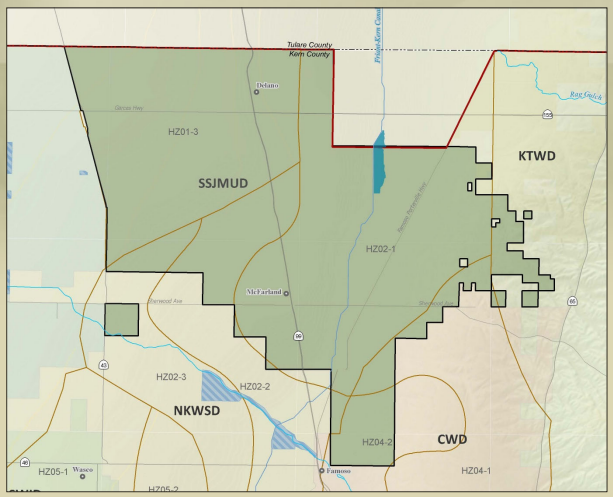
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Sustainable Management Criteria

- (Subbasin) Chronic Lowering of Groundwater Levels Undesirable Result Definition:
  - The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

    This is determined when the Minimum Threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each Management Area). Minimum Thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.

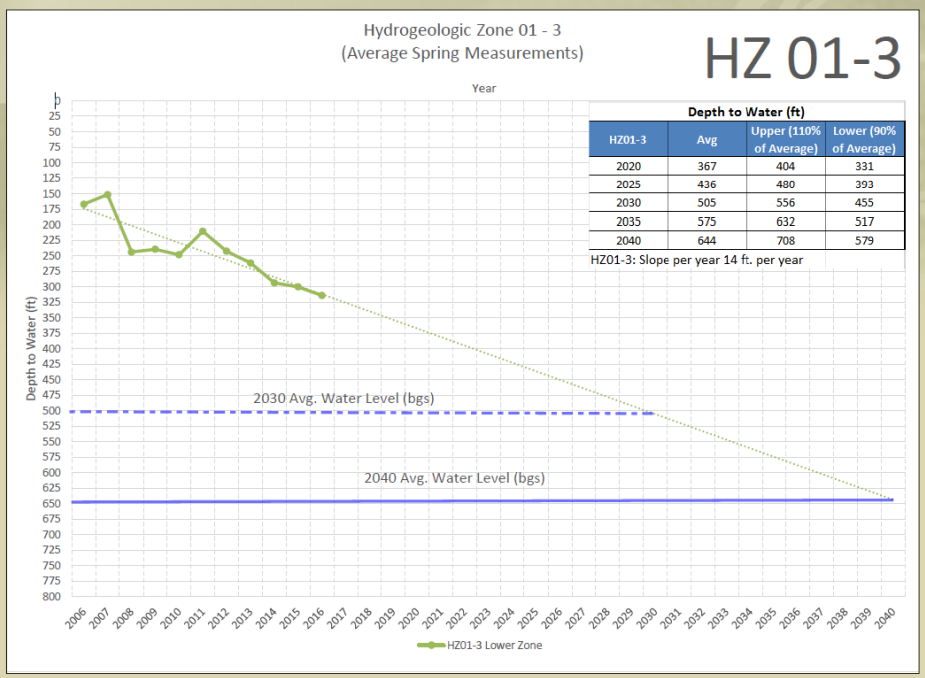
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The Hydrogeologic Zones (HZs) were established using the following data:

- Spring 2015 Groundwater Contours
- USGS Extents of the Corcoran Clay
- Hydrographs for the period from 2006 to 2016

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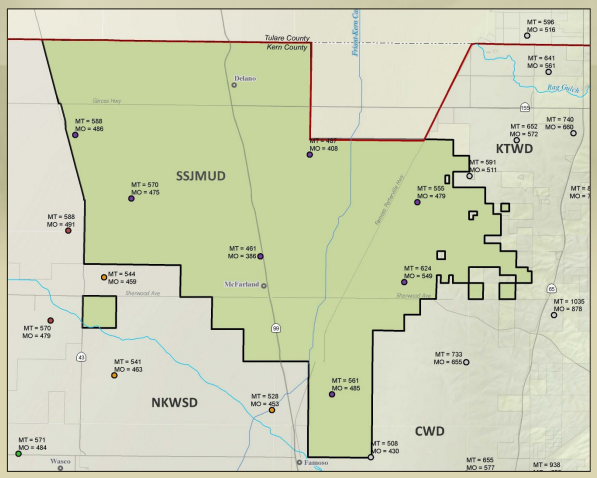


Depth to Water (ft)

HZ01-3	Avg	Upper (110% of Average)	Lower (90% of Average)
2020	367	404	331
2025	436	480	393
2030	505	556	455
2035	575	632	517
2040	644	708	579

HZ01-3: Slope per year 14 ft. per year

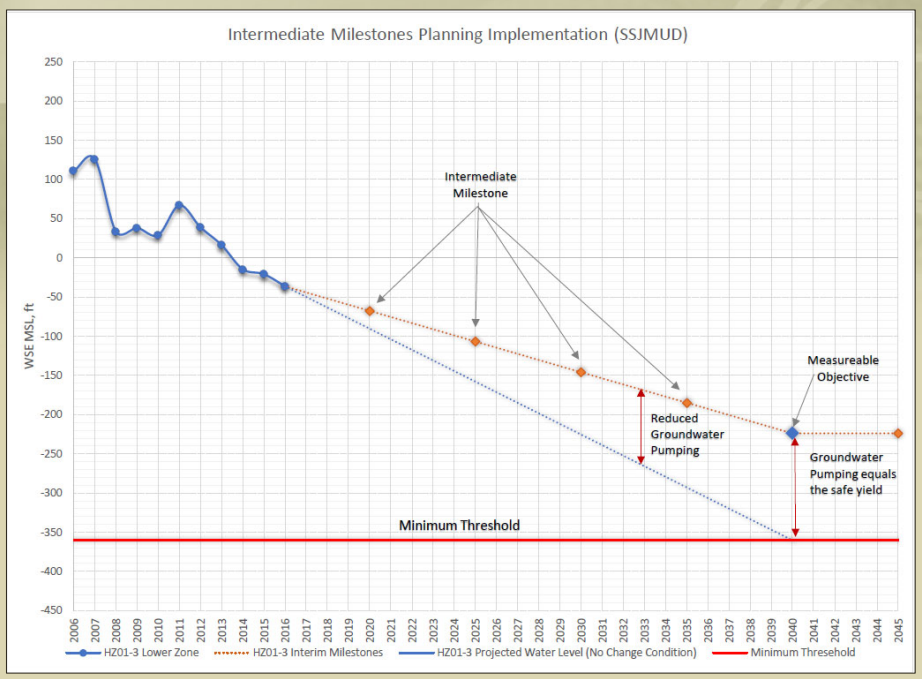
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The Minimum Thresholds (MTs) are set based on the projected 2040 GWLs at each Representative Monitoring Site.

The Measurable Objectives (MOs) are set at each Representative Monitoring Site, based on the projected 2030 GWLs.

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Sustainable Management Criteria

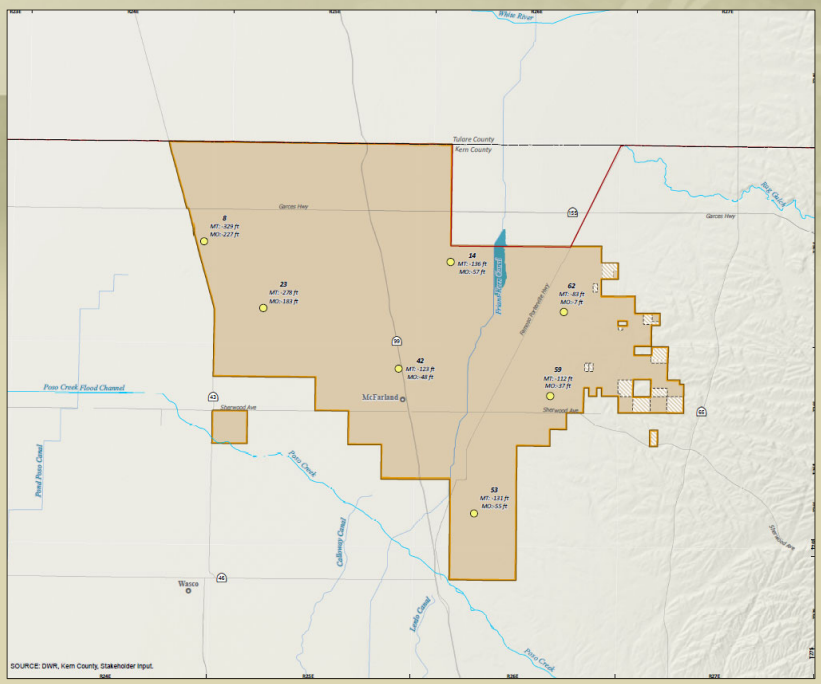
- Groundwater Levels are a proxy for
  - Change in Groundwater Storage
  - Degradation of Groundwater Quality
- Further data is required before setting numerical SMCs for Water Quality and Land Subsidence.
  - Qualitative minimum thresholds and measurable objectives

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Monitoring Network

- Representative monitoring sites for Sustainability Indicators
- Identifies
  - Existing Programs
  - Monitoring Sites
  - Data Gaps
    - Plan for how data gaps will be addressed during implementation of SGMA

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Projects & Management Actions

- Projects - "supply side" of sustainability
  - SSJMUD Projects includes
    - expansion of existing projects
    - development of new projects
- Management Actions -"demand side" of sustainability
  - addresses the data gaps identified in the Basin Setting and Monitoring Network sections

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Projects & Management Actions

- For each Project and Management Action, SGMA requires the identification of:
  - Permitting & regulatory process
  - Source & reliability of water
  - Costs & source of funding
  - CEQA/NEPA Considerations

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Projects

Project Name	Status	Water Savings or Supply Increase (AFY)
City of Delano Spreading Grounds	Initiated	500
In-District Spreading & Recovery Facility	Initiated	2,800
Cawelo Intertie	Conceptual	500
Schuster Intertie (Semitropic)	Conceptual	1,810
NKWSD Intertie	Initiated	4,280
SE Delano Spreading Grounds	Conceptual	2,640
Pond Spreading Grounds	Conceptual	1,840
	ESTIMATED TOTAL	**14,370**

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Management Actions

Management Action	Status	Demand Decrease (AFY)
In-Lieu Recharge Incentive Program	Planning	1,800
Ag to Urban Land Conversion	Planning	1,750
Urban Water Conservation Program	Planning	4,000
	TOTAL DEMAND DECREASE	**7,550**

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Schedule for GSP Completion

Milestone	Start Date	End Date
SSJMUD Board Review and Approval of GSP	August 21	August 21
KGA Board Approval of Chapter GSPs	August 28	August 28
Public Review (90 Days)	**August 30**	**November 29**
Response to Public Comments	November 29	December 20
Preparation of Final GSP	December 20	January 17

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Questions?

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Chapter Groundwater Sustainable Plan (GSP) for Kern Groundwater Authority

Southern San Joaquin Municipal Utility District

Wednesday, July 10, 2019

GEI Consultants

Chapter GSP Development

- The following sections have been reviewed by the district managers and revised by GEI in preparation for submittal to the KGA:
  - Introduction
  - Basin Setting
  - Sustainability Goal and Undesirable Results
  - Monitoring Network
  - Sustainable Management Criteria
  - Projects & Management Actions
  - Communication & Outreach

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Introduction

- The introduction includes the following information:
  - Contact Info for the Districts
  - A general description of the area covered by the chapter, including existing land use, sources of water, and plans already implemented by the districts and municipalities covered in the Chapter GSP
    - AWMP for SSJMUD
    - UWMP for Delano
    - General Plans for the Delano, McFarland, and Kern County

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Basin Setting

- Hydrogeologic Conceptual Model
  - Describes existing conditions in the SSJMUD plan area, including the Sustainability Indicators that must be addressed in the GSP.
  - Consistent with the Umbrella KGA Basin Setting chapter.
- Historical & Projected Water Budgets for SSJMUD.
  - Historical Budget uses average conditions over the period from 1993-2015.
  - Projected Budgets account for estimated changes in supply and demand at 2030 and 2070.

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Basin Setting

Water Year	Irrigation Demand (TAF)	Delano Urban Demand (TAF)	McFarland Urban Demand (TAF)	Delano WWTP Effluent (TAF)	Imported Supply (TAF)	Native Supply* (TAF)	Change in Storage (TAF)
Historic Avg	120.7	9.3	1.7	4.5	104.8	19.4	-3.0
Current	120.7	8.1	1.8	3.7	108.9	19.4	1.4
2030	120.7	11.5	2.3	4.9	116.3	19.4	6.1
2040	120.7	16.3	2.9	6.8	118.1	19.4	4.4

* Reflects a Native Yield Range of 0.15 AF/ac – 0.30 AF/ac (precipitation + subsurface flow)

The Native Yield numbers are subject to change, based on the coordination discussions with the KGA managers.

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Sustainability Goal & Undesirable Results

- Defined at the subbasin level and adopted by KGA and the other GSAs in the subbasin.
  - This section of the Chapter GSP is consistent with the Umbrella KGA document.
  - Four of the Six Sustainability Indicators defined by SGMA are addressed in the Undesirable Results.
    - Declining Groundwater Levels
    - Change in Groundwater Storage
    - Degradation of Water Quality
    - Land Subsidence

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Monitoring Network & SMCs

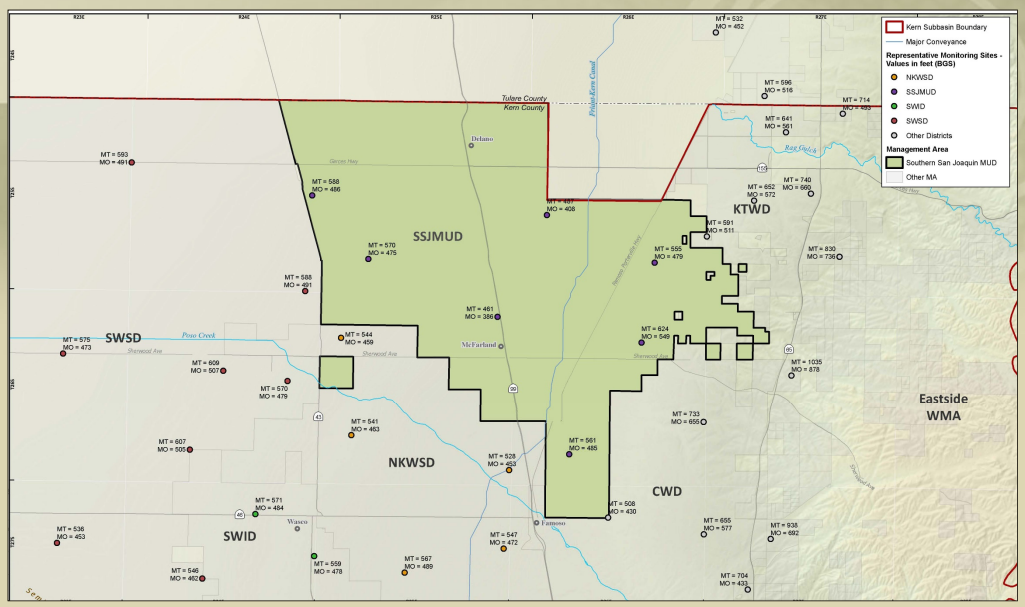
- The Monitoring Network section identifies the existing programs and monitoring sites for the district.
  - Also identifies data gaps and provides a plan for how the data gaps will be addressed during the implementation of SGMA.
  - Representative Monitoring Sites within the districts are identified for the Sustainability Indicators addressed in the Undesirable Results section of the Chapter GSP.

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Monitoring Network & SMCs

- The SMCs section addresses the four Sustainability Indicators for which Undesirable Results were defined.
  - Provides Minimum Thresholds, Measurable Objectives, and Interim Milestones for Groundwater Levels at the Representative Monitoring Sites identified in the Monitoring Network section.
  - GWLs are a proxy for Change in Groundwater Storage.
  - Further data is required before setting numerical SMCs for Water Quality and Land Subsidence. Qualitative thresholds and objectives have been described for the 2020 Plans.

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Projects & Management Actions

- Projects address the "supply side" of sustainability for the district.
  - Describes both expansion of existing projects and the development of new projects.
  - For each project, SGMA requires that we identify:
    - The permitting & regulatory process
    - Source & reliability of water
    - Costs & source of funding
    - CEQA/NEPA Considerations
  - The ability to use Projects to reach/maintain sustainability is dependent on the availability of water to supply those Projects.

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Projects & Management Actions

Project Name	Status	Capacity Increase (AFY)
In-District Spreading & Recovery Facility	Planning	2,800
Schuster Intertie (SWSD)	Conceptual	1,811
Cawelo Intertie	Conceptual	5,00
NKWSD 9-28 Intertie	Planning	4,300
Southeast Delano Spreading Grounds	Planning	2,640
City of Delano Spreading Grounds	Planning/Implementation	580
Pond Rd Spreading Grounds	Planning	1,840
In-District Recharge Basins	Planning	24,000
	TOTAL CAPACITY INCREASE	**38,470**

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Projects & Management Actions

- Management Actions address the "demand side" of sustainability and/or address the data gaps identified in the Basin Setting and Monitoring Network sections.
  - For each Management Action, SGMA requires that we identify:
    - The permitting & regulatory process
    - Source & reliability of water
    - Costs & source of funding
    - CEQA/NEPA Considerations
  - In the absence of Projects, Management Actions are a way for the district to reach/maintain sustainability.

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Projects & Management Actions

Management Action	Status	Demand Decrease (AFY)
Surface Water First Program	Conceptual	1,800
On-Farm Recharge Program	Conceptual	1,200
Ag to Urban Land Conversion	Planning	1,750
Urban Water Conservation Program	Planning	3,600
	TOTAL DEMAND DECREASE	**8,350**

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Communication & Outreach

- July 30, 2019
  - Completion of Internal Draft Chapter
  - Submittal of Draft Chapter to KGA for preparation of Admin Draft (internal)
- Week of August 5, 2019
  - SWSD Committee Review of SWSD Chapter and KGA Umbrella GSP
- August 14, 2019
  - SWSD Board approval of Draft Chapter for public review
- August 28, 2019
  - KGA Approval and release of Draft Kern Groundwater Authority GSP
- August 28 to November 29
  - District and KGA public review period
  - Two public workshops during review period

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Questions?

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SSJMUD
SGMA OPEN HOUSE MAY 14, 2019

Name	Email
Geoff Vanden Heuvel Milk Producers Council	geoff@milkproducers.org
Juan Ramos	Juanr@2bfarminginc.com
Jose A Gomez R	Pepe@2bfarminginc.com
BEN KING KING GOLDEN STATE VEGETABLES	BKing@pacgoldveg.com
Mohammad Yaghmour	mayaghmour@ucanr.edu
Reilly Hossner	reilly@bachandassociates.com
Mark Sherry	msherry@farmmanagementservices.com
Ken H. Stephens	

SSJMUD
SGMA OPEN HOUSE MAY 14, 2019

Name	Email
JEFF LOOKER	jlooker@sunviewvineyards.com

SSJMUD

Southern San Joaquin Municipal Utility District

BOARD OF DIRECTORS

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President

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John Bonkosky
Field Superintendent

ADDRESS

P. O. Box 279
Delano, CA 93216

PH: 661-725-0610
Fax: 661-725-2110

Email
Roland@ssjmud.org

April 10, 2019

Sustainable Groundwater Management Act Stakeholder Workshop

Topic: SGMA – Sustainable Management Criteria and Minimum Thresholds

When: Monday, April 29, 2019 @ 10:00 am – 12:00 pm

Where: Hyatt Place Delano, 1200 Garzoli Ave, Delano CA 93215

You are invited by the Southern San Joaquin Municipal Utility District (SSJMUD) to attend a SGMA workshop at the Hyatt Place Delano (1200 Garzoli Ave, Delano CA 93215) on Monday, April 29, 2019 from 10:00 am to 12:00 pm.

We will provide an update on the district's development of a Groundwater Sustainability Plan and the development of Sustainability Management Criteria, including Minimum Thresholds for groundwater conditions.

If you are planning to attend this workshop, please RSVP to Grace Martin (GEI Consultants) at 661.716.3010 or gemartin@geiconsultants.com by Friday April 26th, 2019 so we can get a head count to ensure adequate seating.

Thank you and we look forward to seeing you at the workshop.

Regards,

Roland Gross
Southern San Joaquin M.U.D.

SSJMUD Landowner Meeting Sign-In

Name	Email
JEFF LOOKER	jlooker@sunviewvineyards.com
RAPHAEL TERRA	rterra@sunpacific.com
Doug Carter	dougcarter@valleycoastal.com
SANTOS Montemayor	montemayor.flc@aol.com
JUVENAL MONTEMAYOR	661-201-4728
Jessie Rodriguez LA Jolla	Jessie@La Jollafarming.com
Juvenal Montemayor JR	Juvenal@laJollafarming.com
Clinton Shick	ccshick@gmail.com
BRUCE KERSEY	KCR@ATGINTERNET.com

SSJMUD Landowner Meeting Sign-In

Name	Email
Ron Fanucchi	rfanucchi@bak.rr.com
Craig Wilson	cwilson@cityofdelano.org
Matt Billings	matt@billingsranches.com
Brent Mulder	brentm@billingsranches.com
Christian Curtelegue	christian@curteleguefarms.com
John J. Lee	
BEN KING	bking@pacgoldag.com
John LEBOEUF	John.Leboeuf@mungerfarms.com
Pres BRITTIAN	pres@prh2o.com.
Luis Katsuragama	Jasmine Vinegrads.
Julio Gonzalez	same ↑
TIM GOBLER	WONDERFUL

SSJMUD Landowner Meeting Sign-In

Name	Email

SSJMUD Landowner Meeting Sign-In

Name	Email
B. Morris	brandon@bdmorrisfarms.com
Joe Bresson	joe.bresson@hronis.net
Sam Etchegary	sam@etchegaryfarms.com
Frank-Arnold	DBJ.farms@nbc
Brian Huens	bhuens@outlook.com
Julio Ramos	julio@ZBFarmingINC.com
Juan Ramos	juanr@ZBFarming inc.com
Roman Dowling	rdowling@cityofdelano.org
Joseph Schechter	JSchechter@sunviewvineyards.com
Babgen Esmailian	babken2ar@yahoo.com
ANDRES HERRERA	ANDRES@ZBFARMINGINC.COM
Kevin Layne	kevin.layne@farmcreditwest.com
David Snell	dsnell59@hotmail.com
Ella Kelsey	her@atginternet.com

Sustainable Groundwater Management Act (SGMA) Stakeholder Outreach

Southern San Joaquin Municipal Utility District

12000 Garzoli Ave – Delano, CA

Monday, April 29, 2019

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Sustainable Groundwater Management Act

- State Legislation passed in **September 2014**, effective **January 2015**
- Provides tools and authorities to Groundwater Sustainability Agencies to manage groundwater (Semitropic is a GSA)
- Requires a Groundwater Sustainability Plan in January 2020
- Requires groundwater basins to be managed "**sustainably**" by 2040

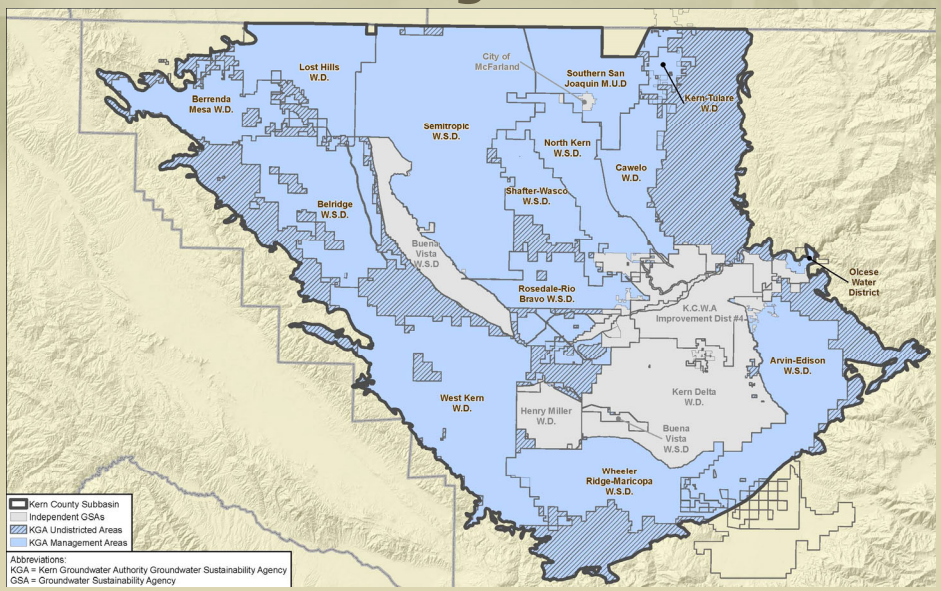
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Who is Doing What in Kern Basin?



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Who is Doing What in Kern Basin?



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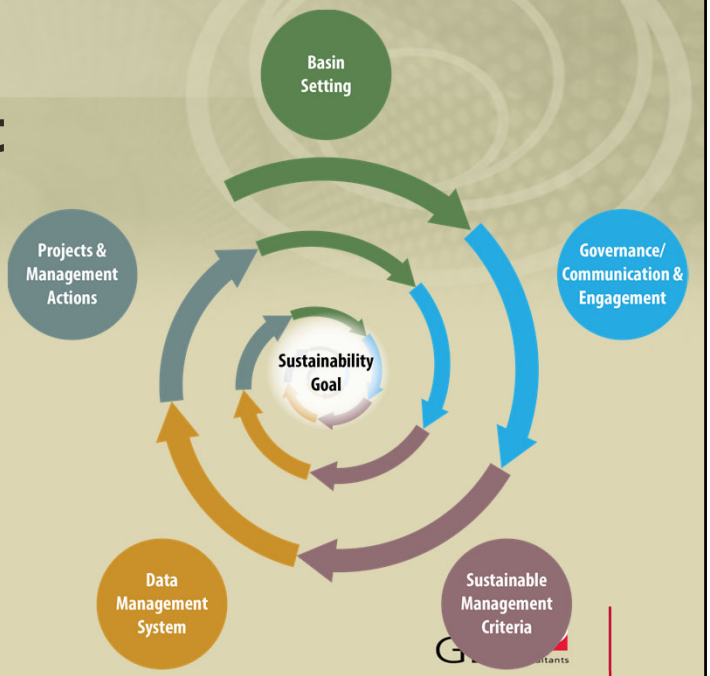
Who Is Doing What in the Kern Basin?

- Kern Groundwater Authority
  - Developing Umbrella GSP for all members
  - Developing guidance for development of "Chapter GSPs"
  - Ensuring Coordination between KGA members and other GSAs (Kern River GSA)
  - Point of Contact to DWR for GSP submittal, updates and annual reporting.

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SSJMUD GSP Development

- Communication & Engagement
  - *Reaching out to local landowners and stakeholders*
- Sustainable Management Criteria
  - *Establishing target groundwater levels*
- Project and Management Actions
  - *How the GSA can mitigate reduced groundwater pumping*
- Prepare a GSP
  - *Consistent with KGA Umbrella GSP*



Communication and Engagement



- Identify stakeholders
  - *Anyone affected/impacted by groundwater in and around basin*
  - *Beneficial uses and users*
  - *Interested parties within and around basin*
  - *Keep landowners/stakeholders informed*
  - *Seek input on key SGMA elements:*
    - Minimum Thresholds and Measurable Objectives
    - Projects and Management Actions
- Stakeholder Communication & Engagement
  - *SSJMUD Board Meetings*
    - 2nd Wednesday of the Month
  - *Landowner Meetings*
  - *KGA Meetings*

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Communication and Engagement



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Sustainable Management Criteria



- Identify which of the six Sustainability Indicators apply within the Basin and the Shafter-Wasco Management Areas, now or in the future.
- Define preliminary definitions for:
  - *Undesirable Results*
    Conditions you don't want to see in the groundwater basin
  - *Minimum Thresholds*
    The level that you never want to go below or exceed
  - *Measurable Objectives*
    Where you want to be operating most of the time

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Sustainable Management Criteria



- Undesirable Results
  - *These have been defined at the subbasin level and adopted at by the KGA.*
  - *The occurrence of an Undesirable Result indicates that the subbasin is not being managed sustainably*
  - *Triggered by the violation of Minimum Thresholds in a significant portion of the subbasin*

Chronic Lowering of Water Levels
Groundwater Storage
Degraded Groundwater Quality Trends
Land Subsidence Trends
Surface Water Depletion
Seawater Intrusion

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Sustainable Management Criteria



Chronic Lowering of Water Levels

The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users

This is determined when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent Management Areas that represent at least 15% of the subbasin or greater than 30% of the subbasin (as measured by each Management Area).

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Sustainable Management Criteria



Groundwater Storage

The point at which significant and unreasonable impacts, as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended drought period. (10-years?).

This is determined when the volume of storage (above the groundwater level minimum thresholds) is depleted to an elevation lower than the groundwater level minimum threshold in at least three (3) adjacent Management Areas that represent at least 15% of the subbasin or greater than 30% of the subbasin (as measured by each Management Area).

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Sustainable Management Criteria



Degraded Groundwater Quality Trends

The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

This is determined when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the designated monitoring points within the basin.

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Sustainable Management Criteria



Land Subsidence Trends

The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure.

This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.

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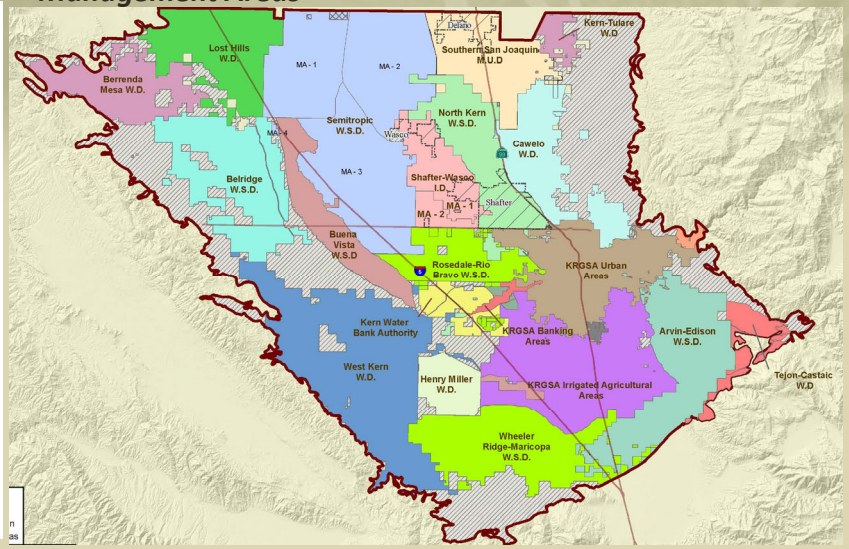
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Sustainable Management Criteria

Sustainable Management Criteria



Management Areas

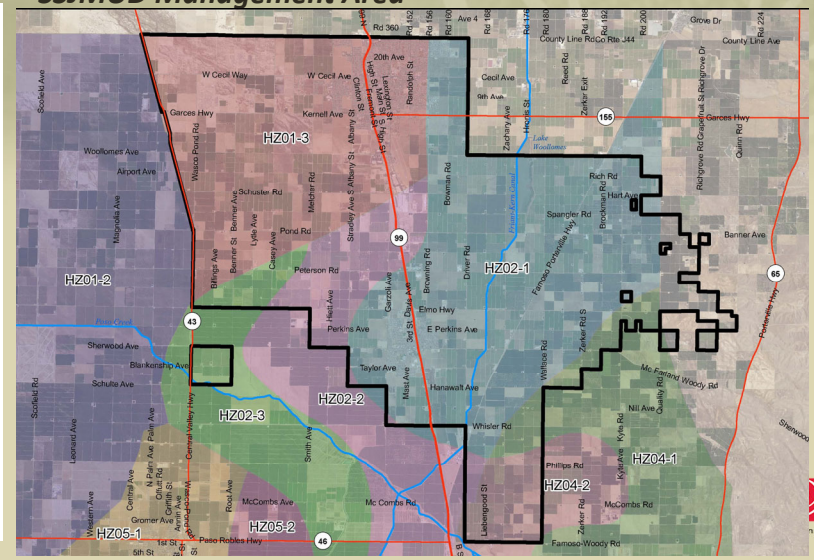


Sustainable Management Criteria

Sustainable Management Criteria



SSJMUD Management Area


HZ01-1
HZ01-2
HZ01-3
HZ02-1
HZ02-2
HZ02-3
HZ04-1
HZ04-2
HZ05-1
HZ05-2
Rd 360
W Cecil Way
W Cecil Ave
20th Ave
Cecil Ave
9th Ave
Garces Hwy
Kernell Ave
Woollomes Ave
Airport Ave
Wasco Pond Rd
Schuster Rd
Melcher Rd
Albany St
Pond Rd
Peterson Rd
Elmo Hwy
E Perkins Ave
Perkins Ave
Sherwood Ave
Blankenship Ave
Schulte Ave
Taylor Ave
Hanawalt Ave
Whisler Rd
Phillips Rd
McCombs Ave
Mc Combs Rd
Paso Robles Hwy
Famoso-Woody Rd
Mc Farland Woody Rd
Nill Ave
Banner Ave
Hart Ave
Rich Rd
Spangler Rd
Zachary Ave
Zerker Exit
Zerker Rd
Wilfong Rd
Driver Rd
Browning Rd
Bowman Rd
Reed Rd
Quinn Rd
Ridgmoor Rd
Casa Real St
Grove Dr
County Line Ave
County Line Rd
Co Rte J44
Lake Woollomes
Famoso Porterville Hwy
Porterville Hwy
Lakengood St
Kyles Rd
Quality Rd
Sherwood
Scofield Ave
Leonard Ave
Scofield Rd
Magnolia Ave
Bellinger Ave
Beamer St
Lyle Ave
Casey Ave
Smedley Ave
Albany St
Heid Ave
Carrotti Ave
3rd St
Davis Ave
Mast Ave
Smith Ave
Central Valley Hwy
Palm Ave
Oak Rd
Garrett St
Gromer Ave
Western Ave
Root Ave
Arbor Ave
Central Ave
1st St
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Sustainable Management Criteria



- Identify which of the six Sustainability Indicators apply within the Basin and SSJMUD's Management Areas, now or in the future.
- Define preliminary definitions for:
  - *Undesirable Results*
    Conditions you don't want to see in the groundwater basin

Chronic Lowering of Water Levels --- YES
Groundwater Storage --- YES
Degraded Groundwater Quality Trends --- NO
Land Subsidence Trends --- Maybe, need more data

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Sustainable Management Criteria



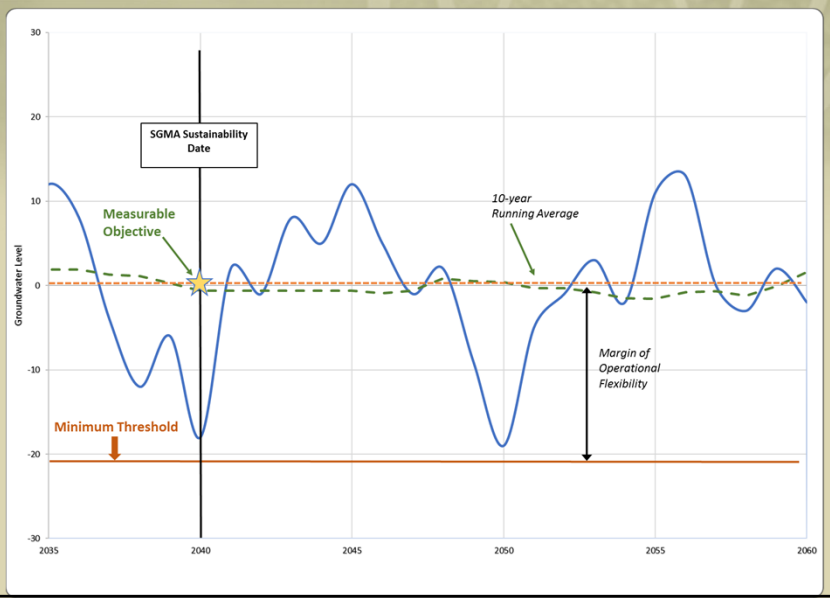
- Identify which of the six Sustainability Indicators apply within the Basin and SSJMUD's Management Areas, now or in the future.
- Define preliminary definitions for:
  - *Minimum Thresholds*
    The level that you never want to go below or exceed
  - *Measurable Objectives*
    Where you want to be operating most of the time

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Sustainable Management Criteria





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Sustainable Management Criteria



Minimum Threshold
- The level that you never want to go below or exceed
- Violation of Minimum Threshold is an indication that a Management Area is not being managed sustainably
- Local call to action

Starting Point:
- Project 2006 – 2016 groundwater conditions to 2040
- Period represents a "worse case" scenario (hydrology and regulatory)

Adjust the Starting Point (if needed)
- Assess impacts to beneficial uses
  - Wells (Ag, domestic and municipal)
  - Water quality
  - Subsidence
  - Storage

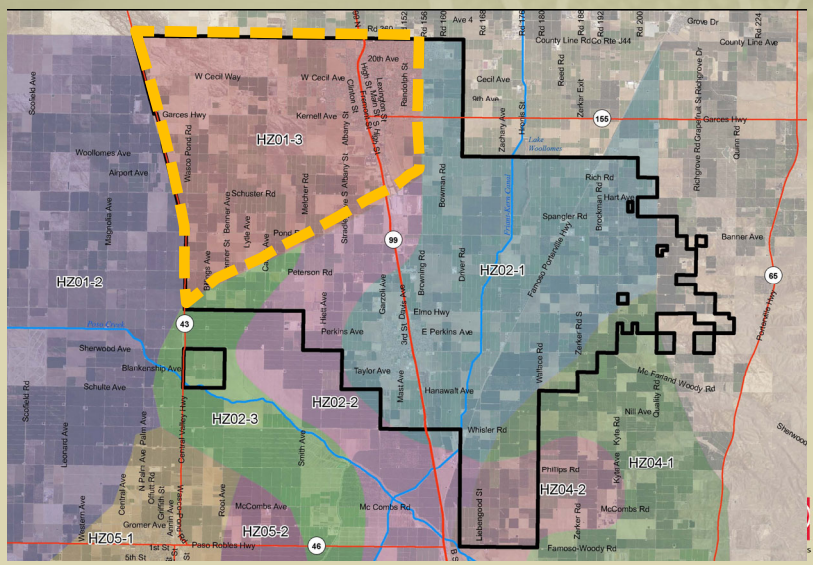
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Sustainable Management Criteria

Sustainable Management Criteria

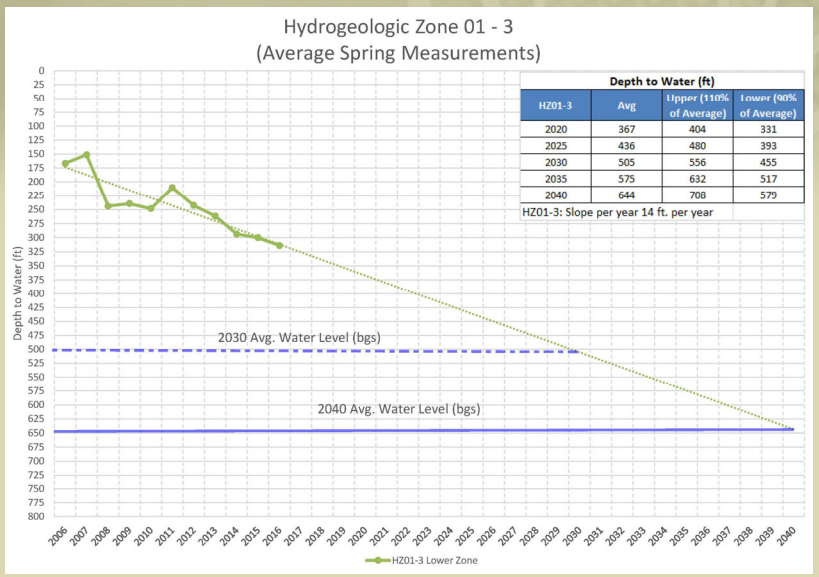




Sustainable Management Criteria

Sustainable Management Criteria





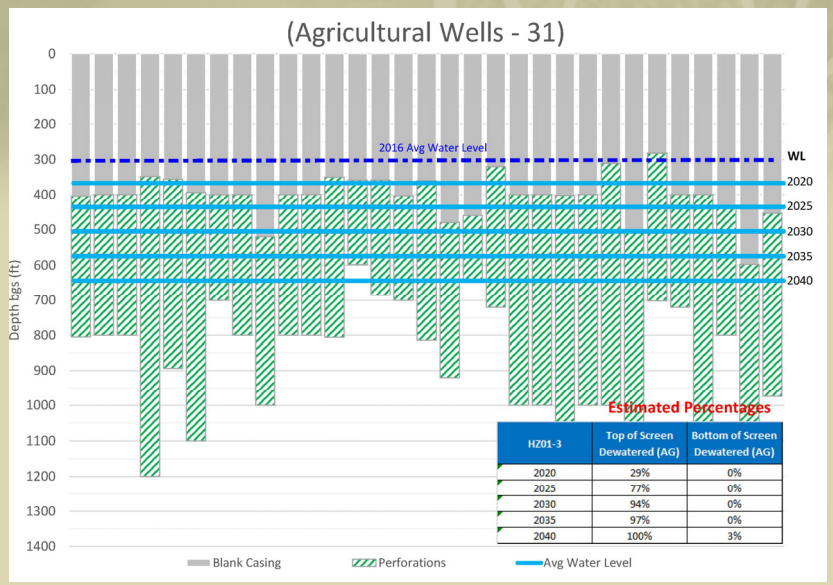
Depth to Water (ft)

HZ01-3	Avg	Upper (110% of Average)	Lower (90% of Average)
2020	367	404	331
2025	436	480	393
2030	505	556	455
2035	575	632	517
2040	644	708	579

HZ01-3: Slope per year 14 ft. per year

Sustainable Management Criteria



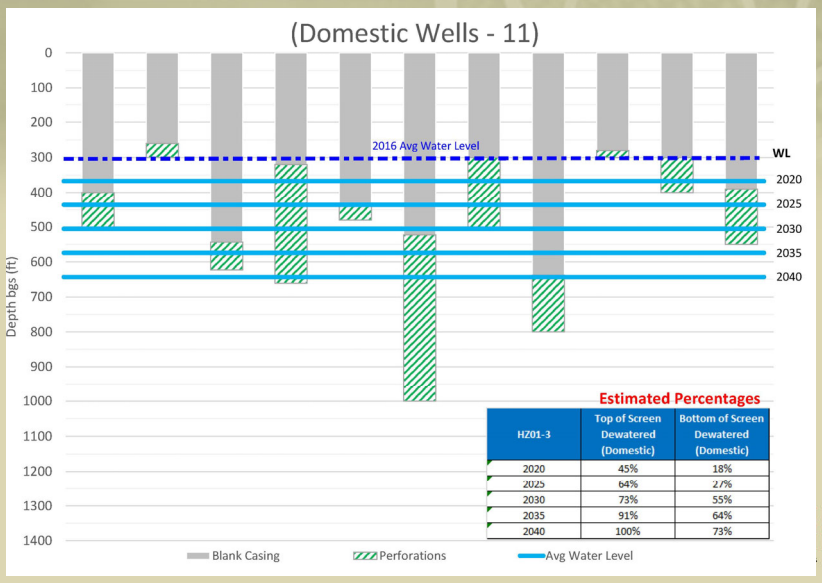


Estimated Percentages

HZ01-3	Top of Screen Dewatered (AG)	Bottom of Screen Dewatered (AG)
2020	29%	0%
2025	77%	0%
2030	94%	0%
2035	97%	0%
2040	100%	3%

Sustainable Management Criteria



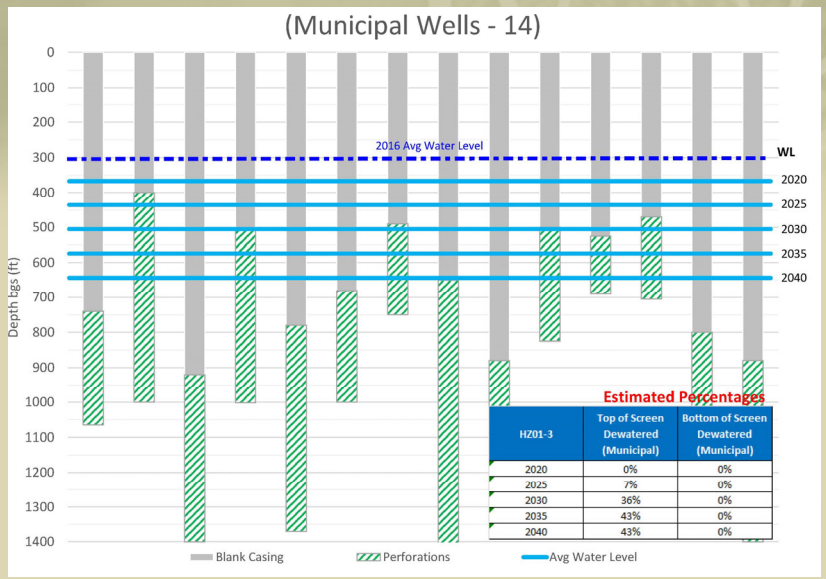


Estimated Percentages

HZ01-3	Top of Screen Dewatered (Domestic)	Bottom of Screen Dewatered (Domestic)
2020	45%	18%
2025	64%	27%
2030	73%	55%
2035	91%	64%
2040	100%	73%

Sustainable Management Criteria





Estimated Percentages

HZ01-3	Top of Screen Dewatered (Municipal)	Bottom of Screen Dewatered (Municipal)
2020	0%	0%
2025	7%	0%
2030	36%	0%
2035	43%	0%
2040	43%	0%

Sustainable Management Criteria



Measurable Objectives
- Where you want to be operating most of the time
- Represents a long-term average, not annual values

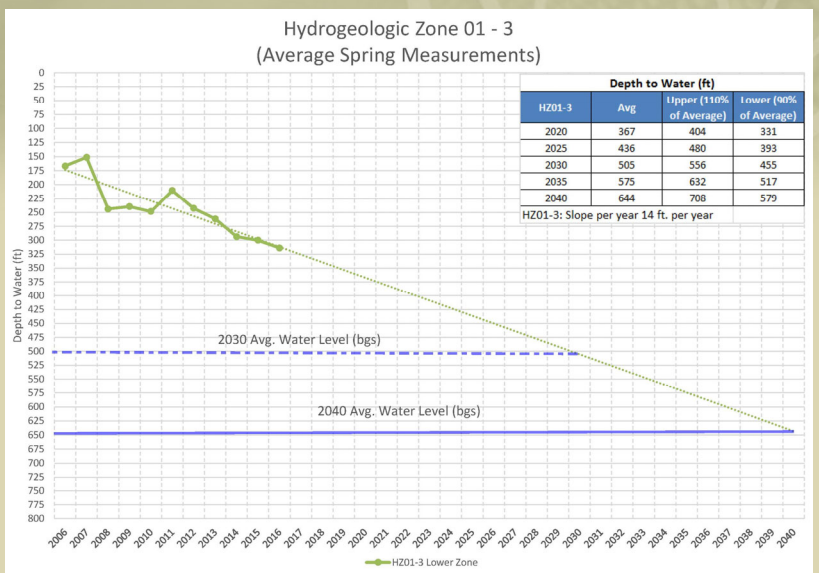
Starting Point:
- Provide a Margin of Operational Flexibility to protect against prolonged droughts – 10 years?

Adjust the Starting Point (if needed)
- Assess impacts to beneficial uses
  - Wells (Ag, domestic and municipal)
  - Water quality
  - Subsidence
  - Storage

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Sustainable Management Criteria





Depth to Water (ft)

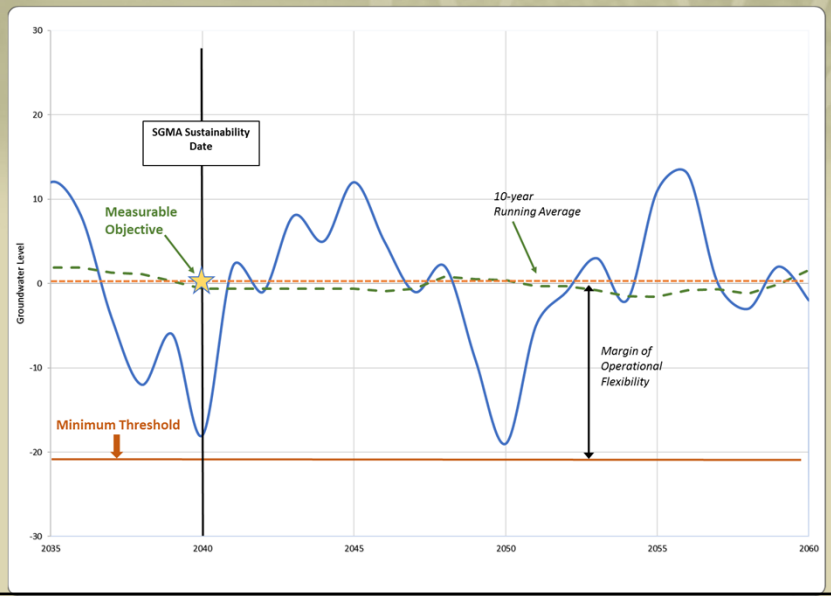
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2020	367	404	331
2025	436	480	393
2030	505	556	455
2035	575	632	517
2040	644	708	579

HZ01-3: Slope per year 14 ft. per year

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Sustainable Management Criteria





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Projects & Management Actions



- Determine deficiency, if any, in groundwater supply (sustainable yield) basinwide
- Formulate, investigate, and implement desired projects and management actions to eliminate the deficiency in groundwater supply and achieve the sustainability goals
- Iterate as necessary to reach ensure the correct mix of projects and management actions
- Update projects and management actions every 5-years for GSP required update

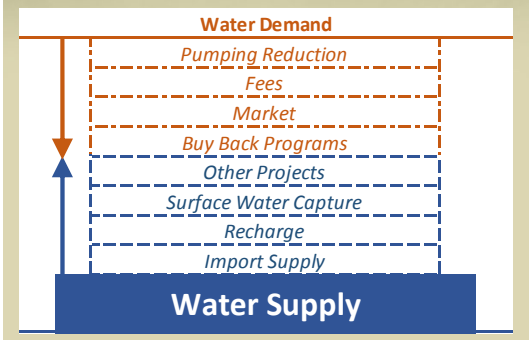
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Projects & Management Actions



Water Supply and Demand Management



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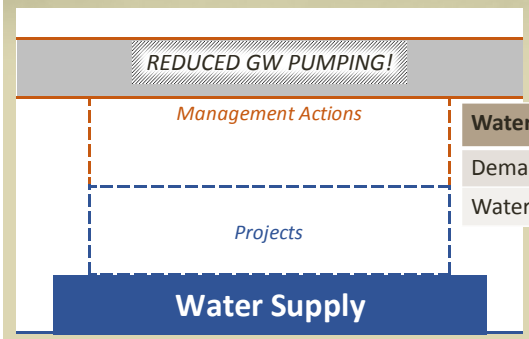
30

Projects & Management Actions

Projects & Management Actions



Adaptive Management to Difference Between Supply and Demand



Water Supply and Demand Management	
Demand Reduction	$$$
Water Supply Projects	$$

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Projects & Management Actions

Projects & Management Actions



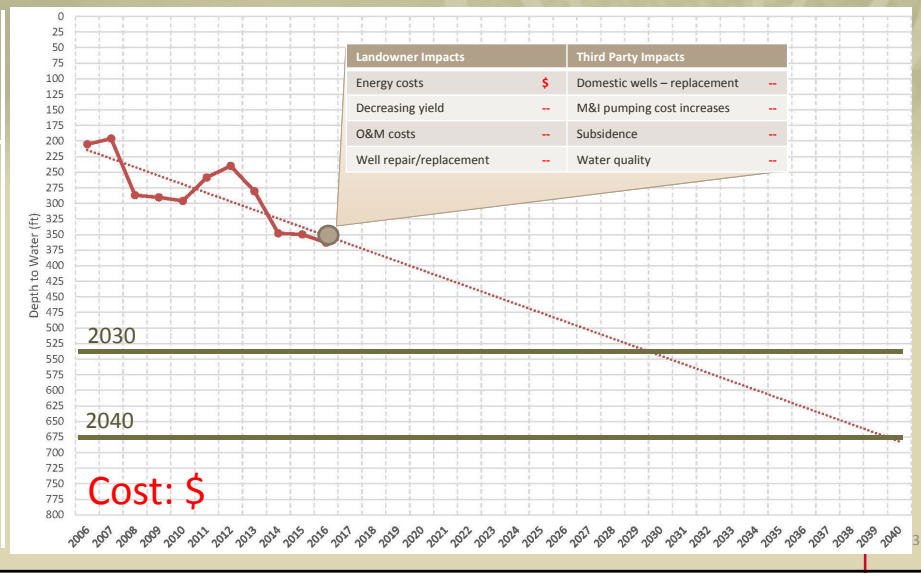
Cost of Sustainability

Landowner Impacts	Third Party Impacts
Energy costs	Domestic wells – replacement
Decreasing yield	M&I Pumping cost increases
O&M costs	Subsidence
Well repair and replacement	Water quality

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Projects & Management Actions

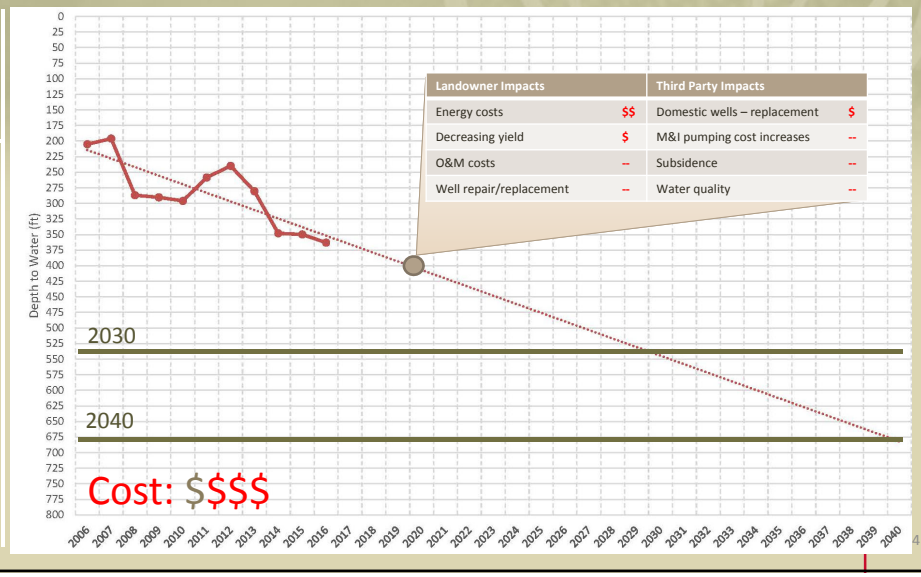




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Projects & Management Actions



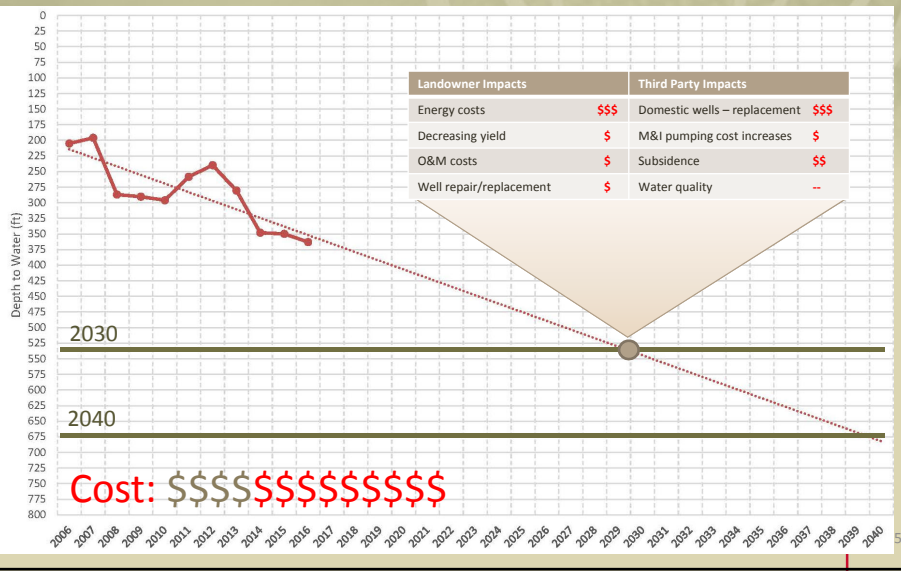


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Projects & Management Actions

Projects & Management Actions



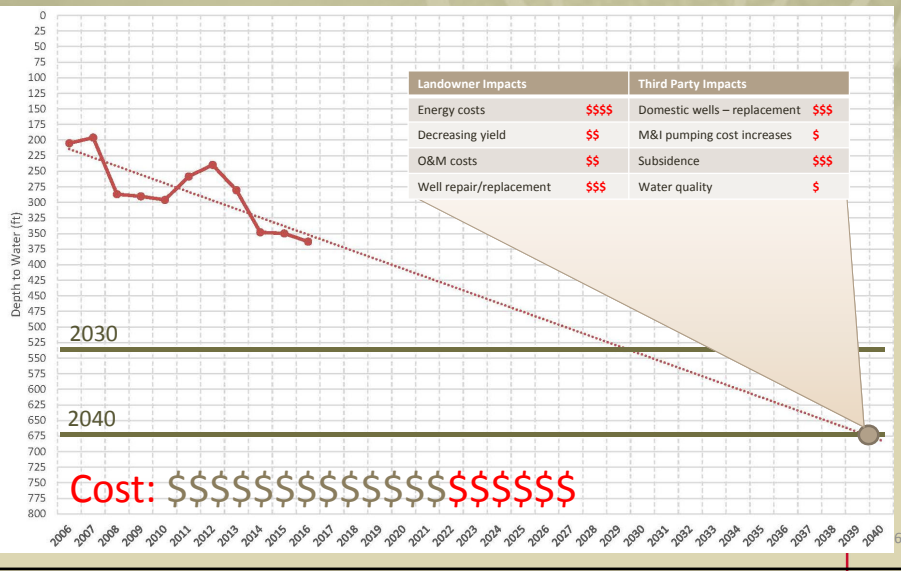


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Projects & Management Actions

Projects & Management Actions

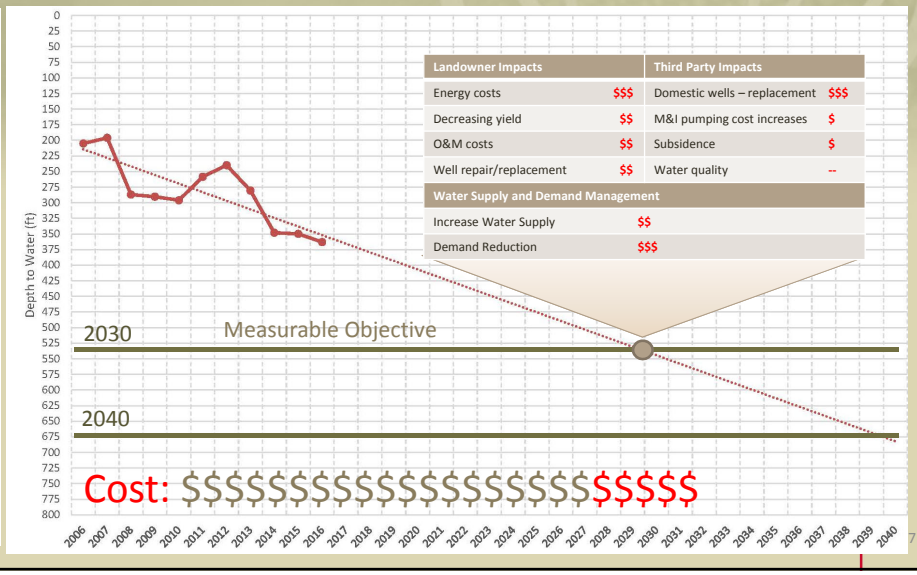




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Projects & Management Actions





Sustainable Management Criteria



Next Steps for Setting Minimum Thresholds

- Work with landowners/stakeholders within discrete areas to review 2040 projections and impacts to wells and groundwater production costs
- Based on input revise Minimum Thresholds as appropriate
- *REMINDER: This is the Point of Avoidance!*

Next Steps for Setting Measurable Objective

- Work with landowners/stakeholders within discrete areas to set the normal operating groundwater elevations
- Based on input revise Measurable Objective.
- *REMINDER: This is the Point of Management!*

Coordination with Kern subbasin neighbors

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Questions?

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Hydrologic Zone 02-1

Meeting: May 2nd from 1-2pm

Name	Company	Email
BEN KING	KING GOLDEN STAR	bking@pacgold.ag..com
Luis Katsuranis ang	Jasmine Vineyards	luis@jasminevineyards.com
Joe Bresson	Hronis, Inc.	joe.bresson@hronis.net
Julio Gonzalez	Jasmine Vineyards	julio@jasminevineyards.com
JEFF LOOKER	~~Jeff Looker~~ SUNVIEW	jlooker@sunviewvineyards.com.
Joseph Schachter	Sunview	Jschachter@sunviewvineyards.com
Clinton Shick		ccshick@gmail.com
KINGSBURG CITMC	BRUCE KELSEY	KCR@ATGINTERNET.COM

Hydrologic Zone 04-1

Meeting: May 2nd from 1-2pm

Name	Company	Email
Ron Fanucchi	Stipe Foster Orchards	rfanucchi@bak.rr.com

Hydrologic Zone 04-2

Meeting: May 2nd from 1-2pm

Name	Company	Email
Ron Fanucchi	DiMuro	rfanucchi@bak.rr.com
Brian King	King County State	bking@pacgoldag.com

Hydrologic Zone 02-3

Meeting: May 2nd from 11-12pm

Name	Company	Email

Hydrologic Zone 02-2

Meeting: May 2nd from 11-12pm

Name	Company	Email
JEFF LOOKER	SUNVIEW	jlooker@sunviewvineyards.com

Hydrologic Zone 01-3

Meeting: May 2nd from 11-12pm

Name	Company	Email
Santos Montemayor	Vista Verde Vineyards	montemayor.FLC@aol.com
Joseph Schachter	Sunview	JSchachter@Sunviewvineyards.com

SSJMUD SGMA Stakeholder Outreach

May 2, 2019 10:00 - 12:00

Name	Phone	Email
Allen Lutz Jr COD	721-3350	alutz@cityofdelano.org
JEFF LOOKER	792-3151	jlooker@sunviewvineyards.com
SANTOS MONTEMAYOR	809-3505	montemayor.FLC@AOL
David Inforo	978-1795	David@altavistacs.com

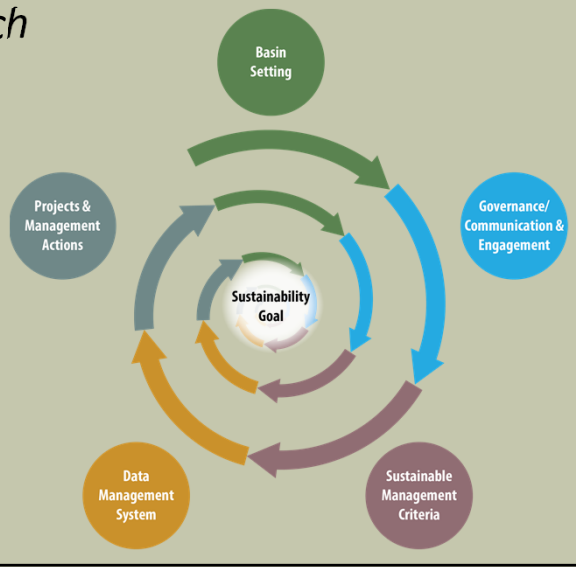
GSP DEVELOPMENT PROCESS

GEI Method and Approach

July 24, 2018

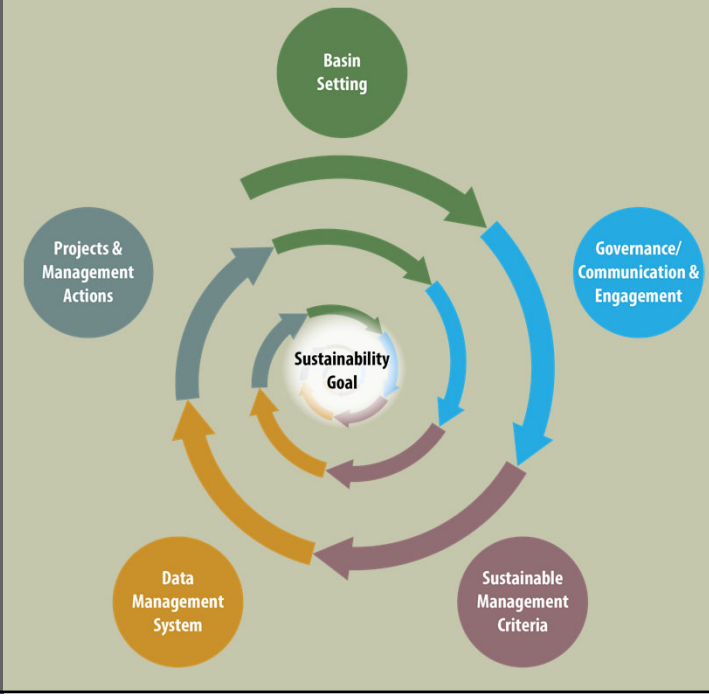
Presented by:
Michelle Ricker
Larry Rodriguez

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ITERATIVE PROCESS

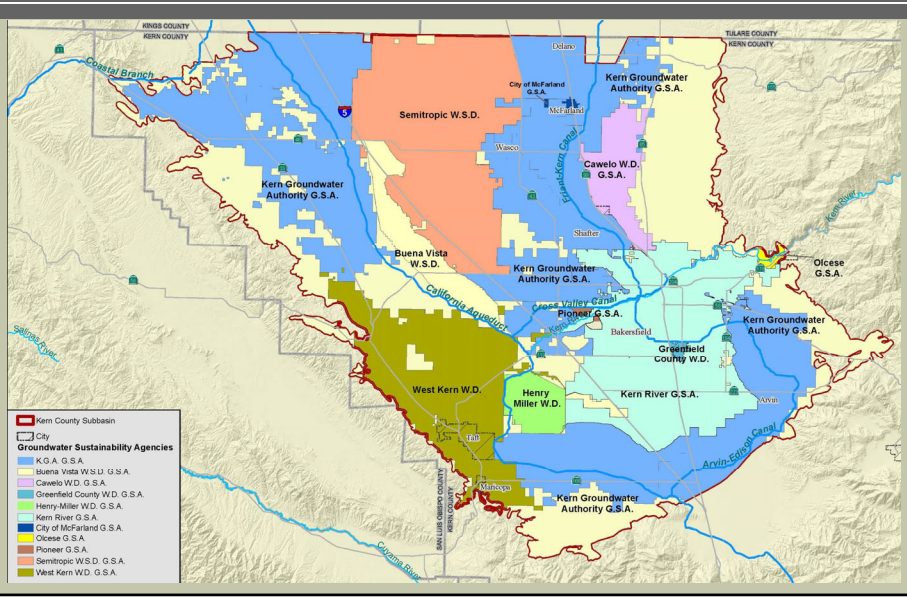
- GSP development is not a linear process
- Steps may be taken in parallel
- Steps may iterate until conclusion is reached
- Process is continuous
- GSAs work toward increased sustainability, adaptively managing and responding to changes over time
- GSPs submitted to DWR will not all be equal



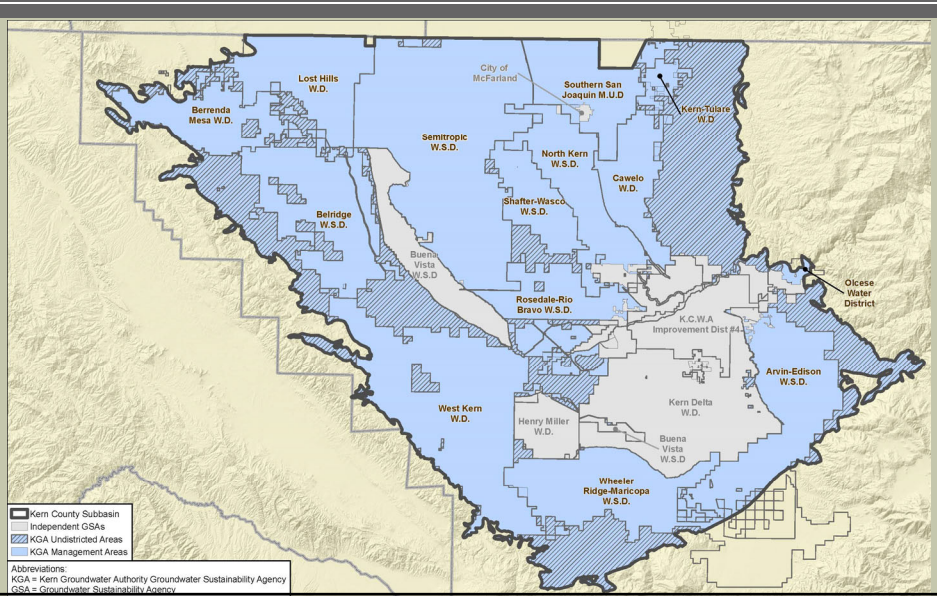
GSP DEVELOPMENT – KERN SUB-BASIN

- The Kern Groundwater Authority (KGA) is preparing an "Umbrella GSP" for all of its members.
  - *North Kern WSD and Shafter-Wasco Irrigation District are members of the KGA*
  - *The KGA is also developing guidance for each of its members to develop "Chapter GSPs"*
- The KGA is also ensuring coordination between its members and other GSAs within the basin (e.g. Kern River GSA)
- The KGA is the point of contact to DWR for GSP submittal, updates, and annual reporting

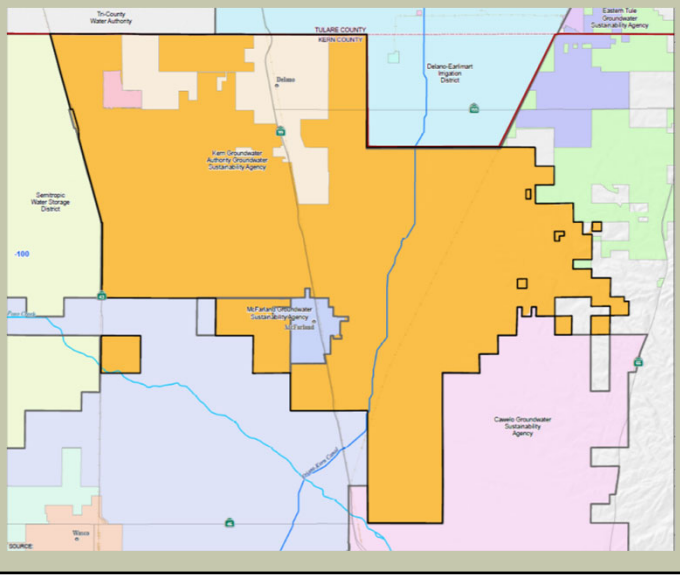
GSP DEVELOPMENT – KERN SUB-BASIN



GSP DEVELOPMENT – KERN SUB-BASIN



GSP DEVELOPMENT – SSJMUD

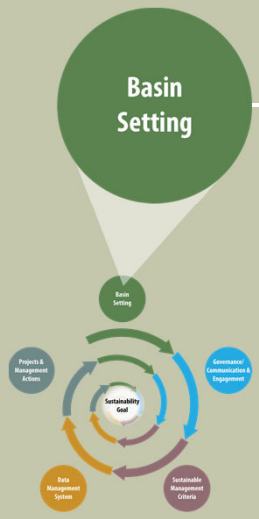


GSP Participants

- **GSA Leadership**
  - *Local water managers and leaders with decision-making responsibilities*
- **Technical Experts**
  - *Local water managers, subject matter experts (local staff), consultants*
- **Stakeholders**
  - *Beneficial users of groundwater, interested parties, impacted parties within and adjacent to the basin*



BASIN SETTING



- Develop basin description and state of the basin
- Develop hydrogeologic conceptual model (HCM)
- Outline what impacts are already happening
- Develop basin numerical model
- Identify structures and costs (i.e. important structures/wells/types of wells/current and future pumping costs, etc.)
- Identify gaps in knowledge
- Develop plan to eliminate data gaps when necessary
- Identify areas where there is disagreement about the basin setting

GOVERNANCE AND COMMUNICATION & ENGAGEMENT



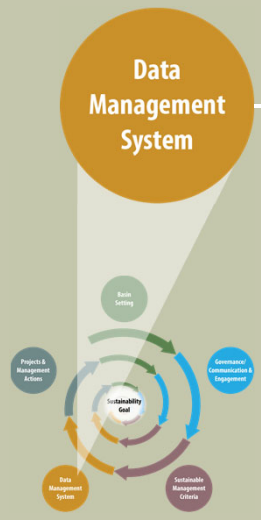
- Identify stakeholders
  - *Anyone affected/impacted by groundwater in and around basin*
  - *Beneficial uses and users*
  - *Interested parties within and around basin*
- Identify technical experts
  - *GSA leadership*
  - *Consultants*
  - *Technical leads*
- Define governance structure
  - *Who makes the decisions for the basin*
  - *How conflicts will be resolved*
  - *How GSA will interact with adjacent basins*
- Develop Stakeholder Communication & Engagement Plan

SUSTAINABLE MANAGEMENT CRITERIA



- Identify which of the six Sustainability Indicators (SI) are possible in the basin, now or in the future.
- Define impacts those SIs are having, and potential future impacts.
- Define a basin level Undesirable Results for each SI.
- Define Minimum Thresholds, Measurable Objectives and Interim Milestones for each SI (could be more than one per SI)
- Begin outreach communications in your basin.
- Identify Representative Monitoring Sites (RMS)

DATA MANAGEMENT SYSTEM



- Establish monitoring program
- Develop DMS – data will be reported to DWR
- Use DMS to track which RMS is monitoring which SI

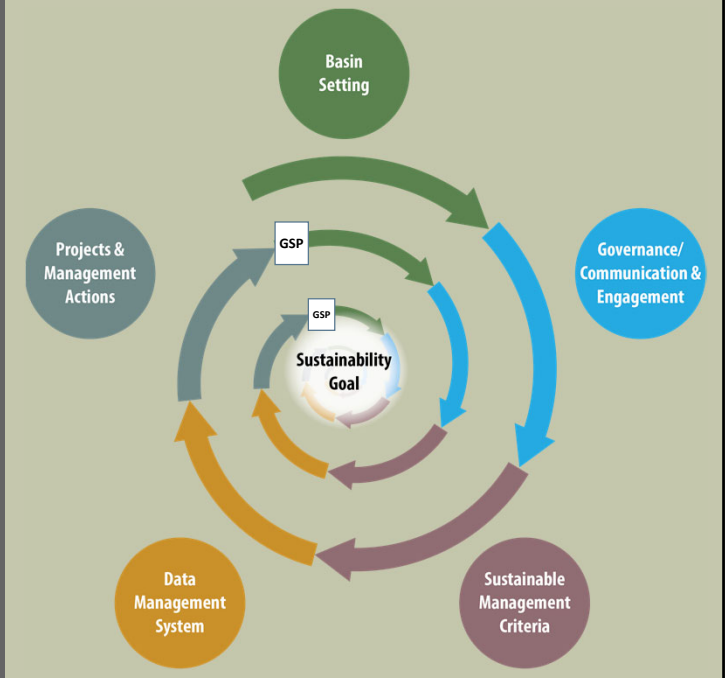
PROJECTS AND MANAGEMENT ACTIONS



- Determine deficiency, if any, in groundwater supply (sustainable yield) basinwide (§354.18(b)(7).
- Iterate as necessary to adjust sustainable management criteria
- Formulate, investigate, and implement desired projects and management actions to eliminate the deficiency in groundwater supply and achieve the GSAs goals
- Iterate as necessary to ensure the correct mix of projects and management actions to work toward sustainability
- Update projects and management actions every 5 years for required GSP updates

SUMMARY

- Iteration required
- Record gaps or disputed data/decisions so can be addressed in GSP
- GSAs will work through these activities differently – some may make many iterations before the first GSP, others may not
- GSPs submitted to DWR will not all be equal or at the same level of sustainability or completeness of information



Sustainable Management Criteria

SUSTAINABLITY

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- Managing and using groundwater in a way that can be sustained over a long period of time
- Sustainable yield is the amount of groundwater that can be withdrawn without causing undesirable results

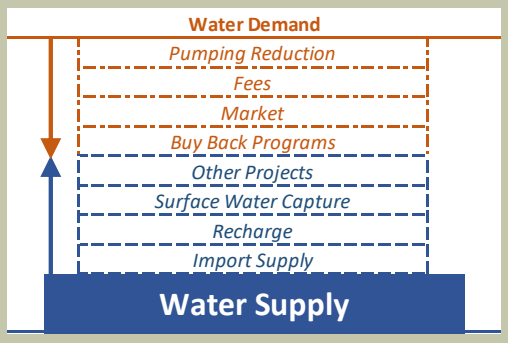


Sustainable Management Criteria

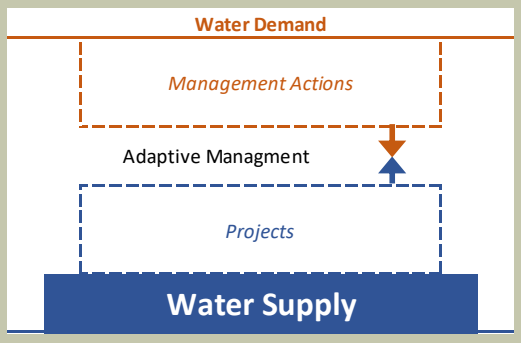
SUSTAINABILIITY

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Project and Management Actions



Adaptive Management to Difference Between Supply and Demand

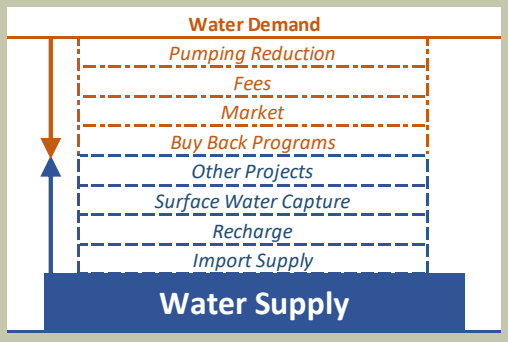


Sustainable Management Criteria

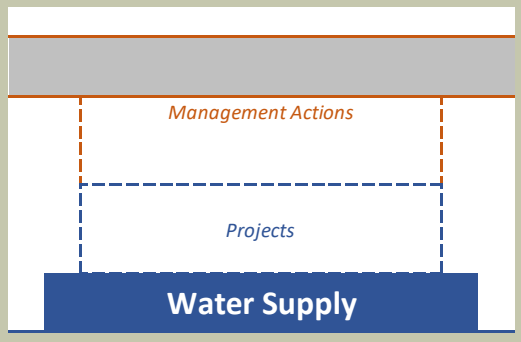
SUSTAINABILITY

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Project and Management Actions



Adaptive Management



HOW TO BECOME INVOLVED

- SSJMUD Board Meetings – GSP Development Update Each Month
- Public Workshops
  - *KGA Board Meetings*
  - *KGA-sponsored Workshops and Meetings*

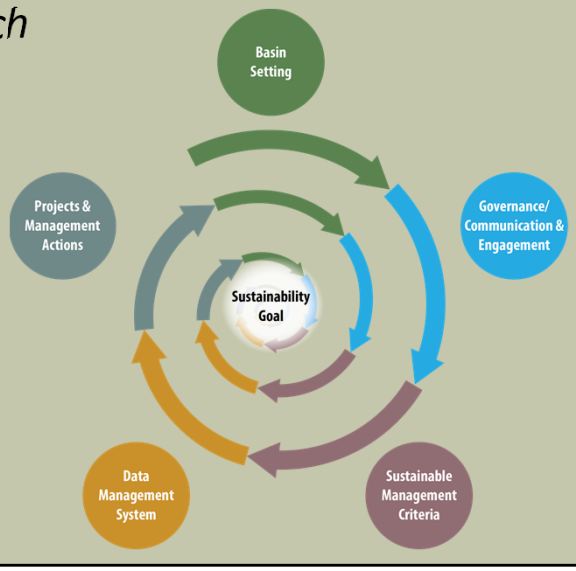
GSP DEVELOPMENT PROCESS

GEI Method and Approach

July 24, 2018

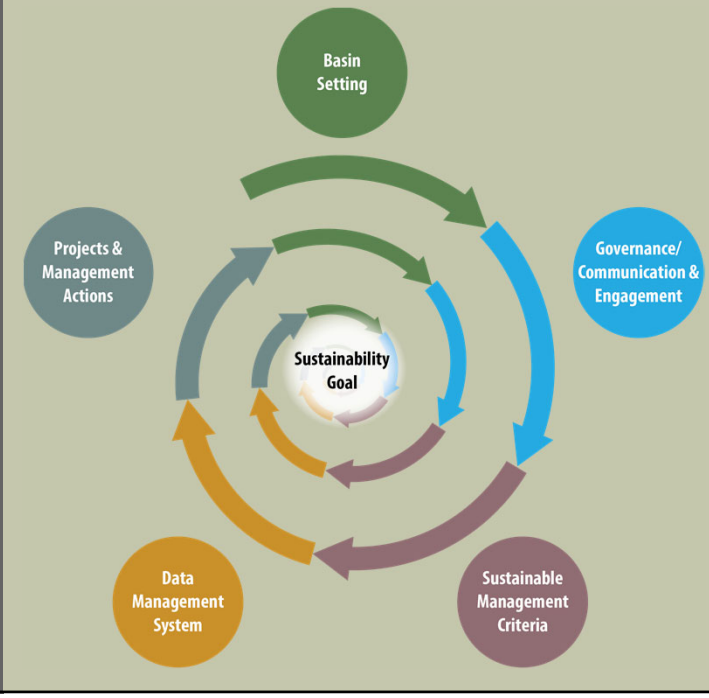
Presented by:
Michelle Ricker
Larry Rodriguez

GEI Consultants



ITERATIVE PROCESS

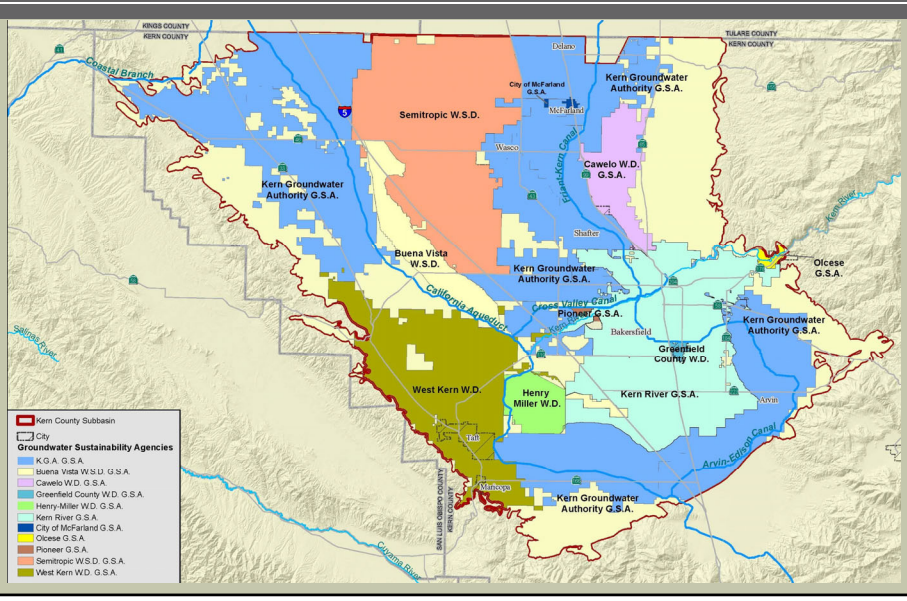
- GSP development is not a linear process
- Steps may be taken in parallel
- Steps may iterate until conclusion is reached
- Process is continuous
- GSAs work toward increased sustainability, adaptively managing and responding to changes over time
- GSPs submitted to DWR will not all be equal



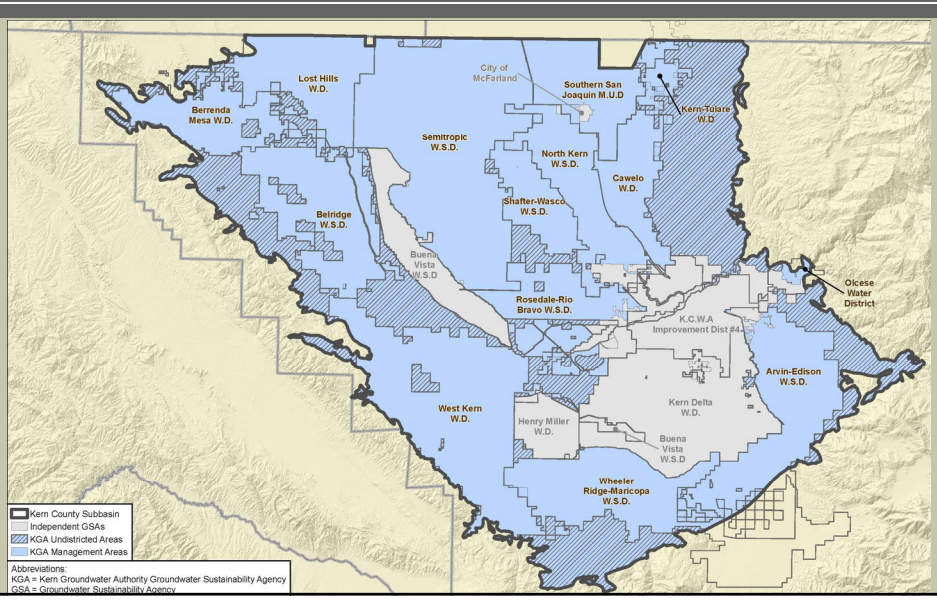
GSP DEVELOPMENT – KERN SUB-BASIN

- The Kern Groundwater Authority (KGA) is preparing an "Umbrella GSP" for all of its members.
  - *North Kern WSD and Shafter-Wasco Irrigation District are members of the KGA*
  - *The KGA is also developing guidance for each of its members to develop "Chapter GSPs"*
- The KGA is also ensuring coordination between its members and other GSAs within the basin (e.g. Kern River GSA)
- The KGA is the point of contact to DWR for GSP submittal, updates, and annual reporting

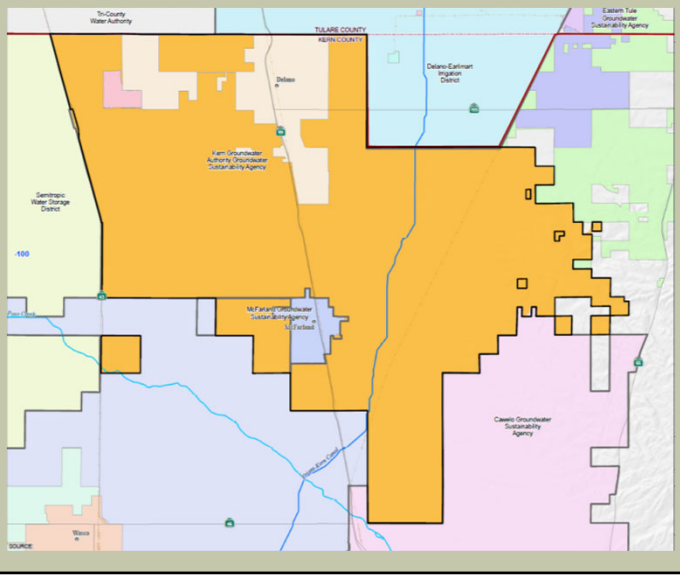
GSP DEVELOPMENT – KERN SUB-BASIN



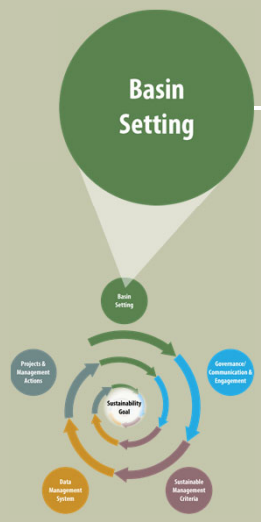
GSP DEVELOPMENT – KERN SUB-BASIN



GSP DEVELOPMENT – SSJMUD



BASIN SETTING



- Develop basin description and state of the basin
- Develop hydrogeologic conceptual model (HCM)
- Outline what impacts are already happening
- Develop basin numerical model
- Identify structures and costs (i.e. important structures/wells/types of wells/current and future pumping costs, etc.)
- Identify gaps in knowledge
- Develop plan to eliminate data gaps when necessary
- Identify areas where there is disagreement about the basin setting

GOVERNANCE AND COMMUNICATION & ENGAGEMENT



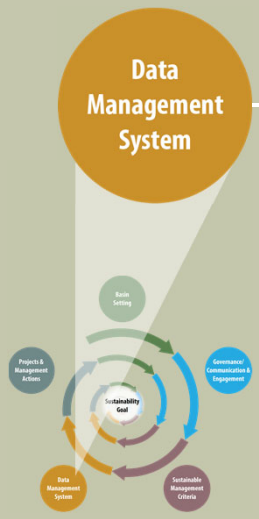
- Identify stakeholders
  - *Anyone affected/impacted by groundwater in and around basin*
  - *Beneficial uses and users*
  - *Interested parties within and around basin*
- Identify technical experts
  - *GSA leadership*
  - *Consultants*
  - *Technical leads*
- Define governance structure
  - *Who makes the decisions for the basin*
  - *How conflicts will be resolved*
  - *How GSA will interact with adjacent basins*
- Develop Stakeholder Communication & Engagement Plan

SUSTAINABLE MANAGEMENT CRITERIA



- Identify which of the six Sustainability Indicators (SI) are possible in the basin, now or in the future.
- Define impacts those SIs are having, and potential future impacts.
- Define a basin level Undesirable Results for each SI.
- Define Minimum Thresholds, Measurable Objectives and Interim Milestones for each SI (could be more than one per SI)
- Begin outreach communications in your basin.
- Identify Representative Monitoring Sites

DATA MANAGEMENT SYSTEM



- Establish monitoring program
- Develop DMS – data will be reported to DWR
- Use DMS to track which RMS is monitoring which SI

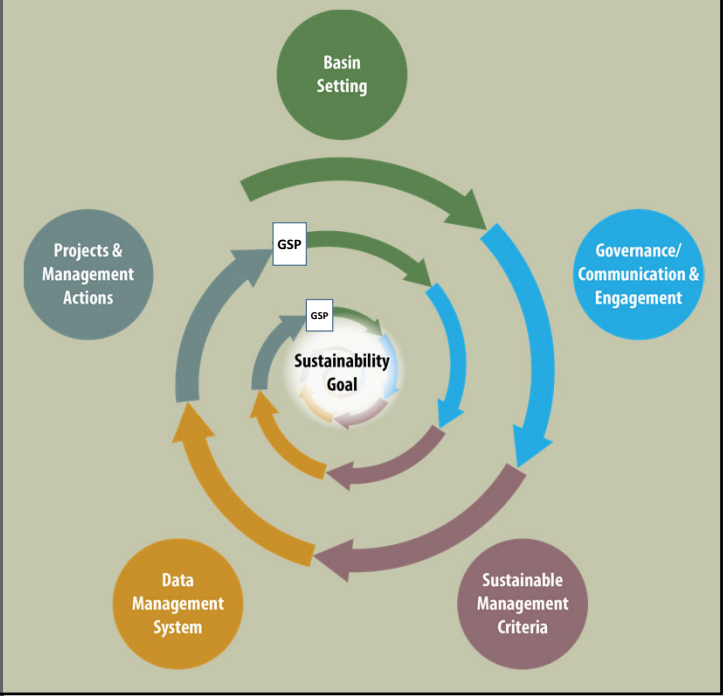
PROJECTS AND MANAGEMENT ACTIONS



- Determine deficiency, if any, in groundwater supply (sustainable yield) basinwide (§354.18(b)(7).
- Iterate as necessary to adjust sustainable management criteria
- Formulate, investigate, and implement desired projects and management actions to eliminate the deficiency in groundwater supply and achieve the GSAs goals

SUMMARY

- Iteration required
- Record gaps or disputed data/decisions so can be addressed in GSP
- GSAs will work through these activities differently – some may make many iterations before the first GSP, others may not
- GSPs submitted to DWR will not all be equal or at the same level of sustainability or completeness of information



Sustainable Management Criteria

SUSTAINABLE MANAGEMENT CRITERIA

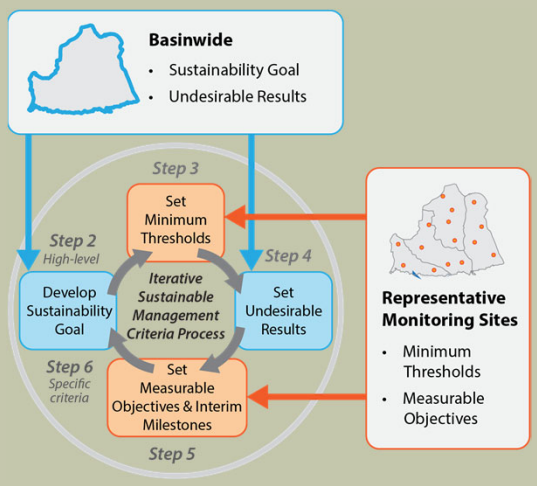
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Set Basinwide

- Undesirable Results
- Sustainability Goals

Set by Management Area

- Minimum Thresholds
- Measurable Objectives
- Interim Milestones



Sustainable Management Criteria

SUSTAINABILIITY GOALS

GEI Consultants

Chronic Lowering of Groundwater Levels

Maintain groundwater levels that continue to support agricultural viability and sustainable communities

Reduction of Groundwater Storage

Maintain groundwater volumes in storage to sustain agriculture and communities during prolonged drought conditions

Degraded Water Quality

Avoid degradation of groundwater quality that would impact sustainable agriculture and communities

Land Subsidence

Reduce or prevent land subsidence that causes impacts to critical infrastructure

Depletions of Interconnected Surface Water

Prevent impacts to groundwater dependent ecosystems

Seawater Intrusion

Not applicable

Sustainable Management Criteria

SUSTAINABILIITY GOALS

GEI Consultants

- Undesirable Results:
  - *High level definition, applicable to the entire sub-basin*
- Example Definitions:
  - *Water Levels*
    - *GW levels that impact >10% of domestic and municipal wells*
    - *Violation of Minimum Thresholds in >10% of the sub-basin (by area)*
  - *Storage – Storage Amounts Equivalent to Double the Volume Needed for Operational Flexibility*
  - *Seawater Intrusion – Not Applicable*
  - *Water Quality – No Migration of Identified Plumes Resulting in new MCL Exceedances*
  - *Subsidence – No Subsidence to Critical Infrastructure Resulting in 2% Loss in Performance*
  - *Depletion of Interconnected Streams – Streamflow Depletion Limited to Less than 1% or Less than 2% Impact to Area of Riparian Impacts*

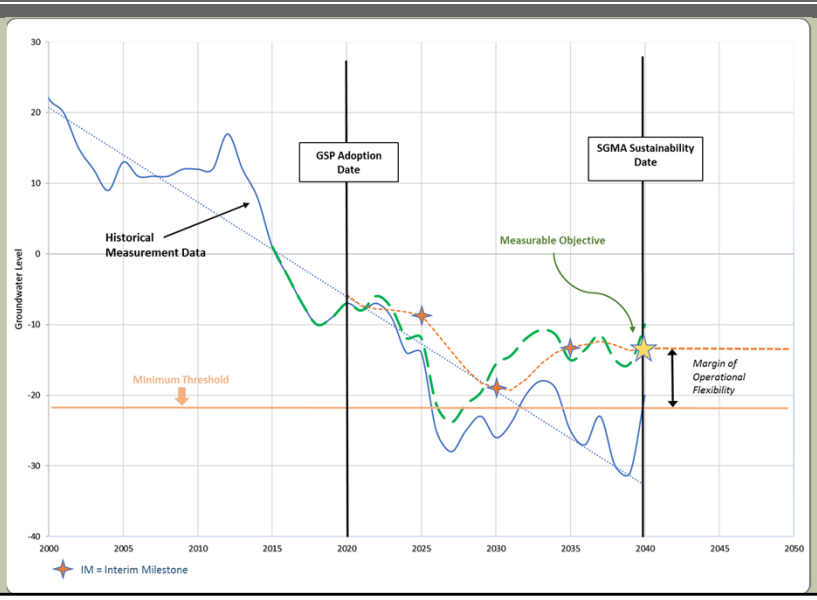
Sustainable Management Criteria

SUSTAINABILIITY GOALS

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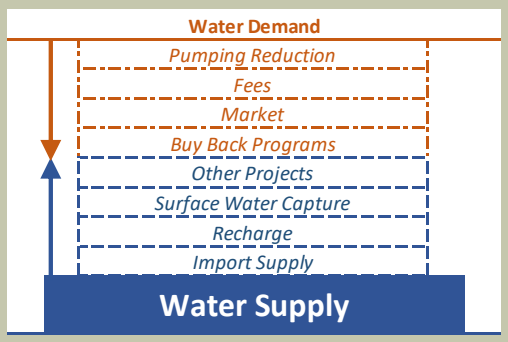
- Minimum Thresholds:
  - *Quantitative value that, when exceeded, can cause Undesirable Results*
  - *Measurable Objective is goal that represents the normal or average groundwater condition*
- Measurable Objectives:
  - *Quantitative goals that reflect the desired groundwater condition of the management area while maintaining a volume of operational flexibility*
  - *A Measurable Objective is a goal that represents the average or normal groundwater condition (GW elevations based on trends, WQ based on discrete values)*
- Interim Milestones:
  - *Trend line values that represent the projected changes in groundwater conditions based on implementation of projects and management actions*

SUSTAINABLE MANAGEMENT CRITERIA

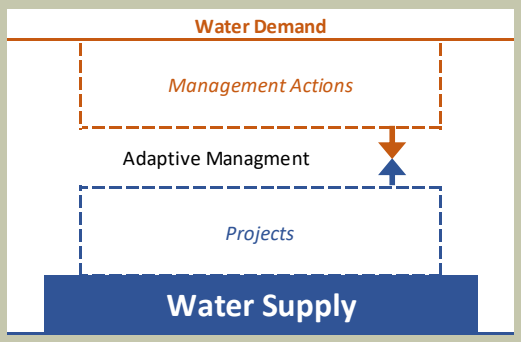


SUSTAINABLE MANAGEMENT CRITERIA

Project and Management Actions

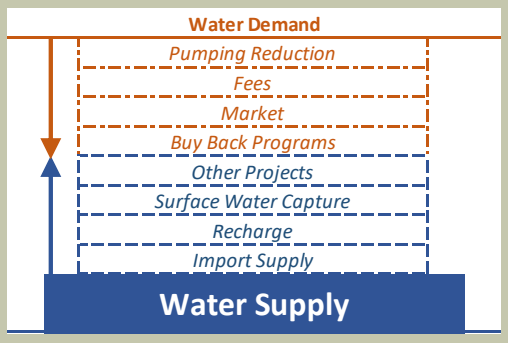


Adaptive Management to Difference Between Supply and Demand

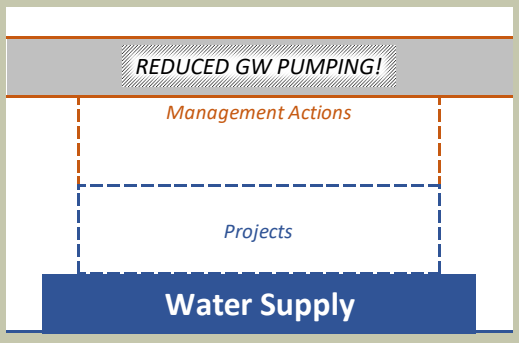


SUSTAINABLE MANAGEMENT CRITERIA

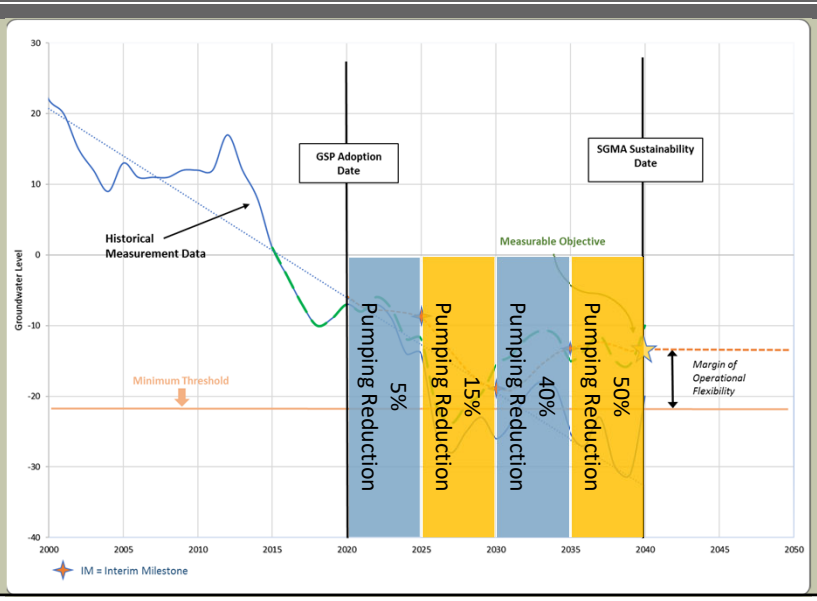
Project and Management Actions



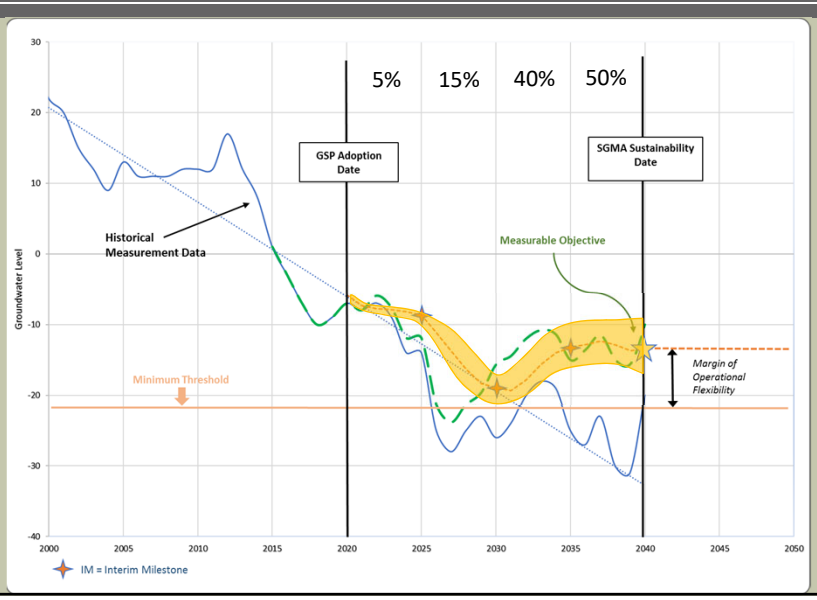
Adaptive Management



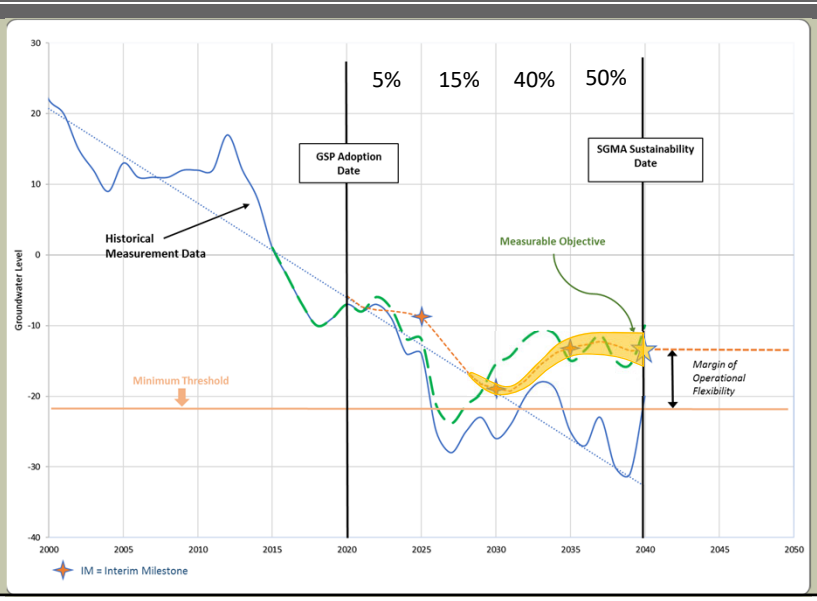
SUSTAINABLE MANAGEMENT CRITERIA



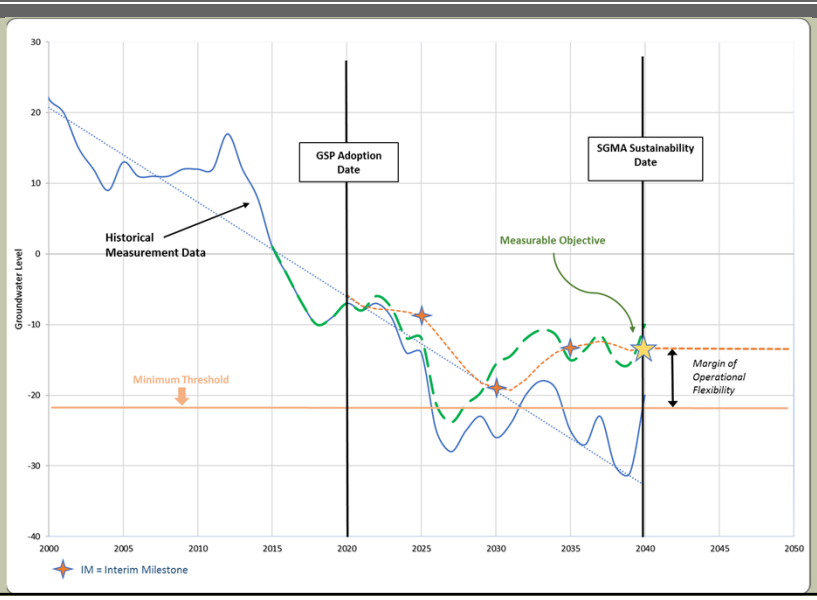
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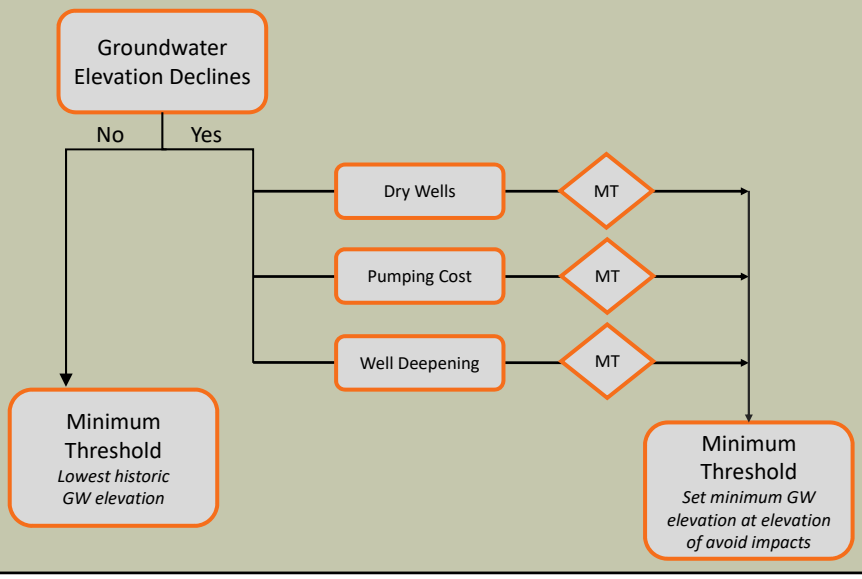
SUSTAINABLE MANAGEMENT CRITERIA



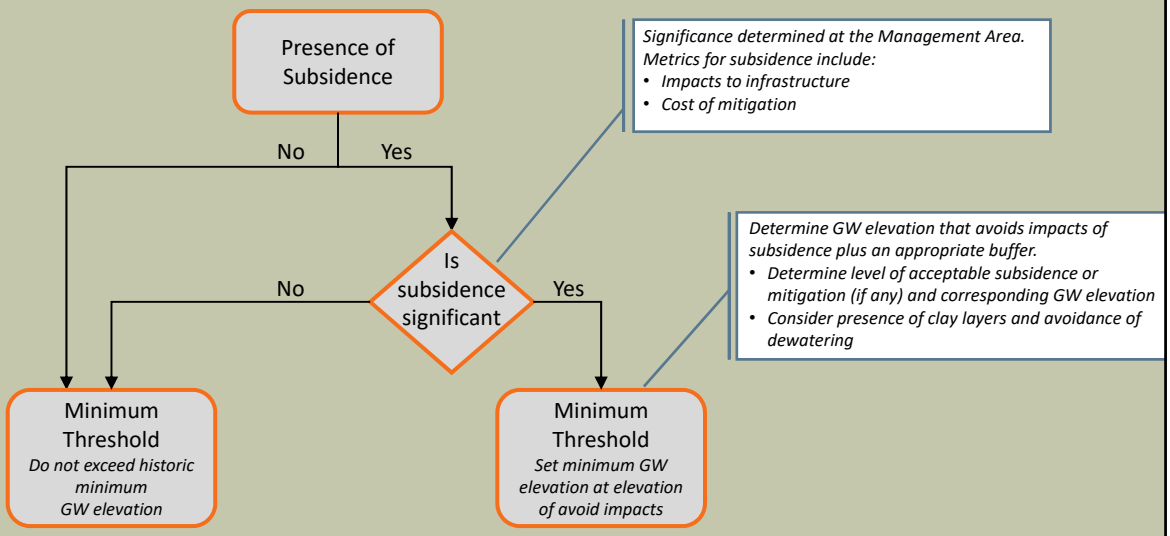
SUSTAINABLE MANAGEMENT CRITERIA



Developing Minimum Thresholds



Developing Minimum Thresholds



NEXT STEPS

- Sub-Basin Level (August)
  - *Set Undesirable Results at the Sub-Basin level*
  - *Develop basic guidance for development of Minimum Thresholds, Measurable Objectives and Interim Milestones*
- GSA Level (Late August - October)
  - *Preliminary cut at Minimum Thresholds, Measurable Objectives and Interim Milestones*

Appendix D

Public Comments Received by SSJMUD

Commentor	Ref #	Comment	Response
Southern San Joaquin Municipal Utility District Received Comments			
Farmland Reserve		"Though not specifically addressed, we are concerned that overlying right to extract groundwater will be allocated among all District landowners based on gross acreage…it ignores accepted principles of law intended to more fairly allocate this right among those who have historically used groundwater for irrigation purposes -- and made substantial investments based on that use."	We have discussed adding language to the Water Budget section of the plan to address the fact that there is currently no in-district allocation of water to the landowners. The language in the Projects & Mgmt Actions section, dealing with in-district allocation as a mgmt action has been revised to address this, as well.
Farmland Reserve		"These numbers should not be seen as establishing a precedent or used to establish some legal right. Therefore, a statement emphasizing the above points should be made."	The discussion on native yield in the Water Budget section of the plan addresses this.
Farmland Reserve		"The Chapter could address the possibility of a market for the exchange or transfer of groundwater credits."	At this time, such a discussion is premature. There is no framework within the districts or the basin at large to allow for the exchange or transfer of groundwater credits. We cannot reasonably address this in the plans for 2020 submittal.
Wonderful Orchards		"The GSPs, management areas, and other planning units in the subbasin should utilize coordinated methods of determining supply sources for native yield, quantifying the native yield, and accounting for it in individual MAPs' water budgets. Unless there are specific hydrogeologic conditions that differentiate certain portions of the basin from the basin at-large (such as a fault line or barrier to groundwater flow), native yield should be considered a basin-wide resource."	The districts have identifed as a management action the coordinated effort to further refine water budget components in the Kern County Subbasin Model. The Model and water budget components will continue to be refined in coordination with the KGA and other GSAs in the basin.
Wonderful Orchards		"In addition to a clear definition of native yield, the final GSP must also include a thorough description of how to calculate the allocation of native yield. Currently, the GSP references native yield in terms of acre-feet per gross acre for water budget purposes. Appendix J of the GSP indicates the subbasin native yield is approximately 0.144 acre-feet per acre. It is our understanding that subsequent to the release of the draft GSP, all MAPs and other GSPs in the basin agreed to utilize the same number for their water budgets. If referencing native yield this way is necessary, the GSP should clarify that it is for initial water budget purposes ONLY, is non-precedent setting, and is not a determination of individual landowner allocations or groundwater rights. Alternatively, in the 2020 plans subbasin native yield could be described as a total volume of water and not associated with a given gross or net area."	The discussion on native yield in the Water Budget section of the plan addresses this already. Further emphasis on the "planning budget" role of the Native Yield estimate has been added to the final draft of the plan. In terms of native yield allocation to the parcel/landowner level, there is no framework currently in place to do so. The development the policies and framework necessary to implement such an allocation cannot be completed in time for the 2020 plan submittal.
Wonderful Orchards		"Markets are essential in facilitating the highest and best use of a limited resource and in giving landowners the most flexibility to minimize the economic impacts of pumping restrictions. To enable a market that works for all landowners in the subbasin, it is imperative that all pumpers know exactly how much marketable water they have available for use or transfer. Unless it is deemed necessary to prevent undesirable results, markets should not place geographic or jurisdictional limitations on transfers within a subbasin and should allow for carry-over of allocations from one year to the next."	At this time, such a discussion is premature. There is no framework within the districts or the basin at large to allow for the exchange or transfer of groundwater credits. We cannot reasonably address this in the plans for 2020 submittal.
Wonderful Orchards		"Wonderful understands that there are instances where it may be necessary to restrict pumping in order to achieve basin-wide sustainability. If this becomes a necessity, the GSAs or MAs should implement pumping restrictions when supported by the best available data and appropriate analytical tools. Furthermore, if possible, pumping should be ramped down gradually over the implementation period to avoid a sudden disruption in economic activity. As with native yield allocations, initial pumping allowances and ramp down schedules should be coordinated across the entire basin so that similarly situated pumpers in the basin are treated equitably regardless of their respective MA (some MAPs include a ramp down schedule for groundwater-only lands and others do not; this is a significant difference and should be reconciled)."	As described in the Management Actions subsection of the Management Area Plan, policies for instituting pumping restrictions have not been developed for the 2020 plan submittal. This has been identifed as a potential management action, should the districts or the basin in general find that it cannot maintain it path to sustainability through the projects and other management actions to be implemented.
Wonderful Orchards		"GSAs must develop clear policies and conditions that protect existing investment in groundwater banking and banked inventory, and without interference with existing rules and regulations. GSAs must also find a way to incentivize additional investment, such as on-farm recharge, and allow flexibility for recharged or banked water to be freely transferrable (subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results). Where possible, GSPs should also identify management areas that may benefit from additional recharge and banking. We also recommend that GSAs work to develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.)."	At this time, the framework to offer such incentives does not exist and would require the districts' boards to develop & adopt policy to put it in place. In the time required to prepare the 2020 submittal of the plan, we cannot develop the structure and policy required to implement this. However, this is discussed in the Projects & Mgmt Actions section of the plan and will be considered for implementation after the 2020 plan submittal, when the districts have an opportunity to develop the policy and framework necessary for such programs.
Wonderful Orchards		"GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	A coordinated DMS is already being developed. However, that effort is currently focused at the district/MA level due to the precision of the data being used. Parcel-level allocation is not at this time being done in the subbasin. It is premature to consider a basin-wide water market, as the data available does not allow for that level of allocation to be done. For consideration in the 2020 plan submittal, we do not have adequate time or resources for the development of such a framework.
Westchester Group Investment Mgmt		The GSP references native yield in terms of acre-feet per gross acre for water budget purposes. If referencing it this way is necessary, the GSP should clarify that these calculations are for initial water budget purposes ONLY, are non-precedent setting, and not a determination of individual landowner allocations or groundwater rights. Alternatively, native yield could be described only as a total volume of water and not associated with a given gross or net area. In the event that allocations are to be made at a landowner or property level, WGIM encourages the KGA and other GSAs in the basin to initiate a stakeholder-driven process to develop a methodology for establishing landowner-level allocations that are coordinated across the basin.	The discussion on native yield in the Water Budget section of the plan addresses this already. More language can be added to emphasize the "planning budget" role of the Native Yield estimate.
Westchester Group Investment Mgmt		GSAs and MAs must develop clear and understandable policies and conditions that protect existing groundwater banking and banked water inventory, and allow them to continue operating as they have been under their existing rules and regulations without interference. They must also incentivize additional investment, such as on-farm recharge by providing pumping credits and allow flexibility for recharged or banked water to be freely transferrable subject to the rights and conditions of use associated with the source water and the avoidance of undesirable results. They should develop incentives for public or private investment to expand recharge and banking capacity, as these facilities help to achieve multiple benefits (e.g., habitat, water quality, drinking water, etc.).	At this time, the framework to offer such incentives does not exist and would require the districts' boards to develop & adopt policy to put it in place. In the time required to prepare the 2020 submittal of the plan, we cannot develop the structure and policy required to implement this. However, this is discussed in the Projects & Mgmt Actions section of the plan and will be considered for implementation after the 2020 plan submittal.

Commentor	Ref #	Comment	Response
Westchester Group Investment Mgmt		GSAs should develop a coordinated basin-wide data management system ("DMS") that is capable of tracking groundwater and surface water use at the landowner, field, or parcel level, and a coordinated methodology for measuring landowner-level use of groundwater. The DMS should also include, or be capable of interfacing with, a groundwater market platform that allows for individual users to conduct transactions. Markets will be most effective if there is confidence in the accuracy of the measurements taken, consistency in the data sources relied upon, and flexibility to allow for transactions across the basin. For instance, GSAs using remote sensing to calculate crop evapotranspiration ("ET") as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower provided information to be included into the ET calculation and calibration. Additionally, GSAs should establish criteria and procedures to address any apparent inaccuracies in the ET calculations (e.g., if calculated ET is greater than applied water and precipitation).	A coordinated DMS is already being developed. However, that effort is currently focused at the district/MA level due to the precision of the data being used. Parcel-level allocation is not at this time being done in the subbasin. It is premature to consider a basin-wide water market, as the data available does not allow for that level of allocation to be done. For consideration in the 2020 plan submittal, we do not have adequate time or resources for the development of such a framework.
Westchester Group Investment Mgmt		"WGIM supports use of efficient and accurate systems to determine groundwater use. GSAs using remote sensing to calculate crop ET as a measurement of consumptive use of groundwater should develop methodologies and quality assurance elements to allow for grower-provided information to be included into the ET calculation and calibration. These methodologies should be developed in consultation with the vendor providing ET data to ensure it is applicable and useful in creating the best available data set. Additionally, GSAs and/or MAs should establish criteria and procedures to address apparent inaccuracies in the ET calculations. An obvious use of the procedure would be in instances where the grower can demonstrate that applied water, plus precipitation, is less than the calculated ET. In these instances, and subject to any requirements established by the GSA, the grower's use of groundwater should be reduced to the applied water total as the ET calculation should not be greater than applied water."	This is already included in the Projects and Management Actions section and is part of the larger action of refining data for the calculation of Water Budget components in future plan updates.
Leadership Council		"The Draft GSP is incomplete and must include additional information for the public to evaluate the GSP. The Draft GSP omits critical data regarding the consideration of drinking water impacts on disadvantaged communities and protected groups, sustainable management criteria that consider all beneficial users, and projects and management actions that address significant and unreasonable impacts to beneficial users."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with the statement, as the information that Leadership Council claims is missing from the GSP is actually included in the management area plans, as appropriate to each respective management area.
Leadership Council		"The KGA is responsible for the disproportionate and disparate impacts that its policies and activities will have on disadvantaged communities belonging to protected groups."	This comment is directed to the KGA GSP and will be addressed by KGA. While the KGA is the GSA entity submitting the plan on behalf of its members, the JPA forming the KGA is such that each member is responsible for the implementation of SGMA within their respective plan areas. The KGA GSP and its management area plans were developed in consideration of all beneficial uses of water and the beneficial users of the groundwater in the subbasin.
Leadership Council		"The Coordination Agreement does not "explain how the plans, implemented together, satisfy the requirements of the Act."	This comment is directed to the KGA GSP and will be addressed by KGA.
Leadership Council		"The GSP was not crafted in a way that adequately considered the input of disadvantaged communities, either at the GSA level or the member agency level."	This comment is directed to the KGA GSP and will be addressed by KGA, pertaining to the KGA level engagement. With respect to the member level engagement, SGMA leaves the manner and frequency of public outreach and engagement to the discretion of the GSA. As described in the introduction of the management area plan, SSJMUD holds monthly publicly-noticed meetings which serve as an opportunity for members of the public to provide feedback to the districts regarding the plan's development and implementation. Furthermore, the districts were active participants in the KGA-level outreach activities as well as hosts of their own workshops, which were publicly-noticed, and coordination with the cities of Delano and McFarland on the development of the plan.
Leadership Council		"The Kern Subbasin Undesirable Results do not comply with existing law."	The definitions for undesirable results were developed in coordination with the other GSAs and take into consideration "significant and unreasonable" impacts to the groundwater which affect all beneficial users. Such beneficial uses include agriculture, domestic, and municipal & industrial.
Leadership Council		"It is not clear what the impacts from reaching this undesirable result will be on beneficial users, and instead seems to be an arbitrary determination of what is "significant and unreasonable."	The impact analysis performed by the GSAs in the subbasin contributed to the development of the undesirable results for declining groundwater level.
Leadership Council		"Like the proposed definition of undesirable results for groundwater levels, the proposed definition of undesirable results for degraded water quality are 'when the minimum threshold for when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area)."	The comment letter cites an incorrect definition. The definition for the undesirable result for water quality is "when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the designated monitoring points within the Subbasin."
Leadership Council		"The GSP's minimum thresholds and measurable objectives were not established in a way that considered the interests of beneficial users including domestic well owners and disadvantaged communities."	The KGA GSP outlines the methods used by its members to establish the Sustainable Management Criteria (SMCs) within their respective plan areas. For the SSJMUD management plan area, projected groundwater levels based on recent historical hydrology were used to analyze the impact to known agricultural, domestic, and municipal wells. While impacts were identified at the minimum thresholds in some management areas, these impacts were determined to not meet the definition of "significant and unreasonable".
Leadership Council		"As in the case of groundwater levels, it is clear that the GSA has not considered the potential impact on drinking water users, in particular disadvantaged communities who are less able to afford solutions to treat contaminated drinking water."	As with the groundwater level SMCs, the KGA GSP outlines the methods used by its members to establish the Sustainable Management Criteria (SMCs) within their respective plan areas. Based on the analysis in the Basin Setting subsection on existing water quality conditions, it was deemed appropriate to use groundwater levels as a proxy for water quality, in addition to water quality and water level measurement at the representative monitoring sites.
Leadership Council		"GSAs must monitor impacts to groundwater for drinking water beneficial users,54 including disadvantaged communities on domestic wells, and must avoid disparate impacts on protected groups pursuant to state law. The GSA's monitoring network does not comply with SGMA regulations, and fails to capture drinking water impacts to disadvantaged communities and domestic wells[...] To ensure the monitoring network adequately captures impacts to all beneficial users, the GSA must ensure the following: Ensure the proposed monitoring network contains representative monitoring wells in or near all disadvantaged communities and clusters of domestic wells in the GSA area; Ensure that monitoring wells and representative monitoring wells in or near disadvantaged communities and clusters of domestic wells are able to measure the groundwater levels at the depth at which the drinking water wells are screened; Explicitly describe any future representative monitoring wells and identify the proposed locations. When assessing the monitoring network data gaps, the GSP must prioritize installing new monitoring wells in locations where disadvantaged communities, small water systems, and domestic well users reside."	The coordinated basin-wide monitoring network was developed using the DWR BMP on SGMA Monitoring Networks, which discusses recommended well density and what constitutes a "SGMA compliant" representative monitoring site. It also allows for (and encourages) GSAs to use existing monitoring programs already in place for collecting data on the Sustainability Indicators identified in a basin's plan. Domestic wells are typically shallow or in the first occurence of groundwater and are, therefore, not representative of the groundwater conditions of the basin as a whole. Further, there are existing programs with which domestic wells and community wells must comply. These have been identified in the Basin Setting and Monitoring Network sections in the discussions of existing programs. In areas of the basin where the well density does not meet the standards used in the plan, proposed well locations have been identified. Per discussion and comments from the cities of Delano and McFarland, four additional wells have been added to the monitoring network within the SSJMUD management area.

Commentor	Ref #	Comment	Response
Leadership Council		The groundwater quality monitoring network does not adequately capture impacts on drinking water users.[…] First, measuring for Arsenic (as in Arvin-Edison WSD) only once a year does not provide the member agency or the GSA with frequent enough information to respond to severe drinking water contamination in a reasonable amount of time. If the member agency's management actions, projects, or decisions to let groundwater decline increase drinking water contamination for families in the management area, the member agency could go a whole year without detecting these impacts. [...] Second, only measuring for compliance with arsenic measurable objectives and minimum thresholds does not protect against increases in other contaminants that exist in other parts of the management area (boron, nitrates, TDS, 123-TCP, iron and manganese). These contaminants could extend, move or increase due to groundwater management activities and pumping patterns. [...] However, avoiding monitoring contaminated areas defeats the purpose of groundwater quality monitoring under SGMA, which is to measure the concentration and spread of contaminant plumes to ensure that groundwater management activities and pumping do not aggravate existing contamination.	The monitoring of water quality for the basin will include the use of data from existing programs (e.g. Title 22, ILRP, CV-SALTS) and sampling coincidental with groundwater level measurements at the representative monitoring sites. As such, the water quality data collected through SGMA will be more frequent than once a year. The constituents of concern to be tested in the water quality sampling at representative monitoring sites vary between the management areas. Therefore, the constituents analyzed will differ according to the management area plan. The selection of representative monitoring sites discouraged the use of wells with existing MCL exceedances because of the nature of the definition of undesirable results for degradation of groundwater quality. The occurence of an increase in concentration for constituents of concern in a representative monitoring site will, by virtue of it being a representative site, will be indicative of the migration of existing contamination.
Leadership Council		The projects and management actions set forth in the Draft GSP do not demonstrate a path towards achieving sustainability goals in the plan, and do not adequately account for the needs of disadvantaged communities pertaining to protected groups under state law. The GSA has allowed member agencies like the Arvin-Edison WSD to use a "glidepath" approach that increases surface water and groundwater recharge before demand reduction measures are implemented. This places the majority of the plan's success on surface water resources, which are variable and may not be able to be procured. The GSA should instead ensure that member agencies implement demand reduction strategies from the beginning so that groundwater levels do not plummet. A critical problem with the structure of the GSA is that member agencies cannot share the cost or responsibility for critical GSA-wide projects. Many more financially powerful agricultural and water banking member agencies could and should be part of a strategy to protect drinking water resources in the GSA area, especially given that they use much larger quantities of groundwater and their continued pumping will likely lead to dry wells and groundwater contamination issues for the most vulnerable homes in the GSA area.	The KGA and its members have the authority under SGMA to prioritize projects and management actions, as they see fit, to demonstrate that the basin can reach sustainability by 2040. The prioritization of projects to increase imported supply for use by districts' customers or for water banking projects protects groundwater for beneficial use in the basin by facilitiating in-lieu banking (where surface water is used whenever it is available, replacing groundwater pumping) or by maintaining groundwater levels through replenishment with banking projects. These projects do not run contrary to the mandate to protect groundwater quality. In fact, with groundwater levels as a proxy Sustainability Indicator for water quality, these projects achieve both the maintenance of groundwater levels and water quality. The agricultural and water banking agencies in the basin, as the customers paying for water deliveries and funding projects via land assessments in their respective districts, can and should be a beneficiary of the projects which they are funding.
Leadership Council		"The KGA GSA should implement or incentivize recharge basins or other recharge activities throughout the subbasin wherever DACs and clusters of domestic wells exist. The GSA should encourage these kinds of recharge projects with health co-benefits over on-farm recharge, which is likely lead to accelerate groundwater contamination."	It is at the discretion of the KGA's member agencies to identify projects to fund, as well as opportunities to collaborate with DACs. SSJMUD is already collaborating with the City of Delano to develop in-district recharge facilities which will be made available to the city when there is capacity available. Conversely, Delano will allow the district to utilize an existing stormwater catch basin as a spreading basin, when it is not in use to manage storm flows. Future projects and management actions which deal specifically with the DACs and domestic wells may be considered for subsequent updates to the GSP and management area plans.
Leadership Council		"For areas vulnerable to declining water levels and loss of production capacity, the KGA GSA should adopt management actions that establish geographical protection areas (buffer zones) by establishing bans, pumping limitations or community-specific management areas around disadvantaged communities and domestic well clusters."	The development of these buffer zones would be predicated on the development of a shallow-zone specific monitoring network and SMCs. As discussed in the response to the Monitoring Network comments, these shallow zones are not representative of groundwater conditions throughout the basin. Furthermore, the framework necessary to implement pumping restrictions or bans does not exist within the KGA or its members. Such policy would not be developed or implemented in time for the 2020 submittal.
Leadership Council		"We also strongly recommend against a groundwater market in the KGA GSA area. The GSP includes potential groundwater market and trading programs. Groundwater markets raise concerns from the perspective of domestic well users and disadvantaged communities."	At this time, the framework to establish a groundwater market in the basin does not exist. The policies and framework that would need to be developed by the KGA and its members is too complex to be completed in time for consideration in the 2020 submittal. Additionally, any groundwater market developed by the KGA or its members would have to comply with SGMA (i.e. prevent localized impacts to the Sustainability Indicators in its implementation).
Leadership Council		"The GSAs should implement and incentivize multi-benefit projects such as wetlands restoration or stormwater drainage ponds that would eliminate flooding and increase groundwater recharge in disadvantaged communities."	It is at the discretion of the KGA's member agencies to identify projects to fund. Future projects and management actions which provide benefits beyond SGMA may be considered for subsequent updates to the GSP and management area plans.
Leadership Council		"Although there are multiple short-term funding sources to leverage for SGMA-related projects, the GSA's and member agencies' operating budgets must be a reliable source of funding over the long-term of GSP implementation, and the GSA and member agencies cannot rely on grant funding for long-term projects and programs that benefit disadvantaged communities. The GSA and member agencies must be responsible for addressing the drinking water issues caused by their policy decisions and activities."	It is entirely appropriate that the KGA's members, when working in collaboration with DACs on a project to benefit groundwater quantity and quality in the basin, seek funding for such projects through state and federal grant funding programs. Grant funding, where the districts are eligible, is applied for to defray the cost of projects (which often far exceed the award amount). The remaining costs of projects and management actions are to be funded with the districts' operating budgets or through special assessments.
Leadership Council		"the Draft GSP allows continued overdraft above the safe yield of the basin, such that drinking water wells (especially domestic wells) will continue to go dry, infringing on the rights of overlying users of groundwater. The GSP must be revised to protect the rights of residents of disadvantaged communities and/or low-income households who hold water rights to groundwater."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with the statement, as the KGA GSP and its included management area plans have demonstrated, the combination of projects, management actions, and established SMCs will bring the basin into balance with its groundwater management by 2040.
Leadership Council		"The reasonable and beneficial use doctrine applies here given the negative impacts of the Draft GSP on groundwater supply and quality, which are likely to unreasonably interfere with the use of groundwater for drinking water and other domestic uses. As the Draft GSP authorizes waste and unreasonable use, it conflicts with the reasonable and beneficial use doctrine and the California Constitution."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with Leadership Council's statement regarding the plan's authorization of "waste and unreasonable use". The beneficial uses of water in the basin include other uses beyond domestic consumption. As such, it is entirely appropriate and in the authority of the GSAs that impacts to groundwater be analyzed in consideration of all beneficial uses identified in the plan.
Leadership Council		"The "public trust" doctrine has recently been applied to groundwater where there is a hydrological connection between the groundwater and a navigable surface water body. In Environmental Law Foundation , the court held that the public trust doctrine applies to "the extraction of groundwater that adversely impacts a navigable waterway" and that the government has an affirmative duty to take the public trust into account in the planning and allocation of water resources. The court also specifically held that SGMA does not supplant the requirements of the common law public trust doctrine. In contrast to these requirements, the Draft GSP does not consider impacts on public trust resources, or attempt to avoid insofar as feasible harm to the public's interest in those resources."	This comment is directed to the KGA GSP and will be addressed by KGA. We respectfully disagree with Leadership Council's position in that the Basin Setting of the KGA GSP and its management area plans have adequately demonstrated that there are no interconnected surface waters in the basin and that this is the existing condition of the basin.

Appendix E

SSJMUD Board Resolution to Adopt Management Area Plan

BEFORE THE BOARD OF DIRECTORS OF
SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

IN THE MATTER OF: **RESOLUTION NO. 19-14**

RESOLUTION APPROVING MANAGEMENT AREA PLAN FOR SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT MANAGEMENT AREA PLAN

WHEREAS, the Kern Groundwater Authority (the "Authority") is duly formed and existing under and pursuant to that certain Second Amended and Restated Agreement Joint Powers Agreement (the "JPA"), for the purposes of carrying out the Sustainable Groundwater Management Act (Water Code § 10720 *et seq.*) (SGMA), including the development, adoption and implementation of a Groundwater Sustainability Plan (GSP) for lands within the boundaries of the Authority's members and elsewhere within the Tulare Lake Groundwater Basin;

WHEREAS, the District is a member of the Authority;

WHEREAS, pursuant to Section 7.01 of the JPA, the District has exercised its option under the JPA to develop a chapter governing SGMA implementation within the boundaries of the District for inclusion in the Authority's GSP, which is titled *Southern San Joaquin Municipal Utility District Management Area Plan* (the "SSJMUD Chapter"); and,

WHEREAS, the District has conducted public outreach, solicited public input on, and, as appropriate, has responded or will respond to public comments on, the SSJMUD Chapter as required under SGMA; and

WHEREAS, following such outreach, solicitation and response, the District's Board of Directors reviewed and evaluated the SSJMUD Chapter.

NOW, THEREFORE, THE BOARD OF DIRECTORS OF THE SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT does hereby resolve, declare and order as follows:

1) Each of the matters set forth above is true and correct and the Board so finds and determines.

2) The Board finds that the SSJMUD Chapter is consistent with the requirements of SGMA, and pursuant to Section 2.03(b) of the JPA approves the Chapter for inclusion in the Authority's GSP.

3) The Board hereby authorizes District staff to undertake such actions as are necessary and appropriate to transmit the SSJMUD Chapter to the Authority and to present the SSJMUD Chapter to the Authority's Board of Directors for consideration of inclusion in the Authority's GSP.

All the foregoing being on motion of Director, seconded by Director, and authorized by the following vote, to wit:

AYES: Fisher, Dulcich, Regan, Zaninovich, Morris

NOES: None

ABSTAIN: None

ABSENT None

I HEREBY CERTIFY that the foregoing resolution is the resolution of said District as duly passed and adopted by said Board of Directors on the 11 day of December 2019.

WITNESS my hand and seal of said Board of Directors this 11 day of December 2019.

Roland Gross, Secretary
of the Board of Directors

Appendix F

Specific Yield Map

TULARE
KERN

DELANO-EARLIMART IRRIGATION DISTRICT

Delano

Pond

Poso

Elmo

McFarland

Jasmine

Famoso

T 25 S.
T 26 S.

T 26 S.
T 27 S.

R 24 E. | R 25 E.

R 25 E. | R 26 E.

R. 26 E. | R 27 E.

R 26 E. R 27 E.

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT BOUNDARY

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT BOUNDARY

N

EXPLANATION

Standard Crop Symbol	Crops	Approx. Water use ac.ft./ac.	
G	Dry farmed hay and grain	0	Dry Farmed
H	Idle crop land	0	
K	Native pasture	0	
C	Truck crops	1.25	Low Use
B I	Potatoes	1.16	
A	Citrus	2.00	
B	Field crops	2.40	
D	Deciduous fruits and nuts	2.54	Moderate Use
E	Olives	2.00	
F	Grapes	2.10	
L	Forage crops	3.36	High Use

150 — Contours - Elevation of water table - Oct. Nov. 1946

5 — Contours - Computed specific yield of sediments in zone of water table fluctuation. 1921 - 1946

USBR, 1948

SCALE IN MILES

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION - REGION II
TULARE BASIN DISTRICT

RELATION OF PUMPING DEMAND AND SPECIFIC YIELD TO ELEVATION OF WATER TABLE

DRAWN AHB. SUBMITTED S.W. Cook
TRACED RECOMMENDED A.R. Nordholm
CHECKED APPROVED R.B. Hayward

TB-68-C | FRESNO CALIFORNIA

PLATE 2

Appendix G

Historical Cross Sections

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

DELANO

R 25 E | R 26 E

R 26 E | R 27 E

25-25-4 | 25-25-3E | 24-25-34C | 25-25-3 | 24-25-35D | 25-25-1E | 24-25-36D | 25-26-6D | 24-26-31B | 25-26-6B | 25-26-5B | 24-26-32 H FRIANT-KERN CANAL | 24-26-32G | 24-26-32I | 25-26-4 | 24-26-33 | 25-26-3E | 24-26-33E | 25-26-3C | 24-26-34E (Geol.) | 25-26-1F | 24-26-36 SOUTHERN PACIFIC RR. | RAG GULCH WASH | 24-27-31

WATER LEVEL FALL 1921

WATER LEVEL NOV. 1946

500 400 300 200 100 SEA LEVEL -100 -200 -300 -400 -500 -600 -700 -800 -900 -1000

LEGEND

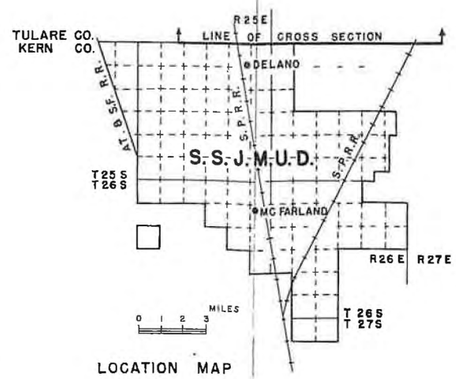
25-26-17C (Geol.) — Well Sampled By Geologist

Well Number

Symbols show material actually logged: unpatterned colored areas give inferred extension from these data.

- Gravel (Very Permeable)
- Sand (Permeable)
- Silt (Relatively Permeable)
- Sandy Clay (of drillers = silt, sandy silt or very fine sand - Relatively Permeable)
- Clay (Relatively Impermeable)
- Blue Strata

GEOLOGIC CROSS SECTION LOOKING NORTH



LOCATION MAP

This profile was prepared from well logs which were either copied from the records of drillers or made by geologists from samples obtained from drillers. The accuracy of the logs varies with the individual and is often open to considerable question. Thus conspicuous and rapid changes in sediment character, from well to well along the profiles are only in part actual, i.e. due to lensing and channeling during deposition. To an indeterminate extent they are merely a result of inconsistancies in the use of descriptive terms by the several drillers.

The 1921 water levels were taken from The California Department of Public Works Ground-water map for that year, and the 1946 water levels were taken from a map by The Bureau of Reclamation.

HORIZONTAL SCALE - MILES

0

VERTICAL SCALE - FEET

100 0 100 200 300

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION - REGION II
TULARE BASIN DISTRICT

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

GEOLOGIC CROSS SECTION ALONG TULARE-KERN COUNTY LINE

DRAWN: W.E.L. R.M.R.	SUBMITTED: J.W. Funk		
TRACED: E.M.K.	RECOMMENDED: A.F. Nordholm		
CHECKED: J.W.F.	APPROVED: R.B. Coggins		
TB - 82 - C	FRESNO, CALIFORNIA	1-20-48	

PLATE 4

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

STONE QUAD | DELANO QUAD — R25E | R26E — DELANO QUAD | RICHGROVE QUAD — R26E | R27E

DELANO

25-24-12 B (GEOL) · 25-25-10 K (GEOL) · 25-25-10 I · 25-25-3 D · 25-25-2 C · SOUTHERN PACIFIC R.R. · HIGHWAY 99 · 25-25-11 F · 25-25-1 E · 25-25-1 C · 25-25-12 E · 25-26-7 E · 25-26-6 E · 25-26-8 B · 25-26-8 A · 25-26-9 C · 25-26-9 E · FRIANT-KERN CANAL · 25-26-3 F · 25-26-10 B · 25-26-2 B · SOUTHERN PACIFIC R.R. · STATE HIGHWAY 65 · 25-26-17 C (Geol.)

WATER LEVEL-FALL 1921

WATER LEVEL-NOV. 1946

SEA LEVEL

500 · 400 · 300 · 200 · 100 · SEA LEVEL · -100 · -200 · -300 · -400 · -500 · -600 · -700 · -800 · -900

GEOLOGIC CROSS SECTION LOOKING NORTH

LEGEND

25-26-17 C (Geol.) — Well Sampled By Geologist

Well Number

Symbols show material actually logged: unpatterned colored areas give inferred extension from these data.

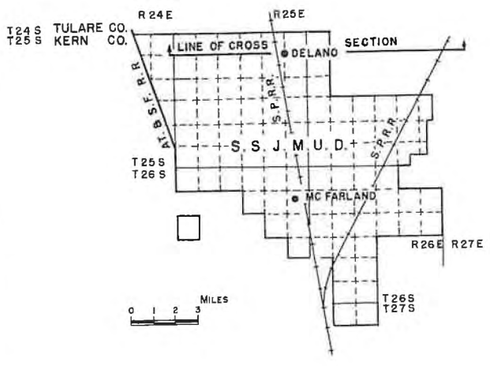
- Gravel (Very Permeable)
- Sand (Permeable)
- Silt (Relatively Permeable)
- Sandy Clay (of drillers = silt, sandy silt or very fine sand – Relatively Permeable)
- Clay (Relatively Impermeable)
- Blue Strata

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The 1921 water levels were taken from The California Department of Public Works Groundwater map for that year, and the 1946 water levels were taken from a map by The Bureau of Reclamation.

HORIZONTAL SCALE — MILES 0

VERTICAL SCALE — FEET 100 0 100 200 300



LOCATION MAP

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION — REGION II
TULARE BASIN DISTRICT

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

GEOLOGIC CROSS-SECTION ONE MILE SOUTH OF TULARE COUNTY LINE

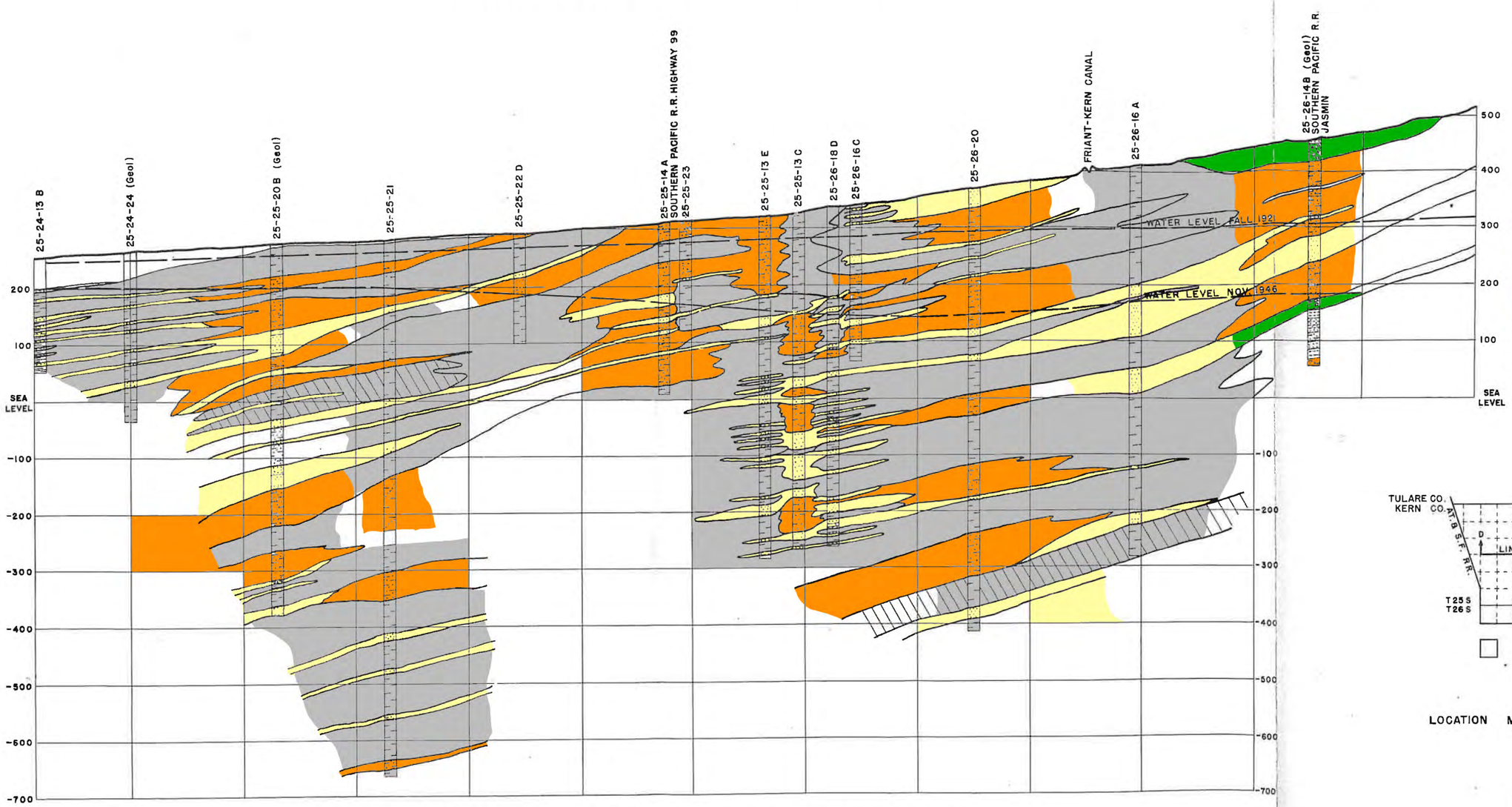
DRAWN: W.E.L. R.M.R.	SUBMITTED:		
TRACED: E.M.K.	RECOMMENDED:		
CHECKED: J.W.F.	APPROVED:		

TB-81-C | FRESNO, CALIFORNIA | 11-26-47

PLATE 5

R25E | POND QUAD | MC FARLAND QUAD | R25E R26E | MC FARLAND QUAD | DEEPWELL RANCH QUAD | R26E

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT



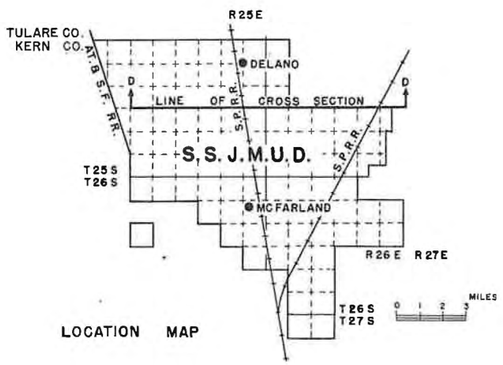
LEGEND

Well Sampled By Geologist

Well Number

Symbols show material actually logged: unpatterned colored areas give inferred extension from these data.

- Gravel (Very Permeable)
- Sand (Permeable)
- Silt (Relatively Permeable)
- Sandy Clay (of drillers = silt, sandy silt or very fine sand – Relatively Permeable)
- Clay (Relatively Impermeable)
- Blue Strata



LOCATION MAP

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The 1921 water levels were taken from The California Department of Public Works Groundwater map for that year, and the 1946 water levels were taken from a map by The Bureau of Reclamation.

GEOLOGIC CROSS SECTION, LOOKING NORTH

HORIZONTAL SCALE - MILES
0

VERTICAL SCALE - FEET
100 0 100 200 300

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION - REGION II
TULARE BASIN DISTRICT

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

GEOLOGIC CROSS SECTION THREE MILES SOUTH OF TULARE COUNTY LINE

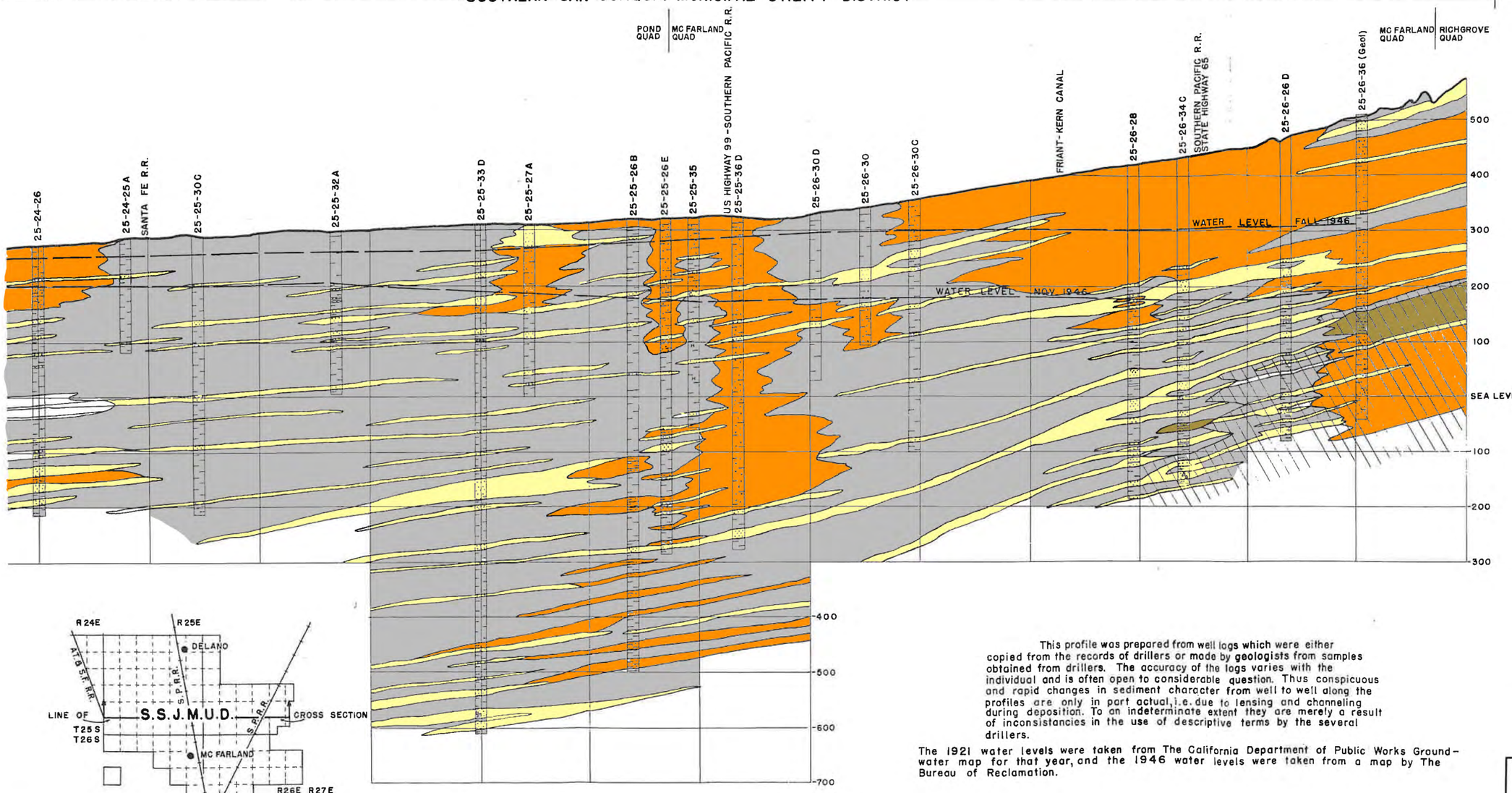
DRAWN: W.E.L. R.M.R. SUBMITTED:
TRACED: E.M.K. RECOMMENDED:
CHECKED: J.W.F. APPROVED:

TB-83-C | FRESNO CALIFORNIA 1-27-48

PLATE 6

R25E | R25E R26E | R26E

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT



LOCATION MAP

GEOLOGIC CROSS SECTION, LOOKING NORTH

This profile was prepared from well logs which were either copied from the records of drillers or made by geologists from samples obtained from drillers. The accuracy of the logs varies with the individual and is often open to considerable question. Thus conspicuous and rapid changes in sediment character from well to well along the profiles are only in part actual, i.e. due to lensing and channeling during deposition. To an indeterminate extent they are merely a result of inconsistancies in the use of descriptive terms by the several drillers.

The 1921 water levels were taken from The California Department of Public Works Ground-water map for that year, and the 1946 water levels were taken from a map by The Bureau of Reclamation.

LEGEND

25-26-36 (Geol) Well Sampled By Geologist

Well Number

Symbols show material actually logged: unpatterned colored areas give inferred extension from these data.

- Gravel (Very Permeable)
- Sand (Permeable)
- Silt (Relatively Permeable)
- Sandy Clay (of drillers = silt, sandy silt very fine sand - Relatively Permeable)
- Clay (Relatively Impermeable)
- Blue Strata

HORIZONTAL SCALE - MILES
0

VERTICAL SCALE - FEET
100 0 100 200 300

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION - REGION II
TULARE BASIN DISTRICT

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

GEOLOGIC CROSS SECTION FIVE MILES SOUTH OF TULARE COUNTY LINE

DRAWN: W.E.L. R.M.R. SUBMITTED: J.W. Wink
TRACED: E.M.K. RECOMMENDED: A.B. Lordsburn
CHECKED: J.W.F. JWF APPROVED: R.B. Stozzens

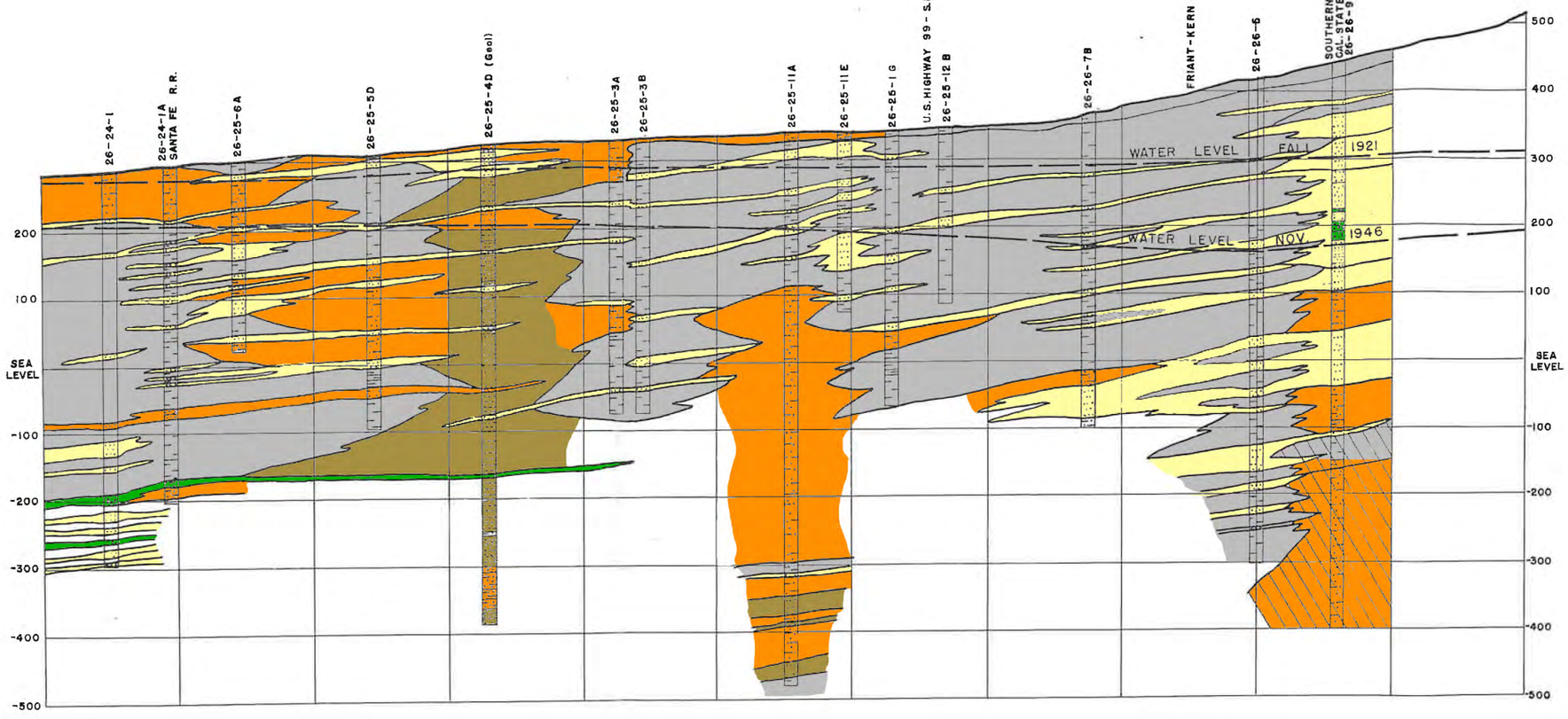
TB-84-C | FRESNO CALIFORNIA 2/2/48

PLATE 7

R 25E | R 25E | R26E | R26E

POND QUAD | MC FARLAND QUAD | MC FARLAND QUAD | DEEPWELL RANCH QUAD

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT



GEOLOGIC CROSS SECTION, LOOKING NORTH

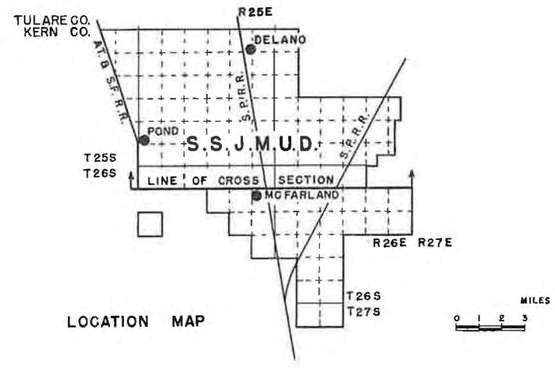
LEGEND

26-25-4D (Geol) — Well Sampled By Geologist

Well Number

Symbols show material actually logged: unpatterned colored areas give inferred extension from these data.

- Gravel (Very Permeable)
- Sand (Permeable)
- Silt (Relatively Permeable)
- Sandy Clay (of drillers = silt, sandy silt or very fine sand – Relatively Permeable)
- Clay (Relatively Impermeable)
- Blue Strata



LOCATION MAP

This profile was prepared from well logs which were either copied from the records of drillers or made by geologists from samples obtained from drillers. The accuracy of the logs varies with the individual and is often open to considerable question. Thus conspicuous and rapid changes in sediment character from well to well along the profiles are only in part actual, i.e. due to lensing and channeling during deposition. To an indeterminate extent they are merely a result of inconsistancies in the use of descriptive terms by the several drillers.

The 1921 water levels were taken from The California Department of Public Works Groundwater map for that year, and the 1946 water levels were taken from a map by The Bureau of Reclamation.

HORIZONTAL SCALE – MILES
1 0 1

VERTICAL SCALE – FEET
100 0 100 200 300

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION - REGION II
TULARE BASIN DISTRICT

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

GEOLOGIC CROSS SECTION SEVEN MILES SOUTH OF TULARE COUNTY LINE

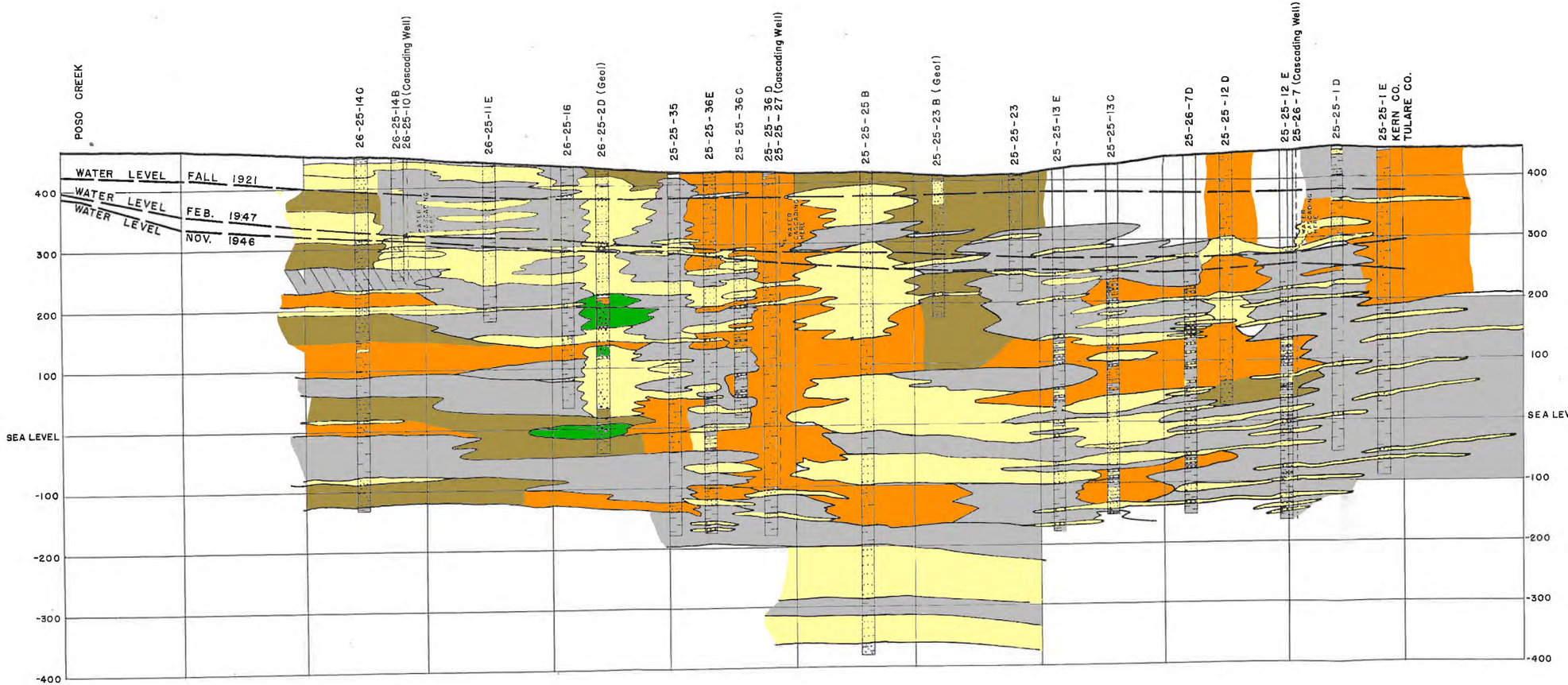
DRAWN: W.E.L. R.M.R. SUBMITTED: J.W. Stipe
TRACED: E.M.K. RECOMMENDED: Q.Y. Handlock
CHECKED: J.W.F. J.W.S. APPROVED: R.B. Cozzens

TB-86-C | FRESNO CALIFORNIA 2-19-48

PLATE 8

POND QUAD | MC FARLAND QUAD | T26S | T25S | MC FARLAND QUAD | DELANO QUAD | T25S | T24S

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT



GEOLOGIC CROSS SECTION, LOOKING NORTH 80° WEST

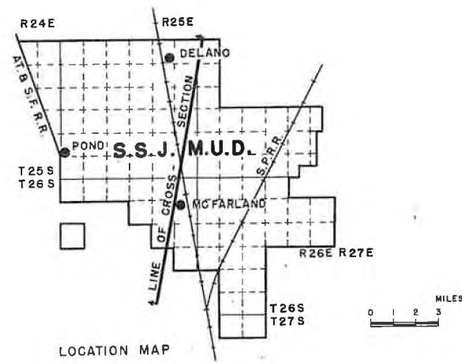
LEGEND

26-25-14C (Geol) — Well Sampled By Geologist

Well Number

Symbols show material actually logged: unpatterned colored areas give inferred extension from these data.

- Gravel (Very Permeable)
- Sand (Permeable)
- Silt (Relatively Permeable)
- Sandy Clay (of drillers = silt, sandy silt or very fine sand – Relatively Permeable)
- Clay (Relatively Impermeable)
- Blue Strata



LOCATION MAP

This profile was prepared from well logs which were either copied from the records of drillers or made by geologists from samples obtained from drillers. The accuracy of the logs varies with the individual and is often open to considerable question. Thus conspicuous and rapid changes in sediment character from well to well along the profiles are only in part actual, i.e. due to lensing and channeling during deposition. To an indeterminate extent they are merely a result of inconsistancies in the use of descriptive terms by the several drillers.

The 1921 water levels were taken from The California Department of Public Works Ground-water map for that year, the 1946 and 1947 water levels were taken from a map by The Bureau of Reclamation.

HORIZONTAL SCALE – MILES
1 0 1

VERTICAL SCALE – FEET
100 0 100 200 300

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION – REGION II
TULARE BASIN DISTRICT

SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT

GEOLOGIC CROSS SECTION
LOOKING NORTH 80° WEST

DRAWN: W.F.L.	SUBMITTED: J. W. Funk		
TRACED: E.M.K.	RECOMMENDED: A. D. Nordholm		
CHECKED: J.W.F.	APPROVED: R. B. Cozzens		
TB-85-C	FRESNO	CALIFORNIA	2/13/48

PLATE 9

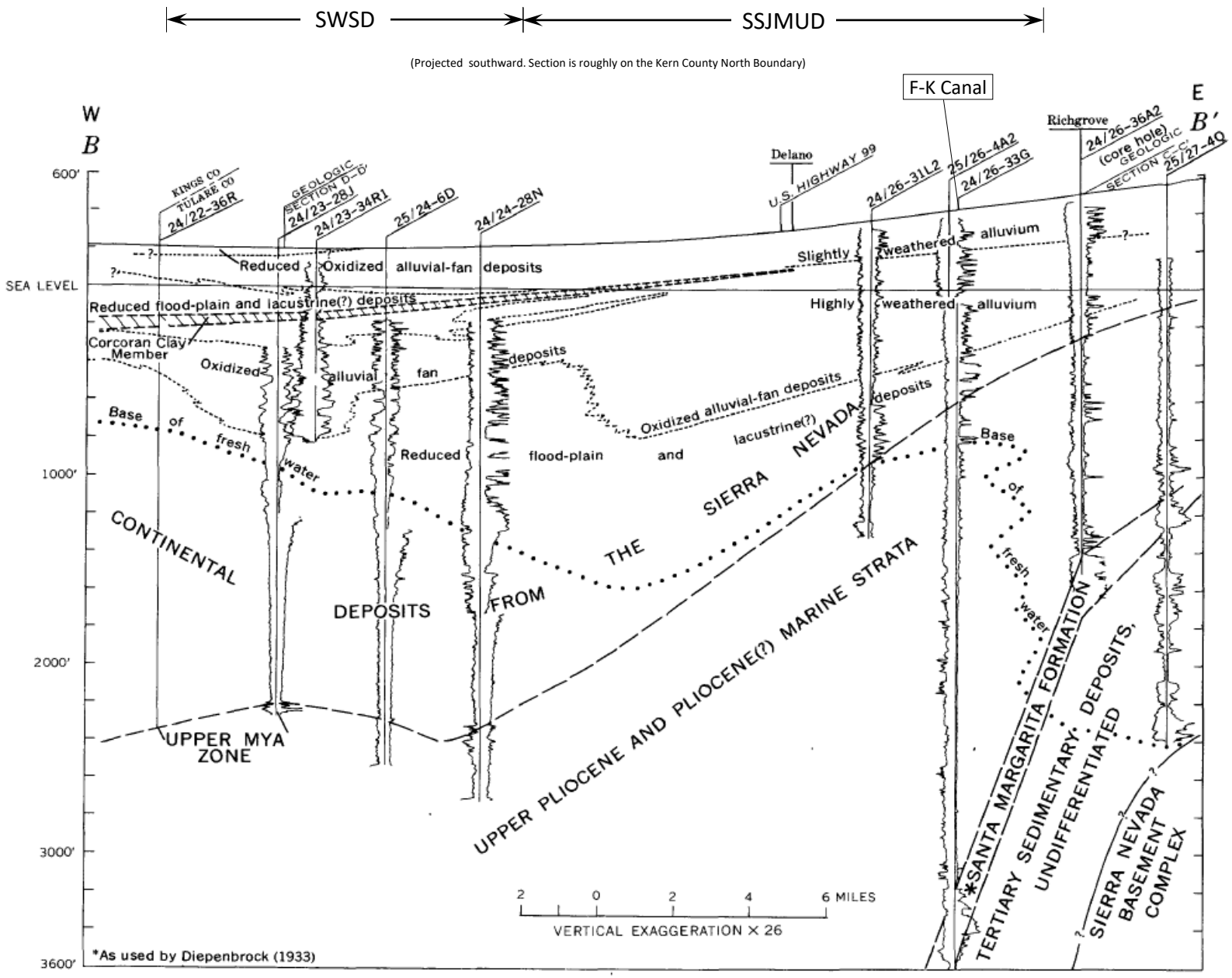


FIGURE 5.—Geologic section *B–B′* through the Richgrove core hole. See figure 6 for location of wells and figure 4 for explanation.

Source: Lofgren and Klausing, 1969

SWSD ⟷ SSJMUD

(Projected southward. Section is roughly on the Kern County North Boundary)

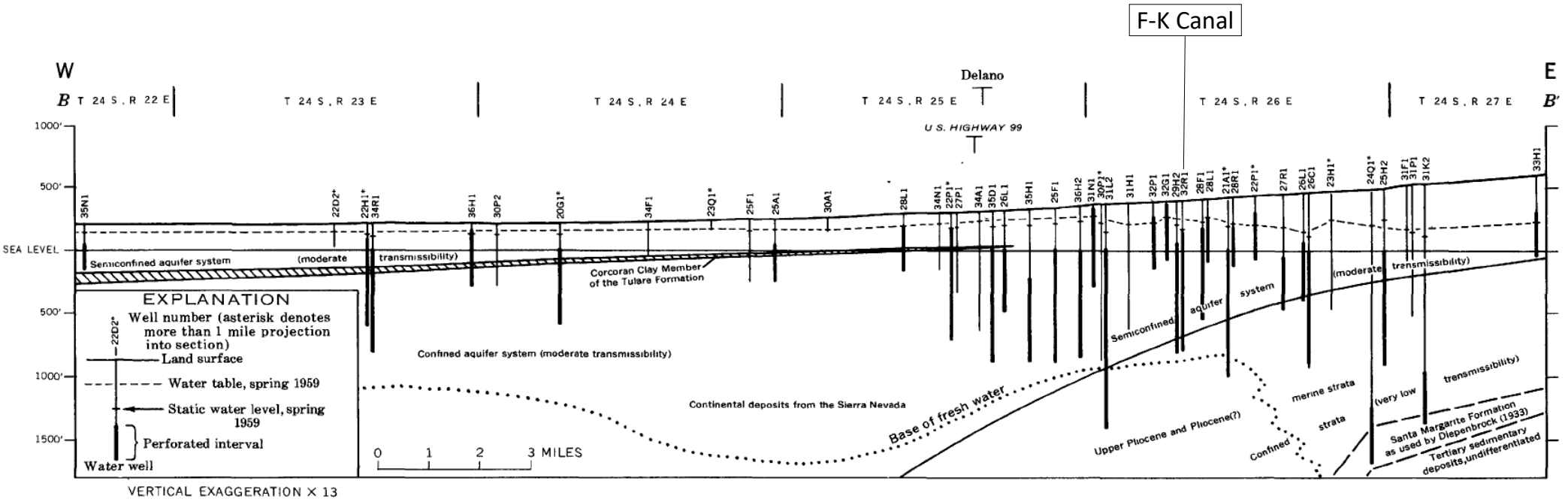
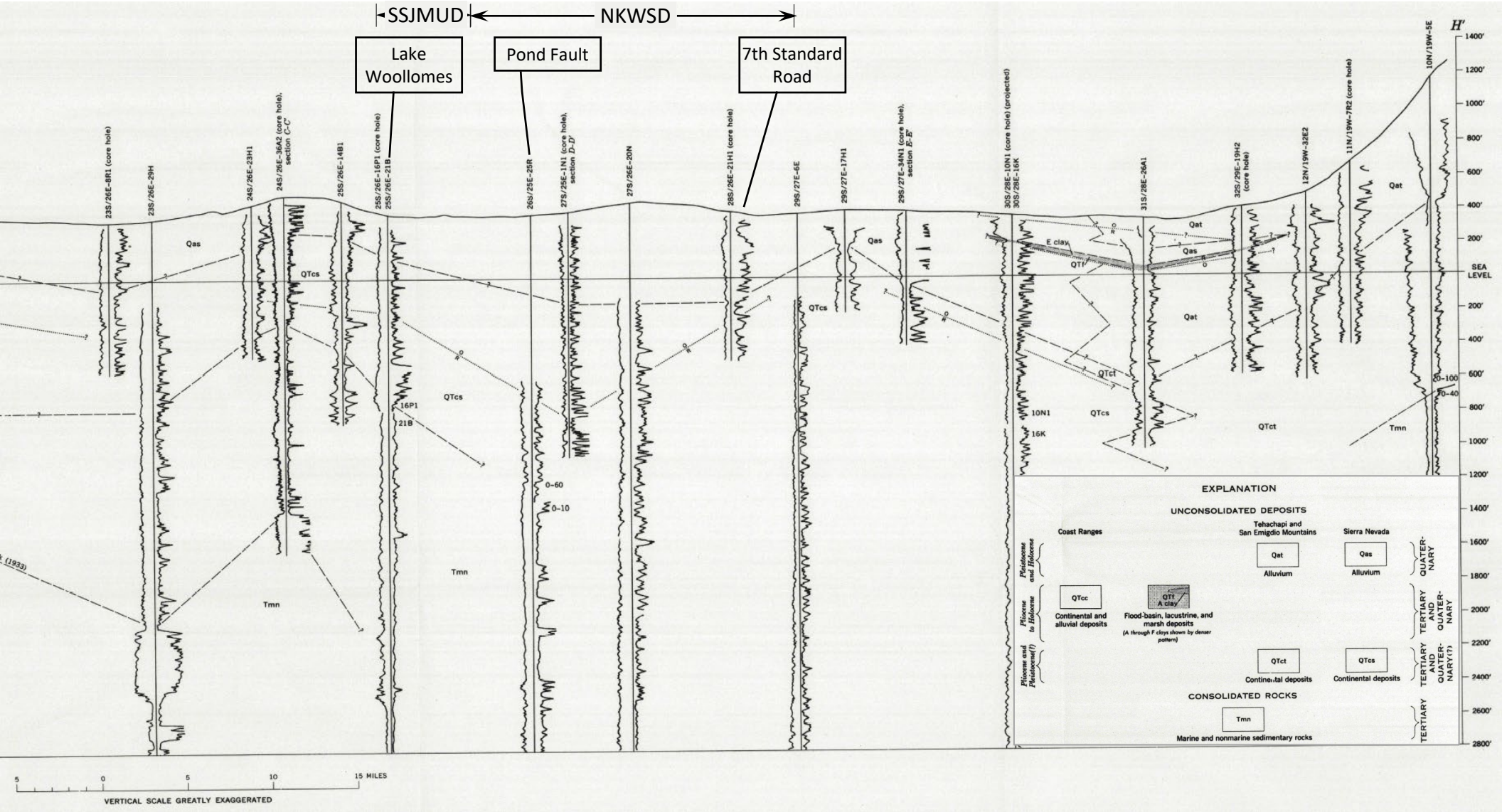


FIGURE 18.—Hydrologic sections *A'–A''* and *B–B'* showing perforated intervals and water levels in wells. Alinement of sections shown in figure 6.

Source: Lofgren and Klausing, 1969

North

South



WATER-SUPPLY PAPER 1999-H
PLATE 1

Source: Croft, 1972

C

SW

C'

NE

SWID | NKWSD | SSJMUD

T28S R25E 31G
T28S R25E 18G
T28S R25E 7G
T27S R25E 32A
T27S R25E 22A
T27S R25E 15C
T27S R25E 1N
T26S R26E 30M
T26S R26E 22E
T26S R26E 21P
T26S R26E 15C
T26S R26E 11H
T26S R27E 8D

"E" EQUIVALENT CLAY

"E" EQUIVALENT CLAY

CONTOURED HORIZON

D U D U

SEA LEVEL DATUM

SEISMIC FORM LINE

FORMATIONAL DATUM CHANGE

-2,000'

POND FAULT ZONE

SCALE

500'

15:1 Vertical Exaggeration

0

0 6,000'

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

GEOLOGIC CROSS SECTION

C - C'

Kern County, California

Author: PGA	Project: KWA P.O. 10376
Drafted By: PGA	Date: 6/91

PLATE VIII

PGA, 1991

Figure 37

SWSD — SSJMUD

West — East

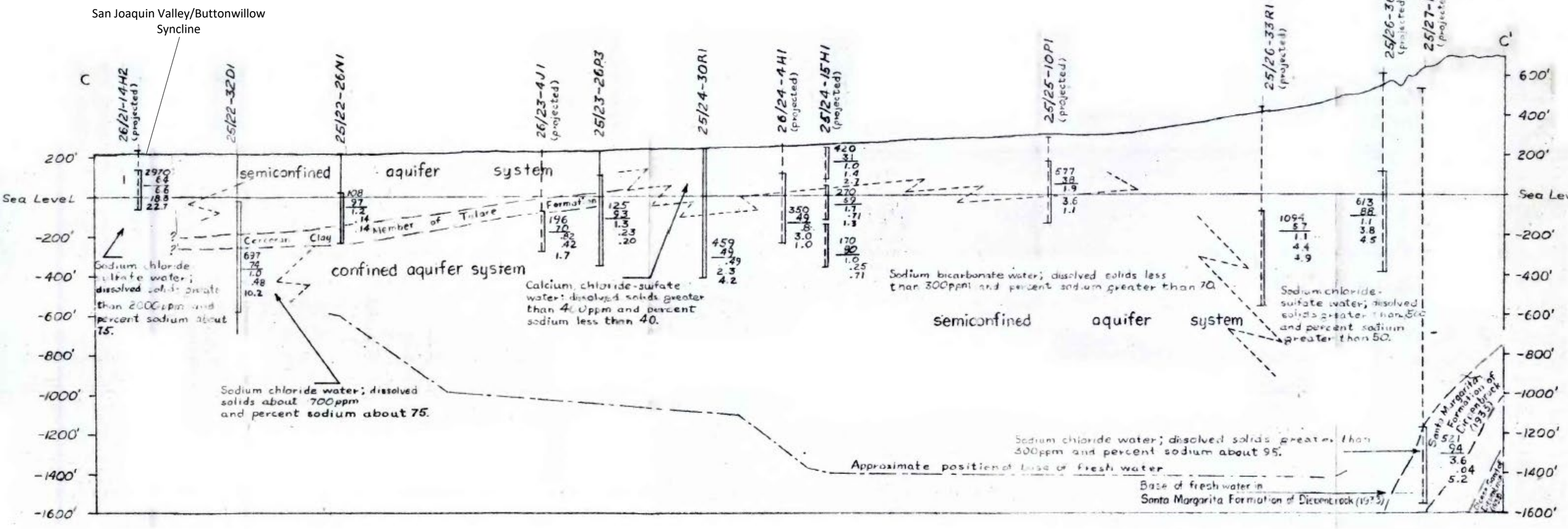


FIGURE 37._GEOCHEMICAL SECTION C-C' IN THE TERRA BELLA-LOST HILLS AREA, CALIFORNIA

Source: OFR 63-47, Hilton et al,1963

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

West

East

SWSD

SSJMUD

ANTELOPE PLAIN

Lost Hills

Delano

San Joaquin Valley/Buttonwillow Syncline

Sodium sulfate water; dissolved solids average above 1,500-4,000 ppm and percent sodium about 50

Sodium sulfate, sulfate chloride, and chloride water; dissolved solids average about 2,000 to 7,000 ppm and percent sodium about 50 to 75

Sodium bicarbonate water; dissolved solids average about 150 ppm and percent sodium about 80

Sodium and calcium chloride sulfate water; dissolved solids average about 400 to 800 ppm and percent sodium about 40

Sodium bicarbonate and bicarbonate sulfate water; dissolved solids average about 300 ppm and percent sodium about 75

Diatomaceous clay

Sea level

Position of perforated casing, where known, is indicated by heavy-line segment. The chemical-character symbol is based on the analysis of water from the pump discharge. The uppermost number indicates dissolved solids in parts per million. No parentheses indicates total solids were determined by weighing. Parentheses indicate dissolved solids calculated as the sum of determined constituents; figure includes silica if determined. Asterisk (*) indicates dissolved solids estimated from electrical conductivity or from empirical formula (Mendenhall and others, 1916, p. 81). The number immediately above the line is the percent sodium. The numbers below the line, reading downward, represent the bicarbonate plus carbonate, sulfate, and chloride content, in equivalents per million

See plate 3 for well locations

EXPLANATION

350*	Dissolved solids
88	Percent sodium
1.8	$HCO_3 + CO_3$
1.5	SO_4
1.7	Cl

GEOCHEMICAL SECTIONS AND GRAPHS, h-h', j-j', AND k-k'

2 0 10 Miles

Analysis seems reliable; however, previous samplings have shows presence of hydroxyl ions indicating possible source of contamination from cement packers between sampled intervals

WATER-SUPPLY PAPER 1469 PLATE 28

Source: Davis et. al. WSP 1469, 1959

West

NE

WATER-SUPPLY PAPER 1469 PLATE 11

ANTELOPE VALLEY

LOST HILLS

SWSD

SSJMUD

San Joaquin Valley/Buttonwillow Syncline

DELANO

RICHGROVE

Oxidized sediments

Reduced sediments

Pyroclastics

Clay

See plate 3 for location of wells

EXPLANATION

Gravel

Gravel and sand

Sand

Sandy clay, silt, silty sand

Clay and gravel; clay, sand and gravel; cemented gravel

Clay, silty clay, shale

Well log plotted from interpretation of electric log is indicated by vertical line through log; generalized interpretation from electric log, as follows:

Well-sorted sand and coarser materials

Poorly sorted sand, sandy clay, sandy silt, and silt

Clay and silty clay

GEOLOGIC SECTION h-h'

2 0 10 Miles

Vertical scale 104 times horizontal scale

WATER-LEVEL PROFILES

1952

1921

1948

Profile of water table
Unconfined or semiconfined water, for year indicated

1948

Profile of piezometric surface
Confined water, for year indicated

Source: Davis et. al. WSP 1469, 1959

Appendix H

Historical Contours and Change in Elevation Maps

PLATE 5

KERN COUNTY WATER AGENCY
BAKERSFIELD, CALIFORNIA

GROUNDWATER SURFACE ELEVATION MAP

UNCONFINED AND EQUIVALENT WELLS USED FOR CONTROL

JANUARY 1991

2 0 2 4
scale miles

K. TURNER

JULY 1991

KINGS COUNTY

TULARE CO

SAN LUIS OBISPO COUNTY

SANTA BARBARA COUNTY

VENTURA COUNTY

LEGEND

- FOOTHILL LINE
- BEDROCK LINE
- FAULT
- CALIFORNIA AQUEDUCT AND TURNOUTS

WATER WELL CLASSIFICATION

- COMPOSITE WELL, ELEVATION CONSISTANT WITH UNCONFINED AQUIFER
- ▲ UNCONFINED WELL
- X WELL LOCATED OUTSIDE CONFINING CORCORAN CLAY OR EQUIVALENT

200' CONTOURS OF GROUNDWATER ELEVATION IN FEET ABOVE SEA LEVEL

P267 POSSIBLE PERCHED WATER INFLUENCE

CONTOUR LINES ARE DASHED WHERE APPROXIMATELY LOCATED OR INFERRED.

MEASUREMENTS TAKEN BY KCWA AND OTHER AGENCIES.

KERN COUNTY WATER AGENCY
BAKERSFIELD, CALIFORNIA

GROUNDWATER SURFACE ELEVATION MAP

UNCONFINED AND EQUIVALENT WELLS USED FOR CONTROL

JANUARY 1992

0 2 0 2 4
scale miles

TOM HASLEBACHER — JULY 1992

KINGS COUNTY

TULARE CO

SAN LUIS OBISPO COUNTY

SANTA BARBARA COUNTY

VENTURA COUNTY

DELANO

McFARLAND

WASCO

SHAFTER

BAKERSFIELD

ARVIN

BUENA VISTA LAKE BED

TAFT

MARICOPA

FELLOWS

FORD CITY

McKITTRICK

LOST HILLS

KERN WILDLIFE REFUGE

Ranchos Los Alamos Y Agua Caliente

Rancho San Emigdio

LAKE of the WOODS

FRAZIER PARK

LEBEC

LEGEND

- FOOTHILL LINE
- BEDROCK LINE
- FAULT
- CALIFORNIA AQUEDUCT AND TURNOUT

WATER WELL CLASSIFICATION

- COMPOSITE WELL, ELEVATION CONSISTANT WITH UNCONFINED AQUIFER
- ▲ UNCONFINED WELL
- X WELL LOCATED OUTSIDE CONFINING CORCORAN CLAY OR EQUIVALENT

200' — CONTOURS OF GROUNDWATER ELEVATION IN FEET ABOVE SEA LEVEL

P267 — POSSIBLE PERCHED WATER INFLUENCE

CONTOUR LINES ARE DASHED WHERE APPROXIMATELY LOCATED OR INFERRED

MEASUREMENTS TAKEN BY KCWA AND OTHER AGENCIES

PLATE 5

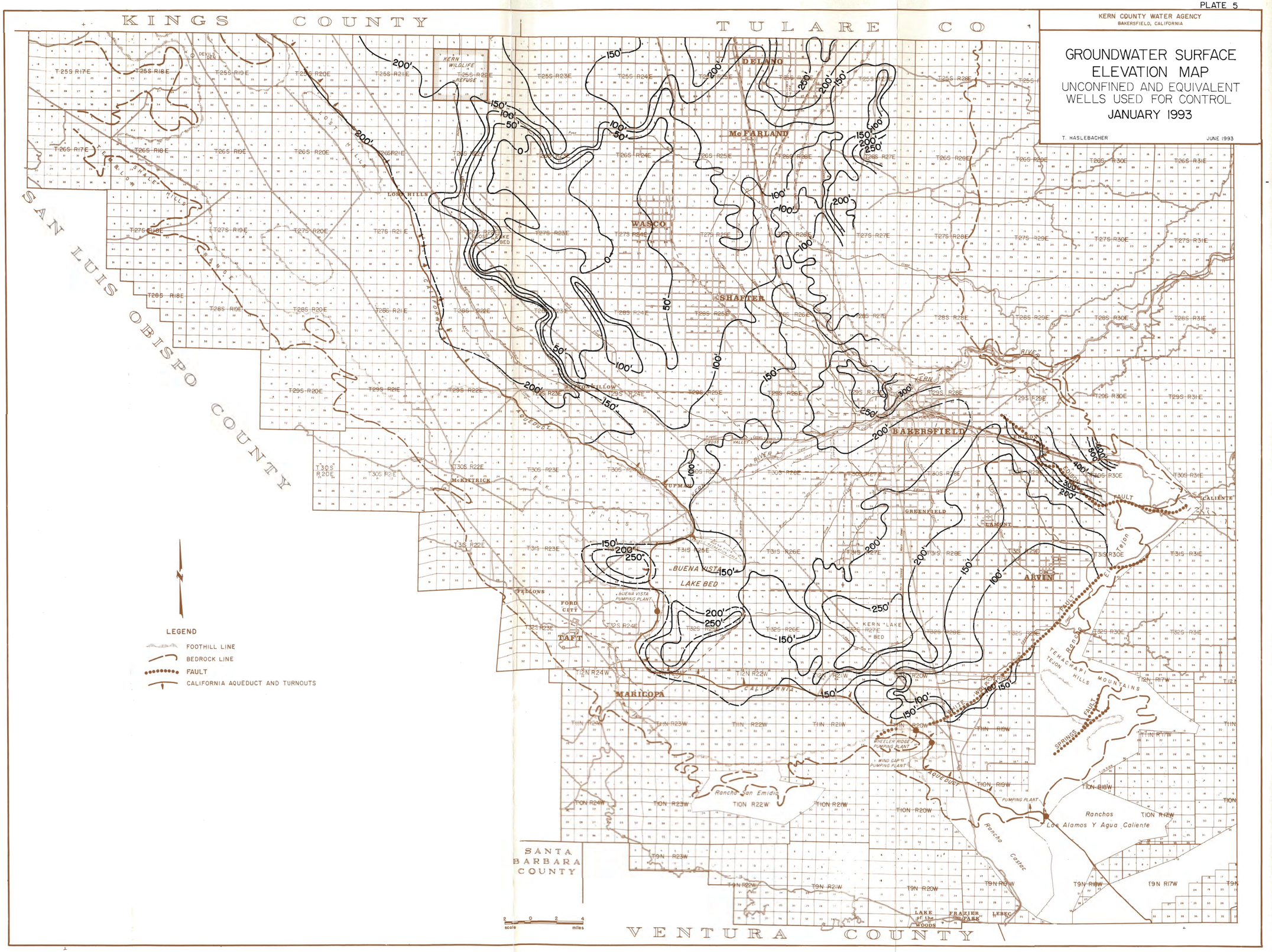
KERN COUNTY WATER AGENCY
BAKERSFIELD, CALIFORNIA

GROUNDWATER SURFACE ELEVATION MAP

UNCONFINED AND EQUIVALENT WELLS USED FOR CONTROL

JANUARY 1993

T. HASLEBACHER — JUNE 1993



LEGEND

- FOOTHILL LINE
- BEDROCK LINE
- FAULT
- CALIFORNIA AQUEDUCT AND TURNOUTS

scale 2 0 2 4 miles

PLATE 5

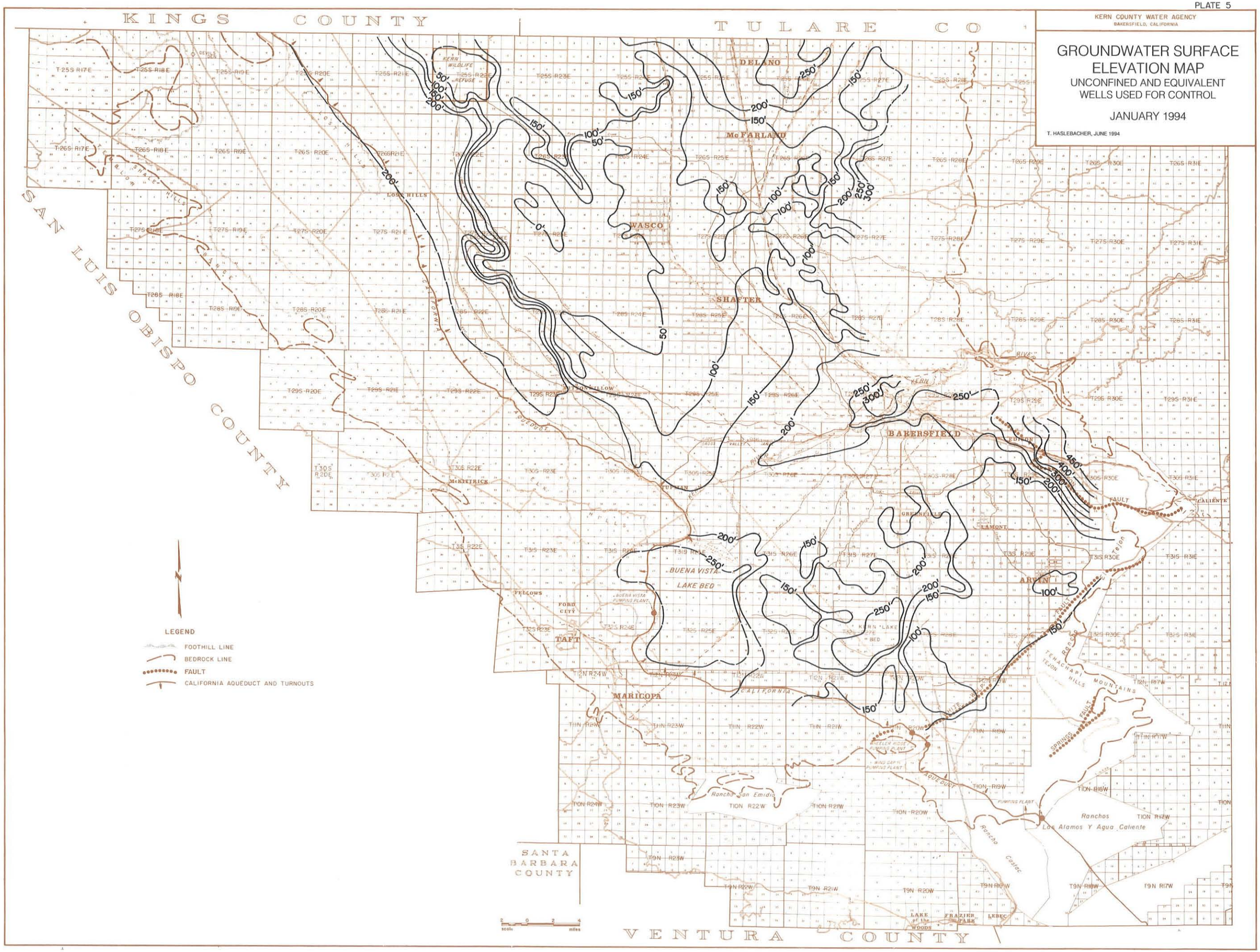
KERN COUNTY WATER AGENCY
BAKERSFIELD, CALIFORNIA

GROUNDWATER SURFACE ELEVATION MAP

UNCONFINED AND EQUIVALENT WELLS USED FOR CONTROL

JANUARY 1994

T. HASLEBACHER, JUNE 1994



KERN COUNTY WATER AGENCY
BAKERSFIELD, CALIFORNIA

GROUND WATER SURFACE ELEVATION

SPRING 1995

K. TURNER JULY 1995

KINGS COUNTY

TULARE CO

SAN LUIS OBISPO COUNTY

SANTA BARBARA COUNTY

VENTURA COUNTY

DELANO

MCFARLAND

WASCO

SHAFTER

BAKERSFIELD

ARVIN

TAFT

MARICOPA

LOST HILLS

BUTTONWILLOW

FELLOWS

FORD CITY

TUPMAN

McKITTRICK

GREENFIELD

LAMONT

LAKE of the WOODS

FRAZIER PARK

LEBEC

KERN WILDLIFE REFUGE

BUENA VISTA LAKE BED

KERN LAKE BED

CALIFORNIA AQUEDUCT

KERN RIVER

EDISON FAULT

SPRINGS FAULT

RICHARD MOUNTAINS

Ranchos Los Alamos Y Agua Caliente

Rancho San Emidio

LEGEND

- FOOTHILL LINE
- BEDROCK LINE
- FAULT
- CALIFORNIA AQUEDUCT AND TURNOUTS

scale 2 0 2 4 miles

PLATE 5

KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER SURFACE ELEVATION

SPRING 1996

T. HASLEBACHER — DECEMBER 1996

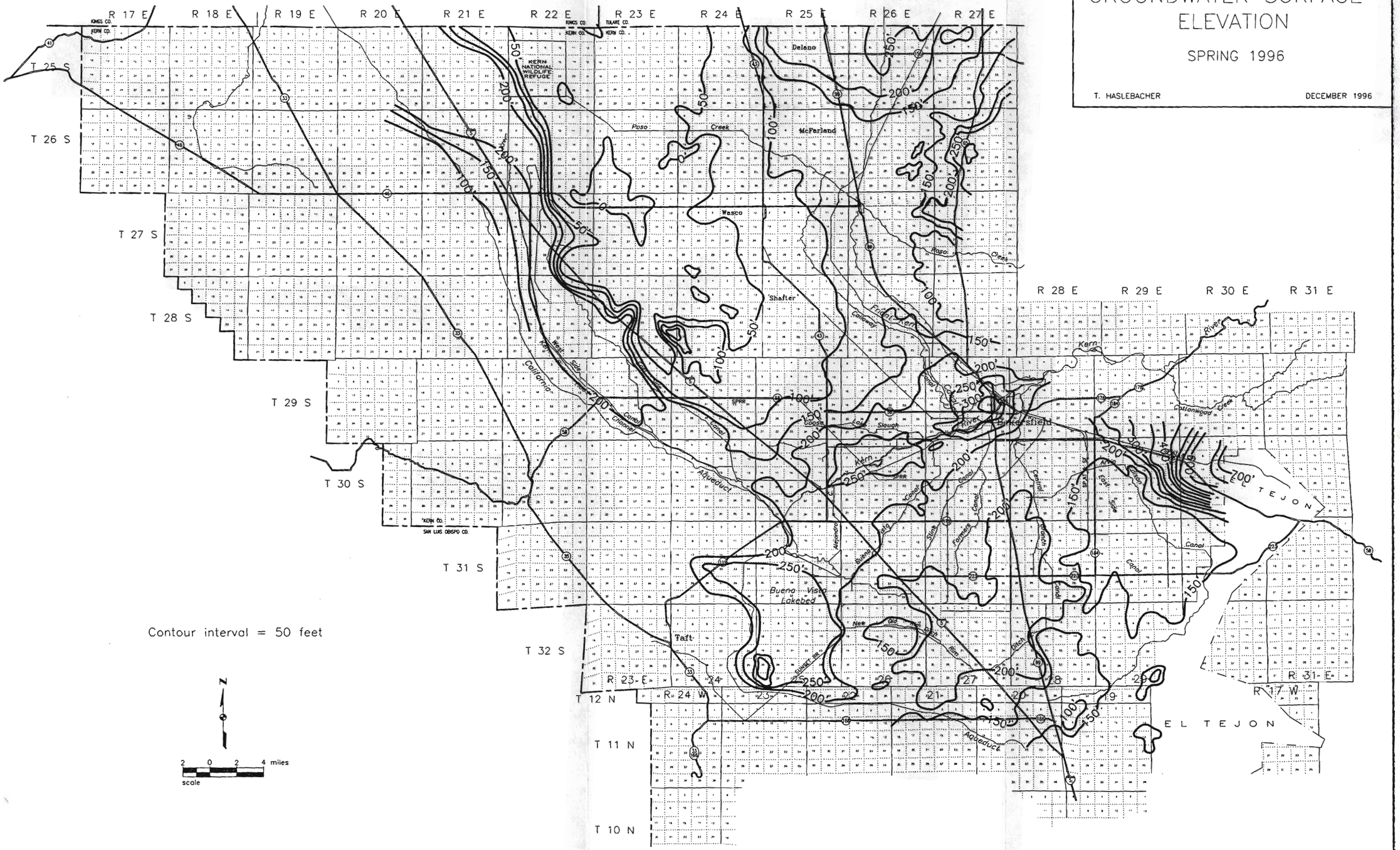


PLATE 5

KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER SURFACE ELEVATION

SPRING 1997

J. GILLICK/T. HASLEBACHER — DECEMBER 1997

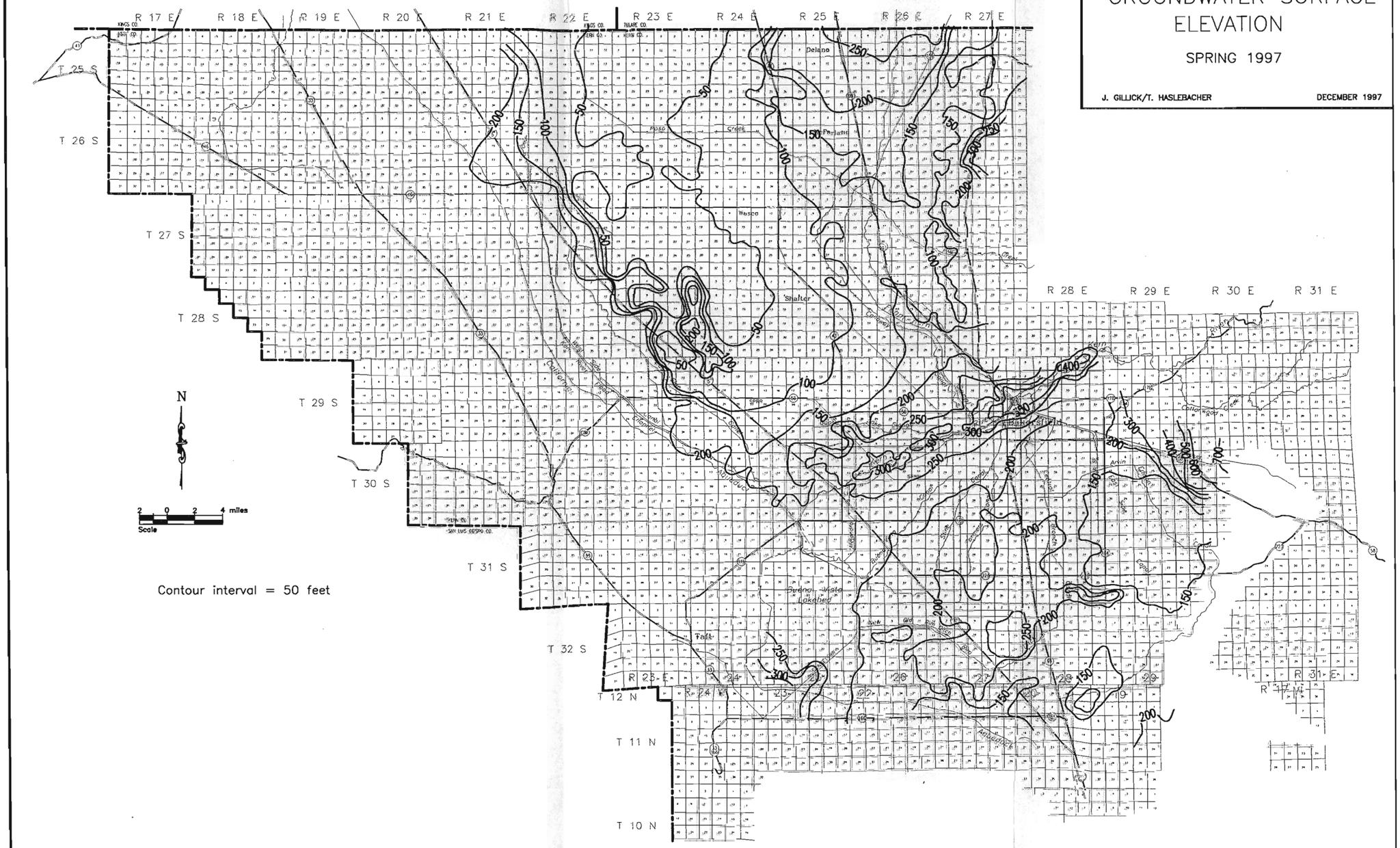


PLATE 5

KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER SURFACE ELEVATION

SPRING 1998

T. HASLEBACHER

DECEMBER 1999

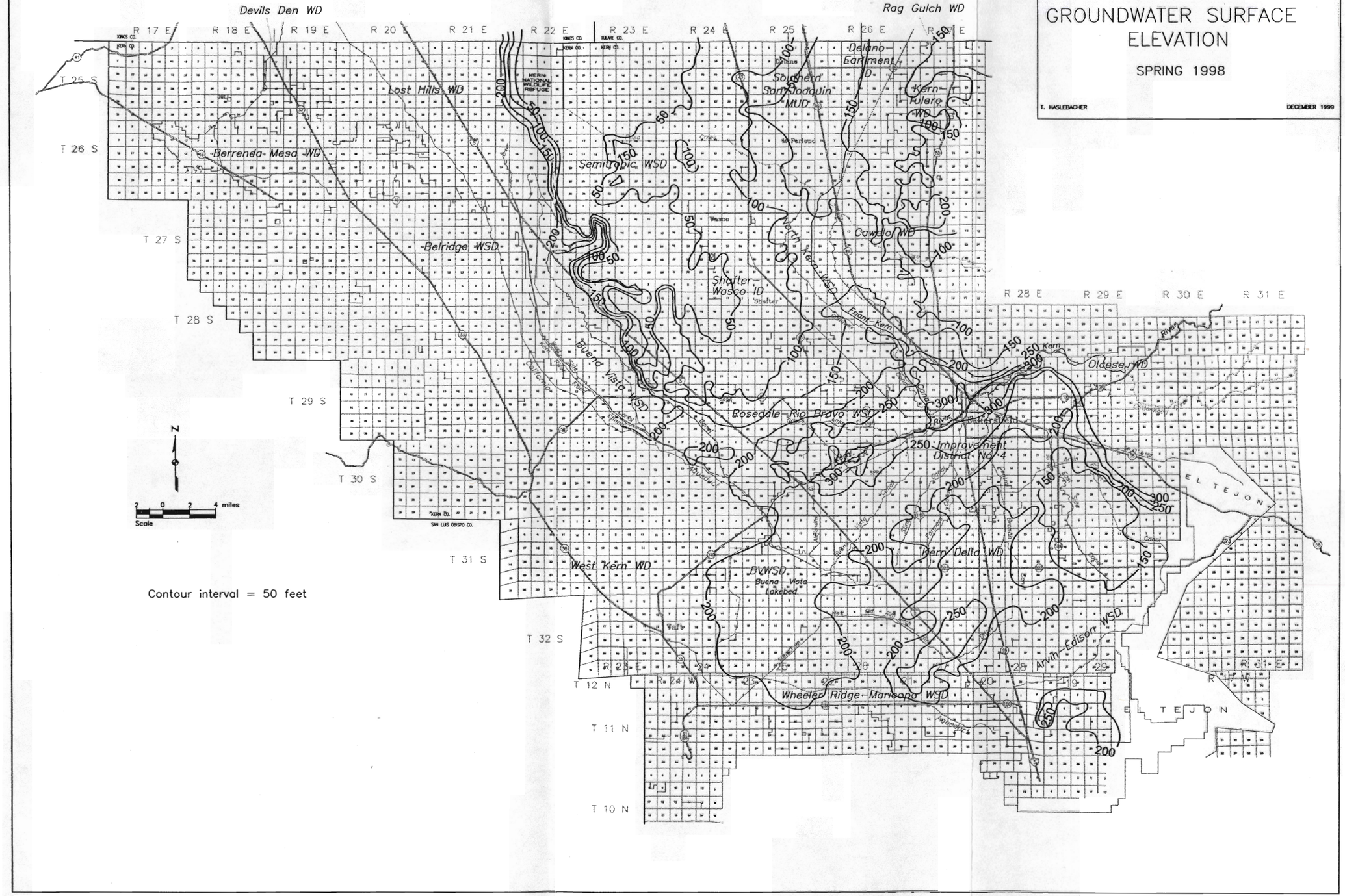


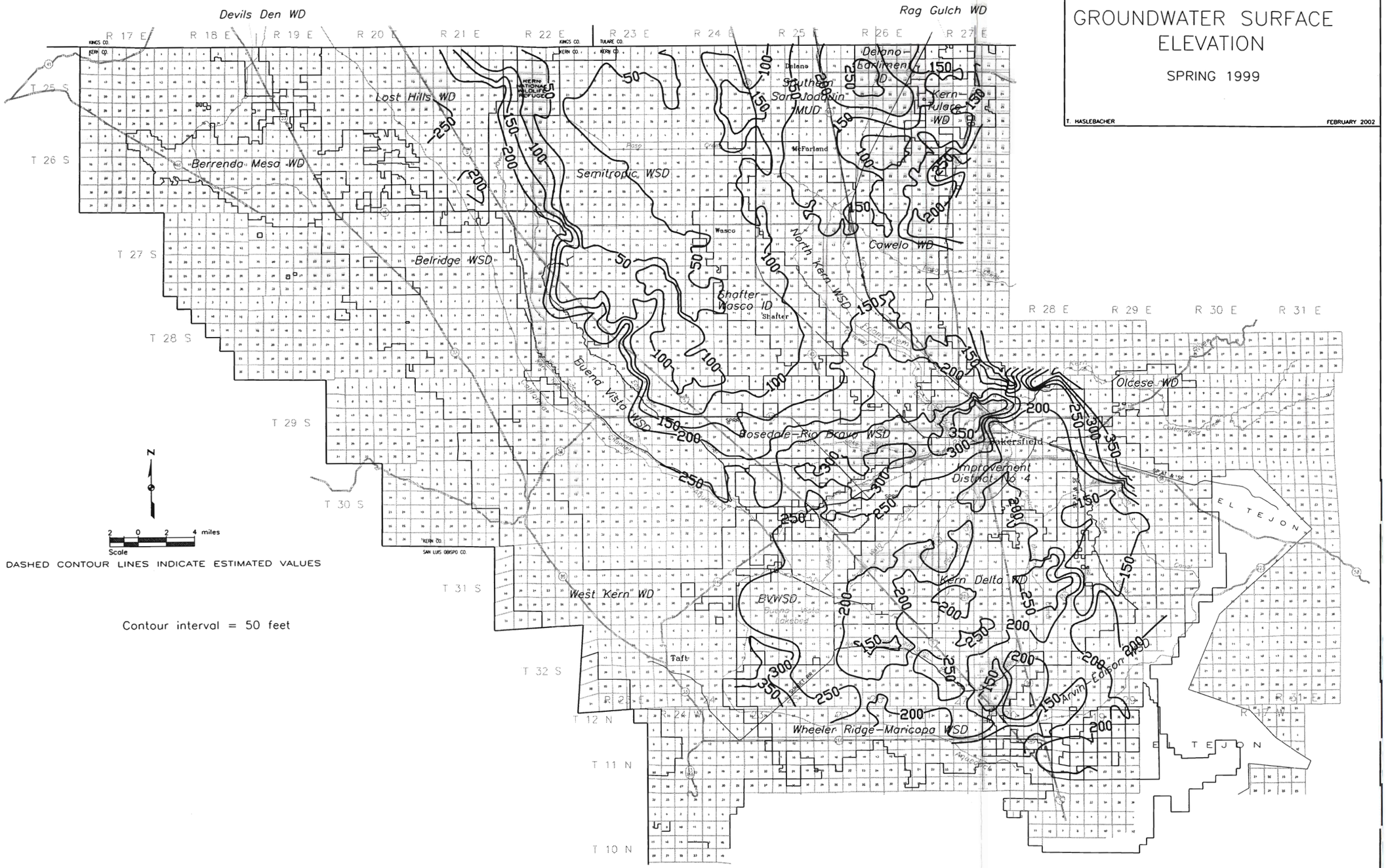
PLATE 5

KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER SURFACE ELEVATION

SPRING 1999

T. HASLEBACHER — FEBRUARY 2002



DASHED CONTOUR LINES INDICATE ESTIMATED VALUES

Contour interval = 50 feet

PLATE 5

KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER SURFACE ELEVATION

SPRING 2000

T. HASLEBACHER

FEBRUARY 2003

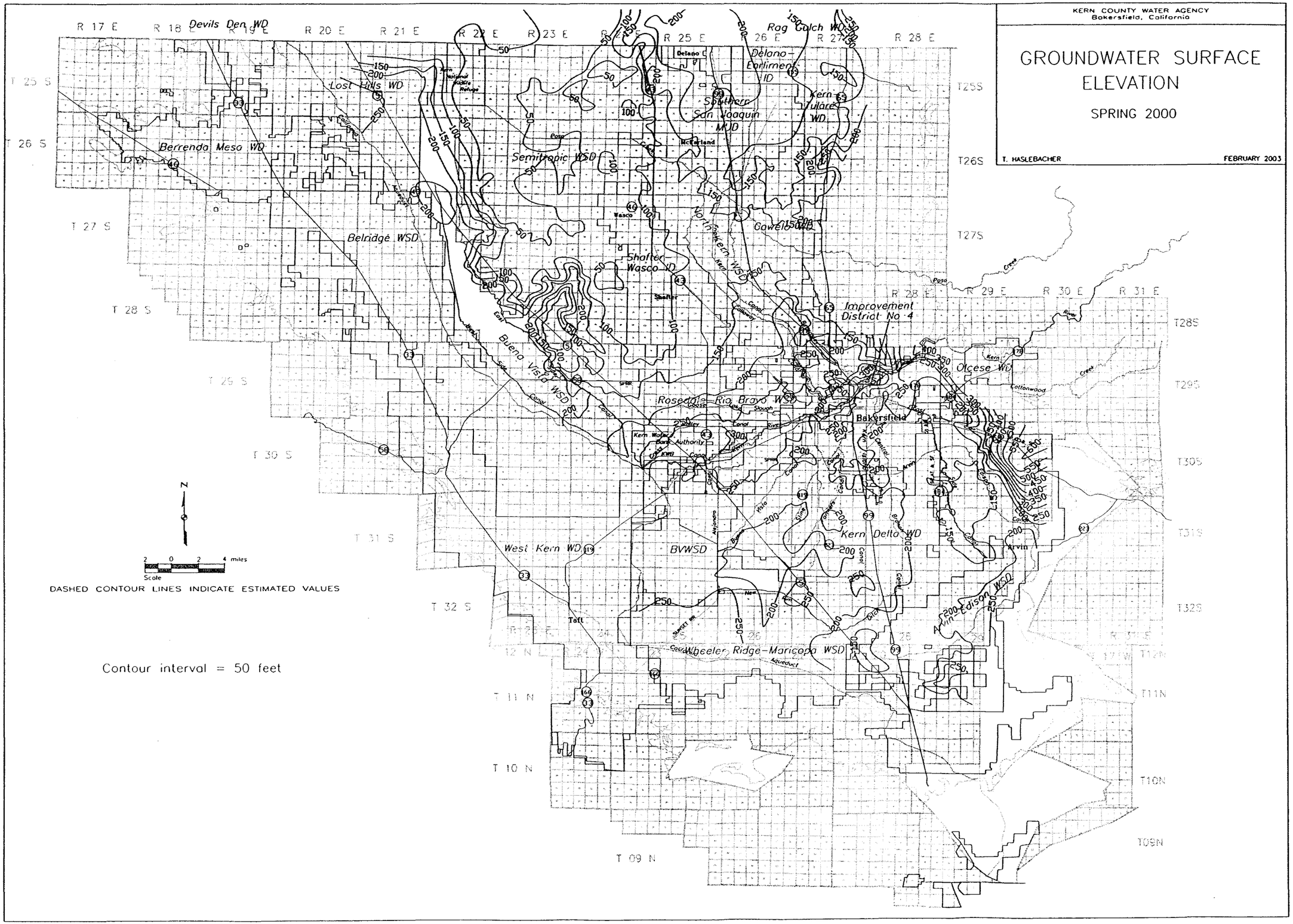


PLATE 6

KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER SURFACE ELEVATION

SPRING 2001

T. HASLEBACHER — MARCH 2005

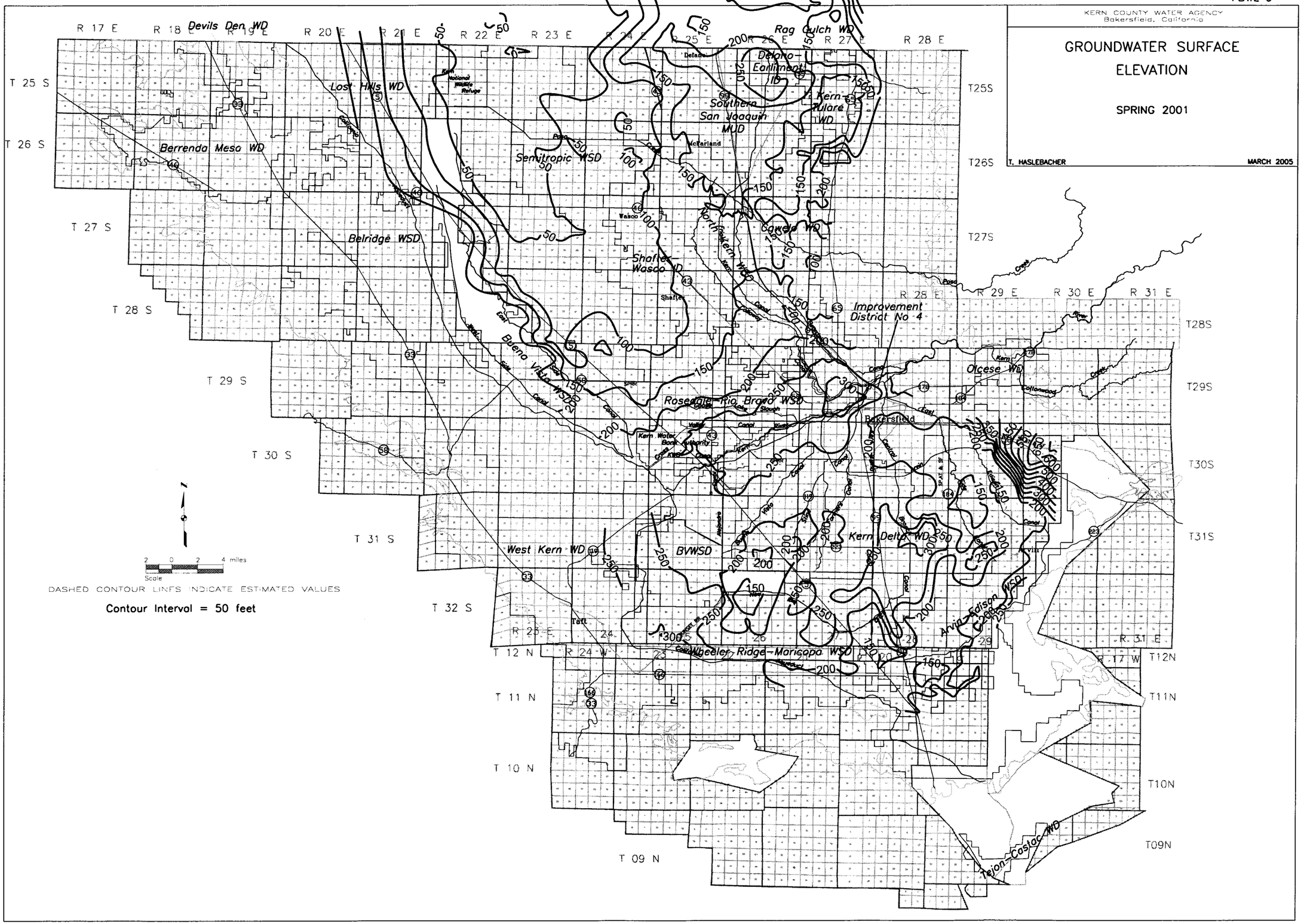


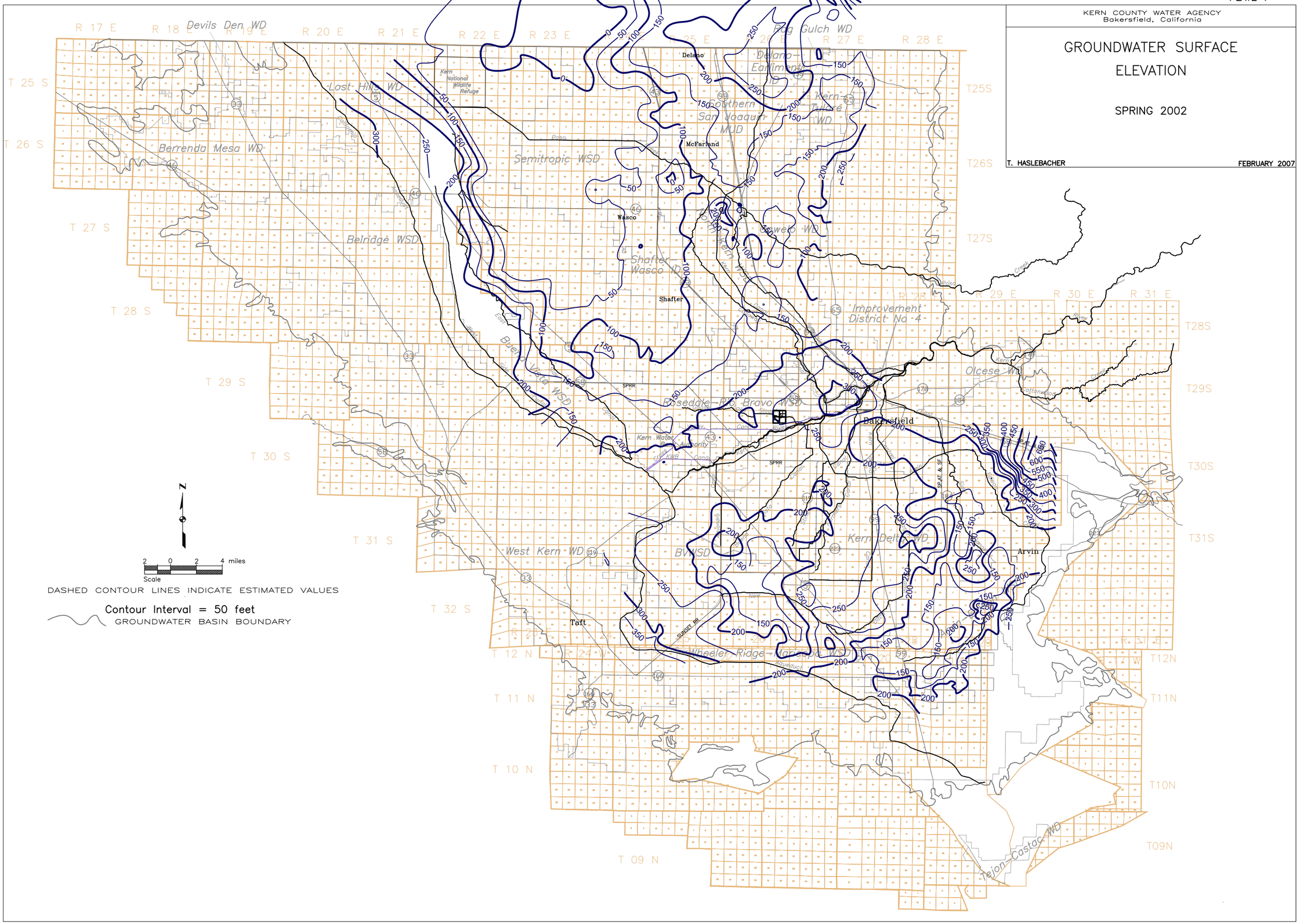
PLATE 7

KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER SURFACE ELEVATION

SPRING 2002

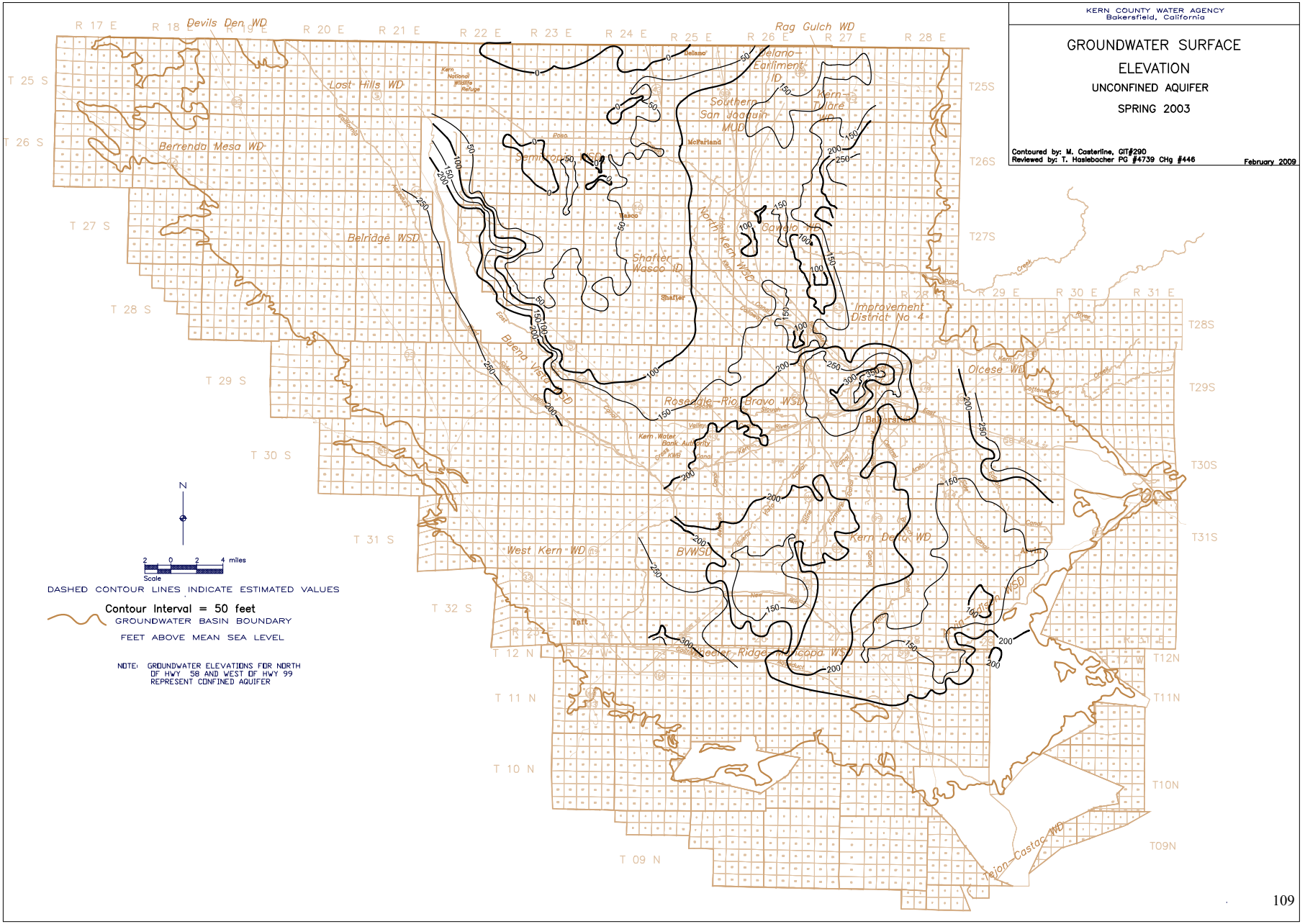
T. HASLEBACHER — FEBRUARY 2007



DASHED CONTOUR LINES INDICATE ESTIMATED VALUES

Contour Interval = 50 feet

GROUNDWATER BASIN BOUNDARY


KERN COUNTY WATER AGENCY
Bakersfield, California
GROUNDWATER SURFACE ELEVATION
UNCONFINED AQUIFER
SPRING 2003
Contoured by: M. Casterline, GIT#290
Reviewed by: T. Haslebacher PG #4739 CHg #446
February 2009
R 17 E
R 18 E
R 19 E
R 20 E
R 21 E
R 22 E
R 23 E
R 24 E
R 25 E
R 26 E
R 27 E
R 28 E
R 29 E
R 30 E
R 31 E
T 25 S
T 26 S
T 27 S
T 28 S
T 29 S
T 30 S
T 31 S
T 32 S
T 12 N
T 11 N
T 10 N
T 09 N
T25S
T26S
T27S
T28S
T29S
T30S
T31S
T12N
T11N
T10N
T09N
Devils Den WD
Rag Gulch WD
Lost Hills WD
Berrenda Mesa WD
Belridge WSD
Delano-Earliment ID
Southern San Joaquin MUD
Kern-Tulare WD
Semitropic WSD
Wasco
Shafter
Shafter-Wasco ID
Improvement District No 4
Buena Vista WSD
Rosedale-Rio Bravo WSD
Bakersfield
Olcese WD
Kern Water Bank Authority
West Kern WD
BVWSD
Kern Delta WD
Taft
Cawelo WD
Kern River
Kern National Wildlife Refuge
McFarland
Delano
Poso Creek
Cross Creek
Calloway Canal
Fruitvale
Stine
Gosford
Alfred
Allen
Kern Island Canal
Cottonwood
Sumner
Valley
Pioneer
Ridge
Vicapa WSD
Tejon-Castac WD
N
2 0 2 4 miles
Scale
DASHED CONTOUR LINES INDICATE ESTIMATED VALUES
Contour Interval = 50 feet
GROUNDWATER BASIN BOUNDARY
FEET ABOVE MEAN SEA LEVEL
NOTE: GROUNDWATER ELEVATIONS FOR NORTH OF HWY 58 AND WEST OF HWY 99 REPRESENT CONFINED AQUIFER

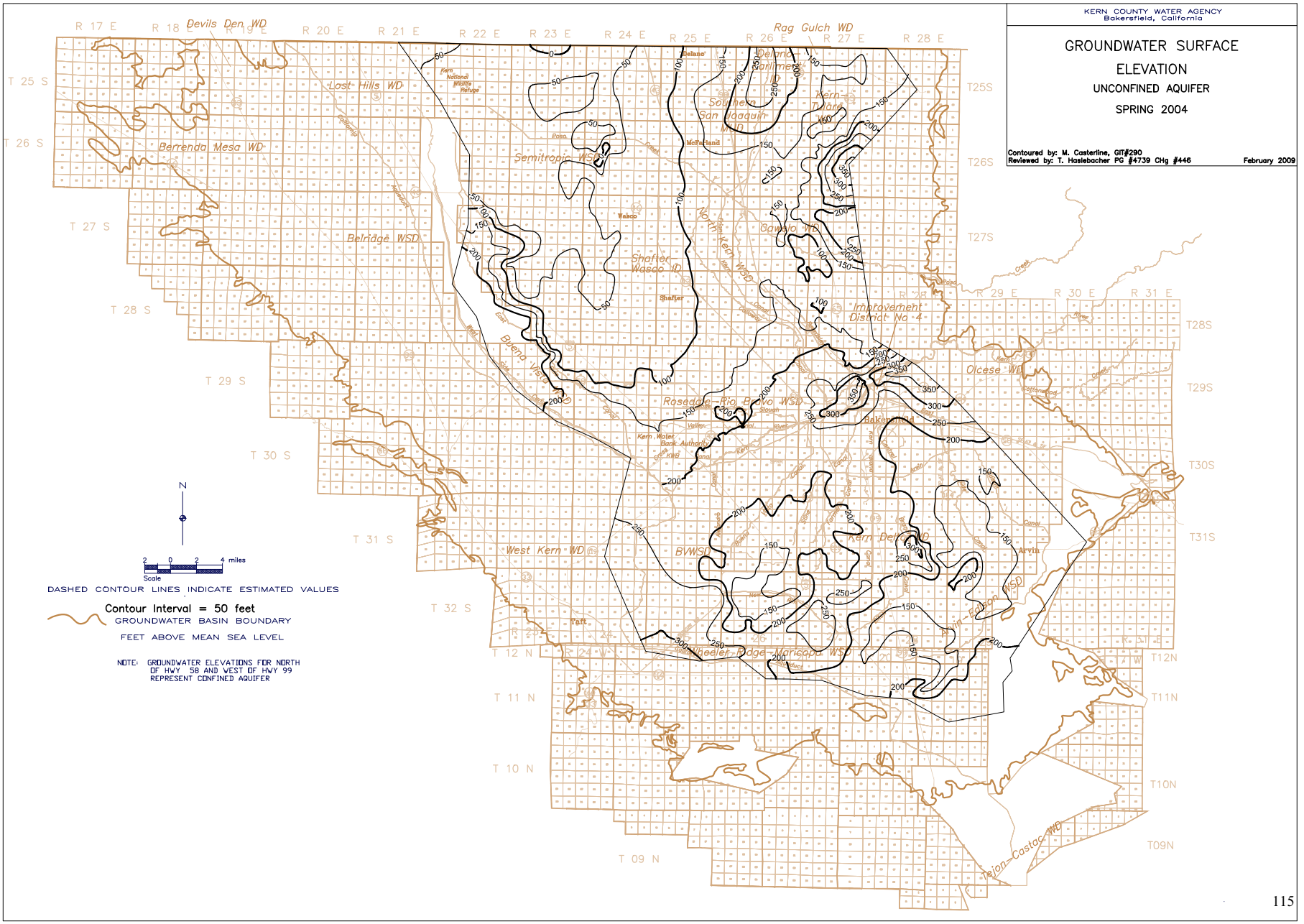

KERN COUNTY WATER AGENCY
Bakersfield, California
GROUNDWATER SURFACE ELEVATION
UNCONFINED AQUIFER
SPRING 2004
Contoured by: M. Casterline, GIT#290
Reviewed by: T. Haslebacher PG #4739 CHg #446
February 2009
R 17 E
R 18 E
R 19 E
R 20 E
R 21 E
R 22 E
R 23 E
R 24 E
R 25 E
R 26 E
R 27 E
R 28 E
R 29 E
R 30 E
R 31 E
T 25 S
T 26 S
T 27 S
T 28 S
T 29 S
T 30 S
T 31 S
T 32 S
T 12 N
T 11 N
T 10 N
T 09 N
T25S
T26S
T27S
T28S
T29S
T30S
T31S
T12N
T11N
T10N
T09N
Devils Den WD
Rag Gulch WD
Lost Hills WD
Berrenda Mesa WD
Belridge WSD
Semitropic WSD
Delano
Delano-Earlimart
Southern San Joaquin MUD
Kern-Tulare
McFarland
Wasco
North Kern WSD
Garzoli WD
Shafter Wasco ID
Shafter
Improvement District No 4
Buena Vista
Olcese WD
Rosedale-Rio Bravo WSD
Bakersfield
Kern Water Bank Authority
Kern Delta WD
Arvin
Edison CSD
West Kern WD
BVWSD
Taft
Wheeler Ridge-Maricopa WSD
Tejon-Castac WD
Kern National Wildlife Refuge
N
2 0 2 4 miles
Scale
DASHED CONTOUR LINES INDICATE ESTIMATED VALUES
Contour Interval = 50 feet
GROUNDWATER BASIN BOUNDARY
FEET ABOVE MEAN SEA LEVEL
NOTE: GROUNDWATER ELEVATIONS FOR NORTH OF HWY 58 AND WEST OF HWY 99 REPRESENT CONFINED AQUIFER

Plate 5a. Groundwater Surface Elevation Unconfined Aquifer Spring 2006

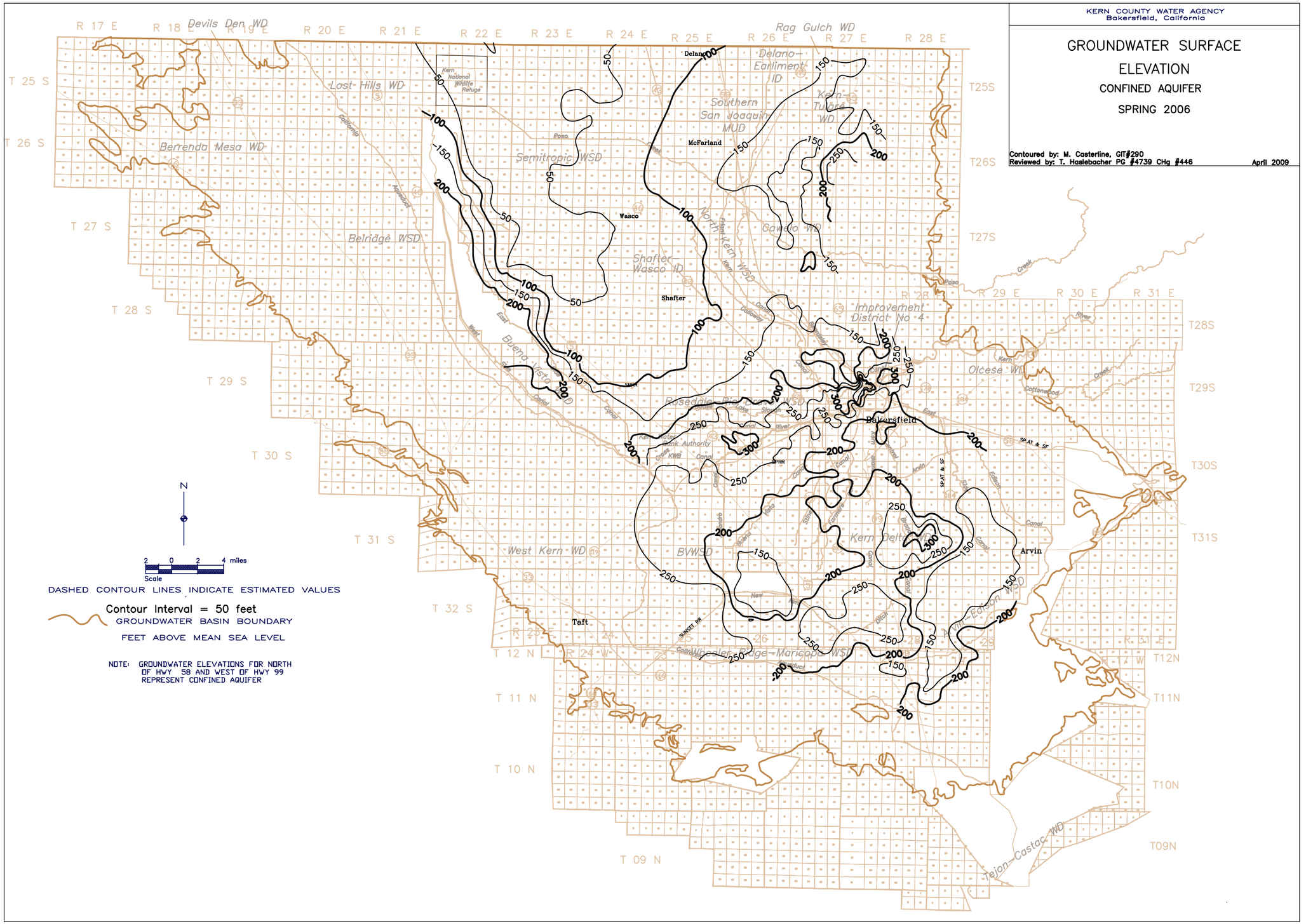


Plate 5b. Groundwater Surface Elevation Unconfined Aquifer Spring 2007

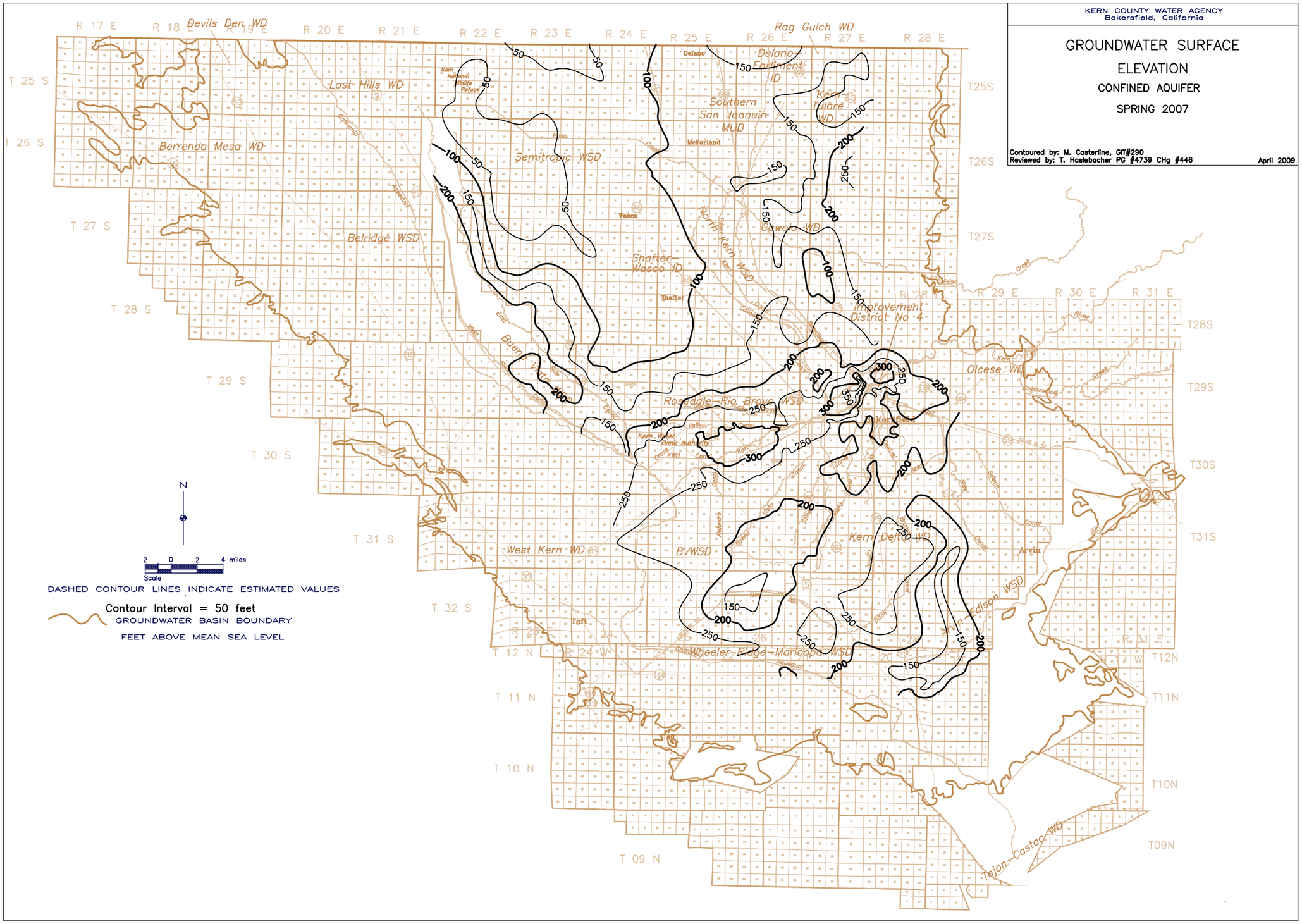


Plate 5. Groundwater Surface Elevation Unconfined Aquifer Spring 2008

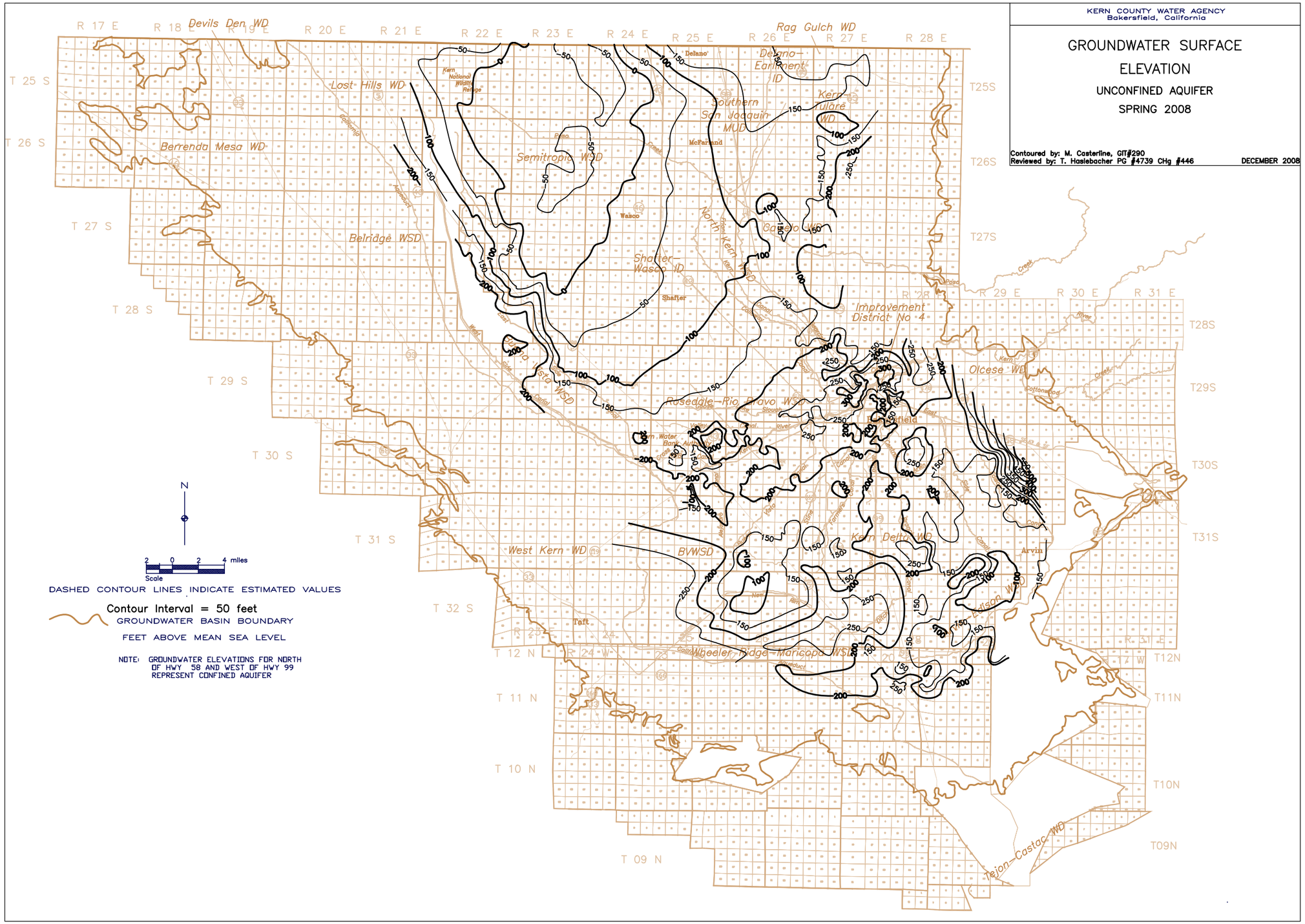


Plate 5. Groundwater Surface Elevation Unconfined Aquifer Spring 2009

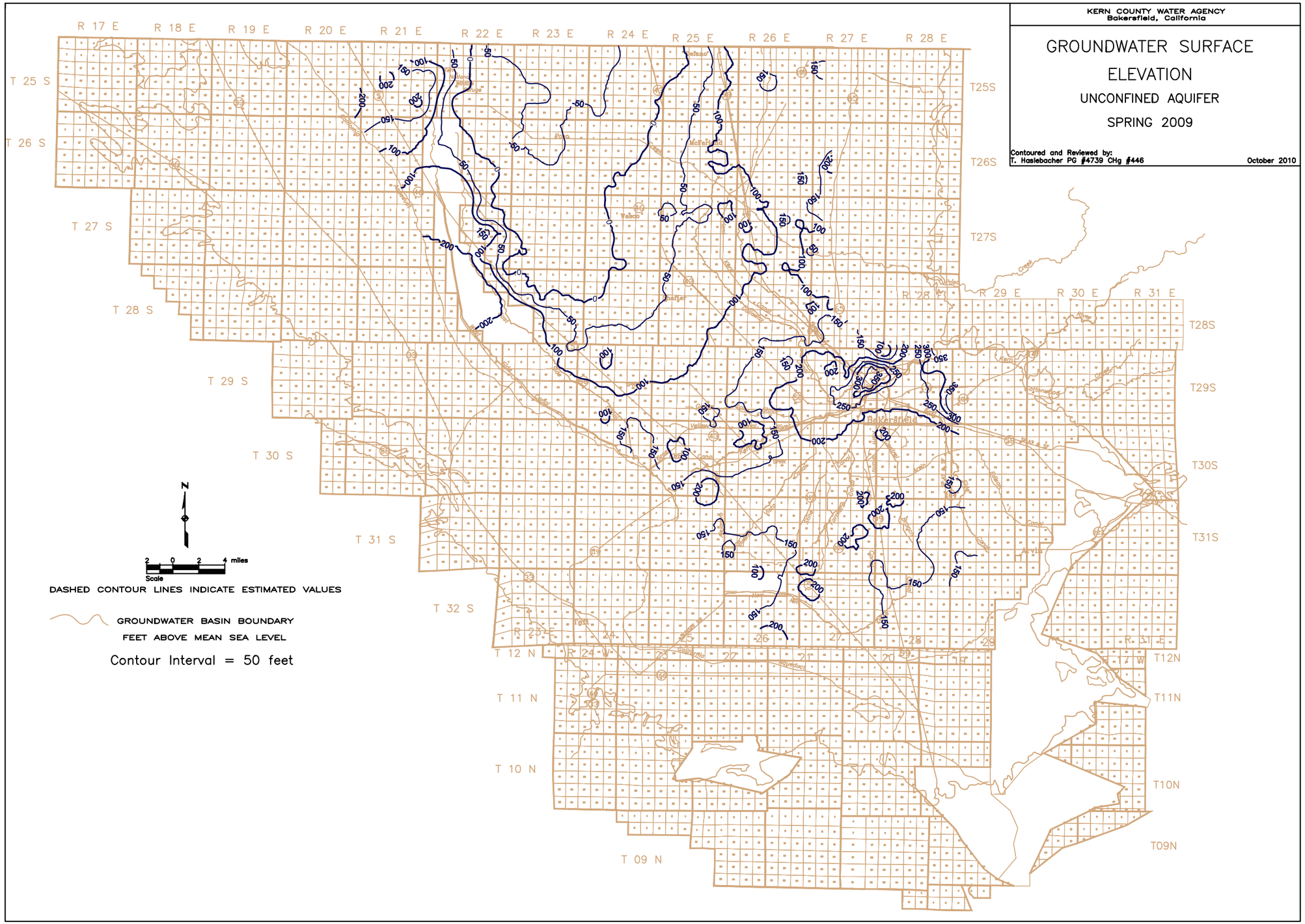


Plate 5. Groundwater Surface Elevation Unconfined Aquifer Spring 2010

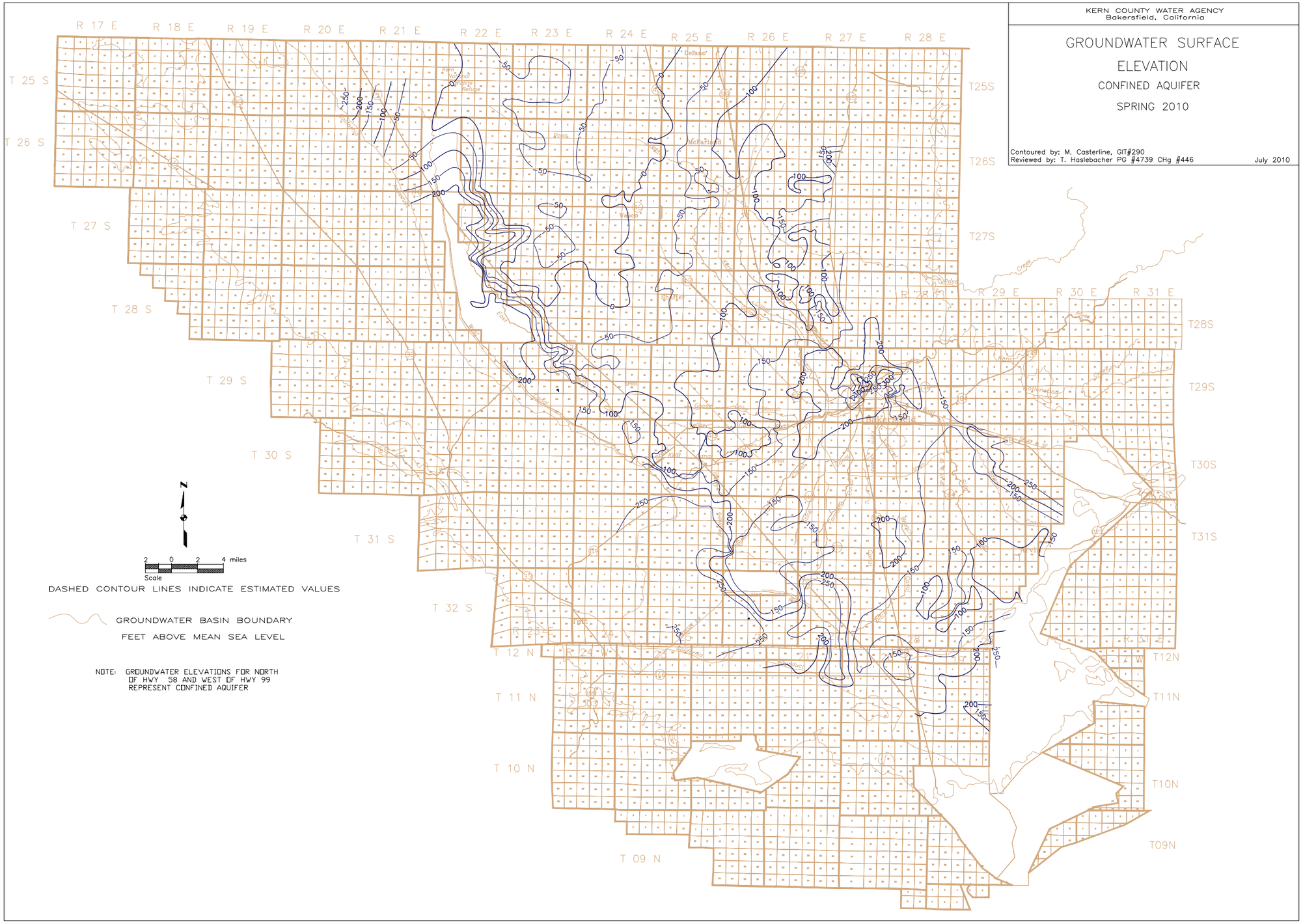


Plate 5. Groundwater Surface Elevation Unconfined Aquifer Spring 2011

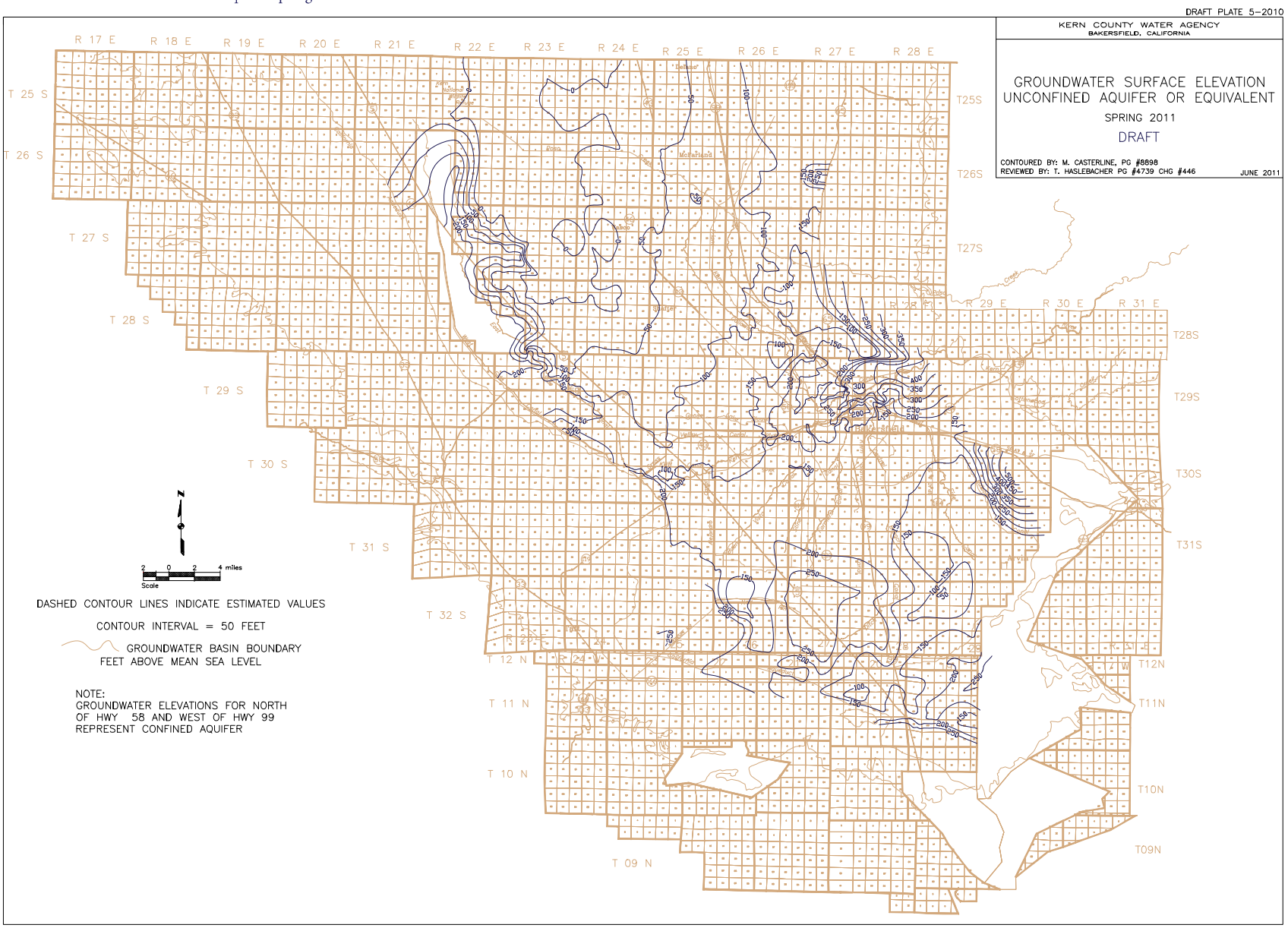


Plate 5. Groundwater Surface Elevation Unconfined Aquifer Spring 2012

PLATE 5-2011

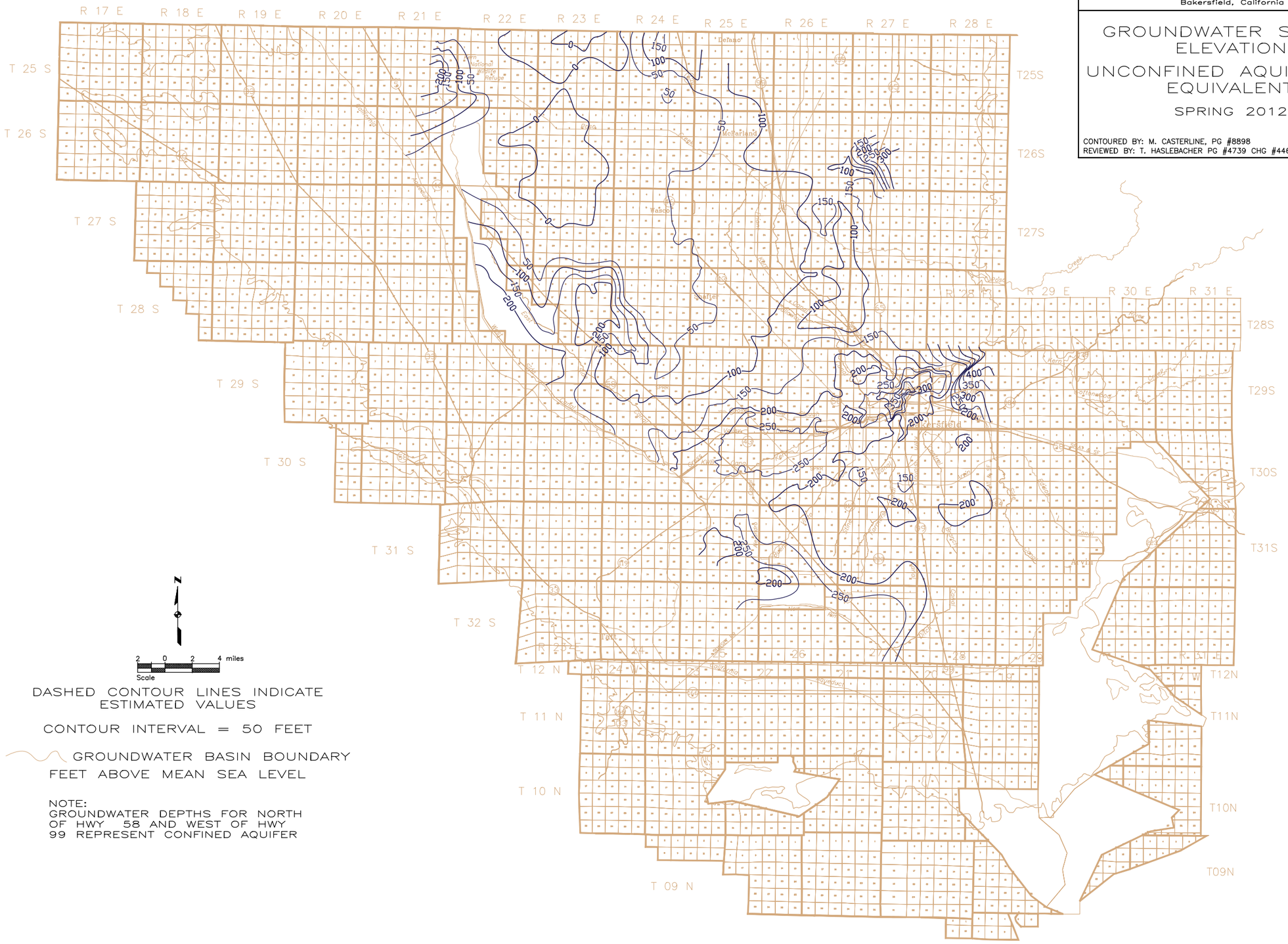
KERN COUNTY WATER AGENCY
Bakersfield, California

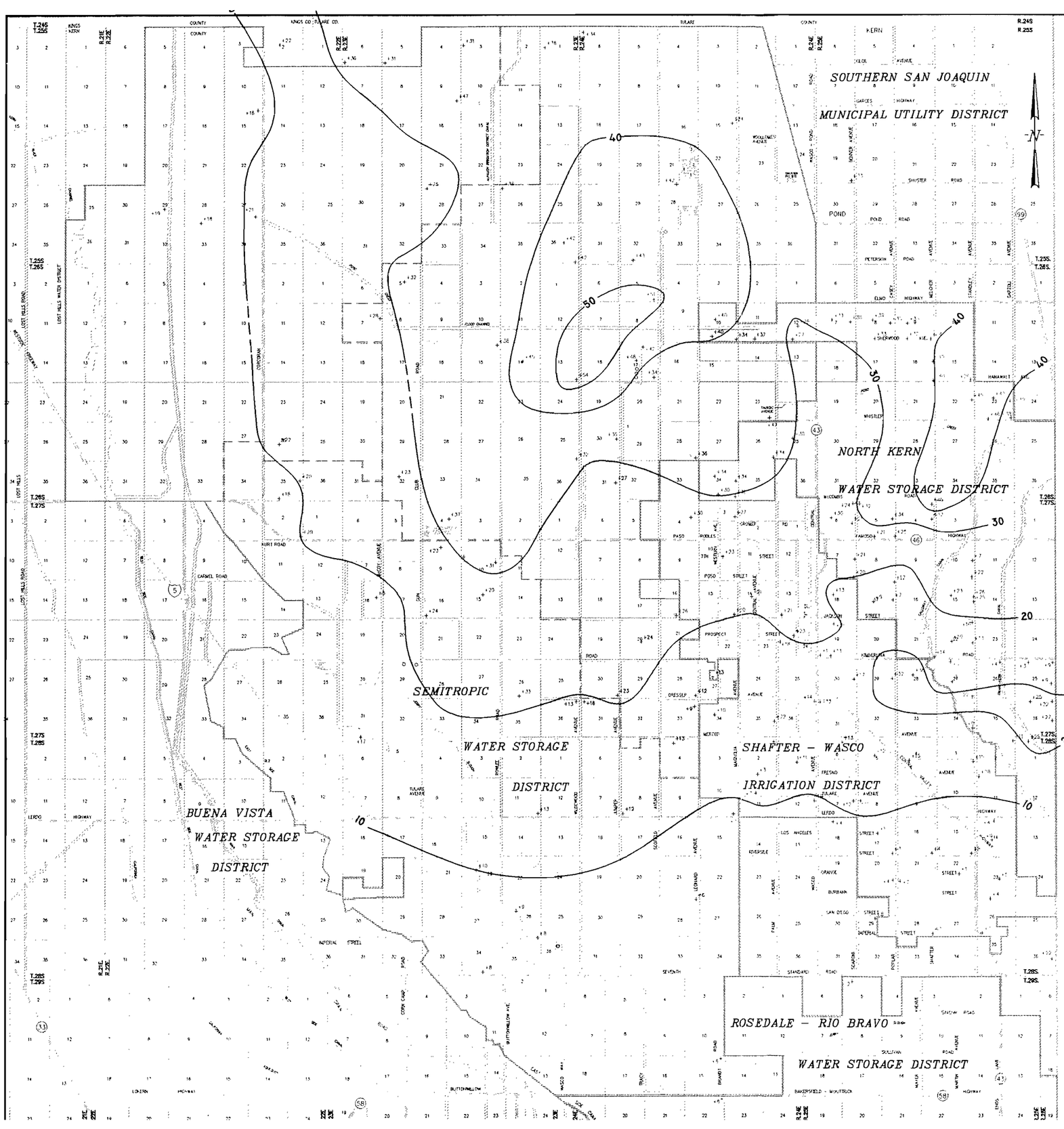
GROUNDWATER SURFACE ELEVATION

UNCONFINED AQUIFER OR EQUIVALENT

SPRING 2012

CONTOURED BY: M. CASTERLINE, PG #8898
REVIEWED BY: T. HASLEBACHER PG #4739 CHG #446 August 2012


R 17 E
R 18 E
R 19 E
R 20 E
R 21 E
R 22 E
R 23 E
R 24 E
R 25 E
R 26 E
R 27 E
R 28 E
R 29 E
R 30 E
R 31 E
T 25 S
T 26 S
T 27 S
T 28 S
T 29 S
T 30 S
T 31 S
T 32 S
T 12 N
T 11 N
T 10 N
T 09 N
T25S
T26S
T27S
T28S
T29S
T30S
T31S
T12N
T11N
T10N
T09N
Delano
McFarland
Wasco
Bakersfield
Kern National Wildlife Refuge
Kern River
Poso Creek
Buena Vista Lake
Tulare Lake
Kern Lake
Goose Lake
Semitropic
Arvin
Edison
Lamont
Weedpatch
Oildale
Rosedale
Shafter
Wasco
Famoso
Pond
Maricopa
Taft
Fellows
Maricopa Flat
Elk Hills
Tupman
Buttonwillow
Dustin Acres
Stockdale
Rio Bravo
Greenfield
Oil City
Old River
Kern Island
Lerdo
Pioneer
Kern Delta
Alpaugh
Allensworth
Earlimart
Delano-Earlimart Irrigation District
Friant-Kern Canal
California Aqueduct
Cross Valley Canal
Kern River
Poso Creek
Kern Canyon
Caliente Creek
Tehachapi Mountains
San Emigdio Mountains
Temblor Range
Sierra Nevada
Kern Plateau
Walker Basin
Breckenridge
Kern Front
Kern Gorge
Edmundson
Pleito
Wheeler Ridge
Maricopa
Midway-Sunset
Lost Hills
Belridge
Cymric
McKittrick
Temblor
Asphalt
Coalinga
Antelope Valley
Carrizo Plain
Cuyama Valley
Ventura
Los Angeles
Kern
Tulare
Kings
San Luis Obispo
Monterey
San Bernardino
Inyo
Mono
Fresno
Kern
Tulare
Kings
Kern
Kern
Kern



EXPLANATION

WELL AND WATER – LEVEL RISE BETWEEN SPRING 1995 AND SPRING 1997

10 FOOT CONTOUR OF EQUAL WATER – LEVEL RISE BETWEEN SPRING 1995 AND SPRING 1997

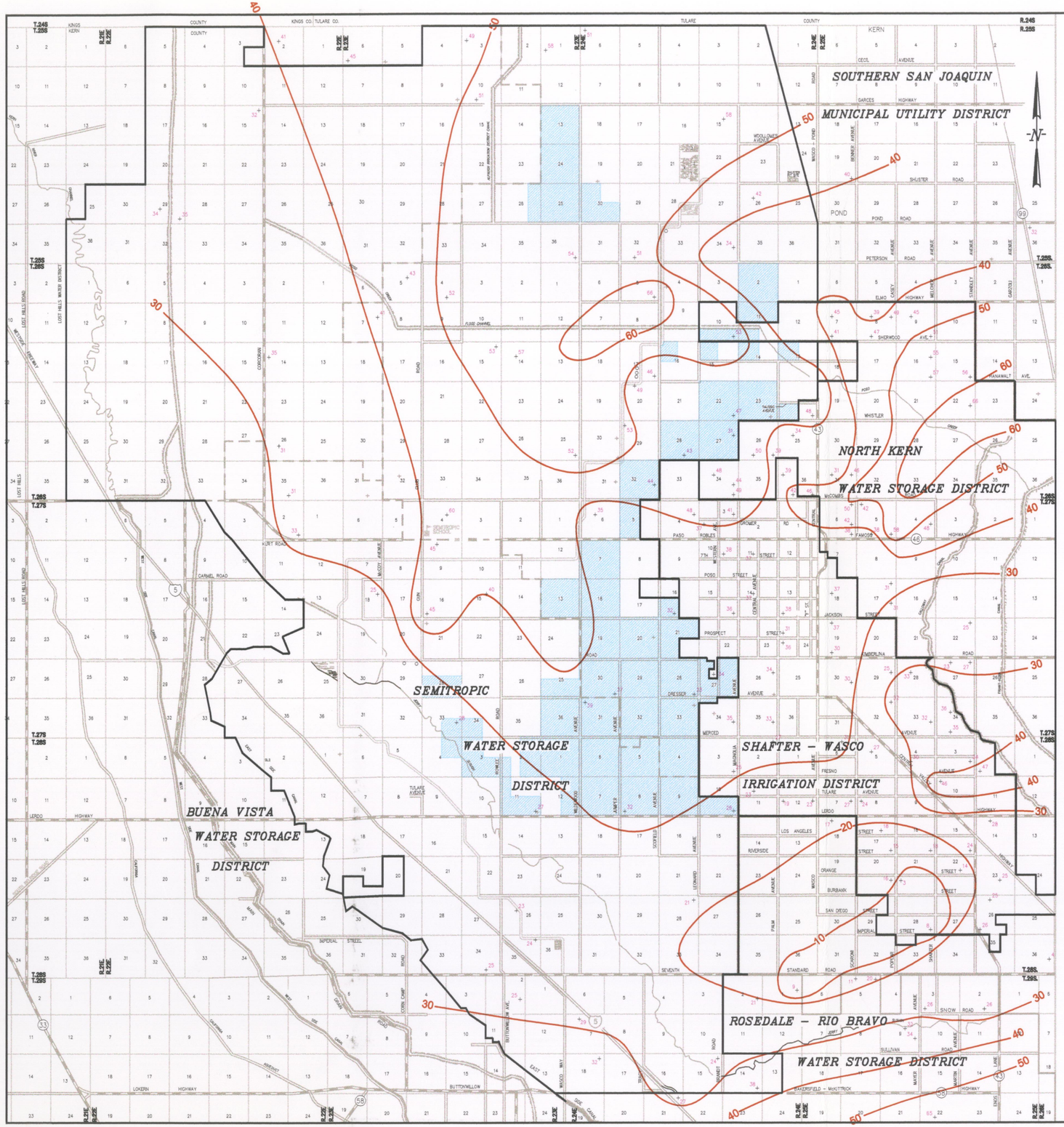
FIGURE 6

WATER – LEVEL RISES IN LOWER ZONE AND FOREBAY AREA, SPRING 1995 – SPRING 1997

SEMITROPIC WATER STORAGE DISTRICT

SCALE OF MILES

1 0 1 2 3



EXPLANATION

+11 WELL AND WATER – LEVEL RISE BETWEEN SPRING 1995 AND SPRING 1999

CONTOUR OF EQUAL WATER – LEVEL RISE BETWEEN SPRING 1995 AND SPRING 1999

FIGURE 6

WATER – LEVEL RISES IN LOWER ZONE AND FOREBAY AREA, SPRING 1995 – SPRING 1999

SEMITROPIC WATER STORAGE DISTRICT

SCALE OF MILES

1 0 1 2 3

CADFILE: XREF: MONIBASE.DWG

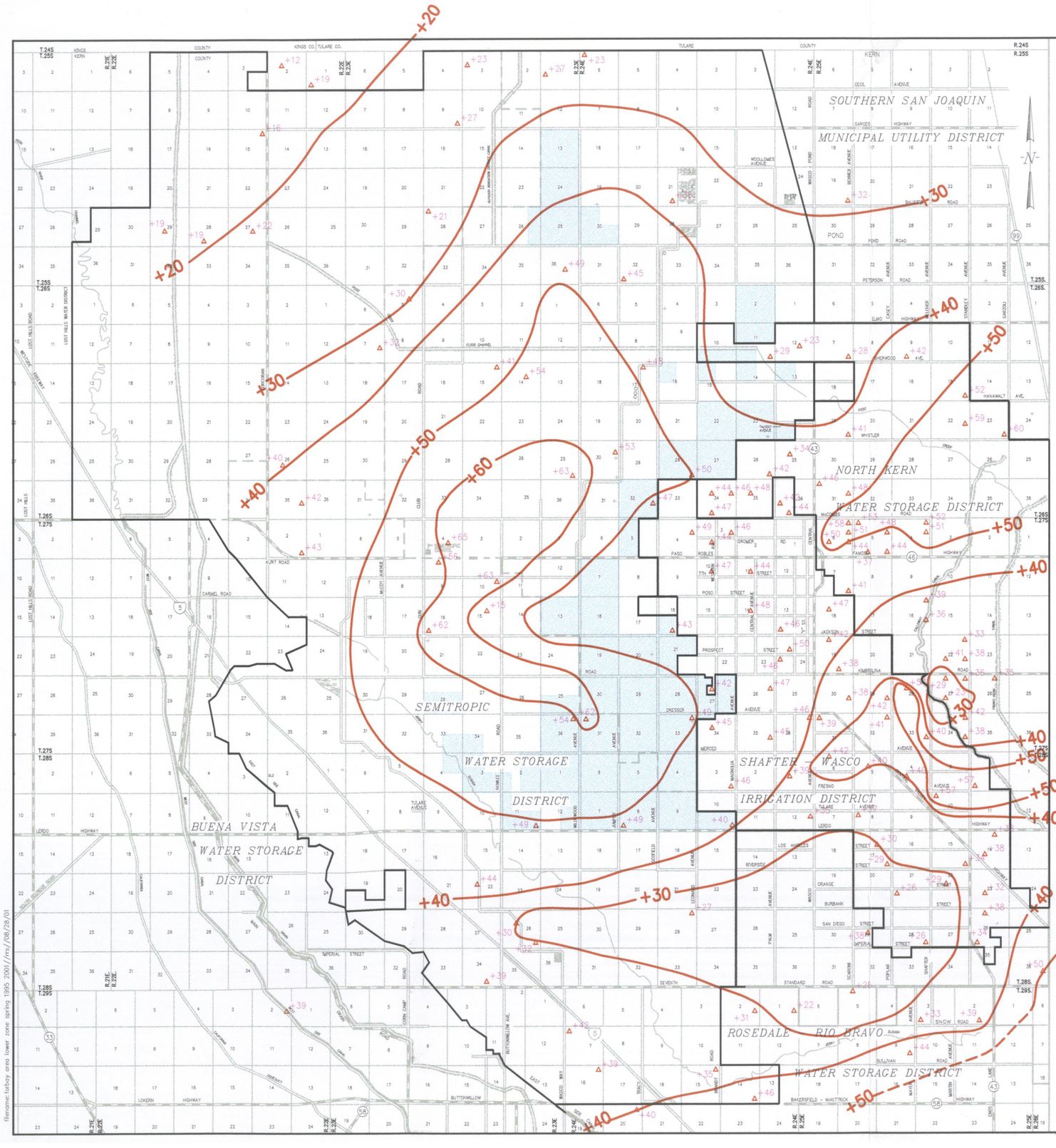


FIGURE 6
WATER-LEVEL RISE IN
FOREBAY AREA AND LOWER ZONE
SPRING 1995 – SPRING 2001

EXPLANATION

+40 Well and water-level rise

contour of water-level rise (feet)

SEMITROPIC WATER STORAGE DISTRICT

SCALE OF MILES

1 0 1 2 3

filename:forbay area lower zone spring 1995 2001//rrs//08/28/01

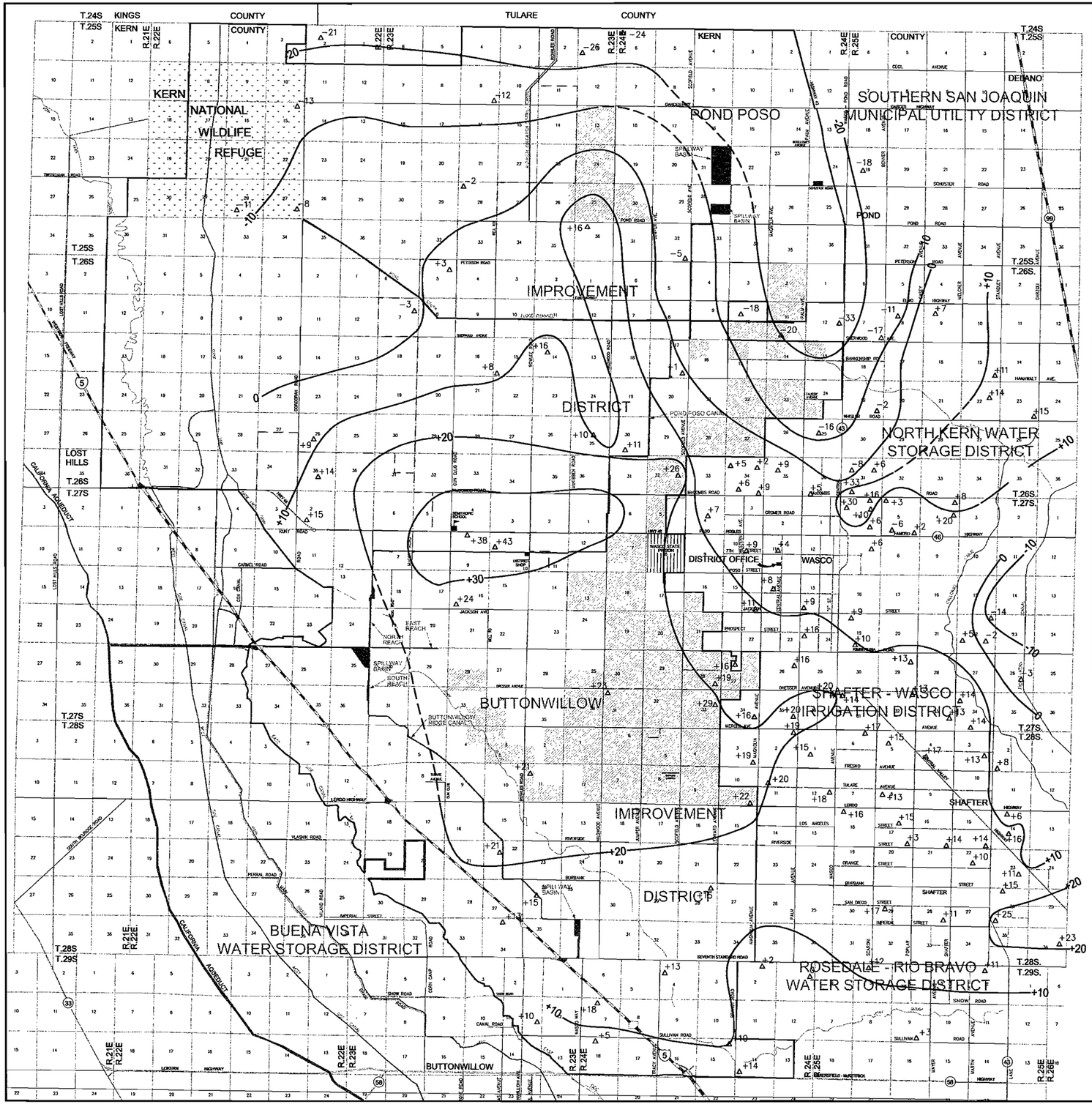


FIGURE 7
WATER - LEVEL CHANGE FOR THE FOREBAY AREA AND LOWER ZONE (SPRING 1995-SPRING 2005)

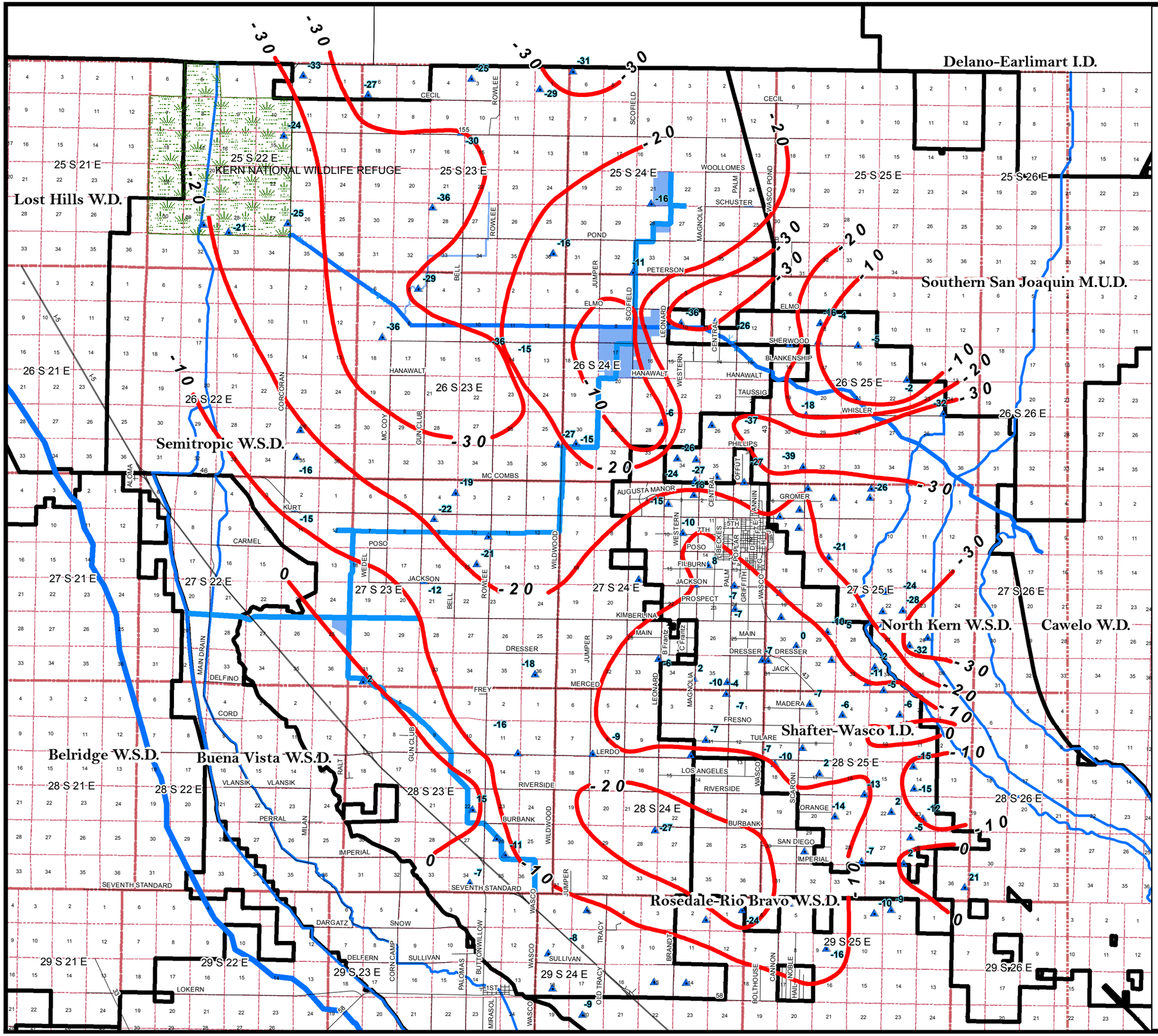
EXPLANATION

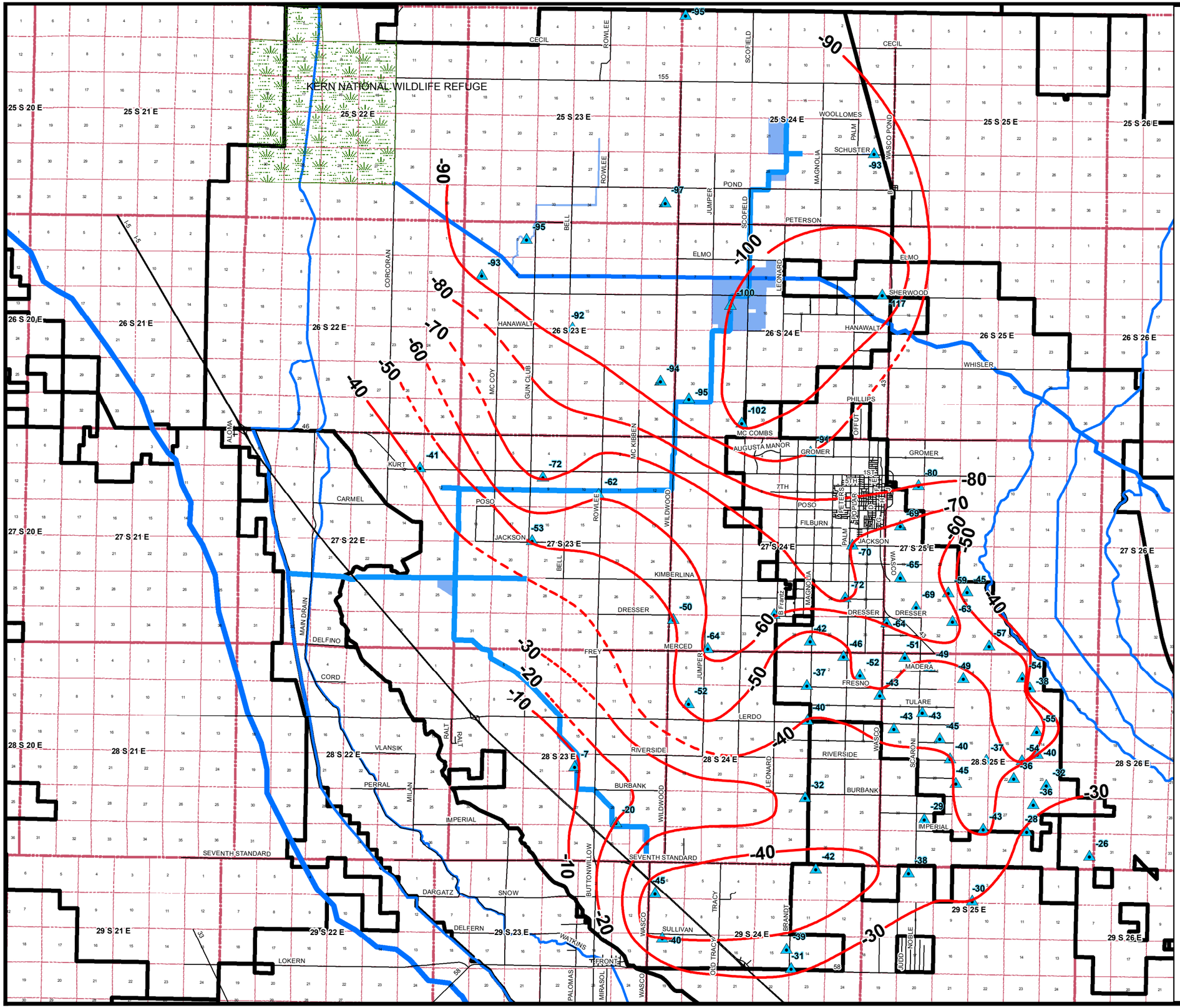
- +24 Δ Well and water-level change (feet)
- \+ Water-level rise
- \- Water-level decline
- +20— Contour of water-level change (feet)

SEMITROPIC WATER STORAGE DISTRICT

SCALE OF MILES

1 0 1 2 3


Delano-Earlimart I.D.
Lost Hills W.D.
Southern San Joaquin M.U.D.
Semitropic W.S.D.
Shafter-Wasco I.D.
North Kern W.S.D.
Cawelo W.D.
Rosedale-Rio Bravo W.S.D.
Belridge W.S.D.
Buena Vista W.S.D.
KERN NATIONAL WILDLIFE REFUGE
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29 S 26 E
CECIL
POND
PETERSON
ELMO
SHERWOOD
BLANKENSHIP
HANAWALT
TAUSSIG
WHISLER
WOOLLOMES
SCHUSTER
AUGUSTA MANOR
GROMER
PHILLIPS
MC COMBS
KURT
CARMEL
POSO
FILBURN
JACKSON
PROSPECT
KIMBERLINA
MAIN
DRESSER
JACK
MERCED
FREY
DELFINO
CORD
MADERA
FRESNO
TULARE
LERDO
LOS ANGELES
RIVERSIDE
BURBANK
ORANGE
SAN DIEGO
IMPERIAL
SEVENTH STANDARD
VLANSIK
PERRAL
DARGATZ
SNOW
DELFERN
SULLIVAN
LOKERN
MIRASOL
ROWLEE
SCOFIELD
JUMPER
BELL
LEONARD
MAGNOLIA
WASCO
WILDWOOD
GUN CLUB
MC COY
CORCORAN
ALOMA
WESTERN
CENTRAL
OFFUT
TANNIN
MAIN DRAIN
RALT
MILAN
WEDEL
TRACY
BRANDT
OLD TRACY
CANNON
BOLTHOUSE
PALOMAS
BUTTONWILLOW
CORN CAMP
SCOFIELD
WASCO POND
PALM
GRIFFITH
SCHONI
I-5
N
Water-Level Changes for the Forebay Area and Lower Zone (Spring 1995 - Spring 2011)
Legend
Well & Water Level Change (Feet)
Water-Level Rise
Water-Level Decline
Contour of Water-Level Change (Feet)
Miles


KERN NATIONAL WILDLIFE REFUGE
CECIL
ROWLEE
SCOFIELD
WOOLLOMES
PALM
WASCO
POND
SCHUSTER
MAGNOLIA
JUMPER
BELL
PETERSON
ELMO
LEONARD
SHERWOOD
HANAWALT
WHISLER
PHILLIPS
OFFUT
MC COMBS
AUGUSTA MANOR
GROMER
CORCORAN
MC COY
GUN CLUB
MC KIBBEN
WILDWOOD
ALOMA
KURT
CARMEL
POSO
7TH
FILBURN
JACKSON
KIMBERLINA
DRESSER
MAIN DRAIN
DELFINO
FREY
MERCED
CORD
FRESNO
MADERA
TULARE
LERDO
VLANSIK
RALT
PERRAL
MILAN
RIVERSIDE
BURBANK
IMPERIAL
SEVENTH STANDARD
BUTTONWILLOW
DARGATZ
SNOW
DELFERN
WATKINS
LOKERN
TRACY
SULLIVAN
OLD TRACY
BRANDT
JUDD
NOBLE
PALOMAS
MIRASOL
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29 S 24 E
29 S 25 E
29 S 26 E
-90
-80
-70
-60
-50
-40
-30
-20
-10
-100
N
Figure 7
Water-Level Changes For The Forebay Area & Lower Zone (Spring 1995 - 2015)
Legend
Well & Water-Level Change (Feet)
Water-Level Rise
Water-Level Decline
Contour of Water-level Change (Feet)
1 0.5 0 1 2 3 4
Miles

KERN NATIONAL WILDLIFE REFUGE

Lost Hills W.D.

Delano-Earlimart I.D.

Southern San Joaquin M.U.D.

Semitropic W.S.D.

Shafter-Wasco I.D.

North Kern W.S.D.

Cawelo W.D.

Belridge W.S.D.

Buena Vista W.S.D.

Rosedale-Rio Bravo W.S.D.

West Kern W.D.

-100

-80

-60

-50

-40

N

Figure 7
Water-Level Changes For The Forebay Area & Lower Zone (Spring 1995 - 2016)

Legend

- Well Location
- Water-Level Decline
- -40 Contour of Water-level Change (Feet)

1 0.5 0 1 2 3 4

Miles

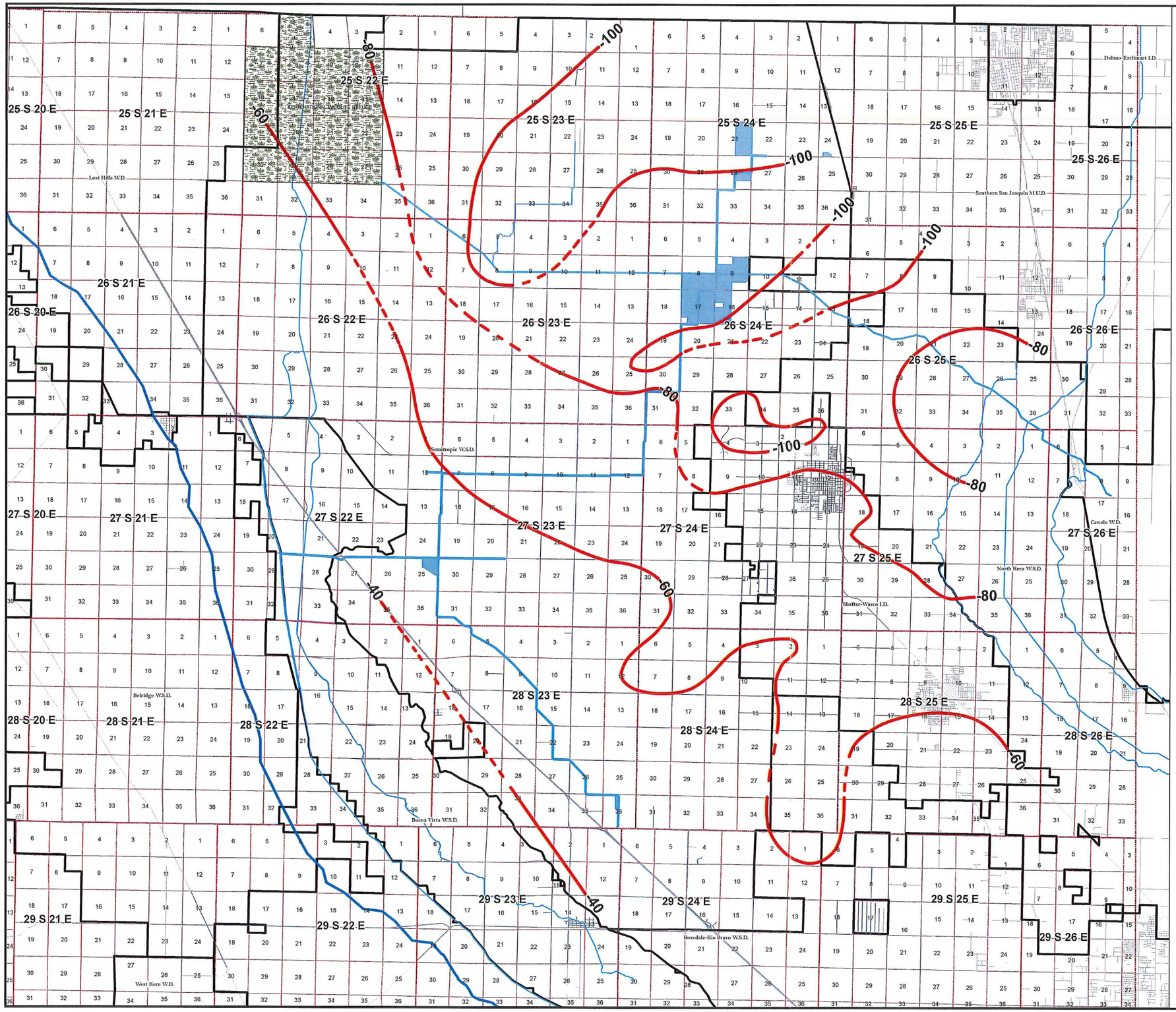


Figure 7
Water-Level Changes For The Forebay Area & Lower Zone (Spring 1995 - 2017)

Legend

- ▲ Well Location
- – Water-Level Decline
- -40 ~ Contour of Water-level Change (Feet)

Appendix I

Hydrographs

Hydrograph Summary
Southern San Joaquin Municipal Utility District

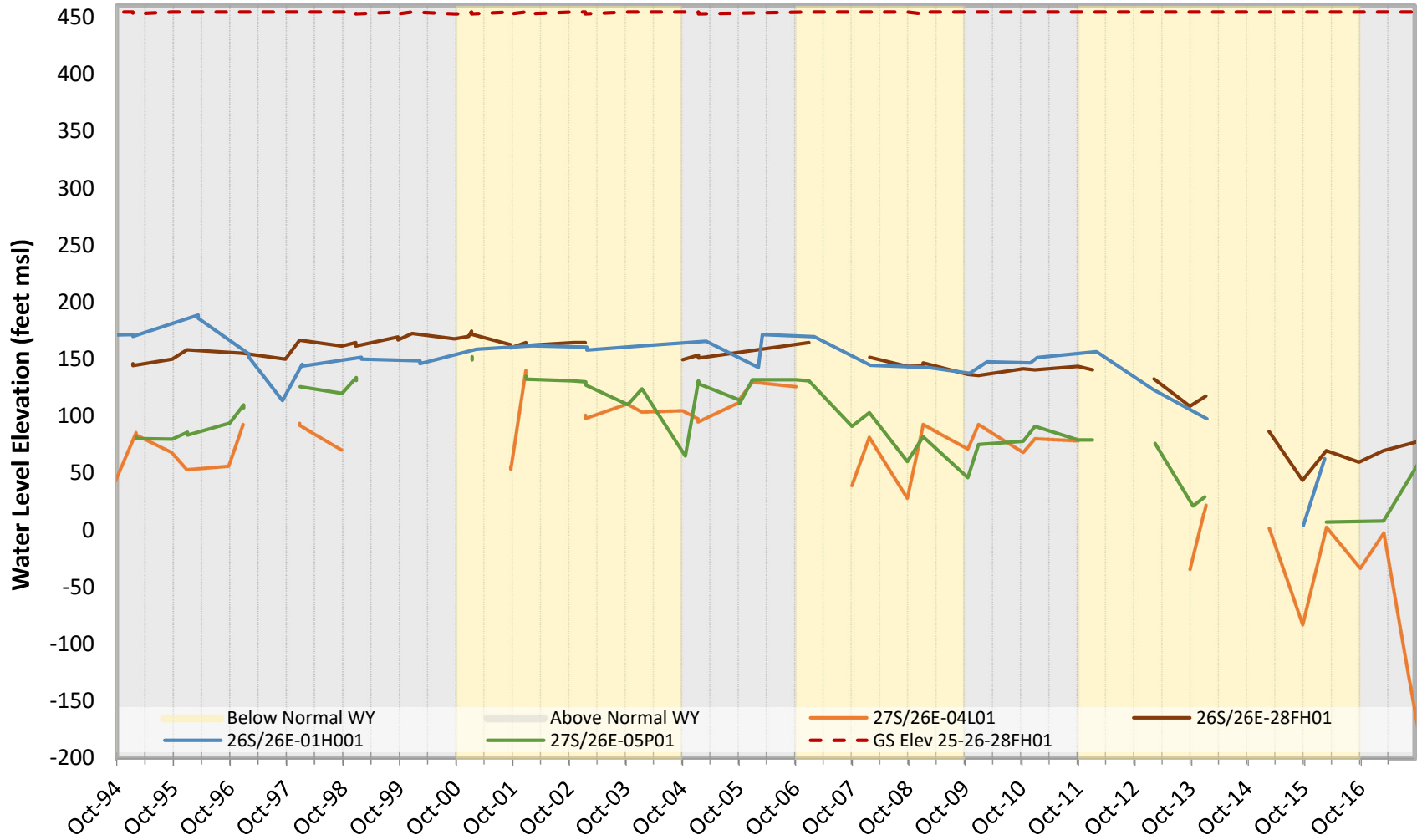
Group	CASGEM ID	SWN	DMS ID	Well Name	Well Name (Original)	Well Name Alt	Well Type	Township	Range	Section	Quarter	RP_Elevation	GS Elevation (Approximate)	Perforation Top (bgs)	Perforation Bottom (bgs)	Aquifer Zone	Data Source
1	356058N1191820W001	27S26E04L001M	6480	27S/26E-04L01	27S/26E-04L01		Production	27	26	4	L	474.7	473.7	640 -730	690 - 1280	Lower	CASGEM
1	356406N1191787W001	26S26E28F001M	7936	26S/26E-28F01	26S/26E-28FH01		Production	26	26	28	F	455.7	454.70	342	710	Lower	CASGEM
1	356986N1191162W001	26S26E01H001M	8488	26S/26E-01H01	26S/26E-01H001			26	26	1	H	603.74	602.74	500	1800	Lower	CASGEM
1	356022N1191956W001	27S26E05P001M	3839	27S/26E-05P01	27S/26E-05P01		Production	27	26	5	P	430.09	428.99			--	CASGEM
2	357719N1193312W001	25S24E12H001M	6552	25S/24E-12H01	25S/24E-12H001			25	24	12	H	256.13	255.63			Upper	CASGEM
2	357172N1192337W001	25S25E36C002M	10255	25S/25E-36C02	25S/25E-36C002			25	25	36	C	321.65	320.65			Lower	CASGEM
2	357289N1192053W001	25S26E30A001M	10109	25S/26E-30A01	25S/26E-30A001			25	26	30	A	353	352			Lower	CASGEM
2	357339N1193126W001	25S25E19R003M	10934	25S/25E-19R03	25S/25E-19R003			25	25	19	R	280.12	279.62			Lower	CASGEM
2	357283N1191698W001	25S26E28H002M	10095	25S/26E-28H02	25S/26E-28H002		Unknown	25	26	28	H	418.68	417.68			--	CASGEM
2	357469N1191838W001	25S26E16P001M	6050	25S/26E-16P01	25S26E16P001M		Production	25	26	16	P	391.17	390.67			--	CASGEM
2	357469N1191838W002	25S26E16P002M	6911	25S/26E-16P02	25S26E16P002M		Production	25	26	16	P	391.67	390.67			--	CASGEM
2	357794N1192806W001	25S25E04R001M	10883	25S/25E-04R01	25S/25E-04R1	SSJMUD Well 6		25	25	4	R	--	278			Lower	SSJMUD
2	--	--	--	25S/24E-12	25S/24E-12	SSJMUD Well 7		25	24	12		--	260.5			--	SSJMUD
2	--	--	--	25S/25E-07R1	25S/25E-7R1	SSJMUD Well 9		25	25	7	R	--	260.5			Lower	SSJMUD
2	--	--	--	26S/26E-31	26S/26E-29	SSJMUD Well 51		26	26	29		--	402			--	SSJMUD
3	357905N1191907W001	25S26E05A003M	12260	25S/26E-05A03	25S/26E-05A			25	26	5	A	--	402			--	DEID
3	--	--	--	25S/26E-17E	25S/26-17E			25	26	17	E	--	368			--	DEID
3	--	24S26E16R001M	18380	24S/26E-16R01	24S/26E-16R			24	26	16	R	--	399			--	DEID

Notes:

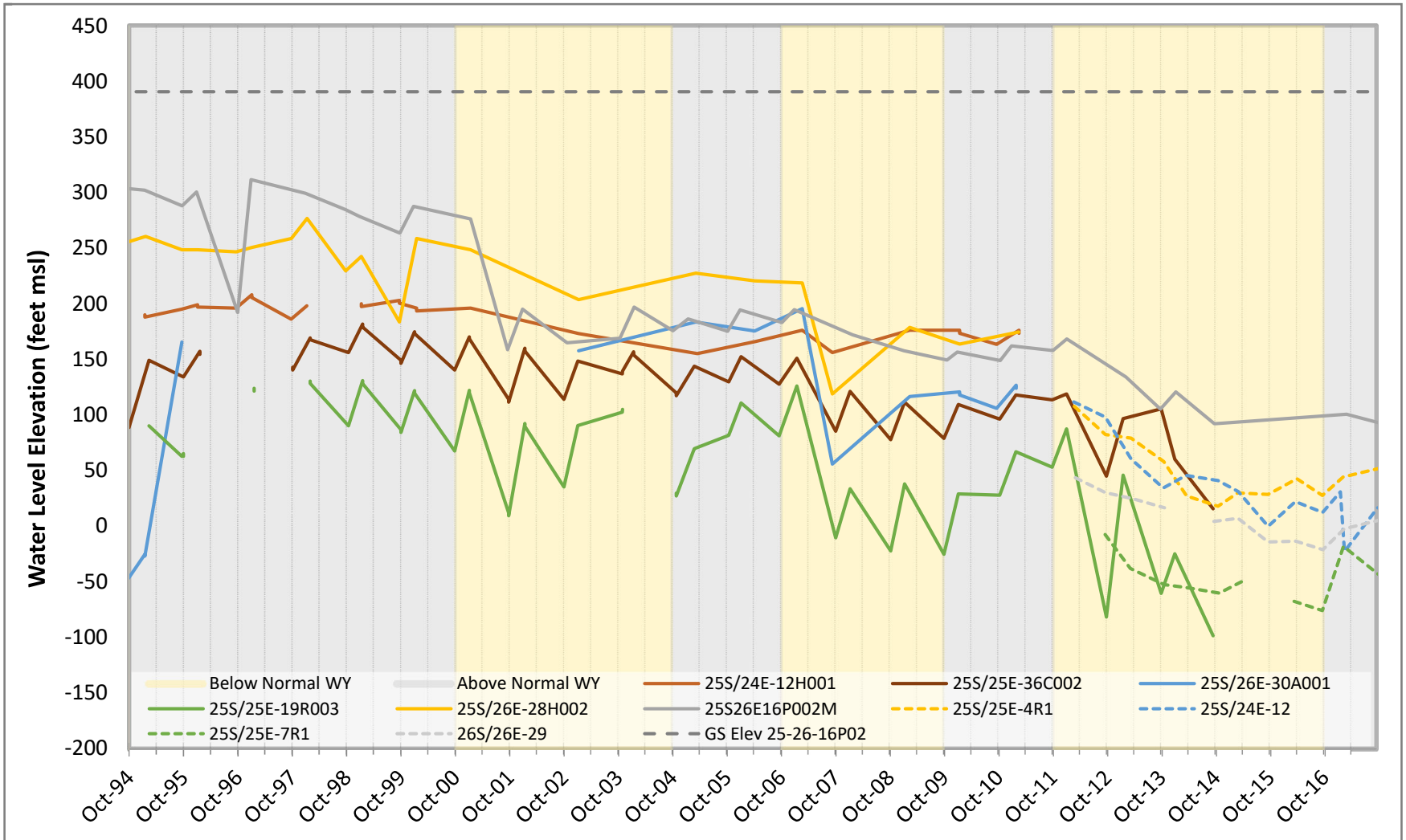
DEID- Delano-Earlimart Irrigation District

SSJMUD- Southern San Joaquin Municipal Utility District

Data need confirmation. They may not be correct.



Hydrogeologic Conceptual Model **Southern San Joaquin Municipal Utility District**	GEI Consultants	**Groundwater Hydrograph:** **Group 1**
Kern County, CA		**February 2019**



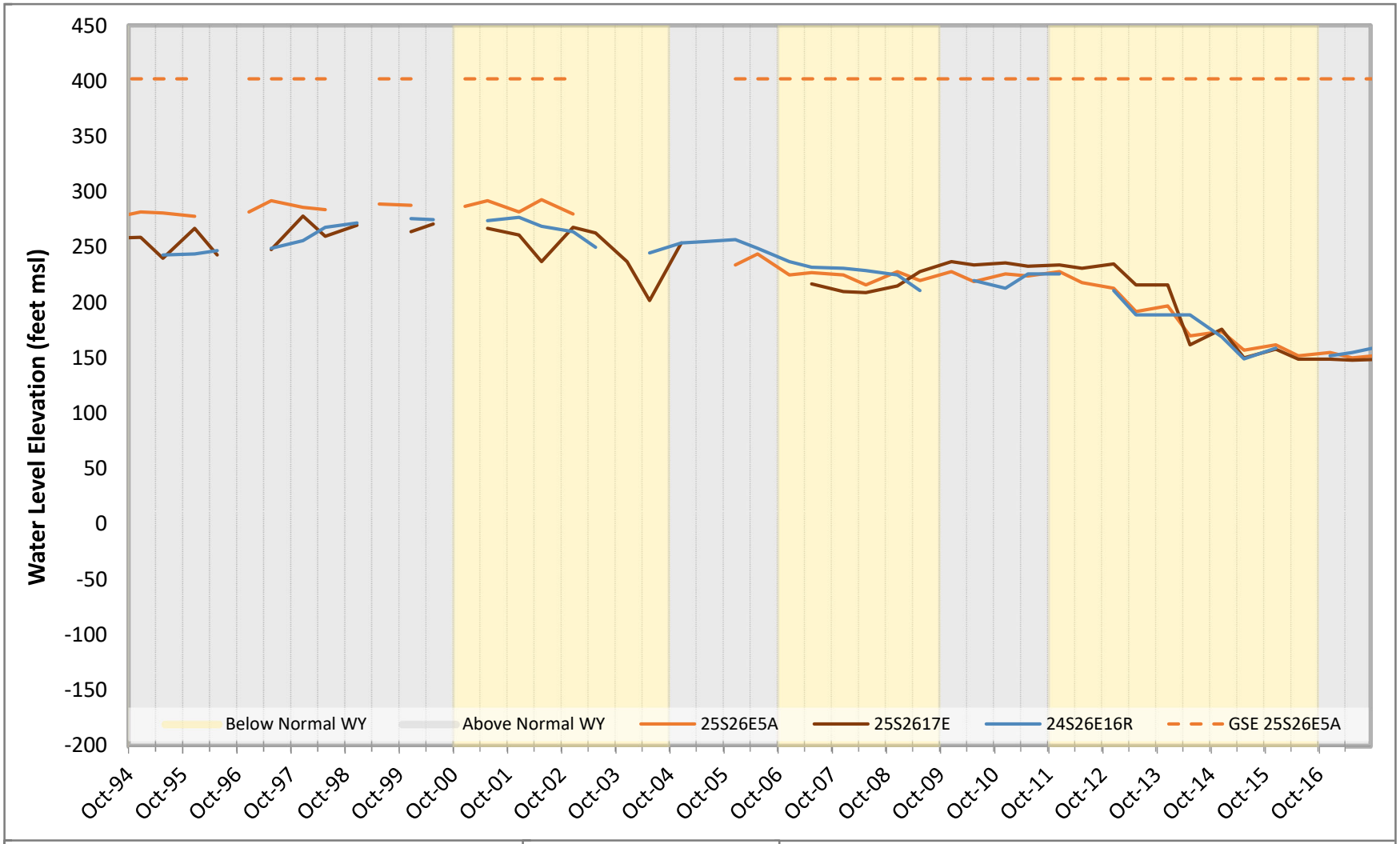
Hydrogeologic Conceptual Model
Southern San Joaquin Municipal Utility District

Kern County, CA

GEI Consultants

Groundwater Hydrograph:
Group 2

February 2019



Hydrogeologic Conceptual Model
Southern San Joaquin Municipal Utility District

Kern County, CA

GEI Consultants

Groundwater Hydrograph:
Group 3

February 2019

Appendix J

Land Subsidence

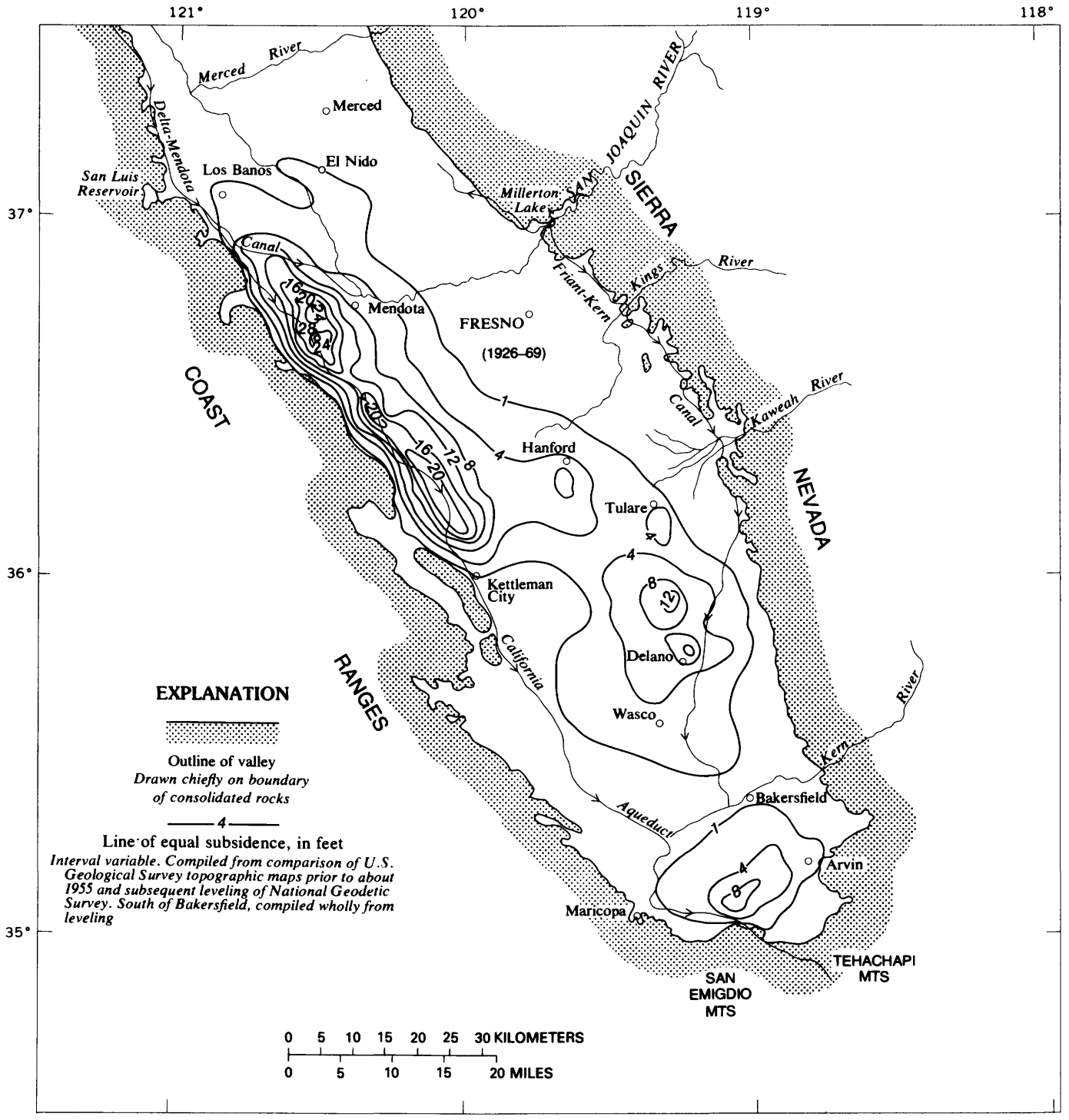


FIGURE 2.—Land subsidence in the San Joaquin Valley, California, 1926–70. Base from U.S. Geological Survey, 1:1,000,000, State of California map, 1940.

Ireland et al, 1984.

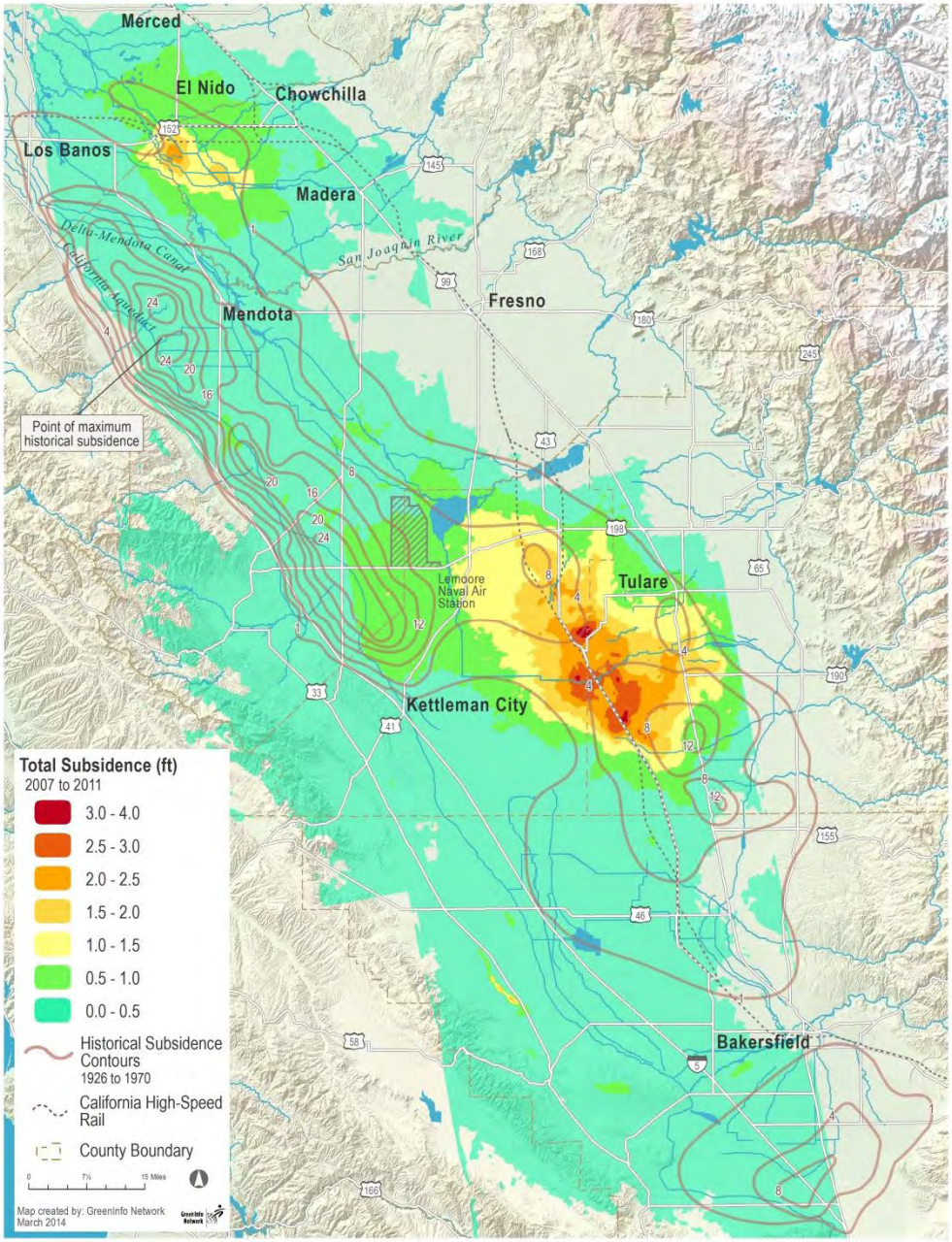
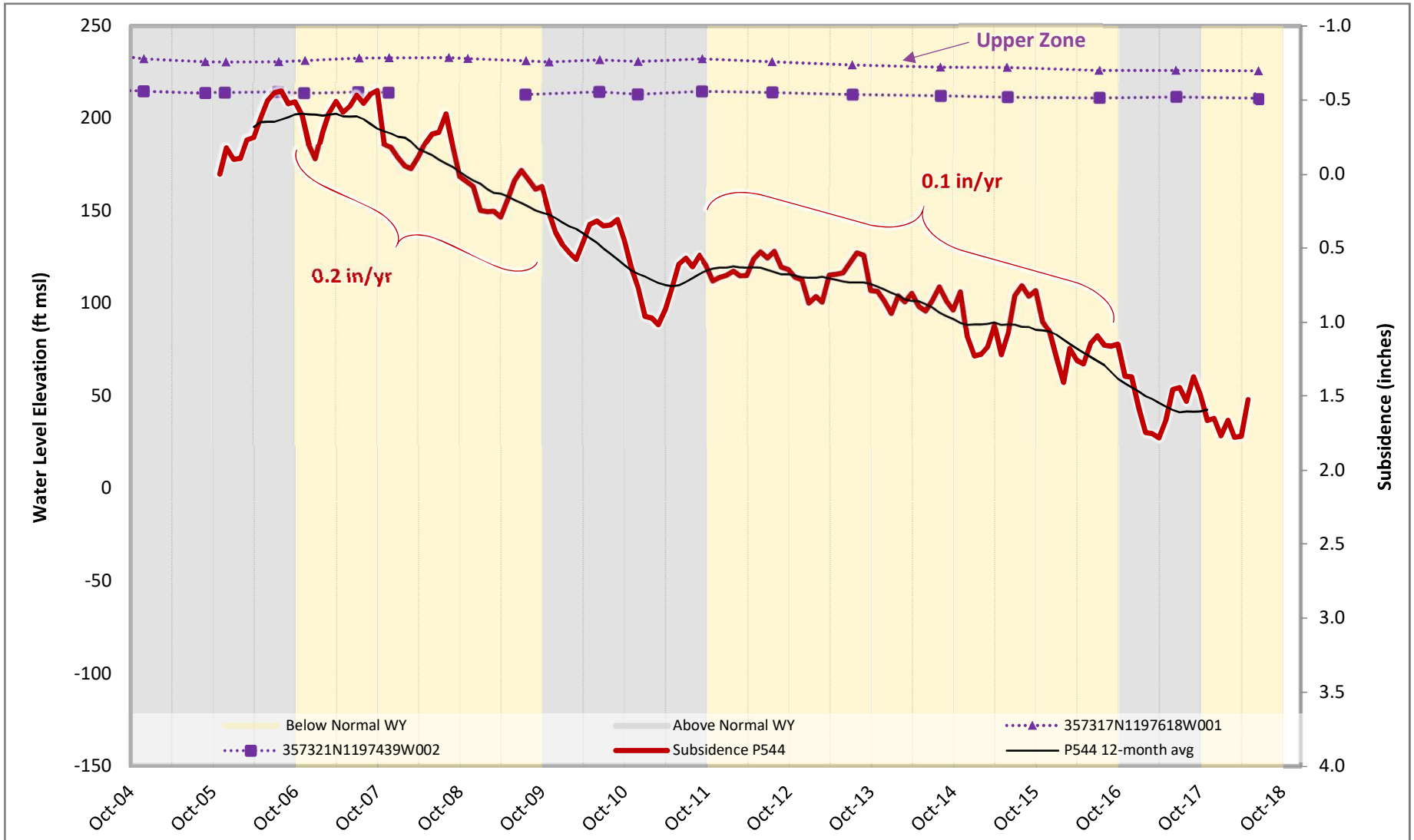


Figure 4-8. Recent subsidence in the in San Joaquin Valley January 2007-March 2011 shown as shaded regions compiled from Interferometric Synthetic Aperture Radar (InSAR) analysis. (InSAR derived subsidence data were provided as preliminary unpublished data courtesy of NASA-JPL.) Subsidence data were composited from three separate interferograms—eastern part of the area, 1/2007-7/2010; central part, 6/2007-6/2010; and western part, 1/2007-3/2011.). Brown contours are lines of equal magnitude of historical land subsidence, in feet, during 1926-1970 (Ireland et al., 1984). The proposed alternative alignments of the California High-Speed Rail system are shown as dotted lines.



Hydrogeologic Conceptual Model
Kern County Subbasin

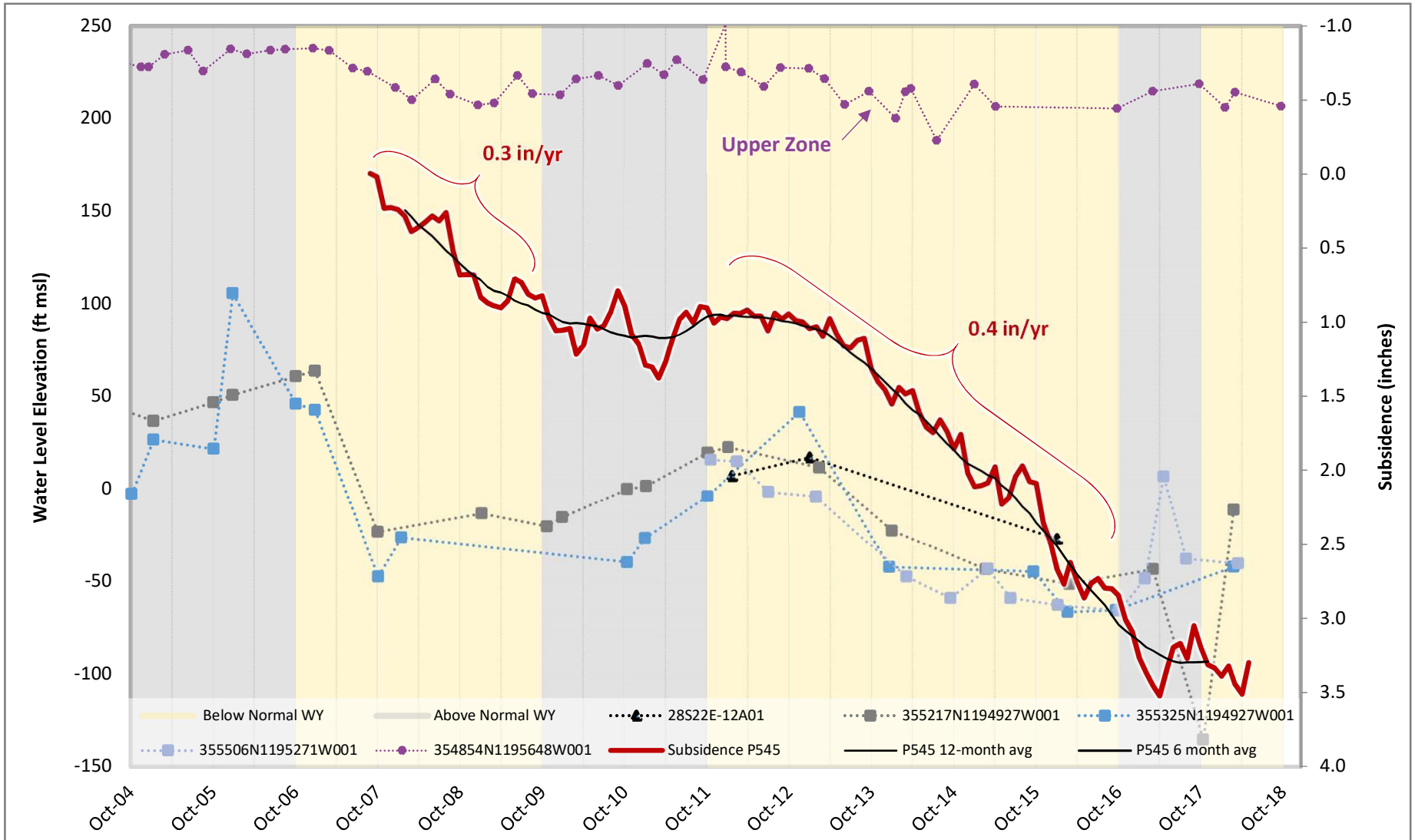
Kern County, CA

GEI Consultants

Monitoring Agency/Groundwater Hydrograph:

P544 Subsidence and Nearby Hydrographs

February 2019



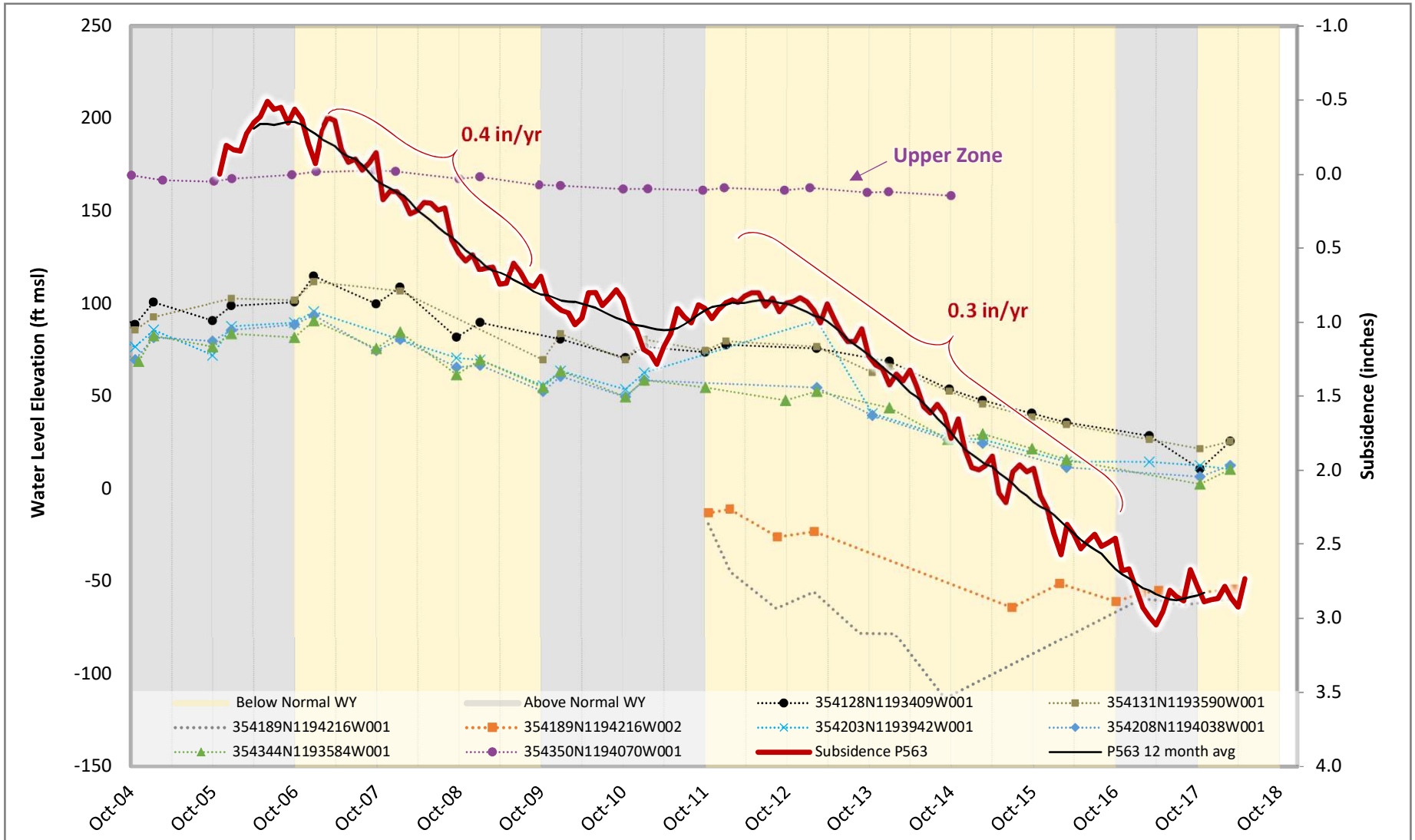
Hydrogeologic Conceptual Model
Kern County Subbasin

Kern County, CA

GEI Consultants

Monitoring Agency/Groundwater Hydrograph:
P545 Subsidence and Nearby Hydrographs

February 2019



Hydrogeologic Conceptual Model
Kern County Subbasin

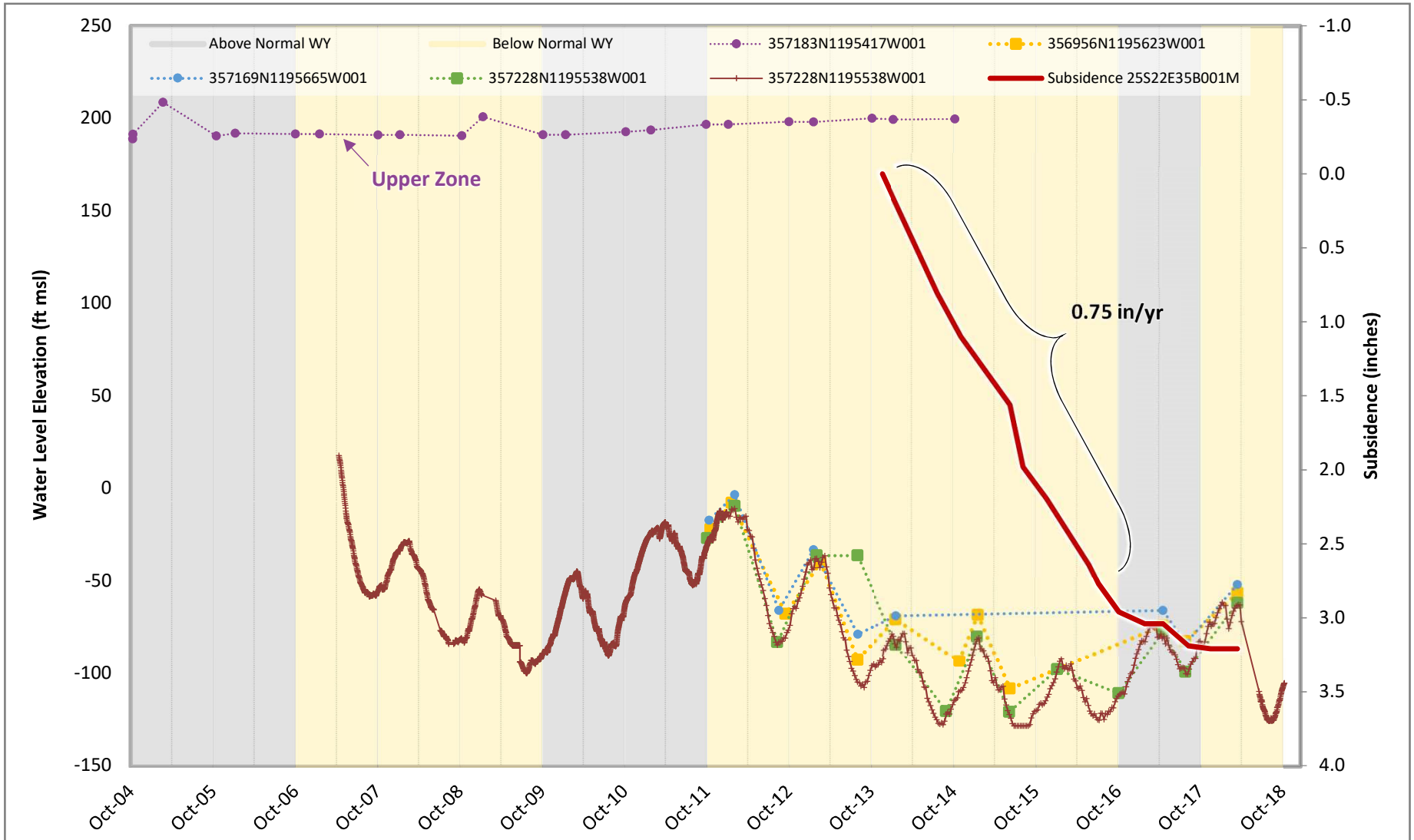
Kern County, CA

GEI Consultants

Monitoring Agency/Groundwater Hydrograph:

P563 Subsidence and Nearby Hydrographs

February 2019



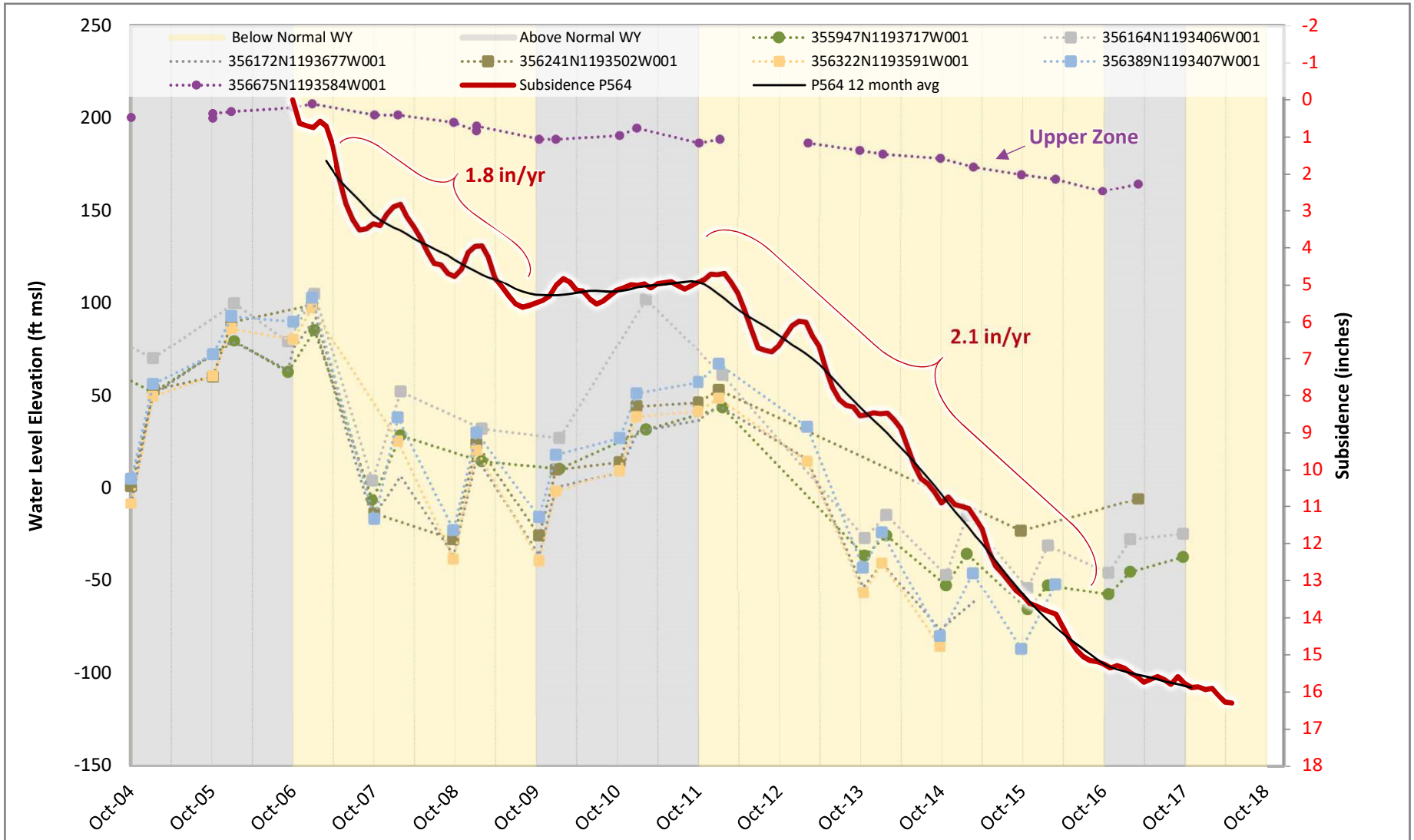
Hydrogeologic Conceptual Model
Kern County Subbasin

Kern County, CA

GEI Consultants

Monitoring Agency/Groundwater Hydrograph:
SWSD Extensometer and Nearby Hydrographs

February 2019



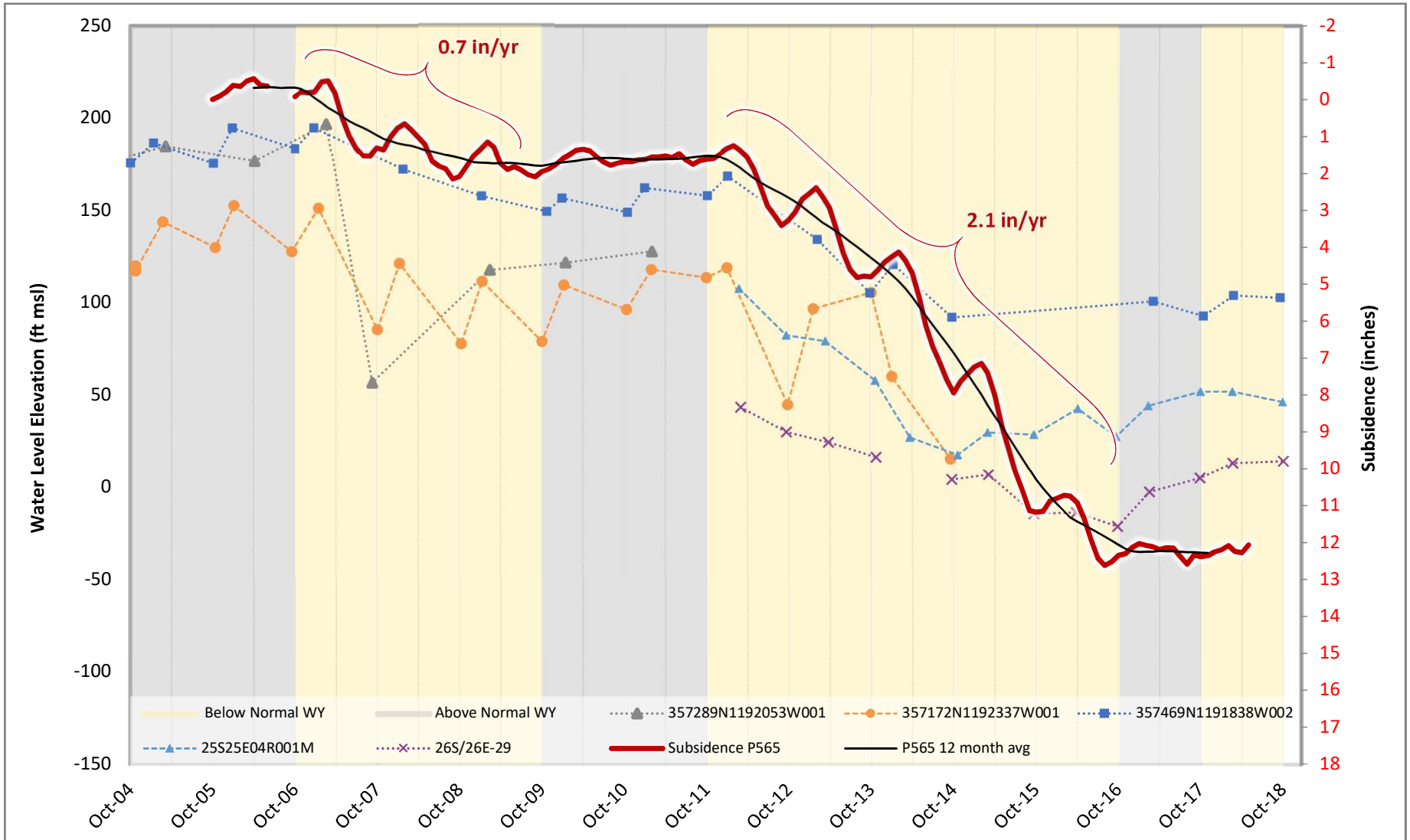
Hydrogeologic Conceptual Model
Kern County Subbasin

Kern County, CA

GEI Consultants

Monitoring Agency/Groundwater Hydrograph:
P564 Subsidence and Nearby Hydrographs

February 2019



Hydrogeologic Conceptual Model
Kern County Subbasin

Kern County, CA

GEI Consultants

Monitoring Agency/Groundwater Hydrograph:
P565 Subsidence and Nearby Hydrographs

February 2019

Appendix K

Existing Monitoring Network

Tulare
Kern
Richgrove
Delano
Pond
McFarland
Wasco
155
99
43

T25S R24E
T25S R25E
T25S R26E
T25S R27E
T26S R24E
T26S R25E
T26S R26E
T26S R27E

Wells
Sections
Township & Range
City
Southern San Joaquin Municipal Utility District
Kern County Subbasin Boundary

SOURCE:

4 2 0 4
Miles

N
W E
S

Hydrogeologic Conceptual Model
for North of River, Kern County Subbasin

GEI Consultants

SOUTHERN SAN JOAQUIN
MUNICIPAL UTILITY DISTRICT

APRIL 2018 **DRAFT** FIGURE

16-Oct-2017 Z:\Projects\1703706_Kern\SSJ_MUD_Wells.mxd SMS

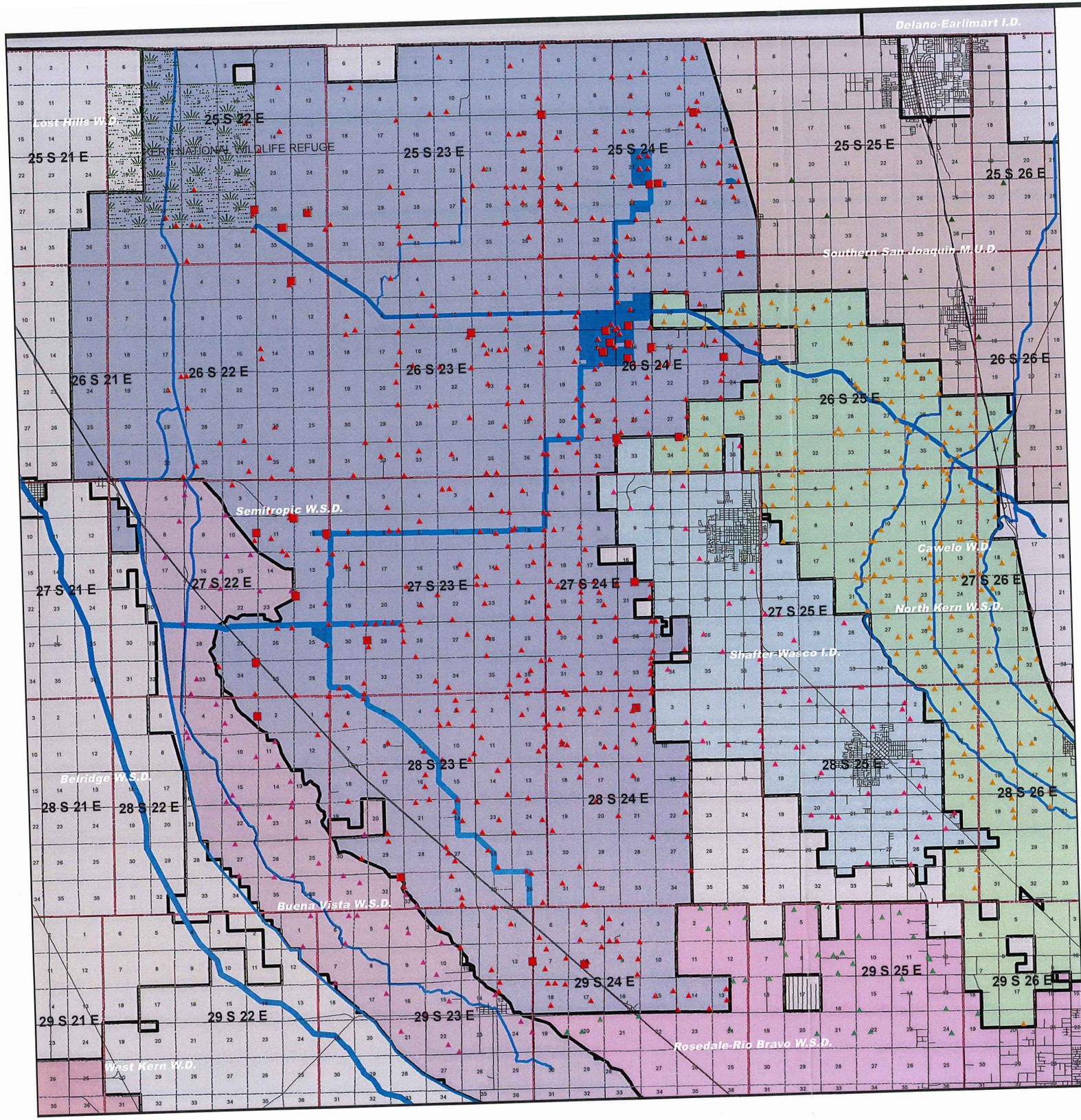


Figure 3
Location of Wells in Water-Level Network

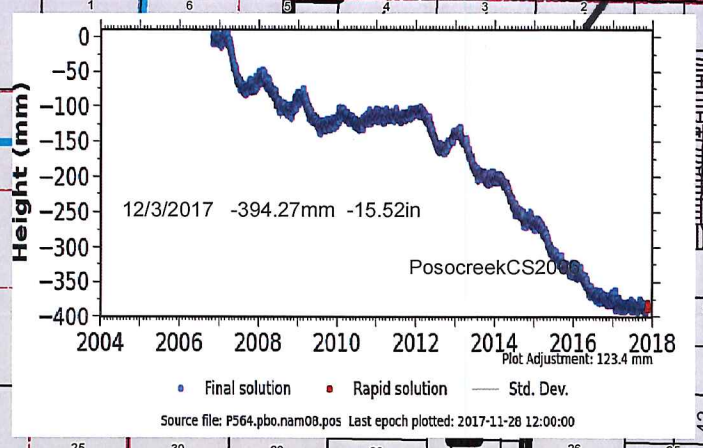
Legend

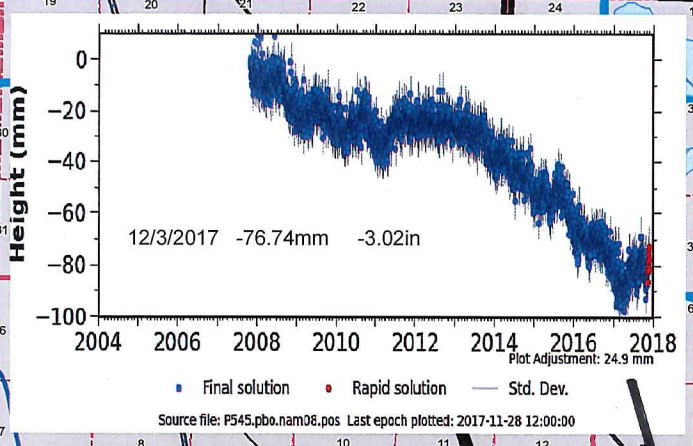
- Monitor Wells

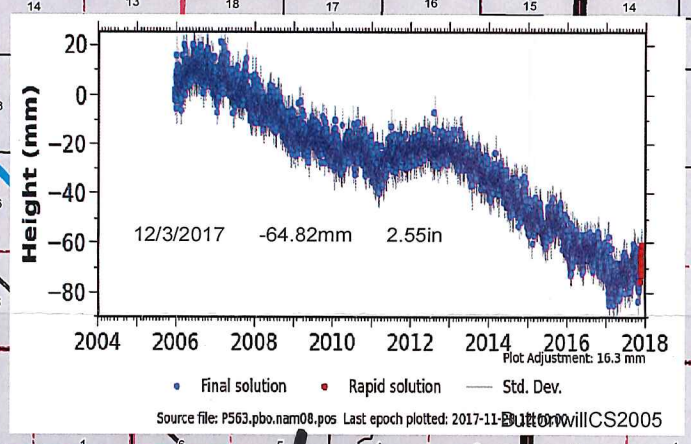
Well Locations

- BVWSD
- NKWSD
- RRBWSD
- SSJMUD
- SWID
- SWSD
- Water Agencies
- Canals

Semitropic WSD Extensometer







Data and site GPS locations provided by https://gis.water.ca.gov/app/gicima/

Legend

- Semitropic WSD Extensometer
- GICIMA Extensomete

Figure 14
Location of Land Subsidence Monitoring Stations

Table 1. GSP Well Monitoring Network (Sustainable Management Criteria for Water Levels)
Southern San Joaquin Municipal Utility District

									Water Levels						
Well No.	DMS ID	CASGEM ID	T-R-S	Monitoring Type	GSP Well Monitoring Status	GSP Parameters Type	Transducer	Aquifer Zone	Minimum Threshold	Measurable Objective	2020 Interim Milestone	2025 Interim Milestone	2030 Interim Milestone	2035 Interim Milestone	2040 Interim Milestone
SSJMUD Well 8		--	25S-24E-13P2	Supply Well	Interim	WL and WQ	--	Main Production							
SSJMUD Well 14		--	25S-26E-19J1	Supply Well	Interim	WL and WQ	--	Main Production							
SSJMUD Well 23		--	25S-25E-29R2	Supply Well	Interim	WL and WQ	--	Main Production							
SSJMUD Well 42		--	25S-26E-01P2	Supply Well	Interim	WL and WQ	--	Main Production							
SSJMUD Well 53		--	26S-26E-32	Supply Well	Interim	WL and WQ	--	Main Production							
SSJMUD Well 59		--	26S-26E-10	Supply Well	Interim	WL and WQ	--	Main Production							
SSJMUD Well 62		--	25S-26E-26	Supply Well	Interim	WL and WQ	--	Main Production							
Delano Well 30		--	25S-25E-01	Supply Well	Interim	WL and WQ	--	Main Production							
Delano Well 14		--	25S-25E-23	Supply Well	Interim	WL and WQ	--	Main Production							
Delano Well 23		--	25S-25E-05	Supply Well	Interim	WL and WQ	--	Main Production							
S-6	8018	357036N1193392W001	25S-24E-36Q	Monitor Well	Primary	WL and WQ	Yes	Lower							
TBD		--	25S-24E-13	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	25S-26E-19	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	25S-25E-29	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	25S-26E-01	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	26S-26E-32	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	26S-26E-10	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	25S-26E-26	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	25S-25E-01	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	25S-26E-26	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	25S-25E-01	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	25S-25E-23	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							
TBD		--	25S-25E-05	Monitor Well	Future Installation	WL and WQ	TBD	Main Production							

Notes
1 - This well categorized as a lower zone well based on hydrograph trends.
2 - Categorized as an upper/lower zone well based on hydrograph trends.
3 - Indicates wells categorized by hydrograph trends instead of perforation relationship to Corcoran Clay. If "Unknown" then the presence of the clay is unknown at this location. Trends similar to Lower Zone.
-- data are not available
DMS - Data Management System
GSP - Groundwater Sustainability Plan
Interim - Well is temporarily used until a permanent replacement is available.
Primary- Permanent monitoring wells that are primary sources of data for the monitoring network
Future Installation - Replacement of interim or new installation to fill data gap.
Secondary- Permanent monitoring wells or supply wells that are secondary sources of data for the monitoring network.
TBD- To be determined
WL - Water Level
WQ - Water Quality

Other Notes
Confirmation of data needed

Table 2. GSP Well Monitoring Network (Sustainable Management Criteria for Water Quality)
Southern San Joaquin Municipal Utility District

								Arsenic							Nitrate							1,2,3-TCP							Na / Cl						
Well No.	DMS ID	CASGEM ID	T-R-S	Monitoring Type	GSP Well Monitoring Status	GSP Parameters Type	Transducer	Aquifer Zone	Minimum Threshold	Measurable Objective	2020 Interim Milestone	2025 Interim Milestone	2030 Interim Milestone	2035 Interim Milestone	2040 Interim Milestone	Minimum Threshold	Measurable Objective	2020 Interim Milestone	2025 Interim Milestone	2030 Interim Milestone	2035 Interim Milestone	2040 Interim Milestone	Minimum Threshold	Measurable Objective	2020 Interim Milestone	2025 Interim Milestone	2030 Interim Milestone	2035 Interim Milestone	2040 Interim Milestone	Minimum Threshold	Measurable Objective	2020 Interim Milestone	2025 Interim Milestone	2030 Interim Milestone	2035 Interim Milestone	2040 Interim Milestone
SSJMUD Well 8		--	25S-24E-13P2	Supply Well	Interim	WL and WQ	--	Main Production																												
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WL - Water Level
WQ - Water Quality

Other Notes
Confirmation of data needed

Department of Water Resources
Karla Nemeth, Director
Taryn Ravizzini, Deputy Director of Statewide Groundwater Management
Craig Altare, Supervising Engineering Geologist
Steven Springhorn, Senior Engineering Geologist
Keith Wallace, Project Manager

State Water Resources Control Board
E. Joaquin Esquivel, SWRCB Board Chair
Dorene D'Adamo, SWRCB Board Member
Tam M. Dudoc, SWRCB Board Member
Sean Maguire, SWRCB Board Member
Laurel Firestone, SWRCB Board Member
Eileen Sobeck, Executive Director
Natalie Stork, Chief of Groundwater Management Program
Andrew Altevogt, Program Coordinator of Safe and Affordable Drinking Water

June 3, 2020

Re: Recommendations for DWR and SWRCB Action Regarding the Kern Groundwater Authority Groundwater Sustainability Plan

Dear Department of Water Resources and State Water Resources Control Board,

Leadership Counsel for Justice and Accountability works with low-income communities of color in the San Joaquin Valley and the Eastern Coachella Valley. We have been engaged in the Sustainable Groundwater Management Act (SGMA) implementation process because most of the communities we work with are wholly dependent on groundwater for their drinking water supplies, and many have already experienced groundwater supply and quality issues. The communities where we work have not been adequately included in decision-making about their precious water resources, and their needs are not prioritized in such decisions.

Disadvantaged communities in the Kern Groundwater Authority GSA have the most to gain and the most to lose from SGMA implementation in the region. Communities like Arvin are majority

Latino and depend on small community water systems and/or domestic wells for their drinking water supply. Because residents in disadvantaged communities do not typically have the financial means to dig deeper wells or to install, operate and maintain drinking water treatment infrastructure, they are more likely to be severely impacted by lowering groundwater levels and groundwater contamination.

As a particularly vulnerable group, the critical drinking water needs of disadvantaged communities and low-income households must be considered and protected by the Groundwater Sustainability Plan (GSP). The Kern Groundwater Authority GSA has not adequately done so in this GSP. As described below, the GSP will likely allow drinking water to be contaminated by existing contaminant plumes, is likely to allow wells to go dry, and has no clear plan to help prevent and mitigate drinking water impacts.

The Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB) must evalue GSPs according to the Human Right to Water, and ensure that the GSPs comply with SGMA, the GSP regulations, and state and federal civil rights law, among other laws and regulations. In 2012, California recognized the Human Right to Water, codifying "the established policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes."[1] Under the Human Right to Water law, DWR and the State Water Resources Control Board must consider the Human Right to Water on review of GSPs.[2] In order to comply with this obligation, the Department and Board must ensure that GSPs do not cause or allow further drinking water crises that interfere with residents' access to an adequate supply of safe drinking water. In coordination with the Community Water Center and Self-Help Enterprises, we have developed a Human Right to Water Scorecard that contains elements necessary for state review of GSPs to comply with the Human Right to Water.[3] We urge DWR and the SWRCB to use this scorecard in evaluating this GSP.

Additionally, SGMA requires GSAs to include disadvantaged communities in decision-making, and create GSPs in a transparent and inclusive way. DWR and the SWRCB must ensure that GSPs do not cause "significant and unreasonable impacts" to the beneficial uses and users of groundwater in the subbasin, that they encourage the participation of a diverse variety of stakeholders,[4] and that they "consider the interests of" an enumerated list of all types of beneficial users, including disadvantaged communities on domestic wells and community water

[1] Water Code § 106.3(a)
[2] Water Code § 106.3(b)
[3] Attached as Exhibit B.
[4] Water Code § 10727.8(a) ["The groundwater sustainability agency shall encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin prior to and during the development and implementation of the groundwater sustainability plan."].

systems.[5] Furthermore, state law provides that no person shall, on the basis of race, national origin, ethnic group identification, and other protected classes, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state.[6] The state's Fair Employment and Housing Act guarantees all Californians the right to hold and enjoy housing without discrimination based on race, color, or national origin.[7] DWR and the SWRCB must evaluate GSPs in accordance with all of these and other relevant legal obligations.

Unfortunately, the Kern Groundwater Authority GSA did not protect the drinking water resources relied upon by disadvantaged communities or low-income households, or avoid disparate impacts, and the GSP is incomplete and does not comply with SGMA and other applicable state laws. As noted above, we reviewed the Kern Groundwater Authority GSP according to our Human Right to Water Scorecard. Our review shows that the GSP does not contain all of the information required under SGMA, does not adequately evaluate "significant" and "unreasonable" impacts to beneficial uses including the drinking water needs of disadvantaged communities, will create a disparate impact on protected classes unless significantly modified, and does not comply with the Human Right to Water statute.

For the reasons discussed in these comments, and in prior written and oral comments provided to the GSA, DWR must not approve the GSP.[8]

~ ~ ~ ~ ~ ~

[5] Water Code § 10723.2.

[6] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].

[7] Gov. Code § 12900 et seq.

[8] Attached as exhibits are certain documents, studies and analysis supporting these comments, which we request be incorporated into the record.

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A. The GSP Does Not Comply with SGMA Because It Lacks Required Information

The GSP must contain all of the elements set forth in the GSP regulations. However, this GSP omits critical data and information to comply with the GSP regulations. As discussed below, the GSP lacks required information and analyses, including among other things critical data regarding the consideration of drinking water impacts on disadvantaged communities and protected groups, sustainable management criteria that consider impacts on all beneficial users, and projects and management actions that address significant and unreasonable impacts to beneficial users. The GSP also fails to demonstrate how its proposed policies and activities will achieve its sustainability goal, which SGMA requires.[9] Therefore, the GSP fails to "include[] the information required by [SGMA] and [its accompanying regulations]," and is thus inadequate.[10] These inadequacies prevent DWR from being able to determine that the GSP will likely achieve its sustainability goal.[11] Given these deficiencies, we ask DWR not to approve the plan.

B. DWR Cannot Approve The GSP Because It Will Cause Disproportionate And Disparate Negative Impacts On Protected Classes.

The Kern Groundwater Authority GSA and DWR must ensure that the GSP does not cause disparate impacts on protected groups, and must prioritize drinking water as an essential pillar of their groundwater sustainability plan. The GSP does not comply with these requirements.

State law provides that no person shall, on the basis of race, national origin, ethnic group identification, and other protected classes, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by any state agency.[12] In addition, the state's Fair Employment and Housing Act guarantees all Californians the right to hold and enjoy housing without discrimination based on race, color, or national origin.[13]

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[9] Water Code sec. 10727.2(b)(2)
[10] 23 CCR § 355.4(a)(2).
[11] Water Code § 10733(a); 23 CCR § 355.4(b).
[12] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].
[13] Gov. Code § 12900 et seq.

The GSP will have disparate impacts on protected classes, including negative and discriminatory impacts on the basis of race, color, ancestry, national origin, and ethnic group identification. "Low-income communities and communities of color in the Central Valley rely disproportionately on private wells because adequate public services were not developed in those communities."[14]As a result, "low-income households, people of color, and communities already burdened with environmental pollution suffered the most severe impacts [from drought]" and dry wells.[15] Similarly, communities of color in the Central Valley are disproportionately impacted by groundwater contamination.[16]

Consistent with these studies, this GSP will cause disproportionate negative impacts on communities of color reliant on small water systems and domestic wells. There are at least 105 disadvantaged unincorporated communities (DUCs) within Kern County, many of which will be impacted by this GSP.[17] Approximately 55% of the population of Kern County DUCs are people of color, slightly higher than the approximately 51% of the population of the County overall who are people of color. Many of the communities we work with and that are most susceptible to falling groundwater levels and groundwater pollution, however, are nearly 100% Latino. For example, according to the most recent American Communities Survey data, Lamont is 95% Hispanic or Latino.[18]

As discussed below, the GSP's determinations and policy decisions will result in many more dry wells, and will not prevent increased drinking water contamination from groundwater activities, particularly for disadvantaged communities reliant on small water systems and domestic wells. This will cause severe harm to residents' health and daily lives, as well as permanent impacts on residents' finances and living situations. Additionally, the GSP contains no measures to mitigate these impacts. Therefore, because the GSP is likely to have significant negative impacts on households reliant on small water systems and domestic wells, and because the people reliant on small water systems and domestic wells are disproportionately people of color, the GSP is likely

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[14] Feinstein et al., "Drought and Equity in California," p. 21 (January 2019), available at https://pacinst.org/wp-content/uploads/2017/01/PI_DroughtAndEquityInCA_Jan_2017.pdf.

[15] *Id. at p. 6.*

[16] *See* Balazs et al., "Social Disparities in Nitrate Contaminated Drinking Water in California's San Joaquin Valley," Environmental Health Perspectives, 19:9 (September 2011), available at https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1002878; Balazs et al., "Environmental Justice Implications of Arsenic Contamination in California's San Joaquin Valley," Environmental Health Perspectives, 11:84 (November 2012), available at https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84.

[17] Flegel et al., "California Unincorporated: Mapping Disadvantaged Communities in the San Joaquin Valley," p. 29,32 (2013), available at https://www.policylink.org/resources-tools/california-unincorporated-mapping-disadvantaged-communities-in-the-san-joaquin-valley; *see also* Kern County General Plan, Housing Element, Chapter 7 (April 2016), available at https://psbweb.co.kern.ca.us/planning/pdfs/he/KCHE_2015.pdf..

[18] Data available at https://data.census.gov/cedsci/, accessed on June 2, 2020.

to cause disparate impacts on protected classes.

C. The GSP Does Not Adequately Evaluate Whether Adverse Impacts Are "Significant And Unreasonable" Or Consider Beneficial Uses And Users.

Under SGMA, DWR must find that a GSP is likely to achieve its sustainability goal before DWR may approve the plan.[19] "'Sustainability goal' means the existence and implementation of one or more groundwater sustainability plans that achieve sustainable groundwater management by identifying and causing the implementation of measures targeted to ensure that the applicable basin is operated within its sustainable yield."[20] "'Sustainable groundwater management' means the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results."[21] An "undesirable result" occurs when a GSP allows a "significant and unreasonable" adverse impact to one of six sustainability indicators, including groundwater levels, groundwater storage, groundwater quality, and land subsidence.[22]

If a GSP is unlikely to achieve its sustainability goal, DWR cannot approve the plan.[23] DWR must also independently determine whether or not the GSP is likely to avoid "significant and unreasonable" adverse impacts with regard to each sustainability indicator, and if not then DWR cannot approve the plan. If a GSP will allow an undesirable result even if implemented effectively, then the GSP cannot achieve sustainable groundwater management.[24] Likewise, a plan that cannot achieve sustainable groundwater management has failed to set a valid sustainability goal, in violation of SGMA.[25] If a GSP does not contain a valid sustainability goal, DWR cannot determine that the GSP is "likely to achieve the sustainability goal for the basin," and DWR cannot approve it.[26]

In addition to defining undesirable results, GSPs must quantify benchmarks for groundwater conditions, or "minimum thresholds," that may cause undesirable results if exceeded.[27] GSPs must include "an explanation of how the Agency has determined that basin conditions at each minimum threshold will avoid undesirable results for each of the sustainability indicators."[28] A GSP's determination of when an undesirable result will occur must be based on analysis of when

[19] Water Code § 10733(a).
[20] Water Code § 10721(u).
[21] Water Code § 10721(v).
[22] Water Code § 10721(x).
[23] Water Code § 10733(a).
[24] Water Code § 10721(v).
[25] Water Code § 10721(u).
[26] Water Code § 10733(a); *see also* 23 CCR 354.24 ("Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline.").
[27] 23 CCR 354.28(a).
[28] 23 CCR 354.28(b)(2).

adverse impacts become "significant" and "unreasonable."[29]

In all of its actions, a GSA must "consider the interests of" all categories of beneficial users, including express requirements to consider disadvantaged communities on domestic wells and community water systems.[30] Failure to consider the interests of a category or categories of beneficial users is itself grounds for DWR to decline to approve a plan.[31] DWR regulations also establish that a failure to consider all beneficial uses and users of groundwater undermines the likelihood that a basin will reach its sustainability goal.[32]

We note that an impact on drinking water that persists for even a relatively short period of time (e.g., months or years rather than decades) may have permanent and irreversible impacts on households and communities. A household is not habitable without access to an adequate supply of safe drinking water, and failed wells thus may have irreparable impacts on community cohesion. These impacts are inconsistent with the very concept of sustainable groundwater management.

As explained below, the GSA has not based their policy determinations on an analysis of what impacts are "significant" and "unreasonable," and have not considered the interests of disadvantaged communities or low-income households reliant on small water systems or domestic wells.

D. DWR Cannot Approve The GSP Because It Was Developed With Inadequate Transparency, Accessibility, Consideration Of Public Input And Representation.

As public agencies, GSAs are subject to the requirements of the Brown Act, which requires transparency of public agencies through notice of meetings and prior posting of agendas, posting of meeting minutes after meetings, and public access to meeting materials upon request by a member of the public.[33] GSAs are also subject to the requirements of the Bilingual Services Act, which requires a public agency to provide interpretation and translate materials into all languages for which there is a "substantial" number of people who it serves who speak that language.[34]

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[29] Water Code § 10721(x); 23 CCR 354.28(b); *see also* Cal. Dep't Water Res., *Draft Best Management Practices for the Sustainable Management of Groundwater* 6 (Nov. 2017) ["GSAs must consider and document the conditions at which each of the six sustainability indicators become significant and unreasonable in their basin, including the reasons for justifying each particular threshold selected."]; *id.* 8 ["The GSP must include an analysis and written interpretation of the information, data, and rationale used to set the minimum threshold."].

[30] Water Code § 10723.2.

[31] Water Code § 10723.2; 23 CCR 355.4(b) ["The Department shall evaluate a Plan … to determine whether the Plan … complies with the Act …."].

[32] 23 CCR 355.4(b)(4).

[33] California Gov. Code § 54954.1

[34] Bilingual Services Act, Gov. Code, §§ 7293, 7295.

In addition, GSAs must also adhere to the specific public participation and inclusivity requirements laid out in SGMA. As discussed above, SGMA requires that a GSA "shall consider the interests of all beneficial uses and users of groundwater," which expressly includes "[h]olders of overlying rights" and "[d]isadvantaged communities, including, but not limited to, those served by private domestic wells or small community water systems."[35] The emergency regulations similarly require that a GSP summarize and identify "opportunities for public engagement and a discussion of how public input and response will be used."[36] GSAs thus must engage "diverse social, cultural, and economic elements of the population within the basin."[37] The regulations recognize that failure to engage adequately with a diverse cross-section of the public undermines the likelihood that a GSP will avoid undesirable results and meet its sustainability goal.[38]

The GSA did not adequately consider the input of disadvantaged communities, either at the GSA level or the member agency level. First, the GSA itself did not adequately engage residents of disadvantaged communities in the GSP creation process. The KGA GSA held regular GSA meetings at times that were not accessible to residents working during the day, so many beneficial user groups could not be adequately represented.

The GSA held several public workshops, but the feedback from these workshops, from meetings and from written comments was not incorporated into the GSP. We submitted a comment letter to the KGA GSA in June 2019 and presented this same letter verbally to the KGA board on June 26, 2019. At this meeting we expressed our initial concerns about GSP development and shared recommendations to ensure the protection of vulnerable water users. Among other things, we asked for the GSP to set protective sustainable management criteria to protect drinking water access in disadvantaged communities, ensure the GSP development process be reflective of all beneficial users by monitoring all primary drinking water contaminants, and to engage with DAC residents. These comments were not incorporated into the GSP or the GSP development process. We repeated these same concerns and recommendations in our comment letter on the final public draft of the GSP.

The GSA had a communications plan and an online Stakeholder Survey that was available most of the GSP development period, but the survey was only in English and was only available online, thereby limiting the opportunity for diverse input from non-English speakers and those without regular access to the internet. The survey was also not promoted outside the KGA agencies' existing networks in an authentic and intentional way to reach all beneficial users including disadvantaged communities. While the GSA worked with Self-Help Enterprises to

[35] Water Code § 10723.2.
[36] 23 CCR 354.10(d).
[37] Guidance Document for Groundwater Sustainability Plan; Stakeholder Communication and Engagement, p. 1.
[38] 23 CCR 355.4(b)(4).

provide interpretation at workshops, it did not provide interpretation at its board meetings. It also did not provide translated materials at its meetings.

Additionally, the decision-making structure of the GSA created barriers to public engagement. Instead of being able to learn about GSP development and provide feedback at GSA meetings, stakeholders also had to engage with a myriad of local member agencies, which all had separate meetings, to fully understand GSP development. The KGA GSP states that, "[t]o capture the intent of SGMA as legislation better served under local control, KGA member agencies played a vital role in the development of this GSP. This process included communication and outreach at the local level, with each KGA member agency engaging with its beneficial users to gather vital input, data, and feedback to ensure the success of this GSP and individual management area plans."[39] However, this decision-making structure meant attending member agency meetings and GSA meetings to understand GSP development, which is overly burdensome to most stakeholders who do not have adequate time in their schedules to attend so many regular meetings.

This burdensome process is compounded by the fact that GSA meetings were held during work hours, and member agencies' websites did not provide adequate notice or agendas for GSP-related meetings. The GSP states that "each KGA member agency engag[ed] with its beneficial users to gather vital input, data, and feedback to ensure the success of this GSP and individual management area plans."[40] However, our organization and residents we work with in Arvin had serious barriers to actively participating in GSP development through their local member agency.

The member agency that has jurisdiction over residents we work with in the GSA area, the Arvin-Edison Water Storage District ("Arvin-Edison WSD"), states in its Management Plan, a chapter of the GSP, that it considered disadvantaged communities by engaging representatives of the Arvin CSD, which contains disadvantaged community residents; by creating a Stakeholder Communication and Engagement Plan; and by "welcom[ing] public participation" at stakeholder workshops, Arvin-Edison WSD board meetings, Arvin CSD board meetings, KGA GSA events and meetings, a stakeholder survey, letters to landowners, and small or one-on-one meetings with individual stakeholders.[41] However, as a community-based organization working directly with residents in the GSA area, we were not included in these conversations until August 15, 2019 when we attended the Arvin- Edison WSD Board meeting where they presented their GSP chapter to its board for approval. Residents we work with did not have any knowledge of the GSP development process in the Arvin-Edison Management Area. We have collaborated with many GSAs to develop more effective outreach materials and procedures for ensuring

[39] Kern Groundwater Authority GSP, p. 37, dated January 2020.
[40] Kern Groundwater Authority GSP, p. 37, dated January 2020.
[41] Arvin-Edison Water Storage District Management Area GSP, p. 3-4, dated December 2019.

disadvantaged community involvement, but it was very difficult to follow the structure of KGA. This made it difficult to relay accurate and complete information to community residents and properly engage them with the topic.

Additionally, during GSP implementation the Arvin WSD's website contained no information on SGMA or GSP meetings. We understand from conversations with staff that the agency sent notices to its list serv, but there was no way to sign up for the list serv on the website, and without knowing when and where meetings are occuring the public could not go to a meeting to sign up and be added to the interested parties list serv. A representative from Arvin CSD brought regular updates to a community meeting, but no meeting notices or agendas about GSP development meetings were published in any publicly available format. This public process did not comply with the Brown Act, the Bilingual Services Act, or the requirements under SGMA.

After we submitted our comments on the draft GSP, including the Arvin-Edison Management Area chapter of the GSP, representatives from Arvin CSD reached out to us to discuss our concerns about their public process and the substance of their portion of the GSP. The representatives from Arvin CSD expressed their commitment to public participation and drinking water needs of the residents of Arvin, and agreed to consider our feedback on improved public participation practices. Since then, Arvin WSD huas updated its website and included a link to sign up for its interested parties listserv. But these efforts, taking place after GSP development was largely complete, did not inform the GSP.

The GSA's public participation process and its choice to delegate GSP development to member agencies did not ensure a transparent and inclusive process for developing the GSP. The public engagement process for this GSP was therefore inadequate. At a minimum, an adequate process must include the following elements, which were not present here:

1. **Notice:**[42] Ensure that the GSA provided clear notice to the public about GSA meetings to develop the GSP, posted in ways that all stakeholders were made aware of the meetings, and translated into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.[43]

[42] Government Code § 54954(a).

[43] Government Code sec. 7296.2: Dymally-Alatorre Bilingual Services Act, stating that local agencies providing services to the public must provide translated materials and interpretation when it serves a substantial number of non-English-speaking people. The law defines a "substantial number of non-English-speaking people" as "members of a group who either do not speak English, or who are unable to effectively communicate in English because it is not their native language, and who comprise 5 percent or more of the people served by the statewide or any local office or facility of a state agency." This is because "effective maintenance and development of a free and democratic society depends on the right and ability of its citizens and residents to communicate with their government and the right and ability of the government to communicate with them."

2. **Translation of materials:**[44] Ensure that the GSA translated materials into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.
3. **Interpretation:**[45] Ensure that the GSA provided interpretation services at board meetings, committee meetings and workshops for all languages spoken by at least 5 percent of the public served by the agency, to allow those who do not speak English or are unable to effectively communicate in English to effectively participate.
4. **Meaningful DAC representation on advisory committee:** Ensure that the GSA developed the GSP with an advisory committee that contained representatives from DACs, such that DAC representatives' voices were not drowned out by the overwhelming majority of another interest group.
5. **DAC representation on GSA boards and Coordination Committee:** Ensure that the GSA developed the GSP with GSA boards and a Coordination Committee that contained representatives from DACs.
6. **Incorporation of stakeholder input:** Ensure that the GSP explicitly describes how stakeholder input was incorporated into the GSP process and decisions, including sustainable management criteria and all projects and management actions.

E. The GSP's Sustainable Management Criteria for Groundwater Levels Are Not Adequate

The sustainable management criteria for groundwater levels must be made after considering the interests of all beneficial user groups, including disadvantaged communities reliant on domestic wells and community water systems,[46] and must be based on an analysis of what are "significant" and "unreasonable" impacts.[47] These policy decisions must also avoid disparate impacts on protected groups pursuant to state and federal law.[48] As discussed below, the GSP does not meet these requirements.

a. The Undesirable Result for Groundwater Levels are Inadequate

Undesirable results are the point at which groundwater conditions cause "significant and unreasonable" impacts on beneficial users. The SGMA regulations require GSAs to justify their undesirable results by including the "[p]otential effects on the beneficial uses and users of

[44] Government Code sec. 7296.2.
[45] Government Code sec. 7296.2.
[46] Water Code § 10723.2.
[47] Water Code § 10721(x); 23 CCR 354.28(b); *see also* Cal. Dep't Water Res., *Draft Best Management Practices for the Sustainable Management of Groundwater* 6 (Nov. 2017) ["GSAs must consider and document the conditions at which each of the six sustainability indicators become significant and unreasonable in their basin, including the reasons for justifying each particular threshold selected."]; *id.* 8 ["The GSP must include an analysis and written interpretation of the information, data, and rationale used to set the minimum threshold."].
[48] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).

groundwater."[49] GSAs must also describe the "processes and criteria relied upon to define undesirable results."[50] These determinations must be made based on an analysis of when decreasing groundwater levels will cause results that are either "significant" or "unreasonable" in light of the context of the basin and the real-world circumstances on the ground. The undesirable results determination does not comply with these requirements because it is unsupported by analysis, it is too vague, and it does not show how the GSA considered the interests of beneficial users in shaping its conclusions.

The KGA GSP defines undesirable results for groundwater levels as "when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area)."[51] Neither the KGA GSP nor the Kern Subbasin Coordination Agreement contain an analysis of how what the concrete impacts would be on beneficial users from reaching these undesirable results, including how many wells could go dry, or a process by which beneficial users were consulted in order to determine whether these potential impacts were "significant and unreasonable."

The undesirable result could allow for more than 30% of the territory in the subbasin to exceed its minimum thresholds for groundwater levels before this undesirable result is triggered. This standard allows localized impacts across the subbasin area, which would cause significant and unreasonable impacts to beneficial users of groundwater for drinking and other domestic purposes. There is no justification for dividing the GSA area up into arbitrary management areas and then defining undesirable results as occurring only where three ***adjacent*** management areas exceed minimum thresholds. In short, the GSP allows domestic and small community wells to be dewatered.

Because the undesirable result for groundwater levels allows significant and unreasonable impacts, the GSP is inadequate.

b. The Measurable Objectives for Groundwater Levels are Inadequate

The SGMA regulations require the GSA to set measurable objectives that "achieve the sustainability goal for the basin within 20 years of Plan implementation and...continue to sustainably manage the groundwater basin over the planning and implementation horizon."[52]

The GSA has not demonstrated that it evaluated how the proposed measurable objectives would contribute to the overall sustainable yield of the Kern Subbasin, which is approximately 324,326

[49] 23 CCR § 354.26.
[50] 23 CCR § 354.26.
[51] Kern Groundwater Authority GSP, p. 170, adopted January 2020.
[52] 23 CCR § 354.30(a)

acre-feet per year, according to the GSP,[53] or maintain sustainability over the implementation and planning horizon.

c. The Minimum Thresholds for Groundwater Levels are Inadequate

The groundwater levels sustainable management criteria set by a GSA must be the point that, "if exceeded, may cause undesirable results."[54] SGMA requires GSAs to analyze both the significance and reasonableness of proposed minimum thresholds,[55] and minimum thresholds must have the purpose of avoiding "significant and unreasonable" impacts on beneficial users.[56] The GSA's determination of what is "significant and unreasonable" must consider the impacts on all types of beneficial users, including disadvantaged communities.[57] For groundwater levels specifically, GSAs must place minimum thresholds for each monitoring site at the level "that may lead to undesirable results."[58] Under DWR regulations, the GSA must provide a description of "the information and criteria relied upon to establish minimum thresholds," an explanation of how the proposed minimum thresholds will "avoid undesirable results," and "how minimum thresholds may affect the interests of beneficial uses and users of groundwater."[59]

The GSP's minimum thresholds were not established in a way that considered the interests of beneficial users including domestic well owners and disadvantaged communities, and the resulting minimum thresholds cause significant and unreasonable impacts on the most vulnerable beneficial users. The GSA delegated the task of creating the sustainable management criteria to member agencies, and in the process, did not ensure that the resulting policies complied with the law. The resulting impact from the proposed sustainable management criteria will likely lead to disparate impacts on protected groups pursuant to state and federal law.

The KGA GSA did not ensure that minimum thresholds created by member agencies considered the interests of all beneficial user groups, or prioritize the security of drinking water in the subbasin, in developing minimum thresholds. For example, the Arvin-Edison Management Area GSP did not consider the impact on drinking water users in setting its minimum thresholds. The AEWSD Management Area Draft GSP details how it calculated historical water lows and divided the Management Area into four "Sustainability Criteria Zones" based on historical low groundwater levels and agency jurisdiction, and how it adjusted the minimum thresholds to protect the canal that brings surface water to farmers.[60] However, it did not evaluate or consider

[53] Kern Groundwater Authority GSP, p. 151, dated January 2020.
[54] 23 CCR § 354.28.
[55] Water Code § 10721(x); 23 CCR 354.26(a). (b), 354.28(b); see also Cal. Dep't Water Res., Draft Best Management Practices for the Sustainable Management of Groundwater 6, 8 (Nov. 2017).
[56] 23 CCR § 354.26.
[57] Water Code § 10723.2.
[58] 23 CCR § 354.28.
[59] 23 CCR § 354.28.
[60] Arvin-Edison Water Storage District Management Area GSP, p. 124, dated December 2019.

how many wells could go dry from its proposed minimum thresholds, or adjust for effects on drinking water. Figures 2-5, 2-6 and 2-7 show all of the domestic wells, public supply wells, and communities dependent on groundwater in the GSA area.[61] The GSA therefore knows the number and location of all drinking water wells, but has chosen not to evaluate what the impacts will be to these wells at the minimum thresholds, and whether those impacts are significant and unreasonable. Therefore the GSA did not consider impacts on drinking water beneficial users, or ensure the protection of drinking water as the highest beneficial use of water, despite having all the information it needed to conduct such a drinking water impact analysis.

The GSP does not show that the impact to beneficial users was evaluated. It lays out the process by which the minimum thresholds and measurable objectives were approved, states that the GSA had workshops about the sustainable management criteria and that these items "appeared as discussion items" at the GSA board meetings, but does not show that the GSA considered the impacts on beneficial users.[62] The GSP contains no evaluation of impacts on beneficial users from reaching these sustainable management criteria, and the GSA's decisions regarding sustainable management criteria were not based on an evaluation of the impacts to beneficial users' access to groundwater resources.

The groundwater levels sustainable management criteria for this GSP are therefore inadequate. At a minimum, adequate groundwater levels sustainable management criteria must include the following elements, which are not present here:

1. **Evaluate the drinking water impact:** Ensure that the GSP includes an analysis of how many drinking water wells (municipal wells, community water system wells, and domestic wells) might go fully or partially dry if groundwater levels reach the undesirable results,[63] measurable objectives and minimum thresholds,[64] including a map of wells that will go fully and partially dry at the measurable objectives and minimum thresholds. Ensure that the GSP includes estimates of the increased pumping costs from additional lift needed to pump water from lower elevations if the undesirable results, measurable objectives and minimum thresholds were to be reached.
2. **Avoid significant and unreasonable impacts to drinking water users in creating sustainable management criteria:**[65] The GSA must analyze "when significant and unreasonable effects ... are caused by groundwater conditions occurring throughout the basin," taking into account the beneficial users of groundwater and the basin's specific circumstances.[66] Therefore the GSP must explicitly state how the GSA considered

[61] Kern Groundwater Authority GSP, pg. 26-28, dated January 2020.
[62] Kern Groundwater Authority GSP, p. 177, dated January 2020.
[63] 23 CCR § 354.26(c)
[64] 23 CCR § 354.28(b)(4)
[65] Water Code § 10723.2
[66] 23 CCR § 354.26.

drinking water impacts in shaping undesirable results, measurable objectives and minimum thresholds for groundwater levels; for example, the GSP could state how its well impact analysis supported setting stricter measurable objectives and minimum thresholds near at-risk communities.

3. **Incorporate new drinking water data into sustainable management criteria:**[67] Ensure that the GSP includes a description of how data gaps and uncertainties of its drinking water well impact assessment will be addressed and serve to reassess the sustainable management criteria, projects and management actions in accordance with new data.
4. **Implement DAC and drinking water user input into sustainable management criteria:**[68] Ensure that the GSP discusses how stakeholder input from DAC community members was considered in the development of undesirable results, measurable objectives and minimum thresholds. For example, the GSP could state how they took the results of the well impact assessment to the public through meetings, workshops, or Advisory Committees, and together with stakeholders decided how to change sustainable management criteria to protect drinking water, or other programs to implement to mitigate these impacts.
5. **Avoid disparate impact:**[69] Ensure that the measurable objectives and minimum thresholds for groundwater levels are established in such a way that prevents a disparate impact from occurring on protected classes in the GSP area. For example, the GSP should ensure that the same minimum threshold methodology across the GSP area will not lead to disproportionately more wells going dry for residents of color than for white residents.

F. The GSP Fails To Adequately Address Groundwater Quality Through Its Sustainable Management Criteria for Groundwater Quality

GSA activities and policies could cause increased contamination in many ways. For example, the proposed timeline for implementation of demand reduction may allow for continued pumping which may create an increase in naturally occurring contaminants and/or migration of contaminant plumes.[70] Recharge projects could also have severe impacts on groundwater quality by facilitating water percolation on land contaminated with years of pesticide, herbicide, fungicide, and fertilizer application and/or by releasing natural contaminants like uranium into groundwater.[71] A groundwater market is also likely to cause geographic concentrations of

[67] 23 CCR § 354.38(e)(3)
[68] 23 CCR § 354.10(d); DWR Guidance Document for Groundwater Sustainability Plans: Stakeholder Communication and Engagement, p.1.
[69] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[70] *See* Smith et al., Overpumping Leads to California Groundwater Arsenic Threat, 9 Nature Communications 2089 (2018), available at https://www.nature.com/articles/s41467-018-04475-3.
[71] See Fakhreddine et al., Protecting Groundwater Quality In California, Management Considerations For Avoiding Naturally Occurring And Emerging Contaminants (2019), available at https://www.edf.org/sites/default/files/documents/groundwater-contaminants-report.pdf ["Recharging water, even clean water, into a previously uncontaminated aquifer can potentially alter the existing geochemistry and hydrology

pumping that increases the likelihood of contaminant plume migration, putting drinking water resources at risk. Oil and gas impacts on groundwater should also be analyzed, since Kern County is one of the largest producers of oil and gas, and reports show oil and gas activities can severely impact groundwater quality.[72]

SGMA charged GSAs with the responsibility to protect water quality from further degradation due to groundwater management practices, and requires GSAs to establish sustainable management criteria to prevent degraded groundwater quality,[73] based on a determination of what is a "significant and unreasonable" impact on all beneficial users, including domestic well users and disadvantaged communities.[74] This GSP only monitors and regulates one contaminant of concern despite its express knowledge that many other more harmful drinking water contaminants exist in its GSP area, which could be impacted by groundwater usage and activities. The GSA's sustainable management criteria for groundwater quality are inadequate.

b. The Undesirable Results Determination for Groundwater Quality Is Inadequate

Undesirable results are the point at which "significant and unreasonable" impacts on beneficial users caused by degraded groundwater quality. The SGMA regulations require GSAs to justify their undesirable results by including the "[p]otential effects on the beneficial uses and users of groundwater."[75] GSAs must also describe the "processes and criteria relied upon to define undesirable results."[76] The undesirable result cannot have a disparate impact on protected groups pursuant to state civil rights law.

Like the undesirable result for groundwater levels, the proposed definition of undesirable results for degraded water quality are "when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the

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and subsequently cause the release of geogenic contaminants from soils and sediments."]; Jurgens, Bryant C., et al. "Effects Of Groundwater Development On Uranium: Central Valley, California, USA," Groundwater 48.6 p. 913 (2010), available at https://ngwa.onlinelibrary.wiley.com/doi/abs/10.1111/j.1745-6584.2009.00635.x; "Groundwater Quality In The Sustainable Groundwater Management Act (SGMA): Scientific Factsheet on Arsenic, Uranium, and Chromium," available at https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1559328800/Groundwater_Quality_in_SGMA_Scientific_factsheet_on_arsenic__uranium__and_chromium.pdf?1559328800

[72] Jackson, Robert B., and DiGuilio, Dominic C., Impact to Underground Sources of Drinking Water and Domestic Wells from Production Well Stimulation and Completion Practices in the Pavillion, Wyoming, Field, Environ. Sci. Technol. 2016, 50, 8, 4524-4536; see also references cited in *Six ways oil and gas development can contaminate land and water (and what to do about it),* by Adam Peltz and Nichole Saunders, Environmental Defense Fund Blogs, found at http://blogs.edf.org/energyexchange/2017/12/29/six-ways-oil-and-gas-development-can-contaminate-land-and-water-and-what-to-do-about-it/ , last viewed November 26th, 2019.

[73] Water Code § 10721(w)(4); 23 CCR § 354.28(c)(4).

[74] Water Code §§ 10727.2(d)(2); 10721(x)(4)

[75] 23 CCR § 354.26.

[76] 23 CCR § 354.26.

Subbasin or greater than 30% of the Subbasin (as measured by each management area)."[77] As with the groundwater levels undesirable results, it is not clear what the impacts from reaching this undesirable result will be on beneficial users, and neither the KGA GSP nor the Kern Subbasin Coordination Agreement contain an analysis of how what the concrete impacts would be on beneficial users from reaching these undesirable results, including how many wells could go dry. Instead of being formed through a process in which beneficial users were consulted in order to determine whether these potential impacts were "significant and unreasonable," the process of defining undesirable results in the Kern subbasin seems to be an arbitrary determination of what is "significant and unreasonable."

The water quality undesirable results will allow significant and unreasonable impacts in localized areas and/or for short to medium periods of time. Given that more than 30% of the territory in the subbasin will be allowed to exceed its minimum thresholds for groundwater quality before this undesirable result is triggered, the GSP allows drinking water users to be impacted by drinking water contamination caused by GSA policies and activities. The definition of undesirable results therefore sets a very low inadequate bar for plan failure, and must be modified to ensure that drinking water is protected within the basin.

Because the undesirable results for groundwater quality allow significant and unreasonable impacts on sources of drinking water, DWR cannot approve the GSP.

b. The Minimum Thresholds and Measurable Objectives for Groundwater Quality Are Inadequate

GSAs must place groundwater quality minimum thresholds for each monitoring site at the level "that may lead to undesirable results."[78] Under the SGMA regulations, the GSP must provide a description of "the information and criteria relied upon to establish minimum thresholds," an explanation of how the proposed minimum thresholds will "avoid undesirable results," and "how minimum thresholds may affect the interests of beneficial uses and users of groundwater."[79] Measurable objectives must lead to compliance with the GSA's sustainable yield by 2040.

The GSP briefly states that each member agency established the minimum thresholds and measurable objectives for their management area, mentions that in many cases groundwater levels serve as a proxy for groundwater quality, lists the minimum thresholds and measurable objectives established by each member agency in Table 3-1, and states that more information can be found in the management area GSPs.[80] For several management areas, Table 3-1 does not list which contaminants are being monitored for compliance with the proposed minimum thresholds

[77] Kern Groundwater Authority GSP, p. 172, dated January 2020.
[78] 23 CCR § 354.28.
[79] 23 CCR § 354.28.
[80] Kern Groundwater Authority GSP, p. 179, dated January 2020.

and measurable objectives. Many management areas have used groundwater levels as a proxy for groundwater quality.

Groundwater levels are not a proxy for groundwater quality, and failure to set adequate minimum thresholds or measurable objectives to protect against discharge of all primary and secondary drinking water contaminants during recharge activities and/or activities that cause shifting contaminant plumes renders the GSP inadequate.

As in the case of groundwater levels, it is clear that the GSA has not considered the potential impact on drinking water users, in particular disadvantaged communities that are less able to afford solutions to treat contaminated drinking water. This has resulted in minimum thresholds and measurable objectives like those in the Arvin GSP, which will only be monitoring for compliance with sustainable management criteria in one well location, and has set the minimum threshold at the drinking water MCL for the contaminant, and the measurable objective at 75% of the MCL. The member agency is only monitoring for compliance with arsenic standards, despite the agency's knowledge of the existence of "nitrate...total dissolved solids (TDS), boron, iron and manganese...within or near the Arvin-Edison Management Area above drinking water standards and/or agricultural water quality goals."[81]

The lack of sufficient groundwater quality sustainable management criteria in areas like Arvin means that the GSP allows drinking water pollution that will be disproportionately felt by disadvantaged communities that are less able to afford treatment solutions. This significant and unreasonable impact is not adequate under SGMA or state and federal law prohibiting policy from resulting in disparate impact. The GSA has not conducted an analysis of how the minimum thresholds and measurable impacts could impact critical drinking water resources, and therefore has not considered the interests of all beneficial user groups, particularly drinking water users.

The GSA has also not specified what actions will be taken if water contamination approaches minimum thresholds, or how minimum thresholds will be triggered. Member agencies such as the Arvin-Edison WSD have not specified this in their plans. The GSA should ensure that minimum thresholds will be triggered after one test shows a violation of an MCL or a trend toward an MCL. The GSA must require that member agencies specify what actions they will take if groundwater quality approaches minimum thresholds, what point or measurement will trigger this action, and how impacted residents will be informed. The GSA must also ensure GSA-wide consistency on when minimum thresholds are triggered and what actions are taken in response, in order to protect drinking water across the GSA area.

[81] Arvin-Edison Water Storage District Management Area Plan, p. 80, dated December 2019.

Because the minimum thresholds and measurable objective fail to consider all beneficial users and cause significant and unreasonable impacts, the GSP is inadequate and DWR cannot approve it.

The groundwater quality sustainable management criteria for this GSP are therefore inadequate. At a minimum, adequate groundwater quality sustainable management criteria must include the following elements, which are not present here:

1. **Ensure that the GSP sets measurable objectives and minimum thresholds at all representative monitoring wells for all of the following contaminants:**[82]
    a. Contaminants with primary drinking water standards,
    b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health, AND
    c. Contaminants like uranium, arsenic and nitrate which are known to increase due to groundwater management practices.
2. **Ensure that the GSP triggers a violation of a minimum threshold after *one* test shows that there has been an increase in contamination since January 1st, 2015**. Once the minimum threshold is reached, the GSA must start the evaluation of whether groundwater management activities or groundwater pumping have caused the increase, or whether the increase was caused by other factors such as natural fluctuation, testing inaccuracy, or activities outside the purview of the GSA. If the increase was caused by groundwater management activities or groundwater pumping, the GSA must immediately stop increasing the contamination and remediate.
3. **Immediately remediate any contamination caused by groundwater conditions since 2015:** The GSA must immediately remediate any increased contamination caused by groundwater management policies or activities (including lack of adequate regulation of pumping) since 2015. The GSA must begin remediation immediately upon establishing causation. The GSA must remediate contamination within two years, or as soon as technologically and hydrologically possible, whichever is faster. Design and implementation of remediation measures must be done in partnership with all groundwater users, primarily disadvantaged communities. The GSA must also clearly identify funding sources for remediation, and identify a timeline for procuring those funds.
4. **Strive to remediate existing drinking water contamination:** Ensure that the GSA will strive to remediate drinking water contaminants that exceeded the MCL before 2015 wherever feasible, through projects, management actions and policies.
5. **Evaluate the drinking water impact:** Ensure that the GSP includes an analysis of how drinking water wells (municipal wells, community water system wells, and domestic

[82] 23 CCR § 354.34(b)(2) and (f)(3)

wells) are likely to be be affected by the undesirable results,[83] measurable objectives and minimum thresholds.[84]

6. **Implement DAC and drinking water user input into sustainable management criteria:**[85] Ensure that the GSP discusses how stakeholder input from DAC community members was considered in the development of undesirable results, measurable objectives and measurable objectives.
7. **Incorporate new drinking water data into sustainable management criteria:**[86] Ensure that the GSP includes a description of how data gaps and uncertainties of its drinking water well impact assessment will be addressed and serve to reassess the sustainable management criteria, projects and management actions in accordance with new data.
8. **Avoid disparate impact:**[87] Ensure that the minimum thresholds for groundwater quality are established in such a way that prevents a disproportionately negative impact on communities of color in the GSP area. For example, the GSP should ensure that the same minimum threshold methodology across the GSP area will not lead to disproportionately more wells going dry for residents of color than for white residents.

G. The Monitoring Network is Inadequate With Respect to Groundwater Levels and Groundwater Quality

GSAs must monitor impacts to groundwater for drinking water beneficial users,[88] including disadvantaged communities on domestic wells,[89] and must avoid disparate impacts on protected groups pursuant to state law.[90]

As discussed below, The GSA's monitoring network does not comply with SGMA regulations, and fails to capture drinking water impacts to disadvantaged communities and domestic wells. Specifically, the GSP lacks representative monitoring wells in areas of the subbasin where drinking water users may be particularly vulnerable to groundwater supply and quality issues, leaving the GSA with no ability to measure and avoid significant and unreasonable impacts to those users. The monitoring wells are also monitored two infrequently to timely detect and prevent falling groundwater levels and/or contamination.

[83] 23 CCR § 354.26(c)
[84] 23 CCR § 354.28(b)(4)
[85] 23 CCR § 354.10(d); DWR Guidance Document for Groundwater Sustainability Plans: Stakeholder Communication and Engagement, p.1.
[86] 23 CCR § 354.38(e)(3)
[87] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[88] 23 CCR § 354.34
[89] Water Code § 10723.2.
[90] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).

The lack of adequate monitoring will make it impossible for the GSA to monitor drinking water to detect and prevent undesirable results, undermining the likelihood that the basin will achieve sustainable groundwater management.

The insufficiency of the representative monitoring network renders the GSP inadequate.

a. Groundwater Level Monitoring

The SGMA regulations state that monitoring networks must include a "sufficient density of monitoring wells to collect representative measurements through depth-discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer."[91] The GSA must also make decisions about the monitoring network in a way that considers the interests of all beneficial users.[92]

The GSP here presents a map of its groundwater levels monitoring wells,[93] but does not show what aquifers the wells are monitoring, and where monitoring wells are in relation to disadvantaged communities on domestic wells and small community water systems. As such, it is not possible for the public or DWR to determine whether there is a sufficient density of wells to collect representative measurements and detect and prevent significant and unreasonable impacts on beneficial users.

The monitoring network for groundwater levels is therefore inadequate and will not detect significant and unreasonable impacts to disadvantaged communities. At a minimum, an adequate groundwater levels monitoring network must include the following elements, which are not present here:

1. **Ensure accurate detection of impacts on drinking water users and DACs:**[94] Ensure that the groundwater level monitoring network includes *representative* monitoring wells *in or near DACs*, and placed in a way that detects impacts to the *vast majority* of drinking water users in the GSP area. If new monitoring wells are required, ensure that the GSP contains a concrete plan to fund and construct new representative monitoring wells within the first year of GSP implementation to ensure that vulnerable communities' drinking water resources are monitored. The plan to improve the monitoring network should include testing of domestic wells in the interim as wells are constructed.
2. **Clearly show representative monitoring well locations in relation to DACs:**[95] Ensure that the representative monitoring wells (RMWs) for groundwater levels are presented on maps and in tables that identify which set of minimum thresholds and measurable

[91] 23 CCR § 354.34(c)(1)(A)
[92] 23 CCR § 354.34(b)(2)
[93] Kern Groundwater Authority GSP, Figure 3-3, p. 186-189, dated January 2020.
[94] 23 CCR § 354.34(b)(2) and (f)(3)
[95] 23 CCR § 354.34(b)(2) and (f)(3)

objectives will be applied to which RMWs, and that these maps clearly identify the locations of DACs, small water systems and other sensitive users.

3. **Identify and address other drinking water data gaps:**[96] Ensure that the GSP clearly identifies any other gaps in data regarding impacts to drinking water users, and that the GSP contains a clear plan to fill data gaps regarding impacts to drinking water users. The GSP explains how it will fill some monitoring data gaps, but does not ensure that these gaps will capture impacts on all drinking water users, particularly disadvantaged communities.

b. Groundwater Quality Monitoring

SGMA regulations require that GSPs create a groundwater quality monitoring network that will "collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues."[97]

The groundwater quality monitoring network does not adequately capture impacts on drinking water users. For example, in the case of the Arvin GSP, the member agency will only monitor for compliance with its minimum threshold and measurable objective for arsenic once a year in one well, ACSD Well #14, which is one of the wells that provide drinking water to the community of Arvin.[98]

First, measuring for Arsenic only once a year does not provide the member agency or the GSA with frequent enough information to detect and respond to severe drinking water contamination in a reasonable amount of time. If the member agency's management actions, projects, or decisions to let groundwater decline increase drinking water contamination for families in the management area, the member agency could go a whole year without detecting these impacts. Meanwhile, it will not be responsive to the drinking water impacts from other contaminants which it may have moved or increased from its activities. Instead, the member agency must measure for all contaminants of concern every month.

Second, only measuring for compliance with arsenic measurable objectives and minimum thresholds does not protect against increases in other contaminants that exist in other parts of the management area (boron, nitrates, TDS, 123-TCP, iron and manganese). These contaminants could extend, move or increase due to groundwater management activities and pumping patterns. The Arvin GSP does plan to monitor for these contaminants in seven other wells outside of Arvin,[99] but has not set minimum thresholds and measurable objectives for these wells, and does

[96] 23 CCR § 354.38(e)(3)
[97] 23 CCR § 354.34(c)(4)
[98] Arvin-Edison Water Storage District Management Area Plan, p. 144, dated December 2019.
[99] Arvin-Edison Water Storage District Management Area Plan, p. 144-145, dated December 2019.

not have plans to do so. Without standards against which to compare detected levels of contaminants, and concrete commitments to preventing increased contamination, inclusion of these monitoring networks are meaningless.

Furthermore, Arvin is currently experiencing 123-TCP contamination that threatens the health of Arvin residents, so the GSP must monitor for compliance with 123-TCP standards in particular. In order to ensure that member agencies are detecting new contaminant plumes that could impact drinking water quality, the GSA must ensure that these representative monitoring wells monitor for all contaminants with primary drinking water standards, as well as contaminants known to increase with groundwater management activities such as uranium.[100] The GSA must also ensure that all representative monitoring wells are held to minimum thresholds and measurable objectives, measure the extent and spread of known contaminant plumes, and are able to measure the groundwater levels at the depth at which the drinking water wells are screened.

Third, the well that was chosen, ACSD Well #14, was chosen because it does not have contaminants that are known to exist in wells in the northern part of the management area, which are not currently in use by Arvin CSD, according to our conversation with Arvin-Edison WSD staff at the Kern Subbasin Open House on September 26th, 2019. Avoiding monitoring contaminated areas is inappropriate and fails to ensure that groundwater management activities and pumping do not aggravate existing contamination. The GSA should ensure that the member agency instead monitors for all existing contaminants at minimum throughout the area and especially in areas where contamination is known to exist, and sets minimum thresholds and measurable objectives that apply to all monitoring wells.

The groundwater quality monitoring network for this GSP is therefore inadequate. At a minimum, an adequate groundwater quality monitoring network must include the following elements, which are not present here:

1. **Ensure that the GSP plans to measure the following contaminants at all representative monitoring wells:[101]**
    a. Contaminants of concern with primary drinking water standards
    b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health
    c. Contaminants like uranium, arsenic and nitrate which are known to increase due to groundwater management practices

[100] Smith et al., "Overpumping Leads to California Arsenic Threat," Nature Communications (June 2018) [arsenic discharge from clay correlated with overpumping]; Jurgens et al., "Effects of Groundwater Development on Uranium" (November 2010) [strong correlation between high bicarbonate irrigation and recharge water and leaching of uranium from shallow sediments to groundwater].
[101] 23 CCR § 354.34(b)(2) and (f)(3)

2. **Clearly describe how the GSA will monitor for drinking water impacts:** Ensure that the GSP includes a description of how the GSA(s) will monitor groundwater contamination that could affect drinking water in the GSA area. Ensure that the representative monitoring wells (RMWs) for groundwater quality are presented on maps and in tables, and that the maps of RMWs clearly identify the locations of DACs, small water systems and other sensitive users.
3. **Ensure that the GSP plans to measure the following contaminants at all representative monitoring wells:**[102]
    a. Contaminants of concern with primary drinking water standards
    b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health
    c. Contaminants like uranium, arsenic and nitrate which are known to increase due to groundwater management practices
4. **Clearly describe how the GSA will monitor for drinking water impacts:** Ensure that the GSP includes a description of how the GSA will monitor groundwater contamination that could affect drinking water in the GSA area. Ensure that the representative monitoring wells (RMWs) for groundwater quality are presented on maps and in tables, and that the maps of RMWs clearly identify the locations of DACs, small water systems and other sensitive users.
5. **Ensure accurate detection of impacts on drinking water users and DACs:**[103] Ensure that the groundwater level monitoring network includes *representative* monitoring wells *in or near DACs*, and placed in a way that detects impacts to the *vast majority* of drinking water users in the GSP area. If new monitoring wells are required, ensure that the GSP contains a concrete plan to fund and construct new representative monitoring wells within the first year of GSP implementation to ensure that vulnerable communities' drinking water resources are monitored. The plan to improve the monitoring network should include testing of domestic wells at least as an interim measure as wells are constructed.
6. **Identify baseline contaminant levels:** Ensure that the GSP identifies the current contaminant levels, minimum thresholds and measurable objectives at each RMW, so that it is clear to the public how the contamination could change at each RMW site.
7. **Frequent testing:** Ensure that the groundwater quality monitoring network tests for contaminants of concern frequently, in a way that avoids persistent drinking water contamination. Testing should be done monthly.
8. **Collaboration with other agencies:**[104] Ensure that the GSP explains how the GSA will share data with and collaborate with other groundwater quality regulatory programs, such as ILRP, IRWM, and CV SALTS, and nonregulatory programs such as SB 200, the

[102] 23 CCR § 354.34(b)(2) and (f)(3)
[103] 23 CCR § 354.34(b)(2) and (f)(3)
[104] 23 CCR § 354.34(e)

SWRCB's needs assessment and the GAMA program, in order to build better regional understanding of groundwater quality issues, commit to clear roles, and better respond to groundwater quality impacts caused by groundwater management.

H. Projects and Management Actions Are Inadequate

The GSA must consider the interests of all beneficial users including domestic well owners and disadvantaged communities[105] and avoid disparate impacts on protected groups.[106] The GSP must also concretely outline how each objective and the overall sustainability goal will be achieved.[107] The projects and management actions set forth in the GSP do not demonstrate a plan for achieving sustainability goals, and do not adequately account for the needs of disadvantaged communities pertaining to protected groups under state law. This undermines the likelihood that the basin will reach its sustainability goal by 2040, as required by SGMA.[108]

a. The Projects and Management Actions are Inadequate, Do Not Protect Drinking Water for Disadvantaged Communities, and Will Likely Cause Disparate Impacts.

The projects and management actions set forth in the GSP does not demonstrate a path towards achieving sustainability goals in the plan. The GSA has not demonstrated how they have considered the interests of beneficial users including domestic well owners and disadvantaged communities.[109] The resulting impact from the proposed sustainable management criteria will likely lead to disparate impacts on protected groups pursuant to state and federal law.[110]

The GSA has allowed member agencies like the Arvin-Edison WSD to rely heavily on increasing use of surface water.[111] This places the majority of the plan's success on surface water resources, which are variable and may not be able to be procured. The GSA must ensure that member agencies implement demand reduction strategies from the beginning to ensure that the

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[105] Water Code § 10723.2.
[106] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[107] Water Code § 10727.2(b)(2).
[108] Water Code § 10727.2(b)(1).
[109] Water Code sec. 10723.2.
[110] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].
[111] Arvin-Edison Water Storage District Management Area Plan, p. 153-154, dated December 2019.

GSP is on a path to sustainability within the statutory time period. The GSA will not achieve its sustainability goals if water use is not limited through fully-implemented demand reduction requirements immediately. The chosen management actions undermine the likelihood that the basin will reach its sustainability goal by 2040, as required by SGMA.[112]

Despite the fact that drinking water wells may go dry at the GSP's groundwater levels minimum thresholds, and the fact that drinking water contamination is likely to occur because of changing pumping patterns and recharge activities, the GSA does not have a plan for preventing or mitigating these impacts. Furthermore, the GSA's description of projects does not include a description of any potential negative impacts on beneficial uses of water, such as groundwater contamination, and how such impacts will be mitigated and monitored.

A critical problem with the structure of the GSA is that member agencies are not required to share the cost or responsibility for critical GSA-wide projects. Many more financially powerful agricultural and water banking member agencies could and should be part of a strategy to protect drinking water resources in the GSA area as a whole, especially given that they use much larger quantities of groundwater and their continued pumping will likely lead to dry wells and groundwater contamination issues for the most vulnerable homes in the GSA area. Given that California has recognized drinking water as a human right, and the importance of drinking water that we all experience in our own lives, the GSA member agencies should collectively come together to ensure that no family has to go days, months or years without safe tap water in their home. The Arvin GSP contains two projects for treating water quality in Arvin, but these projects were already under way and fully funded so should not be included in the GSP. The GSP has no overall drinking water protection program to protect residents against dry wells and contaminated drinking water from its policies and groundwater management activities.

b. Minimum Requirements for Projects and Management Actions

The projects and management actions for this GSP are inadequate. At a minimum, adequate projects and management actions must include the following elements, which are not present here:

1. **Include a Drinking Water Well Impact Mitigation Program:** Ensure that the GSP contains a drinking water protection program to prevent impacts to drinking water users and mitigate the drinking water impacts that occur. Please reference the Framework for a Drinking Water Well Impact Mitigation Program that our organization developed with the Community Water Center and Self-Help Enterprises for more details, a draft of which is attached as part of the Human Right to Water Scorecard in Exhibit B.

[112] Water Code § 10727.2(b)(1).

2. **Establish a clear and proactive plan for demand reduction.** Demand reduction should be implemented immediately.
3. **Describe the potential drinking water impacts of each project or management action.**
4. **Include management actions to measure groundwater extraction using the most scientifically accurate method.** From our conversations with scholars, it is clear that metering is the most accurate way of measuring groundwater extraction. Metering should be required for all users, particularly large agricultural pumpers.
5. **Ensure that the GSP's projects and management actions will not cause a disparate impact:**[113] Ensure that the GSP's projects and management actions, taken as a whole, prevent a disproportionately negative impact on communities of color in the GSP area. Projects and management actions may not cause, or fail to prevent, disproportionately more dry wells and contaminated water for residents of color than for white residents in the GSP area.

I. Plan Implementation Section is Inadequate

GSPs must include a planning and implementation horizon[114] and must show how the sustainability goal will be achieved by 2040.[115] GSP implementation must continue to consider the interests of all beneficial user groups and engage a diversity of stakeholders. The GSP's plan implementation section is insufficient in regards to public engagement/outreach and does not contain adequate information regarding annual reporting or the potential to make amendments to the GSP. Absent this information, DWR cannot evaluate when and whether the plan is likely to achieve sustainable groundwater management, so DWR cannot approve the plan.[116]

The GSA's Communications and Engagement plan states that "[d]uring the implementation phase, communication and engagement efforts will be shifted to educational and informational awareness of the requirements and processes for reaching groundwater sustainability. Active involvement of all stakeholders is encouraged during this phase, and public notices are required for any public meetings and prior to imposing, and later increasing, any fees."[117] It is concerning that this statement communicates that the public will not be engaged in decisions about projects and management actions, annual reports, five year updates, or potential modifications to the sustainable management criteria and monitoring network. The public must be engaged in in all decisions about GSA policies and activities, to ensure that impacts to all beneficial users are considered.

[113] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[114] Water Code § 10727.2.(c)
[115] Water Code § 10727.2(b)(1).
[116] Water Code § 10733(a); 23 CCR 355.4(b).
[117] Kern Groundwater Authority GSP, Appendix E, pg. I-6, dated January 2020.

The GSA does not include commitments to provide translated, accessible notice about agency meetings and decisions. The GSA does not commit to providing interpretation and translated materials at workshops and board meetings, or creating an Advisory Committee with representation from disadvantaged communities. The GSP also lacks a commitment to working with local community-based organizations to ensure effective outreach and engagement of disadvantaged communities.

The plan implementation section for this GSP is therefore inadequate. At a minimum, an adequate plan implementation section must include the following elements, which are not present here:

1. **Description of DAC engagement:** Ensure that the GSP describes how ongoing engagement will be conducted during GSP implementation, including but not limited to engagement regarding: decisions about projects, management actions, modifying sustainable management criteria, changes to monitoring networks, and conducting GSP updates.
2. **Notice:**[118] Ensure that the GSP states that ongoing engagement will include clear notices about GSA meetings and workshops that are posted in ways that all stakeholders were made aware of the meetings, and translated into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.[119]
3. **Translation of materials:**[120] Ensure that the GSP states that ongoing engagement will include translation of materials into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.
4. **Interpretation:**[121] Ensure that the GSP states that ongoing engagement will include. interpretation services provided at board meetings, committee meetings and workshops into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.
5. **Accessible workshops:** Ensure that the GSP states that ongoing engagement will include workshops held at accessible times and locations for disadvantaged community residents.
6. **DAC representation on advisory committee and board:** Ensure that the GSP states that ongoing engagement will include an advisory committee and a GSA Board containing representatives from DACs. The GSA must include representatives on the the GSA board, and should include representatives from DACs on all advisory committees such that their voices can be as strong as other beneficial user groups.

[118] Government Code § 54954(a).
[119] Government Code sec. 7296.2.
[120] Government Code sec. 7296.2.
[121] Government Code sec. 7296.2.

7. **Partnership with local community based organizations:** Ensure that the GSP states that ongoing engagement will include partnership between the GSA and community based organizations and nonprofits.
8. **Engagement on key decisions:** Ensure that the GSP states that ongoing engagement will include strategies to keep the public informed and engaged during and prior to critical decisions about the GSP, including but not limited to the five year GSP review, modification of sustainable management criteria, design and adoption of any projects and management actions, and development and adoption of the programs to assist with impaired wells.
9. **Engagement on financial issues:** Ensure that the GSP states that it will conduct meaningful outreach to DACs and incorporate feedback before approving operating budgets and enacting groundwater fees.

J. The GSP Does Not Comply With California Water Law.

a. The GSP Conflicts With Water Code § 106.3.

As noted above, California codified access to an adequate supply of safe and affordable drinking water as a human right in 2012. Water Code § 106.3(a) provides as follows:

> It is hereby declared to be the established policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes.

It is often incorrectly stated that this section is not binding. This is a misnomer for several reasons. First, § 106.3(b) expressly states in that "[a]ll relevant state agencies, including the department, the state board, and the State Department of Public Health, ***shall*** consider this state policy when revising, adopting, or establishing policies, regulations, and grant criteria when those policies, regulations, and criteria are pertinent to the uses of water described in this section." (emphasis added.) The use of the mandatory "shall" rather than a permissive "may" indicates that the requirement of subsection (b) to consider the Human Right to Water is a mandatory duty of DWR and the SWRCB.

Moreover, there is nothing in § 106.3 that indicates that either a GSA or a state agency may take an action that conflicts with the human right of all Californians to access safe and affordable drinking water. Rather, the section and its requirements are subject to only three narrow exceptions. First, subsection (c) states that "[t]his section does not expand any obligation of the state to provide water or to require the expenditure of additional resources to develop water infrastructure beyond the obligations that may exist pursuant to subdivision (b)." This exception

applies only to the "state," and does not apply to GSAs. Further, it speaks only to the obligation to provide water or to require development of water infrastructure, not to any obligation to manage groundwater resources in a way that protects existing access to drinking water.

Second, subsection (d) states that "[t]his section shall not apply to water supplies for new development." It is silent regarding water supplies for existing households.

Third, subsection (e) states that "[T]he implementation of this section shall not infringe on the rights or responsibilities of any public water system." As a GSA is not a public water system, this exception is not relevant here.

Given that none of the three exceptions contained in § 106.3 apply to the development and implementation of the GSP, it must be consistent with the Human Right to Water, and separately, DWR must consider the human right on review of GSP. Because the GSP conflicts with § 106.3 by interfering with access to safe and affordable drinking water, DWR cannot approve it.

b. The GSP Threatens to Infringe Upon Water Rights

In enacting SGMA, the legislature found and declared that "[f]ailure to manage groundwater to prevent long-term overdraft infringes on groundwater rights."[122] The text of SGMA further notes that "[n]othing in this part, or in any groundwater management plan adopted pursuant to this part, determines or alters surface water rights or groundwater rights under common law or any provision of law that determines or grants surface water rights."[123] As discussed in detail above, the GSP allows continued overdraft above the safe yield of the basin, such that drinking water wells (especially domestic wells) will continue to go dry, infringing upon the rights of overlying users of groundwater. DWR cannot approve the GSP until it is revised to protect the rights of residents of disadvantaged communities and/or low-income households who hold overlying rights.[124]

c. The GSP Conflicts with the Reasonable And Beneficial Use Doctrine

The "reasonable and beneficial use" doctrine is codified in the California Constitution. It requires that "the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the

[122] AB 1739 (2014).
[123] Water Code § 10720.5(b).
[124] *See also* Water Code § 10723.2 [The groundwater sustainability agency shall consider the interests of all beneficial uses and users of groundwater… [including] Domestic well owners."].

reasonable and beneficial use thereof in the interest of the people and for the public welfare."[125] The doctrine applies to all water users, regardless of basis of water right, and all water rights and methods of diversion.[126] A determination of reasonableness of a use "cannot be resolved in vacuo isolated from statewide considerations of transcendent importance."[127]

DWR and the Water Board must ensure that GSP's water allocations are consistent with the reasonable and beneficial use doctrine.[128] In doing so, DWR and the Board must follow the Legislature's directive to prioritize domestic use of water resources over irrigated agriculture[129] and ensure that SGMA implementation furthers the human right to safe and affordable drinking water[130] — both statewide considerations of transcendent importance. In other words, a GSP that allows use of water for irrigation at the expense of use of water for domestic purposes is not consistent with the reasonable and beneficial use doctrine.

The reasonable and beneficial use doctrine applies here given the negative impacts of the GSP on groundwater supply and quality, which are likely to unreasonably interfere with the use of groundwater for drinking water and other domestic uses. As the GSP authorizes waste and unreasonable use, and indeed does not even analyze the reasonable and beneficial use doctrine at all, it conflicts with the reasonable and beneficial use doctrine and the California Constitution. As a result, DWR cannot approve the GSP as presently drafted.

d. The GSP Conflicts with the Public Trust Doctrine

The public trust doctrine applies to the waters of the State, and establishes that "the state, as trustee, has a duty to preserve this trust property from harmful diversions by water rights holders" and that thus "no one has a vested right to use water in a manner harmful to the state's waters."[131]

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[125] Cal Const, Art. X § 2; see also Water Code § 100; United States v. State Water Resources Control Bd. (1986) 182 Cal.App.3d 82, 105 ["…superimposed on those basic principles defining water rights is the overriding constitutional limitation that the water be used as reasonably required for the beneficial use to be served."].

[126] Peabody v. Vallejo (1935) 2 Cal.2d 351, 367, 372; Light v. State Water Resources Control Board, (2014) 226 Cal. App. 4th 1463, 1479.

[127] Joslin v. Marin Municipal Water Dist. (1967) 67 Cal.2d 132, 140.

[128] Water Code § 275 ["The department and board shall take all appropriate proceedings or actions before executive, legislative, or judicial agencies to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water in this state"]; *Light*, 226 Cal.App.4th at 1482-83 [same].

[129] Water Code § 106 ["It is hereby declared to be the established policy of this State that the use of water for domestic purposes is the highest use of water and that the next highest use is for irrigation"]; *United States v. State Water Resources Control Board* (1986) 182 Cal.App.3d 82, 103 .

[130] Water Code § 106.3.

[131] *United States v. State Water Resources Control Bd.* (1986) 182 Cal.App.3d 82, 106; *see also Nat'l Audubon Soc'y v. Superior Court* (1983) 33 Cal.3d 419, 426 ["before state courts and agencies approve water diversions they should consider the effect of such diversions upon interests protected by the public trust, and attempt, so far as feasible, to avoid or minimize any harm to those interests."].

The public trust doctrine has recently been applied to groundwater where there is a hydrological connection between the groundwater and a navigable surface water body.[132] In *Environmental Law Foundation v. State Water Resources Control Board* ("*ELF*"), the court held that the public trust doctrine applies to "the extraction of groundwater that adversely impacts a navigable waterway" and that the government has an affirmative duty to take the public trust into account in the planning and allocation of water resources.[133] Under *ELF*, the Public Trust doctrine imposes an affirmative and independent obligation to consider the public trust that applies to DWR's decisions regarding submitted GSPs, imposing a legal duty on DWR to not only consider the potential adverse impacts of groundwater extractions on navigable waterways but also "to protect public trust uses whenever feasible."[134] The court also specifically held that SGMA does not supplant the requirements of the common law public trust doctrine.[135]

Notably, the public trust doctrine applies to both currently navigable surface water bodies and surface water bodies that were historically navigable at the time of statehood.[136]

In contrast to these requirements, the GSP does not consider impacts on public trust resources, or attempt to avoid insofar as feasible harm to the public's interest in those resources. DWR cannot approve the GSP without evaluating impacts to public trust resources and protecting public trust uses whenever feasible. Specifically, DWR must (1) identify any public trust resources within the basin; (2) identify any public trust uses within the basin; (3) identify and analyzing potential adverse impacts of groundwater extractions on public trust resources and uses; and (4) determine the feasibility of protecting public trust uses and protect such uses whenever feasible.

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DWR cannot approve the GSP because it fails to protect beneficial users and access to drinking water. We welcome the opportunity to further discuss our concerns with the Department of Water Resources and the State Water Resources Control Board. Furthermore, we urge DWR to review this and all other GSPs according to the Human Right to Water Scorecard, as we have done in this letter.[137] We hope to successfully work with the GSA, communities, DWR and the SWRCB to ensure that groundwater management is equitable and sufficiently protective of vital drinking water resources. Going forward, we ask DWR to ensure that the GSP adhere to the

[132] *Environmental Law Foundation v. State Water Resources Control Bd.* (2018) 26 Cal.App.5th 844, 844.
[133] *Id.* at 856-62.
[134] Id. at 865.
[135] *Id.* at 862-870.
[136] *See San Francisco Baykeeper, Inc. v. State Lands Com.* (2015) 242 Cal.App.4th 202, 232 citing *Western Oil & Gas Asso. v. State Lands Com.* (1980) 105 Cal.App.3d 554, 562 ["When California became a state in 1850 it succeeded to sovereign ownership of various tidelands and submerged lands under the terms of common law trust doctrine… ."]; PPL Montana, LLC v. Montana (2012) 565 U.S. 576, 592 ["For state title under the equal-footing doctrine, navigability is determined at the time of statehood...and based on the 'natural and ordinary condition' of the water."] [internal citation omitted].
[137] Attached as Exhibit B.

standards in the Human Right to Water Scorecard, and that these standards are followed during GSP implementation.

Sincerely,

Jasmene del Aguila and Amanda Monaco

Leadership Counsel for Justice and Accountability

EXHIBIT A

Attached:

Appendix A: Human Right to Water Letter and Scorecard...p. X-Y

Appendix B: Framework and Guidance for Developing a Drinking Water Well Impact Mitigation Program ..... p. Y-Z

Appendix A: Human Right to Water Letter and Scorecard

California Natural Resources Agency
Wade Crowfoot, Secretary

Department of Water Resources
Karla Nemeth, Director
Taryn Ravizzini, Deputy Director of Statewide Groundwater Management
Craig Altare, Supervising Engineering Geologist
Steven Springhorn, Senior Engineering Geologist
Keith Wallace, Project Manager

California Environmental Protection Agency
Kristin Peer, Deputy Secretary and Special Counsel for Water Policy

State Water Resources Control Board
E. Joaquin Esquivel, SWRCB Board Chair
Dorene D'Adamo, SWRCB Board Member
Tam M. Dudoc, SWRCB Board Member
Sean Maguire, SWRCB Board Member
Laurel Firestone, SWRCB Board Member
Eileen Sobeck, Executive Director
Natalie Stork, Chief of Groundwater Management Program

Andrew Altevogt, Program Coordinator of Safe and Affordable Drinking Water

February 10th, 2020

Re: Reviewing Groundwater Sustainability Plans In Accordance With State Agency Obligations to Consider the Human Right to Drinking Water

Our collective organizations write to express our concern regarding implementation thus far of the Sustainable Groundwater Management Act (SGMA), specifically with respect to its treatment of (or lack of consideration for) safe drinking water in many of the most vulnerable California communities -- and to urge the Department and Board to review Groundwater Sustainability Plans in accordance with state agency obligations to consider California's Human Right to Water law.

We have engaged in the SGMA implementation processes throughout the state because many of the communities with whom we work are dependent on groundwater for their drinking water supplies, and have already experienced groundwater quality and supply issues. We have participated in meetings, commented on dozens of groundwater plans, and supported engagement of residents from several communities in the development of Groundwater Sustainability Plans (GSPs). But despite our engagement and the engagement of disadvantaged community residents, most GSPs do not adequately address threats to drinking water quality or reliability for disadvantaged communities.

Historically, many of the communities most impacted by depleted and tainted groundwater sources have been excluded from the decision-making tables that determined where water would flow and what infrastructure would be laid. But California took historic steps forward with the recognition of the Human Right to Water as a state-wide goal in 2012 and with the passage of SGMA in 2014 which included requirements for a transparent and inclusive process and consideration of vulnerable communities. Specifically, decision-making processes related to groundwater management must include disadvantaged communities, and groundwater management plans must respond to the unique vulnerabilities of disadvantaged communities,[1] consider their drinking water needs,[2] and avoid causing disproportionately negative impacts on low income communities of color.[3]

Unfortunately, many of the draft GSPs released to date pose a significant threat to safe drinking water access in low-income communities. Few account for drinking water impacts on local communities dependent on groundwater— the vast majority of small communities in the San Joaquin Valley. When

[1] Water Code § 10723.2
[2] Water Code § 106.3
[3] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].

implemented, these GSPs have the potential to threaten severe and irreparable harm to drinking water supplies and the communities dependent on those supplies. As such, many of the recently approved draft GSPs undermine Governor Newsom's vision of a California where everyone has safe drinking water and run counter to California's Human Right to Drinking Water (AB 685).

With these grave concerns in mind, we urge the state to abide by the mandate the Human Right to Water demands.

The Human Right to Drinking Water in GSP Evaluation and Approval

The human right to safe and affordable water for drinking and sanitation was codified by AB 685 in 2012, which modified Water Code section 106.3 to include: "it is...the established policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes."[4] The law obligates "all relevant state agencies" to "consider this state policy when revising, adopting, or establishing policies, regulations, and grant criteria...pertinent to" drinking water purposes.[5] The law specifically names the Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB).

The Human Right to Water has catalyzed and facilitated several new state initiatives. The State Water Resources Control Board has created a Human Right to Water Portal on its website which shows drinking water quality in all public water systems in the state and passed a resolution aligning State Board priorities and values with the Human Right to Water. The human right to water has also been used as underpinning for two successful legislative campaigns: AB 401 (2015) and the Safe and Affordable Drinking Water Fund, or SB 200 (2019). The former mandated a state-wide study of the best mechanism for delivering affordable drinking water in all publicly regulated water systems; the latter created a state-wide fund for installing, operating and maintaining drinking water infrastructure for disadvantaged communities and schools suffering from water quality and water supply issues. Governor Newsom played a strong role in the passage of the Safe and Affordable Drinking Water Fund as part of his personal commitment to securing safe water for all Californians.

These initiatives represent clear steps forward towards achieving safe and affordable drinking water for all Californians, but the state remains far from achieving the law's goal of guaranteeing "safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes" to "every human being" in the state of California.[6] In the San Joaquin Valley alone, tens of thousands of vulnerable families, including those with whom we work, suffer from contaminated drinking water, unaffordable drinking water costs, and the impacts of inadequate water supply such as dry wells and water pressure problems. As many as 350,000 people lack access to potable water in the San Joaquin Valley alone, and Hispanic communities are disproportionately impacted: while Hispanics make up just under half, or 49 percent, of the total population of the San Joaquin Valley, they represent more than two-thirds of residents in these unincorporated communities and 57 percent of all residents served by out-of-compliance water systems.[7] This number does not account for those unincorporated communities

[4] Water Code sec. 106.3(a)
[5] Water Code sec. 106.3(b)
[6] Water Code sec. 106.3(a)
[7] The Struggle for Water Justice in California's San Joaquin Valley: A Focus on Disadvantaged Unincorporated Communities, London & Fencl et al., University of California Davis, February 2018.

on private domestic wells, many of which also have contaminated water which goes unmonitored and unregulated.

Groundwater management practices have historically aggravated drinking water issues in the San Joaquin Valley by allowing agribusiness and other actors to pump unrestricted amounts of groundwater, leaving local communities with dry wells, and unreliable drinking water supplies. Moreover, there has been limited regulation on agricultural impacts to groundwater quality, leading to contamination of drinking water for communities in the San Joaquin Valley. Low-income families living in disadvantaged communities do not have the financial means to replace or deepen wells, install costly treatment mechanisms, or transition to alternative water supplies such as surface water.

SGMA created both an unprecedented and quite possibly a last opportunity to avoid further encroachment on the basic human right to water, yet our review of GSPs in the San Joaquín, Salinas and Coachella Valleys indicates that GSAs have not leveraged this opportunity. Rather, the GSPs we have reviewed rarely account for impacts on local communities dependent on groundwater, and prioritize the continued economic viability of agriculture at the expense of drinking water for low income communities. For example, some Central Valley GSPs have established minimum thresholds—or failure points—that, if reached, would allow up to 85% of domestic wells to go fully or partially dry within the GSP area. Overall, a technical review that the Community Water Center and Self-Help Enterprises commissioned of drinking water impacts of 13 GSPs in the San Joaquin Valley shows more than 8,000 wells will be dewatered in the area covered by the GSPs. Draft GSPs allow continued groundwater quality degradation in excess of water quality objectives, violating the Porter-Cologne Water Quality Control Act (Water Code sec. 13000 et seq.), the antidegradation policy, and the non-point-source policy. Even worse, some GSPs ignore water quality impacts entirely.

DWR and the SWRCB are now tasked with evaluating and deciding whether to approve GSPs. The agencies must determine whether to approve policies in these documents that set out the level to which GSAs will allow groundwater levels to decline, the extent to which GSAs will protect local drinking water users from contamination resulting from groundwater management activities, and which projects and management actions the GSA will implement to impact local groundwater resources. All of these decisions have vast drinking water implications for communities within each GSP area. As such, evaluation and approval of GSPs falls squarely within the category of "revising, adopting, or establishing policies, regulations, and grant criteria...pertinent to" drinking water purposes.[8] DWR and the State Water Resources Control Board must therefore "consider this state policy"[9] "that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes"[10] in their review of each GSP. In order to comply with this obligation, the Department and Board must ensure that GSPs do not cause or allow further drinking water crises.

Implementing the Human Right to Drinking Water in GSP Evaluation and Approval

We have compiled and attached a "Human Right to Drinking Water GSP Scorecard" which identifies the elements that must exist in GSPs in order for GSPs to adequately protect the Human Right to Drinking Water. We urge the Department of Water Resources and the State Water Resources Control Board to integrate this analysis into their review of GSPs, and to require that each GSP contain these elements

[8] Water Code § 106.3(b)
[9] Water Code § 106.3(b)
[10] Water Code § 106.3(a)

before it grants approval of the GSP. This scorecard could also be adapted to create a general evaluation rubric that is used by the two agencies as part of a drinking water review protocol for all drinking water-related activities. Additionally, we encourage DWR to use this letter and scorecard to develop a "Human Right to Water"/"Protecting Drinking Water" Best Management Practices guidance document for GSAs to consider when developing, updating and implementing GSPs. Additionally, the Scorecard references a framework that we have developed to show what an effective drinking water protection program would look like, which we have also attached.

We look forward to discussing this Human Right to Water Scorecard with you, and supporting implementation of such a scoring methodology in GSP evaluation and approval. Please do not hesitate to contact Amanda Monaco (amonaco@leadershipcounsel.org), Deborah Ores (deborah.ores@communitywatercenter.org), or Liesbet Olaerts (olaerts@selfhelpenterprises.org) with any follow-up questions or for more information.

Sincerely,

Amanda Monaco
Leadership Counsel for Justice and Accountability

Aysha Massell
Director, California Integrated Water Systems
American Rivers

Tom Collishaw
CEO
Self-Help Enterprises

Coreen Weintraub
Sr. Outreach and Campaign Coordinator
Union of Concerned Scientists

Debi Ores
Senior Attorney
Community Water Center

Jennifer Clary
Water Program Manager
Clean Water Action

Attachments:

Human Right To Water Scorecard for the Review of Groundwater Sustainability Plans……..p. 6-14

Framework and Guidance for Developing a Drinking Water Well Impact Mitigation Program (Working Draft)..……..…..p. 15-24

Human Right To Water Scorecard for the Review of Groundwater Sustainability Plans

Review Criteria *(All Indicators Must be Present in Order to Protect the Human Right to Water)*		Yes/No
A	**Plan Area**	
1	**Does the GSP identify, describe, and provide maps of all of the following beneficial users in the GSA area?**[11] a. Disadvantaged Communities (DACs). b. Tribes. c. Community water systems d. Private well communities.	
2	**Land use policies and practices:**[12] Does the GSP review all relevant policies and practices of land use agencies which could impact groundwater resources? These include but are not limited to the following: a. Water use policies General Plans and local land use and water planning documents b. Plans for development and rezoning c. Processes for permitting activities which will increase water consumption	
B	**Basin Setting (Groundwater Conditions and Water Budget)**	
1	Does the **groundwater level conditions** section include past and current drinking water supply issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities?	

[11] 23 CCR § 354.8(a) and (b)
[12] 23 CCR § 354.8(f)

2	Does the **groundwater quality conditions** section include past and current drinking water quality issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities, including public water wells that had or have MCLs exceedances?[13]	
3	Does the **groundwater quality conditions** section include a review of all contaminants with primary drinking water standards known to exist in the GSP area, as well as hexavalent chromium, and PFOs/PFOAs?[14]	
4	**Incorporating drinking water needs into the water budget:**[15] Does the Future/Projected Water Budget section explicitly include both the current and projected future drinking water needs of communities on domestic wells and community water systems (including but not limited to infill development and communities' plans for infill development, installation of additional services, and housing growth in disadvantaged communities), taking into account increased climate variability due to climate change ?	
C	**Sustainability Goal**	
1	Does the **sustainability goal** explicitly include considerations about the needs of drinking water users?[16]	
D	**Sustainable Management Criteria (SMC) for Groundwater Levels**	
1	**Evaluation of drinking water impact:** Does the GSP include an analysis of how many drinking water wells (municipal wells, community water system wells, and domestic wells) might go fully or partially dry if groundwater levels reach the Undesirable Results (URs),[17] Measurable Objectives (MOs) and Measurable Objectives (MTs),[18] including a map of wells that will go fully and partially dry at the MOs and MTs? Does this include Does the GSP include estimates of the increased pumping costs from additional lift needed to pump water from lower elevations if the URs,[19] MOs and MTs[20] were to be reached?	
2	**Considering drinking water impacts in creating SMC:**[21] Does the GSP explicitly state how it considered drinking water impacts in shaping URs, MOs, and MTs for groundwater levels? For example, the GSP could state how its well impact analysis supported on setting stricter MTs and MOs near at risk communities.	

[13] 23 CCR § 354.16(d)
[14] 23 CCR § 354.16(d)
[15] 23 CCR § 354.18(c)(2)(b)
[16] 23 CCR § 354.24: Sustainability goal must "culminate in the absence of undesirable results within 20 years."
[17] 23 CCR § 354.26(c)
[18] 23 CCR § 354.28(b)(4)
[19] 23 CCR § 354.26(c)
[20] 23 CCR § 354.28(b)(4)
[21] Water Code § 10723.2

3	**Incorporating new drinking water data into SMC:**[22] Does the GSP include a description of how data gaps and uncertainties of its drinking water well impact assessment will be addressed and serve to reassess the sustainable management criteria, projects and management actions in accordance with new data?	
4	**Implementing DAC and drinking water user input into SMC:**[23] Does the GSP discuss how stakeholder input from DAC community members was considered in the development of URs, MOs, and MTs? For example, the GSP could state how they took the results of the well impact assessment to the public through meetings, workshops, or Advisory Committees, and together with stakeholders decided how to change SMC to protect drinking water, or other programs to implement to mitigate these impacts.	
5	**Avoiding a disparate impact:**[24] Are the MOs and MTs for groundwater levels established in such a way that prevents a disproportionately negative ("disparate") impact from occurring on communities of color in the GSP area? For example, the GSP should ensure that the same MT methodology across the GSP area will not lead to disproportionately more wells going dry for residents of color than for white residents.	
E	**Sustainable Management Criteria for Groundwater Quality**	
1	**Evaluation of drinking water impact:** Does the GSP include an analysis of how drinking water wells (municipal wells, community water system wells, and domestic wells) might be affected by the Undesirable Results (URs),[25] Measurable Objectives (MOs) and Measurable Objectives (MTs)?[26]	
2	**Does the GSP set MOs and MTs at all representative monitoring wells for the following contaminants?**[27] a. Contaminants with primary drinking water standards, b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health, AND c. Contaminants like Uranium which are known to increase due to groundwater management practices.	

[22] 23 CCR § 354.38(e)(3)

[23] 23 CCR § 354.10(d); DWR Guidance Document for Groundwater Sustainability Plans: Stakeholder Communication and Engagement, p.1.

[24] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].

[25] 23 CCR § 354.26(c)

[26] 23 CCR § 354.28(b)(4)

[27] 23 CCR § 354.34(b)(2) and (f)(3)

3	**Strive to remediate:** Does the GSP state that the GSA will strive to remediate groundwater quality wherever feasible, through projects, management actions and policies?	
4	**Description of when minimum threshold is triggered:** Does the GSP trigger a violation of a minimum threshold after *one* test shows that there has been an increase in contamination since January 1st, 2015?	
5	**Implementing DAC and drinking water user input into SMC:**[28] Does the GSP discuss how stakeholder input from DAC community members was considered in the development of URs, MOs, and MTs?	
6	**Incorporating new drinking water data into SMC:**[29] Does the GSP include a description of how data gaps and uncertainties of its drinking water well impact assessment will be addressed and serve to reassess the sustainable management criteria, projects and management actions in accordance with new data?	
7	**Avoiding a disparate impact:**[30] Are the minimum thresholds for groundwater quality established in such a way that prevents a disproportionately negative ("disparate") impact from occurring on communities of color in the GSP area? For example, the GSP should ensure that the same MT methodology across the GSP area will lead to disproportionately more wells go dry for residents of color than for white residents.	
F	**Monitoring Network for Groundwater Levels**	
1	**Accurately detecting impacts on drinking water users and DACs:**[31] Does the groundwater level monitoring network include *representative* monitoring wells *in or near DACs*, and placed in a way that detects impacts to the *vast majority* of drinking water users in the GSP area? If not, does the GSP contain a concrete plan to fund and implement new representative monitoring wells to ensure that vulnerable communities' drinking water resources are monitored? Such a plan could include testing of domestic wells in the interim.	
2	**Clearly showing representative monitoring well locations in relation to DACs:**[32] Are the representative monitoring wells (RMWs) for groundwater levels presented on maps and in tables that identify which set of MTs/MOs will be applied to which RMWs? Do these maps clearly identify the locations of DACs, small water systems and other sensitive users?	

[28] 23 CCR § 354.10(d); DWR Guidance Document for Groundwater Sustainability Plans: Stakeholder Communication and Engagement, p.1.
[29] 23 CCR § 354.38(e)(3)
[30] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[31] 23 CCR § 354.34(b)(2) and (f)(3)
[32] 23 CCR § 354.34(b)(2) and (f)(3)

3	**Identifying and addressing other drinking water data gaps:**[33] Does the GSP clearly identify any other gaps in data regarding impacts to drinking water users? Does the GSP contain a clear plan to fill data gaps regarding impacts to drinking water users?	
G	**Monitoring Network for Groundwater Quality**	
1	**Does the GSP plan to measure the following contaminants at all representative monitoring wells?**[34] a. Contaminants of concern with primary drinking water standards b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health c. Contaminants like Uranium which are known to increase due to groundwater management practices	
2	**Clear description of effective monitoring for drinking water impacts:** Does the GSP include a description of how the GSA(s) will monitor groundwater contamination that could affect drinking water in the GSA area? Are the representative monitoring wells (RMWs) for groundwater quality presented on maps and in tables, and do the maps of RMWs clearly identify the locations of DACs, small water systems and other sensitive users?	
3	**Accurately detecting impacts on drinking water users and DACs:**[35] Does the groundwater quality monitoring network include *representative* monitoring wells (RMWs) *in or near all DACs* AND placed in a way that detects impacts to the *vast majority* of drinking water users in the GSP area, including domestic well users? If not, does the GSP contain a concrete plan to fund and implement new representative monitoring wells to ensure that vulnerable communities' drinking water resources are monitored? This plan could include testing of domestic wells in the interim.	
4	**Baseline contaminant levels:** Does the GSP identify the current contaminant levels, MTs and MOs at each RMW, so that it is clear to the public how the contamination will change at each RMW site?	
5	**Frequent monitoring:** Does the groundwater quality monitoring network test for contaminants of concern frequently, in a way that avoids persistent drinking water contamination?	
6	**Collaboration with other agencies:**[36] Does the GSP explain how the GSA(s) will share data with and collaborate with other groundwater quality regulatory programs, such as ILRP, IRWM, and CV SALTS, in order to build better regional understanding of groundwater quality issues and better respond to groundwater quality impacts caused by groundwater management?	
H	**Projects and Management Actions**	

[33] 23 CCR § 354.38(e)(3)
[34] 23 CCR § 354.34(b)(2) and (f)(3)
[35] 23 CCR § 354.34(b)(2) and (f)(3)
[36] 23 CCR § 354.34(e)

1	**Does the GSP describe the potential drinking water impacts of each project or management action?** Example of impacts are provided below: a. **Recharge and on-farm recharge projects:** Carefully designed and implemented recharge projects can simultaneously increase groundwater storage and levels, as well as dilute contaminant plumes and improve groundwater quality. However, if not properly designed, recharge projects, in particular on-farm recharge, may mobilize nitrates, pesticides, fertilizers, and naturally occurring contaminants, which can lead to the further degradation of groundwater quality, negatively impacting drinking water wells. Even relatively unpolluted water used for recharge, such as most purchased water or streamflow, may contain constituents of concern and/-or mobilize contaminants. Therefore GSAs must consider potential impacts to water quality when planning groundwater recharge projects.[37] b. **Groundwater market management action:** Groundwater markets are very likely to put drinking water resources at risk for communities and residents who do not have the financial, political and technical power to participate equally in a market. Groundwater markets have the potential to seriously aggravate existing lack of equity in access to critical groundwater resources. We therefore recommend that GSAs do not include groundwater markets as a potential management action. In particular, local groundwater markets are not a viable option where the potential impacts of trading are not well understood, where trading rules cannot sufficiently address negative externalities, or where the expected benefits of a market do not outweigh the burdens and uncertainties associated with designing and implementing it. If GSAs wish to consider groundwater markets, a well-designed trading program requires a fair and adequate allocation of groundwater for drinking water uses, an additional margin for future growth prior to allocating water for trading purposes, and trading rules that avoid undesirable results as well as avoid or mitigate potential impacts to communities and ecosystems dependent on groundwater. If these components are missing, the market can have significant negative impacts upon a community's drinking water supply and the environment. Some impacts include, but are not limited to: localized drying of community and domestic wells, increased contamination levels, or unaffordable water rates.[38] c. **Funding mechanisms/Delinquent fees management action:** Any fee and/or extraction penalties structure should take into consideration that small communities have fewer economic opportunities, have a small role in overall groundwater pumping percentage, and are burdened with lower technical, managerial, and financial capacity for operations and maintenance. Overall, small drinking water systems should be exempted from GSA's fees or financial penalties for over-use to support their efforts on providing affordable safe water according to AB 685. If exemption is not viable, the GSA should create special considerations such as discounts, reduced costs, rebates, or other to ensure	

[37] State Water Boards, Water Quality Frequently Asked Questions document: https://www.waterboards.ca.gov/water_issues/programs/gmp/docs/sgma/sgma_water_quality_faq.pdf

[38] Community Water Center et al., *Groundwater Markets: Recommendations to Ensure Drinking Water Protection for Communities* (guidance document to be published soon)

	drinking water affordability. Alternatively, small drinking water systems should receive warnings prior to financial penalties tied to an appeal process. Doing so may allow these communities to explain why the overuse occurred, providing mechanisms for transparency and support on addressing the problems. d. **Groundwater allocation management action:** Any groundwater allocation scheme must protect all current and future drinking water needs for disadvantaged communities.	
2	**Drinking water protection and mitigation program:** Does the GSP contain a drinking water protection program to prevent impacts to drinking water users and mitigate the drinking water impacts that occur? Such a program should also identify the following: a. How it will be funded. b. An estimate of how much it will cost. c. How program beneficiaries will be eligible to participate. d. How it will be designed in collaboration with impacted stakeholders. e. What type of mitigation measurements it will provide. f. Timeline for program implementation. **Please refer to the attached **Framework and Guidance for Developing a Drinking Water Well Impact Mitigation Program** for a more in-depth description of what an effective drinking water mitigation program should look like.*	
3	**Demand reduction:** Does the GSP contain robust demand reduction management actions? Plans that depend mainly on imported surface water (supply augmentation through recharge projects) do not clearly demonstrate a path towards sustainability, since climate variability puts these resources at risk.	
4	**Accurate measurement of groundwater extraction:** Does the GSP include management actions to measure groundwater extraction using the most scientifically accurate method?	
5	**Avoiding a disparate impact:**[39] Do the GSP's projects and management actions, taken as a whole, prevent a disproportionately negative ("disparate") impact from occurring on communities of color in the GSP area? Projects and management actions may not cause disproportionately more dry wells and contaminated water for residents of color than for white residents in the GSA area.	
I	**Public Participation and Transparency**	
1	Is a **Stakeholder Communication and Engagement Plan** included in the GSP?	
DAC and drinking water user engagement during GSP development[40]		

[39] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).

[40] Water Code § 10723.2; Water Code § 10727.8(a) The groundwater sustainability agency shall encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin prior to and during the development and implementation of the groundwater sustainability plan.

2	**Description of DAC engagement:** Does the GSP specifically identify how DAC beneficial users were engaged in the planning process?	
3	**Notice:**[41] Did the GSA provide clear notice to the public about GSA meetings to develop the GSP, posted in ways that all stakeholders were made aware of the meetings, and translated into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English? [42]	
4	**Translation of materials:**[43] Did the GSA translate materials into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?	
5	**Interpretation:**[44] Did the GSA(s) provide interpretation services at board meetings, committee meetings and workshops into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?	
6	**Accessible workshops:** Did the GSA(s) host workshops held at accessible times and locations for disadvantaged community residents?	
7	**DAC representation on advisory committee:** Did the GSA(s) develop the GSP with an advisory committee that contained representatives from DACs?	
8	**DAC representation on GSA board:** Did the GSA(s) develop the GSP with a Board that contained representatives from DACs?	
9	**Partnership with local community based organizations:** Did the GSA partner with community based organizations and nonprofits on outreach and engagement?	
10	**Public Comment Period:** Did the GSA provide a robust public comment period of at least 60 days, with opportunity for the public to discuss comments and proposed agency responses with staff and the GSA before GSP approval?	
11	**Incorporation of stakeholder input:** Does the GSP explicitly describe how stakeholder input was incorporated into the GSP process and decisions?	
DAC and drinking water user engagement during GSP implementation		

[41] Government Code § 54954(a).

[42] Government Code sec. 7296.2: Dymally-Alatorre Bilingual Services Act, stating that local agencies providing services to the public must provide translated materials and interpretation when it serves a substantial number of non-English-speaking people. The law defines a "substantial number of non-English-speaking people" as "members of a group who either do not speak English, or who are unable to effectively communicate in English because it is not their native language, and who comprise 5 percent or more of the people served by the statewide or any local office or facility of a state agency." This is because "effective maintenance and development of a free and democratic society depends on the right and ability of its citizens and residents to communicate with their government and the right and ability of the government to communicate with them."

[43] Government Code sec. 7296.2.

[44] Government Code sec. 7296.2.

12	**Description of DAC engagement:** Does the GSP describe how ongoing engagement will be conducted during GSP implementation, including but not limited to engagement regarding: decisions about projects, management actions, modifying sustainable management criteria, changes to monitoring networks, and conducting GSP updates?	
13	**Notice:**[45] Does the GSP state that ongoing engagement will include clear notices about GSA meetings and workshops that are posted in ways that all stakeholders were made aware of the meetings, and translated into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?[46]	
14	**Translation of materials:**[47] Does the GSP state that ongoing engagement will include translation of materials into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?	
15	**Interpretation:**[48] Does the GSP state that ongoing engagement will include interpretation services provided at board meetings, committee meetings and workshops into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?	
16	**Accessible workshops:** Does the GSP state that ongoing engagement will include workshops held at accessible times and locations for disadvantaged community residents?	
17	**DAC representation on advisory committee and board:** Does the GSP state that ongoing engagement will include advisory committees and Boards containing representatives from DACs?	
18	**Partnership with local community based organizations:** Does the GSP state that ongoing engagement will include partnership between GSA and community based organizations and nonprofits?	
19	**Engagement on key decisions:** Does the GSP state that ongoing engagement will include strategies to keep the public informed and engaged during and prior to critical decisions about the GSP, including but not limited to the five year GSP review, modification of sustainable management criteria, design and adoption of any projects and management actions, and development and adoption of the programs to assist with impaired wells?	
20	**Engagement on financial issues:** Does the GSP state that it will conduct outreach to DACs before approving operating budgets and enacting groundwater fees?	

[45] Government Code § 54954(a).
[46] Government Code sec. 7296.2.
[47] Government Code sec. 7296.2.
[48] Government Code sec. 7296.2.

Appendix B: Framework and Guidance for Developing a Drinking Water Well Impact Mitigation Program [Working Draft]

Management Action Name:
Drinking Water Well Impact Mitigation Program

Potential Implementing Organization(s):
Groundwater Sustainability Agencies (GSAs) in partnership with project participants.

Purpose Statement:
The purpose of this document is to be utilized by GSAs to mitigate, prevent, and address any adverse effects on drinking water wells caused by pumping volume or location, conjunctive management, or any other forms of active management as part of Groundwater Sustainability Plan (GSP) implementation. By doing so, GSAs can better achieve the goals of the Sustainable Groundwater Management Act (SGMA), avoid jeopardizing access to safe water in vulnerable communities, and also avoid violating California laws that establish a state-wide Human Right to Water and that protect access to safe water. Adverse effects can include both issues with access to safe drinking water due to increased contamination, as well as issues with sustained access to water due to changes in groundwater levels.

This document provides a framework of elements to consider when GSAs are developing a drinking water well impact mitigation plan. Every community and every GSA will have to evaluate their own needs and particular considerations in order to develop a mitigation program that works best for all users. This document is broken down into the following sections:

1) Importance of drinking water well mitigation programs;
2) Framework for developing program / key elements to consider;
3) Cost considerations for short term and long term solutions and potential funding sources; and
4) Four local case studies of existing drinking water well mitigation programs.

Section 1. Importance of a Drinking Water Well Impact Mitigation Program:

How can GSP implementation impact domestic wells and small community wells?

Across the state, critically overdrafted basins have developed Groundwater Sustainability Plans (GSPs) to manage groundwater resources sustainably under the Sustainable Groundwater Management Act

(SGMA). Many GSPs have developed sustainable management criteria, including minimum thresholds (MTs) and measurable objectives (MOs), that if reached, would cause significant impacts to access to safe and affordable drinking water for vulnerable communities. GSP implementation, including management actions and projects, can cause changes in groundwater levels and groundwater quality that could lead to:

- Completely dewatered wells;
- Partially dewatered wells:
    - needing to lower the well pump,
    - needing to clean the well screen,
    - needing to drill deeper;
- An increased movement of contaminant plumes;
- An increase in the concentration or release of contaminants;
- An increase in salinity due to sea water intrusion in coastal wells;
- Higher energy costs from having to drill or pump from a deeper depth; and
- Emotional, psychological, and health impacts related to not having access to safe water.

If GSP sustainable management criteria are developed in a way that could potentially cause significant impact on drinking water users, the GSP must also include a robust drinking water well impact program to prevent and mitigate the drinking water impacts that occur. In some GSAs, up to 85% of domestic wells are at risk of being dewatered or partially dewatered. In these same GSAs, rural domestic and small water system demand does not contribute substantially to the overdraft conditions, yet the risks imposed on these drinking water users are overlooked and neglected, creating a disproportionate impact on already vulnerable communities.

What are the drinking water challenges of disadvantaged communities?

Without an adequate groundwater sustainability plan that is protective of groundwater sources near or within communities, more drinking water wells will run dry or be unable to provide safe, potable water to residents. This will further jeopardize the livelihood of California's most vulnerable communities. Vulnerable communities, including severely disadvantaged communities (SDACs), disadvantaged communities (DACs), small water systems, and domestic well owners, have limited technical, managerial, and financial capacity to respond to drinking water challenges.

Climate change further exacerbates drinking water challenges with more frequent, longer and more severe droughts and flood periods expected. Small water systems and rural communities reliant on domestic wells are, and will continue to be, the most adversely impacted and most at risk of experiencing water shortages and/ or having to rely on contaminated drinking water supplies. In order to increase water system resiliency, the golden rule is to protect current water sources— especially if the quality of the water is meeting safe drinking water standards. Other ways to increase resiliency are to secure more than one water source, assist communities with maintenance and operation costs, and ensure water affordability. A drinking water well mitigation program is key to increasing water resilience through minimizing risks of both short-term and long-term impacts. Having adequate plans and policies to support drinking water resilience in the face of climate change is essential to reducing the amount of emergency funding needed to respond to a water shortage emergency and to prevent human health crises. A carefully designed and implemented well impact mitigation program can support efforts to ensure all communities have long-term and sustainable access to clean, safe, and affordable drinking water.

How does California law prioritize drinking water?

A GSP which lacks a mitigation program to curtail the effects of projects and management actions on the safety, quality, affordability, or availability of domestic water, violates both SGMA itself and the Human

Right to Water law. The Human Right to Water (AB 685) (HR2W) was signed in 2012 and added § 106.3 to the California Water Code, declaring, "the established policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes."[49] The HR2W applies to all state agencies, requiring that they "...shall consider this state policy when revising, adopting, or establishing policies, regulations, and grant criteria when those policies, regulations, and criteria are pertinent to the uses of water…".[50] With this passage of AB 685, relevant state agencies, including the State Water Resources Control Board (SWRCB) and the Department of Water Resources (DWR), are now required to consider this state policy when revising, adopting, or establishing policies, regulations, and grant criteria that may impact the uses of water for domestic purposes. These agencies must consider how state actions may impact the Human Right to Water. To ensure compliance with the legislature's long established position and accordance with 23 CCR §350.4, the HR2W requires that DWR must consider the effects on domestic water users when reviewing and approving GSPs.[51] The SWB should be consulted as part of GSP review as part of the Board's expertise on water quality matters.

Further, the California legislature has recognized that water used for domestic purposes has priority over all other uses since 1913.[52] Reserving top priority for domestic water use was later codified in 1943, in Water Code § 106, which declares it the, "established policy of this State that the use of water for domestic purposes is the highest use of water and that the next highest use is for irrigation."[53] Further, the passage of the Safe and Affordable Drinking Water Act by Governor Newsom[54] indicates a clear state-level commitment to providing safe and affordable drinking water to California's most vulnerable residents. Poor implementation of SGMA would threaten the success of the Safe and Affordable Drinking Water Fund and would run counter to Governor Newsom's vision of providing safe water to all.

A carefully designed and implemented Drinking Water Well Impact Mitigation Program can support a statewide goal of ensuring DACs' access to clean, safe, reliable, and affordable drinking water. Including this type of program in a GSP also helps to create a groundwater management plan that understands DACs' unique social and economic vulnerabilities, is sensitive to their drinking water needs, and avoids causing a further disparate impact on low-income communities.

Section 2. Key elements and a framework for developing a Drinking Water Well Mitigation Program:

This section provides a framework of elements to consider when GSAs are developing a drinking water well impact mitigation plan. This section is broken down into the following categories:

i. Drinking water well monitoring network;
ii. Adaptive management and trigger system;
iii. Drinking water well impact tool/model;
iv. Public outreach and education;
v. Mitigation measures;
vi. Program eligibility.

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[49] WAT § 106.3 (a).
[50] WAT § 106.3(b).
[51] *See generally,* WAT § 106.3 (b).
[52] California Water Commission Act of 1913 § 20.
[53] WAT§ 106; This policy is also noted in the Legislative Counsel's Digest for AB 685.
[54] SB 200, Monning (2019).

i. Drinking water well monitoring network: As required by GSP Regulation, Section 354.34, GSAs must describe how potential impacts to groundwater users and uses will be monitored. It must be recognized that most public water systems have wells deeper than domestic wells, thus monitoring networks must be able to capture impacts to deeper public water system wells as well as shallow domestic wells. The following approach will allow GSAs to comply with GSP regulations and take a proactive approach to protect DACs' and domestic well owners' access to safe and affordable drinking water:

- Map and assess drinking water well vulnerabilities to better understand:
  (1) Locations and depth of drinking water wells (both domestic and public supply wells);
  (2) Whether changes in groundwater levels and quality may be exacerbated in specific areas by pumping volume or location, conjunctive management (i.e. groundwater recharge projects) or other forms of active management as part of GSP implementation;
  (3) The proximity of potentially impacted wells to nearby existing public water systems; and
  (4) If there are areas with a high density of likely impacted wells.
  Assessment should acknowledge that not all existing and utilized wells may be documented in available resources from DWR or Counties.

- Designate key monitoring wells to assess impacts to drinking water wells: Based on the drinking water well vulnerability assessment, identify which wells from the GSP proposed monitoring network are critical to assess impacts to drinking water wells caused by changes to groundwater levels and quality. Expand and improve the monitoring network to assess potential impacts in particular for groundwater conditions near DACs, areas with high density of private domestic wells, and water systems serving schools. The monitoring network needs to be representative of conditions in all aquifers in general, including the shallow aquifer upon which domestic wells rely. The water quality monitoring network needs to routinely monitor for all contaminants that could impact public health (not only nitrate, but also chromium-6, arsenic, 123-TCP, uranium, and DBCP). This will allow the GSA to better comply with GSP regulations Section 354.34, which requires GSAs to describe how potential impacts to groundwater users and uses will be monitored, and to take a proactive approach to protect DACs and domestic well owners' access to safe and affordable drinking water.

ii. Develop an adaptive management/trigger system: Develop a protective warning system, also referred to as an adaptive management approach. Such an approach can alert groundwater managers when groundwater levels and groundwater quality are dropping to a level that could potentially negatively affect drinking water users. These "triggers" are essential for groundwater management and can be adjusted to fit the needs of different management actions as well as the basin as a whole. The table below provides an example of what a warning system might look like, using green, yellow, and red light indicators or triggers, and some potential corrective actions groundwater managers can take to remedy the problem. Ultimately, this approach allows for the evaluation of current conditions in order to respond accordingly to prevent or mitigate negative impacts.

Triggers	Groundwater Status	Potential Corrective Actions
Green-light	Groundwater levels and quality are stable.	No action required
Yellow-light	Groundwater levels and quality are approaching concerning levels and impacts may occur or are occurring at a	- Undertake an analysis to pinpoint the cause; - Undertake water quality testing for selected domestic and public supply wells; - Provide immediate support to groundwater users experiencing impacts;

	low rate. Some corrective actions are needed.	- Reassess pumping allocation and pumping patterns. Consider restricting or limiting groundwater extraction near the impacted area.
Red-light	Time to stop groundwater pumping and management actions and mitigate as significant impacts are imminent or are occurring.	- Reassess pumping allocation and pumping patterns. Consider further restricting or limiting groundwater extraction near the triggered area or reevaluating minimum thresholds or measurable objectives; - Provide interim emergency solution while working with impacted groundwater users to pursue a permanent, long-term solution.

iii. Drinking water well impact tool/model: Develop a tool or model tied to the monitoring network and the adaptive management framework (trigger system) to evaluate groundwater levels and predict potential groundwater impacts to drinking water wells. Update model regularly and develop a prediction of the potential groundwater impacts to drinking water wells. Results of this assessment should be incorporated into an annual GSP progress report to domestic well owners and DACs water systems. The tool or model could be used to:

- Monitor and forecast changes in groundwater levels and quality;
- Monitor and forecast any localized areas for special attention and/or monitoring;
- Attempt to identify domestic wells or small public supply wells at risk of impacts, and;
- Determine if triggers have been met based on the adaptive management framework.

iv. Public outreach and education: Develop public outreach and educational materials to increase awareness of groundwater management activities within the GSA. This outreach could inform groundwater pumpers of the rules, restrictions, and impacts of groundwater over-pumping. This outreach could also inform residents about the potential well impacts that could occur based on groundwater management actions, describe potential options available for well mitigation, and include information for who to contact in the event their wells experience negative impacts. This outreach could take place in the form of pamphlets, mailers, additions to the public website, or radio announcements. This information can also be included in regular GSA updates. To ensure that this program can benefit S/DAC residents, information about the program must be disseminated widely, and such materials must be translated into all threshold languages. The GSA should work with local agencies, organizations and associations to spread materials about the program. The GSA should work with local agencies and organizations to ensure that residents with impacted wells are referred quickly to the GSA for assistance. GSAs should conduct regular, door-to-door outreach (in partnership with other outreach experts as needed) to ensure that communities — particularly for communities location in areas the trigger system identifies within the yellow and red-light ranges— are aware of the well mitigation program and know who to contact in times of emergency.

v. Mitigation measures: Mitigation measures should be implemented as soon as the trigger system reaches its yellow light indicator. Groundwater should be managed in a way that prevents or avoids reaching the red light indicator and before wells become unusable. This will allow communities working with the GSA to access funding and develop a long-term plan that protects community member access to drinking water. The mitigation program should be designed to be proactive, rather than reactive to public health harms. When mechanical failures or other operational problems have occurred, or are likely to occur, due to declining water levels or deteriorating groundwater quality, mitigation should be provided as described below:

- **Third Party Determination of Causality:** Work with an objective third party to establish whether their policies and actions caused the drinking water impact. Based on a field inspection and discussion with the residents impacted, define the level of mitigation that is necessary. Verify well construction information and pump setting information, if possible;
- **Interim Drinking Water Supply Solution:** Provide short-term drinking water supply while a permanent solution is pursued. Short-term interim solutions serve to address the immediate impacts and ensure access to both water suitable for consumptive and other domestic needs, such as sanitation. Short-term emergency supplies shall be provided as soon as reasonably possible and can include bottled water, bottled water paired with tanked water, or another combination. For groundwater quality issues, bottled water may be an acceptable interim solution but if the issue is lack of access to water, providing bottled water is not an adequate interim solution and would require a combination of solutions as well as a long-term sustainable plan.
- Since short-term solutions are expensive over a prolonged period of time, it would be important to quickly identify potential long-term solutions. As an example, GEI's feasibility study for East Porterville at the height of the drought in 2016 estimated tank and bottled water programs cost $633,500 per month just for East Porterville, which has an estimated population of 7,331 residents.
- Long-term water supply can include (where appropriate):
    - Providing funding to lower a well pump and/or deepen the well;
    - Financial and technical support to complete a connection to a nearby municipal and/or industrial water provider;
    - Providing an equivalent water supply from an alternate source;
    - Providing funding to replace the affected well with a deeper well;
    - Providing funding to treat contaminated water;
    - Reducing or adjusting pumping near the impacted drinking water well as necessary to avoid the impact; and/or
    - Providing other acceptable mitigation through a collaboration with the affected drinking water well users.

  Note that lowering the pump and/or deepening the well will increase operational costs of the well and may require additional monitoring to ensure the well is not dewatered again. Further, these solutions may not address water quality concerns, depending upon aquifer conditions and screen depths.
- For a long-term water supply option, connecting current domestic well users to a nearby public water system should be pursued whenever possible. In areas with a high density of domestic wells, the establishment of a new small public water system may also be feasible. Public water systems have an obligation to test water quality for water served, and although some public water systems have limited resources, they do have a greater ability to install treatment systems to address water quality impacts, recoup funds for litigated contamination such as 1,2,3-TCP, and apply for and receive grant funding for beneficial projects. Because of this, public water systems, including small community water systems, often provide a more reliable drinking water source than privately-owned domestic wells. It should be noted that once a resident is connected to a public water system, they are then subject to water bills that will likely be higher than the operation costs of the well. As these long-term solutions are being developed, the community should be engaged in the process to learn about the benefits of a public water supply in terms of water reliability and water quality, and should also be informed of why water bills may be more costly. It is possible that some residents may request some sort of stipend to assist with the monthly water bills associated with their new water connection.

xi. Eligibility: Eligible beneficiaries should include communities that quality as DAC or SDAC, and households who qualify as low income. S/DAC residents should not be required to undertake burdensome actions or overcome other barriers to entry in order to benefit from the program. For example, residents should not be required to register before impacts occur in order to benefit from the program, and beneficiaries should not be required to prove that the GSA's activities or lack of action caused impacts. Instead, the GSA should proactively identify all well locations and information. When the GSA is notified of an impacted well, it should use the well information collected to rapidly evaluate the cause of the impact and provide adequate mitigation measures. Some questions GSAs could consider when determining eligibility are:

- What is the process for determining eligibility?
- Who determines if the well is eligible?
- What documentation does the well owner need to demonstrate eligibility? Is there an unreasonable onus on the owner to demonstrate past use that would constitute a barrier to access?
- When a well is found to have been constructed in a way that is not consistent with current regulations, is it still eligible?
- If a well is poorly constructed, does the program address replacing or repairing the well rather than just deepening it?

Section 3. Costs and Potential Funding Sources:

Costs: Costs are dependent on many factors including: how protective the GSA defines its sustainability goal and related sustainability criteria, the number of vulnerable wells, the condition of the vulnerable wells, proximity to existing public water systems, the depth of the aquifer, local contractor costs, fluctuations in material costs, etc. For comparison purposes, the San Antonio well mitigation project materials include the following average costs:

- Perform well diagnostics ($2,700);
- Lower pump ($4,000);
- Drill/outfit/connect replacement well ($58,000);
- Water purveyor connection ($5,000), and close existing well ($4,500).

The table below provides examples of interim and long-term solution costs based on Self-Help Enterprises' experience in providing solutions to disadvantaged communities in the San Joaquin Valley during the 2012-2014 drought. Costs are provided for illustrative purposes only and should be considered as rough estimates.

Solution	Problem	Options	General Overview of Pros and Cons	Estimate of Costs[1]
Interim solution	Water quality	Point-of-Use (POU)	Treats water for one tap within the household. While this option does provide safe drinking water in the home, if everything is perfect, maintenance is less likely to be carried out and assistance must be provided until a long-term solution is implemented. Costs estimates include initial capital costs (installation, treatment system, monitoring system) and also ongoing operation, maintenance, routine	$1000 to $1500 / unit per home.

			monitoring, and waste disposal costs.	
		Bottled water	Bottled water provides an effective and reliable source of safe drinking water and may be the only option available depending upon contaminant concentrations. However, bottled water can be expensive over a long period of time and can come with distribution challenges.	$30 to $50 per month per house, includes delivery.
	Access to water	Water tank program with bottled water	Tank water can meet basic sanitation needs but should not be used to meet drinking water needs, as tank water is susceptible to bacteriological or other issues making it unsafe for consumptive purposes. Instead, the program must be paired with delivery of bottled water to meet drinking water needs.	- 2,600 gallon water tank and materials roughly $2100.00. - Labor and tank installation $1500.00, does not include mileage. - Electrical permit $80.00, depending on the county. - Tank water between $300 to $500 depending on delivery charge by water hauler, per load or per hour. - $30 to $50 per month per house, includes delivery.
Permanent solution	Water quality	Water treatment system	Technical, managerial, and financial capacity of the community should be considered when assessing water treatment options.	Costs vary depending on the technology, water contaminant, and number of households.
		Alternate supply source	Options include surface water, construction of a new well, and consolidation with a nearby water system.	Costs vary depending on the desired solution, technology, and number of households.
	Access to water	Lowering of well pump	Less expensive long-term solution, if conditions allow. The following factors should be taken into account: lowering of a pump in the well is limited by the depth of the well, proximity of pump to the base of the well increases energy consumption, may require more frequent screen cleaning, and water quality may be degraded due to sediments that are drawn in.	Less than $10K, maybe around 5K.
		Drill a new deeper well	A well test is necessary to assess yield capacity and water quality on deeper levels.	Build a new private well: $20k to $45k.
				Build a new well for a water systems: up to $1.5 million.

		Alternative water supply source	Options include surface water or consolidation with a nearby water system. Recommend considering consolidation when households understand and agree with the advantages and disadvantages of connecting to a local water system.	Costs vary depending on the desired solution, technology, and number of households.

Potential Funding Sources: A secure and reliable funding source and mechanism for the implementation of this type of mitigation program needs to be identified in the GSP. While grant or emergency funding could potentially be available to support a mitigation program, the availability of these funds is not certain. Therefore, the GSA should plan to establish a more secure, on-going funding mechanism that accrues funds that would be available as water levels decline in the future. Funding for these types of programs should be considered as an operational cost of the GSA and funded with other ongoing costs such as administration and monitoring and should be included in the annual budget for the GSA. The following are potential other sources of funding to consider:

- Service or land-based fee assessments using Proposition 26 or Proposition 218;
- State Water Resource Control Board programs such as Proposition 1 Groundwater Grant Program and Prop 68 Groundwater Treatment and Remediation Grant Program;
- Department of Water Resources funding programs for groundwater projects and technical assistance programs to aid SGMA implementation;
- Central Valley Basin Plan Amendment (BPA) project funding: The BPA for the regulation of salts and nitrates has been approved by the SWRCB and implementation may result in additional funding sources for nitrate contaminated aquifers. If appropriate, GSAs should consider coordinating with nitrate dischargers forming Management Zones in order to comply with the BPA in order to streamline administrative costs and leverage resources;
- United States Department of Agriculture (USDA) Rural Development Utilities funding (if available).

Note that any well mitigation projects should be coordinated with the SWRCB's Safe and Affordable Drinking Water Fund Program (which will be seeking to implement short and long-term drinking water solutions within vulnerable communities) via the SWRCB's Division of Drinking Water. Funding from the SWRCB's Safe and Affordable Drinking Water Fund Program should not be utilized to ameliorate negative impacts to safe drinking water access in vulnerable communities that are a result of implementation of the GSPs.

Mitigation measures should not put a financial burden on S/DAC residents and communities. Where feasible, coordinate with relevant agencies to procure funding for cost-effective and affordable solutions. Solicit stipends and grants from agencies where there will be an added cost on residents.
Wherever consolidation is possible, the GSA should assist in pursuit of feasibility studies and assist in negotiations with public water systems. GSAs should also assist in pursuit of grants/funds to ensure that this water is affordable. This work must be initiated with community involvement, oversight, and leadership during "yellow light" phase. GSAs play a unique role in regional groundwater management and the ability to convene multiple agencies to leverage multiple funding sources can support both long-term access to safe and affordable drinking water while also supporting sustainable groundwater management.

For questions or for more information about the scorecard or the mitigation program, please contact:

Leadership Counsel for Justice and Accountability: Amanda Monaco, amonaco@leadershipcounsel.org
Community Water Center: Debi Ores, deborah.ores@communitywatercenter.org
Self Help Enterprises: Liesbet Olaerts, liesbeto@selfhelpenterprises.org

EXHIBIT B









Drought and Equity in California

Laura Feinstein, Rapichan Phurisamban, Amanda Ford,
Christine Tyler, Ayana Crawford

PACIFIC INSTITUTE

The Environmental Justice Coalition for Water
Water Justice for All

January 2017

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Lead Authors
Laura Feinstein, *Senior Research Associate, Pacific Institute*
Rapichan Phurisamban, *Research Associate, Pacific Institute*
Amanda Ford, *Coalition Coordinator, Environmental Justice Coalition for Water*
Christine Tyler, *Water Policy Leadership Intern, Pacific Institute*
Ayana Crawford, *Water Policy Leadership Intern, Pacific Institute*

Drought and Equity Advisory Committee and Contributing Authors
The Drought and Equity Advisory Committee members acted as contributing authors, but all final editorial decisions were made by lead authors.
Sara Aminzadeh, *Executive Director, California Coastkeeper Alliance*
Colin Bailey, *Executive Director, Environmental Justice Coalition for Water*
Carolina Balazs, *Visiting Scholar, University of California, Berkeley*
Wendy Broley, *Staff Engineer, California Urban Water Agencies*
Amanda Fencl, *PhD Student, University of California, Davis Center for Environmental Policy and Behavior*
Kelsey Hinton, *Program Associate, Community Water Center*
Gita Kapahi, Director, *Office of Public Participation, State Water Resources Control Board*
Brittani Orona, *Environmental Justice and Tribal Affairs Specialist and Native American Studies Doctoral Student, University of California, Davis*
Brian Pompeii, *Lecturer, California Polytechnic State University, San Luis Obispo*
Tim Sloane, *Executive Director, Institute for Fisheries Resources*

ISBN-978-1-893790-76-6
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Pacific Institute
654 13th Street, Preservation Park
Oakland, California 94612
Phone: 510.251.1600 | Facsimile: 510.251.2203
www.pacinst.org



Cover Photos: Clockwise from top left: NNehring, Debargh, Yykkaa, Marilyn Nieves
Designer: Bryan Kring, Kring Design Studio

ABOUT THE PACIFIC INSTITUTE

The Pacific Institute envisions a world in which society, the economy, and the environment have the water they need to thrive now and in the future. In pursuit of this vision, the Institute creates and advances solutions to the world's most pressing water challenges, such as unsustainable water management and use; climate change; environmental degradation; food, fiber, and energy production; and basic lack of access to fresh water and sanitation. Since 1987, the Pacific Institute has cut across traditional areas of study and actively collaborated with a diverse set of stakeholders, including leading policymakers, scientists, corporate leaders, international organizations such as the United Nations, advocacy groups, and local communities. This interdisciplinary and independent approach helps bring diverse groups together to forge effective real-world solutions. More information about the Pacific Institute and its staff, board of directors, and programs can be found at www.pacinst.org.

ABOUT THE ENVIRONMENTAL JUSTICE COALITION FOR WATER

The Environmental Justice Coalition for Water (EJCW) works within a Community-to-Capital framework, connecting the most pressing needs of our disadvantaged community partners to our network of partners and agencies statewide. Since 1999, EJCW's work has been rooted in the communities most affected by environmental injustice. Issues and solutions are identified through regional chapters and statewide work groups. EJCW is positioned in the state capital, in order to connect communities with state agencies to bring about change multilaterally through advocacy, education, training, litigation, community organizing, and capacity-building, and by providing technical assistance. EJCW aims to effectively influence the intersections of water justice and environmental justice, community health, and human rights issues from community to global levels.

ABOUT THE AUTHORS

LAURA FEINSTEIN, *Senior Research Associate, Pacific Institute*

Laura Feinstein joined the Water Program at the Pacific Institute in 2016. Laura conducts research on aquatic ecosystems; the impacts of climate change on water resources, water, and energy; and environmental health and justice. Prior to joining the Pacific Institute, she was a research scientist and project manager with the California Council on Science and Technology. She also served as a Science and Technology Policy Fellow with the California Senate Committee on Environmental Quality and was a California SeaGrant Delta Science Fellow. Laura holds a BA in Anthropology from the University of California, Berkeley and a PhD in Ecology from the University of California, Davis.

RAPICHAN PHURISAMBAN, *Research Associate, Pacific Institute*

Rapichan Phurisamban has worked in the Pacific Institute's Water Program since 2014, focusing on economic and policy analysis relating to domestic and international water resources. Prior to joining the Pacific Institute, she was a research consultant and project coordinator at a nonprofit organization in Thailand, where she promoted sustainable food and agricultural systems. Rapichan holds a BA in Economics from the University of British Columbia and an MPP from the University of California, Berkeley.

AMANDA FORD, *Coalition Coordinator, Environmental Justice Coalition for Water*

Rev. Ford is based in Sacramento, California. In addition to being an ordained interfaith minister, she has an MA in Sustainable International Development from Brandeis University with an emphasis in Environmental Peacebuilding and Project Management. Amanda leads the development, coordination, and implementation of EJCW's environmental justice coalition efforts, programs and advocacy campaigns at a statewide level, including Human Right to Water (AB 685) implementation, pollution prevention, democratic water governance, and tribal outreach. She has worked on environmental peacebuilding and environmental justice projects in 20+ countries and still actively advises projects around the world.

CHRISTINE TYLER, *Water Policy Leadership Intern, Pacific Institute*

Christine Tyler was a Congressman George Miller Water Policy Leadership Intern with Pacific Institute in 2016. Christine holds a BA in Political Science from the University of California, Berkeley. Her research interests revolve around international development, water and resource rights, colonialism, and climate change's effect on marginalized communities. She has previously worked on wastewater management and land rights issues in Oakland and abroad.

AYANA CRAWFORD, *Water Policy Leadership Intern, Pacific Institute*

Ayana Crawford was a Congressman George Miller Water Policy Leadership Intern with Pacific Institute in 2016. Ayana holds a BA in Environmental Studies from the University of California, Santa Cruz, where she completed a number of research and conservation internships and focused her coursework on social and environmental justice. Ayana pursued these passions after graduation through her work with the Pacific Institute, which revolved around water equity and water access, and as a research intern at Food First, a food justice think tank. She is presently studying Spanish at the University of Granada in Spain.

ACKNOWLEDGMENTS

This work was supported by a grant from the TomKat Foundation. We thank them for their generosity. The Drought and Equity Advisory Committee and report authors wish to thank the many people who gave their time to assist us in writing this report. Staff of the Community Water Center (CWC) organized two meetings with impacted communities. Marina Perez and Esther Tracy from the California State Water Resources Control Board (SWRCB) joined our Advisory Committee meetings. Many people participated in interviews or shared useful data with us, including Bruce Barton, Dave Bitts, Chris Brady, Donald Brafford, Larry Collins, Lori French, Kathy Frevert, Max Gomberg, Chook-Chook Hillman, Steve Lindley, Michael O'Farrell, Mike Ricketts, and Kurt Souza. East Porterville for Water Justice (EPWJ) and la Asociación de Gente Unida por el Agua (AGUA) Coalition met with us to discuss report recommendations. Heather Cooley gave many helpful review comments, and Matthew Heberger provided input and technical support. Brendan McLaughlin copyedited our dubious prose. Finally, our communications team, Rebecca Olson and Deb Janes, helped guide this report through its final stages. The opinions expressed in this report are those of the authors and do not necessarily reflect the views of the Drought and Equity Advisory Committee or the project funder. All conclusions and errors are our own.

Acronyms and Abbreviations

ACS – American Community Survey

AGUA – Association of People United for Water (or la Asociación de Gente Unida por el Agua)

CA HSC – California Health and Safety Code

CalEPA – California Environmental Protection Agency

CBC – Cumulatively Burdened Communities

CCF – Centum Cubic Feet (100 cubic feet)

CDPH – California Department of Public Health

CUWA – California Urban Water Association

CWS – Community Water System

DAC – Disadvantaged Community

DWR – Department of Water Resources

ESA – Endangered Species Act

GAMA – Groundwater Ambient Monitoring and Assessment Program

GPCD – Gallons Per Capita Per Day

IHS – Indian Health Service

LWS EAR – Large Water System Electronic Annual Reports

MCL – Maximum Contaminant Level

MHI – Median Household Income

NOAA – National Oceanic and Atmospheric Administration

OES – Office of Emergency Services

PFMC – Pacific Fishery Management Council

PWS – Public Water System

SDWIS – State Drinking Water Information System

SSWS – State Small Water System

SWAMP – Surface Water Ambient Monitoring Program

SWRCB – State Water Resources Control Board

U.S. EPA – United States Environmental Protection Agency

USBR – United States Bureau of Reclamation

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EXECUTIVE SUMMARY

Water is essential for life, yet not everyone in California has access to safe, affordable water. Five years of drought has highlighted these inequities. Recent reviews of the impact of the ongoing drought found that cities and farms, despite feeling the effects of curtailed water supplies, demonstrated great resilience overall (Cooley et al. 2015; Hanak et al. 2015). Small water suppliers and natural systems have not fared as well. Some small systems struggled to provide safe water to their customers, thousands of household wells ran dry, and endangered fish reached the brink of extinction (Braxton Little 2016; Moyle 2014; State of California 2016). Across California, those on low or fixed incomes have struggled with the rising cost of water (Cooley et al. 2016).

In this report, we examine three major impacts of the ongoing California drought. The first two, supply shortages and rising costs, affected people's access to safe, affordable water in their homes. We also investigated the impacts of the drought on salmon and, by extension, commercial and tribal fishermen reliant on salmon for income, food, and cultural traditions. We found that low-income households, people of color, and communities already burdened with environmental pollution suffered the most severe impacts. The good news is that there are solutions to these problems, some of which are already being implemented. We conclude with a set of policy recommendations to improve our ability to cope with drought and minimize its inequitable consequences in the future.

During the drought, some small systems struggled to provide safe water to their customers, thousands of household wells ran dry, and endangered fish reached the brink of extinction.

DOMESTIC WATER SHORTAGES

Despite a great deal of public attention on drinking water shortages since the drought began in 2012, this is the first statewide summary of reported water supply vulnerabilities. Using information collected by state and local agencies, we classified water systems as "drought-impacted" if they reported actual or near shortages, received emergency drought funding, or, in the case of tribal water systems, were identified by United States Indian Health Services (IHS) as "high risk." We examined water systems serving more than 25 people year round or at least 15 connections (referred to as public water systems) and those serving fewer than 25 people year round, such as private wells (referred to as non-public water systems). We found that:

1. Most (76 percent) of the 149 drought-impacted public water systems were small, serving 1,000 connections or fewer. This is similar to the overall percentage of small water systems in California. Drought-impacted public water systems served an estimated 480,000 people—approximately equivalent to the population of Sacramento.
2. Drought-impacted public water systems were widespread, with at least one found in 39 of the state's 58 counties, but were concentrated in the San Joaquin Valley, the North Coast, and the Central Coast. There were no reports of drought-impacted systems in the easternmost portions of the state or in the San Francisco Bay Area.
3. From January 2014 through early August 2016, the state received nearly 4,000 reports of shortages from households served by small, non-public water systems. Household shortages were reported in 38 of 58 counties across the state but were concentrated in the southern San Joaquin Valley. Tulare County accounted for 42 percent of reported household water shortages.
4. A large proportion of drought-impacted public water systems and household outages were in Disadvantaged and Cumulatively Burdened Communities.[1] Of the 92 drought-impacted public water systems for which we know the location, two-thirds served a disadvantaged community, and nearly one-third served a cumulatively burdened community. Similarly, of the household shortages reported in Tulare County, two-thirds were in a disadvantaged community, and nearly 90 percent were in a cumulatively burdened community.

To improve the drought resilience of domestic water supplies, we recommend that state and local agencies enact the following measures:

1. Establish a statewide, quantitative metric for measuring water supply reliability for public water systems;
2. Require water shortage contingency plans for all public water systems and establish regional plans for non-public systems;
3. Increase oversight of new private wells;
4. Systematically collect information on water shortages for public and non-public water systems;
5. Identify areas where private wells and other non-public water systems are likely to run dry in future droughts;
6. Identify areas where water system consolidation can resolve supply problems.

DROUGHT CHARGES AND WATER AFFORDABILITY

The cost of water can go up during a drought if, for example, the water utility must purchase more expensive supplies, increase treatment for lower quality water, or pump groundwater from greater depths. Moreover, as water use declines due to mandatory or voluntary restrictions, water utilities may implement a temporary drought charge to cover their costs, most of which are fixed. Such price increases can exacerbate affordability concerns for low-income households. In examining the impact of drought charges on low-income households in 2015, we found that:

1. More than half of the utilities analyzed increased the price of water regardless of the amount a household used, resulting in price increases for all single-family households.
2. About one-fifth of the utilities levied drought charges by increasing the price of water used

1 Disadvantaged Communities have a median household income of less than 80 percent of the state median. Cumulatively Burdened Communities are those that rank in the top quarter of census tracts in the state for environmental burdens and socioeconomic vulnerability.

in excess of some threshold. While the intent was to avoid increasing prices for basic water use, even relatively efficient households with many members still experienced an increase in the price of water.

3. Approximately one-fifth of the utilities only added drought charges if a household exceeded a customized water budget based on household size, raising the price of water only for wasteful use.
4. Drought charges exacerbated affordability concerns for low-income households. Single-family households earning less than $25,000 a year paid an average of 1.8 percent of their household income for basic water service without drought charges. This amount increased to 2.1 percent with drought charges, exceeding State of California and United States Environmental Protection Agency affordability thresholds. The effect was even more extreme for households earning less than $10,000, raising costs from 4.4 to 5.3 percent of income. These households have little or no disposable income, so any increase in water costs poses a major problem.

To reduce the inequitable impact of drought charges on low-income households, we recommend the following:

1. Ensure drought surcharges are not applied to basic water use, preferably by calculating household water budgets based on the number of people in a residence;
2. Provide technical and financial assistance to water utilities, especially the smallest ones, to implement drought charges that do not unfairly burden low-income households;
3. Target water conservation and efficiency programs to low-income households by offering, for example, point-of-sale coupons, targeted education and outreach, and direct-install programs;



Source: Photographereddie

4. Develop low-income rate assistance programs within current legal constraints and reform Proposition 218 to allow greater latitude in funding such programs;
5. Wherever possible, require meters and sub-meters to allow for more equitable drought charges based on volumetric water use;
6. Develop approaches that effectively target hard-to-reach customers, such as renters and residents of multi-unit buildings, for rate assistance and conservation programs.

DROUGHT IMPACTS ON SALMON FISHERIES

Water disputes in California are sometimes framed as "fish versus people," but this perspective overlooks those who rely on fishing for their livelihoods and traditions. While the link between drought and the collapse of endangered fish stocks has been extensively documented (Hanak et al. 2015), surprisingly little research has traced

the relationship between drought, low river flows, and the health of commercial and tribal fisheries in California. Salmon populations decline during droughts because of reduced stream flows and higher water temperatures, which lead to disease outbreaks, more competition from invasive fish species, and higher risk of predation. Habitat loss from human activity has compromised their capacity to survive and rebound from droughts. There are many factors contributing to the decline of salmon, of which drought is just one.

We examined the available data and information on trends in commercial and tribal fishing over time. We found that:

1. The commercial salmon fishing fleet has declined dramatically over the last three decades, from 6,000 vessels in 1982 to just over 1,000 vessels in 2014. Many factors have contributed to the decline, including fewer salmon, income insecurity brought about by events such as the fishery closure of 2008-2009, rising costs of fishing, and loss of support infrastructure (such as fuel docks).
2. From 2014 to 2015, Sacramento winter-run Chinook salmon had the poorest survival for juvenile fish on record due to drought conditions and water diversions from the Sacramento River, resulting in an abbreviated 2016 fishing season for much of the state.
3. Extremely low flows in the Klamath River, caused by drought and water diversions for irrigation, contributed to an outbreak of fungal infections in salmon in 2014 and 2015. The subsequent poor reproduction will impact fishermen two to five years later, when eggs hatched in 2014 and 2015 return from the ocean as mature adults.
4. Declines in salmon populations, made worse by drought, have meant that tribes cannot obtain the fish that are an essential part of their diet and an integral part of their spiritual and cultural traditions.

To reduce the impact of drought on salmon fishermen, we recommend the following:

1. Expand the goal of emergency drought responses beyond preserving endangered species to include protection of commercially-fished salmon species.
2. Manage stream flows to better serve the needs of fish.
3. Restore habitat to improve salmon resilience to drought.
4. Provide income assistance and insurance protection for fishing communities during drought emergencies.
5. Create mechanisms for meaningful and timely tribal engagement with local, regional, state, and federal agencies.
6. Evaluate ways to re-operate California hatcheries to achieve parallel goals of sustaining commercial fisheries and assisting in the recovery of naturally-spawned salmon runs.
7. Assess the use and effectiveness of instream flow regulations to protect salmon populations.
8. Develop integrated, comprehensive datasets tracking salmon populations and their environment throughout the state.

Inequities in access to water in California existed before the drought began in 2012, but lack of water made the outcome of these inequities more severe. Low-income families, those who are disproportionately burdened by multiple sources of pollution, and those who depend on aquatic ecosystems for their livelihood and traditions

are highly vulnerable to problems of supply shortages, rising unaffordability, and insufficient streamflows. Unless we act, drought's impacts on these communities will become more severe as climate change progresses, given that scientists predict longer, more severe, and more frequent droughts. We offer the Drought and Equity report and the recommendations within as a tool for community members and decision-makers to improve the resilience of all Californians, including the most vulnerable, to future droughts.

INTRODUCTION

California recently suffered the driest four years in state history, and despite somewhat wetter conditions since late 2015, 75 percent of the state remains in drought conditions as of December 2016 (U.S. Drought Monitor 2016). Cities and farms, despite feeling the effects of curtailed water supplies, have by and large demonstrated great resilience (Hanak et al. 2015; Cooley et al. 2015), but small water suppliers and natural systems have not fared as well. Some public water systems struggled to deliver safe water to their customers, thousands of household wells ran dry, and endangered fish reached the brink of extinction (Moyle 2014; Braxton Little 2016; State of California 2016). And while urban water suppliers maintained clean water delivery during the drought, many of their low-income customers struggled with the rising cost of water (Cooley et al. 2016).

In this report, we examine three major impacts of the drought. The first two—shortages and price hikes—affected people's access to safe, affordable, adequate water in their homes. The third arena we investigate is salmon fishery performance during the drought, and how it affected commercial and tribal fishermen reliant on salmon for income, food, and cultural traditions. We selected these topics based on input from a diverse set of stakeholders. While we were unable to explore them in-depth in this report, the impact of drought on farmworkers, water quality, and subsistence fishermen (beyond the tribes we discuss in Section 3), are also critical issue areas that deserve further analysis.

Our goals were to synthesize available information from the state, media outlets, and non-governmental organizations (NGOs) and develop recommendations on how to mitigate the impacts of future droughts. This report is intended to provide information to community groups to advocate for their own interests, as well as to inform policymakers and other decision-makers interested in crafting more effective drought response strategies, particularly to address the needs of the state's most vulnerable communities.

This project was conceived of cooperatively by the Pacific Institute and the Environmental Justice Coalition for Water (EJCW). To oversee the project, we convened a nine-member California Drought and Equity Advisory Committee representing a range of perspectives and interests:

Sara Aminzadeh, *Executive Director, California Coastkeeper Alliance*

Colin Bailey, *Executive Director, Environmental Justice Coalition for Water*

Carolina Balazs, *Visiting Scholar, University of California, Berkeley*

Wendy Broley, *Staff Engineer, California Urban Water Agencies*

Amanda Fencl, *PhD Student, University of California, Davis Center for Environmental Policy and Behavior*

Kelsey Hinton, *Program Associate, Community Water Center*

Gita Kapahi, *Director, Office of Public Participation, State Water Resources Control Board*

Brittani Orona, *Environmental Justice and Tribal Affairs Specialist and Native American Studies Doctoral Student, University of California, Davis*

Brian Pompeii, *Lecturer, California Polytechnic State University, San Luis Obispo*

Tim Sloane, *Executive Director, Institute of Fisheries Resources*

The Advisory Committee helped determine the scope, identified project outcomes, developed recommendations, and reviewed the report. Profiles of the Advisory Committee members and their organizations are given in Appendix IA.

This report builds on previous work by the Pacific Institute and EJCW focused on the San Francisco Bay Area, which brought together eight community partners to identify drought impacts and concerns and develop a set of recommendations for addressing them. This work was summarized in a report on Drought and Equity in the San Francisco Bay Area (Cooley et al. 2016), and culminated in a day-long summit in July 2016 that brought together representatives of Bay Area community organizations, water managers, local government, and water and justice nonprofits.

The report is divided into three sections. Section 1 highlights domestic water shortages both in public and the non-public systems that serve very few people, such as private wells. Section 2 examines drought surcharges, and how they affected water affordability for low-income households. Section 3 examines the impact of the drought on commercial and tribal fishermen reliant on salmon for their livelihood and cultural traditions. We conclude each section with recommendations for mitigating impacts of future droughts for the impacted communities.

SECTION 1.
DROUGHT AND DOMESTIC WATER SHORTAGES

OVERVIEW

With the recent passage of the Human Right to Water (CA Water Code Section 106.3), California has declared that access to sufficient water for cooking, consumption, and sanitation is a basic human right. Yet, water shortages for basic household needs have been widely reported over the last several years due to the ongoing drought (Braxton Little 2016; SWRCB 2016a; Becerra 2014; Lurie 2016). Since 2012, thousands of households reported that their wells have run dry, while hundreds of public water systems have applied for financial assistance to address dwindling or contaminated supplies. The state spent $66 million on emergency drought responses related to drinking water from July 2013 to June 2016 for programs such as delivering water to households, deepening wells, and consolidating water systems (Legislative Analyst's Office 2016). Addressing the underlying vulnerabilities in domestic water supplies is all the more urgent given that droughts are likely to become longer, more frequent, and more severe due to climate change (Dettinger et al. 2011).

Despite growing public concern and several state and local programs to address water shortages, the scope and severity of the statewide problem are not well understood. Rural, low-income, primarily Latino communities in the San Joaquin Valley such as East Porterville deservedly received a great deal of media attention when families' private wells ran dry and residents had to survive without running water, often for years (Box 1-1). But outside the intense coverage of the worst-affected communities, the overall extent and severity of water shortages during the drought is not well understood. Water utilities resorted to hauling in tanks of water and delivering bottled water as stopgaps while they identified long-term solutions to water shortages, but these problems were often only reported in the local paper, if at all. Here we pull together a number of datasets to gain a statewide perspective on domestic water shortages during the ongoing drought. Where did shortages occur? What types of water systems were impacted? What were the demographic and socioeconomic characteristics of the impacted communities? Our goal is to better understand which water sources were most vulnerable to drought, so we can improve the resiliency of domestic water supplies in future dry periods.

METHODS

Categories of Water Systems

We divided water systems into seven categories based on size, type of customers, and how they are regulated. This is consistent with the approach used in a recent Department of Water Resources report, *Californians Without Safe Water and Sanitation* (DWR 2014a). A public water system is defined in

Box 1-1.

Experiences of Tulare County Residents Living With Water Shortages

On Dec. 12, 2016, California Drought and Equity report authors, and Kelsey Hinton of Community Water Center and the Drought and Equity Advisory Committee, addressed a meeting of the AGUA Coalition (la Asociación de Gente Unida por el Agua, or the Association of People United for Water). AGUA is a regional, grassroots coalition of impacted community residents and allied non-profit organizations dedicated to securing safe, clean, and affordable drinking water for the San Joaquin Valley. It works closely with the Community Water Center.

We presented a summary of the report findings and recommendations, and asked meeting attendees to add their recommendations or tell us experiences that should be documented. Here are some of the responses.

"I've lived without water for two years, seven months. It's important to point out the urgency to get long-term solutions more rapidly than we're getting them now."

"I've been to at least two meetings where people address the Board of Supervisors of Tulare county, and a Supervisor says, 'Well my well went dry too, and I had to drill a new well.' But there's a big difference between that and someone whose well went dry, and then they had to go without water for more than two years."

"Many agencies got money to help, but maybe what is missing is a group, like the AGUA coalition, that even when the money runs out, they continue to work on this issue. People have submitted applications to agencies for money, but the money has already run out, and then the organization just shuts down. People have problems where they submitted original documents to an agency that ran out of money and haven't gotten them back so they can't put in a new application. So agencies need to stick around."

"Our community has been without clean water for more than 10 years. Then who do we call? We call the county, they're closed, or they give you a different number... nobody knows who to call."

the California Health and Safety Code (CA HSC) as a system that has "15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year" (CA HSC § 116275). The California State Water Resources Control Board (SWRCB) oversees approximately 8,000 public water systems in the state that deliver drinking water to the vast majority of the population. The U.S. Environmental Protection Agency (U.S. EPA) regulates the 125 tribal water systems in the state.

Systems too small to meet the threshold for a public water system are referred to as non-public water systems.[1] There are three types of non-public water systems: state small water systems, local small water

1 A public water system has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year (CA Health and Safety Code Section 116275(h)). In this report, we use the term "non-public water system" to refer to any system that has fewer than 15 service connections and serves fewer than 25 individuals daily.

systems, and private domestic wells (or surface diversions). Water quality of state small water systems is regulated at the county and local level; water quality in local and private systems has relatively few regulations. Table 1-1 summarizes the seven categories of water systems.

Table 1-1. Categories of Water Systems in California

Name	Definition	Estimated Population Served (2016)[1]	Drinking Water Quality Regulating Agency	Typical Customer Type
Public Water System	15 or more service connections or serves at least 25 individuals daily at least 60 days out of the year (CA HSC § 116275(h))			
Community Water System	At least 15 service connections used by year-long residents or regularly serves at least 25 year-long residents of the area served by the system (CA HSC § 116275(i))	41,300,000	SWRCB	Residential areas; can also include non-residential areas in addition to homes
Transient Non-Community Water System	Does not regularly serve at least 25 of the same persons over six months per year (CA HSC § 116275(o))	981,000	SWRCB	Restaurants, campgrounds, parks, motels and other non-residential areas
Non-Transient Non-Community Water System	At least 25 of the same persons over six months per year (CA HSC § 116275(k))	412,000	SWRCB	Schools, workplaces
Tribal Water System	At least 15 connections or 25 people daily, serving a federally recognized tribe	224,000	U.S. EPA	Facilities on tribal land
Non-Public Water System	Fewer than 15 service connections or serves fewer than 25 individuals daily at least 60 days out of the year			
State Small Water System	At least five, but not more than 14, service connections and does not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year (CA HSC § 116275(n))	Data not available	County and local health departments	Small number of people served in any type of location
Local Water System	2-4 service connections[2]	Data not available	N/A	"
Private Domestic Well (or Surface Diversion)	1 service connection[2]	600,000 – 2,000,000 use wells; population served by surface diversions unknown	N/A	"

1. Population served figures are approximations made by the water utilities. Note that the populations served by the different types of water systems overlap. Numbers rounded to three significant figures. Data from Safe Drinking Water Information System (SDWIS) (SWRCB 2016c), except domestic wells from DWR (2013), and Tribal Water Systems from U.S. EPA(2016).
2. Definition given in "Californians Without Safe Water and Sanitation: California Water Plan Update" (DWR 2014a).

Analysis 1: Drought-Impacted Public Water Systems

We identified drought-impacted public water systems using three statewide datasets:

- Community water systems and non-transient non-community water systems serving schools that had applied for assistance from the SWRCB as of July 2016, due to drought-related impacts on drinking water supply or quality that could not be addressed with their existing funding (SWRCB 2016e);
- A SWRCB survey in December 2015 of community water systems with 15-3,000 service connections on their ability to provide water if the drought continued through 2016 (SWRCB 2016d); and
- a July 2015 assessment of tribal water systems for multiple factors linked to drought vulnerability, such as changes in supply and availability of an alternative source of water (IHS 2015).

These datasets have a number of limitations. To our knowledge there is no single, comprehensive dataset on public water system shortages during the ongoing drought. The list we compiled reflects a best effort with available data and should be viewed as a preliminary, and likely incomplete, assessment of public water systems that have experienced drought impacts that actually, or nearly, resulted in shortages. A more careful, consistent means of collecting information on drought shortages would enable a more thorough understanding of vulnerable water systems. Nonetheless, the list provides an indication of where the known problems are concentrated, as well as a minimum number of systems affected by the drought.

Once we compiled a master list of drought-impacted systems, we mapped the locations of the systems and quantified the number serving vulnerable communities. We used two definitions of a vulnerable community, following definitions used by state agencies. A Disadvantaged Community (DAC) is a census block groups with a median household income under 80 percent of the state median household income (Department of Water Resources (DWR) 2016). A Cumulatively Burdened Community (CBC) is a census tract that ranks in the top quarter of tracts in the state for environmental burdens and socioeconomic vulnerability (California Environmental Protection Agency (CalEPA) 2014).[2]

We give further details on datasets used in the analysis of drought-impacted public water systems in Appendix 1A.

Analysis 2: Water Shortages in Households Served by Non-Public Water Systems

We also looked at shortages in households served by water systems too small to be regulated as public water systems. These data are likely an undercount of the true number of household shortages.[3] But as with the data on drought-impacted public water systems, they indicate where the known problems were concentrated, as well as a minimum number of households affected. In Tulare County, we had sufficiently detailed data on household shortage locations to map them, and calculate how many were in DACs and CBCs.

2 This definition takes into account 20 factors in the categories of pollution exposure indicators, environmental effects indicators, sensitive population indicators, and socioeconomic indicators. Two of the factors relate directly to water quality: groundwater threats and drinking water contaminants.

3 Household shortages may not be included in the statewide dataset for a number of reasons, including: not all counties had reporting mechanism in place; people that are financially able to deepen or drill a new well themselves are unlikely to communicate a problem to the officials; and people may choose not to report a shortage because they prefer to avoid interaction with government officials.

RESULTS AND DISCUSSION

Drought-Impacted Public Water Systems

For our first analysis, we identified 127 community water systems with potential or actual drought impacts to their water supply between 2014 and 2016 (Table 1-2), and an additional 22 non-community water systems facing supply vulnerabilities. Most of the community water systems (72 percent) were small, serving 1,000 connections or fewer. This is consistent with the fact that 77 percent of community water systems in California are small. The drought-impacted systems in our list served approximately 480,000 people.[4] A complete list of the 149 drought-impacted systems is provided in Appendix 1B.

Drought-impacted systems were found in most California counties (Figure 1-1a). The greatest number were in Madera (24) and Tulare (12) counties. There was also a relatively large number of drought-impacted systems in Mendocino County (13). The impacts correspond roughly to

4 Population served was calculated by adding the population served listed either in SDWIS (SWRCB 2016c) or the U.S. EPA's list of tribal water systems (U.S. EPA 2016). This number is an approximation of population served, and individuals can be served by more than one system in their home versus other places they visit.

Table 1-2.

Drought-Impacted Public Water Systems in California

	A	B	C	D	E
	Data Source				
	Applications for Drought Assistance Funding	Small Supplier Conservation Report	Tribal Systems at High Risk Due to Drought	Total Drought-Impacted Systems[3]	Estimated Population Served[4]
Community Water Systems	**87**	**34**	**12**	**127**	**473,000**
No. Connections:					
1-1,000	57	29	10	92	18,200
1,001-3,300	15	2	2	18	34,300
>3,300	15	3	0	17	421,000
Non-Transient Non-Community	**13[1]**	**3**	**NA**	**16**	**5,550**
Transient Non-Community	**NA[2]**	**6**	**NA**	**6**	**1,660**
				Grand Total: 149	**480,000**

1. Of non-transient non-community systems, only systems serving schools were eligible for funds.
2. Transient non-community systems were not eligible to apply for funds.
3. Columns A-C do not necessarily sum to the total in Column D because duplicates appearing in both Columns A and B were eliminated.
4. Rounded to three significant figures. Figures may not sum to total due to rounding errors.

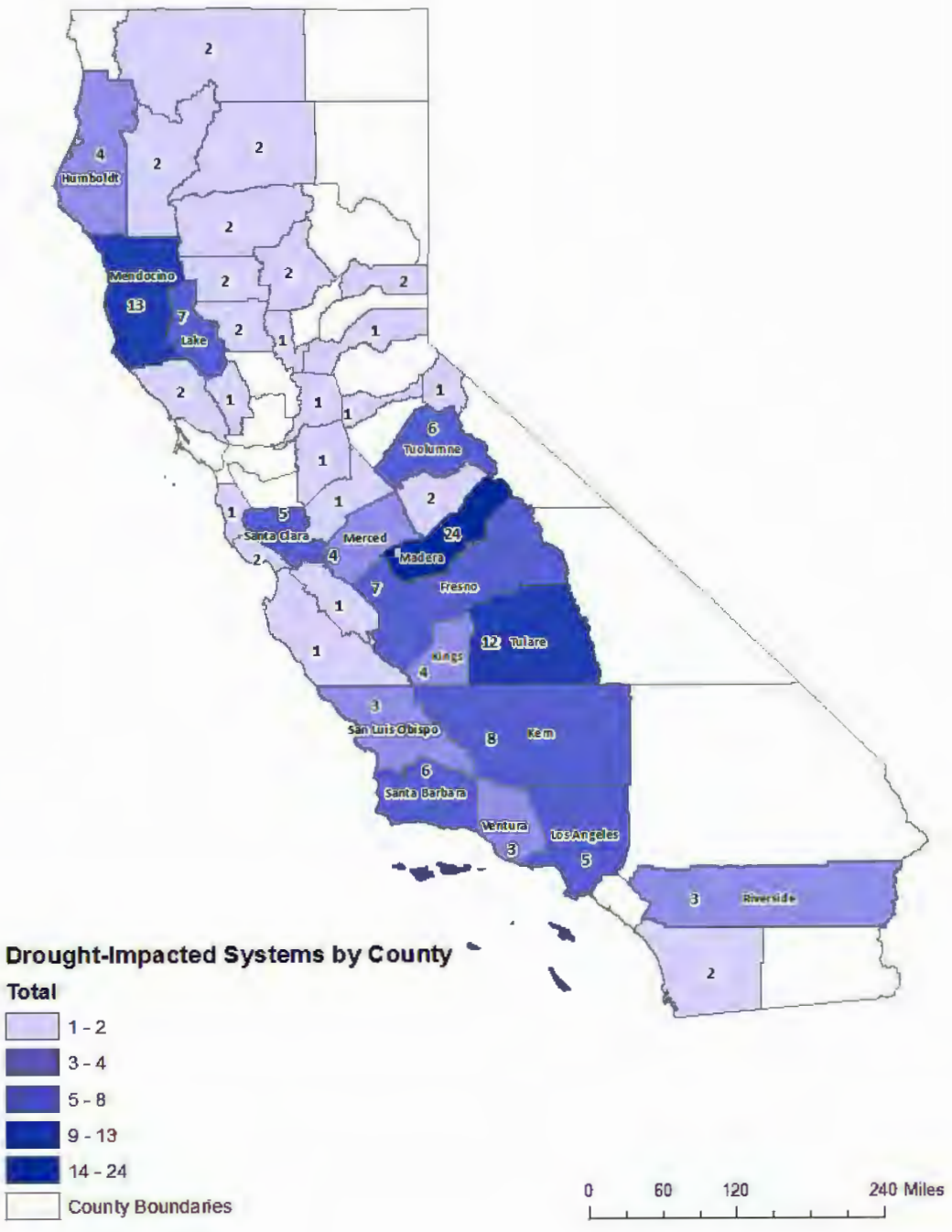
Note: Columns A-C summarize three sources of information on drought-impacted public water systems in California.

Sources: Column A based on data from SWRCB (2016e), Applications for Drought Assistance Funding. Column B based on data from SWRCB (2016d), Small Supplier Conservation Reports. Column C based on data from IHS (2015), July 2015 Drought Vulnerability and Risk Assessments for Tribal Drinking Water Systems. Column E based on SDWIS (SWRCB 2016c).

the state's hydrologic regions, with no impacted systems found in the eastern regions of North and South Lahontan, nor in the San Francisco hydrologic region. The greatest concentrations were in the San Joaquin River, Tulare, North Coast, and Central Coast hydrologic regions. The population served by impacted systems shows somewhat different patterns. The five counties

Figure 1-1a.

Number of Drought-Impacted Public Water Systems in Each County



Notes: Numbers and shading indicate drought-impacted public water system in each county, with darker colors signifying greater numbers. Blank counties had zero drought-impacted systems reported in the datasets surveyed.

Sources: Data compiled in Appendix 1B, from SWRCB (2016c), SWRCB (2016e), SWRCB (2016d), IHS (2015).

with the greatest number of people served by drought-imapcted systems were Santa Barbara (estimated 210,000 people served), Tulare (82,000), Kings (74,000), Tuolomne (23,000), and Mendocino (20,000) (Figure 1-1b).

A large proportion of drought-impacted community water systems were located in low-income and disadvantaged communities. The publicly available map of California's public water systems only gives information for some of

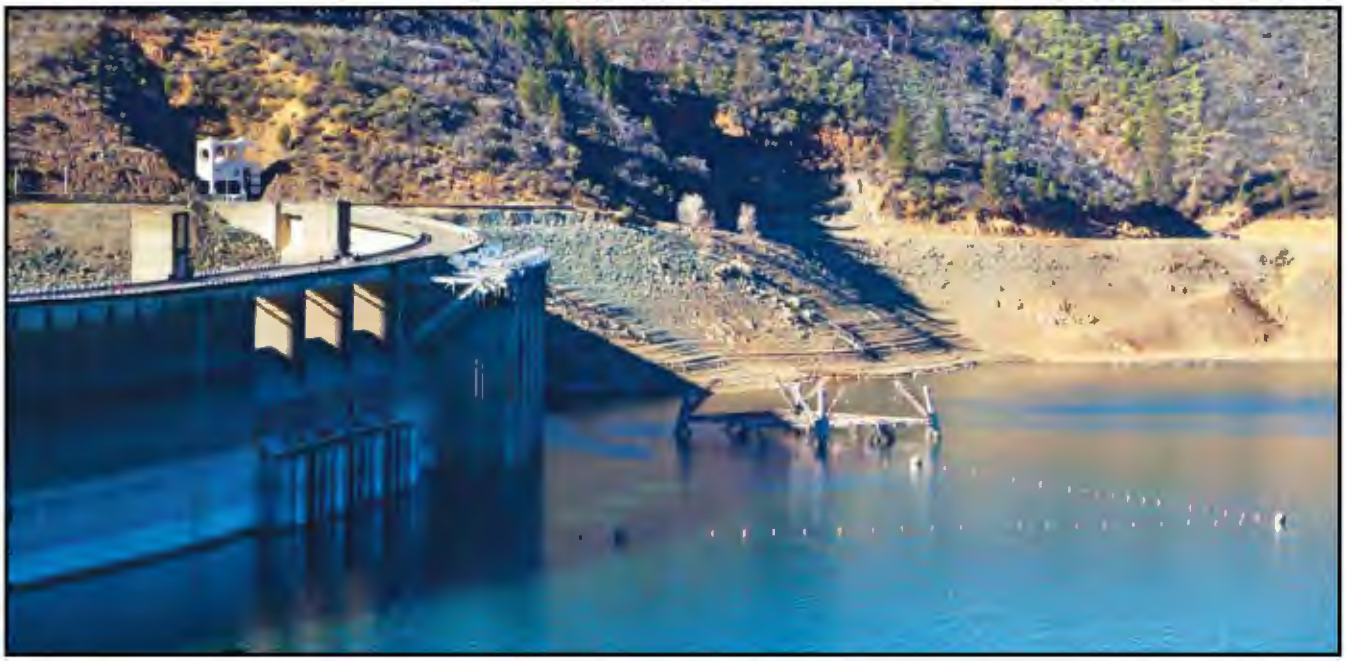
Figure 1-1b.

Population Served by Drought-Impacted Public Water Systems in Each County



Notes: Numbers and shading indicate the estimated number of persons served by drought-impacted public water system in each county, with darker colors signifying greater numbers. Blank counties had zero drought-impacted systems reported in the datasets surveyed.

Sources: Data compiled in Appendix 1B, from SWRCB (2016c), SWRCB (2016e), SWRCB (2016d), IHS (2015).



Source: Slobo

the state's systems, so we were able to map only 97 of the 144 drought-impacted community water systems. Of those, 65 (67 percent) served a DAC, while 28 (29 percent) served a CBC.

Among the 122 public water systems that applied for emergency drought funding, nearly half received funding to haul in water via truck, or deliver bottled water to customers. These systems had reached acute emergencies in which they could not provide safe, sufficient tap water. In total, 52 systems fit this description: 27 received funding to haul water, 24 for bottled water, and 1 for both. The remaining funding was directed to long-term solutions to drought emergencies, such as well overhauls, new wells, new interties to neighboring systems, and new filtration devices. In most cases, whether the underlying problem was one of quality or quantity was ambiguous. In only one case did the project description explicitly mention that the water system's well had run dry. On the other hand, there were 20 project descriptions that indicated that the project intended to address quality concerns; usually the funded project included at least bottled water delivery, and sometimes a long-term solution as well, such as a new filtration device. A portion of the emergency drought assistance funds were explicitly for "contaminated drinking water supplies exacerbated by drought conditions" (CA Budget Act of 2014, Statutes of 2015). This funding was intended to address concerns that drought was causing contamination of water supplies. However, the relationship between drought and the quality of water Californians drink is complex, and we could not find evidence that the quality of drinking water in the state deteriorated because of drought (Box 1-2).

Water Shortages and Non-Public Water Systems

For our second analysis, we looked at shortages reported by households served by non-public water systems. From January 2014 through August 8, 2016, the state received 3,749 reports of shortages in households served by non-public water systems (serving under 15 connections/25 individuals). Most of the reports were concentrated in the counties that are in the San Joaquin Valley, with

Box 1-2.

Drought and Drinking Water Quality

We did not directly seek to document impacts of drought on drinking water quality in this report. However, our Advisory Committee members flagged this as a key concern for public health during droughts. Water systems can experience supply problems either because of an insufficient volume of water, or an insufficient amount of clean water. Emergency drought funding criteria include the intertwined nature of water quality and quantity, making funds available both for supply shortages and for contamination of drinking water exacerbated by drought (Assembly Bill 91, Statutes of 2015, Section 31). Here we review the available literature on the potential link between drought and declining water quality, and its impacts on DACs.

Droughts may cause significant changes in water quality and adversely impact drinking water supplies. For example, warmer surface water temperature, reduced flows, and high nutrient concentrations have resulted in algal blooms in lakes and reservoirs throughout California. These potentially toxic blue-green algae, or cyanobacteria, were the cause of poorer taste and smell of drinking water supplied to East Bay residents in 2015 (EBMUD 2015). Treatment processes can remove harmful substances, and thus these blooms have not been linked to health concerns. A major water quality problem that needs to be carefully managed during drought is the potential for salt water to intrude further into the Sacramento-Bay Delta, contaminating not only water distributed throughout the state via the State Water Project and Central Valley Project, but also water used by Delta farmers and water districts in nearby Contra Costa, Alameda, and San Joaquin counties (DWR 2014b). Other surface water quality indicators relating to the drought such as nutrient concentrations, dissolved oxygen, and organic carbon have shown mixed responses (Mosley 2015).

Communities most vulnerable to degraded water quality because of drought are likely to be those depending on non-public water systems, including private domestic wells and those served by water systems with less than 15 service connections, as these sources are not as intensively regulated or monitored. Up to two million California residents rely on private domestic wells, and unknown numbers use water from local and state small systems (SWRCB 2015b). Private domestic well owners and non-public water system operators are responsible for maintaining their water supplies and ensuring that water quality meets drinking water standards, but problems are likely to remain undetected or unaddressed due to the lack of financial and technical resources.

Drought conditions may exacerbate existing water quality problems. Given that the presence and concentration of arsenic are related to hydrologic and biogeochemical processes, higher evapotranspiration rates can increase arsenic concentrations in surface water and shallow groundwater (Beard, Fujii, and Shanks 1994; Gao, Tanji, and Bañuelos 2007). The drilling of deeper wells as a response to water shortages may cause releases of arsenic from sedimentary rocks. However, there is limited understanding of arsenic transport in sediments in all of California's key groundwater basins. Uranium, another naturally-occurring element, may also increase its concentrations in groundwater during a drought. Jurgens et al. suggested that changes in the chemistry of recharge water and increases

Box 1-2. (*Continued*)

Drought and Drinking Water Quality

in the rate of downward groundwater flow have led to uranium concentrations above drinking water standards in both domestic and public wells. Higher recharge temperatures have been found to correlate with uranium levels (Jurgens et al. 2010). Moreover, uranium contamination is linked to nitrate, which plays a role in increasing the solubility of uranium in water (Nolan and Weber 2015). This secondary uranium contamination is expected to worsen in areas with high agricultural activities and groundwater dependence.

Despite some evidence of drought's negative impacts on water quality, further research is needed to document and assess the mechanisms and implications of these impacts. While drought can alter the quality of water supplies, water systems have methods to remediate the problem by treatment and mixing with higher-quality sources. Little is still known about the extent of drought impacts on the quality of water that reaches customers' taps, how many people receive lower-quality water during a drought, and how reduced water quality during drought affects minorities or socio-economically disadvantaged communities across the state. Some limited data and monitoring programs already exist. Water quality reports required under the Safe Drinking Water Act may be used to track water quality changes during the drought, but they do not include very small drinking water systems and private domestic wells. SWRCB's Surface Water Ambient Monitoring Program (SWAMP) and Groundwater Ambient Monitoring and Assessment Program (GAMA) can provide relevant resources to monitor water quality and trends. However, they also have limited temporal and geographic scopes. Data on groundwater levels are generally lacking or of poor quality, although efforts are being made under the Sustainable Groundwater Management Act (2014) to standardize and expand groundwater data collection and monitoring activities. In addition to data gaps, the complexity of hydrologic and biogeochemical processes presents another challenge in drawing clear relationships between the drought and water quality issues. More attention should be given to determining these linkages, especially in relation to drinking water supplies, to protect communities from unsafe drinking water.

Water quality issues have been shown to disproportionately affect minorities and residents of lower socio-economic status for community water systems that are subjected to federal and state drinking water regulations. (Balazs et al. 2012) found that community water systems serving predominantly low-income and socially disadvantaged groups have high arsenic levels in drinking water and are more likely to receive a Maximum Contaminant Level (MCL) violation.

1,571 (42 percent) in Tulare County alone (Figure 1-2). In Tulare County, these numbers generally reflect households that needed deliveries of bottled water and tanks of non-potable water hooked up to their plumbing. Typically, households that could resolve the problem on their own by drilling or deepening a well did not report a shortage to the county (A. Fencl, PhD Student, UC Davis, personal communication, Dec. 13, 2016). A list of all shortages by county is provided in Appendix 1C.

Figure 1-2.

Household Water Supply Outages Reported by County



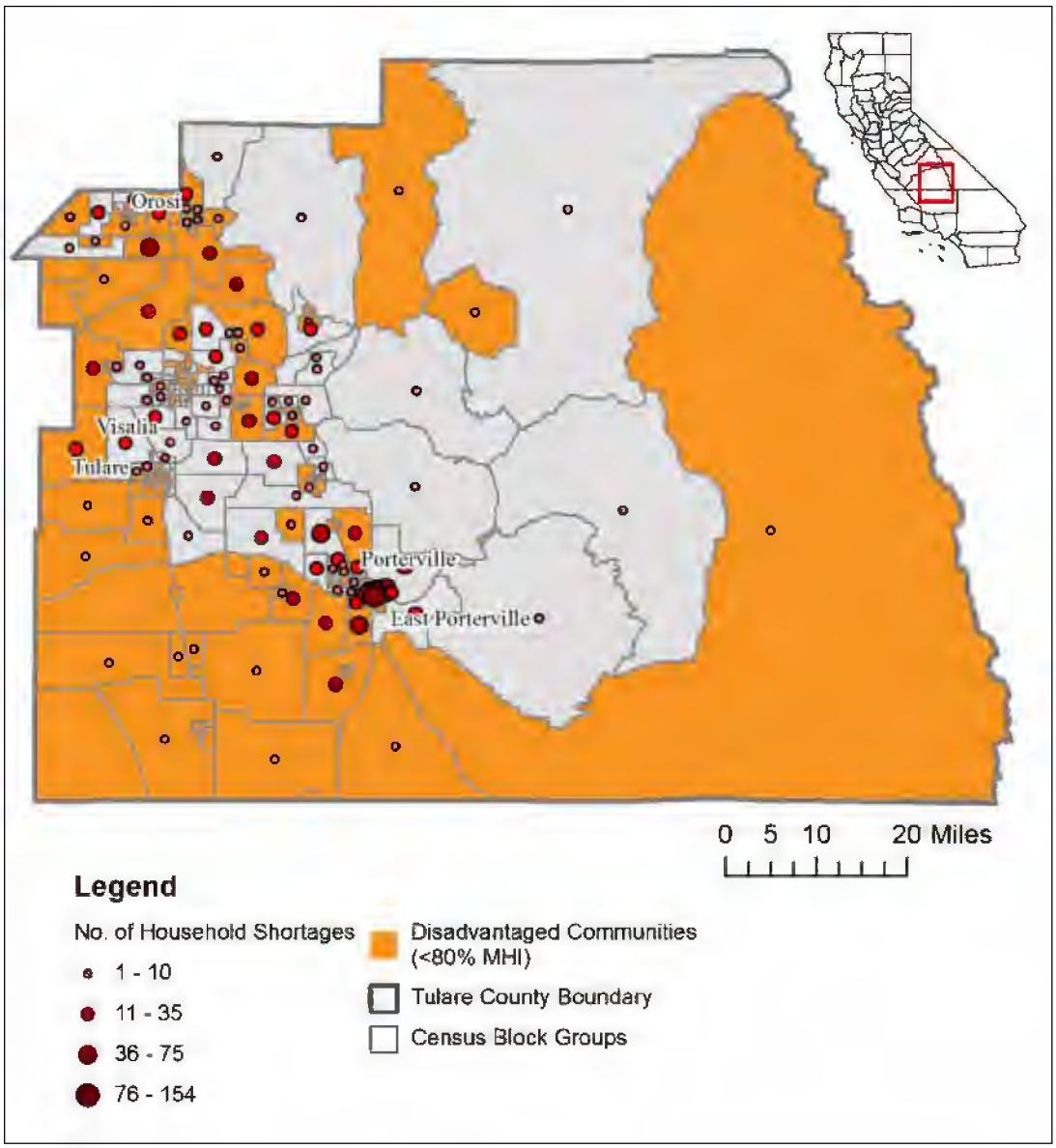
Notes: Map shows cumulative reports of household water supply shortages by county from July 2014 to August 2016. Counties with "no reports" may represent zero shortages, or simply a lack of data collection and reporting. Households reported dry wells and surface water supply shortages. Figures include active outages, active supply problems, resolved outages, and outages where interim solutions have been implemented. Only eleven counties report interim and/or permanently resolved outages.

Source: Reproduced from the State of California Household Water Supply Shortage Reporting System (State of California 2016).

For Tulare County (the only county for which detailed data are available), we mapped the number of reported shortages (Figure 1-3). The outages all occurred in the western and central portion of the county. Sixty-six percent of the reported shortages occurred in a DAC, and 89 percent occurred in a CBC. Households in DACs will likely need financial assistance to resolve their water shortage. Drilling a new individual domestic drinking water well in the San Joaquin Valley is prohibitively expensive for a low-income household, costing between $25,000 to $35,000 in 2016 (Susan Atkins, Self Help Enterprises, personal communication, July 28, 2016). Median

Figure 1-3a.

Household Water Shortages in Tulare County by DAC Block Group



Notes: Tulare County with census block groups classified as disadvantaged in orange, non-disadvantaged shown as grey. Household shortages reported to Tulare County Office of Emergency Services shown as red dots. Larger dots indicate more shortages in a census block. Dots are located at the center of the block group where the shortage(s) they represent occurred.

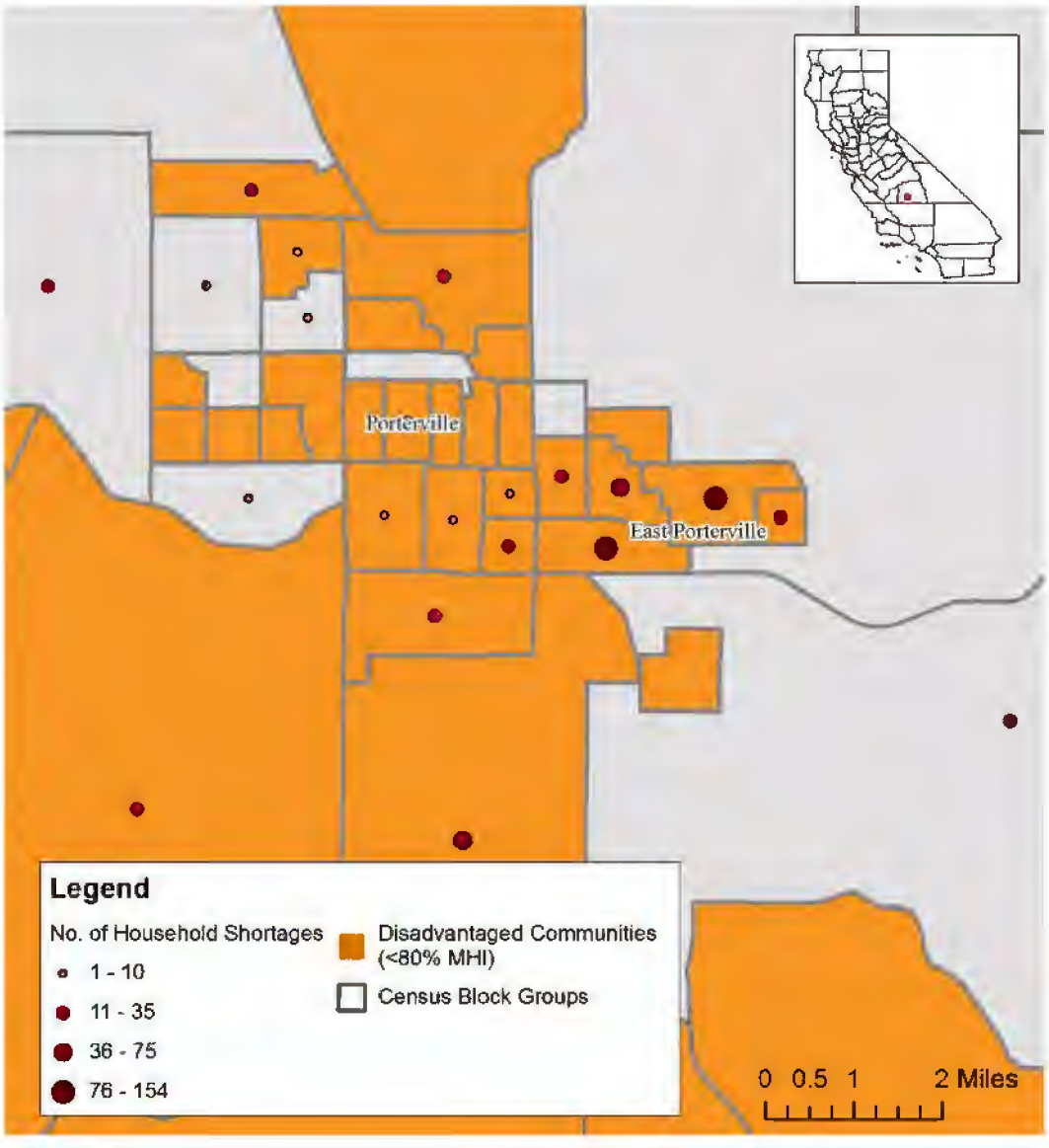
Sources: Data on household shortages from Tulare County OES (2016); data on DACs from DWR (2016a).

household income in a DAC was $49,191 in 2016 (DWR 2016a). Many of these communities are already known to be sensitive populations and to be heavily burdened by other environmental problems, underscoring the urgency of resolving their water shortages, which can aggravate public health problems (CDPH and TCHHSA, 2015).

While most reported well shortages occurred in DACs and CBCs, it is unclear what drives the pattern, and whether the link is anything but a coincidence. There are a number of non-exclusive possible causes for the clustering of shortages in central Tulare County, and their overlap with DACs and CBCs. Some possible drivers for the

Figure 1-3b.

Detail of Household Water Shortages in East Porterville, Tulare County, by DAC Block Group



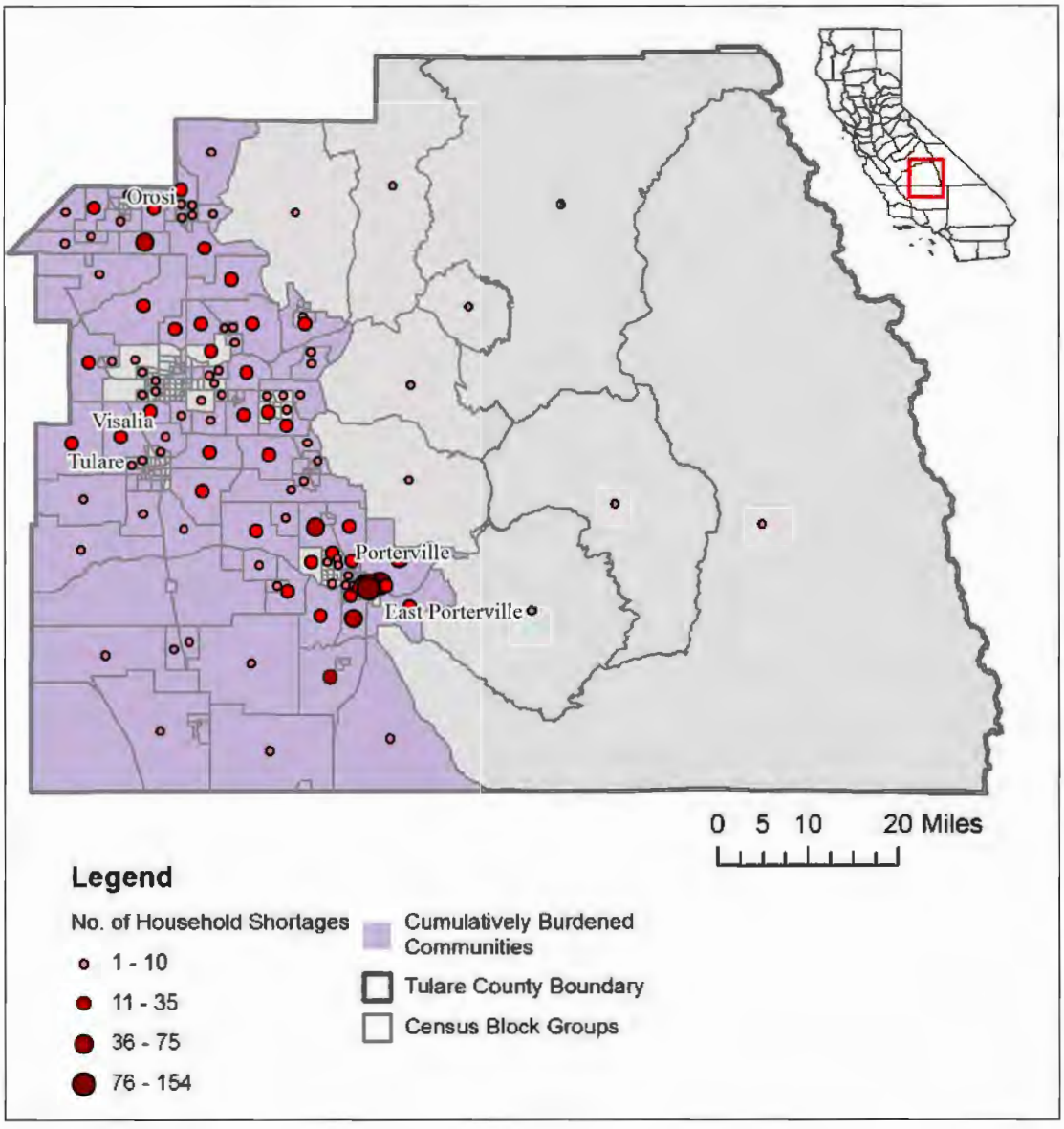
Notes: Tulare County with census block groups classified as disadvantaged in orange, non-disadvantaged shown as grey. Household shortages reported to Tulare County Office of Emergency Services shown as red dots. Larger dots indicate more shortages in a census block group. Dots are located at the center of the block group where the shortage(s) they represent occurred.

Sources: Data on household shortages from Tulare OES (2016); data on DACs from DWR (2016a).

spatial pattern of shortages are hydrogeological. Many of these wells are quite shallow and susceptible to short-term fluctuations in the water table, or tap low-permeability fractured hard rock aquifers that are vulnerable to drought (DWR 1991; Jones 2014; DWR 2016b). The clusters of shortages may simply occur in the areas with the greatest density of wells. On the other hand, there could be systematic reasons for the correlation. Low-income communities and communities of color in the Central Valley rely disproportionately on private wells because adequate public services were not developed in those communities (Bliss 2016). The outages in domestic wells may also

Figure 1-3c.

Household Water Shortages in Tulare County by CBC Block Group



Notes: Location of household shortages reported in Tulare County (red dots) and disadvantaged census block groups (purple shading). Larger dot indicates more shortages. Dots are located at the center of the block group where the shortage(s) they represent occurred.

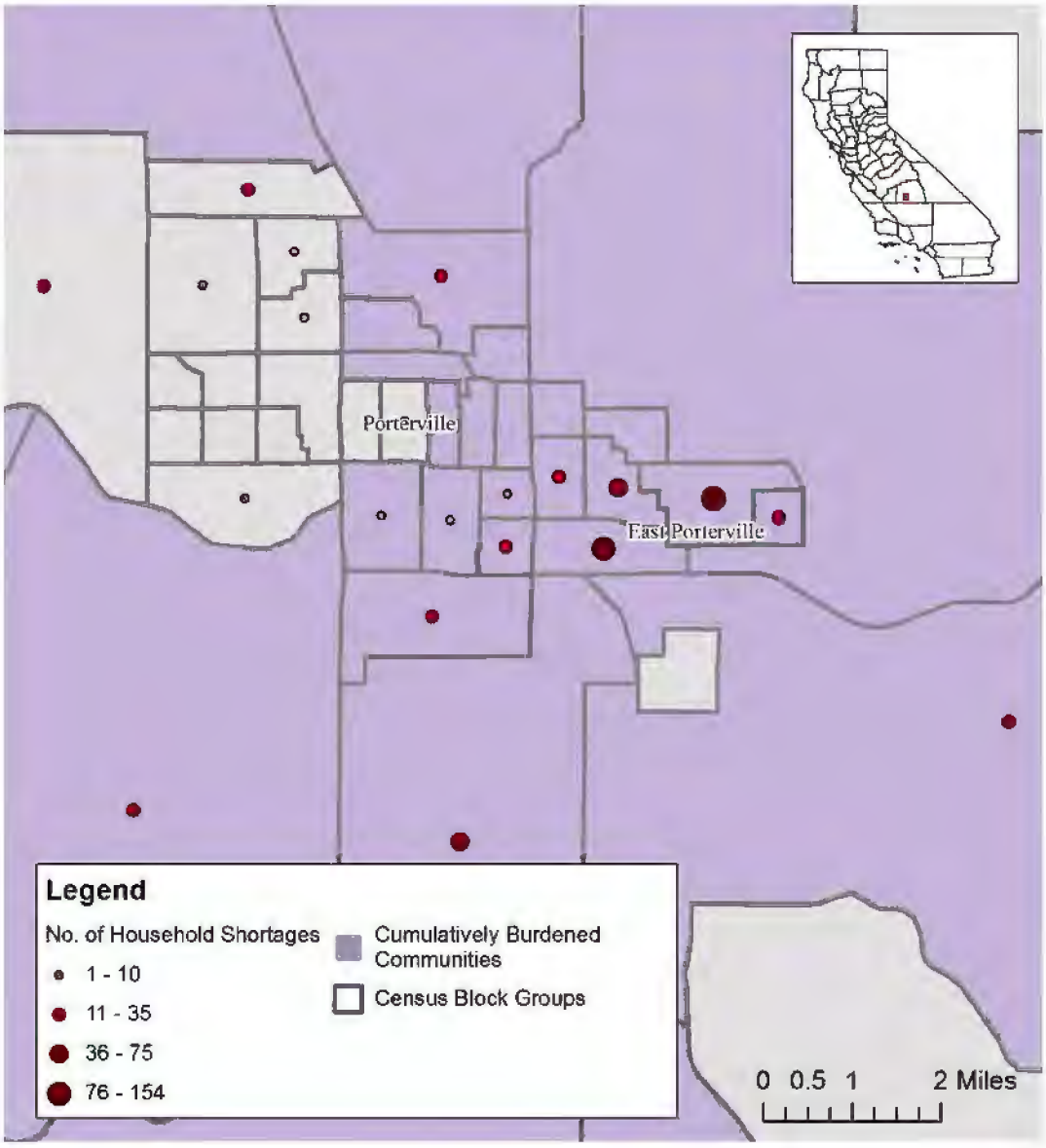
Sources: Data on household outages Tulare County OES (2016). Data on CBCs from http://www.calepa.ca.gov/EnvJustice/GHGInvest/.

be at least partially caused by rapid pumping by deeper irrigation wells.

Reporting bias could also be a factor: residents typically reported a shortage when they were seeking bottled and hauled water deliveries; those with the financial means to resolve their water shortage were less likely to report a shortage. To fully understand the drivers of household outages would require a complex study beyond the scope of this report.

Figure 1-3d.

Detail of Household Water Shortages in East Porterville, Tulare County, by CBC Block Group



Notes: Location of household outages reported in Tulare County (red dots) and disadvantaged census block groups (purple shading). Larger dots indicate more shortages in a census tract. Dots are located at the center of the block group where the shortage(s) they represent occurred.

Sources: Data on household outages in Tulare County from OES (2016). Data on CBCs from http://www.calepa.ca.gov/EnvJustice/GHGInvest/.

Conclusions and Reccomendations

We found 149 public water systems, serving an estimated 480,000 people, reported drought-related impacts to their supplies. These systems were concentrated in the southern San Joaquin Valley, as well as the North Coast and Central Coast regions. We estimated that approximately two-thirds of these public water systems served a DAC, and one-third served a CBC. Of the nearly 4,000 shortages in households served by non-public water systems, most were concentrated in the San Joaquin Valley, with 42 percent of the reports in Tulare County. Of the shortages reported to the county, 66 percent were in a DAC, and 89 percent were located in a CBC. Our findings demonstrate that, while they were concentrated in the San Joaquin Valley, shortages in both public and non-public systems were more widespread geographically in the state than has been represented in media reports. Supply problems during the drought were frequently found in DACs and CBCs, suggesting that in many cases these systems have insufficient capacity to resolve their problems without outside technical, managerial or financial support. We recommend that the state undertake a more uniform, thorough effort to document which public and non-public systems experienced near or actual supply shortages. This data would allow an analysis of the characteristics that made systems more vulnerable to drought, and inform efforts to improve future resilience.

RECOMMENDATIONS TO IMPROVE DROUGHT RESILIENCE OF DOMESTIC WATER SUPPLIES

Mitigating Impacts of Drought on Domestic Water Supplies for Communities

1-1. Establish a Quantitative Metric for Measuring Supply Reliability in Public Water Systems

Assessing supply reliability is an important step in identifying public water systems that need improvements to prevent shortages in future dry years. The data to inform a quantitative "supply reliability" metric should be collected for all public water systems. At present, there is relatively little scrutiny on supply reliability for water systems too small to meet Urban Water Supplier[5] reporting requirements, even though smaller suppliers struggled most during the drought. Data collected and quantified should include at least the following:

- Predicted production to demand ratio in an average year, as well as droughts lasting one, three, and five years.
- Any recent shortfalls in supply that resulted in an inability to deliver enough water for consumption, cooking, and sanitation to residential customers, drops in pressure or outages, or water hauling, along with the dates of any such events, and the volume of the shortfall.

1-2. Require Water Shortage Contingency Plans of All Public, State Small[6], and Local Water Systems[7]

Small and rural communities tend to be the most vulnerable to drought, yet often lack comprehensive plans to cope with the impacts. At present, only urban water suppliers are required to prepare and file water shortage contingency plans with DWR and stress tests with the SWRCB. We recommend that the state require all public water

5 Urban Water Suppliers are defined as "providing water for municipal purposes either directly or indirectly to more than 3,000 customers or supplying more than 3,000 acre-feet of water annually." (CA Water Code Section 10617). Urban Water Suppliers report information on supply reliability under the SWRCB's Emergency Urban Water Conservation Requirements, as well as DWR's Urban Water Management Plans.

6 A State Small Water System has 5-14 service connections and does not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year.

7 A Local Water System has 2-4 service connections.

systems to file water shortage contingency plans, and that the state provide technical and financial assistance as needed in preparing the plans. At the regional level, counties should draft a water shortage contingency plan template appropriate for state small and local water systems and require the systems within their jurisdiction to modify the plan as necessary and adopt it. The IHS' California Area Office's work with tribal water systems to develop drought contingency plans can serve as a model of how to work with small water systems to develop water shortage contingency plans.

1-3. Increase Oversight of New Wells

Thousands of households reliant on private wells and surface diversions lost access to water during the drought, while those with the resources to drill deeper wells continued to pump groundwater at record-breaking rates. Counties should place restrictions on new well permits in basins where domestic water wells are at risk of outages. The Sustainable Groundwater Management Act begins to go into effect for high and medium priority basins subject to critical conditions of overdraft in 2020, and for other high and medium priority basins in 2022. Until then, counties, in collaboration with other well-permitting authorities, should exercise their authority to regulate groundwater use by issuing permits on the condition that the applicant demonstrate that water is available to serve the well.

Further Study and Data Collection on Domestic Water Shortages

1-4. Collect Information on Well Depth from Drilling Permit Applications

At present, well permits collected at the county level do not always include well depth information. Including this information would enable county officials to flag and require modifications to drilling plans for new wells likely to overdraft an aquifer that supplies domestic wells.

Shortages in both public and non-public systems were more widespread geographically in the state than has been represented in media reports.

1-5. Systematically Collect Data on Private Supply Shortages

We know from voluntary reporting compiled by the state[8] that there have been thousands of private domestic well shortages and surface diversions during the ongoing drought. However, the data set on private supply shortages is incomplete and inconsistent because reporting is voluntary and handled differently across counties. We recommend that the state develop a mandatory, standardized system for reporting private supply shortages to the counties that can be compiled into a statewide dataset. Likewise, the U.S. EPA and IHS should collect data on shortages in private well and surface diversions on tribal lands.

1-6. Identify Geographic Areas at Risk of Groundwater Supply Shortages

High-quality data on household outages would enable an analysis of the causes of wells shortages or failures. Factors to consider are the rate of groundwater decline, the type of aquifer, the proximity, depth and demand of nearby wells, and nearby land uses. A more complete understanding of the causes of well outages and failures could enable predictions of where future outages are

8 See the State of California Household Water Supply Shortage Reporting System at https://mydrywatersupply.water.ca.gov/report/publicpage.

likely to occur, and allow proactive planning to find reliable water sources before shortages occur.

1-7. Identify Public Water Systems at Risk of Future Supply Problems

Can we identify characteristics of public water systems that made them more likely to experience supply impacts during the ongoing drought? In various reports and media outlets, observers have pointed to myriad factors such as system size, region, groundwater versus surface water, diversity of supplies, and ability to transfer water from other systems as indicators of drought resilience. We recommend a rigorous assessment of the common factors in systems that experienced supply impacts during the ongoing drought. This can inform further discussion about systems likely to experience problems in the future, and how to prevent shortfalls.

1-8. Identify Areas with High Potential for Consolidation or Extension of Service

The SWRCB has supported voluntary system-level consolidations, and as of 2015 has the authority in certain circumstances to mandate consolidations. High-quality data on public water systems that experienced supply problems and private supply shortages would enable the state to identify areas that could benefit the most from consolidation, either by connecting many households reliant on private wells or surface diversions into a new public water system, or by connecting them to an existing public water system that has the capacity to serve them.

SECTION 2.
DROUGHT CHARGES AND WATER AFFORDABILITY

OVERVIEW

Affordability is a central element for ensuring basic access to water—a human right recognized by the state of California—yet many Californians struggle to pay their water bills. Studies in select regions of the state have found that the cost of water for 20 to 50 percent of households with average water use exceed the U.S. Environmental Protection Agency's affordability thresholds for water and wastewater (Christian-Smith et al. 2013; United States Conference of Mayors 2014). Rising water costs are exacerbating water affordability concerns. Hanak et al. (2014) found that water bills in California's urban areas increased two to three times faster than inflation between 2000 and 2010 to cover infrastructure and other system costs. To make matters worse, Proposition 218, a ballot measure approved by California voters in 1996, prevents publicly-owned water utilities from using water-rate revenue to subsidize low-income customers (Box 2-1).

Water rates tend to rise during a drought, worsening affordability concerns. Costs may increase, for example, if a water utility must purchase more expensive drinking water supplies, install or upgrade treatment technologies for lower quality water, or pump groundwater from greater depths. For example, the East Bay Municipal Utility District drew from a more expensive emergency supply in both 2014 and 2015 (Figueroa 2014; Figueroa 2015). Administering conservation programs can also increase costs for utilities. As water use declines during the drought, water sales may become insufficient to cover the utility's operational costs, most of which are fixed. In response, water utilities may implement temporary drought surcharges, fees, and/or penalties to help cover their costs.

Raising rates or charging additional fees during a drought has important benefits, as it maintains the financial viability of water utilities, and can be an effective means of incentivizing conservation and efficiency. On April 1, 2015, following the lowest Sierra snowpack ever recorded, Governor Jerry Brown issued Executive Order B-29-15, which established a mandatory statewide water conservation target of 25 percent. It also stated:

> *"The Water Board shall direct urban water suppliers to develop rate structures and other pricing mechanisms, including but not limited to surcharges, fees, and penalties, to maximize water conservation consistent with statewide water restrictions."*

While raising per-unit costs is a key component of drought response plans for water utilities, it is nonetheless important to consider the potential equity impacts of raising water prices. Fixed

increases in water costs represent a greater proportion of the annual income for low-income households. High water bills may interfere with a family's ability to pay for other necessities, or cause them to fall behind on their water bills. Late charges can accumulate, or worse, utilities can shut off service for lack of payment. Service disconnections are three times more likely to impact the lowest income households than the average household (Cromwell 2010). Lack of water can lead to health problems, loss of custody of one's children, eviction and foreclosure, and even criminal charges (Jones and Moulton, 2016).

Low-income households tend to use less water, so designing rates, and drought charges, to keep costs low for low-volume users will benefit most low-income households (Mayer et al. 1999; Mini 2013; Rubin 2005). However, there are some complicating factors at play. First, low-income households tend to have more members, and thus larger water bills despite having relatively low per-person use (Saunders 1998). Second, other researchers have argued that low-income customers face financial challenges in upgrading their homes to be efficient, and therefore may be unable to keep their water use low (Cromwell 2010). Repairing leaks and upgrading fixtures and appliances is costly. Furthermore, many low-income customers are renters without the authority to alter their homes.

In this section, we examined available data on drought charges imposed in 2015, including information on the structure of those charges. We evaluated the impact of the structure of drought charges on meeting basic water needs. We then undertook case studies on three water utilities, estimating the monthly bill, with and without drought charges, for an average-size household using 55 gallons per capita per day (GPCD). We also examined the percentage of income that the water bill would represent for households in each of nine income brackets to understand the additional cost burden imposed by drought charges on households, some of which were already paying unaffordable rates.

While increasing costs is a key component of drought management, it is important to consider the equity impacts of raising prices.

METHODS

There are varying definitions of what constitutes affordable water. A common approach adopted by regulatory agencies has been to compare the average residential water bill to the median household income (MHI) for a given region. The California State Water Resources Control Board (SWRCB) uses average residential drinking water costs in excess of 1.5 percent of median community household income as a threshold for affordability, while the U.S. EPA uses a threshold of 2.5 percent (U.S. EPA 1998; SWRCB 2016b). This approach is referred to as "macro-affordability" because it gives a sense of average affordability for an entire region without assessing the burden of water bills for sub-groups within that region. Some have criticized the macro-affordability approach because it masks the cost of water for those that deviate from average income or water use. By contrast, micro-scale indicators of affordability disaggregate households by income group, family type (e.g., household size), or geographic sub-region (Herrington 2003). Past work in California has assessed affordability across the range of income levels within a region (United States Conference of Mayors 2014; Christian-Smith et al. 2013). Others have called for researchers to look at actual, rather than average, water bills by

income, because income is negatively correlated with water use (Osann 2016). To our knowledge there has not yet been an analysis in California that parses out affordability for different water use levels by income or household size.

For this report, we sought to keep our analysis of affordability consistent with earlier work by the SWRCB while addressing some of the criticisms of traditional affordability metrics. Given that this report focuses on California, we used the SWRCB's definition of affordable water as 1.5 percent of household income. However, rather than looking at affordability for median-income households, we divided single-family households into nine income brackets. Additionally, rather than basing water bills on average water use, we estimated water bills, with and without drought charges, for meeting basic water needs (defined below). This approach is a useful starting point to observe how additional charges imposed during drought altered costs for low-income households, and how those charges can be structured to incentivize conservation while minimizing impacts on low-income customers for basic water needs.

As with affordability, there is no single definition for the volume of water necessary to meet basic water needs. The California Human Right to Water declares that all humans have a right to water adequate for human consumption, cooking, and sanitary purposes (CA Water Code § 106.3). In their resolution adopting the Human Right to Water as a core value, the SWRCB pointed to two numbers in California laws and regulations: "The Water Efficiency Act of 2009 identifies 55 gallons per capita per day as a provisional conservation standard for 'indoor residential water use' by 2020" (Wat. Code, § 10608.20, subd. (b)(2)(A)). Similarly, a prior SWRCB emergency regulation established an exemption from a prohibition on diverting water, under specified circumstances, up to a maximum of 50 gallons per capita daily in order to meet 'minimum health and safety needs' (Cal. Code Regs., tit. 23, § 878.1, subds. (a)-(b) [operative March 30, 2015 and repealed Dec. 29, 2015]). By comparison, DeOreo et al. (2011) found that mean indoor household use in California was 63 GPCD in 2007-2009. Other studies suggest that homes equipped with high-efficiency appliances and fixtures would use between 32 GPCD (Heberger, Cooley, and Gleick 2014) and 36 GPCD (DeOreo et al. 2011). Table 2-1 reviews select standards and studies on indoor water needs.

For this report, we defined 55 GPCD as a reasonable volume for meeting basic water needs, based on the indoor water standard established by

Table 2-1.

Indoor Water Benchmarks—How Much Water Do People Need for Indoor Uses?

Gallons Per Capita Per Day (GPCD)	Description	Source
63	Mean water use in a sample of 700 homes in 10 service areas in CA from 2007-2009	DeOreo et al. (2011)
55	Provisional conservation standard for 'indoor residential water use' by 2020	CA Wat. Code, § 10608.20, subd. (b)(2)(A)
36	Mean water use in homes built with best available technologies as of 2010 for toilets, clothes washers, showers, and faucets	DeOreo et al. (2011
32	Theoretical water budget for home built using efficient appliances and fixtures and no household leaks	Heberger et al. (2014)

the California Water Efficiency Act of 2009. This is lower than the average per capita residential water use reported in DeOreo et al. (2011), but more generous than the efficient benchmarks identified by DeOreo (2011) and Heberger et al. (2014).

Structure of Drought Charges

Incomplete data are available on the number of water utilities that have instituted drought charges. We obtained state-collected data on surcharges, fees, and penalties from the SWRCB's 2015 Large Water System Electronic Annual Reports (LWS EAR) (SWRCB 2015a). The LWS EAR are annual reports from public water systems with at least 999 service connections. The 2015 database had records for 731 public water utilities (out of the 8,302 total public water systems in the state listed in the State Drinking Water Information System). All but 10 were community water systems.

In 2015, the report questionnaire asked water utilities two questions that provide some insight on drought charges: "Do you have other surcharges?" and if so, "What are the other surcharges?" The 2015 LWS EAR contained 725 answers to the question. Of these, one-third stated that they had other surcharges and used terms such as surcharges, fees, and penalties to describe them. We did a keyword search for the term "drought" in the surcharge description and found 28 water utilities that reported imposing a drought charge. We believe this is only a sample of water utilities that imposed drought charges and not a complete count. For the 28 utilities reporting drought charges, we used the water utilities' websites or contacted them via phone to determine the structure of the charges. We made up to four phone calls to a supplier and were able to obtain the relevant information for 27 of the 28 utilities.

Given that the structure of drought charges varied widely by utility and customer type, we focused on drought charges imposed on single-family households and categorized each system according to how the utility determined the minimum volume of water at which to add an additional drought charge. Our goal was to determine whether households using less than 55 GPCD would pay drought charges in each service area. The classifications we used were:

a. Threshold type (fixed or customized): Whether the threshold volume for paying a drought charge was fixed or customized according to estimated household needs. In addition, there were two types of customized thresholds:
   i. Customized by household size: The threshold was calculated based on the number of residents in the household;
   ii. Customized by prior use: The threshold was calculated as a percentage of prior use (e.g. every household was asked to reduce their pre-drought water use by a given percentage).

b. Threshold volume: The monthly threshold volume of water at which a customer paid a drought charge.

In cases where billing was bimonthly, we divided the threshold for imposing a drought surcharge by two to make it comparable with those utilities billing on a monthly basis. The results of our survey were then used as the basis for an assessment of the impact of drought charges on affordability.

Impact of Drought Charges to Affordability

Of the 27 water utilities for which data are available, we provide detailed case studies for three. We chose the two utilities with the greatest proportion of their service area in a Disadvantaged Community (DAC): Elsinore Valley Municipal Water District and the City of Glendale Water and

Power.[1] For comparative purposes, we selected at random one of the two utilities that had none of its service area in a DAC, the City of Benicia.

For each supplier, we estimated the water bill for a single-family household using 55 GPCD with and without drought charges for the main city that they serve. We used the data from the United States Census Bureau (United States Census Bureau 2010; United States Census Bureau 2014) to find mean household size and household income for the Cities of Lake Elsinore, Glendale, and Benicia, and calculated monthly indoor water needs for that household. Table 2-2 summarizes this information.

Using the University of North Carolina, Chapel Hill Water & Wastewater Residential Rates Affordability Assessment Tool (UNC—Chapel Hill Environmental Finance Center 2016), we estimated the proportion of income a mean-size single family household would pay to meet monthly indoor water needs, and compared the water bill to household income in nine income categories, ranging from below $10,000 to more than $150,000 annually. We then calculated how drought surcharges affected the percentage of income spent on water for the three lowest income brackets ($24,999 annual income and below). We reported the mean change in the cost of paying for monthly indoor water needs along with the standard deviation.

RESULTS AND DISCUSSION

Structure of Drought Charges

The 27 utilities for which we obtained data were all community water systems and were distributed across 11 counties. They were broadly dispersed geographically, but none were north of Sacramento County. One-third offered lifeline rates or low-income subsidies. Detailed information on drought charges for the utilities surveyed is provided in Appendix 2A.

1 DACs are areas with a median household income less than 80 percent of statewide median household income.

Table 2-2.

Characteristics of Cities Profiled in Affordability Case Studies

	Lake Elsinore	Glendale	Benicia
Population[1]	51,821	191,719	27,450
Number of Households[2]	14,788	72,269	10,686
Median Household Income ($)[3]	63,303	52,451	89,094
Mean Household Size[2]	3.48	2.63	2.52
Basic Household Monthly Water Use (in gallons)[4]	5,800	4,400	4,200
Water Supplier	Elsinore Valley	Glendale City	City of Benicia
Public Water System ID	CA3310012	CA1910043	CA4810001

1. Data from 2010-2014 ACS: 5-year average.
2. Data from 2010 Census: Households and Families.
3. Data from 2014 ACS.
4. Calculated as 55 GPCD × mean household size.

Among the 27 utilities surveyed, we identified four categories of drought charge structures. Table 2-3 summarizes the types of drought charges found in our sample. Those with low, fixed thresholds raised costs for everyone, regardless of the volume of water use. The exact threshold was set at either 0 gallons per month or 750 gallons a month (1 CCF), presumably because 750 gallons is the minimum sensitivity of the water meter. In this case, all customers paid an additional drought charge. Those with high, fixed thresholds raised costs for those households using more than a given volume of water. The minimum volume ranged from about 6,000 to 9,000 gallons (8-12 CCF) per month, depending on the utility. In this case, households with large total water use—such as households with many members—experienced a rate increase. The third category of drought charges had customized thresholds based on prior use—that is, water prices went up unless the household reduced their water use by a given percentage. In this case, households that cut water use sufficiently avoided drought charges. The fourth category has a customized threshold based on household size, raising costs for water use only if per-person household use was high. This is also referred to as a budget-based approach for drought charges.

Understanding how the various drought charge structures will affect water bills for low-income customers is complex because it depends on multiple factors. Figure 2-1 demonstrates the interaction between drought charges, household size, and household income across three types of drought charge structures. We held per-capita water use constant to show how the various drought charge structures would raise costs by different amounts for households using the same amount of water per person. The first scenario shows the cost of water with an additional drought charge of $2.02 on every 750 gallons (1 CCF) (Figures 2-1a&b). The second scenario (Figures 2-1c&d) shows the cost of water if drought charges were levied only on households using at least 7,500 gallons (10 CCF) a month. Figures 2-1e&f show the cost of water if drought charges were levied only on households using more than 55 gallons per household member.

Fixed-threshold drought charges aggravated affordability concerns for low-income customers, and the effect is more pronounced for large households. Only utilities that customized the minimum threshold for levying a drought charge by household size avoid raising rates for large, efficient households with high total usage.

Table 2-3.

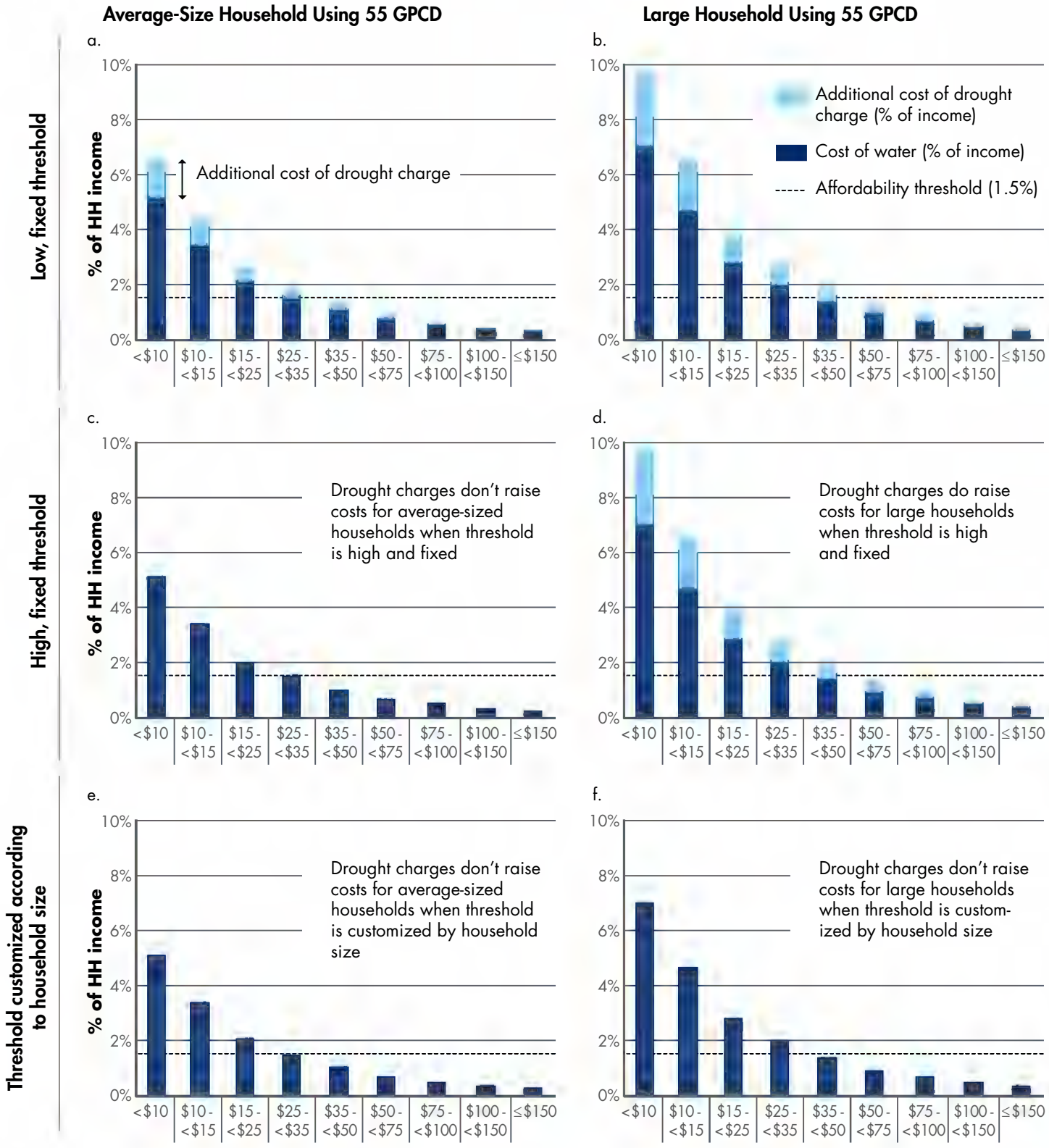
Four Types of Drought Charge Structures

Threshold Type	Volume Threshold	Change to cost of basic water needs	Num. of Utilities (%)
Low fixed threshold	750 gal (1 CCF) or less per month	Increased	15 (56%)
High fixed threshold	5,980-8,980 gal (8-12 CCF) per month	Increased for large households	5 (19%)
Customized threshold based on prior use	70% of household's Summer 2012 or Winter 2013 monthly use	Increased if the household already had relatively low baseline of use	1 (4%)
Customized threshold based on household size	Threshold increased by at least 1,680 gal (2.24 CCF) per month for each additional person	No change	6 (22%)

Notes: Abbreviations: gal = gallons, CCF = centum cubic feet. "Basic water needs" estimated as 55 GPCD.

Figure 2-1.

Cost of Basic Water Use Under Three Drought Charges Structures Across Income Levels and Household Sizes



Notes: All households assumed to use 55 GPCD. Household income in $1,000s. Left column depicts costs for average-size households, with 2.63 members. Right column depicts costs for large (top 10 percent) of households, with 5 members. Low, fixed threshold = 750 gal/household/month. High, fixed threshold = 7,500 gal/household/month. Data parameters were based on City of Glendale water rates and population census data.

Impact of Drought Charges on Affordability

We conducted three in-depth case studies on drought charge in Elsinore Valley Mutual Water District in Riverside Count, the City of Glendale Water and Power in Los Angeles County, and the City of Benicia in Solano County. All three utilities imposed fixed-threshold drought charges on households using 0 to 1 CCF per month, increasing costs for homes using even relatively small amounts of water. The effect of drought charges on water affordability, however, depended on the price increase and household income level.

For all three utilities, average-sized households earning the median income paid less than 1.5 percent of their annual income for their basic water needs, with or without drought charges. With drought charges, they paid $85 more annually for their basic water needs, or 0.15 percent (less than 1/600th) of their annual income.

If, rather than focus on the median income, we use finer-resolution data on income, the story is more complex. Here, the proportion of income spent on water, and the impact of drought charges on water affordability, was much higher for low-income households (Figure 2-2). Without drought charges, single-family households earning less than $25,000 annually, which represented 11-26 percent of households in the three service areas, paid an average of 1.8 percent (±0.31) of their income for basic water needs. With drought charges, however, households pay 2.1 percent (±0.49) of their income on basic water needs. Drought charges had an even greater impact on the lowest-income households. For example, in the City of Glendale, an average-sized household earning $10,000 a year and using 55 GPCD would pay an additional 1.4 percent of their annual income on drought charges alone, increasing the cost of basic water needs from 5.1 to 6.5 percent of their income.

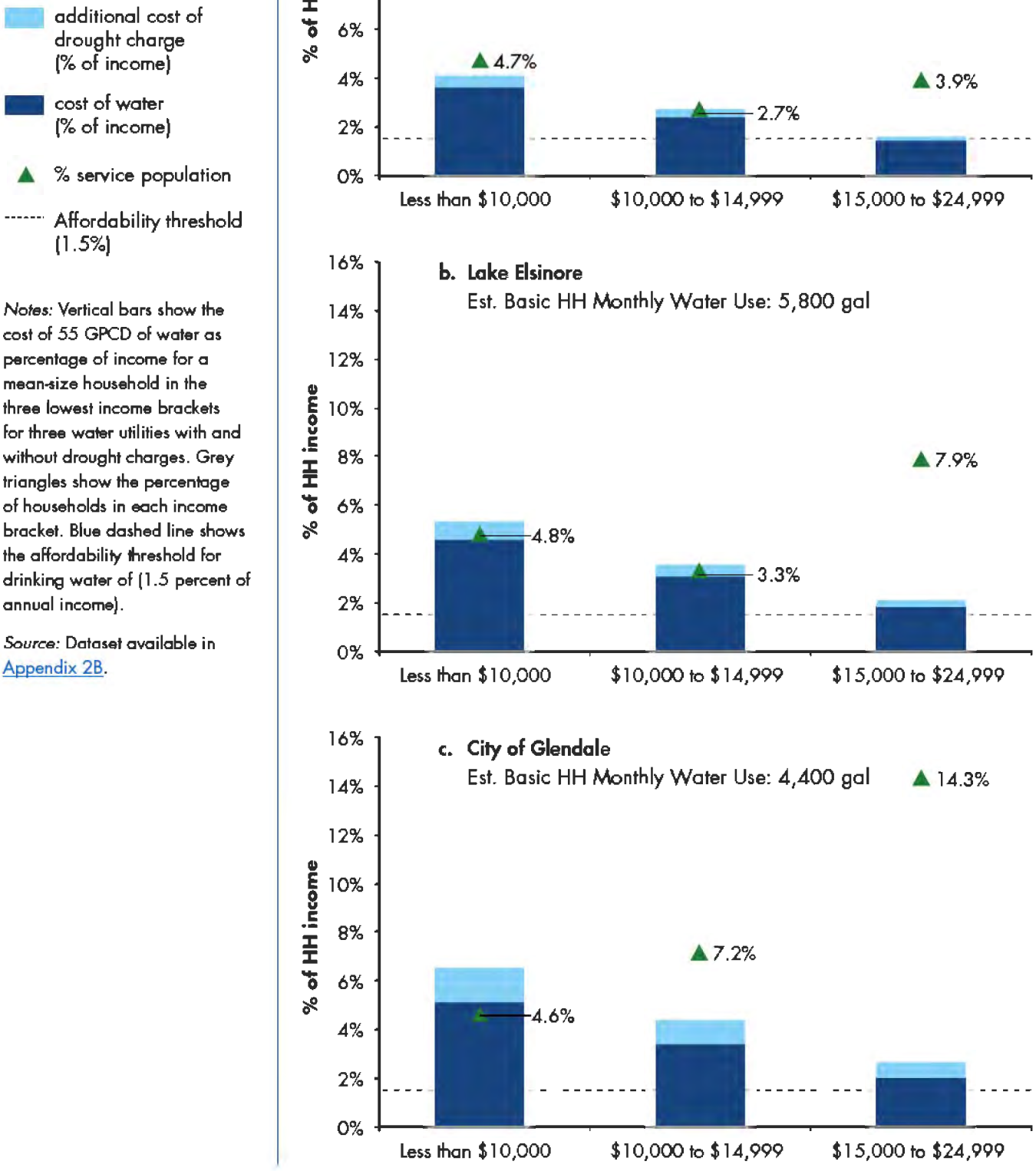
Of the three utilities, only the City of Benicia - the utility with the fewest low-income customers—offered financial assistance to low-income seniors in 2015; that program was expanded to provide a discount for all low-income customers in November 2016 (City of Benicia 2016).

Overall, drought charges raised the proportion of income that customers spent on water by a small amount compared to the baseline cost of water. However, the surcharges have a much larger impact on the lowest-income households, underscoring equity concerns. To better understand affordability, water utilities should evaluate how the rate structure affects the cost of meeting basic water needs for low-income households and the potential for drought charges to exacerbate affordability concerns.

An unfortunate limitation of the dataset is that it only represented large water utilities. Work by the California Urban Water Association (CUWA) confirms that affordability is a serious problem in urban areas, even those that appear relatively affluent based on median household income levels. In an assessment of water affordability in 2014-2015 for 10 urban water utilities in California, CUWA found that nearly 21 percent of households earned less than $25,000 annually and spent an average of 4.5 percent of their income on water (CUWA 2016). Information about affordability in rural areas of California is limited. However, Christian-Smith et al. (2013) compared affordability in the urban Sacramento metropolitan area and rural Tulare Lake Basin and found that, while water was unaffordable for a large number of low-income customers in both regions, the problem was more widespread in the rural region. Additionally, some rural customers must also purchase bottled water due to water contamination concerns, further increasing water costs.

Figure 2-2.

Cost of Basic Water Use for Low-Income Households, With and Without Drought Charges, in Three Cities.



Notes: Vertical bars show the cost of 55 GPCD of water as percentage of income for a mean-size household in the three lowest income brackets for three water utilities with and without drought charges. Grey triangles show the percentage of households in each income bracket. Blue dashed line shows the affordability threshold for drinking water of (1.5 percent of annual income).

Source: Dataset available in Appendix 2B.

Box 2-1.

Proposition 218, Tiered Water Rates, and Customer Assistance Programs

Proposition 218, adopted as a California constitutional amendment in 1996, prohibits public water utilities from charging their customers more than the cost of providing water service. In order to implement tiers, water utilities must demonstrate that the price of water at each tier is justified by the cost of providing water service to that tier. This requirement prevents water utilities from using water-rate revenue to subsidize low income customers by offering them lower rates or providing financial assistance programs. Despite this limitation, a survey of customer assistance programs nationwide found 55 such programs in California (U.S. EPA 2016). Some were investor-owned utilities regulated by the California Public Utilities Commission, and as such are not subject to Proposition 218. Others have used alternative sources of funding such as state or federal grants, private charities, and property leases (Cooley et al. 2016).

An assumption of this analysis is that customers can meet their basic water needs for consumption, cooking, and sanitation with the 55 GPCD identified as a provisional conservation standard in California statute. While several studies indicate that reducing leaks and using modern fixtures and appliances can reduce water use well below 55 GPCD, low-income customers may not be able to afford these upgrades, may lack the ready cash to take advantage of rebate programs, and, if they rent, may not have the authority to make alterations to their home. As a result, imposing drought charges on inefficient water users should go hand-in-hand with programs to assist low-income customers to reduce their water use.

CONCLUSIONS AND RECOMMENDATIONS

Drought fees, penalties, and surcharges are considered an important strategy for coping with drought—both by encouraging customers to save water, and ensuring financial stability for water utilities. They can, however, raise water affordability concerns for low-income households that must be addressed. Prior studies have demonstrated that low-income customers tend to be relatively low water users. As a result, rate structures and drought charges that keep costs lower for basic water use tend to keep costs low for the majority of low-income households. There are three promising strategies for minimizing the impacts of drought charges on water affordability: (1) impose drought surcharges on water usage above some threshold, e.g., 55 GPCD, and adjust for household size; (2) target efficiency programs to low-income households; and (3) offer financial assistance programs to offset costs for low-income households. These strategies, however, can be challenging for utilities to administer, particularly small systems that have limited technical, managerial, and financial capacity. With awareness about the equity impacts of drought charges, and technical assistance for those that need it, utilities should be able to develop drought charges that do not make basic water needs unaffordable for their low-income customers.

RECOMMENDATIONS TO IMPROVE DROUGHT COST EQUITY

Mitigating Impacts of Drought Charges on Water Affordability for Low-Income Customers

2-1. Keep per-unit water costs low for low water users during droughts

An unintended consequence of drought charges can be to increase the cost of meeting basic indoor water needs for low-income customers. To minimize the cost burden of drought charges on efficient, low-income households, water utilities should adopt drought charges that keep per-unit costs down for low water users. Specifically, we recommend that public water systems:

- Waive drought charges on water consumed at or below the amount necessary to meet basic water needs.
- Calculate each household's threshold for incurring additional drought charges based on household size to avoid unfairly penalizing large households (commonly referred to as variances).

2-2. Target conservation and efficiency programs to low-income customers

Water utilities should offer conservation and efficiency programs that enable low-income customers to keep their water use low enough to take advantage of cost structures that charge less per unit for low water users. These programs should include renters and residents of multi-unit homes who do not directly pay a water bill, as the cost of water is generally passed on to them through their rent or other fees. We recommend that utilities:

- Use strategies to reduce up-front costs for home efficiency upgrades to encourage participation by low-income households. Low-income customers are less likely to participate in rebate programs. They are more likely to take advantage of point-of-sale coupons on efficient fixtures and appliances, and programs to distribute or directly install efficient fixtures free-of-charge.
- Make informational materials available in multiple languages, do in-person outreach as well as send written materials, and reach out to customers who do not receive bills (predominantly renters and residents of multi-unit homes).
- Target conservation and efficiency programs to tenants by distributing free fixtures that are simple to install, such as low-flow showerheads and faucet aerators.
- Target incentive-based conservation and efficiency programs to landlords by offering incentives for building audits, rebates, or tax deductions for efficiency upgrades and leak repairs.

2-3 Develop low-income rate assistance programs within current legal constraints, and reform Proposition 218 to allow greater latitude in funding such programs

The best option for minimizing cost increases during droughts for efficient, low-income households is to design drought charges in a fashion that minimizes cost increases for low water users. If that is not possible, then a rate assistance program targeted at low-income customers can counteract price increases for households in need. Low-income rate assistance programs generally do not enroll all the qualified customers, so ideally they should be used in addition to, not instead of, equitably designed rate and drought charge structures. Under Proposition 218, public utilities cannot use ratepayer fees to fund low-income rate assistance programs. Water systems can use other sources of revenue such as leasing land or donations.

2-4. Address structural problems that prevent water systems from enacting equitable drought charge structures

Underlying issues prevent water utilities from addressing the greater cost burden placed on low-income customers by their water bills, both with and without drought charges. Our first recommendation, to keep per-unit costs low for low water users during droughts, requires that water systems have adequate technical, managerial and financial capacity. Stakeholders in government, water utilities and non-governmental organizations should collaborate to develop this capacity by:

- Installing and maintaining water meters and sub-meters for all customers of public water systems. Most low-income customers are low water users, but their bills do not reflect their actual water use if they live in areas without meters for single-family homes or sub-meters for units in multifamily buildings.
- Supporting water systems in developing equitable drought charge structures, and adding information about equitable approaches to drought charges to existing state programs that provide technical education for small water systems. Small water utilities need greater technical capacity to develop more complex, equitable drought charges such as tiers, variances for large households, and bill discounts for low-income customers.

Further Study and Data Collection on Drought and Affordability

2-5. Collect and analyze data on how to target hard-to-reach customers such as renters and residents of multi-unit buildings.

Designing financial assistance and efficiency programs to effectively serve renters and residents of multi-unit buildings is challenging. Better understanding how existing programs have managed to target these hard-to-reach customers could inform best practices going forward.

2-6. Determine if low-income households have less efficient fixtures and appliances, or more leaks, and therefore use more water to meet their basic needs.

The energy sector has provided ample evidence that low-income customers are more cost-burdened, mainly because they use more inefficient household appliances. This research has galvanized efforts to improve energy efficiency in low-income homes because it benefits the customer and the environment. Similar research is needed in the water sector.

2-7. The state should collect complete information on drought surcharges, fees, and penalties.

Present data collection is limited in the type of water utilities reporting data, and, given the improbably small number that reported drought charges in 2015, it seems nearly certain that even among utilities that submit an LWS EAR, most are not reporting their drought charges.

2-8. Publicly release a complete, accurate map of all public water systems in the state

A complete map of water system boundaries would enable non-government entities to assess the cost of water in relation to local income levels.

SECTION 3.
DROUGHT IMPACTS ON SALMON FISHERIES

OVERVIEW

Reports of drought impacts on California's fishing communities have been relatively limited. Many still frame water problems in California as "fish versus farms" or "humans versus ecosystems" (for example, Pollak 2016; Abcarian 2016). However, fish are essential to the well-being of communities that rely on them for food and income. We highlight salmon in this analysis due to its economic and cultural importance in many California riparian and coastal communities. A particular focus is given to the fall-run and Klamath spring-run Chinook salmon, which are the only remaining taxa that can be managed as a fishery. To examine the equity issues tied to drought impacts on salmon, we analyzed trends in the performance of commercial and tribal fisheries over the past several decades.

Ultimately, the current drought is not the only cause of the decline of California's salmon fishery; after all, salmon have coped with periodic droughts throughout their evolutionary history. However, salmon populations likely face greater difficulty surviving and rebounding from droughts given the barriers to migration to colder stretches of the river, loss of habitat, competition from non-native species, and water quality degradation (for example, Zeug et al. 2011; Jones and Nguyen 2010). In 2008, the United States District Court for the Eastern District of California issued a ruling that California water systems place wild salmon "unquestionably in jeopardy" (Jones and Nguyen 2010). Improving conditions for California's salmon, and the well-being of the communities dependent on them, will require improving management responses during short-term drought emergencies while addressing the underlying problems of habitat alteration and degradation, water allocation for the environment, and inequitable fishery access.

Salmon Natural History and Status in California

Many California rivers are breeding grounds for salmon. Chinook salmon (commonly known as King salmon) is the most abundant species in California and off its coast, but Coho, Pink, and Chum salmon are also found within the state. Chinook salmon are further divided into populations referred to as runs that migrate and breed during different seasons—namely fall, late-fall, winter, and spring, reflecting the long history of adaptation to California's seasonal flows (Hanak et al. 2011).

Salmon are an anadromous fish that spend part of their life in freshwater and the other part in the ocean. When salmon grow into small fish, they

undergo a physical change, or "smolting," to survive in saltier water as they move downstream to estuaries, where ocean water blends with freshwater and food is abundant. Those born in California rivers typically migrate to the ocean in their first few months of life, while some linger behind until they are over a year old (Fry 1979). In the ocean, salmon may stay relatively close to the mouth of the river in which they were born or swim long distances to find another feeding ground. After two to five years at sea, mature salmon return to their native river to spawn and die, with most returning at age three.

Interacting environmental and human-related factors influence annual fluctuations in salmon abundance. For example, the survival and growth of salmon can be greatly affected by changes in freshwater flows, which in many cases are regulated by upstream dams (e.g., Shasta Dam on the Sacramento River). These flows, in turn, affect water temperature, availability of floodplain habitat, water turbidity, interactions with predators and competitors, and the ability of mature fish to migrate to spawning grounds. Sufficient flows of water during migration periods are crucial for both outmigration of juvenile salmon downstream and migration of mature salmon to spawn upstream. Temperature is a key factor affecting survival of salmon at every life stage. The optimal temperature for eggs and fry is about 48 to 55 degrees F. Smolts can thrive in warmer waters, optimally about 50 to 66 degrees F (McCullough 1999, cited in Moyle, Israel, and Purdy 2008, 127-128). Other water quality parameters, including dissolved oxygen, pH (Carter 2008), and turbidity (Bash, Berman, and Bolton 2001), are also important determinants of salmon growth and survival.

Historically, salmon are remarkably abundant and widely distributed in California, from the Central Valley up to the northern region and as far inland as the Sierra Nevada and Eastern Cascades (Myers et al. 1998). The Sacramento and San Joaquin river systems are California's largest salmon-producing rivers on the West Coast, followed by the Klamath River (Fry 1979; Rankel 1982, cited in Hardy, Addley, and Saraeva 2006). As recently as the 1930s, California's residents observed spawning salmon so thick that they looked like a sheet of silver glass as far as the eye could see (Levene et al. 1976, cited in NMFS 2012).

Dams now block Central Valley Chinook salmon and steelhead from over 90% of their spawning habitat.

However, the salmon population has declined drastically over the past century, and many salmon taxa are heading toward extinction (Katz et al. 2013). Dams now block Central Valley Chinook salmon and steelhead from over 90% of their spawning habitat (NOAA 2014). For example, Coho salmon in certain reaches of the river and winter-run Chinook salmon are currently listed as endangered by the state and federal government (CDFW 2016).[1] Currently, the only salmon runs that can be harvested for subsistence, sale, or recreational purposes are the fall-run and Klamath-Trinity River spring-run Chinook salmon.[2]

A complex set of factors contributed to the widespread decline in California's salmon population. These include overfishing in the late 1800s and early 1900s (Clark 1929); extensive

1 Threatened and endangered species status may be specific to certain areas. For example, Coho salmon is listed as threatened from Punta Gorda to the northern border of California, but it is listed as endangered from south of Punta Gorda to the U.S./Mexico border. Similarly, spring run Chinook salmon is only listed as threatened for the Sacramento River drainage.

2 Commercial harvest of Coho salmon has been prohibited since 1992.

hydroelectric and irrigation development in the mid-20th century (Lichatowich 1999; Hanak et al. 2011); habitat alteration and degradation (Figure 3-1); competition for freshwater; and invasive fish species that prey on young salmon and eggs or compete with salmon for food (Moyle, Katz, and Quiñones 2011). Additionally, while salmon hatcheries—facilities that artificially breed and rear salmon—play an important role in salmon recovery and help support sustainable fisheries, there remain concerns about the hatchery's long-term impacts on wild salmon stocks from interbreeding and reductions in the genetic diversity of wild salmon (Buhle et al. 2009;

Figure 3-1.

Habitat Loss and Current Extent of Salmon-Accessible Waterways



Source: Hanak et al. (2011).



Source: ImagineGolf

Chilcote, Goodson, and Falcy 2011; Araki, Cooper, and Blouin 2009). More recently, a dramatic decline in the Sacramento River fall Chinook salmon population in 2008 and 2009 was likely due to ocean conditions (e.g., temperature and nutrients affecting food availability), an inaccurate forecast of salmon escapement, ongoing degradation of freshwater and estuarine habitats, and heavy reliance on hatchery production (Lindley et al. 2009).

RESULTS AND DISCUSSION

Commercial Salmon Fishery Trends Over Time

DECLINE OF COMMERCIAL SALMON FISHERY

California's commercial salmon fishing communities were initially established around the mid-1800s. During the gold rush, settlers recognized the rich resources of the area and salmon fishing took off (Pomeroy, Thompson, and Stevens 2010; Smith and Kato 1977). San Francisco Bay and the Sacramento-San Joaquin Delta region were the first major fishery conducted by Euro-American immigrants in the state (Yoshiyama, Fisher, and Moyle 1998). Annual catches of the early Sacramento-San Joaquin in-river fishery were 4 -10 million pounds. An early estimate of the Central Valley Chinook salmon stock was 1-2 million spawning fish annually. The depletion of runs, however, led to legislation to restrict access to the fishery in 1980 (CDFG 2001). Presently, commercial salmon fishing in California is undertaken by small troll boats, usually with one or two people. As income from salmon is typically not enough for an entire year for most fishermen, they also harvest Dungeness crab.

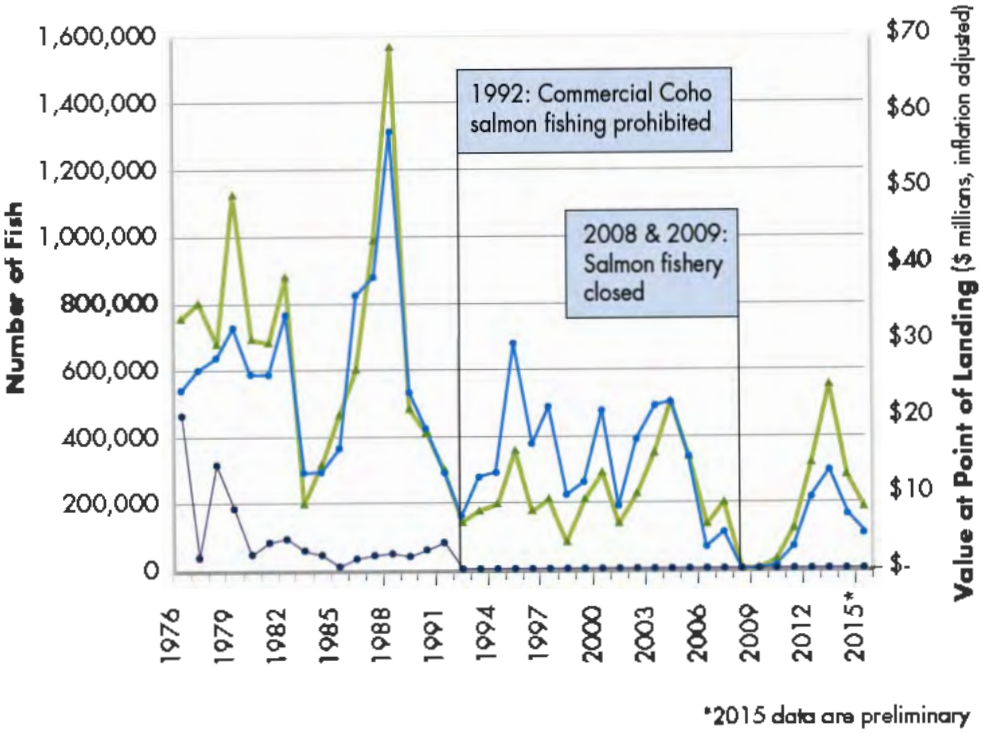
Data from the PFMC show that the number of salmon caught and landed in California has declined over the last 40 years. Between 1976 and 1980, fishermen caught an average of 830,000 fish annually. The harvest declined by 80 percent to 170,000 per year between 2011 and 2015 (Figure 3-2), a result of the fall in salmon abundance as well as regulations that limited salmon fishing to more sustainable levels.

Figure 3-2 also illustrates how the value of salmon catch to fishermen, referred to as exvessel value, has trended gradually downward over the past 30 years. For 2011 to 2015, the exvessel value averaged $13 million per year—a 64 percent decrease from the 1976 to 1980 average of $36 million per year. It should be noted that the rise in salmon prices in recent years to an average of $6.15 per pound has helped mitigate the impacts of decreased salmon catch.[3]

3 We derived the average price from the PFMC's Review of Ocean Salmon Fisheries data. All values are in 2015 dollars.

Figure 3-2.

Number and Dollar Value of Commercially Harvested Chinook and Coho Salmon.



Notes: Coho salmon is now listed as an endangered species. Commercial fishing of Coho salmon has been prohibited since 1992. The value of salmon at the point to landing is termed exvessel value. It is expressed in 2015 dollars (inflation adjusted).

Source: PFMC (2016b).

Some of the decline in harvest was related to the number of commercial fishing days and areas opened to salmon fishing. Historically, California's (unregulated) commercial salmon season ran from April through October, but the fall in salmon abundance prompted the California Department of Fish and Wildlife (CDFW) to limit the number of commercial salmon fishing days. The CDFW also limits the extent of fishing grounds and shortens the commercial fishing season in certain years to avoid unintended by-catch of listed threatened and endangered species. In 2016, the Pacific Fishery Management Council noted that "long running drought conditions, coupled with suboptimal ocean conditions, have raised serious concerns for Sacramento River winter Chinook salmon." As a result, fishing seasons south of Point Arena, California, were shortened to minimize interactions with winter Chinook. Figure 3-3 highlights the curtailment of fishing seasons during recent drought years (2014-2016), with the greatest cut of 23% in 2016 compared to the 2001-2005 average.

OTHER SIGNS OF THE FISHERY DECLINE

Due to the pressures of a declining harvest and the rising cost of entry into the fishery and fishing-related inputs (e.g., ice and fuel), many fishermen have retired their permits.[4] As a result, the size of commercial salmon fleet has decreased dramatically over time (Dave Bitts, salmon fisherman, personal communication, Oct. 19, 2016).[5] Only one-sixth of the boats with salmon permits remained in 2014 compared to 1982, two years after the permitting program started (Figure 3-4). Despite a clear downward trend in total harvest, annual gross income per boat has fluctuated dramatically with no clear trend, perhaps a result of various counterbalancing

4 The entry cost is higher than before because an aspiring salmon fisherman must find a retiring fisherman to purchase the permit from.

5 The restricted access program, which came into effect in 1980, limits the number of fishing permits available. Permits may be transferable between fishermen or vessels. Under certain conditions, permits may be transferred from retired to new vessels (CDFG 2001).

Figure 3-3.

Length of Salmon Fishing Season.

Sources: 2001 – 2005, 2014, and 2015 data from PFMC (2014) and PFMC (2016b). Table C-1. 2016 data from https://www.wildlife.ca.gov/Fishing/Ocean/Regulations/Salmon.



effects: declining salmon stock, price changes, and less competition as the salmon fleet became smaller (Figure 3-5). Gross income from salmon bottomed out in 2008 and 2009 when the fishery was closed for two seasons, but it reached a record high of $35,000 per boat in 2013.[6] High income variability affects job security and reflects the fact that it is becoming more difficult to make a living as a salmon fisherman. In Morro Bay, for example, the salmon fishing community has gotten much smaller, and the average age of fishermen has been increasing as less young people enter the fishery (Lori French, salmon fisherman, personal communication, Oct. 18, 2016). We interviewed fishermen about their personal experiences to get their perspective on the challenges facing them (Box 3-1).

The salmon fishery not only provides income for those directly participating in the industry, but also supports the local economy by driving demand for goods and services in the community. During the current drought year (2012-2015), California's total (both direct and indirect) inflation-adjusted personal income from commercial salmon fishing was $27 million (PFMC 2016b).[7] The indirect economic impacts from the salmon fishery depend on the importance of the fishery to the community's economic base and whether other economic opportunities exist during a poor salmon harvest eason. Due to data limitation, we are not able to show any local or statewide trends.[8] However, it is expected that impacts from the decline in the salmon fishery could be quite dramatic for communities that heavily rely on salmon harvest.

6 The average gross income between 2006 and 2015 was $17,000 per boat per year, not including years 2008 and 2009. The fishery closure was a result of a drastic salmon population decline due to unfavorable ocean temperature and food availability conditions, not the drought (Jones and Nguyen 2010).

7 Actual impacts will vary by community and its economic base. Direct impacts consist of personal income earned by those participating directly in the fishery, including vessel owners, crew members, and processing workers. Indirect impacts are related to services provided for the fishery, processing and recreational operations, wholesale, retail and restaurant sales of locally caught fish, fishing, harbor tourism, and income re-spent in the community (e.g., income of grocery store owners and health professionals).

8 The change in PFMC's methodology limits comparable data to the last six years. However, we cannot compare data from 2012-2015 (drought years) and 2010 or 2011 as the fishery was recovering from the closure during those years.

Figure 3-4.

Boats with Salmon Permits and Salmon Boats Landed 1960-2015.



Notes: The Restricted Access Program, which requires all salmon fishermen to have a salmon fishing permit, started in 1980.

Source: PFMC (2016b).

Figure 3-5.

Gross Salmon Income 1960-2015.



Notes: Data only include the value per boat of Coho salmon up to 1991 since Coho salmon harvest has been prohibited in subsequent years. Average income from salmon per boat is based on total exvessel value (i.e., value of salmon at the point to landing) and the number of active fishing boats. Values are expressed in 2015 dollars (inflation adjusted).

Source: PFMC (2016b).

Box 3-1. The Salmon Fishery Through the Lens of Fishing Communities

We interviewed tribal members and four fishermen to gain better insights into broader impacts of the decline in salmon harvests. Summaries of their responses are provided below.

Brittani Orona (Hoopa Valley Tribe, Northern California)

Our whole culture revolves around fish and the watershed. My grandfather likes to say that we are 'River People.' Salmon feed us physically and spiritually. We rely on them for our World Renewal Ceremony by asking spiritual beings to help keep the world in balance and maintain healthy river and fish populations. There has definitely been a change in the rivers since I was young (about 20 years ago). Water quality has gotten worse and flows have reduced. The decline of salmon comes with economic depression, but more importantly it affects our spiritual health and how we live as Hupa people.

Box 3-1 *(Continued).*

The Salmon Fishery Through the Lens of Fishing Communities

Chook-Chook Hillman (Karuk Tribe, Northern California)
Unlike the Yurok and Hoopa Valley tribes, Karuk people do not have recognized tribal salmon fishing rights, and the only authorized fishing location is at Ishi Pishi Falls. Sport fishing licenses are available for sale, but it is a burden for tribal people because they cost money and fishing, to us, is not for sports. We have malnutrition and physical and mental health issues because we cannot be tribal people—being able to continue our traditional way of life.

Dave Bitts (Fisherman from Eureka)
I started fishing about 40 years ago and half of my income on average is from salmon and the other half is from Dungeness crab. I had an epiphany a few years back about the real value of the salmon fishery. We have been consulted when a natural gas industry was going to come in and it could impact the fishery. Having fishermen around gives Humboldt people a sense of place since they can buy fish locally and interact directly with us. It's our identity and we'd be culturally impoverished without the salmon fishery.

Larry Collins (Fisherman from San Francisco)
My wife and I first started fishing in 1983/84 and we were able to raise kids and pay off our house from salmon fishing. We consider fish, crabs, and other seafood as public trust resources and more attention should be given to protecting the fish's habitats. The fishery needs three things to succeed: (1) abundance of fish; (2) market; and (3) infrastructure to move fish to land, such as port, services for fuel and ice. In a bad harvest year, fishermen must live off their savings, and some people might decide to retire altogether.

Mike Ricketts (Fisherman from Monterey)
I have been fishing commercially for 40 years. Fishermen typically have one or two fisheries that they depend on, for example salmon and Dungeness crab. When we have a good salmon season, we fish less crab, and vice versa. Fishermen with a salmon fishing permit might not choose to fish salmon in a bad year because the overhead can be about $10,000 per year to start a boat up and cover the fuel, insurance, and other costs.

Lori French (Fisherman from Morro Bay)
The fishing community has gotten much smaller in Morro Bay and it's also graying out. Fishermen are getting older and the fishery is not attractive enough for younger people to enter. Salmon fishing is so uncertain that younger people don't want to risk it. For us, we are fishermen and we do not really have a backup plan in terms of what to do besides fishing. Typically, our main source of income is 80 percent Dungeness crab and 20 percent salmon, but it was probably 60-70 percent crab and 30-40 percent salmon some 30 years ago.

Impacts of the Drought on Salmon Fishery

Drought is a natural occurrence, and salmon populations in California have survived periods of water scarcity throughout their evolutionary history. The full effects of the current drought are yet to be determined; as of this writing, salmon that hatched and migrated to the ocean during the early part of the drought are just starting to return to spawning grounds. It is likely that alterations to their habitats, migration barriers, and competing uses of water, as mentioned in the previous section, have reduced their resilience to survive extended dry periods.[9] Lower streamflows and higher water temperatures associated with the drought have reduced the amount of cold water available for salmon during key life stages, such as for hatching, migration to the sea, and spawning (Shukla et al. 2015; Seager et al. 2014). Indeed, far fewer Sacramento Chinook salmon reached the ocean during the 2007-2009 drought years than the much wetter 2011 (Michel et al. 2015). Drought conditions, coupled with suboptimal ocean conditions, have also led to very low survival of the juvenile endangered winter-run Chinook salmon in 2014 and 2015 (PFMC 2016a; USBR 2015). These negative impacts likely hold true for the commercially fished salmon runs as well.

Biological stressors further contributed to salmon mortality during droughts. A review of the effects of temperature on salmonids shows that the parasites Ceratomyxa shasta and Ichthyophthirius multifiliis (commonly known as "Ich") are more virulent in warmer water (Carter 2005). The Klamath River system had an Ich outbreak in 2014 (Orcutt 2015), and up to 91 percent of Coho salmon juveniles were infected in 2014 and 2015 (Houston 2016a). Additionally, drought affects the overall health of the ecosystem and the food web that salmon rely on. Food is typically less abundant during drought, and salmon face more competition from invasive fish species that thrive in warm, altered habitats such as reservoirs and ponds (Moyle et al. 2013). The threats to salmon also increase as their predators, such as striped bass, can tolerate warmer water (CDFW 2010). Reduced flows also lead to higher risk of predation for juvenile salmon; less water lowers the turbidity and limits their camouflage ability. There is also less physical space for predator and prey to occupy as deep pools of cool water become shallower and warmer, and riffle stretches of river—important for the construction of salmon spawning nest and incubation—dry up (Tim Sloane, Executive Director, Pacific Coast Federation of Fishermen's Associations, personal communication, Oct. 12, 2016).

Water management decisions during the drought are critical for ensuring sufficient flows and temperature requirements for salmon; however, they have been the subject of debate and litigation following the low survival rate of juvenile winter-run Chinook salmon and mass die-offs of juvenile Coho salmon in 2014 and 2015.[10] For example, in 2015 the National Resources Defense Council and other environmental organizations took legal action against the United States Bureau of Reclamation (USBR), other federal agencies, and Central Valley water districts for not devoting enough water to the endangered winter-run Chinook salmon (Kasler 2015). In 2016, the Hoopa Valley Tribe and a group led by the Yurok Tribe also filed a separate lawsuit against the USBR and

9 See Bisson, Dunham, and Reeves (2009) for more details about freshwater ecosystems and resilience of Pacific salmon.

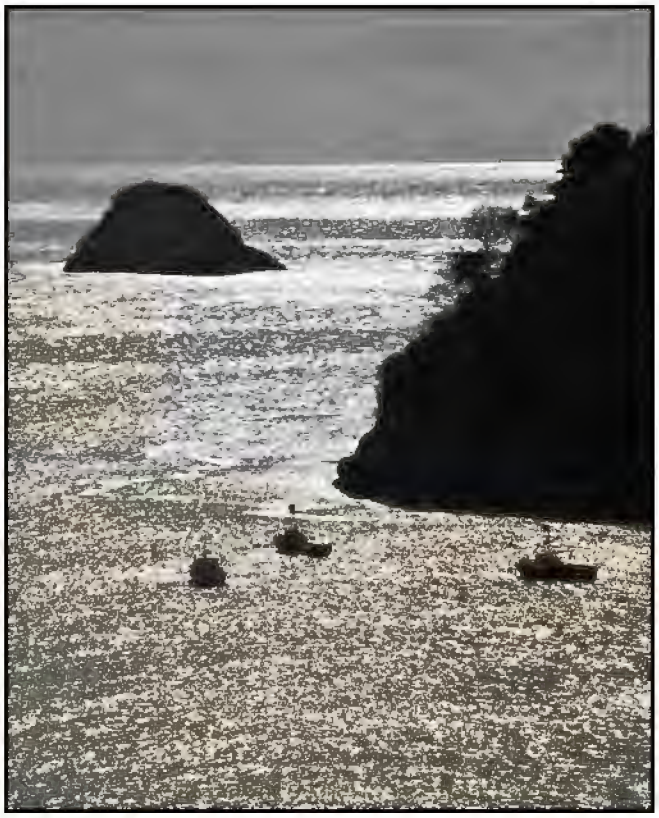
10 Documents regarding Sacramento River Temperature Management can be found on the SWRCB's website. NMFS biological opinions and actions, as well as the USBR's long-term plan for protecting salmon in the Lower Klamath River (and associated comment letters), can be found here and here, respectively.

the National Marine Fisheries Service (NMFS) for contributing to Ich infections and mortality of the endangered Coho salmon (The Eureka Times-Standard 2016; Houston 2016b).

Finally, climate change will likely compound existing problems and accelerate the decline in salmon population. Seasonal duration of lethally-warm stream temperatures at watershed outlets is expected to lengthen and the average annual stream temperature is projected to exceed 75 degrees F earlier in the spring (Null et al. 2013). Moyle et al. (2013) concluded that climate change will increase the vulnerability of spring-run Chinook salmon and Coho salmon in California, and ultimately lead to their total extinction by 2100 if conservation measures are not pursued.

FISHERMEN'S VIEWS OF DROUGHT IMPACTS

Responses from our interviews with salmon fishermen, conducted in October 2016, further revealed some devastating effects of the current drought. Dave Bitts, a fisherman of 40 years from Eureka, recounted that for eight of the 10 years between 1995 and 2004, fishermen could easily catch 50 fish per day. It is now very challenging to catch 10 fish a day and many people have to live off their savings or take on a different job. Lori French, who fishes with her husband in Morro Bay, revealed that during this drought, for the first time in her husband's life, he could not catch any fish in two consecutive days. Mike Ricketts, a fisherman from Monterey, similarly mentioned that conditions have been particularly devastating in the last couple of years. While many salmon fishermen also engage in the Dungeness crab fishery, the postponement and shortening of the crabbing season in late 2015 created a significant economic burden. According to Mike Ricketts, the decline in salmon harvest has also affected infrastructure that supports the fishery, such as fuel docks, ice stores, and markets, making each



Source: CampPhoto

drought recovery more difficult than the one before. To address these impacts, Larry Collins, a fisherman from San Francisco, highlighted that it is important for the public to think of fish, crabs, and other seafood as public trust resources and give more attention to protecting fish's habitats.

Tribal Salmon Harvest

TRENDS OF DECLINE EXPERIENCED BY TRIBES

Salmon are an integral part of life for Native Americans in California and the Pacific Northwest (Shilling et al. 2014; Lichatowich 1999; Yoshiyama 1999; Gunther 1926). For centuries, Native Americans have relied on salmon not only as a source of sustenance, but also for its spiritual and cultural significance, as can be seen in the First Salmon Ceremony honoring the relationship between salmon and people (Gunther 1926). Presently, the Yurok and Hoopa Valley Tribes share a federally-reserved right to 50 percent of the

Klamath River Chinook salmon harvest surplus (Pierce 1998).[11]

Subsistence fishing has always been a major part of the tribes' livelihoods, but the current salmon consumption level appears to be much lower than it was historically. Shilling et al. (2014) conducted a survey of 12 tribes throughout California to examine traditional and contemporary fish usage, fishing areas, and barriers to fish use. Results showed that salmon was the most relied-upon fish in the North Coast and was traditionally used by all tribes interviewed, except for the Timbisha Shoshone in the Death Valley area.[12] However, the interviews suggested that use of fish has declined compared to historical rates, and especially more so in recent years.

Other evidence also points to a significant decline in tribal salmon harvest and consumption. The PFMC provides a systematic collection of tribal Chinook salmon harvest data dating back to 1987, although they are quite limited in temporal and geographic scope. From the PFMC's database, we found that the average number of salmon caught by the Yurok and Hoopa tribes combined from 1995-2015 was 21,000 for subsistence and 17,000 for commercial sale (more information on the subsistence and commercial tribal harvests is provided in Appendix 3A). As of 2010, the most recent year for which we have tribal population data, the number of salmon harvested for subsistence would correspond to 10 fish per year for a family of four, or about 20 to 38 pounds of salmon per person per year.[13] This estimate greatly contrasts with pre-contact consumption estimates by Hewes (1973), which indicated that the Yurok and Hoopa Valley tribes were consuming about 365 pounds of salmon per person per year. Fish consumption by the Karuk tribe has also dropped sharply (Table 3-1). A study by Norgaard (2005) showed that the lack of fishing rights, coupled with salmon population declines, impacted the health of members of the Karuk Tribe upstream on the Klamath River. Norgaard found that the Karuk Tribe experienced a loss of livelihood, diet-related illnesses, and poverty when their fish resources become degraded or destroyed. This experience is

11 Indigenous fishing rights allow tribal members to fish for salmon at traditional fishing sites and with traditional equipment, such as gill nets. The Yurok Tribe's allocation is 80 percent and Hoopa Valley Tribe's allocation is 20 percent of the tribal allocation (Pierce 1998).

12 Tribes that have been interviewed by Shilling et al. (2014) include Habematolel Band Pomo, Paiute, Big Valley Band Pomo, Scotts Valley Band Pomo, Kahia Band Pomo, Me-Wuk, Wiyot, Yurok, Yuki, Pit, Pomo, Nomlacki, Concow, Wailaki, Mattole, Northern Paiute, Timbisha Shoshone, Maidu, Mono, Monache, Wintun-Wailaki, Chumash, Chemehuevi, Mohave, Achomawi, and Atsugewi.

13 Authors' calculations based on Yurok and Hoopa Valley Tribal population from the US Census Bureau (2013). Table 19. American Indian and Alaska Native Population by Tribe for California: 2010. Estimated consumption per capita assumes that the dressed weight of salmon (i.e., weight after inedible or undesirable parts have been removed) ranges from 8 to 15 pounds per fish.

Table 3-1.

Estimated Present and Historical Karuk Tribe Fish Consumption

	Tribal Population	Est. Total Fish for Tribe (pounds)	Per Capita (pounds/person/year)
Pre-contact	1,500	675,000	450
Year 2003-04	3,300	<1,000	< 5
Year 2004-05	3,300	< 100	< 0.5

Sources: Adapted from Norgaard (2005). Pre-contact data from Hewes (1973).

likely shared by many Native American tribes in California.

CHALLENGES UNIQUE TO PRESERVING TRADITIONAL PRACTICES

Regulated environmental conditions are responsible for current limits on traditional fish consumption and harvest practices (Shilling et al. 2014). Dam construction, water diversions, and diseases, for example, contribute to the diminishing salmon population, but tribes also face fishing restrictions and many do not have indigenous rights to fish in traditional fishing sites (Chook-Chook Hillman, member of Karuk Tribe, personal communication, Sept. 27, 2016). Illegal, water-intensive marijuana cultivation in Northern California is another driver of reduced flows and environmental degradation. Marijuana's high economic value has attracted some tribal members to work in plantations (Crane-Murdoch 2015; Anderson 2015). These activities increase pesticide pollution in waterways, change the character of the creek, and further compromise water availability for salmon.

Multiple drought years have exacerbated existing problems relating to the overall decline in salmon abundance and the loss of livelihood. According to Chook-Chook Hillman, a Karuk Tribal member, the Klamath salmon runs narrowly escaped a complete collapse when the USBR approved emergency reservoir releases to protect juvenile and spawning salmon (personal communication, Sept. 27, 2016). Tribal activists fight almost annually for "emergency flows," which is especially critical during droughts (Brittani Orona, member of Hoopa Valley Tribe, personal communication, Nov. 23, 2016). As a result, tribes are currently asking for "preventive flows" to ensure the survival of the salmon population, which ultimately links to the survival of traditional cultures. The cultural wealth of tribes depends on the availability of salmon, which members use for ceremonies. When a tribal person cannot catch enough salmon to subsist, he or she must buy, trade, be given fish, or go without. It is highly probable that a continuation of the drought will result in more severe social, economic, and cultural impacts on tribal communities.

CONCLUSIONS AND RECOMMENDATIONS

A complex set of factors have contributed to the widespread decline in California's salmon population. Alterations to habitats, migration barriers, invasive species, and competing uses of water have likely decreased salmon's resilience in the face of extended dry periods. Droughts can impact salmon in many ways, principally via reduced flows and higher water temperatures. They also increase biological stress, lead to disease outbreaks, increase competition from invasive fish species, and augment predation risk. The diminished water supply during droughts intensifies competition for water between user groups, many of which are on unequal playing fields.

The commercial salmon fishery has been experiencing an overall decline, and the salmon fishing community has been shrinking as a result of (1) a downward trend in salmon harvest over the past 40 years; (2) a lack of income security among salmon fishermen; (3) rising costs of fishing (e.g., fishing regulations and cost of inputs); and (4) the decline of infrastructure that supports the fishing fleet (e.g., fuel docks and ice stores). Native American tribes are also significantly impacted by salmon decline, as observed in their harvest and consumption patterns. Tribal salmon consumption was historically much higher than the present level, according to interviews with tribal members

and our review of the literature. Tribes face unique challenges to preserve their traditional practices, including dam construction and operations, water diversions, fishing restrictions, the absence of fishing rights, and illegal marijuana cultivation. The ongoing California drought is seen by interviewed tribal members and fishermen as an additional stressor to an already stressed system, causing further decreases in fish harvest and income. For commercial fishermen, impacts contribute to the decline of the fishery and its capacity to remain financially viable. For tribes, the impacts threaten traditional livelihoods and cultural wealth.

RECOMMENDATIONS TO IMPROVE DROUGHT RESILIENCE OF THE SALMON FISHERY

Mitigating Impacts of Drought on Commercially Fished Salmon Runs

3-1. Enhance emergency drought response to protect anadromous populations that are important to fishing communities.

A small number of drought response activities directly address impacts on anadromous fish populations depended upon by tribes and commercial fishing communities. Efforts to ensure the protection of fish listed under the federal and California Endangered Species Act (ESA), such as improving flow conditions for winter-run Sacramento Chinook, may have positive spillover effects on non-threatened species. However, they leave out drought-affected rivers and tributaries that can no longer support threatened and endangered species. Strategies to enhance these responses include an improved management of reservoirs (e.g., on the Sacramento River) to prevent warm water releases that may harm salmon eggs and juveniles; emergency salmon rescue and transportation past compromised stretches of the river to coastal net pens during critical periods; and expanded Voluntary Drought Initiatives that have been carried out by NMFS and CDFW.

3-2. Reduce pressures on critical aquatic ecosystems.

The enforcement of the Reasonable and Beneficial Use Doctrine in California's water rights law is especially important during periods of water scarcity. More monitoring and enforcement activities are needed to prevent illegal water diversions (e.g., for marijuana cultivation). Additionally, statewide water conservation and efficiency measures, as well as expansion of alternative water supplies (e.g., stormwater capture and water recycling), can reduce pressures on critical aquatic ecosystems and, in some instances, improve river flows. Minimum environmental flows should be established and maintained in key waterways, especially during salmon migrating seasons.

3-3. Provide income and/or food assistance and insurance protection for fishing communities during drought emergencies.

Native American tribes and commercial fishermen greatly depend on the salmon fishery. According to interviews with tribal members and salmon fishermen, a poor salmon harvest year can create high economic and cultural burdens on fishing communities. State and federal agencies should recognize the inequitable impacts of the drought on these communities and provide income and/or food assistance during a drought emergency as appropriate. A federally supported fishermen's insurance program, similar to a crop insurance program, might be created as a risk management tool to protect fishermen against loss of income during times of extremely low harvest.

3-4. Build resilience and limit vulnerabilities of the salmon fishery.

Integrated management of water and fishery resources is key to improving the resilience of the salmon population. A statewide strategy for

aquatic conservation is needed to coordinate efforts and track results. These efforts include:

- Engaging in physical habitat restoration projects to better approximate natural conditions, such as the San Joaquin River salmon restoration efforts and those outlined in the Golden Gate Salmon Association's Salmon Rebuilding Plan (Golden Gate Salmon Association (GGSA) 2016);
- Creating salmon sanctuaries or stretches of rivers and streams dedicated to salmon conservation;
- Adjusting dam operation and state and federal water projects to ensure minimum environmental flows, maintain water quality, and balance water uses;
- Improving federal and California ESA protections for listed salmonids during times of low water supply to avoid a repeat of the winter-run Chinook salmon's mass die-offs in 2014 and 2015. Such protections are likely to provide indirect benefits for the salmon fishery as well;
- Re-operating fish hatcheries to protect wild salmon population;
- Restoring access to cold-water habitat to improve resilience against droughts, such as creating more fish-friendly waterways and fish passage facilities; and
- Removing dams that no longer provide enough hydropower to justify operational, maintenance, and environmental costs. These dam removals can increase cold water spawning and rearing habitats for migrating fish. The new Klamath Basin Agreements are a recent example. Signed April 2016, the agreements have created a roadmap for four dam removals on the Klamath River by 2020, while helping irrigators to avoid potentially adverse financial and regulatory impacts from the dam removal.

3-5. Create mechanisms for meaningful and timely tribal engagement with local, regional, state, and federal agencies.

Indigenous communities are known as stewards of the land and the water. They have practiced sustainable management of natural resources for millennia and their perspectives and input should be considered in policy decisions that will ultimately impact their communities, such as dam operations and fishery management. Many government agencies have developed and/or adopted tribal consultation principles and practices with varying degrees of inclusivity and timeliness, but these engagements should be fully institutionalized into relevant agency operations. An example of improving this consultation process is the creation of a tribal policy advisory committee or office within all levels of government that deal with issues impacting Native Americans.

Further Study and Data Collection on the Salmon Fishery and Drought

3-6. Formalize integrated biological and environmental data systems for salmon populations throughout California.

Better and more integrated data is needed to strategize and optimize responses to protect important salmon runs. Current monitoring efforts, especially on non-threatened salmon runs, are limited; these data gaps hinder timely response to changes in flows, temperatures, and other factors that may harm spawning adult and juvenile salmon. Some efforts are already underway to support collaborative and coordinated monitoring activities to improve fish population and watershed health, such as the Klamath Basin Monitoring Program and the California Cooperative Anadromous Fish and Habitat Data Program. However, these programs still leave gaps in temporal and spatial coverage.

Formalizing these efforts would help to maintain consistency and availability of timely data and identify gaps that should be addressed.

3-7. Comprehensively examine drought impacts on the fishery from economic, environmental, and cultural perspectives.

A better understanding of drought impacts on the fishery from economic, environmental, and cultural perspectives can help identify and address inequity issues around fishery and water resource management in California. The declining salmon population is a complex legacy problem through which many factors intersect, including the loss of habitat and environmental degradation. The drought provides an opportunity to draw attention to salmon's diminished resilience to extended dry periods and its implications for fishing communities.

3-8. Evaluate ways to re-operate hatcheries in California to achieve both goals of sustaining commercial fisheries and assisting in the recovery of naturally spawned salmon runs.

Sustainable fishery management depends on genetically-diverse wild fish stock that is resilient and adaptive to the changing environment. However, hatchery fish, which are bred to thrive in hatchery conditions, are known to weaken the genetic makeup of the wild (naturally spawned) fish population as a result of interbreeding (Buhle et al. 2009; Chilcote, Goodson, and Falcy 2011; Araki, Cooper, and Blouin 2009). How can the hatchery be managed and re-operated to limit negative impacts on the wild population while continuing to support the fishery? What are the most effective and cost-efficient approaches? These questions have been explored to some extent and continued research is needed to improve the health of the fisheries.

3-9. Assess the use and effectiveness of instream flow regulations to protect the salmon population.

At present, much of the research on the impact of instream flows on salmon populations focuses on endangered and threatened species. Management decisions can be made more effective through a better understanding of the relationship between flows and fish populations that are harvested for subsistence, sale, or recreation. For example, pulse flows may be used as a measure to assist in salmon migration during a drought period. Further research is needed to understand flow-migration relationships on a per-tributary basis and to assess the effectiveness of flow regulation measures.

3-10. Examine potential impacts on stock sustainability and socioeconomic implications of expanding reserved indigenous fishing rights.

Native American tribes have relied on salmon for food and cultural uses for millennia, but only two out of over a hundred tribes have reserved rights to fish in traditional sites with traditional equipment. The issue of equity and fairness of fishery access should be explored with considerations to potential impacts on fish stocks as well as tribes and other groups with recognized fishing rights.

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APPENDIX INTRODUCTION A

DROUGHT AND EQUITY ADVISORY COMMITTEE MEMBERS AND ORGANIZATION PROFILES

Sara Aminzadeh, *Executive Director, California Coastkeeper Alliance*

Colin Bailey, *Executive Director, Environmental Justice Coalition for Water*

Carolina Balazs, *Visiting Scholar, University of California, Berkeley*

Wendy Broley, *Staff Engineer, California Urban Water Agencies*

Amanda Fencl, *PhD Student, University of California, Davis Center for Environmental Policy and Behavior*

Kelsey Hinton, *Program Associate, Community Water Center*

Gita Kapahi, Director, *Office of Public Participation, State Water Resources Control Board*

Brittani Orona, *Environmental Justice and Tribal Affairs Specialist and Native American Studies Doctoral Student, University of California, Davis*

Brian Pompeii, *Lecturer, California Polytechnic State University, San Luis Obispo*

Tim Sloane, *Executive Director, Institute for Fisheries Resources*



SARA AMINZADEH

As the Executive Director of California Coastkeeper Alliance (CCKA), Sara Aminzadeh develops and executes campaigns to ensure swimmable, fishable, drinkable waters for California's communities and watersheds, in concert with locally-based California Waterkeepers. In addition to her policy work as an attorney and advocate, Sara creates and mobilizes new coalitions for clean water. Sara founded and directs CCKA's Blue Business Council, the California business network for clean water, and the California Water Partnership, a coalition of environmental and environmental justice organizations dedicated to securing a sustainable and equitable water future for California. Sara frequently writes about human rights and climate change issues, most recently authoring a chapter Rising to the Challenge: California Climate Change Adaptation in the 2014 Oxford University textbook, Climate Change Impacts on Ocean and Coastal Law. Sara holds a Bachelor of Arts (BA) in environmental studies and political science from the University of California, Santa Barbara, and a Juris Doctor (JD) from the University of California, Hastings College of the Law.

California Coastkeeper Alliance

California Coastkeeper Alliance was founded in 1999 with the belief that a healthy ocean and coast and clean water is vital to California's economy, public health, and way of life. California Coastkeeper Alliance and California Waterkeeper organizations are members of the international Waterkeeper Alliance, a network of water advocates with more than 200 programs in 21 countries on 6 continents led by Robert F. Kennedy Jr. Using law, policy, science, and creative media, CCKA is an experienced advocate that advances statewide policies and programs for healthy and clean waters. CCKA and local Waterkeeper groups develop, implement and defend policies that meet the needs of California's distinct communities and ecosystems. Together, CCKA and its network of Waterkeepers provide the public with the tools and information needed to hold decision-makers accountable and to be effective local water stewards.



COLIN BAILEY

Colin Bailey is the Executive Director of the Environmental Justice Coalition for Water and is based in Sacramento, California. He is fluent in English and conversant in Spanish. He has his Juris Doctorate from UCLA with a certificate from the Program in Public Interest Law and Policy and a concentration in Critical Race Studies. An accomplished social justice attorney, Colin leads EJCW's effort to implement the human right to water and supports EJCW's statewide policy agenda, programs, outreach and education, and grassroots member organizations.In addition, he leads EJCW's work with the Environmental Water Caucus, Community Engineering Corps, Ecological Society of America, Sacramento Valley Water Justice Network, US Human Rights Network, and more.

The Environmental Justice Coalition for Water

The Environmental Justice Coalition for Water (EJCW) works within a Community-to-Capital framework, connecting the most pressing needs of our disadvantaged community partners to our network of partners and agencies statewide. Since 1999, EJCW's work has been rooted in the communities most affected by environmental injustice. Issues and solutions are identified through regional chapters and statewide work groups. EJCW is positioned in the state capital, in order to connect communities with state agencies to bring about change multilaterally through advocacy, education, training, litigation, community organizing, and capacity-building, and by providing technical assistance. EJCW aims to effectively influence the intersections of water justice and environmental justice, community health, and human rights issues from community to global levels.

CAROLINA BALAZS

Carolina has been a UC President's Post-Doctoral Fellow at the University of California, Davis (UC Davis), bridging the academic-community water justice research community. She is also a consulting Research Scientist with California Environmental Protection Agency's Office of Environmental Health Hazards Assessment (OEHHA). At OEHHA, she is leading the development of a "Human Right to Water" tracking tool for the state of California. Her doctoral research examined drinking water quality problems in California's Central Valley and the environmental justice implications. Following graduate school, Carolina worked as a Research Scientist at the Community Water Center, promoting community-based participatory research and developing community-led water justice solutions. She holds a Bachelor of Science (BS) in Environmental Science from Brown University and both a Master of Science (MS) and Doctor of Philosophy (PhD) from the Energy and Resources Group at the University of California, Berkeley (UC Berkeley).

WENDY BROLEY

Wendy Broley is staff engineer at California Urban Water Agencies (CUWA) and Water Reuse Leader at Brown and Caldwell. Wendy is a licensed professional engineer with over 14 years of experience in water and wastewater engineering and operations, membrane technology and biosolids solutions, as well as business development for both municipal and industrial markets. She is committed to the development of a diverse and resilient water portfolio for her clients using an integrated "One Water" approach to water management. With a specific focus on transforming the perception of wastewater treatment plants into "resource recovery facilities," Wendy has stepped into the role as Water Reuse Leader at Brown and Caldwell. Wendy started her career as a consulting engineer supporting the membrane operations of multiple advanced water treatment facilities for indirect potable reuse applications totaling over 100 MGD of production capacity. Mrs. Broley holds a BS in Chemical Engineering from University of California, San Diego (UCSD).

California Urban Water Agencies

CUWA's mission is to provide a forum for combining the expertise and resources of its member agencies to advance reliable, high-quality water supplies for the State's current and future urban water needs in a cost-effective manner for the public, the environment and the economy. CUWA's efforts are guided by its 11 member agencies and supported by an Executive Director. Member agencies' resources are pooled to study water management issues, develop consensus solutions among the urban water community, and engage with California water leaders.

AMANDA FENCL

Amanda Fencl has been a member of the Center for Environmental Policy and Behavior (CEPB) for four years as a PhD student in the University of California, Davis Geography Graduate Group. Her dissertation explores the ways that drought can exacerbate California's drinking water disparities. As a PhD student she interned with the Governor's Office of Planning and Research (OPR) on drought policy, and assists OPR's Local Drought Liaison with a project on household water shortages and drought vulnerability. Since summer 2015, she has worked with Dr. Julia Ekstrom at the University of California, Davis Policy Institute's Climate Adaptation Initiative to look at extreme event impacts on California's drinking water quality. She and Dr. Ekstrom have a state grant to understand drought impacts on and responses of small, self-sufficient drinking water systems. Her dissertation is supported through a National Science Foundation (NSF) Graduate Research Fellowship (2015-2018), a NSF Climate Change, Water and Society IGERT (2013-2015) traineeship, and University of California, Davis research grants. She was a Staff Scientist at the U.S. Center of the Stockholm Environment Institute (SEI) for 6 years and has a BA in International Relations and Environmental Studies from Tufts University.

Center for Environmental Policy and Behavior

The mission of the CEPB is scientific analysis of the interactions among policy institutions, human behavior, and political decisions in the context of environmental and natural resource conflicts. Through developing and testing theoretical models from social science, CEPB seeks to derive practical lessons that can be used to improve environmental policy. We focus on a wide variety of environmental problems and issues, including watershed management, climate change, forest management, marine/coastal systems, biodiversity, and agriculture. The CEPB team includes an actively engaged group of faculty and graduate students who come from diverse backgrounds. CEPB is co-directed by Dr. Mark Lubell and Dr. Gwen Arnold, housed in the Department of Environmental Science and Policy at University of California, Davis, and affiliated with researchers from other academic universities, government agencies, and other University of California, Davis programs and departments.



KELSEY HINTON

AKelsey Hinton joined the Community Water Center (CWC) in 2015. As the former AmeriCorps Fellow, now Program Associate, Kelsey works to build the capacity of CWC through communications, fund development and policy work in order to improve and expand programs to provide disadvantaged communities with access to safe and affordable drinking water. An Indiana native, Kelsey recently graduated from Indiana University's School of Public and Environmental Affairs (SPEA) with a degree in Environmental Management. Her senior thesis focused on the feasibility of direct potable water reuse in Las Vegas. She is currently pursuing her Master's of Public Affairs (MPA) with a concentration in Policy Analysis at SPEA and will graduate in May 2017.

Community Water Center

The CWC is a non-profit environmental justice organization based in California's San Joaquin Valley, whose mission is to act as a catalyst for community-driven water solutions through organizing, education, and advocacy. CWC's fundamental goal is to ensure that all communities have access to safe, clean, and affordable water. CWC helps build strategic grassroots capacity to address water challenges in small, rural, low-income communities and communities of color. For more information, visit CWC's website at www.communitywatercenter.org and follow us on Twitter at @CWaterC.



GITA KAPAHI

Gita Kapahi is the Director of the Office of Public Participation (OPP) for the State Water Resources Control Board (SWRCB), and has been since the office was created in late 2007. In this office she serves in many capacities, including ombudsman, tribal liaison, environmental justice coordinator, small business liaison, agricultural liaison, education and outreach coordinator, facilitator, and public participation consultant. She has been with the SWRCB for 24 years, first as an Environmental Scientist in the Division of Water Quality, then in the Division of Water Rights, serving as Chief of the Bay Delta Unit. Prior to that, she was a fisheries consultant to the Canadian Department of Fisheries and Oceans.

Office of Public Participation, California State Resources Water Board

The OPP responds to public inquiries about SWRCB programs. The SWRCB created this program to strengthen our efforts at involving the public in our decision-making process. The office intends to reach out to environmental justice and other communities and have better communication and interaction with tribal governments and others. Additionally the office will assist staff with designing and implementing effective stakeholder involvement processes, including translation and other services, to ensure all interested parties can participate in SWRCB activities.

BRITTANI ORONA

Brittani is an enrolled member of the Hoopa Valley Tribe. She graduated with a BA in History from Humboldt State University, has an MA in Public History from California State University Sacramento, and is currently a doctoral student at University of California, Davis in Native American Studies with a Designated Emphasis on Human Rights. Her research focuses on indigenous memory and meaning in land use and environmental justice initiatives in California. Brittani helped to coordinate an exhibit and oral history project about the removal of four PacifiCorp dams on the Klamath River. She has also acted as an exhibit consultant for the Autry Museum of the American West, the Maidu Museum and Historic Site, and the Goudi'ni Native American Arts Gallery at Humboldt State University on exhibits related to environmental justice and water rights. Brittani has worked at the California Government Operations Agency, California State Indian Museum, the California State Office of Historic Preservation, California State Archives, and the Maidu Museum and Historic Site.

BRIAN POMPEII

Brian Pompeii is a human-environmental geographer at California Polytechnic State University, San Luis Obispo (Cal Poly) with research interests in water resources, sustainability, vulnerability, hazards, and climate adaptation. His current research project explores how drought-strained surface water access has led to an increase in groundwater usage for industrial agriculture, and subsequently a disaster-level increase in domestic well failure in disadvantaged unincorporated communities in the San Joaquin Valley of California. He received his PhD in Geography from Arizona State University.

California Polytechnic State University, San Luis Obispo

Cal Poly is a nationally ranked, four-year, comprehensive public university located in San Luis Obispo, halfway between San Francisco and Los Angeles on California's Central Coast. It is a distinctive learning community offering academically focused students a hands-on educational experience that prepares them for today's scientific and technical world.



TIM SLOANE

Tim is Executive Director for the Institute for Fisheries Resources (IFR), having begun his career with IFR and its sister organization, the Pacific Coast Federation of Fishermen's Associations (PCFFA), under the direction of William F. "Zeke" Grader, Jr. He advocates for clean, sustainable, and productive fisheries, protection of aquatic habitat, and workable fisheries management legislation. He is a member of the Marine Fish Conservation Network's National Policy Committee, and holds a seat on the Golden Gate Salmon Association Board of Directors. He received his BA in history from University of California, Berkeley, and a JD from Golden Gate University with a certificate in environmental law. He is a member of the State Bar of California.

Institute of Fisheries Resources

Established in 1993 by the PCFFA, IFR is responsible for carrying out the fishery research and conservation needs of working fishing men and women. Initially, IFR helped fishermen in California and the Pacific Northwest address salmon protection and restoration issues, with particular focus on dam, water diversion, and forestry concerns. Since 1998, IFR's range of programs has greatly expanded to encompass conservation projects and policy debates at the regional, national, and international levels. The IFR is dedicated to the protection and restoration of fish resources and the human economies that depend on them. By establishing alliances among fishing men and women, government agencies, and concerned citizens, IFR unites resource stakeholders, protects fish populations, and restores aquatic habitats.



The Environmental Justice Coalition for Water

Water Justice for All

The Environmental Justice Coalition for Water
PO Box 188911, Sacramento, CA 95818-8911
909 12th Street, Suite 200, Sacramento, CA 95814
916-432-EJCW (3529) | info@ejcw.org | ejcw.org



Pacific Institute
654 13th Street, Preservation Park, Oakland, CA 94612
510-251-1600 | info@pacinst.org | pacinst.org

ISBN-13: 978-1-893790-76-6

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EXHIBIT C

Social Disparities in Nitrate-Contaminated Drinking Water in California's San Joaquin Valley

Carolina Balazs,[1] Rachel Morello-Frosch,[2,3] Alan Hubbard,[2] and Isha Ray[1]

[1]Energy and Resources Group, [2]School of Public Health, and [3]Environmental Science Policy and Management, University of California, Berkeley, California, USA

BACKGROUND: Research on drinking water in the United States has rarely examined disproportionate exposures to contaminants faced by low-income and minority communities. This study analyzes the relationship between nitrate concentrations in community water systems (CWSs) and the racial/ethnic and socioeconomic characteristics of customers.

OBJECTIVES: We hypothesized that CWSs in California's San Joaquin Valley that serve a higher proportion of minority or residents of lower socioeconomic status have higher nitrate levels and that these disparities are greater among smaller drinking water systems.

METHODS: We used water quality monitoring data sets (1999–2001) to estimate nitrate levels in CWSs, and source location and census block group data to estimate customer demographics. Our linear regression model included 327 CWSs and reported robust standard errors clustered at the CWS level. Our adjusted model controlled for demographics and water system characteristics and stratified by CWS size.

RESULTS: Percent Latino was associated with a 0.04-mg nitrate-ion (NO_3)/L increase in a CWS's estimated NO_3 concentration [95% confidence interval (CI), –0.08 to 0.16], and rate of home ownership was associated with a 0.16-mg NO_3/L decrease (95% CI, –0.32 to 0.002). Among smaller systems, the percentage of Latinos and of homeownership was associated with an estimated increase of 0.44 mg NO_3/L (95% CI, 0.03–0.84) and a decrease of 0.15 mg NO_3/L (95% CI, –0.64 to 0.33), respectively.

CONCLUSIONS: Our findings suggest that in smaller water systems, CWSs serving larger percentages of Latinos and renters receive drinking water with higher nitrate levels. This suggests an environmental inequity in drinking water quality.

KEY WORDS: California, drinking water, environmental justice, nitrate, public health, Safe Drinking Water Act, social disparities, water systems. *Environ Health Perspect* 119:1272–1278 (2011). http://dx.doi.org/10.1289/ehp.1002878 [Online 3 June 2011]

An array of drinking water–related problems still exists in the United States, despite a history of investment in sophisticated water infrastructure and the existence of federal laws such as the Clean Water Act of 1972 and Safe Drinking Water Act of 1974 (SDWA) that regulate source contamination and protect the public's health. These problems include increasing source contamination (Dubrovsky et al. 2010), exposure to chemical and microbial contaminants, poor implementation of water laws (Burke 2009; Duhigg 2009), and degrading infrastructure (Levin et al. 2002). Rural areas often face the largest burden, as aquifers are contaminated by intensive agriculture and livestock production (Dubrovsky et al. 1998). Some rural unincorporated areas, such as some communities along the U.S.–Mexico border, lack access to adequate infrastructure, service provision, and clean water (Olmstead 2004; Pilley et al. 2009).

Despite these problems, there is a paucity of studies that examine social disparities in exposure to unsafe water. A literature review in the 1990s (Calderon et al. 1993) recommended that more quantitative analyses examine whether vulnerable populations, including people of color and the poor, are disproportionately affected by drinking water contamination. Since then, a handful of studies have addressed different aspects of this issue. In San Joaquin County, California, one study found a weak but significant relationship between areas with higher poverty and greater proportions of minorities and poor drinking water quality (Byrne 2003). Research in the Navajo Nation found bacteriological and chemical contamination in unregulated drinking water sources (Murphy et al. 2009). In Arizona, researchers examined whether public water systems serving higher fractions of minority or low-socioeconomic-status (SES) residents were more likely to exceed the arsenic maximum contaminant level (MCL) than were those serving higher fractions of whites or high-SES residents. They found a positive association between the percentage of Latino residents and the likelihood of exceeding the MCL of arsenic. However, they concluded that environmental justice concerns were unwarranted for Latinos, because there was no difference between the percentages of Latinos who were served by water systems with and without violations. (Cory and Rahman 2009). In New Mexico, preliminary research documented high arsenic levels in drinking water sources that provided water to predominantly Latino border communities known as "colonias" (Pilley et al. 2009).

Our research addresses several methodological limitations of previous studies, particularly regarding appropriate unit of analysis, characterization of exposure, and scale. For example, Byrne (2003) estimated average trichloroethylene levels and MCL exceedances in drinking water systems and characterized exposure as a continuous measure across San Joaquin County; the community level, however, is more appropriate when considering community-level exposure. Cory and Rahman (2009) characterized the association between percent minority and a binary outcome of arsenic, rather than a continuous measure of arsenic levels, and they did not explore this association among smaller systems where they noted that most arsenic violations occurred.

Our study used the community as the unit of analysis to examine the relationship between nitrate concentration in community water systems (CWSs) and social factors. CWSs are public water systems that serve water year-round to at least 25 people or have > 15 service connections [U.S. Environmental Protection Agency (EPA) 2010b]. We characterized potential exposure to nitrate because it is one of the most common contaminants found in groundwater (Harter 2009; Spalding and Exner 1993) yet has received little attention regarding social disparities in exposure.

Nitrate in drinking water is associated with methemoglobinemia (i.e., "blue baby syndrome") in infants (Fan and Steinberg 1996; U.S. EPA 2010a), although other risk factors include enteric infections (Charamandari et al. 2001; Hanukoglu and Danon 1996) and foods

Address correspondence to C. Balazs, 310 Barrows Hall, University of California, Berkeley, CA 94720-3050 USA. Telephone: (510) 642-1640. Fax: (510) 642-1085. E-mail: carolinabalazs@berkeley.edu

Supplemental Material is available online (http://dx.doi.org/ 10.1289/ehp.1002878).

We thank L. Firestone, S. de Anda, and M. Herrera; R. Haberman [former San Joaquin Valley Regional Engineer for California Department of Public Health (CDPH) Drinking Water Program], D. Spath (former Chief of the Division of Drinking Water and Environmental Management, CDPH), and C. Peterman for support and feedback on analysis; CDPH and Tulare County Environmental Health Services for data; and B. Nerness for research assistance.

This research was supported by a National Science Foundation graduate research fellowship, the California Endowment through a collaborative research grant between Community Water Center and University of California–Berkeley, and the Switzer Environmental Fellowship.

The authors declare they have no actual or potential competing financial interests.

Received 19 August 2010; accepted 3 June 2011.

high in nitrates (Sanchez-Echaniz et al. 2001). Epidemiologic data also suggest an association between nitrate levels in drinking water and reproductive toxicity, developmental effects, and various cancers (Fan and Steinberg 1996; Ward et al. 2005, 2010), although the consistency of these associations varies. To protect against methemoglobinemia, the SDWA has established an MCL of 45 mg/L as nitrate ion (NO_3) or 10 mg/L as nitrate-nitrogen in drinking water (U.S. EPA 2010a).

California's San Joaquin Valley is an important site for examining potential disparities in exposure to nitrate. With its intensive irrigated agriculture, the valley has two of the most contaminated aquifers in the nation and some of the highest nitrate levels in the country (Dubrovsky et al. 1998, 2010). Because nearly 95% of the valley's population relies on groundwater for drinking [Permits, Inspections, Compliance, Monitoring and Evaluation (PICME) [California Department of Public Health (CDPH) 2008a], groundwater contamination is a particular health risk. This risk is compounded by the fact that with high costs of mitigation, few systems actually treat for nitrate. The San Joaquin Valley also has some of the highest rates of poverty and minority populations—particularly Latinos—in the state (U.S. Census Bureau 2007). These communities are economically and socially disadvantaged, making it harder for them to afford mitigation or to address related health consequences of nitrate contamination. The continued use of nitrogen-based fertilizers (Dubrovsky et al. 2010; Ruddy et al. 2006) and the increasing demand for groundwater (Glover 2010) further highlight the importance of this contaminant, because exposure may become increasingly widespread.

Given this context, we used water quality monitoring data from the CDPH to analyze the association between racial/ethnic and SES characteristics of people served by CWSs and nitrate levels of these systems in the San Joaquin Valley. With few exceptions (Byrne 2003), there has been limited use of CDPH monitoring data to examine whether certain groups are disproportionately affected by exposure to drinking water contaminants. Similarly, despite an acknowledgment of the burden faced by small systems (Committee on Small Water Systems 1997), few studies have explored associated social disparities.

We hypothesized that CWSs serving a higher percentage of minority or lower-SES residents have higher nitrate levels and that these disparities are likely to be greater among smaller drinking water systems. Disparities in nitrate exposures, if they exist, could signal a potential environmental injustice. This analysis expands the emerging literature on drinking water quality and social disparities in the United States and informs national- and state-level policy on the needs of underresourced water systems.

Materials and Methods

Our units of observation were CWSs in California's San Joaquin Valley. We used three measures to test our study's hypotheses: *a*) estimated average nitrate concentrations for each CWS to describe average water quality served to customers; *b*) population potentially exposed (PEP) to three nitrate levels to estimate the population affected by nitrate contamination; and *c*) nitrate concentrations at points of entry into each CWS's distribution system to assess the relationship between demographic characteristics of customers and CWS nitrate levels. The first two measures were used in a series of descriptive statistical analyses. The third measure was used as the outcome variable in linear regression models that estimated the relationships between race/ethnicity and SES and a system's nitrate concentration.

Sample selection and time period. We included CWSs that were active in the San Joaquin Valley between 1999 and 2001, had at least one point-of-entry source with a nitrate sample reported for this period, and had any source (i.e., point of entry or not) with geographic coordinate data available to estimate CWS demographics. Point-of-entry sources can be defined as sources of supply (e.g., well with no treatment or effluent from a well/surface water plant) that directly enter into the distribution system (Figure 1). We used nitrate-sampling data from 1999 to 2001 and demographic data from the 2000 Census. The sampling period represents one full compliance period under the SDWA [California Code of Regulations (CCR) 2008, §64400.25]. Of the 873 CWSs that were active during 1999–2001, 711 had sources with geographic coordinates. Of these, 327 (37%) had nitrate water quality sampling data and were included in our final sample.

Average nitrate concentration for CWSs. To estimate nitrate concentration for each CWS, we selected two types of point-of-entry sources for inclusion (Figure 1): *a*) sources, such as well fields or surface water plants, that were in active use and had no treatment or that were treated for contaminants other than nitrate, and *b*) treatment plants in active use that potentially treated for nitrate. In both cases, we included only sources that were last in line to enter the distribution system (i.e., did not flow to another source before entering), to avoid double counting of nitrate levels. We used the CDPH's Permits, Inspections, Compliance, Monitoring and Enforcement database (CDPH 2008a) to identify source types, their location in relation to the distribution system, and their possible treatment techniques. If a plant had a treatment technique commonly used for nitrate (e.g., reverse osmosis), we assumed that it treated for nitrate.

We then used nitrate-sampling data for these sources from the CDPH (2008b) Water Quality Monitoring database to determine nitrate concentration at points of entry. This served as a proxy for water quality in each CWS's distribution system and for tap water quality. Nitrate levels are unlikely to change from these entry points to the tap (unless systems chloraminate, which those in the valley do not) (Haberman R, personal communication). CWSs using groundwater are required to sample each source for nitrate annually (unless a single sample or average of two samples exceeds the MCL, in which case the system must sample quarterly); CWSs using surface water must sample quarterly (CCR 2008, §64432.1). In practice, however, systems often fail to sample regularly (Haberman R, personal communication). If a nitrate sample was below the detection limit

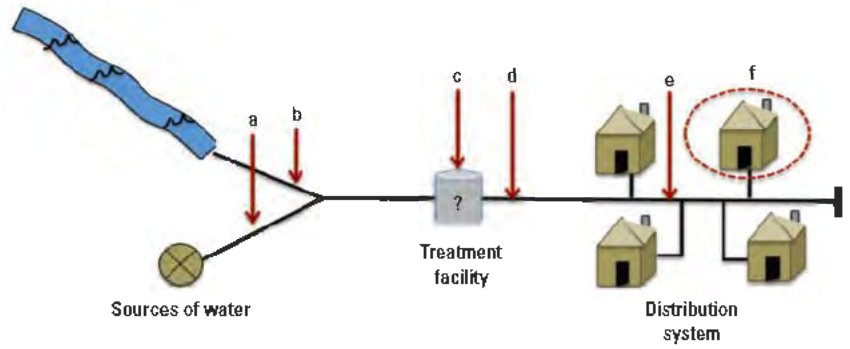


Figure 1. Schematic of a community water system (CWS) indicating the location of point-of-entry sources and the use of average nitrate concentration in the distribution system as a proxy for tap water quality. Water entering the distribution system may flow from a groundwater well (point a) or from a surface water source (i.e., stream; point b). Water may then be treated (point c; different treatment techniques may be used, depending on the contaminant of interest and original source). Water then enters the distribution system at points of entry (point d). In this example, nitrate samples would be used from point d, because points a and b flow into the same point of entry. Average nitrate level at point d is used to represent average water quality in the distribution system (point e). Nitrate levels in the distribution system are a proxy for tap water quality (point f). If points a and b are separate points of entry (i.e., do not flow into a shared point d), nitrate sample points would be used from each source separately. Constant and equal flows are assumed.

of 2 mg NO_3/L (CCR 2008, §64432), we took the square root of the value as a proxy for that sample's nitrate level (Lubin et al. 2004). We did not have flow measurements for the individual sources that contributed water to each CWS's distribution system. Therefore, we could not determine a flow-weighted measure of distribution water quality for each CWS based on the nitrate level measured in samples from each contributing source. Instead, we assumed that each point-of-entry source contributed independently and equally to a CWS's distribution system, and that each source contributed a constant amount to the system, regardless of season.

Finally, we determined the average nitrate level for each point-of-entry source and averaged the resulting values across all sources to estimate an average systemwide nitrate level. The systemwide average was then used to categorize each CWS's average nitrate concentration as *a*) low, defined as < MCL/2 (< 22.5 mg NO_3/L); *b*) medium (22.5–44.9 mg NO_3/L); and *c*) high (≥ 45 mg NO_3/L, the MCL for nitrate). These categories correspond to those used to assess source-level nitrate concentrations for regulatory purposes (CCR 2008, §64432.1). Besides the high category, the medium category is important to consider because research suggests that exposure to nitrate in drinking water at half the MCL can cause adverse health effects among susceptible subpopulations (DeRoos et al. 2003). In addition to calculating average nitrate levels, we used nitrate MCL violation data from PICME to verify whether CWSs with high nitrates did in fact receive violations, and to run a sensitivity analysis on PEP data.

Potentially exposed population. Using a method by Storm (1994), we computed the potentially exposed population (PEP) by apportioning the total population served by each CWS into three exposure categories based on the proportion of sources for that CWS with average nitrate levels that were low, medium, or high, as defined above. The population in each category was then summed across all CWS to estimate the total population potentially exposed to the three nitrate levels. The approach to calculate the PEP for the high-nitrate category is summarized by the following equation:

$$PEP = \sum_{i=1}^{327} [(X_i \times s_{il}/S_{it}) + (X_i \times s_{im}/S_{it}) + (X_i \times s_{ih}/S_{it})], \quad [1]$$

where X_i is the total population served in CWS i; s_{ih} is the number of sources for CWS i with average nitrate concentrations classified as high (h); and S_{it} is the total number of point-of-entry sources for CWS i. To calculate the PEP for the low (l) or medium (m) nitrate categories, we replaced s_{ih} with s_{il} or s_{im}, respectively. We used PICME 2008 data on the number of people served by each CWS to calculate the population size in each exposure category during 1999 to 2001. If the number of customers served by a CWS was not available from the PICME data, we used information from the CDPH Water Quality Monitoring database. To estimate population counts of potentially exposed individuals according to demographic characteristics (e.g., race/ethnicity) we multiplied the potentially exposed population in each nitrate category for each CWS by the estimated proportion of customers in each demographic subgroup for the CWS, and then summed these values across all CWS for each nitrate category. Because home ownership is based on housing units rather than population count, we did not derive a count of housing units.

Statistical analysis of nitrate levels and CWS characteristics. We used a linear regression model to analyze the relationship between CWS demographics and nitrate levels. We fitted a model selected *a priori* that controlled for known or hypothesized system-level confounders. We originally used a mixed model approach to account for clustering (Laird and Ware 1982). However, diagnostics of the mixed model indicated a very non-normal distribution of residuals. Therefore, we used an approach that provided inference that was robust under laxer modeling assumptions. To derive the inference (i.e., standard errors), we clustered outcomes at the water system level (i.e., point-of-entry nitrate concentrations measured on a given day for a given source). Thus, our final model reported sandwich-type robust standard errors (Huber 1967) that allow for arbitrary correlation, including correlation within or across sources in a CWS.

Our outcome variable, Y_{ijk}, is nitrate concentration for the ith water system, the jth source in system i, on day k (since 1 January 1999). Although nitrate samples from individual sources are our outcome measurements, the CWS is the primary unit of analysis, consistent with average nitrate level calculations discussed above. Our final model did not reweight CWSs with more samples (as the mixed model might have, depending on the implied estimated correlation structure), because we wanted CWS to contribute measurements based on a proxy of the number of people served. Thus, systems with more measurements contributed more to the estimates. We addressed this assumption by stratifying by system size, to see if smaller CWSs (with fewer samples) had a different effect than did larger CWSs. Because differences between the estimates of the mixed model and the linear model were small, this comparison provided evidence that the nonweighted approach of our final model was reasonable.

Key independent variables were the percentage of Latino and non-Latino people of color served by CWSs (referent category was non-Latino whites) and percent home ownership in the area served by a CWS. Latinos were analyzed separately because they are the largest ethnic group in the valley (40%; U.S. Census Bureau 2007). SES was represented by home ownership rate, which is a proxy for wealth and political representation (Krieger et al. 1997; Morello-Frosch et al. 2001; Oliver and Shapiro 1997). Because of our focus on CWS-level exposures, these variables were measured at the CWS level. We assumed these remained constant for all 3 years.

Race/ethnicity and home ownership data were derived from the 2000 U.S. Census (U.S. Census Bureau 2000). Because CWS service areas do not follow census boundaries, we used two spatial approaches in geographic information systems to estimate demographic variables for each CWS. We first compared an aerially weighted approach using digitized CWS boundaries in two pilot counties (Tulare and Fresno) with a second approach joining spatial coordinates from CDPH data for all sources (well fields, surface water intakes, and treatment plants) to census block groups. Based on spatial and goodness-of-fit comparisons, we concluded that it was reasonable to use the latter approach [for details on the aerially weighted approach and the comparison between the two methods, see Supplemental Material (http://dx.doi.org/10.1289/ehp.1002878)]. In brief, for each CWS, we estimated a population-based average of each variable across all block groups that included sources for the CWS. For example, if a CWS had two sources in two census block groups, we determined the population-weighted average of the variable across both census block groups and used that value to derive a percent estimate of demographic groups (e.g., 50% Latino) served by each CWS.

We controlled for other water system characteristics that could be potential confounders: source of water (groundwater or groundwater plus surface water vs. surface water alone), whether the system served a city (i.e., incorporated) or an unincorporated area, ownership structure of the system [publicly vs. privately owned and not regulated by the Public Utility Commission (PUC), with privately owned PUC-regulated systems as the referent category], system location (agricultural valley floor or not), season (summer/fall or winter/spring), year of sampling (2000 or 2001, with 1999 as referent category), and number of service connections (< 200 or ≥ 200 connections). CWSs with < 200 connections are generally considered "small" (CCR 2008, §64432.1). We determined ownership structure by combining data in PICME with data from the PUC's list

of regulated systems. We obtained all other characteristics from PICME. With the exception of year and season, which were measured at the source level, all covariates were measured at the water system level.

In addition to models including all CWSs, we stratified by system size to assess whether demographic effects on water quality might be stronger among smaller systems and to test the hypothesis that scale alone explains water quality. We also used our final model to estimate the amount of nitrate contamination attributable to the proportion of the population that is Latino. We did so by using the final model to predict expected values for each observation if percent Latino equaled zero, as described in Greenland and Drescher (1993). All statistical analyses were conducted using Stata (version 10; StataCorp LP, College Station, TX). We used Stata's cluster command (clustering at the CWS level) to derive robust SEs.

Results

Descriptive statistics. The 327 systems in our sample served approximately 2.95 million people, or 96% of the San Joaquin Valley population served by CWSs (Table 1). The distribution of average system-level nitrate concentrations is right-skewed and ranges from 0 to 150 mg NO_3/L. This distribution and range are similar for average source-level nitrate concentrations and for individual sampling points (data not shown). The mean proportion of Latinos served across these CWSs was 32%, with an interquartile range (IQR) of 10–50%. The mean proportion of homeownership was 70%, with an IQR of 60–82%. Compared with all the CWSs in the valley active from 1999 to 2001, our study sample underrepresented small CWSs that have < 200 connections (49% vs. 73%; Table 1). The number of samples per source in systems with < 200 connections ranged from 1 to 110 (mean, 3.2), compared with a range of 1–133 (mean, 4.5) for systems with ≥ 200 connections. Six percent of samples had concentrations below the detection limit.

Overall, 3% (n = 10) of all CWSs in our sample had high average nitrate concentrations (above the MCL of 45 mg NO_3/L) for at least some part of the study period, 10% (n = 33) had medium average concentrations (MCL/2 to MCL), and 87% (n = 284) had low average concentrations (< MCL/2; Figure 2). Of the 10 CWSs with an average nitrate concentration > MCL, 9 had < 200 connections and 8 had only one or two sources. All but 1 of these 10 CWSs received at least one MCL violation during the study period, and 14 CWSs in our sample (serving ~ 92,268 people) received at least one MCL violation [PICME (CDPH 2008a); see also Supplemental Material, Table 1 (http://dx.doi.org/ 10.1289/ehp.1002878)].

CWSs that served higher fractions of Latinos and lower fractions of homeowners (i.e., more renters) had higher average nitrate levels. Figure 3 shows that in the two highest Latino quartiles, proportionately more systems had average nitrate concentrations > MCL (i.e., 5% and 7% in the two higher quartiles compared with 0% in both of the lower quartiles). These two quartiles also had the largest fractions of CWSs in the medium nitrate category. The two quartiles with the lowest rates of home ownership had the

Table 1. CWSs included in study sample compared with all active CWSs, San Joaquin Valley, California, 1999–2001.

Variable of interest	Active CWSs with source location (n = 327)	CWSs in study (n = 327)	CWSs with < 200 connections (n = 160)	CWSs with ≥ 200 connections (n = 167)
Total population	3,047,822[a]	2,948,346	27,165	2,921,181
Latino population (%)	34	39	29	40
White population (%)	58	47	64	47
Population above poverty level[b] (%)	57	57	59	57
Population served (mean/median)	4,206/150	9,016/565	170/100	17,492/430
Incorporated[c] (%)	9	18	2	34
< 200 connections (n)	73	49	100	0
Only groundwater[d] (%)	89	90	97	84
Groundwater and surface water[d] (%)	5	8	3	13

[a]Approximately 71,418 people were served by CWSs whose sources did not have geographic coordinates, and 80 CWSs had no population estimates available; including these sources, the estimate of "true" population served by active CWSs was at least 3,119,240. [b]Above 200% of the poverty level. [c]A CWS that serves a city that is a legally recognized municipal corporation with a charter from the state and governing officials that is incorporated, as opposed to a water system that serves an unincorporated area. [d]Reference group, surface water only.

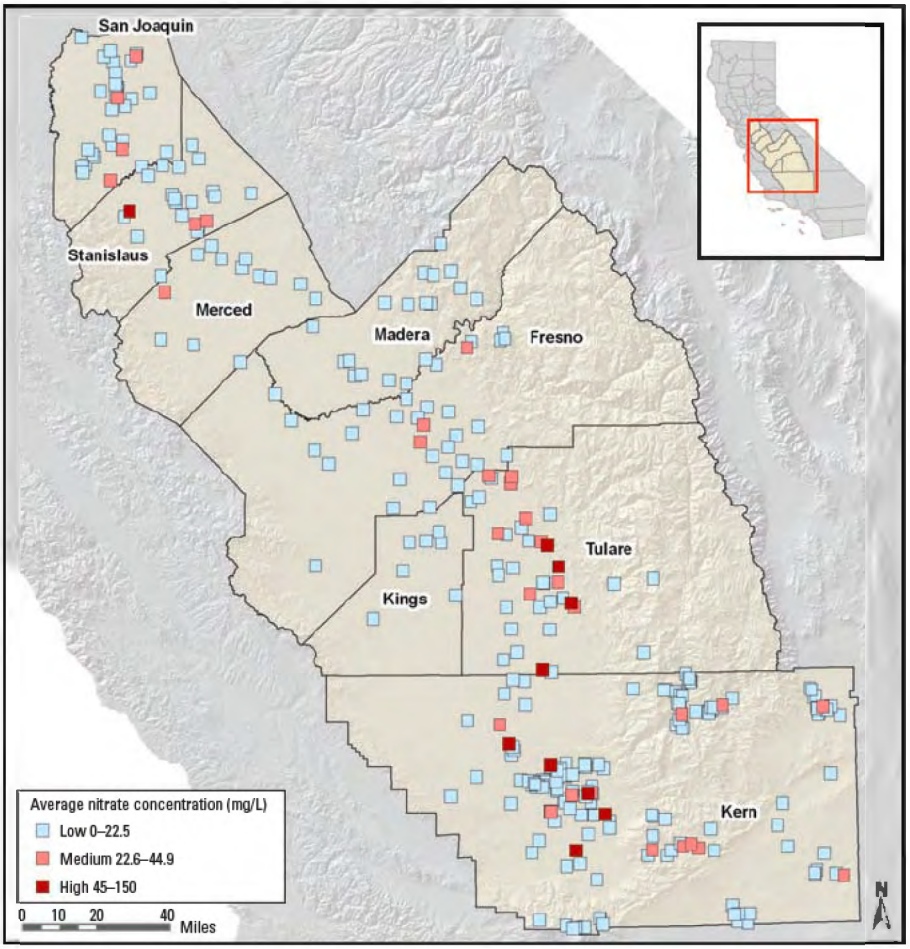


Figure 2. Average nitrate concentration of CWSs in California's San Joaquin Valley, 1999–2001 (n = 327). Estimates are based on an average of each point-of-entry source's average concentration. Data are from CDPH (2008) Water Quality Monitoring and PICME databases (CDPH 2008a, 2008b). Approximate locations of CWSs are depicted, but not true boundaries. Because of close proximity of some CWSs, some CWSs not fully visible.

largest proportions of systems in the medium and high nitrate categories (15% and 22%, respectively), compared with the two quartiles with the highest rates of home ownership (which had 7% and 8%, respectively).

Of the population served in our sample, approximately 84.6% (~ 2,494,442 people) were potentially exposed to low nitrate levels, 15.2% (~ 448,729 people) to medium nitrate levels, and 0.2% (~ 5,176 people) to high nitrate levels (Table 2). Of the 5,176 people served water with nitrates above the MCL, 56% were people of color (50% Latinos and 6% non-Latino), compared with 52% in the low and medium nitrate categories (Table 2).The percentage of Latinos served by high-nitrate CWSs was higher than the percentage of Latinos served by CWSs in the other two nitrate categories (39% and 40% for low and medium nitrate, respectively). This percentage was also greater than the percentage of Latinos in our entire study sample (39%; Table 1). This percentage was also higher than the percentage of Latinos served by CWSs in the other two nitrate categories (39% and 40% for low and medium nitrate, respectively).

Model results. Table 3 shows the multivariate modeling results. Unadjusted models indicate that percent Latino was positively and significantly [β = 0.14; 95% confidence interval (CI), 0.04–0.24] correlated with the average nitrate concentration in the distribution system. Conversely, home ownership was negatively correlated with average nitrate concentration but only marginally significant (β = –0.15; 95% CI, –0.30 to 0.003).

Our adjusted model suggests that, on average, a 1% increase in Latinos served by a CWS was associated with an increase of 0.04 mg NO_3/L (95% CI, –0.08 to 0.16). For home ownership, each percent increase was associated with a decrease of 0.16 mg NO_3/L (95% CI, –0.33 to 0.002). For systems with < 200 connections, the associations between percent Latino and home ownership and nitrate concentration were consistent with both the unadjusted model and adjusted model for all CWSs, but the strength of the association for percent Latino increased. Specifically, on average, each percent increase in Latino was associated with a 0.44 mg NO_3/L increase (95% CI, 0.03–0.84) in the smaller systems. A 1% increase in home ownership was associated with a 0.15 mg NO_3/L decrease (95% CI, –0.64 to 0.33), although the association was not statistically significant. In systems with ≥ 200 connections, neither race/ethnicity nor home ownership was associated with nitrate concentrations. Using the final model to predict expected values, we estimated that among small systems, nitrate levels for CWSs with 0% Latinos would be, on average, 6 mg NO_3/L lower compared with CWSs at the mean.

Discussion

To our knowledge, this is the first study to examine the relationship between nitrate levels in CWSs and social disparities in the United States. After stratifying by system size, we found that among systems with < 200 connections, those serving higher percentages of Latinos had higher nitrate levels. We found an inverse but not statistically significant association between home ownership and nitrate levels for smaller systems. For large systems, we did not find significant associations between race/ethnicity or home ownership and nitrate levels. Our findings corroborate previous drinking water studies (e.g., Byrne 2003) that showed a positive relationship between percent minority and poor water quality but are specific to nitrate contamination at the community level. That water quality varied by percent Latino or home ownership matters not only because of environmental equity but also because elevated nitrate levels could pose a greater hazard to subpopulations that may have less access to health care.

The association of race/ethnicity and SES with nitrate levels could be due to several factors. Race/ethnicity could have been related to proximity to agriculture, as well as the ability of residents to participate in the governance of their CWSs. For example, in systems with higher fractions of Latinos, language abilities, citizenship status, or lack of political clout could inhibit residents from speaking out and demanding improvements in water quality (for a discussion in relation to electoral politics, see Michelson 2000). Home ownership could have been negatively associated with nitrate levels because renter-based communities may have had a lower capacity to pay for improvements in water infrastructure or to hold a CWS accountable, assuming they received notices of violation as required (CCR 2008, §64463). Or, it might indicate that a lack of economic resources may influence whether CWSs can hire capable water managers or comply with regulations.

That > 5,000 people in our study sample were potentially exposed to drinking water with nitrate concentrations above the MCL raises health concerns. As noted, acute and chronic health effects have been found for vulnerable populations (e.g., infants and pregnant women) exposed to nitrate exceeding the MCL (Ward et al. 2005). Furthermore, that many of the water systems in this category had only one or two sources can lead to increased chances of high exposure for residents if these are high-nitrate sources, because there is no immediate alternative water source to draw from or blend with. These small systems often go years with high nitrate levels, until a new water source can be developed (Spath D, personal communication). PICME (CDPH 2008a) data corroborates this observation: of the 10 systems whose average nitrate concentration exceeded the MCL, 6 had recurring MCL violations over an 8-year time frame. In these systems, customers may be continually exposed (although exposure would be lower if people frequently use alternative sources). Additionally, because customers in the

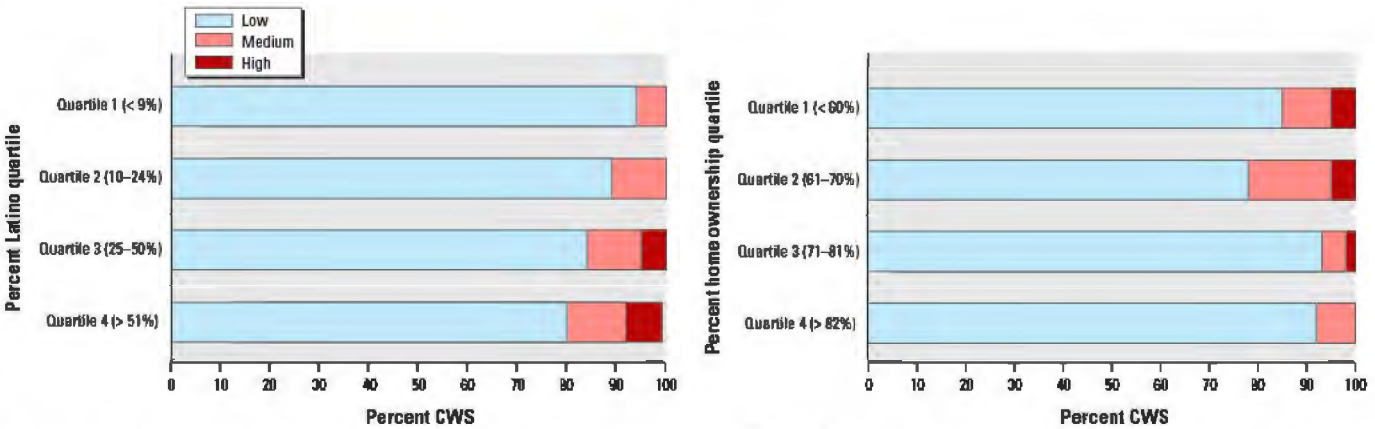


Figure 3. Percentage of CWSs with low, medium, and high average nitrate concentrations, by quartiles of percent Latino and home ownership. Average system-level nitrate concentration is derived from the average of each source's average nitrate concentration at point of entry. Low is < one half the MCL of 45 mg NO_3/L. Medium is one half the MCL up to the MCL (22.5 mg/L to 44.9 mg/L NO_3). High is ≥ to the MCL.

San Joaquin Valley often cope by purchasing bottled water, they pay two water bills—one for tap water and the other for bottled water (Moore et al. 2011).

Our results also highlight a less frequently discussed issue—approximately 448,700 residents, served by 33 CWSs, in our sample received water with medium nitrate levels (< MCL but > MCL/2). Nitrate levels in these systems could be approaching the MCL in some cases. In our study, one-third of CWSs in this category had average concentrations > 30 mg NO_3/L. Residents in these systems could be at risk of adverse health outcomes and/or could experience additional economic costs. For example, in one study, the risk of colon cancer increased for certain susceptible subgroups (e.g., those with low vitamin C intake or high meat intake) whose water had nitrate levels > MCL/2 for at least 10 years (DeRoos et al. 2003). More generally, although several authors have suggested that the current nitrate MCL could be increased to a less stringent level of regulation (L'hirondel and L'hirondel 2002), others have argued that the standard should not be changed (Ward et al. 2005) because of uncertainties in the exposure assessment data and health effect estimates of the epidemiologic study upon which the current MCL is based (Walton 1951). Some authors also argue that the MCL includes no safety factor, and documented cases of infant methemoglobinemia have occurred at levels below the MCL (Fan and Steinberg 1996). Thus, exposure to nitrates in the middle category is important to consider.

Monitoring of water quality by these CWSs is also an important consideration. CWSs with any source whose nitrate levels exceed MCL/2 (> 22.5 mg NO_3/L) are required to increase their monitoring frequency from annual to quarterly sampling (CCR 2008, §64432.1). At best, the cost of increased monitoring must be passed along to consumers. At worst, the funding and staffing constraints can limit the capacity of small CWSs to monitor; these CWSs may have nitrate levels approaching the MCL but neither the system operators nor customer base would know (Haberman R, personal communication). Such a scenario would undermine the aim of the SDWA, which is supposed to protect the public from harmful exposures and requires systems to notify their customers so that precautionary measures can be taken to reduce exposures (CCR 2008, §64480; Fan and Steinberg 1996).

This study used an appropriate unit of analysis (i.e., CWS) for estimating system-level nitrate exposure. The methods we used could be applied to other contaminants and to other regions of the United States. However, sources of error exist in our demographic estimate because *a*) surface intakes/well fields could fall in census block groups not served by the CWS, *b*) not all census block groups served by a CWS have an intake/field located within them, and *c*) Latinos in census data could be undercounted because of legal status. Despite these potential errors, for most CWSs, sources fell within the same census block groups that overlapped with service area boundaries of CWSs. And, for 9 of the 10 systems in the high-nitrate category, all sources were in the same census block groups as those included in each CWS service area [see Supplemental Material (http://dx.doi.org/10.1289/ehp.1002878)]. Additional sources of error include possible misclassification of points of entry to the distribution system because of errors in PICME. Furthermore, because the relative flow of different sources contributing to each CWS was not known, our method may have over- or underestimated average nitrate levels. However, at least among CWSs with average concentrations over the MCL, the estimated concentrations were similar to the measured concentrations for which that CWS received one or more MCL violations. Our measure of exposure was limited by data availability, so for systems with fewer samples tested for nitrates, our estimate may be less accurate. Although the number of persons potentially exposed to nitrate over the MCL is small, it is likely to be an underestimate of the actual population affected in the San Joaquin Valley. This is partly because our study underrepresented smaller CWSs, and partly because we used average rather than maximum nitrate levels or other measures of nitrate (e.g., MCL violations). Thus, our estimate is likely to be a conservative measure of potential exposure. The estimate of the PEP may also contain some error, because there may be some differences among utilities in how population estimates are calculated. Finally, although our results are based on data that are 10 years old, we believe that, at a minimum, they capture current trends in the San Joaquin Valley because nitrate concentrations generally

Table 2. Demographic profile of total PEP[a] in study sample by average level of nitrate concentration.

Variable of interest	Nitrate level		
	Low	Medium	High
Percent total population (n = 2,948,346)	84.6	15.2	0.2
Percent Latino (n = 1,164,714)	39	40	50
Percent non-Latino people of color (n = 389,336)	13	12	6
Percent white (n = 1,394,296)	47	48	44

Low is less than one-half the MCL of 45 mg NO_3/L; medium is one-half the MCL up to the MCL (22.5 mg/L to 44.9 mg/L NO_3); high is equal to or greater than the MCL.
[a]Per water system, PEP is the population count of the demographic variable of interest x (number of point-of-entry sources in one of three nitrate levels ÷ by the total number of point-of-entry sources). PEP displayed in table is equal to the sum across all water systems. This value can also be interpreted as the estimated number of people served water at this level.

Table 3. Regression for factors associated with nitrate concentration (mg NO_3/L) in CWSs, with beta coefficients, 95% CIs, and levels of significance.

Variable	Model A[a]	Model B[a]	Model C[b]	Model D (< 200 con.)	Model E (≥ 200 con.)
Constant	14.2 (9.1 to 19.4)#	27.1 (16.3 to 38.0)*	6.3 (–11.4 to 24.0)	10.8 (–32.3 to 53.9)	3.2 (–15.5 to 21.9)
Percent Latino	0.14 (0.04 to 0.24)#		0.04 (–0.08 to 0.16)	0.44 (0.03 to 0.84)**	–0.01 (–0.12 to 0.10)
Percent non-Latino people of color	–0.18 (–0.62 to 0.25)		–0.15 (–0.47 to 0.18)	–0.44 (–1.1 to 0.27)	–0.13 (–0.45 to 0.18)
Percent home ownership		–0.15 (–0.30 to 0.003)*	–0.16 (–0.33 to 0.002)*	–0.15 (–0.64 to 0.33)	–0.10 (–0.27 to 0.07)
Incorporated			–4.4 (–9.3 to 0.56)	–2.9 (–31.8 to 25.9)	–4.1 (–9.3 to 1.1)
Groundwater or combined[c]			9.7 (4.3 to 15.2)#	NA	11.7 (7.9 to 15.4)#
Private non-PUC regulated[d]			2.7 (–5.4 to 10.9)	5.5 (–2.7 to 13.7)	–0.23 (–4.5 to 4.1)
Public[d]			7.2 (2.8 to 11.5)#	10.3 (–17.4 to 38.0)	7.3 (3.6 to 11.1)
< 200 service connections			9.1 (–2.5 to 20.7)	NA	NA
Valley floor			7.9 (1.6 to 14.2)**	1.7 (–12.0 to 15.4)	7.4 (1.0 to 13.9)
2000[e]			1.3 (–0.44 to 3.1)	5.0 (1.2 to 8.8)#	0.71 (–1.1 to 2.6)
2001[e]			1.4 (–0.26 to 3.1)*	5.5 (1.9 to 9.1)#	0.67 (–0.98 to 2.3)
Summer/fall			1.3 (–0.30 to 2.9)	3.2 (0.31 to 6.3)**	1.1 (–0.72 to 3.0)

NA, not applicable, because no CWS in this model run contains this factor, or all CWSs have this factor. Data are regression statistics with robust SEs, clustered by CWSs. Coefficients represent the estimated difference in mean concentration at the system level associated with a unit change in the covariate (95% CI). Empty cells indicate that the unadjusted model included only the key variables of interest.
[a]Unadjusted models, all CWSs included. [b]Adjusted model, all CWSs included. [c]Surface water is referent category. [d]Privately owned PUC-regulated CWSs are referent category. [e]1999 is referent year. *$p < 0.10$. **$p < 0.05$. #$p < 0.01$.

change slowly in deeper public supply wells and have been increasing in most locations because of increasing fertilizer use (Dubrovsky et al. 2010).

Conclusion

Our study is one of the first to analyze the relationships between drinking water contamination, race/ethnicity, and SES in the United States and the first that focuses on social disparities in nitrate contamination. Our results indicate that Latinos in the San Joaquin Valley may be disproportionately exposed to higher levels of nitrates and that this exposure is particularly prevalent in smaller water systems. With the increasing use of nitrogen-based fertilizers and growing demand for groundwater, these trends are likely to worsen in future years. Regulatory and policy strategies to address scale-related vulnerabilities in drinking water quality have generally ignored the environmental justice implications for CWSs. Given the U.S. EPA's renewed focus on environmental justice (U.S. EPA 2009) and the paucity of environmental justice studies on drinking water, this study highlights the importance of targeting funding for mitigation and source water protection efforts for underserved communities and those with nitrate levels over the MCL. Furthermore, there is a need for resources to better monitor water quality and develop precautionary mitigation for communities with nitrate levels > MCL/2.

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EXHIBIT D

Balazs et al. Environmental Health 2012, 11:84
http://www.ehjournal.net/content/11/1/84

ENVIRONMENTAL HEALTH

RESEARCH Open Access

Environmental justice implications of arsenic contamination in California's San Joaquin Valley: a cross-sectional, cluster-design examining exposure and compliance in community drinking water systems

Carolina L Balazs[1*], Rachel Morello Frosch[2,3], Alan E Hubbard[2] and Isha Ray[1]

Abstract

Background: Few studies of environmental justice examine inequities in drinking water contamination. Those studies that have done so usually analyze either disparities in exposure/harm *or* inequitable implementation of environmental policies. The US EPA's 2001 Revised Arsenic Rule, which tightened the drinking water standard for arsenic from 50 μg/L to 10 μg/L, offers an opportunity to analyze both aspects of environmental justice.

Methods: We hypothesized that Community Water Systems (CWSs) serving a higher proportion of minority residents or residents of lower socioeconomic status (SES) have higher drinking water arsenic levels and higher odds of non compliance with the revised standard. Using water quality sampling data for arsenic and maximum contaminant level (MCL) violation data for 464 CWSs actively operating from 2005–2007 in California's San Joaquin Valley we ran bivariate tests and linear regression models.

Results: Higher home ownership rate was associated with lower arsenic levels (ß coefficient= −0.27 μg As/L, 95% (CI), 0.5, 0.05). This relationship was stronger in smaller systems (ß coefficient= −0.43, CI, 0.84, 0.03). CWSs with higher rates of homeownership had lower odds of receiving an MCL violation (OR, 0.33; 95% CI, 0.16, 0.67); those serving higher percentages of minorities had higher odds (OR, 2.6; 95% CI, 1.2, 5.4) of an MCL violation.

Conclusions: We found that higher arsenic levels and higher odds of receiving an MCL violation were most common in CWSs serving predominantly socio economically disadvantaged communities. Our findings suggest that communities with greater proportions of low SES residents not only face disproportionate arsenic exposures, but unequal MCL compliance challenges.

Keywords: Revised arsenic rule, Arsenic, Drinking water, Social disparities, Environmental justice, Water systems, Safe drinking water act, Exposure

* Correspondence: carolinabalazs@berkeley.edu
[1]Energy and Resources Group, University of California, Berkeley, CA 94720, USA
Full list of author information is available at the end of the article

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Background

Arsenic in drinking water is linked to skin, lung, bladder and kidney cancers [1-3]. The most common exposure pathway is consumption of groundwater containing arsenic [4]. Many epidemiological studies examining health effects of arsenic in drinking water have been conducted in areas with extremely high levels (i.e., > 100 μg As/L)—such as Argentina, Bangladesh and Taiwan. But high concentrations (i.e., 50–100 μg As/L) also occur in the U.S, especially in western regions such as Utah, Nevada, Arizona and California [5-8]. Here, arsenic in groundwater is generally naturally occurring, but can also derive from agricultural activities including pesticide application and industrial uses (e.g. wood treatment) [4,9]. In California's San Joaquin Valley, arsenic can reach elevated concentrations due to mobilization caused by agricultural activities. In particular, irrigation and drainage enhance arsenic releases, while high evapotranspiration rates can concentrate arsenic in surface water and shallow groundwater [4,10,11].

In 2001, on the basis of epidemiologic evidence and cost-benefit considerations [12] the U.S. Environmental Protection Agency (EPA) issued the Revised Arsenic Rule, reducing allowable arsenic concentrations in drinking water from 50 μg/L to 10 μg/L. The revision of this drinking water standard came with much debate. Critics of the standard argued that there was uncertainty in the risk assessment, and that the cost-benefit analyses overestimated benefits in relation to costs of compliance. Ultimately, however, the EPA's Science Advisory Board and the National Research Council (NRC) concluded that the science was sufficient to warrant a more health-protective standard [12-14].

The revised rule elicited considerable discussion regarding equity considerations for small water systems [15,16]. Of the estimated 5.5% of community water systems that were expected to be affected by the Revised Arsenic Rule, nearly 97% were small systems serving fewer than 10,000 customers [17]. Benefit-cost analyses concluded that although there would be a net benefit for households, the average annual compliance costs for residents served by smaller systems would be much greater. Recognizing this discrepancy, the US EPA extended the compliance date by two years for systems serving fewer than 10,000 customers, assessed alternative affordable technologies for small systems and focused on analyzing additional impacts that would be felt by these systems [14]. Effective in 2002, the Revised Arsenic Rule required all public water systems to comply with the new standard by January 23, 2006 [14].

Besides these scale-related considerations, however, little attention was given to other potential social disparities that could arise in, for example, exposure to arsenic, or the types of small systems that would be able to comply with the revised standard. In response, several environmental justice-oriented studies explored potential inequities in exposure to arsenic [18,19] and in enforcement of the arsenic standard [5]. Generally, these studies focused on two types of distributional issues: (1) disparities in environmental harms, such as exposure to contaminants, or disparities in health outcomes, and (2) disparities in the inequitable implementation of policies and programs, including access to federal funds or capacity to comply.

Attention to both components of environmental justice is certainly warranted. We argue, however, that a joint focus – on compliance challenges as well as exposure to contaminants – is most helpful for understanding the health and social implications of drinking water policies, including the Revised Arsenic Rule. Quantifying a water system's compliance with the arsenic MCL is important to know which systems are in violation, and to consider whether they are equipped to comply. This "compliance burden" allows for an exploration of whether certain groups or communities have unequal abilities in the capacity to meet the standard. Quantifying exposure levels and their distribution is important, given known health risks at levels even below the new standard. Thus this study employs what we term a "joint burden analysis," to analyze the environmental justice implications of compliance capacity and exposure related to arsenic contamination. Together, these analyses provide a picture of the joint burdens that water systems and residents may face.

We applied a cross-sectional analysis of social disparities related to the Revised Arsenic Rule. We conducted our study in California's San Joaquin Valley, one of the poorest regions in the country with some of the most contaminated drinking water sources in California [20], including high nitrate and high arsenic levels [21]. We focused on community water systems (CWSs), which are public water systems that serve at least twenty five customers or fifteen service connections year-round [22]. We hypothesized that CWSs serving a higher proportion of minority or lower socioeconomic status (SES) residents have a higher odds of non-compliance with the revised arsenic standard and that these CWSs serve drinking water with higher levels of arsenic.

Our analysis provides two contributions to the arsenic and drinking water literature. By assessing exposure disparities and compliance burdens at the time of the enactment of the Revised Arsenic Rule, we assess the potential exposure and compliance disparities that existed but were not fully incorporated into policy assessments. Secondly, we consider the compliance challenges that CWSs could face moving forward, broadening the discussion of policy implementation issues that must be considered by drinking water regulators and the US EPA.

Given the U.S. EPA's renewed discussion of the impact of the Revised Rule on small systems, and on how to help small systems achieve compliance, the results of this study are timely for policy circles as well. For example, the U.S. EPA recently convened a working group on arsenic in small water systems to provide input on barriers to the use of point-of-use and point-of-entry treatment units, as well as alternative affordability criteria that pay particular attention to small, rural, and lower income communities [23]. Our study's quantitative analysis of the distribution of exposure and compliance burdens therefore adds to the environmental justice literature and informs these policy discussions.

Methods

Sample selection and selection of point-of-entry sources

We selected CWSs located in California's San Joaquin Valley that were actively operating between 2005 and 2007, had at least one source with a geographic coordinate that could be used to estimate customer demographics, and had at least one active point-of-entry source with an arsenic sample reported during this period. These selection criteria resulted in a slight under-representation of smaller systems (i.e., < 200 connections) in our final sample (see Additional file 1: Table A1). Our time period represents one full compliance period under the SDWA, in which each CWS should have taken at least one arsenic sample [24].

Point-of-entry sources are those that directly enter the distribution system. We selected two types of point-of-entry sources: (1) sources in active use that had no arsenic treatment, or that treated for contaminants other than arsenic, and (2) treatment plants in active use that potentially treated for arsenic (Additional fle 2: Figure A1). We used the California Department of Public Health's (CDPH) Permits, Inspections, Compliance, Monitoring and Enforcement (PICME) database [25] to identify source types, their location in relation to the distribution system, and their possible treatment techniques. We confirmed the existence of arsenic treatment technologies with state and county regulators.

For the six CWSs with confirmed arsenic treatment plants that were in use during the study period, we used all point-of-entry sampling points prior to installation of treatment, and only sampling points from treatment plants after the installation date. For CWSs with no confirmed arsenic treatment, we selected systems where either all point-of-entry sources were labeled as untreated, or all point-of-entry sources were labeled as having treatment. In practice a CWS may have both treated and untreated sources. But because the CDPH databases did not allow us to accurately ascertain whether untreated sources entered the distribution system if treated sources were also available, we conservatively selected CWSs in this manner. We tested the sensitivity of this decision by comparing regression results using our final sample to results using all CWSs. Our final sample included 464 of the 671 CWS active in the Valley from 2005 to 2007.

Outcome measures and independent variables

In order to assess compliance with the Revised Arsenic Rule (i.e., MCL violations) and exposure burdens, we conducted two main sets of analyses: one focused on MCL violations, the other on exposure. Specifically, for each CWS, we derived four main outcome measures: (1) officially recorded arsenic MCL violations, (2) average system and source-level arsenic concentrations, (3) population potentially exposed to arsenic, and (4) water quality samples of arsenic concentrations at point-of-entry to the distribution system. We used the first measure to analyze compliance. We used the second two measures to derive descriptive exposure statistics and run sensitivity analyses. We used the fourth measure as the outcome variable in a linear regression model. We calculated average arsenic measures because (1) the MCL for arsenic is assessed using running annual average of arsenic concentrations for water systems; and (2) this MCL is based on a consideration of long-term chronic exposure making the average concentration of arsenic a suitable metric.

Arsenic MCL violations

The key outcome for our compliance analysis was officially recorded arsenic MCL violations derived from the PICME database. We created a binary variable indicating whether a system had received at least one MCL violation during the study period. This measure helped control for bias that could occur because CWSs with higher arsenic levels are required to sample more frequently [26], thereby increasing the probability that they would receive more MCL violations.

Average system and source-level arsenic concentrations

To estimate arsenic concentrations in the distribution system we used arsenic water quality sampling data for the selected point-of-entry sources from CDPH's Water Quality Monitoring database [27] (Additional file 2: Figure A1). Previous studies have noted the benefit of using such publicly available water quality monitoring records as an alternative to costly tap water samples [28]. Using these data points, we derived the average arsenic concentration served by each CWS for the entire compliance period. We calculated this by averaging the average source concentrations for each system during our time period. As in previous studies [5,19], we assumed average system-level concentrations represent the average arsenic concentration in water served to residents. We also calculated each CWS's yearly average arsenic concentration to conduct sensitivity analyses. Because we did not have flow

measurements for individual sources, we assumed that each point-of-entry source contributed independently, constantly and equally, to a CWS's distribution system, regardless of season. For sampling points below the detection limit, we took the square root of the detection limit as a proxy for the arsenic concentration [29].

We categorized source-level and system-level averages into three concentration categories defined in relation to the revised arsenic rule (> 10 μg As/L) and the old rule (> 50 μg As/L): (1) < 10 μg As/L ("low"), (2) 10–49.9 μg As/L ("medium"), and (3) ≥ 50 μg As/L ("high"). In addition, we used average source and system-level concentrations to create binary variables that we used in bivariate analyses. Here, average levels were coded as 1 (≥ 10 μg As/L), or 0 (< 10 μg As/L).

Potentially exposed population

Using a previously developed method [30] described in Balazs et al. [31], we computed the population potentially exposed to the three aforementioned exposure categories. The approach to calculate the potentially exposed population (PEP) for the high-arsenic category is summarized by the following equation:

$$PEP_h = \sum_{i=1}^{464} (X_i \times s_{ih}/S_{it}) \quad (1)$$

where X_i is the total population served in CWS i; s_{ih} is the number of sources for CWS i with average arsenic concentrations classified as high (h); and S_{it} is the total number of point-of-entry sources for CWS i. To calculate the PEP for the low (l) or medium (m) categories, we replaced s_{ih} with s_{il} or s_{im}, respectively. We used PICME data on the number of people served by each CWS to calculate the population size. If the number of customers served by a CWS was not available from the PICME database, we used information from the Water Quality Monitoring database. To estimate counts of potentially exposed individuals according to demographic characteristics (e.g. race/ethnicity) we multiplied the PEP in each arsenic category for each CWS by the estimated proportion of customers in each demographic subgroup for the CWS (e.g. 50% people of color), and then summed these counts across all CWSs for each arsenic category.

Concentration of arsenic at point-of-entry

Arsenic sampling data for each point-of-entry source were used as the outcome variable in our regression model, as described under "Regression Model" below.

Analyses

Compliance analyses

We used our binary arsenic MCL violation variable to analyze whether CWSs with higher fractions of people of color or lower SES faced greater compliance violations. Because only 34 CWSs had at least one MCL violation we did not have enough outcomes to use multivariate regression techniques. Instead we ran Fisher's Exact tests for contingency tables, comparing the presence of at least one MCL violation to CWSs with high or low levels of our variables of interest (i.e. race/ethnicity or homeownership). To determine the threshold for high and low levels of race/ethnicity (i.e., percent people of color) or homeownership rate we used the median value of these variables.

To consider the impact of under- or mis-reported violations, we ran sensitivity analyses in which we replaced official MCL violations with the number of CWSs with any source whose average yearly arsenic concentrations exceeded the MCL during the study period, and the number of CWSs with any source whose compliance period average exceeded the MCL. This allowed for an approximation of whether a system may have exceeded the MCL (and so should have been issued an MCL violation) since arsenic MCL violations are based on a running annual average [26]. Thus these sensitivity analyses should capture differences due to MCL exceedances that went under-reported.

Exposure analyses

To assess the relationship between demographics of customers served by CWSs and potential exposure, we first examined the demographic characteristics of the population potentially exposed to three different arsenic levels, and additional characteristics of the systems at those levels. To further analyze the relationship, we used our binary variables for average system-level arsenic concentrations to conduct Fisher's Exact tests.

Finally, we examined the relationship between system-level demographics and arsenic levels using our continuous measure of arsenic concentrations. We used a linear cross-sectional regression model with robust standard errors to account for clustering. To derive the inference, we clustered outcomes at the CWS-level (i.e. point-of-entry arsenic concentrations measured on a given day for a given source). Our final model reported sandwich-type robust standard errors [32] that allowed for arbitrary correlation, including correlation within CWS units. The a priori selected model controlled for known or hypothesized potential system-level confounders.

The model's outcome variable, $Y_{ijk,}$ was arsenic concentration for the i^{th} water system, the j^{th} source in system i, on day k (since January 1st, 2005). While arsenic samples from individual sources were our outcome measurements, the CWS was the primary unit of analysis, consistent with other calculations above. Our final model did not re-weight CWSs with more samples; thus systems with more

measurements contributed more to the estimates. We addressed this issue by stratifying by system size to see if smaller CWSs (with fewer samples) had a different effect on water quality than larger CWSs.

Key independent variables were the percentage of people of color served by CWSs (referent category non-Latino whites) and percent home ownership in each CWS. Home ownership rate is a proxy metric for wealth and political representation [33]. We used this SES measure as an indicator of the economic resources available to a water system to mitigate contamination [34]. Race/ethnicity and home ownership data were derived from the 2000 U.S. Census, measured at the CWS-level, and assumed to be constant for all three years [35]. Since CWS service areas do not follow Census boundaries we used a spatial approach in Geographic Information Systems (GIS) to estimate demographic variables for each CWS. In brief, for each CWS, we estimated a population-weighted average of each variable across all block groups that contained sources for the CWS. This value was used to derive a percent estimate of demographic characteristics (e.g. 50% homeownership) served by that CWS [31].

We controlled for other potentially confounding water system characteristics including: source of water (ground water or groundwater and surface water versus surface water alone); system ownership (public, privately owned and not regulated by the Public Utility Commission (PUC), with private PUC-regulated as referent category); geographic location (Valley floor and foothills, with mountains as referent category); season (summer/fall or winter/spring); year of sampling (2006 and 2007, with 2005 as referent category); and number of service connections (< 200 or ≥ 200 connections). We determined ownership structure by combining data in PICME with data from the PUC's list of regulated systems. We obtained all other characteristics from PICME. With the exception of year and season, all covariates were measured at the water system level.

We stratified by system size to assess if demographic effects on water quality might be stronger among smaller systems, and to test the hypothesis that scale alone explains water quality. We used number of connections as a threshold for small versus large CWSs, where those with fewer than 200 connections are considered "small" [26]. We used our final model to estimate the amount of arsenic contamination attributable to the proportion of the population that are homeowners by predicting expected values for each observation if percent homeownership equaled 100%, as described by Greenland and Drescher [36]. All statistical analyses were conducted using Stata v10 (College Station, Texas). We used Stata's cluster command to derive robust standard errors.

Results

Descriptive statistics

The 464 CWSs in our study sample served 1.134 million people, representing 37% of the total population served by CWSs between 2005 and 2007, and 69% of all CWSs active through 2007 (Table 1). The mean percentage of people of color served by each CWSs was 39% [inter-quartile range (IQR), 16-57%]. The mean percent of homeownership was 70% (IQR, 60-81%). The yearly average arsenic concentration in 2005, 2006 and 2007 was 7.0 μg/L (median = 3 μg/L) 7.9 μg/L (median = 2.5 μg/L), respectively and 6.8 μg/L (median = 3 μg/L), respectively. Approximately 12% of samples were below the detection limit.

Nearly 15% of all CWSs in the sample had average arsenic concentrations between 10 and 50 μg As/L, and were therefore affected by the revised standard (Table 2). Among these, 66% had fewer than 200 connections, and 86% had three active wells or less. For each CWS with average arsenic in this range, the average percentage of a CWS's sources that exceeded the revised MCL was 87% (Table 2). Less than 1% of CWSs had average levels greater than 50 μg As/L. Among these, all had fewer than 200 connections. CWSs west of Highway 99 and in the central portion of the Valley had higher arsenic levels, as did some areas in the foothills and in southeastern Kern County (Figure 1).

Of the population served in our sample, approximately 14% was potentially exposed to arsenic levels over 10 μg/L MCL (Table 3). Of the population potentially exposed to 10–50 μg As/L, 61% were people of color (i.e. Latinos and non-Latino people of color). This is higher than the corresponding percentage in the entire study sample (i.e., 55%, Table 1).

Statistical analyses

Compliance analyses: MCL violations

Thirty-four CWSs, serving 151,391 people, received at least one arsenic MCL violation during the study period. Of these, 31 had average system-level arsenic concentrations over 10 μg As/L and 3 had average concentrations of 8, 8.8 and 9.9 μg As/L. CWSs serving higher percentages of homeowners had a 67% lower chance of having at least one MCL violation (Table 4). CWSs serving higher percentages of people of color had a 260% higher chance of having at least one MCL violation. Sensitivity analyses in which we used average source-level concentrations were consistent, yielding results of similar strength and direction (see Additional file 3: Table A2).

Binary measure of exposure

CWSs serving higher percentages of homeowners had a 57% lower chance of having average arsenic levels above the revised MCL (Table 5). CWSs serving higher

Table 1 Characteristics of community water systems (CWSs) in study sample compared to all CWSs in study region with geographic coordinates, 2005-2007, San Joaquin Valley, CA

Variable of interest	Active CWS with geographic coordinates n = 644	CWS in study: active, w/ coordinates and arsenic samples n = 464	CWS in study: < 200 connections n = 324	CWS in study: ≥ 200 connections n = 140
Total population (count)	3,037,785	1,134,017	49,340	1,084,677
Population Characteristics (%)				
People of Color (Latinos and Non Latinos)	53	55	38	56
White population	47	45	62	44
Population above poverty[a]	57	54	60	54
Water System Characteristics (%)				
Mean People of Color	42	39	35	50
Mean Home Ownership	67	70	72	67
Population served (mean/median)	4,717/163	2,444/180	152/100	7,748/2537
Incorporated [b]	10	9	1	29
< 200 Connections	72	70	100	0
Groundwater Alone (GW)[c]	88	92	95	87
GW and surface water[c]	7	4	2	9
Publicly owned[d]	32	32	13	75
Privately owned non PUC reg.[d]	60	61	80	16
Water Quality Characteristics				
Min Max; mean (μg As/L)	NA	0 158; 6.0	0 158; 6.2	0 42; 57
IQR (μg As/L)	NA	1.4, 6.3	1.4, 6.2	1.4, 7.3
CWS with ^{3}1 As MCL Viol	44	34	15	19

NA not applicable because not all active sources had arsenic samples, *IQR* interquartile range.
[a] Above 200% the poverty level; [b] A water system that serves a city that is a legally recognized municipal corporation with a charter from the state and governing officials that is incorporated, as opposed to a water system that serves an unincorporated area; [c] Reference group=surface water only; [d] Reference group=privately owned and Public Utility Commission (PUC) regulated or unknown.

percentages of people of color had a 130% higher chance of having average arsenic levels above the revised MCL.

Absolute measure of arsenic exposure

Results from the multivariate regression model examining the relationship between CWS demographics and absolute arsenic concentrations generally parallel descriptive findings. Unadjusted models had beta coefficients of –0.14 (95% Confidence Interval (CI), -0.34, 0.06) for homeownership, and –0.01 for percentage of people of color (95% CI, -.11, 0.08). Our adjusted model had a beta-coefficient of –0.27 (95% CI, -0.50, -0.05) for

Table 2 Characteristics of community water systems (CWSs) at three average arsenic levels, 2005–2007, San Joaquin Valley, CA

	Average arsenic concentration		
CWS characteristics	**< 10 μg/L**	**10 49.9 μg/L**	**≥ 50 μg/L**
% CWS	84.5	14.6	0.9
Mean Population Served (median)	2496 (180)	2277 (200)	127 (64)
% Privately owned, non PUC Regulated	61	59	100
% < 200 Connections	70	66	100
Range of Mean Arsenic (μg As/L)	0 9.9	10.1 41.7	59.5 158
Mean μg As/L (Median)	3 (2)	19 (16)	97 (85)
Mean % of Sources > MCL (IQR)	.1 (0,0)	87 (75, 100)	100 (100, 100)
CWSs with arsenic treatment plant	2	4	0

IQR Interquartile range, *PUC* Public Utility Commission.

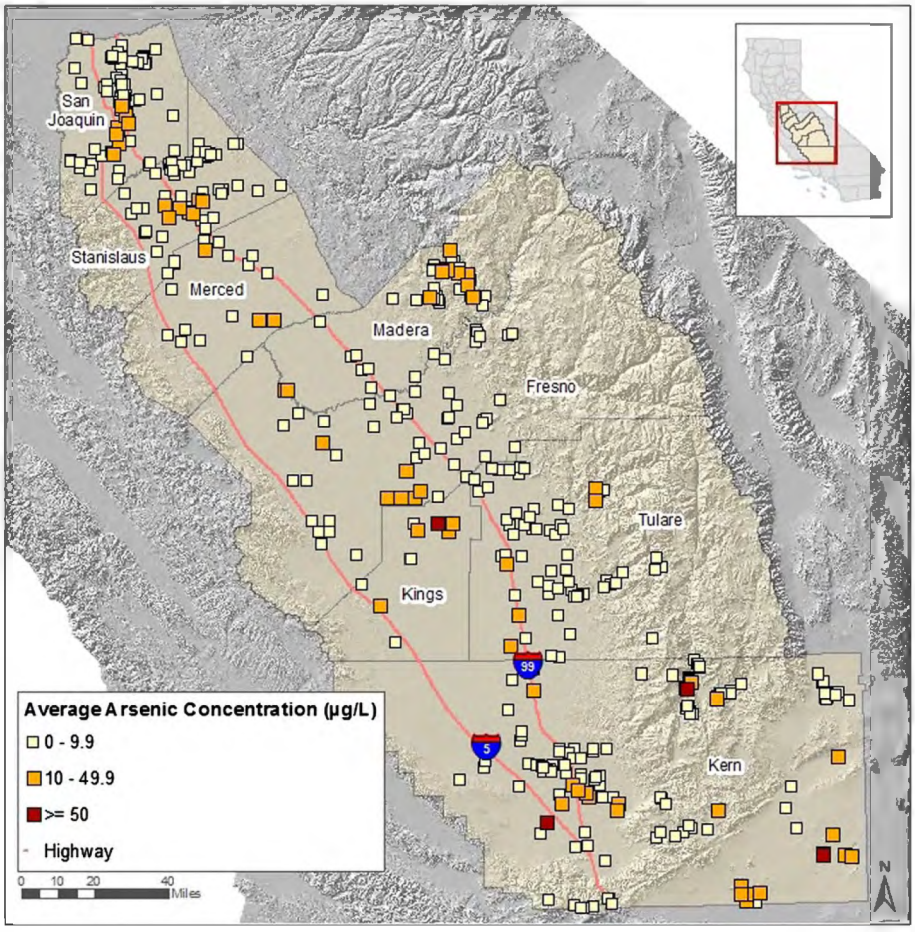


Figure 1 Average arsenic concentration[a] of community water systems (CWS [b,c]) in study sample, (n = 464), 2005 2007. [a] Estimate based on average of each point of entry source's average concentration; [b] Sources of data: CDPH Water Quality Monitoring and PICME databases (CDPH 2008a,b); [c] Approximate location of CWSs are depicted, but not true boundaries. Due to close proximity of some CWSs, map partially covers some CWSs.

homeownership. This suggests that, on average, a 10% decrease in homeownership was associated with a 2.7 μg As/L increase, or roughly one third the mean arsenic concentration across all CWSs (6.0 μg As/L, see Table 1). The beta coefficient for percentage people of color was −0.02 (95% CI, -0.13, 0.09). This suggests that a 10% increase in the percentage of people of color served by a CWS was associated with an increase of .2 μg As/L, though this association was not statistically significant.

Results from our stratified model (Table 6) suggest similar, but stronger, trends among smaller systems. Among systems with less than 200 connections, the beta coefficient for homeownership was −0.43 (95% CI, -0.84, -0.03). This suggests that, on average, a 10% decrease in homeownership is associated with a 4.3 μg As/L increase, or nearly 70% of the mean arsenic concentration across all CWSs. The beta coefficient for percentage people of color was −0.17 μg As/L (95% CI, -0.36, 0.02), although this result was not statistically significant. In systems with at least 200 connections, the coefficients on percent homeownership and people of color were −0.19 (95% CI, -0.40, 0.02) and 0.03 (95% CI, -0.09, 0.15), respectively; neither of these results was statistically significant. Using this final stratified model to predict expected values, we estimated that arsenic levels in

Table 3 Demographic profile of potentially exposed population (PEP [a]) by average arsenic levels, 2005–2007, San Joaquin Valley, CA

Population characteristics	Average arsenic concentration		
	< 10 μg/L	10 49.9 μg/L	≥ 50 μg/L
% Total Population (1,134,017)	86.1	13.7	0.2
% People of Color[b]	54	61	24
% Non Latino White	46	39	76

[a] Per water system, PEP = population count of demographic of interest x (# of sources in one of three arsenic level/total # of sources sampled). PEP displayed in table is equal to sum across all water systems. This value can also be interpreted as the estimated number of people served water at this level.
[b] People of color refer to both Latino and non Latino people of color.

Table 4 Fisher's exact tests and related odds ratio (OR) for maximum contaminant level (MCL) violations, 2005–2007, San Joaquin Valley, CA

Variable of interest	≥ 1 MCL violation	No MCL violation	OR (95% CI)	P value
High % Homeownership	12	269	.33 (.16, .67)	.003
Low % Homeownership	22	161		
High % People of Color	24	207	2.6 (1.2, 5.4)	.01
Low % People of Color	10	223		

Fisher's Exact test compares high and low category for variable of interest, where threshold is determined by median value across all CWS, and includes related odds ratio. Test compares demographics in community water systems that received at least one MCL violation to those with zero violations.

CWSs with 100% home ownership would be, on average, 3.1 μg As/L lower, compared to CWSs at the mean.

Discussion

This study analyzed demographic differences in exposure and compliance burdens associated with the Revised Arsenic Rule in the San Joaquin Valley. We found that communities with lower rates of home ownership and greater proportions of people of color had higher odds of having an MCL violation. We also found a negative association between homeownership rates and arsenic concentrations in drinking water, with a stronger effect among smaller CWSs. These results indicate that communities with fewer economic resources faced a dual burden—they were not only exposed to higher arsenic levels, but were also served by systems more likely to receive an MCL violation.

Nearly 14% of the population in the study sample was potentially exposed to average arsenic levels above the revised standard, highlighting the health risks faced by Valley residents. At the revised level, cancer risks are estimated to be 12 in 10,000 and 23 in 10,000 for bladder cancer among women and men, respectively, and 18 in 10,000 and 14 in 10,000 for lung cancer, among women and men [12]. While we did not find a significant association between race/ethnicity and arsenic levels, a disproportionate number of the population potentially exposed to levels of 10 μg As/L or more were people of color. This indicates that as a whole, this group may still face disproportionate exposure.

Our results are consistent with previous findings that CWSs with higher arsenic levels serve customers with lower income levels [19]. Our results differ somewhat from a previous study [5] that found that while percent Latino was positively associated with the likelihood of exceeding the arsenic MCL, so was high SES. This difference could be due to differences in trends across states (i.e. Arizona vs. California), our additional measurements of exposure and compliance, or our focus on CWSs rather than all public water systems.

Study limitations

Some limitations in our study are worth noting. As noted, the selection criteria we used (source location and arsenic samples) led to a slight under-representation of smaller systems in our final sample. Because the smallest systems had slightly higher arsenic levels and serve higher percentages of people of color and homeowners, this selection bias could also lead to an underestimate of our observed associations.

There are also several potential sources of measurement error in our dependent and independent variables. Under-reporting or under-issuing of violations could impact the count of MCL violations. However, sensitivity analyses comparing MCL violations in our final sample to results including all CWSs yielded consistent results. Similarly, sensitivity analyses comparing results using the binary MCL variable to binary measures that used average source-level concentrations were similar. Because of this consistent negative relationship between SES and each of these measures, we expect minimal impact on our results due to this potential under-reporting. This does not, however, explain why 41 CWSs (out of 72) had average system-level concentrations above the MCL but had no violation recorded; this may be related to selective enforcement and is worth further investigation.

Table 5 Fisher's exact tests and related odds ratio (OR) for average arsenic level, 2005-2007, San Joaquin Valley, CA

Variable of interest	≥ 10 μg As/L	< 10 μg As/L	OR (95% CI)	p value
High % Homeownership	28	233	.45 (.25, .72)	.002
Low % Homeownership	44	159		
High % People of Color	35	162	1.3 (.81, 2.2)	.3
Low % People of Color	37	230		

Fisher's Exact test compares high and low categories of the variable of interest to CWSs whose average arsenic was above or below the revised MCL. The threshold for the variable of interest is determined by median value across all CWS, and includes related odds ratio. Test compares demographics for community water systems whose average arsenic was above or below the revised MCL.

Table 6 Regression† for factors associated with arsenic concentration (μg/L) in community water systems (CWS), 2005-2007, San Joaquin Valley, CA (n=464)

Variable	Model A[a]	Model B[a]	Model C[b]	Model D (< 200 Conections)	Model E (≥ 200 Connections)
Constant	20.0 (6.7, 33.3)	11.2 (6.1, 16.4)	9.7 (11.8, 31.3)	18.2 (11.9, 49.1)	8.7 (11.7, 49.1)
% People of Color		0.01 (0.11, 0.08)	0.02 (.13, 0.09)	0.17* (0.36, 0.02)	.03 (0.09, 0.15)
% Home ownership	.14 (0.34, 0.05)		0.27** (0.50, 0.05)	0.43** (0.84, 0.03)	.19* (0.40, 0.02)
Groundwater or combined[c]			11.4*** (7.5, 15.2)	11.5*** (6.1, 16.9)	8.4*** (4.2, 12.6)
Private non PUC regulated[d]			5.6* (1.0, 12.2)	8.5** (0.73, 16.3)	1.2 (5.4, 7.9)
Public[d]			6.9** (0.61, 13.11)	7.5* (0.76, 15.8)	6.4* (0.99, 13.8)
< 200 service connections			2.6 (1.2, 6.5)	na	na
2006[e]			2.8** (0.52, 5.1)	4.4** (0.27, 8.4)	1.8 (.76, 4.3)
2007[e]			1.2 (0.51, 2.9)	2.4* (0.11, 4.9)	.52 (1.8, 2.9)
Summer/fall			.27 (1.9, 1.4)	.43 (3.1, 4.0)	.27 (2.1, 1.5)
Valley [f]			1.4 (6.5, 3.7)	6.4 (2.3, 14.9)	4.4 (10.6, 1.8)
Foothills [f]			6.9* (0.32, 13.5)	12.1*** (3.9, 20.4)	5.1 (1.0, 11.3)

†Regression with robust standard errors, clustered by CWS. Coefficients represent the estimated difference in mean concentration at the system level associated with a unit change in the covariate (95% CI); na=not applicable, as no CWSs in this model run contains this factor, or all CWSs have this factor.
[a]Unadjusted models, all CWSs included; [b]Adjusted model, all CWSs included; [c] Surface water is referent category; combined refers to combination of groundwater and surface water sources; [d]Privately owned PUC regulated CWS as referent category; [e] 2005 is referent year; [f] Mountains is referent category.
* p < .10, ** p < .05, *** p < .01; R^2 in Model B = .08; R^2 in Model C = .09.

There may also be some misclassification of points-of-entry into the distribution system. However, sensitivity analyses, including and excluding CWSs with treated and untreated point-of-entry sources yielded consistent regression coefficients for home ownership. While results for estimated exposure and compliance burdens are nearly five years old, we believe that, at a minimum, they capture current trends because unless CWSs have installed treatment plants or are using water from new wells (which is unlikely for small systems), temporal variability of arsenic levels is likely to be small [37]. Since our study focused only on CWSs, which excludes private well owners and communities with fewer than 15 service connections, the estimated number of potentially exposed people and impacted systems is likely to be an underestimate.

There may be errors in our demographic estimates, as we had to use data from the U.S. Census 2000 to approximate demographics between 2005 and 2007. There could also be error in our demographic estimates from: (1) surface intakes/well fields falling in Census block groups not served by the CWS, (2) not all Census block groups served by a CWS having an intake/field located within them, and (3) Latinos in Census data being undercounted due to legal status. For the majority of CWSs, sources fell within the same Census block groups that overlapped with the service area boundaries of CWSs [31]. But, because not all source/intake locations fell within block groups that intersect with service area boundaries of CWSs [31], this could lead to misclassification error of our demographic variables. This could result in a bias of the estimated association, but given the relatively small proportion of these systems, and the independence of SES status and inclusion in a linked census block group/water service boundary, this bias will be relatively trivial.

Study implications

In California's San Joaquin Valley, elevated arsenic levels are primarily derived from sedimentary deposits that can be mobilized by groundwater withdrawals and irrigation practices [10,11]. This means that our observed association could be partly explained by the location of low SES communities in relation to these agricultural activities. However, one would not necessarily expect a Valley-wide relationship between low SES and high arsenic levels, since arsenic is largely naturally occurring, and there are other areas in the Valley where low SES systems rely on shallower water.

Instead, our results can be understood as a reflection of the mediating role of system-level capacity. Smaller water systems often lack the economies of scale and resource-base to ensure the technical, managerial and financial (TMF) capacity to reduce contaminant levels [34,38]. They may be less able to install treatment, apply for funding, or drill new wells. The socioeconomic status of residents directly influences TMF capacity, because it affects the ability of a water system to leverage internal (e.g., rate increases) or external (e.g., loans) resources [34]. Thus, CWSs with lower SES customers may have been less able to support adequate TMF or to ensure compliance with the revised arsenic standard by 2007. That four of the six CWSs with treatment had more than 200 connections suggests that larger CWSs (with more resources and greater economies of scale) were

able to comply more quickly with the revised standard, a result supported by previous research and acknowledged by the U.S. EPA [14,38]. Furthermore, that the majority of CWSs with average arsenic concentrations over the revised standard were small and had a high fraction of their wells with high arsenic levels indicates that these systems had few alternative sources of clean drinking water to begin with, making short-term solutions unattainable.

Our joint burden analysis highlights the need to consider not only exposure and current states of compliance, but also the *future* mitigation potential of impacted water systems and the households they serve. We have shown that CWSs with lower SES residents faced the greatest exposure and compliance burdens. Looking forward in time, these same systems may be the least equipped to comply with EPA drinking water standards for three reasons. First, these CWSs are often less able to develop long-term plans to reduce contamination. For example, some low SES communities in the Valley have secured funding to upgrade their infrastructure, but their plans failed to include steps to enter into compliance with the new arsenic standard [39]. Second, low-SES CWSs may be less able to apply for funding. By 2010, 13 of the 72 CWSs in our study with medium and high arsenic levels were not listed as having applied to the State Revolving Fund to help pay for mitigation options [40]. These CWSs were mainly small (< 200 connections) and had lower rates of home ownership (60% vs. 65%, $p < .10$) compared to CWSs that were listed. Funding sources, such as the State Revolving Fund, may further disadvantage small CWSs' efforts to mitigate arsenic exposures and comply with the standard, because they require that systems have adequate TMF capacity to be eligible for funding. Finally, even with funding secured, low-SES water systems with low TMF capacity may be unable to maintain compliance. For example, some CWSs have installed arsenic treatment technologies, only to be forced to shut the plants down because they could not pay for ongoing treatment costs [41].

The combination of the low-SES of residents and low-TMF and compliance ability of CWSs not only impacts mitigation potential and exposure levels, it can also result in significant economic burdens for poorer households. In general, CWSs that are able to mitigate arsenic contamination will incur costs that are passed along to customers. Low-income residents find it hard to pay these higher rates, and may oppose mitigation efforts because of the impact on household budgets [42]. If a CWS cannot mitigate exposure, households may be forced to cope by buying bottled water, creating an additional economic burden. However, low-income residents may forgo such exposure-reduction measures, or only partially implement them [43]. In these cases, if a CWS remains in continuous non-compliance, chronic arsenic exposure risks will be prolonged.

Current debates regarding implementation of the Revised Arsenic Rule have discussed the option of using variances for small water systems, since the Safe Drinking Water Act allows for exemptions to meet compliance rules [23]. However, a short-term variance may only serve to create and perpetuate a two-tiered and inequitable system of regulation, in which low SES residents endure higher arsenic levels in their drinking water or are forced to rely on costly bottled water as an exposure reduction measure. Rather than variances, the regulatory system should provide targeted planning and technical support for small, disadvantaged communities to enter into compliance, so that provision of safe drinking water becomes logistically feasible. This support could include funding mechanisms to support regional system consolidation efforts that help small systems achieve economies of scale or draw on alternative water supplies.

Conclusions

Using a "joint burden" approach, we examined the extent of exposure and compliance burdens in the San Joaquin Valley from 2005 to 2007. Our findings suggest that environmental justice concerns related to arsenic contamination in drinking water must consider both exposure and compliance burdens. Our work also highlights the need to better address how water systems serving low-SES residents can apply for and secure resources to enter into compliance, particularly if current funding criteria are tied to the technical, managerial and financial capacity of CWSs. That small, disadvantaged communities face greater compliance challenges highlights the need for appropriate regulatory measures and technical support. Ultimately, regional solutions that consolidate smaller CWSs serving economically disadvantaged communities within larger CWSs may be the best approach to addressing these disparities. In the interim, however, small water systems serving low SES residents will need enhanced funding and technical support to reduce community-level arsenic exposures.

Additional files

Additional file 1: Table A1. Shows a comparison of the initial population of active water systems, to the final sub sample of systems.

Additional file 2: Figure A1. Presents a schematic of a community water system that explains selection of point of entry sources.

Additional file 3: Table A2. Presents results from two sets of sensitivity analyses using source level average arsenic concentrations.

Abbreviations

As: Arsenic; CDPH: California Department of Public Health; CI: Confidence Interval; CWS: Community water system; GIS: Geographic Information System; IQR: Interquartile range; MCL: Maximum contaminant level; OR: Odds ratio; PEP: Population potentially exposed; PICME: Permits, Inspections, Compliance, Monitoring and Evaluation; PUC: Public utility commission; SDWA: Safe drinking water act; SES: Socioeconomic status;

TMF: Technical, managerial and financial capacity; US EPA: United States environmental protection agency; µg As/L: Micrograms of arsenic per liter.

Competing interests
The authors declare they have no competing interests.

Authors' contributions
CB conceived of the study and its design, acquired the data, performed statistical analyses and was the lead author of the article. RMF contributed to the design of the study, statistical analysis, and the writing of this article. AH contributed to the study design and statistical analysis. IR contributed to the design of the study and results analysis and played a significant role in the writing of the manuscript. All authors read, edited and approved the final manuscript.

Acknowledgements
This research was supported by the NSF Graduate Research Fellowship, the California Endowment (through a collaborative grant between Community Water Center and UC Berkeley), the California Environmental Protection Agency (#07 020), and the Switzer Environmental Fellowship. We thank Laurel Firestone, Susana de Anda and Maria Herrera; Rich Haberman (former San Joaquin Valley Regional Engineer for CA Department of Public Health (CDPH) Drinking Water Program, Dave Spath (former Chief of the Division of Drinking Water and Environmental Management, CDPH), Dr. Karl Longley and Sarge Green (California State University, Fresno); the Energy and Resources Group's Water Group; and Bhavna Shamasunder for support and feedback on analysis; CDPH and Tulare County Environmental Health Services for water quality data; Barbara Nerness for research assistance.

Author details
[1]Energy and Resources Group, University of California, Berkeley, CA 94720, USA. [2]School of Public Health, University of California, Berkeley, CA 94720, USA. [3]Department of Environmental Science Policy and Management, University of California, Berkeley, CA 94720, USA.

Received: 9 May 2012 Accepted: 22 October 2012
Published: 14 November 2012

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doi:10.1186/1476 069X 11 84
Cite this article as: Balazs *et al.*: Environmental justice implications of arsenic contamination in California's San Joaquin Valley: a cross sectional, cluster design examining exposure and compliance in community drinking water systems. *Environmental Health* 2012 11:84.

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California Unincorporated:
Mapping Disadvantaged Communities in the San Joaquin Valley



In partnership with California Rural Legal Assistance, Inc.
and California Rural Legal Assistance Foundation

PolicyLink is a national research and action institute advancing economic and social equity by Lifting Up What Works®.

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Design by: Leslie Yang

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In partnership with California Rural Legal Assistance, Inc. and California Rural Legal Assistance Foundation

Chione Flegal
Solana Rice
Jake Mann
Jennifer Tran
POLICYLINK

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Acknowledgments

The Community Equity Initiative would like to thank the many people who have made this work possible. Foremost, we would like to acknowledge the following for their continued commitment and dedication to improving California's disadvantaged unincorporated communities:

Martha Guzman-Aceves
Brian Augusta
Erika Bernabei
Kara Brodfueherer
Juan Carlos Cancino
Cara Carrillo
Amparo Cid
Maria Sofia Corona
Olivia Faz
Niva Flor
Verónica Garibay
Rubén Lizardo
Emily Long
Laura Massie
Cristina Mendez
Enid Picart
Walter Ramirez
Ruby Renteria
Victor Rubin
Phoebe Seaton
Esmeralda Soria
Elica Vafaie
Ariana Zeno

Thank you to the following who contributed content and research expertise:

Carolina Balazs
Rebecca Baran-Rees
John Capitman
Dhanya Elizabeth Elias
Ann Moss Joyner
Jonathan London
Nathaniel Roth
Stephan Schmidt
Michelle Wilde Anderson

Thanks to the PolicyLink editorial and production teams.

Finally, this work would not have been possible without the generous support of:

The James Irvine Foundation
The California Endowment
The Open Society Foundations
The Women's Foundation of California
The Kresge Foundation

Preface

The Community Equity Initiative (CEI), a partnership of California Rural Legal Assistance Foundation, California Rural Legal Assistance, Inc. (CRLA, Inc.), and PolicyLink, is dedicated to advancing innovative solutions to address poor infrastructure quality and service delivery in communities with a particular focus on the unincorporated communities in California's San Joaquin Valley and the Coachella Valley. The initiative aims to improve the conditions in some of California's most underinvested communities, and provide models for forging new leadership and capacity within communities and developing effective policies to dismantle and overcome historical patterns of exclusion and neglect.

Early in the development of the Community Equity Initiative, the three partner organizations engaged a diverse set of stakeholders and advisors from within communities, universities, foundations, government, and the nonprofit sector to discuss how planning and infrastructure investment can build healthy, sustainable community change. As a result, the initiative pursues a four-pronged strategy that includes: increasing community capacity for political participation and advocacy, improving local and state policy, legal representation, and research.

As part of the research agenda, the initiative has developed a new methodology to shed light on and describe communities that have gone overlooked, ignored, and underinvested for decades. Using and analyzing 2000 census data and other publicly available data, the research has uncovered thousands of Californians who are living in these invisible communities, what the CEI calls "Disadvantaged Unincorporated Communities" or DUCs. Disadvantaged Unincorporated Communities are disproportionately low-income places that are densely settled and not within city limits. For the legal definition, please visit SB 244 Section 65302.10.

This document describes the new methods for identifying, measuring, and mapping disadvantaged unincorporated communities and a first account of the findings from applying these new methods to the San Joaquin Valley. For readers seeking the complete technical details of the data sources and methods, please see the Technical Guide on the Community Equity Initiative website.

All charts, tables, and maps within this report are derived from an analysis of 2000 census data, and county parcel and boundary data. This methodology will also be applied to 2010 census data with research findings to come. Ultimately, it is hoped that this new mapping methodology will help improve policies and decision-making practices not only within California's unincorporated communities but also in America's unincorporated communities at large.

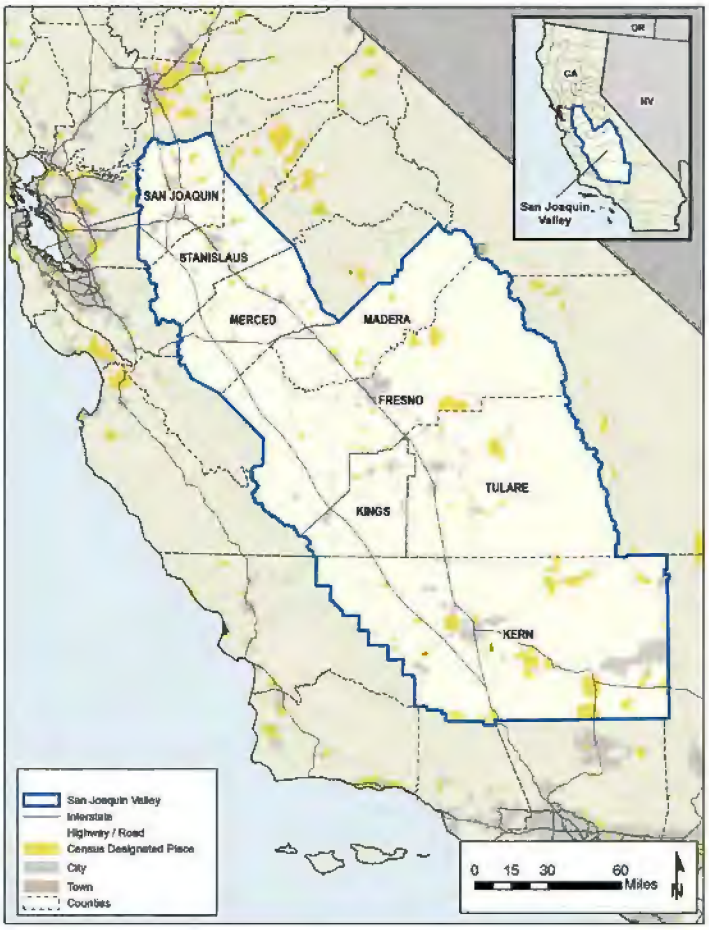
For more on the Community Equity Initiative, please click **here**.

Introduction

California's San Joaquin Valley is one of the most agriculturally rich regions in our nation, contributing over half of the state's total value in agricultural production.[1] It is also home to some of the nation's poorest communities. A 2010 study found the San Joaquin Valley's 20th congressional district ranked the lowest in the nation on resident well-being, based on an assessment of health, education, and income.[2] Among the poorest and most isolated of these communities are places outside of city limits that lack the most basic features of a safe, healthy, sustainable neighborhood—potable drinking water, sewer systems, safe housing, public transportation, parks, sidewalks, and streetlights. People of color make up 54 percent of those living in the San Joaquin Valley, and make up a disproportionate number of those living in underinvested neighborhoods. Historically, these communities have been home to mostly African American and Latinos, and a growing Southeast Asian population. Governed by counties, which were not set up to provide services to dense urban areas, and lacking the representation of a city council, they are systematically underserved in the overall allocation of public resources and are frequently left out of local decision-making processes. Concentrated poverty, institutional and individual racism, and California's systems of public finance and land use regulation exacerbate the plight of disadvantaged unincorporated communities.

To make matters worse, many decision makers and county officials do not know that these communities exist. A map delineates boundaries, records a name, facilitates (though does not guarantee) data collection by the United States Census Bureau and other data collection entities, and provides a basis for demographic and special analysis used to direct programs and services from the federal or state to local level. For residents and organizations living and working in these communities the lack of official recognition and the data that flow from it presents a huge barrier. It becomes very challenging to capture political attention, aggregate and provide a sense of scale to the challenges faced across communities, and readily access critical public resources that are distributed based on community-level data. Identifying the places and their particular challenges (drinking water, waste water systems, safe roads, etc.) is the first step in a longer process to develop strategies and priorities, and to organize, and mobilize to address these challenges.

Eight Counties of San Joaquin Valley



Source: 2000 U.S. census.

1 See Great Valley Center. "Assessing the Region Via Indicators, The Economy." 2009.

2 Based on the Human Development Index of the Social Science Research Council: http://www.measureofamerica.org/maps/.

Purpose of This Research

The Community Equity Initiative developed this report, and the methodology discussed within it, as part of a larger effort to make visible the hundreds of communities that have gone neglected and ignored and are suffering critical challenges of livability as a result. Through this work, the initiative seeks to provide local and state officials, policymakers, advocates, and community organizations with a better sense of where underserved, unincorporated communities are located, and seeks to bring the problems they face into the public view. The research presented here is the first step in quantifying and locating the number of places and people that have been left off the map in the eight-county San Joaquin Valley region. It brings attention to some of California's most forgotten and underinvested places, and starts to make the case for more coordinated long-range planning, targeted resources, and community capacity building for improved quality of life.

This research aims to:

- **equip residents, community-based organizations, and policymakers** with more tools for organizing, case-making, and advocacy;
- **increase public awareness** of the breadth and scale of disadvantaged unincorporated communities and the challenges they face; and
- **support better research and data collection** of disadvantaged unincorporated communities through a new tool that can be used as a basis for future research about quality of services and infrastructure.

Key Findings

The following are key takeaways from the analysis of 2000 U.S. census data and other publicly available data for California.

3.6 million

Californians found by the Census Bureau living in Census Designated Places in 2000

2.8 million

Additional number of Californians living in unincorporated neighborhoods not recognized by the 2000 census because their communities were not characterized as Census Designated Places

310,000

People living in low-income unincorporated communities in the San Joaquin Valley

This is 70,000 more than what the Census Bureau included in its low-income Census Designated Places in the San Joaquin Valley

People of color were disproportionately represented in Disadvantaged Unincorporated Communities in comparison to cities, counties, and Census Designated Places.

65%

Percentage of the population living in disadvantaged unincorporated communities that were of color

57%

Percentage of the population living in cities that were of color

64%

Percentage of households in the San Joaquin Valley's disadvantaged unincorporated communities that were low income

This was a significantly higher percentage than in cities and counties in California where 48% of households were low income, and in Census Designated Places where 51% of the households were low income.

Emerging Areas of Impact

This research is helping to make the case for advocacy, build public awareness, and contribute to new knowledge around inequities that exist.

Supporting Organizing, Case-Making, and Advocacy

There is power in being made visible. Once a community is visible, a shared collective identity can develop, which in turn serves as the foundation for residents' capacity to organize themselves and mobilize for change. Mapping equips residents with information about their communities and others', provides them with a tool in their advocacy, and facilitates recognition within the policymaking process. This work provides an important foundation for advocates, researchers, and policymakers to layer additional information and stories about the conditions and history of these communities.

Tulare Lake Basin Study – In 2008, SB1xx and AB2356 appropriated millions of dollars to address drinking water quality and waste water services in the Tulare Lake Basin region. With the tremendous support of community advocates, these bills provide targeted funding for planning and construction of projects in disadvantaged areas. The CEI mapping of low-income unincorporated areas was one of the many data points considered when identifying disadvantaged communities for targeted inclusion in the planning process and in the outreach phase of the project. The CEI mapping helped identify some of the smaller communities that may not have shown up in an initial scan of disadvantaged communities through the census.

Increasing Public Awareness

A community's needs cannot be properly addressed—or assets leveraged—if the community itself is not known to the larger world. Early work of the initiative indicated that many policymakers at the county and state level did not know of the existence of disadvantaged unincorporated communities generally, nor were they aware of the existence of such communities within their electoral districts. Many more continue to be unaware of the basic infrastructure deficits so many of these communities face. Once these communities are officially mapped, have a name to identify them, and are tracked and recorded by the U.S. Census Bureau or city or county agencies they stand a better chance of being well represented and well served.

Local Government Support – Several local and state-level policymakers have looked to this mapping to understand the scale, location, and character of the issues in previously invisible unincorporated areas. Specifically, the mapping has supported the implementation of SB 244 that requires local government agencies—specifically LAFCOs, cities, and counties—to plan for disadvantaged unincorporated areas. The Local Agency Formation Commissions (LAFCOs) of Fresno and Tulare Counties have requested the CEI mapping to help identify and prioritize underserved areas in their planning process.

Contributing to Research

The U.S. Census Bureau is the most accessible source of periodic demographic data for unincorporated communities, yet it does not capture all unincorporated communities. Many unincorporated communities, including many low-income unincorporated communities, are too small, lack clear boundaries, or are simply not sufficiently known or recognized to be included in the census as a place. With the exception of surveying individual households, communities

are left without a reliable source of data to describe their neighborhood. As a result, their needs are often unaccounted for, they are not acknowledged in planning processes, and they cannot compete for infrastructure investments on a level playing field. This is particularly true when eligibility for these programs is tied to being able to demonstrate that community-level demographics meet specified criteria. This research begins to fill this gap. It creates a set of maps that will continue to evolve, and that identify hundreds of communities not previously mapped. These new maps can serve as the basis for layering additional information about demographics, infrastructure, and quality of life.

Sharing with the U.S. Census Bureau – Most recently, the data have served to inform the Census Bureau about additional places to consider including as 2010 Census Designated Places (CDPs) which are unincorporated places that are surveyed and tracked much like cities and towns. Typically, counties submit the names of communities that they recommend become Census Designated Places.[3] Having CDP status means that residents and local governments have more and better access to information about their communities and how they have changed over time. This is particularly important when applying for grants and loans for infrastructure and services. As a result of this new mapping, CEI staff recommended that the Census staff include 39 additional communities in their 2010 Census Designated Places survey. Nearly half of these recommended communities became CDPs in 2010. CEI staff is currently analyzing 2010 data and will continue to share findings with the Census Bureau staff.

3 Counties use a process called Census Participant Statistical Area Program to recommend Census Designated Places. Census Designated Places are defined by the U.S. Census Bureau as places that are closely settled, named, unincorporated communities that generally contain a mixture of residential, commercial, and retail areas similar to those found in incorporated places of similar sizes.

U.S. Census Bureau: Current Definitions

The most accessible source of data about unincorporated communities comes from the U.S. Census Bureau, which calls these neighborhoods Census Designated Places (CDPs). In the year 2000, the U.S. Census Bureau identified 600 Census Designated Places across California that were home to 3.6 million people. Of the 600 CDPs in California in 2000, 250 (42 percent) of them were low income. For purposes of this research, low-income communities are defined as places where half of all households have a median household income of less than 80 percent of the state's median household income. Simply put, half of all households in these communities had annual incomes of $38,000 or less. One million people lived in these low-income Census Designated Places.

Census Designated Places are areas that are closely settled, named, unincorporated communities that generally contain a mixture of residential, commercial, and retail areas similar to those found in incorporated places of similar sizes.

COMPARING LOW-INCOME CENSUS DESIGNATED PLACES

	Number of Communities Total	2000 Population (% of state population)
Total California Population	N/A	33,871,648
Total CDPs in California*	600	3,669,329 (10.8%)
Total Low-Income CDPs in California	250	1,069,778 (3.2%)
Total Low-Income CDPs in San Joaquin Valley	80	241,968 (0.7%)

*CDPs with population greater than zero.
Source: 2000 U.S. census.

While low-income CDPs are found throughout California, they are most heavily concentrated in the San Joaquin Valley. This eight-county region is home to nearly one-third of all low-income CDPs in California. Eighty of the state's 256 low-income CDPs are located in the region. There are nearly a quarter million people living in these communities, approximately 25 percent of all Californians living in low-income CDPs.

While the 2000 census tracked 3.6 million people in CDPs, in that same year nearly 2.8 million additional people lived in unincorporated areas that were not defined as CDPs. Upon launching the Community

Equity Initiative, staff at the partner organizations saw that many, if not the majority, of communities the initiative is concerned with are not captured by the Census Bureau's CDPs. CRLA, Inc. staff working in the communities found that these places were usually either not on maps, or were mapped incorrectly. PolicyLink staff working to develop a clear picture of the communities struggled with the same absent or inaccurate data. Subsequent mapping and resident interviews confirmed how widespread this phenomenon of exclusion was.

As a result of not being a CDP, these communities are not only usually left off of maps; they are rarely tracked in any systematic way, and are largely invisible to the larger public and policymakers. The mapping methodology, discussed in the next section, has established a way to identify these places using publicly available data, making it possible to begin to address their challenges and needs.



Source: 2000 U.S. census.

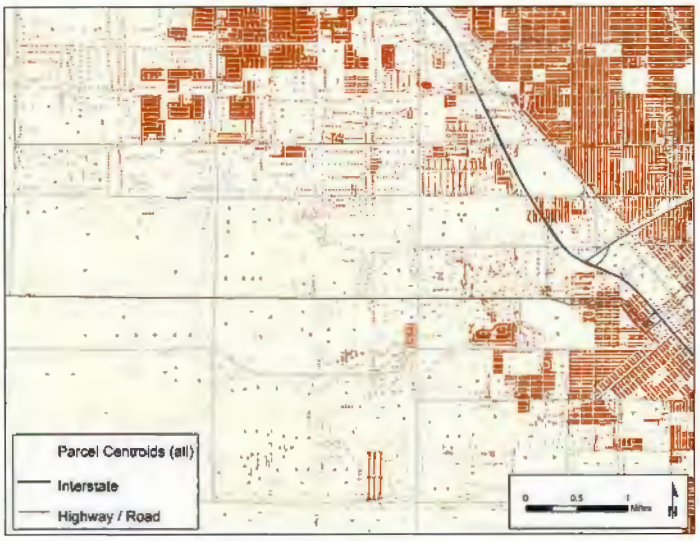
Mapping Disadvantaged Unincorporated Communities: The Methodology

This project used Geographic Information Systems (GIS) technology[4] to identify unincorporated communities in the eight-county San Joaquin Valley region. The following abbreviated methodology describes the steps and results for this initial phase of identifying what the Community Equity Initiative has termed as disadvantaged unincorporated communities or DUCs—places that are densely settled, outside of city limits, and low income.[5] For a more detailed explanation of the data and methods used, please refer to the **Community Equity Initiative** website for technical appendixes. The technical appendixes provide step-by-step guidance on data sources and methods to replicating this mapping research.

CEI used four basic types of data to identify these places:

Unincorporated Status: The project used boundary shape files from cities, counties, or from the U.S. Census Bureau to determine unincorporated status (all areas that are not within city limits).

Parcel Density: The project focused on identifying places that are closely settled with a large number of homes, rather than very spread out rural communities. From publicly available sources, the outlines of parcels (land that is subdivided into lots) were gathered. The areas with a density of at least 250 parcels per square mile were identified. This benchmark was chosen because it is comparable to the density of Census Designated Places (unincorporated communities tracked by the Census Bureau).



Sample map of parcels to determine density.



Sample map of visual inspection for each DUC.

4 ESRI ArcView for ArcMap 9.3.1 with the Spatial Analyst 9.3 extension, Windows machine with an Intel Core 2 Quad CPU.

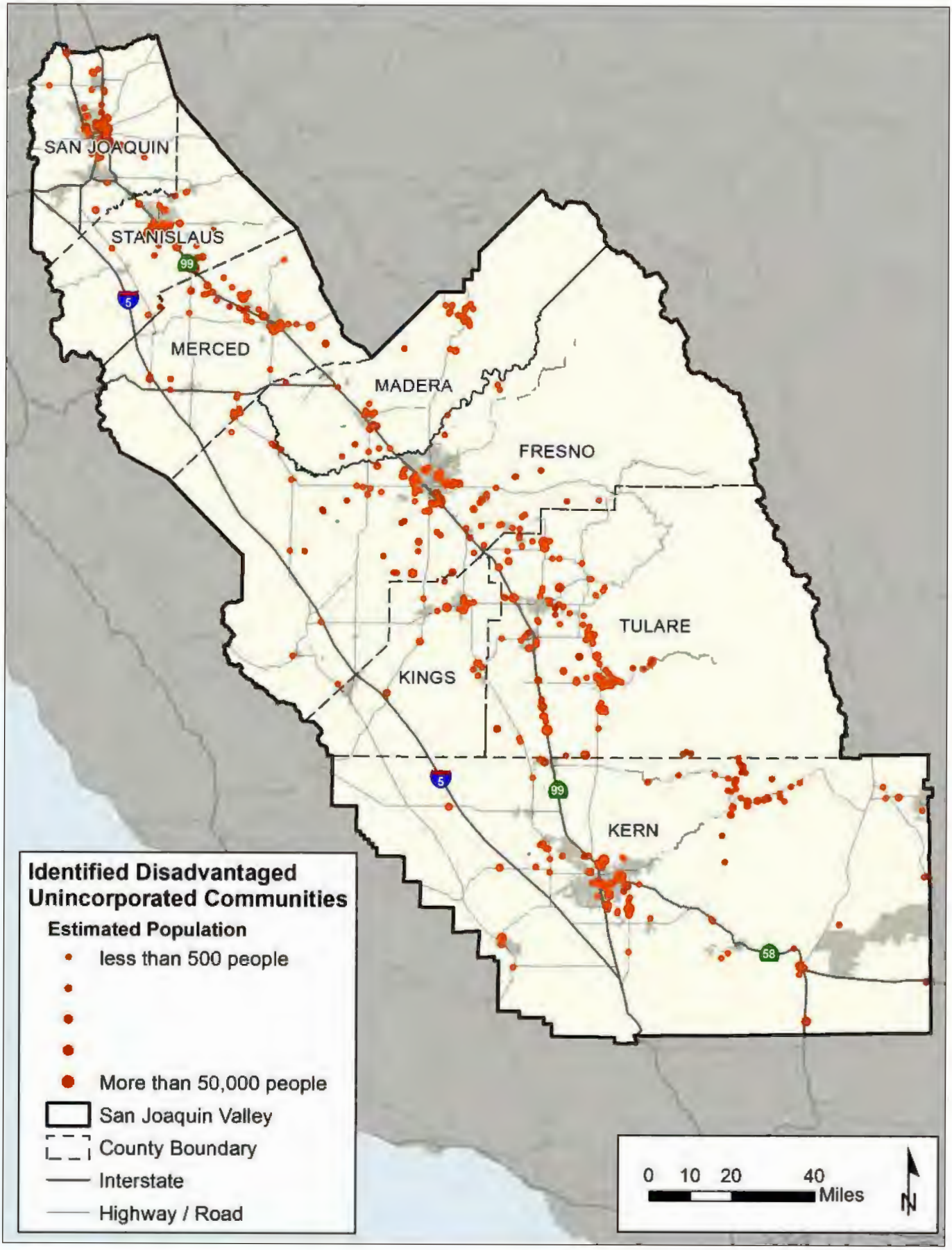
5 This term was developed by CEI to describe low-income, densely settled, unincorporated communities.

Low-Income Neighborhoods: In the work of the CEI, we have found that many low-income unincorporated communities also face infrastructure challenges. Because there is no single indicator, or discrete set of indicators, which allows us to assess infrastructure conditions, the initiative's work began by identifying low-income unincorporated communities. It used 2000 census[6] block group data to identify places of interest. Since the income status of households relative to those across the state is a frequently used criteria for state-funded programs, the initiative selected those block groups where the median household income was less than 80 percent of the median household income of the state. This is a benchmark used in several state-level infrastructure funding programs that target low-income communities, including the **Safe Drinking Water State Revolving Fund** and the **Storm Water Management program**. In 2000, the median household income of the state of California was $47,493, so any census block group with a median income of less than $37,994 was included in our analysis.

This threshold is not a perfect metric for identifying disadvantaged unincorporated communities because there are many places, like resort communities, that may have low recorded incomes, but are not actually home to significant populations of low-income people.

Visual Inspection & Additional Filters: The project mapped land use to help filter out agricultural land, and used information from aerial photography and Google street view to verify that the places highlighted by our analysis were indeed underserved communities. Through this review it was found that some communities at the edge of cities had been "low-income" agricultural fields during the 1990 census but have since been developed. Communities that had been identified as less than three-quarters of an acre in size were also removed as they often contained only one or two houses, if any.

6 While dated, the 2000 census provided a more accurate depiction of income levels at the block group level than more recent American Community Survey data.



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

525 Communities: Findings and Analysis

Once the four types of data were overlaid on one another, 525 distinct, low-income, densely settled, unincorporated areas emerged that are home to over 300,000 people in the San Joaquin Valley. In 2000, the U.S. Census Bureau recorded only 80 unincorporated communities that were low income. This research identified many communities that are smaller communities than Census Designated Places. One hundred forty-nine of these disadvantaged unincorporated communities were located within existing Census Designated Places and 23 of these 149 DUCs were small communities that fell within larger, wealthier Census Designated Places that would not have been identified by solely relying on an analysis of low-income CDPs. For those low-income communities that depend on Census Bureau data to inform their grants, advocacy, and communications work, being located and lumped in with a wealthier CDP could very well mask the challenges of the communities.

Many of the communities (188 to be exact) were named places either because they were existing CDPs or were recognized by community members. As part of the process of verifying the methodology, CEI staff hosted several workshop sessions with community members to solicit their input on maps. Participants were asked if they recognized the identified places as neighborhoods with names and did some "ground-truthing" to verify that the places highlighted were indeed places with infrastructure challenges. A listing of named places is included in Appendix 2: County Map Gallery. Those places without names were assigned a number.

Comparing Counties

The eight counties of the San Joaquin Valley vary significantly in terms of size and population distribution within incorporated and unincorporated areas. The research found that while Fresno is the most populated county, accounting for 24 percent of the valley's population, only 9 percent of the population living in the region's disadvantaged unincorporated communities are in Fresno County. On the other hand, Kern and Tulare Counties have disproportionately high percentages of their populations living in disadvantaged unincorporated communities. Kern is home to 20 percent of the region's population, but 42 percent of the population living in disadvantaged unincorporated communities, and Tulare has 11 percent of the

Comparing Disadvantaged Unincorporated Communities in the San Joaquin Valley

	Number of Communities	Population (% of San Joaquin Valley population)
Disadvantaged Unincorporated Communities in the Valley	525	310,231 (9.3%)
Disadvantaged Unincorporated Areas in CDPs in the Valley	149	187,180 (5.7%)
Low-income CDPs in the Valley	80	242,216 (7.3%)

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

total valley population but 18 percent of the valley's DUCs. This can largely be explained by the fact that a significant portion of the total population in Kern (46 percent) and Tulare (36 percent) Counties live in unincorporated areas. Tulare and Kern also have the highest percentages of their unincorporated populations living in low-income, densely settled communities, with 49 percent and 38 percent respectively.

Maps of each county are available in Appendix 2: County Map Gallery. The Appendix includes a breakdown of each type of community (Island, Fringe, and Legacy discussed later) listed, as well as population summaries.

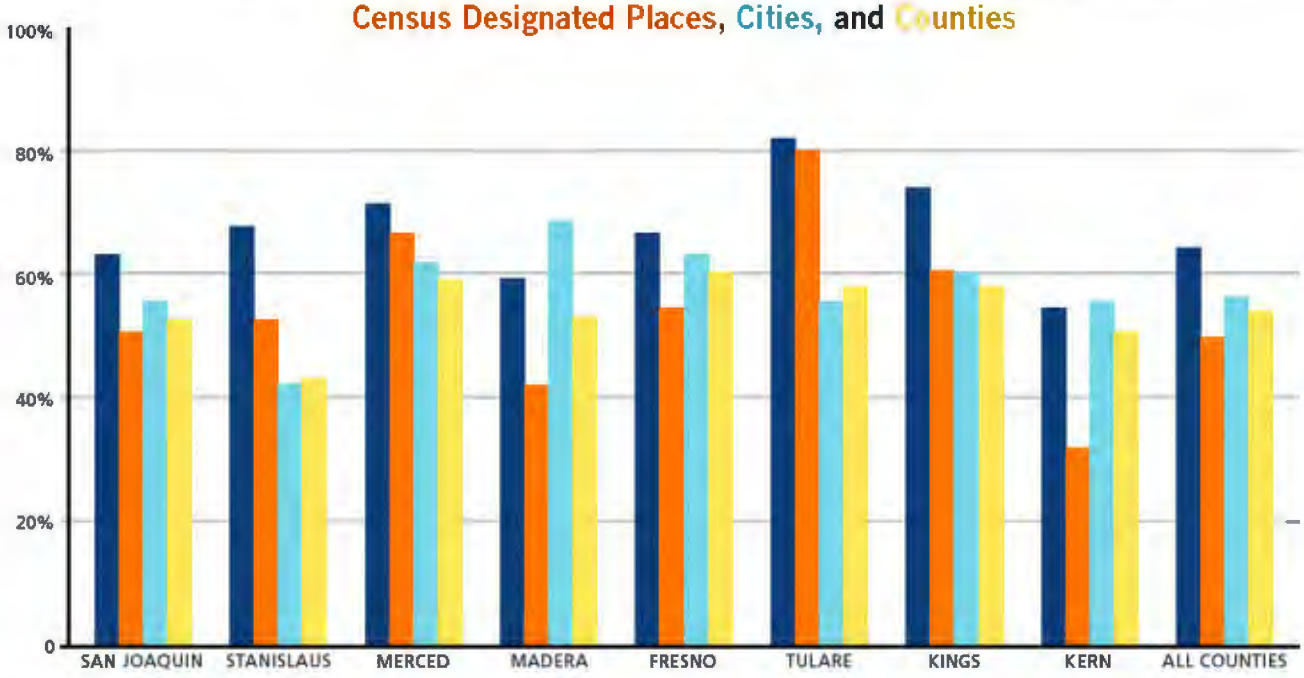
Demographic Analysis

Examining the racial makeup and economic status of DUCs and comparing those to cities, other parts of unincorporated counties, and to counties, helps demonstrate whether or not underinvestment in infrastructure is correlated to race and class. The work of the CEI in large part stemmed from litigation against discriminatory practices in Stanislaus County and the city of Modesto. This case revealed that the city of Modesto was excluding low-income neighborhoods and communities of color from its growth, development, and most basic infrastructure and services.

This current research looks to build from the evidence prepared for Modesto and other cases to better understand and describe the relationship between race, income, and infrastructure quality. The new mapping and analysis shows that disadvantaged unincorporated communities are largely home to people of color,[7] making up 65 percent of the population living in San Joaquin Valley's DUCs. This number is especially high compared to the fact that throughout all of the counties, people of color make up only 54 percent of the population.

The CEI compared the racial and ethnic makeup and number of low-income households in DUCs to Census Designated Places, cities, and counties. Since Census Designated Places are the only unincorporated communities that are tracked by the U.S. Census Bureau, this is an important scale of comparison. Comparing DUCs to cities is important for understanding how much incorporated status can influence and drive

Percent People of Color in Disadvantaged Unincorporated Communities, Census Designated Places, Cities, and Counties



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

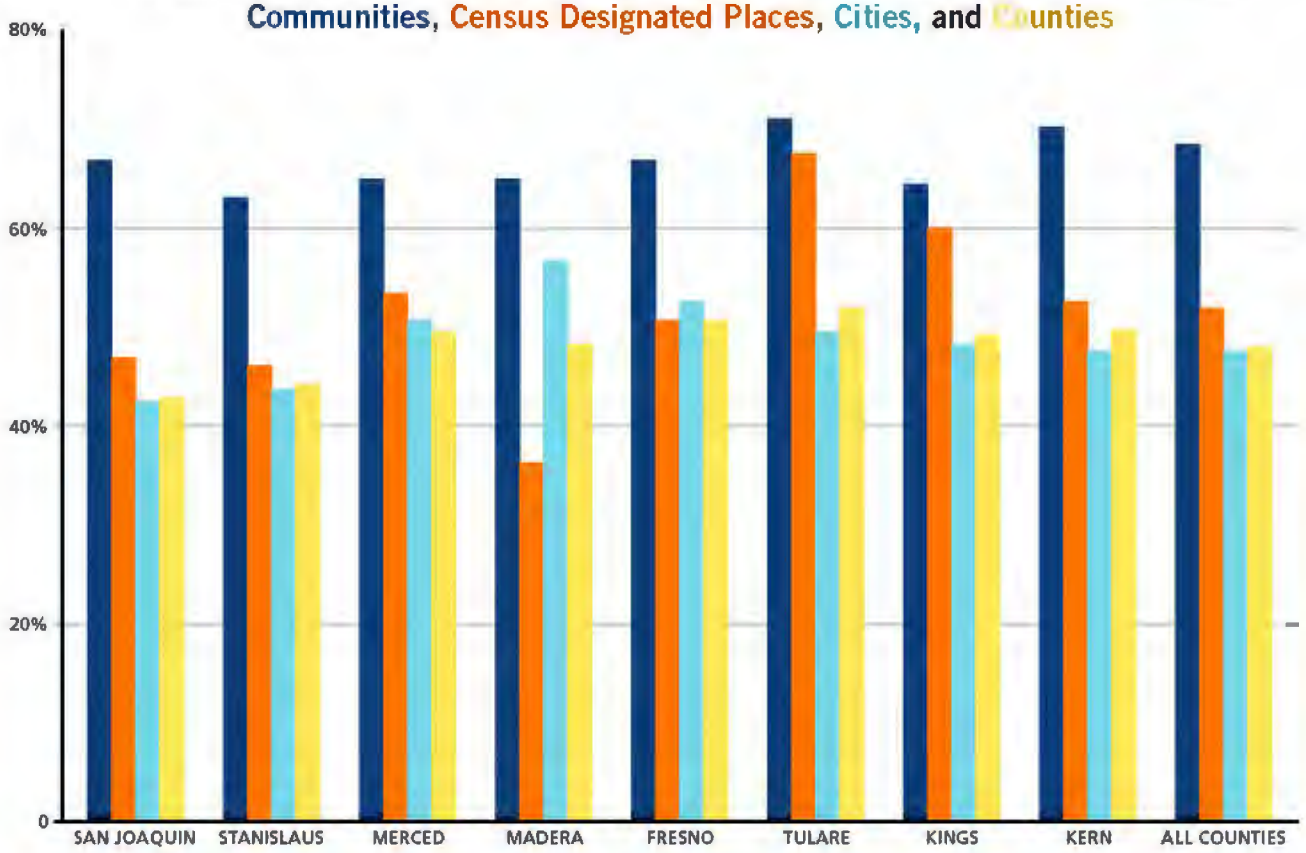
7 "People of color" describes the sum of all racial/ethnic groups that are not white (or non-Hispanic white).

disparities. A comparison to counties provides the context in which DUCs reside. Ideally, the research should find that low-income households and people of color are equally represented in all three scales.

As the graph on the previous page illustrates, in every county people of color in DUCs are overrepresented in comparison to the percentage of people of color living in CDPs, cities, and the county population as a whole.

Although the people who live in DUCs are partly defined by the fact that they meet specified income criteria, the study also wanted to understand how their income characteristics compared to other incorporated and unincorporated population groups in the region. The research found that low-income households are overrepresented in disadvantaged unincorporated communities in comparison to CDPs, cities, and counties. The results are conservative estimates due to the limitations of the census.[8] The graph below illustrates that the percentage of low-income households in DUCs across the San Joaquin Valley ranges between 11 and 20 percentage points higher than their respective counties. When compared to CDPs, DUCs generally have a much greater percentage of low-income households; the exception being in Tulare and Kings Counties where low-income households are proportionate in CDPs and DUCs. Across the entire San Joaquin Valley, it was estimated that 64 percent of households living in DUCs are low income compared to much lower rates in CDPs (51 percent), cities (48 percent), and counties (48 percent).

Percentage of Households that are Low-Income in Disadvantaged Unicorporated Communities, Census Designated Places, Cities, and Counties



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

8 For purposes of this research, low income is defined as household income below 80 percent of state household median, which is $37,994. The 2000 census only provides household income in ranges. These results include all households with income below $34,999.

Please refer to **Appendix 1** (Demographic Analysis) for a detailed table comparing the demographics of DUCs to counties, cities, and Census Designated Places.

Types of Communities

While documenting the number of communities is an important step in telling the story of the San Joaquin Valley's unincorporated communities, proximity to a neighboring community or city plays an important role in determining the opportunities that these places have to improve their infrastructure. A community that is, for example, 20 miles away from a city will have different concerns and opportunities for infrastructure investment than one that sits close or adjacent to a city, and different again from a neighborhood nearly or completely surrounded by the same city. Because of this, our work looked to further describe these communities based on their spatial relationship to incorporated areas.

Island and Fringe Communities

During the agricultural and industrial boom of the early and mid-twentieth century, communities developed on the edges of cities where industry was concentrated and housing was more affordable. As the cities grew, they annexed land around the unincorporated communities—avoiding and excluding communities of color and low-income communities. Decades of neglect and exclusion by cities and counties have been reinforced by the state's counterproductive system of taxation and land use policies. These communities find themselves stuck between the county and their neighboring city. The city does not want to invest in county territory, nor does the county wish to invest in a community that, once improved, will be more attractive for incorporation by a neighboring city.

Today there are unincorporated communities that are like an island, completely surrounded by incorporated city territory but are on county land and therefore do not receive city services. Fringe communities are neighborhoods that are adjacent to incorporated areas or within a city's sphere of influence[9] but are located on county land. The isolation faced by fringe and island communities is stark: their neighbors within city limits—across the street even—receive services that they do not. Some communities may literally have city infrastructure running under or through their community but are not linked into that infrastructure to receive its benefits. Seventy percent of the population of the disadvantaged unincorporated communities identified live in island or fringe communities. As the table below shows, this is over 200,000 people in 274 island and fringe communities. Distinguishing these communities in this way is important because

Comparing Types of Disadvantaged Unincorporated Communities

	Number	Estimated Population (% of DUCs)
Total Disadvantaged Unincorporated Communities	**525**	**310,231**
Island communities	**44**	**45,501 (14.7%)**
Fringe communities	**230**	**172,237 (55.5%)**
Legacy communities	**231**	**92,358 (29.8%)**

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

9 According to the California Association of Local Agency Formation Commissions, a sphere of influence is a planning boundary typically beyond a city or special district that ensures the provision of efficient services while discouraging urban sprawl and the premature conversion of agricultural or open space lands.

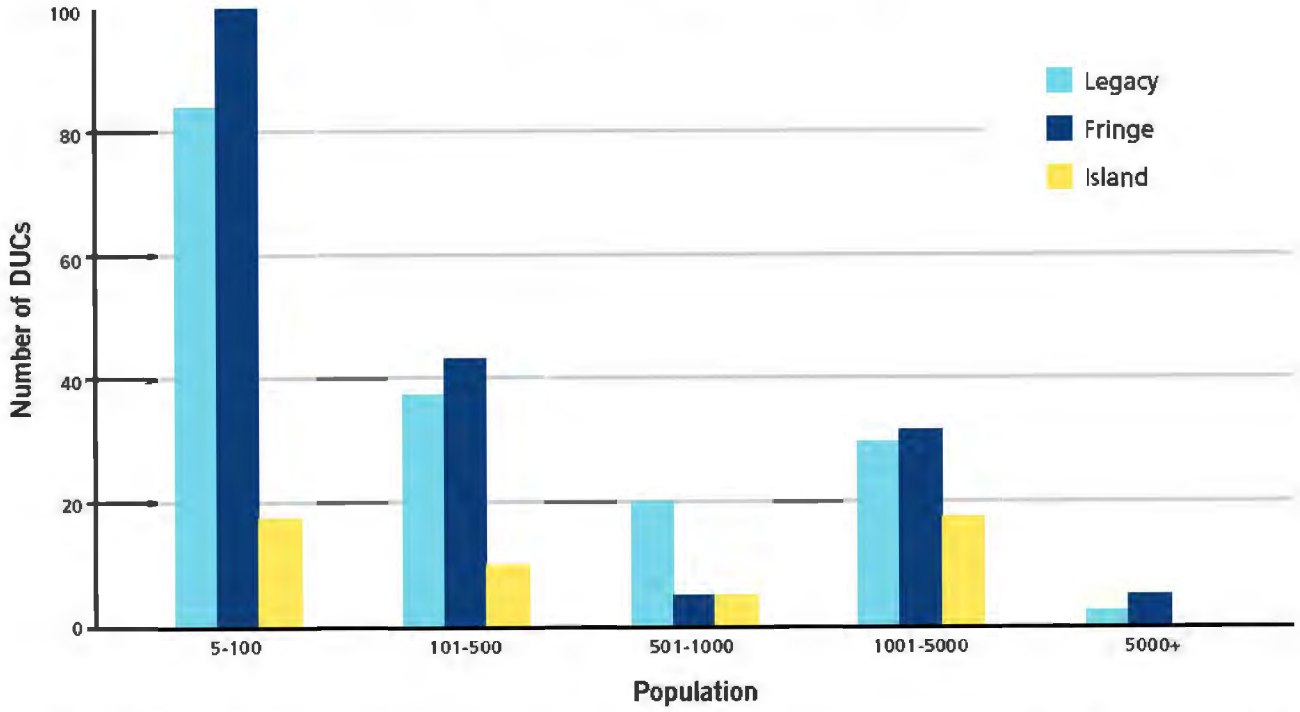
the potential strategies for addressing infrastructure deficits vary depending on the proximity to cities and other communities. For example, several fringe communities have worked out agreements with neighboring cities or townships for sharing service provision or infrastructure investments like water resources.

Legacy Communities

A third type—legacy communities—are more remote. These communities lie beyond the growth boundaries of incorporated cities, and have been in existence at least 50 years.[10] Legacy communities started growing in the early to mid 20th century, principally due to the advent of industrialized agriculture. As demand for low-wage agricultural labor increased, these communities became home to workers from the American South, the Depression-era Dustbowl, and Mexico seeking work as farm laborers. Legacy communities grew close to the farms where workers labored, and over time, these communities have become stable, year-round residential areas, but without the investment to make them healthy and sustainable. Nearly 100,000 people live in legacy communities. The geographic isolation of these places means that they cannot as readily rely on shared service provisions and the typically small population size means that privately funded infrastructure investment is cost prohibitive because of a lack of economies of scale. Leveraging targeted public funding is a necessity in legacy communities.

The graph below illustrates the distribution of disadvantaged unincorporated communities by population range, number of communities in each population range, and their spatial relationship to incorporated areas (Island / Fringe / Legacy). A majority (81 percent) of these communities are small—fewer than 500 residents. While only 12 communities have populations greater than 5,000, these 12 communities make up 45 percent of the total DUC population across the valley.

Number of Disadvantaged Unincorporated Communities by Type and Population



The methods tended to underestimate population size in very small rural communities. One hundred and thirty-five of the 525 communities have an estimated population of less than five people and are not displayed here.

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

10 Definition in part from the Senate Bill No. 244.

Next Steps

Cities and counties cannot plan for, and serve, communities that they do not even know exist. Administrators and elected officials must understand the scale and scope of issues within their jurisdiction. This research will help build their understanding of the scope of the issues impacting unincorporated communities and will support local and regional efforts to plan for infrastructure improvements and more coherent, sustainable land uses. The Community Equity Initiative will continue hosting sessions where community members and organizations can help verify and name places on maps identified by this methodology.

The data used for this first run of the model are limited because the census has historically undercounted minority and rural populations. Also, the income data are from 2000, which are dated and do not reflect changes brought by the most recent recession. The CEI will be updating its research with more recent American Community Survey data and 2010 U.S. census data. It is also adding demographic data such as median age, length and type of housing tenure, education, and more. We are in the process of undertaking additional investigation to better understand the breadth and depth of challenges that these communities face.

The next phase of mapping will include additional "ground-truthing" with residents, further exploration of the demographics of these communities, and gathering and analysis of information about the quality of infrastructure, amenities, and services. This foundational mapping will allow us to better describe potential infrastructure challenges, disparities in investments, and trends in population over time beyond the race and income data included here. The next phase of this work, for example, may draw closer parallels between race and income and infrastructure investment per capita.

The initiative will continue to share this information with community organizations and groups who find it useful. For example, it is currently sharing its findings with community organizations and researchers who are studying how nitrate contamination in groundwater is affecting communities in the San Joaquin Valley and across California. The pairing of these data sets will add dimension to both the water quality data and the mapping of disadvantaged communities. A clearer picture should emerge of the types of communities that do not have healthy drinking water, along with increased understanding about the water quality in underserved communities. This dual approach will inform the decision-making process around setting priorities for allocating resources to areas in need.

This mapping has also sparked interest in collecting and sharing data about unincorporated areas more broadly, including access to parks, air quality data, and environmental hazards. Ultimately, the Community Equity Initiative is committed to using the information that is gathered to empower residents in California and elsewhere as advocates for better, healthier communities.

For more information about the work of the Community Equity Initiative, our successes, and our research, visit: **www.PolicyLink.org/communityequityinitiative** or **www.crla.org/node/30**. You may also contact Chione Flegal at PolicyLink by email at chione@policylink.org or Phoebe Seaton at California Rural Legal Assistance, Inc. by email at **pseaton@crla.org**.

Appendix 1: Detailed Table of Demographic Analysis

The following tables compare demographics for counties, cities, Census Designated Places, and disadvantaged unincorporated communities by county. The data have been summarized in preceding charts but are presented here more comprehensively and include:

- **Total population and number** of households
- **Population and percentage** of people of color (people of color defined as the sum of all racial and ethnic groups that are not white or non-Hispanic white)
- **Total and percentage** of low-income households (households with income less than $34,999 annually)

Countywide Estimates

COUNTY	County Population	Unincorporated Population	Percentage of County Population Living in Unincorporated Areas
FRESNO	799,407	170,191	21%
KERN	661,645	266,821	40%
KINGS	129,461	37,369	29%
MADERA	123,109	69,074	56%
MERCED	210,554	78,738	37%
SAN JOAQUIN	563,598	129,891	23%
STANISLAUS	446,997	122,107	27%
TULARE	368,021	142,510	39%
COUNTIES	3,302,792	1,016,701	31%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Countywide Estimates

COUNTY	Population People of Color	Percentage of Countywide Population that are People of Color	Total People of Color Living in Unincorporated Areas	Percentage of Unincorporated Population that are People of Color
FRESNO	481,885	60%	85,749	50%
KERN	334,455	51%	114,373	43%
KINGS	75,644	58%	20,498	55%
MADERA	65,718	53%	28,676	42%
MERCED	124,969	59%	43,032	55%
SAN JOAQUIN	296,596	53%	56,544	44%
STANISLAUS	190,996	43%	54,617	45%
TULARE	214,105	58%	87,786	62%
COUNTIES	1,784,368	54%	491,275	48%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Countywide Estimates

COUNTY	Total Households in County	Households in Unincorporated Areas	Total Low-Income Households in County (Earning <$34,999)	Percentage of Households in Counties that are Low Income
FRESNO	253,304	72,329	127,527	50%
KERN	208,786	92,571	103,134	49%
KINGS	34,429	10,851	16,810	49%
MADERA	36,207	24,862	17,373	48%
MERCED	63,933	28,399	31,485	49%
SAN JOAQUIN	181,612	50,273	77,225	43%
STANISLAUS	145,253	42,784	63,291	44%
TULARE	110,356	50,336	56,563	51%
COUNTIES	1,033,880	372,405	493,408	48%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Citywide Estimates

COUNTY	Total City Population	Total Population People of Color in Cities	Percentage of City Population that are People of Color	Total Household in Cities	Estimated Total Households in Cities that are Low Income	Percentage of Households in Cities that are Low Income
FRESNO	629,216	396,136	63%	200,517	104,841	52%
KERN	394,817	220,079	56%	122,530	57,754	47%
KINGS	92,092	55,146	60%	25,032	11,928	48%
MADERA	54,035	37,042	69%	14,558	8,146	56%
MERCED	131,816	81,937	62%	40,999	20,673	50%
SAN JOAQUIN	433,707	240,052	55%	141,336	60,062	43%
STANISLAUS	324,890	136,379	42%	112,620	48,395	43%
TULARE	225,511	126,319	56%	70,442	34,491	49%
COUNTIES	2,286,084	1,293,090	57%	728,034	346,290	48%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Census Designated Places (CDPs)

COUNTY	Total CDP population	Population People of Color in CDPs	Percentage of CDP Population that are People of Color	Total Households in CDPs	Total Low-income Households in CDPs (Earning < $34,999)	Percentage of Households in CDPs that are Low Income
FRESNO	18,793	10,270	55%	5,956	3,005	51%
KERN	128,136	40,877	32%	45,380	23,758	52%
KINGS	13,453	8,159	61%	3,334	1,992	60%
MADERA	26,657	11,229	42%	8,466	3,034	36%
MERCED	29,175	19,533	67%	8,042	4,259	53%
SAN JOAQUIN	52,430	26,410	50%	16,350	7,602	47%
STANISLAUS	52,430	27,794	53%	14,900	6,801	46%
TULARE	56,125	45,154	80%	14,161	9,482	67%
COUNTIES	377,144	189,426	50%	116,589	59,933	51%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Disadvantaged Unincorporated Communities (DUCs)

COUNTY	Number of Disadvantaged Unincorporated Areas (DUCs)	Estimated Population in DUCs	Percentage of Countywide Population Living in DUCs	Percentage of Population in Unincorporated Areas Living in DUCs
FRESNO	93	27,704	2%	9%
KERN	105	130,388	2%	5%
KINGS	24	7,494	11%	39%
MADERA	44	8,558	12%	21%
MERCED	47	20,861	15%	21%
SAN JOAQUIN	51	29,203	14%	61%
STANISLAUS	47	31,127	7%	26%
TULARE	114	54,775	4%	10%
COUNTIES	525	310,230	9%	1%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Disadvantaged Unincorporated Communities (DUCs)

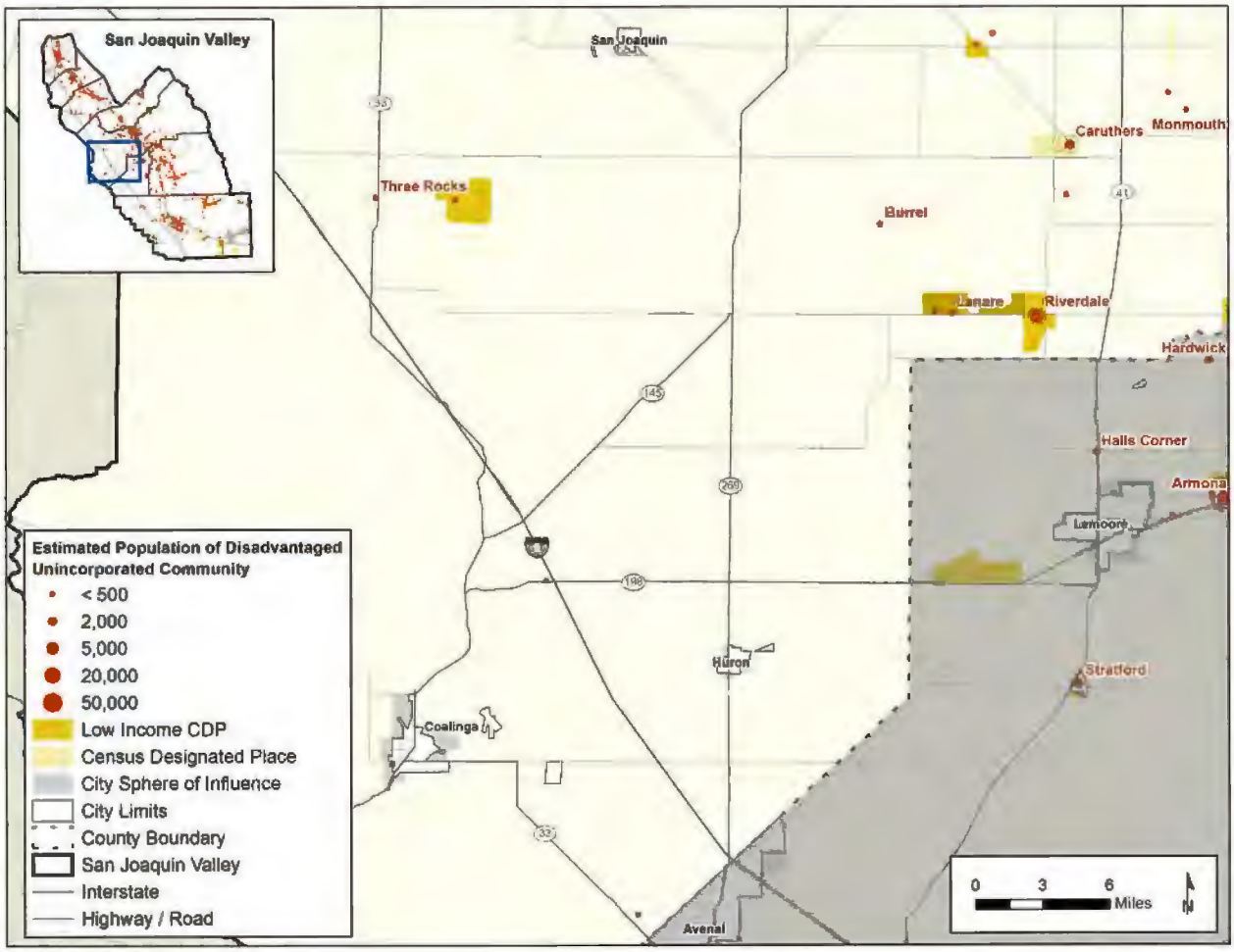
COUNTY	People of Color in DUCs	Percentage People of Color Countywide Living in DUCs	Percentage of DUC Population that are People of Color	Estimated Total households in DUCs	Estimated Total Low-Income Households in DUCs (Earning < $34,999)	Percentage of Households in DUCs that are Low Income
FRESNO	18,439	6%	67%	7,457	4,648	62%
KERN	71,561	39%	55%	28,820	17,715	66%
KINGS	5,561	10%	74%	458	276	60%
MADERA	5,106	13%	60%	983	598	61%
MERCED	14,926	17%	72%	3,001	1,814	60%
SAN JOAQUIN	18,433	10%	63%	7,456	4,627	62%
STANISLAUS	21,249	16%	68%	6,240	3,622	58%
TULARE	45,080	26%	82%	5,701	3,815	67%
COUNTIES	200,355	17%	65%	58,117	37,113	64%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Appendix 2: County Map Gallery

The following maps illustrate the location and approximate population of disadvantaged unincorporated communities (DUCs) in each of the eight counties of the San Joaquin Valley. Tables associated with the maps show the estimated population by type of community (island, legacy, or fringe). Each county is accompanied by a list of the names of some DUCs.

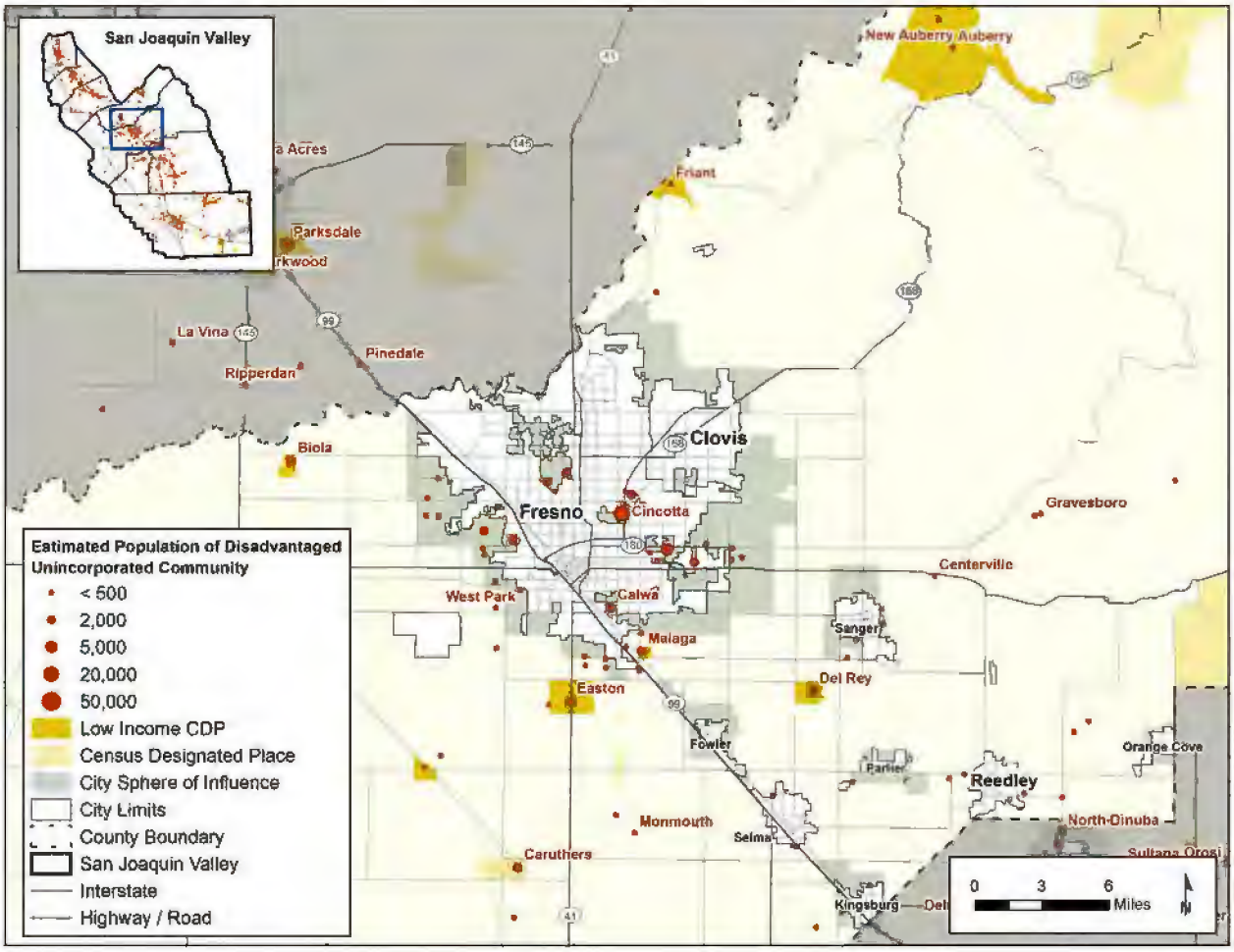
Fresno County (West)



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

FRESNO COUNTY	Number of DUCs	Estimated Total Population
Total	**93**	**27, 704**
Fringe	34	3,616
Legacy	49	8,156
Island	10	15,932

Fresno County (Central)

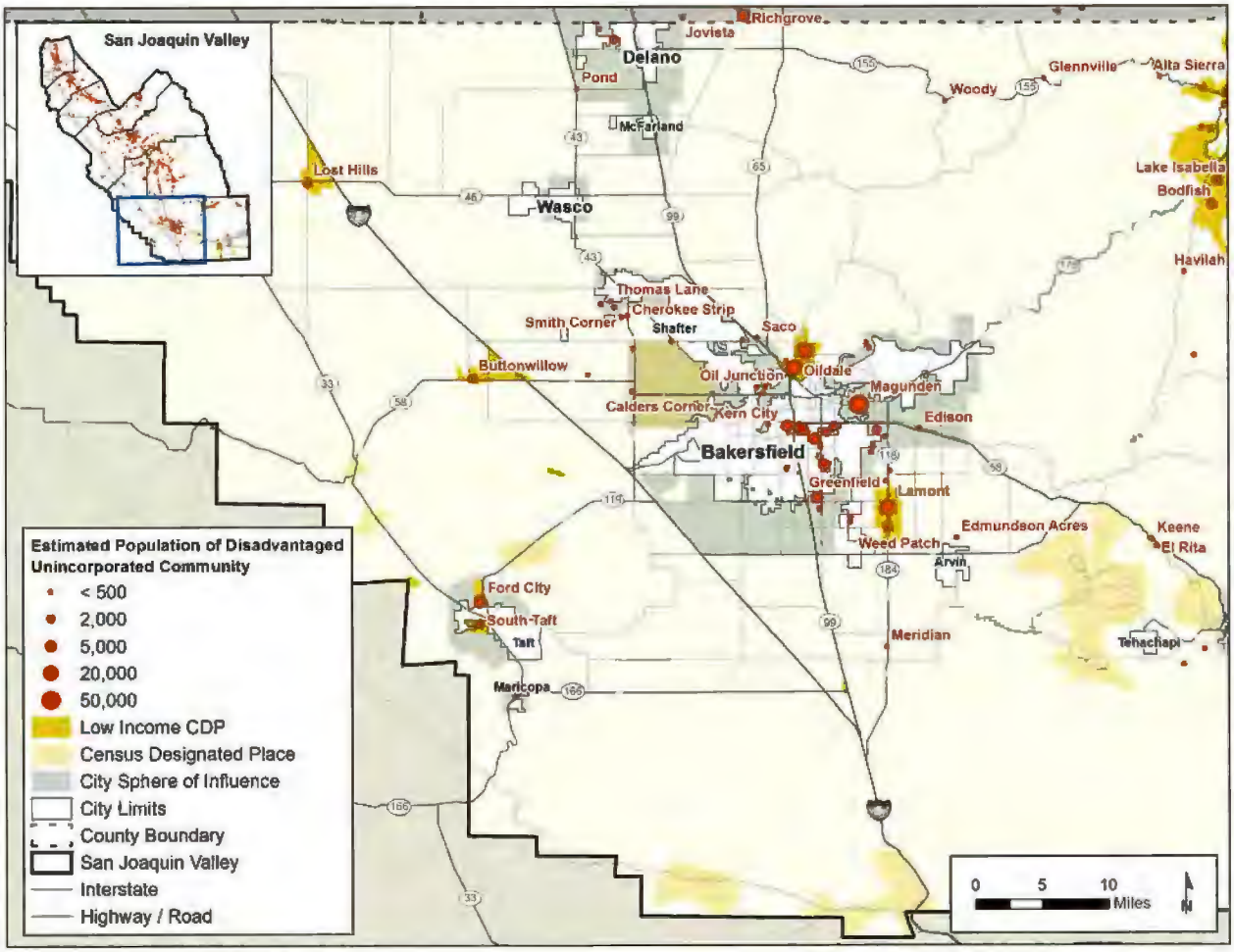


Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

DUCs with commonly recognized names in Fresno County:

Auberry	Del Rey	Laton
Biola	Del Rio	Malaga
Burrel	Dos Palos	Miramonte
Calwa	Easton	Monmouth
Caruthers	Friant	New Auberry
Centerville	Granz (historical)	Riverdale
Cincotta	Gravesboro	Three Rocks
Date Street	Lanare	West Park

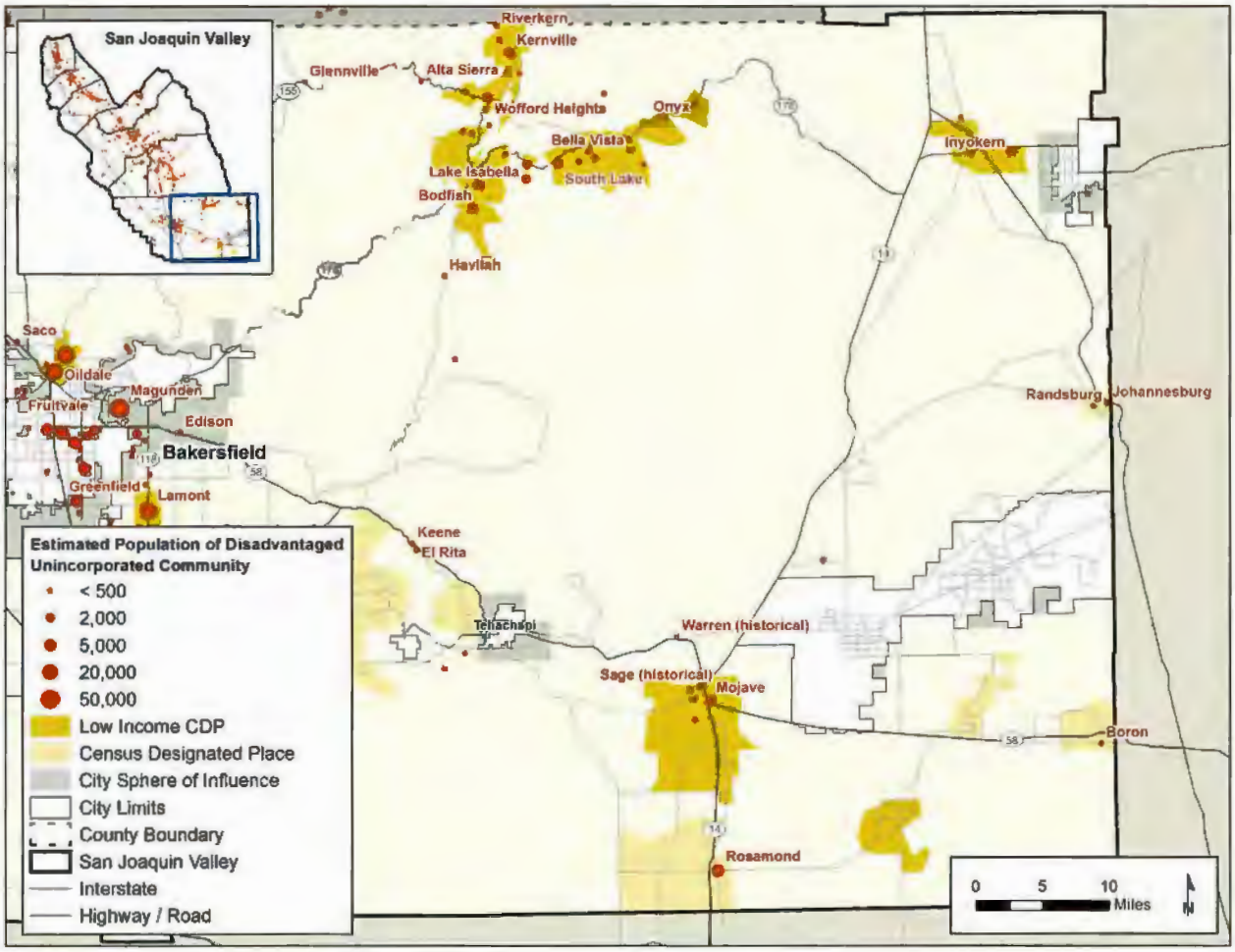
Kern County (West)



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

KERN COUNTY	Number of DUCs	Estimated Total Population
Total	**105**	**130,388**
Fringe	31	79,302
Legacy	64	33,083
Island	10	18,003

Kern County (East)

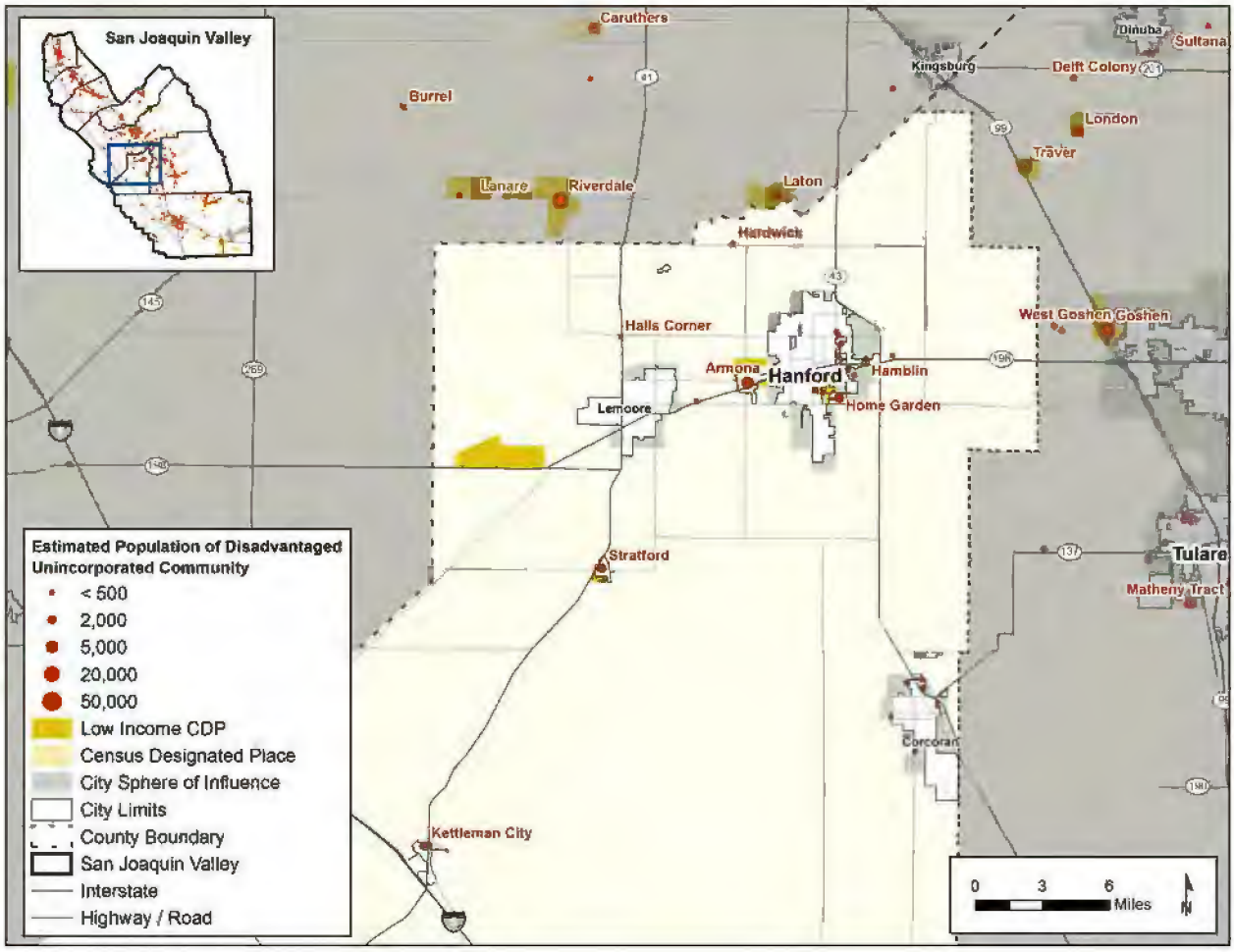


Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

DUCs with commonly recognized names in Kern County:

Alta Sierra
Bella Vista
Bodfish
Boron
Buttonwillow
Calders Corner
Cherokee Strip
Crome-Heights Corner
Edison
Edmundson Acres
El Rita
Ford City
Fruitvale
Fuller Acres
Glennville
Greenfield
Havilah
Inyokern
Johannesburg
Keene
Kern City
Kernville
Lake Isabella
Lamont
Lonsmith
Lost Hills
Magunden
Mayfair
Meridian
Mexican Colony
Mojave
Mountain Mesa
Oil Junction
Oildale
Onyx
Pond
Randsburg
Riverkern
Rosamond
Saco
Sage (historical)
Smith Corner
South Lake
South Taft
Squirrel Mountain Valley
Thomas Lane
Warren (historical)
Weed Patch
Weed Patch Highway
Wofford Heights
Woody

Kings County



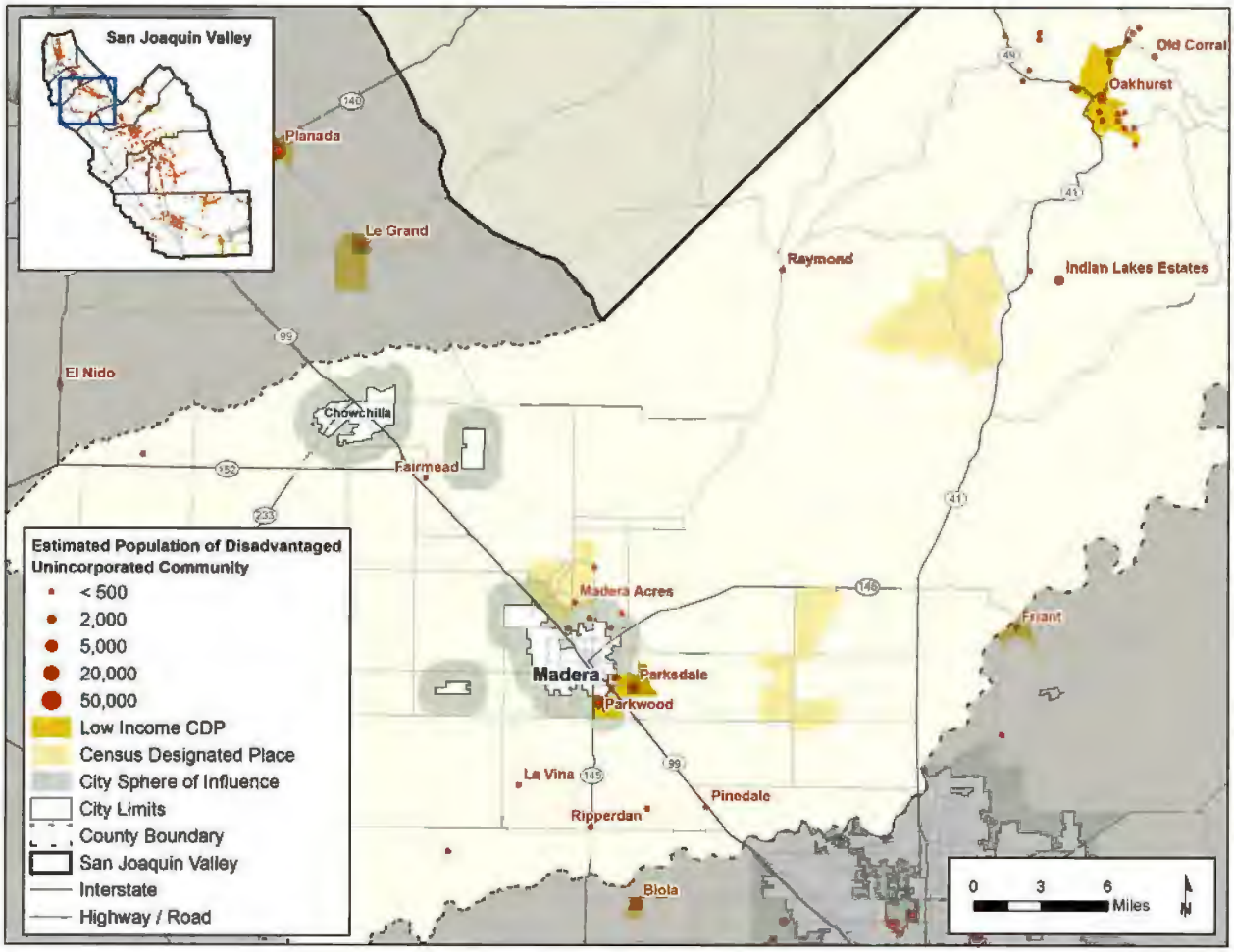
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

KINGS COUNTY	Number of DUCs	Estimated Total Population
Total	**24**	**7,494**
Fringe	20	7,428
Legacy	4	66
Island	0	0

DUCs with commonly recognized names in Kings County:

Armona
Halls Corner
Hamblin
Hardwick
Home Garden
Kettleman City
Stratford

Madera County



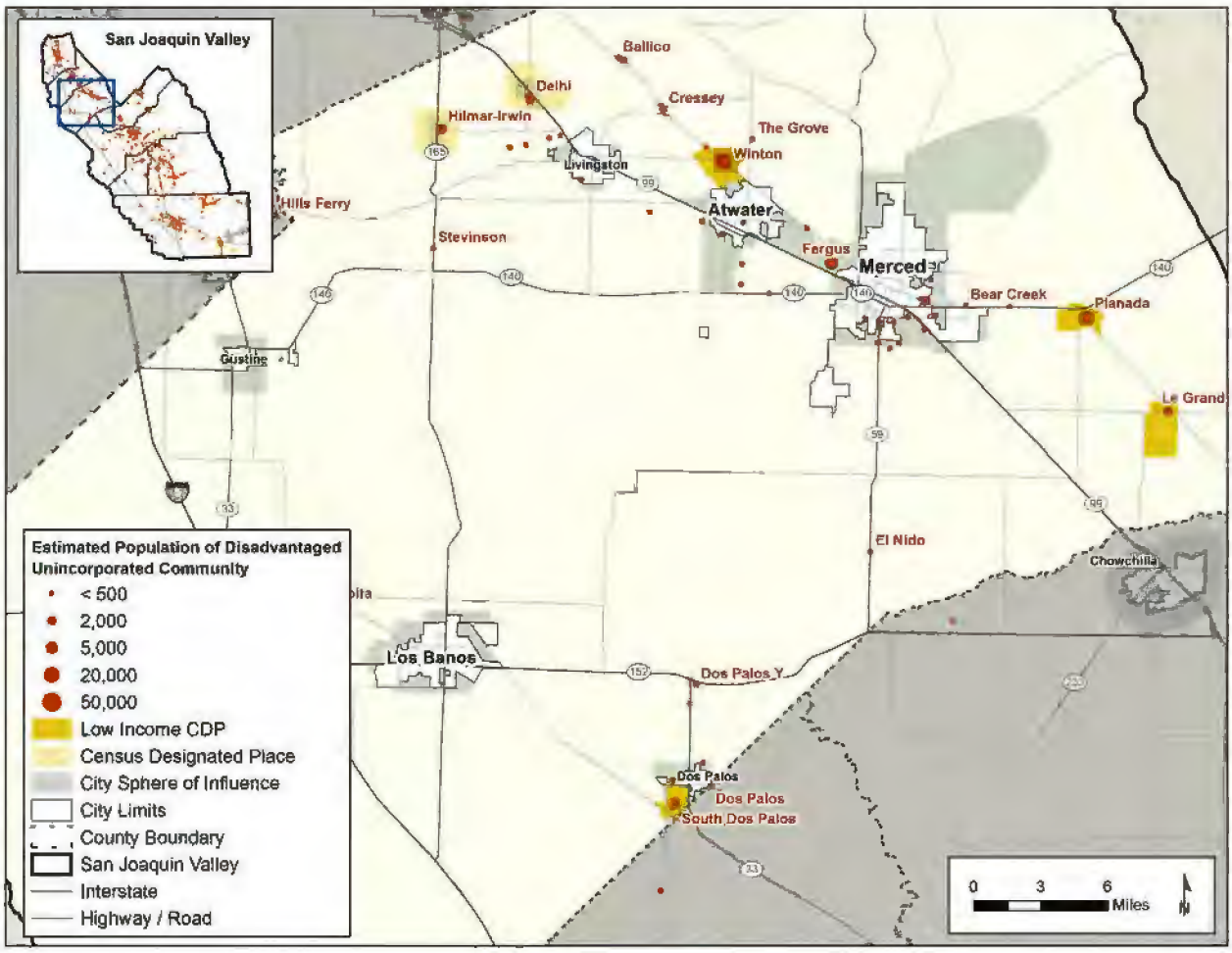
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

MADERA COUNTY	Number of DUCs	Estimated Total Population
Total	**44**	**8,558**
Fringe	10	3,074
Legacy	54	5,484
Island	0	0

DUCs with commonly recognized names in Madera County:

Fairmead
Indian Lakes Estates
La Vina
Madera Acres
Oakhurst
Old Corral
Parksdale
Parkwood
Pinedale
Raymond
Ripperdan

Merced County



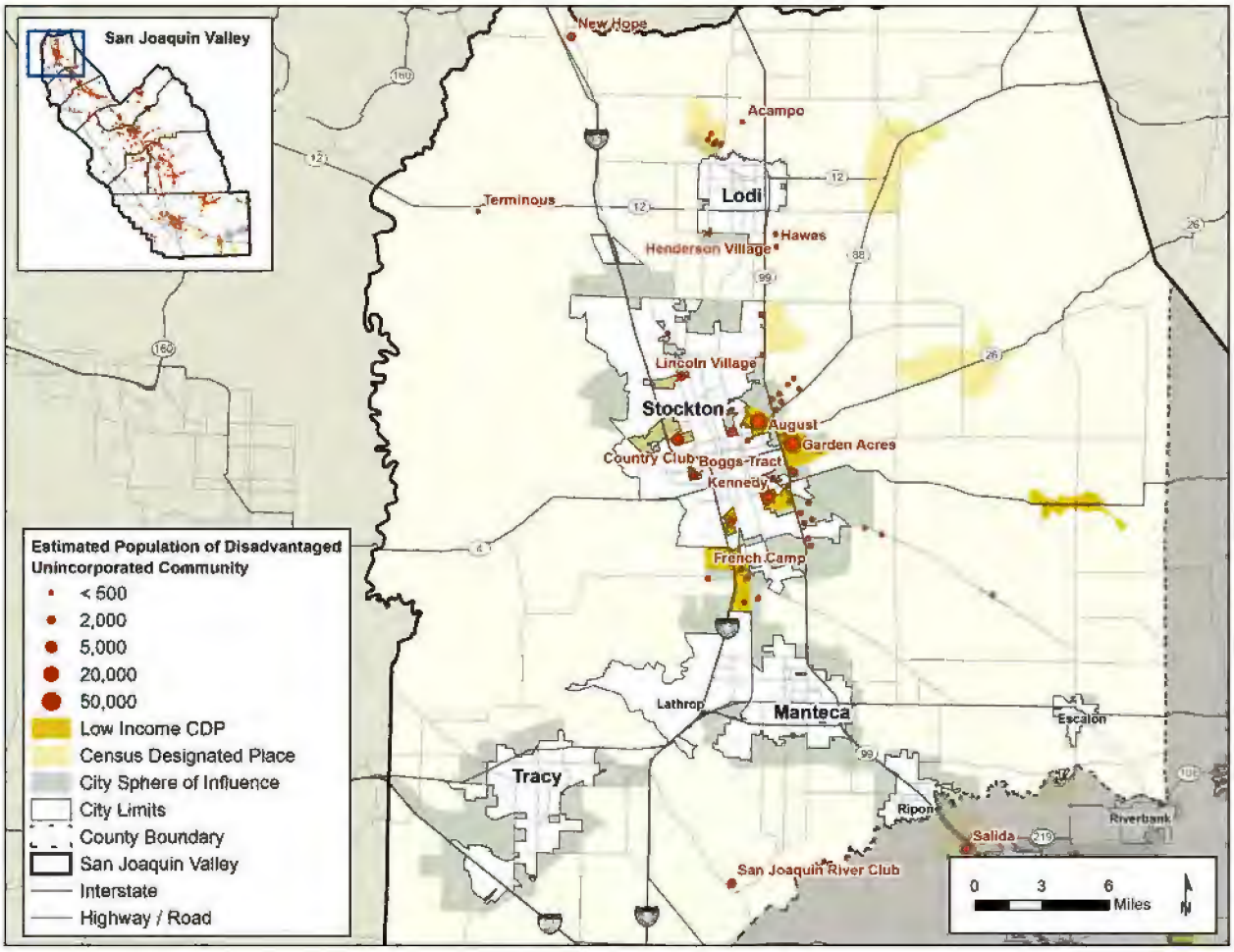
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

MERCED COUNTY	Number of DUCs	Estimated Total Population
Total	**47**	**20,861**
Fringe	29	20,537
Legacy	17	251
Island	1	73

DUCs with commonly recognized names in Merced County:

Ballico
Bear Creek
Cressey
Delhi
Dos Palos Y
El Nido
Fergus
Hilmar-Irwin
Le Grand
Planada
Santa Nella Village
Snelling
South Dos Palos
Stevinson
The Grove
Volta
Winton

San Joaquin County



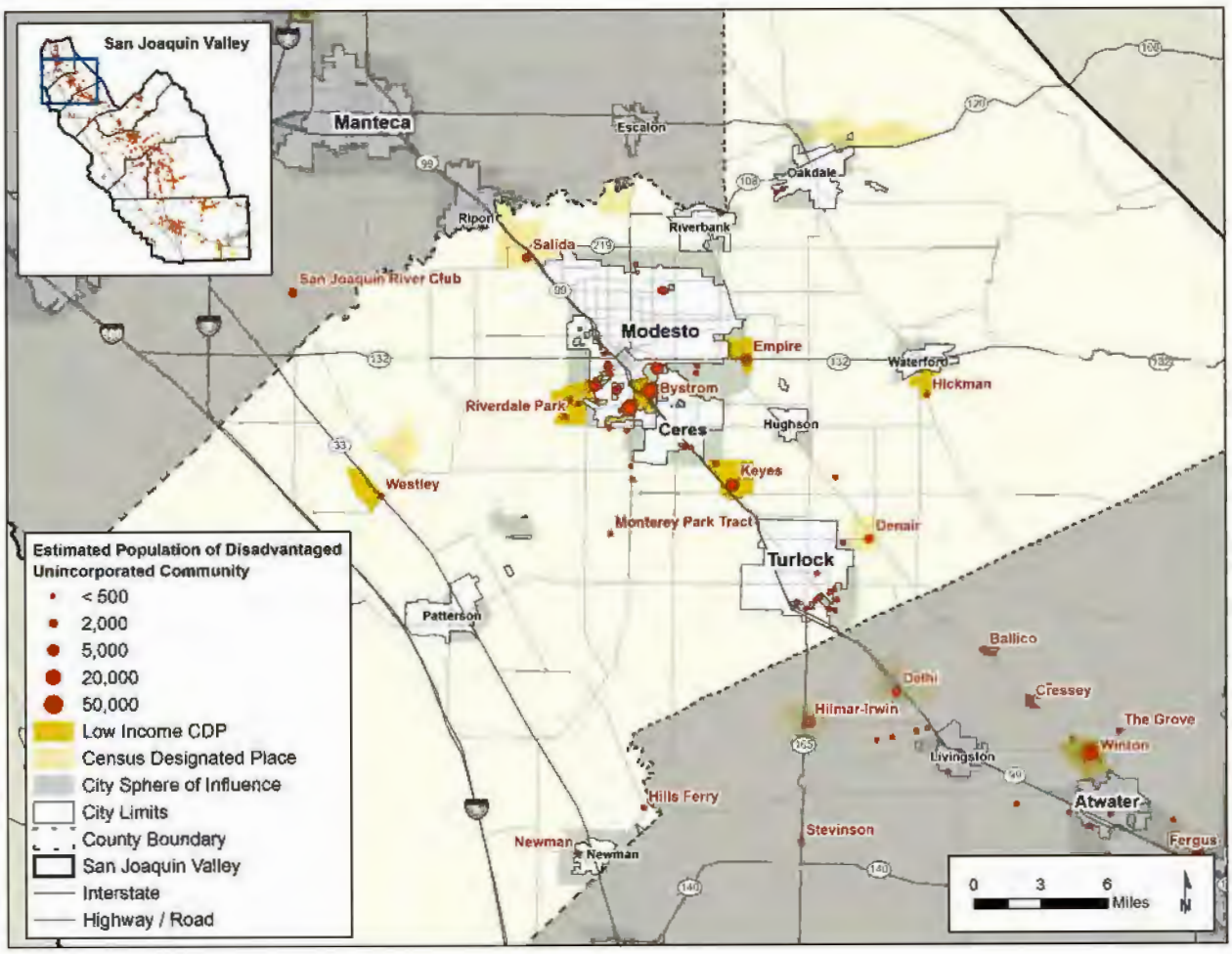
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

SAN JOAQUIN COUNTY	Number of DUCs	Estimated Total Population
Total	**51**	**29,203**
Fringe	26	21,678
Legacy	17	1,705
Island	8	5,820

DUCs with commonly recognized names in San Joaquin County:

Acampo
August
Boggs Tract
Country Club
El Pinal
French Camp
Garden Acres
Hawes
Henderson Village
Kennedy
Lincoln Village
New Hope
San Joaquin River Club
Terminous

Stanislaus County



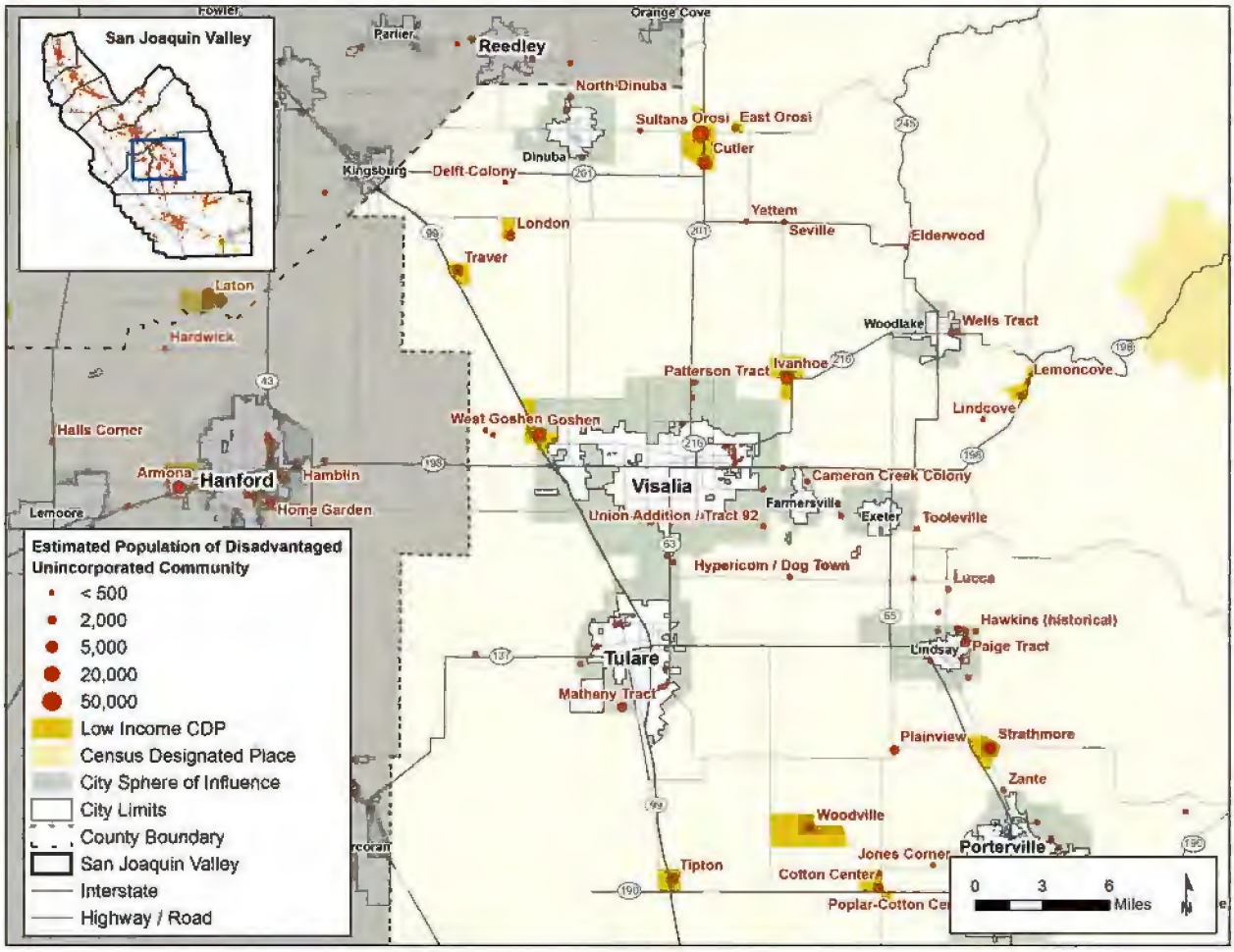
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

STANISLAUS COUNTY	Number of DUCs	Estimated Total Population
Total	**47**	**31,247**
Fringe	27	24,569
Legacy	13	4,768
Island	7	1,910

DUCs with commonly recognized names in Stanislaus County:

Bystrom
Denair
Don Pedro area
Empire
Garden
Hickman
Hills Ferry
Keyes
Monterey Park Tract
Newman
Riverdale Park
Riverside
Salida
Shackelford
Westley

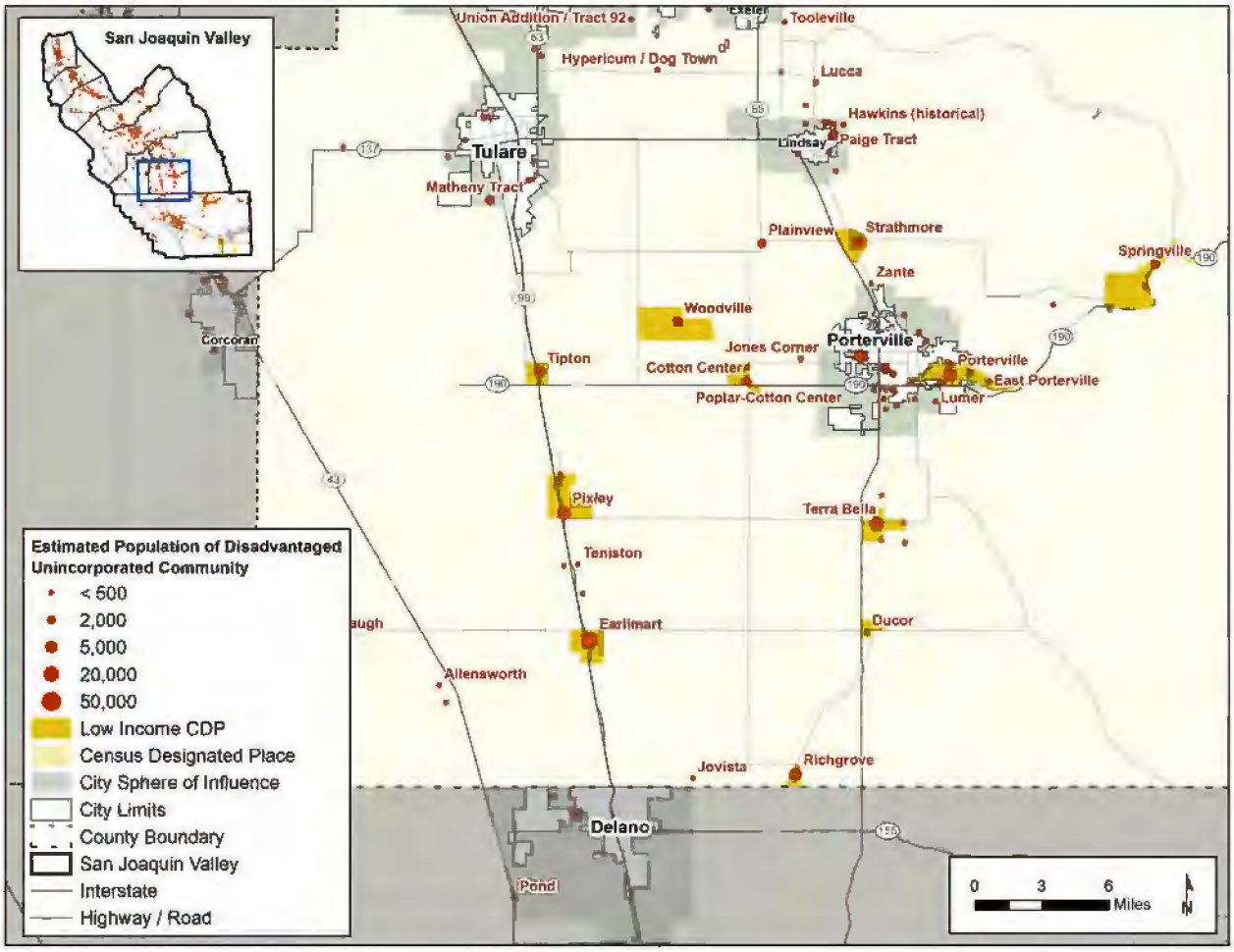
Tulare County (North)



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

TULARE COUNTY	Number of DUCs	Estimated Total Population
Total	**114**	**54,775**
Fringe	53	12,168
Legacy	53	38,846
Island	8	3,761

Tulare County (South)



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

DUCs with commonly recognized names in Tulare County:

Allensworth
Alpaugh
Cameron Creek Colony
Cotton Center
Cutler
Delft Colony
Ducor
Earlimart
East Orosi
East Porterville
Elderwood
Goshen
Hawkins (historical)
Hypericum / Dog Town
Idlewild
Ivanhoe
Jones Corner
Jovista
Lemoncove
Lindcove
London
Lucca
Lumer
Matheny Tract
North Dinuba
Orosi
Paige Tract
Patterson Tract
Pixley
Plainview
Plano
Poplar-Cotton Center
Porterville
Richgrove
Seville
Springville
Strathmore
Sultana
Teniston
Terra Bella
Tipton
Tooleville
Traver
Union Addition / Tract 92
Wells Tract
West Goshen
Woodville
Yettem
Zante

Authors' Biographies

Chione Flegal is an associate director with PolicyLink. She works to ensure that infrastructure and land use policy promote economic, social, and environmental equity. She leads the organization's policy work in California, as well as efforts to address disparities faced by low-income unincorporated communities.

Solana Rice is a senior associate with PolicyLink. As a researcher and policy advocate, she works to advance opportunity for low-income communities and communities of color by promoting equitable solutions to community development through wealth building, small business development, and other economically focused strategies.

Jake Mann is a temporary research assistant with PolicyLink supporting the mapping and analysis for the Community Equity Initiative.

Jennifer Tran is a program associate with PolicyLink. Her work focuses on equitable economic growth, conducting research, data analysis, and GIS mapping.

Lifting Up What Works®

PolicyLink

Headquarters:
1438 Webster Street
Suite 303
Oakland, CA 94612
t 510 663-2333
f 510 663-9684

Communications:
55 West 39th Street
11th Floor
New York, NY 10018
t 212 629-9570
f 212 768-2350

www.policylink.org

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EXHIBIT F

Chapter 7
Analysis of Underserved Disadvantaged Unincorporated Communities

A. Introduction

Senate Bill (SB) 244 (Wolk) was approved by the state in October 2011 and requires cities and counties to address the infrastructure needs of disadvantaged unincorporated communities (DUC) in city and county general plans, Local Agency Formation Commission (LAFCo) Municipal Service Reviews (MSR), and annexation decisions.

Government Code Section 65302.10(a) requires that before the due date for adoption of the next housing element after January 1, 2012, the general plan land use element must be updated to identify and describe each DUC (fringe community, legacy community, and/or island community) that exists within unincorporated areas of the county or in spheres of influence of each city; analyze for each identified community the water, wastewater, stormwater drainage, and structural fire protection needs; and identify financial funding alternatives for the extension of services to any identified communities. SB 244 defines a DUC as a place that meets the following criteria:

- Contains 10 or more dwelling units in close proximity to one another where 12 or more registered voters reside. For the purpose of this analysis, "close proximity" in the Kern County analysis was based on the threshold of more than one dwelling unit per acre. Information on the exact number of dwelling units was sometimes not available; in these cases, the number of residential units was used, and an assumption was made that one unit was equivalent to approximately one dwelling unit.

- Is either within a city sphere of influence (also known as a fringe community), is an island within a city boundary (also known as an island community), or is geographically isolated and has existed for at least 50 years (also known as a legacy community). **Figure 7a** graphically depicts these types of communities. Only legacy communities potentially occur in the unincorporated area of Kern County. The other two types of unincorporated communities occur in city spheres of influence or in unincorporated areas surrounded by incorporated cities.

- Has a median household income that is 80 percent or less of the statewide median household income. (According to the US Census Bureau, American Community Survey (ACS), the median household income for California between 2009 and 2013 was $61,094; therefore, communities with an area median income of $48,875 or lower qualify.)

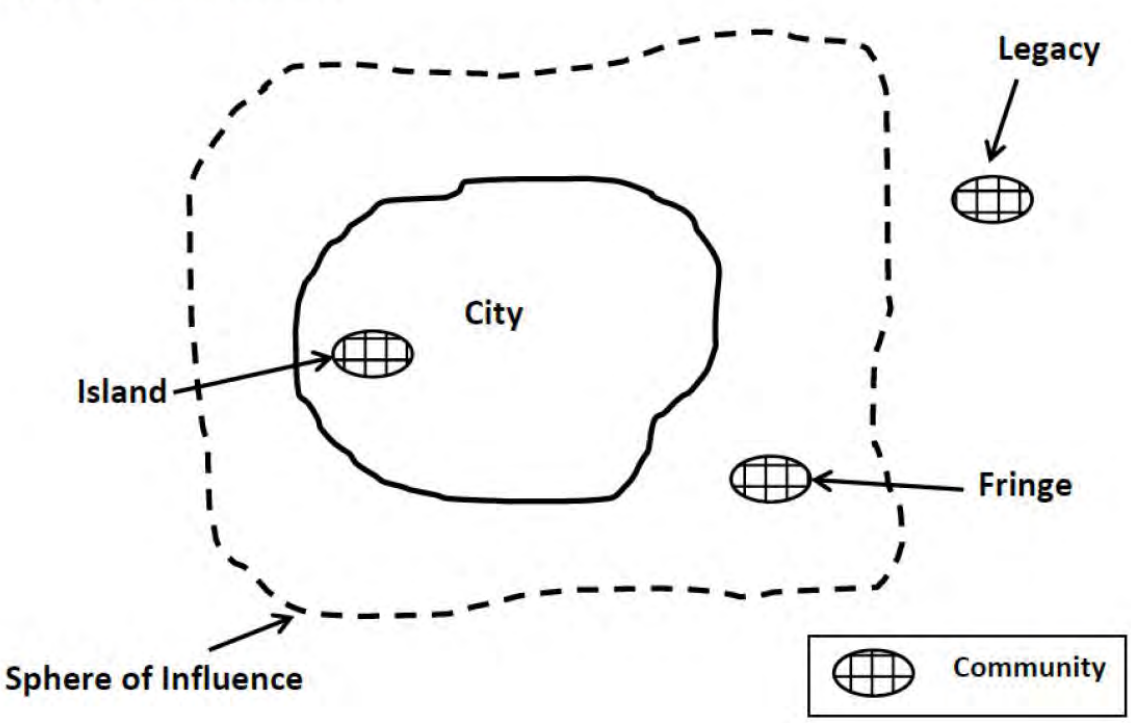
Table 70 lists the DUCs assessed in unincorporated Kern County.

Table 70. Assessed DUC Communities in Kern County

DUC Community
DUC 1: Bodfish
DUC 2: Boron
DUC 3: Buttonwillow
DUC 4: Cherokee Strip
DUC 5: Edmundson Acres
DUC 6: Fuller Acres
DUC 7: Johannesburg
DUC 8: Lake Isabella
DUC 9: Lake of the Woods
DUC 10: Lamont
DUC 11: Lost Hills
DUC 12: Mettler
DUC 13: Mexican Colony
DUC 14: Mojave
DUC 15: Mountain Mesa
DUC 16: Oildale
DUC 17: Onyx
DUC 18: Randsburg
DUC 19: USDA Ruben J. Blunt Village
DUC 20: Weedpatch
DUC 21: Weldon
DUC 22: Wofford Heights

Source: Kern County 2015

Figure 7a: Types of Communities That May Be DUCs



Source: OPR 2013

B. Analysis of Kern County Disadvantaged Unincorporated Communities

An analysis to identify DUCs in unincorporated Kern County was conducted in order to address the requirements of SB 244. In conducting the analysis, resources utilized included the SB 244 Technical Advisory (OPR 2013); the Municipal Service Reviews (MSR) of Kern County, independent agencies, and special districts in the county; and the city limit boundary maps of the cities in Kern County using geographic information systems (GIS).

Disadvantaged Unincorporated Communities

Twenty-two unincorporated communities were identified using Census Designated Place (CDP) information as possible DUCs and were considered for inclusion as communities for analysis. Several additional unincorporated agricultural labor communities were also identified for analysis as DUCs. Some CDPs and agricultural labor communities were eliminated because they did not meet the qualifications, based on census income data, mapping information, County staff knowledge, and plat records. Twenty-two communities met all of the criteria for analysis of services. Services to these communities were then assessed. **Figure 7b** shows the relative location of the disadvantaged unincorporated communities in the county. **Figures 7c** through **7g** show the more specific DUCs by region. In these figures, some of the DUCs are divided into several clusters of housing and are labeled A, B, C, D, etc.

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T:_GIS\Kern_County\MapsHousing_Element_2015\SB244\DUCs Countywide.mxd (2/29/2016)

Lost Hills
Cherokee Strip
Mexican Colony
Buttonwillow
Oildale
Fuller Acres
Lamont (includes USDA Lamont H.R. Olson)
Weedpatch
Edmundson Acres
USDA Ruben J. Blunt Village
Mettler
Lake of the Woods
Wofford Heights
Onyx
Mountain Mesa
Lake Isabella
Weldon
Bodfish
Johannesburg
Randsburg
Mojave
Boron

Richgrove
Posey
DELANO
Delano Muni Airport
Garces Hwy
155
Glennville
Woody
McFarland
Kernville
Wofford Heights
Onyx
Isabella Lake
Lake Isabella
Bodfish
Granite Rd
Porterville Hwy
WASCO
SHAFTER
W Lerdo Hwy
West Side Fwy
Westside Hwy
Kern River Canyon Rd
Fay Mountain Rd
501
178
Meadows Fld
OILDALE
Bakersfield
Bakersfield Muni Airport
Edison
McKittrick Hwy
Buttonwillow
58
Stockdale Hwy
Kern River
5
43
Tupman
McKittrick
119
LAMONT
Caliente
ARVIN
223
99
Fellows
Taft
Maricopa
166
New Cuyama
Grapevine
Lebec
Frazier Park
Ventucopa
Caswell
Keene
Bakersfield-Tehachapi Hwy
TEHACHAPI
Midland Trl
California City Blvd
CALIFORNIA CITY
Mojave
Mojave Airport
Edwards Af Aux North Base
Edwards
Edwards Afb
ROSAMOND
W Avenue D
138
14
70th St W
60th St W
General Wm J Fox
Bodfish Canyon Rd
Cantil
Redrock Randsburg Rd
Red Mountain
Inyokern
China Lake Naws
China Lake
RIDGECREST
395
Trona Rd
SAN BERNARDINO
VENTURA
LOS ANGELES

Legend

- Disadvantaged Unincorporated Community (DUC)
- County Boundary

Source: ESRI; Kern County, 2015; Michael Baker International, 2015

N

0 4 8
Miles

Figure **7b**
Disadvantaged Unincorporated Communities (DUCs) in Kern County

Michael Baker INTERNATIONAL

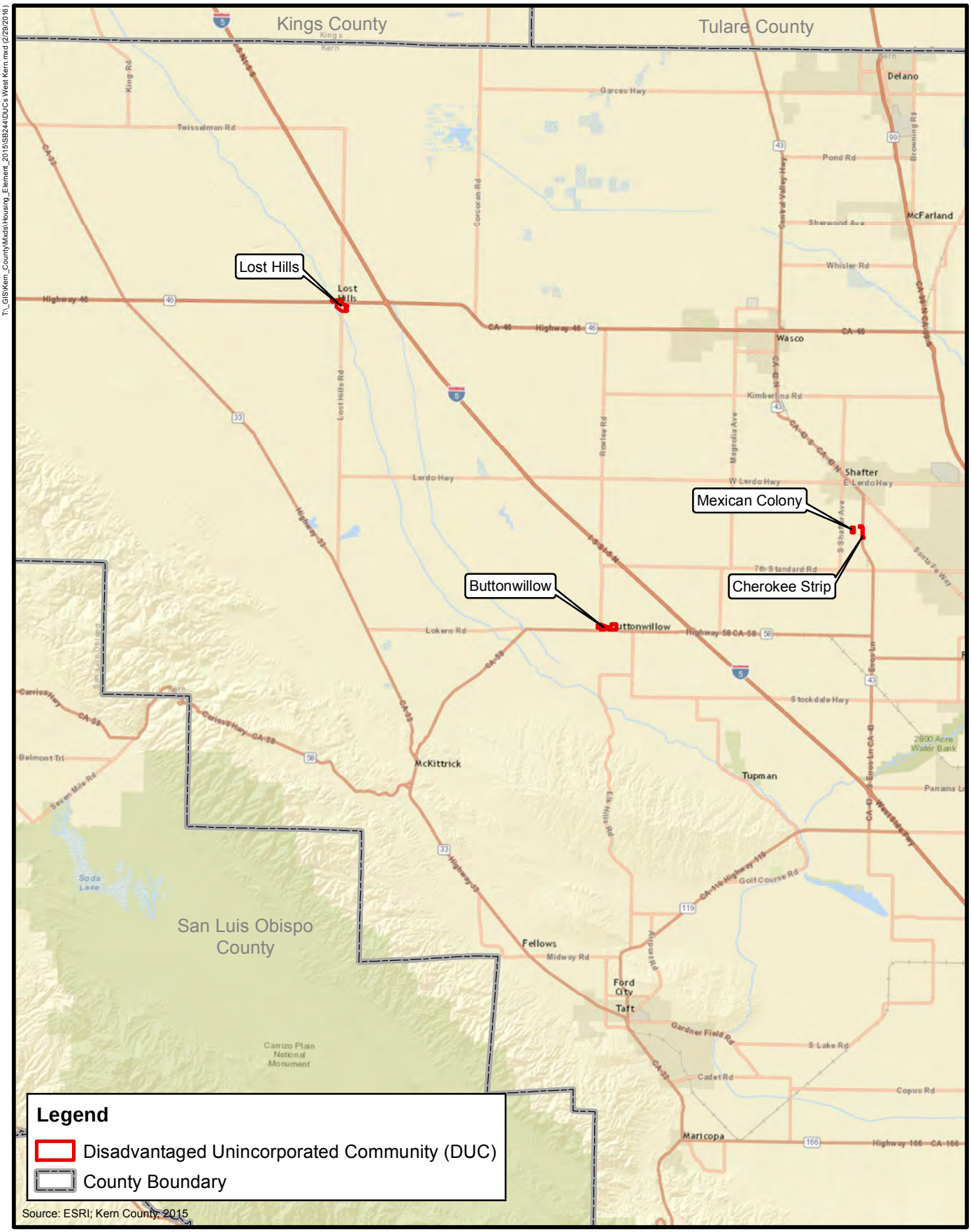


Figure **7c**
Disadvantaged Unincorporated Communities in Kern County
Western Kern

Michael Baker INTERNATIONAL

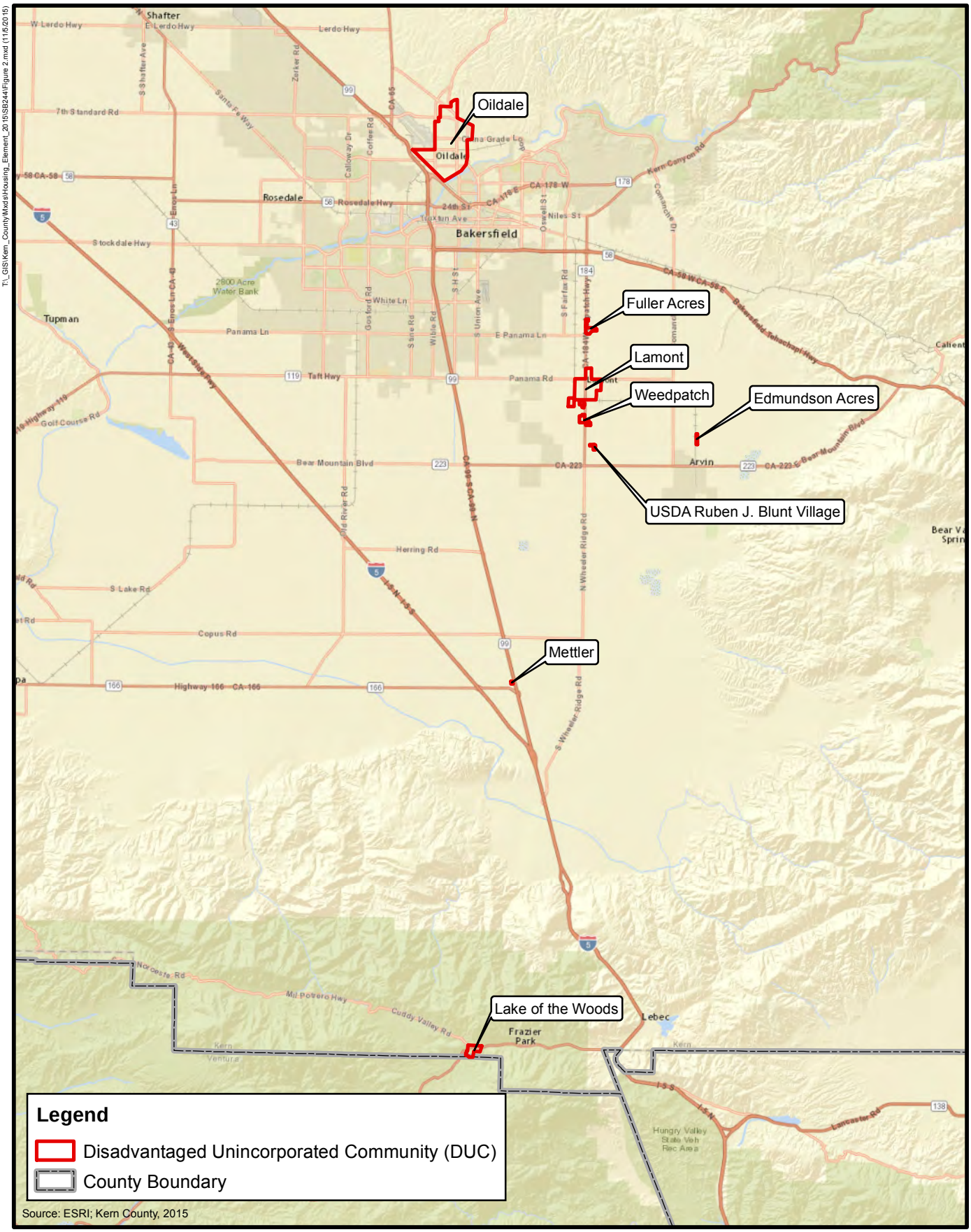


Figure **7d**
Disadvantaged Unincorporated Communities in Kern County
Metro Bakersfield and South Kern

Michael Baker INTERNATIONAL

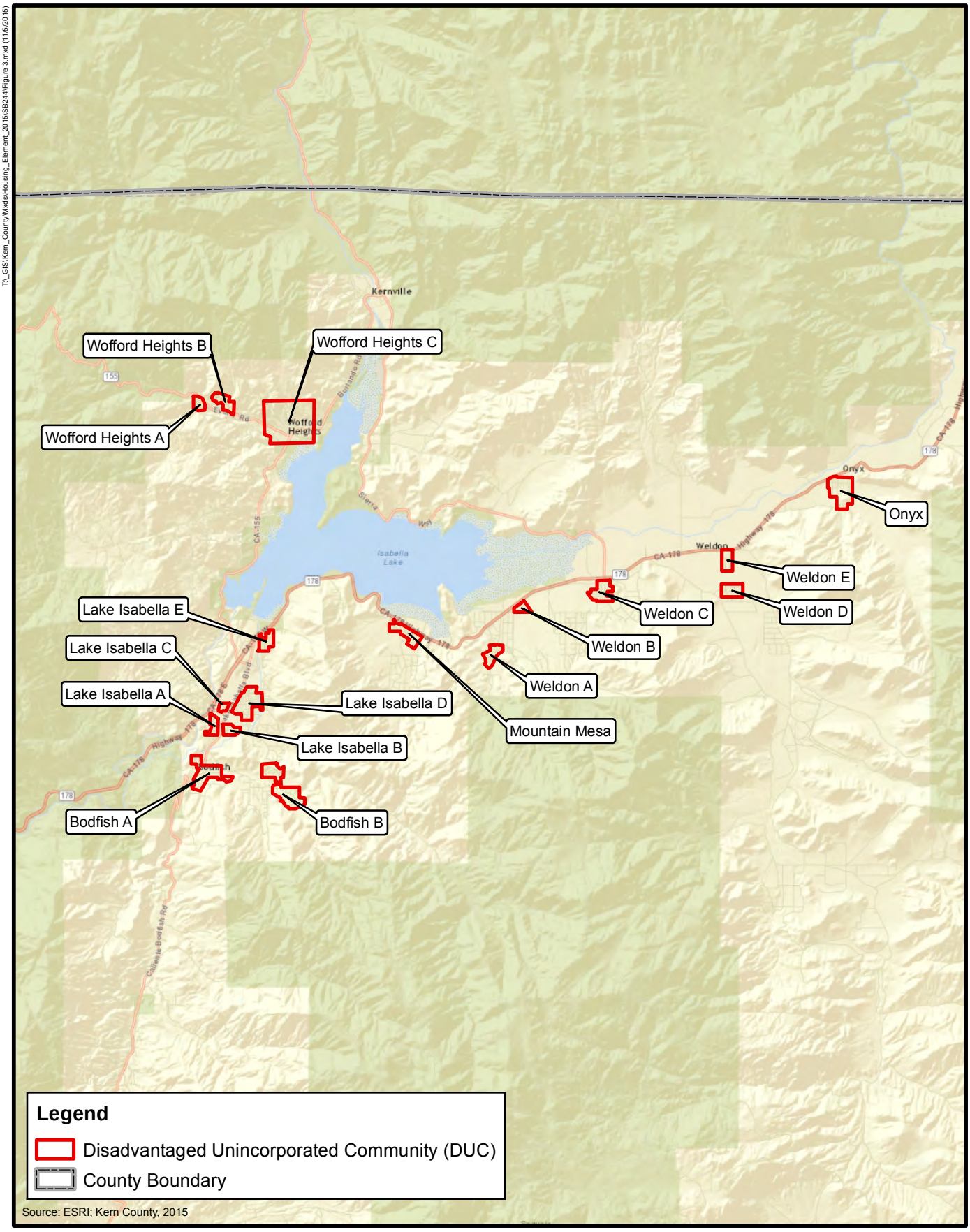


Figure **7e**
Disadvantaged Unincorporated Communities in Kern County
Isabella Lake/North Kern

Michael Baker INTERNATIONAL

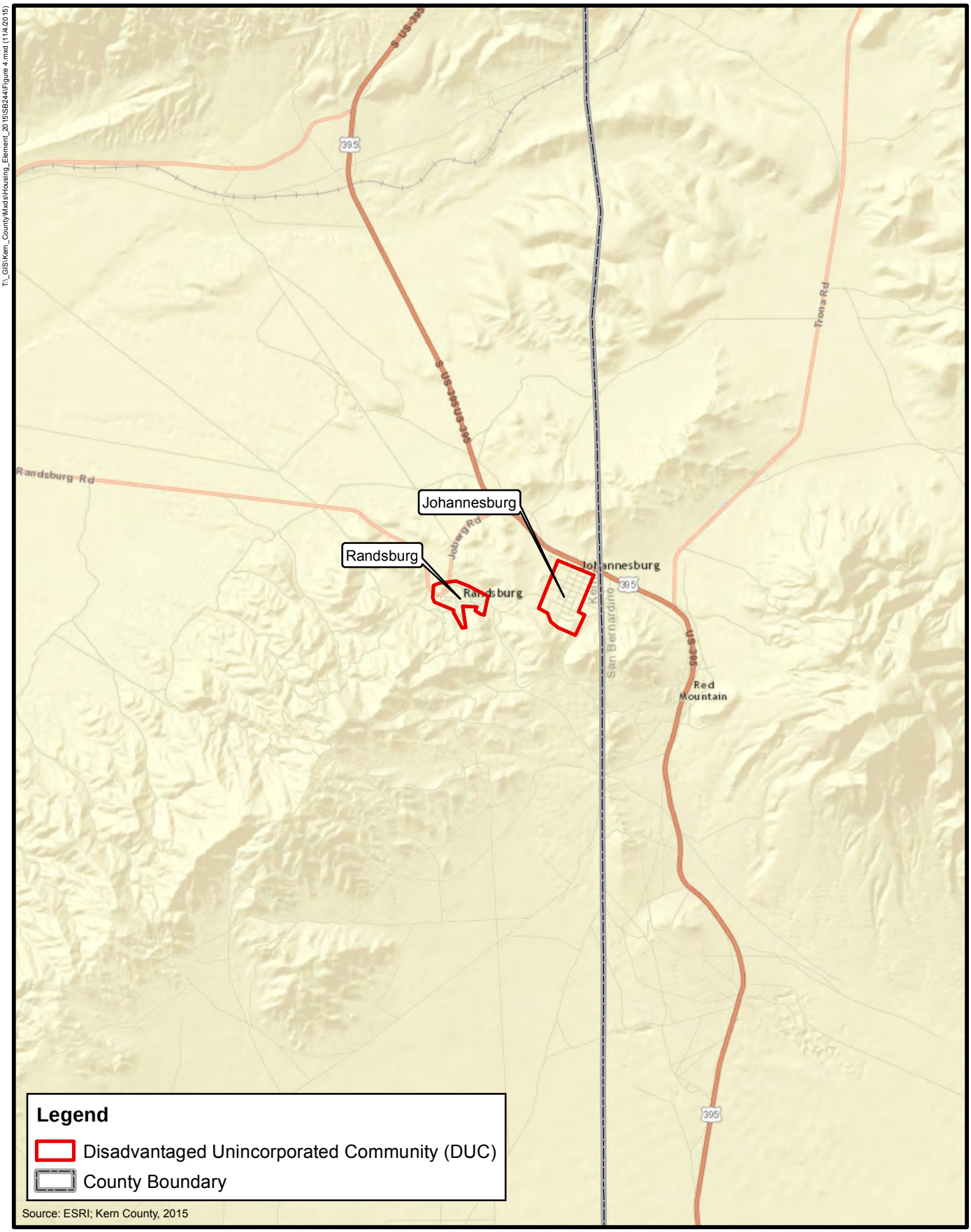


Figure **7f**
Disadvantaged Unincorporated Communities in Kern County
East Kern

Michael Baker INTERNATIONAL

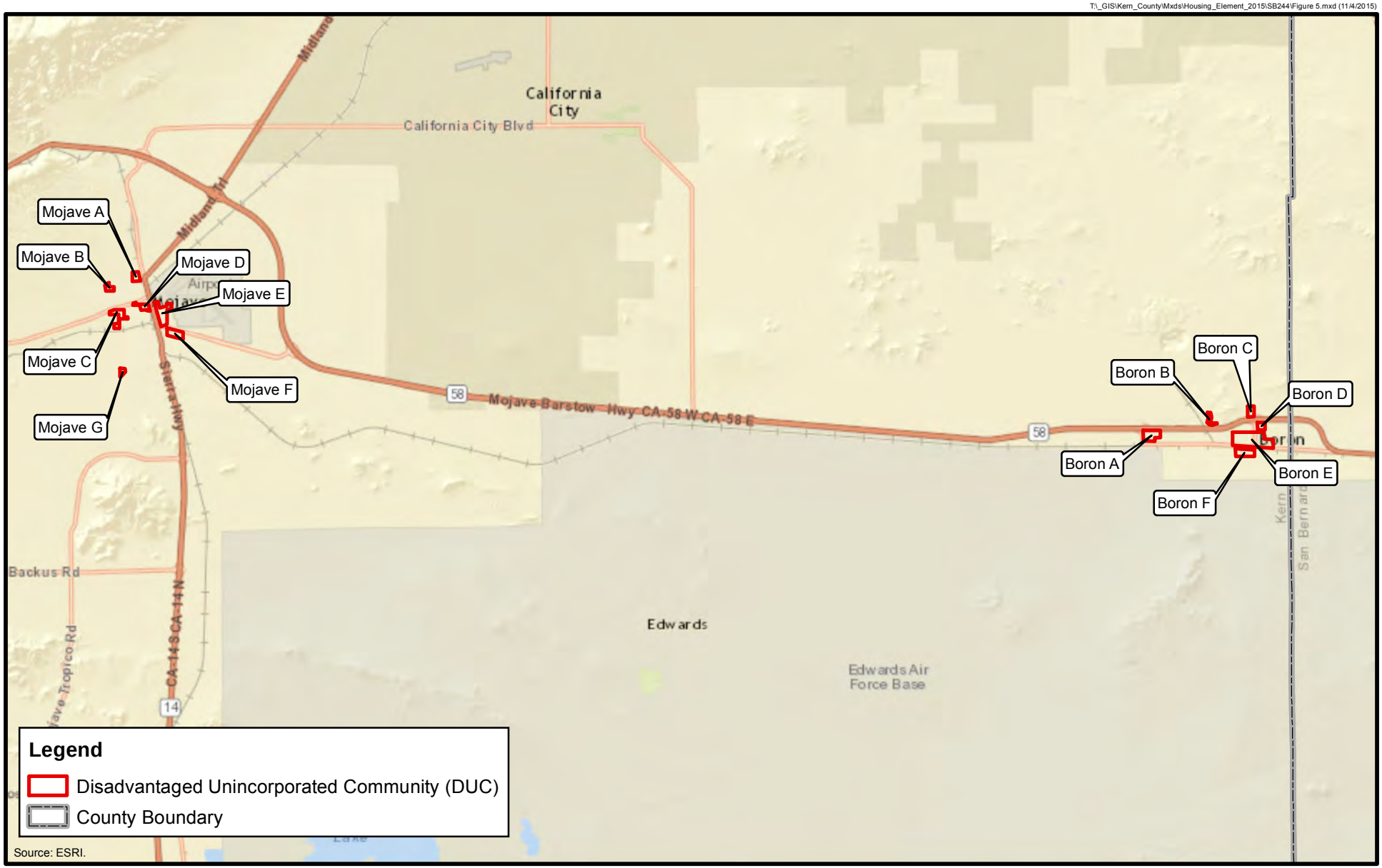


Figure 7**g**
Disadvantaged Unincorporated Communities in Kern County
Southeast Kern

Michael Baker INTERNATIONAL

DUC 1 (Bodfish)

DUC 1 is the Census Designated Place known as Bodfish, approximately 40 miles northeast of Bakersfield. The community is located off State Route (SR) 178, south of Lake Isabella, as shown on **Figure 7e**. Bodfish has two concentrations of residential development; together containing 838 units over 334 acres. This results in an approximate density of 2.51 units per acre. The CDP has a median household income of $21,461 according to the 2009–2013 ACS, according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 2 (Boron)

DUC 2 is the Census Designated Place of Boron, located on the southeast corner of Kern County, approximately 20 miles south of California City. The community is directly west of the intersection of SR 58 and US Route 395, as shown on **Figure 7g**. Boron has six clusters of residential units, covering 212 acres of land. This results in an approximate density of 3.53 units per acre. The median income in Boron, $36,308, is below the qualifying income threshold for DUCs.

DUC 3 (Buttonwillow)

DUC 3 is the Census Designated Place of Buttonwillow, approximately 25 miles west of Bakersfield. The community is a concentration of 336 units at the intersection of SR 58 with Interstate 5 (I-5), as shown on **Figure 7c**. The community is approximately 66 acres, with an overall density of approximately 5 units per acre. Buttonwillow has a median household income of $34,732, according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 4 (Cherokee Strip)

DUC 4 is the Census Designated Place known as Cherokee Strip, located approximately 17 miles northwest of Bakersfield, as shown on **Figure 7c**. The community is a small concentration of residences surrounded by agricultural fields west of SR 43. Cherokee Strip has 60 residential units making up 17 acres, which results in an overall density of approximately 3.5 units per acre. The CDP has a median household income of $43,125, according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 5 (Edmundson Acres)

DUC 5 is the Census Designated Place known as Edmundson Acres. This community is adjacent to the northern boundary of Arvin, as shown on **Figure 7d**. The community has a single concentration of residences on approximately 62 units making up 17 acres. The community has an overall density of approximately 3.6 units per acre. The 2009–2013 ACS reports that Edmundson Acres has a median household income of $35,833, which is less than the qualifying income threshold of $48,856.

DUC 6 (Fuller Acres)

DUC 6 is a Census Designated Place known as Fuller Acres, approximately 7 miles southeast of Bakersfield. The community is south of SR 58 and centered around SR 184, as shown on **Figure 7d.** Residences are concentrated in one area containing 213 units over 67 acres. The community has an overall density of approximately 3.2 units per acre. The 2009–2013 ACS reports that Fuller Acres has a median household income of $35,833, which is less than the qualifying income threshold of $48,856.

DUC 7 (Johannesburg)

DUC 7 is the Census Designated Place known as Johannesburg, approximately 15 miles northeast of California City. The community is located off US Route 395, as shown on **Figure 7f**. Johannesburg has a single concentration of residential development, containing 106 units over 29 acres, which results in an approximate density of 3.56 units per acre. The CDP has a median household income of $32,360according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 8 (Lake Isabella)

DUC 8 is the Census Designated Place of Lake Isabella, approximately 40 miles northeast of Bakersfield. The community is located off SR 178, adjacent to the south side of Lake Isabella, as shown on **Figure 7e**. The Lake Isabella CDP has five clusters of residences in close proximity, totaling 1,323 units on 278 acres. This results in an approximate density of 4.2 units per acre. The CDP has a median household income of $20,678 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 9 (Lake of the Woods)

DUC 9 is the Census Designated Place known as Lake of the Woods, approximately 40 miles northeast of Bakersfield. The community is located off SR 178, adjacent to the south side of Lake Isabella, as shown on **Figure 7d**. Lake of the Woods is a cluster of residences on 384 units in close proximity, making up 49.6 acres, which results in an approximate density of 7.74 units per acre. The CDP has a median household income of $48,750 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 10 (Lamont)

DUC 10 is the Census Designated Place of Lamont, approximately 10 miles southeast of Bakersfield. The community is south of SR 58 and centered around SR 184. Residences are concentrated in one area containing 2,361 units over 452 acres as shown on **Figure 7d**. This DUC contains the USDA Lamont H.R. Olson farmworker housing community. The community has an overall density of approximately 3.2 units per acre. The 2009–2013 ACS reports that Lamont has a median household income of $35,833, which is less than the qualifying income threshold of $48,856.

DUC 11 (Lost Hills)

DUC 11 is the Census Designated Place of Lost Hills, approximately 25 miles west of Wasco. The community is centered at the intersection of I-5 and CA-46. Residences are concentrated in one area containing 296 units over 56.8 acres, as shown on **Figure 7c**. The community has an overall density of approximately 5.2 units per acre. The 2009–2013 ACS reports that the Lost Hills CDP has a median household income of $30,795, which is less than the qualifying income threshold of $48,856.

DUC 12 (Mettler)

DUC 12 is the Census Designated Place known as Mettler, in the southeast portion of Kern County. The community is located along SR 99 just north of the intersection with I-5, as shown on **Figure 7d**. Mettler has roughly 26 residential units in close proximity across 5.3 acres, which results in an approximate density of 4.9 units per acre. The CDP has a median household income of $38,750 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 13 (Mexican Colony)

DUC 13 is the Census Designated Place known as Mexican Colony, in the northwest portion of Kern County. The community is located west of SR 43 just south of the City of Shafter, as shown on **Figure 7c**. Mexican Colony has roughly 78 residential units in close proximity across 20.48 acres, which results in an approximate density of 3.8 units per acre. The CDP has a median household income of $21,250 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 14 (Mojave)

DUC 14 is the Census Designated Place of Mojave, approximately 14 miles southwest of California City. The community is located along SR 14, as shown on **Figure 7g**. Mojave includes seven small clusters of residences, containing 894 units in close proximity on a total of 182 acres, which results in an approximate density of 4.9 units per acre. The CDP has a median household income of $48,750 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 15 (Mountain Mesa)

DUC 15 is the Census Designated Place known as Mountain Mesa, in the northeast portion of Kern County, located below the Sequoia National Forest. The community is 48 miles from downtown Bakersfield, as shown on **Figure 7e**. Mountain Mesa has roughly 349 residential units in close proximity across 73 acres, which results in an approximate density of 4.8 units per acre. The CDP has a median household income of $29,712 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 16 (Oildale)

DUC 16, Oildale, is a Census Designated Place located along Bakersfield's northern border, as shown on **Figure 7d**. Oildale contains 8,739 residential units across 1,832 acres, which results in an approximate density of 2.0 units per acre. The CDP has a median household income of $33,305 according to the 2009-2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 17 (Onyx)

DUC 17 is the Census Designated Place of Onyx in northeast Kern County. The community is located along SR 178 about 20 miles east of Lake Isabella, as shown on **Figure 7e**. Residences are concentrated in one area containing 259 units over 104 acres. The community has an overall density of approximately 2.5 units per acre. The 2009–2013 ACS reports that the Onyx CDP has a median household income of $32,679, which is less than the qualifying income threshold of $48,856.

DUC 18 (Randsburg)

DUC 18, Randsburg, is a Census Designated Place located along Kern County's eastern border, as shown on **Figure 7f**. The community is adjacent to US Route 395. Randsburg contains 77 residential units across 17 acres, which results in an approximate density of 4.5 units per acre. The CDP has a median household income of $26,280 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 19 (USDA Ruben J. Blunt Village)

DUC 19 is the Census Designated Place located along Bakersfield's northern border, as shown on **Figure 7d**. The CDP contains 8,739 residential units across 1,832 acres, which results in an approximate density of 2.0 units per acre. The community has a median household income of $33,305 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 20 (Weedpatch)

DUC 20, Weedpatch, is a Census Designated Place located in central Kern County 15 miles south of Bakersfield's northern border, as shown on **Figure 7d.** Weedpatch has two clusters of residential units in close proximity that together contain 363 residential units across 80 acres. This results in an approximate density of 4.5 units per acre. The CDP has a median household income of $28,508 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 21 (Weldon)

DUC 21, Weldon, is the Census Designated Place located along Lake Isabella in the northeastern part of Kern County, as shown on **Figure 7e.** The community has five clusters of residential units in close proximity that together contain 925

residential units across 332 acres, which results in an approximate density of 1.6 units per acre. The Weldon CDP has a median household income of $24,972 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 22 (Wofford Heights)

DUC 22 is a Census Designated Place known as Wofford Heights located along the northwestern side of Lake Isabella, as shown on **Figure 7e.** Wofford Heights contains three clusters of residential units that together contain 1,087 residential units across 327 acres. This results in an approximate density of 3.3 units per acre. The CDP has a median household income of $28,917 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

C. Municipal Infrastructure and Services Review

1. Water

DUC 1 (Bodfish)

The community of Bodfish has two water providers. The California Water Service (Cal Water) Kern River Valley District serves lower Bodfish, and the Canyon Meadows Water Company serves upper Bodfish. According to the Cal Water 2010 Urban Water Management Plan, it has adequate water supply to meet service connection needs throughout the district. The Canyon Meadows Water Company is a small co-op with 150 connections on several groundwater wells. The co-op president (Cannell 2015) indicates that water levels in the wells remain high and that the current wells have enough capacity to meet current need. The wells meet water quality standards.

DUC 2 (Boron)

Water service to Boron is provided by the Boron Community Services District. The district has 600 connections and is supplied by groundwater or through the Antelope Valley-Eastern Kern Water Agency (Dewar 2015). Supply from these sources is blended and then distributed. The current groundwater well owned by the district is contaminated with arsenic but it concentrations are below the US Environmental Protection Agency's (EPA) maximum contaminant level for arsenic. The district is drilling an additional well, due to be completed by 2016.

DUC 3 (Buttonwillow)

Buttonwillow is provided water by the Buttonwillow County Water District. The district has 150 connections and 434 residential and business units. The district solely uses groundwater, which is adequate to meet current water needs (Houchin 2015a). The groundwater wells owned by the district provide water that meets standards and is of good quality.

DUC 4 (Cherokee Strip)

This area receives water from the City of Shafter. According to Shafter's Public Works Director (James, 2016), this area does not have drinking water quality issues and they have sufficient capacity for their current needs. However, they do not have capacity for expansion or new development.

DUC 5 (Edmundson Acres)

Water to Edmundson Acres is provided by the Edmundson Acres Water System. The system provides all supply through groundwater. Future projects involve replacing old wells with new wells that will not require treatment for arsenic or other constituents. Arsenic is a contaminant that is above the maximum concentration limit of 10 ug/l in all of the system's older wells. Edmundson Acres Water System is upgrading its distribution system and being consolidated with neighboring Arvin Community Services District (ACSD) to correct high arsenic problems. The ACSD is currently under a compliance order from the EPA to solve the problem. Because of arsenic concerns, the Edmundson Acres Water System applied for a Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006 (Proposition 84) grant to help it achieve compliance with the order. The system is implementing a plan to drill new replacement wells in areas with unacceptable water quality, including arsenic contamination. If wells do not have acceptable levels of arsenic, centralized arsenic treatment will be installed.

DUC 6 (Fuller Acres)

According to County staff (Rojas 2016) most of the properties in the Fuller Acres DUC are served by a private water wells or water is provided by the Fuller Acres Water Company. For homes on private water wells, no information was available regarding capacity to serve current or future residents or water quality. Regarding Fuller Acres Water Company, according to Company Staff (Alcorn 2016), the Company has capacity to serve all of their current customers. However, they do not have sufficient capacity for expansion. There are no water quality issues.

DUC 7 (Johannesburg)

Water service in Johannesburg is provided by the Rand Communities Water District. The district provides water to Johannesburg, as well as to Randsburg and Red Mountain in San Bernardino County, serving a total population of 920. The district has roughly 220 connections in Kern County and another 40 connections in San Bernardino County. Based on communications with the district's general manager (Powell 2015), water levels in the district's three wells have remained constant, even during recent drought conditions, and the district has ample supply to meet existing and projected water demand. One of the wells does not meet the EPA's maximum contaminant level for arsenic. The district is currently able to meet demand with only one of the two remaining wells. In addition, the district's distribution system is failing due to age, and breaking or leaking occurs with relative frequency. The district has applied for funds through Proposition 84 grant

funding to make infrastructure improvements. This funding may result in an additional well but will not address all of the district's infrastructure needs.

DUC 8 (Lake Isabella)

Water service in Lake Isabella is primarily provided by the Lake Isabella Community Services District. Additionally, small numbers of residences are served by Cal Water and the Kern River Valley Community Services District. The Lake Isabella Community Services District has 184 total service connections, of which 145 are active. Based on communications with the district's office manager (Loseph 2015), the district purchases water from the Urston Creek Water District and operates three groundwater wells. The district reports that it has ample supply to meet existing and projected water demand. All water sources meet quality standards.

DUC 9 (Lake of the Woods)

Water service here is provided by the Lake of the Woods Water District. Currently the district is able to provide water to residents from their wells; however in the recent past they had to supplement this with water brought from the Lebec County Water District. This is because some of the wells are not as productive as they once were. The State is mandating that the Lake of the Woods Water District go to metering. They are looking into potentially annexing into the Frazier Park Public Utilities District (Jarecki, 2016).

DUC 10 (Lamont)

Water service in Lamont is provided by the Lamont Public Utility District, which currently serves a population of 19,152. Currently, the entire district is on groundwater wells. The district's 2014 Urban Water Management Plan reports that the district is currently in overdraft during the drought period and is working with neighboring water jurisdictions to secure additional supply. The district has adequate financing to develop projects to continue to meet current and projected demand. The district's water sources meet quality standards.

DUC 11 (Lost Hills)

County staff (Downs 2016) indicates that residents in this area receive water and sewer service from a local Public Utilities District.

DUC 12 (Mettler)

Water service in Mettler is provided by the Mettler County Water District. The district supplies water for 45 connections, supplied through two groundwater wells. District staff (Houchin 2015b) indicates that water supply is adequate to meet needs and that no water quality problems exist.

DUC 13 (Mexican Colony)

This area receives water from the City of Shafter. According to Shafter's Public Works Director (James, 2016), this area does not have drinking water quality issues and they have sufficient capacity for their current needs. However, they do not have capacity for expansion or new development.

DUC 14 (Mojave)

Water service in Mojave is provided by the Mojave Public Utility District, which currently has 112 water connections. The district has two sources of water, including local groundwater wells and contract supply through the Antelope Valley-East Kern Water Agency. Combined, the sources provide 1,600 acre-feet of water per year, which is greater than the current and projected needs of the community. The district's water sources meet water quality standards.

DUC 15 (Mountain Mesa)

Water service in Mountain Mesa is provided by the Mountain Mesa Water Company, which is operated by Cal Water by contract. The water supply has ongoing quality issues with nitrate and arsenic, but detected levels do not exceed standards. The district is currently making improvements to the treatment plant in order to reduce nitrate and arsenic concentrations in the groundwater supply.

DUC 16 (Oildale)

Water service in Oildale is provided by the Oildale Mutual Water Company, which has 10,200 connections supplied through groundwater wells. The company manager indicates that groundwater levels are sufficient and that the company has adequate supply to meet current and projected needs (Nunneley, 2015). All water sources meet water quality standards.

DUC 17 (Onyx)

Onyx is geographically isolated and topographically constrained. Residents there receive their water from private wells according to an employee (Aguirre, 2016) at the Lake Isabella Kern River KOA Campground. (This KOA is one of the "Possible Partnering Agencies" on the Integrated Regional Water Management Plan for the Weldon Regional Water Project.) No information on capacity or water quality was available.

DUC 18 (Randsburg)

Water service in Randsburg is provided by the Rand Communities Water District. The district also provides water to Johannesburg and Red Mountain in San Bernardino County, serving a total population of 920. The district has roughly 220 connections in Kern County and another 40 connections in San Bernardino County. Based on communications with the district's general manager (Powell 2015), water levels in the district's three wells has remained constant, even during

recent drought conditions, and the district has ample supply to meet existing and projected water demand. One of the wells does not meet the EPA's maximum contaminant level for arsenic. The district is currently able to meet demand with only one of the two remaining wells. In addition, the district's distribution system is failing due to age, and breaking or leaking occurs with relative frequency. The district has applied for funds through Proposition 84 grant funding to make infrastructure improvements. This funding may result in an additional well but will not address all of the district's infrastructure needs.

DUC 19 (USDA Ruben J. Blunt Village)

According to the Facilities Area Supervisor of the Kern County Housing Authority (Greenoe, 2016), water here is provided by the Lamont Public Utility District, which currently serves a population of 19,152. Currently, the entire district is on groundwater wells. The district's 2014 Urban Water Management Plan reports that the district is currently in overdraft during the drought period and is working with neighboring water jurisdictions to secure additional supply. The district has adequate financing to develop projects to continue to meet current and projected demand. The district's water sources meet water quality standards.

DUC 20 (Weedpatch)

Water service in Weedpatch is provided by the Lamont Public Utility District, which currently serves a population of 19,152. Currently, the entire district is on groundwater wells. The district's 2014 Urban Water Management Plan reports that the district is currently in overdraft during the drought period and is working with neighboring water jurisdictions to secure additional supply. The district has adequate financing to develop projects to continue to meet current and projected demand. The district's water sources meet water quality standards.

DUC 21 (Weldon)

According to County staff, Weldon gets its water supply from several small water co-ops and private entities, including the Long Canyon Water Company, Rainbird Valley Mutual Water Company, Tradewinds Water Association, Inc., Bella Vista Mutual Water Company, South Fork Women's Club, and Lake Isabella Kern River KOA Campground. Several of these private entities have arsenic and nitrate quality concerns.

DUC 22 (Wofford Heights)

County staff (Downs 2016) indicates that water here is provided by the California Water Service Company.

Wastewater

DUC 1 (Bodfish)

All of Bodfish depends on small private septic systems. County staff (Popiemlarp 2015) indicates that many of these systems are old and in need of replacement, but they are located on very small lot sizes and in some cases are in poor soils. Both lot size and soils can present challenges for replacement with modern and effective septic systems. Other infrastructure improvements may therefore be necessary.

DUC 2 (Boron)

All of Boron depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 3 (Buttonwillow)

The Buttonwillow County Water District provides wastewater collection, treatment, and disposal in limited areas of the community. The district has adequate infrastructure to meet current demand. The rest of the community is on private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 4 (Cherokee Strip)

County staff (Downs 2016) indicates that residences are on small private septic systems. The area has experienced numerous septic failures and resultant water quality impacts. State funding is currently being sought to remedy this situation.

DUC 5 (Edmundson Acres)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 6 (Fuller Acres)

All of Fuller Acres depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 7 (Johannesburg)

All of Johannesburg depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 8 (Lake Isabella)

As seen in **Figure 7e**, there are four portions (labeled A-D) which comprise the Lake Isabella DUC. County staff (Downs 2016) indicates that residents in Lake Isabella A are served by sewer. The sewer system in this area is 27 years old. A portion of residents in Lake Isabella D are on a private sewer that serves some commercial and a mobile home park. Lake Isabella areas B and C depend on small private septic systems. County staff (Popiemlarp 2015) indicates that many of these systems are old and in need of replacement, but they are located on very small lots and in some cases are in poor soils. Both lot size and soils can present challenges for replacement with modern and effective septic systems. Other infrastructure improvements may therefore be necessary.

DUC 9 (Lake of the Woods)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 10 (Lamont)

Wastewater service in Lamont is provided by the Lamont Public Utility District. The district's service area comprises approximately 2,000 acres, and it operates 35 miles of sewer collection pipes and one secondary-level wastewater treatment plant. The district does not indicate that there are currently any wastewater infrastructure needs.

DUC 11 (Lost Hills)

All of Lost Hills depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 12 (Mettler)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 13 (Mexican Colony)

County staff (Downs 2016) indicates that the area is on sewer. The sewer system has no known capacity or water quality issues.

DUC 14 (Mojave)

Portions of Mojave depend on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time. The remaining portions

of the community are served by the Mojave Public Utility District wastewater system, which has adequate infrastructure and wastewater treatment capacity to meet current needs.

DUC 15 (Mountain Mesa)

All of Mountain Mesa depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 16 (Oildale)

Wastewater service in Oildale is provided by the North of River Sanitary District. The district operates four treated effluent storage ponds and one wastewater treatment plant. The district has the infrastructure to meet sanitary needs. However, the existing sewers will eventually need to be paralleled and/or replaced with larger diameter sewers as flow from Oildale increases. The district's 2013 Master Sewer Plan establishes a timeline and financing options for making capacity improvements as demand increases.

DUC 17 (Onyx)

All of Onyx depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 18 (Randsburg)

All of Randsburg depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 19 (USDA Ruben J. Blunt Village)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 20 (Weedpatch)

Portions of Weedpatch depend on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time. The remaining portions of the community are served by the Lamont Public Utility Wastewater system, which has adequate infrastructure and wastewater treatment capacity to meet current needs.

DUC 21 (Weldon)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 22 (Wofford Heights)

All of Wofford Heights depends on small private septic systems. County staff (Popiemlarp 2015) indicates that many of these systems are old and in need of replacement. High groundwater levels, sloping geography, and erosion have led to water leaching issues in the area. Infrastructure improvements may therefore be necessary.

Stormwater

DUC 1 (Bodfish)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 2 (Boron)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 3 (Buttonwillow)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and pump station;
- Flood protection infrastructure capacity issues are known to exist; and
- The County has Drainage Improvement Plans for this area.

Stormwater and flood protection infrastructure is insufficient in this area.

DUC 4 (Cherokee Strip)

County staff (Hamilton, 2016) indicates that there is no stormwater infrastructure in place and it is not in a 100-year floodplain. Flooding is not a known issue here, according to County staff (Evans, 2016).

DUC 5 (Edmundson Acres)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Capacity issues are not known to exist; and
- The County has Drainage Improvement Plans for this area.

Stormwater and flood protection infrastructure is sufficient in this area.

DUC 6 (Fuller Acres)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain. County Staff (Evans, 2016) indicates that Caliente Creek has caused repeated historical flooding in Fuller Acres.

DUC 7 (Johannesburg)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place and that it is not in a 100-year floodplain. There is not a known history of flooding, as indicated by County staff (Evans, 2016).

DUC 8 (Lake Isabella)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Flood protection infrastructure capacity issues are known to exist;
- The County has Drainage Improvement Plans and Tract Improvement Plans for this area; and
- This area is in a 100-year floodplain.

According to the Kern County Roads Department *2015 Flood Map* for the Kern River Valley and correspondence with County staff (Evans, 2016), within this DUC, adjacent to Erskine Creek, Lake Isabella Boulevard at Lake Isabella Park (Tank Park) experiences frequent flooding and road closures. Major flooding occurs here approximately every ten years. This is a rural area and generally this road is the only access to towns in the Kern River Valley. Closures can impact a few hundred residents at a time.

Stormwater and flood protection infrastructure is insufficient in this area.

DUC 9 (Lake of the Woods)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain. County Staff (Evans, 2016) indicates that Cuddy Creek has caused historical flooding in this area.

DUC 10 (Lamont)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Flood protection infrastructure capacity issues are not known to exist;
- The County has Drainage Improvement Plans and Tract Improvement Plans for this area; and
- This area is within the NPDES Permit Boundary. Stormwater samples are collected by the Public Works Department biannually for analysis. No water quality issues are known to exist.

County staff (Downs 2016) indicates that there are known flooding issues in the USDA Lamont H.R. Olson farmworker community portion of this area. Stormwater and flood protection infrastructure is insufficient in this area.

DUC 11 (Lost Hills)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Capacity issues are not known to exist; and
- The County has Drainage Improvement Plans for this area.

Stormwater and flood protection infrastructure is sufficient in this area.

DUC 12 (Mettler)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place and it is in a 100-year floodplain. Furthermore, this area is known to flood routinely, as indicated by County staff (Evans, 2016).

DUC 13 (Mexican Colony)

County staff (Hamilton, 2016) indicates that stormwater infrastructure, in the form of a drainage basin, is in place. County staff (Hamilton, 2016) indicates that the County has a Drainage Improvement Plan for this area. County staff (Evans, 2016) indicates that there are flood protection infrastructure capacity issues.

DUC 14 (Mojave)

County staff (Hamilton, 2016) indicates that the area is in a 100-year floodplain. As seen on **Figure 7g**, Mojave includes seven small clusters of residences. Theses clusters are identified as A-G. County staff (Hamilton, 2016) indicates the following:

Area A. No stormwater infrastructure is in place.

Area B. No stormwater infrastructure is in place.

Area C. No stormwater infrastructure is in place in this area, except in the mobile home park, which has private streets and a private drainage basin. The County is in possession of a grading plan from the mobile home park.

Area D. No stormwater infrastructure is in place in this area, except in the apartment complex, which has a private drainage basin. The County is in possession of a grading plan from the apartment complex in this area.

Area E. Stormwater infrastructure is in place here, in the form of the Victor Avenue Basin. The County has a Drainage Improvement Plan.

Area F. No stormwater infrastructure is in place in this area, except in the apartment complex, which has a private drainage basin. The County is in possession of a grading plan from the apartment complex.

Area G. Stormwater infrastructure is in place, under the purview of the private community with private streets. The County is in possession of a grading plan and Tract 4522 improvement plans.

County staff (Evans, 2016) indicates that there are no known flood protection infrastructure capacity or flooding issues here.

DUC 15 (Mountain Mesa)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 16 (Oildale)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Flood protection infrastructure capacity issues are known to exist;
- The County has Drainage Improvement Plans Tract Improvement Plans and Parcel Map Improvement Plans; and
- No water quality issues are known to exist.

According to the Kern County Roads Department *2015 Flood Map* for Metro Bakersfield and correspondence with County staff (Evans, 2016), within this DUC, generally all of the Airport Drive underpasses are frequently flooded. This is because the pumps are not big enough to remove the water fast enough. It happens frequently- every normal rain year. It will happen numerous times in an El Nino Winter. While these events are not severe enough to shut down traffic and there are alternate routes available, the flooding poses an inconvenience to motorists. Stormwater and flood protection infrastructure is insufficient in this area.

DUC 17 (Onyx)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 18 (Randsburg)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place and that it is not in a 100-year floodplain. There is not a known history of flooding, as indicated by County staff (Evans, 2016).

DUC 19 (USDA Ruben J. Blunt Village)

According to staff from the Kern County Public Works Department (Hamilton, 2016), stormwater infrastructure in the form of curb/gutter, drainage areas and drainage basins are in place here. According to the Facilities Area Supervisor of the Kern County Housing Authority (Greenoe, 2016), this site had repairs to their drainage system last summer. No drainage issues currently exist. This site is located in a 100 year flood zone, however, the drainage basin located behind the property is of adequate size.

DUC 20 (Weedpatch)

This area straddles Highway 184, which runs north-south. County staff (Hamilton, 2016) indicates that the area is not in a 100-year floodplain.

West of highway 184: County staff (Hamilton, 2016) indicates that the portion of the area to the west of Highway 184 has stormwater infrastructure, in the form of a drainage basin. County staff (Hamilton, 2016) indicates that the County has a Drainage Improvement Plan for the area served by the drainage basin. County staff (Evans, 2016) indicates that there are flood protection infrastructure capacity issues.

East of highway 184: County staff (Hamilton, 2016) indicates that the portion of the area to the east of Highway 184 does not have stormwater infrastructure. County staff (Evans, 2016) indicates that there are considerable flooding issues in this area, especially northeast of Weedpatch (east Lamont).

DUC 21 (Weldon)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 22 (Wofford Heights)

County staff (Hamilton, 2016) indicates that there is no stormwater infrastructure in place and that the area is in a 100-year floodplain. Despite this, flooding is not a known issue here, according to County staff (Evans, 2016).

Fire Protection

DUC 1 (Bodfish)

Kern County contracts with the California Department of Forestry and Fire Protection (Cal Fire) to provide fire services for certain unincorporated areas, including Bodfish. Station 72 is the nearest responding fire station.

DUC 2 (Boron)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Boron. Station 17 is the nearest responding fire station.

DUC 3 (Buttonwillow)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Buttonwillow. Station 25 is the nearest responding fire station.

DUC 4 (Cherokee Strip)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Cherokee Strip. Station 32 is the nearest responding fire station.

DUC 5 (Edmundson Acres)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Edmundson Acres. Station 54 is the nearest responding fire station.

DUC 6 (Fuller Acres)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Fuller Acres. Station 51 is the nearest responding fire station.

DUC 7 (Johannesburg)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Johannesburg. Station 75 is the nearest responding fire station.

DUC 8 (Lake Isabella)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Lake Isabella. Station 72 is the nearest responding fire station.

DUC 9 (Lake of the Woods)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Lake of the Woods. Station 57 is the nearest responding fire station.

DUC 10 (Lamont)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Lamont. Station 51 is the nearest responding fire station.

DUC 11 (Lost Hills)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Lost Hills. Station 26 is the nearest responding fire station.

DUC 12 (Mettler)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Mettler. Station 72 is the nearest responding fire station.

DUC 13 (Mexican Colony)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Mexican Colony. Station 32 is the nearest responding fire station.

DUC 14 (Mojave)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Mojave. Station 14 is the nearest responding fire station.

DUC 15 (Mountain Mesa)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Mountain Mesa. Station 71 is the nearest responding fire station.

DUC 16 (Oildale)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Oildale. Station 63 is the nearest responding fire station.

DUC 17 (Onyx)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Onyx. Station 71 is the nearest responding fire station.

DUC 18 (Randsburg)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Randsburg. Station 75 is the nearest responding fire station.

DUC 19 (USDA Ruben J. Blunt Village)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including USDA Ruben J. Blunt Village. Station 51 is the nearest responding fire station.

DUC 20 (Weedpatch)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Weedpatch. Station 51 is the nearest responding fire station.

DUC 21 (Weldon)

Kern County contracts Cal Fire to provide fire services for certain unincorporated areas, including Weldon. Station 71 is the nearest responding fire station.

DUC 22 (Wofford Heights)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Wofford Heights. Station 76 is the nearest responding fire station.

Table 71. Summary of Service to DUCs in Kern County

DUC	Water Sufficient	Wastewater Treatment Sufficient	Stormwater Infrastructure Sufficient	Fire Protection Sufficient	Underserved DUC
DUC 1: Bodfish	Yes	No	No	Yes	Yes
DUC 2: Boron	Yes	Yes	No	Yes	Yes
DUC 3: Buttonwillow	Yes	Yes	No	Yes	Yes
DUC 4: Cherokee Strip	Yes	No	Yes	Yes	Yes
DUC 5: Edmundson Acres	No	Yes	Yes	Yes	Yes
DUC 6: Fuller Acres	Yes	Yes	No	Yes	Yes
DUC 7: Johannesburg	No	Yes	Yes	Yes	Yes
DUC 8: Lake Isabella	Yes	No	No	Yes	Yes
DUC 9: Lake of the Woods	No	Yes	No	Yes	Yes
DUC 10: Lamont	No	Yes	Yes	Yes	Yes
DUC 11: Lost Hills	Yes	Yes	Yes	Yes	No
DUC 12: Mettler	Yes	Yes	No	Yes	Yes
DUC 13: Mexican Colony	Yes	Yes	No	Yes	Yes
DUC 14: Mojave	Yes	Yes	Yes	Yes	No
DUC 15: Mountain Mesa	Yes	Yes	No	Yes	Yes
DUC 16: Oildale	Yes	Yes	No	Yes	Yes
DUC 17: Onyx	Yes	Yes	No	Yes	Yes
DUC 18: Randsburg	No	Yes	Yes	Yes	Yes
DUC 19: USDA Ruben J. Blunt Village	No	Yes	Yes	Yes	Yes
DUC 20: Weedpatch	No	Yes	No	Yes	Yes
DUC 21: Weldon	No	Yes	No	Yes	Yes
DUC 22: Wofford Heights	Yes	No	Yes	Yes	Yes

D. Future Annexations Considered

Kern County Planning staff was consulted to determine whether any annexations from the County into any Kern County cities are anticipated. Annexations are considered on a case-by-case basis and at this time none of these DUCs have contacted the County or are under consideration for annexation into cities.

E. Conclusion

While Bakersfield average housing costs ($170,000) are shown to be consistent with the average housing costs in the United States, California's home prices and rents have risen faster than the U.S. average since the 1940's and resistance to density and the California Environmental Quality Act continue to delay or stop new housing development. Appendices B and C of this Housing Element contain two recent reports on housing development in California. Both reports were prepared by the California Legislative Analyst Office: Perspectives on Helping Low Income Californians Afford Housing, dated February 9, 2016, and California's High Housing Costs: Causes and Consequences, dated March 17, 2015. The reports indicate that "living in decent, affordable, and reasonably located housing is one of the most important determinates of well-being for every Californian. More than just basic shelter, housing affects our lives in other important ways, determining our access to work, education, recreation, and shopping. The cost and availability of housing also matters for the State's economy, affecting the ability of business and other employers to hire and retain qualified workers and influencing their decisions about whether to locate, expend, or remain in California." The report released in March 2015, and confirmed again in the report from February 2016, notes barriers to providing more housing for low income and special needs populations. The reports further identify and discuss the following challenges and concerns to expanding existing programs at the State level.

- Expanding Assistance Programs would be very expensive.
- Affordable housing construction requires large public subsidies.
- Expanding housing vouchers would be expensive and a scarcity of housing undermines the voucher program causing rents to rise.
- Environmental protection policies constrain housing development.
- Home builders are often forced to compete for limited development opportunities.

The reports conclude that while vouchers, inclusionary housing requirements and rent control have provided limited solutions, increasing the housing supply is the only factor that will ensure availability.

While there is a need to develop and identify new affordable housing developments, there is also a need to provide adequate infrastructure to those areas currently being underserved. Based on information contained in this analysis,

expansion of services will be required for 20 of the disadvantaged unincorporated communities (DUC) described above. Water quality or supply issues exist in Bodfish, Edmundson Acres, Johannesburg, Lake of the Woods, Lamont, Randsburg, U.S.D.A. Ruben J. Blunt Village, Weedpatch, and Weldon. Wastewater issues relating to private septic systems exist in Bodfish, Cherokee Strip, Lake Isabella, and Wofford Heights. Lack of stormwater and flood protection infrastructure is an issue in Bodfish, Boron, Buttonwillow, Fuller Acres, Lake Isabella, Lake of the Woods, Mettler, Mexican Colony, Mountain Mesa, Oildale, Onyx, Weedpatch, and Weldon. All of these DUCs are considered underserved. The County will continue to identify additional financing alternatives and mechanisms for improving water quality and providing better septic or installing sewer systems in these existing DUC's. **Table 72** provides an outline of potential infrastructure funding opportunities that the County can pursue to facilitate additional infrastructure projects within these identified DUC areas.

Table 72. Potential Funding Sources for Extension and Improvement of Services

Agency	Program (Year Passed or Created)	Funding Provided (in million $)	Funding Remaining/Available (in million $)	Limitations/Barriers on Use of Funds for Drinking Water Treatment (capital or O&M)
California Department of Public Health (CDPH)	Safe Drinking Water State Revolving Fund (SDWSRF) (1996) (grants and loans)	Generally $100-$150: Low-interest loans and some grants to support water systems with technical, managerial, and financial development and infrastructure improvements.	$130-$150 (revolving funds) (annually)	▪ 20 to 30% of annual federal contribution can be used for grants. The remainder must be committed to loans. ▪ Funds can be used only for capital costs. Cannot be used for O&M ▪ Only loans (not grants) for privately owned water systems. ▪ Some funds available for feasibility and planning studies for eligible projects/systems. ▪ Can only be used for Public Water Systems (not domestic wells or State Small Systems)
	Proposition 84 (2006) (grants)	$180: Small Community Improvements. --- $60: Protection and reduction of contamination of groundwater sources. $50 Matching funds for federal DWSRF --- $10: Emergency and urgent projects.	$0 (Over subscribed) --- $0 (Fully allocated) Will be fully committed with the current year grant but not yet liquidated --- ~$7	▪ Funds can be used only for capital costs. Cannot be used for O&M. ▪ Some funding available for feasibility and planning studies for eligible projects/systems. ▪ Can only be used for Public Water Systems not domestic wells or State Small Systems --- ▪ Used to address sudden unanticipated emergency situation such as fires, earthquakes and mud slides that damage critical water infrastructure. May fund short term mitigations such as hauled water.
	Proposition 50 (2002) (grants) (fully allocated)	$50: Water security for drinking water systems. --- $69: Community treatment facilities and monitoring programs. --- $105: Matching funds for federal grants for public water system infrastructure improvements.	$0 (fully allocated) --- $0 (fully allocated) --- $0 fully allocated, mostly liquidated	▪ Can only be used for capital costs. Cannot be used for O&M. ▪ Can only be used for Public Water Systems not domestic wells or State Small Systems

Agency	Program (Year Passed or Created)	Funding Provided (in million $)	Funding Remaining/Available (in million $)	Limitations/Barriers on Use of Funds for Drinking Water Treatment (capital or O&M)
State Water Resources Control Board (State Water Board)	Clean Water State Revolving Fund (Expanded Use Program) (CWSRF) (1987) (loans)	$200-$300 per year: Water quality protection projects, wastewater treatment, nonpoint source contamination control, and watershed management.	$50 per agency per year; can be waived	Eligible Uses: Stormwater treatment and diversion, sediment and erosion control, stream restoration, land acquisition. Drinking water treatment generally not eligible except under certain Expanded Use scenarios. Capital cost only. O&M not eligible.
	Small Community Groundwater Grants (Prop 40) (2004, amended 2007) (grants)	$9.5. Assist small disadvantage communities (<20,000pp) with projects where the existing groundwater supply exceeds maximum contaminant levels, particularly for arsenic or nitrate	$1.4 remaining- $0.3 available to encumber; $1.1 available to appropriate	Eligible Uses: Funds can go to local government or NGO. Must demonstrate financial hardship. Can only provide alternate water supply. No O&M costs. Program not currently active due to staff resource limitations
	State Water Quality Control Fund: Cleanup and Abatement Account (2009)	$10 in 2012 (varies annually): Projects to (a) clean up waste or abate its effects on waters of the state, when there is no viable responsible party, or (b) address a significant unforeseen water pollution problem (regional water boards only). Funds can be allocated to: Public Agencies, specified tribal governments, and not-for profit organizations that serve disadvantaged communities	$10, but varies.	Eligible Uses: Emergency cleanup projects; projects to clean up waste or abate its effects on waters of the state; regional water board projects to address a significant unforeseen water pollution problem. Recipient must have authority to clean up waste. Under certain circumstances this fund has been used to provide drinking water O&M for limited durations.
	Integrated Regional Water Management (IRWM) (2002) (grants) (fully allocated)	$380 (Prop 50): Planning ($15) and implementation ($365) projects related to protecting and improving water quality.	$0, fully committed	
California Department of Water Resources (DWR)	Integrated Regional Water Management (IRWM) (2002) (grants)	$600 remaining (Prop 84): Regional water planning and implementation.	~$28 (central coast projects) ~$33 (Tulare/Kern projects)	Must be consistent with an adopted IRWM Plan and other program requirements. For capital investment only

Agency	Program (Year Passed or Created)	Funding Provided (in million $)	Funding Remaining/Available (in million $)	Limitations/Barriers on Use of Funds for Drinking Water Treatment (capital or O&M)
(California Department of Water Resources (DWR))	Contaminant treatment or removal technology pilot and demonstration studies (2002) (grants)	Up to $5 per grant	$15 million available	Eligible applicants are public water systems under the regulatory jurisdiction of CDPH and other public entities For capital investment only
	Safe Drinking Water Bond Law (Prop 81) (1988)	Up to $74 to be awarded to current priority list. $0.025 max per project	Remaining balance to be determined	Provides funding for projects that investigate and identify alternatives for drinking water system improvements
	Drinking water disinfecting projects using UV technology and ozone treatment (2002) (grants)	$0.05 minimum, up to $5 m per grant	$19 m remaining	Eligible applicants are public water systems under the regulatory jurisdiction of CDPH For capital investment only
iBank (CA Infrastructure and Development Bank)	Infrastructure State Revolving Fund (ISRF) Program (2000) (loans)	$0.25 to $10 per project to finance water infrastructure that promotes job opportunities. Eligible projects include - construction or repair of publicly owned water supply, treatment, and distribution systems.	$52.6 million approved to date for Water Supply, Water Treatment and Distribution Applications continually accepted	Finances system capital improvements only. Must show job creation. Special loan tier for DACs was discontinued.
State Water Resources Control Board (State Water Board) & California Department of Water Resources (DWR)	Proposition 1 Water Quality, Supply and Infrastructure Improvement Act of 2014	Prop 1 was approved by voters on November 4, 2014 and authorizes $7.545 billion in general obligation bonds for water projects including surface and groundwater storage, ecosystem and watershed protection and restoration, and drinking water protection. DWR and the State Water Board will administer various Prop 1 funds.	Various. Applications ongoing.	See Appendix D for a detailed breakdown of various funding programs authorized under the passage of Proposition 1.

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EXHIBIT G

Regional Changes in Extreme Climatic Events: A Future Climate Scenario

JASON L. BELL, LISA C. SLOAN, AND MARK A. SNYDER

Department of Earth Sciences, University of California, Santa Cruz, Santa Cruz, California

(Manuscript received 10 July 2002, in final form 11 February 2003)

ABSTRACT

In this study a regional climate model is employed to expand on modeling experiments of future climate change to address issues of 1) the timing and length of the growing season and 2) the frequency and intensity of extreme temperatures and precipitation. The study focuses on California as a climatically complex region that is vulnerable to changes in water supply and delivery. Statistically significant increases in daily minimum and maximum temperatures occur with a doubling of atmospheric carbon dioxide concentration. Increases in daily temperatures lead to increases in prolonged heat waves and length of the growing season. Changes in total and extreme precipitation vary depending upon geographic location.

1. Introduction

Analysis of long-term temperature and precipitation records has revealed changes in the mean climatic state as atmospheric carbon dioxide (CO_2) levels have increased since the industrial revolution (Easterling et al. 1997; Gaffen and Ross 1998; Plummer et al. 1999; Salinger and Griffiths 2001). Research employing global climate models (GCMs) indicates potentially greater changes for future climate states (Cao et al. 1992; Zwiers and Kharin 1998; McGuffie et al. 1999; Yonetani and Gordon 2001). Changes in the mean climate state have been found to affect the frequency and intensity of extreme climatic events as well (Mearns et al. 1984; Katz and Brown 1992; Groisman et al. 1999; Meehl et al. 2000). Extremes in temperature and precipitation have important impacts on vital aspects of society, including crop yield, power consumption and production, and human health (Easterling et al. 2000; Meehl et al. 2000; Walther et al. 2002). Responses to climate change and mitigation of negative impacts must be resolved at regional and local levels in order for effective action to be taken; therefore, it is important to assess the potential for climate change on a regional level.

Regional changes in climate are highly variable and cannot be adequately represented by GCMs at this time. This inability necessitates the use of regional climate models (RCMs) to address potential climate change on the regional scale. Snyder et al. (2002) used an RCM to demonstrate the potential for significant changes in the mean climate of the California region due to a doubling of atmospheric CO_2 levels. The present study addresses potential changes in the frequency and intensity of extreme daily temperatures and precipitation events for the same region and CO_2 scenarios.

Corresponding author address: J. L. Bell, Department of Earth Sciences, University of California, Santa Cruz, Santa Cruz, CA 95064.
E-mail: jbell@es.ucsc.edu

2. Model description and experiment design

The model description and experiment design is similar to that of Snyder et al. (2002) with a few key differences. Snyder et al. (2002) performed a sensitivity study of California climate with doubled CO_2 using a limited ensemble approach. The limited ensemble approach utilized identical GCM boundary conditions with multiple RCM simulations. Two CO_2 scenarios were compared and each scenario was comprised of three ensemble members of 5 years in length. While this approach was successful at limiting computational expense the results indicate that the GCM is responsible for the majority of the variability. Snyder et al. (2002) discovered that the year-to-year variability within a given simulation was much greater than the variability between ensemble members. Based on these conclusions we use a single 15-yr simulation for each of the CO_2 scenarios and present results based on twice-daily model output.

We used the National Center for Atmospheric Research (NCAR) Community Climate Model version 3.6.6 (CCM3) (Kiehl et al. 1998) as the global driver for our regional model. We first used a version of CCM3 with a slab ocean–thermodynamic sea ice model to perform two 15-yr simulations. The two simulations differed only in the atmospheric CO_2 concentrations, which were 280 ppm (preindustrial level) and 560 ppm (hereafter referred to as $1 \times CO_2$ and $2 \times CO_2$ scenarios, respectively). Due to the model output only being saved at monthly intervals the calculated sea surface temper-

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atures (SSTs) were used to drive a second set of CCM3 simulations. These simulations, using the prescribed SSTs for the corresponding CO_2 concentrations, were run for 22 years and results were saved at 12-h intervals. The first 4 years of each simulation were removed as equilibration time and the remaining 18 yr of results were used to drive the RCM.

This study employs a modified version of the second-generation NCAR Regional Climate Model (RegCM2) (Giorgi and Shields 1999) (hereafter referred to as RegCM2.5) as described by Snyder et al. (2002). RegCM2.5 was run with a horizontal resolution of 40 km and a domain centered over California. We performed two 18-yr simulations with the first three years removed for equilibration. These simulations varied only in the specified atmospheric CO_2 concentrations (280 and 560 ppm).

3. Validation

It is important when discussing the need for more regional and local scale studies of climate change and impacts to be able to demonstrate the capability for such studies. Here we demonstrate 1) the ability of the regional model to adequately capture both the general (seasonal temperature and precipitation) and specific [diurnal temperature range (DTR), growing season length, frequency and intensity of extreme events] characteristics of regional climate observed for the modern day and 2) that regional models are currently better suited for this type of analysis than global models. Mearns et al. (1999) have performed a similar validation for RegCM2 with a domain centered on Nebraska while Snyder et al. (2002) performed a more general validation over California.

a. Modern climate

Here we compare the results of a modern-day regional climate simulation to observations. The model simulation of present-day conditions is similar in design to our $1 \times CO_2$ and $2 \times CO_2$ scenarios. CCM3 was run for 22 years forced with a single climatological year of SSTs (calculated from observations for the period from 1950 to 1979). The first 4 yr were removed for equilibration and the last 18 yr were used to drive RegCM2.5. The first 3 yr of the RegCM2.5 simulation were removed for equilibration and the last 15 yr are used for the analysis presented here. The atmospheric CO_2 concentration in both models was 360 ppm.

The observational data used are historical weather station data collected by the Western Regional Climate Center (2003). The types and scope of data available vary depending on the climate characteristics of interest. For each comparison with the model results we treat all data in as similar a manner as possible. For the analyses of seasonal temperature and precipitation we used climatological data calculated with a minimum of 22 yr of data from the period 1971–2001. For the more specific analyses (DTR, growing season, and extremes) the available data ranges from 27 to 100 yr in length (on average 49.4 yr) for the period from 1901 to 2001. We began our analysis with ~55 stations and, due to the shear volume of available data, narrowed it to stations where the actual and model-derived elevations differed by no more than 100 m. What remained were 16 stations representing a wide range of latitude, longitude, and elevations across California.

TABLE 1. Summary of comparison between observations (obs) and RegCM2.5 (rcm) modern-day simulation.

	obs	rcm	obs−rcm
	Temperature		
Annual mean (°C)	32.7	32.0	0.7
DJF (°C)	25.3	23.9	1.4
MAM (°C)	31.4	29.0	2.4
JJA (°C)	40.4	40.8	−0.4
SON (°C)	33.6	34.1	−0.5
$T \geq 32.2$°C (days)	71.4	43.8	27.6
$T \geq 0$°C (days)	68.5	38.2	30.3
1-day max (°C)	44.1	40.1	4.0
1-day min (°C)	−15.2	−12.9	−2.3
	DTR		
Annual mean (°C)	15.4	9.7	5.7
DJF (°C)	12.2	6.0	6.2
MAM (°C)	15.0	9.2	5.8
JJA (°C)	18.3	13.4	4.9
SON (°C)	15.9	10.2	5.7
	Precipitation*		
Annual mean (cm)	52.9	56.7	−3.8
DJF (cm)	26.6	31.6	−5.0
MAM (cm)	13.9	16.6	−2.7
JJA (cm)	2.2	0.5	1.7
SON (cm)	8.6	8.1	0.5
Light (days)	88.9	97.1	−8.2
Moderate (days)	12.3	13.3	−1.0
Heavy (days)	5.5	5.7	−0.2
1-day max (cm)	12.1	10.8	1.3

* Precipitation intensities are defined as: light days < 1.27 cm, moderate days < 2.54 cm, and heavy days ≥ 2.54 cm.

Overall the comparison between modern-day regional model results and weather station data is very good. This is especially the case considering the data record is much longer than the model simulation and therefore provides a larger sample population. Furthermore the weather stations provide point data, while the model results are derived from single grid cells with 40-km horizontal resolution. Still there are some issues with the model results, especially for the DTR and the seasonality of precipitation.

The regional model adequately captures the seasonal changes in temperature as well as the annual mean temperature. On average the RCM is only 0.7°C cooler for the annual mean and no more than 2.4°C different seasonally than the observations (Table 1). The RCM more accurately captures the summer [Jun–Aug (JJA)] and fall [Sep–Nov (SON)] temperatures than the winter [Dec–Feb (DJF)] and spring [Mar–May (MAM)] tem-

peratures. The DTR is too small by ~5° to 6°C annually and seasonally (Table 1). The growing season starts on average 16.5 days too soon and ends 13.8 days too late. For extremes the model simulates ~28 too few hot (32.2°C) days per year and ~30 too few cold (0°C) days per year (Table 1). While the model simulates too few extreme events it does not overestimate the intensity of simulated extreme events. The historic 1-day events simulated by the model fall within the range of historic events in the longer observational record (Table 1).

The regional model outputs temperature twice a day at noon and midnight. These temperatures are used as proxies for the daily maximum and minimum and are not the actual maximum and minimum temperatures. As a result, the proxy maximum temperatures are too cool and the proxy minimum temperatures are too warm, producing a dampened DTR. The use of the proxy minimum also affects the calculated beginning and end of the growing season. The growing season appears to start earlier and end later due to the use of the proxy minimum temperature. Finally the use of these proxy temperatures results in extreme events that do not appear as extreme as those in the observational record.

Annually the regional model slightly overestimates total precipitation (+3.8 cm yr^{-1}) and poorly captures the seasonality of precipitation. The model overestimates winter and spring precipitation and underestimates summer and fall precipitation (Table 1). The model also simulates ~8 too many light rainfall days per year (<1.27 cm day^{-1}). For moderate (1.27–2.54 cm day^{-1}) and heavier (>2.54 cm day^{-1}) rainfall days the model is much more accurate (Table 1). The model simulates one day too many per year of moderate precipitation and only 0.2 too many days per year of heavier rainfall. The model does a good job simulating historic 1-day events considering the differences in sample sizes. The average 1-day high is 1.3 cm less in the model than in the observations (Table 1).

b. GCM versus RCM

A RCM offers higher spatial resolution than a GCM, allowing for greater topographic complexity and smaller-scale atmospheric dynamics to be simulated and investigated. Theoretically, higher resolution should lead to more realistic simulations of regional-scale climate. The biggest weakness with RCMs is the dependence on lateral boundary input either via GCM, reanalysis, or observational data. If an RCM receives poor quality input it is not likely to output much higher quality results. So, if quality GCM input is needed, then is the use of an RCM necessary? The answer to that question depends on the inquiry to be addressed. Obviously a RCM would be inadequate to address issues of global, or even hemispheric, changes in atmospheric circulation. Likewise a GCM may not be appropriately suited for questions that are subcontinental in scale, especially for complex regions. California is a climatically and topographically complex region and therefore a study of the regional climate there warrants the use of a RCM.

Having already demonstrated that RegCM2.5 does a good job of simulating the modern observed climate of California we must answer another question: Does the RCM do a better job of simulating California climate than the GCM? The modern-day CCM3 simulation was analyzed in the same manner as the RCM output. We compared the CCM3 results for temperature and precipitation to the 16 weather stations discussed earlier. For over 540 individual comparisons of GCM and RCM versus observational data the GCM compared more favorably than the RCM only 25% of the time. Furthermore there was no one specific climatic feature or characteristic that the GCM consistently simulated better than the RCM. Clearly there is utility in using the RCM, and not just the GCM, to address issues of changes in climate for a complex region.

Overall RegCM2.5 does a good job simulating the main features of the modern-day climate, though it is not perfect. RegCM2.5 also does a much better job simulating the California climate than CCM3. Any inherent biases in RegCM2.5 will be present in both of our CO_2 scenarios. Therefore, since this is a sensitivity study, these model biases will be mitigated when calculating changes in the climate due to the doubling of CO_2.

4. Analysis methods

California spans a wide latitudinal range and contains a variety of microclimates. Due to this diversity of microclimates, we perform our analysis on the hydrologic basin scale, as defined by the California Department of Water Resources (1998) (Fig. 1). The methods for analysis of changes in extreme events are similar to those of Salinger and Griffiths (2001). Annual extreme events are defined based on the 5th and 95th percentiles of the $1 \times CO_2$ results.

a. Temperature

We define three types of extreme temperature events and examine changes between the $1 \times CO_2$ and $2 \times CO_2$ scenarios. The first type of extreme event is based on the 95th and 5th percentiles of daily maximum and minimum temperatures, respectively. These percentiles correspond to the 18th hottest maximum and coldest minimum temperatures in a year (based on the number of events per year multiplied by the percentile). For all 15 years of the $1 \times CO_2$ simulation the annual 5th-percentile events were averaged together to create a long-term extreme cold index value, likewise for the annual 95th-percentile events. These long-term indices are used for the evaluation of changes in extreme events. The second type of extreme event examined is based on specific temperature thresholds. We examine the frequency of events below 0°C and above 32.2°C. The third type of extreme event is a prolonged extreme event.

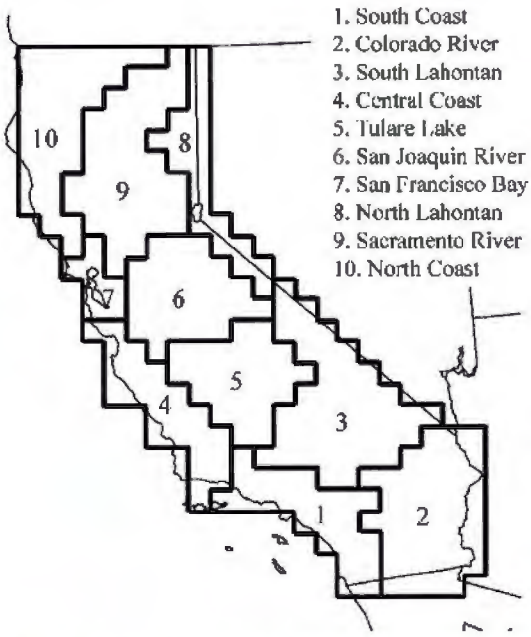


FIG. 1. The hydrologic basins of California shown here are adapted from the California Department of Water Resources (1998) to the 40-km RCM grid. Note the area shown here is a subset of the total regional model domain used in this study.

These are events where the maximum (or minimum) temperature exceeds the long-term 95th (or 5th) percentile for seven or more consecutive days.

Indices of temperature examined are the following:

- Changes in mean daily temperature maximum, minimum, and range: T_{max}, T_{min}, T_{range}, respectively.
- The frequency of days with maximum (minimum) temperatures above (below) the 95th (5th) percentile: T_{95} (T_{05}). (Extreme event of type 1 described above.)
- The frequency of days with temperatures above (below) 32.2°C (0°C): T_{32} (T_0). (Extreme event of type 2 described above.)
- Changes in prolonged extreme events, including frequency, mean length, and mean temperature of prolonged hot and cold extreme events. (Extreme event of type 3 described above.)
- Changes in the beginning and length of the annual growing season (based on the frost-free period).

b. Precipitation

Precipitation in California is highly variable on all temporal and spatial scales. For each basin we examine changes in daily and annual rainfall and the frequency of extremely heavy rainfall events. Heavy rainfall events are defined using the 95th percentile as explained above for extremely high temperatures.

Indices of precipitation examined are the following:

- Changes in mean annual rain.
- Changes in mean rain per rain day[1] and number of rain days per year.
- The frequency of extreme events exceeding the 95th percentile (as above): P_{95}.

5. Results

a. Temperature

In general the 2 × CO_2 scenario is hotter than the 1 × CO_2 scenario. For every basin the mean daily maximum and minimum temperatures are greater in the 2 × CO_2 scenario than in the 1 × CO_2 scenario (Table 2), with differences statistically significant at the 95% confidence level (5% significance level). While the increases in both maximum and minimum are similar, the increase in daily maximum is greater, for 9 of 10 basins, than the increase in daily minimum. This leads to an increased mean DTR in these regions. Although the change in DTR is relatively small, it is still significant in 7 of 10 basins (Table 2). Our results indicate an increase in extremely hot days (T_{95}), days exceeding 32.2°C, and in prolonged hot spells (Table 3). Not only are there more prolonged hot events in the 2 × CO_2 scenario, but these events are longer and hotter on average than the prolonged events in the 1 × CO_2 scenario (Table 3). While the maximum temperatures are rising in the 2 × CO_2 scenario, so are the minimum temperatures, resulting in a decrease in days below the 5th percentile (T_{05}) and in days below 0°C (Table 2). Due to the decrease in days with temperatures less than 0°C the frost-free period begins, on average, 25 days earlier in the 2 × CO_2 scenario and is on average 38 days longer. In our 2 × CO_2 scenario we also find that prolonged cold events occur less often and are shorter and warmer on average than in the 1 × CO_2 scenario.

b. Precipitation

We find decreases in mean annual rainfall across the state (Table 4). Only the North Coast and North Lahontan basins have increased rain, 1% and 3%, respectively. On average there is very little change in mean rainfall per rain day, although there are generally fewer rain days per year in each basin (~5 days). With the exceptions of the North Coast and North Lahontan basins there is also a decrease in extremely heavy rainfall (P_{95}) events as well (Table 4). On average, 2.4 fewer heavy events occur per year per basin, while the North Coast and North Lahontan basins average 2.5 *additional* heavy rainfall events per year compared to the 1 × CO_2 scenario.

[1] We define a rain day as any day with basin average of 0.1 mm or more of precipitation.

EXHIBIT H

nature COMMUNICATIONS

ARTICLE

DOI: 10.1038/s41467-018-04475-3 OPEN

Overpumping leads to California groundwater arsenic threat

Ryan Smith [1], Rosemary Knight[1] & Scott Fendorf [2]

Water resources are being challenged to meet domestic, agricultural, and industrial needs. To complement finite surface water supplies that are being stressed by changes in precipitation and increased demand, groundwater is increasingly being used. Sustaining groundwater use requires considering both water quantity and quality. A unique challenge for groundwater use, as compared with surface water, is the presence of naturally occurring contaminants within aquifer sediments, which can enter the water supply. Here we find that recent groundwater pumping, observed through land subsidence, results in an increase in aquifer arsenic concentrations in the San Joaquin Valley of California. By comparison, historic groundwater pumping shows no link to current groundwater arsenic concentrations. Our results support the premise that arsenic can reside within pore water of clay strata within aquifers and is released due to overpumping. We provide a quantitative model for using subsidence as an indicator of arsenic concentrations correlated with groundwater pumping.

[1] Department of Geophysics, Stanford University, 397 Panama Mall, Stanford, California 94305, USA. [2] Department of Earth System Science, Stanford University, 473 Via Ortega, Stanford, California 94305, USA. Correspondence and requests for materials should be addressed to R.S. (email: rgsmith@stanford.edu)

Globally, groundwater provides almost half of all drinking water[1], making it one of the world's most important resources. Within the United States, the Central Valley of California accounts for roughly 20% of groundwater withdrawals[2]. The Central Valley is an arid region that supports a $17 billion agricultural industry. In the southern, highly productive region of the valley (known as the San Joaquin Valley), aquifers are particularly stressed due to the high water demands. Further, groundwater is the main source of drinking water for roughly one million people in the San Joaquin Valley. Herein, we focus on threats to groundwater quality induced by naturally occurring arsenic, which may have devastating impacts on both human health and food production.

Arsenic is a ubiquitous, naturally occurring contaminant that is a common problem in many aquifers that are pumped for drinking water[3]; most notably, it is presently having a devasting impact on groundwater quality throughout Asia[4]. When present in significant amounts, it increases the risk of cancer, heart disease, and diabetes[5]. Hazardous levels of arsenic typically result from anaerobic conditions, as noted for the shallow, Holocene aquifers of Asia[4], or from high pH (pH > 8.5) often observed in high arsenic regions of the Andes[6]. In addition, overpumping an aquifer system has been noted to increase the arsenic levels in Southeast Asia by drawing arsenic from less permeable anaerobic clay strata into the aquifer[7].

Arsenic within pumped groundwater of the San Joaquin Valley has been noted for decades. Approximately 10% of the wells tested within the last 10 years have shown arsenic (As) concentrations above 10 µg/L (p.p.b.), the level recommended as the maximum acceptable by the World Health Organization (WHO). As groundwater is increasingly being pumped to meet agricultural and domestic needs, preserving groundwater resources (i.e., maintaining water quality) is imperative. Here we seek to determine the source of arsenic contamination within groundwater of the Central Valley, CA, and to develop quantitative means for predicting degradation of groundwater quality. We focus our study on the Tulare basin (Fig. 1), a highly productive agricultural region of the San Joaquin Valley where groundwater is essential for meeting water demands.

Groundwater pumping in the San Joaquin Valley has caused declines of ~ 60 m in groundwater levels over the past century, leading to subsidence as high as ~ 9 m from 1925 to 1970, a rate of 20 cm/year[8]. Rates of subsidence as high as 25 cm/year have been observed in more recent droughts spanning from 2007 to 2010 and from 2012 to 2016[9, 10]. Subsidence due to groundwater pumping is caused by a pore pressure drop in aquifer materials, which increases the effecive stress, σ_e, defined as $\sigma_e = \sigma_T - P_p$, where σ_T is the total stress and P_p is the pore pressure[11]. Increasing the effective stress results in aquifer compaction. The majority of compaction and linked subsidence of the overlying ground surface is caused by drainage of clays due to their weaker geomechanical properties, as indicated by their higher skeletal specific storage. Thus, the high subsidence levels provide a measure of overpumping in aquifers having substantial clay content, such as the aquifers of the San Joaquin Valley. In this region, the upper 500 m, which is the greatest depth typically drilled for groundwater pumping, consists of alternating layers of sand, gravel, and clay. In general, the aquifer system is divided into an upper aquifer, a thick clay confining unit known as the Corcoran clay, and a lower aquifer. The upper and lower aquifers contain sands and gravels, as well as numerous thin clay layers[12]. As a measure of overpumping, we use subsidence, derived from Interferometric Synthetic Aperture Radar (InSAR) data, to predict arsenic levels quantitatively.

We find that subsidence data have a strong correlation with concurrent arsenic concentrations. This demonstrates a quantitative link between overpumping of groundwater systems and arsenic contamination, a mechanism that has been proposed previously[7] but never statistically demonstrated.

Results and Discussion

Modeling arsenic concentration. We integrated estimates of subsidence with additional variables known from previous studies[13] to affect arsenic levels into a random forest model that accounts for nonlinear relationships, as well as interdependencies of different variables. Two models were developed, one that predicts recent (2007 to 2015) arsenic concentrations and a second that predicts historic (1986 to 1993) arsenic concentrations. These dates were chosen because they both span long droughts in the San Joaquin Valley, during which time appreciable groundwater decline and subsidence occurred (Supplementary Fig. 5). We did not include the mild drought conditions from 1999 to 2005, because we had limited subsidence data over that period, and because we considered more intense droughts to produce a stronger signal for our analysis. We used the output of the random forest models to assess the effect of overpumping as indicated by subsidence on arsenic levels. We found that in both models, concurrent subsidence markedly increases the risk of arsenic contamination. As both models establish similar relationships (capturing the time periods of recent and past periods of drought), we focus our discussion on the recent arsenic concentration model, pointing out where key differences exist. The full results of both models are shown in the Supplementary Information (Supplementary Figs. 1–4)

Mechanism for arsenic contamination from overpumping. The relationship between subsidence and arsenic concentration is linked to clay strata (Fig. 1). It has been noted that clay particles become enriched in arsenic due to their reactivity and high surface area to volume ratio relative to sand sized particles[4]. Arsenic has been transported to the San Joaquin Valley from the Sierra Nevada and coastal mountain ranges by rivers, which cut through arsenic bearing formations, for millions of years[14]. Clays at or near the surface at the time of deposition are the primary host of transported arsenic, which has been shown to adsorb on clay surfaces in significant amounts in the San Joaquin Valley[15], in a process similar to what occurs in other sedimentary basins, including those throughout Asia[4]. As the clays are buried over geologic time, their restricted oxygen supply results in reduction of the arsenic at depths > 60 m[14], resulting in dissolution of the arsenic within the clay pore water[7]. This mechanism for arsenic concentration in clays is supported by other studies in the area[13], who have found a positive relationship between aquifer clay content and arsenic concentration in the San Joaquin Valley.

When unperturbed, groundwater within the aquifer primarily flows horizontally through the sediments with highest permeability, typically sands and gravels. Thus, pumped groundwater comes mostly from sands and gravels, which have lower arsenic concentrations. When the aquifer system is stressed from overpumping, high vertical hydraulic gradients cause a larger volume of water to be drawn from less permeable clays, inducing the release of water with high arsenic concentrations. As a consequence, overpumping increases arsenic concentrations, as noted for the lower Mekong Delta, Vietnam[7]. Concomitant with decreased pore pressures is compaction of the aquifer and resulting land subsidence. Thus, the dual consequence of overpumping is land subsidence and increased extraction of pore water from clay layers, giving rise to a link between land subsidence and groundwater arsenic concentrations.

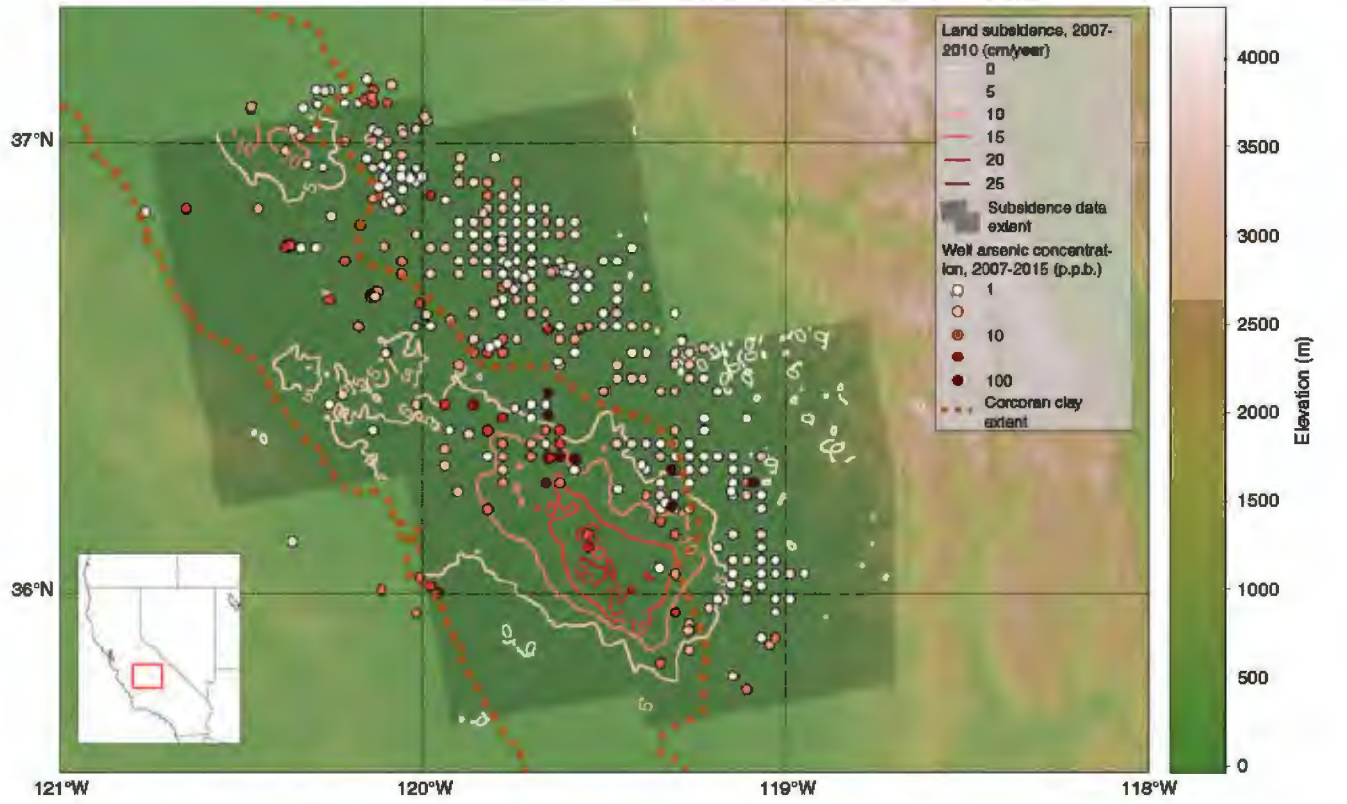


Fig. 1 Comparison of subsidence, arsenic concentration, and clay extent within the San Joaquin Valley, CA. Arsenic concentrations increase toward the center of the valley where subsidence is more extensive and a confining clay layer (known as the Corcoran clay) is present[12]. The grayed-out region is the area where recent subsidence data (obtained from InSAR) were processed. Arsenic concentrations vary by orders of magnitude and are thus shown with a logarithmic color bar (see Supplementary Fig. 8 for arsenic concentration histograms). The arsenic concentration data points were sourced from[17]. The basemap was created using elevation data from the Shuttle Radar Topography Mission[18]

Quantifying the impact of overpumping on groundwater arsenic concentrations. We highlighted four of the most important variables describing arsenic concentration within the Tulare Basin in the recent model, shown in Fig. 2a d. Of these, the thickness of the Corcoran Clay (a confining unit that overlies a lower aquifer) shows a positive correlation with arsenic con centrations due to increased clay content. Elevation has a negative correlation, as lower areas are more likely to have been water saturated and thus anaerobic. A positive correlation was found between $\log_{10}$(Mn) and arsenic concentrations, as the presence of manganese indicates an anoxic environment, in which arsenic tends to be more soluble. Significantly, recent subsidence from InSAR showed a positive correlation, as overpumping leads to increased pore water drainage from clays. The first three variables are well known from the literature and not related to human activity. The quantitative link between pumping induced sub sidence and arsenic concentrations has not been shown before, and is directly related to human activity.

By comparing the historic and recent arsenic concentration models, we see the transient nature of the relationship between pumping induced subsidence and arsenic concentrations (Fig. 2e). Although historic subsidence has a high impact on historic arsenic concentrations, it has virtually no impact on recent arsenic concentrations. A lack of correlation between present arsenic concentrations and historic subsidence (related to over pumping) suggests that arsenic levels due to overpumping slowly return to their original levels after the groundwater pumping is decreased, implying that arsenic is flushed from the auqifer. Thus, our findings indicated that avoiding overpumping of aquifers, easily seen in InSAR data, should improve water quality, at least for the San Joaquin Valley.

The historic arsenic concentration model shows a weaker, but still positive, correlation between Corcoran clay thickness and arsenic concentration, as well as manganese concentration and arsenic concentration. Due to the dynamic nature of groundwater chemistry, the relative importance of different mechanisms for arsenic contamination change over time, highlighting the need for regular calibration with up to date datasets.

To further quantify the impact of overpumping on arsenic concentrations, we simulated three different hypothetical scenar ios with our predictive random forest model: oxic, suboxic, and anoxic subsurface conditions. We used a variation of the partial dependence plot that averages all variables except subsidence, which is varied from 0 to 10 cm/year, and $\log_{10}$(Mn), which is set at 0, 1, and 2 for oxic, suboxic, and anoxic scenarios, respectively, to estimate the probability that the predicted arsenic levels exceeded the WHO's standard of 10 μg/L arsenic (Fig. 3). At ca. 8 cm/year subsidence, the probability that arsenic exceeds the WHO standard dramatically accelerates. This inflection point is also present at roughly the same location in the historic arsenic model (Fig. 2e). As inelastic deformation of clay beds begins, the rate of subsidence increases significantly[10]. As inelastic deforma tion occurs when pore pressure drops below the lowest level previously experienced, it releases pore water that has not been mixed with the main aquifer previously, which in the present case results in arsenic rich pore water being captured within the pumped groundwater.

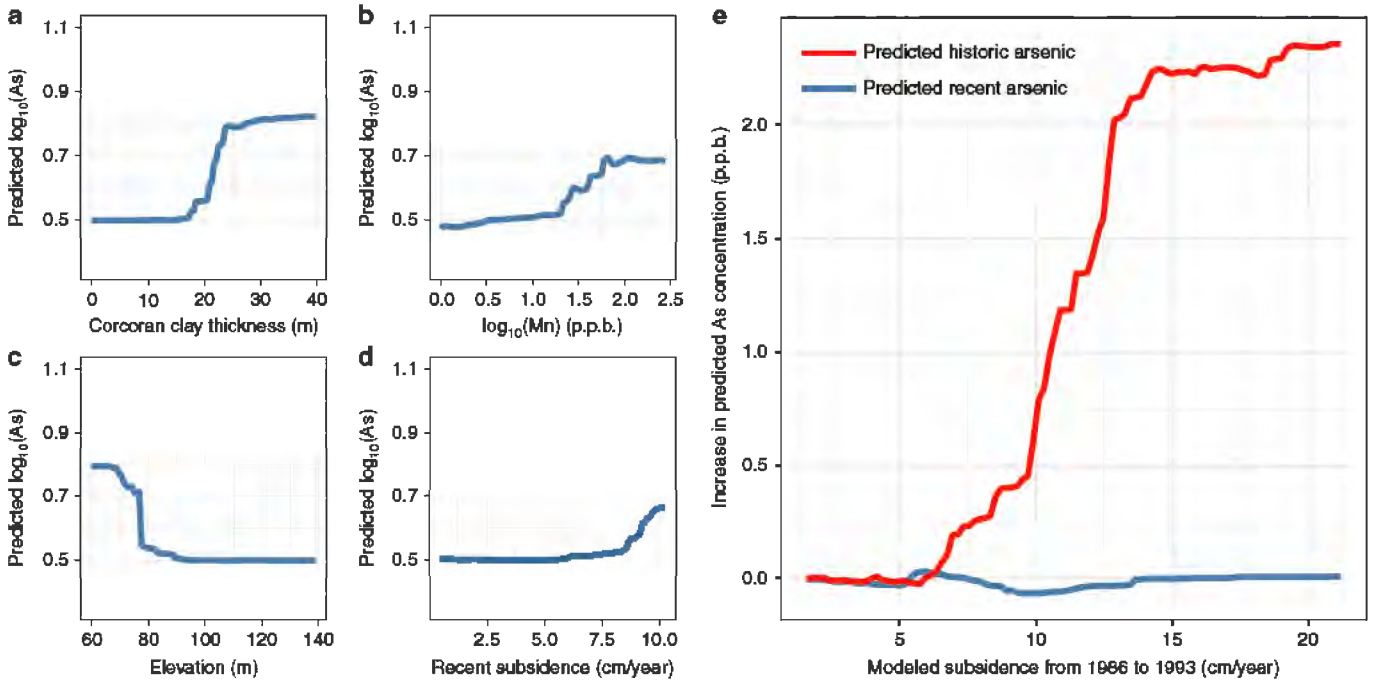


Fig. 2 Partial dependence plots of primary descriptors of groundwater arsenic concentrations. These include **a** confining clay thickness, **b** dissolved Mn concentrations, **c** elevation, and **d** recent subsidence. **e** Comparison of partial dependence plots of historic and recent subsidence. Note that historic subsidence has a great effect on historic arsenic levels but little effect on recent arsenic levels (**e**), whereas recent subsidence has a great effect on recent arsenic levels (**d**). All blue lines are derived from models predicting recent (2007–2015) arsenic concentrations, whereas the red line is derived from models predicting historic (1986–1993) arsenic concentrations

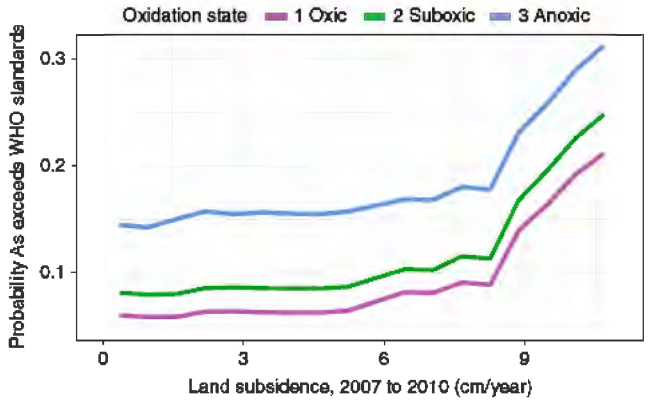


Fig. 3 Probability that arsenic levels exceeded the WHO standard. This was calculated based on recent subsidence for each arsenic risk category

Land subsidence due to overpumping increases the probability that groundwater is contaminated beyond the WHO drinking water standard by a factor of 2 to 3 for the San Joaquin Valley. Importantly, decreasing pumping below the threshold of inestastic aquifer compression will decrease arsenic concentra tions and the aquifers can recover to normal levels if over pumping is halted. Thus, subsidence maps produced by InSAR provide a means of measuring the increased risk of arsenic contamination due to overpumping of aquifers, a critically important factor as groundwater is the main source of drinking water for roughly one million people in our study area alone[16]. Moreover, with a global trend toward increase use of ground water, effectively managing water quality with quantity is essential to preserve the use of this critical resource.

Methods

Data acquisition and processing. There are many factors that control natural variation in arsenic concentration. We developed a statistical model using numerous datasets to asses the role each plays as a predictor of arsenic concentrations. We obtained arsenic level data, as well as proxy information on redox potential from manganese and sulfate concentrations, from 838 wells over the 2007 to 2015 time frame, and 424 wells over the 1986 to 1993 time frame, from the GAMA database[17], which monitors groundwater quality in California (http://geotracker.waterboards.ca.gov/gama/datadownload). We used a previously developed groundwater model[2] which provided us with several useful predictors of arsenic concentrations: percent of total water use from groundwater, which is directly related to pumping; total aquifer clay content, which sets an upper limit on available arsenic from clays; top and bottom of perforated well interval, both of which indicate the depth from which pumping occurred, a soft indicator of the oxidation state; subsidence from 1962 to 1976 and subsidence from 1986 to 1993, which provide historic measures of pumping-induced clay drainage. Elevation was also used as a predictor, obtained from the Shuttle Radar Topography Mission[18]; this is an indicator of closed-basin conditions, where contaminants such as arsenic tend to be concentrated. Slope was also derived from this dataset. As slope closely tracks predevelopment head[19], we used this with the clay content to estimate historic groundwater flow, which was also included as a predictor; our assumption being that enhanced groundwater flow would flush the system over time and reduce arsenic concentrations. We used average temperature data from PRISM; temperature variations have been related to changes in arsenic in previous work[13]. We also used evapotranspiration (ET) estimates (both from 2002 to 2007 and from 2007 to 2015)[20]; this can be used as a proxy of groundwater pumping that is independent of our InSAR measurements.

We chose not to include pesticide application as a predictor of groundwater arsenic contamination. Arsenic-bearing pesticides are largely restricted to lead arsenicals that were used predominantly on cotton and specific tree fruits (largely apples) but have been banned since the 1970's within the United States. Within the aerated surface soils, arsenic exists as arsenate[15], and would have limited mobility[4]. Thus, downward migration of surface applied arsenic is unlikely to contribute to groundwater contamination. Further, our analysis shows a correlation of groundwater arsenic with recent (last 10 years) subsidence and no correlation with older periods of subsidence. Our time series therefore further removes the possibility of arsenic pesticides impacting groundwater.

The arsenic levels, manganese levels and sulfate levels were obtained from GAMA. These levels were assumed to have a lowest detectable value of 2 p.p.b. from histogram analysis, so all values less than this were set to 2 p.p.b. As measurements of arsenic, sulfate, and manganese vary greatly with high outliers,

Table 1 Summary of scenes used for InSAR processing

Frame (region)	Path	No. of scenes	No. of interferograms
Tulare	218	15	82
Fresno	218	17	71
Mendota	219	19	82
Porterville	217	17	84

the logarithm of each was used in the statistical model to dampen the effect of outliers.

The historic groundwater flow was calculated using hydraulic conductivity (K) estimates across the Central Valley from the aforementioned groundwater model[2]. We assumed that the historic groundwater gradient ($\frac{\partial h}{\partial l}$) was equal to the land surface gradient[18]. We then used Darcy's equation to estimate flow:

$$q = K\left(\frac{\partial h}{\partial l}\right) \quad (1)$$

where q is the flux per unit area.

The distance to the nearest river was computed by determining the distance from each well to all major rivers in the study area, and taking the minimum distance as the distance to the nearest river.

InSAR processing. InSAR provides high-quality estimates of subsidence over large regions. InSAR measures subsidence over time with centimeter- to millimeter-scale accuracy over large regions with high (10 s to 100 s of meters) spatial resolution.

We acquired 68 SAR scenes from the ALOS PALSAR sensor, covering the time period from 2007 to 2010, over four frames (see Table 1) for InSAR processing from the Alaska Satellite Facility (https://www.asf.alaska.edu/). We then processed 319 interferograms using these scenes. We used 30 looks in azimuth and 10 looks in range to reduce noise in the pixels, resulting in a pixel size of roughly ~ 250 m by 250 m. We unwrapped the interferograms using the snaphu code[21]. Next, we used the small baseline subset method[22] to estimate the long-term deformation signal. This produced maps of the mean subsidence velocity for each of the four frames, which we merged to create one map of mean subsidence velocity. Overlapping areas were averaged. We then applied a moving average filter to further smooth the results, with a window size of 15 by 15 pixels. As the long-term signal dominated the total signal, seasonal fluctuations are muted over a multi-year time period. Thus, because of the temporal resolution of our arsenic measurements, we only considered the long-term signal. The resulting subsidence map is shown in Fig. 1 of the paper.

Random forest model. Groundwater overpumping, as indicated by subsidence, is one of many complex mechanisms that influence groundwater arsenic contamiantion. In order to account for additional mechanisms, as well as the interplay between various mechanisms, we employed the random forest model[23]. Random forest models can account for nonlinear relationships between multiple variables and handle outliers well . The random forest model creates ntree number of decision trees. Each decision tree makes an independent prediction of the variable of interest, in our case arsenic concentration. The best estimate is the average of the estimates from all decision trees.

Each decision tree is built using a subset of the total data. The subset is selected using random sampling without replacement, or bagging. At each split (node), the variables to be considered for that node are also randomly sampled from the list of total variables. The values of the split are chosen to maximize the variance reduction, defined as the difference between the variance before the split and the sum of the variance of the points for which the split is true, and the variance of the points for which the split is false[24].

The number of variables to be considered at each node is described by the variable *mtry*. The variables ntree and mtry are known as tuning parameters. The overall fit of the model is dependent on these tuning parameters.

In practice, increasing ntree both improves the accuracy of the results and increases the computational cost of the algorithm. Typically, increasing ntree does not significantly improve the results after roughly 100. To be conservative we chose a value of 500 for ntree. We determined the optimal value for mtry using a validation dataset. We randomly selected 75% of the dataset to calibrate the random forest model, and used the remaining 25% of the dataset as the validation to test the accuracy of the model. We chose the value for mtry that minimized the mean squared error (MSE) in the validation dataset.

We created two random forest models, one that predicted arsenic concentrations from 2007 to 2015 (recent) and one that predicted arsenic concentrations from 1986 to 1993 (historic). The response variable was $\log_{10}$(As). The variables used in calibrating both models were identical except that the recent subsidence from InSAR was not included in the historic arsenic concentrations model. In addition, the concentrations of arsenic, manganese and sulfate used to calibrate the models were taken from each respective time window (Supplementary Table 1). The resulting values for mtry were both 5, with an MSE of 0.05 and 0.10, for the recent and historic random forest models, respectively. We used these calibrated, tuned random forest models to predict arsenic concentrations and establish relationships between the variables used in the model and arsenic concentrations.

Random forests are one of many machine learning regression algorithms. In this study, we also developed models using neural networks, support vector machines, and boosted gradient trees. Our analysis showed that random forests provided the best fit to the observed data. However, similar relationships between subsidence and arsenic were observed with these additional machine learning methods.

Variable importance. With random forests, the impact of each variable in the outcome can be assessed in multiple ways. One way is to randomly shuffle (permute) each variable, and observe the increase in MSE between predicted and observed arsenic concentrations. The higher the MSE, the more important that variable is to the outcome. Another way to assess variable importance is to use partial dependence plots.

Partial dependence plots. Partial dependence plots are a common way to visualize random forest models[25]. The goal of a partial dependence plot is to show how varying one variable impacts the outcome of the prediction, while accounting for all possible values from the other variables. The partial dependence plot is calculated as shown below:

$$\tilde{f}(x) = \frac{1}{n}\sum_{i}^{n} f(x, x_{ic}) \quad (2)$$

where $\tilde{f}(x)$ is the partial dependence, n is the number of rows of the dataset, x is the predictor variable of interest, x_{ic} are the values of all other variables, and f is a function representing the random forest model The output can either be the best estimate of $\log_{10}$(As), or the probability that arsenic concentration exceeded 10 p.p.b. For the latter, we used all trees from the random forest model. Our random forest model produced 'best guess' estimates of arsenic levels, which are the mean of the estimates from all trees. It also produced an estimate for each of the 500 trees, for each observation. This provided us with a distribution which we used to determine the probability that the predicted arsenic levels exceeded the WHO standard.

Random forest models are limited in their predictions to observed data. For this reason, in the partial dependence plots of the main article (Figs. 2 and 3), we restricted the independent variable at the 5th and 95th percentile of each predictor variable. With those limits, 90% of the available data are displayed in the partial dependence plots. This reduces the likelihood of presenting results which are unconstrained by data. In the Supplementary Information section, we presented all of the data, but displayed dashed lines indicating the 5th and 95th percentiles (Supplementary Figs. 1-4).

Data availability. The geological, elevation, precipitation, temperature, ET, and water quality data have been cited throughout the paper, are listed in Supplementary Table 1, and are publicly available. The SAR data used for processing interferograms are available from the Alaska Satellite Facility following registration. The datasets developed by the authors, i.e., the processed deformation maps, estimated historic groundwater flow, and distance from each point to the nearest river, as well as the code used to produce the results, are available upon request from the corresponding author.

Received: 27 September 2017 Accepted: 26 April 2018
Published online: 05 June 2018

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Acknowledgements

R.S.'s contribution was supported by a National Science Foundation Fellowship (Award Number DGE-114747). S.F.'s contribution was supported, in part, by the US Department of Energy, Office of Biological and Environmental Research, Subsurface Biogeochemistry Program (Award Number DE-SC0016544) and the SLAC SFA Project, FWP 10094). We thank Joseph Ayotte and Kenneth Belitz for providing feedback on arsenic concentration databases in California.

Author contributions

R.S., R.K., and S.F. conceived of the study. R.S. acquired, processed, and analyzed the data. R.S. developed and interpreted the models with input from S.F. and R.K. R.S., R.K., and S.F. wrote the manuscript.

Additional information

Supplementary Information accompanies this paper at https://doi.org/10.1038/s41467-018-04475-3.

Competing interests: The authors declare no competing interests.

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EXHIBIT I

Protecting Groundwater Quality in California

MANAGEMENT CONSIDERATIONS FOR AVOIDING NATURALLY OCCURRING AND EMERGING CONTAMINANTS

Environmental Defense Fund
Sarah Fakhreddine
Christina Babbitt

Stanford School of Earth, Energy, and Environmental Sciences
Allison Sherris
Alandra Lopez
Arden Wells
Randall Holmes
Scott Fendorf

Green Science Policy Institute
Tom Bruton

Earth and Environmental Sciences Area, Lawrence Berkeley National Laboratory
Peter Nico

EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work | Stanford SCHOOL OF EARTH, ENERGY & ENVIRONMENTAL SCIENCES | EARTH & ENVIRONMENTAL SCIENCES

Environmental Defense Fund is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food, and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic, and social support because they are nonpartisan, cost-effective, and fair.

The Stanford School of Earth, Energy & Environmental Sciences works to gain a better understanding of our planet's history and its future, the energy and resource base that supports society, geologic hazards that impact a growing population, a changing climate, and the challenge of sustainability.

The Green Policy Institute is made up primarily of Ph.D. scientists who specialize in the publication and communication of peer-reviewed research. We collaborate with leading scientists on policy-relevant research projects and translate scientific information to educate key decision makers, the press, and the public.

The Earth and Environmental Sciences Area of Berkeley Lab is committed to a future where society can make informed decisions about the sustainable use of our planets' energy, water, and environmental resources based on advanced scientific knowledge of the integrated Earth System.

Support for this report was provided by the Wyncote Foundation and the Water Foundation.

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The complete report is available online at edf.org/groundwater-contaminants-report.

1. Introduction

Protecting groundwater quality is an essential component of sustainable water management. However, active groundwater management often focuses on maintaining groundwater quantity – a target that does not always ensure groundwater quality goals are met. In fact, there are many ways in which both supply- and demand-side management actions can inadvertently impact groundwater quality. These impacts range from improving groundwater quality to unintentionally creating new groundwater quality problems. For example, the implementation of a managed aquifer recharge (MAR) project aimed to increase groundwater supplies can mobilize soil contaminants (e.g., nitrate) into the underlying groundwater. Similarly, water trading programs can alter the timing, magnitude, and spatial distribution of pumping, potentially resulting in changes to irrigation return flows and contaminant loading. Potential water quality impacts of management actions are particularly important to consider in the context of the Sustainable Groundwater Management Act (SGMA) (see Box 1). However, if management actions are planned in a holistic way that incorporates both water quantity and quality considerations, unintended contamination can be avoided, and in some cases, groundwater quality can even be improved.

The purpose of this document is to provide guidance to groundwater managers, consultants, and stakeholders on groundwater quality considerations associated with management actions and methods for preventing unintended groundwater contamination. Specifically, this document focuses on naturally occurring (or geogenic) contaminants (e.g., iron, manganese, arsenic, chromium, uranium, vanadium, and selenium) and other contaminants for which limited guidance currently exists (e.g., 1,2,3-trichloropropane (TCP) and per- and polyfluoroalkyl substances (PFASs)). We focus on these specific contaminants due to their prevalence in California, their impacts to human and ecosystem health, and the lack of existing guidance for addressing these types of contaminants. This document does not address groundwater contamination by nitrate and salts; nitrate and salts are only discussed in the context of their interactions with geogenic and emerging contaminants. While nitrate and salts threaten groundwater quality in many regions throughout California, there are already a number of helpful resources and regulatory programs available that are specifically aimed at addressing these contaminants.[1,2,3,4]

Water Quality and the Sustainable Groundwater Management Act

The 2014 Sustainable Groundwater Management Act (SGMA) requires local agencies to achieve sustainable groundwater conditions within 20 years. SGMA defines sustainability as the avoidance of six "undesirable results" including: (1) declining groundwater levels, (2) reduction of groundwater storage, (3) seawater intrusion, (4) degraded water quality, (5) land subsidence, and (6) depletions of interconnected surface water.

Degraded water quality is unique from other undesirable results in that it can be caused or exacerbated by water management actions aimed to help achieve sustainability goals. For example, a managed aquifer recharge project can improve groundwater levels and groundwater storage, mitigate seawater intrusion and land subsidence, and provide benefits to interconnected surface waters (avoiding all other undesirable results). However, the same managed aquifer recharge project can also adversely impact groundwater quality by transporting or releasing contaminants into groundwater.

Briefly, geogenic contaminants are naturally abundant in Earth's soils and sediments and can be released to groundwater under certain geochemical and hydrological conditions. Emerging contaminants are contaminants that have not previously been identified as water quality concerns and pose a risk to human and ecosystem health. They are typically unregulated, but often expected to become regulated as research and awareness of their health impacts grows.

In this paper, we first present a set of key considerations for protecting water quality to set the context for why it is important to consider groundwater quality outcomes at the onset of initiating any new management action. We then describe geogenic and emerging contaminants and their importance to water management (Section 2), and then outline the main processes controlling groundwater quality as it relates to these contaminants (Section 3). Section 4 highlights management considerations and guidance for protecting groundwater quality during the planning and implementation of new management actions. Finally, Section 5 provides expanded summaries of key contaminants and the processes controlling their fate and transport.

Summary of key groundwater quality considerations

A summary of the key groundwater quality considerations discussed in Section 4 are briefly described here. If management actions are planned in a holistic way that incorporates both water quantity and quality considerations, unintended contamination can be avoided, and in some cases, groundwater quality can even be improved. Some key considerations include:

1. Careful site selection for both groundwater quantity and quality

Management actions can cause improvements or unintended impairments to water quality depending on the type of action and site conditions that existed prior to the action. For instance, if a management action is planned in an area with pristine drinking water wells and no current groundwater quality problems, a shift in geochemical and hydrological conditions can cause the release of geogenic contaminants and/or the introduction and/or migration of other contaminants. However, if a project is being considered in an aquifer with previous contamination, it is possible that the proposed management action can provide groundwater quality improvements. Careful consideration should be given to both the site suitability for the management action and its proximity to drinking water supplies.

2. Characterization of current and anticipated geochemical and hydrological conditions

Understanding the current geochemical and hydrological conditions of a site is critical for both (1) identifying any existing water quality issues and (2) defining the existing conditions in order to avoid perturbations. If possible, avoiding any significant shifts in geochemical and hydrological conditions can help minimize the likelihood of causing or exacerbating contamination.

3. Development of a monitoring program

Anticipating potential changes in geochemical and hydrological conditions can help to inform a water quality monitoring program. For example, certain contaminants are more likely to appear in groundwater when dissolved oxygen is introduced into an aquifer without previous exposure to oxygen. Based on the anticipated geochemical and hydrological shifts and site characterization, a list of the most likely contaminants can be determined. Monitoring programs should focus on these contaminants and on capturing critical geochemical and hydrological perturbations. Additionally, where possible, monitoring programs should be designed to allow sufficient response time between identification of water quality problems and arrival of contaminated water to users so that the problem can be addressed prior to reaching users.

4. Implementation of managed aquifer recharge projects

Managed aquifer recharge projects are the most likely management action to cause significant shifts in geochemical and/or hydrological conditions. Accordingly, such projects deserve special attention when evaluating potential water quality impacts. Recharging water, even clean water, into a previously uncontaminated aquifer can potentially alter the existing geochemistry and hydrology and subsequently cause the release of geogenic contaminants from soils and sediments. Specific considerations should be made for MAR projects including characterizing baseline aquifer geochemistry, the source recharge water chemistry and historical land use of the area selected for recharge. These considerations vary slightly depending on the type of MAR. A thorough understanding of the site-specific geochemical and hydrological conditions can inform the design of MAR projects that not only avoid new water quality problems, but also potentially offer water quality improvements.

5. Development of contingency plans

While precautions should be taken to avoid groundwater quality problems, a plan should be in place to address potential groundwater contamination events. This is particularly relevant if groundwater supplies are used for drinking water.

2. Geogenic and emerging contaminants

What are geogenic contaminants?

Geogenic contaminants are elements that naturally occur in Earth's soils and sediments. Some common geogenic contaminants include: iron, manganese, arsenic, chromium, uranium, vanadium, and selenium. These contaminants occur naturally in groundwater. Shifts in geochemical and hydrological conditions within an aquifer can cause new mobilization of these contaminants from primary minerals or release from soils and sediments into groundwater, where they pose a much larger risk to human and ecosystem health. Additionally, if groundwater is used for irrigation, these contaminants can threaten agricultural productivity.

Iron and manganese are only toxic at very high concentrations compared to the other geogenic contaminants discussed in this document; they are more commonly associated with taste and odor issues in water. However, iron and manganese are highly reactive in groundwater and can control the occurrence of other contaminants in an aquifer through their interactions with other contaminants. Arsenic, some forms of chromium, and uranium are toxic at very low (or trace) concentrations (on the order of micrograms per liter (µg/L)) and have both anthropogenic (man-made) and naturally occurring sources.

Naturally occurring contaminants have been increasingly associated with groundwater quality issues throughout California, particularly in the Central Valley. Vanadium is also increasingly being recognized as a groundwater contaminant, and health effects of vanadium exposure are actively being researched. While vanadium is currently not subject to enforceable regulation, it does have state drinking water Notification and Response Levels[5], and it is anticipated to be considered for more formal regulation in the future.

Selenium toxicity is a greater threat to fish and waterfowl than human health, and notable issues of geogenic selenium exposure in waterfowl have occurred in the San Joaquin Valley as a result of irrigated agriculture drainage to wetlands.

Since the source of these contaminants is natural soils and sediments, which exist in spatially extensive layers and formations, contamination can occur over large areas. This potentially large scale and diffuse source poses a significant and costly challenge for remediation once a contaminant has been released, emphasizing the importance of preventing their mobilization to groundwater.

Protection of groundwater quality requires managing aquifers so that geochemical and hydrological conditions are unlikely to cause contaminants to be released from soils and sediments into groundwater. These conditions are specific to each contaminant, can sometimes be contradictory (i.e., what is good for one is bad for another), and are further complicated by the complex interactions between contaminants and other water quality parameters.

Importantly, geogenic contaminants of concern occur in most groundwater at very low concentrations due to the ubiquity of many of these natural elements in the earth's crust – the materials and sediments derived from those rocks through which groundwater flows. Some of these elements are essential nutrients (e.g., some forms of chromium, selenium, iron, and manganese) and are important to human health. However, at contaminant-specific, higher concentration thresholds these geogenic elements become contaminants in drinking water or other beneficial uses of water and begin to pose a risk to human and ecosystem health.

What are emerging contaminants?

Emerging contaminants are contaminants that have not previously been identified or have only recently been identified as a water quality concern. Emerging contaminants often do not have established regulatory standards. Emerging contaminants may pose a risk to human and ecosystem health, though these risks may not be well understood.

Notably, vanadium is an emerging contaminant as it has no current regulation. Since it is also a geogenic contaminant, we include it in the discussion of other geogenic contaminants that behave similarly in the environment. We also discuss considerations related to 1,2,3-trichloropropane (TCP) and per- and polyfluoroalkyl substances (PFASs) which are both anthropogenic contaminants. PFASs have anthropogenic (man-made) sources and are currently unregulated. Similarly, TCP remained unregulated until 2017. We consider TCP an emerging contaminant despite its recent regulation because there remains a need for research and guidance to address TCP contamination in groundwater.

Anthropogenic contaminants can be *point source contaminants*, meaning they have specific, identifiable sources, or *nonpoint contaminants*, which originate from diffuse sources (e.g., runoff from large agricultural areas containing elevated concentrations of pesticides). TCP has both agricultural and industrial sources and can fall under either category. TCP is highly persistent in groundwater and is toxic at extremely low concentrations (on the order of nanograms per liter (ng/L)). It is important to prevent inadvertently placing new wells in areas with TCP contamination. Additionally, a disturbance to a groundwater aquifer can transport TCP into previously uncontaminated wells within the aquifer.

3. Factors controlling groundwater quality

Groundwater quality is controlled by the geology of an area, historic land use, and the resulting geochemical and hydrological conditions within the aquifer. While the geology and historic land use cannot be changed, management can significantly impact geochemical and hydrological conditions. Knowing the historic land use of a given region can help determine possible anthropogenic sources of contaminants. For example, the use of certain soil fumigants introduced TCP into groundwater at specific sites (see Section 5.8). Here, we provide an overview of relevant geological information related to the occurrence of geogenic contaminants. We also describe key geochemical and hydrological processes as they relate to overall groundwater quality.

3.1 Geology

The geology of an area determines which types of earth materials (minerals and organic material that make up soils and sediments) are present in an aquifer. Different sediment types have distinct chemical properties and concentrations of geogenic contaminants. While groundwater quality will ultimately be determined by how these particles respond to the geochemical and hydrological conditions in the aquifer, an understanding of the underlying and regional geology will provide some insight into which geogenic contaminants may be more problematic than others in a given region. During rock weathering, geogenic contaminants are deposited within the soils and sediments that compose groundwater aquifers.

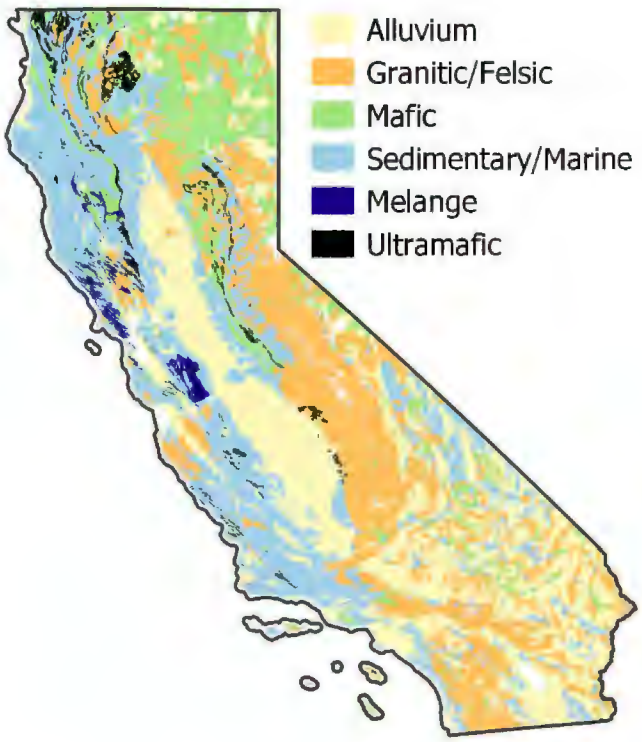


Figure 1: Map of relevant geologic features associated with various geogenic contaminants in California. Shales are included in the Sedimentary/ Marine category. Map is adapted from the California Department of Conservation and California Geological Survey's geologic map of California (Jennings et al., 2010).

Figure 1 highlights key geologic features within California that are relevant to the geogenic contaminants discussed within this document. Following aluminum, iron and manganese are the second and third most abundant metal elements in Earth's crust, respectively. Therefore, they are found in high concentrations in soils and sediments and are ubiquitous within most geologic features especially in *mafic rocks*. Arsenic and uranium are found in higher abundance in granitic materials like those comprising the Sierra Nevada. The Sierra Nevada has weathered over time, leading to the deposition of sediments containing these elements within the Central Valley. Chromium is elevated in mafic and *ultramafic rocks*. Vanadium is also enriched in mafic rocks although generally not in ultramafic rocks. Both vanadium and selenium are also associated with the marine *shales* of the California Coast Range, with selenium particularly concentrated in the Southern Coast Range and in areas affected by hydrothermal fluids (naturally heated water found in the environment).

Continued rock and mineral weathering followed by alluvial (water) transport and deposition leads to the formation of soils and sediments that compose groundwater aquifers. While not all the aquifers in California are alluvial aquifers, they are the most relevant to the water management actions described here and we use them to introduce and describe concepts related to groundwater quality.

Most groundwater aquifers, including those comprised of alluvial sediments, are heterogeneous, meaning they have multiple discontinuous layers of different types of earth materials and sediments (Figure 2). These layers vary in both their chemical and physical properties. In general, shallow portions of an aquifer have higher amounts of dissolved oxygen (DO) in groundwater as they are closer to the surface and have likely been recharged more recently, while deeper portions of an aquifer typically have older groundwater with limited DO concentrations.

The presence of oxygen and other substances affects the types of minerals and associated elements present in the aquifer. Portions of an aquifer with abundant dissolved oxygen (DO) tend to be rich in minerals like iron oxides (or rust particles/surfaces). Iron oxides are a critical mineral affecting the overall chemistry of groundwater and are discussed in Section 5.1. Deeper portions of an aquifer that typically have less abundant oxygen do not support the formation of iron oxides. Both the geochemical and physical heterogeneity of aquifers means that contaminant fate and transport can vary greatly throughout various zones of an aquifer, both vertically and laterally.

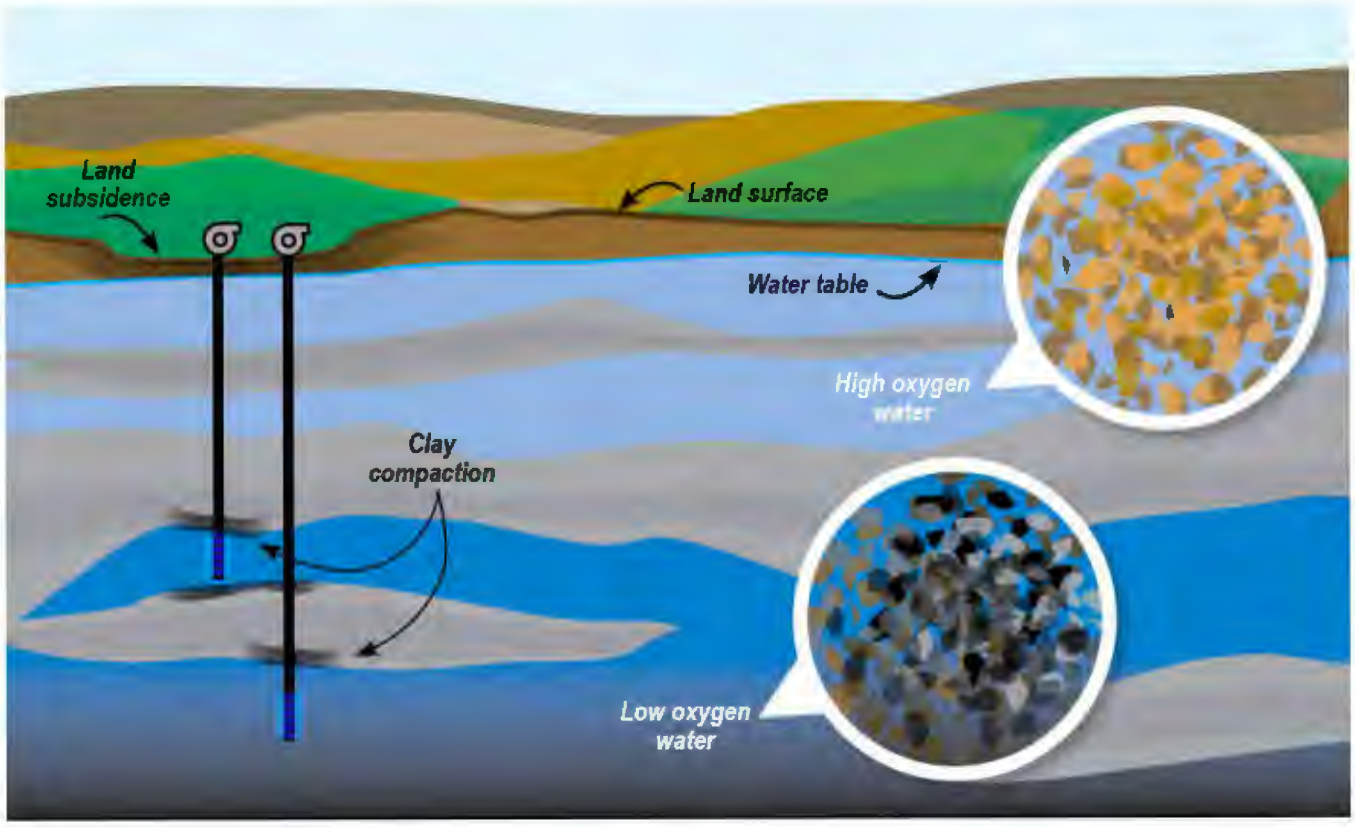


Figure 2: Generalized cross-section showing the physical and chemical heterogeneity of an alluvial groundwater aquifer system with interbedded clay layers. Shallower regions with higher oxygen abundance in groundwater tend to be enriched in minerals including orange-colored iron oxides while deeper regions with low oxygen content in groundwater tend to be enriched in darker-colored sulfide-bearing minerals. Additionally, activities like heavy pumping can compact clay layers affecting the physical (hydraulic) and chemical properties of the aquifer system.

3.2 Geochemistry

The fate and transport of contaminants depends on the geochemical reactions occurring within the aquifer system. The reactions of primary concern are those that occur at the interface between sediment materials and the surrounding groundwater. In general, contaminants are either incorporated into minerals, adsorbed to mineral surfaces, or dissolved in groundwater where they are transported by groundwater flow (Figure 3).

A contaminant that is dissolved in groundwater is considered mobile and is readily transported with the flow of groundwater. When contaminants are adsorbed to aquifer materials, they are no longer dissolved in groundwater. They can be transported when small particles (called colloids) move with the water; however, these particles are relatively easy to filter or settle out of water. In general, adsorption processes make groundwater contaminants relatively immobile unless a geochemical or hydrological trigger causes them to desorb from their host surface. Under some conditions, groundwater contaminants precipitate (form solids) and are removed from groundwater where they become immobile and remain on the aquifer solids.

Different contaminants have different levels of partitioning between the water and mineral surfaces (i.e., varying tendencies to adsorb to solids versus dissolve in groundwater) and are controlled by various chemical reactions. To avoid degrading water quality, management actions should promote geochemical conditions that favor maintaining contaminants on aquifer solids rather than geochemical conditions that release them into groundwater, or those that ensure that any such mobilization is spatially limited such that it does not materially affect extracted groundwater quality. This is a technically challenging task as multiple contaminants co-occur within aquifer solids and have varying, sometimes opposite, geochemical conditions leading to release.

Examples of the types of geochemical conditions that can control contaminant retention and release include **red**uction-**ox**idation (*redox*), *pH* (a measure of acidity), and *solubility* (ability to dissolve in water). Redox and pH refer to the state of the groundwater while solubility refers to properties of different substances found in both an aquifers' materials and groundwater. Below is a brief overview of redox, pH, and solubility as they relate to contaminant release. While the ionic strength and hardness of water can also influence its reactivity, these tend to be less concerning than shifts in redox and pH.

3.2.1 Redox reactions

Redox reactions are reactions that involve the transfer of electrons (particles with negative charge) from one substance to another. The *oxidation state* of a substance is a measure of how many electrons it has gained or lost relative to its elemental state (its pure, uncharged, and unreacted state). *Reduction* is a gain of electrons resulting in a decrease in oxidation state. Conversely, *oxidation* is a loss of electrons resulting in an increase in oxidation state. Substances gain or lose electrons by reacting with other substances. Dissolved oxygen (DO) is involved in many redox reactions and is a strong *oxidant* (it causes the oxidation of another substance, meaning it strips them of electrons).

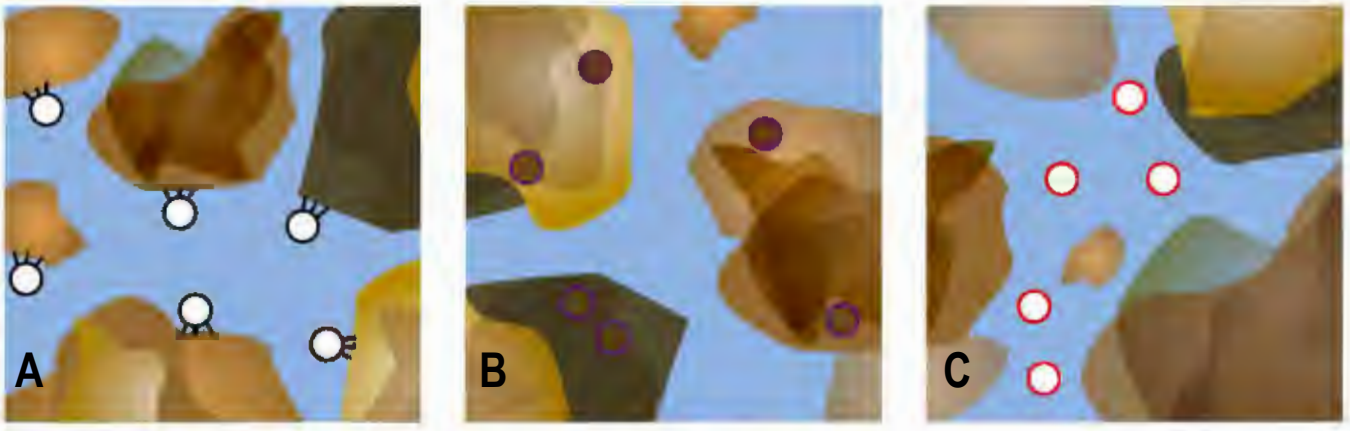


Figure 3: Contaminants in groundwater aquifers can either be (A) adsorbed to aquifer particles, (B) incorporated into aquifer particles, or (C) released to the surrounding groundwater.

Most geogenic contaminants are redox active, meaning that they are commonly found in more than one oxidation state, and each of these states may have different mobility and toxicity. For example, chromium in the environment can be found in both a trivalent (+3) oxidation state and in a hexavalent (+6) oxidation state. Trivalent chromium, Cr(III), is considered a micronutrient in human nutrition and is relatively immobile due to its low solubility and propensity to adsorb on aquifer minerals.

Generally, when oxygen is abundant, substances are more likely to be present in their more oxidized form.

By contrast, hexavalent chromium, Cr(VI), binds poorly to aqu1ifer solids and is thus mobile in groundwater. It is also toxic to humans (at concentrations greater than 0.02 µg/L according to the Public Health Goal (PHG), see Section 5). Changes in redox conditions in an aquifer can cause trivalent chromium, Cr(III), to turn into the toxic, mobile hexavalent chromium, Cr(VI), and vice versa. Therefore, it is critical to understand the redox conditions in an aquifer and how management actions can cause redox conditions to shift. Even a small change in redox condition can have a large impact on contaminant behavior in groundwater.

There are methods for determining the redox conditions within an aquifer. Groundwater monitoring wells can be measured for oxidation reduction potential (ORP), which is a commonly used metric for redox condition. Interpreting ORP as a standalone measurement can be challenging because the measurement depends on a reference measurement that can vary depending on the ORP method used. However, ORP is useful as a relative indicator of changes in redox condition. Sharp changes in ORP can signal that redox conditions within an aquifer are changing, and therefore shifts in groundwater quality could also be occurring.

Dissolved oxygen (DO) is also often used as a proxy for redox conditions within an aquifer. Generally, when oxygen is abundant, substances are more likely to be present in their more oxidized form. When oxygen is absent or very low, contaminants are more likely to be present in their more reduced form. For simplicity, we will use the terms *oxygen-abundant* (DO > 2 mg/L) and *oxygen-limited* (DO < 2 mg/L) to describe the redox conditions of an aquifer.

For example, the impacts of DO on redox condition can be visually observed with iron. In groundwater with no exposure to oxygen, iron is well-dissolved and mobile in groundwater. With exposure to DO, iron oxidizes and forms rusty solid particles (or iron oxide minerals) that separate out of water and/or coat other mineral surfaces (Figure 4). These rust particles range in color from yellow to red, with orange predominating, and can be seen in soils and sediment which have been exposed to oxygen.

Knowing the DO concentration of water is a strong indicator of whether iron will be dissolved in water or present as an iron oxide solid. More generally, knowledge of oxygen concentrations can serve as a useful proxy for redox condition and understanding of which geogenic contaminants may exist in groundwater. Measurement of DO is typically easier and more cost-effective than analyzing trace metal concentrations. Therefore, it can be measured more frequently than other *analytes* (the substances being measured) in a monitoring program. Based on which redox-sensitive analytes are measured, the redox processes occurring can be more thoroughly characterized using existing United States Geological Survey (USGS) resources for characterizing redox chemistry.[6]



Figure 4: Oxygen-limited (anoxic) groundwater rich in dissolved iron seeping into a stream, oxidizing due to exposure to the atmosphere where oxygen is abundant. This causes oxidization of the dissolved iron to occur, converting it into solid iron oxides (rust particles). (Photo credit J. Walton http://windowoutdoors.com/WindowOutdoors/Iron%20in%20Springs%20and%20Seeps.html)

3.2.3 pH

pH is one of the most important groundwater quality parameters and often strongly correlates with the presence of different contaminants. Low pH values are acidic and higher pH values are basic. Typical groundwater pH values fluctuate near neutral (pH of 7). Groundwater pH depends on the composition of the groundwater (i.e., which substances are present) and the chemical reactions occurring within the aquifer. For example, aquifers with high carbonate concentrations tend to have a higher pH and a high buffering capacity (meaning pH does not easily change). pH affects the substances dissolved in groundwater because certain chemical reactions are more likely to occur at higher or lower pH values.

Similarly, a solid mineral surface can be positively or negatively charged depending on the pH, and this in turn affects the ability of contaminants to adsorb to those surfaces and be removed from the groundwater (Figure 5). pH can also make certain minerals in sediment particles or within the rock structure more or less likely to dissolve in groundwater. In general, negatively charged ions (such as arsenic) are more mobile at high pH (> 8.5), while positively charged ions (such as iron and manganese) are mobilized at low pH.

3.2.4 Solubility and groundwater age

Solubility in the context of groundwater geochemistry refers to the maximum concentration at which a substance can be found dissolved within groundwater. Solubility can refer to solids (e.g., minerals), liquids (e.g., solvents, pesticides), and gases (e.g., oxygen, carbon dioxide) and their ability to dissolve in water. Some of these substances are more likely to dissolve (i.e., more soluble) compared to others. For example, table salt (sodium chloride) is highly soluble and dissolves when mixed with water, releasing both sodium and chloride ions into the surrounding water.

The materials that adsorb or contain contaminants have varying degrees of solubility. In the presence of water, highly soluble materials will not retain their solid form in water and will dissolve, releasing contaminants embedded within the sediment particle/rock matrix to groundwater. Insoluble contaminants will stay in the sediment particle/rock matrix and will not contaminate groundwater unless conditions promoting their dissolution evolve. For example, under certain geochemical conditions arsenic will reside in a sulfidic (sulfide-containing) mineral called arsenian pyrite. This mineral has limited solubility but can dissolve under certain low pH and/or oxygen-abundant conditions, causing arsenic to be released into groundwater.

The rate (how quickly) a substance dissolves also determines how likely it is to be found in groundwater. Near natural recharge sources, such as streams, groundwater may contain relatively small amounts of total dissolved solids (TDS) which is a measure of the amount of dissolved *species*. This is because the water is not in equilibrium with the soils and sediments (i.e.,

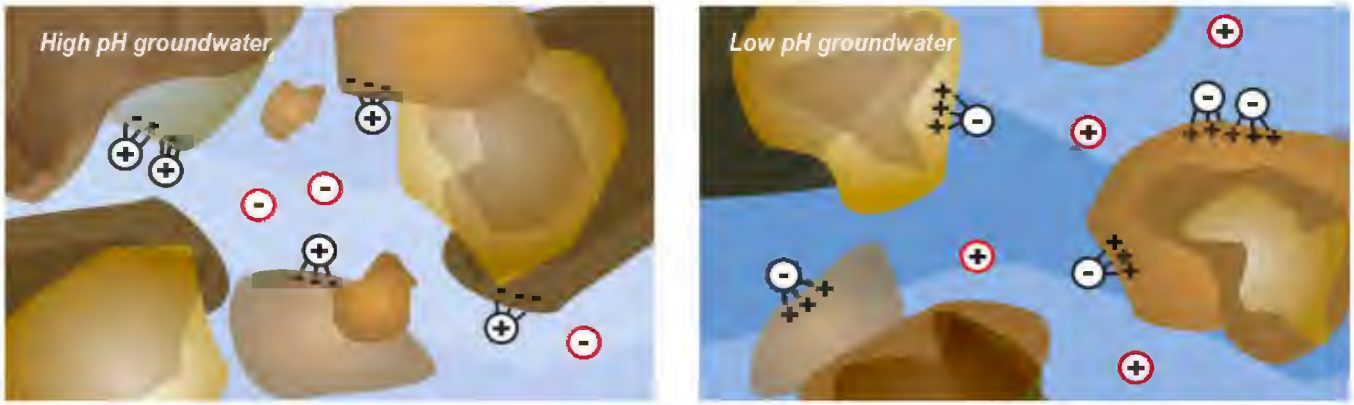


Figure 5: Schematic showing pH effects on charged particles. Mineral surface charge changes with the pH of the surrounding groundwater, causing changes in the type of contaminant likely to occur in groundwater.

the minerals in soils and sediments have not had time to dissolve because freshwater is recharging faster than the minerals are dissolving). The mineral surfaces of the sediment particles gradually dissolve over time.

These rates are an important concept relating groundwater chemistry to groundwater age. Older groundwater is typically more enriched in TDS (including naturally occurring contaminants) compared to younger groundwater. However, younger groundwater will often respond quicker to management actions owing to shorter recharge times. More information relating groundwater age to groundwater vulnerability is available through the USGS.[7]

3.3 Hydrological impacts on geochemistry

The hydrology and geochemistry of a groundwater system are closely intertwined. As water flows in the subsurface, it carries contaminants as well as other dissolved (or aqueous) substances which can react with each other. Additionally, many of the chemical reactions occurring in groundwater occur at different timescales; some are very fast while others are extremely slow. Generally, groundwater moves slowly, allowing enough time for reactions to occur between aquifer solids and groundwater. However, in heavily pumped or managed systems, groundwater movement can be accelerated and the aqueous substances in the groundwater may have less time to react with aquifer solids.

A significant rise or fall in the depth of the water table in response to pumping or recharge will also change the interaction between groundwater and the overlying unsaturated (vadose) zone, potentially affecting contaminant partitioning between the solid and mobile, dissolved phase. Depending on which chemical reactions are possible in a given aquifer, this can either have a positive, negative, or minimal impact on groundwater quality. In summary, the physical movement of groundwater can induce different types of geochemical responses.

4. Protecting groundwater quality

4.1 Managing for both groundwater quantity and quality

To the extent possible, management actions should be planned in a holistic way that incorporates both water quantity and quality considerations. Special caution should be taken if a new management action is planned in an area containing drinking water wells with no current groundwater quality problems. In these locations, there is a risk of causing groundwater contamination by changing the geochemical and hydrological conditions within the aquifer that may lead to the release of geogenic contaminants.

By the same token, if a project is being considered in an aquifer with existing contamination, it is important that the problem not be worsened by management actions. It is possible to design a proposed management action in ways that may provide groundwater quality improvements. For example, if a proposed managed aquifer recharge project does not create adverse shifts in water quality (i.e., no shifts in redox or pH which release contaminants), it has the potential to reduce existing contaminant concentrations.

Understanding the geochemical and hydrological conditions in these cases will be critical to anticipating whether contaminated water can potentially be diluted or will spread contamination to previously uncontaminated areas of the aquifer. Table 1 lists common water management actions and how they might impact groundwater quality. As mentioned previously, these projects can also offer water quality improvements. However, here we focus on the protection of groundwater supplies and prevention of unintentional, new contamination resulting from management actions. Additionally, while we provide general guidance, much of the considerations will depend on site-specific characteristics and local contaminants of concern.

TABLE 1

Common water management actions and potential impacts

Management action	Common examples	Potential water quality impacts
Managed aquifer recharge (MAR)	**Infiltration ponds**	If the infiltrating water is of a different chemistry than the native groundwater, geochemical changes can occur during infiltration (e.g., change in pH, redox chemistry). Infiltration processes gradually introduce recharge water which can allow enough time for the aquifer sediments to buffer changes in water chemistry. Infiltration can alter the shallow groundwater levels and/or cause a fluctuating water table. Resulting changes in the water table and the wetting and dewatering of shallow sediments can induce changes in redox chemistry.
	Injection wells	Potential impacts are similar to those of infiltration ponds (i.e., differences in recharge water chemistry and native groundwater chemistry can cause adverse interactions). However, during direct injection, these changes are likely to be more abrupt compared to infiltration processes as injection wells can also alter the flow regime and can cause faster transport between different zones of the aquifer.
	Agricultural managed aquifer recharge (Ag-MAR)	Ag-MAR involves the use of irrigation water for recharge on agricultural lands during fall, winter, and/or spring. Because the water has continuously been introduced to the aquifer through previous irrigation, it is unlikely to create new, abrupt changes to geochemical conditions. Since volumes of recharge water are similar to past recharge volumes, hydrological conditions would not be expected to deviate strongly from historic conditions. These areas can still mobilize contaminants, but new and significant water quality problems are less likely to occur compared to other types of recharge.
	Flood-managed aquifer recharge (Flood-MAR)	Flood-MAR involves the use of flood water from rainfall or snow melt for recharge on agricultural and working lands (e.g., refuges, floodplains). Here, the recharge water may be of differing chemistry than the native groundwater or previously applied irrigation water which may cause geochemical changes releasing geogenic or other existing contaminants. Additionally, hydrological changes may also occur and contribute to the transport of contaminants and/or changes in the underlying water table. The Department of Water Resources is working to identify research needs, including water quality, for Flood-MAR projects (see Section 4.4).
Changing timing, magnitude, and/or spatial distribution of pumping	**Water trading**	Trading programs can change the volume and use of groundwater supplies in ways that may affect return flows, magnitude and timing of pumping, and contaminant loading. Some examples include (1) increasing pumping in an area with deteriorated water quality and subsequently causing the migration of contaminants or (2) increased water use by a user with higher contaminant loading, resulting in higher contaminant concentration in return flows.
	New pumping	New pumping can increase vertical and lateral movement of water, resulting in transport of contaminants or reactants that may induce contaminant mobilization. Pumping in new regions of an aquifer can also cause fluctuating water tables which can alter geochemical conditions.
	Retiring wells	While inactive wells are no longer causing movement of groundwater via pumping, they can still serve as conduits for groundwater. Shallow groundwater, often of poorer quality, can migrate downward and degrade deeper water supplies (Gailey, 2017).

When planning and selecting locations for a new management action, careful consideration should be given to the proximity of the management action to production wells and the ultimate end use of water produced from those wells. As a first principle, it is best to exercise caution to avoid actions that are likely to cause significant geochemical and/or hydrological changes in the vicinity of clean drinking water supplies.

If a management action in the vicinity of clean drinking water supplies is required, appropriate stakeholder engagement is necessary to ensure that the whole suite of community and stakeholder considerations is acknowledged in shaping the proposed project. To aid in this process, Community Water Center (CWC) has developed guidance focused on protecting drinking water under SGMA.[8,9] Projects in these areas can take the three steps outlined below to help protect groundwater quality.

Step 1. Characterize existing groundwater quality issues where new management actions are planned.

Any existing groundwater quality issues should be identified when first planning management actions in order to avoid exacerbating or spreading existing contamination. Precautions should also be taken to avoid causing new contamination. Any available groundwater quality data should be analyzed to understand which contaminants are currently present and what trends exist for those contaminants, both spatially and temporally (i.e., Do concentrations vary seasonally? Is it a constant problem? Are concentrations increasing over time or is it getting worse?).

A summary of publicly available datasets is included in a report by Stanford University's Program on Water in the West, titled "A Guide to Water Quality Requirements under the Sustainable Groundwater Management Act" (Moran and Belin, 2019). All water quality data collected by water agencies is also publicly available via formal public records request if it is not otherwise accessible via a state or local database.

Additionally, if groundwater age data is available, it can help estimate how quickly groundwater quality will respond to new management actions. Younger groundwater tends to be more responsive to new management actions than older groundwater supplies.

Step 2. Anticipate how aquifer geochemistry and hydrology might change as a result of the planned management action.

Anticipating changes to aquifer geochemistry and hydrology requires a knowledge and understanding of the existing geochemical and hydrological conditions. Of key concern are indicators of redox condition (both DO and ORP), pH, and water composition (concentrations of substances including salts, carbonates, sulfates, phosphate). A change in redox condition is the most likely to trigger the release of geogenic contaminants, followed by a change in pH and then ionic composition (the type and concentration of different ions in the water). If the management action involves introducing a new water source into the aquifer (e.g., MAR with surface water in a region where previous recharge has been primarily from irrigation reliant on groundwater), characterizing the chemistry of this new water source will help determine if any adverse shifts may occur.

The principal means by which a shift in redox can occur is either the influx of water with differing oxygen levels or influx of an organic carbon compound that stimulates biological (e.g., bacterial) activity and the subsequent consumption of oxygen. For example, if a MAR project introduces high concentrations of organic carbon (e.g., recycled wastewater) into an oxygen-abundant aquifer, oxygen may be consumed and reducing conditions may evolve within the now oxygen-limited aquifer. Similarly, if a recharge project introduces water with high DO concentrations into a previously oxygen-limited aquifer, a shift in redox will occur.

pH-related release of certain contaminants can occur when infiltrating or injecting recharge water with a differing pH than the native groundwater. A shift in pumping regime can also cause the mixing of groundwaters with various chemistry if water from various regions within the aquifer is being transported to new locations. Therefore, it is important to obtain information on baseline geochemical conditions (including pH, DO, ORP) and, if available, any previously collected soil and/or sediment analyses or samples (e.g., soil cores and drill cuttings). These samples can be used for laboratory analysis to determine their composition and likelihood of contaminant release.

Step 3. Potential management strategies can be identified to minimize adverse changes in geochemical conditions.

Limiting changes in geochemical and hydrological baseline conditions will help limit potential adverse impacts. For instance, if recharging water, is it possible for the recharge water to have a more similar geochemical composition to the native groundwater? This could be achieved by pretreating recharge water or using an alternate source of water for recharge. If matching source water chemistry is not possible, see Table 2 to determine which contaminants to prioritize in a robust monitoring program.

Soil and aquifer sediment samples (e.g., soil cores and drill cuttings) also provide valuable information about the aquifer solids and the chemical state of contaminants residing within those solids, but are more expensive than water sampling. If there is potential for significant geochemical shifts, sediment samples should be obtained to measure the abundance of various natural contaminants in the region where the management action is taking place and what chemical form these contaminants are in.

In some areas, it may be possible to retrieve old samples from previous well drilling or core activity as a more cost-effective way of obtaining samples. While older samples may not retain the same chemical properties as those found *in situ*, they can provide valuable information about the total contaminant concentrations. It is possible that soils or sediments can contain high concentrations of certain contaminants either naturally or as a result of historic anthropogenic inputs that accumulate. Soil and sediment heterogeneity pose a complex challenge to sampling as concentrations can vary greatly within small spatial areas. Priority sampling locations should be in the region closest to the proposed management actions where the most significant shifts in geochemical and/or hydrological conditions are likely to occur. For a MAR project that includes use of recycled water, the construction of required monitoring wells presents an opportunity to collect aquifer solids samples.

For the installation of new water supply wells and associated well screening, it should be taken into account that wells can affect the transport and mixing of water from different zones within an aquifer (Gailey, 2018). For example, if contamination exists in a shallow portion of the aquifer, high rates of deep pumping can draw shallow groundwater down over time. Additionally, production wells with large screened intervals can serve as a preferential pathway connecting and transporting groundwater from different depths and potentially of varying quality. Generally, clay layers are likely to have more elevated concentrations of geogenic contaminants. While wells are typically not screened in clay layers because of their poor hydraulic conductivity, caution should be taken to avoid these layers for groundwater quality considerations as well.

4.2 Managing for co-occurring contaminants

It is likely that there will be multiple contaminants to consider and monitor, including geogenic and emerging contaminants as well as nitrates and salts. As an oxidant, nitrates create problems for geogenic contaminants that are released under oxidizing conditions, which include uranium and selenium. The co-occurrence of contaminants can be exacerbated in projects that mobilize nitrate into systems with limited prior exposure to oxygen or other oxidants.

The migration of dissolved salts into groundwater supplies can also have adverse impacts for other contaminants. One concerning example of this is the migration of high calcium and carbonate waters into groundwater prone to uranium release. Calcium and carbonate can react with uranium to form a complex that prevents uranium from adsorbing to solids and releases it into groundwater (see Section 5.5).

Table 2 describes the geochemical conditions that can cause the release of each contaminant. Rather than considering each contaminant as an individual management concern, contaminants can be conceptually grouped by the geochemical conditions that cause their release. Then, management actions can be taken to avoid specific geochemical conditions and the group of contaminants associated with those conditions. In general, trying to maintain native aquifer geochemical conditions will minimize the likelihood of releasing new contaminants.

TCP and PFASs are not included in Table 2 as they are not geochemically released like geogenic contaminants. Sections 5.8 and 5.9 provide specific information related to the management of TCP and PFAS contaminated aquifers, respectively.

TABLE 2

Groundwater conditions that can result in an increase or decrease in the mobility of each contaminant

	Contaminant Mobility Due to Aquifer Conditions				
Contaminant	Oxygen-abundant	Oxygen-limited	High pH	Low pH	Aquifer conditions to avoid
Iron (Fe)	↓	↑	↓	↑	Oxygen-limited, low pH
Manganese (Mn)	↓	↑	↓	↑	Oxygen-limited, low pH
Arsenic (As)	↓	↑	↑	↓	Oxygen-limited, high pH, high phosphate, compaction of clay layers from overpumping
Chromium (Cr)	↑	↓	↑	↓	Oxygen-abundant, high pH, fluctuating water table
Uranium (U)	↑	↓	↑	↓	Oxygen-abundant, high pH, high bicarbonate, high nitrate
Vanadium (V)	↑	↓	↑	↓	Oxygen-abundant, high pH
Selenium (Se)	↑	↓	↑	↓	Oxygen-abundant, high pH

4.3 Developing a monitoring program

A monitoring program will be critical for new management projects where an initial assessment determined that existing geochemical and hydrological conditions may be perturbed. A survey of existing wells appropriate for monitoring and resources available for drilling additional monitoring wells will help determine how best to deploy new monitoring efforts.

Detailed design of a water quality monitoring program is beyond the scope of this report, but the following are some suggestions to inform early thinking and conceptualization of a rigorous monitoring program. Design of an appropriate water quality monitoring program should be conducted by a qualified professional in an adaptive process with thorough stakeholder engagement. More detailed resources and guidance on monitoring networks and programs are available through the California Department of Water Resources (DWR).[10, 11]

Monitoring wells should provide adequate spatial and temporal coverage to identify groundwater quality problems in a timely manner. Spatial requirements will depend on the scale of the project and regulatory requirements. Understanding the flow and transport conditions in the aquifer will be critical for determining the spatial extent of monitoring. Accordingly, groundwater flow (level) monitoring should be used to help design appropriate groundwater quality monitoring programs, since groundwater gradients determine the direction and speed of groundwater flow.

Coupled with and informed by the groundwater level monitoring, groundwater flow models with particle tracking and/or mass transport capabilities or planned empirical tracer tests can help determine how fast and in which directions groundwater is movingfurther informing the appropriate design of water quality monitoring programs. This is important because there are often delayed effects; problems can arise as water moves downgradient. Monitoring wells should be placed in locations between the new project and production wells/users in such a way that provides sufficient response time should a migrating groundwater problem be observed. If groundwater quality issues are first observed in drinking water wells or in monitoring wells placed too close to the supply well to provide an adequate response time, it will be too late to address the issue before contaminated water reaches users.

Additionally, monitoring wells should span the impacted depths of the aquifer. Multi-screened wells and/or nested wells provide depth resolved data and should be used where appropriate.

Temporal coverage should allow enough frequency of monitoring to capture seasonal and short-term trends in groundwater quality. Seasonal variation in geochemical and hydrological conditions occurs naturally, and similarly, management projects often have seasonal variation (e.g., recharging in specific seasons). Looking at historical seasonal trends of groundwater quality data can provide some insights into the timescales of seasonal trends in a given location. It should be noted that seasonal timescales may vary year to year and with future variations in dry and wet conditions.

Lastly, measuring contaminants at trace concentrations is often expensive and requires laboratory instrumentation. If it is not feasible to directly measure trace contaminants on a regular basis, then close attention should be paid to the measurement of other common water quality parameters that control contaminant concentrations. Most critically, monitoring programs should include regular measurement of pH, dissolved oxygen, and ORP as proxies for the geochemical conditions in the aquifer. These parameters can be measured *in situ* at relatively low cost. Should shifts in pH, DO, and/or ORP be observed in monitoring data, there is a higher likelihood that contaminant mobilization is occurring, and samples should be taken immediately to assess whether contaminants are present. Table 2 summarizes which contaminants are most likely to occur under various geochemical conditions.

4.4 Careful implementation of managed aquifer recharge

Managed aquifer recharge is an increasingly applied method of artificially recharging groundwater aquifers. Of the possible management actions discussed in this document, MAR projects are the most likely to alter the native or preexisting geochemical and hydrological conditions within an aquifer. Accordingly, in addition to the above general guidelines, we highlight some specific recommendations for MAR. There are various types of MAR projects and each can have differing impacts on the geochemistry and hydrology of a site as summarized in Table 1.

First, the extent to which MAR will cause new changes to geochemical and hydrological conditions depends on historic recharge and land use in the area. For example, in the case of Ag-MAR, the volume and chemistry of the recharge water is the same (or very similar) to historic irrigation. Therefore, geochemical and hydrological conditions are not likely to deviate substantially from preexisting conditions, which may be less concerning for the release of geogenic contaminants as compared to other types of recharge. For Ag-MAR, knowing the historical nutrient and pesticide application is important for determining the likelihood of anthropogenic contaminants like TCP and nutrient release to groundwater. By contrast, MAR via injection wells can cause a direct, abrupt change in water chemistry. For example, if an injection well is drilled in a deep, confined aquifer with limited prior exposure to oxygen and oxic water is used for recharge, a sudden shift in redox chemistry can occur and cause the release of geogenic contaminants.

In general, sandy soils are less likely to contain, and subsequently release, geogenic contaminants. Agricultural areas will have additional water quality considerations related to legacy pesticides, nitrate, and salts. Recharge projects can be designed to help dilute pesticides, nitrate, and salt. However, in addition to mobilizing these substances, introducing nitrate and salts into the underlying groundwater can impact geogenic contaminants in the area. For example, nitrate can transform uranium into a more mobile form (see Section 5.5).

Calcium and carbonate can be introduced into underlying groundwater supplies and can also react with uranium to increase its mobility in groundwater. In general, prioritizing areas with sandy soils that have high infiltration rates and low calcium and carbonate contents is beneficial to avoiding issues related to uranium release. Additionally, continued use of the same infiltration site will deplete calcium and carbonate concentrations, decreasing the threat of contaminant mobilization over time compared to developing new recharge sites.

Water quality impacts of MAR remain a subject of ongoing research. Information and expertise specific to managed aquifer recharge on agricultural lands using flood water from rainfall or snowmelt (Flood-MAR) is currently being developed by DWR.[12] Current research at the University of California Santa Cruz includes the use of permeable reactive barriers made of woodchips for changing redox chemistry to remove nitrates during MAR via infiltration at a site in Pajaro Valley, CA (Beganskas et al., 2018).

4.5 Developing a contingency plan for groundwater contamination

After all necessary precautions have been taken to avoid creating new contamination or exacerbating existing issues, a plan should be developed if a groundwater contamination event occurs. This is particularly important if groundwater supplies are used for drinking water. The plan should account for how to (1) increase or augment monitoring, (2) assess the potential for end user well contamination, (3) notify users of water supplies, and if necessary, (4) provide alternate, safe water supplies, (5) discontinue use of affected water supplies as needed, (6) address the contamination by remediation or permanently discontinuing use, and (7) develop targeted future monitoring once the problem has been addressed to ensure it does not occur again. Having a plan for how to address these points will lead to improved response times and protection of water users.

5. Contaminant summary overview

Each contaminant behaves uniquely in the environment and is affected differently by various management actions. In this section, we provide a brief summary of each contaminant and its mobility in the environment. We include the public health considerations and regulatory limits. Some contaminants are regulated using a primary maximum contaminant level (MCL) while others have a secondary MCL. In California, the State's primary and secondary MCLs are enforceable. MCLs are determined based on the technical and economic feasibility of water treatment for each contaminant in addition to their toxicity to human health.

Notification Levels exist for certain contaminants that do not have MCLs and represent the concentration at which certain public notification requirements and recommendations apply depending on the contaminant. Notification Levels may turn into MCLs as toxicological and public health knowledge of a contaminant increases.

Finally, California's Office of Environmental Health Hazard Assessment (OEHHA) has public health goals (PHGs) for certain contaminants that are non-enforceable goals based only on toxicity and health hazards. These are summarized for each contaminant in Table 3. Detailed information on regulatory requirements surrounding groundwater quality is provided in a report recently published by Stanford University's Program on Water in the West titled "A Guide to Water Quality Requirements under the Sustainable Groundwater Management Act" (Moran and Belin, 2019).

TABLE 3

Regulatory limits and public health goals for California

Contaminant	Level of regulation	Limit	Public Health Goal (OEHHA)
Arsenic	Primary MCL	10 µg/L	0.004 µg/L
Chromium	Primary MCL	50 µg/L (total)	0.02 µg/L (hexavalent)
Uranium	Primary MCL	20 pCi/L	0.43 pCi/L
Vanadium	Notification level	50 µg/L	-
Manganese	Secondary MCL	50 µg/L	-
Iron	Secondary MCL	300 µg/L	-
Selenium	Primary MCL	50 µg/L	30 µg/L
1,2,3 TCP	Primary MCL	0.005 µg/L	0.0007 µg/L
PFASs	Notification level	0.013 µg/L for PFOA	-
		0.014 µg/L for PFOS	-

Each contaminant summary in this section shows maps of groundwater concentrations over the last year (January 2018 – January 2019) of available data from the Groundwater Ambient Monitoring and Assessment (GAMA) Program (SWRCB, 2018a). Groundwater concentrations are listed as mass of contaminant in micrograms per liter of water. These data are obtained from multiple sources including the GAMA Domestic Well Project, the USGS, Lawrence Livermore National Lab (LLNL), and public water system well data collected by the State Water Resources Control Board's (SWRCB's) Division of Drinking Water (DDW). For PFASs which are more data-limited, we include all available measurement for public supply wells on the GAMA website, which spans a measurement period from August 2016 – May 2019.

It should be noted that these data are collected at various times of year and different aquifer depths. Variation in temporal trends and depth often occurs and cannot be inferred from these maps. Additionally, these data include contamination from both anthropogenic and natural sources. We present these data to provide an overview of the magnitude of concentrations generally observed in California as well as the spatial extent of each contaminant's impact on groundwater quality.

Similarly, we show soil concentrations for each map from the USGS mineralogical database (Smith et al., 2014). Soil concentrations are listed as mass of contaminant in milligrams per kilogram of bulk soil, with the exception of iron which is listed at percent iron by weight of the bulk soil owing to iron's high abundance in soils. The soil concentrations are shown for the C horizon, which is approximately 2.6-3.3 feet deep within the soils examined, and consists primarily of unconsolidated, weathered parent material (i.e., rock or deposited sediments).

Soil C horizons are much shallower than groundwater aquifers and wells. These soil concentration maps do not provide depth information about geogenic contaminants. Ultimately, contaminant concentrations within the aquifer waters will depend on several factors including the chemical conditions of the aquifer and historic anthropogenic inputs. We show the soil C horizon maps to offer a general summary of the abundance of these contaminants as well as their relationship with underlying geologic formations.

5.1 Contaminant Summaries

Within this section, we begin with summaries of iron and manganese. Iron has limited toxicity and is of concern only at very high concentrations. Furthermore, iron and manganese solids are highly reactive in groundwater systems and are presented first because they (1) have major impacts on the overall chemistry of an aquifer, often regulating the concentration of contaminants through adsorption processes, and (2) are excellent indicators of the redox condition of an aquifer. Next, we provide summaries for arsenic, chromium, uranium, vanadium, and selenium. Finally, we discuss TCP as an emerging contaminant of critical concern.

5.2 Iron

5.2.1 Background

Iron is an essential nutrient for human health at low concentrations and has a secondary MCL of 300 µg/L. Compared to other contaminants discussed in this document, it is much less toxic and is generally associated with taste and odor issues in drinking water. Iron is highly reactive and is involved in many important chemical reactions that affect the concentrations of other toxic contaminants including arsenic, chromium, and uranium. It is important to understand iron geochemistry, as it plays a critical role in controlling overall groundwater quality.

5.2.2 Iron in the environment

In most natural systems, iron exists as either "ferrous iron" or "ferric iron." In oxygen-limited environments, ferrous iron exists and is dissolved in groundwater. By contrast, under oxygen-abundant conditions, ferric iron exists and readily forms iron oxide solids of limited solubility. There are various types of iron oxides, which collectively are commonly known as "rust." Iron oxides have colors ranging from yellow to red, with orange solids predominating, and they are a critical component of aquifer solids that control the overall groundwater quality by interacting with numerous contaminants as discussed below. From an operational standpoint, iron oxide solids can also cause clogging and biofouling issues in wells. Biofouling occurs when bacteria that consume iron are active near the well and create a slimy film of

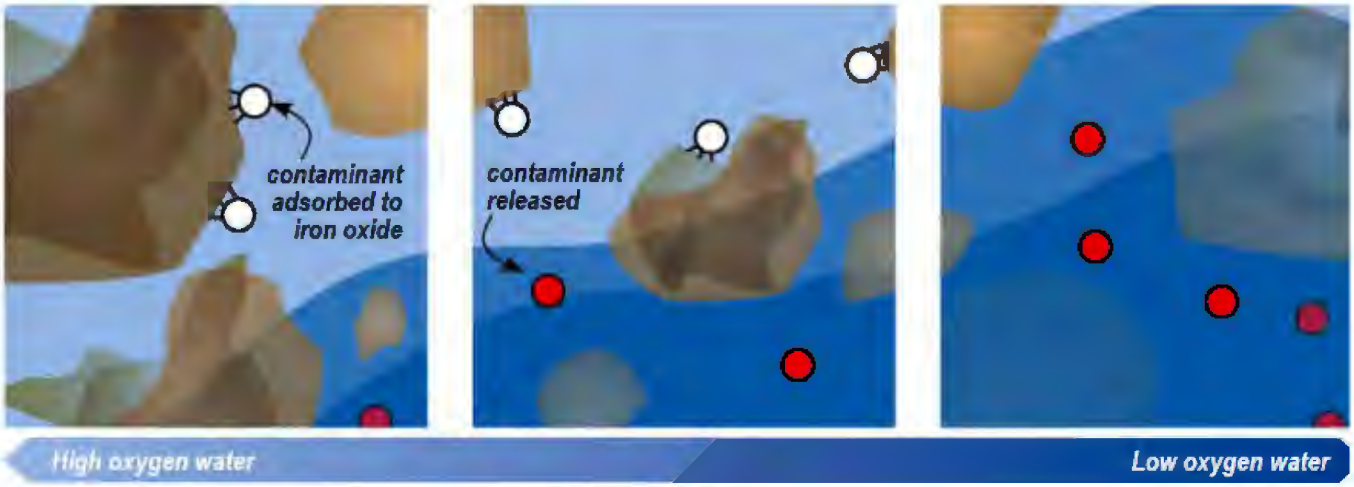


Figure 6: Iron oxides dissolving as DO concentrations become limited and subsequent release of contaminants adsorbed to the iron oxides.

bacterial residue. Both clogging and biofouling reduce water flow in a well and can cause staining.

5.2.3 Iron oxides as contaminant sinks

Dissolved contaminants including arsenic, chromium, and uranium have a strong ability to adsorb or "stick to" iron oxide solids. This adsorption process removes contaminants from groundwater and immobilizes them on iron oxide solids. Subsequently, the concentration of groundwater contaminants often depends on the stability of these iron oxide solids. For example, if oxygen becomes limited within an aquifer, the redox conditions will shift and iron oxides will no longer be stable. Once the iron oxides dissolve, they will release any adsorbed contaminants, causing an increase in iron and previously adsorbed contaminant concentrations into groundwater (Figure 6). Each contaminant has a varying ability to adsorb on iron oxides and some contaminants adsorb more strongly than others. Additionally, the extent of contaminant adsorption on iron oxides is usually pH dependent -- and may also change with the composition of the surrounding water.

5.2.4 Iron in California

Iron is widely distributed across rock types and associated soils and sediments. It is the second most

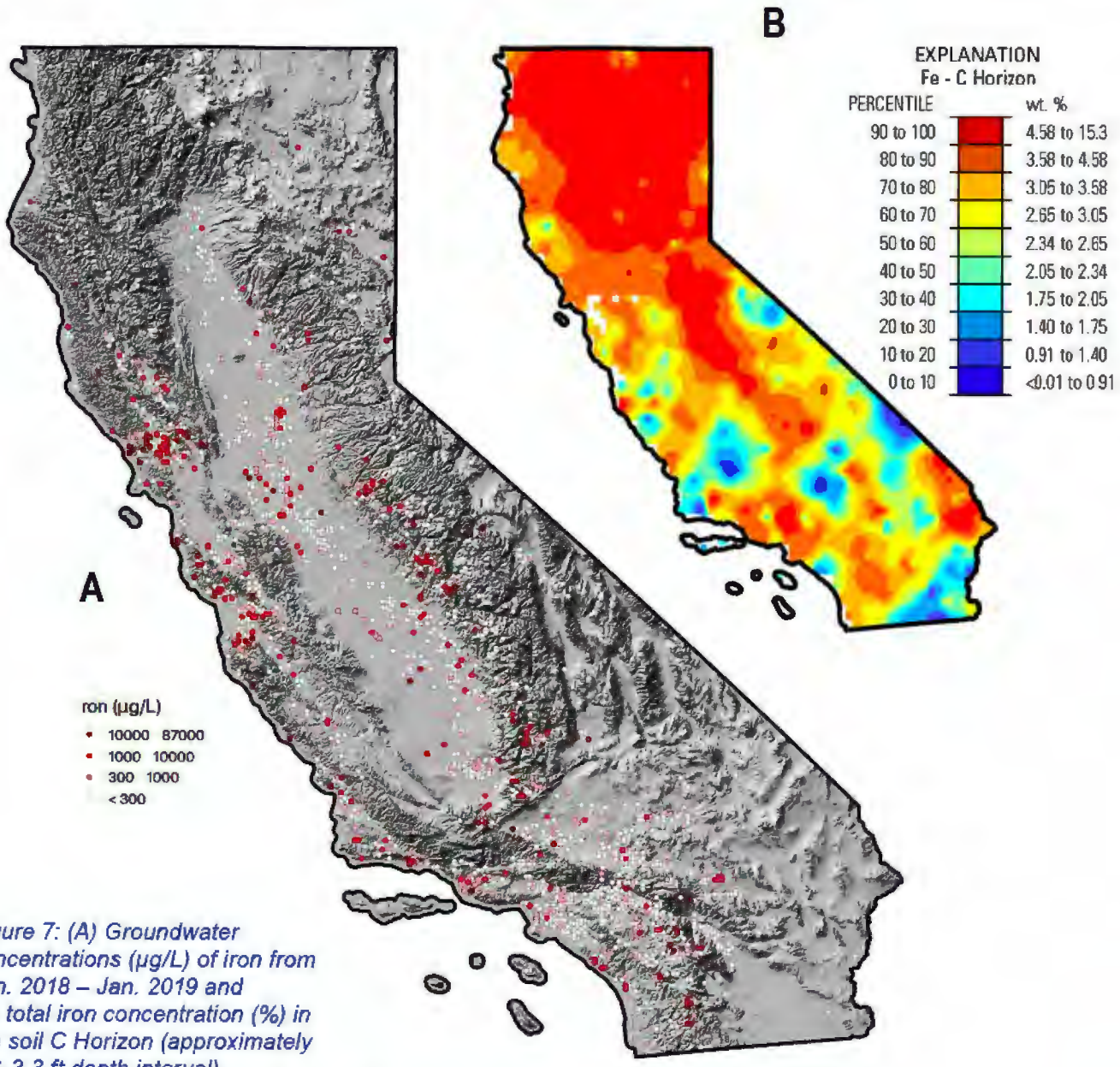


Figure 7: (A) Groundwater concentrations (µg/L) of iron from Jan. 2018 – Jan. 2019 and (B) total iron concentration (%) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The secondary MCL for iron is 300 µg/L.

abundant metal element in the Earth's crust and can be found at much higher concentrations than other geogenic metals throughout soils (Figure 7). Subsequently, iron in groundwater can occur at any location with geochemical conditions conducive to iron release. Generally, oxygen-limited groundwaters have higher iron concentrations in groundwater.

5.2.5 Management considerations for iron

If an aquifer has abundant oxygen, iron will generally reside as an iron oxide solid, and thus dissolved concentrations of iron are low. The largest threat to the stability of iron oxides is a shift in the oxygen content of an aquifer; if oxygen becomes limiting, iron oxides will dissolve. Should iron oxides dissolve, iron concentrations will increase in the groundwater, which can cause operational problems including clogging and biofouling in production wells. Conversely, if water with high concentrations of DO is introduced into an aquifer with perennially low DO, significant quantities of iron oxides could be produced through the oxidation of existing iron. This could decrease the concentration of other contaminants in the water by providing mineral surfaces with iron oxides to adsorb them.

5.3 Manganese

5.3.1 Background

Manganese is geochemically similar to iron in many ways. At low concentrations, manganese is an essential nutrient for human health. However, at high concentrations manganese causes neurological disorders, particularly in children, who are more susceptible to manganese exposure. Manganese has a secondary MCL of 50 µg/L, and a notification level of 500 µg/L. Like iron, manganese causes operational problems in wells, including clogging and staining. In drinking water, it is often associated with odor and a metallic taste. Manganese also forms oxide minerals which can adsorb and subsequently immobilize groundwater contaminants on aquifer solids, much like iron oxides.

5.3.2 Manganese in the environment

Manganese is the third most abundant metal element in Earth's crust. Under oxygen-limited conditions, manganese can dissolve in groundwater. At pH values greater than 7, manganese increasingly adsorbs to mineral surfaces within aquifer solids and groundwater concentrations will decrease. It forms solid manganese carbonates above pH 7.5, further removing it from groundwater. Under oxygen-abundant conditions, manganese forms manganese oxide solids which limit its groundwater concentrations.

5.3.3 Manganese interactions with other contaminants

Similar to iron oxides, manganese oxides play a critical role in determining the overall groundwater quality of an aquifer. Several toxic contaminants including arsenic, uranium, and selenium adsorb strongly to manganese oxides, limiting their concentrations in groundwater. However, in most oxygen-abundant groundwater systems, iron oxides will be more prevalent than manganese oxides owing to the higher abundance of iron. Therefore, iron oxides generally exert a greater control than manganese oxides on contaminant retention. Additionally, manganese oxides can have a large impact on groundwater quality through their ability to oxidize contaminants. After DO, manganese oxides are among the most reactive oxidants found in the environment and are capable of reacting with other contaminants. Manganese oxides have the most notable effect on chromium; they have the ability to transform chromium from its benign form (trivalent chromium) into a highly toxic and mobile form (hexavalent chromium), as discussed in Section 5.4.

5.3.4 Manganese in California

Similar to iron, manganese is widely distributed and abundant in rocks and associated soils and sediments (Figure 8). Manganese concentrations can be observed in groundwater in any aquifer under oxygen-limiting conditions. Historically, approximately 30 percent of drinking water supplies which monitor for manganese have observed manganese above the detection limit (SWRCB, 2019).

5.3.5 Management considerations for manganese

To promote the stability of manganese oxides and avoid manganese concentrations in groundwater, oxygen-limited conditions should be avoided. In oxygenated groundwater, manganese (like iron) will usually persist as manganese oxides. Similar to management considerations for iron, a depletion of oxygen will dissolve manganese oxides, increasing dissolved manganese concentrations and releasing adsorbed contaminants.

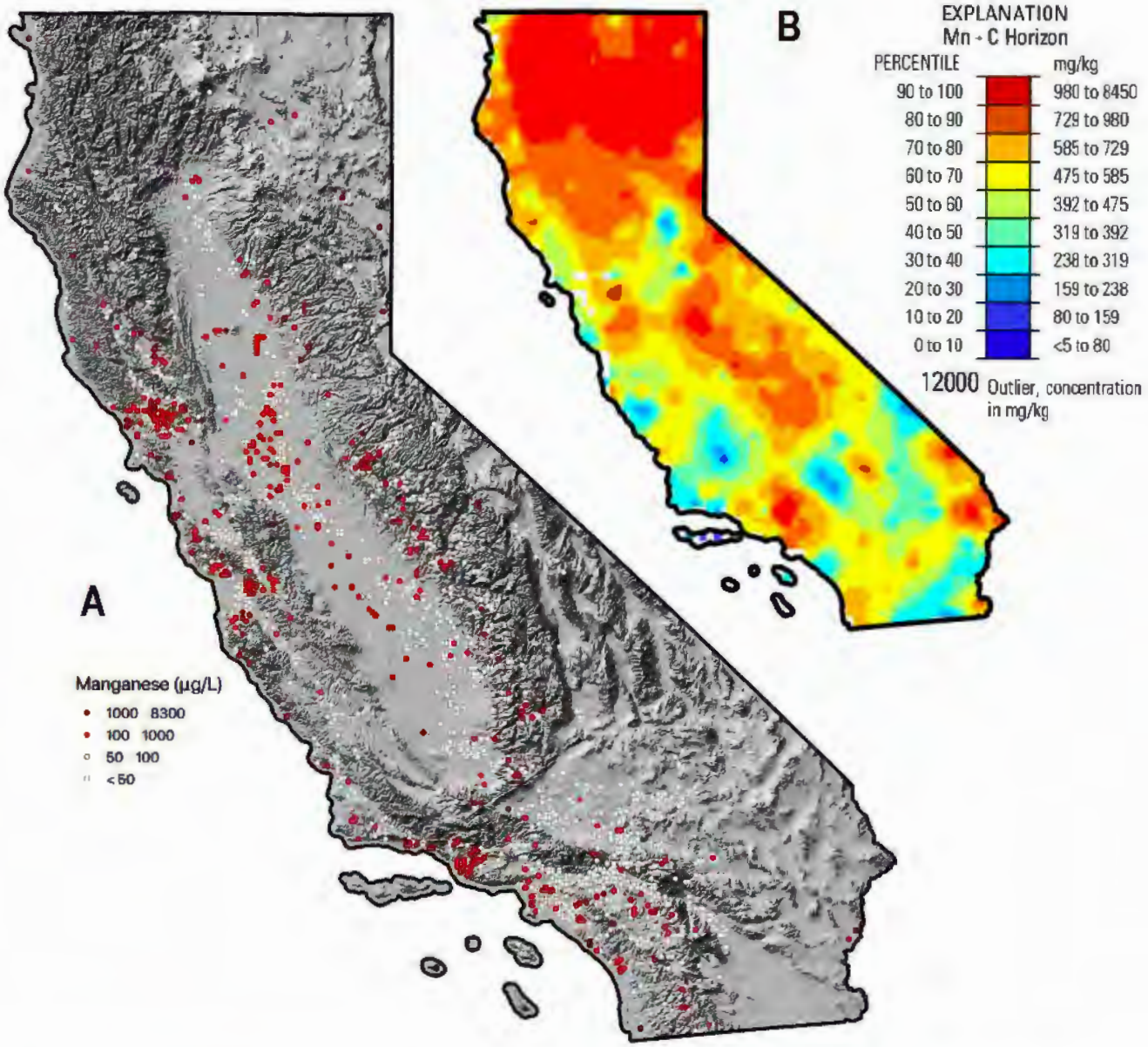


Figure 8: (A) Groundwater concentrations (µg/L) of manganese from Jan. 2018 – Jan. 2019 and (B) total manganese concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The secondary MCL for manganese is 50 µg/L.

5.4 Arsenic

5.4.1 Background

Arsenic is one of the most toxic and ubiquitous geogenic contaminants. While arsenic can be incorporated into food supplies (e.g., rice crops) through contaminated soil and irrigation water, it poses the greatest threat to public health in drinking water supplies. Chronic exposure to arsenic-contaminated drinking water is known to cause cancers of the lungs, skin, bladder, and kidneys. The primary MCL for arsenic in drinking water is 10 µg/L and the PHG is set at 0.004 µg/L. While anthropogenic sources of arsenic, including mining and pesticide application, have historically led to point source contamination of groundwater, both natural and anthropogenic mobilization of arsenic has led to wide-scale contamination of groundwater aquifers.

5.4.2 Arsenic in the environment

Under most environmental conditions, arsenic can be found in one of two forms. Under oxygen-limited conditions, arsenic exists as arsenite in the +3 oxidation state (AsIII). Arsenite is generally considered more soluble in groundwater and more toxic than the oxidized form, arsenate, which occurs in the +5 oxidation state (AsV). This is because arsenate binds strongly to minerals found in soils and sediments under oxygen-abundant conditions including iron oxides. Under oxygen-limited conditions, these oxidized host minerals are not stable, and arsenic is more likely to exist as arsenite.

There are three primary biogeochemical triggers that mobilize arsenic from soils and sediments into groundwater. First, the most common trigger is a change in redox condition from an oxygen-abundant environment to oxygen-limited conditions. This can transform arsenate to the more soluble arsenite and/or dissolve the iron oxides hosting the adsorbed arsenate which releases it to groundwater. Shifts in redox condition can result in concentrated releases of arsenic. A second trigger of arsenic release is an increase in pH to values greater than 8.5. At these elevated pH values, iron oxides are less effective sorbents for arsenic due to changes in surface charge characteristics and lead to the release of arsenic to groundwater. Third, competitive ions can cause the mobilization of arsenic. Competitive ions are ions that closely resemble arsenic in structure and chemistry and will therefore compete for the same surface sites to bind onto minerals (Figure 9). Competitive ions like phosphate can replace arsenate on the surface of an iron oxide mineral and cause its release into groundwater.

5.4.3 Arsenic in California

In addition to the geochemical triggers of arsenic release described above, arsenic is increasingly being linked to historic pumping. Several regions within California have existing problems with geogenic arsenic, particularly the Central Valley, where arsenic release has been exacerbated by historic pumping. In the Central Valley, arsenic is deposited by granitic materials from the Sierra Nevada. Additionally, recent work has attributed arsenic release to land subsidence due to overpumping in the Tulare Basin in the San Joaquin Valley (Smith et al., 2018). Arsenic can reside in the porewater of clay layers (where oxygen-limited conditions persist). As aquifer pressures decrease and these layers compact during subsidence (Figure 2), arsenic is released and mobilized

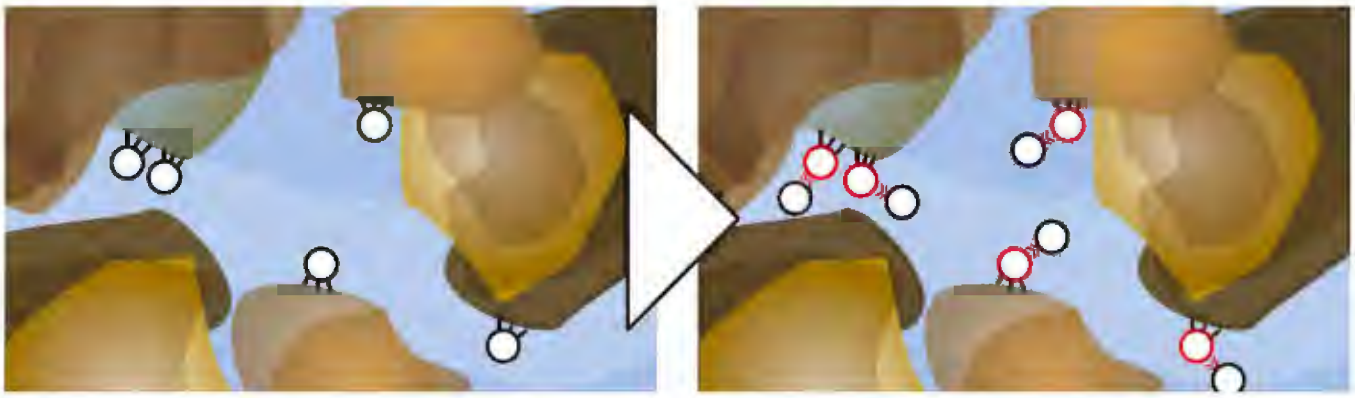


Figure 9: Competitive ion displacement. Ions with similar properties displace each other and limit adsorption to aquifer particles.

into productive aquifer units where it can reach pumping wells. This has been analogized to the release of dirty water when a sponge is squeezed. Once overpumping stops, arsenic concentrations can gradually decrease, declining to background levels as the aquifer is flushed.

5.4.4 Management considerations for arsenic

Conditions to avoid due to arsenic concerns are primarily oxygen-limited conditions and high pH (> 8.5). Inputs of competitive ions including phosphate, sulfate, and carbonate are a secondary concern. In other words, arsenic is generally not expected to be a problem in well-aerated, oxygen-abundant environments with pH values below 8.5. With respect to arsenic release from overpumping, managing for land subsidence will concurrently limit the arsenic release associated with compaction of clay layers and allow impacted aquifers to recover to background concentrations.

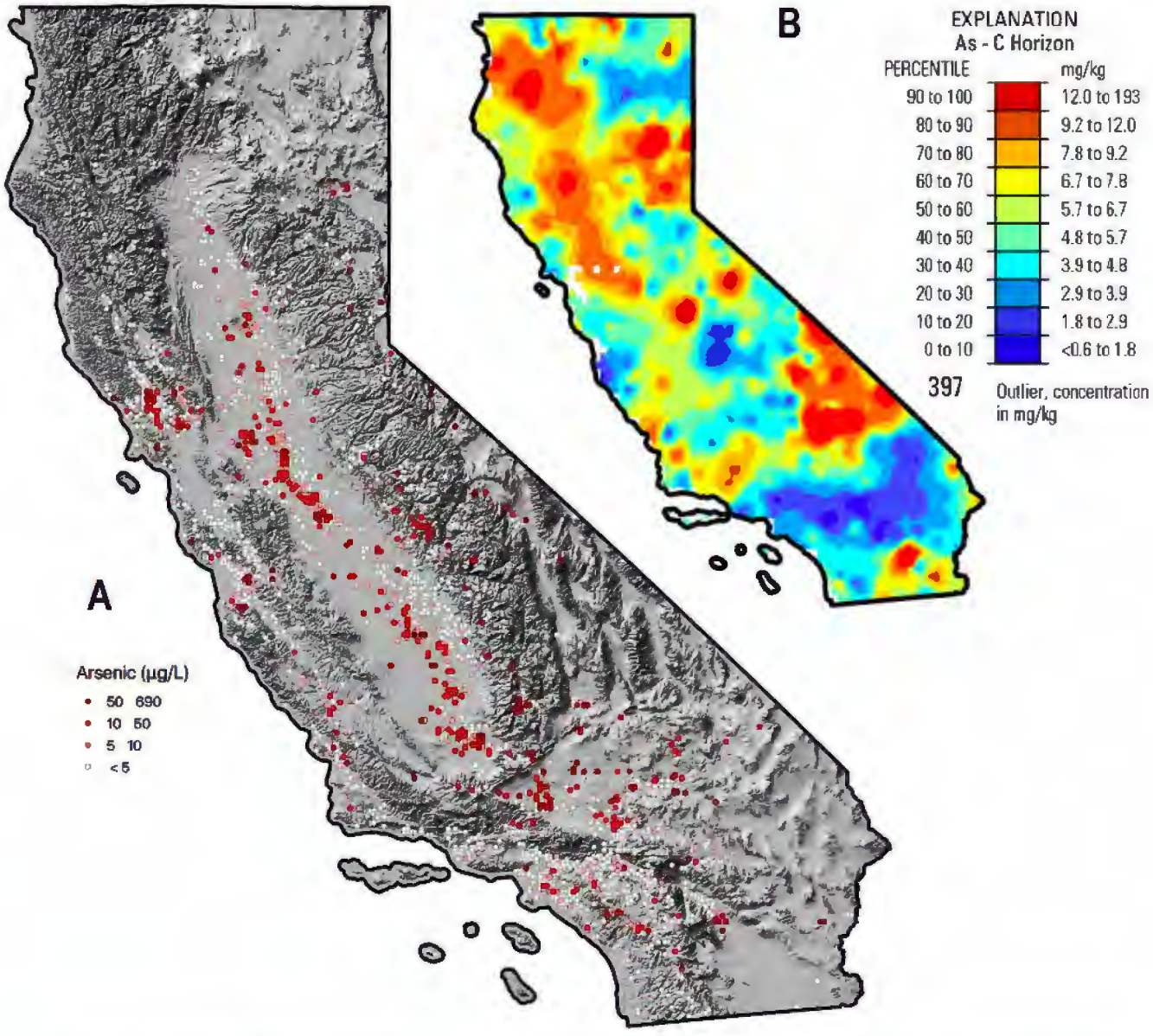


Figure 10: (A) Groundwater concentrations (µg/L) of arsenic from Jan. 2018 – Jan. 2019 and (B) total arsenic concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The primary MCL for arsenic is 10 µg/L.

5.5 Chromium

5.5.1 Background

Chromium is a naturally occurring metal that is widely used in industrial processes (e.g., electroplating, automobile and steel manufacturing, leather tanning, pigmentation, wood treatment). It persists in two forms within natural environments: trivalent chromium (Cr3+) and hexavalent chromium (Cr6+). Hexavalent chromium is toxic, mutagenic, and carcinogenic, while trivalent chromium is non-hazardous and considered an essential micronutrient in human nutrition. Hexavalent chromium is known to damage the lungs, GI tract, liver, and kidneys and is a known carcinogen that causes cancer by inhalation and possibly by ingestion. The federal MCL for total chromium in drinking water is 100 µg/L. California currently enforces a limit of 50 µg/L. In 2014, California's Department of Public Health set a separate MCL for hexavalent chromium (not total chromium) at 10 µg/L, but this MCL was repealed in 2017 due to the analytical limitations of many water districts (SWRCB, 2018b). The PHG for hexavalent chromium is 0.02 µg/L, stressing the severe toxicity of the chemical to human health. The conversion of hexavalent chromium to trivalent chromium by human stomach acid has been documented, but this was not incorporated in the development of the PHG.

5.5.2 Chromium in the environment

Hexavalent chromium is much more mobile in groundwater than trivalent chromium because it does not bind extensively to minerals within soils and sediments. By contrast, trivalent chromium binds strongly to organic matter and mineral surfaces and may exist as solid minerals (e.g., chromite, aluminosilicate clays, hydroxides). Trivalent chromium is generally stable in oxygen-limited environments. The primary natural pathway for trivalent chromium transformation to hexavalent chromium occurs by reaction with manganese oxides. Although both trivalent chromium and manganese oxides reside in solids of limited solubility, they can react when in close proximity, leading to the generation of toxic hexavalent chromium. Oxygen can also generate hexavalent chromium, but this reaction is only significant at pH values greater than 9. For example, within high-pH, oxygen-abundant aquifers with very slow recharge rates or long residence times — such as in parts of the Mojave Desert, California — indigenous hexavalent chromium generation is appreciable (Izbicki et al., 2008). Once oxidized, hexavalent chromium does not adsorb to aquifer solids extensively and is easily replaced on surfaces by competitive ions such as sulfate and phosphate. Hexavalent chromium is more likely to remain in groundwater and pose a water quality threat.

5.5.3 Hexavalent chromium in California

Industrial activities that use chromium are important point sources of hexavalent chromium contamination in California, particularly in the San Francisco Bay and Los Angeles areas. In addition, geogenic chromium can be unintentionally oxidized by oxidants (e.g., permanganate, persulfate, hydrogen peroxide) injected during *in situ* chemical oxidation, a clean-up process for organic solvent pollution. Hexavalent chromium contamination in groundwater has historically been linked to industrial practices; however, widespread natural occurrences of hexavalent chromium concentrations approaching or exceeding the MCL also occur in groundwater wells unaffected by upstream industrial sources (Hausladen et al., 2018). These high hexavalent chromium levels in oxygen-abundant, alkaline groundwater are associated with the natural oxidation of geogenic chromium and typically affect larger geographic areas and more people than industrial sources.

In California, mafic and ultramafic rocks extend throughout the Coast Range, Klamath Mountains, northern Sierra Foothills, and San Gabriel Mountains. Soils derived from mafic/ultramafic parent material contain high amounts of geogenic chromium-bearing minerals. This leads to soil chromium concentrations exceeding the global average. Recent work proposed that distance from ultramafic outcrops is a primary control on hexavalent chromium concentrations in groundwater in some areas of California, like the western Sacramento Valley (Hausladen et al., 2018, Manning et al., 2015). The western Sacramento Valley receives extensive chromium-rich sediment deposition from the Coast Range Mountains. Here, hexavalent chromium concentrations reach up to 46 µg/L, and 11% of the measured public supply wells have hexavalent chromium levels that exceed 10 µg/L (Izbicki et al., 2015). Groundwater with mafic/ultramafic contributions also tends to be alkaline, which supports hexavalent chromium mobility. It is important to highlight that the high correlation with mafic/ultramafic outcrop proximity does not hold across all of California due in part to sediment transport processes. In these locations, hexavalent chromium contamination in groundwater may also be strongly influenced by human activities, such as agriculture.

5.5.4 Management considerations for hexavalent chromium

Multiple studies have examined geochemical signatures of groundwater in California and posited links between high hexavalent chromium concentrations and human activities, including agriculture (Izbicki et al., 2015, 2008, Hausladen et al., 2018, Manning et al., 2015, Mills et al., 2011). For example, hexavalent chromium is commonly correlated with nitrate concentrations in public-supply wells across the Central Valley. It is presumed that water management practices, like irrigation regimes, influence the geochemical processes driving hexavalent chromium contamination; however, we currently lack direct scientific evidence to confirm and explain how agricultural practices contribute to hexavalent chromium concentrations. Below is a summary of considerations about hexavalent chromium for water management based on laboratory experiments and spatial analyses of groundwater chemistry.

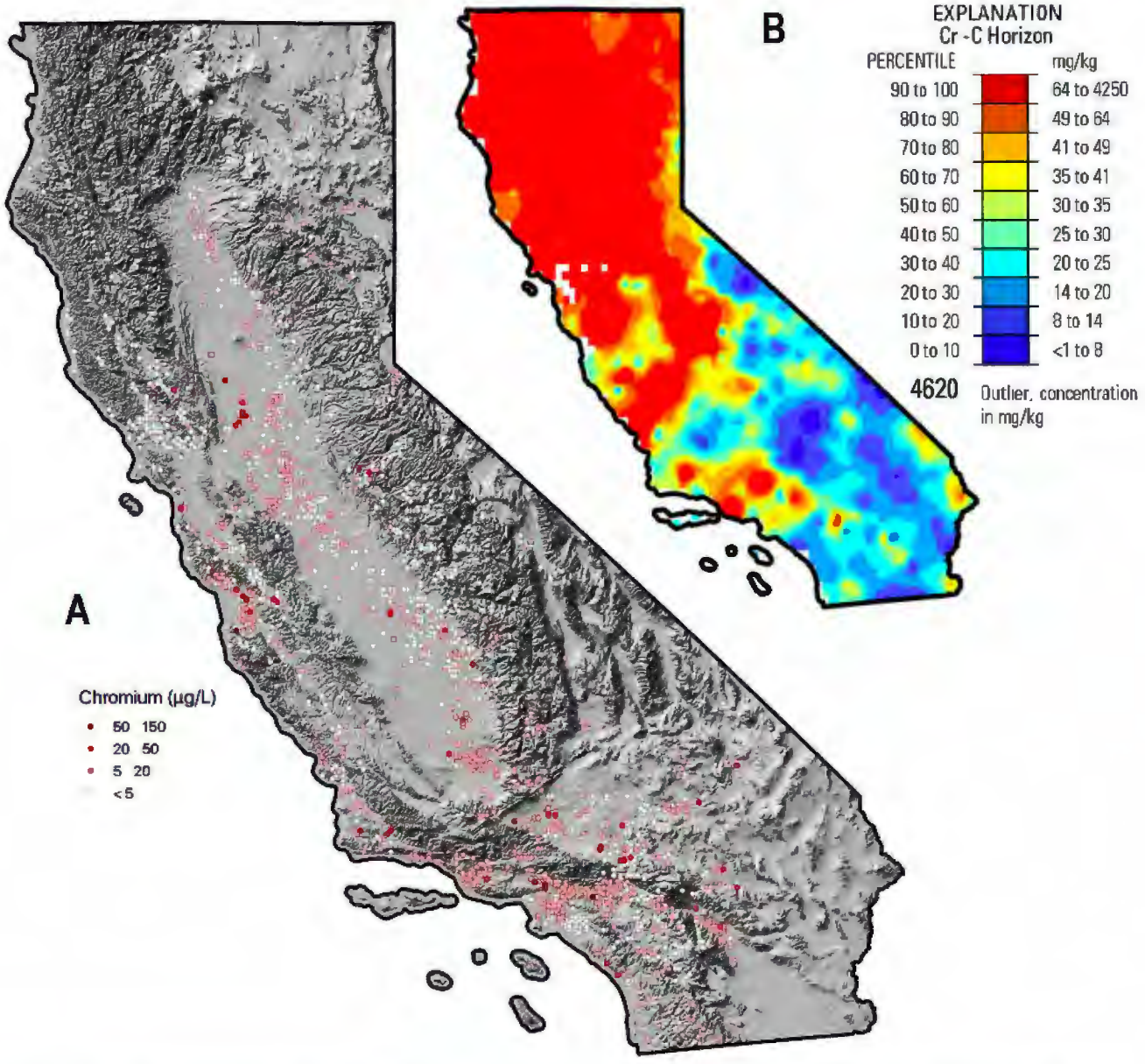


Figure 11: (A) Groundwater concentrations (µg/L) of chromium from Jan. 2018 – Jan. 2019 and (B) total Cr concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The primary MCL for chromium is 50 µg/L.

In environments containing mafic/ultramafic-derived sediments, biogeochemical conditions to avoid for hexavalent chromium in groundwater are oxygen-abundant, alkaline (pH > 7.5) conditions. Hexavalent chromium is not considered a concern in oxygen-limited aquifers where dissolved iron is present. The use of ammonium fertilizers can introduce acidity to soil and multiple studies suggest that nitrification enhances trivalent chromium release, which leads to greater oxidation by manganese oxides (Mills et al., 2011, 2012). The downward migration of hexavalent chromium generated in the unsaturated zone to shallow aquifers can be accelerated by irrigation recharge.

Although the process remains poorly understood, hexavalent chromium concentrations have been shown to correlate with heavily pumped agricultural areas. One hypothesis is that irrigation schemes which cause the regular wetting and drying of soils leads to manganese oxides dissolving and reforming in new locations at the water table, which in turn leads to the formation of hexavalent chromium. This suggests that irrigation schemes can be modified to decrease or inhibit hexavalent chromium contamination in aquifers. When the water table fluctuates frequently, such as on a weekly basis from turning pumps on and off, soil redox conditions oscillate and activate manganese cycling. Dissolved manganese migrates in the soil during oxygen-limited, saturated conditions, and reforms manganese oxides near chromium-bearing minerals during unsaturated conditions, inducing greater hexavalent chromium production. It is suspected that by changing the pumping schedule to allow for gradual declines in the water table and more stable redox conditions in the subsurface soil and sediments, manganese cycling can be disrupted or stopped, which minimizes hexavalent chromium generation. If an irrigated area does not currently have problems with hexavalent chromium in groundwater and a management action may lead to new irrigation practices which cause intermittent wetting and drying, it should be noted that this can potentially cause the release of hexavalent chromium particularly in areas near ultramafic outcrops.

5.6 Uranium

5.6.2 Background

Uranium is a metal that naturally occurs in rocks. Igneous rocks, like the Sierra Nevada granites, typically contain more uranium than other types of rocks. The MCL for uranium in California is 20 picocuries per liter (pCi/L), which is roughly equivalent to the federal drinking water limit of 30 µg/L. While uranium is radioactive, radioactivity is not a health concern near the MCL. However, the chemical toxicity of uranium in drinking water above the MCL can lead to kidney damage.

5.6.2 Uranium in the environment

Uranium exists in the environment in two different forms: the more reduced form, uranium(IV) and the more oxidized form, uranium(VI). Uranium in groundwater is almost always uranium(VI). Uranium(IV) typically occurs in oxygen-limited environments and forms a solid that precipitate out of water and are sparingly soluble. Dissolved uranium also adsorbs to aquifer solids and organic matter. Uranium(IV) can be transformed to uranium(VI) by reacting with oxygen and nitrate within groundwater. Shallow groundwater tends to contain

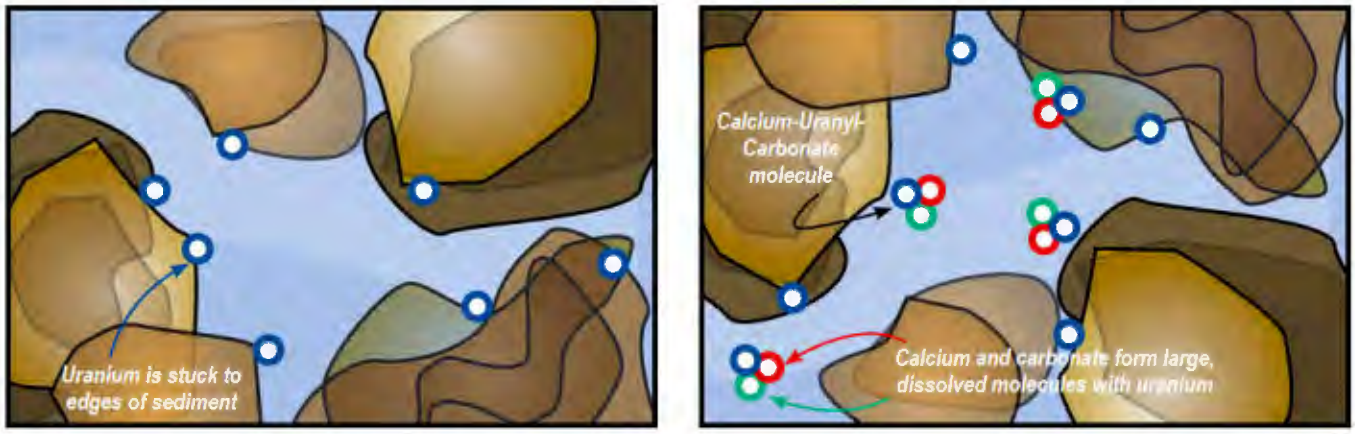


Figure 12: Schematic of calcium-uranyl-carbonate molecule keeping uranium concentrations in groundwater and preventing adsorption.

more DO, leading to uranium(VI). Deeper aquifers often have lower DO, and resulting oxygen-limited conditions promote uranium(IV) solids and subsequently lower uranium concentrations in groundwater. This is one reason why shallower wells tend to pump water with higher uranium concentrations whereas deeper wells have lower concentrations. Additionally, nitrate, when present, also tends to be higher in shallower aquifers, making uranium(VI) a concern in agricultural areas with legacy nitrate contamination.

Although uranium(VI) does not form solids regularly, it does adsorb on aquifer solids, which can limit its dissolved concentrations and mobility. However, uranium(VI) also forms molecules with calcium and carbonate that limit its ability to stick to aquifer solids, thus leading to higher groundwater concentrations of uranium. Groundwater with high levels of calcium and carbonate lead to calcium-uranyl-carbonato complexes (Figure 12) that do not easily adsorb to sediments. Studies have identified a link between increasing uranium concentrations in the Central Valley and increasing bicarbonate concentrations in groundwater due to the effects of increased plant productivity and irrigation return flow (Jurgens et al, 2009). Increased pCO2 in the root zone results in increased bicarbonate in shallow groundwater; high bicarbonate concentrations lead to higher uranium concentrations.

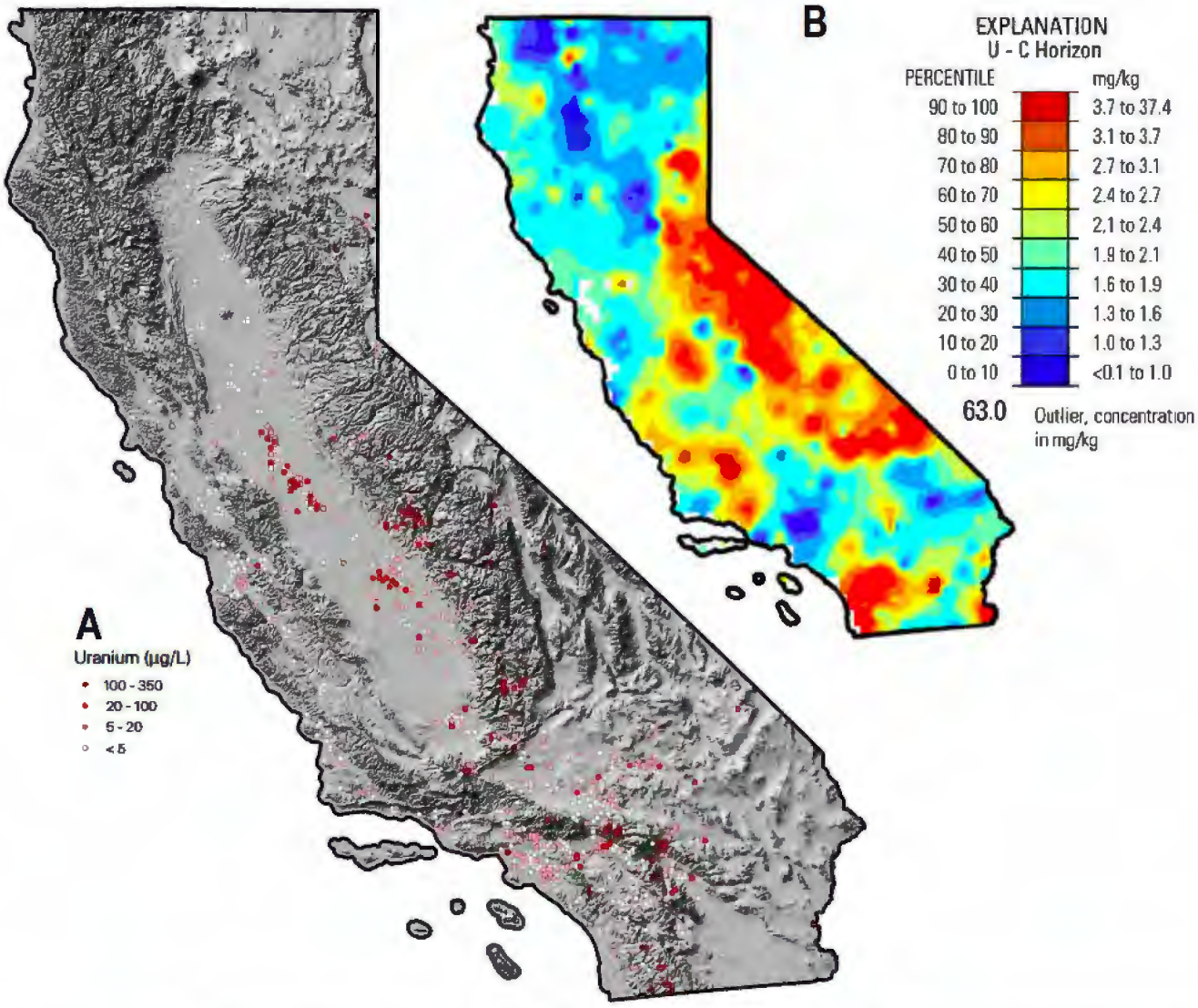


Figure 13: (A) Groundwater concentrations (pCi/L) of uranium from Jan. 2018 – Jan. 2019 and (B) total uranium concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The primary MCL for uranium is 20 pCi/L.

5.6.3 Uranium in California

In California, wells with high uranium concentrations often occur near the Sierra Nevada (Figure 13). This is because the groundwater picks up uranium from the granitic rocks in the Sierra Nevada or from sediments in valleys that are derived from granitic materials in the Sierra Nevada (like the Eastern San Joaquin Valley). Uranium concentrations in these regions are higher in shallow wells as opposed to deeper wells. Increased pumping can transport uranium from shallow to deeper parts of the aquifer. In parts of the Eastern San Joaquin Valley, uranium levels in some wells have increased significantly over the past 30 years.

5.6.4 Management considerations for uranium

Conditions to avoid to prevent uranium contamination include increasing concentrations of DO or nitrate in an aquifer with limited prior concentrations. The transport of calcium and carbonate to the groundwater below is an additional concern. For example, during managed aquifer recharge via infiltration, when recharge water flows through shallow, calcareous (calcium carbonate containing)-alkaline soils, it can dissolve calcium and carbonate. This also can occur by when waters have elevated carbon dioxide concentrations, which leads to increased carbonates in the water. The calcium- and carbonate-rich water can then react with uranium adsorbed to sediment, promoting release (desorption) of uranium from the sediments into the groundwater. By infiltrating through sandy areas or by removing shallow, calcareous layer of soil in an infiltration basin, calcium and carbonate can be prevented from entering the groundwater. This is particularly relevant for field flooding in the Eastern San Joaquin Valley with legacy agricultural contamination.

5.7 Vanadium

5.7.1 Background

Vanadium is becoming more recognized as a geogenic groundwater contaminant. There is no formal MCL for vanadium, but a Notification Level of 50 µg/L exists. Daily exposure through food is assumed not to have negative impacts, but experiments on rats and mice have shown elevated developmental problems correlated with increasing exposure to vanadium. Concern over potential health effects has led the US Environmental Protection Agency (EPA) to list vanadium on its Contaminant Candidate List 4, which lists contaminants that are not currently regulated at the federal level but may become so in the future.

5.7.2 Vanadium in the environment

Vanadium has three forms most commonly found in the environment: vanadium(III), vanadium(IV), and vanadium(V). Vanadium is considered immobile under oxygen-limited conditions because the reduced form, vanadium(III), forms a solid of limited solubility and will thus be separate from groundwater. The geochemistry of vanadium(IV) and vanadium(V) is more complex owing to their ability to adsorb on various mineral surfaces. Vanadium(IV) is only appreciably present and mobile in groundwater at very low pH, which is generally not relevant to most natural systems. Vanadium(V) tends to partition into groundwater and is thus mobile; it is found under oxygenated conditions. If vanadium is observed in groundwater, it most likely exists as vanadium(V). While vanadium(V) can adsorb to aquifer solids including iron oxides, adsorption is limited at pH values greater than 9.

5.7.3 Vanadium in California

Vanadium is generally more abundant in mafic rocks, and shales have been shown to have extremely high concentrations reaching 16,000 mg/kg in some parts of the world (Nriagu, 1998). In California, vanadium concentrations above 25 µg/L are associated with oxygen-abundant and alkaline (pH > 8) groundwater that interacts with vanadium-bearing source rock. This interaction can take place two ways. First, the water can be located with the source rock. Second, the water can be on the borders of areas with vanadium-bearing source rock. This is evident in the eastern San Joaquin Valley near the western Mojave,Temecula Valley, and in the Tule River Basin of the Sierra Nevada. However, the presence of source rock does not necessarily mean that there will be groundwater vanadium concentrations above 25 µg/L. For instance, the Cascades, Modoc Plateau, and Sonoma Volcanics of the Northern Coast Ranges have vanadium-bearing source rocks but low vanadium concentrations in the groundwater. This is attributed to their oxygen-limited and low pH conditions. However, areas such as the Owens Valley have been shown to have volcanic source rock and oxygen-abundant, alkaline groundwater, but also have low vanadium concentrations. Other areas, such as parts of the North Coast Range and the Owens Valley, also have vanadium-bearing source rocks but do not have groundwater vanadium concentrations above 25 µg/L. This indicates the need to establish and pay close attention to the hydrologic flow paths of the

regions, as well as establishing the redox conditions of the groundwater in areas of concern (Wright and Belitz, 2010).

5.7.4 Management considerations for vanadium

General conditions which cause vanadium release to groundwater are oxygen-rich and alkaline (pH > 8) waters. This is also true for uranium and chromium, and vanadium has similar management considerations to both uranium and chromium. If an aquifer has previously limited exposure to oxygen, any management practice that introduces oxygen can cause vanadium mobilization to groundwater. Additionally, uranium and vanadium concentrations are often correlated in groundwater. If an aquifer is experiencing issues with uranium, it is recommended to also monitor for vanadium as there is a possibility these contaminants will co-occur.

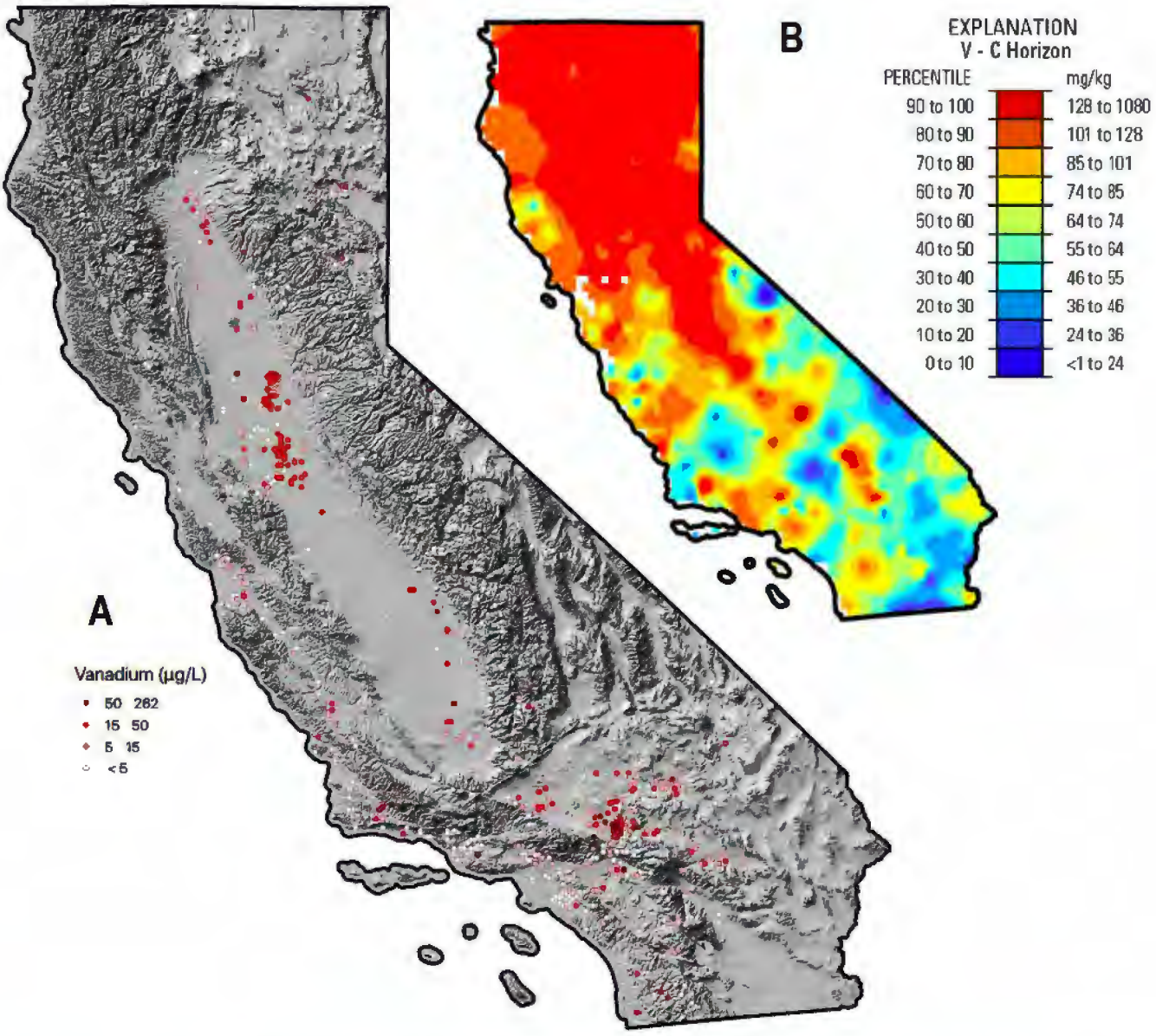


Figure 14: (A) Groundwater concentrations (µg/L) of vanadium from Jan. 2018 – Jan. 2019 and (B) total vanadium concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The notification level for vanadium is 50 µg/L.

5.8 Selenium

5.8.1 Background

Selenium is an essential nutrient at low, trace concentrations. However, excessive selenium concentrations are toxic to human and ecosystem health. The current MCL is 50 µg/L and long-term exposure of selenium at concentrations above the MCL has been shown to cause damage to kidneys, livers, and nervous and circulatory systems in humans. Historically, selenium has been more dangerous for fish and waterfowl, for whom it is known to cause congenital disorders and death through ingestion of high doses which bioaccumulate in food sources. Anthropogenic sources of selenium include mining metal ores and coal burning.

5.8.2 Selenium in the environment

Under most environmental conditions, selenium can be found as either the oxidized selenate or the reduced selenite. Under oxygen-abundant conditions, selenium exists as selenate and is more likely to be found in groundwater owing to selenate's limited ability to adsorb to aquifer solids. Selenate is also the more toxic form of selenium. By contrast, under oxygen-limited

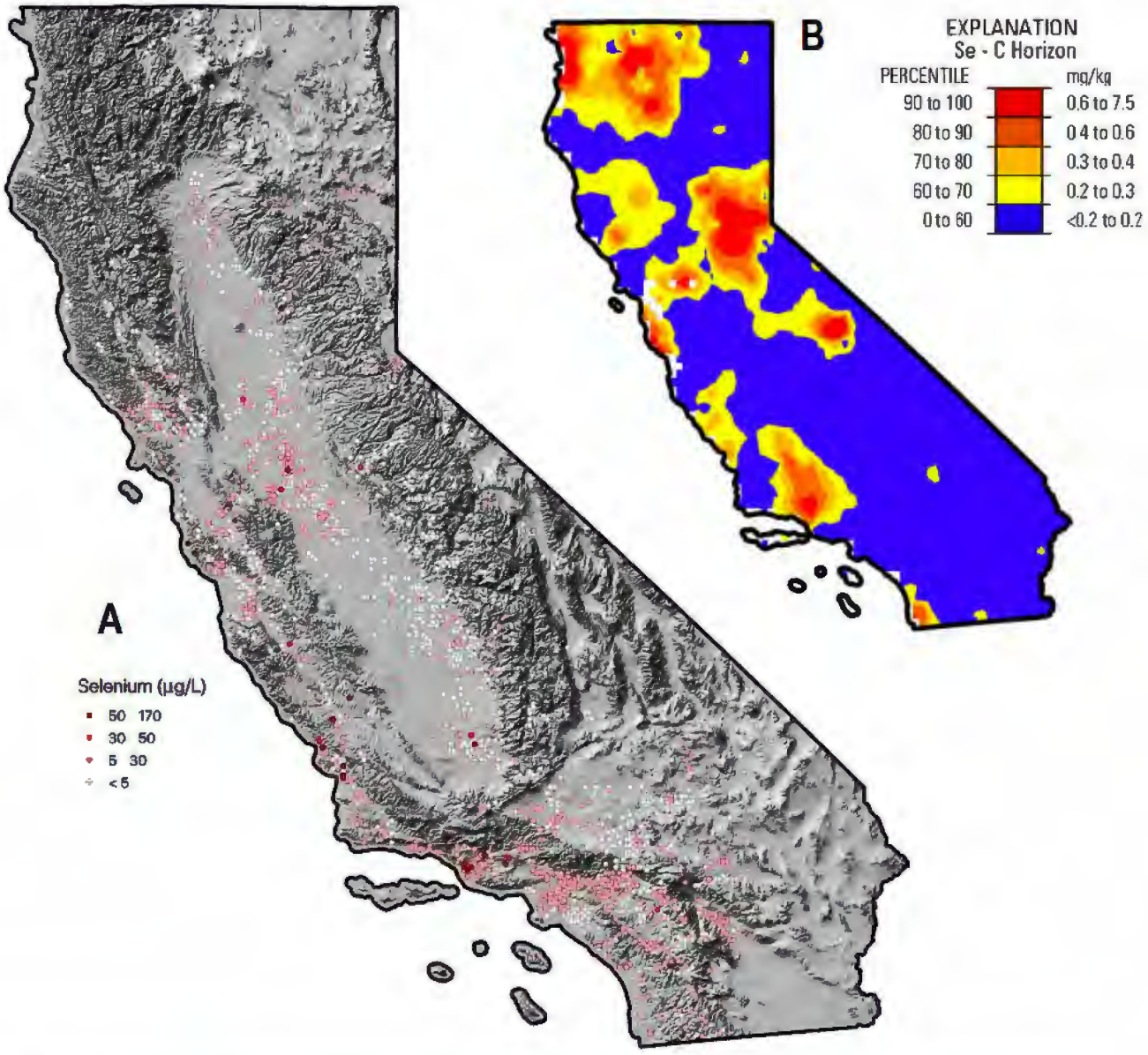


Figure 15: (A) Groundwater concentrations (µg/L) of selenium from Jan. 2018 – Jan. 2019 and (B) total selenium concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The primary MCL for selenium is 50 µg/L.

conditions, selenium exists as selenite and will adsorb strongly to aquifer particles, limiting its concentration in groundwater. High selenium concentrations are typically found under oxygen-abundant conditions. Additionally, at high pH values, both selenate and selenite do not adsorb strongly to aquifer solids and concentrations will increase in groundwater. Similar to arsenic, selenium can be mobilized through the presence of competitive ions (e.g., phosphate). While groundwater selenium concentrations are typically low (Plant et al. 2003) and not problematic for human health, contaminated groundwater that may reach surface water bodies, particularly surface water bodies subject to high evaporation, can have adverse impacts on fish and waterfowl.

5.8.3 Selenium in California

Generally, groundwater selenium concentrations are low and soil concentrations tend to correlate with the source bedrock of the California Coast Ranges (Figure 15). Selenium is concentrated in shallow groundwaters in semi-arid regions under irrigation (Deverel et al., 1994). Irrigation water can mobilize geogenic selenium and high evaporation rates can subsequently concentrate salt and selenium concentrations on the surface. Historically, this phenomenon has been observed in the San Joaquin Valley. In the 1980's in the San Joaquin Valley, this led to one of the most documented cases of selenium toxicity in animals. Near the Kesterson reservoir, agricultural drainage tiles were installed to mitigate soil salinization problems. The agricultural drainage water that flowed into the reservoir had high selenium concentrations (250 – 650 µg/L) which were further concentrated due to evaporation losses in the reservoir. This caused significant health effects on fish and wildlife, leading to the death of at least 1,000 birds (Plant et al., 2003).

5.8.4 Management considerations for selenium

Conditions to avoid for selenium release to groundwater include oxygen-abundant and high pH environments. Of secondary concern is a high influx of phosphate concentrations. Introducing nitrate (e.g., infiltration from nitrate-contaminated areas) can also transform selenium to its more mobile form and cause an increase in groundwater concentrations. Additionally, the pumping of groundwater for irrigation can concentrate selenium in addition to concentrating salts. Selenium mobilization could be an issue during changes to irrigation methods, agricultural drainage, or on-farm recharge.

5.9 TCP

5.9.1 Background

1,2,3-Trichloropropane (TCP) has recently been identified as a widespread, emerging contaminant in California. Unlike the geogenic contaminants described above, TCP does not have natural sources. This clear, colorless liquid was present in certain agricultural products applied in California throughout the 20th century, leading to widespread nonpoint contamination. In addition, TCP was historically used as an industrial solvent and cleaning agent, and therefore has many urban point sources. Because TCP does not easily break down, groundwater contamination from these historic practices remains an issue today.

TCP is of concern for human health because of its cancer-causing properties. Research by the National Toxicology Program (NTP) found that TCP causes tumors in multiple sites in both rats and mice at low doses (Irwin, Haseman, & Eustis, 1995). Based on these and other findings, TCP is considered a known human carcinogen by the State of California. California established an MCL for TCP in drinking water (0.005 µg/L) in December 2017, recognizing TCP's health risks and widespread distribution (Figure 16).

5.9.2 TCP in the environment

TCP is not known to have the same geochemical controls as redox-sensitive and ionic contaminants. Nonetheless, TCP is detected at much higher frequencies within oxic groundwater, suggesting it could be impacted by redox conditions; however, this mechanism is currently not well documented (Burow, 2019). Transport of TCP in groundwater is therefore controlled primarily by the physical properties of TCP, the mode of source application, and the characteristics of the affected aquifer, rather than geochemical or redox conditions.

TCP is a short hydrocarbon molecule with a chlorine atom bonded to each carbon. TCP is dense, slightly water soluble, and moderately volatile (prone to evaporation). While less volatile than industrial counterparts like trichloroethylene (TCE), TCP tends to evaporate from surface water. However, TCP does not adsorb easily to soil, and TCP that does not volatilize will migrate into groundwater.

Because it is denser (heavier) than water, TCP is classified as a dense non-aqueous phase liquid (DNAPL). Like all DNAPLs, TCP that enters an aquifer will sink downward, and eventually dissolve into groundwater.

TCP that originates from a diffuse, nonpoint source will tend to dissolve relatively quickly into groundwater. However, when a large amount of TCP enters the aquifer at a single location (generally from a point source), the pure, "free product" TCP can remain in the application source zone for decades – or centuries. This free product may be trapped in large pore spaces as "residual" free product or "pooled" above low-permeability sediments, often with highly irregular distribution within the source zone. Because TCP free product dissolves very slowly over time, groundwater passing through source zones may become enriched in TCP even after application has ceased.

Once dissolved into groundwater, TCP will be transported with groundwater flow. TCP is chemically stable and resistant to degradation. A typical molecule of TCP has a half-life of 44-74 years (i.e., it takes 44-74 years to degrade to half the initial concentration in water) (Ellington, 1986). Therefore, TCP plumes persist until they are diluted by diffusion or mixing.

5.9.3 TCP in California

TCP was detected above the MCL in 8% of domestic wells and 5% of public-supply wells recently sampled in California (Burow 2019). These detections are concentrated in the San Joaquin Valley, with some affected wells in the Los Angeles basin and Salinas Valley (Figure 16). In the San Joaquin Valley, 16-18% of domestic and public supply wells have TCP concentrations above the MCL.

Unlike geogenic contaminants, the distribution of TCP is largely determined by the location of historic source applications. In agricultural regions, TCP in groundwater likely originates from the use of TCP-containing soil fumigants marketed as D-D and, later, Telone, Telone II, and Vidden D. These fumigants were composed primarily of 1,3-dichloropropene (1,3,-DCP) and 1,2-dichloropropene (1,2-DCP) but contained up to 7% TCP by weight (Cheremisinoff & Rosenfeld, 2011). TCP-containing fumigants were widely applied beginning in the 1940s to many of California's croplands, including citrus fruits, pineapples, soy beans, cotton, tomatoes, sugar beets, grapes, potatoes, and various row crops, until they were discontinued in 1984 (CH2M Hill, 2005).

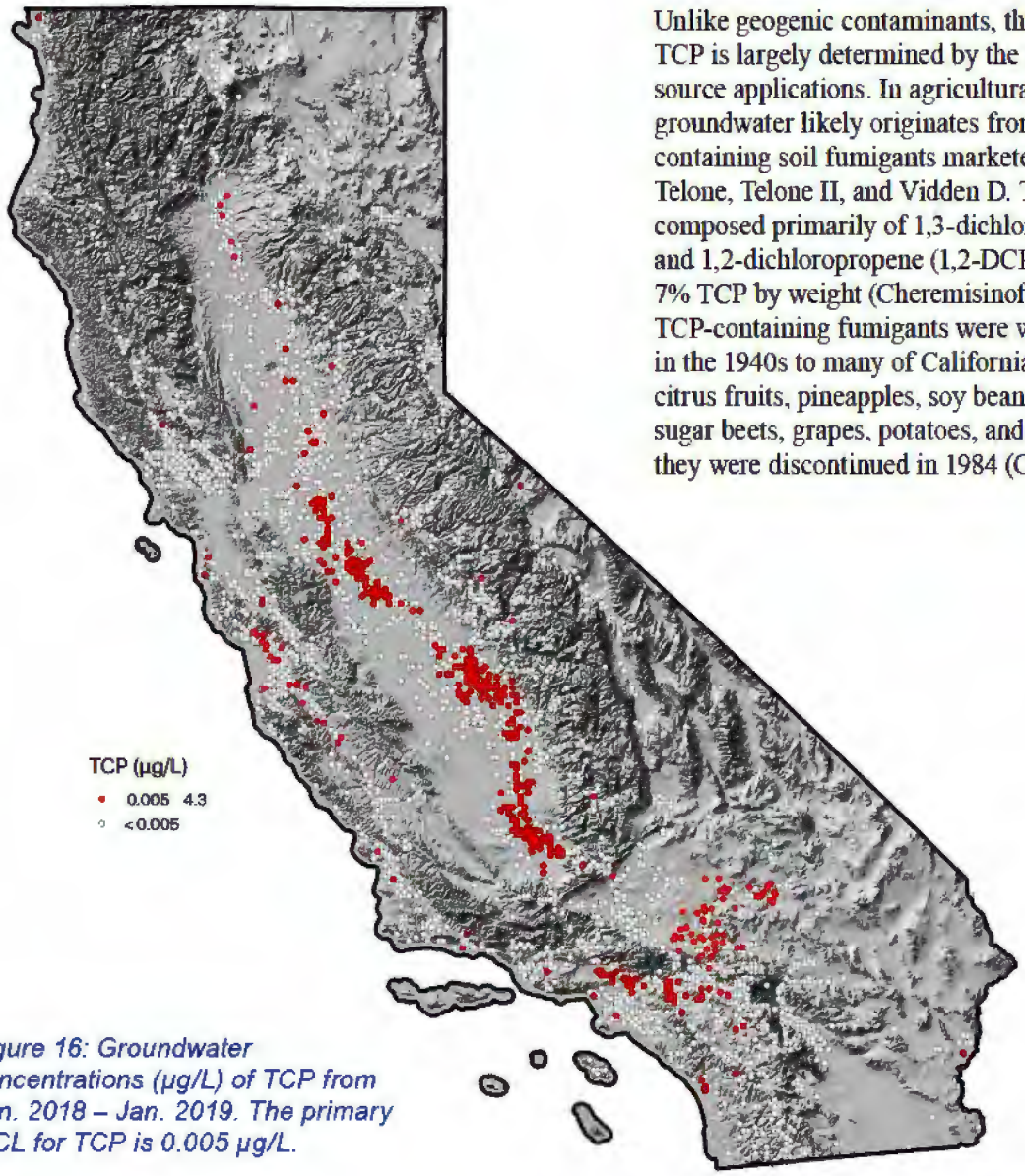


Figure 16: Groundwater concentrations (µg/L) of TCP from Jan. 2018 – Jan. 2019. The primary MCL for TCP is 0.005 µg/L.

TCP also has many point sources. These include facilities where TCP-containing fumigants were stored or where TCP was used as a solvent or cleaning agent. Suspected point sources of TCP in California include agricultural chemical supply sites, aviation facilities, chemical processing and manufacturing plants, and waste disposal sites (CH2MHill 2005, Burow 2019).

A recent evaluation of TCP in California groundwater identified several factors that are associated with TCP occurrence and concentrations: oxygen-abundant conditions; young, shallow groundwater; orchard/vineyard land use in the early 1990s; and high recharge rates (Burow 2019). Overall, TCP was found to be most prevalent and at highest concentrations near alluvial fans in the central and southern San Joaquin Valley, where orchards and vineyards are common and coarse-grained sediments and irrigation lead to high recharge. TCP was prevalent at similar rates in wells of all depths, though TCP concentrations were slightly higher in shallower wells. The authors also found that TCP co-occurs with 1,2-dibromo-3-chloropropane (DBCP, another soil fumigant) and 1,2-DCP (a TCP breakdown product and primary component of TCP-containing fumigants).

5.9.4 Management considerations for TCP

Active groundwater remediation is not a focus of this document. Best practices for TCP *in situ* remediation are still under study and will depend on the specific conditions of each plume. In general, *in situ* remediation of TCP can be achieved by injection of a strong oxidant and catalyst or by reductive dechlorination with zero-valent iron. However, California considers pump-and-treat with Granular Activated Carbon (GAC) as the Best Available Technology for affected water systems (SWRCB, 2018c).

Without active treatment, TCP plumes are likely to persist for many years. However, an awareness of aquifer characteristics, hydrology, and current/former land use can help water managers to avoid increasing TCP concentrations. Managers can avoid siting new wells in areas known to be associated with higher TCP concentrations, particularly shallow groundwater near orchards and vineyards in the central and southern San Joaquin Valley. Wells with elevated concentrations of DBCP and 1,2-DCP are also more likely to have elevated TCP.

Water managers should also be aware of historic point sources of TCP. As described above, residual or pooled TCP may be found near application zones in the pore spaces of coarse sediments or in lenses above low-permeability sediments. If water pumped from these strata becomes enriched in TCP relative to up-gradient wells, free product may be present. Subsurface soil samples can also reveal whether free product remains in source zones.

Depending on hydrological conditions of the site, managed aquifer recharge can help to reduce TCP concentrations through dilution of existing contamination. However, recharge zones should also avoid historic point source TCP contamination, as free product in the subsurface may dissolve into percolating groundwater and reach previously unaffected water supplies. Monitoring groundwater conditions down-gradient of the recharge will also allow water managers to track changes in TCP concentrations following recharge.

5.10 PFASs

5.10.1 Background

Per- and polyfluoroalkyl substances (PFASs) are a large and diverse class of fluorinated organic compounds. Like TCP, PFASs are synthetic chemicals that have no natural sources. PFASs are used to make consumer products stain-, soil-, and water-repellent, and in aqueous film-forming foam (AFFF) to extinguish flammable liquid fires. The carbon-fluorine chemical bonds that give PFASs their useful properties also make many of these chemicals extremely persistent. Interest in PFASs has increased due to recent discoveries of their widespread environmental occurrence and potential impacts on human health and biota.

Perfluoroalkyl acids (PFAAs) are a subclass of PFASs that are the focus of much scientific and regulatory attention. Exposure to PFAAs such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) is associated with human health harm including immune suppression, liver damage, high cholesterol, cancer, thyroid disease, reduced fertility, low birth weight, and effects on children's cognitive and neurobehavioral development. In 2016, U.S. EPA issued a Lifetime Health Advisory Level of 70 ng/L for PFOA, PFOS, or the sum of both. Researchers know less about the prevalence and toxicity of other PFASs, but the science is evolving rapidly.

PFOA, PFOS, and other long-chain PFASs have been phased out in the U.S. due to concerns over their

persistent, bioaccumulative, and toxic properties. Over the past 15 years, industry has replaced long-chain PFASs with short-chain PFASs and perfluoroether carboxylic and sulfonic acids. One notable perfluoroether carboxylic acid called GenX is used as a PFOA replacement in fluoropolymer manufacturing. GenX contamination has recently been detected in several watersheds in the eastern U.S.

5.10.2 PFASs in the environment

PFOA, PFOS, and other PFAAs are highly persistent. They are not expected to degrade at appreciable rates under environmental conditions. PFAAs are strong acids that usually carry a negative charge, which contributes to their relatively high water solubility and low volatility. PFAA releases are often associated with dissolved phase plumes. However, considerable PFAA mass can also be retained in source zones, especially in unsaturated soils. Partitioning to sediment and bioaccumulation are more pronounced for longer-chain PFAAs.

In contrast to PFAAs, polyfluorinated compounds contain a fluorinated carbon chain and at least one nonfluorinated carbon. The nonfluorinated carbons make polyfluorinated compounds more reactive than PFAAs, and some are susceptible to oxidation reactions. Polyfluorinated compounds that produce PFAAs are known as PFAA-precursors. Little is known about the fate, transport, or toxicity of many PFAA-precursors. Most are not included in standard analytical methods. PFAA-precursors are likely to serve as an ongoing source of PFAAs (e.g., PFOA) in the environment. Analytical techniques for measuring PFAA-precursors, such as the total oxidizable precursor (TOP) Assay, are increasingly available.

Important point sources of PFAS contamination include manufacturing facilities that make or use PFASs, locations where AFFF firefighting foam was used, landfills, and wastewater treatment plants.

5.10.3 PFASs in California

PFASs are not regulated under the Safe Drinking Water Act and public water systems are not required to perform routine monitoring of these chemicals. PFASs were detected in 133 drinking water samples from California through EPA's Third Unregulated Contaminant Monitoring Rule (UCMR3). The same study identified nine public water systems in the state with detections of PFOA and/or PFOS above EPA's 70 ng/L health advisory.

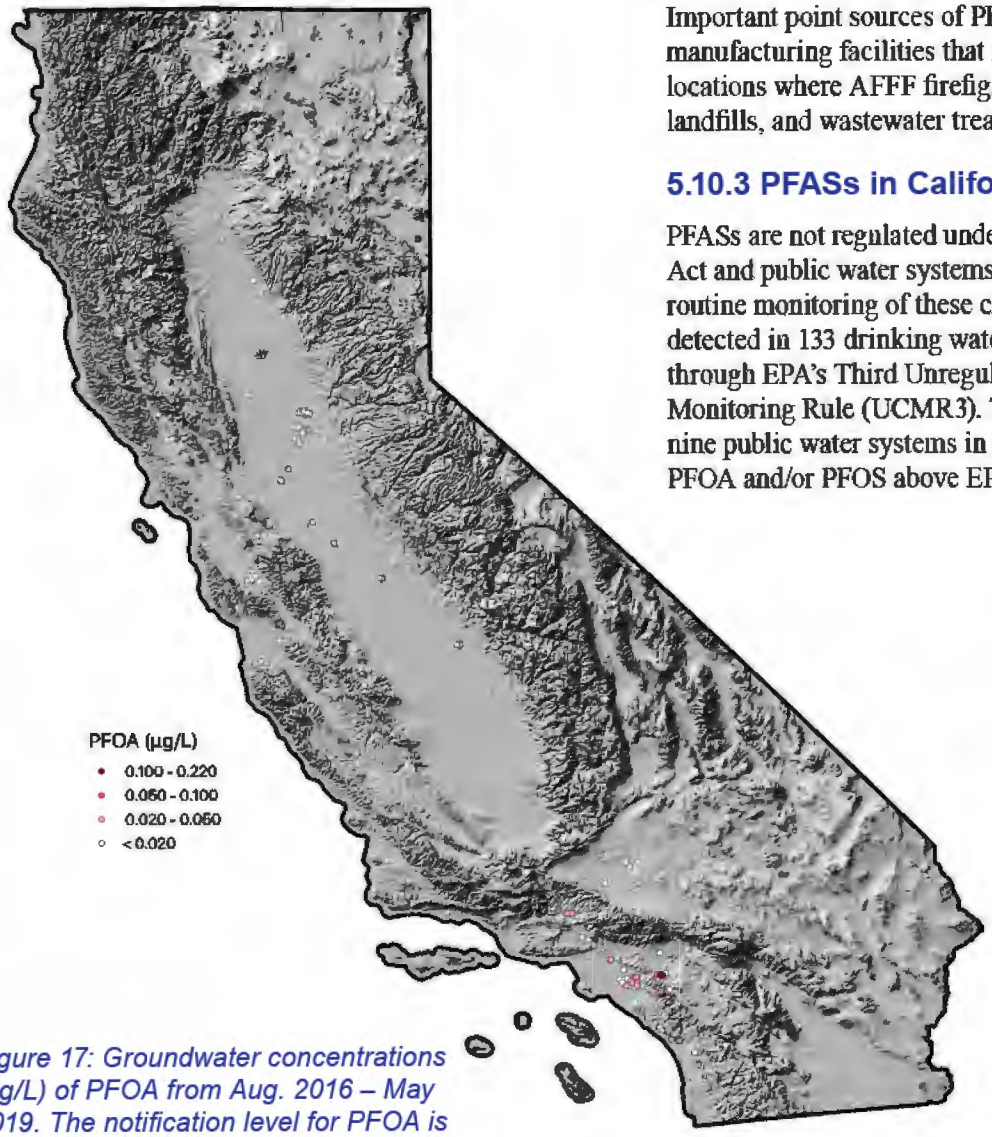


Figure 17: Groundwater concentrations (µg/L) of PFOA from Aug. 2016 – May 2019. The notification level for PFOA is 0.013 µg/L.

Aside from the UCMR3 study, there is a lack of drinking water monitoring data for PFASs in California. The Department of Defense has identified high PFAS concentrations in groundwater at military sites where AFFF was used, but none of these sites are known to have impacted drinking water off-base in California. In 2019, the State Water Resources Control Board announced a plan to require PFAS monitoring at hundreds of suspected release sites around the state, including manufacturing facilities, airports, landfills, refineries, wastewater treatment plants, and urban wildfire areas. The results of this monitoring should increase our understanding of the extent and sources of PFASs in California groundwater. When the state of Michigan carried out a similar testing program in 2018, it identified dozens of previously unknown PFAS contamination sites.

California's Division of Drinking Water has established notification levels of 13 ng/L and 14 ng/L, respectively, for PFOS and PFOA, and a response level of 70 ng/L for each individual compound of the sum of both.

5.10.4 Management considerations for PFASs

Under aerobic conditions, PFAA-precursors can undergo biotic transformation reactions to form PFAAs. Thus, if PFAA-precursors are present, management actions that introduce oxygen to an aquifer may have the unintended effect of increasing PFAA concentrations. Examples of such actions include remedial activities designed to treat contaminants other than PFASs, such as biosparging or in-situ chemical oxidation.

Recycled water is a potential source of PFASs in receiving aquifers. Given the decreasing trend in PFAS regulatory values, water managers should consider monitoring for PFASs before implementing aquifer recharge with recycled water.

Glossary

Analytes: substances being measured

Anoxic: Condition with low concentrations of dissolved oxygen

Anthropogenic: Man-made

Aqueous: Dissolved in water

Calcareous: rich in calcium carbonate

Cation: positively charged substance

Competitive ion: an ion (or charged substance) that behaves similar to another ion. Because they behave similarly, they

Desorption: The process of a substance adsorbed to a particle surface being released into the surrounding water

Felsic: describes type of volcanic rock that is rich in minerals like feldspar and quartz

Geogenic: naturally occurring in rocks

Mafic: describes a type of volcanic rock that is rich in magnesium and iron

Mobility: ability of a substance to move or be transported with water

Nonpoint source: contamination resulting from a diffuse source

Oxidant: a substance which causes the oxidation of another substance

Oxidation: the process of losing electrons or increasing oxidation state

Oxidation reduction potential: a measure of redox conditions

Oxidation state: a measure of the number of electrons a substance has gained or lost relative to its native state

Oxyanion: negatively charged substance

pH: a measure of the acidity of water

Point source: contamination resulting from a single, specific source (e.g., a leaking waste container)

Redox: chemistry related to the gain or loss of electrons also called the reduction or oxidation of substances

Reductant: a substance which causes the reduction of another substance

Reduction: the process of gaining electrons or decreasing oxidation state

Sediment: sediments are materials consisting of rocks and minerals, and remains of plants and animals; they are moved to new locations and deposited by water, ice, or wind

Sedimentary: describes rocks formed by deposition of other rocks

Shale: a fine-grained, sedimentary rock that forms when silt and clay-size mineral particles compact

Soil: unlike sediments, soil weathers in place and requires time and a stable ground surface to develop. It is a mixture of organic material, rock and mineral particles

Solubility: ability to dissolve in water

Sorption: the process of a substance adsorbing to a particle surface

Specie: a chemical substance or entity such as an atom, ion, or molecule

Ultramafic: describes a type of volcanic rock with very low silica content

Unsaturated zone: zone of an aquifer above the water table

Acknowledgements

Thank you to the following reviewers for providing valuable feedback during the preparation of this document. The views expressed in this document are those of the authors and do not necessarily represent the views of the individuals and organizations listed.

Andrew Ayres, Environmental Defense Fund

Letty Belin, Water in the West, Stanford University

Karen Burow, United States Geological Survey

Jason Dadakis, Orange County Water District

Katherine Dlubac, State Water Resources Control Board

Ana Lucia Garcia Briones, Environmental Defense Fund

Melissa Rohde, The Nature Conservancy

Arturo Keller, University of California, Santa Barbara

Maurice Hall, Environmental Defense Fund

Thomas Harter, University of California, Davis

Christopher Higgins, Colorado School of Mines

Lisa Hunt, American Rivers

Ronna Kelly, Environmental Defense Fund

Aysha Massell, American Rivers

Deborah Ores, Community Water Center

Andrew Renshaw, State Water Resources Control Board

Endnotes

1 SWRCB's Nitrate Project https://www.waterboards.ca.gov/water_issues/programs/nitrate_project/

2 CV-SALTS https://www.cvsalinity.org/

3 SWRCB's Irrigated Lands Regulatory Program (ILRP) https://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/

4 Sustainable Conservation's Nutrient Management Field Guide https://suscon.org/pdfs/dairies/pdfs/NMFieldGuideFinal.pdf

5 For certain contaminants, the SWRCB has contaminant-specific thresholds for which it is recommended to notify users. The response level refers to a concentration threshold greater than the notification level where the SWRCB recommends the water source be taken out of service. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/NotificationLevels.html

6 USGS 'An Excel Workbook for Identifying Redox Processes in Ground Water' https://pubs.usgs.gov/of/2009/1004/

7 USGS Report "Factors affecting public-supply-well vulnerability to contamination: understanding observed water quality and anticipating future water quality" https://pubs.usgs.gov/circ/1385/pdf/Cir1385.pdf

8 Community Water Center and Stanford's "Groundwater Quality in the Sustainable Groundwater Management Act: Scientific Factsheet on Arsenic, Uranium, and Chromium" https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1560371896/CWC_FS_GrndwtrQual_06.03.19a.pdf?1560371896

9 Community Water Center's "Guide to Protecting Drinking Water Quality Under the Sustainable Groundwater Management Act" https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1559328858/Guide_to_Protecting_Drinking_Water_Quality_Under_the_Sustainable_Groundwater_Management_Act.pdf?1559328858

10 DWR's Best Management Practices 1 'Monitoring Protocols Standards and Sites' https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-1-Monitoring-Protocols-Standards-and-Sites.pdf

11 DWR's Best Management Practices 2 'Monitoring Networks and Identification of Data Gaps' https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-2-Monitoring-Networks-and-Identification-of-Data-Gaps.pdf

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(212) 505-2100

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EXHIBIT J

ground water

Case Study/

Effects of Groundwater Development on Uranium: Central Valley, California, USA

by Bryant C. Jurgens[1,2], Miranda S. Fram[2], Kenneth Belitz[3], Karen R. Burow[2], and Matthew K. Landon[3]

Abstract

Uranium (U) concentrations in groundwater in several parts of the eastern San Joaquin Valley, California, have exceeded federal and state drinking water standards during the last 20 years. The San Joaquin Valley is located within the Central Valley of California and is one of the most productive agricultural areas in the world. Increased irrigation and pumping associated with agricultural and urban development during the last 100 years have changed the chemistry and magnitude of groundwater recharge, and increased the rate of downward groundwater movement. Strong correlations between U and bicarbonate suggest that U is leached from shallow sediments by high bicarbonate water, consistent with findings of previous work in Modesto, California. Summer irrigation of crops in agricultural areas and, to lesser extent, of landscape plants and grasses in urban areas, has increased Pco_2 concentrations in the soil zone and caused higher temperature and salinity of groundwater recharge. Coupled with groundwater pumping, this process, as evidenced by increasing bicarbonate concentrations in groundwater over the last 100 years, has caused shallow, young groundwater with high U concentrations to migrate to deeper parts of the groundwater system that are tapped by public-supply wells. Continued downward migration of U-affected groundwater and expansion of urban centers into agricultural areas will likely be associated with increased U concentrations in public-supply wells. The results from this study illustrate the potential long-term effects of groundwater development and irrigation-supported agriculture on water quality in arid and semiarid regions around the world.

Introduction

The Central Valley is one of the most productive agricultural regions in the world, with a cash value of more than $20 billion in 2007 (U.S. Department of Agriculture 2007). Seven counties within the Central Valley are among the top 10 counties in the United States for agricultural products sold (U.S. Department of Agriculture 2007). Nearly two-thirds of all groundwater withdrawals in California occur in the Central Valley, primarily for agricultural irrigation (Hutson et al. 2004; Maupin and Barber 2005). The San Joaquin Valley makes up the southern two-thirds of the Central Valley, and most of the population and associated municipal or public groundwater use is in the eastern San Joaquin Valley (ESJV). Reliance on groundwater as a source of drinking water in the ESJV is expected to increase with rapid population growth and diminishing availability of surface water supplies.

Uranium (U) concentrations above the California Maximum Contaminant Level (CA-MCL) of 20 picocuries per liter (pCi/L)—approximately equivalent to the U.S. Environmental Protection Agency Maximum Contaminant Level (U.S. EPA MCL) of 30 micrograms per liter (µg/L)—has led to the removal of at least 23 public-supply wells (PSWs) from service within the last 20 years in the ESJV (based on data from the California

[1]Corresponding author: U.S. Geological Survey, California Water Science Center, 6000 J St Placer Hall, Sacramento, CA 95819; bjurgens@usgs.gov

[2]U.S. Geological Survey, California Water Science Center, 6000 J St Placer Hall, Sacramento, CA 95819.

[3]U.S. Geological Survey, California Water Science Center, 4165 Spruance Road, Ste 200, San Diego, CA 92101.

Received May 2009, accepted August 2009.

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doi: 10.1111/j.1745-6584.2009.00635.x

Department of Public Health [CDPH] Database, accessed September 2008). Groundwater from several other wells affected by high U is either blended with water containing low U or removed by ion exchange to meet regulatory requirements (Ashton 2006).

Previous studies have shown that anthropogenically introduced contaminants, such as pesticides and nitrate, have degraded the quality of groundwater within the ESJV (Nightingale 1972; Schmidt and Sherman 1987; Domagalski 1997; Burow et al. 2008; Wright et al. 2004). The spatial distribution of these contaminants in groundwater is linked to patterns of fertilizer and pesticide use and their rate of application at the surface. In contrast to these agricultural contaminants, U is naturally abundant in soils and aquifer sediments in the ESJV and is not linked to the application of fertilizers or pesticides (Jurgens et al. 2008).

Uranium is mobile in oxygenated groundwater and generally only forms stable minerals in sulfate-reducing environments; formation of stable U minerals in oxic environments requires very high concentrations of U (greater than 1000 µg/L). Uranium in oxic groundwater has a valence of +6 [U(VI)] and will form the oxycation uranyl (UO_2^{+2}) in the absence of complexing ions, such as dissolved inorganic carbon (DIC) (Langmuir 1978). The aqueous concentration of U(VI) is normally limited by uranyl adsorption to iron oxyhydroxide coatings on sediment grains, clay mineral edges, or to organic matter (Hsi and Langmuir 1985; Waite et al. 1994; Davis and Curtis 2004; Catalano and Brown 2005). However, the presence of complexing ions, particularly DIC species, can increase the solubility and mobility of U(VI) (Langmuir 1978; Hsi and Langmuir 1985; Waite et al. 1994; Davis and Curtis 2004). Recent work has also shown that calcium can enhance desorption of uranyl-carbonate ternary complexes (Fox et al. 2006) and that the calcium-uranyl-carbonate complex, $Ca_2UO_2(CO_3)_3^0$, may be the dominate species of dissolved U(VI) in calcium-rich groundwater systems (Bernhard et al. 2001).

Plant root respiration and microbial oxidation of organic matter in soils produce carbon dioxide (CO_2), resulting in CO_2 partial pressures (Pco_2) in the soil zone that are greater than atmospheric pressure (Russell 1973). Water percolating through the soil equilibrates with the soil atmosphere by dissolving $CO_2(g)$ to form carbonic acid. The carbonic acid participates in mineral weathering reactions that increase DIC concentrations in water, primarily in the form of bicarbonate. Soil calcite will also dissolve under high Pco_2 pressures and therefore can be an added source of DIC to water (Appelo and Postma 1996). Water that is not taken up by plants or evaporated from the soil eventually percolates to the groundwater system as recharge. ESJV climate is characterized by cool, wet winters and hot, dry summers; thus, under natural conditions, biological productivity is limited by the lack of soil moisture during the summer season. During the last 100 years, the ESJV has been extensively developed for agricultural use, and increasingly for urban use. Warm-season irrigation (March through September) of agricultural crops and urban landscapes has greatly increased biological productivity. It is our hypothesis that increased soil zone Pco_2 beneath irrigated lands has resulted in increased bicarbonate concentrations in groundwater, and that this bicarbonate has enhanced the mobility of U.

In addition, the application of surface water and groundwater for agricultural irrigation and pumping from deep parts of the aquifer for irrigation and public supply has increased the rate of downward groundwater flow (Williamson et al. 1989; Phillips et al. 2007). The vertical movement of water from the water table to deeper parts of the groundwater flow system has increased by more than sixfold in many parts of the valley since development and caused head gradients to be in a downward direction almost everywhere (Williamson et al. 1989). It is also our hypothesis that these changes in groundwater flow patterns have caused U concentrations to increase in many PSWs throughout the ESJV.

Because the developed portion of the ESJV aquifer system is largely oxic, uranium is expected to remain mobile in groundwater and therefore poses a significant threat to the long-term sustainability of groundwater as a potable source.

This paper describes the likely linkage between the development of groundwater resources in the ESJV since the 1850s and temporal increases in U concentrations in groundwater. Data collected by the U.S. Geological Survey (USGS) for the California Ground Water Ambient Monitoring and Assessment program Priority Basin Project (USGS-GAMA), data previously collected by the USGS National Water Quality Assessment (NAWQA) program and other USGS studies (USGS historical), and data compiled by the CDPH are used to demonstrate that high U concentrations are associated with shallow, modern-age groundwater that has high concentrations of bicarbonate. We show that bicarbonate concentrations in ESJV groundwater have increased with time and that bicarbonate is likely associated with warm-season irrigation return water. Finally, we show that U concentrations in the deeper portions of the aquifer system tapped by PSWs are increasingly affected by shallow U-laden groundwater that is driven downward in response to pumping. The paper also shows that irrigation and development of lands for agricultural and urban uses can mobilize inorganic contaminants that may otherwise be sequestered under natural conditions. The results of this paper therefore illustrate the potential long-term effects of groundwater development and irrigation-supported agriculture on water quality in arid and semiarid regions around the world.

Description of Study Area

The study area is the eastern half of the San Joaquin Valley, which occupies the southern two-thirds of the Central Valley of California (Figure 1). The Central Valley is a large, northwest-trending, asymmetric structural trough

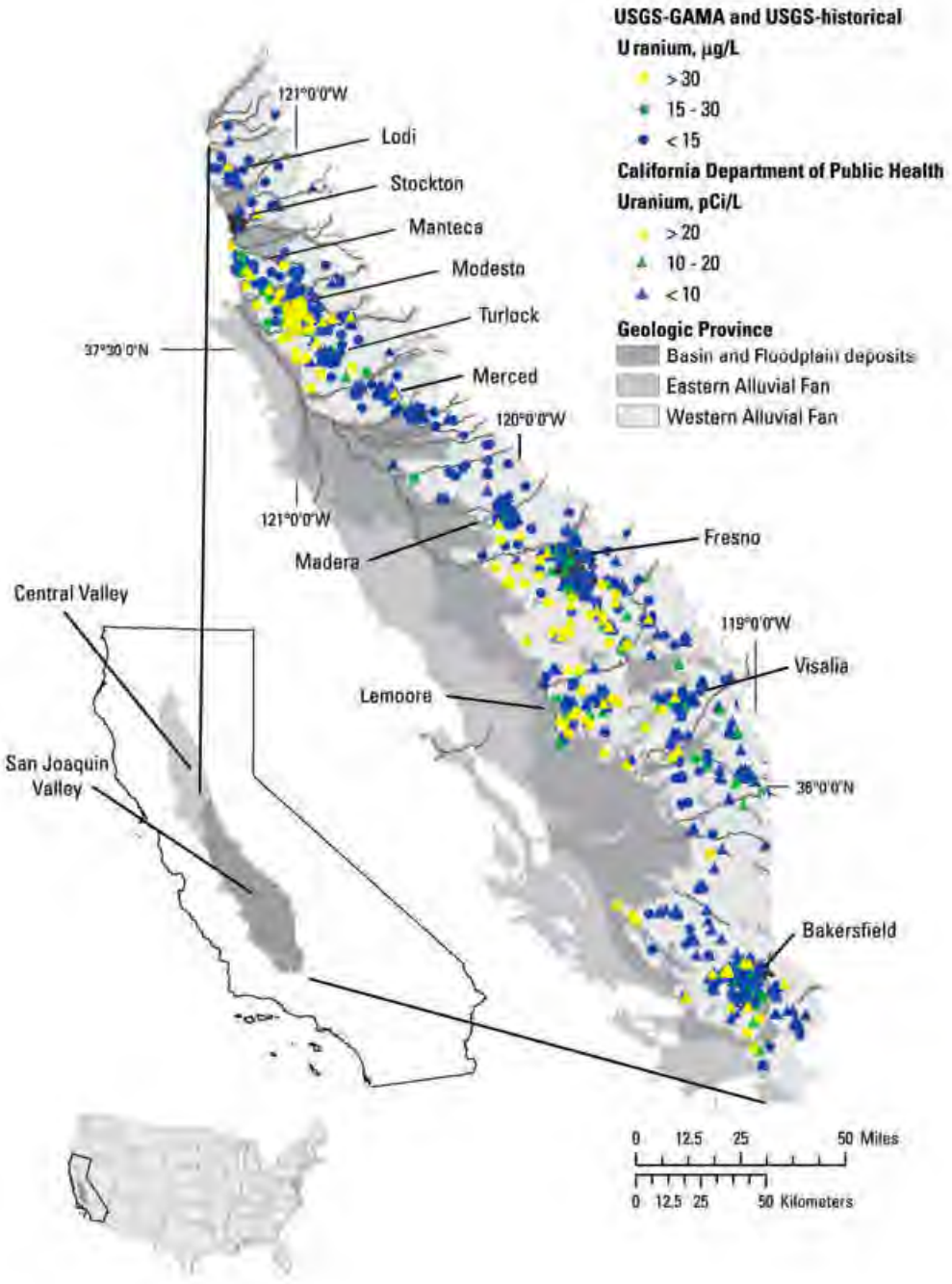


Figure 1. Location, physiographic features, and concentration of uranium in groundwater in the eastern San Joaquin Valley, California.

filled with marine and continental sediments up to 6 miles (mi) thick (Page 1986). The San Joaquin Valley is more than 248 mi long and 19 to 56 mi wide. East of the valley, the Sierra Nevada rise to an altitude of more than 8000 feet; west of the valley, the Coast Ranges form a series of parallel ridges up to 5000 feet high (Gronberg et al. 1998). Streams in the northern part of the San Joaquin Valley drain northward through the San Joaquin River to the San Francisco Bay; the southern part of the valley is a hydrologically closed basin.

Land-surface elevation rises from near sea level along the axial trough in the center of the valley to more than 300 feet at the top of dissected older alluvium near the valley margins. The climate is arid-to-semiarid, characterized by cool, wet winters and hot, dry summers. Mean annual precipitation ranges from less than 5 inches in the south to about 16 inches in the north (Gronberg et al. 1998).

Hydrogeology

Most groundwater withdrawals in the ESJV are from the upper 1000 feet of the basin-fill deposits. This part of the aquifer system mainly comprises a series of overlapping, stacked alluvial fan sequences deposited by streams draining the Sierra Nevada during the Holocene, Pleistocene, and Pliocene (Page 1986; Bartow 1991;

Weissmann et al. 2005). These unconsolidated to semiconsolidated deposits are primarily derived from granitic rocks of the Sierra Nevada, with minor contributions from metavolcanic and metasedimentary rocks of the foothills (Page 1986; Bartow 1991). Beneath these sediments, Miocene and Pliocene deposits of andesitic volcanic detritus occur in areas draining the central and northern parts of the Sierra Nevada (Burow et al. 2004).

The aquifer system can be generally described as an unconfined to semiconfined aquifer underlain by a confined aquifer, particularly where separated by a regional lacustrine clay unit commonly referred to as the Corcoran Clay (Williamson et al. 1989; Bertoldi et al. 1991). Aquifer materials are dominated by eastern and western alluvial fan deposits interspersed with fine-grained basin and floodplain deposits, and coarser-grained fluvial deposits (Figure 1).

Predevelopment Groundwater Flow

A numerical model of the predevelopment (prior to about 1850) groundwater flow system in the Central Valley suggests that recharge and discharge averaged about 2 million acre-feet/year (Williamson et al. 1989). The groundwater system was recharged primarily by streams entering the valley near the mountain fronts, and to a lesser extent by precipitation. Groundwater generally moved from areas of recharge along the valley margins toward the central low-lying areas in the basin, where artesian conditions were common. Groundwater in the northern half of the ESJV discharged to the San Joaquin River and surrounding marshlands, whereas groundwater in the southern half discharged to perennial lakes in closed basins.

Postdevelopment Groundwater Flow

Since 1850, diversion of surface water from streams and intensive groundwater pumping associated with agricultural irrigation and urban growth have significantly altered the natural flow system (Davis et al. 1959; Page and Balding 1973; Londquist 1981; Williamson et al. 1989). Development of the groundwater resource accelerated after about 1930 due to improvements to the turbine pump, which allowed farmers to pump groundwater from greater depths at greater rates (Williamson et al. 1989). Currently, percolating irrigation water is the primary form of groundwater recharge, and pumping is the primary form of groundwater discharge (Faunt 2009). Recharge and discharge are now approximately 12 million acre-feet/year (Faunt 2009).

The application of irrigation water and pumping from deep parts of the groundwater system have caused increased downward movement of groundwater. Williamson et al. (1989) simulated the predevelopment and postdevelopment groundwater flow system and found that vertical flow had increased by more than six times in many parts of the valley. In addition, repeated irrigation and pumping cycles can cause water moving laterally along the regional groundwater flow direction to be pumped and reapplied at the surface multiple times (Burow et al. 2004).

The widespread use of groundwater has caused water level declines in many parts of the valley and has greatly reduced the extent of artesian conditions. The depth-to-water table varies east-to-west and north-to-south. In the northern half of the valley, depth-to-water can be more than 60 feet near the valley margins in the east and less than 10 feet near the axial trough in the center of the basin. In the southern half of the valley, depth-to-water can be greater than 150 feet near the valley margins and less than 60 feet near the center of the basin (Faunt 2009). In urban areas, focused groundwater pumping and relatively low recharge rates have caused water level depressions within many cities in the valley (Bertoldi et al. 1991).

Methods

Description of Well Networks and Datasets

Between December 2004 and June 2008, 120 wells were sampled for U in the ESJV as part of the Priority Basin Project of the California Ground Water Ambient Monitoring and Assessment (GAMA) program (Bennett et al. 2006; Landon and Belitz 2008; Shelton et al. 2008, 2009; Burton et al. 2008). GAMA's Priority Basin Project is a statewide assessment of water quality in groundwater resources used for public supply in California (Belitz et al. 2003). The project is administered by the California State Water Resources Control Board and the USGS is the project's technical lead. Groundwater samples, primarily from PSWs, were collected for the GAMA program to assess groundwater quality in the ESJV. Samples for major ions, nitrate, and trace elements, including U, were collected from 120 wells. Additional wells were sampled by the GAMA program but were not analyzed for U. Tritium (^{3}H) and dissolved noble gas samples were analyzed from 83 of the 120 wells and carbon-14 (^{14}C) was collected from 88 wells. This dataset is referred to as USGS-GAMA.

Additional chemistry data were compiled from previous and ongoing USGS investigations in the ESJV, including the San Joaquin-Tulare Basin NAWQA program (Dubrovsky et al. 1998; Burow et al. 1998, 2008), the NAWQA Transport of Anthropogenic and Natural Contaminants project (Jurgens et al. 2008), and the San Joaquin Valley Drainage program (Fujii and Swain 1995). Combined, these sources provided data from 230 wells analyzed for major ions and trace elements since 1989 in the study area; these data are publically available in the USGS National Water Information System (NWIS) database (http://waterdata.usgs.gov/ca/nwis/). The median U concentration was used for wells that had more than one analysis. A subset of the wells also had tritium data. This dataset is referred to as USGS historical.

The CDPH maintains a database of water quality data collected from public-supply sources for regulatory purposes. The database contains U data for 941 wells sampled between 1986 and 2006. The maximum U

concentration from each well was used to describe the occurrence and distribution of high U in PSWs in the ESJV. Most of these wells were sampled for U more than once. Because U was not widely collected from wells between 1986 and 1990 (less than 10% of the total number of wells), recent U trends were examined with U data beginning on January 1, 1990, and ending on December 31, 2005 (16 years).

Sample Collection and Analysis

USGS-GAMA data were collected in accordance with the protocols established by the USGS NAWQA program (Koterba et al. 1995) and the USGS National Field Manual (USGS, variously dated). These sampling protocols ensure that a representative sample of the raw groundwater resource is collected from each well and that samples are collected and handled in a way that minimizes the potential for contamination. All public-supply well samples were collected at discharge points upstream of any chlorination or well-head treatment systems. Detailed descriptions of sample collection procedures, analytical methods, and quality-assurance results, and compilations of data can be found in Bennett et al. (2006); Burton et al. (2008); Landon and Belitz (2008); and Shelton et al. (2008, 2009). Historical chemistry data from other USGS investigations in the ESJV were collected and analyzed using the same or similar methods.

Samples for major ions, nitrate, uranium, and other trace elements were analyzed at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Carbon-14 was analyzed at the University of Waterloo and IsoTrace Laboratory (Ontario, Canada) by accelerated mass spectrometry. The activity of ^{14}C—expressed as percent modern carbon (pmc)—is reported with a one-sigma estimate of precision relative to the 1950 National Bureau of Standards oxalic acid standard. Samples for the noble gases, neon (Ne), argon (Ar), krypton (Kr), and xenon (Xe), were collected in copper tubes (25-cm-long, 3/8-inch [0.95] diameter) using reinforced nylon tubing connected to a hose bib at the wellhead. Copper tubes were flushed with groundwater and clamped at both ends to seal the sample. Tritium was collected in a 1-L glass bottle with each noble gas sample. Tritium, Ne, Ar, Kr, and Xe were measured at Lawrence Livermore National Laboratory (LLNL). Tritium was determined by the helium in-growth method (Bayer et al. 1989). Helium was analyzed using a VG-5400 noble gas mass spectrometer; dissolved Ne, Kr, and Xe were analyzed using a quadrupole mass spectrometer and argon was measured using a high-sensitivity capacitive manometer (Beyerle et al. 2000; Moore et al. 2006; Cey et al. 2008).

Uranium data reported in the CDPH database were collected for regulatory compliance, and California regulates U activity, rather than U mass concentration. Uranium results from the CDPH database were analyzed using standard radiochemical methods and reported in pCi/L (U.S. Environmental Protection Agency 1980). These data were assumed to be adequate for describing the occurrence, distribution, and trends in U concentrations in those PSWs having U analyses. The mass to activity conversion factor in groundwater depends on the activity of each U isotope, particularly the ratio of ^{234}U to ^{238}U. Because the U activity ratio (UAR) of ^{234}U to ^{238}U is not constant in groundwater, the mass to activity conversion factor varies. Therefore, U reported in activity units by the CDPH was not compared directly with U results reported in mass units by the USGS.

Nonparametric, rank-based methods were used for statistical analysis because the data were not normally distributed. The significance level (α) used for hypothesis testing was 5% ($\alpha = 0.05$). Correlations were investigated using Spearman's method to calculate the rank-order correlation coefficient (ρ, rho) between continuous variables. The Kruskal-Wallis rank sum test was used to test differences among groups (Conover 1980). If the Kruskal-Wallis rank sum test indicated a significant difference in more than two groups, the multiple stage Kruskal-Wallis test was used to determine whether a significant difference exists between successive groups (Helsel and Hirsch 2002). The significance level used for the multiple stage Kruskal-Wallis test was $\alpha_p = 0.025$. The signed-rank test was used to evaluate the differences in matched pairs of data.

Reduction/oxidation (redox) conditions were evaluated on the basis of dissolved oxygen (DO), nitrate (NO_3^-), manganese (Mn^{2+}), iron (Fe^{2+}), and sulfate (SO_4^{2-}) concentrations using the classification scheme of McMahon and Chapelle (2008). Because redox processes in groundwater tend to segregate into zones dominated by a single electron-accepting process, the redox framework uses the concentration of the redox sensitive species above to assign the predominant redox process to groundwater samples. An automated workbook program was used to assign the redox classification to each sample (Jurgens et al. 2009).

Recharge temperatures for 83 samples were determined from dissolved Ne, Ar, Kr, and Xe using methods described in Aeschbach-Hertig et al. (1999). Only modeled recharge temperatures having a probability greater than 1% were accepted ($P < 0.01$; Aeschbach-Hertig et al. 2000).

Speciation of dissolved U, calculated partial pressure of carbon dioxide (Pco_2), and saturation indices of U minerals and calcite in groundwater were calculated using PHREEQC, version 2.15 (Parkhurst and Appelo 1999). Data for the following species were included in the calculations: calcium, magnesium, sodium, potassium, chloride, alkalinity, sulfate, fluoride, nitrate, phosphate, barium, and strontium. Not all samples had nitrate, phosphate, barium, or strontium data, although more than 90% of the samples had data for each of these constituents. The LLNL thermodynamic database, included with PHREEQC, was modified for speciation calculations. Formation constants for U complexes were updated using thermodynamic data reported by Grenthe et al. (1992), and ternary complexes of uranyl and carbonate with the alkaline earth metals reported by Dong and Brooks (2006)

were added to the database. A two-site surface complexation model (SCM) was developed with the diffuse double layer model (Dzombak and Morel 1990) using PHREEQC. The surface species and formation constants for surface reactions were taken from Waite et al. (1994). The bidentate surface reaction expressions of Waite et al. (1994) were formatted for use with PHREEQC by Payne (1999) so that the mass action equation uses one mole of hydrous ferric oxide while the mole balance equation uses two. Model solutions contained 10^{-5} M U(VI) and aqueous U(VI) concentrations were calculated for pH values ranging from 6.25 to 9.5, the predominant pH range of ESJV groundwater. Moles of iron were estimated from ten 0.5 M HCl-hydroxylamine extractions (Jurgens unpublished data 2008). The average iron concentration was 80 mmol/L and was used to calculate site densities. The site densities were those of Waite et al. (1994): 0.8732 moles of weak sites per mole of iron and 0.0018 moles of strong sites per mole of iron. Three models were created for varying concentrations of total DIC: $10^{-3.0}$, $10^{-2.5}$, and $10^{-2.0}$ M. Each of these models had two forms: one without calcium and one with calcium at 1.2475 mmol/L (50 mg/L), a typical concentration in ESJV groundwater.

Land use was classified using an "enhanced" version of the satellite-derived (30-m pixel resolution), nationwide USGS National Land Cover Dataset (Vogelmann et al. 2001; Price et al. 2003). This dataset has been used in previous national and regional studies relating land use to water quality (Gilliom et al. 2006; Zogorski et al. 2006). The data represent land use during approximately the early 1990s. The imagery is classified into 25 land-cover classifications (Nakagaki and Wolock 2005). These 25 land-cover classifications were further classified into three principal land-use categories: urban, agricultural, and natural. Land-use statistics for circles with a radius of 500 m around each well were calculated for classified datasets using ArcGIS (version 9.2) (Johnson and Belitz 2009). Wells were then categorized by dominant land use. Mixed use was assigned where neither agricultural, urban, or natural land uses comprised more than 50% of the land surrounding the well.

Results and Discussion

Spatial Distribution of Uranium in Groundwater

Groundwater with high U content has been found throughout the ESJV (Figure 1). U concentrations for the 350 wells from the USGS-GAMA and USGS-historical datasets range from less than the detection limit (0.04) to 2,500 µg/L (Table 1). Approximately 19% of the wells (65 of 350) had a concentration greater than the US-MCL of 30 µg/L, and an additional 12% of the wells had U concentrations greater than one-half of the US-MCL.

PSWs from the CDPH database are not uniformly distributed across the ESJV and tend to be clustered in urban areas and along major transportation corridors (Figure 1). Approximately 11% (103 of 941) of the PSWs had at least one U analysis greater than the CA-MCL of 20 pCi/L, and an additional 5% of the wells had at least one U analysis greater than one-half of the CA-MCL. U concentrations ranged from less than the detection limit (1) to 102 pCi/L. Of the 941 CDPH wells, 848 wells remained active as of 2006. Twenty-three of the 93 inactive wells were abandoned because of high U concentrations.

Most of the U values greater than the CA-MCL in the CDPH dataset were in PSWs near Modesto, Fresno, and Bakersfield, major population centers in the ESJV. However, because the density of PSWs was also greatest in these areas, the clustering of high U values may reflect increased sample density. The USGS-GAMA and USGS-historical datasets show a wider distribution of wells with U concentrations above the US-MCL. USGS-GAMA wells were selected using a spatially distributed, randomized method (Scott 1990) to provide a statistically robust representation of the areal extent of the portion of the ESJV aquifer system used for public supply. The USGS-historical dataset was dominated by domestic and monitoring wells, which generally have perforation intervals in shallower portions of the aquifer than do PSWs. For example, the cluster of wells near Lemoore primarily includes monitoring and domestic wells. The USGS-GAMA and USGS-historical datasets therefore represent a larger portion of the aquifer system than the CDPH dataset, and show that groundwater with high U concentrations is indeed widespread in the ESJV.

The occurrence of groundwater with high U concentrations appears to be significantly greater in the ESJV than in other areas of the United States. In a recent survey of domestic wells in the United States (Focazio et al. 2006), U concentrations above 30 µg/L (US-MCL) were found in less than 4% of the wells (note that domestic wells are not subject to regulation). In contrast, 25% of the domestic wells in USGS-historical and USGS-GAMA datasets in the ESJV had U concentrations above the US-MCL.

High concentrations of U may not be as widespread as nitrate is in ESJV groundwater, which is above the US-MCL (10 mg/L as N) in 32% of domestic wells and 24% of all the wells in the USGS datasets. However, the percentage of wells affected by high U approaches that of nitrate and indicates that U does pose a significant threat to the continued operation of many PSWs in the ESJV.

Relation of Uranium Concentrations to Depth below Water Table and Age Tracers

The USGS-GAMA and USGS-historical datasets include well construction information and can therefore be used to estimate the vertical distribution of U within the aquifer system. Monitoring wells had the highest U concentrations, highest percentage of wells above the US-MCL, and the shallowest depths below the water table (Figure 2; Table 1). These wells are typically screened over short intervals (less than 5 feet) and provide water quality at discrete points in the aquifer system. Domestic wells, which tend to be located in rural areas, also had a high percentage of wells with U greater than 30 µg/L, but a lower median U concentration and greater depth

Table 1
Summary of Uranium Concentrations in Groundwater from Different Well Types in Eastern San Joaquin Valley, California; U.S. Geological Survey National Water Information System (NWIS)

Well Type	Number of Wells with U Analysis	Uranium (µg/L)			Number of Wells with U > 30 µg/L	Range in Depth below Water Table to Top of Uppermost Perforated Interval (feet)	Median Screen Length
		Minimum	Median	Maximum			
Observation	98	0.09	18.0	2500	31 (32%)	0.66–307 [55]	5
Domestic	122	0.04	8.7	503	30 (25%)	9.6–454 [82]	20.5
Public supply	121	0.04	1.8	41.3	3 (2.5%)	7.0–917 [140]	211
Irrigation	9	0.20	7.8	91.9	1 (11%)	42–557 [160]	175
All USGS data[1]	350	0.04	6.7	2500	65 (19%)	0.66–917 [98]	50

Notes: Percent of wells in parentheses. Median in brackets. [1]Uranium was not detected in six wells.

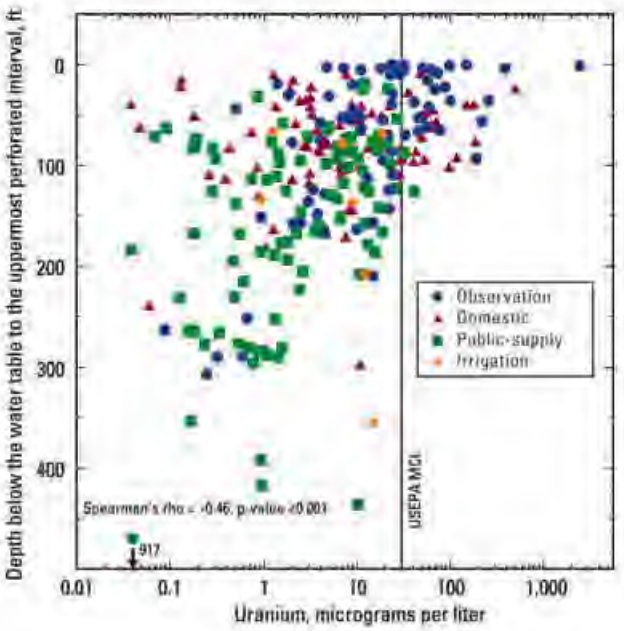


Figure 2. Relation between uranium in groundwater and depth below the water table to the uppermost perforated interval among well types in the eastern San Joaquin Valley, California.

below the water table than monitoring wells. PSWs had the lowest median U concentration. These wells tend to be located within urban areas, are perforated at deeper depths than monitoring and domestic wells, and generally have long screens (greater than 50 feet). PSWs in the ESJV typically withdraw water at rates between 200 and 2,500 gpm, much greater than those for domestic wells. Irrigation wells had the greatest depth below the water table of all the wells, but had higher U concentrations than PSWs. However, only nine irrigation wells were sampled for U in this study, and therefore may not accurately represent U concentrations in irrigation wells throughout the ESJV.

Uranium concentrations were significantly correlated to depth below the water table with the highest concentrations near the water table and decreasing with depth (Figure 2; Spearman's rho $= -0.46$, P-value < 0.001). Groundwater having U above 30 µg/L occurred in wells having perforated intervals beginning less than 150 feet below the water table, and most groundwater above 10 µg/L occurred in wells with perforated intervals starting less than 200 feet below the water table. Groundwater from less than 200 feet below the water table had a median U concentration of 8.4 µg/L; that from greater than 200 feet had a median U concentration of 0.73 µg/L.

Uranium concentrations also were significantly higher in wells with ^{3}H concentrations greater than 1 tritium unit (TU) and ^{14}C greater than 90 pmc (Kruskal-Wallis test; P-value < 0.001; Figure 3). ^{3}H activities greater than 1 TU indicate the presence of groundwater recharged after 1950 and ^{14}C activities greater than 90 pmc indicate the likely absence of groundwater with residence times greater than about 1,000 years. Together, these two age-dating criteria identify "modern" groundwater, that is, groundwater that was recharged since large-scale agricultural and urban development began in the ESJV. The median U concentration in groundwater samples with ^{3}H greater than 1 TU was 9.0 µg/L, compared with 0.60 µg/L for samples with less than 1 TU. Likewise, the median U concentration in groundwater samples with ^{14}C greater than 90 pmc was 7.2 and 0.93 µg/L for samples with less than 90 pmc. These results indicate that high U concentrations in the ESJV are preferentially associated with modern, shallow groundwater.

Uranium Mobilization

Source of Uranium

Uranium is naturally abundant in sediments in the ESJV, which are derived from granitic rocks of the Sierra Nevada. Aerial gamma-ray surveys of U in the ESJV show that U concentrations in surficial sediments range from 1.22 to 4.20 ppm and average about 3 ppm (Phillips et al. 1993). In contrast, surficial sediments of the conterminous United States have an average U concentration of 1.83 ppm. The average abundance of U in the ESJV is above the 90th percentile of U for surficial sediments of the United States. Because most of the geologic formations used for domestic and public

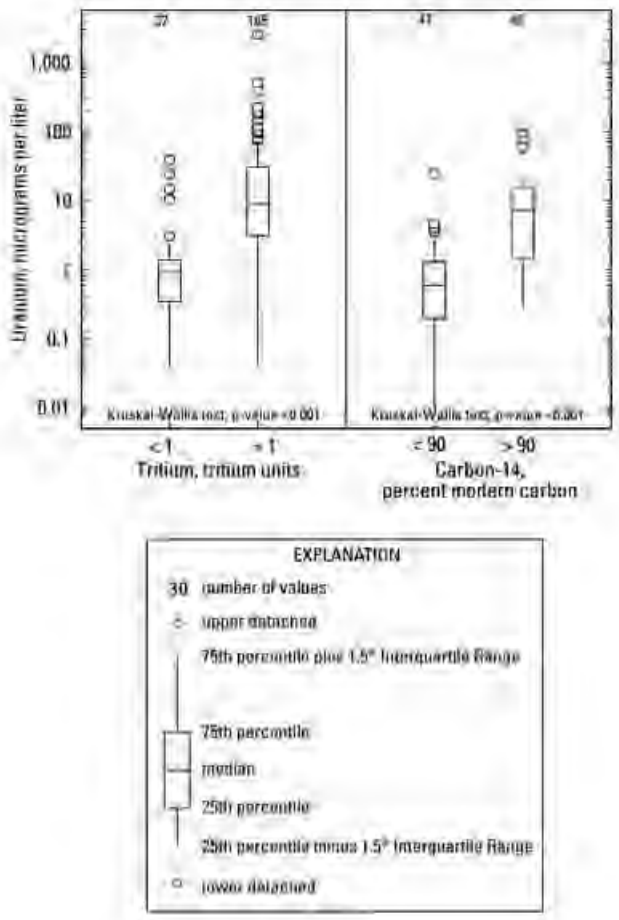


Figure 3. Uranium concentration in samples having tritium less than (<) 1 tritium unit (TU), tritium greater than (>) 1 TU, carbon-14 < 90 percent modern carbon (pmc), and carbon-14 > 90 pmc.

supply are also derived from the granitic rocks of the Sierra Nevada, it is probable that the concentration of U in aquifer sediments is similar to the concentrations in surficial sediments. However, the amount of U that may be easily mobilized is typically only a small fraction of the total U content of the sediment. This fraction is normally adsorbed to mineral surfaces on sediment grains, primarily iron oxide and oxyhydroxide coatings, and the edges of clay minerals (Hsi and Langmuir 1985; Waite et al. 1994; Davis and Curtis 2004; Catalano and Brown 2005).

Jurgens et al. (2008) measured the labile portion of U in sediments from core collected in Modesto (Figure 1). U was extracted from aquifer sediment samples using a 0.1-M sodium bicarbonate solution at a pH of 9.45 (Kohler et al. 2004). The labile portion of U in aquifer sediments ranged from less than 0.02 to 0.11 ppm (mg/kg), although the bulk U composition of the sediments was nearly constant. Leachates from the shallowest sediments (less than 60 feet below land surface [bls]) contained the least U, suggesting that some of the labile U had already been leached out. Leachates from the deepest sediments (greater than 200 feet bls) contained the most U, suggesting that deeper parts of the aquifer had not yet experienced leaching.

More strongly bound U was also extracted from sediments using 10% HNO_3 and ranged from 0.23 to 1.2 mg/kg and increased with depth below land surface (Spearman's rho = 0.75, P-value < 0.03; Jurgens et al. 2008). These results indicate that both the labile and more strongly bound fractions of U of shallow sediments have experienced leaching. Inorganic carbon was undetectable (less than 0.01%) in all sediment samples collected from the aquifer (Jurgens et al. 2008). Although calcite has been shown to host U in its structure (Kelly et al. 2006), the amount of U that could potentially be associated with undetectable levels of calcite in the aquifer would be minor in comparison to fractions associated with the labile and more strongly bound fractions.

Jurgens et al. (2008) also evaluated the potential for adsorption of U to aquifer sediments under similar pH values and bicarbonate concentrations found at the depths from which the sediment samples were collected. Adsorption experiments for the shallower sediments (less than 180 feet bls) showed no adsorption of U. In contrast, the deeper sediments (greater than 200 feet bls) showed linear type adsorption of U. The difference in adsorption behavior was not likely because of a difference in abundance of adsorption sites for U. Iron oxyhydroxide coatings on mineral grains (the primary location of absorption sites) were dissolved from sediment samples using 0.5 M HCl-hydroxylamine solutions, and the iron concentrations of resulting leachates did not vary systematically with sediment depth or U-adsorption behavior (Jurgens unpublished data 2008). These results suggest that higher U concentrations in shallower groundwater compared with deeper groundwater are because of differences in groundwater geochemistry with depth, not to reduction in the abundance of adsorption sites in the shallow sediments.

Mechanism of Mobilization—the Role of Bicarbonate

Three-hundred and ten of the 350 wells in the USGS-GAMA and USGS-historical datasets had data for DO concentrations; DO data are not compiled by CDPH. Approximately 86% (268 out of 310) of the groundwater samples had DO concentrations above 0.5 mg/L and were classified as oxic in the McMahon and Chapelle (2008) classification system. Median concentrations of DO, NO_3^-, Mn^{2+}, Fe^{2+}, and SO_4^{2-} in ESJV groundwater were 4.5, 4.8, < 0.02, < 0.1, and 22.7 mg/L respectively. Uranium in oxic groundwater had a median concentration of 6.5 µg/L. Uranium was significantly lower in anoxic groundwater (median = 0.93 µg/L; multiple stage Kruskal-Wallis rank sum test, P-value = 0.003). The reduced mobility of U under reducing conditions is likely because of reduction to U(IV) and the low solubility of U(IV) phases. Anoxic conditions occurred in less than 6% of wells and were mostly found in wells located near the basin and floodplain deposits (Figure 1). It is possible that some of the extremely high occurrences of U near the center of the basin was caused by the oxidation of U(IV) minerals as a result of irrigation and groundwater pumping; although past studies have attributed some of the high U occurrences in shallow wells in and near the center of

the basing to evaporative concentration (Fujii and Swain 1995). However, remobilization of U from redox fronts in the system does not appear to cause the vast majority of high U concentrations in groundwater. About 8% of wells had mixed redox conditions, where DO > 0.5 mg/L and manganese or iron was above 50 µg/L. Wells with mixed redox conditions had a wide range of U concentrations (0.04 to 503 µg/L; median = 16.0 µg/L). However, wells in the eastern alluvial fans that represent the bulk of the used groundwater resource in the ESJV were generally oxic.

Dissolved U species in oxic groundwater samples (262 oxic wells had measurable U) were calculated using PHREEQC. More than 85% of the dissolved U in almost all groundwater samples was in the form of ternary complexes of uranyl carbonate with calcium ($Ca_2UO_2(CO_3)_3^0$, $CaUO_2(CO_3)_3^{-2}$) and was primarily in the form of the neutral calcium-uranyl-carbonate complex. Calcium-uranyl-carbonate species comprised less than 50% of the dissolved U in just 2% of the oxic groundwater samples. Phosphate complexes comprised less than 1% in all groundwater samples. Speciation calculations indicate that magnesium-uranyl complexes are present ($MgUO_2(CO_3)_3^{-2}$), but generally comprise about 1% and at most 5% of dissolved U.

Strong correlations between U and bicarbonate (Figure 4; Spearman's rho = 0.74, P-value < 0.001) and U and calcium (Spearman's rho = 0.77, P-value < 0.001) concentrations are consistent with speciation calculations. Although the species is a complex between uranyl and the carbonate anion, the formation of the species is likely between uranyl and any one of the three inorganic carbon ions ($H_2CO_3^{0*}$, HCO_3^-, CO_3^{-2}). The predominant form of DIC species in water is pH dependent. Groundwater from this study had pH values that ranged from 6.7 to 9.7 (median pH = 7.6), and bicarbonate is the principal form of DIC in that pH range (Appelo and Postma 1996).

$$UO_2^{+2} + 2Ca^{+2} + 3HCO_3^- \leftrightarrow Ca_2UO_2(CO_3)_3^0 + 3H^+$$
$$\log K = -0.29 \text{ (modified from Dong and Brooks [2006])}$$

Calcium in groundwater is mostly a result of the dissolution of minerals in the soil zone and partly from the application of soil amendments and fertilizers at the land surface. Calcium is present in all sediments, primarily as plagioclase feldspar, and most soils contain some calcite. In many agricultural parts of the valley, gypsum is often added to irrigated soils to promote infiltration and nitrate fertilizers often contain calcium (Jurgens et al. 2008).

Strong correlations between U and bicarbonate and the results of the U extractions indicate that high concentrations of U in shallow groundwater were at least partially mobilized from adsorption sites from shallow sediments. Adsorption of U to sediments is mainly dependent on pH and the concentration of DIC (Hsi and Langmuir 1985; Waite et al. 1994; Davis et al. 2004). Calculations from

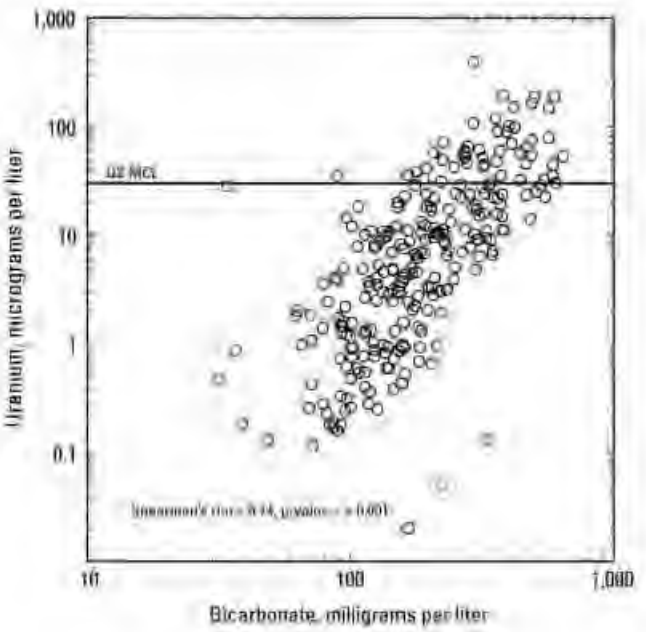


Figure 4. Relation between uranium and bicarbonate in oxic groundwater in the eastern San Joaquin Valley, California.

PHREEQC predict that U(VI) minerals are highly undersaturated in the 262 groundwater samples, suggesting that U concentrations are most likely controlled by adsorption processes. Adsorption of U(VI) is strongest at near circumneutral pH values while high pH values tend to weaken adsorption of U(VI). However, high concentrations of DIC can limit the adsorption of U. In the ESJV, U decreases with increasing pH (Spearman's rho = −0.23, P-value < 0.001; Figure 5). Consequently, U is highest in groundwater with more neutral pH values and higher concentrations of DIC, whereas groundwater with low U tends to have higher pH values and lower concentrations of DIC.

To demonstrate the effect that DIC has on U(VI) adsorption, the SCM of Waite et al. (1994) was used to calculate the dissolved U(VI) concentrations at different total DIC concentrations and pH values observed in groundwater (Figure 5; dashed lines). Dissolved U(VI) was at least an order of magnitude greater in the presence of high concentrations of DIC (0.01 M) than at lower concentrations of DIC (0.001 M). However, the SCM tended to underpredict U(VI) concentrations in groundwater at high concentrations of DIC. Fox et al. (2006) showed that the presence of calcium in solution can also reduce the adsorption of U(VI) to iron oxyhydroxides under conditions that favor the formation of the neutral calcium-uranyl-carbonate complex, $Ca_2UO_2(CO_3)_3^0$. By including a typical calcium concentration (50 mg/L) in each model, the predicted behavior of U(VI) in equilibrium with iron oxyhydroxides is remarkably similar to U and DIC concentrations observed in ESJV groundwater, especially for higher concentrations of U(VI) and DIC (Figure 5;

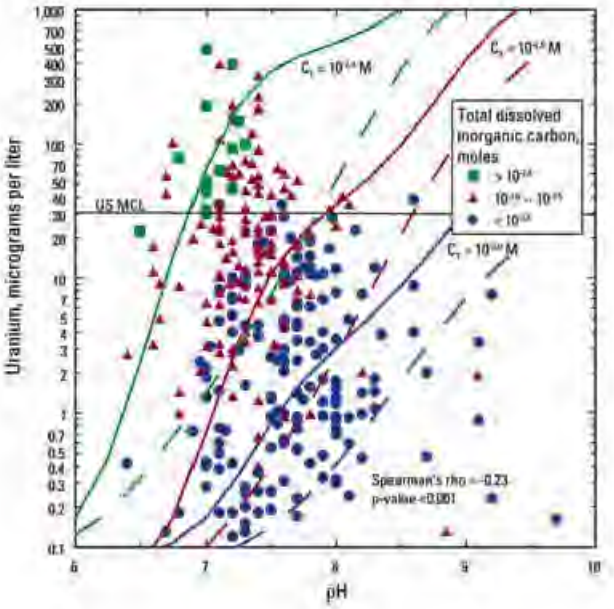


Figure 5. Relation between pH and uranium [U(VI)] in groundwater in the eastern San Joaquin Valley, California. Symbols are colored according to the concentration of total dissolved inorganic carbon (DIC). Dashed lines are equilibrium concentrations of dissolved U(VI) from a surface complexation model (SCM) based on the work of Waite et al. (1994). Solid lines are equilibrium concentrations of U(VI) from the same SCM with a calcium concentration of 1.2475 mmol/L. Each line color represents the equilibrium concentration of U(VI) for different concentrations of total DIC. $T = 25°C$; $I = 0.1$ M; U(VI) total = 0.01 mmol/L; Fe = 80 mmol/L (average concentration of 10 aquifer core samples using 0.5 M HCl-hydroxylamine extraction). Site densities were from Waite et al. (1994): total sites 0.875 moles/mole of Fe; strong sites = 0.0018 moles/mole of Fe; and weak sites = 0.8732 moles/mole of Fe.

solid lines). These results are also consistent with speciation calculations that predict the calcium-uranyl-carbonate species to predominate in ESJV groundwater.

Long-Term Bicarbonate Trends and Relation to Land Use

Comparison between data from Mendenhall et al. (1916) and data from the USGS-GAMA and USGS-historical datasets showed that concentrations of bicarbonate in ESJV groundwater have increased over the last 100 years (Figure 6). In 1910, the median bicarbonate concentration of groundwater in the ESJV was 119 mg/L. The median bicarbonate concentration from this study was 178 mg/L and is statistically greater than concentrations in 1910 (Kruskal-Wallis rank sum test, P-value < 0.001).

Wells from 100 years ago were typically shallower. The median well depth in Mendenhall's dataset was 95 feet compared to 205 feet in this study. Of course, the water table was not as deep 100 years ago as it is in many parts of the valley today. Most wells 100 years ago were probably perforated in shallower parts of the groundwater system than modern wells because of construction limitations and because the yield and quality of groundwater at those depths were sufficient for most purposes (Mendenhall et al. 1916).

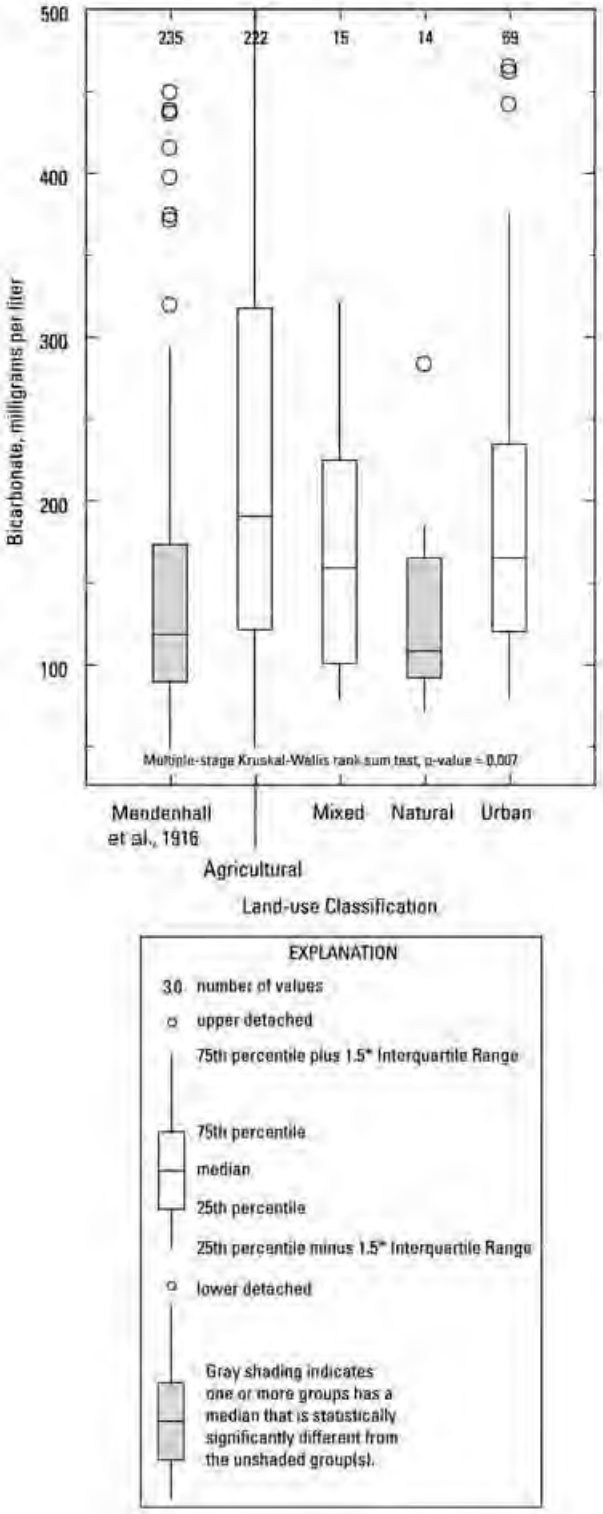


Figure 6. Bicarbonate concentrations in groundwater in 1910 (Mendenhall et al. 1916) and from this study (GAMA + USGS historical [since 1989]) among different land uses surrounding the wells in the eastern San Joaquin Valley, California. The mixed use category was assigned to wells where neither agricultural, urban, or natural land uses were more than 50% of the land surrounding the well.

The increase in bicarbonate concentration over the last 100 years is related to land-use patterns. Bicarbonate concentrations in wells surrounded predominantly

by natural land use (median = 108 mg/L) and in wells sampled in 1910 (median = 119 mg/L) were significantly lower than bicarbonate concentrations in wells surrounded predominantly by agricultural (median = 191 mg/L), urban (median = 166 mg/L), and mixed (median = 160 mg/L) land uses (Figure 6) (multiple stage Kruskal-Wallis rank sum test, P-value < 0.001). Although many of the wells sampled in 1910 were in agricultural areas, large-scale irrigation had not yet been developed, and thus water use on the landscape more closely resembled natural conditions.

Urban areas in the ESJV are typically surrounded by agricultural land, and urban groundwater pumping is areally concentrated. Consequently, bicarbonate concentrations beneath urban areas are likely affected by adjacent agricultural land use, which tends to be associated with higher bicarbonate concentrations.

Connection between Increased Bicarbonate Concentrations and Irrigation

The relations between bicarbonate concentrations, Pco_2, recharge temperature, and depth in groundwater in the ESJV suggest that high bicarbonate concentrations in shallow groundwater are the result of groundwater recharge by water that has percolated through irrigated soils. Pco_2 in the soil zone can range from equal to atmospheric Pco_2 (0.035%) to greater than 100 times atmospheric Pco_2, and is generally positively correlated with soil moisture, soil temperature, and plant growth (e.g., Russell 1973). In arid to semiarid climates, plant growth and microbial decomposition of soil organic matter are generally limited by low soil moisture. Addition of water via precipitation or irrigation results in a rise in biological activity and thus a rise in soil zone Pco_2.

Equilibrium Pco_2 values were calculated from groundwater major ion chemistry and pH data using PHREEQC. Groundwater Pco_2 ranged from 0.1 to 430 times atmospheric Pco_2 and decreased with depth below the water table (Spearman's rho = −0.51, P-value < 0.001; Figure 7). Most groundwater within 50 feet of the water table had Pco_2 pressures greater than 40 times atmospheric Pco_2, indicating that the biological activity within the soil zone has influenced the chemistry of recent recharge.

In addition, Pco_2 pressures were higher in groundwater beneath agricultural land than in groundwater beneath other land uses (multiple stage Kruskal-Wallis rank sum test, P-value < 0.001; Figure 7). The median Pco_2 pressure for groundwater beneath agricultural land was $10^{-2.1}$ atmospheres (atm) or approximately 22 times atmospheric concentrations. The median Pco_2 pressure for groundwater beneath other land uses was $10^{-2.5}$ atm or approximately nine times atmospheric concentrations. pH was not collected in data from Mendenhall et al. (1916), and therefore, Pco_2 pressures could not be directly compared. However, groundwater beneath natural land had similar bicarbonate concentrations to groundwater from 100 years ago and Pco_2 pressures beneath natural land were lowest among all land uses (median = $10^{-3.0}$ or approximately three times atmospheric concentrations). Therefore, the increase in bicarbonate concentrations in shallow groundwater over the last 100 years likely resulted from recharge water having higher Pco_2 pressures as a result of irrigation.

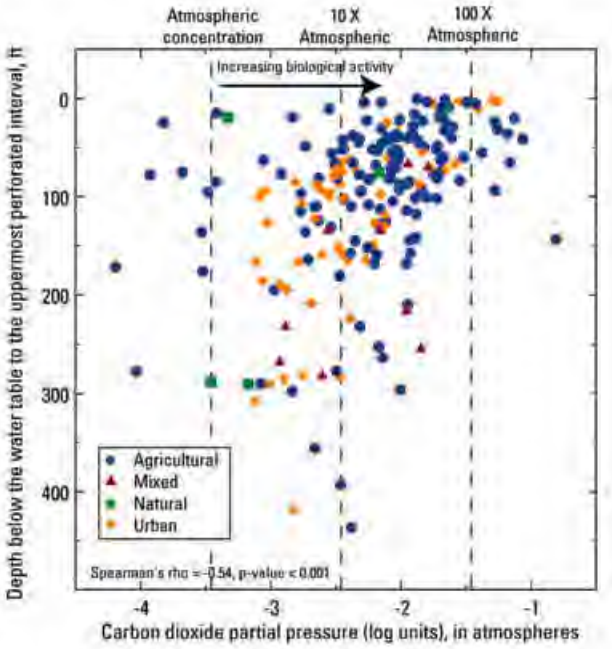


Figure 7. Relation between calculated equilibrium carbon dioxide partial pressures in groundwater and depth below the water table to the uppermost perforated interval in the eastern San Joaquin Valley, California.

Higher Pco_2 pressures can also cause the dissolution of carbonate minerals, namely calcite, within the soil zone (Appelo and Postma 1996). Calcite is present in most soils in the ESJV, but is generally much less than 5% (Schoups et al. 2005) and calcite was below detectable levels (0.01%) in core from Modesto, California (Jurgens et al. 2008). Bicarbonate and calcium (and uranium) were correlated with increasing calcite saturation (log ratio of the ion activity product to the equilibrium solubility constant). Most groundwater with elevated and high concentrations of U (U > 15 µg/L) was saturated with calcite (median = 0.13), whereas groundwater with lower U concentrations (U < 15µg/L) was mostly undersaturated (median = −0.16). The dissolution of calcite under high Pco_2 pressures could give rise to increases in bicarbonate and calcium concentrations with concomitant high calcite saturation in recharge water. Recent research also shows that calcite can accommodate uranyl in its structure and that the occurrence of uranyl in calcite formed in near-surface environments may be more common than previously thought (Kelly et al. 2006). Although the amount of U from soil calcite that would potentially contribute to groundwater is unknown, extraction results and extremely low abundance of calcite in the aquifer sediments suggest that calcite dissolution may not be an important source of

U to groundwater. Furthermore, the results of the extraction experiments indicated that the amount of U mobilized from adsorption sites would likely be sufficient to account for the increase in dissolved U concentrations in groundwater.

Higher recharge temperatures, calculated from dissolved noble gas concentrations, are associated with higher Pco_2pressures (and bicarbonate) in groundwater (Spearman's rho = 0.49, P-value $\leq$ 0.001; Figure 8). Calculated median recharge temperatures were one degree higher (18.8°C) for wells surrounded by agricultural land than for those surrounded by urban, natural, and mixed land (multiple stage Kruskal-Wallis rank sum test, P-value $<$ 0.02). High recharge temperatures and high Pco_2 pressures are consistent with recharge derived from summer irrigation, as would be found in agricultural areas in the ESJV. Under natural conditions, recharge occurred almost entirely during winter months (November through May) and therefore recharge temperatures were likely more influenced by winter air temperatures. Most of the recharge now occurs from the application of irrigation water during the summer months when air temperatures are highest.

Recharge temperatures and Pco_2 pressures were positively correlated to total dissolved solids (TDS) and $\delta^{18}O$. As stated earlier, the acidity derived by the rise in Pco_2 pressures in the soil zone is buffered by the dissolution of minerals (mainly plagioclase), such that the primary products are an increase in pH, formation of bicarbonate, and addition of cations to the residual water. Consequently, higher Pco_2 pressures will tend to lead to increases in these weathering products and in the overall TDS of the water. Calculated Pco_2 pressures (and U) were correlated with all of the major cations in ESJV groundwater. TDS has also increased in the last 100 years. The median TDS in wells from 1910 was 210 mg/L and was 311 mg/L in the USGS-GAMA and USGS-historical dataset (Kruskal-Wallis rank sum test, P-value $<$ 0.001). Correlations with $\delta^{18}O$ also suggest that the increase in bicarbonate concentrations may be partly because of evaporation of irrigation water during the summer growing season; although strong evaporation trends were not evident from stable isotope values.

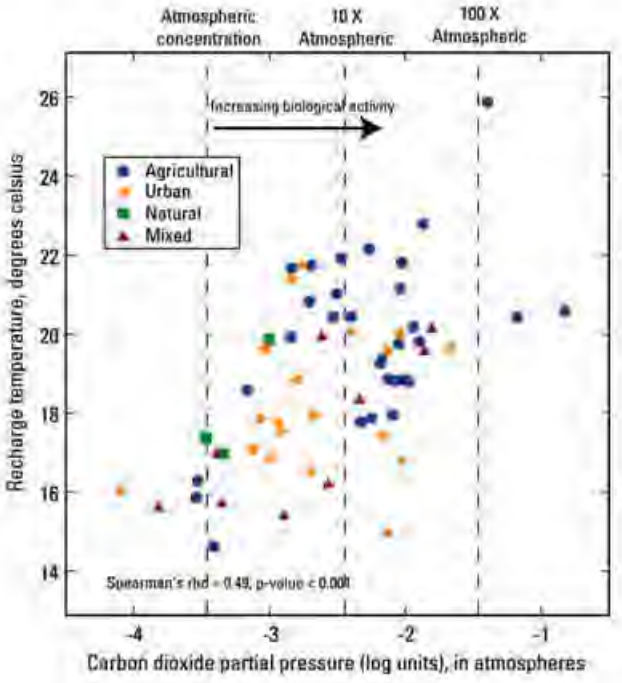


Figure 8. Relation between recharge temperature and the partial pressure of carbon dioxide in groundwater beneath different land-use settings in the eastern San Joaquin Valley, California.

Recent Uranium Trends

Recent U trends in wells from the CDPH database were evaluated using data for wells that were sampled from January 1, 1990, to December 31, 2005. This time period provided an even split in years (8), and similar number of wells analyzed during the two time periods (Table 2). For wells with more than one U analysis, the median activity from each well was used to calculate population statistics. The number of wells having at least one U sample above the CA-MCL of 20 pCi/L increased from 38 for samples collected from 1990 to 1998 to 56 from 1998 to 2006 (Table 2).

U data were available in both time periods for 317 wells. The median activity of U in these wells increased from 4.3 pCi/L between 1990 and 1998 to 5.0 pCi/L between 1998 and 2006 (signed-rank test, P-value $<$ 0.001). The average change in concentration was 1.2

Table 2
Summary of Uranium Concentrations in Groundwater from Public-Supply Wells Sampled between 1990 and 2006 in Eastern San Joaquin Valley, California; California Department of Public Health

		Uranium (pCi/L)			
Uranium Date Range	Number of Wells	Minimum	Median	Maximum	Number of Wells with U > 20 pCi/L
1990–2006	848	<1	3.7	63.9	81 (9.6%)
1990–1998	556	<1	3.6	49.4	38 (6.8%)
1998–2006	610	<1	4.2	102	56 (9.2%)

Note: Percentage of wells in parentheses.

pCi/L. U activity increased by more than 0.2 pCi/L in 53% of the wells, decreased by more than 0.2 pCi/L in 35% of the wells, and changed by less than 0.2 pCi/L in the remaining 12% of wells. These results indicate that U has increased in the majority of PSWs in the ESJV. Bicarbonate concentrations in paired samples also increased for the same time period by about 2.7 mg/L. Wells that had increased U concentrations had a median increase in bicarbonate of 6.3 mg/L, whereas wells that had decreased U concentrations had a median decrease in bicarbonate of 1.6 mg/L. These results indicate that increased U concentrations are accompanied with increased bicarbonate concentrations.

The median U concentration for unpaired samples also increased over the 16-year period (Table 2). The median for these samples increased by 0.6 pCi/L for the time period evaluated.

Conclusions

Development of the groundwater resource since the 1850s has caused two major changes that have resulted in uranium concentrations above drinking water standards in domestic and PSWs in the ESJV: (1) changes in the chemistry of recharge water and (2) increases in the rate of downward groundwater flow.

ESJV sediments have comparatively high concentrations of uranium and a fraction of this uranium is readily leachable by bicarbonate solutions. Uranium is strongly correlated with calcium and bicarbonate, the principal form of DIC in groundwater. Speciation calculations indicate that the primary form of U in oxic groundwater is a calcium-uranyl-carbonate complex. The results of the U extractions and co-occurrence of elevated concentrations of U, bicarbonate, and calcium are consistent with results from the SCM, suggesting that U likely has been leached from adsorption sites on mineral surfaces in sediment. Because bicarbonate concentrations have increased over the last 100 years, it is reasonable to assume that dissolved U has also increased during this period.

The increase in bicarbonate in groundwater over the last 100 years is primarily related to the agricultural development of the ESJV. Bicarbonate concentrations in groundwater have increased in response to an increase in recharge and the growth of crops in agricultural areas and, to lesser extent, the growth of landscape plants and grasses in urban areas. Both recharge and the growth of crops occur mostly during the summer growing season when temperatures are warmest. Consequently, groundwater beneath agricultural land tends to have higher recharge temperatures and higher P_{CO_2} pressures. Ultimately, the increase in bicarbonate concentrations in recharge water has led to the widespread occurrence of high U in shallow groundwater.

Groundwater pumping, primarily from deeper parts of the aquifer system, and increased recharge from the application of irrigation water have increased the downward movement of groundwater. Consequently, constituents that enter the groundwater system at shallow depths are moved downward at a faster rate than would be expected under natural conditions. Shallow high U groundwater has thus moved downward, resulting in increasing U in PSWs. The overall increase in the median U concentration for all wells is small (0.6 pCi/L), but the percentage of wells with at least one U analysis greater than 20 pCi/L (CA-MCL) has increased from 7% to 9% in just 16 years. Continued irrigation and pumping in the ESJV will likely be followed by additional U increases in PSWs.

This paper also shows that irrigation and development of lands for agricultural and urban uses can mobilize inorganic contaminants that may otherwise be sequestered under natural conditions. The results of this paper therefore could have broader implications for other agriculturally based arid and semiarid regions around the world.

Acknowledgments

This work was supported by the California State Water Resources Control Board with help from landowners and water purveyors throughout the San Joaquin Valley. We thank the three anonymous reviewers for their constructive comments and helpful suggestions. Major improvements also resulted from reviews by Robert A. Zielinski and Steven P. Phillips. We also thank David L. Parkhurst for his helpful guidance with the surface complexation model used in this paper.

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EXHIBIT K

COMMUNITY WATER CENTER
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Stanford
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Groundwater Quality in the Sustainable Groundwater Management Act (SGMA):

Scientific Factsheet on Arsenic, Uranium, and Chromium

Groundwater is an important resource that we depend on to drink, bathe, grow food, and more. Through the implementation of the Sustainable Groundwater Management Act (SGMA) local groups called Groundwater Sustainability Agencies (GSAs) are developing Groundwater Sustainability Plans (GSPs) that indicate how they will manage groundwater in their area. One requirement of the Groundwater Sustainability Plans is to *"avoid significant and unreasonable degradation of groundwater quality"* (Water Code Section 10721(x)(4)).

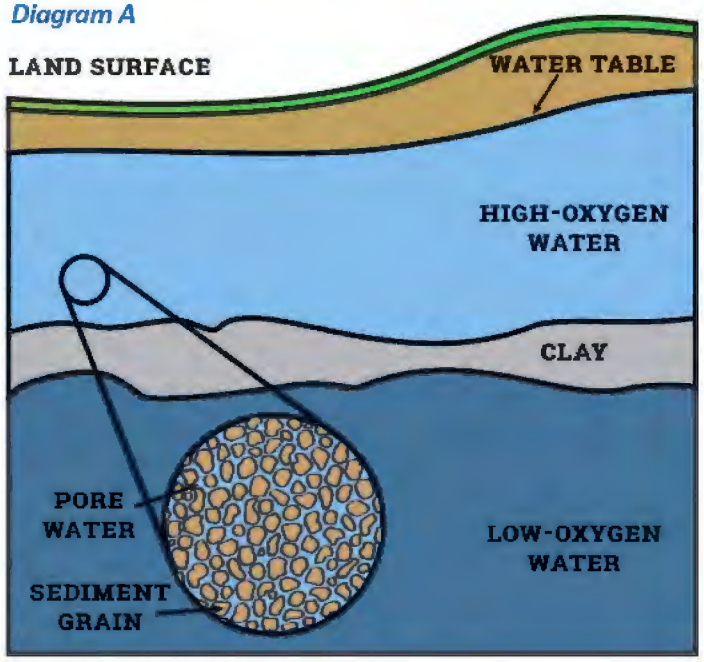
Groundwater can become contaminated through the use of human-made chemicals, fertilizers, or improperly managed waste facilities. Groundwater contamination can also occur naturally from elements in soils and sediments (See Box 1). Some elements naturally present in rocks are toxic and harmful to health when they are dissolved in water, sometimes even at low concentrations. The most widespread of these metals are **arsenic** and **uranium. Chromium** is also of concern, primarily in a specific form (hexavalent chromium).

This factsheet explains how three elements — arsenic, uranium, and chromium — enter groundwater from soils and sediments, and how to address these already present impacts and work to prevent, limit, or reverse issues related to these contaminants. If you know these contaminants are present in your groundwater basin, we recommend you encourage your Groundwater Sustainability Agency to invest in additional monitoring and management practices to keep from worsening the problem. This factsheet provides illustrations based on recent scientific research to inform the design of those monitoring and management programs. For more information about best management practices for addressing drinking water in Groundwater Sustainability Plans, review Community Water Center's ***Protecting Drinking Water Under SGMA Guide.***

What Is Groundwater? How Can Naturally Occurring Metals Like Arsenic and Uranium Enter Groundwater?

Groundwater is water that exists below the earth's surface, either in the space between grains of sand, gravel, and clay, or in the fractures of solid rocks. The layers of rock and sand that contain groundwater are called aquifers *(Diagram A)*. Underground sediments and rocks contain many different minerals and metals, either attached to the surface of the grain, or as part of the sediment/rock itself. Under certain conditions, these minerals and metals can move into the groundwater, or become dissolved.

Diagram A



There are many conditions that affect and accelerate the movement of metals from rocks into groundwater including the pH (level of acidity) and the amount of dissolved oxygen in the water. Changes in pH and oxygen can lead to higher concentrations of dissolved metals in groundwater but each metal responds differently to these conditions.

Importance of Monitoring and Using Groundwater Information to Manage Groundwater Quality:

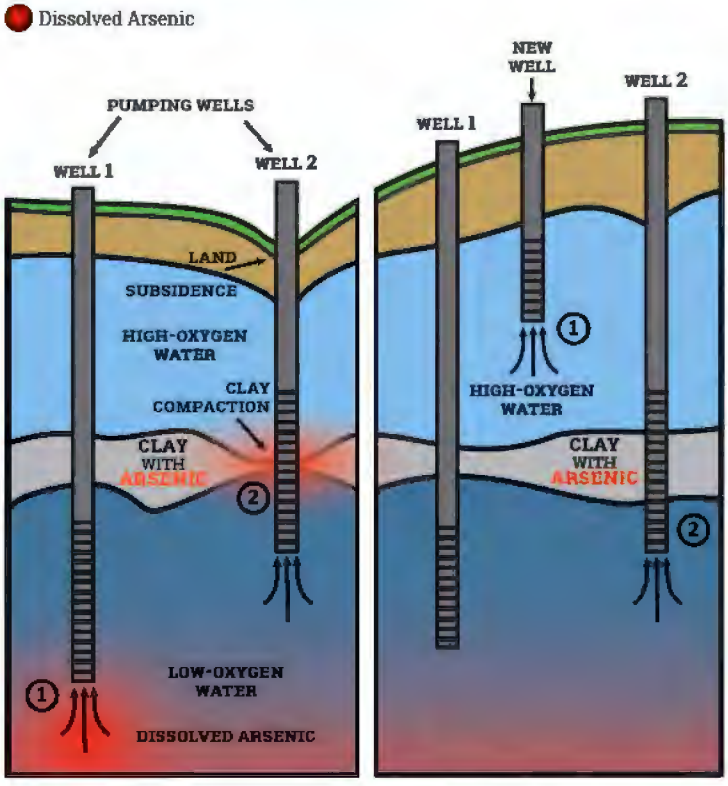
Many of the factors that cause naturally occurring contaminants to enter groundwater can be prevented or mitigated using a robust groundwater monitoring and information gathering strategy. Determining the best management technique often requires some trial-and-error. Recommendations include:

- Regularly measure levels of naturally occurring contaminants (arsenic, uranium, and chromium) in well as the conditions that can cause contamination (changes in pH, dissolved oxygen, nitrate, and electrical conductivity)
- Evaluate groundwater flow paths (for example, through the use of groundwater tracer tests) to know where contaminated water may travel over time, and use this information to strategically install monitoring wells that are upgradient of supply wells.
- Use well logs during well installation to ensure screen intervals are a maximum distance from clay layers.

ARSENIC *(Diagram B)*

PROBLEMS	SOLUTIONS
Low-oxygen conditions *(Diagram C)* When an aquifer becomes low in oxygen (~1% or lower dissolved oxygen), bacteria will dissolve the iron minerals that contain arsenic, and the arsenic itself will also change forms (from the molecule arsenate to arsenite). The outcome is an increase in dissolved arsenic in the groundwater. This is the most common cause of arsenic contamination of groundwater.	For a new well design or a well modification, avoid drawing groundwater from low oxygen zones if there is a concern about arsenic in that area.
Over-pumping Most wells draw groundwater from aquifers made of sand and gravel sediments, where water can be pumped out of the spaces between sediment grains. Aquifers can also have clay layers that may contain low-oxygen conditions and dissolved arsenic. When an aquifer is over-pumped, the clay layers can be compressed, squeezing the water with arsenic out from the clay and into the main aquifer.	Avoid over-pumping from confined aquifers to the point of clay compression (subsidence). Avoid drilling wells in aquifers with high clay content, or where pumped water may draw from clays containing arsenic.
An increase in pH When the pH of groundwater goes above 8.5, arsenic is displaced from mineral surfaces and dissolves into the groundwater.	Limit drawing from groundwater with pH greater than 8.5.

Diagram B: Problems and Solutions



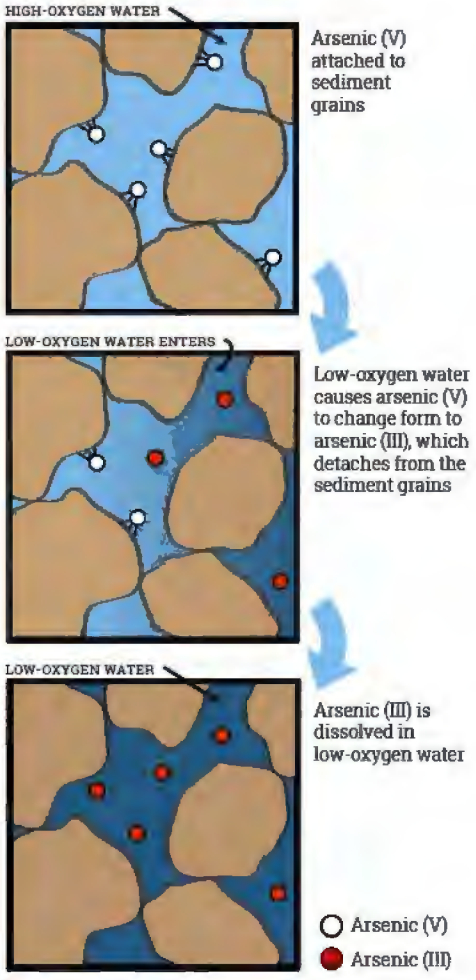
PROBLEMS

1. Low-oxygen conditions cause arsenic to dissolve into water pumped by Well 1.
2. Well 2 pumps at a high flow rate, causing the clay with arsenic to compact and high-arsenic pore water is "squished" out.

MANAGEMENT SOLUTIONS

1. New well drilled in an area with high-oxygen water and low dissolved arsenic.
2. Well 2 uses a lower flow rate, which stops high-arsenic water from coming out of the clay.

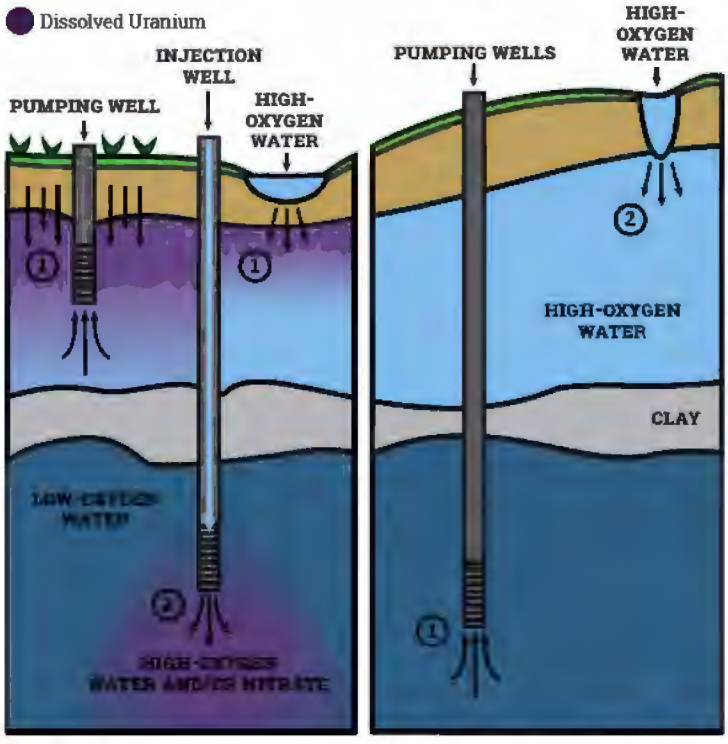
Diagram C: Arsenic dissolves in low-oxygen water (desorption)



URANIUM *(Diagram D)*

PROBLEMS *(Diagram E)*	SOLUTIONS
An increase in dissolved bicarbonate and calcium Uranium is often "stuck" (adsorbed) to the edges of sediments. When uranium comes into contact with dissolved bicarbonate and calcium, it can form large molecules that are easily dissolved, increasing uranium concentrations in groundwater. Bicarbonate and calcium are naturally present in soils and are usually more concentrated at the surface because of higher biological activity (plants and microorganisms) and evaporation. As a result, water percolating through the soils, will increase in calcium and bicarbonate, which increases dissolved uranium concentrations as well.	Natural infiltration through soil from rain or drip irrigation cannot be avoided. However, if uranium is present in the proposed recharge area, managed aquifer recharge (MAR) should limit percolation through soil with high bicarbonate and/or calcium content. If there are high levels of bicarbonate or calcium in the upper layers of the soil, using recharge ponds or ditches/canals excavated through the soil (~6 to 8 ft deep) may prevent uranium contamination.
An increase in nitrate or high-oxygen conditions When uranium is present in low-oxygen conditions, it does not dissolve into groundwater. However, when nitrate or high-oxygen water enter the aquifer, they can react with uranium and change it into a form that readily dissolves, increasing uranium concentrations in groundwater.	Avoid over-pumping from confined aquifers to the point of clay compression (subsidence). Avoid drilling wells in aquifers with high clay content, or where pumped water may draw from clays containing arsenic.
Drawdown of shallow groundwater Dissolved uranium concentrations are often higher in shallow groundwater, where there are high-oxygen conditions and more dissolved bicarbonate and calcium. High rates of pumping in deep wells may draw down this shallow water, increasing the amount of dissolved uranium in extracted water.	Monitor uranium content and prevent drawdown of shallow, uranium-rich groundwater by reducing pump rates or promoting injection wells as necessary.

Diagram D: Problems and Solutions



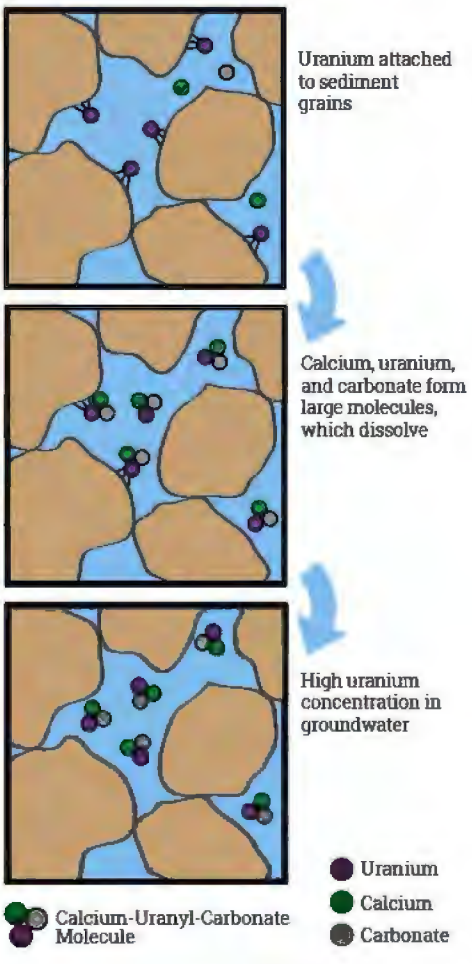
PROBLEMS

1. Recharge through vegetated area and infiltration pond leads to an increase in bicarbonate and calcium, which causes uranium to dissolve.
2. Injection well introduces high-oxygen water or nitrate, releasing uranium.

MANAGEMENT SOLUTIONS

1. Well pumps water from deeper aquifer without bicarbonate and calcium.
2. Managed aquifer recharge through excavated ditch prevents uranium contamination.

Diagram E: Uranium dissolves as part of molecule



Arsenic and Uranium, Combined Management

When dissolved arsenic and uranium are both present in groundwater, certain management practices can help to reduce concentrations of both elements:

- Maintain pH below 8.5 to limit dissolved arsenic. If pH exceeds 8.5, more investigation is necessary.
- If uranium is present in oxygen-rich zones, keep calcium and bicarbonate concentrations low to help to keep it out of the water.
- Prevent high rates of pumping that draw uranium from shallow groundwater or arsenic from low-oxygen zones.
- Monitor levels of arsenic, uranium, dissolved oxygen and oxidation-reduction potential (ORP) in groundwater. If arsenic concentrations increase, the aquifer may be low in oxygen. If uranium concentrations increase, the aquifer may be too oxygenated.
- For recharge project recommendations, please consult CWC's Protecting Drinking Water Under SGMA Guide.

What about CHROMIUM?

When dissolved arsenic and uranium are both present in groundwater, certain management practices can help to reduce concentrations of both elements:

- Increased groundwater pumping and fluctuations in groundwater levels;
- High-oxygen conditions at the surface generate hexavalent chromium, which is pulled down into the aquifer through recharge or pumping;
- Naturally occurring manganese converts trivalent to hexavalent chromium.

More research is needed to determine the best way to minimize hexavalent chromium production and concentrations in groundwater. Where active recharge is being conducted, following strategies for uranium mitigation is likely the best practice.

GLOSSARY:

- **Adsorbed:** "Stuck" to the edges of sediments.
- **Dissolved:** In liquid form; part of the groundwater.
- **High-oxygen and low-oxygen:** Conditions that reflect how much oxygen is dissolved into groundwater. High-oxygen conditions are sometimes called "aerated", while low-oxygen (~1% or lower dissolved oxygen) is called "reduced".
- **pH:** A measure of the acidity of the water. Groundwater pH is generally between 6.5 and 8.5. Water with lower pH is more acidic, while higher pH indicates alkaline (basic) conditions.
- **Naturally occurring:** Present within the rocks that make up the aquifer; not due to human activity.

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ACKNOWLEDGEMENTS:

This guide was made possible through generous support from Proposition 1 Sustainable Groundwater Planning grant funding from the California Department of Water Resources as well as with the support from the California Water Foundation, an initiative of the Resources Legacy Fund.

Factsheet authors from Stanford University:
Scott Fendorf
Allison Sherris
Aria Hamann
Arden Wells

Thank you to the many individuals who contributed their time and expertise to the development of this guide including:

Community Water Center staff:
Adriana Renteria, David Okita, Debi Ores, Heather Lukacs, Kelsey Hinton

Liesbet Olaerts
Self-Help Enterprises

Jennifer Clary
Clean Water Fund

Sarah Fakhreddine
Environmental Defense Fund

To learn more, contact Adriana Renteria at adriana.renteria@communitywatercenter.org or 559-733-0219.

COMMUNITY WATER CENTER
EL CENTRO COMUNITARIO POR EL AGUA
www.communitywatercenter.org

900 W. Oak Avenue
Visalia, CA, 93291
Tel. (559) 733-0219

716 10th Street, Suite 300
Sacramento, CA 95814
Tel. (916) 706-3346

406 Main Street, Suite 421
Watsonville, CA 95076
Tel. (831) 288-0450



Groundwater Management and Safe Drinking Water in the San Joaquin Valley

Analysis of Critically Over-drafted Basins' Groundwater Sustainability Plans

June 2020

WATER FOUNDATION

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"These bills take the much needed steps to preserve and restore a limited and indispensable resource—groundwater."

—Senator Fran Pavley on the passage of the Sustainable Groundwater Management Act, September 2014

"Nothing in the budget makes me more proud than this. I'm dead serious about that. Some people wonder why the hell you get into politics. This is why."

—Governor Gavin Newsom on signing SB 200, the Safe and Affordable Drinking Water Fund, July 2019

Summary

Successful implementation of the Sustainable Groundwater Management Act (SGMA) is critical to California's prosperity, collaboration that achieves shared benefits for people and nature, and the Newsom administration's commitment to the human right to water for all residents. In 2014, California passed SGMA, a set of three laws that are intended to help the state sustainably manage its groundwater resources. Between 30% and 60% of the state's water supply comes from groundwater in any given year, and is used for drinking water, growing food, supporting industry, and maintaining a healthy environment. Groundwater over-pumping affects drinking water wells and surface water rights, pollutes water due to seawater intrusion or migrating contaminant plumes, harms ecosystems, and causes land subsidence, among other problems.

In January 2020, newly formed Groundwater Sustainability Agencies (GSAs) submitted their first Groundwater Sustainability Plans (GSPs or plans) to the state for the "critically over-drafted" sub basins, or those in the direst circumstances. Most of these sub basins are located in the San Joaquin Valley.

Since then, the COVID-19 pandemic has exposed how deeply public health, economic security, and clean water are intertwined. Put simply, a livable future in California depends on clean, reliable water, which is one of the main reasons why SGMA was passed. California's groundwater depletion challenges preceded the global pandemic and continue to persist in ways that impact drinking water, farming, economic development, public health, and environmental quality.

To support the state's implementation of SGMA and its continued progress on the human right to water, the Water Foundation commissioned an analysis of 26 GSPs in the San Joaquin Valley to understand how private domestic drinking water wells in the region will be affected on the path to sustainability. This analysis does not look at any of the other associated impacts or costs of declining groundwater levels, such as land subsidence, surface water rights, or groundwater dependent ecosystems.

California's state regulatory agencies have never had this level of detailed information about the effects of severe groundwater overdraft on the lives and livelihoods of residents, farmworkers, and rural households. Conducted in spring 2020 and using conservative estimates based on publicly available data, this analysis estimates that the goals in these San Joaquin Valley GSPs, if not proactively addressed, will result in:

- **Between roughly 4,000 and 12,000 partially or completely dry drinking water wells by 2040**
- **Between roughly 46,000 and 127,000 people who lose some or all of their primary water supply by 2040**
- **Between $88 million to $359 million in costs to restore access to drinking water**

These concerning results point to a simple fact: In spite of actions aimed at managing groundwater more sustainably, recently submitted GSPs still forecast that thousands, or tens of thousands, of Californians will lose their drinking water supply, which is inconsistent with the intent of SGMA and threatens to undermine the governor's commitment to safe and affordable drinking water for all residents. This analysis of drinking water and continued declines in groundwater also suggest that the goals of SGMA to avoid other undesirable results of groundwater mining also may not be fully addressed by GSPs.

Further analysis beyond the scope of this report is required to explore the effect of GSPs on other areas of concern, such as impacts on the environment and on important infrastructure due to land subsidence. As state decision-makers conduct their GSP review process, we hope that this brief will help bring greater attention to vulnerable Californians and their most basic need: safe, clean, and affordable water.

Key Terms

Human right to water: As defined by AB 685, "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes."

Groundwater sustainability: As defined by SGMA, "management and use of groundwater in a manner that can be maintained…without causing undesirable results."

Undesirable results: Negative results that GSAs and GSPs are required to avoid under SGMA. There are six undesirable results: groundwater level lowering, reduction of groundwater storage, seawater intrusion, land subsidence, water quality degradation, and depletions of interconnected surface water.

Measurable objective: A basin's self-determined groundwater level goal to achieve sustainability under SGMA.

Minimum threshold: A basin's self-determined minimally acceptable level of groundwater decline. Beyond this threshold, a GSA anticipates it will face undesirable results.

Partially dry drinking water well: A drinking water well that has lost or will lose most of its usable water due to unsustainable groundwater practices. These wells are also called partially dewatered wells.

Completely dry drinking water well: A drinking water well that has lost or will lose all useable water due to unsustainable groundwater practices. These wells are also called dewatered wells.

Right to Water Depends on Sustainable Groundwater

Safe drinking water for Californians and groundwater management are inextricably connected. California has enshrined the concept of the human right to water – that all Californians have a basic right to safe and affordable drinking water and sanitation – into state code. However, unsafe drinking water has been an ongoing environmental justice challenge for decades. More than 1 million Californians go without safe and affordable drinking water each year, and low-income communities of color are disproportionately affected by this water crisis. These same communities are also on the frontlines of climate change and are hit the hardest by drought conditions.



Leonicio Ramirez and Guillermina Avila in East Porterville. Florence Low / California Department of Water Resources

Yet, too often, water policy deliberations and decision-making proceed as if the water in our rivers, the water underground, and the water flowing out of our taps are distinct from one another. That is not true.

The COVID-19 pandemic has shown California how we are all better off when everyone has the basic resources to protect themselves and their neighbors. By that same token of interdependence, the health of groundwater in California is the health of families, economies, and nature. In the San Joaquin Valley, 95% of communities rely on groundwater as their main drinking water source. Valley groundwater also fuels the operations of large and small farms and sustains a hub of world-class biodiversity.

For over 100 years, California has drained San Joaquin Valley rivers and groundwater faster than nature and humans can replenish them. A changing climate is exacerbating the effects of this behavior as it delivers more devastating and longer droughts. Between 2012 and 2016, California experienced the most intense drought on record since the 1400s. Over-pumping during the drought sank roads and homes, polluted wells, lowered river flows, and put farms and communities at severe risk.

Still, in the middle of that economic, social, environmental, and public health crisis, recognizing that it was a question of when, not if, another major drought will start, California residents living in the hardest hit parts of the state spurred their elected representatives to act to save groundwater for themselves and for future generations.

In 2014, for the first time in the state's history, legislators passed, and the governor signed, a series of laws to put California on a path that reaches groundwater sustainability by 2040 or 2042, depending on the basin. These laws are known as the Sustainable Groundwater Management Act (SGMA).

Californians' ability to work together and look out for one another will shape SGMA's success in turning groundwater into a drought-proof water resource. State leaders must ensure effective governance and that local plans dependably lead to groundwater sustainability, including protecting communities that rely on private drinking water wells. Local agencies charged with implementing SGMA must use science as a foundation for their plans and meaningfully engage and represent the communities directly affected by their decisions.



Inside a groundwater monitoring well. Kelly M. Grow / California Department of Water Resources

Under the Newsom administration—the first administration to review SGMA GSPs—new initiatives are poised to support full, fair, and effective execution of the law. The Newsom administration has also underscored its commitment to fulfilling the promise of the human right to water in California.

To advance these goals, the California Department of Water Resources (DWR) has started to collect and publish data on the depth of groundwater below the surface and groundwater elevation, which can help proactively identify threats to sustainability, including at-risk drinking water wells. These domestic wells tend to be very shallow, which means they dry up sooner than agricultural or municipal wells. When groundwater levels plummet and leave private wells dry, few San Joaquin communities and residents who are dependent on them as sources of drinking water have the capital to continuously drill and maintain deeper wells.



Farm workers in Pajaro Valley. Lance Cheung / US Department of Agriculture

To conduct this analysis for the Water Foundation, consultants at EKI Environment & Water, Inc. used DWR's latest Groundwater Center Interactive Map Application dataset and other publicly available information to understand how implementation of some of the first GSPs in critically over-drafted sub basins in the San Joaquin Valley would affect local drinking water wells. Because DWR's dataset does not include every part of the San Joaquin Valley, this analysis is limited to 26 GSPs in ten critically over-drafted sub basins. Further, one-quarter of the records in the dataset lack basic information about well depths and screening levels, and therefore could not be included in this evaluation.

Considering these data limitations, this analysis provides a conservative baseline assessment of how the estimated water decline predicted in these recently submitted GSPs will impact people who rely on groundwater for their primary water source. Because this analysis only addresses the ongoing impacts of GSP implementation on drinking water, additional research may be necessary to understand the impacts and costs on other undesirable results, such as land subsidence, impacts to ecosystems, and surface water flows.

Key Findings

- **Between roughly 4,000 and 12,000 drinking water wells will go partially or completely dry by 2040**
- **Between roughly 46,000 and 127,000 people will lose some or all of their current water supply by 2040**
- **It will cost between $88 million to $359 million to restore access to drinking water**

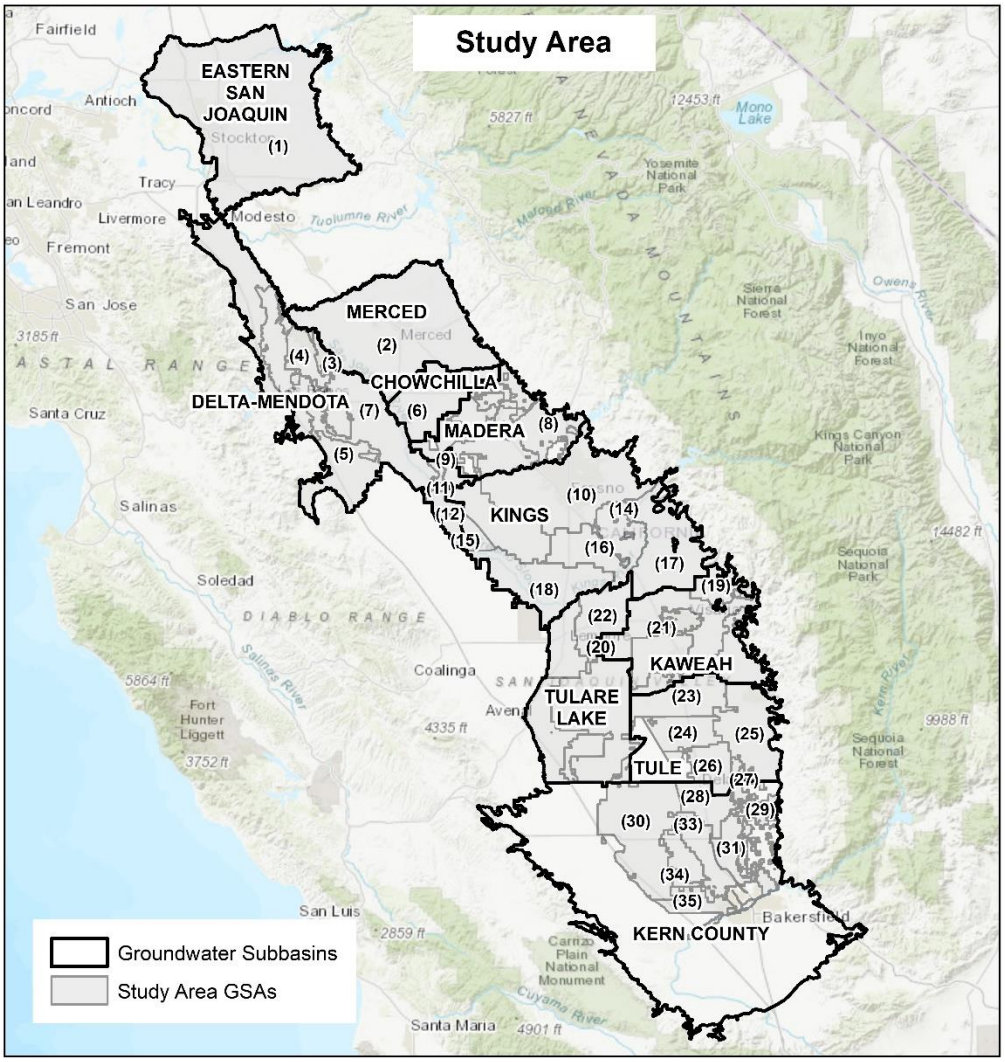
While these findings are deeply disturbing, they are not carved in stone. State regulatory agencies can work with these GSAs over the next two years to implement SGMA in a manner that avoids or mitigates these impacts, achieves groundwater sustainability by 2040, and strengthens the right to water for all California residents.

Analysis Results

Study Area: San Joaquin Valley

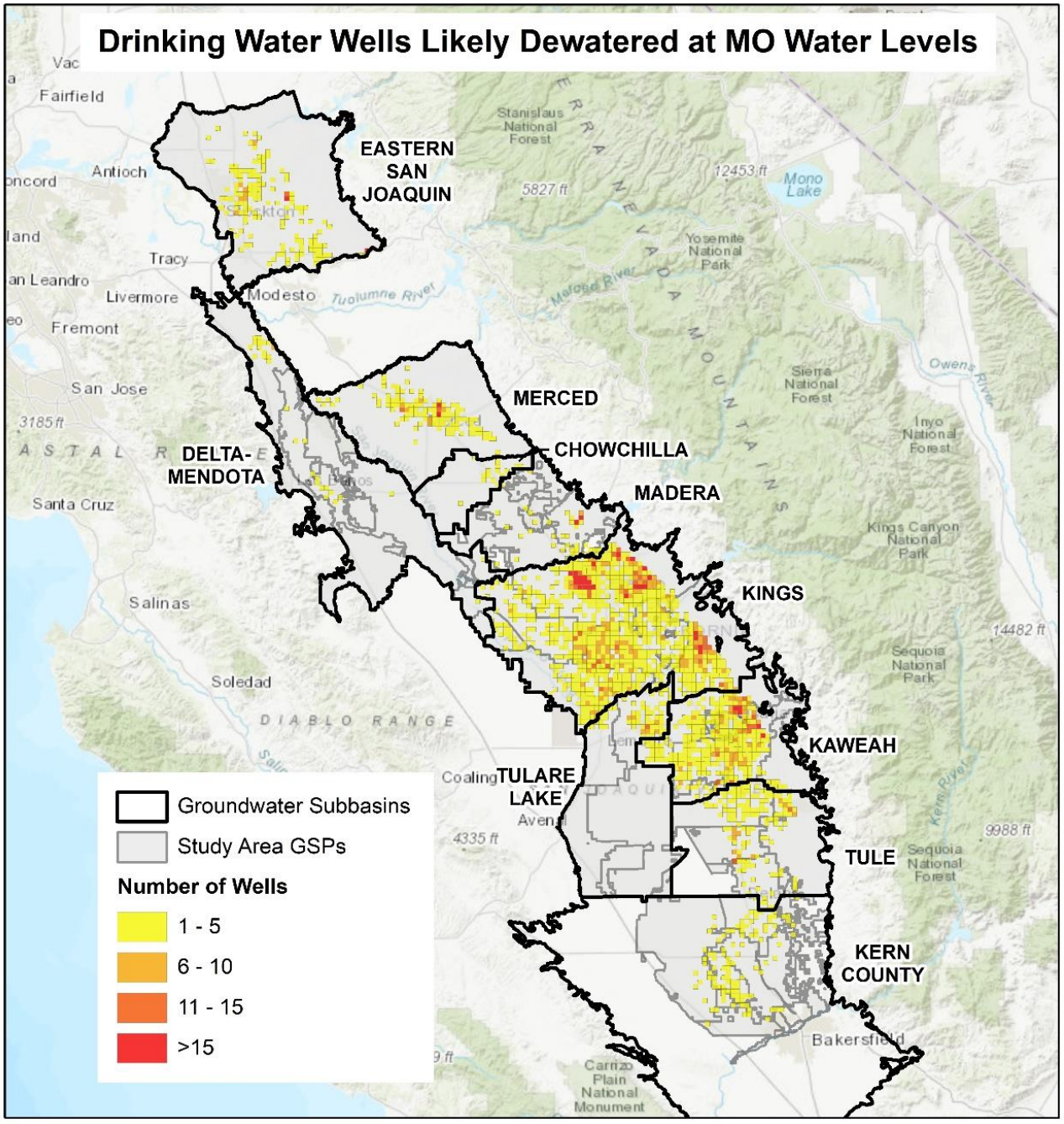
In the areas analyzed in this report, there are approximately 400,000 California residents who rely on private drinking water wells for their water supply and nearly 45,000 known drinking water wells.

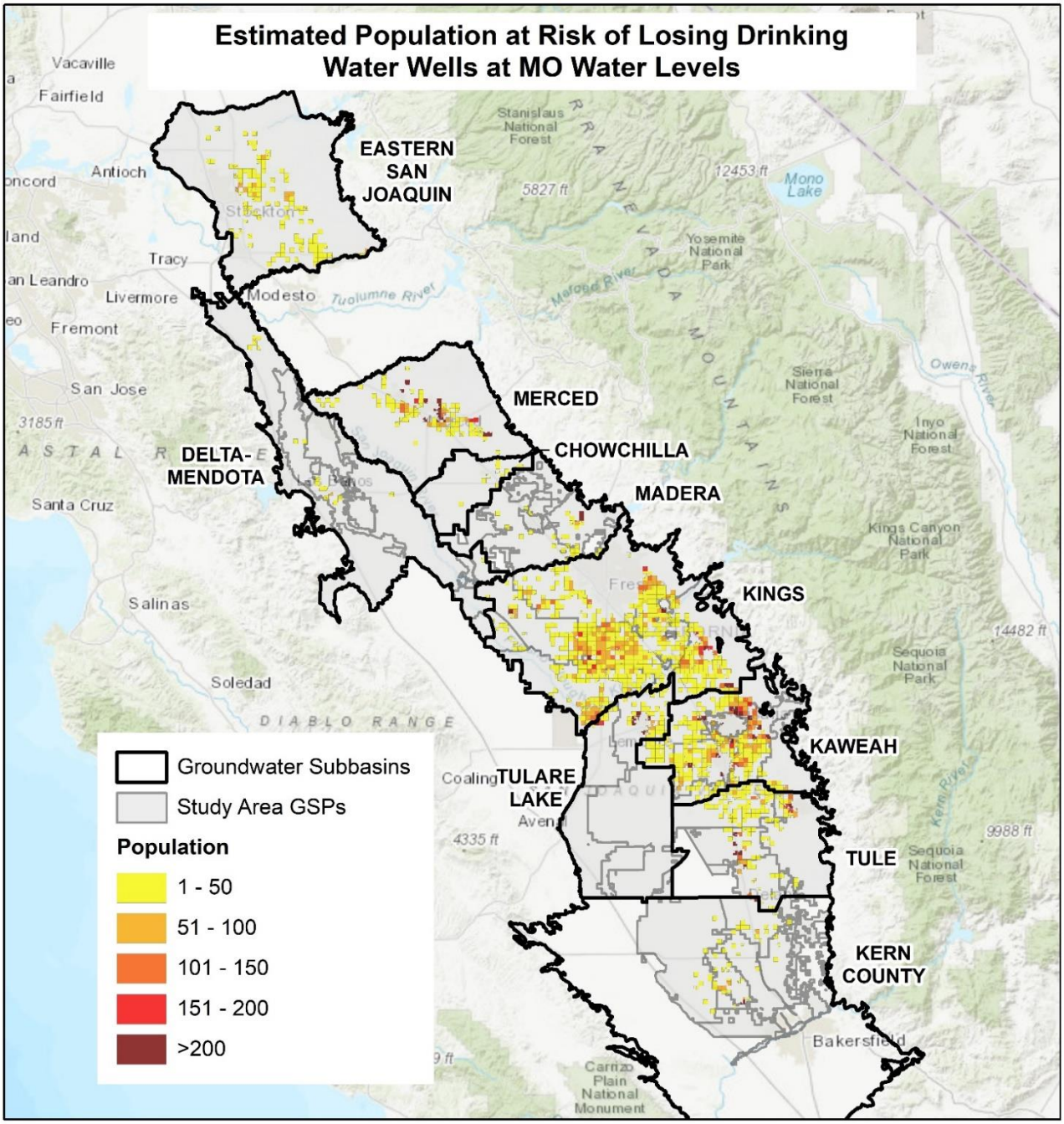
Of these wells, approximately 7,000 have already been dewatered due to declining groundwater levels and another 13,000+ could not be analyzed due to insufficient data. After accounting for these factors, this analysis assessed how approximately 24,500 drinking water wells will be affected at the levels identified in their respective GSPs.



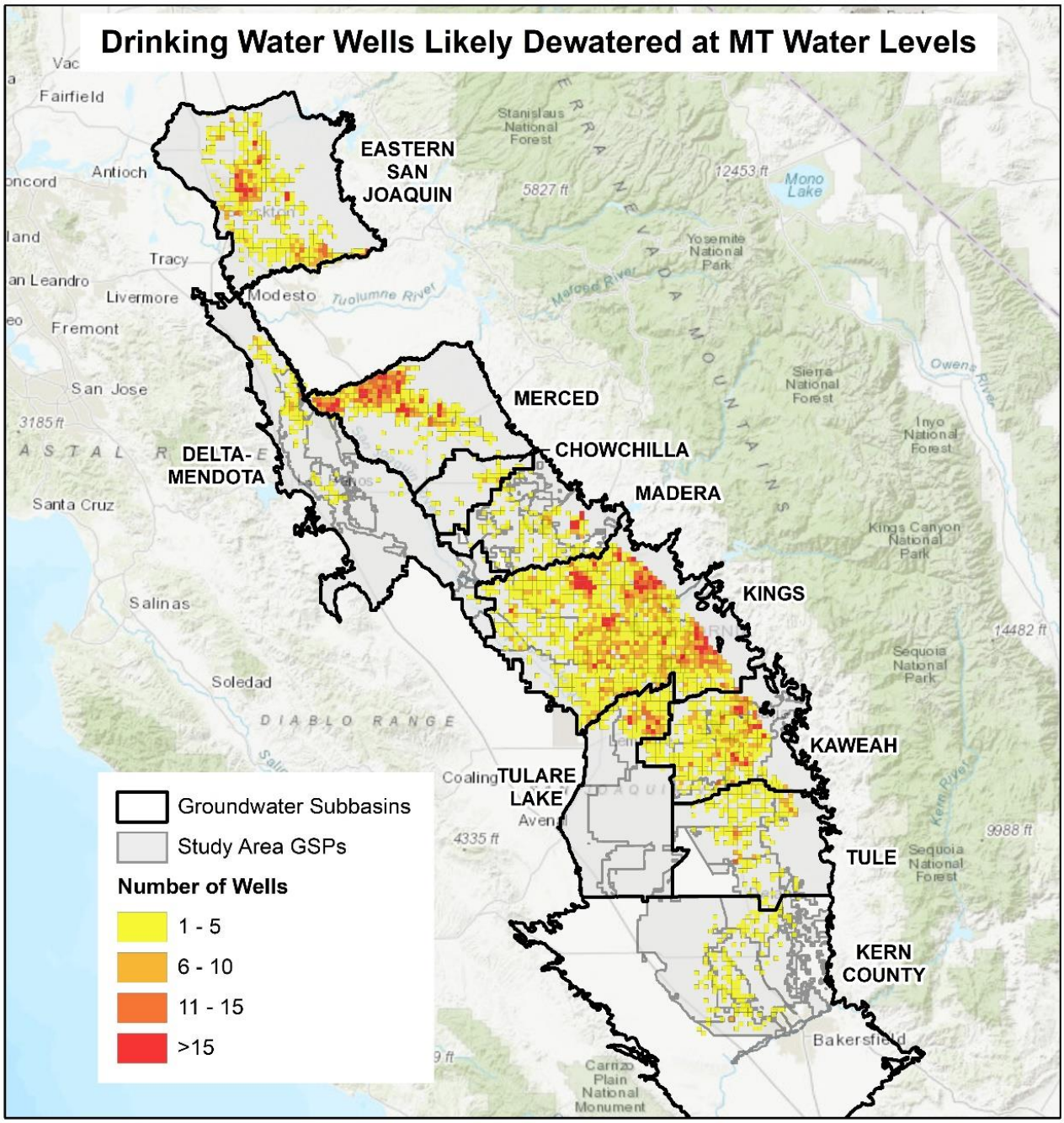
GSPs' Projected Water Levels Will Drain up to 12,000 Drinking Water Wells, Affecting up to 127,000 Residents

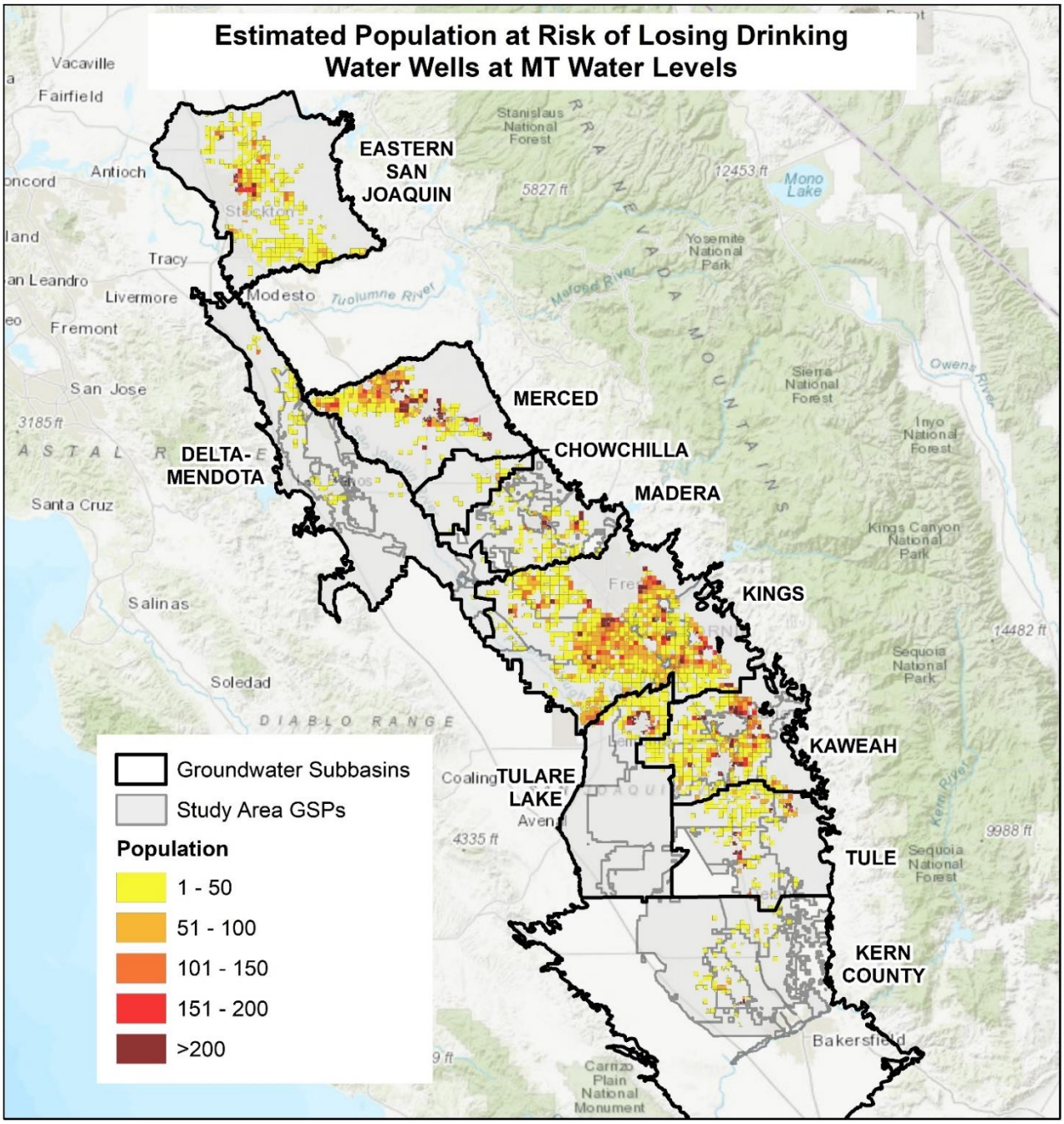
The GSPs have been developed with a goal of reaching sustainability by 2040. Based on the target water levels, or measurable objectives, defined in the GSPs, up to 5,600 drinking water wells in the region will go partially or completely dry. Under these circumstances, between 45,700 and 62,500 people will lose their primary drinking water source.




Estimated Population at Risk of Losing Drinking Water Wells at MO Water Levels
EASTERN SAN JOAQUIN
MERCED
CHOWCHILLA
MADERA
DELTA-MENDOTA
KINGS
KAWEAH
TULARE LAKE
TULE
KERN COUNTY
Groundwater Subbasins
Study Area GSPs
Population
1 - 50
51 - 100
101 - 150
151 - 200
>200
Vacaville
Fairfield
Antioch
Stockton
Tracy
Livermore
Modesto
Fremont
San Jose
Santa Cruz
Salinas
Soledad
Coalinga
Bakersfield
Stanislaus National Forest
Yosemite National Park
Sierra National Forest
Inyo National Forest
Kings Canyon National Park
Sequoia National Park
Sequoia National Forest
Carrizo Plain National Monument
Mono Lake
Tuolumne River
Merced River
Owens River
Kern River
DIABLO RANGE
12453 ft
5827 ft
3185 ft
14482 ft
9988 ft
4335 ft

This analysis concludes that even if GSPs achieve their measurable objectives, groundwater levels will likely fall below those levels to minimum acceptable levels. Under this scenario, between now and 2040, up to roughly 12,000 drinking water wells in the region, or 49% of wells, could go partially or completely dry. Under these circumstances, between roughly 106,000 and 127,000 people will lose their primary drinking water source. This is a conservative estimate because it assumes that all of the actions in the GSPs will be taken and will be successful.



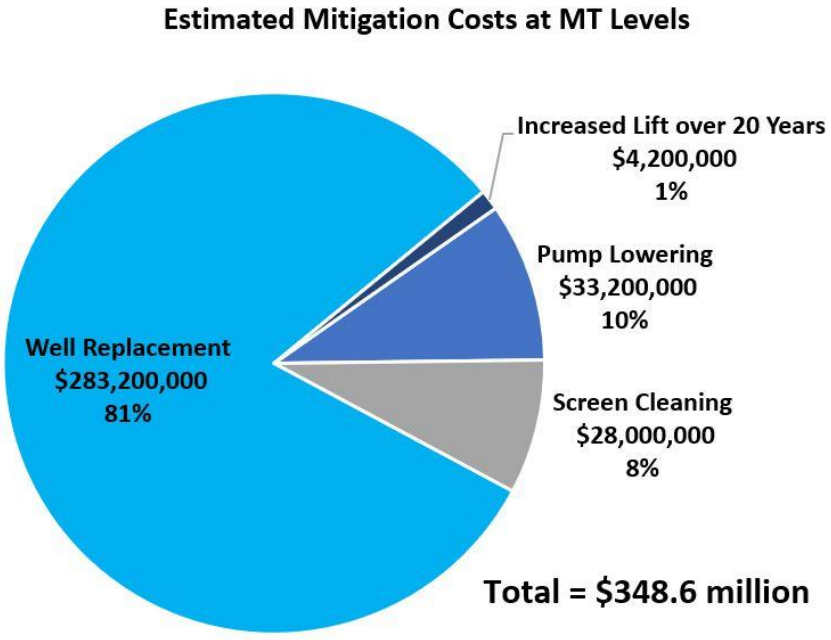

Estimated Population at Risk of Losing Drinking Water Wells at MT Water Levels
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Study Area GSPs
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51 - 100
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151 - 200
>200
Vacaville
Fairfield
Antioch
Tracy
Livermore
Modesto
Fremont
San Jose
Santa Cruz
Salinas
Soledad
Stockton
Coalinga
Bakersfield
Yosemite National Park
Sierra National Forest
Kings Canyon National Park
Sequoia National Park
Sequoia National Forest
Inyo National Forest
Carrizo Plain National Monument
Mono Lake
Stanislaus National Forest
Tuolumne River
Merced River
Owens River
Kern River
DIABLO RANGE
12453 ft
5827 ft
14482 ft
9988 ft
4335 ft
3185 ft

Restoring Water Access Could Cost between $88 and $359 Million

The stark findings detailed above demand action by GSAs to implement policies and programs to ensure that community members maintain access to reliable and safe drinking water. The first priority for GSAs must be to do more to stop groundwater declines to the extent possible. This is all the more important given that the impact of continually declining groundwater also includes worsening subsidence, dry rivers, and degradation of water quality below safe drinking water levels. Those impacts are worthy of further analysis.

DWR and the State Water Board (Board) have two years from January 31, 2020 to review critically over-drafted sub basin GSPs and make an initial determination to either 1) approve as is, 2) reject, or 3) conditionally approve with modifications. As DWR and the Board review and evaluate GSPs, they must ensure that GSAs take proactive action today to achieve sustainability and avoid devastating impacts to communities, economies, and the environment.

If this does not happen, community members will face high costs to mitigate those impacts. To ensure that community members maintain access to drinking water under circumstances where it is not possible to avoid declines in groundwater levels, drinking water well owners and users can conduct repeated well screen cleanings, drill deeper wells, develop new replacement wells, and/or spend more on operations and energy costs to lift the water from deeper underground. Based on this analysis, we expect that it will cost community members between $88 million and $359 million to pay for these mitigation measures to maintain and restore use of existing drinking water wells.



While these capital, operations, and maintenance costs are not insignificant, it is vital that GSAs and state agencies acknowledge this issue and take proactive steps to prevent these impacts. These costs are a fraction of what it will likely cost to address these issues on an emergency basis as vast and remote communities lose their drinking water wells.

For example, during the 2012-2016 drought, California taxpayers paid about $650,000 per month to provide temporary replacement bottled water to the East Porterville residents. The number of residents who will lose their primary drinking water source over the implementation of these GSPs is equivalent to up to 17 East Portervilles. Unlike the 2012-2016 drought, however, GSAs and state agencies have the benefit of the comprehensive scientific data compiled in these GSPs to plan for and address these issues before they become another more severe crisis.

The stakes are high. Failure by GSAs and state agencies charged with implementing SGMA to prevent these negative impacts will increase the current number of Californians without safe drinking water.

In 2019, the Safe and Affordable Drinking Water Fund was established to end the toxic taps crisis facing 1 million Californians today. However, the Fund was not designed or intended to address costs that could be avoided by knowledgeable and informed planning by GSAs that have failed to consider communities in their planning processes. The impacts summarized here are foreseeable, and if not proactively addressed, would add additional unnecessary demands on state and local budgets.

KEY DATES FOR SGMA AND HUMAN RIGHT TO WATER

Jan 31, 2020: GSPs Due from Critically Over-drafted Basins

May 15, 2020: First 2020 GSP Public Comment Deadline

June 3, 2020: Second 2020 GSP Public Comment Deadline

July 1, 2020: State Water Board Expenditure Plan for Safe and Affordable Drinking Water Fund Due

Jan 31, 2022: DWR Deadline to Evaluate Critically Over-drafted GSPs

Jan 31, 2022: GSPs Due from Remaining High- and Medium-Priority Basins

Considerations for California's Water Future

Californians have a shared commitment to the human right to water. Residents and their elected representatives have said clearly that they want clean, affordable, and reliable tap water for all families. They want California farming to prosper, and they want to protect the breathtaking beauty of the state's land and wildlife.

This year marks the start of a new era in California water policy, where state laws and funding recognize and reflect how closely the trajectory of groundwater sustainability and safe drinking water are intertwined. As policymakers and GSAs work diligently to implement SGMA in a manner that supports the state's economy, its communities, and nature, this analysis can conservatively fill existing data gaps on how unsustainable groundwater practices directly affect drinking water wells.

GSAs must make policy decisions in GSPs that protect drinking water. As part of the state's review of GSPs, DWR and the Board should ask key questions to help achieve sustainability and avoid undesirable results. These questions, which are detailed in the Human Right to Water Scorecard shared below, include:

- If minimum thresholds are reached in the GSP, how many Californians might lose access to water?
- How might the measurable objectives and minimum thresholds set by the GSP affect water quality for vulnerable communities?
- How can GSPs go further to avoid declining groundwater levels and the associated impacts on drinking water and other undesirable results?
- What is the GSP's plan to mitigate impacts to water quantity and quality for vulnerable communities?
- How does DWR and the Board intend to assess and analyze the GSP's impacts to drinking water quality and quantity for vulnerable communities?

Thorough evaluations and smart policy decisions today will ensure SGMA implementation protects drinking water for rural communities and residents, advances the legislature's and governor's commitments to the human right to water, and turns groundwater into a drought-proof resource for generations to come.

Related Resources

Human Right to Drinking Water GSP Scorecard: Developed by Leadership Counsel for Justice and Accountability, Community Water Center, and Self-Help Enterprises, the scorecard identifies the elements that must exist in GSPs for those plans to adequately protect the human right to water.

Drinking Water Well Impact Mitigation Program Framework: Developed by Community Water Center, Leadership Counsel for Justice and Accountability, and Self-Help Enterprises, the framework provides information to GSAs to both prevent impacts to drinking water resources and to mitigate those impacts should they occur. The framework recommends best practices, including setting up monitoring networks to quickly identify if negative impacts are occurring near drinking water wells, a trigger system for when correction actions are necessary, and what should be done if impacts occur.

Community Water Center Drinking Water Tool: This interactive, online tool helps communities and decision-makers better prepare to protect drinking water in future droughts. The tool shows 1) who manages and makes decisions about your water supply; 2) the groundwater quality where you live; 3) potential impacts to groundwater supply from future droughts; and 4) how to get involved in local groundwater management decisions.

Groundwater Markets: Recommendations to Ensure Drinking Water Protections for Communities: Developed by Community Water Center, Environmental Defense Fund, Self-Help Enterprises, The Nature Conservancy, and Union of Concerned Scientists, this guide helps GSAs considering a groundwater market or trading system help, or at least prevent harm, to shallow groundwater users.

White Paper: **Estimated Numbers of Californians Reliant on Domestic Wells Impacted as a Result of the Sustainability Criteria Defined in Selected San Joaquin Valley Groundwater Sustainability Plans and Associated Costs to Mitigate Those Impacts:** Developed by EKI Environment & Water, Inc., this document provides the detailed analyses that are summarized in this brief.

Acknowledgements & Sources

This brief was made possible through analysis by EKI Environment & Water Inc. and research by Community Water Center, Robert M. Gailey Consulting Hydrogeologist PC, and the University of California Berkeley Water Equity Science Shop. Thank you to the individuals at these and other organizations, including Clean Water Action, Leadership Counsel for Justice and Accountability, and Self-Help Enterprises, who contributed their time and expertise to analyze state datasets, review GSPs, and develop this brief.

To conduct the analysis summarized in this brief, the following data sources were used:

- Fall 2018 depth to groundwater contours, available from the California Department of Water Resources' Groundwater Information Center Interactive Map Application
- California Department of Water Resources' California Statewide Groundwater Elevation Monitoring system
- United States Geological Survey 10-meter Digital Elevation Model
- University of California Berkeley Water Equity Science Shop's 2019 domestic well dataset
- California Department of Water Resources' Online System for Well Completion Reports
- Robert M. Gailey's PhD dissertation, Approaches for Groundwater Management in Times of Depletion and Regulatory Change
- California Supply Well Impact Analysis for Drinking Water Vulnerability Webtool, prepared by Robert M. Gailey Consulting Hydrogeologist PC for Community Water Center



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WaterFdn.org
info@waterfdn.org
(916) 414-3310

The Water Foundation and its partners advance lasting water solutions for communities, economies, and the environment.

Cover photo: Kelly M. Grow / California Department of Water Resources

Department of Water Resources
Karla Nemeth, Director
Taryn Ravizzini, Deputy Director of Statewide Groundwater Management
Craig Altare, Supervising Engineering Geologist
Steven Springhorn, Senior Engineering Geologist
Keith Wallace, Project Manager

State Water Resources Control Board
E. Joaquin Esquivel, SWRCB Board Chair
Dorene D'Adamo, SWRCB Board Member
Tam M. Dudoc, SWRCB Board Member
Sean Maguire, SWRCB Board Member
Laurel Firestone, SWRCB Board Member
Eileen Sobeck, Executive Director
Natalie Stork, Chief of Groundwater Management Program
Andrew Altevogt, Program Coordinator of Safe and Affordable Drinking Water

June 3, 2020

Re: Recommendations for DWR and SWRCB Action Regarding the Kern Groundwater Authority Groundwater Sustainability Plan

Dear Department of Water Resources and State Water Resources Control Board,

Leadership Counsel for Justice and Accountability works with low-income communities of color in the San Joaquin Valley and the Eastern Coachella Valley. We have been engaged in the Sustainable Groundwater Management Act (SGMA) implementation process because most of the communities we work with are wholly dependent on groundwater for their drinking water supplies, and many have already experienced groundwater supply and quality issues. The communities where we work have not been adequately included in decision-making about their precious water resources, and their needs are not prioritized in such decisions.

Disadvantaged communities in the Kern Groundwater Authority GSA have the most to gain and the most to lose from SGMA implementation in the region. Communities like Arvin are majority

Latino and depend on small community water systems and/or domestic wells for their drinking water supply. Because residents in disadvantaged communities do not typically have the financial means to dig deeper wells or to install, operate and maintain drinking water treatment infrastructure, they are more likely to be severely impacted by lowering groundwater levels and groundwater contamination.

As a particularly vulnerable group, the critical drinking water needs of disadvantaged communities and low-income households must be considered and protected by the Groundwater Sustainability Plan (GSP). The Kern Groundwater Authority GSA has not adequately done so in this GSP. As described below, the GSP will likely allow drinking water to be contaminated by existing contaminant plumes, is likely to allow wells to go dry, and has no clear plan to help prevent and mitigate drinking water impacts.

The Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB) must evalue GSPs according to the Human Right to Water, and ensure that the GSPs comply with SGMA, the GSP regulations, and state and federal civil rights law, among other laws and regulations. In 2012, California recognized the Human Right to Water, codifying "the established policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes."[1] Under the Human Right to Water law, DWR and the State Water Resources Control Board must consider the Human Right to Water on review of GSPs.[2] In order to comply with this obligation, the Department and Board must ensure that GSPs do not cause or allow further drinking water crises that interfere with residents' access to an adequate supply of safe drinking water. In coordination with the Community Water Center and Self-Help Enterprises, we have developed a Human Right to Water Scorecard that contains elements necessary for state review of GSPs to comply with the Human Right to Water.[3] We urge DWR and the SWRCB to use this scorecard in evaluating this GSP.

Additionally, SGMA requires GSAs to include disadvantaged communities in decision-making, and create GSPs in a transparent and inclusive way. DWR and the SWRCB must ensure that GSPs do not cause "significant and unreasonable impacts" to the beneficial uses and users of groundwater in the subbasin, that they encourage the participation of a diverse variety of stakeholders,[4] and that they "consider the interests of" an enumerated list of all types of beneficial users, including disadvantaged communities on domestic wells and community water

[1] Water Code § 106.3(a)
[2] Water Code § 106.3(b)
[3] Attached as Exhibit B.
[4] Water Code § 10727.8(a) ["The groundwater sustainability agency shall encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin prior to and during the development and implementation of the groundwater sustainability plan."].

systems.[5] Furthermore, state law provides that no person shall, on the basis of race, national origin, ethnic group identification, and other protected classes, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state.[6] The state's Fair Employment and Housing Act guarantees all Californians the right to hold and enjoy housing without discrimination based on race, color, or national origin.[7] DWR and the SWRCB must evaluate GSPs in accordance with all of these and other relevant legal obligations.

Unfortunately, the Kern Groundwater Authority GSA did not protect the drinking water resources relied upon by disadvantaged communities or low-income households, or avoid disparate impacts, and the GSP is incomplete and does not comply with SGMA and other applicable state laws. As noted above, we reviewed the Kern Groundwater Authority GSP according to our Human Right to Water Scorecard. Our review shows that the GSP does not contain all of the information required under SGMA, does not adequately evaluate "significant" and "unreasonable" impacts to beneficial uses including the drinking water needs of disadvantaged communities, will create a disparate impact on protected classes unless significantly modified, and does not comply with the Human Right to Water statute.

For the reasons discussed in these comments, and in prior written and oral comments provided to the GSA, DWR must not approve the GSP.[8]

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[5] Water Code § 10723.2.

[6] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].

[7] Gov. Code § 12900 et seq.

[8] Attached as exhibits are certain documents, studies and analysis supporting these comments, which we request be incorporated into the record.

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A. The GSP Does Not Comply with SGMA Because It Lacks Required Information

The GSP must contain all of the elements set forth in the GSP regulations. However, this GSP omits critical data and information to comply with the GSP regulations. As discussed below, the GSP lacks required information and analyses, including among other things critical data regarding the consideration of drinking water impacts on disadvantaged communities and protected groups, sustainable management criteria that consider impacts on all beneficial users, and projects and management actions that address significant and unreasonable impacts to beneficial users. The GSP also fails to demonstrate how its proposed policies and activities will achieve its sustainability goal, which SGMA requires.[9] Therefore, the GSP fails to "include[] the information required by [SGMA] and [its accompanying regulations]," and is thus inadequate.[10] These inadequacies prevent DWR from being able to determine that the GSP will likely achieve its sustainability goal.[11] Given these deficiencies, we ask DWR not to approve the plan.

B. DWR Cannot Approve The GSP Because It Will Cause Disproportionate And Disparate Negative Impacts On Protected Classes.

The Kern Groundwater Authority GSA and DWR must ensure that the GSP does not cause disparate impacts on protected groups, and must prioritize drinking water as an essential pillar of their groundwater sustainability plan. The GSP does not comply with these requirements.

State law provides that no person shall, on the basis of race, national origin, ethnic group identification, and other protected classes, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by any state agency.[12] In addition, the state's Fair Employment and Housing Act guarantees all Californians the right to hold and enjoy housing without discrimination based on race, color, or national origin.[13]

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[9] Water Code sec. 10727.2(b)(2)
[10] 23 CCR § 355.4(a)(2).
[11] Water Code § 10733(a); 23 CCR § 355.4(b).
[12] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].
[13] Gov. Code § 12900 et seq.

The GSP will have disparate impacts on protected classes, including negative and discriminatory impacts on the basis of race, color, ancestry, national origin, and ethnic group identification. "Low-income communities and communities of color in the Central Valley rely disproportionately on private wells because adequate public services were not developed in those communities."[14]As a result, "low-income households, people of color, and communities already burdened with environmental pollution suffered the most severe impacts [from drought]" and dry wells.[15] Similarly, communities of color in the Central Valley are disproportionately impacted by groundwater contamination.[16]

Consistent with these studies, this GSP will cause disproportionate negative impacts on communities of color reliant on small water systems and domestic wells. There are at least 105 disadvantaged unincorporated communities (DUCs) within Kern County, many of which will be impacted by this GSP.[17] Approximately 55% of the population of Kern County DUCs are people of color, slightly higher than the approximately 51% of the population of the County overall who are people of color. Many of the communities we work with and that are most susceptible to falling groundwater levels and groundwater pollution, however, are nearly 100% Latino. For example, according to the most recent American Communities Survey data, Lamont is 95% Hispanic or Latino.[18]

As discussed below, the GSP's determinations and policy decisions will result in many more dry wells, and will not prevent increased drinking water contamination from groundwater activities, particularly for disadvantaged communities reliant on small water systems and domestic wells. This will cause severe harm to residents' health and daily lives, as well as permanent impacts on residents' finances and living situations. Additionally, the GSP contains no measures to mitigate these impacts. Therefore, because the GSP is likely to have significant negative impacts on households reliant on small water systems and domestic wells, and because the people reliant on small water systems and domestic wells are disproportionately people of color, the GSP is likely

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[14] Feinstein et al., "Drought and Equity in California," p. 21 (January 2019), available at https://pacinst.org/wp-content/uploads/2017/01/PI_DroughtAndEquityInCA_Jan_2017.pdf.

[15] *Id. at p. 6.*

[16] *See* Balazs et al., "Social Disparities in Nitrate Contaminated Drinking Water in California's San Joaquin Valley," Environmental Health Perspectives, 19:9 (September 2011), available at https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1002878; Balazs et al., "Environmental Justice Implications of Arsenic Contamination in California's San Joaquin Valley," Environmental Health Perspectives, 11:84 (November 2012), available at https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84.

[17] Flegel et al., "California Unincorporated: Mapping Disadvantaged Communities in the San Joaquin Valley," p. 29,32 (2013), available at https://www.policylink.org/resources-tools/california-unincorporated-mapping-disadvantaged-communities-in-the-san-joaquin-valley; *see also* Kern County General Plan, Housing Element, Chapter 7 (April 2016), available at https://psbweb.co.kern.ca.us/planning/pdfs/he/KCHE_2015.pdf..

[18] Data available at https://data.census.gov/cedsci/, accessed on June 2, 2020.

to cause disparate impacts on protected classes.

C. The GSP Does Not Adequately Evaluate Whether Adverse Impacts Are "Significant And Unreasonable" Or Consider Beneficial Uses And Users.

Under SGMA, DWR must find that a GSP is likely to achieve its sustainability goal before DWR may approve the plan.[19] "'Sustainability goal' means the existence and implementation of one or more groundwater sustainability plans that achieve sustainable groundwater management by identifying and causing the implementation of measures targeted to ensure that the applicable basin is operated within its sustainable yield."[20] "'Sustainable groundwater management' means the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results."[21] An "undesirable result" occurs when a GSP allows a "significant and unreasonable" adverse impact to one of six sustainability indicators, including groundwater levels, groundwater storage, groundwater quality, and land subsidence.[22]

If a GSP is unlikely to achieve its sustainability goal, DWR cannot approve the plan.[23] DWR must also independently determine whether or not the GSP is likely to avoid "significant and unreasonable" adverse impacts with regard to each sustainability indicator, and if not then DWR cannot approve the plan. If a GSP will allow an undesirable result even if implemented effectively, then the GSP cannot achieve sustainable groundwater management.[24] Likewise, a plan that cannot achieve sustainable groundwater management has failed to set a valid sustainability goal, in violation of SGMA.[25] If a GSP does not contain a valid sustainability goal, DWR cannot determine that the GSP is "likely to achieve the sustainability goal for the basin," and DWR cannot approve it.[26]

In addition to defining undesirable results, GSPs must quantify benchmarks for groundwater conditions, or "minimum thresholds," that may cause undesirable results if exceeded.[27] GSPs must include "an explanation of how the Agency has determined that basin conditions at each minimum threshold will avoid undesirable results for each of the sustainability indicators."[28] A GSP's determination of when an undesirable result will occur must be based on analysis of when

[19] Water Code § 10733(a).
[20] Water Code § 10721(u).
[21] Water Code § 10721(v).
[22] Water Code § 10721(x).
[23] Water Code § 10733(a).
[24] Water Code § 10721(v).
[25] Water Code § 10721(u).
[26] Water Code § 10733(a); *see also* 23 CCR 354.24 ("Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline.").
[27] 23 CCR 354.28(a).
[28] 23 CCR 354.28(b)(2).

adverse impacts become "significant" and "unreasonable."[29]

In all of its actions, a GSA must "consider the interests of" all categories of beneficial users, including express requirements to consider disadvantaged communities on domestic wells and community water systems.[30] Failure to consider the interests of a category or categories of beneficial users is itself grounds for DWR to decline to approve a plan.[31] DWR regulations also establish that a failure to consider all beneficial uses and users of groundwater undermines the likelihood that a basin will reach its sustainability goal.[32]

We note that an impact on drinking water that persists for even a relatively short period of time (e.g., months or years rather than decades) may have permanent and irreversible impacts on households and communities. A household is not habitable without access to an adequate supply of safe drinking water, and failed wells thus may have irreparable impacts on community cohesion. These impacts are inconsistent with the very concept of sustainable groundwater management.

As explained below, the GSA has not based their policy determinations on an analysis of what impacts are "significant" and "unreasonable," and have not considered the interests of disadvantaged communities or low-income households reliant on small water systems or domestic wells.

D. DWR Cannot Approve The GSP Because It Was Developed With Inadequate Transparency, Accessibility, Consideration Of Public Input And Representation.

As public agencies, GSAs are subject to the requirements of the Brown Act, which requires transparency of public agencies through notice of meetings and prior posting of agendas, posting of meeting minutes after meetings, and public access to meeting materials upon request by a member of the public.[33] GSAs are also subject to the requirements of the Bilingual Services Act, which requires a public agency to provide interpretation and translate materials into all languages for which there is a "substantial" number of people who it serves who speak that language.[34]

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[29] Water Code § 10721(x); 23 CCR 354.28(b); *see also* Cal. Dep't Water Res., *Draft Best Management Practices for the Sustainable Management of Groundwater* 6 (Nov. 2017) ["GSAs must consider and document the conditions at which each of the six sustainability indicators become significant and unreasonable in their basin, including the reasons for justifying each particular threshold selected."]; *id.* 8 ["The GSP must include an analysis and written interpretation of the information, data, and rationale used to set the minimum threshold."].

[30] Water Code § 10723.2.

[31] Water Code § 10723.2; 23 CCR 355.4(b) ["The Department shall evaluate a Plan … to determine whether the Plan … complies with the Act …."].

[32] 23 CCR 355.4(b)(4).

[33] California Gov. Code § 54954.1

[34] Bilingual Services Act, Gov. Code, §§ 7293, 7295.

In addition, GSAs must also adhere to the specific public participation and inclusivity requirements laid out in SGMA. As discussed above, SGMA requires that a GSA "shall consider the interests of all beneficial uses and users of groundwater," which expressly includes "[h]olders of overlying rights" and "[d]isadvantaged communities, including, but not limited to, those served by private domestic wells or small community water systems."[35] The emergency regulations similarly require that a GSP summarize and identify "opportunities for public engagement and a discussion of how public input and response will be used."[36] GSAs thus must engage "diverse social, cultural, and economic elements of the population within the basin."[37] The regulations recognize that failure to engage adequately with a diverse cross-section of the public undermines the likelihood that a GSP will avoid undesirable results and meet its sustainability goal.[38]

The GSA did not adequately consider the input of disadvantaged communities, either at the GSA level or the member agency level. First, the GSA itself did not adequately engage residents of disadvantaged communities in the GSP creation process. The KGA GSA held regular GSA meetings at times that were not accessible to residents working during the day, so many beneficial user groups could not be adequately represented.

The GSA held several public workshops, but the feedback from these workshops, from meetings and from written comments was not incorporated into the GSP. We submitted a comment letter to the KGA GSA in June 2019 and presented this same letter verbally to the KGA board on June 26, 2019. At this meeting we expressed our initial concerns about GSP development and shared recommendations to ensure the protection of vulnerable water users. Among other things, we asked for the GSP to set protective sustainable management criteria to protect drinking water access in disadvantaged communities, ensure the GSP development process be reflective of all beneficial users by monitoring all primary drinking water contaminants, and to engage with DAC residents. These comments were not incorporated into the GSP or the GSP development process. We repeated these same concerns and recommendations in our comment letter on the final public draft of the GSP.

The GSA had a communications plan and an online Stakeholder Survey that was available most of the GSP development period, but the survey was only in English and was only available online, thereby limiting the opportunity for diverse input from non-English speakers and those without regular access to the internet. The survey was also not promoted outside the KGA agencies' existing networks in an authentic and intentional way to reach all beneficial users including disadvantaged communities. While the GSA worked with Self-Help Enterprises to

[35] Water Code § 10723.2.
[36] 23 CCR 354.10(d).
[37] Guidance Document for Groundwater Sustainability Plan; Stakeholder Communication and Engagement, p. 1.
[38] 23 CCR 355.4(b)(4).

provide interpretation at workshops, it did not provide interpretation at its board meetings. It also did not provide translated materials at its meetings.

Additionally, the decision-making structure of the GSA created barriers to public engagement. Instead of being able to learn about GSP development and provide feedback at GSA meetings, stakeholders also had to engage with a myriad of local member agencies, which all had separate meetings, to fully understand GSP development. The KGA GSP states that, "[t]o capture the intent of SGMA as legislation better served under local control, KGA member agencies played a vital role in the development of this GSP. This process included communication and outreach at the local level, with each KGA member agency engaging with its beneficial users to gather vital input, data, and feedback to ensure the success of this GSP and individual management area plans."[39] However, this decision-making structure meant attending member agency meetings and GSA meetings to understand GSP development, which is overly burdensome to most stakeholders who do not have adequate time in their schedules to attend so many regular meetings.

This burdensome process is compounded by the fact that GSA meetings were held during work hours, and member agencies' websites did not provide adequate notice or agendas for GSP-related meetings. The GSP states that "each KGA member agency engag[ed] with its beneficial users to gather vital input, data, and feedback to ensure the success of this GSP and individual management area plans."[40] However, our organization and residents we work with in Arvin had serious barriers to actively participating in GSP development through their local member agency.

The member agency that has jurisdiction over residents we work with in the GSA area, the Arvin-Edison Water Storage District ("Arvin-Edison WSD"), states in its Management Plan, a chapter of the GSP, that it considered disadvantaged communities by engaging representatives of the Arvin CSD, which contains disadvantaged community residents; by creating a Stakeholder Communication and Engagement Plan; and by "welcom[ing] public participation" at stakeholder workshops, Arvin-Edison WSD board meetings, Arvin CSD board meetings, KGA GSA events and meetings, a stakeholder survey, letters to landowners, and small or one-on-one meetings with individual stakeholders.[41] However, as a community-based organization working directly with residents in the GSA area, we were not included in these conversations until August 15, 2019 when we attended the Arvin- Edison WSD Board meeting where they presented their GSP chapter to its board for approval. Residents we work with did not have any knowledge of the GSP development process in the Arvin-Edison Management Area. We have collaborated with many GSAs to develop more effective outreach materials and procedures for ensuring

[39] Kern Groundwater Authority GSP, p. 37, dated January 2020.
[40] Kern Groundwater Authority GSP, p. 37, dated January 2020.
[41] Arvin-Edison Water Storage District Management Area GSP, p. 3-4, dated December 2019.

disadvantaged community involvement, but it was very difficult to follow the structure of KGA. This made it difficult to relay accurate and complete information to community residents and properly engage them with the topic.

Additionally, during GSP implementation the Arvin WSD's website contained no information on SGMA or GSP meetings. We understand from conversations with staff that the agency sent notices to its list serv, but there was no way to sign up for the list serv on the website, and without knowing when and where meetings are occuring the public could not go to a meeting to sign up and be added to the interested parties list serv. A representative from Arvin CSD brought regular updates to a community meeting, but no meeting notices or agendas about GSP development meetings were published in any publicly available format. This public process did not comply with the Brown Act, the Bilingual Services Act, or the requirements under SGMA.

After we submitted our comments on the draft GSP, including the Arvin-Edison Management Area chapter of the GSP, representatives from Arvin CSD reached out to us to discuss our concerns about their public process and the substance of their portion of the GSP. The representatives from Arvin CSD expressed their commitment to public participation and drinking water needs of the residents of Arvin, and agreed to consider our feedback on improved public participation practices. Since then, Arvin WSD huas updated its website and included a link to sign up for its interested parties listserv. But these efforts, taking place after GSP development was largely complete, did not inform the GSP.

The GSA's public participation process and its choice to delegate GSP development to member agencies did not ensure a transparent and inclusive process for developing the GSP. The public engagement process for this GSP was therefore inadequate. At a minimum, an adequate process must include the following elements, which were not present here:

1. **Notice:**[42] Ensure that the GSA provided clear notice to the public about GSA meetings to develop the GSP, posted in ways that all stakeholders were made aware of the meetings, and translated into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.[43]

[42] Government Code § 54954(a).

[43] Government Code sec. 7296.2: Dymally-Alatorre Bilingual Services Act, stating that local agencies providing services to the public must provide translated materials and interpretation when it serves a substantial number of non-English-speaking people. The law defines a "substantial number of non-English-speaking people" as "members of a group who either do not speak English, or who are unable to effectively communicate in English because it is not their native language, and who comprise 5 percent or more of the people served by the statewide or any local office or facility of a state agency." This is because "effective maintenance and development of a free and democratic society depends on the right and ability of its citizens and residents to communicate with their government and the right and ability of the government to communicate with them."

2. **Translation of materials:**[44] Ensure that the GSA translated materials into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.
3. **Interpretation:**[45] Ensure that the GSA provided interpretation services at board meetings, committee meetings and workshops for all languages spoken by at least 5 percent of the public served by the agency, to allow those who do not speak English or are unable to effectively communicate in English to effectively participate.
4. **Meaningful DAC representation on advisory committee:** Ensure that the GSA developed the GSP with an advisory committee that contained representatives from DACs, such that DAC representatives' voices were not drowned out by the overwhelming majority of another interest group.
5. **DAC representation on GSA boards and Coordination Committee:** Ensure that the GSA developed the GSP with GSA boards and a Coordination Committee that contained representatives from DACs.
6. **Incorporation of stakeholder input:** Ensure that the GSP explicitly describes how stakeholder input was incorporated into the GSP process and decisions, including sustainable management criteria and all projects and management actions.

E. The GSP's Sustainable Management Criteria for Groundwater Levels Are Not Adequate

The sustainable management criteria for groundwater levels must be made after considering the interests of all beneficial user groups, including disadvantaged communities reliant on domestic wells and community water systems,[46] and must be based on an analysis of what are "significant" and "unreasonable" impacts.[47] These policy decisions must also avoid disparate impacts on protected groups pursuant to state and federal law.[48] As discussed below, the GSP does not meet these requirements.

a. The Undesirable Result for Groundwater Levels are Inadequate

Undesirable results are the point at which groundwater conditions cause "significant and unreasonable" impacts on beneficial users. The SGMA regulations require GSAs to justify their undesirable results by including the "[p]otential effects on the beneficial uses and users of

[44] Government Code sec. 7296.2.
[45] Government Code sec. 7296.2.
[46] Water Code § 10723.2.
[47] Water Code § 10721(x); 23 CCR 354.28(b); *see also* Cal. Dep't Water Res., *Draft Best Management Practices for the Sustainable Management of Groundwater* 6 (Nov. 2017) ["GSAs must consider and document the conditions at which each of the six sustainability indicators become significant and unreasonable in their basin, including the reasons for justifying each particular threshold selected."]; *id.* 8 ["The GSP must include an analysis and written interpretation of the information, data, and rationale used to set the minimum threshold."].
[48] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).

groundwater."[49] GSAs must also describe the "processes and criteria relied upon to define undesirable results."[50] These determinations must be made based on an analysis of when decreasing groundwater levels will cause results that are either "significant" or "unreasonable" in light of the context of the basin and the real-world circumstances on the ground. The undesirable results determination does not comply with these requirements because it is unsupported by analysis, it is too vague, and it does not show how the GSA considered the interests of beneficial users in shaping its conclusions.

The KGA GSP defines undesirable results for groundwater levels as "when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area)."[51] Neither the KGA GSP nor the Kern Subbasin Coordination Agreement contain an analysis of how what the concrete impacts would be on beneficial users from reaching these undesirable results, including how many wells could go dry, or a process by which beneficial users were consulted in order to determine whether these potential impacts were "significant and unreasonable."

The undesirable result could allow for more than 30% of the territory in the subbasin to exceed its minimum thresholds for groundwater levels before this undesirable result is triggered. This standard allows localized impacts across the subbasin area, which would cause significant and unreasonable impacts to beneficial users of groundwater for drinking and other domestic purposes. There is no justification for dividing the GSA area up into arbitrary management areas and then defining undesirable results as occurring only where three ***adjacent*** management areas exceed minimum thresholds. In short, the GSP allows domestic and small community wells to be dewatered.

Because the undesirable result for groundwater levels allows significant and unreasonable impacts, the GSP is inadequate.

b. The Measurable Objectives for Groundwater Levels are Inadequate

The SGMA regulations require the GSA to set measurable objectives that "achieve the sustainability goal for the basin within 20 years of Plan implementation and...continue to sustainably manage the groundwater basin over the planning and implementation horizon."[52]

The GSA has not demonstrated that it evaluated how the proposed measurable objectives would contribute to the overall sustainable yield of the Kern Subbasin, which is approximately 324,326

[49] 23 CCR § 354.26.
[50] 23 CCR § 354.26.
[51] Kern Groundwater Authority GSP, p. 170, adopted January 2020.
[52] 23 CCR § 354.30(a)

acre-feet per year, according to the GSP,[53] or maintain sustainability over the implementation and planning horizon.

c. The Minimum Thresholds for Groundwater Levels are Inadequate

The groundwater levels sustainable management criteria set by a GSA must be the point that, "if exceeded, may cause undesirable results."[54] SGMA requires GSAs to analyze both the significance and reasonableness of proposed minimum thresholds,[55] and minimum thresholds must have the purpose of avoiding "significant and unreasonable" impacts on beneficial users.[56] The GSA's determination of what is "significant and unreasonable" must consider the impacts on all types of beneficial users, including disadvantaged communities.[57] For groundwater levels specifically, GSAs must place minimum thresholds for each monitoring site at the level "that may lead to undesirable results."[58] Under DWR regulations, the GSA must provide a description of "the information and criteria relied upon to establish minimum thresholds," an explanation of how the proposed minimum thresholds will "avoid undesirable results," and "how minimum thresholds may affect the interests of beneficial uses and users of groundwater."[59]

The GSP's minimum thresholds were not established in a way that considered the interests of beneficial users including domestic well owners and disadvantaged communities, and the resulting minimum thresholds cause significant and unreasonable impacts on the most vulnerable beneficial users. The GSA delegated the task of creating the sustainable management criteria to member agencies, and in the process, did not ensure that the resulting policies complied with the law. The resulting impact from the proposed sustainable management criteria will likely lead to disparate impacts on protected groups pursuant to state and federal law.

The KGA GSA did not ensure that minimum thresholds created by member agencies considered the interests of all beneficial user groups, or prioritize the security of drinking water in the subbasin, in developing minimum thresholds. For example, the Arvin-Edison Management Area GSP did not consider the impact on drinking water users in setting its minimum thresholds. The AEWSD Management Area Draft GSP details how it calculated historical water lows and divided the Management Area into four "Sustainability Criteria Zones" based on historical low groundwater levels and agency jurisdiction, and how it adjusted the minimum thresholds to protect the canal that brings surface water to farmers.[60] However, it did not evaluate or consider

[53] Kern Groundwater Authority GSP, p. 151, dated January 2020.
[54] 23 CCR § 354.28.
[55] Water Code § 10721(x); 23 CCR 354.26(a). (b), 354.28(b); see also Cal. Dep't Water Res., Draft Best Management Practices for the Sustainable Management of Groundwater 6, 8 (Nov. 2017).
[56] 23 CCR § 354.26.
[57] Water Code § 10723.2.
[58] 23 CCR § 354.28.
[59] 23 CCR § 354.28.
[60] Arvin-Edison Water Storage District Management Area GSP, p. 124, dated December 2019.

how many wells could go dry from its proposed minimum thresholds, or adjust for effects on drinking water. Figures 2-5, 2-6 and 2-7 show all of the domestic wells, public supply wells, and communities dependent on groundwater in the GSA area.[61] The GSA therefore knows the number and location of all drinking water wells, but has chosen not to evaluate what the impacts will be to these wells at the minimum thresholds, and whether those impacts are significant and unreasonable. Therefore the GSA did not consider impacts on drinking water beneficial users, or ensure the protection of drinking water as the highest beneficial use of water, despite having all the information it needed to conduct such a drinking water impact analysis.

The GSP does not show that the impact to beneficial users was evaluated. It lays out the process by which the minimum thresholds and measurable objectives were approved, states that the GSA had workshops about the sustainable management criteria and that these items "appeared as discussion items" at the GSA board meetings, but does not show that the GSA considered the impacts on beneficial users.[62] The GSP contains no evaluation of impacts on beneficial users from reaching these sustainable management criteria, and the GSA's decisions regarding sustainable management criteria were not based on an evaluation of the impacts to beneficial users' access to groundwater resources.

The groundwater levels sustainable management criteria for this GSP are therefore inadequate. At a minimum, adequate groundwater levels sustainable management criteria must include the following elements, which are not present here:

1. **Evaluate the drinking water impact:** Ensure that the GSP includes an analysis of how many drinking water wells (municipal wells, community water system wells, and domestic wells) might go fully or partially dry if groundwater levels reach the undesirable results,[63] measurable objectives and minimum thresholds,[64] including a map of wells that will go fully and partially dry at the measurable objectives and minimum thresholds. Ensure that the GSP includes estimates of the increased pumping costs from additional lift needed to pump water from lower elevations if the undesirable results, measurable objectives and minimum thresholds were to be reached.
2. **Avoid significant and unreasonable impacts to drinking water users in creating sustainable management criteria:**[65] The GSA must analyze "when significant and unreasonable effects ... are caused by groundwater conditions occurring throughout the basin," taking into account the beneficial users of groundwater and the basin's specific circumstances.[66] Therefore the GSP must explicitly state how the GSA considered

[61] Kern Groundwater Authority GSP, pg. 26-28, dated January 2020.
[62] Kern Groundwater Authority GSP, p. 177, dated January 2020.
[63] 23 CCR § 354.26(c)
[64] 23 CCR § 354.28(b)(4)
[65] Water Code § 10723.2
[66] 23 CCR § 354.26.

drinking water impacts in shaping undesirable results, measurable objectives and minimum thresholds for groundwater levels; for example, the GSP could state how its well impact analysis supported setting stricter measurable objectives and minimum thresholds near at-risk communities.

3. **Incorporate new drinking water data into sustainable management criteria:**[67] Ensure that the GSP includes a description of how data gaps and uncertainties of its drinking water well impact assessment will be addressed and serve to reassess the sustainable management criteria, projects and management actions in accordance with new data.
4. **Implement DAC and drinking water user input into sustainable management criteria:**[68] Ensure that the GSP discusses how stakeholder input from DAC community members was considered in the development of undesirable results, measurable objectives and minimum thresholds. For example, the GSP could state how they took the results of the well impact assessment to the public through meetings, workshops, or Advisory Committees, and together with stakeholders decided how to change sustainable management criteria to protect drinking water, or other programs to implement to mitigate these impacts.
5. **Avoid disparate impact:**[69] Ensure that the measurable objectives and minimum thresholds for groundwater levels are established in such a way that prevents a disparate impact from occurring on protected classes in the GSP area. For example, the GSP should ensure that the same minimum threshold methodology across the GSP area will not lead to disproportionately more wells going dry for residents of color than for white residents.

F. The GSP Fails To Adequately Address Groundwater Quality Through Its Sustainable Management Criteria for Groundwater Quality

GSA activities and policies could cause increased contamination in many ways. For example, the proposed timeline for implementation of demand reduction may allow for continued pumping which may create an increase in naturally occurring contaminants and/or migration of contaminant plumes.[70] Recharge projects could also have severe impacts on groundwater quality by facilitating water percolation on land contaminated with years of pesticide, herbicide, fungicide, and fertilizer application and/or by releasing natural contaminants like uranium into groundwater.[71] A groundwater market is also likely to cause geographic concentrations of

[67] 23 CCR § 354.38(e)(3)
[68] 23 CCR § 354.10(d); DWR Guidance Document for Groundwater Sustainability Plans: Stakeholder Communication and Engagement, p.1.
[69] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[70] *See* Smith et al., Overpumping Leads to California Groundwater Arsenic Threat, 9 Nature Communications 2089 (2018), available at https://www.nature.com/articles/s41467-018-04475-3.
[71] See Fakhreddine et al., Protecting Groundwater Quality In California, Management Considerations For Avoiding Naturally Occurring And Emerging Contaminants (2019), available at https://www.edf.org/sites/default/files/documents/groundwater-contaminants-report.pdf ["Recharging water, even clean water, into a previously uncontaminated aquifer can potentially alter the existing geochemistry and hydrology

pumping that increases the likelihood of contaminant plume migration, putting drinking water resources at risk. Oil and gas impacts on groundwater should also be analyzed, since Kern County is one of the largest producers of oil and gas, and reports show oil and gas activities can severely impact groundwater quality.[72]

SGMA charged GSAs with the responsibility to protect water quality from further degradation due to groundwater management practices, and requires GSAs to establish sustainable management criteria to prevent degraded groundwater quality,[73] based on a determination of what is a "significant and unreasonable" impact on all beneficial users, including domestic well users and disadvantaged communities.[74] This GSP only monitors and regulates one contaminant of concern despite its express knowledge that many other more harmful drinking water contaminants exist in its GSP area, which could be impacted by groundwater usage and activities. The GSA's sustainable management criteria for groundwater quality are inadequate.

b. The Undesirable Results Determination for Groundwater Quality Is Inadequate

Undesirable results are the point at which "significant and unreasonable" impacts on beneficial users caused by degraded groundwater quality. The SGMA regulations require GSAs to justify their undesirable results by including the "[p]otential effects on the beneficial uses and users of groundwater."[75] GSAs must also describe the "processes and criteria relied upon to define undesirable results."[76] The undesirable result cannot have a disparate impact on protected groups pursuant to state civil rights law.

Like the undesirable result for groundwater levels, the proposed definition of undesirable results for degraded water quality are "when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the

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and subsequently cause the release of geogenic contaminants from soils and sediments."]; Jurgens, Bryant C., et al. "Effects Of Groundwater Development On Uranium: Central Valley, California, USA," Groundwater 48.6 p. 913 (2010), available at https://ngwa.onlinelibrary.wiley.com/doi/abs/10.1111/j.1745-6584.2009.00635.x; "Groundwater Quality In The Sustainable Groundwater Management Act (SGMA): Scientific Factsheet on Arsenic, Uranium, and Chromium," available at https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1559328800/Groundwater_Quality_in_SGMA_Scientific_factsheet_on_arsenic__uranium__and_chromium.pdf?1559328800

[72] Jackson, Robert B., and DiGuilio, Dominic C., Impact to Underground Sources of Drinking Water and Domestic Wells from Production Well Stimulation and Completion Practices in the Pavillion, Wyoming, Field, Environ. Sci. Technol. 2016, 50, 8, 4524-4536; see also references cited in *Six ways oil and gas development can contaminate land and water (and what to do about it),* by Adam Peltz and Nichole Saunders, Environmental Defense Fund Blogs, found at http://blogs.edf.org/energyexchange/2017/12/29/six-ways-oil-and-gas-development-can-contaminate-land-and-water-and-what-to-do-about-it/ , last viewed November 26th, 2019.

[73] Water Code § 10721(w)(4); 23 CCR § 354.28(c)(4).

[74] Water Code §§ 10727.2(d)(2); 10721(x)(4)

[75] 23 CCR § 354.26.

[76] 23 CCR § 354.26.

Subbasin or greater than 30% of the Subbasin (as measured by each management area)."[77] As with the groundwater levels undesirable results, it is not clear what the impacts from reaching this undesirable result will be on beneficial users, and neither the KGA GSP nor the Kern Subbasin Coordination Agreement contain an analysis of how what the concrete impacts would be on beneficial users from reaching these undesirable results, including how many wells could go dry. Instead of being formed through a process in which beneficial users were consulted in order to determine whether these potential impacts were "significant and unreasonable," the process of defining undesirable results in the Kern subbasin seems to be an arbitrary determination of what is "significant and unreasonable."

The water quality undesirable results will allow significant and unreasonable impacts in localized areas and/or for short to medium periods of time. Given that more than 30% of the territory in the subbasin will be allowed to exceed its minimum thresholds for groundwater quality before this undesirable result is triggered, the GSP allows drinking water users to be impacted by drinking water contamination caused by GSA policies and activities. The definition of undesirable results therefore sets a very low inadequate bar for plan failure, and must be modified to ensure that drinking water is protected within the basin.

Because the undesirable results for groundwater quality allow significant and unreasonable impacts on sources of drinking water, DWR cannot approve the GSP.

b. The Minimum Thresholds and Measurable Objectives for Groundwater Quality Are Inadequate

GSAs must place groundwater quality minimum thresholds for each monitoring site at the level "that may lead to undesirable results."[78] Under the SGMA regulations, the GSP must provide a description of "the information and criteria relied upon to establish minimum thresholds," an explanation of how the proposed minimum thresholds will "avoid undesirable results," and "how minimum thresholds may affect the interests of beneficial uses and users of groundwater."[79] Measurable objectives must lead to compliance with the GSA's sustainable yield by 2040.

The GSP briefly states that each member agency established the minimum thresholds and measurable objectives for their management area, mentions that in many cases groundwater levels serve as a proxy for groundwater quality, lists the minimum thresholds and measurable objectives established by each member agency in Table 3-1, and states that more information can be found in the management area GSPs.[80] For several management areas, Table 3-1 does not list which contaminants are being monitored for compliance with the proposed minimum thresholds

[77] Kern Groundwater Authority GSP, p. 172, dated January 2020.
[78] 23 CCR § 354.28.
[79] 23 CCR § 354.28.
[80] Kern Groundwater Authority GSP, p. 179, dated January 2020.

and measurable objectives. Many management areas have used groundwater levels as a proxy for groundwater quality.

Groundwater levels are not a proxy for groundwater quality, and failure to set adequate minimum thresholds or measurable objectives to protect against discharge of all primary and secondary drinking water contaminants during recharge activities and/or activities that cause shifting contaminant plumes renders the GSP inadequate.

As in the case of groundwater levels, it is clear that the GSA has not considered the potential impact on drinking water users, in particular disadvantaged communities that are less able to afford solutions to treat contaminated drinking water. This has resulted in minimum thresholds and measurable objectives like those in the Arvin GSP, which will only be monitoring for compliance with sustainable management criteria in one well location, and has set the minimum threshold at the drinking water MCL for the contaminant, and the measurable objective at 75% of the MCL. The member agency is only monitoring for compliance with arsenic standards, despite the agency's knowledge of the existence of "nitrate...total dissolved solids (TDS), boron, iron and manganese...within or near the Arvin-Edison Management Area above drinking water standards and/or agricultural water quality goals."[81]

The lack of sufficient groundwater quality sustainable management criteria in areas like Arvin means that the GSP allows drinking water pollution that will be disproportionately felt by disadvantaged communities that are less able to afford treatment solutions. This significant and unreasonable impact is not adequate under SGMA or state and federal law prohibiting policy from resulting in disparate impact. The GSA has not conducted an analysis of how the minimum thresholds and measurable impacts could impact critical drinking water resources, and therefore has not considered the interests of all beneficial user groups, particularly drinking water users.

The GSA has also not specified what actions will be taken if water contamination approaches minimum thresholds, or how minimum thresholds will be triggered. Member agencies such as the Arvin-Edison WSD have not specified this in their plans. The GSA should ensure that minimum thresholds will be triggered after one test shows a violation of an MCL or a trend toward an MCL. The GSA must require that member agencies specify what actions they will take if groundwater quality approaches minimum thresholds, what point or measurement will trigger this action, and how impacted residents will be informed. The GSA must also ensure GSA-wide consistency on when minimum thresholds are triggered and what actions are taken in response, in order to protect drinking water across the GSA area.

[81] Arvin-Edison Water Storage District Management Area Plan, p. 80, dated December 2019.

Because the minimum thresholds and measurable objective fail to consider all beneficial users and cause significant and unreasonable impacts, the GSP is inadequate and DWR cannot approve it.

The groundwater quality sustainable management criteria for this GSP are therefore inadequate. At a minimum, adequate groundwater quality sustainable management criteria must include the following elements, which are not present here:

1. **Ensure that the GSP sets measurable objectives and minimum thresholds at all representative monitoring wells for all of the following contaminants:**[82]
    a. Contaminants with primary drinking water standards,
    b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health, AND
    c. Contaminants like uranium, arsenic and nitrate which are known to increase due to groundwater management practices.
2. **Ensure that the GSP triggers a violation of a minimum threshold after *one* test shows that there has been an increase in contamination since January 1st, 2015**. Once the minimum threshold is reached, the GSA must start the evaluation of whether groundwater management activities or groundwater pumping have caused the increase, or whether the increase was caused by other factors such as natural fluctuation, testing inaccuracy, or activities outside the purview of the GSA. If the increase was caused by groundwater management activities or groundwater pumping, the GSA must immediately stop increasing the contamination and remediate.
3. **Immediately remediate any contamination caused by groundwater conditions since 2015:** The GSA must immediately remediate any increased contamination caused by groundwater management policies or activities (including lack of adequate regulation of pumping) since 2015. The GSA must begin remediation immediately upon establishing causation. The GSA must remediate contamination within two years, or as soon as technologically and hydrologically possible, whichever is faster. Design and implementation of remediation measures must be done in partnership with all groundwater users, primarily disadvantaged communities. The GSA must also clearly identify funding sources for remediation, and identify a timeline for procuring those funds.
4. **Strive to remediate existing drinking water contamination:** Ensure that the GSA will strive to remediate drinking water contaminants that exceeded the MCL before 2015 wherever feasible, through projects, management actions and policies.
5. **Evaluate the drinking water impact:** Ensure that the GSP includes an analysis of how drinking water wells (municipal wells, community water system wells, and domestic

[82] 23 CCR § 354.34(b)(2) and (f)(3)

wells) are likely to be be affected by the undesirable results,[83] measurable objectives and minimum thresholds.[84]

6. **Implement DAC and drinking water user input into sustainable management criteria:**[85] Ensure that the GSP discusses how stakeholder input from DAC community members was considered in the development of undesirable results, measurable objectives and measurable objectives.
7. **Incorporate new drinking water data into sustainable management criteria:**[86] Ensure that the GSP includes a description of how data gaps and uncertainties of its drinking water well impact assessment will be addressed and serve to reassess the sustainable management criteria, projects and management actions in accordance with new data.
8. **Avoid disparate impact:**[87] Ensure that the minimum thresholds for groundwater quality are established in such a way that prevents a disproportionately negative impact on communities of color in the GSP area. For example, the GSP should ensure that the same minimum threshold methodology across the GSP area will not lead to disproportionately more wells going dry for residents of color than for white residents.

G. The Monitoring Network is Inadequate With Respect to Groundwater Levels and Groundwater Quality

GSAs must monitor impacts to groundwater for drinking water beneficial users,[88] including disadvantaged communities on domestic wells,[89] and must avoid disparate impacts on protected groups pursuant to state law.[90]

As discussed below, The GSA's monitoring network does not comply with SGMA regulations, and fails to capture drinking water impacts to disadvantaged communities and domestic wells. Specifically, the GSP lacks representative monitoring wells in areas of the subbasin where drinking water users may be particularly vulnerable to groundwater supply and quality issues, leaving the GSA with no ability to measure and avoid significant and unreasonable impacts to those users. The monitoring wells are also monitored two infrequently to timely detect and prevent falling groundwater levels and/or contamination.

[83] 23 CCR § 354.26(c)
[84] 23 CCR § 354.28(b)(4)
[85] 23 CCR § 354.10(d); DWR Guidance Document for Groundwater Sustainability Plans: Stakeholder Communication and Engagement, p.1.
[86] 23 CCR § 354.38(e)(3)
[87] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[88] 23 CCR § 354.34
[89] Water Code § 10723.2.
[90] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).

The lack of adequate monitoring will make it impossible for the GSA to monitor drinking water to detect and prevent undesirable results, undermining the likelihood that the basin will achieve sustainable groundwater management.

The insufficiency of the representative monitoring network renders the GSP inadequate.

a. Groundwater Level Monitoring

The SGMA regulations state that monitoring networks must include a "sufficient density of monitoring wells to collect representative measurements through depth-discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer."[91] The GSA must also make decisions about the monitoring network in a way that considers the interests of all beneficial users.[92]

The GSP here presents a map of its groundwater levels monitoring wells,[93] but does not show what aquifers the wells are monitoring, and where monitoring wells are in relation to disadvantaged communities on domestic wells and small community water systems. As such, it is not possible for the public or DWR to determine whether there is a sufficient density of wells to collect representative measurements and detect and prevent significant and unreasonable impacts on beneficial users.

The monitoring network for groundwater levels is therefore inadequate and will not detect significant and unreasonable impacts to disadvantaged communities. At a minimum, an adequate groundwater levels monitoring network must include the following elements, which are not present here:

1. **Ensure accurate detection of impacts on drinking water users and DACs:**[94] Ensure that the groundwater level monitoring network includes *representative* monitoring wells *in or near DACs*, and placed in a way that detects impacts to the *vast majority* of drinking water users in the GSP area. If new monitoring wells are required, ensure that the GSP contains a concrete plan to fund and construct new representative monitoring wells within the first year of GSP implementation to ensure that vulnerable communities' drinking water resources are monitored. The plan to improve the monitoring network should include testing of domestic wells in the interim as wells are constructed.
2. **Clearly show representative monitoring well locations in relation to DACs:**[95] Ensure that the representative monitoring wells (RMWs) for groundwater levels are presented on maps and in tables that identify which set of minimum thresholds and measurable

[91] 23 CCR § 354.34(c)(1)(A)
[92] 23 CCR § 354.34(b)(2)
[93] Kern Groundwater Authority GSP, Figure 3-3, p. 186-189, dated January 2020.
[94] 23 CCR § 354.34(b)(2) and (f)(3)
[95] 23 CCR § 354.34(b)(2) and (f)(3)

objectives will be applied to which RMWs, and that these maps clearly identify the locations of DACs, small water systems and other sensitive users.

3. **Identify and address other drinking water data gaps:**[96] Ensure that the GSP clearly identifies any other gaps in data regarding impacts to drinking water users, and that the GSP contains a clear plan to fill data gaps regarding impacts to drinking water users. The GSP explains how it will fill some monitoring data gaps, but does not ensure that these gaps will capture impacts on all drinking water users, particularly disadvantaged communities.

b. Groundwater Quality Monitoring

SGMA regulations require that GSPs create a groundwater quality monitoring network that will "collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues."[97]

The groundwater quality monitoring network does not adequately capture impacts on drinking water users. For example, in the case of the Arvin GSP, the member agency will only monitor for compliance with its minimum threshold and measurable objective for arsenic once a year in one well, ACSD Well #14, which is one of the wells that provide drinking water to the community of Arvin.[98]

First, measuring for Arsenic only once a year does not provide the member agency or the GSA with frequent enough information to detect and respond to severe drinking water contamination in a reasonable amount of time. If the member agency's management actions, projects, or decisions to let groundwater decline increase drinking water contamination for families in the management area, the member agency could go a whole year without detecting these impacts. Meanwhile, it will not be responsive to the drinking water impacts from other contaminants which it may have moved or increased from its activities. Instead, the member agency must measure for all contaminants of concern every month.

Second, only measuring for compliance with arsenic measurable objectives and minimum thresholds does not protect against increases in other contaminants that exist in other parts of the management area (boron, nitrates, TDS, 123-TCP, iron and manganese). These contaminants could extend, move or increase due to groundwater management activities and pumping patterns. The Arvin GSP does plan to monitor for these contaminants in seven other wells outside of Arvin,[99] but has not set minimum thresholds and measurable objectives for these wells, and does

[96] 23 CCR § 354.38(e)(3)
[97] 23 CCR § 354.34(c)(4)
[98] Arvin-Edison Water Storage District Management Area Plan, p. 144, dated December 2019.
[99] Arvin-Edison Water Storage District Management Area Plan, p. 144-145, dated December 2019.

not have plans to do so. Without standards against which to compare detected levels of contaminants, and concrete commitments to preventing increased contamination, inclusion of these monitoring networks are meaningless.

Furthermore, Arvin is currently experiencing 123-TCP contamination that threatens the health of Arvin residents, so the GSP must monitor for compliance with 123-TCP standards in particular. In order to ensure that member agencies are detecting new contaminant plumes that could impact drinking water quality, the GSA must ensure that these representative monitoring wells monitor for all contaminants with primary drinking water standards, as well as contaminants known to increase with groundwater management activities such as uranium.[100] The GSA must also ensure that all representative monitoring wells are held to minimum thresholds and measurable objectives, measure the extent and spread of known contaminant plumes, and are able to measure the groundwater levels at the depth at which the drinking water wells are screened.

Third, the well that was chosen, ACSD Well #14, was chosen because it does not have contaminants that are known to exist in wells in the northern part of the management area, which are not currently in use by Arvin CSD, according to our conversation with Arvin-Edison WSD staff at the Kern Subbasin Open House on September 26th, 2019. Avoiding monitoring contaminated areas is inappropriate and fails to ensure that groundwater management activities and pumping do not aggravate existing contamination. The GSA should ensure that the member agency instead monitors for all existing contaminants at minimum throughout the area and especially in areas where contamination is known to exist, and sets minimum thresholds and measurable objectives that apply to all monitoring wells.

The groundwater quality monitoring network for this GSP is therefore inadequate. At a minimum, an adequate groundwater quality monitoring network must include the following elements, which are not present here:

1. **Ensure that the GSP plans to measure the following contaminants at all representative monitoring wells:[101]**
    a. Contaminants of concern with primary drinking water standards
    b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health
    c. Contaminants like uranium, arsenic and nitrate which are known to increase due to groundwater management practices

[100] Smith et al., "Overpumping Leads to California Arsenic Threat," Nature Communications (June 2018) [arsenic discharge from clay correlated with overpumping]; Jurgens et al., "Effects of Groundwater Development on Uranium" (November 2010) [strong correlation between high bicarbonate irrigation and recharge water and leaching of uranium from shallow sediments to groundwater].
[101] 23 CCR § 354.34(b)(2) and (f)(3)

2. **Clearly describe how the GSA will monitor for drinking water impacts:** Ensure that the GSP includes a description of how the GSA(s) will monitor groundwater contamination that could affect drinking water in the GSA area. Ensure that the representative monitoring wells (RMWs) for groundwater quality are presented on maps and in tables, and that the maps of RMWs clearly identify the locations of DACs, small water systems and other sensitive users.
3. **Ensure that the GSP plans to measure the following contaminants at all representative monitoring wells:**[102]
    a. Contaminants of concern with primary drinking water standards
    b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health
    c. Contaminants like uranium, arsenic and nitrate which are known to increase due to groundwater management practices
4. **Clearly describe how the GSA will monitor for drinking water impacts:** Ensure that the GSP includes a description of how the GSA will monitor groundwater contamination that could affect drinking water in the GSA area. Ensure that the representative monitoring wells (RMWs) for groundwater quality are presented on maps and in tables, and that the maps of RMWs clearly identify the locations of DACs, small water systems and other sensitive users.
5. **Ensure accurate detection of impacts on drinking water users and DACs:**[103] Ensure that the groundwater level monitoring network includes *representative* monitoring wells *in or near DACs*, and placed in a way that detects impacts to the *vast majority* of drinking water users in the GSP area. If new monitoring wells are required, ensure that the GSP contains a concrete plan to fund and construct new representative monitoring wells within the first year of GSP implementation to ensure that vulnerable communities' drinking water resources are monitored. The plan to improve the monitoring network should include testing of domestic wells at least as an interim measure as wells are constructed.
6. **Identify baseline contaminant levels:** Ensure that the GSP identifies the current contaminant levels, minimum thresholds and measurable objectives at each RMW, so that it is clear to the public how the contamination could change at each RMW site.
7. **Frequent testing:** Ensure that the groundwater quality monitoring network tests for contaminants of concern frequently, in a way that avoids persistent drinking water contamination. Testing should be done monthly.
8. **Collaboration with other agencies:**[104] Ensure that the GSP explains how the GSA will share data with and collaborate with other groundwater quality regulatory programs, such as ILRP, IRWM, and CV SALTS, and nonregulatory programs such as SB 200, the

[102] 23 CCR § 354.34(b)(2) and (f)(3)
[103] 23 CCR § 354.34(b)(2) and (f)(3)
[104] 23 CCR § 354.34(e)

SWRCB's needs assessment and the GAMA program, in order to build better regional understanding of groundwater quality issues, commit to clear roles, and better respond to groundwater quality impacts caused by groundwater management.

H. Projects and Management Actions Are Inadequate

The GSA must consider the interests of all beneficial users including domestic well owners and disadvantaged communities[105] and avoid disparate impacts on protected groups.[106] The GSP must also concretely outline how each objective and the overall sustainability goal will be achieved.[107] The projects and management actions set forth in the GSP do not demonstrate a plan for achieving sustainability goals, and do not adequately account for the needs of disadvantaged communities pertaining to protected groups under state law. This undermines the likelihood that the basin will reach its sustainability goal by 2040, as required by SGMA.[108]

a. The Projects and Management Actions are Inadequate, Do Not Protect Drinking Water for Disadvantaged Communities, and Will Likely Cause Disparate Impacts.

The projects and management actions set forth in the GSP does not demonstrate a path towards achieving sustainability goals in the plan. The GSA has not demonstrated how they have considered the interests of beneficial users including domestic well owners and disadvantaged communities.[109] The resulting impact from the proposed sustainable management criteria will likely lead to disparate impacts on protected groups pursuant to state and federal law.[110]

The GSA has allowed member agencies like the Arvin-Edison WSD to rely heavily on increasing use of surface water.[111] This places the majority of the plan's success on surface water resources, which are variable and may not be able to be procured. The GSA must ensure that member agencies implement demand reduction strategies from the beginning to ensure that the

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[105] Water Code § 10723.2.
[106] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[107] Water Code § 10727.2(b)(2).
[108] Water Code § 10727.2(b)(1).
[109] Water Code sec. 10723.2.
[110] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].
[111] Arvin-Edison Water Storage District Management Area Plan, p. 153-154, dated December 2019.

GSP is on a path to sustainability within the statutory time period. The GSA will not achieve its sustainability goals if water use is not limited through fully-implemented demand reduction requirements immediately. The chosen management actions undermine the likelihood that the basin will reach its sustainability goal by 2040, as required by SGMA.[112]

Despite the fact that drinking water wells may go dry at the GSP's groundwater levels minimum thresholds, and the fact that drinking water contamination is likely to occur because of changing pumping patterns and recharge activities, the GSA does not have a plan for preventing or mitigating these impacts. Furthermore, the GSA's description of projects does not include a description of any potential negative impacts on beneficial uses of water, such as groundwater contamination, and how such impacts will be mitigated and monitored.

A critical problem with the structure of the GSA is that member agencies are not required to share the cost or responsibility for critical GSA-wide projects. Many more financially powerful agricultural and water banking member agencies could and should be part of a strategy to protect drinking water resources in the GSA area as a whole, especially given that they use much larger quantities of groundwater and their continued pumping will likely lead to dry wells and groundwater contamination issues for the most vulnerable homes in the GSA area. Given that California has recognized drinking water as a human right, and the importance of drinking water that we all experience in our own lives, the GSA member agencies should collectively come together to ensure that no family has to go days, months or years without safe tap water in their home. The Arvin GSP contains two projects for treating water quality in Arvin, but these projects were already under way and fully funded so should not be included in the GSP. The GSP has no overall drinking water protection program to protect residents against dry wells and contaminated drinking water from its policies and groundwater management activities.

b. Minimum Requirements for Projects and Management Actions

The projects and management actions for this GSP are inadequate. At a minimum, adequate projects and management actions must include the following elements, which are not present here:

1. **Include a Drinking Water Well Impact Mitigation Program:** Ensure that the GSP contains a drinking water protection program to prevent impacts to drinking water users and mitigate the drinking water impacts that occur. Please reference the Framework for a Drinking Water Well Impact Mitigation Program that our organization developed with the Community Water Center and Self-Help Enterprises for more details, a draft of which is attached as part of the Human Right to Water Scorecard in Exhibit B.

[112] Water Code § 10727.2(b)(1).

2. **Establish a clear and proactive plan for demand reduction.** Demand reduction should be implemented immediately.
3. **Describe the potential drinking water impacts of each project or management action.**
4. **Include management actions to measure groundwater extraction using the most scientifically accurate method.** From our conversations with scholars, it is clear that metering is the most accurate way of measuring groundwater extraction. Metering should be required for all users, particularly large agricultural pumpers.
5. **Ensure that the GSP's projects and management actions will not cause a disparate impact:**[113] Ensure that the GSP's projects and management actions, taken as a whole, prevent a disproportionately negative impact on communities of color in the GSP area. Projects and management actions may not cause, or fail to prevent, disproportionately more dry wells and contaminated water for residents of color than for white residents in the GSP area.

I. Plan Implementation Section is Inadequate

GSPs must include a planning and implementation horizon[114] and must show how the sustainability goal will be achieved by 2040.[115] GSP implementation must continue to consider the interests of all beneficial user groups and engage a diversity of stakeholders. The GSP's plan implementation section is insufficient in regards to public engagement/outreach and does not contain adequate information regarding annual reporting or the potential to make amendments to the GSP. Absent this information, DWR cannot evaluate when and whether the plan is likely to achieve sustainable groundwater management, so DWR cannot approve the plan.[116]

The GSA's Communications and Engagement plan states that "[d]uring the implementation phase, communication and engagement efforts will be shifted to educational and informational awareness of the requirements and processes for reaching groundwater sustainability. Active involvement of all stakeholders is encouraged during this phase, and public notices are required for any public meetings and prior to imposing, and later increasing, any fees."[117] It is concerning that this statement communicates that the public will not be engaged in decisions about projects and management actions, annual reports, five year updates, or potential modifications to the sustainable management criteria and monitoring network. The public must be engaged in in all decisions about GSA policies and activities, to ensure that impacts to all beneficial users are considered.

[113] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[114] Water Code § 10727.2.(c)
[115] Water Code § 10727.2(b)(1).
[116] Water Code § 10733(a); 23 CCR 355.4(b).
[117] Kern Groundwater Authority GSP, Appendix E, pg. I-6, dated January 2020.

The GSA does not include commitments to provide translated, accessible notice about agency meetings and decisions. The GSA does not commit to providing interpretation and translated materials at workshops and board meetings, or creating an Advisory Committee with representation from disadvantaged communities. The GSP also lacks a commitment to working with local community-based organizations to ensure effective outreach and engagement of disadvantaged communities.

The plan implementation section for this GSP is therefore inadequate. At a minimum, an adequate plan implementation section must include the following elements, which are not present here:

1. **Description of DAC engagement:** Ensure that the GSP describes how ongoing engagement will be conducted during GSP implementation, including but not limited to engagement regarding: decisions about projects, management actions, modifying sustainable management criteria, changes to monitoring networks, and conducting GSP updates.
2. **Notice:**[118] Ensure that the GSP states that ongoing engagement will include clear notices about GSA meetings and workshops that are posted in ways that all stakeholders were made aware of the meetings, and translated into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.[119]
3. **Translation of materials:**[120] Ensure that the GSP states that ongoing engagement will include translation of materials into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.
4. **Interpretation:**[121] Ensure that the GSP states that ongoing engagement will include. interpretation services provided at board meetings, committee meetings and workshops into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English.
5. **Accessible workshops:** Ensure that the GSP states that ongoing engagement will include workshops held at accessible times and locations for disadvantaged community residents.
6. **DAC representation on advisory committee and board:** Ensure that the GSP states that ongoing engagement will include an advisory committee and a GSA Board containing representatives from DACs. The GSA must include representatives on the the GSA board, and should include representatives from DACs on all advisory committees such that their voices can be as strong as other beneficial user groups.

[118] Government Code § 54954(a).
[119] Government Code sec. 7296.2.
[120] Government Code sec. 7296.2.
[121] Government Code sec. 7296.2.

7. **Partnership with local community based organizations:** Ensure that the GSP states that ongoing engagement will include partnership between the GSA and community based organizations and nonprofits.
8. **Engagement on key decisions:** Ensure that the GSP states that ongoing engagement will include strategies to keep the public informed and engaged during and prior to critical decisions about the GSP, including but not limited to the five year GSP review, modification of sustainable management criteria, design and adoption of any projects and management actions, and development and adoption of the programs to assist with impaired wells.
9. **Engagement on financial issues:** Ensure that the GSP states that it will conduct meaningful outreach to DACs and incorporate feedback before approving operating budgets and enacting groundwater fees.

J. The GSP Does Not Comply With California Water Law.

a. The GSP Conflicts With Water Code § 106.3.

As noted above, California codified access to an adequate supply of safe and affordable drinking water as a human right in 2012. Water Code § 106.3(a) provides as follows:

> It is hereby declared to be the established policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes.

It is often incorrectly stated that this section is not binding. This is a misnomer for several reasons. First, § 106.3(b) expressly states in that "[a]ll relevant state agencies, including the department, the state board, and the State Department of Public Health, ***shall*** consider this state policy when revising, adopting, or establishing policies, regulations, and grant criteria when those policies, regulations, and criteria are pertinent to the uses of water described in this section." (emphasis added.) The use of the mandatory "shall" rather than a permissive "may" indicates that the requirement of subsection (b) to consider the Human Right to Water is a mandatory duty of DWR and the SWRCB.

Moreover, there is nothing in § 106.3 that indicates that either a GSA or a state agency may take an action that conflicts with the human right of all Californians to access safe and affordable drinking water. Rather, the section and its requirements are subject to only three narrow exceptions. First, subsection (c) states that "[t]his section does not expand any obligation of the state to provide water or to require the expenditure of additional resources to develop water infrastructure beyond the obligations that may exist pursuant to subdivision (b)." This exception

applies only to the "state," and does not apply to GSAs. Further, it speaks only to the obligation to provide water or to require development of water infrastructure, not to any obligation to manage groundwater resources in a way that protects existing access to drinking water.

Second, subsection (d) states that "[t]his section shall not apply to water supplies for new development." It is silent regarding water supplies for existing households.

Third, subsection (e) states that "[T]he implementation of this section shall not infringe on the rights or responsibilities of any public water system." As a GSA is not a public water system, this exception is not relevant here.

Given that none of the three exceptions contained in § 106.3 apply to the development and implementation of the GSP, it must be consistent with the Human Right to Water, and separately, DWR must consider the human right on review of GSP. Because the GSP conflicts with § 106.3 by interfering with access to safe and affordable drinking water, DWR cannot approve it.

b. The GSP Threatens to Infringe Upon Water Rights

In enacting SGMA, the legislature found and declared that "[f]ailure to manage groundwater to prevent long-term overdraft infringes on groundwater rights."[122] The text of SGMA further notes that "[n]othing in this part, or in any groundwater management plan adopted pursuant to this part, determines or alters surface water rights or groundwater rights under common law or any provision of law that determines or grants surface water rights."[123] As discussed in detail above, the GSP allows continued overdraft above the safe yield of the basin, such that drinking water wells (especially domestic wells) will continue to go dry, infringing upon the rights of overlying users of groundwater. DWR cannot approve the GSP until it is revised to protect the rights of residents of disadvantaged communities and/or low-income households who hold overlying rights.[124]

c. The GSP Conflicts with the Reasonable And Beneficial Use Doctrine

The "reasonable and beneficial use" doctrine is codified in the California Constitution. It requires that "the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the

[122] AB 1739 (2014).
[123] Water Code § 10720.5(b).
[124] *See also* Water Code § 10723.2 [The groundwater sustainability agency shall consider the interests of all beneficial uses and users of groundwater… [including] Domestic well owners."].

reasonable and beneficial use thereof in the interest of the people and for the public welfare."[125] The doctrine applies to all water users, regardless of basis of water right, and all water rights and methods of diversion.[126] A determination of reasonableness of a use "cannot be resolved in vacuo isolated from statewide considerations of transcendent importance."[127]

DWR and the Water Board must ensure that GSP's water allocations are consistent with the reasonable and beneficial use doctrine.[128] In doing so, DWR and the Board must follow the Legislature's directive to prioritize domestic use of water resources over irrigated agriculture[129] and ensure that SGMA implementation furthers the human right to safe and affordable drinking water[130] — both statewide considerations of transcendent importance. In other words, a GSP that allows use of water for irrigation at the expense of use of water for domestic purposes is not consistent with the reasonable and beneficial use doctrine.

The reasonable and beneficial use doctrine applies here given the negative impacts of the GSP on groundwater supply and quality, which are likely to unreasonably interfere with the use of groundwater for drinking water and other domestic uses. As the GSP authorizes waste and unreasonable use, and indeed does not even analyze the reasonable and beneficial use doctrine at all, it conflicts with the reasonable and beneficial use doctrine and the California Constitution. As a result, DWR cannot approve the GSP as presently drafted.

d. The GSP Conflicts with the Public Trust Doctrine

The public trust doctrine applies to the waters of the State, and establishes that "the state, as trustee, has a duty to preserve this trust property from harmful diversions by water rights holders" and that thus "no one has a vested right to use water in a manner harmful to the state's waters."[131]

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[125] Cal Const, Art. X § 2; see also Water Code § 100; United States v. State Water Resources Control Bd. (1986) 182 Cal.App.3d 82, 105 ["…superimposed on those basic principles defining water rights is the overriding constitutional limitation that the water be used as reasonably required for the beneficial use to be served."].

[126] Peabody v. Vallejo (1935) 2 Cal.2d 351, 367, 372; Light v. State Water Resources Control Board, (2014) 226 Cal. App. 4th 1463, 1479.

[127] Joslin v. Marin Municipal Water Dist. (1967) 67 Cal.2d 132, 140.

[128] Water Code § 275 ["The department and board shall take all appropriate proceedings or actions before executive, legislative, or judicial agencies to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water in this state"]; *Light*, 226 Cal.App.4th at 1482-83 [same].

[129] Water Code § 106 ["It is hereby declared to be the established policy of this State that the use of water for domestic purposes is the highest use of water and that the next highest use is for irrigation"]; *United States v. State Water Resources Control Board* (1986) 182 Cal.App.3d 82, 103 .

[130] Water Code § 106.3.

[131] *United States v. State Water Resources Control Bd.* (1986) 182 Cal.App.3d 82, 106; *see also Nat'l Audubon Soc'y v. Superior Court* (1983) 33 Cal.3d 419, 426 ["before state courts and agencies approve water diversions they should consider the effect of such diversions upon interests protected by the public trust, and attempt, so far as feasible, to avoid or minimize any harm to those interests."].

The public trust doctrine has recently been applied to groundwater where there is a hydrological connection between the groundwater and a navigable surface water body.[132] In *Environmental Law Foundation v. State Water Resources Control Board* ("*ELF*"), the court held that the public trust doctrine applies to "the extraction of groundwater that adversely impacts a navigable waterway" and that the government has an affirmative duty to take the public trust into account in the planning and allocation of water resources.[133] Under *ELF*, the Public Trust doctrine imposes an affirmative and independent obligation to consider the public trust that applies to DWR's decisions regarding submitted GSPs, imposing a legal duty on DWR to not only consider the potential adverse impacts of groundwater extractions on navigable waterways but also "to protect public trust uses whenever feasible."[134] The court also specifically held that SGMA does not supplant the requirements of the common law public trust doctrine.[135]

Notably, the public trust doctrine applies to both currently navigable surface water bodies and surface water bodies that were historically navigable at the time of statehood.[136]

In contrast to these requirements, the GSP does not consider impacts on public trust resources, or attempt to avoid insofar as feasible harm to the public's interest in those resources. DWR cannot approve the GSP without evaluating impacts to public trust resources and protecting public trust uses whenever feasible. Specifically, DWR must (1) identify any public trust resources within the basin; (2) identify any public trust uses within the basin; (3) identify and analyzing potential adverse impacts of groundwater extractions on public trust resources and uses; and (4) determine the feasibility of protecting public trust uses and protect such uses whenever feasible.

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DWR cannot approve the GSP because it fails to protect beneficial users and access to drinking water. We welcome the opportunity to further discuss our concerns with the Department of Water Resources and the State Water Resources Control Board. Furthermore, we urge DWR to review this and all other GSPs according to the Human Right to Water Scorecard, as we have done in this letter.[137] We hope to successfully work with the GSA, communities, DWR and the SWRCB to ensure that groundwater management is equitable and sufficiently protective of vital drinking water resources. Going forward, we ask DWR to ensure that the GSP adhere to the

[132] *Environmental Law Foundation v. State Water Resources Control Bd.* (2018) 26 Cal.App.5th 844, 844.
[133] *Id.* at 856-62.
[134] Id. at 865.
[135] *Id.* at 862-870.
[136] *See San Francisco Baykeeper, Inc. v. State Lands Com.* (2015) 242 Cal.App.4th 202, 232 citing *Western Oil & Gas Asso. v. State Lands Com.* (1980) 105 Cal.App.3d 554, 562 ["When California became a state in 1850 it succeeded to sovereign ownership of various tidelands and submerged lands under the terms of common law trust doctrine… ."]; PPL Montana, LLC v. Montana (2012) 565 U.S. 576, 592 ["For state title under the equal-footing doctrine, navigability is determined at the time of statehood...and based on the 'natural and ordinary condition' of the water."] [internal citation omitted].
[137] Attached as Exhibit B.

standards in the Human Right to Water Scorecard, and that these standards are followed during GSP implementation.

Sincerely,

Jasmene del Aguila and Amanda Monaco

Leadership Counsel for Justice and Accountability

EXHIBIT A

Attached:

Appendix A: Human Right to Water Letter and Scorecard...p. X-Y

Appendix B: Framework and Guidance for Developing a Drinking Water Well Impact Mitigation Program ..... p. Y-Z

Appendix A: Human Right to Water Letter and Scorecard

California Natural Resources Agency
Wade Crowfoot, Secretary

Department of Water Resources
Karla Nemeth, Director
Taryn Ravizzini, Deputy Director of Statewide Groundwater Management
Craig Altare, Supervising Engineering Geologist
Steven Springhorn, Senior Engineering Geologist
Keith Wallace, Project Manager

California Environmental Protection Agency
Kristin Peer, Deputy Secretary and Special Counsel for Water Policy

State Water Resources Control Board
E. Joaquin Esquivel, SWRCB Board Chair
Dorene D'Adamo, SWRCB Board Member
Tam M. Dudoc, SWRCB Board Member
Sean Maguire, SWRCB Board Member
Laurel Firestone, SWRCB Board Member
Eileen Sobeck, Executive Director
Natalie Stork, Chief of Groundwater Management Program

Andrew Altevogt, Program Coordinator of Safe and Affordable Drinking Water

February 10th, 2020

Re: Reviewing Groundwater Sustainability Plans In Accordance With State Agency Obligations to Consider the Human Right to Drinking Water

Our collective organizations write to express our concern regarding implementation thus far of the Sustainable Groundwater Management Act (SGMA), specifically with respect to its treatment of (or lack of consideration for) safe drinking water in many of the most vulnerable California communities -- and to urge the Department and Board to review Groundwater Sustainability Plans in accordance with state agency obligations to consider California's Human Right to Water law.

We have engaged in the SGMA implementation processes throughout the state because many of the communities with whom we work are dependent on groundwater for their drinking water supplies, and have already experienced groundwater quality and supply issues. We have participated in meetings, commented on dozens of groundwater plans, and supported engagement of residents from several communities in the development of Groundwater Sustainability Plans (GSPs). But despite our engagement and the engagement of disadvantaged community residents, most GSPs do not adequately address threats to drinking water quality or reliability for disadvantaged communities.

Historically, many of the communities most impacted by depleted and tainted groundwater sources have been excluded from the decision-making tables that determined where water would flow and what infrastructure would be laid. But California took historic steps forward with the recognition of the Human Right to Water as a state-wide goal in 2012 and with the passage of SGMA in 2014 which included requirements for a transparent and inclusive process and consideration of vulnerable communities. Specifically, decision-making processes related to groundwater management must include disadvantaged communities, and groundwater management plans must respond to the unique vulnerabilities of disadvantaged communities,[1] consider their drinking water needs,[2] and avoid causing disproportionately negative impacts on low income communities of color.[3]

Unfortunately, many of the draft GSPs released to date pose a significant threat to safe drinking water access in low-income communities. Few account for drinking water impacts on local communities dependent on groundwater— the vast majority of small communities in the San Joaquin Valley. When

[1] Water Code § 10723.2
[2] Water Code § 106.3
[3] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].

implemented, these GSPs have the potential to threaten severe and irreparable harm to drinking water supplies and the communities dependent on those supplies. As such, many of the recently approved draft GSPs undermine Governor Newsom's vision of a California where everyone has safe drinking water and run counter to California's Human Right to Drinking Water (AB 685).

With these grave concerns in mind, we urge the state to abide by the mandate the Human Right to Water demands.

The Human Right to Drinking Water in GSP Evaluation and Approval

The human right to safe and affordable water for drinking and sanitation was codified by AB 685 in 2012, which modified Water Code section 106.3 to include: "it is...the established policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes."[4] The law obligates "all relevant state agencies" to "consider this state policy when revising, adopting, or establishing policies, regulations, and grant criteria...pertinent to" drinking water purposes.[5] The law specifically names the Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB).

The Human Right to Water has catalyzed and facilitated several new state initiatives. The State Water Resources Control Board has created a Human Right to Water Portal on its website which shows drinking water quality in all public water systems in the state and passed a resolution aligning State Board priorities and values with the Human Right to Water. The human right to water has also been used as underpinning for two successful legislative campaigns: AB 401 (2015) and the Safe and Affordable Drinking Water Fund, or SB 200 (2019). The former mandated a state-wide study of the best mechanism for delivering affordable drinking water in all publicly regulated water systems; the latter created a state-wide fund for installing, operating and maintaining drinking water infrastructure for disadvantaged communities and schools suffering from water quality and water supply issues. Governor Newsom played a strong role in the passage of the Safe and Affordable Drinking Water Fund as part of his personal commitment to securing safe water for all Californians.

These initiatives represent clear steps forward towards achieving safe and affordable drinking water for all Californians, but the state remains far from achieving the law's goal of guaranteeing "safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes" to "every human being" in the state of California.[6] In the San Joaquin Valley alone, tens of thousands of vulnerable families, including those with whom we work, suffer from contaminated drinking water, unaffordable drinking water costs, and the impacts of inadequate water supply such as dry wells and water pressure problems. As many as 350,000 people lack access to potable water in the San Joaquin Valley alone, and Hispanic communities are disproportionately impacted: while Hispanics make up just under half, or 49 percent, of the total population of the San Joaquin Valley, they represent more than two-thirds of residents in these unincorporated communities and 57 percent of all residents served by out-of-compliance water systems.[7] This number does not account for those unincorporated communities

[4] Water Code sec. 106.3(a)
[5] Water Code sec. 106.3(b)
[6] Water Code sec. 106.3(a)
[7] The Struggle for Water Justice in California's San Joaquin Valley: A Focus on Disadvantaged Unincorporated Communities, London & Fencl et al., University of California Davis, February 2018.

on private domestic wells, many of which also have contaminated water which goes unmonitored and unregulated.

Groundwater management practices have historically aggravated drinking water issues in the San Joaquin Valley by allowing agribusiness and other actors to pump unrestricted amounts of groundwater, leaving local communities with dry wells, and unreliable drinking water supplies. Moreover, there has been limited regulation on agricultural impacts to groundwater quality, leading to contamination of drinking water for communities in the San Joaquin Valley. Low-income families living in disadvantaged communities do not have the financial means to replace or deepen wells, install costly treatment mechanisms, or transition to alternative water supplies such as surface water.

SGMA created both an unprecedented and quite possibly a last opportunity to avoid further encroachment on the basic human right to water, yet our review of GSPs in the San Joaquín, Salinas and Coachella Valleys indicates that GSAs have not leveraged this opportunity. Rather, the GSPs we have reviewed rarely account for impacts on local communities dependent on groundwater, and prioritize the continued economic viability of agriculture at the expense of drinking water for low income communities. For example, some Central Valley GSPs have established minimum thresholds—or failure points—that, if reached, would allow up to 85% of domestic wells to go fully or partially dry within the GSP area. Overall, a technical review that the Community Water Center and Self-Help Enterprises commissioned of drinking water impacts of 13 GSPs in the San Joaquin Valley shows more than 8,000 wells will be dewatered in the area covered by the GSPs. Draft GSPs allow continued groundwater quality degradation in excess of water quality objectives, violating the Porter-Cologne Water Quality Control Act (Water Code sec. 13000 et seq.), the antidegradation policy, and the non-point-source policy. Even worse, some GSPs ignore water quality impacts entirely.

DWR and the SWRCB are now tasked with evaluating and deciding whether to approve GSPs. The agencies must determine whether to approve policies in these documents that set out the level to which GSAs will allow groundwater levels to decline, the extent to which GSAs will protect local drinking water users from contamination resulting from groundwater management activities, and which projects and management actions the GSA will implement to impact local groundwater resources. All of these decisions have vast drinking water implications for communities within each GSP area. As such, evaluation and approval of GSPs falls squarely within the category of "revising, adopting, or establishing policies, regulations, and grant criteria...pertinent to" drinking water purposes.[8] DWR and the State Water Resources Control Board must therefore "consider this state policy"[9] "that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes"[10] in their review of each GSP. In order to comply with this obligation, the Department and Board must ensure that GSPs do not cause or allow further drinking water crises.

Implementing the Human Right to Drinking Water in GSP Evaluation and Approval

We have compiled and attached a "Human Right to Drinking Water GSP Scorecard" which identifies the elements that must exist in GSPs in order for GSPs to adequately protect the Human Right to Drinking Water. We urge the Department of Water Resources and the State Water Resources Control Board to integrate this analysis into their review of GSPs, and to require that each GSP contain these elements

[8] Water Code § 106.3(b)
[9] Water Code § 106.3(b)
[10] Water Code § 106.3(a)

before it grants approval of the GSP. This scorecard could also be adapted to create a general evaluation rubric that is used by the two agencies as part of a drinking water review protocol for all drinking water-related activities. Additionally, we encourage DWR to use this letter and scorecard to develop a "Human Right to Water"/"Protecting Drinking Water" Best Management Practices guidance document for GSAs to consider when developing, updating and implementing GSPs. Additionally, the Scorecard references a framework that we have developed to show what an effective drinking water protection program would look like, which we have also attached.

We look forward to discussing this Human Right to Water Scorecard with you, and supporting implementation of such a scoring methodology in GSP evaluation and approval. Please do not hesitate to contact Amanda Monaco (amonaco@leadershipcounsel.org), Deborah Ores (deborah.ores@communitywatercenter.org), or Liesbet Olaerts (olaerts@selfhelpenterprises.org) with any follow-up questions or for more information.

Sincerely,

Amanda Monaco
Leadership Counsel for Justice and Accountability

Aysha Massell
Director, California Integrated Water Systems
American Rivers

Tom Collishaw
CEO
Self-Help Enterprises

Coreen Weintraub
Sr. Outreach and Campaign Coordinator
Union of Concerned Scientists

Debi Ores
Senior Attorney
Community Water Center

Jennifer Clary
Water Program Manager
Clean Water Action

Attachments:

Human Right To Water Scorecard for the Review of Groundwater Sustainability Plans……..p. 6-14

Framework and Guidance for Developing a Drinking Water Well Impact Mitigation Program (Working Draft)..……..…..p. 15-24

Human Right To Water Scorecard for the Review of Groundwater Sustainability Plans

Review Criteria *(All Indicators Must be Present in Order to Protect the Human Right to Water)*		Yes/No
A	**Plan Area**	
1	**Does the GSP identify, describe, and provide maps of all of the following beneficial users in the GSA area?**[11] a. Disadvantaged Communities (DACs). b. Tribes. c. Community water systems d. Private well communities.	
2	**Land use policies and practices:**[12] Does the GSP review all relevant policies and practices of land use agencies which could impact groundwater resources? These include but are not limited to the following: a. Water use policies General Plans and local land use and water planning documents b. Plans for development and rezoning c. Processes for permitting activities which will increase water consumption	
B	**Basin Setting (Groundwater Conditions and Water Budget)**	
1	Does the **groundwater level conditions** section include past and current drinking water supply issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities?	

[11] 23 CCR § 354.8(a) and (b)
[12] 23 CCR § 354.8(f)

2	Does the **groundwater quality conditions** section include past and current drinking water quality issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities, including public water wells that had or have MCLs exceedances?[13]	
3	Does the **groundwater quality conditions** section include a review of all contaminants with primary drinking water standards known to exist in the GSP area, as well as hexavalent chromium, and PFOs/PFOAs?[14]	
4	**Incorporating drinking water needs into the water budget:**[15] Does the Future/Projected Water Budget section explicitly include both the current and projected future drinking water needs of communities on domestic wells and community water systems (including but not limited to infill development and communities' plans for infill development, installation of additional services, and housing growth in disadvantaged communities), taking into account increased climate variability due to climate change ?	
C	**Sustainability Goal**	
1	Does the **sustainability goal** explicitly include considerations about the needs of drinking water users?[16]	
D	**Sustainable Management Criteria (SMC) for Groundwater Levels**	
1	**Evaluation of drinking water impact:** Does the GSP include an analysis of how many drinking water wells (municipal wells, community water system wells, and domestic wells) might go fully or partially dry if groundwater levels reach the Undesirable Results (URs),[17] Measurable Objectives (MOs) and Measurable Objectives (MTs),[18] including a map of wells that will go fully and partially dry at the MOs and MTs? Does this include Does the GSP include estimates of the increased pumping costs from additional lift needed to pump water from lower elevations if the URs,[19] MOs and MTs[20] were to be reached?	
2	**Considering drinking water impacts in creating SMC:**[21] Does the GSP explicitly state how it considered drinking water impacts in shaping URs, MOs, and MTs for groundwater levels? For example, the GSP could state how its well impact analysis supported on setting stricter MTs and MOs near at risk communities.	

[13] 23 CCR § 354.16(d)
[14] 23 CCR § 354.16(d)
[15] 23 CCR § 354.18(c)(2)(b)
[16] 23 CCR § 354.24: Sustainability goal must "culminate in the absence of undesirable results within 20 years."
[17] 23 CCR § 354.26(c)
[18] 23 CCR § 354.28(b)(4)
[19] 23 CCR § 354.26(c)
[20] 23 CCR § 354.28(b)(4)
[21] Water Code § 10723.2

3	**Incorporating new drinking water data into SMC:**[22] Does the GSP include a description of how data gaps and uncertainties of its drinking water well impact assessment will be addressed and serve to reassess the sustainable management criteria, projects and management actions in accordance with new data?	
4	**Implementing DAC and drinking water user input into SMC:**[23] Does the GSP discuss how stakeholder input from DAC community members was considered in the development of URs, MOs, and MTs? For example, the GSP could state how they took the results of the well impact assessment to the public through meetings, workshops, or Advisory Committees, and together with stakeholders decided how to change SMC to protect drinking water, or other programs to implement to mitigate these impacts.	
5	**Avoiding a disparate impact:**[24] Are the MOs and MTs for groundwater levels established in such a way that prevents a disproportionately negative ("disparate") impact from occurring on communities of color in the GSP area? For example, the GSP should ensure that the same MT methodology across the GSP area will not lead to disproportionately more wells going dry for residents of color than for white residents.	
E	**Sustainable Management Criteria for Groundwater Quality**	
1	**Evaluation of drinking water impact:** Does the GSP include an analysis of how drinking water wells (municipal wells, community water system wells, and domestic wells) might be affected by the Undesirable Results (URs),[25] Measurable Objectives (MOs) and Measurable Objectives (MTs)?[26]	
2	**Does the GSP set MOs and MTs at all representative monitoring wells for the following contaminants?**[27] a. Contaminants with primary drinking water standards, b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health, AND c. Contaminants like Uranium which are known to increase due to groundwater management practices.	

[22] 23 CCR § 354.38(e)(3)

[23] 23 CCR § 354.10(d); DWR Guidance Document for Groundwater Sustainability Plans: Stakeholder Communication and Engagement, p.1.

[24] Gov. Code § 11135 ["No person in the State of California shall, on the basis of sex, race, color, religion, ancestry, national origin, ethnic group identification, age, mental disability, physical disability, medical condition, genetic information, marital status, or sexual orientation, be unlawfully denied full and equal access to the benefits of, or be unlawfully subjected to discrimination under, any program or activity that is conducted, operated, or administered by the state or by any state agency, is funded directly by the state, or receives any financial assistance from the state."]; Gov. Code § 65008 [Any discriminatory action taken "pursuant to this title by any city, county, city and county, or other local governmental agency in this state is null and void if it denies to any individual or group of individuals the enjoyment of residence, land ownership, tenancy, or any other land use in this state…"]; Government Code §§ 12955, subd. (l) [unlawful to discriminate through public or private land use practices, decisions or authorizations].

[25] 23 CCR § 354.26(c)

[26] 23 CCR § 354.28(b)(4)

[27] 23 CCR § 354.34(b)(2) and (f)(3)

3	**Strive to remediate:** Does the GSP state that the GSA will strive to remediate groundwater quality wherever feasible, through projects, management actions and policies?	
4	**Description of when minimum threshold is triggered:** Does the GSP trigger a violation of a minimum threshold after *one* test shows that there has been an increase in contamination since January 1st, 2015?	
5	**Implementing DAC and drinking water user input into SMC:**[28] Does the GSP discuss how stakeholder input from DAC community members was considered in the development of URs, MOs, and MTs?	
6	**Incorporating new drinking water data into SMC:**[29] Does the GSP include a description of how data gaps and uncertainties of its drinking water well impact assessment will be addressed and serve to reassess the sustainable management criteria, projects and management actions in accordance with new data?	
7	**Avoiding a disparate impact:**[30] Are the minimum thresholds for groundwater quality established in such a way that prevents a disproportionately negative ("disparate") impact from occurring on communities of color in the GSP area? For example, the GSP should ensure that the same MT methodology across the GSP area will lead to disproportionately more wells go dry for residents of color than for white residents.	
F	**Monitoring Network for Groundwater Levels**	
1	**Accurately detecting impacts on drinking water users and DACs:**[31] Does the groundwater level monitoring network include *representative* monitoring wells *in or near DACs*, and placed in a way that detects impacts to the *vast majority* of drinking water users in the GSP area? If not, does the GSP contain a concrete plan to fund and implement new representative monitoring wells to ensure that vulnerable communities' drinking water resources are monitored? Such a plan could include testing of domestic wells in the interim.	
2	**Clearly showing representative monitoring well locations in relation to DACs:**[32] Are the representative monitoring wells (RMWs) for groundwater levels presented on maps and in tables that identify which set of MTs/MOs will be applied to which RMWs? Do these maps clearly identify the locations of DACs, small water systems and other sensitive users?	

[28] 23 CCR § 354.10(d); DWR Guidance Document for Groundwater Sustainability Plans: Stakeholder Communication and Engagement, p.1.
[29] 23 CCR § 354.38(e)(3)
[30] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).
[31] 23 CCR § 354.34(b)(2) and (f)(3)
[32] 23 CCR § 354.34(b)(2) and (f)(3)

3	**Identifying and addressing other drinking water data gaps:**[33] Does the GSP clearly identify any other gaps in data regarding impacts to drinking water users? Does the GSP contain a clear plan to fill data gaps regarding impacts to drinking water users?	
G	**Monitoring Network for Groundwater Quality**	
1	**Does the GSP plan to measure the following contaminants at all representative monitoring wells?**[34] a. Contaminants of concern with primary drinking water standards b. PFOs/PFOAs and chrome-6, which are contaminants known to be very harmful to human health c. Contaminants like Uranium which are known to increase due to groundwater management practices	
2	**Clear description of effective monitoring for drinking water impacts:** Does the GSP include a description of how the GSA(s) will monitor groundwater contamination that could affect drinking water in the GSA area? Are the representative monitoring wells (RMWs) for groundwater quality presented on maps and in tables, and do the maps of RMWs clearly identify the locations of DACs, small water systems and other sensitive users?	
3	**Accurately detecting impacts on drinking water users and DACs:**[35] Does the groundwater quality monitoring network include *representative* monitoring wells (RMWs) *in or near all DACs* AND placed in a way that detects impacts to the *vast majority* of drinking water users in the GSP area, including domestic well users? If not, does the GSP contain a concrete plan to fund and implement new representative monitoring wells to ensure that vulnerable communities' drinking water resources are monitored? This plan could include testing of domestic wells in the interim.	
4	**Baseline contaminant levels:** Does the GSP identify the current contaminant levels, MTs and MOs at each RMW, so that it is clear to the public how the contamination will change at each RMW site?	
5	**Frequent monitoring:** Does the groundwater quality monitoring network test for contaminants of concern frequently, in a way that avoids persistent drinking water contamination?	
6	**Collaboration with other agencies:**[36] Does the GSP explain how the GSA(s) will share data with and collaborate with other groundwater quality regulatory programs, such as ILRP, IRWM, and CV SALTS, in order to build better regional understanding of groundwater quality issues and better respond to groundwater quality impacts caused by groundwater management?	
H	**Projects and Management Actions**	

[33] 23 CCR § 354.38(e)(3)
[34] 23 CCR § 354.34(b)(2) and (f)(3)
[35] 23 CCR § 354.34(b)(2) and (f)(3)
[36] 23 CCR § 354.34(e)

1	**Does the GSP describe the potential drinking water impacts of each project or management action?** Example of impacts are provided below: a. **Recharge and on-farm recharge projects:** Carefully designed and implemented recharge projects can simultaneously increase groundwater storage and levels, as well as dilute contaminant plumes and improve groundwater quality. However, if not properly designed, recharge projects, in particular on-farm recharge, may mobilize nitrates, pesticides, fertilizers, and naturally occurring contaminants, which can lead to the further degradation of groundwater quality, negatively impacting drinking water wells. Even relatively unpolluted water used for recharge, such as most purchased water or streamflow, may contain constituents of concern and/-or mobilize contaminants. Therefore GSAs must consider potential impacts to water quality when planning groundwater recharge projects.[37] b. **Groundwater market management action:** Groundwater markets are very likely to put drinking water resources at risk for communities and residents who do not have the financial, political and technical power to participate equally in a market. Groundwater markets have the potential to seriously aggravate existing lack of equity in access to critical groundwater resources. We therefore recommend that GSAs do not include groundwater markets as a potential management action. In particular, local groundwater markets are not a viable option where the potential impacts of trading are not well understood, where trading rules cannot sufficiently address negative externalities, or where the expected benefits of a market do not outweigh the burdens and uncertainties associated with designing and implementing it. If GSAs wish to consider groundwater markets, a well-designed trading program requires a fair and adequate allocation of groundwater for drinking water uses, an additional margin for future growth prior to allocating water for trading purposes, and trading rules that avoid undesirable results as well as avoid or mitigate potential impacts to communities and ecosystems dependent on groundwater. If these components are missing, the market can have significant negative impacts upon a community's drinking water supply and the environment. Some impacts include, but are not limited to: localized drying of community and domestic wells, increased contamination levels, or unaffordable water rates.[38] c. **Funding mechanisms/Delinquent fees management action:** Any fee and/or extraction penalties structure should take into consideration that small communities have fewer economic opportunities, have a small role in overall groundwater pumping percentage, and are burdened with lower technical, managerial, and financial capacity for operations and maintenance. Overall, small drinking water systems should be exempted from GSA's fees or financial penalties for over-use to support their efforts on providing affordable safe water according to AB 685. If exemption is not viable, the GSA should create special considerations such as discounts, reduced costs, rebates, or other to ensure	

[37] State Water Boards, Water Quality Frequently Asked Questions document: https://www.waterboards.ca.gov/water_issues/programs/gmp/docs/sgma/sgma_water_quality_faq.pdf

[38] Community Water Center et al., *Groundwater Markets: Recommendations to Ensure Drinking Water Protection for Communities* (guidance document to be published soon)

	drinking water affordability. Alternatively, small drinking water systems should receive warnings prior to financial penalties tied to an appeal process. Doing so may allow these communities to explain why the overuse occurred, providing mechanisms for transparency and support on addressing the problems. d. **Groundwater allocation management action:** Any groundwater allocation scheme must protect all current and future drinking water needs for disadvantaged communities.	
2	**Drinking water protection and mitigation program:** Does the GSP contain a drinking water protection program to prevent impacts to drinking water users and mitigate the drinking water impacts that occur? Such a program should also identify the following: a. How it will be funded. b. An estimate of how much it will cost. c. How program beneficiaries will be eligible to participate. d. How it will be designed in collaboration with impacted stakeholders. e. What type of mitigation measurements it will provide. f. Timeline for program implementation. **Please refer to the attached **Framework and Guidance for Developing a Drinking Water Well Impact Mitigation Program** for a more in-depth description of what an effective drinking water mitigation program should look like.*	
3	**Demand reduction:** Does the GSP contain robust demand reduction management actions? Plans that depend mainly on imported surface water (supply augmentation through recharge projects) do not clearly demonstrate a path towards sustainability, since climate variability puts these resources at risk.	
4	**Accurate measurement of groundwater extraction:** Does the GSP include management actions to measure groundwater extraction using the most scientifically accurate method?	
5	**Avoiding a disparate impact:**[39] Do the GSP's projects and management actions, taken as a whole, prevent a disproportionately negative ("disparate") impact from occurring on communities of color in the GSP area? Projects and management actions may not cause disproportionately more dry wells and contaminated water for residents of color than for white residents in the GSA area.	
I	**Public Participation and Transparency**	
1	Is a **Stakeholder Communication and Engagement Plan** included in the GSP?	
DAC and drinking water user engagement during GSP development[40]		

[39] Gov. Code § 11135; Gov. Code § 65008; Government Code §§ 12955, subd. (l).

[40] Water Code § 10723.2; Water Code § 10727.8(a) The groundwater sustainability agency shall encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin prior to and during the development and implementation of the groundwater sustainability plan.

2	**Description of DAC engagement:** Does the GSP specifically identify how DAC beneficial users were engaged in the planning process?	
3	**Notice:**[41] Did the GSA provide clear notice to the public about GSA meetings to develop the GSP, posted in ways that all stakeholders were made aware of the meetings, and translated into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English? [42]	
4	**Translation of materials:**[43] Did the GSA translate materials into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?	
5	**Interpretation:**[44] Did the GSA(s) provide interpretation services at board meetings, committee meetings and workshops into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?	
6	**Accessible workshops:** Did the GSA(s) host workshops held at accessible times and locations for disadvantaged community residents?	
7	**DAC representation on advisory committee:** Did the GSA(s) develop the GSP with an advisory committee that contained representatives from DACs?	
8	**DAC representation on GSA board:** Did the GSA(s) develop the GSP with a Board that contained representatives from DACs?	
9	**Partnership with local community based organizations:** Did the GSA partner with community based organizations and nonprofits on outreach and engagement?	
10	**Public Comment Period:** Did the GSA provide a robust public comment period of at least 60 days, with opportunity for the public to discuss comments and proposed agency responses with staff and the GSA before GSP approval?	
11	**Incorporation of stakeholder input:** Does the GSP explicitly describe how stakeholder input was incorporated into the GSP process and decisions?	
DAC and drinking water user engagement during GSP implementation		

[41] Government Code § 54954(a).

[42] Government Code sec. 7296.2: Dymally-Alatorre Bilingual Services Act, stating that local agencies providing services to the public must provide translated materials and interpretation when it serves a substantial number of non-English-speaking people. The law defines a "substantial number of non-English-speaking people" as "members of a group who either do not speak English, or who are unable to effectively communicate in English because it is not their native language, and who comprise 5 percent or more of the people served by the statewide or any local office or facility of a state agency." This is because "effective maintenance and development of a free and democratic society depends on the right and ability of its citizens and residents to communicate with their government and the right and ability of the government to communicate with them."

[43] Government Code sec. 7296.2.

[44] Government Code sec. 7296.2.

12	**Description of DAC engagement:** Does the GSP describe how ongoing engagement will be conducted during GSP implementation, including but not limited to engagement regarding: decisions about projects, management actions, modifying sustainable management criteria, changes to monitoring networks, and conducting GSP updates?	
13	**Notice:**[45] Does the GSP state that ongoing engagement will include clear notices about GSA meetings and workshops that are posted in ways that all stakeholders were made aware of the meetings, and translated into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?[46]	
14	**Translation of materials:**[47] Does the GSP state that ongoing engagement will include translation of materials into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?	
15	**Interpretation:**[48] Does the GSP state that ongoing engagement will include interpretation services provided at board meetings, committee meetings and workshops into all languages spoken by at least 5 percent of the public served by the agency, who do not speak English or are unable to effectively communicate in English?	
16	**Accessible workshops:** Does the GSP state that ongoing engagement will include workshops held at accessible times and locations for disadvantaged community residents?	
17	**DAC representation on advisory committee and board:** Does the GSP state that ongoing engagement will include advisory committees and Boards containing representatives from DACs?	
18	**Partnership with local community based organizations:** Does the GSP state that ongoing engagement will include partnership between GSA and community based organizations and nonprofits?	
19	**Engagement on key decisions:** Does the GSP state that ongoing engagement will include strategies to keep the public informed and engaged during and prior to critical decisions about the GSP, including but not limited to the five year GSP review, modification of sustainable management criteria, design and adoption of any projects and management actions, and development and adoption of the programs to assist with impaired wells?	
20	**Engagement on financial issues:** Does the GSP state that it will conduct outreach to DACs before approving operating budgets and enacting groundwater fees?	

[45] Government Code § 54954(a).
[46] Government Code sec. 7296.2.
[47] Government Code sec. 7296.2.
[48] Government Code sec. 7296.2.

Appendix B: Framework and Guidance for Developing a Drinking Water Well Impact Mitigation Program [Working Draft]

Management Action Name:
Drinking Water Well Impact Mitigation Program

Potential Implementing Organization(s):
Groundwater Sustainability Agencies (GSAs) in partnership with project participants.

Purpose Statement:
The purpose of this document is to be utilized by GSAs to mitigate, prevent, and address any adverse effects on drinking water wells caused by pumping volume or location, conjunctive management, or any other forms of active management as part of Groundwater Sustainability Plan (GSP) implementation. By doing so, GSAs can better achieve the goals of the Sustainable Groundwater Management Act (SGMA), avoid jeopardizing access to safe water in vulnerable communities, and also avoid violating California laws that establish a state-wide Human Right to Water and that protect access to safe water. Adverse effects can include both issues with access to safe drinking water due to increased contamination, as well as issues with sustained access to water due to changes in groundwater levels.

This document provides a framework of elements to consider when GSAs are developing a drinking water well impact mitigation plan. Every community and every GSA will have to evaluate their own needs and particular considerations in order to develop a mitigation program that works best for all users. This document is broken down into the following sections:

1) Importance of drinking water well mitigation programs;
2) Framework for developing program / key elements to consider;
3) Cost considerations for short term and long term solutions and potential funding sources; and
4) Four local case studies of existing drinking water well mitigation programs.

Section 1. Importance of a Drinking Water Well Impact Mitigation Program:

How can GSP implementation impact domestic wells and small community wells?

Across the state, critically overdrafted basins have developed Groundwater Sustainability Plans (GSPs) to manage groundwater resources sustainably under the Sustainable Groundwater Management Act

(SGMA). Many GSPs have developed sustainable management criteria, including minimum thresholds (MTs) and measurable objectives (MOs), that if reached, would cause significant impacts to access to safe and affordable drinking water for vulnerable communities. GSP implementation, including management actions and projects, can cause changes in groundwater levels and groundwater quality that could lead to:

- Completely dewatered wells;
- Partially dewatered wells:
    - needing to lower the well pump,
    - needing to clean the well screen,
    - needing to drill deeper;
- An increased movement of contaminant plumes;
- An increase in the concentration or release of contaminants;
- An increase in salinity due to sea water intrusion in coastal wells;
- Higher energy costs from having to drill or pump from a deeper depth; and
- Emotional, psychological, and health impacts related to not having access to safe water.

If GSP sustainable management criteria are developed in a way that could potentially cause significant impact on drinking water users, the GSP must also include a robust drinking water well impact program to prevent and mitigate the drinking water impacts that occur. In some GSAs, up to 85% of domestic wells are at risk of being dewatered or partially dewatered. In these same GSAs, rural domestic and small water system demand does not contribute substantially to the overdraft conditions, yet the risks imposed on these drinking water users are overlooked and neglected, creating a disproportionate impact on already vulnerable communities.

What are the drinking water challenges of disadvantaged communities?

Without an adequate groundwater sustainability plan that is protective of groundwater sources near or within communities, more drinking water wells will run dry or be unable to provide safe, potable water to residents. This will further jeopardize the livelihood of California's most vulnerable communities. Vulnerable communities, including severely disadvantaged communities (SDACs), disadvantaged communities (DACs), small water systems, and domestic well owners, have limited technical, managerial, and financial capacity to respond to drinking water challenges.

Climate change further exacerbates drinking water challenges with more frequent, longer and more severe droughts and flood periods expected. Small water systems and rural communities reliant on domestic wells are, and will continue to be, the most adversely impacted and most at risk of experiencing water shortages and/ or having to rely on contaminated drinking water supplies. In order to increase water system resiliency, the golden rule is to protect current water sources— especially if the quality of the water is meeting safe drinking water standards. Other ways to increase resiliency are to secure more than one water source, assist communities with maintenance and operation costs, and ensure water affordability. A drinking water well mitigation program is key to increasing water resilience through minimizing risks of both short-term and long-term impacts. Having adequate plans and policies to support drinking water resilience in the face of climate change is essential to reducing the amount of emergency funding needed to respond to a water shortage emergency and to prevent human health crises. A carefully designed and implemented well impact mitigation program can support efforts to ensure all communities have long-term and sustainable access to clean, safe, and affordable drinking water.

How does California law prioritize drinking water?

A GSP which lacks a mitigation program to curtail the effects of projects and management actions on the safety, quality, affordability, or availability of domestic water, violates both SGMA itself and the Human

Right to Water law. The Human Right to Water (AB 685) (HR2W) was signed in 2012 and added § 106.3 to the California Water Code, declaring, "the established policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes."[49] The HR2W applies to all state agencies, requiring that they "...shall consider this state policy when revising, adopting, or establishing policies, regulations, and grant criteria when those policies, regulations, and criteria are pertinent to the uses of water…".[50] With this passage of AB 685, relevant state agencies, including the State Water Resources Control Board (SWRCB) and the Department of Water Resources (DWR), are now required to consider this state policy when revising, adopting, or establishing policies, regulations, and grant criteria that may impact the uses of water for domestic purposes. These agencies must consider how state actions may impact the Human Right to Water. To ensure compliance with the legislature's long established position and accordance with 23 CCR §350.4, the HR2W requires that DWR must consider the effects on domestic water users when reviewing and approving GSPs.[51] The SWB should be consulted as part of GSP review as part of the Board's expertise on water quality matters.

Further, the California legislature has recognized that water used for domestic purposes has priority over all other uses since 1913.[52] Reserving top priority for domestic water use was later codified in 1943, in Water Code § 106, which declares it the, "established policy of this State that the use of water for domestic purposes is the highest use of water and that the next highest use is for irrigation."[53] Further, the passage of the Safe and Affordable Drinking Water Act by Governor Newsom[54] indicates a clear state-level commitment to providing safe and affordable drinking water to California's most vulnerable residents. Poor implementation of SGMA would threaten the success of the Safe and Affordable Drinking Water Fund and would run counter to Governor Newsom's vision of providing safe water to all.

A carefully designed and implemented Drinking Water Well Impact Mitigation Program can support a statewide goal of ensuring DACs' access to clean, safe, reliable, and affordable drinking water. Including this type of program in a GSP also helps to create a groundwater management plan that understands DACs' unique social and economic vulnerabilities, is sensitive to their drinking water needs, and avoids causing a further disparate impact on low-income communities.

Section 2. Key elements and a framework for developing a Drinking Water Well Mitigation Program:

This section provides a framework of elements to consider when GSAs are developing a drinking water well impact mitigation plan. This section is broken down into the following categories:

i. Drinking water well monitoring network;
ii. Adaptive management and trigger system;
iii. Drinking water well impact tool/model;
iv. Public outreach and education;
v. Mitigation measures;
vi. Program eligibility.

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[49] WAT § 106.3 (a).
[50] WAT § 106.3(b).
[51] *See generally,* WAT § 106.3 (b).
[52] California Water Commission Act of 1913 § 20.
[53] WAT§ 106; This policy is also noted in the Legislative Counsel's Digest for AB 685.
[54] SB 200, Monning (2019).

i. Drinking water well monitoring network: As required by GSP Regulation, Section 354.34, GSAs must describe how potential impacts to groundwater users and uses will be monitored. It must be recognized that most public water systems have wells deeper than domestic wells, thus monitoring networks must be able to capture impacts to deeper public water system wells as well as shallow domestic wells. The following approach will allow GSAs to comply with GSP regulations and take a proactive approach to protect DACs' and domestic well owners' access to safe and affordable drinking water:

- Map and assess drinking water well vulnerabilities to better understand:
  (1) Locations and depth of drinking water wells (both domestic and public supply wells);
  (2) Whether changes in groundwater levels and quality may be exacerbated in specific areas by pumping volume or location, conjunctive management (i.e. groundwater recharge projects) or other forms of active management as part of GSP implementation;
  (3) The proximity of potentially impacted wells to nearby existing public water systems; and
  (4) If there are areas with a high density of likely impacted wells.
  Assessment should acknowledge that not all existing and utilized wells may be documented in available resources from DWR or Counties.

- Designate key monitoring wells to assess impacts to drinking water wells: Based on the drinking water well vulnerability assessment, identify which wells from the GSP proposed monitoring network are critical to assess impacts to drinking water wells caused by changes to groundwater levels and quality. Expand and improve the monitoring network to assess potential impacts in particular for groundwater conditions near DACs, areas with high density of private domestic wells, and water systems serving schools. The monitoring network needs to be representative of conditions in all aquifers in general, including the shallow aquifer upon which domestic wells rely. The water quality monitoring network needs to routinely monitor for all contaminants that could impact public health (not only nitrate, but also chromium-6, arsenic, 123-TCP, uranium, and DBCP). This will allow the GSA to better comply with GSP regulations Section 354.34, which requires GSAs to describe how potential impacts to groundwater users and uses will be monitored, and to take a proactive approach to protect DACs and domestic well owners' access to safe and affordable drinking water.

ii. Develop an adaptive management/trigger system: Develop a protective warning system, also referred to as an adaptive management approach. Such an approach can alert groundwater managers when groundwater levels and groundwater quality are dropping to a level that could potentially negatively affect drinking water users. These "triggers" are essential for groundwater management and can be adjusted to fit the needs of different management actions as well as the basin as a whole. The table below provides an example of what a warning system might look like, using green, yellow, and red light indicators or triggers, and some potential corrective actions groundwater managers can take to remedy the problem. Ultimately, this approach allows for the evaluation of current conditions in order to respond accordingly to prevent or mitigate negative impacts.

Triggers	Groundwater Status	Potential Corrective Actions
Green-light	Groundwater levels and quality are stable.	No action required
Yellow-light	Groundwater levels and quality are approaching concerning levels and impacts may occur or are occurring at a	- Undertake an analysis to pinpoint the cause; - Undertake water quality testing for selected domestic and public supply wells; - Provide immediate support to groundwater users experiencing impacts;

	low rate. Some corrective actions are needed.	- Reassess pumping allocation and pumping patterns. Consider restricting or limiting groundwater extraction near the impacted area.
Red-light	Time to stop groundwater pumping and management actions and mitigate as significant impacts are imminent or are occurring.	- Reassess pumping allocation and pumping patterns. Consider further restricting or limiting groundwater extraction near the triggered area or reevaluating minimum thresholds or measurable objectives; - Provide interim emergency solution while working with impacted groundwater users to pursue a permanent, long-term solution.

iii. Drinking water well impact tool/model: Develop a tool or model tied to the monitoring network and the adaptive management framework (trigger system) to evaluate groundwater levels and predict potential groundwater impacts to drinking water wells. Update model regularly and develop a prediction of the potential groundwater impacts to drinking water wells. Results of this assessment should be incorporated into an annual GSP progress report to domestic well owners and DACs water systems. The tool or model could be used to:

- Monitor and forecast changes in groundwater levels and quality;
- Monitor and forecast any localized areas for special attention and/or monitoring;
- Attempt to identify domestic wells or small public supply wells at risk of impacts, and;
- Determine if triggers have been met based on the adaptive management framework.

iv. Public outreach and education: Develop public outreach and educational materials to increase awareness of groundwater management activities within the GSA. This outreach could inform groundwater pumpers of the rules, restrictions, and impacts of groundwater over-pumping. This outreach could also inform residents about the potential well impacts that could occur based on groundwater management actions, describe potential options available for well mitigation, and include information for who to contact in the event their wells experience negative impacts. This outreach could take place in the form of pamphlets, mailers, additions to the public website, or radio announcements. This information can also be included in regular GSA updates. To ensure that this program can benefit S/DAC residents, information about the program must be disseminated widely, and such materials must be translated into all threshold languages. The GSA should work with local agencies, organizations and associations to spread materials about the program. The GSA should work with local agencies and organizations to ensure that residents with impacted wells are referred quickly to the GSA for assistance. GSAs should conduct regular, door-to-door outreach (in partnership with other outreach experts as needed) to ensure that communities — particularly for communities location in areas the trigger system identifies within the yellow and red-light ranges— are aware of the well mitigation program and know who to contact in times of emergency.

v. Mitigation measures: Mitigation measures should be implemented as soon as the trigger system reaches its yellow light indicator. Groundwater should be managed in a way that prevents or avoids reaching the red light indicator and before wells become unusable. This will allow communities working with the GSA to access funding and develop a long-term plan that protects community member access to drinking water. The mitigation program should be designed to be proactive, rather than reactive to public health harms. When mechanical failures or other operational problems have occurred, or are likely to occur, due to declining water levels or deteriorating groundwater quality, mitigation should be provided as described below:

- **Third Party Determination of Causality:** Work with an objective third party to establish whether their policies and actions caused the drinking water impact. Based on a field inspection and discussion with the residents impacted, define the level of mitigation that is necessary. Verify well construction information and pump setting information, if possible;
- **Interim Drinking Water Supply Solution:** Provide short-term drinking water supply while a permanent solution is pursued. Short-term interim solutions serve to address the immediate impacts and ensure access to both water suitable for consumptive and other domestic needs, such as sanitation. Short-term emergency supplies shall be provided as soon as reasonably possible and can include bottled water, bottled water paired with tanked water, or another combination. For groundwater quality issues, bottled water may be an acceptable interim solution but if the issue is lack of access to water, providing bottled water is not an adequate interim solution and would require a combination of solutions as well as a long-term sustainable plan.
- Since short-term solutions are expensive over a prolonged period of time, it would be important to quickly identify potential long-term solutions. As an example, GEI's feasibility study for East Porterville at the height of the drought in 2016 estimated tank and bottled water programs cost $633,500 per month just for East Porterville, which has an estimated population of 7,331 residents.
- Long-term water supply can include (where appropriate):
    - Providing funding to lower a well pump and/or deepen the well;
    - Financial and technical support to complete a connection to a nearby municipal and/or industrial water provider;
    - Providing an equivalent water supply from an alternate source;
    - Providing funding to replace the affected well with a deeper well;
    - Providing funding to treat contaminated water;
    - Reducing or adjusting pumping near the impacted drinking water well as necessary to avoid the impact; and/or
    - Providing other acceptable mitigation through a collaboration with the affected drinking water well users.

  Note that lowering the pump and/or deepening the well will increase operational costs of the well and may require additional monitoring to ensure the well is not dewatered again. Further, these solutions may not address water quality concerns, depending upon aquifer conditions and screen depths.
- For a long-term water supply option, connecting current domestic well users to a nearby public water system should be pursued whenever possible. In areas with a high density of domestic wells, the establishment of a new small public water system may also be feasible. Public water systems have an obligation to test water quality for water served, and although some public water systems have limited resources, they do have a greater ability to install treatment systems to address water quality impacts, recoup funds for litigated contamination such as 1,2,3-TCP, and apply for and receive grant funding for beneficial projects. Because of this, public water systems, including small community water systems, often provide a more reliable drinking water source than privately-owned domestic wells. It should be noted that once a resident is connected to a public water system, they are then subject to water bills that will likely be higher than the operation costs of the well. As these long-term solutions are being developed, the community should be engaged in the process to learn about the benefits of a public water supply in terms of water reliability and water quality, and should also be informed of why water bills may be more costly. It is possible that some residents may request some sort of stipend to assist with the monthly water bills associated with their new water connection.

xi. Eligibility: Eligible beneficiaries should include communities that quality as DAC or SDAC, and households who qualify as low income. S/DAC residents should not be required to undertake burdensome actions or overcome other barriers to entry in order to benefit from the program. For example, residents should not be required to register before impacts occur in order to benefit from the program, and beneficiaries should not be required to prove that the GSA's activities or lack of action caused impacts. Instead, the GSA should proactively identify all well locations and information. When the GSA is notified of an impacted well, it should use the well information collected to rapidly evaluate the cause of the impact and provide adequate mitigation measures. Some questions GSAs could consider when determining eligibility are:

- What is the process for determining eligibility?
- Who determines if the well is eligible?
- What documentation does the well owner need to demonstrate eligibility? Is there an unreasonable onus on the owner to demonstrate past use that would constitute a barrier to access?
- When a well is found to have been constructed in a way that is not consistent with current regulations, is it still eligible?
- If a well is poorly constructed, does the program address replacing or repairing the well rather than just deepening it?

Section 3. Costs and Potential Funding Sources:

Costs: Costs are dependent on many factors including: how protective the GSA defines its sustainability goal and related sustainability criteria, the number of vulnerable wells, the condition of the vulnerable wells, proximity to existing public water systems, the depth of the aquifer, local contractor costs, fluctuations in material costs, etc. For comparison purposes, the San Antonio well mitigation project materials include the following average costs:

- Perform well diagnostics ($2,700);
- Lower pump ($4,000);
- Drill/outfit/connect replacement well ($58,000);
- Water purveyor connection ($5,000), and close existing well ($4,500).

The table below provides examples of interim and long-term solution costs based on Self-Help Enterprises' experience in providing solutions to disadvantaged communities in the San Joaquin Valley during the 2012-2014 drought. Costs are provided for illustrative purposes only and should be considered as rough estimates.

Solution	Problem	Options	General Overview of Pros and Cons	Estimate of Costs[1]
Interim solution	Water quality	Point-of-Use (POU)	Treats water for one tap within the household. While this option does provide safe drinking water in the home, if everything is perfect, maintenance is less likely to be carried out and assistance must be provided until a long-term solution is implemented. Costs estimates include initial capital costs (installation, treatment system, monitoring system) and also ongoing operation, maintenance, routine	$1000 to $1500 / unit per home.

			monitoring, and waste disposal costs.	
		Bottled water	Bottled water provides an effective and reliable source of safe drinking water and may be the only option available depending upon contaminant concentrations. However, bottled water can be expensive over a long period of time and can come with distribution challenges.	$30 to $50 per month per house, includes delivery.
	Access to water	Water tank program with bottled water	Tank water can meet basic sanitation needs but should not be used to meet drinking water needs, as tank water is susceptible to bacteriological or other issues making it unsafe for consumptive purposes. Instead, the program must be paired with delivery of bottled water to meet drinking water needs.	- 2,600 gallon water tank and materials roughly $2100.00. - Labor and tank installation $1500.00, does not include mileage. - Electrical permit $80.00, depending on the county. - Tank water between $300 to $500 depending on delivery charge by water hauler, per load or per hour. - $30 to $50 per month per house, includes delivery.
Permanent solution	Water quality	Water treatment system	Technical, managerial, and financial capacity of the community should be considered when assessing water treatment options.	Costs vary depending on the technology, water contaminant, and number of households.
		Alternate supply source	Options include surface water, construction of a new well, and consolidation with a nearby water system.	Costs vary depending on the desired solution, technology, and number of households.
	Access to water	Lowering of well pump	Less expensive long-term solution, if conditions allow. The following factors should be taken into account: lowering of a pump in the well is limited by the depth of the well, proximity of pump to the base of the well increases energy consumption, may require more frequent screen cleaning, and water quality may be degraded due to sediments that are drawn in.	Less than $10K, maybe around 5K.
		Drill a new deeper well	A well test is necessary to assess yield capacity and water quality on deeper levels.	Build a new private well: $20k to $45k.
				Build a new well for a water systems: up to $1.5 million.

		Alternative water supply source	Options include surface water or consolidation with a nearby water system. Recommend considering consolidation when households understand and agree with the advantages and disadvantages of connecting to a local water system.	Costs vary depending on the desired solution, technology, and number of households.

Potential Funding Sources: A secure and reliable funding source and mechanism for the implementation of this type of mitigation program needs to be identified in the GSP. While grant or emergency funding could potentially be available to support a mitigation program, the availability of these funds is not certain. Therefore, the GSA should plan to establish a more secure, on-going funding mechanism that accrues funds that would be available as water levels decline in the future. Funding for these types of programs should be considered as an operational cost of the GSA and funded with other ongoing costs such as administration and monitoring and should be included in the annual budget for the GSA. The following are potential other sources of funding to consider:

- Service or land-based fee assessments using Proposition 26 or Proposition 218;
- State Water Resource Control Board programs such as Proposition 1 Groundwater Grant Program and Prop 68 Groundwater Treatment and Remediation Grant Program;
- Department of Water Resources funding programs for groundwater projects and technical assistance programs to aid SGMA implementation;
- Central Valley Basin Plan Amendment (BPA) project funding: The BPA for the regulation of salts and nitrates has been approved by the SWRCB and implementation may result in additional funding sources for nitrate contaminated aquifers. If appropriate, GSAs should consider coordinating with nitrate dischargers forming Management Zones in order to comply with the BPA in order to streamline administrative costs and leverage resources;
- United States Department of Agriculture (USDA) Rural Development Utilities funding (if available).

Note that any well mitigation projects should be coordinated with the SWRCB's Safe and Affordable Drinking Water Fund Program (which will be seeking to implement short and long-term drinking water solutions within vulnerable communities) via the SWRCB's Division of Drinking Water. Funding from the SWRCB's Safe and Affordable Drinking Water Fund Program should not be utilized to ameliorate negative impacts to safe drinking water access in vulnerable communities that are a result of implementation of the GSPs.

Mitigation measures should not put a financial burden on S/DAC residents and communities. Where feasible, coordinate with relevant agencies to procure funding for cost-effective and affordable solutions. Solicit stipends and grants from agencies where there will be an added cost on residents.
Wherever consolidation is possible, the GSA should assist in pursuit of feasibility studies and assist in negotiations with public water systems. GSAs should also assist in pursuit of grants/funds to ensure that this water is affordable. This work must be initiated with community involvement, oversight, and leadership during "yellow light" phase. GSAs play a unique role in regional groundwater management and the ability to convene multiple agencies to leverage multiple funding sources can support both long-term access to safe and affordable drinking water while also supporting sustainable groundwater management.

For questions or for more information about the scorecard or the mitigation program, please contact:

Leadership Counsel for Justice and Accountability: Amanda Monaco, amonaco@leadershipcounsel.org
Community Water Center: Debi Ores, deborah.ores@communitywatercenter.org
Self Help Enterprises: Liesbet Olaerts, liesbeto@selfhelpenterprises.org

EXHIBIT B









Drought and Equity in California

Laura Feinstein, Rapichan Phurisamban, Amanda Ford,
Christine Tyler, Ayana Crawford

PACIFIC INSTITUTE

The Environmental Justice Coalition for Water
Water Justice for All

January 2017

Drought and Equity in California

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Lead Authors
Laura Feinstein, *Senior Research Associate, Pacific Institute*
Rapichan Phurisamban, *Research Associate, Pacific Institute*
Amanda Ford, *Coalition Coordinator, Environmental Justice Coalition for Water*
Christine Tyler, *Water Policy Leadership Intern, Pacific Institute*
Ayana Crawford, *Water Policy Leadership Intern, Pacific Institute*

Drought and Equity Advisory Committee and Contributing Authors
The Drought and Equity Advisory Committee members acted as contributing authors, but all final editorial decisions were made by lead authors.
Sara Aminzadeh, *Executive Director, California Coastkeeper Alliance*
Colin Bailey, *Executive Director, Environmental Justice Coalition for Water*
Carolina Balazs, *Visiting Scholar, University of California, Berkeley*
Wendy Broley, *Staff Engineer, California Urban Water Agencies*
Amanda Fencl, *PhD Student, University of California, Davis Center for Environmental Policy and Behavior*
Kelsey Hinton, *Program Associate, Community Water Center*
Gita Kapahi, Director, *Office of Public Participation, State Water Resources Control Board*
Brittani Orona, *Environmental Justice and Tribal Affairs Specialist and Native American Studies Doctoral Student, University of California, Davis*
Brian Pompeii, *Lecturer, California Polytechnic State University, San Luis Obispo*
Tim Sloane, *Executive Director, Institute for Fisheries Resources*

ISBN-978-1-893790-76-6
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Pacific Institute
654 13th Street, Preservation Park
Oakland, California 94612
Phone: 510.251.1600 | Facsimile: 510.251.2203
www.pacinst.org



Cover Photos: Clockwise from top left: NNehring, Debargh, Yykkaa, Marilyn Nieves
Designer: Bryan Kring, Kring Design Studio

ABOUT THE PACIFIC INSTITUTE

The Pacific Institute envisions a world in which society, the economy, and the environment have the water they need to thrive now and in the future. In pursuit of this vision, the Institute creates and advances solutions to the world's most pressing water challenges, such as unsustainable water management and use; climate change; environmental degradation; food, fiber, and energy production; and basic lack of access to fresh water and sanitation. Since 1987, the Pacific Institute has cut across traditional areas of study and actively collaborated with a diverse set of stakeholders, including leading policymakers, scientists, corporate leaders, international organizations such as the United Nations, advocacy groups, and local communities. This interdisciplinary and independent approach helps bring diverse groups together to forge effective real-world solutions. More information about the Pacific Institute and its staff, board of directors, and programs can be found at www.pacinst.org.

ABOUT THE ENVIRONMENTAL JUSTICE COALITION FOR WATER

The Environmental Justice Coalition for Water (EJCW) works within a Community-to-Capital framework, connecting the most pressing needs of our disadvantaged community partners to our network of partners and agencies statewide. Since 1999, EJCW's work has been rooted in the communities most affected by environmental injustice. Issues and solutions are identified through regional chapters and statewide work groups. EJCW is positioned in the state capital, in order to connect communities with state agencies to bring about change multilaterally through advocacy, education, training, litigation, community organizing, and capacity-building, and by providing technical assistance. EJCW aims to effectively influence the intersections of water justice and environmental justice, community health, and human rights issues from community to global levels.

ABOUT THE AUTHORS

LAURA FEINSTEIN, *Senior Research Associate, Pacific Institute*

Laura Feinstein joined the Water Program at the Pacific Institute in 2016. Laura conducts research on aquatic ecosystems; the impacts of climate change on water resources, water, and energy; and environmental health and justice. Prior to joining the Pacific Institute, she was a research scientist and project manager with the California Council on Science and Technology. She also served as a Science and Technology Policy Fellow with the California Senate Committee on Environmental Quality and was a California SeaGrant Delta Science Fellow. Laura holds a BA in Anthropology from the University of California, Berkeley and a PhD in Ecology from the University of California, Davis.

RAPICHAN PHURISAMBAN, *Research Associate, Pacific Institute*

Rapichan Phurisamban has worked in the Pacific Institute's Water Program since 2014, focusing on economic and policy analysis relating to domestic and international water resources. Prior to joining the Pacific Institute, she was a research consultant and project coordinator at a nonprofit organization in Thailand, where she promoted sustainable food and agricultural systems. Rapichan holds a BA in Economics from the University of British Columbia and an MPP from the University of California, Berkeley.

AMANDA FORD, *Coalition Coordinator, Environmental Justice Coalition for Water*

Rev. Ford is based in Sacramento, California. In addition to being an ordained interfaith minister, she has an MA in Sustainable International Development from Brandeis University with an emphasis in Environmental Peacebuilding and Project Management. Amanda leads the development, coordination, and implementation of EJCW's environmental justice coalition efforts, programs and advocacy campaigns at a statewide level, including Human Right to Water (AB 685) implementation, pollution prevention, democratic water governance, and tribal outreach. She has worked on environmental peacebuilding and environmental justice projects in 20+ countries and still actively advises projects around the world.

CHRISTINE TYLER, *Water Policy Leadership Intern, Pacific Institute*

Christine Tyler was a Congressman George Miller Water Policy Leadership Intern with Pacific Institute in 2016. Christine holds a BA in Political Science from the University of California, Berkeley. Her research interests revolve around international development, water and resource rights, colonialism, and climate change's effect on marginalized communities. She has previously worked on wastewater management and land rights issues in Oakland and abroad.

AYANA CRAWFORD, *Water Policy Leadership Intern, Pacific Institute*

Ayana Crawford was a Congressman George Miller Water Policy Leadership Intern with Pacific Institute in 2016. Ayana holds a BA in Environmental Studies from the University of California, Santa Cruz, where she completed a number of research and conservation internships and focused her coursework on social and environmental justice. Ayana pursued these passions after graduation through her work with the Pacific Institute, which revolved around water equity and water access, and as a research intern at Food First, a food justice think tank. She is presently studying Spanish at the University of Granada in Spain.

ACKNOWLEDGMENTS

This work was supported by a grant from the TomKat Foundation. We thank them for their generosity. The Drought and Equity Advisory Committee and report authors wish to thank the many people who gave their time to assist us in writing this report. Staff of the Community Water Center (CWC) organized two meetings with impacted communities. Marina Perez and Esther Tracy from the California State Water Resources Control Board (SWRCB) joined our Advisory Committee meetings. Many people participated in interviews or shared useful data with us, including Bruce Barton, Dave Bitts, Chris Brady, Donald Brafford, Larry Collins, Lori French, Kathy Frevert, Max Gomberg, Chook-Chook Hillman, Steve Lindley, Michael O'Farrell, Mike Ricketts, and Kurt Souza. East Porterville for Water Justice (EPWJ) and la Asociación de Gente Unida por el Agua (AGUA) Coalition met with us to discuss report recommendations. Heather Cooley gave many helpful review comments, and Matthew Heberger provided input and technical support. Brendan McLaughlin copyedited our dubious prose. Finally, our communications team, Rebecca Olson and Deb Janes, helped guide this report through its final stages. The opinions expressed in this report are those of the authors and do not necessarily reflect the views of the Drought and Equity Advisory Committee or the project funder. All conclusions and errors are our own.

Acronyms and Abbreviations

ACS – American Community Survey

AGUA – Association of People United for Water (or la Asociación de Gente Unida por el Agua)

CA HSC – California Health and Safety Code

CalEPA – California Environmental Protection Agency

CBC – Cumulatively Burdened Communities

CCF – Centum Cubic Feet (100 cubic feet)

CDPH – California Department of Public Health

CUWA – California Urban Water Association

CWS – Community Water System

DAC – Disadvantaged Community

DWR – Department of Water Resources

ESA – Endangered Species Act

GAMA – Groundwater Ambient Monitoring and Assessment Program

GPCD – Gallons Per Capita Per Day

IHS – Indian Health Service

LWS EAR – Large Water System Electronic Annual Reports

MCL – Maximum Contaminant Level

MHI – Median Household Income

NOAA – National Oceanic and Atmospheric Administration

OES – Office of Emergency Services

PFMC – Pacific Fishery Management Council

PWS – Public Water System

SDWIS – State Drinking Water Information System

SSWS – State Small Water System

SWAMP – Surface Water Ambient Monitoring Program

SWRCB – State Water Resources Control Board

U.S. EPA – United States Environmental Protection Agency

USBR – United States Bureau of Reclamation

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EXECUTIVE SUMMARY

Water is essential for life, yet not everyone in California has access to safe, affordable water. Five years of drought has highlighted these inequities. Recent reviews of the impact of the ongoing drought found that cities and farms, despite feeling the effects of curtailed water supplies, demonstrated great resilience overall (Cooley et al. 2015; Hanak et al. 2015). Small water suppliers and natural systems have not fared as well. Some small systems struggled to provide safe water to their customers, thousands of household wells ran dry, and endangered fish reached the brink of extinction (Braxton Little 2016; Moyle 2014; State of California 2016). Across California, those on low or fixed incomes have struggled with the rising cost of water (Cooley et al. 2016).

In this report, we examine three major impacts of the ongoing California drought. The first two, supply shortages and rising costs, affected people's access to safe, affordable water in their homes. We also investigated the impacts of the drought on salmon and, by extension, commercial and tribal fishermen reliant on salmon for income, food, and cultural traditions. We found that low-income households, people of color, and communities already burdened with environmental pollution suffered the most severe impacts. The good news is that there are solutions to these problems, some of which are already being implemented. We conclude with a set of policy recommendations to improve our ability to cope with drought and minimize its inequitable consequences in the future.

During the drought, some small systems struggled to provide safe water to their customers, thousands of household wells ran dry, and endangered fish reached the brink of extinction.

DOMESTIC WATER SHORTAGES

Despite a great deal of public attention on drinking water shortages since the drought began in 2012, this is the first statewide summary of reported water supply vulnerabilities. Using information collected by state and local agencies, we classified water systems as "drought-impacted" if they reported actual or near shortages, received emergency drought funding, or, in the case of tribal water systems, were identified by United States Indian Health Services (IHS) as "high risk." We examined water systems serving more than 25 people year round or at least 15 connections (referred to as public water systems) and those serving fewer than 25 people year round, such as private wells (referred to as non-public water systems). We found that:

1. Most (76 percent) of the 149 drought-impacted public water systems were small, serving 1,000 connections or fewer. This is similar to the overall percentage of small water systems in California. Drought-impacted public water systems served an estimated 480,000 people—approximately equivalent to the population of Sacramento.
2. Drought-impacted public water systems were widespread, with at least one found in 39 of the state's 58 counties, but were concentrated in the San Joaquin Valley, the North Coast, and the Central Coast. There were no reports of drought-impacted systems in the easternmost portions of the state or in the San Francisco Bay Area.
3. From January 2014 through early August 2016, the state received nearly 4,000 reports of shortages from households served by small, non-public water systems. Household shortages were reported in 38 of 58 counties across the state but were concentrated in the southern San Joaquin Valley. Tulare County accounted for 42 percent of reported household water shortages.
4. A large proportion of drought-impacted public water systems and household outages were in Disadvantaged and Cumulatively Burdened Communities.[1] Of the 92 drought-impacted public water systems for which we know the location, two-thirds served a disadvantaged community, and nearly one-third served a cumulatively burdened community. Similarly, of the household shortages reported in Tulare County, two-thirds were in a disadvantaged community, and nearly 90 percent were in a cumulatively burdened community.

To improve the drought resilience of domestic water supplies, we recommend that state and local agencies enact the following measures:

1. Establish a statewide, quantitative metric for measuring water supply reliability for public water systems;
2. Require water shortage contingency plans for all public water systems and establish regional plans for non-public systems;
3. Increase oversight of new private wells;
4. Systematically collect information on water shortages for public and non-public water systems;
5. Identify areas where private wells and other non-public water systems are likely to run dry in future droughts;
6. Identify areas where water system consolidation can resolve supply problems.

DROUGHT CHARGES AND WATER AFFORDABILITY

The cost of water can go up during a drought if, for example, the water utility must purchase more expensive supplies, increase treatment for lower quality water, or pump groundwater from greater depths. Moreover, as water use declines due to mandatory or voluntary restrictions, water utilities may implement a temporary drought charge to cover their costs, most of which are fixed. Such price increases can exacerbate affordability concerns for low-income households. In examining the impact of drought charges on low-income households in 2015, we found that:

1. More than half of the utilities analyzed increased the price of water regardless of the amount a household used, resulting in price increases for all single-family households.
2. About one-fifth of the utilities levied drought charges by increasing the price of water used

1 Disadvantaged Communities have a median household income of less than 80 percent of the state median. Cumulatively Burdened Communities are those that rank in the top quarter of census tracts in the state for environmental burdens and socioeconomic vulnerability.

in excess of some threshold. While the intent was to avoid increasing prices for basic water use, even relatively efficient households with many members still experienced an increase in the price of water.

3. Approximately one-fifth of the utilities only added drought charges if a household exceeded a customized water budget based on household size, raising the price of water only for wasteful use.
4. Drought charges exacerbated affordability concerns for low-income households. Single-family households earning less than $25,000 a year paid an average of 1.8 percent of their household income for basic water service without drought charges. This amount increased to 2.1 percent with drought charges, exceeding State of California and United States Environmental Protection Agency affordability thresholds. The effect was even more extreme for households earning less than $10,000, raising costs from 4.4 to 5.3 percent of income. These households have little or no disposable income, so any increase in water costs poses a major problem.

To reduce the inequitable impact of drought charges on low-income households, we recommend the following:

1. Ensure drought surcharges are not applied to basic water use, preferably by calculating household water budgets based on the number of people in a residence;
2. Provide technical and financial assistance to water utilities, especially the smallest ones, to implement drought charges that do not unfairly burden low-income households;
3. Target water conservation and efficiency programs to low-income households by offering, for example, point-of-sale coupons, targeted education and outreach, and direct-install programs;



Source: Photographereddie

4. Develop low-income rate assistance programs within current legal constraints and reform Proposition 218 to allow greater latitude in funding such programs;
5. Wherever possible, require meters and sub-meters to allow for more equitable drought charges based on volumetric water use;
6. Develop approaches that effectively target hard-to-reach customers, such as renters and residents of multi-unit buildings, for rate assistance and conservation programs.

DROUGHT IMPACTS ON SALMON FISHERIES

Water disputes in California are sometimes framed as "fish versus people," but this perspective overlooks those who rely on fishing for their livelihoods and traditions. While the link between drought and the collapse of endangered fish stocks has been extensively documented (Hanak et al. 2015), surprisingly little research has traced

the relationship between drought, low river flows, and the health of commercial and tribal fisheries in California. Salmon populations decline during droughts because of reduced stream flows and higher water temperatures, which lead to disease outbreaks, more competition from invasive fish species, and higher risk of predation. Habitat loss from human activity has compromised their capacity to survive and rebound from droughts. There are many factors contributing to the decline of salmon, of which drought is just one.

We examined the available data and information on trends in commercial and tribal fishing over time. We found that:

1. The commercial salmon fishing fleet has declined dramatically over the last three decades, from 6,000 vessels in 1982 to just over 1,000 vessels in 2014. Many factors have contributed to the decline, including fewer salmon, income insecurity brought about by events such as the fishery closure of 2008-2009, rising costs of fishing, and loss of support infrastructure (such as fuel docks).
2. From 2014 to 2015, Sacramento winter-run Chinook salmon had the poorest survival for juvenile fish on record due to drought conditions and water diversions from the Sacramento River, resulting in an abbreviated 2016 fishing season for much of the state.
3. Extremely low flows in the Klamath River, caused by drought and water diversions for irrigation, contributed to an outbreak of fungal infections in salmon in 2014 and 2015. The subsequent poor reproduction will impact fishermen two to five years later, when eggs hatched in 2014 and 2015 return from the ocean as mature adults.
4. Declines in salmon populations, made worse by drought, have meant that tribes cannot obtain the fish that are an essential part of their diet and an integral part of their spiritual and cultural traditions.

To reduce the impact of drought on salmon fishermen, we recommend the following:

1. Expand the goal of emergency drought responses beyond preserving endangered species to include protection of commercially-fished salmon species.
2. Manage stream flows to better serve the needs of fish.
3. Restore habitat to improve salmon resilience to drought.
4. Provide income assistance and insurance protection for fishing communities during drought emergencies.
5. Create mechanisms for meaningful and timely tribal engagement with local, regional, state, and federal agencies.
6. Evaluate ways to re-operate California hatcheries to achieve parallel goals of sustaining commercial fisheries and assisting in the recovery of naturally-spawned salmon runs.
7. Assess the use and effectiveness of instream flow regulations to protect salmon populations.
8. Develop integrated, comprehensive datasets tracking salmon populations and their environment throughout the state.

Inequities in access to water in California existed before the drought began in 2012, but lack of water made the outcome of these inequities more severe. Low-income families, those who are disproportionately burdened by multiple sources of pollution, and those who depend on aquatic ecosystems for their livelihood and traditions

are highly vulnerable to problems of supply shortages, rising unaffordability, and insufficient streamflows. Unless we act, drought's impacts on these communities will become more severe as climate change progresses, given that scientists predict longer, more severe, and more frequent droughts. We offer the Drought and Equity report and the recommendations within as a tool for community members and decision-makers to improve the resilience of all Californians, including the most vulnerable, to future droughts.

INTRODUCTION

California recently suffered the driest four years in state history, and despite somewhat wetter conditions since late 2015, 75 percent of the state remains in drought conditions as of December 2016 (U.S. Drought Monitor 2016). Cities and farms, despite feeling the effects of curtailed water supplies, have by and large demonstrated great resilience (Hanak et al. 2015; Cooley et al. 2015), but small water suppliers and natural systems have not fared as well. Some public water systems struggled to deliver safe water to their customers, thousands of household wells ran dry, and endangered fish reached the brink of extinction (Moyle 2014; Braxton Little 2016; State of California 2016). And while urban water suppliers maintained clean water delivery during the drought, many of their low-income customers struggled with the rising cost of water (Cooley et al. 2016).

In this report, we examine three major impacts of the drought. The first two—shortages and price hikes—affected people's access to safe, affordable, adequate water in their homes. The third arena we investigate is salmon fishery performance during the drought, and how it affected commercial and tribal fishermen reliant on salmon for income, food, and cultural traditions. We selected these topics based on input from a diverse set of stakeholders. While we were unable to explore them in-depth in this report, the impact of drought on farmworkers, water quality, and subsistence fishermen (beyond the tribes we discuss in Section 3), are also critical issue areas that deserve further analysis.

Our goals were to synthesize available information from the state, media outlets, and non-governmental organizations (NGOs) and develop recommendations on how to mitigate the impacts of future droughts. This report is intended to provide information to community groups to advocate for their own interests, as well as to inform policymakers and other decision-makers interested in crafting more effective drought response strategies, particularly to address the needs of the state's most vulnerable communities.

This project was conceived of cooperatively by the Pacific Institute and the Environmental Justice Coalition for Water (EJCW). To oversee the project, we convened a nine-member California Drought and Equity Advisory Committee representing a range of perspectives and interests:

Sara Aminzadeh, *Executive Director, California Coastkeeper Alliance*

Colin Bailey, *Executive Director, Environmental Justice Coalition for Water*

Carolina Balazs, *Visiting Scholar, University of California, Berkeley*

Wendy Broley, *Staff Engineer, California Urban Water Agencies*

Amanda Fencl, *PhD Student, University of California, Davis Center for Environmental Policy and Behavior*

Kelsey Hinton, *Program Associate, Community Water Center*

Gita Kapahi, *Director, Office of Public Participation, State Water Resources Control Board*

Brittani Orona, *Environmental Justice and Tribal Affairs Specialist and Native American Studies Doctoral Student, University of California, Davis*

Brian Pompeii, *Lecturer, California Polytechnic State University, San Luis Obispo*

Tim Sloane, *Executive Director, Institute of Fisheries Resources*

The Advisory Committee helped determine the scope, identified project outcomes, developed recommendations, and reviewed the report. Profiles of the Advisory Committee members and their organizations are given in Appendix IA.

This report builds on previous work by the Pacific Institute and EJCW focused on the San Francisco Bay Area, which brought together eight community partners to identify drought impacts and concerns and develop a set of recommendations for addressing them. This work was summarized in a report on Drought and Equity in the San Francisco Bay Area (Cooley et al. 2016), and culminated in a day-long summit in July 2016 that brought together representatives of Bay Area community organizations, water managers, local government, and water and justice nonprofits.

The report is divided into three sections. Section 1 highlights domestic water shortages both in public and the non-public systems that serve very few people, such as private wells. Section 2 examines drought surcharges, and how they affected water affordability for low-income households. Section 3 examines the impact of the drought on commercial and tribal fishermen reliant on salmon for their livelihood and cultural traditions. We conclude each section with recommendations for mitigating impacts of future droughts for the impacted communities.

SECTION 1.
DROUGHT AND DOMESTIC WATER SHORTAGES

OVERVIEW

With the recent passage of the Human Right to Water (CA Water Code Section 106.3), California has declared that access to sufficient water for cooking, consumption, and sanitation is a basic human right. Yet, water shortages for basic household needs have been widely reported over the last several years due to the ongoing drought (Braxton Little 2016; SWRCB 2016a; Becerra 2014; Lurie 2016). Since 2012, thousands of households reported that their wells have run dry, while hundreds of public water systems have applied for financial assistance to address dwindling or contaminated supplies. The state spent $66 million on emergency drought responses related to drinking water from July 2013 to June 2016 for programs such as delivering water to households, deepening wells, and consolidating water systems (Legislative Analyst's Office 2016). Addressing the underlying vulnerabilities in domestic water supplies is all the more urgent given that droughts are likely to become longer, more frequent, and more severe due to climate change (Dettinger et al. 2011).

Despite growing public concern and several state and local programs to address water shortages, the scope and severity of the statewide problem are not well understood. Rural, low-income, primarily Latino communities in the San Joaquin Valley such as East Porterville deservedly received a great deal of media attention when families' private wells ran dry and residents had to survive without running water, often for years (Box 1-1). But outside the intense coverage of the worst-affected communities, the overall extent and severity of water shortages during the drought is not well understood. Water utilities resorted to hauling in tanks of water and delivering bottled water as stopgaps while they identified long-term solutions to water shortages, but these problems were often only reported in the local paper, if at all. Here we pull together a number of datasets to gain a statewide perspective on domestic water shortages during the ongoing drought. Where did shortages occur? What types of water systems were impacted? What were the demographic and socioeconomic characteristics of the impacted communities? Our goal is to better understand which water sources were most vulnerable to drought, so we can improve the resiliency of domestic water supplies in future dry periods.

METHODS

Categories of Water Systems

We divided water systems into seven categories based on size, type of customers, and how they are regulated. This is consistent with the approach used in a recent Department of Water Resources report, *Californians Without Safe Water and Sanitation* (DWR 2014a). A public water system is defined in

Box 1-1.

Experiences of Tulare County Residents Living With Water Shortages

On Dec. 12, 2016, California Drought and Equity report authors, and Kelsey Hinton of Community Water Center and the Drought and Equity Advisory Committee, addressed a meeting of the AGUA Coalition (la Asociación de Gente Unida por el Agua, or the Association of People United for Water). AGUA is a regional, grassroots coalition of impacted community residents and allied non-profit organizations dedicated to securing safe, clean, and affordable drinking water for the San Joaquin Valley. It works closely with the Community Water Center.

We presented a summary of the report findings and recommendations, and asked meeting attendees to add their recommendations or tell us experiences that should be documented. Here are some of the responses.

"I've lived without water for two years, seven months. It's important to point out the urgency to get long-term solutions more rapidly than we're getting them now."

"I've been to at least two meetings where people address the Board of Supervisors of Tulare county, and a Supervisor says, 'Well my well went dry too, and I had to drill a new well.' But there's a big difference between that and someone whose well went dry, and then they had to go without water for more than two years."

"Many agencies got money to help, but maybe what is missing is a group, like the AGUA coalition, that even when the money runs out, they continue to work on this issue. People have submitted applications to agencies for money, but the money has already run out, and then the organization just shuts down. People have problems where they submitted original documents to an agency that ran out of money and haven't gotten them back so they can't put in a new application. So agencies need to stick around."

"Our community has been without clean water for more than 10 years. Then who do we call? We call the county, they're closed, or they give you a different number... nobody knows who to call."

the California Health and Safety Code (CA HSC) as a system that has "15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year" (CA HSC § 116275). The California State Water Resources Control Board (SWRCB) oversees approximately 8,000 public water systems in the state that deliver drinking water to the vast majority of the population. The U.S. Environmental Protection Agency (U.S. EPA) regulates the 125 tribal water systems in the state.

Systems too small to meet the threshold for a public water system are referred to as non-public water systems.[1] There are three types of non-public water systems: state small water systems, local small water

1 A public water system has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year (CA Health and Safety Code Section 116275(h)). In this report, we use the term "non-public water system" to refer to any system that has fewer than 15 service connections and serves fewer than 25 individuals daily.

systems, and private domestic wells (or surface diversions). Water quality of state small water systems is regulated at the county and local level; water quality in local and private systems has relatively few regulations. Table 1-1 summarizes the seven categories of water systems.

Table 1-1. Categories of Water Systems in California

Name	Definition	Estimated Population Served (2016)[1]	Drinking Water Quality Regulating Agency	Typical Customer Type
Public Water System	15 or more service connections or serves at least 25 individuals daily at least 60 days out of the year (CA HSC § 116275(h))			
Community Water System	At least 15 service connections used by year-long residents or regularly serves at least 25 year-long residents of the area served by the system (CA HSC § 116275(i))	41,300,000	SWRCB	Residential areas; can also include non-residential areas in addition to homes
Transient Non-Community Water System	Does not regularly serve at least 25 of the same persons over six months per year (CA HSC § 116275(o))	981,000	SWRCB	Restaurants, campgrounds, parks, motels and other non-residential areas
Non-Transient Non-Community Water System	At least 25 of the same persons over six months per year (CA HSC § 116275(k))	412,000	SWRCB	Schools, workplaces
Tribal Water System	At least 15 connections or 25 people daily, serving a federally recognized tribe	224,000	U.S. EPA	Facilities on tribal land
Non-Public Water System	Fewer than 15 service connections or serves fewer than 25 individuals daily at least 60 days out of the year			
State Small Water System	At least five, but not more than 14, service connections and does not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year (CA HSC § 116275(n))	Data not available	County and local health departments	Small number of people served in any type of location
Local Water System	2-4 service connections[2]	Data not available	N/A	"
Private Domestic Well (or Surface Diversion)	1 service connection[2]	600,000 – 2,000,000 use wells; population served by surface diversions unknown	N/A	"

1. Population served figures are approximations made by the water utilities. Note that the populations served by the different types of water systems overlap. Numbers rounded to three significant figures. Data from Safe Drinking Water Information System (SDWIS) (SWRCB 2016c), except domestic wells from DWR (2013), and Tribal Water Systems from U.S. EPA(2016).
2. Definition given in "Californians Without Safe Water and Sanitation: California Water Plan Update" (DWR 2014a).

Analysis 1: Drought-Impacted Public Water Systems

We identified drought-impacted public water systems using three statewide datasets:

- Community water systems and non-transient non-community water systems serving schools that had applied for assistance from the SWRCB as of July 2016, due to drought-related impacts on drinking water supply or quality that could not be addressed with their existing funding (SWRCB 2016e);
- A SWRCB survey in December 2015 of community water systems with 15-3,000 service connections on their ability to provide water if the drought continued through 2016 (SWRCB 2016d); and
- a July 2015 assessment of tribal water systems for multiple factors linked to drought vulnerability, such as changes in supply and availability of an alternative source of water (IHS 2015).

These datasets have a number of limitations. To our knowledge there is no single, comprehensive dataset on public water system shortages during the ongoing drought. The list we compiled reflects a best effort with available data and should be viewed as a preliminary, and likely incomplete, assessment of public water systems that have experienced drought impacts that actually, or nearly, resulted in shortages. A more careful, consistent means of collecting information on drought shortages would enable a more thorough understanding of vulnerable water systems. Nonetheless, the list provides an indication of where the known problems are concentrated, as well as a minimum number of systems affected by the drought.

Once we compiled a master list of drought-impacted systems, we mapped the locations of the systems and quantified the number serving vulnerable communities. We used two definitions of a vulnerable community, following definitions used by state agencies. A Disadvantaged Community (DAC) is a census block groups with a median household income under 80 percent of the state median household income (Department of Water Resources (DWR) 2016). A Cumulatively Burdened Community (CBC) is a census tract that ranks in the top quarter of tracts in the state for environmental burdens and socioeconomic vulnerability (California Environmental Protection Agency (CalEPA) 2014).[2]

We give further details on datasets used in the analysis of drought-impacted public water systems in Appendix 1A.

Analysis 2: Water Shortages in Households Served by Non-Public Water Systems

We also looked at shortages in households served by water systems too small to be regulated as public water systems. These data are likely an undercount of the true number of household shortages.[3] But as with the data on drought-impacted public water systems, they indicate where the known problems were concentrated, as well as a minimum number of households affected. In Tulare County, we had sufficiently detailed data on household shortage locations to map them, and calculate how many were in DACs and CBCs.

2 This definition takes into account 20 factors in the categories of pollution exposure indicators, environmental effects indicators, sensitive population indicators, and socioeconomic indicators. Two of the factors relate directly to water quality: groundwater threats and drinking water contaminants.

3 Household shortages may not be included in the statewide dataset for a number of reasons, including: not all counties had reporting mechanism in place; people that are financially able to deepen or drill a new well themselves are unlikely to communicate a problem to the officials; and people may choose not to report a shortage because they prefer to avoid interaction with government officials.

RESULTS AND DISCUSSION

Drought-Impacted Public Water Systems

For our first analysis, we identified 127 community water systems with potential or actual drought impacts to their water supply between 2014 and 2016 (Table 1-2), and an additional 22 non-community water systems facing supply vulnerabilities. Most of the community water systems (72 percent) were small, serving 1,000 connections or fewer. This is consistent with the fact that 77 percent of community water systems in California are small. The drought-impacted systems in our list served approximately 480,000 people.[4] A complete list of the 149 drought-impacted systems is provided in Appendix 1B.

Drought-impacted systems were found in most California counties (Figure 1-1a). The greatest number were in Madera (24) and Tulare (12) counties. There was also a relatively large number of drought-impacted systems in Mendocino County (13). The impacts correspond roughly to

4 Population served was calculated by adding the population served listed either in SDWIS (SWRCB 2016c) or the U.S. EPA's list of tribal water systems (U.S. EPA 2016). This number is an approximation of population served, and individuals can be served by more than one system in their home versus other places they visit.

Table 1-2.

Drought-Impacted Public Water Systems in California

	A	B	C	D	E
	Data Source				
	Applications for Drought Assistance Funding	Small Supplier Conservation Report	Tribal Systems at High Risk Due to Drought	Total Drought-Impacted Systems[3]	Estimated Population Served[4]
Community Water Systems	**87**	**34**	**12**	**127**	**473,000**
No. Connections:					
1-1,000	57	29	10	92	18,200
1,001-3,300	15	2	2	18	34,300
>3,300	15	3	0	17	421,000
Non-Transient Non-Community	**13[1]**	**3**	**NA**	**16**	**5,550**
Transient Non-Community	**NA[2]**	**6**	**NA**	**6**	**1,660**
				Grand Total: 149	**480,000**

1. Of non-transient non-community systems, only systems serving schools were eligible for funds.
2. Transient non-community systems were not eligible to apply for funds.
3. Columns A-C do not necessarily sum to the total in Column D because duplicates appearing in both Columns A and B were eliminated.
4. Rounded to three significant figures. Figures may not sum to total due to rounding errors.

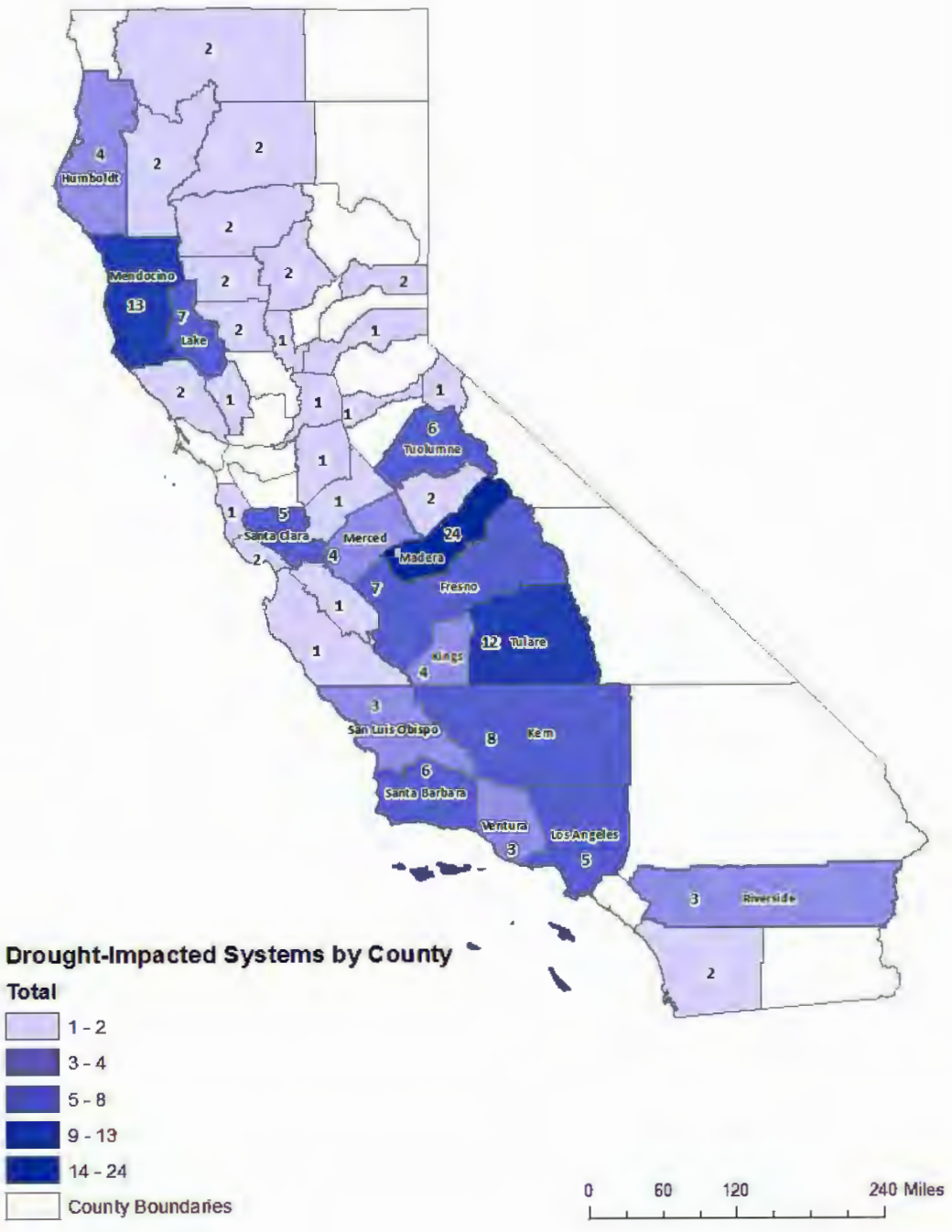
Note: Columns A-C summarize three sources of information on drought-impacted public water systems in California.

Sources: Column A based on data from SWRCB (2016e), Applications for Drought Assistance Funding. Column B based on data from SWRCB (2016d), Small Supplier Conservation Reports. Column C based on data from IHS (2015), July 2015 Drought Vulnerability and Risk Assessments for Tribal Drinking Water Systems. Column E based on SDWIS (SWRCB 2016c).

the state's hydrologic regions, with no impacted systems found in the eastern regions of North and South Lahontan, nor in the San Francisco hydrologic region. The greatest concentrations were in the San Joaquin River, Tulare, North Coast, and Central Coast hydrologic regions. The population served by impacted systems shows somewhat different patterns. The five counties

Figure 1-1a.

Number of Drought-Impacted Public Water Systems in Each County



Notes: Numbers and shading indicate drought-impacted public water system in each county, with darker colors signifying greater numbers. Blank counties had zero drought-impacted systems reported in the datasets surveyed.

Sources: Data compiled in Appendix 1B, from SWRCB (2016c), SWRCB (2016e), SWRCB (2016d), IHS (2015).

with the greatest number of people served by drought-imapcted systems were Santa Barbara (estimated 210,000 people served), Tulare (82,000), Kings (74,000), Tuolomne (23,000), and Mendocino (20,000) (Figure 1-1b).

A large proportion of drought-impacted community water systems were located in low-income and disadvantaged communities. The publicly available map of California's public water systems only gives information for some of

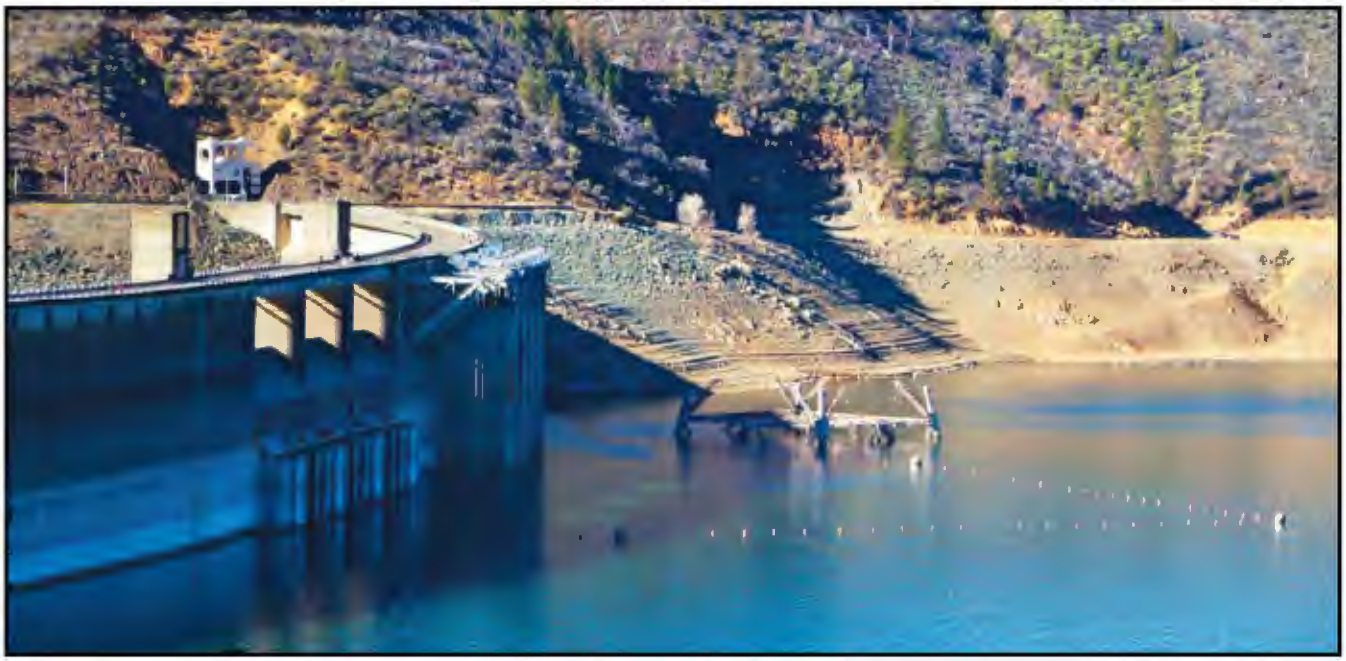
Figure 1-1b.

Population Served by Drought-Impacted Public Water Systems in Each County



Notes: Numbers and shading indicate the estimated number of persons served by drought-impacted public water system in each county, with darker colors signifying greater numbers. Blank counties had zero drought-impacted systems reported in the datasets surveyed.

Sources: Data compiled in Appendix 1B, from SWRCB (2016c), SWRCB (2016e), SWRCB (2016d), IHS (2015).



Source: Slobo

the state's systems, so we were able to map only 97 of the 144 drought-impacted community water systems. Of those, 65 (67 percent) served a DAC, while 28 (29 percent) served a CBC.

Among the 122 public water systems that applied for emergency drought funding, nearly half received funding to haul in water via truck, or deliver bottled water to customers. These systems had reached acute emergencies in which they could not provide safe, sufficient tap water. In total, 52 systems fit this description: 27 received funding to haul water, 24 for bottled water, and 1 for both. The remaining funding was directed to long-term solutions to drought emergencies, such as well overhauls, new wells, new interties to neighboring systems, and new filtration devices. In most cases, whether the underlying problem was one of quality or quantity was ambiguous. In only one case did the project description explicitly mention that the water system's well had run dry. On the other hand, there were 20 project descriptions that indicated that the project intended to address quality concerns; usually the funded project included at least bottled water delivery, and sometimes a long-term solution as well, such as a new filtration device. A portion of the emergency drought assistance funds were explicitly for "contaminated drinking water supplies exacerbated by drought conditions" (CA Budget Act of 2014, Statutes of 2015). This funding was intended to address concerns that drought was causing contamination of water supplies. However, the relationship between drought and the quality of water Californians drink is complex, and we could not find evidence that the quality of drinking water in the state deteriorated because of drought (Box 1-2).

Water Shortages and Non-Public Water Systems

For our second analysis, we looked at shortages reported by households served by non-public water systems. From January 2014 through August 8, 2016, the state received 3,749 reports of shortages in households served by non-public water systems (serving under 15 connections/25 individuals). Most of the reports were concentrated in the counties that are in the San Joaquin Valley, with

Box 1-2.

Drought and Drinking Water Quality

We did not directly seek to document impacts of drought on drinking water quality in this report. However, our Advisory Committee members flagged this as a key concern for public health during droughts. Water systems can experience supply problems either because of an insufficient volume of water, or an insufficient amount of clean water. Emergency drought funding criteria include the intertwined nature of water quality and quantity, making funds available both for supply shortages and for contamination of drinking water exacerbated by drought (Assembly Bill 91, Statutes of 2015, Section 31). Here we review the available literature on the potential link between drought and declining water quality, and its impacts on DACs.

Droughts may cause significant changes in water quality and adversely impact drinking water supplies. For example, warmer surface water temperature, reduced flows, and high nutrient concentrations have resulted in algal blooms in lakes and reservoirs throughout California. These potentially toxic blue-green algae, or cyanobacteria, were the cause of poorer taste and smell of drinking water supplied to East Bay residents in 2015 (EBMUD 2015). Treatment processes can remove harmful substances, and thus these blooms have not been linked to health concerns. A major water quality problem that needs to be carefully managed during drought is the potential for salt water to intrude further into the Sacramento-Bay Delta, contaminating not only water distributed throughout the state via the State Water Project and Central Valley Project, but also water used by Delta farmers and water districts in nearby Contra Costa, Alameda, and San Joaquin counties (DWR 2014b). Other surface water quality indicators relating to the drought such as nutrient concentrations, dissolved oxygen, and organic carbon have shown mixed responses (Mosley 2015).

Communities most vulnerable to degraded water quality because of drought are likely to be those depending on non-public water systems, including private domestic wells and those served by water systems with less than 15 service connections, as these sources are not as intensively regulated or monitored. Up to two million California residents rely on private domestic wells, and unknown numbers use water from local and state small systems (SWRCB 2015b). Private domestic well owners and non-public water system operators are responsible for maintaining their water supplies and ensuring that water quality meets drinking water standards, but problems are likely to remain undetected or unaddressed due to the lack of financial and technical resources.

Drought conditions may exacerbate existing water quality problems. Given that the presence and concentration of arsenic are related to hydrologic and biogeochemical processes, higher evapotranspiration rates can increase arsenic concentrations in surface water and shallow groundwater (Beard, Fujii, and Shanks 1994; Gao, Tanji, and Bañuelos 2007). The drilling of deeper wells as a response to water shortages may cause releases of arsenic from sedimentary rocks. However, there is limited understanding of arsenic transport in sediments in all of California's key groundwater basins. Uranium, another naturally-occurring element, may also increase its concentrations in groundwater during a drought. Jurgens et al. suggested that changes in the chemistry of recharge water and increases

Box 1-2. (*Continued*)

Drought and Drinking Water Quality

in the rate of downward groundwater flow have led to uranium concentrations above drinking water standards in both domestic and public wells. Higher recharge temperatures have been found to correlate with uranium levels (Jurgens et al. 2010). Moreover, uranium contamination is linked to nitrate, which plays a role in increasing the solubility of uranium in water (Nolan and Weber 2015). This secondary uranium contamination is expected to worsen in areas with high agricultural activities and groundwater dependence.

Despite some evidence of drought's negative impacts on water quality, further research is needed to document and assess the mechanisms and implications of these impacts. While drought can alter the quality of water supplies, water systems have methods to remediate the problem by treatment and mixing with higher-quality sources. Little is still known about the extent of drought impacts on the quality of water that reaches customers' taps, how many people receive lower-quality water during a drought, and how reduced water quality during drought affects minorities or socio-economically disadvantaged communities across the state. Some limited data and monitoring programs already exist. Water quality reports required under the Safe Drinking Water Act may be used to track water quality changes during the drought, but they do not include very small drinking water systems and private domestic wells. SWRCB's Surface Water Ambient Monitoring Program (SWAMP) and Groundwater Ambient Monitoring and Assessment Program (GAMA) can provide relevant resources to monitor water quality and trends. However, they also have limited temporal and geographic scopes. Data on groundwater levels are generally lacking or of poor quality, although efforts are being made under the Sustainable Groundwater Management Act (2014) to standardize and expand groundwater data collection and monitoring activities. In addition to data gaps, the complexity of hydrologic and biogeochemical processes presents another challenge in drawing clear relationships between the drought and water quality issues. More attention should be given to determining these linkages, especially in relation to drinking water supplies, to protect communities from unsafe drinking water.

Water quality issues have been shown to disproportionately affect minorities and residents of lower socio-economic status for community water systems that are subjected to federal and state drinking water regulations. (Balazs et al. 2012) found that community water systems serving predominantly low-income and socially disadvantaged groups have high arsenic levels in drinking water and are more likely to receive a Maximum Contaminant Level (MCL) violation.

1,571 (42 percent) in Tulare County alone (Figure 1-2). In Tulare County, these numbers generally reflect households that needed deliveries of bottled water and tanks of non-potable water hooked up to their plumbing. Typically, households that could resolve the problem on their own by drilling or deepening a well did not report a shortage to the county (A. Fencl, PhD Student, UC Davis, personal communication, Dec. 13, 2016). A list of all shortages by county is provided in Appendix 1C.

Figure 1-2.

Household Water Supply Outages Reported by County



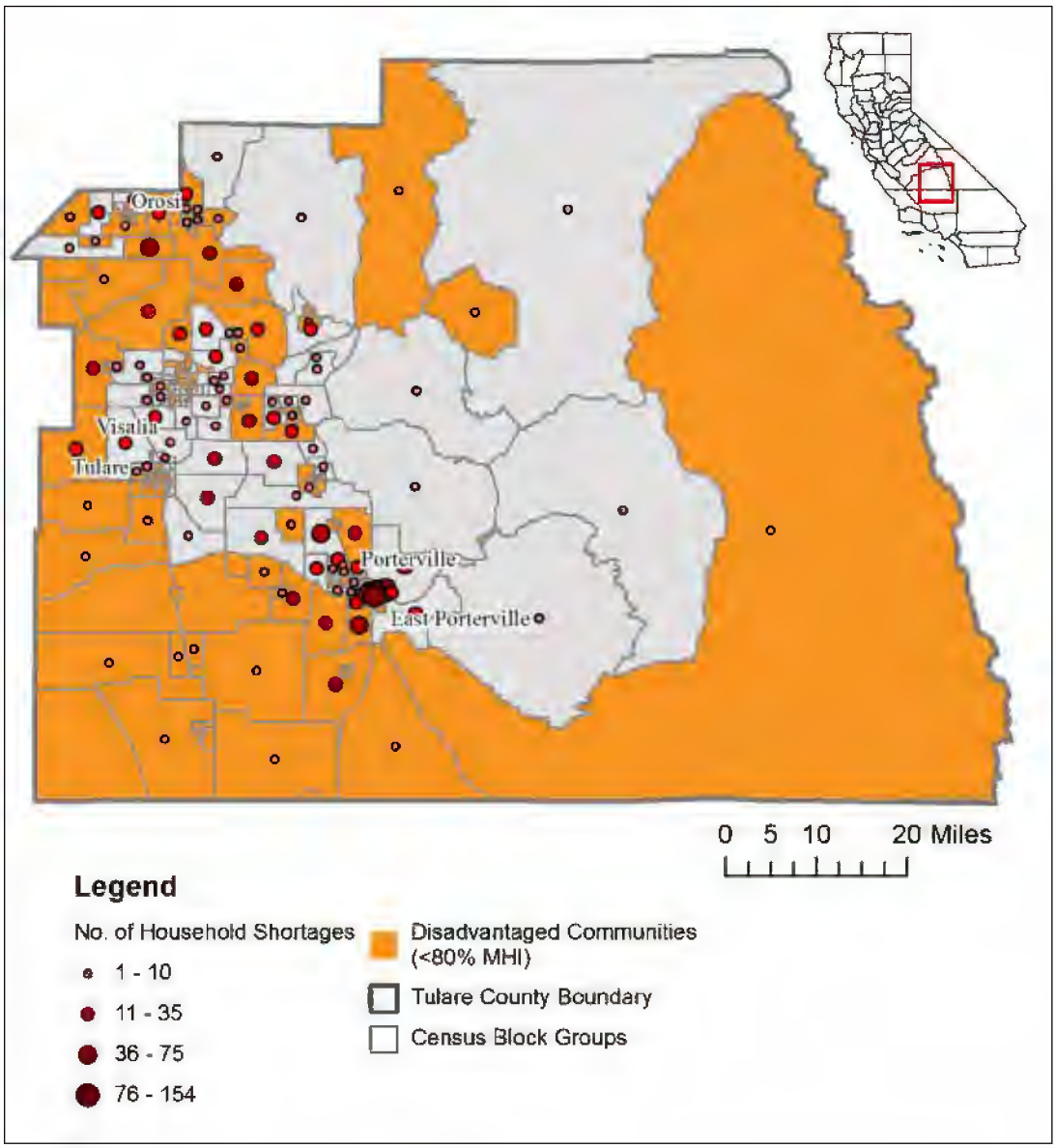
Notes: Map shows cumulative reports of household water supply shortages by county from July 2014 to August 2016. Counties with "no reports" may represent zero shortages, or simply a lack of data collection and reporting. Households reported dry wells and surface water supply shortages. Figures include active outages, active supply problems, resolved outages, and outages where interim solutions have been implemented. Only eleven counties report interim and/or permanently resolved outages.

Source: Reproduced from the State of California Household Water Supply Shortage Reporting System (State of California 2016).

For Tulare County (the only county for which detailed data are available), we mapped the number of reported shortages (Figure 1-3). The outages all occurred in the western and central portion of the county. Sixty-six percent of the reported shortages occurred in a DAC, and 89 percent occurred in a CBC. Households in DACs will likely need financial assistance to resolve their water shortage. Drilling a new individual domestic drinking water well in the San Joaquin Valley is prohibitively expensive for a low-income household, costing between $25,000 to $35,000 in 2016 (Susan Atkins, Self Help Enterprises, personal communication, July 28, 2016). Median

Figure 1-3a.

Household Water Shortages in Tulare County by DAC Block Group



Notes: Tulare County with census block groups classified as disadvantaged in orange, non-disadvantaged shown as grey. Household shortages reported to Tulare County Office of Emergency Services shown as red dots. Larger dots indicate more shortages in a census block. Dots are located at the center of the block group where the shortage(s) they represent occurred.

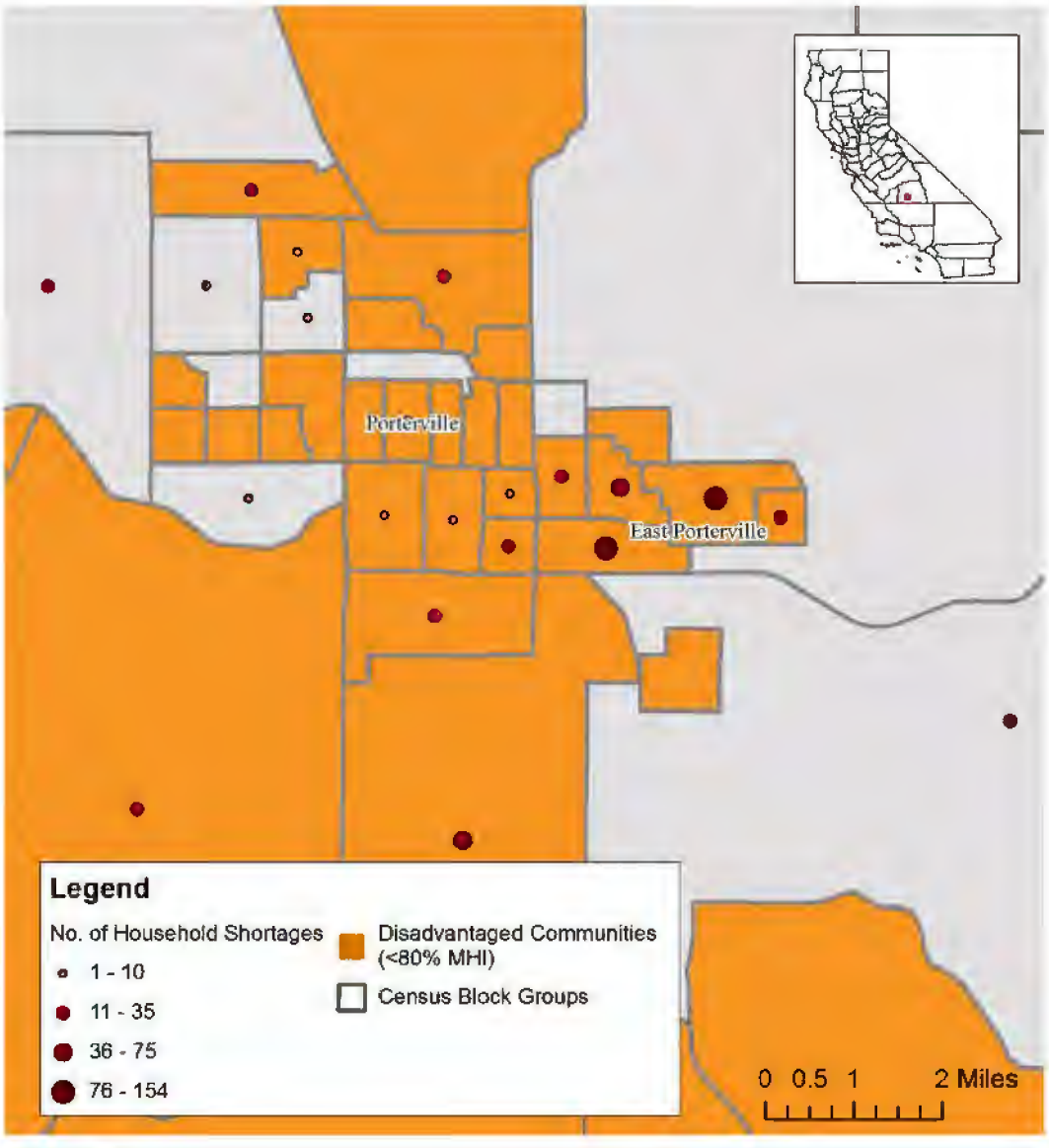
Sources: Data on household shortages from Tulare County OES (2016); data on DACs from DWR (2016a).

household income in a DAC was $49,191 in 2016 (DWR 2016a). Many of these communities are already known to be sensitive populations and to be heavily burdened by other environmental problems, underscoring the urgency of resolving their water shortages, which can aggravate public health problems (CDPH and TCHHSA, 2015).

While most reported well shortages occurred in DACs and CBCs, it is unclear what drives the pattern, and whether the link is anything but a coincidence. There are a number of non-exclusive possible causes for the clustering of shortages in central Tulare County, and their overlap with DACs and CBCs. Some possible drivers for the

Figure 1-3b.

Detail of Household Water Shortages in East Porterville, Tulare County, by DAC Block Group



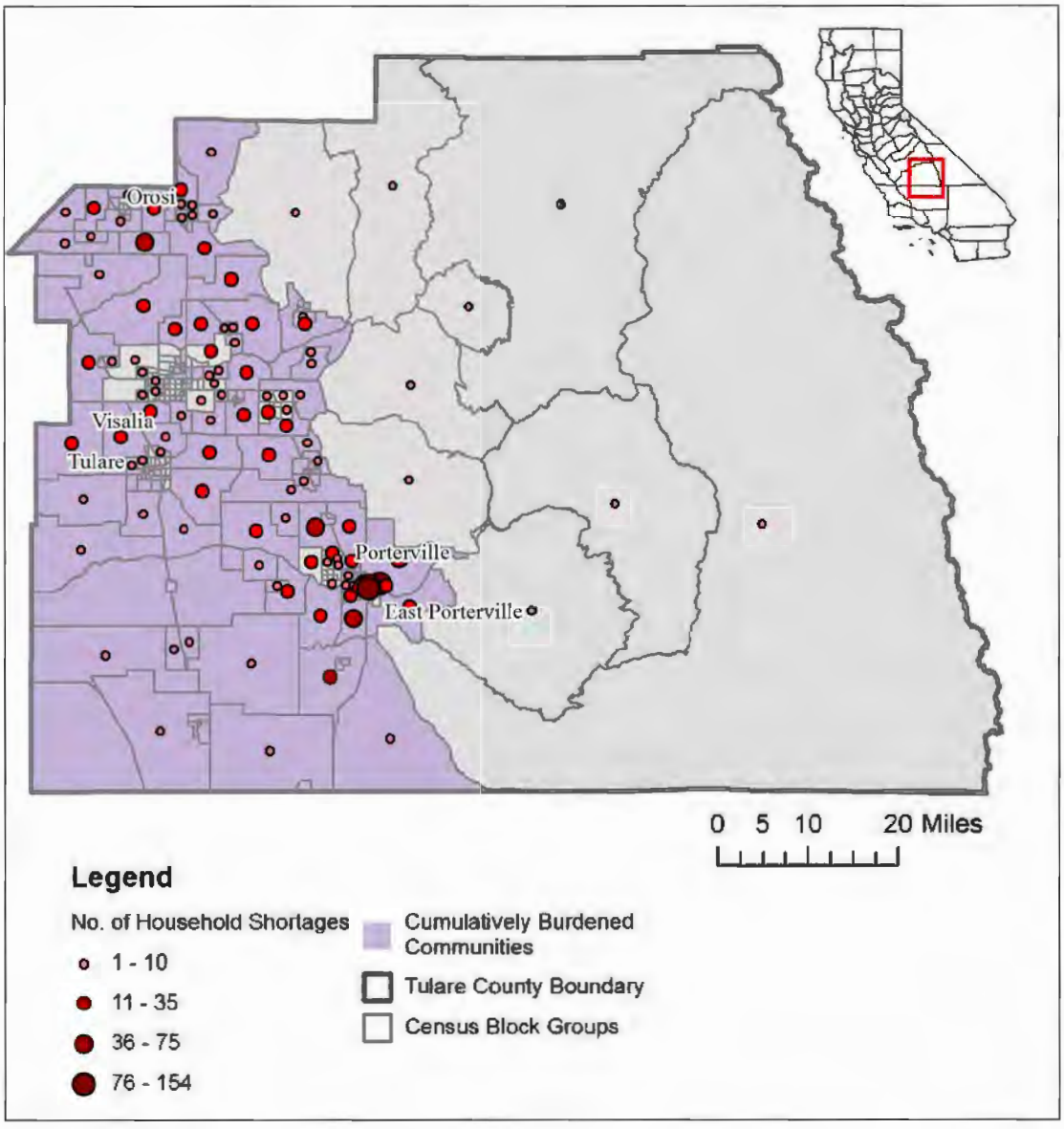
Notes: Tulare County with census block groups classified as disadvantaged in orange, non-disadvantaged shown as grey. Household shortages reported to Tulare County Office of Emergency Services shown as red dots. Larger dots indicate more shortages in a census block group. Dots are located at the center of the block group where the shortage(s) they represent occurred.

Sources: Data on household shortages from Tulare OES (2016); data on DACs from DWR (2016a).

spatial pattern of shortages are hydrogeological. Many of these wells are quite shallow and susceptible to short-term fluctuations in the water table, or tap low-permeability fractured hard rock aquifers that are vulnerable to drought (DWR 1991; Jones 2014; DWR 2016b). The clusters of shortages may simply occur in the areas with the greatest density of wells. On the other hand, there could be systematic reasons for the correlation. Low-income communities and communities of color in the Central Valley rely disproportionately on private wells because adequate public services were not developed in those communities (Bliss 2016). The outages in domestic wells may also

Figure 1-3c.

Household Water Shortages in Tulare County by CBC Block Group



Notes: Location of household shortages reported in Tulare County (red dots) and disadvantaged census block groups (purple shading). Larger dot indicates more shortages. Dots are located at the center of the block group where the shortage(s) they represent occurred.

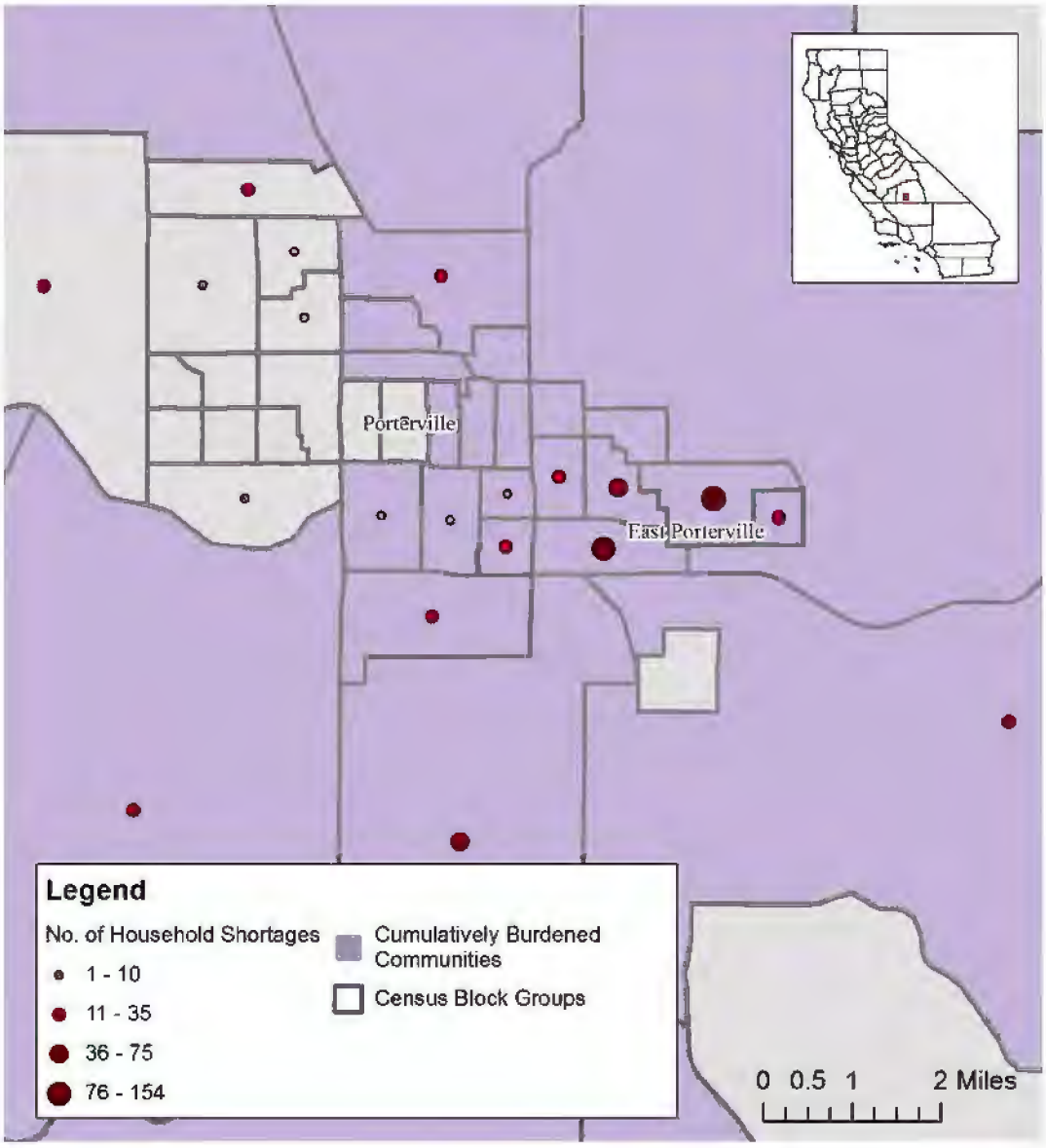
Sources: Data on household outages Tulare County OES (2016). Data on CBCs from http://www.calepa.ca.gov/EnvJustice/GHGInvest/.

be at least partially caused by rapid pumping by deeper irrigation wells.

Reporting bias could also be a factor: residents typically reported a shortage when they were seeking bottled and hauled water deliveries; those with the financial means to resolve their water shortage were less likely to report a shortage. To fully understand the drivers of household outages would require a complex study beyond the scope of this report.

Figure 1-3d.

Detail of Household Water Shortages in East Porterville, Tulare County, by CBC Block Group



Notes: Location of household outages reported in Tulare County (red dots) and disadvantaged census block groups (purple shading). Larger dots indicate more shortages in a census tract. Dots are located at the center of the block group where the shortage(s) they represent occurred.

Sources: Data on household outages in Tulare County from OES (2016). Data on CBCs from http://www.calepa.ca.gov/EnvJustice/GHGInvest/.

Conclusions and Reccomendations

We found 149 public water systems, serving an estimated 480,000 people, reported drought-related impacts to their supplies. These systems were concentrated in the southern San Joaquin Valley, as well as the North Coast and Central Coast regions. We estimated that approximately two-thirds of these public water systems served a DAC, and one-third served a CBC. Of the nearly 4,000 shortages in households served by non-public water systems, most were concentrated in the San Joaquin Valley, with 42 percent of the reports in Tulare County. Of the shortages reported to the county, 66 percent were in a DAC, and 89 percent were located in a CBC. Our findings demonstrate that, while they were concentrated in the San Joaquin Valley, shortages in both public and non-public systems were more widespread geographically in the state than has been represented in media reports. Supply problems during the drought were frequently found in DACs and CBCs, suggesting that in many cases these systems have insufficient capacity to resolve their problems without outside technical, managerial or financial support. We recommend that the state undertake a more uniform, thorough effort to document which public and non-public systems experienced near or actual supply shortages. This data would allow an analysis of the characteristics that made systems more vulnerable to drought, and inform efforts to improve future resilience.

RECOMMENDATIONS TO IMPROVE DROUGHT RESILIENCE OF DOMESTIC WATER SUPPLIES

Mitigating Impacts of Drought on Domestic Water Supplies for Communities

1-1. Establish a Quantitative Metric for Measuring Supply Reliability in Public Water Systems

Assessing supply reliability is an important step in identifying public water systems that need improvements to prevent shortages in future dry years. The data to inform a quantitative "supply reliability" metric should be collected for all public water systems. At present, there is relatively little scrutiny on supply reliability for water systems too small to meet Urban Water Supplier[5] reporting requirements, even though smaller suppliers struggled most during the drought. Data collected and quantified should include at least the following:

- Predicted production to demand ratio in an average year, as well as droughts lasting one, three, and five years.
- Any recent shortfalls in supply that resulted in an inability to deliver enough water for consumption, cooking, and sanitation to residential customers, drops in pressure or outages, or water hauling, along with the dates of any such events, and the volume of the shortfall.

1-2. Require Water Shortage Contingency Plans of All Public, State Small[6], and Local Water Systems[7]

Small and rural communities tend to be the most vulnerable to drought, yet often lack comprehensive plans to cope with the impacts. At present, only urban water suppliers are required to prepare and file water shortage contingency plans with DWR and stress tests with the SWRCB. We recommend that the state require all public water

5 Urban Water Suppliers are defined as "providing water for municipal purposes either directly or indirectly to more than 3,000 customers or supplying more than 3,000 acre-feet of water annually." (CA Water Code Section 10617). Urban Water Suppliers report information on supply reliability under the SWRCB's Emergency Urban Water Conservation Requirements, as well as DWR's Urban Water Management Plans.

6 A State Small Water System has 5-14 service connections and does not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year.

7 A Local Water System has 2-4 service connections.

systems to file water shortage contingency plans, and that the state provide technical and financial assistance as needed in preparing the plans. At the regional level, counties should draft a water shortage contingency plan template appropriate for state small and local water systems and require the systems within their jurisdiction to modify the plan as necessary and adopt it. The IHS' California Area Office's work with tribal water systems to develop drought contingency plans can serve as a model of how to work with small water systems to develop water shortage contingency plans.

1-3. Increase Oversight of New Wells

Thousands of households reliant on private wells and surface diversions lost access to water during the drought, while those with the resources to drill deeper wells continued to pump groundwater at record-breaking rates. Counties should place restrictions on new well permits in basins where domestic water wells are at risk of outages. The Sustainable Groundwater Management Act begins to go into effect for high and medium priority basins subject to critical conditions of overdraft in 2020, and for other high and medium priority basins in 2022. Until then, counties, in collaboration with other well-permitting authorities, should exercise their authority to regulate groundwater use by issuing permits on the condition that the applicant demonstrate that water is available to serve the well.

Further Study and Data Collection on Domestic Water Shortages

1-4. Collect Information on Well Depth from Drilling Permit Applications

At present, well permits collected at the county level do not always include well depth information. Including this information would enable county officials to flag and require modifications to drilling plans for new wells likely to overdraft an aquifer that supplies domestic wells.

Shortages in both public and non-public systems were more widespread geographically in the state than has been represented in media reports.

1-5. Systematically Collect Data on Private Supply Shortages

We know from voluntary reporting compiled by the state[8] that there have been thousands of private domestic well shortages and surface diversions during the ongoing drought. However, the data set on private supply shortages is incomplete and inconsistent because reporting is voluntary and handled differently across counties. We recommend that the state develop a mandatory, standardized system for reporting private supply shortages to the counties that can be compiled into a statewide dataset. Likewise, the U.S. EPA and IHS should collect data on shortages in private well and surface diversions on tribal lands.

1-6. Identify Geographic Areas at Risk of Groundwater Supply Shortages

High-quality data on household outages would enable an analysis of the causes of wells shortages or failures. Factors to consider are the rate of groundwater decline, the type of aquifer, the proximity, depth and demand of nearby wells, and nearby land uses. A more complete understanding of the causes of well outages and failures could enable predictions of where future outages are

8 See the State of California Household Water Supply Shortage Reporting System at https://mydrywatersupply.water.ca.gov/report/publicpage.

likely to occur, and allow proactive planning to find reliable water sources before shortages occur.

1-7. Identify Public Water Systems at Risk of Future Supply Problems

Can we identify characteristics of public water systems that made them more likely to experience supply impacts during the ongoing drought? In various reports and media outlets, observers have pointed to myriad factors such as system size, region, groundwater versus surface water, diversity of supplies, and ability to transfer water from other systems as indicators of drought resilience. We recommend a rigorous assessment of the common factors in systems that experienced supply impacts during the ongoing drought. This can inform further discussion about systems likely to experience problems in the future, and how to prevent shortfalls.

1-8. Identify Areas with High Potential for Consolidation or Extension of Service

The SWRCB has supported voluntary system-level consolidations, and as of 2015 has the authority in certain circumstances to mandate consolidations. High-quality data on public water systems that experienced supply problems and private supply shortages would enable the state to identify areas that could benefit the most from consolidation, either by connecting many households reliant on private wells or surface diversions into a new public water system, or by connecting them to an existing public water system that has the capacity to serve them.

SECTION 2.
DROUGHT CHARGES AND WATER AFFORDABILITY

OVERVIEW

Affordability is a central element for ensuring basic access to water—a human right recognized by the state of California—yet many Californians struggle to pay their water bills. Studies in select regions of the state have found that the cost of water for 20 to 50 percent of households with average water use exceed the U.S. Environmental Protection Agency's affordability thresholds for water and wastewater (Christian-Smith et al. 2013; United States Conference of Mayors 2014). Rising water costs are exacerbating water affordability concerns. Hanak et al. (2014) found that water bills in California's urban areas increased two to three times faster than inflation between 2000 and 2010 to cover infrastructure and other system costs. To make matters worse, Proposition 218, a ballot measure approved by California voters in 1996, prevents publicly-owned water utilities from using water-rate revenue to subsidize low-income customers (Box 2-1).

Water rates tend to rise during a drought, worsening affordability concerns. Costs may increase, for example, if a water utility must purchase more expensive drinking water supplies, install or upgrade treatment technologies for lower quality water, or pump groundwater from greater depths. For example, the East Bay Municipal Utility District drew from a more expensive emergency supply in both 2014 and 2015 (Figueroa 2014; Figueroa 2015). Administering conservation programs can also increase costs for utilities. As water use declines during the drought, water sales may become insufficient to cover the utility's operational costs, most of which are fixed. In response, water utilities may implement temporary drought surcharges, fees, and/or penalties to help cover their costs.

Raising rates or charging additional fees during a drought has important benefits, as it maintains the financial viability of water utilities, and can be an effective means of incentivizing conservation and efficiency. On April 1, 2015, following the lowest Sierra snowpack ever recorded, Governor Jerry Brown issued Executive Order B-29-15, which established a mandatory statewide water conservation target of 25 percent. It also stated:

> *"The Water Board shall direct urban water suppliers to develop rate structures and other pricing mechanisms, including but not limited to surcharges, fees, and penalties, to maximize water conservation consistent with statewide water restrictions."*

While raising per-unit costs is a key component of drought response plans for water utilities, it is nonetheless important to consider the potential equity impacts of raising water prices. Fixed

increases in water costs represent a greater proportion of the annual income for low-income households. High water bills may interfere with a family's ability to pay for other necessities, or cause them to fall behind on their water bills. Late charges can accumulate, or worse, utilities can shut off service for lack of payment. Service disconnections are three times more likely to impact the lowest income households than the average household (Cromwell 2010). Lack of water can lead to health problems, loss of custody of one's children, eviction and foreclosure, and even criminal charges (Jones and Moulton, 2016).

Low-income households tend to use less water, so designing rates, and drought charges, to keep costs low for low-volume users will benefit most low-income households (Mayer et al. 1999; Mini 2013; Rubin 2005). However, there are some complicating factors at play. First, low-income households tend to have more members, and thus larger water bills despite having relatively low per-person use (Saunders 1998). Second, other researchers have argued that low-income customers face financial challenges in upgrading their homes to be efficient, and therefore may be unable to keep their water use low (Cromwell 2010). Repairing leaks and upgrading fixtures and appliances is costly. Furthermore, many low-income customers are renters without the authority to alter their homes.

In this section, we examined available data on drought charges imposed in 2015, including information on the structure of those charges. We evaluated the impact of the structure of drought charges on meeting basic water needs. We then undertook case studies on three water utilities, estimating the monthly bill, with and without drought charges, for an average-size household using 55 gallons per capita per day (GPCD). We also examined the percentage of income that the water bill would represent for households in each of nine income brackets to understand the additional cost burden imposed by drought charges on households, some of which were already paying unaffordable rates.

While increasing costs is a key component of drought management, it is important to consider the equity impacts of raising prices.

METHODS

There are varying definitions of what constitutes affordable water. A common approach adopted by regulatory agencies has been to compare the average residential water bill to the median household income (MHI) for a given region. The California State Water Resources Control Board (SWRCB) uses average residential drinking water costs in excess of 1.5 percent of median community household income as a threshold for affordability, while the U.S. EPA uses a threshold of 2.5 percent (U.S. EPA 1998; SWRCB 2016b). This approach is referred to as "macro-affordability" because it gives a sense of average affordability for an entire region without assessing the burden of water bills for sub-groups within that region. Some have criticized the macro-affordability approach because it masks the cost of water for those that deviate from average income or water use. By contrast, micro-scale indicators of affordability disaggregate households by income group, family type (e.g., household size), or geographic sub-region (Herrington 2003). Past work in California has assessed affordability across the range of income levels within a region (United States Conference of Mayors 2014; Christian-Smith et al. 2013). Others have called for researchers to look at actual, rather than average, water bills by

income, because income is negatively correlated with water use (Osann 2016). To our knowledge there has not yet been an analysis in California that parses out affordability for different water use levels by income or household size.

For this report, we sought to keep our analysis of affordability consistent with earlier work by the SWRCB while addressing some of the criticisms of traditional affordability metrics. Given that this report focuses on California, we used the SWRCB's definition of affordable water as 1.5 percent of household income. However, rather than looking at affordability for median-income households, we divided single-family households into nine income brackets. Additionally, rather than basing water bills on average water use, we estimated water bills, with and without drought charges, for meeting basic water needs (defined below). This approach is a useful starting point to observe how additional charges imposed during drought altered costs for low-income households, and how those charges can be structured to incentivize conservation while minimizing impacts on low-income customers for basic water needs.

As with affordability, there is no single definition for the volume of water necessary to meet basic water needs. The California Human Right to Water declares that all humans have a right to water adequate for human consumption, cooking, and sanitary purposes (CA Water Code § 106.3). In their resolution adopting the Human Right to Water as a core value, the SWRCB pointed to two numbers in California laws and regulations: "The Water Efficiency Act of 2009 identifies 55 gallons per capita per day as a provisional conservation standard for 'indoor residential water use' by 2020" (Wat. Code, § 10608.20, subd. (b)(2)(A)). Similarly, a prior SWRCB emergency regulation established an exemption from a prohibition on diverting water, under specified circumstances, up to a maximum of 50 gallons per capita daily in order to meet 'minimum health and safety needs' (Cal. Code Regs., tit. 23, § 878.1, subds. (a)-(b) [operative March 30, 2015 and repealed Dec. 29, 2015]). By comparison, DeOreo et al. (2011) found that mean indoor household use in California was 63 GPCD in 2007-2009. Other studies suggest that homes equipped with high-efficiency appliances and fixtures would use between 32 GPCD (Heberger, Cooley, and Gleick 2014) and 36 GPCD (DeOreo et al. 2011). Table 2-1 reviews select standards and studies on indoor water needs.

For this report, we defined 55 GPCD as a reasonable volume for meeting basic water needs, based on the indoor water standard established by

Table 2-1.

Indoor Water Benchmarks—How Much Water Do People Need for Indoor Uses?

Gallons Per Capita Per Day (GPCD)	Description	Source
63	Mean water use in a sample of 700 homes in 10 service areas in CA from 2007-2009	DeOreo et al. (2011)
55	Provisional conservation standard for 'indoor residential water use' by 2020	CA Wat. Code, § 10608.20, subd. (b)(2)(A)
36	Mean water use in homes built with best available technologies as of 2010 for toilets, clothes washers, showers, and faucets	DeOreo et al. (2011
32	Theoretical water budget for home built using efficient appliances and fixtures and no household leaks	Heberger et al. (2014)

the California Water Efficiency Act of 2009. This is lower than the average per capita residential water use reported in DeOreo et al. (2011), but more generous than the efficient benchmarks identified by DeOreo (2011) and Heberger et al. (2014).

Structure of Drought Charges

Incomplete data are available on the number of water utilities that have instituted drought charges. We obtained state-collected data on surcharges, fees, and penalties from the SWRCB's 2015 Large Water System Electronic Annual Reports (LWS EAR) (SWRCB 2015a). The LWS EAR are annual reports from public water systems with at least 999 service connections. The 2015 database had records for 731 public water utilities (out of the 8,302 total public water systems in the state listed in the State Drinking Water Information System). All but 10 were community water systems.

In 2015, the report questionnaire asked water utilities two questions that provide some insight on drought charges: "Do you have other surcharges?" and if so, "What are the other surcharges?" The 2015 LWS EAR contained 725 answers to the question. Of these, one-third stated that they had other surcharges and used terms such as surcharges, fees, and penalties to describe them. We did a keyword search for the term "drought" in the surcharge description and found 28 water utilities that reported imposing a drought charge. We believe this is only a sample of water utilities that imposed drought charges and not a complete count. For the 28 utilities reporting drought charges, we used the water utilities' websites or contacted them via phone to determine the structure of the charges. We made up to four phone calls to a supplier and were able to obtain the relevant information for 27 of the 28 utilities.

Given that the structure of drought charges varied widely by utility and customer type, we focused on drought charges imposed on single-family households and categorized each system according to how the utility determined the minimum volume of water at which to add an additional drought charge. Our goal was to determine whether households using less than 55 GPCD would pay drought charges in each service area. The classifications we used were:

a. Threshold type (fixed or customized): Whether the threshold volume for paying a drought charge was fixed or customized according to estimated household needs. In addition, there were two types of customized thresholds:
   i. Customized by household size: The threshold was calculated based on the number of residents in the household;
   ii. Customized by prior use: The threshold was calculated as a percentage of prior use (e.g. every household was asked to reduce their pre-drought water use by a given percentage).

b. Threshold volume: The monthly threshold volume of water at which a customer paid a drought charge.

In cases where billing was bimonthly, we divided the threshold for imposing a drought surcharge by two to make it comparable with those utilities billing on a monthly basis. The results of our survey were then used as the basis for an assessment of the impact of drought charges on affordability.

Impact of Drought Charges to Affordability

Of the 27 water utilities for which data are available, we provide detailed case studies for three. We chose the two utilities with the greatest proportion of their service area in a Disadvantaged Community (DAC): Elsinore Valley Municipal Water District and the City of Glendale Water and

Power.[1] For comparative purposes, we selected at random one of the two utilities that had none of its service area in a DAC, the City of Benicia.

For each supplier, we estimated the water bill for a single-family household using 55 GPCD with and without drought charges for the main city that they serve. We used the data from the United States Census Bureau (United States Census Bureau 2010; United States Census Bureau 2014) to find mean household size and household income for the Cities of Lake Elsinore, Glendale, and Benicia, and calculated monthly indoor water needs for that household. Table 2-2 summarizes this information.

Using the University of North Carolina, Chapel Hill Water & Wastewater Residential Rates Affordability Assessment Tool (UNC—Chapel Hill Environmental Finance Center 2016), we estimated the proportion of income a mean-size single family household would pay to meet monthly indoor water needs, and compared the water bill to household income in nine income categories, ranging from below $10,000 to more than $150,000 annually. We then calculated how drought surcharges affected the percentage of income spent on water for the three lowest income brackets ($24,999 annual income and below). We reported the mean change in the cost of paying for monthly indoor water needs along with the standard deviation.

RESULTS AND DISCUSSION

Structure of Drought Charges

The 27 utilities for which we obtained data were all community water systems and were distributed across 11 counties. They were broadly dispersed geographically, but none were north of Sacramento County. One-third offered lifeline rates or low-income subsidies. Detailed information on drought charges for the utilities surveyed is provided in Appendix 2A.

1 DACs are areas with a median household income less than 80 percent of statewide median household income.

Table 2-2.

Characteristics of Cities Profiled in Affordability Case Studies

	Lake Elsinore	Glendale	Benicia
Population[1]	51,821	191,719	27,450
Number of Households[2]	14,788	72,269	10,686
Median Household Income ($)[3]	63,303	52,451	89,094
Mean Household Size[2]	3.48	2.63	2.52
Basic Household Monthly Water Use (in gallons)[4]	5,800	4,400	4,200
Water Supplier	Elsinore Valley	Glendale City	City of Benicia
Public Water System ID	CA3310012	CA1910043	CA4810001

1. Data from 2010-2014 ACS: 5-year average.
2. Data from 2010 Census: Households and Families.
3. Data from 2014 ACS.
4. Calculated as 55 GPCD × mean household size.

Among the 27 utilities surveyed, we identified four categories of drought charge structures. Table 2-3 summarizes the types of drought charges found in our sample. Those with low, fixed thresholds raised costs for everyone, regardless of the volume of water use. The exact threshold was set at either 0 gallons per month or 750 gallons a month (1 CCF), presumably because 750 gallons is the minimum sensitivity of the water meter. In this case, all customers paid an additional drought charge. Those with high, fixed thresholds raised costs for those households using more than a given volume of water. The minimum volume ranged from about 6,000 to 9,000 gallons (8-12 CCF) per month, depending on the utility. In this case, households with large total water use—such as households with many members—experienced a rate increase. The third category of drought charges had customized thresholds based on prior use—that is, water prices went up unless the household reduced their water use by a given percentage. In this case, households that cut water use sufficiently avoided drought charges. The fourth category has a customized threshold based on household size, raising costs for water use only if per-person household use was high. This is also referred to as a budget-based approach for drought charges.

Understanding how the various drought charge structures will affect water bills for low-income customers is complex because it depends on multiple factors. Figure 2-1 demonstrates the interaction between drought charges, household size, and household income across three types of drought charge structures. We held per-capita water use constant to show how the various drought charge structures would raise costs by different amounts for households using the same amount of water per person. The first scenario shows the cost of water with an additional drought charge of $2.02 on every 750 gallons (1 CCF) (Figures 2-1a&b). The second scenario (Figures 2-1c&d) shows the cost of water if drought charges were levied only on households using at least 7,500 gallons (10 CCF) a month. Figures 2-1e&f show the cost of water if drought charges were levied only on households using more than 55 gallons per household member.

Fixed-threshold drought charges aggravated affordability concerns for low-income customers, and the effect is more pronounced for large households. Only utilities that customized the minimum threshold for levying a drought charge by household size avoid raising rates for large, efficient households with high total usage.

Table 2-3.

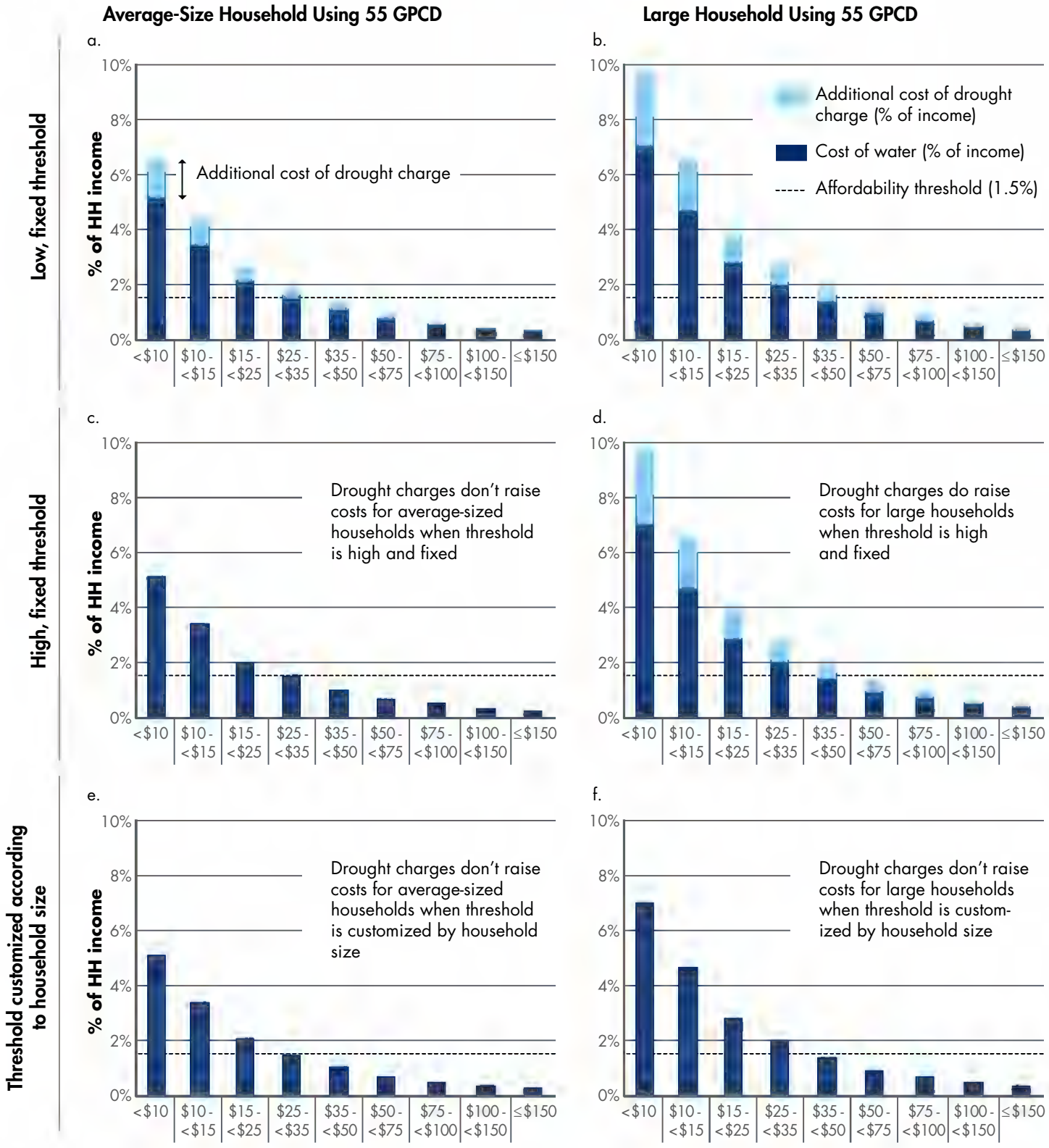
Four Types of Drought Charge Structures

Threshold Type	Volume Threshold	Change to cost of basic water needs	Num. of Utilities (%)
Low fixed threshold	750 gal (1 CCF) or less per month	Increased	15 (56%)
High fixed threshold	5,980-8,980 gal (8-12 CCF) per month	Increased for large households	5 (19%)
Customized threshold based on prior use	70% of household's Summer 2012 or Winter 2013 monthly use	Increased if the household already had relatively low baseline of use	1 (4%)
Customized threshold based on household size	Threshold increased by at least 1,680 gal (2.24 CCF) per month for each additional person	No change	6 (22%)

Notes: Abbreviations: gal = gallons, CCF = centum cubic feet. "Basic water needs" estimated as 55 GPCD.

Figure 2-1.

Cost of Basic Water Use Under Three Drought Charges Structures Across Income Levels and Household Sizes



Notes: All households assumed to use 55 GPCD. Household income in $1,000s. Left column depicts costs for average-size households, with 2.63 members. Right column depicts costs for large (top 10 percent) of households, with 5 members. Low, fixed threshold = 750 gal/household/month. High, fixed threshold = 7,500 gal/household/month. Data parameters were based on City of Glendale water rates and population census data.

Impact of Drought Charges on Affordability

We conducted three in-depth case studies on drought charge in Elsinore Valley Mutual Water District in Riverside Count, the City of Glendale Water and Power in Los Angeles County, and the City of Benicia in Solano County. All three utilities imposed fixed-threshold drought charges on households using 0 to 1 CCF per month, increasing costs for homes using even relatively small amounts of water. The effect of drought charges on water affordability, however, depended on the price increase and household income level.

For all three utilities, average-sized households earning the median income paid less than 1.5 percent of their annual income for their basic water needs, with or without drought charges. With drought charges, they paid $85 more annually for their basic water needs, or 0.15 percent (less than 1/600th) of their annual income.

If, rather than focus on the median income, we use finer-resolution data on income, the story is more complex. Here, the proportion of income spent on water, and the impact of drought charges on water affordability, was much higher for low-income households (Figure 2-2). Without drought charges, single-family households earning less than $25,000 annually, which represented 11-26 percent of households in the three service areas, paid an average of 1.8 percent (±0.31) of their income for basic water needs. With drought charges, however, households pay 2.1 percent (±0.49) of their income on basic water needs. Drought charges had an even greater impact on the lowest-income households. For example, in the City of Glendale, an average-sized household earning $10,000 a year and using 55 GPCD would pay an additional 1.4 percent of their annual income on drought charges alone, increasing the cost of basic water needs from 5.1 to 6.5 percent of their income.

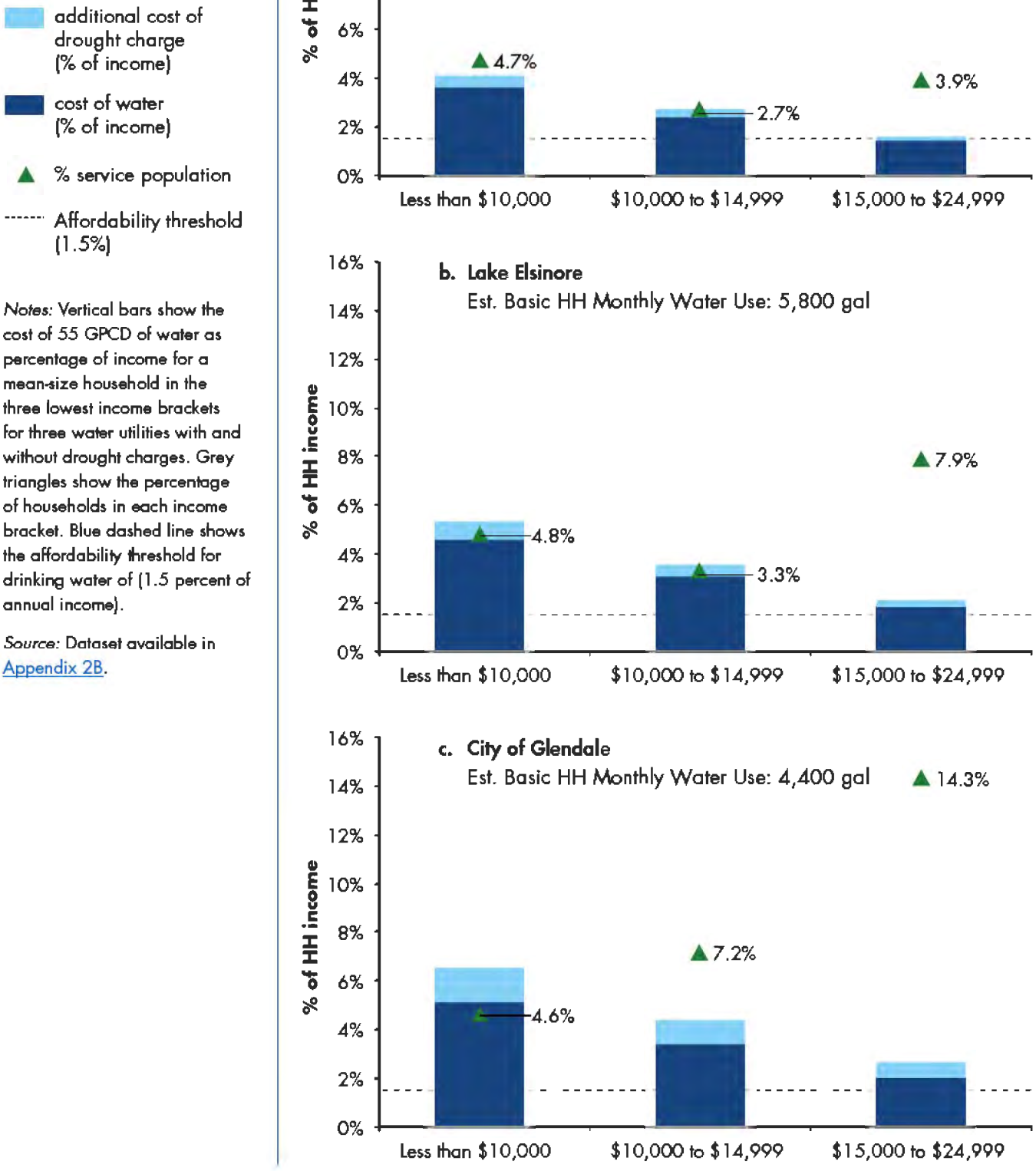
Of the three utilities, only the City of Benicia - the utility with the fewest low-income customers—offered financial assistance to low-income seniors in 2015; that program was expanded to provide a discount for all low-income customers in November 2016 (City of Benicia 2016).

Overall, drought charges raised the proportion of income that customers spent on water by a small amount compared to the baseline cost of water. However, the surcharges have a much larger impact on the lowest-income households, underscoring equity concerns. To better understand affordability, water utilities should evaluate how the rate structure affects the cost of meeting basic water needs for low-income households and the potential for drought charges to exacerbate affordability concerns.

An unfortunate limitation of the dataset is that it only represented large water utilities. Work by the California Urban Water Association (CUWA) confirms that affordability is a serious problem in urban areas, even those that appear relatively affluent based on median household income levels. In an assessment of water affordability in 2014-2015 for 10 urban water utilities in California, CUWA found that nearly 21 percent of households earned less than $25,000 annually and spent an average of 4.5 percent of their income on water (CUWA 2016). Information about affordability in rural areas of California is limited. However, Christian-Smith et al. (2013) compared affordability in the urban Sacramento metropolitan area and rural Tulare Lake Basin and found that, while water was unaffordable for a large number of low-income customers in both regions, the problem was more widespread in the rural region. Additionally, some rural customers must also purchase bottled water due to water contamination concerns, further increasing water costs.

Figure 2-2.

Cost of Basic Water Use for Low-Income Households, With and Without Drought Charges, in Three Cities.



Notes: Vertical bars show the cost of 55 GPCD of water as percentage of income for a mean-size household in the three lowest income brackets for three water utilities with and without drought charges. Grey triangles show the percentage of households in each income bracket. Blue dashed line shows the affordability threshold for drinking water of (1.5 percent of annual income).

Source: Dataset available in Appendix 2B.

Box 2-1.

Proposition 218, Tiered Water Rates, and Customer Assistance Programs

Proposition 218, adopted as a California constitutional amendment in 1996, prohibits public water utilities from charging their customers more than the cost of providing water service. In order to implement tiers, water utilities must demonstrate that the price of water at each tier is justified by the cost of providing water service to that tier. This requirement prevents water utilities from using water-rate revenue to subsidize low income customers by offering them lower rates or providing financial assistance programs. Despite this limitation, a survey of customer assistance programs nationwide found 55 such programs in California (U.S. EPA 2016). Some were investor-owned utilities regulated by the California Public Utilities Commission, and as such are not subject to Proposition 218. Others have used alternative sources of funding such as state or federal grants, private charities, and property leases (Cooley et al. 2016).

An assumption of this analysis is that customers can meet their basic water needs for consumption, cooking, and sanitation with the 55 GPCD identified as a provisional conservation standard in California statute. While several studies indicate that reducing leaks and using modern fixtures and appliances can reduce water use well below 55 GPCD, low-income customers may not be able to afford these upgrades, may lack the ready cash to take advantage of rebate programs, and, if they rent, may not have the authority to make alterations to their home. As a result, imposing drought charges on inefficient water users should go hand-in-hand with programs to assist low-income customers to reduce their water use.

CONCLUSIONS AND RECOMMENDATIONS

Drought fees, penalties, and surcharges are considered an important strategy for coping with drought—both by encouraging customers to save water, and ensuring financial stability for water utilities. They can, however, raise water affordability concerns for low-income households that must be addressed. Prior studies have demonstrated that low-income customers tend to be relatively low water users. As a result, rate structures and drought charges that keep costs lower for basic water use tend to keep costs low for the majority of low-income households. There are three promising strategies for minimizing the impacts of drought charges on water affordability: (1) impose drought surcharges on water usage above some threshold, e.g., 55 GPCD, and adjust for household size; (2) target efficiency programs to low-income households; and (3) offer financial assistance programs to offset costs for low-income households. These strategies, however, can be challenging for utilities to administer, particularly small systems that have limited technical, managerial, and financial capacity. With awareness about the equity impacts of drought charges, and technical assistance for those that need it, utilities should be able to develop drought charges that do not make basic water needs unaffordable for their low-income customers.

RECOMMENDATIONS TO IMPROVE DROUGHT COST EQUITY

Mitigating Impacts of Drought Charges on Water Affordability for Low-Income Customers

2-1. Keep per-unit water costs low for low water users during droughts

An unintended consequence of drought charges can be to increase the cost of meeting basic indoor water needs for low-income customers. To minimize the cost burden of drought charges on efficient, low-income households, water utilities should adopt drought charges that keep per-unit costs down for low water users. Specifically, we recommend that public water systems:

- Waive drought charges on water consumed at or below the amount necessary to meet basic water needs.
- Calculate each household's threshold for incurring additional drought charges based on household size to avoid unfairly penalizing large households (commonly referred to as variances).

2-2. Target conservation and efficiency programs to low-income customers

Water utilities should offer conservation and efficiency programs that enable low-income customers to keep their water use low enough to take advantage of cost structures that charge less per unit for low water users. These programs should include renters and residents of multi-unit homes who do not directly pay a water bill, as the cost of water is generally passed on to them through their rent or other fees. We recommend that utilities:

- Use strategies to reduce up-front costs for home efficiency upgrades to encourage participation by low-income households. Low-income customers are less likely to participate in rebate programs. They are more likely to take advantage of point-of-sale coupons on efficient fixtures and appliances, and programs to distribute or directly install efficient fixtures free-of-charge.
- Make informational materials available in multiple languages, do in-person outreach as well as send written materials, and reach out to customers who do not receive bills (predominantly renters and residents of multi-unit homes).
- Target conservation and efficiency programs to tenants by distributing free fixtures that are simple to install, such as low-flow showerheads and faucet aerators.
- Target incentive-based conservation and efficiency programs to landlords by offering incentives for building audits, rebates, or tax deductions for efficiency upgrades and leak repairs.

2-3 Develop low-income rate assistance programs within current legal constraints, and reform Proposition 218 to allow greater latitude in funding such programs

The best option for minimizing cost increases during droughts for efficient, low-income households is to design drought charges in a fashion that minimizes cost increases for low water users. If that is not possible, then a rate assistance program targeted at low-income customers can counteract price increases for households in need. Low-income rate assistance programs generally do not enroll all the qualified customers, so ideally they should be used in addition to, not instead of, equitably designed rate and drought charge structures. Under Proposition 218, public utilities cannot use ratepayer fees to fund low-income rate assistance programs. Water systems can use other sources of revenue such as leasing land or donations.

2-4. Address structural problems that prevent water systems from enacting equitable drought charge structures

Underlying issues prevent water utilities from addressing the greater cost burden placed on low-income customers by their water bills, both with and without drought charges. Our first recommendation, to keep per-unit costs low for low water users during droughts, requires that water systems have adequate technical, managerial and financial capacity. Stakeholders in government, water utilities and non-governmental organizations should collaborate to develop this capacity by:

- Installing and maintaining water meters and sub-meters for all customers of public water systems. Most low-income customers are low water users, but their bills do not reflect their actual water use if they live in areas without meters for single-family homes or sub-meters for units in multifamily buildings.
- Supporting water systems in developing equitable drought charge structures, and adding information about equitable approaches to drought charges to existing state programs that provide technical education for small water systems. Small water utilities need greater technical capacity to develop more complex, equitable drought charges such as tiers, variances for large households, and bill discounts for low-income customers.

Further Study and Data Collection on Drought and Affordability

2-5. Collect and analyze data on how to target hard-to-reach customers such as renters and residents of multi-unit buildings.

Designing financial assistance and efficiency programs to effectively serve renters and residents of multi-unit buildings is challenging. Better understanding how existing programs have managed to target these hard-to-reach customers could inform best practices going forward.

2-6. Determine if low-income households have less efficient fixtures and appliances, or more leaks, and therefore use more water to meet their basic needs.

The energy sector has provided ample evidence that low-income customers are more cost-burdened, mainly because they use more inefficient household appliances. This research has galvanized efforts to improve energy efficiency in low-income homes because it benefits the customer and the environment. Similar research is needed in the water sector.

2-7. The state should collect complete information on drought surcharges, fees, and penalties.

Present data collection is limited in the type of water utilities reporting data, and, given the improbably small number that reported drought charges in 2015, it seems nearly certain that even among utilities that submit an LWS EAR, most are not reporting their drought charges.

2-8. Publicly release a complete, accurate map of all public water systems in the state

A complete map of water system boundaries would enable non-government entities to assess the cost of water in relation to local income levels.

SECTION 3.
DROUGHT IMPACTS ON SALMON FISHERIES

OVERVIEW

Reports of drought impacts on California's fishing communities have been relatively limited. Many still frame water problems in California as "fish versus farms" or "humans versus ecosystems" (for example, Pollak 2016; Abcarian 2016). However, fish are essential to the well-being of communities that rely on them for food and income. We highlight salmon in this analysis due to its economic and cultural importance in many California riparian and coastal communities. A particular focus is given to the fall-run and Klamath spring-run Chinook salmon, which are the only remaining taxa that can be managed as a fishery. To examine the equity issues tied to drought impacts on salmon, we analyzed trends in the performance of commercial and tribal fisheries over the past several decades.

Ultimately, the current drought is not the only cause of the decline of California's salmon fishery; after all, salmon have coped with periodic droughts throughout their evolutionary history. However, salmon populations likely face greater difficulty surviving and rebounding from droughts given the barriers to migration to colder stretches of the river, loss of habitat, competition from non-native species, and water quality degradation (for example, Zeug et al. 2011; Jones and Nguyen 2010). In 2008, the United States District Court for the Eastern District of California issued a ruling that California water systems place wild salmon "unquestionably in jeopardy" (Jones and Nguyen 2010). Improving conditions for California's salmon, and the well-being of the communities dependent on them, will require improving management responses during short-term drought emergencies while addressing the underlying problems of habitat alteration and degradation, water allocation for the environment, and inequitable fishery access.

Salmon Natural History and Status in California

Many California rivers are breeding grounds for salmon. Chinook salmon (commonly known as King salmon) is the most abundant species in California and off its coast, but Coho, Pink, and Chum salmon are also found within the state. Chinook salmon are further divided into populations referred to as runs that migrate and breed during different seasons—namely fall, late-fall, winter, and spring, reflecting the long history of adaptation to California's seasonal flows (Hanak et al. 2011).

Salmon are an anadromous fish that spend part of their life in freshwater and the other part in the ocean. When salmon grow into small fish, they

undergo a physical change, or "smolting," to survive in saltier water as they move downstream to estuaries, where ocean water blends with freshwater and food is abundant. Those born in California rivers typically migrate to the ocean in their first few months of life, while some linger behind until they are over a year old (Fry 1979). In the ocean, salmon may stay relatively close to the mouth of the river in which they were born or swim long distances to find another feeding ground. After two to five years at sea, mature salmon return to their native river to spawn and die, with most returning at age three.

Interacting environmental and human-related factors influence annual fluctuations in salmon abundance. For example, the survival and growth of salmon can be greatly affected by changes in freshwater flows, which in many cases are regulated by upstream dams (e.g., Shasta Dam on the Sacramento River). These flows, in turn, affect water temperature, availability of floodplain habitat, water turbidity, interactions with predators and competitors, and the ability of mature fish to migrate to spawning grounds. Sufficient flows of water during migration periods are crucial for both outmigration of juvenile salmon downstream and migration of mature salmon to spawn upstream. Temperature is a key factor affecting survival of salmon at every life stage. The optimal temperature for eggs and fry is about 48 to 55 degrees F. Smolts can thrive in warmer waters, optimally about 50 to 66 degrees F (McCullough 1999, cited in Moyle, Israel, and Purdy 2008, 127-128). Other water quality parameters, including dissolved oxygen, pH (Carter 2008), and turbidity (Bash, Berman, and Bolton 2001), are also important determinants of salmon growth and survival.

Historically, salmon are remarkably abundant and widely distributed in California, from the Central Valley up to the northern region and as far inland as the Sierra Nevada and Eastern Cascades (Myers et al. 1998). The Sacramento and San Joaquin river systems are California's largest salmon-producing rivers on the West Coast, followed by the Klamath River (Fry 1979; Rankel 1982, cited in Hardy, Addley, and Saraeva 2006). As recently as the 1930s, California's residents observed spawning salmon so thick that they looked like a sheet of silver glass as far as the eye could see (Levene et al. 1976, cited in NMFS 2012).

Dams now block Central Valley Chinook salmon and steelhead from over 90% of their spawning habitat.

However, the salmon population has declined drastically over the past century, and many salmon taxa are heading toward extinction (Katz et al. 2013). Dams now block Central Valley Chinook salmon and steelhead from over 90% of their spawning habitat (NOAA 2014). For example, Coho salmon in certain reaches of the river and winter-run Chinook salmon are currently listed as endangered by the state and federal government (CDFW 2016).[1] Currently, the only salmon runs that can be harvested for subsistence, sale, or recreational purposes are the fall-run and Klamath-Trinity River spring-run Chinook salmon.[2]

A complex set of factors contributed to the widespread decline in California's salmon population. These include overfishing in the late 1800s and early 1900s (Clark 1929); extensive

1 Threatened and endangered species status may be specific to certain areas. For example, Coho salmon is listed as threatened from Punta Gorda to the northern border of California, but it is listed as endangered from south of Punta Gorda to the U.S./Mexico border. Similarly, spring run Chinook salmon is only listed as threatened for the Sacramento River drainage.

2 Commercial harvest of Coho salmon has been prohibited since 1992.

hydroelectric and irrigation development in the mid-20th century (Lichatowich 1999; Hanak et al. 2011); habitat alteration and degradation (Figure 3-1); competition for freshwater; and invasive fish species that prey on young salmon and eggs or compete with salmon for food (Moyle, Katz, and Quiñones 2011). Additionally, while salmon hatcheries—facilities that artificially breed and rear salmon—play an important role in salmon recovery and help support sustainable fisheries, there remain concerns about the hatchery's long-term impacts on wild salmon stocks from interbreeding and reductions in the genetic diversity of wild salmon (Buhle et al. 2009;

Figure 3-1.

Habitat Loss and Current Extent of Salmon-Accessible Waterways



Source: Hanak et al. (2011).



Source: ImagineGolf

Chilcote, Goodson, and Falcy 2011; Araki, Cooper, and Blouin 2009). More recently, a dramatic decline in the Sacramento River fall Chinook salmon population in 2008 and 2009 was likely due to ocean conditions (e.g., temperature and nutrients affecting food availability), an inaccurate forecast of salmon escapement, ongoing degradation of freshwater and estuarine habitats, and heavy reliance on hatchery production (Lindley et al. 2009).

RESULTS AND DISCUSSION

Commercial Salmon Fishery Trends Over Time

DECLINE OF COMMERCIAL SALMON FISHERY

California's commercial salmon fishing communities were initially established around the mid-1800s. During the gold rush, settlers recognized the rich resources of the area and salmon fishing took off (Pomeroy, Thompson, and Stevens 2010; Smith and Kato 1977). San Francisco Bay and the Sacramento-San Joaquin Delta region were the first major fishery conducted by Euro-American immigrants in the state (Yoshiyama, Fisher, and Moyle 1998). Annual catches of the early Sacramento-San Joaquin in-river fishery were 4 -10 million pounds. An early estimate of the Central Valley Chinook salmon stock was 1-2 million spawning fish annually. The depletion of runs, however, led to legislation to restrict access to the fishery in 1980 (CDFG 2001). Presently, commercial salmon fishing in California is undertaken by small troll boats, usually with one or two people. As income from salmon is typically not enough for an entire year for most fishermen, they also harvest Dungeness crab.

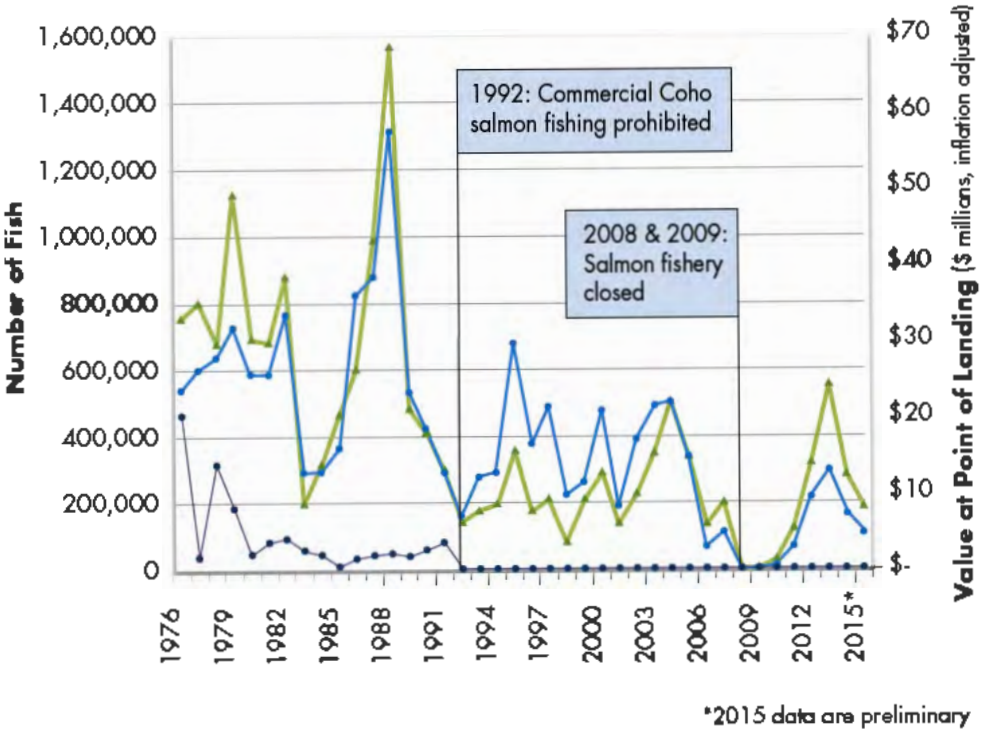
Data from the PFMC show that the number of salmon caught and landed in California has declined over the last 40 years. Between 1976 and 1980, fishermen caught an average of 830,000 fish annually. The harvest declined by 80 percent to 170,000 per year between 2011 and 2015 (Figure 3-2), a result of the fall in salmon abundance as well as regulations that limited salmon fishing to more sustainable levels.

Figure 3-2 also illustrates how the value of salmon catch to fishermen, referred to as exvessel value, has trended gradually downward over the past 30 years. For 2011 to 2015, the exvessel value averaged $13 million per year—a 64 percent decrease from the 1976 to 1980 average of $36 million per year. It should be noted that the rise in salmon prices in recent years to an average of $6.15 per pound has helped mitigate the impacts of decreased salmon catch.[3]

3 We derived the average price from the PFMC's Review of Ocean Salmon Fisheries data. All values are in 2015 dollars.

Figure 3-2.

Number and Dollar Value of Commercially Harvested Chinook and Coho Salmon.



Notes: Coho salmon is now listed as an endangered species. Commercial fishing of Coho salmon has been prohibited since 1992. The value of salmon at the point to landing is termed exvessel value. It is expressed in 2015 dollars (inflation adjusted).

Source: PFMC (2016b).

Some of the decline in harvest was related to the number of commercial fishing days and areas opened to salmon fishing. Historically, California's (unregulated) commercial salmon season ran from April through October, but the fall in salmon abundance prompted the California Department of Fish and Wildlife (CDFW) to limit the number of commercial salmon fishing days. The CDFW also limits the extent of fishing grounds and shortens the commercial fishing season in certain years to avoid unintended by-catch of listed threatened and endangered species. In 2016, the Pacific Fishery Management Council noted that "long running drought conditions, coupled with suboptimal ocean conditions, have raised serious concerns for Sacramento River winter Chinook salmon." As a result, fishing seasons south of Point Arena, California, were shortened to minimize interactions with winter Chinook. Figure 3-3 highlights the curtailment of fishing seasons during recent drought years (2014-2016), with the greatest cut of 23% in 2016 compared to the 2001-2005 average.

OTHER SIGNS OF THE FISHERY DECLINE

Due to the pressures of a declining harvest and the rising cost of entry into the fishery and fishing-related inputs (e.g., ice and fuel), many fishermen have retired their permits.[4] As a result, the size of commercial salmon fleet has decreased dramatically over time (Dave Bitts, salmon fisherman, personal communication, Oct. 19, 2016).[5] Only one-sixth of the boats with salmon permits remained in 2014 compared to 1982, two years after the permitting program started (Figure 3-4). Despite a clear downward trend in total harvest, annual gross income per boat has fluctuated dramatically with no clear trend, perhaps a result of various counterbalancing

4 The entry cost is higher than before because an aspiring salmon fisherman must find a retiring fisherman to purchase the permit from.

5 The restricted access program, which came into effect in 1980, limits the number of fishing permits available. Permits may be transferable between fishermen or vessels. Under certain conditions, permits may be transferred from retired to new vessels (CDFG 2001).

Figure 3-3.

Length of Salmon Fishing Season.

Sources: 2001 – 2005, 2014, and 2015 data from PFMC (2014) and PFMC (2016b). Table C-1. 2016 data from https://www.wildlife.ca.gov/Fishing/Ocean/Regulations/Salmon.



effects: declining salmon stock, price changes, and less competition as the salmon fleet became smaller (Figure 3-5). Gross income from salmon bottomed out in 2008 and 2009 when the fishery was closed for two seasons, but it reached a record high of $35,000 per boat in 2013.[6] High income variability affects job security and reflects the fact that it is becoming more difficult to make a living as a salmon fisherman. In Morro Bay, for example, the salmon fishing community has gotten much smaller, and the average age of fishermen has been increasing as less young people enter the fishery (Lori French, salmon fisherman, personal communication, Oct. 18, 2016). We interviewed fishermen about their personal experiences to get their perspective on the challenges facing them (Box 3-1).

The salmon fishery not only provides income for those directly participating in the industry, but also supports the local economy by driving demand for goods and services in the community. During the current drought year (2012-2015), California's total (both direct and indirect) inflation-adjusted personal income from commercial salmon fishing was $27 million (PFMC 2016b).[7] The indirect economic impacts from the salmon fishery depend on the importance of the fishery to the community's economic base and whether other economic opportunities exist during a poor salmon harvest eason. Due to data limitation, we are not able to show any local or statewide trends.[8] However, it is expected that impacts from the decline in the salmon fishery could be quite dramatic for communities that heavily rely on salmon harvest.

6 The average gross income between 2006 and 2015 was $17,000 per boat per year, not including years 2008 and 2009. The fishery closure was a result of a drastic salmon population decline due to unfavorable ocean temperature and food availability conditions, not the drought (Jones and Nguyen 2010).

7 Actual impacts will vary by community and its economic base. Direct impacts consist of personal income earned by those participating directly in the fishery, including vessel owners, crew members, and processing workers. Indirect impacts are related to services provided for the fishery, processing and recreational operations, wholesale, retail and restaurant sales of locally caught fish, fishing, harbor tourism, and income re-spent in the community (e.g., income of grocery store owners and health professionals).

8 The change in PFMC's methodology limits comparable data to the last six years. However, we cannot compare data from 2012-2015 (drought years) and 2010 or 2011 as the fishery was recovering from the closure during those years.

Figure 3-4.

Boats with Salmon Permits and Salmon Boats Landed 1960-2015.



Notes: The Restricted Access Program, which requires all salmon fishermen to have a salmon fishing permit, started in 1980.

Source: PFMC (2016b).

Figure 3-5.

Gross Salmon Income 1960-2015.



Notes: Data only include the value per boat of Coho salmon up to 1991 since Coho salmon harvest has been prohibited in subsequent years. Average income from salmon per boat is based on total exvessel value (i.e., value of salmon at the point to landing) and the number of active fishing boats. Values are expressed in 2015 dollars (inflation adjusted).

Source: PFMC (2016b).

Box 3-1. The Salmon Fishery Through the Lens of Fishing Communities

We interviewed tribal members and four fishermen to gain better insights into broader impacts of the decline in salmon harvests. Summaries of their responses are provided below.

Brittani Orona (Hoopa Valley Tribe, Northern California)

Our whole culture revolves around fish and the watershed. My grandfather likes to say that we are 'River People.' Salmon feed us physically and spiritually. We rely on them for our World Renewal Ceremony by asking spiritual beings to help keep the world in balance and maintain healthy river and fish populations. There has definitely been a change in the rivers since I was young (about 20 years ago). Water quality has gotten worse and flows have reduced. The decline of salmon comes with economic depression, but more importantly it affects our spiritual health and how we live as Hupa people.

Box 3-1 *(Continued).*

The Salmon Fishery Through the Lens of Fishing Communities

Chook-Chook Hillman (Karuk Tribe, Northern California)
Unlike the Yurok and Hoopa Valley tribes, Karuk people do not have recognized tribal salmon fishing rights, and the only authorized fishing location is at Ishi Pishi Falls. Sport fishing licenses are available for sale, but it is a burden for tribal people because they cost money and fishing, to us, is not for sports. We have malnutrition and physical and mental health issues because we cannot be tribal people—being able to continue our traditional way of life.

Dave Bitts (Fisherman from Eureka)
I started fishing about 40 years ago and half of my income on average is from salmon and the other half is from Dungeness crab. I had an epiphany a few years back about the real value of the salmon fishery. We have been consulted when a natural gas industry was going to come in and it could impact the fishery. Having fishermen around gives Humboldt people a sense of place since they can buy fish locally and interact directly with us. It's our identity and we'd be culturally impoverished without the salmon fishery.

Larry Collins (Fisherman from San Francisco)
My wife and I first started fishing in 1983/84 and we were able to raise kids and pay off our house from salmon fishing. We consider fish, crabs, and other seafood as public trust resources and more attention should be given to protecting the fish's habitats. The fishery needs three things to succeed: (1) abundance of fish; (2) market; and (3) infrastructure to move fish to land, such as port, services for fuel and ice. In a bad harvest year, fishermen must live off their savings, and some people might decide to retire altogether.

Mike Ricketts (Fisherman from Monterey)
I have been fishing commercially for 40 years. Fishermen typically have one or two fisheries that they depend on, for example salmon and Dungeness crab. When we have a good salmon season, we fish less crab, and vice versa. Fishermen with a salmon fishing permit might not choose to fish salmon in a bad year because the overhead can be about $10,000 per year to start a boat up and cover the fuel, insurance, and other costs.

Lori French (Fisherman from Morro Bay)
The fishing community has gotten much smaller in Morro Bay and it's also graying out. Fishermen are getting older and the fishery is not attractive enough for younger people to enter. Salmon fishing is so uncertain that younger people don't want to risk it. For us, we are fishermen and we do not really have a backup plan in terms of what to do besides fishing. Typically, our main source of income is 80 percent Dungeness crab and 20 percent salmon, but it was probably 60-70 percent crab and 30-40 percent salmon some 30 years ago.

Impacts of the Drought on Salmon Fishery

Drought is a natural occurrence, and salmon populations in California have survived periods of water scarcity throughout their evolutionary history. The full effects of the current drought are yet to be determined; as of this writing, salmon that hatched and migrated to the ocean during the early part of the drought are just starting to return to spawning grounds. It is likely that alterations to their habitats, migration barriers, and competing uses of water, as mentioned in the previous section, have reduced their resilience to survive extended dry periods.[9] Lower streamflows and higher water temperatures associated with the drought have reduced the amount of cold water available for salmon during key life stages, such as for hatching, migration to the sea, and spawning (Shukla et al. 2015; Seager et al. 2014). Indeed, far fewer Sacramento Chinook salmon reached the ocean during the 2007-2009 drought years than the much wetter 2011 (Michel et al. 2015). Drought conditions, coupled with suboptimal ocean conditions, have also led to very low survival of the juvenile endangered winter-run Chinook salmon in 2014 and 2015 (PFMC 2016a; USBR 2015). These negative impacts likely hold true for the commercially fished salmon runs as well.

Biological stressors further contributed to salmon mortality during droughts. A review of the effects of temperature on salmonids shows that the parasites Ceratomyxa shasta and Ichthyophthirius multifiliis (commonly known as "Ich") are more virulent in warmer water (Carter 2005). The Klamath River system had an Ich outbreak in 2014 (Orcutt 2015), and up to 91 percent of Coho salmon juveniles were infected in 2014 and 2015 (Houston 2016a). Additionally, drought affects the overall health of the ecosystem and the food web that salmon rely on. Food is typically less abundant during drought, and salmon face more competition from invasive fish species that thrive in warm, altered habitats such as reservoirs and ponds (Moyle et al. 2013). The threats to salmon also increase as their predators, such as striped bass, can tolerate warmer water (CDFW 2010). Reduced flows also lead to higher risk of predation for juvenile salmon; less water lowers the turbidity and limits their camouflage ability. There is also less physical space for predator and prey to occupy as deep pools of cool water become shallower and warmer, and riffle stretches of river—important for the construction of salmon spawning nest and incubation—dry up (Tim Sloane, Executive Director, Pacific Coast Federation of Fishermen's Associations, personal communication, Oct. 12, 2016).

Water management decisions during the drought are critical for ensuring sufficient flows and temperature requirements for salmon; however, they have been the subject of debate and litigation following the low survival rate of juvenile winter-run Chinook salmon and mass die-offs of juvenile Coho salmon in 2014 and 2015.[10] For example, in 2015 the National Resources Defense Council and other environmental organizations took legal action against the United States Bureau of Reclamation (USBR), other federal agencies, and Central Valley water districts for not devoting enough water to the endangered winter-run Chinook salmon (Kasler 2015). In 2016, the Hoopa Valley Tribe and a group led by the Yurok Tribe also filed a separate lawsuit against the USBR and

9 See Bisson, Dunham, and Reeves (2009) for more details about freshwater ecosystems and resilience of Pacific salmon.

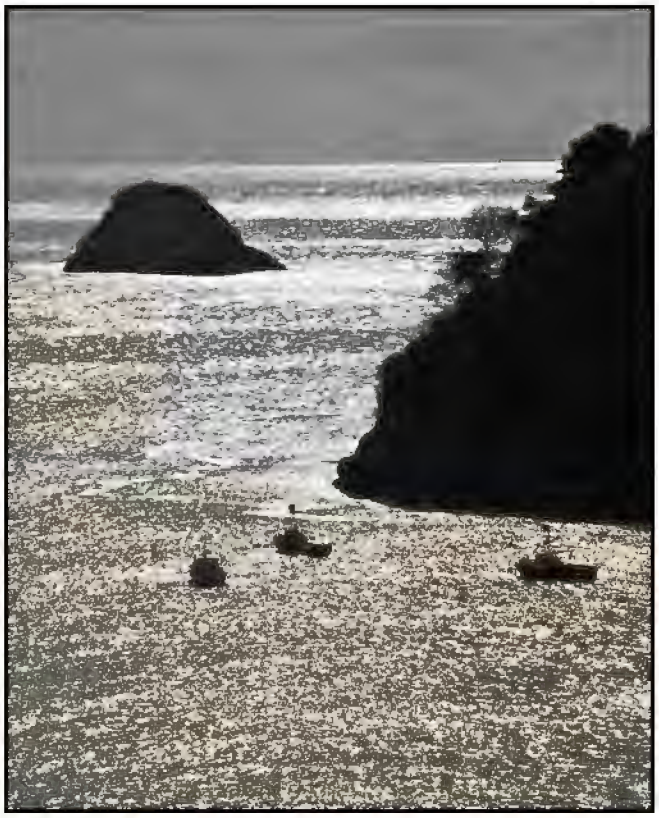
10 Documents regarding Sacramento River Temperature Management can be found on the SWRCB's website. NMFS biological opinions and actions, as well as the USBR's long-term plan for protecting salmon in the Lower Klamath River (and associated comment letters), can be found here and here, respectively.

the National Marine Fisheries Service (NMFS) for contributing to Ich infections and mortality of the endangered Coho salmon (The Eureka Times-Standard 2016; Houston 2016b).

Finally, climate change will likely compound existing problems and accelerate the decline in salmon population. Seasonal duration of lethally-warm stream temperatures at watershed outlets is expected to lengthen and the average annual stream temperature is projected to exceed 75 degrees F earlier in the spring (Null et al. 2013). Moyle et al. (2013) concluded that climate change will increase the vulnerability of spring-run Chinook salmon and Coho salmon in California, and ultimately lead to their total extinction by 2100 if conservation measures are not pursued.

FISHERMEN'S VIEWS OF DROUGHT IMPACTS

Responses from our interviews with salmon fishermen, conducted in October 2016, further revealed some devastating effects of the current drought. Dave Bitts, a fisherman of 40 years from Eureka, recounted that for eight of the 10 years between 1995 and 2004, fishermen could easily catch 50 fish per day. It is now very challenging to catch 10 fish a day and many people have to live off their savings or take on a different job. Lori French, who fishes with her husband in Morro Bay, revealed that during this drought, for the first time in her husband's life, he could not catch any fish in two consecutive days. Mike Ricketts, a fisherman from Monterey, similarly mentioned that conditions have been particularly devastating in the last couple of years. While many salmon fishermen also engage in the Dungeness crab fishery, the postponement and shortening of the crabbing season in late 2015 created a significant economic burden. According to Mike Ricketts, the decline in salmon harvest has also affected infrastructure that supports the fishery, such as fuel docks, ice stores, and markets, making each



Source: CampPhoto

drought recovery more difficult than the one before. To address these impacts, Larry Collins, a fisherman from San Francisco, highlighted that it is important for the public to think of fish, crabs, and other seafood as public trust resources and give more attention to protecting fish's habitats.

Tribal Salmon Harvest

TRENDS OF DECLINE EXPERIENCED BY TRIBES

Salmon are an integral part of life for Native Americans in California and the Pacific Northwest (Shilling et al. 2014; Lichatowich 1999; Yoshiyama 1999; Gunther 1926). For centuries, Native Americans have relied on salmon not only as a source of sustenance, but also for its spiritual and cultural significance, as can be seen in the First Salmon Ceremony honoring the relationship between salmon and people (Gunther 1926). Presently, the Yurok and Hoopa Valley Tribes share a federally-reserved right to 50 percent of the

Klamath River Chinook salmon harvest surplus (Pierce 1998).[11]

Subsistence fishing has always been a major part of the tribes' livelihoods, but the current salmon consumption level appears to be much lower than it was historically. Shilling et al. (2014) conducted a survey of 12 tribes throughout California to examine traditional and contemporary fish usage, fishing areas, and barriers to fish use. Results showed that salmon was the most relied-upon fish in the North Coast and was traditionally used by all tribes interviewed, except for the Timbisha Shoshone in the Death Valley area.[12] However, the interviews suggested that use of fish has declined compared to historical rates, and especially more so in recent years.

Other evidence also points to a significant decline in tribal salmon harvest and consumption. The PFMC provides a systematic collection of tribal Chinook salmon harvest data dating back to 1987, although they are quite limited in temporal and geographic scope. From the PFMC's database, we found that the average number of salmon caught by the Yurok and Hoopa tribes combined from 1995-2015 was 21,000 for subsistence and 17,000 for commercial sale (more information on the subsistence and commercial tribal harvests is provided in Appendix 3A). As of 2010, the most recent year for which we have tribal population data, the number of salmon harvested for subsistence would correspond to 10 fish per year for a family of four, or about 20 to 38 pounds of salmon per person per year.[13] This estimate greatly contrasts with pre-contact consumption estimates by Hewes (1973), which indicated that the Yurok and Hoopa Valley tribes were consuming about 365 pounds of salmon per person per year. Fish consumption by the Karuk tribe has also dropped sharply (Table 3-1). A study by Norgaard (2005) showed that the lack of fishing rights, coupled with salmon population declines, impacted the health of members of the Karuk Tribe upstream on the Klamath River. Norgaard found that the Karuk Tribe experienced a loss of livelihood, diet-related illnesses, and poverty when their fish resources become degraded or destroyed. This experience is

11 Indigenous fishing rights allow tribal members to fish for salmon at traditional fishing sites and with traditional equipment, such as gill nets. The Yurok Tribe's allocation is 80 percent and Hoopa Valley Tribe's allocation is 20 percent of the tribal allocation (Pierce 1998).

12 Tribes that have been interviewed by Shilling et al. (2014) include Habematolel Band Pomo, Paiute, Big Valley Band Pomo, Scotts Valley Band Pomo, Kahia Band Pomo, Me-Wuk, Wiyot, Yurok, Yuki, Pit, Pomo, Nomlacki, Concow, Wailaki, Mattole, Northern Paiute, Timbisha Shoshone, Maidu, Mono, Monache, Wintun-Wailaki, Chumash, Chemehuevi, Mohave, Achomawi, and Atsugewi.

13 Authors' calculations based on Yurok and Hoopa Valley Tribal population from the US Census Bureau (2013). Table 19. American Indian and Alaska Native Population by Tribe for California: 2010. Estimated consumption per capita assumes that the dressed weight of salmon (i.e., weight after inedible or undesirable parts have been removed) ranges from 8 to 15 pounds per fish.

Table 3-1.

Estimated Present and Historical Karuk Tribe Fish Consumption

	Tribal Population	Est. Total Fish for Tribe (pounds)	Per Capita (pounds/person/year)
Pre-contact	1,500	675,000	450
Year 2003-04	3,300	<1,000	< 5
Year 2004-05	3,300	< 100	< 0.5

Sources: Adapted from Norgaard (2005). Pre-contact data from Hewes (1973).

likely shared by many Native American tribes in California.

CHALLENGES UNIQUE TO PRESERVING TRADITIONAL PRACTICES

Regulated environmental conditions are responsible for current limits on traditional fish consumption and harvest practices (Shilling et al. 2014). Dam construction, water diversions, and diseases, for example, contribute to the diminishing salmon population, but tribes also face fishing restrictions and many do not have indigenous rights to fish in traditional fishing sites (Chook-Chook Hillman, member of Karuk Tribe, personal communication, Sept. 27, 2016). Illegal, water-intensive marijuana cultivation in Northern California is another driver of reduced flows and environmental degradation. Marijuana's high economic value has attracted some tribal members to work in plantations (Crane-Murdoch 2015; Anderson 2015). These activities increase pesticide pollution in waterways, change the character of the creek, and further compromise water availability for salmon.

Multiple drought years have exacerbated existing problems relating to the overall decline in salmon abundance and the loss of livelihood. According to Chook-Chook Hillman, a Karuk Tribal member, the Klamath salmon runs narrowly escaped a complete collapse when the USBR approved emergency reservoir releases to protect juvenile and spawning salmon (personal communication, Sept. 27, 2016). Tribal activists fight almost annually for "emergency flows," which is especially critical during droughts (Brittani Orona, member of Hoopa Valley Tribe, personal communication, Nov. 23, 2016). As a result, tribes are currently asking for "preventive flows" to ensure the survival of the salmon population, which ultimately links to the survival of traditional cultures. The cultural wealth of tribes depends on the availability of salmon, which members use for ceremonies. When a tribal person cannot catch enough salmon to subsist, he or she must buy, trade, be given fish, or go without. It is highly probable that a continuation of the drought will result in more severe social, economic, and cultural impacts on tribal communities.

CONCLUSIONS AND RECOMMENDATIONS

A complex set of factors have contributed to the widespread decline in California's salmon population. Alterations to habitats, migration barriers, invasive species, and competing uses of water have likely decreased salmon's resilience in the face of extended dry periods. Droughts can impact salmon in many ways, principally via reduced flows and higher water temperatures. They also increase biological stress, lead to disease outbreaks, increase competition from invasive fish species, and augment predation risk. The diminished water supply during droughts intensifies competition for water between user groups, many of which are on unequal playing fields.

The commercial salmon fishery has been experiencing an overall decline, and the salmon fishing community has been shrinking as a result of (1) a downward trend in salmon harvest over the past 40 years; (2) a lack of income security among salmon fishermen; (3) rising costs of fishing (e.g., fishing regulations and cost of inputs); and (4) the decline of infrastructure that supports the fishing fleet (e.g., fuel docks and ice stores). Native American tribes are also significantly impacted by salmon decline, as observed in their harvest and consumption patterns. Tribal salmon consumption was historically much higher than the present level, according to interviews with tribal members

and our review of the literature. Tribes face unique challenges to preserve their traditional practices, including dam construction and operations, water diversions, fishing restrictions, the absence of fishing rights, and illegal marijuana cultivation. The ongoing California drought is seen by interviewed tribal members and fishermen as an additional stressor to an already stressed system, causing further decreases in fish harvest and income. For commercial fishermen, impacts contribute to the decline of the fishery and its capacity to remain financially viable. For tribes, the impacts threaten traditional livelihoods and cultural wealth.

RECOMMENDATIONS TO IMPROVE DROUGHT RESILIENCE OF THE SALMON FISHERY

Mitigating Impacts of Drought on Commercially Fished Salmon Runs

3-1. Enhance emergency drought response to protect anadromous populations that are important to fishing communities.

A small number of drought response activities directly address impacts on anadromous fish populations depended upon by tribes and commercial fishing communities. Efforts to ensure the protection of fish listed under the federal and California Endangered Species Act (ESA), such as improving flow conditions for winter-run Sacramento Chinook, may have positive spillover effects on non-threatened species. However, they leave out drought-affected rivers and tributaries that can no longer support threatened and endangered species. Strategies to enhance these responses include an improved management of reservoirs (e.g., on the Sacramento River) to prevent warm water releases that may harm salmon eggs and juveniles; emergency salmon rescue and transportation past compromised stretches of the river to coastal net pens during critical periods; and expanded Voluntary Drought Initiatives that have been carried out by NMFS and CDFW.

3-2. Reduce pressures on critical aquatic ecosystems.

The enforcement of the Reasonable and Beneficial Use Doctrine in California's water rights law is especially important during periods of water scarcity. More monitoring and enforcement activities are needed to prevent illegal water diversions (e.g., for marijuana cultivation). Additionally, statewide water conservation and efficiency measures, as well as expansion of alternative water supplies (e.g., stormwater capture and water recycling), can reduce pressures on critical aquatic ecosystems and, in some instances, improve river flows. Minimum environmental flows should be established and maintained in key waterways, especially during salmon migrating seasons.

3-3. Provide income and/or food assistance and insurance protection for fishing communities during drought emergencies.

Native American tribes and commercial fishermen greatly depend on the salmon fishery. According to interviews with tribal members and salmon fishermen, a poor salmon harvest year can create high economic and cultural burdens on fishing communities. State and federal agencies should recognize the inequitable impacts of the drought on these communities and provide income and/or food assistance during a drought emergency as appropriate. A federally supported fishermen's insurance program, similar to a crop insurance program, might be created as a risk management tool to protect fishermen against loss of income during times of extremely low harvest.

3-4. Build resilience and limit vulnerabilities of the salmon fishery.

Integrated management of water and fishery resources is key to improving the resilience of the salmon population. A statewide strategy for

aquatic conservation is needed to coordinate efforts and track results. These efforts include:

- Engaging in physical habitat restoration projects to better approximate natural conditions, such as the San Joaquin River salmon restoration efforts and those outlined in the Golden Gate Salmon Association's Salmon Rebuilding Plan (Golden Gate Salmon Association (GGSA) 2016);
- Creating salmon sanctuaries or stretches of rivers and streams dedicated to salmon conservation;
- Adjusting dam operation and state and federal water projects to ensure minimum environmental flows, maintain water quality, and balance water uses;
- Improving federal and California ESA protections for listed salmonids during times of low water supply to avoid a repeat of the winter-run Chinook salmon's mass die-offs in 2014 and 2015. Such protections are likely to provide indirect benefits for the salmon fishery as well;
- Re-operating fish hatcheries to protect wild salmon population;
- Restoring access to cold-water habitat to improve resilience against droughts, such as creating more fish-friendly waterways and fish passage facilities; and
- Removing dams that no longer provide enough hydropower to justify operational, maintenance, and environmental costs. These dam removals can increase cold water spawning and rearing habitats for migrating fish. The new Klamath Basin Agreements are a recent example. Signed April 2016, the agreements have created a roadmap for four dam removals on the Klamath River by 2020, while helping irrigators to avoid potentially adverse financial and regulatory impacts from the dam removal.

3-5. Create mechanisms for meaningful and timely tribal engagement with local, regional, state, and federal agencies.

Indigenous communities are known as stewards of the land and the water. They have practiced sustainable management of natural resources for millennia and their perspectives and input should be considered in policy decisions that will ultimately impact their communities, such as dam operations and fishery management. Many government agencies have developed and/or adopted tribal consultation principles and practices with varying degrees of inclusivity and timeliness, but these engagements should be fully institutionalized into relevant agency operations. An example of improving this consultation process is the creation of a tribal policy advisory committee or office within all levels of government that deal with issues impacting Native Americans.

Further Study and Data Collection on the Salmon Fishery and Drought

3-6. Formalize integrated biological and environmental data systems for salmon populations throughout California.

Better and more integrated data is needed to strategize and optimize responses to protect important salmon runs. Current monitoring efforts, especially on non-threatened salmon runs, are limited; these data gaps hinder timely response to changes in flows, temperatures, and other factors that may harm spawning adult and juvenile salmon. Some efforts are already underway to support collaborative and coordinated monitoring activities to improve fish population and watershed health, such as the Klamath Basin Monitoring Program and the California Cooperative Anadromous Fish and Habitat Data Program. However, these programs still leave gaps in temporal and spatial coverage.

Formalizing these efforts would help to maintain consistency and availability of timely data and identify gaps that should be addressed.

3-7. Comprehensively examine drought impacts on the fishery from economic, environmental, and cultural perspectives.

A better understanding of drought impacts on the fishery from economic, environmental, and cultural perspectives can help identify and address inequity issues around fishery and water resource management in California. The declining salmon population is a complex legacy problem through which many factors intersect, including the loss of habitat and environmental degradation. The drought provides an opportunity to draw attention to salmon's diminished resilience to extended dry periods and its implications for fishing communities.

3-8. Evaluate ways to re-operate hatcheries in California to achieve both goals of sustaining commercial fisheries and assisting in the recovery of naturally spawned salmon runs.

Sustainable fishery management depends on genetically-diverse wild fish stock that is resilient and adaptive to the changing environment. However, hatchery fish, which are bred to thrive in hatchery conditions, are known to weaken the genetic makeup of the wild (naturally spawned) fish population as a result of interbreeding (Buhle et al. 2009; Chilcote, Goodson, and Falcy 2011; Araki, Cooper, and Blouin 2009). How can the hatchery be managed and re-operated to limit negative impacts on the wild population while continuing to support the fishery? What are the most effective and cost-efficient approaches? These questions have been explored to some extent and continued research is needed to improve the health of the fisheries.

3-9. Assess the use and effectiveness of instream flow regulations to protect the salmon population.

At present, much of the research on the impact of instream flows on salmon populations focuses on endangered and threatened species. Management decisions can be made more effective through a better understanding of the relationship between flows and fish populations that are harvested for subsistence, sale, or recreation. For example, pulse flows may be used as a measure to assist in salmon migration during a drought period. Further research is needed to understand flow-migration relationships on a per-tributary basis and to assess the effectiveness of flow regulation measures.

3-10. Examine potential impacts on stock sustainability and socioeconomic implications of expanding reserved indigenous fishing rights.

Native American tribes have relied on salmon for food and cultural uses for millennia, but only two out of over a hundred tribes have reserved rights to fish in traditional sites with traditional equipment. The issue of equity and fairness of fishery access should be explored with considerations to potential impacts on fish stocks as well as tribes and other groups with recognized fishing rights.

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APPENDIX INTRODUCTION A

DROUGHT AND EQUITY ADVISORY COMMITTEE MEMBERS AND ORGANIZATION PROFILES

Sara Aminzadeh, *Executive Director, California Coastkeeper Alliance*

Colin Bailey, *Executive Director, Environmental Justice Coalition for Water*

Carolina Balazs, *Visiting Scholar, University of California, Berkeley*

Wendy Broley, *Staff Engineer, California Urban Water Agencies*

Amanda Fencl, *PhD Student, University of California, Davis Center for Environmental Policy and Behavior*

Kelsey Hinton, *Program Associate, Community Water Center*

Gita Kapahi, Director, *Office of Public Participation, State Water Resources Control Board*

Brittani Orona, *Environmental Justice and Tribal Affairs Specialist and Native American Studies Doctoral Student, University of California, Davis*

Brian Pompeii, *Lecturer, California Polytechnic State University, San Luis Obispo*

Tim Sloane, *Executive Director, Institute for Fisheries Resources*



SARA AMINZADEH

As the Executive Director of California Coastkeeper Alliance (CCKA), Sara Aminzadeh develops and executes campaigns to ensure swimmable, fishable, drinkable waters for California's communities and watersheds, in concert with locally-based California Waterkeepers. In addition to her policy work as an attorney and advocate, Sara creates and mobilizes new coalitions for clean water. Sara founded and directs CCKA's Blue Business Council, the California business network for clean water, and the California Water Partnership, a coalition of environmental and environmental justice organizations dedicated to securing a sustainable and equitable water future for California. Sara frequently writes about human rights and climate change issues, most recently authoring a chapter Rising to the Challenge: California Climate Change Adaptation in the 2014 Oxford University textbook, Climate Change Impacts on Ocean and Coastal Law. Sara holds a Bachelor of Arts (BA) in environmental studies and political science from the University of California, Santa Barbara, and a Juris Doctor (JD) from the University of California, Hastings College of the Law.

California Coastkeeper Alliance

California Coastkeeper Alliance was founded in 1999 with the belief that a healthy ocean and coast and clean water is vital to California's economy, public health, and way of life. California Coastkeeper Alliance and California Waterkeeper organizations are members of the international Waterkeeper Alliance, a network of water advocates with more than 200 programs in 21 countries on 6 continents led by Robert F. Kennedy Jr. Using law, policy, science, and creative media, CCKA is an experienced advocate that advances statewide policies and programs for healthy and clean waters. CCKA and local Waterkeeper groups develop, implement and defend policies that meet the needs of California's distinct communities and ecosystems. Together, CCKA and its network of Waterkeepers provide the public with the tools and information needed to hold decision-makers accountable and to be effective local water stewards.



COLIN BAILEY

Colin Bailey is the Executive Director of the Environmental Justice Coalition for Water and is based in Sacramento, California. He is fluent in English and conversant in Spanish. He has his Juris Doctorate from UCLA with a certificate from the Program in Public Interest Law and Policy and a concentration in Critical Race Studies. An accomplished social justice attorney, Colin leads EJCW's effort to implement the human right to water and supports EJCW's statewide policy agenda, programs, outreach and education, and grassroots member organizations.In addition, he leads EJCW's work with the Environmental Water Caucus, Community Engineering Corps, Ecological Society of America, Sacramento Valley Water Justice Network, US Human Rights Network, and more.

The Environmental Justice Coalition for Water

The Environmental Justice Coalition for Water (EJCW) works within a Community-to-Capital framework, connecting the most pressing needs of our disadvantaged community partners to our network of partners and agencies statewide. Since 1999, EJCW's work has been rooted in the communities most affected by environmental injustice. Issues and solutions are identified through regional chapters and statewide work groups. EJCW is positioned in the state capital, in order to connect communities with state agencies to bring about change multilaterally through advocacy, education, training, litigation, community organizing, and capacity-building, and by providing technical assistance. EJCW aims to effectively influence the intersections of water justice and environmental justice, community health, and human rights issues from community to global levels.

CAROLINA BALAZS

Carolina has been a UC President's Post-Doctoral Fellow at the University of California, Davis (UC Davis), bridging the academic-community water justice research community. She is also a consulting Research Scientist with California Environmental Protection Agency's Office of Environmental Health Hazards Assessment (OEHHA). At OEHHA, she is leading the development of a "Human Right to Water" tracking tool for the state of California. Her doctoral research examined drinking water quality problems in California's Central Valley and the environmental justice implications. Following graduate school, Carolina worked as a Research Scientist at the Community Water Center, promoting community-based participatory research and developing community-led water justice solutions. She holds a Bachelor of Science (BS) in Environmental Science from Brown University and both a Master of Science (MS) and Doctor of Philosophy (PhD) from the Energy and Resources Group at the University of California, Berkeley (UC Berkeley).

WENDY BROLEY

Wendy Broley is staff engineer at California Urban Water Agencies (CUWA) and Water Reuse Leader at Brown and Caldwell. Wendy is a licensed professional engineer with over 14 years of experience in water and wastewater engineering and operations, membrane technology and biosolids solutions, as well as business development for both municipal and industrial markets. She is committed to the development of a diverse and resilient water portfolio for her clients using an integrated "One Water" approach to water management. With a specific focus on transforming the perception of wastewater treatment plants into "resource recovery facilities," Wendy has stepped into the role as Water Reuse Leader at Brown and Caldwell. Wendy started her career as a consulting engineer supporting the membrane operations of multiple advanced water treatment facilities for indirect potable reuse applications totaling over 100 MGD of production capacity. Mrs. Broley holds a BS in Chemical Engineering from University of California, San Diego (UCSD).

California Urban Water Agencies

CUWA's mission is to provide a forum for combining the expertise and resources of its member agencies to advance reliable, high-quality water supplies for the State's current and future urban water needs in a cost-effective manner for the public, the environment and the economy. CUWA's efforts are guided by its 11 member agencies and supported by an Executive Director. Member agencies' resources are pooled to study water management issues, develop consensus solutions among the urban water community, and engage with California water leaders.

AMANDA FENCL

Amanda Fencl has been a member of the Center for Environmental Policy and Behavior (CEPB) for four years as a PhD student in the University of California, Davis Geography Graduate Group. Her dissertation explores the ways that drought can exacerbate California's drinking water disparities. As a PhD student she interned with the Governor's Office of Planning and Research (OPR) on drought policy, and assists OPR's Local Drought Liaison with a project on household water shortages and drought vulnerability. Since summer 2015, she has worked with Dr. Julia Ekstrom at the University of California, Davis Policy Institute's Climate Adaptation Initiative to look at extreme event impacts on California's drinking water quality. She and Dr. Ekstrom have a state grant to understand drought impacts on and responses of small, self-sufficient drinking water systems. Her dissertation is supported through a National Science Foundation (NSF) Graduate Research Fellowship (2015-2018), a NSF Climate Change, Water and Society IGERT (2013-2015) traineeship, and University of California, Davis research grants. She was a Staff Scientist at the U.S. Center of the Stockholm Environment Institute (SEI) for 6 years and has a BA in International Relations and Environmental Studies from Tufts University.

Center for Environmental Policy and Behavior

The mission of the CEPB is scientific analysis of the interactions among policy institutions, human behavior, and political decisions in the context of environmental and natural resource conflicts. Through developing and testing theoretical models from social science, CEPB seeks to derive practical lessons that can be used to improve environmental policy. We focus on a wide variety of environmental problems and issues, including watershed management, climate change, forest management, marine/coastal systems, biodiversity, and agriculture. The CEPB team includes an actively engaged group of faculty and graduate students who come from diverse backgrounds. CEPB is co-directed by Dr. Mark Lubell and Dr. Gwen Arnold, housed in the Department of Environmental Science and Policy at University of California, Davis, and affiliated with researchers from other academic universities, government agencies, and other University of California, Davis programs and departments.



KELSEY HINTON

AKelsey Hinton joined the Community Water Center (CWC) in 2015. As the former AmeriCorps Fellow, now Program Associate, Kelsey works to build the capacity of CWC through communications, fund development and policy work in order to improve and expand programs to provide disadvantaged communities with access to safe and affordable drinking water. An Indiana native, Kelsey recently graduated from Indiana University's School of Public and Environmental Affairs (SPEA) with a degree in Environmental Management. Her senior thesis focused on the feasibility of direct potable water reuse in Las Vegas. She is currently pursuing her Master's of Public Affairs (MPA) with a concentration in Policy Analysis at SPEA and will graduate in May 2017.

Community Water Center

The CWC is a non-profit environmental justice organization based in California's San Joaquin Valley, whose mission is to act as a catalyst for community-driven water solutions through organizing, education, and advocacy. CWC's fundamental goal is to ensure that all communities have access to safe, clean, and affordable water. CWC helps build strategic grassroots capacity to address water challenges in small, rural, low-income communities and communities of color. For more information, visit CWC's website at www.communitywatercenter.org and follow us on Twitter at @CWaterC.



GITA KAPAHI

Gita Kapahi is the Director of the Office of Public Participation (OPP) for the State Water Resources Control Board (SWRCB), and has been since the office was created in late 2007. In this office she serves in many capacities, including ombudsman, tribal liaison, environmental justice coordinator, small business liaison, agricultural liaison, education and outreach coordinator, facilitator, and public participation consultant. She has been with the SWRCB for 24 years, first as an Environmental Scientist in the Division of Water Quality, then in the Division of Water Rights, serving as Chief of the Bay Delta Unit. Prior to that, she was a fisheries consultant to the Canadian Department of Fisheries and Oceans.

Office of Public Participation, California State Resources Water Board

The OPP responds to public inquiries about SWRCB programs. The SWRCB created this program to strengthen our efforts at involving the public in our decision-making process. The office intends to reach out to environmental justice and other communities and have better communication and interaction with tribal governments and others. Additionally the office will assist staff with designing and implementing effective stakeholder involvement processes, including translation and other services, to ensure all interested parties can participate in SWRCB activities.

BRITTANI ORONA

Brittani is an enrolled member of the Hoopa Valley Tribe. She graduated with a BA in History from Humboldt State University, has an MA in Public History from California State University Sacramento, and is currently a doctoral student at University of California, Davis in Native American Studies with a Designated Emphasis on Human Rights. Her research focuses on indigenous memory and meaning in land use and environmental justice initiatives in California. Brittani helped to coordinate an exhibit and oral history project about the removal of four PacifiCorp dams on the Klamath River. She has also acted as an exhibit consultant for the Autry Museum of the American West, the Maidu Museum and Historic Site, and the Goudi'ni Native American Arts Gallery at Humboldt State University on exhibits related to environmental justice and water rights. Brittani has worked at the California Government Operations Agency, California State Indian Museum, the California State Office of Historic Preservation, California State Archives, and the Maidu Museum and Historic Site.

BRIAN POMPEII

Brian Pompeii is a human-environmental geographer at California Polytechnic State University, San Luis Obispo (Cal Poly) with research interests in water resources, sustainability, vulnerability, hazards, and climate adaptation. His current research project explores how drought-strained surface water access has led to an increase in groundwater usage for industrial agriculture, and subsequently a disaster-level increase in domestic well failure in disadvantaged unincorporated communities in the San Joaquin Valley of California. He received his PhD in Geography from Arizona State University.

California Polytechnic State University, San Luis Obispo

Cal Poly is a nationally ranked, four-year, comprehensive public university located in San Luis Obispo, halfway between San Francisco and Los Angeles on California's Central Coast. It is a distinctive learning community offering academically focused students a hands-on educational experience that prepares them for today's scientific and technical world.



TIM SLOANE

Tim is Executive Director for the Institute for Fisheries Resources (IFR), having begun his career with IFR and its sister organization, the Pacific Coast Federation of Fishermen's Associations (PCFFA), under the direction of William F. "Zeke" Grader, Jr. He advocates for clean, sustainable, and productive fisheries, protection of aquatic habitat, and workable fisheries management legislation. He is a member of the Marine Fish Conservation Network's National Policy Committee, and holds a seat on the Golden Gate Salmon Association Board of Directors. He received his BA in history from University of California, Berkeley, and a JD from Golden Gate University with a certificate in environmental law. He is a member of the State Bar of California.

Institute of Fisheries Resources

Established in 1993 by the PCFFA, IFR is responsible for carrying out the fishery research and conservation needs of working fishing men and women. Initially, IFR helped fishermen in California and the Pacific Northwest address salmon protection and restoration issues, with particular focus on dam, water diversion, and forestry concerns. Since 1998, IFR's range of programs has greatly expanded to encompass conservation projects and policy debates at the regional, national, and international levels. The IFR is dedicated to the protection and restoration of fish resources and the human economies that depend on them. By establishing alliances among fishing men and women, government agencies, and concerned citizens, IFR unites resource stakeholders, protects fish populations, and restores aquatic habitats.



The Environmental Justice Coalition for Water

Water Justice for All

The Environmental Justice Coalition for Water
PO Box 188911, Sacramento, CA 95818-8911
909 12th Street, Suite 200, Sacramento, CA 95814
916-432-EJCW (3529) | info@ejcw.org | ejcw.org



Pacific Institute
654 13th Street, Preservation Park, Oakland, CA 94612
510-251-1600 | info@pacinst.org | pacinst.org

ISBN-13: 978-1-893790-76-6

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EXHIBIT C

Social Disparities in Nitrate-Contaminated Drinking Water in California's San Joaquin Valley

Carolina Balazs,[1] Rachel Morello-Frosch,[2,3] Alan Hubbard,[2] and Isha Ray[1]

[1]Energy and Resources Group, [2]School of Public Health, and [3]Environmental Science Policy and Management, University of California, Berkeley, California, USA

BACKGROUND: Research on drinking water in the United States has rarely examined disproportionate exposures to contaminants faced by low-income and minority communities. This study analyzes the relationship between nitrate concentrations in community water systems (CWSs) and the racial/ethnic and socioeconomic characteristics of customers.

OBJECTIVES: We hypothesized that CWSs in California's San Joaquin Valley that serve a higher proportion of minority or residents of lower socioeconomic status have higher nitrate levels and that these disparities are greater among smaller drinking water systems.

METHODS: We used water quality monitoring data sets (1999–2001) to estimate nitrate levels in CWSs, and source location and census block group data to estimate customer demographics. Our linear regression model included 327 CWSs and reported robust standard errors clustered at the CWS level. Our adjusted model controlled for demographics and water system characteristics and stratified by CWS size.

RESULTS: Percent Latino was associated with a 0.04-mg nitrate-ion (NO_3)/L increase in a CWS's estimated NO_3 concentration [95% confidence interval (CI), –0.08 to 0.16], and rate of home ownership was associated with a 0.16-mg NO_3/L decrease (95% CI, –0.32 to 0.002). Among smaller systems, the percentage of Latinos and of homeownership was associated with an estimated increase of 0.44 mg NO_3/L (95% CI, 0.03–0.84) and a decrease of 0.15 mg NO_3/L (95% CI, –0.64 to 0.33), respectively.

CONCLUSIONS: Our findings suggest that in smaller water systems, CWSs serving larger percentages of Latinos and renters receive drinking water with higher nitrate levels. This suggests an environmental inequity in drinking water quality.

KEY WORDS: California, drinking water, environmental justice, nitrate, public health, Safe Drinking Water Act, social disparities, water systems. *Environ Health Perspect* 119:1272–1278 (2011). http://dx.doi.org/10.1289/ehp.1002878 [Online 3 June 2011]

An array of drinking water–related problems still exists in the United States, despite a history of investment in sophisticated water infrastructure and the existence of federal laws such as the Clean Water Act of 1972 and Safe Drinking Water Act of 1974 (SDWA) that regulate source contamination and protect the public's health. These problems include increasing source contamination (Dubrovsky et al. 2010), exposure to chemical and microbial contaminants, poor implementation of water laws (Burke 2009; Duhigg 2009), and degrading infrastructure (Levin et al. 2002). Rural areas often face the largest burden, as aquifers are contaminated by intensive agriculture and livestock production (Dubrovsky et al. 1998). Some rural unincorporated areas, such as some communities along the U.S.–Mexico border, lack access to adequate infrastructure, service provision, and clean water (Olmstead 2004; Pilley et al. 2009).

Despite these problems, there is a paucity of studies that examine social disparities in exposure to unsafe water. A literature review in the 1990s (Calderon et al. 1993) recommended that more quantitative analyses examine whether vulnerable populations, including people of color and the poor, are disproportionately affected by drinking water contamination. Since then, a handful of studies have addressed different aspects of this issue. In San Joaquin County, California, one study found a weak but significant relationship between areas with higher poverty and greater proportions of minorities and poor drinking water quality (Byrne 2003). Research in the Navajo Nation found bacteriological and chemical contamination in unregulated drinking water sources (Murphy et al. 2009). In Arizona, researchers examined whether public water systems serving higher fractions of minority or low-socioeconomic-status (SES) residents were more likely to exceed the arsenic maximum contaminant level (MCL) than were those serving higher fractions of whites or high-SES residents. They found a positive association between the percentage of Latino residents and the likelihood of exceeding the MCL of arsenic. However, they concluded that environmental justice concerns were unwarranted for Latinos, because there was no difference between the percentages of Latinos who were served by water systems with and without violations. (Cory and Rahman 2009). In New Mexico, preliminary research documented high arsenic levels in drinking water sources that provided water to predominantly Latino border communities known as "colonias" (Pilley et al. 2009).

Our research addresses several methodological limitations of previous studies, particularly regarding appropriate unit of analysis, characterization of exposure, and scale. For example, Byrne (2003) estimated average trichloroethylene levels and MCL exceedances in drinking water systems and characterized exposure as a continuous measure across San Joaquin County; the community level, however, is more appropriate when considering community-level exposure. Cory and Rahman (2009) characterized the association between percent minority and a binary outcome of arsenic, rather than a continuous measure of arsenic levels, and they did not explore this association among smaller systems where they noted that most arsenic violations occurred.

Our study used the community as the unit of analysis to examine the relationship between nitrate concentration in community water systems (CWSs) and social factors. CWSs are public water systems that serve water year-round to at least 25 people or have > 15 service connections [U.S. Environmental Protection Agency (EPA) 2010b]. We characterized potential exposure to nitrate because it is one of the most common contaminants found in groundwater (Harter 2009; Spalding and Exner 1993) yet has received little attention regarding social disparities in exposure.

Nitrate in drinking water is associated with methemoglobinemia (i.e., "blue baby syndrome") in infants (Fan and Steinberg 1996; U.S. EPA 2010a), although other risk factors include enteric infections (Charamandari et al. 2001; Hanukoglu and Danon 1996) and foods

Address correspondence to C. Balazs, 310 Barrows Hall, University of California, Berkeley, CA 94720-3050 USA. Telephone: (510) 642-1640. Fax: (510) 642-1085. E-mail: carolinabalazs@berkeley.edu

Supplemental Material is available online (http://dx.doi.org/ 10.1289/ehp.1002878).

We thank L. Firestone, S. de Anda, and M. Herrera; R. Haberman [former San Joaquin Valley Regional Engineer for California Department of Public Health (CDPH) Drinking Water Program], D. Spath (former Chief of the Division of Drinking Water and Environmental Management, CDPH), and C. Peterman for support and feedback on analysis; CDPH and Tulare County Environmental Health Services for data; and B. Nerness for research assistance.

This research was supported by a National Science Foundation graduate research fellowship, the California Endowment through a collaborative research grant between Community Water Center and University of California–Berkeley, and the Switzer Environmental Fellowship.

The authors declare they have no actual or potential competing financial interests.

Received 19 August 2010; accepted 3 June 2011.

high in nitrates (Sanchez-Echaniz et al. 2001). Epidemiologic data also suggest an association between nitrate levels in drinking water and reproductive toxicity, developmental effects, and various cancers (Fan and Steinberg 1996; Ward et al. 2005, 2010), although the consistency of these associations varies. To protect against methemoglobinemia, the SDWA has established an MCL of 45 mg/L as nitrate ion (NO_3) or 10 mg/L as nitrate-nitrogen in drinking water (U.S. EPA 2010a).

California's San Joaquin Valley is an important site for examining potential disparities in exposure to nitrate. With its intensive irrigated agriculture, the valley has two of the most contaminated aquifers in the nation and some of the highest nitrate levels in the country (Dubrovsky et al. 1998, 2010). Because nearly 95% of the valley's population relies on groundwater for drinking [Permits, Inspections, Compliance, Monitoring and Evaluation (PICME) [California Department of Public Health (CDPH) 2008a], groundwater contamination is a particular health risk. This risk is compounded by the fact that with high costs of mitigation, few systems actually treat for nitrate. The San Joaquin Valley also has some of the highest rates of poverty and minority populations—particularly Latinos—in the state (U.S. Census Bureau 2007). These communities are economically and socially disadvantaged, making it harder for them to afford mitigation or to address related health consequences of nitrate contamination. The continued use of nitrogen-based fertilizers (Dubrovsky et al. 2010; Ruddy et al. 2006) and the increasing demand for groundwater (Glover 2010) further highlight the importance of this contaminant, because exposure may become increasingly widespread.

Given this context, we used water quality monitoring data from the CDPH to analyze the association between racial/ethnic and SES characteristics of people served by CWSs and nitrate levels of these systems in the San Joaquin Valley. With few exceptions (Byrne 2003), there has been limited use of CDPH monitoring data to examine whether certain groups are disproportionately affected by exposure to drinking water contaminants. Similarly, despite an acknowledgment of the burden faced by small systems (Committee on Small Water Systems 1997), few studies have explored associated social disparities.

We hypothesized that CWSs serving a higher percentage of minority or lower-SES residents have higher nitrate levels and that these disparities are likely to be greater among smaller drinking water systems. Disparities in nitrate exposures, if they exist, could signal a potential environmental injustice. This analysis expands the emerging literature on drinking water quality and social disparities in the United States and informs national- and state-level policy on the needs of underresourced water systems.

Materials and Methods

Our units of observation were CWSs in California's San Joaquin Valley. We used three measures to test our study's hypotheses: *a*) estimated average nitrate concentrations for each CWS to describe average water quality served to customers; *b*) population potentially exposed (PEP) to three nitrate levels to estimate the population affected by nitrate contamination; and *c*) nitrate concentrations at points of entry into each CWS's distribution system to assess the relationship between demographic characteristics of customers and CWS nitrate levels. The first two measures were used in a series of descriptive statistical analyses. The third measure was used as the outcome variable in linear regression models that estimated the relationships between race/ethnicity and SES and a system's nitrate concentration.

Sample selection and time period. We included CWSs that were active in the San Joaquin Valley between 1999 and 2001, had at least one point-of-entry source with a nitrate sample reported for this period, and had any source (i.e., point of entry or not) with geographic coordinate data available to estimate CWS demographics. Point-of-entry sources can be defined as sources of supply (e.g., well with no treatment or effluent from a well/surface water plant) that directly enter into the distribution system (Figure 1). We used nitrate-sampling data from 1999 to 2001 and demographic data from the 2000 Census. The sampling period represents one full compliance period under the SDWA [California Code of Regulations (CCR) 2008, §64400.25]. Of the 873 CWSs that were active during 1999–2001, 711 had sources with geographic coordinates. Of these, 327 (37%) had nitrate water quality sampling data and were included in our final sample.

Average nitrate concentration for CWSs. To estimate nitrate concentration for each CWS, we selected two types of point-of-entry sources for inclusion (Figure 1): *a*) sources, such as well fields or surface water plants, that were in active use and had no treatment or that were treated for contaminants other than nitrate, and *b*) treatment plants in active use that potentially treated for nitrate. In both cases, we included only sources that were last in line to enter the distribution system (i.e., did not flow to another source before entering), to avoid double counting of nitrate levels. We used the CDPH's Permits, Inspections, Compliance, Monitoring and Enforcement database (CDPH 2008a) to identify source types, their location in relation to the distribution system, and their possible treatment techniques. If a plant had a treatment technique commonly used for nitrate (e.g., reverse osmosis), we assumed that it treated for nitrate.

We then used nitrate-sampling data for these sources from the CDPH (2008b) Water Quality Monitoring database to determine nitrate concentration at points of entry. This served as a proxy for water quality in each CWS's distribution system and for tap water quality. Nitrate levels are unlikely to change from these entry points to the tap (unless systems chloraminate, which those in the valley do not) (Haberman R, personal communication). CWSs using groundwater are required to sample each source for nitrate annually (unless a single sample or average of two samples exceeds the MCL, in which case the system must sample quarterly); CWSs using surface water must sample quarterly (CCR 2008, §64432.1). In practice, however, systems often fail to sample regularly (Haberman R, personal communication). If a nitrate sample was below the detection limit

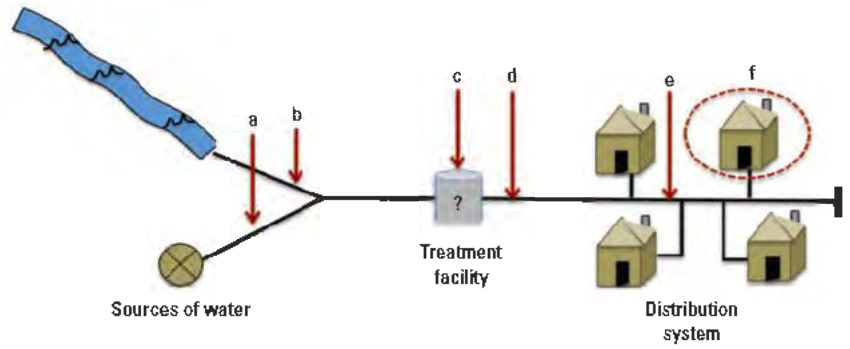


Figure 1. Schematic of a community water system (CWS) indicating the location of point-of-entry sources and the use of average nitrate concentration in the distribution system as a proxy for tap water quality. Water entering the distribution system may flow from a groundwater well (point a) or from a surface water source (i.e., stream; point b). Water may then be treated (point c; different treatment techniques may be used, depending on the contaminant of interest and original source). Water then enters the distribution system at points of entry (point d). In this example, nitrate samples would be used from point d, because points a and b flow into the same point of entry. Average nitrate level at point d is used to represent average water quality in the distribution system (point e). Nitrate levels in the distribution system are a proxy for tap water quality (point f). If points a and b are separate points of entry (i.e., do not flow into a shared point d), nitrate sample points would be used from each source separately. Constant and equal flows are assumed.

of 2 mg NO_3/L (CCR 2008, §64432), we took the square root of the value as a proxy for that sample's nitrate level (Lubin et al. 2004). We did not have flow measurements for the individual sources that contributed water to each CWS's distribution system. Therefore, we could not determine a flow-weighted measure of distribution water quality for each CWS based on the nitrate level measured in samples from each contributing source. Instead, we assumed that each point-of-entry source contributed independently and equally to a CWS's distribution system, and that each source contributed a constant amount to the system, regardless of season.

Finally, we determined the average nitrate level for each point-of-entry source and averaged the resulting values across all sources to estimate an average systemwide nitrate level. The systemwide average was then used to categorize each CWS's average nitrate concentration as *a*) low, defined as < MCL/2 (< 22.5 mg NO_3/L); *b*) medium (22.5–44.9 mg NO_3/L); and *c*) high (≥ 45 mg NO_3/L, the MCL for nitrate). These categories correspond to those used to assess source-level nitrate concentrations for regulatory purposes (CCR 2008, §64432.1). Besides the high category, the medium category is important to consider because research suggests that exposure to nitrate in drinking water at half the MCL can cause adverse health effects among susceptible subpopulations (DeRoos et al. 2003). In addition to calculating average nitrate levels, we used nitrate MCL violation data from PICME to verify whether CWSs with high nitrates did in fact receive violations, and to run a sensitivity analysis on PEP data.

Potentially exposed population. Using a method by Storm (1994), we computed the potentially exposed population (PEP) by apportioning the total population served by each CWS into three exposure categories based on the proportion of sources for that CWS with average nitrate levels that were low, medium, or high, as defined above. The population in each category was then summed across all CWS to estimate the total population potentially exposed to the three nitrate levels. The approach to calculate the PEP for the high-nitrate category is summarized by the following equation:

$$PEP = \sum_{i=1}^{327} [(X_i \times s_{il}/S_{it}) + (X_i \times s_{im}/S_{it}) + (X_i \times s_{ih}/S_{it})], \quad [1]$$

where X_i is the total population served in CWS i; s_{ih} is the number of sources for CWS i with average nitrate concentrations classified as high (h); and S_{it} is the total number of point-of-entry sources for CWS i. To calculate the PEP for the low (l) or medium (m) nitrate categories, we replaced s_{ih} with s_{il} or s_{im}, respectively. We used PICME 2008 data on the number of people served by each CWS to calculate the population size in each exposure category during 1999 to 2001. If the number of customers served by a CWS was not available from the PICME data, we used information from the CDPH Water Quality Monitoring database. To estimate population counts of potentially exposed individuals according to demographic characteristics (e.g., race/ethnicity) we multiplied the potentially exposed population in each nitrate category for each CWS by the estimated proportion of customers in each demographic subgroup for the CWS, and then summed these values across all CWS for each nitrate category. Because home ownership is based on housing units rather than population count, we did not derive a count of housing units.

Statistical analysis of nitrate levels and CWS characteristics. We used a linear regression model to analyze the relationship between CWS demographics and nitrate levels. We fitted a model selected *a priori* that controlled for known or hypothesized system-level confounders. We originally used a mixed model approach to account for clustering (Laird and Ware 1982). However, diagnostics of the mixed model indicated a very non-normal distribution of residuals. Therefore, we used an approach that provided inference that was robust under laxer modeling assumptions. To derive the inference (i.e., standard errors), we clustered outcomes at the water system level (i.e., point-of-entry nitrate concentrations measured on a given day for a given source). Thus, our final model reported sandwich-type robust standard errors (Huber 1967) that allow for arbitrary correlation, including correlation within or across sources in a CWS.

Our outcome variable, Y_{ijk}, is nitrate concentration for the ith water system, the jth source in system i, on day k (since 1 January 1999). Although nitrate samples from individual sources are our outcome measurements, the CWS is the primary unit of analysis, consistent with average nitrate level calculations discussed above. Our final model did not reweight CWSs with more samples (as the mixed model might have, depending on the implied estimated correlation structure), because we wanted CWS to contribute measurements based on a proxy of the number of people served. Thus, systems with more measurements contributed more to the estimates. We addressed this assumption by stratifying by system size, to see if smaller CWSs (with fewer samples) had a different effect than did larger CWSs. Because differences between the estimates of the mixed model and the linear model were small, this comparison provided evidence that the nonweighted approach of our final model was reasonable.

Key independent variables were the percentage of Latino and non-Latino people of color served by CWSs (referent category was non-Latino whites) and percent home ownership in the area served by a CWS. Latinos were analyzed separately because they are the largest ethnic group in the valley (40%; U.S. Census Bureau 2007). SES was represented by home ownership rate, which is a proxy for wealth and political representation (Krieger et al. 1997; Morello-Frosch et al. 2001; Oliver and Shapiro 1997). Because of our focus on CWS-level exposures, these variables were measured at the CWS level. We assumed these remained constant for all 3 years.

Race/ethnicity and home ownership data were derived from the 2000 U.S. Census (U.S. Census Bureau 2000). Because CWS service areas do not follow census boundaries, we used two spatial approaches in geographic information systems to estimate demographic variables for each CWS. We first compared an aerially weighted approach using digitized CWS boundaries in two pilot counties (Tulare and Fresno) with a second approach joining spatial coordinates from CDPH data for all sources (well fields, surface water intakes, and treatment plants) to census block groups. Based on spatial and goodness-of-fit comparisons, we concluded that it was reasonable to use the latter approach [for details on the aerially weighted approach and the comparison between the two methods, see Supplemental Material (http://dx.doi.org/10.1289/ehp.1002878)]. In brief, for each CWS, we estimated a population-based average of each variable across all block groups that included sources for the CWS. For example, if a CWS had two sources in two census block groups, we determined the population-weighted average of the variable across both census block groups and used that value to derive a percent estimate of demographic groups (e.g., 50% Latino) served by each CWS.

We controlled for other water system characteristics that could be potential confounders: source of water (groundwater or groundwater plus surface water vs. surface water alone), whether the system served a city (i.e., incorporated) or an unincorporated area, ownership structure of the system [publicly vs. privately owned and not regulated by the Public Utility Commission (PUC), with privately owned PUC-regulated systems as the referent category], system location (agricultural valley floor or not), season (summer/fall or winter/spring), year of sampling (2000 or 2001, with 1999 as referent category), and number of service connections (< 200 or ≥ 200 connections). CWSs with < 200 connections are generally considered "small" (CCR 2008, §64432.1). We determined ownership structure by combining data in PICME with data from the PUC's list

of regulated systems. We obtained all other characteristics from PICME. With the exception of year and season, which were measured at the source level, all covariates were measured at the water system level.

In addition to models including all CWSs, we stratified by system size to assess whether demographic effects on water quality might be stronger among smaller systems and to test the hypothesis that scale alone explains water quality. We also used our final model to estimate the amount of nitrate contamination attributable to the proportion of the population that is Latino. We did so by using the final model to predict expected values for each observation if percent Latino equaled zero, as described in Greenland and Drescher (1993). All statistical analyses were conducted using Stata (version 10; StataCorp LP, College Station, TX). We used Stata's cluster command (clustering at the CWS level) to derive robust SEs.

Results

Descriptive statistics. The 327 systems in our sample served approximately 2.95 million people, or 96% of the San Joaquin Valley population served by CWSs (Table 1). The distribution of average system-level nitrate concentrations is right-skewed and ranges from 0 to 150 mg NO_3/L. This distribution and range are similar for average source-level nitrate concentrations and for individual sampling points (data not shown). The mean proportion of Latinos served across these CWSs was 32%, with an interquartile range (IQR) of 10–50%. The mean proportion of homeownership was 70%, with an IQR of 60–82%. Compared with all the CWSs in the valley active from 1999 to 2001, our study sample underrepresented small CWSs that have < 200 connections (49% vs. 73%; Table 1). The number of samples per source in systems with < 200 connections ranged from 1 to 110 (mean, 3.2), compared with a range of 1–133 (mean, 4.5) for systems with ≥ 200 connections. Six percent of samples had concentrations below the detection limit.

Overall, 3% (n = 10) of all CWSs in our sample had high average nitrate concentrations (above the MCL of 45 mg NO_3/L) for at least some part of the study period, 10% (n = 33) had medium average concentrations (MCL/2 to MCL), and 87% (n = 284) had low average concentrations (< MCL/2; Figure 2). Of the 10 CWSs with an average nitrate concentration > MCL, 9 had < 200 connections and 8 had only one or two sources. All but 1 of these 10 CWSs received at least one MCL violation during the study period, and 14 CWSs in our sample (serving ~ 92,268 people) received at least one MCL violation [PICME (CDPH 2008a); see also Supplemental Material, Table 1 (http://dx.doi.org/ 10.1289/ehp.1002878)].

CWSs that served higher fractions of Latinos and lower fractions of homeowners (i.e., more renters) had higher average nitrate levels. Figure 3 shows that in the two highest Latino quartiles, proportionately more systems had average nitrate concentrations > MCL (i.e., 5% and 7% in the two higher quartiles compared with 0% in both of the lower quartiles). These two quartiles also had the largest fractions of CWSs in the medium nitrate category. The two quartiles with the lowest rates of home ownership had the

Table 1. CWSs included in study sample compared with all active CWSs, San Joaquin Valley, California, 1999–2001.

Variable of interest	Active CWSs with source location (n = 327)	CWSs in study (n = 327)	CWSs with < 200 connections (n = 160)	CWSs with ≥ 200 connections (n = 167)
Total population	3,047,822[a]	2,948,346	27,165	2,921,181
Latino population (%)	34	39	29	40
White population (%)	58	47	64	47
Population above poverty level[b] (%)	57	57	59	57
Population served (mean/median)	4,206/150	9,016/565	170/100	17,492/430
Incorporated[c] (%)	9	18	2	34
< 200 connections (n)	73	49	100	0
Only groundwater[d] (%)	89	90	97	84
Groundwater and surface water[d] (%)	5	8	3	13

[a]Approximately 71,418 people were served by CWSs whose sources did not have geographic coordinates, and 80 CWSs had no population estimates available; including these sources, the estimate of "true" population served by active CWSs was at least 3,119,240. [b]Above 200% of the poverty level. [c]A CWS that serves a city that is a legally recognized municipal corporation with a charter from the state and governing officials that is incorporated, as opposed to a water system that serves an unincorporated area. [d]Reference group, surface water only.

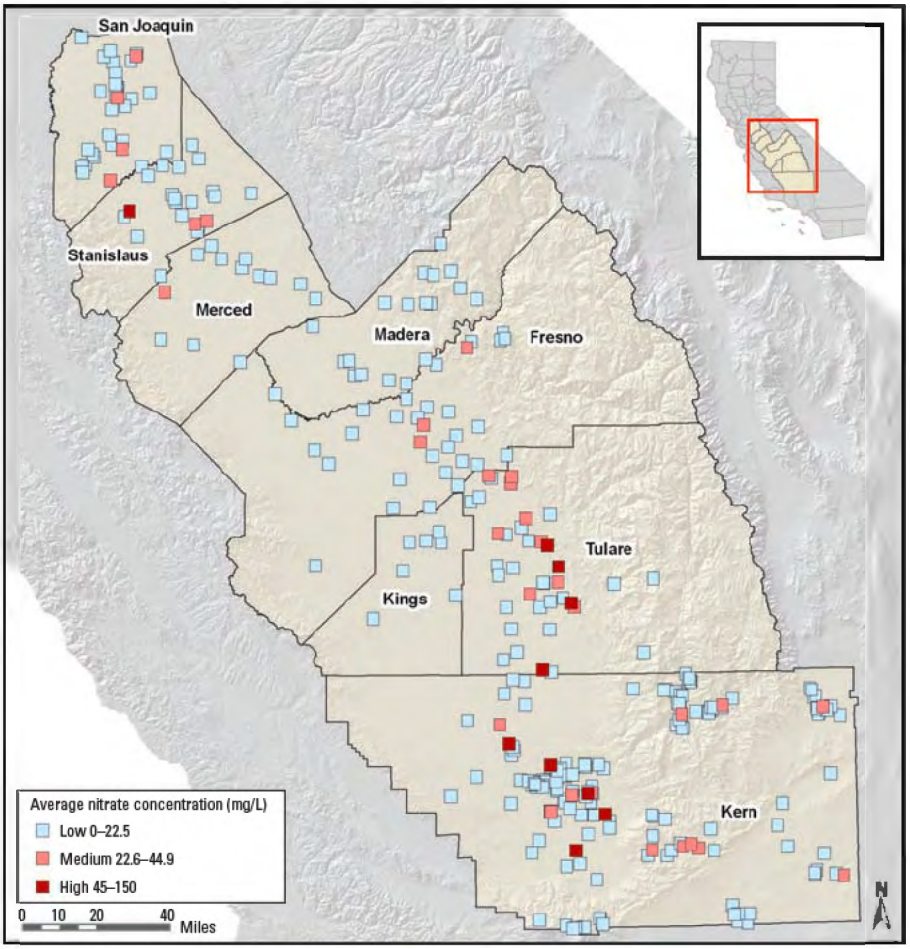


Figure 2. Average nitrate concentration of CWSs in California's San Joaquin Valley, 1999–2001 (n = 327). Estimates are based on an average of each point-of-entry source's average concentration. Data are from CDPH (2008) Water Quality Monitoring and PICME databases (CDPH 2008a, 2008b). Approximate locations of CWSs are depicted, but not true boundaries. Because of close proximity of some CWSs, some CWSs not fully visible.

largest proportions of systems in the medium and high nitrate categories (15% and 22%, respectively), compared with the two quartiles with the highest rates of home ownership (which had 7% and 8%, respectively).

Of the population served in our sample, approximately 84.6% (~ 2,494,442 people) were potentially exposed to low nitrate levels, 15.2% (~ 448,729 people) to medium nitrate levels, and 0.2% (~ 5,176 people) to high nitrate levels (Table 2). Of the 5,176 people served water with nitrates above the MCL, 56% were people of color (50% Latinos and 6% non-Latino), compared with 52% in the low and medium nitrate categories (Table 2).The percentage of Latinos served by high-nitrate CWSs was higher than the percentage of Latinos served by CWSs in the other two nitrate categories (39% and 40% for low and medium nitrate, respectively). This percentage was also greater than the percentage of Latinos in our entire study sample (39%; Table 1). This percentage was also higher than the percentage of Latinos served by CWSs in the other two nitrate categories (39% and 40% for low and medium nitrate, respectively).

Model results. Table 3 shows the multivariate modeling results. Unadjusted models indicate that percent Latino was positively and significantly [β = 0.14; 95% confidence interval (CI), 0.04–0.24] correlated with the average nitrate concentration in the distribution system. Conversely, home ownership was negatively correlated with average nitrate concentration but only marginally significant (β = –0.15; 95% CI, –0.30 to 0.003).

Our adjusted model suggests that, on average, a 1% increase in Latinos served by a CWS was associated with an increase of 0.04 mg NO_3/L (95% CI, –0.08 to 0.16). For home ownership, each percent increase was associated with a decrease of 0.16 mg NO_3/L (95% CI, –0.33 to 0.002). For systems with < 200 connections, the associations between percent Latino and home ownership and nitrate concentration were consistent with both the unadjusted model and adjusted model for all CWSs, but the strength of the association for percent Latino increased. Specifically, on average, each percent increase in Latino was associated with a 0.44 mg NO_3/L increase (95% CI, 0.03–0.84) in the smaller systems. A 1% increase in home ownership was associated with a 0.15 mg NO_3/L decrease (95% CI, –0.64 to 0.33), although the association was not statistically significant. In systems with ≥ 200 connections, neither race/ethnicity nor home ownership was associated with nitrate concentrations. Using the final model to predict expected values, we estimated that among small systems, nitrate levels for CWSs with 0% Latinos would be, on average, 6 mg NO_3/L lower compared with CWSs at the mean.

Discussion

To our knowledge, this is the first study to examine the relationship between nitrate levels in CWSs and social disparities in the United States. After stratifying by system size, we found that among systems with < 200 connections, those serving higher percentages of Latinos had higher nitrate levels. We found an inverse but not statistically significant association between home ownership and nitrate levels for smaller systems. For large systems, we did not find significant associations between race/ethnicity or home ownership and nitrate levels. Our findings corroborate previous drinking water studies (e.g., Byrne 2003) that showed a positive relationship between percent minority and poor water quality but are specific to nitrate contamination at the community level. That water quality varied by percent Latino or home ownership matters not only because of environmental equity but also because elevated nitrate levels could pose a greater hazard to subpopulations that may have less access to health care.

The association of race/ethnicity and SES with nitrate levels could be due to several factors. Race/ethnicity could have been related to proximity to agriculture, as well as the ability of residents to participate in the governance of their CWSs. For example, in systems with higher fractions of Latinos, language abilities, citizenship status, or lack of political clout could inhibit residents from speaking out and demanding improvements in water quality (for a discussion in relation to electoral politics, see Michelson 2000). Home ownership could have been negatively associated with nitrate levels because renter-based communities may have had a lower capacity to pay for improvements in water infrastructure or to hold a CWS accountable, assuming they received notices of violation as required (CCR 2008, §64463). Or, it might indicate that a lack of economic resources may influence whether CWSs can hire capable water managers or comply with regulations.

That > 5,000 people in our study sample were potentially exposed to drinking water with nitrate concentrations above the MCL raises health concerns. As noted, acute and chronic health effects have been found for vulnerable populations (e.g., infants and pregnant women) exposed to nitrate exceeding the MCL (Ward et al. 2005). Furthermore, that many of the water systems in this category had only one or two sources can lead to increased chances of high exposure for residents if these are high-nitrate sources, because there is no immediate alternative water source to draw from or blend with. These small systems often go years with high nitrate levels, until a new water source can be developed (Spath D, personal communication). PICME (CDPH 2008a) data corroborates this observation: of the 10 systems whose average nitrate concentration exceeded the MCL, 6 had recurring MCL violations over an 8-year time frame. In these systems, customers may be continually exposed (although exposure would be lower if people frequently use alternative sources). Additionally, because customers in the

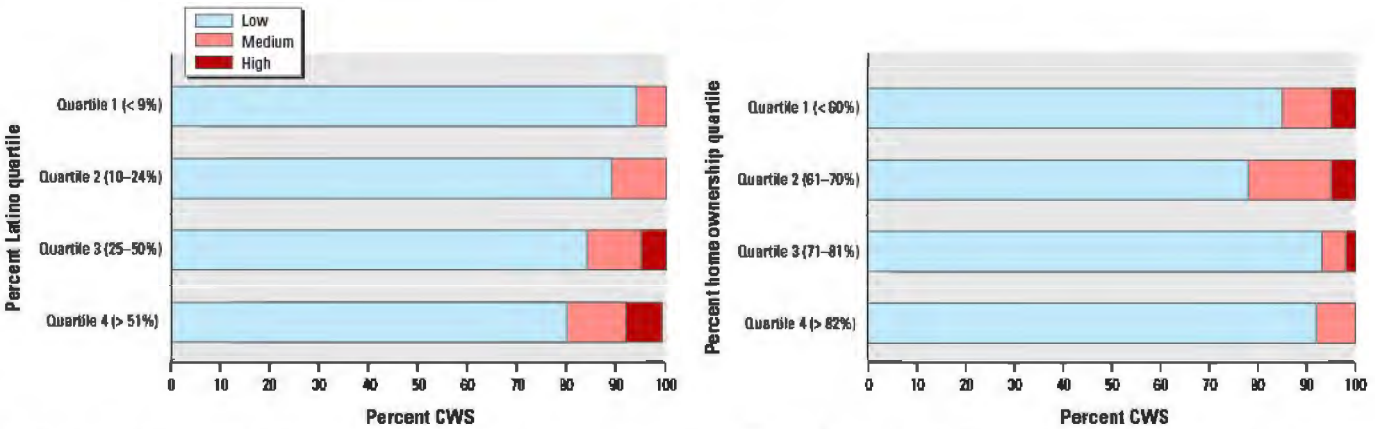


Figure 3. Percentage of CWSs with low, medium, and high average nitrate concentrations, by quartiles of percent Latino and home ownership. Average system-level nitrate concentration is derived from the average of each source's average nitrate concentration at point of entry. Low is < one half the MCL of 45 mg NO_3/L. Medium is one half the MCL up to the MCL (22.5 mg/L to 44.9 mg/L NO_3). High is ≥ to the MCL.

San Joaquin Valley often cope by purchasing bottled water, they pay two water bills—one for tap water and the other for bottled water (Moore et al. 2011).

Our results also highlight a less frequently discussed issue—approximately 448,700 residents, served by 33 CWSs, in our sample received water with medium nitrate levels (< MCL but > MCL/2). Nitrate levels in these systems could be approaching the MCL in some cases. In our study, one-third of CWSs in this category had average concentrations > 30 mg NO_3/L. Residents in these systems could be at risk of adverse health outcomes and/or could experience additional economic costs. For example, in one study, the risk of colon cancer increased for certain susceptible subgroups (e.g., those with low vitamin C intake or high meat intake) whose water had nitrate levels > MCL/2 for at least 10 years (DeRoos et al. 2003). More generally, although several authors have suggested that the current nitrate MCL could be increased to a less stringent level of regulation (L'hirondel and L'hirondel 2002), others have argued that the standard should not be changed (Ward et al. 2005) because of uncertainties in the exposure assessment data and health effect estimates of the epidemiologic study upon which the current MCL is based (Walton 1951). Some authors also argue that the MCL includes no safety factor, and documented cases of infant methemoglobinemia have occurred at levels below the MCL (Fan and Steinberg 1996). Thus, exposure to nitrates in the middle category is important to consider.

Monitoring of water quality by these CWSs is also an important consideration. CWSs with any source whose nitrate levels exceed MCL/2 (> 22.5 mg NO_3/L) are required to increase their monitoring frequency from annual to quarterly sampling (CCR 2008, §64432.1). At best, the cost of increased monitoring must be passed along to consumers. At worst, the funding and staffing constraints can limit the capacity of small CWSs to monitor; these CWSs may have nitrate levels approaching the MCL but neither the system operators nor customer base would know (Haberman R, personal communication). Such a scenario would undermine the aim of the SDWA, which is supposed to protect the public from harmful exposures and requires systems to notify their customers so that precautionary measures can be taken to reduce exposures (CCR 2008, §64480; Fan and Steinberg 1996).

This study used an appropriate unit of analysis (i.e., CWS) for estimating system-level nitrate exposure. The methods we used could be applied to other contaminants and to other regions of the United States. However, sources of error exist in our demographic estimate because *a*) surface intakes/well fields could fall in census block groups not served by the CWS, *b*) not all census block groups served by a CWS have an intake/field located within them, and *c*) Latinos in census data could be undercounted because of legal status. Despite these potential errors, for most CWSs, sources fell within the same census block groups that overlapped with service area boundaries of CWSs. And, for 9 of the 10 systems in the high-nitrate category, all sources were in the same census block groups as those included in each CWS service area [see Supplemental Material (http://dx.doi.org/10.1289/ehp.1002878)]. Additional sources of error include possible misclassification of points of entry to the distribution system because of errors in PICME. Furthermore, because the relative flow of different sources contributing to each CWS was not known, our method may have over- or underestimated average nitrate levels. However, at least among CWSs with average concentrations over the MCL, the estimated concentrations were similar to the measured concentrations for which that CWS received one or more MCL violations. Our measure of exposure was limited by data availability, so for systems with fewer samples tested for nitrates, our estimate may be less accurate. Although the number of persons potentially exposed to nitrate over the MCL is small, it is likely to be an underestimate of the actual population affected in the San Joaquin Valley. This is partly because our study underrepresented smaller CWSs, and partly because we used average rather than maximum nitrate levels or other measures of nitrate (e.g., MCL violations). Thus, our estimate is likely to be a conservative measure of potential exposure. The estimate of the PEP may also contain some error, because there may be some differences among utilities in how population estimates are calculated. Finally, although our results are based on data that are 10 years old, we believe that, at a minimum, they capture current trends in the San Joaquin Valley because nitrate concentrations generally

Table 2. Demographic profile of total PEP[a] in study sample by average level of nitrate concentration.

Variable of interest	Nitrate level		
	Low	Medium	High
Percent total population (n = 2,948,346)	84.6	15.2	0.2
Percent Latino (n = 1,164,714)	39	40	50
Percent non-Latino people of color (n = 389,336)	13	12	6
Percent white (n = 1,394,296)	47	48	44

Low is less than one-half the MCL of 45 mg NO_3/L; medium is one-half the MCL up to the MCL (22.5 mg/L to 44.9 mg/L NO_3); high is equal to or greater than the MCL.
[a]Per water system, PEP is the population count of the demographic variable of interest x (number of point-of-entry sources in one of three nitrate levels ÷ by the total number of point-of-entry sources). PEP displayed in table is equal to the sum across all water systems. This value can also be interpreted as the estimated number of people served water at this level.

Table 3. Regression for factors associated with nitrate concentration (mg NO_3/L) in CWSs, with beta coefficients, 95% CIs, and levels of significance.

Variable	Model A[a]	Model B[a]	Model C[b]	Model D (< 200 con.)	Model E (≥ 200 con.)
Constant	14.2 (9.1 to 19.4)#	27.1 (16.3 to 38.0)*	6.3 (–11.4 to 24.0)	10.8 (–32.3 to 53.9)	3.2 (–15.5 to 21.9)
Percent Latino	0.14 (0.04 to 0.24)#		0.04 (–0.08 to 0.16)	0.44 (0.03 to 0.84)**	–0.01 (–0.12 to 0.10)
Percent non-Latino people of color	–0.18 (–0.62 to 0.25)		–0.15 (–0.47 to 0.18)	–0.44 (–1.1 to 0.27)	–0.13 (–0.45 to 0.18)
Percent home ownership		–0.15 (–0.30 to 0.003)*	–0.16 (–0.33 to 0.002)*	–0.15 (–0.64 to 0.33)	–0.10 (–0.27 to 0.07)
Incorporated			–4.4 (–9.3 to 0.56)	–2.9 (–31.8 to 25.9)	–4.1 (–9.3 to 1.1)
Groundwater or combined[c]			9.7 (4.3 to 15.2)#	NA	11.7 (7.9 to 15.4)#
Private non-PUC regulated[d]			2.7 (–5.4 to 10.9)	5.5 (–2.7 to 13.7)	–0.23 (–4.5 to 4.1)
Public[d]			7.2 (2.8 to 11.5)#	10.3 (–17.4 to 38.0)	7.3 (3.6 to 11.1)
< 200 service connections			9.1 (–2.5 to 20.7)	NA	NA
Valley floor			7.9 (1.6 to 14.2)**	1.7 (–12.0 to 15.4)	7.4 (1.0 to 13.9)
2000[e]			1.3 (–0.44 to 3.1)	5.0 (1.2 to 8.8)#	0.71 (–1.1 to 2.6)
2001[e]			1.4 (–0.26 to 3.1)*	5.5 (1.9 to 9.1)#	0.67 (–0.98 to 2.3)
Summer/fall			1.3 (–0.30 to 2.9)	3.2 (0.31 to 6.3)**	1.1 (–0.72 to 3.0)

NA, not applicable, because no CWS in this model run contains this factor, or all CWSs have this factor. Data are regression statistics with robust SEs, clustered by CWSs. Coefficients represent the estimated difference in mean concentration at the system level associated with a unit change in the covariate (95% CI). Empty cells indicate that the unadjusted model included only the key variables of interest.
[a]Unadjusted models, all CWSs included. [b]Adjusted model, all CWSs included. [c]Surface water is referent category. [d]Privately owned PUC-regulated CWSs are referent category. [e]1999 is referent year. *$p < 0.10$. **$p < 0.05$. #$p < 0.01$.

change slowly in deeper public supply wells and have been increasing in most locations because of increasing fertilizer use (Dubrovsky et al. 2010).

Conclusion

Our study is one of the first to analyze the relationships between drinking water contamination, race/ethnicity, and SES in the United States and the first that focuses on social disparities in nitrate contamination. Our results indicate that Latinos in the San Joaquin Valley may be disproportionately exposed to higher levels of nitrates and that this exposure is particularly prevalent in smaller water systems. With the increasing use of nitrogen-based fertilizers and growing demand for groundwater, these trends are likely to worsen in future years. Regulatory and policy strategies to address scale-related vulnerabilities in drinking water quality have generally ignored the environmental justice implications for CWSs. Given the U.S. EPA's renewed focus on environmental justice (U.S. EPA 2009) and the paucity of environmental justice studies on drinking water, this study highlights the importance of targeting funding for mitigation and source water protection efforts for underserved communities and those with nitrate levels over the MCL. Furthermore, there is a need for resources to better monitor water quality and develop precautionary mitigation for communities with nitrate levels > MCL/2.

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EXHIBIT D

Balazs et al. Environmental Health 2012, 11:84
http://www.ehjournal.net/content/11/1/84

ENVIRONMENTAL HEALTH

RESEARCH Open Access

Environmental justice implications of arsenic contamination in California's San Joaquin Valley: a cross-sectional, cluster-design examining exposure and compliance in community drinking water systems

Carolina L Balazs[1*], Rachel Morello Frosch[2,3], Alan E Hubbard[2] and Isha Ray[1]

Abstract

Background: Few studies of environmental justice examine inequities in drinking water contamination. Those studies that have done so usually analyze either disparities in exposure/harm *or* inequitable implementation of environmental policies. The US EPA's 2001 Revised Arsenic Rule, which tightened the drinking water standard for arsenic from 50 μg/L to 10 μg/L, offers an opportunity to analyze both aspects of environmental justice.

Methods: We hypothesized that Community Water Systems (CWSs) serving a higher proportion of minority residents or residents of lower socioeconomic status (SES) have higher drinking water arsenic levels and higher odds of non compliance with the revised standard. Using water quality sampling data for arsenic and maximum contaminant level (MCL) violation data for 464 CWSs actively operating from 2005–2007 in California's San Joaquin Valley we ran bivariate tests and linear regression models.

Results: Higher home ownership rate was associated with lower arsenic levels (ß coefficient= −0.27 μg As/L, 95% (CI), 0.5, 0.05). This relationship was stronger in smaller systems (ß coefficient= −0.43, CI, 0.84, 0.03). CWSs with higher rates of homeownership had lower odds of receiving an MCL violation (OR, 0.33; 95% CI, 0.16, 0.67); those serving higher percentages of minorities had higher odds (OR, 2.6; 95% CI, 1.2, 5.4) of an MCL violation.

Conclusions: We found that higher arsenic levels and higher odds of receiving an MCL violation were most common in CWSs serving predominantly socio economically disadvantaged communities. Our findings suggest that communities with greater proportions of low SES residents not only face disproportionate arsenic exposures, but unequal MCL compliance challenges.

Keywords: Revised arsenic rule, Arsenic, Drinking water, Social disparities, Environmental justice, Water systems, Safe drinking water act, Exposure

* Correspondence: carolinabalazs@berkeley.edu
[1]Energy and Resources Group, University of California, Berkeley, CA 94720, USA
Full list of author information is available at the end of the article

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Background

Arsenic in drinking water is linked to skin, lung, bladder and kidney cancers [1-3]. The most common exposure pathway is consumption of groundwater containing arsenic [4]. Many epidemiological studies examining health effects of arsenic in drinking water have been conducted in areas with extremely high levels (i.e., > 100 μg As/L)—such as Argentina, Bangladesh and Taiwan. But high concentrations (i.e., 50–100 μg As/L) also occur in the U.S, especially in western regions such as Utah, Nevada, Arizona and California [5-8]. Here, arsenic in groundwater is generally naturally occurring, but can also derive from agricultural activities including pesticide application and industrial uses (e.g. wood treatment) [4,9]. In California's San Joaquin Valley, arsenic can reach elevated concentrations due to mobilization caused by agricultural activities. In particular, irrigation and drainage enhance arsenic releases, while high evapotranspiration rates can concentrate arsenic in surface water and shallow groundwater [4,10,11].

In 2001, on the basis of epidemiologic evidence and cost-benefit considerations [12] the U.S. Environmental Protection Agency (EPA) issued the Revised Arsenic Rule, reducing allowable arsenic concentrations in drinking water from 50 μg/L to 10 μg/L. The revision of this drinking water standard came with much debate. Critics of the standard argued that there was uncertainty in the risk assessment, and that the cost-benefit analyses overestimated benefits in relation to costs of compliance. Ultimately, however, the EPA's Science Advisory Board and the National Research Council (NRC) concluded that the science was sufficient to warrant a more health-protective standard [12-14].

The revised rule elicited considerable discussion regarding equity considerations for small water systems [15,16]. Of the estimated 5.5% of community water systems that were expected to be affected by the Revised Arsenic Rule, nearly 97% were small systems serving fewer than 10,000 customers [17]. Benefit-cost analyses concluded that although there would be a net benefit for households, the average annual compliance costs for residents served by smaller systems would be much greater. Recognizing this discrepancy, the US EPA extended the compliance date by two years for systems serving fewer than 10,000 customers, assessed alternative affordable technologies for small systems and focused on analyzing additional impacts that would be felt by these systems [14]. Effective in 2002, the Revised Arsenic Rule required all public water systems to comply with the new standard by January 23, 2006 [14].

Besides these scale-related considerations, however, little attention was given to other potential social disparities that could arise in, for example, exposure to arsenic, or the types of small systems that would be able to comply with the revised standard. In response, several environmental justice-oriented studies explored potential inequities in exposure to arsenic [18,19] and in enforcement of the arsenic standard [5]. Generally, these studies focused on two types of distributional issues: (1) disparities in environmental harms, such as exposure to contaminants, or disparities in health outcomes, and (2) disparities in the inequitable implementation of policies and programs, including access to federal funds or capacity to comply.

Attention to both components of environmental justice is certainly warranted. We argue, however, that a joint focus – on compliance challenges as well as exposure to contaminants – is most helpful for understanding the health and social implications of drinking water policies, including the Revised Arsenic Rule. Quantifying a water system's compliance with the arsenic MCL is important to know which systems are in violation, and to consider whether they are equipped to comply. This "compliance burden" allows for an exploration of whether certain groups or communities have unequal abilities in the capacity to meet the standard. Quantifying exposure levels and their distribution is important, given known health risks at levels even below the new standard. Thus this study employs what we term a "joint burden analysis," to analyze the environmental justice implications of compliance capacity and exposure related to arsenic contamination. Together, these analyses provide a picture of the joint burdens that water systems and residents may face.

We applied a cross-sectional analysis of social disparities related to the Revised Arsenic Rule. We conducted our study in California's San Joaquin Valley, one of the poorest regions in the country with some of the most contaminated drinking water sources in California [20], including high nitrate and high arsenic levels [21]. We focused on community water systems (CWSs), which are public water systems that serve at least twenty five customers or fifteen service connections year-round [22]. We hypothesized that CWSs serving a higher proportion of minority or lower socioeconomic status (SES) residents have a higher odds of non-compliance with the revised arsenic standard and that these CWSs serve drinking water with higher levels of arsenic.

Our analysis provides two contributions to the arsenic and drinking water literature. By assessing exposure disparities and compliance burdens at the time of the enactment of the Revised Arsenic Rule, we assess the potential exposure and compliance disparities that existed but were not fully incorporated into policy assessments. Secondly, we consider the compliance challenges that CWSs could face moving forward, broadening the discussion of policy implementation issues that must be considered by drinking water regulators and the US EPA.

Given the U.S. EPA's renewed discussion of the impact of the Revised Rule on small systems, and on how to help small systems achieve compliance, the results of this study are timely for policy circles as well. For example, the U.S. EPA recently convened a working group on arsenic in small water systems to provide input on barriers to the use of point-of-use and point-of-entry treatment units, as well as alternative affordability criteria that pay particular attention to small, rural, and lower income communities [23]. Our study's quantitative analysis of the distribution of exposure and compliance burdens therefore adds to the environmental justice literature and informs these policy discussions.

Methods

Sample selection and selection of point-of-entry sources

We selected CWSs located in California's San Joaquin Valley that were actively operating between 2005 and 2007, had at least one source with a geographic coordinate that could be used to estimate customer demographics, and had at least one active point-of-entry source with an arsenic sample reported during this period. These selection criteria resulted in a slight under-representation of smaller systems (i.e., < 200 connections) in our final sample (see Additional file 1: Table A1). Our time period represents one full compliance period under the SDWA, in which each CWS should have taken at least one arsenic sample [24].

Point-of-entry sources are those that directly enter the distribution system. We selected two types of point-of-entry sources: (1) sources in active use that had no arsenic treatment, or that treated for contaminants other than arsenic, and (2) treatment plants in active use that potentially treated for arsenic (Additional fle 2: Figure A1). We used the California Department of Public Health's (CDPH) Permits, Inspections, Compliance, Monitoring and Enforcement (PICME) database [25] to identify source types, their location in relation to the distribution system, and their possible treatment techniques. We confirmed the existence of arsenic treatment technologies with state and county regulators.

For the six CWSs with confirmed arsenic treatment plants that were in use during the study period, we used all point-of-entry sampling points prior to installation of treatment, and only sampling points from treatment plants after the installation date. For CWSs with no confirmed arsenic treatment, we selected systems where either all point-of-entry sources were labeled as untreated, or all point-of-entry sources were labeled as having treatment. In practice a CWS may have both treated and untreated sources. But because the CDPH databases did not allow us to accurately ascertain whether untreated sources entered the distribution system if treated sources were also available, we conservatively selected CWSs in this manner. We tested the sensitivity of this decision by comparing regression results using our final sample to results using all CWSs. Our final sample included 464 of the 671 CWS active in the Valley from 2005 to 2007.

Outcome measures and independent variables

In order to assess compliance with the Revised Arsenic Rule (i.e., MCL violations) and exposure burdens, we conducted two main sets of analyses: one focused on MCL violations, the other on exposure. Specifically, for each CWS, we derived four main outcome measures: (1) officially recorded arsenic MCL violations, (2) average system and source-level arsenic concentrations, (3) population potentially exposed to arsenic, and (4) water quality samples of arsenic concentrations at point-of-entry to the distribution system. We used the first measure to analyze compliance. We used the second two measures to derive descriptive exposure statistics and run sensitivity analyses. We used the fourth measure as the outcome variable in a linear regression model. We calculated average arsenic measures because (1) the MCL for arsenic is assessed using running annual average of arsenic concentrations for water systems; and (2) this MCL is based on a consideration of long-term chronic exposure making the average concentration of arsenic a suitable metric.

Arsenic MCL violations

The key outcome for our compliance analysis was officially recorded arsenic MCL violations derived from the PICME database. We created a binary variable indicating whether a system had received at least one MCL violation during the study period. This measure helped control for bias that could occur because CWSs with higher arsenic levels are required to sample more frequently [26], thereby increasing the probability that they would receive more MCL violations.

Average system and source-level arsenic concentrations

To estimate arsenic concentrations in the distribution system we used arsenic water quality sampling data for the selected point-of-entry sources from CDPH's Water Quality Monitoring database [27] (Additional file 2: Figure A1). Previous studies have noted the benefit of using such publicly available water quality monitoring records as an alternative to costly tap water samples [28]. Using these data points, we derived the average arsenic concentration served by each CWS for the entire compliance period. We calculated this by averaging the average source concentrations for each system during our time period. As in previous studies [5,19], we assumed average system-level concentrations represent the average arsenic concentration in water served to residents. We also calculated each CWS's yearly average arsenic concentration to conduct sensitivity analyses. Because we did not have flow

measurements for individual sources, we assumed that each point-of-entry source contributed independently, constantly and equally, to a CWS's distribution system, regardless of season. For sampling points below the detection limit, we took the square root of the detection limit as a proxy for the arsenic concentration [29].

We categorized source-level and system-level averages into three concentration categories defined in relation to the revised arsenic rule (> 10 μg As/L) and the old rule (> 50 μg As/L): (1) < 10 μg As/L ("low"), (2) 10–49.9 μg As/L ("medium"), and (3) ≥ 50 μg As/L ("high"). In addition, we used average source and system-level concentrations to create binary variables that we used in bivariate analyses. Here, average levels were coded as 1 (≥ 10 μg As/L), or 0 (< 10 μg As/L).

Potentially exposed population

Using a previously developed method [30] described in Balazs et al. [31], we computed the population potentially exposed to the three aforementioned exposure categories. The approach to calculate the potentially exposed population (PEP) for the high-arsenic category is summarized by the following equation:

$$PEP_h = \sum_{i=1}^{464} (X_i \times s_{ih}/S_{it}) \quad (1)$$

where X_i is the total population served in CWS i; s_{ih} is the number of sources for CWS i with average arsenic concentrations classified as high (h); and S_{it} is the total number of point-of-entry sources for CWS i. To calculate the PEP for the low (l) or medium (m) categories, we replaced s_{ih} with s_{il} or s_{im}, respectively. We used PICME data on the number of people served by each CWS to calculate the population size. If the number of customers served by a CWS was not available from the PICME database, we used information from the Water Quality Monitoring database. To estimate counts of potentially exposed individuals according to demographic characteristics (e.g. race/ethnicity) we multiplied the PEP in each arsenic category for each CWS by the estimated proportion of customers in each demographic subgroup for the CWS (e.g. 50% people of color), and then summed these counts across all CWSs for each arsenic category.

Concentration of arsenic at point-of-entry

Arsenic sampling data for each point-of-entry source were used as the outcome variable in our regression model, as described under "Regression Model" below.

Analyses

Compliance analyses

We used our binary arsenic MCL violation variable to analyze whether CWSs with higher fractions of people of color or lower SES faced greater compliance violations. Because only 34 CWSs had at least one MCL violation we did not have enough outcomes to use multivariate regression techniques. Instead we ran Fisher's Exact tests for contingency tables, comparing the presence of at least one MCL violation to CWSs with high or low levels of our variables of interest (i.e. race/ethnicity or homeownership). To determine the threshold for high and low levels of race/ethnicity (i.e., percent people of color) or homeownership rate we used the median value of these variables.

To consider the impact of under- or mis-reported violations, we ran sensitivity analyses in which we replaced official MCL violations with the number of CWSs with any source whose average yearly arsenic concentrations exceeded the MCL during the study period, and the number of CWSs with any source whose compliance period average exceeded the MCL. This allowed for an approximation of whether a system may have exceeded the MCL (and so should have been issued an MCL violation) since arsenic MCL violations are based on a running annual average [26]. Thus these sensitivity analyses should capture differences due to MCL exceedances that went under-reported.

Exposure analyses

To assess the relationship between demographics of customers served by CWSs and potential exposure, we first examined the demographic characteristics of the population potentially exposed to three different arsenic levels, and additional characteristics of the systems at those levels. To further analyze the relationship, we used our binary variables for average system-level arsenic concentrations to conduct Fisher's Exact tests.

Finally, we examined the relationship between system-level demographics and arsenic levels using our continuous measure of arsenic concentrations. We used a linear cross-sectional regression model with robust standard errors to account for clustering. To derive the inference, we clustered outcomes at the CWS-level (i.e. point-of-entry arsenic concentrations measured on a given day for a given source). Our final model reported sandwich-type robust standard errors [32] that allowed for arbitrary correlation, including correlation within CWS units. The a priori selected model controlled for known or hypothesized potential system-level confounders.

The model's outcome variable, $Y_{ijk,}$ was arsenic concentration for the i^{th} water system, the j^{th} source in system i, on day k (since January 1st, 2005). While arsenic samples from individual sources were our outcome measurements, the CWS was the primary unit of analysis, consistent with other calculations above. Our final model did not re-weight CWSs with more samples; thus systems with more

measurements contributed more to the estimates. We addressed this issue by stratifying by system size to see if smaller CWSs (with fewer samples) had a different effect on water quality than larger CWSs.

Key independent variables were the percentage of people of color served by CWSs (referent category non-Latino whites) and percent home ownership in each CWS. Home ownership rate is a proxy metric for wealth and political representation [33]. We used this SES measure as an indicator of the economic resources available to a water system to mitigate contamination [34]. Race/ethnicity and home ownership data were derived from the 2000 U.S. Census, measured at the CWS-level, and assumed to be constant for all three years [35]. Since CWS service areas do not follow Census boundaries we used a spatial approach in Geographic Information Systems (GIS) to estimate demographic variables for each CWS. In brief, for each CWS, we estimated a population-weighted average of each variable across all block groups that contained sources for the CWS. This value was used to derive a percent estimate of demographic characteristics (e.g. 50% homeownership) served by that CWS [31].

We controlled for other potentially confounding water system characteristics including: source of water (ground water or groundwater and surface water versus surface water alone); system ownership (public, privately owned and not regulated by the Public Utility Commission (PUC), with private PUC-regulated as referent category); geographic location (Valley floor and foothills, with mountains as referent category); season (summer/fall or winter/spring); year of sampling (2006 and 2007, with 2005 as referent category); and number of service connections (< 200 or ≥ 200 connections). We determined ownership structure by combining data in PICME with data from the PUC's list of regulated systems. We obtained all other characteristics from PICME. With the exception of year and season, all covariates were measured at the water system level.

We stratified by system size to assess if demographic effects on water quality might be stronger among smaller systems, and to test the hypothesis that scale alone explains water quality. We used number of connections as a threshold for small versus large CWSs, where those with fewer than 200 connections are considered "small" [26]. We used our final model to estimate the amount of arsenic contamination attributable to the proportion of the population that are homeowners by predicting expected values for each observation if percent homeownership equaled 100%, as described by Greenland and Drescher [36]. All statistical analyses were conducted using Stata v10 (College Station, Texas). We used Stata's cluster command to derive robust standard errors.

Results

Descriptive statistics

The 464 CWSs in our study sample served 1.134 million people, representing 37% of the total population served by CWSs between 2005 and 2007, and 69% of all CWSs active through 2007 (Table 1). The mean percentage of people of color served by each CWSs was 39% [inter-quartile range (IQR), 16-57%]. The mean percent of homeownership was 70% (IQR, 60-81%). The yearly average arsenic concentration in 2005, 2006 and 2007 was 7.0 μg/L (median = 3 μg/L) 7.9 μg/L (median = 2.5 μg/L), respectively and 6.8 μg/L (median = 3 μg/L), respectively. Approximately 12% of samples were below the detection limit.

Nearly 15% of all CWSs in the sample had average arsenic concentrations between 10 and 50 μg As/L, and were therefore affected by the revised standard (Table 2). Among these, 66% had fewer than 200 connections, and 86% had three active wells or less. For each CWS with average arsenic in this range, the average percentage of a CWS's sources that exceeded the revised MCL was 87% (Table 2). Less than 1% of CWSs had average levels greater than 50 μg As/L. Among these, all had fewer than 200 connections. CWSs west of Highway 99 and in the central portion of the Valley had higher arsenic levels, as did some areas in the foothills and in southeastern Kern County (Figure 1).

Of the population served in our sample, approximately 14% was potentially exposed to arsenic levels over 10 μg/L MCL (Table 3). Of the population potentially exposed to 10–50 μg As/L, 61% were people of color (i.e. Latinos and non-Latino people of color). This is higher than the corresponding percentage in the entire study sample (i.e., 55%, Table 1).

Statistical analyses

Compliance analyses: MCL violations

Thirty-four CWSs, serving 151,391 people, received at least one arsenic MCL violation during the study period. Of these, 31 had average system-level arsenic concentrations over 10 μg As/L and 3 had average concentrations of 8, 8.8 and 9.9 μg As/L. CWSs serving higher percentages of homeowners had a 67% lower chance of having at least one MCL violation (Table 4). CWSs serving higher percentages of people of color had a 260% higher chance of having at least one MCL violation. Sensitivity analyses in which we used average source-level concentrations were consistent, yielding results of similar strength and direction (see Additional file 3: Table A2).

Binary measure of exposure

CWSs serving higher percentages of homeowners had a 57% lower chance of having average arsenic levels above the revised MCL (Table 5). CWSs serving higher

Table 1 Characteristics of community water systems (CWSs) in study sample compared to all CWSs in study region with geographic coordinates, 2005-2007, San Joaquin Valley, CA

Variable of interest	Active CWS with geographic coordinates n = 644	CWS in study: active, w/ coordinates and arsenic samples n = 464	CWS in study: < 200 connections n = 324	CWS in study: ≥ 200 connections n = 140
Total population (count)	3,037,785	1,134,017	49,340	1,084,677
Population Characteristics (%)				
People of Color (Latinos and Non Latinos)	53	55	38	56
White population	47	45	62	44
Population above poverty[a]	57	54	60	54
Water System Characteristics (%)				
Mean People of Color	42	39	35	50
Mean Home Ownership	67	70	72	67
Population served (mean/median)	4,717/163	2,444/180	152/100	7,748/2537
Incorporated [b]	10	9	1	29
< 200 Connections	72	70	100	0
Groundwater Alone (GW)[c]	88	92	95	87
GW and surface water[c]	7	4	2	9
Publicly owned[d]	32	32	13	75
Privately owned non PUC reg.[d]	60	61	80	16
Water Quality Characteristics				
Min Max; mean (μg As/L)	NA	0 158; 6.0	0 158; 6.2	0 42; 57
IQR (μg As/L)	NA	1.4, 6.3	1.4, 6.2	1.4, 7.3
CWS with ^{3}1 As MCL Viol	44	34	15	19

NA not applicable because not all active sources had arsenic samples, *IQR* interquartile range.
[a] Above 200% the poverty level; [b] A water system that serves a city that is a legally recognized municipal corporation with a charter from the state and governing officials that is incorporated, as opposed to a water system that serves an unincorporated area; [c] Reference group=surface water only; [d] Reference group=privately owned and Public Utility Commission (PUC) regulated or unknown.

percentages of people of color had a 130% higher chance of having average arsenic levels above the revised MCL.

Absolute measure of arsenic exposure

Results from the multivariate regression model examining the relationship between CWS demographics and absolute arsenic concentrations generally parallel descriptive findings. Unadjusted models had beta coefficients of –0.14 (95% Confidence Interval (CI), -0.34, 0.06) for homeownership, and –0.01 for percentage of people of color (95% CI, -.11, 0.08). Our adjusted model had a beta-coefficient of –0.27 (95% CI, -0.50, -0.05) for

Table 2 Characteristics of community water systems (CWSs) at three average arsenic levels, 2005–2007, San Joaquin Valley, CA

	Average arsenic concentration		
CWS characteristics	**< 10 μg/L**	**10 49.9 μg/L**	**≥ 50 μg/L**
% CWS	84.5	14.6	0.9
Mean Population Served (median)	2496 (180)	2277 (200)	127 (64)
% Privately owned, non PUC Regulated	61	59	100
% < 200 Connections	70	66	100
Range of Mean Arsenic (μg As/L)	0 9.9	10.1 41.7	59.5 158
Mean μg As/L (Median)	3 (2)	19 (16)	97 (85)
Mean % of Sources > MCL (IQR)	.1 (0,0)	87 (75, 100)	100 (100, 100)
CWSs with arsenic treatment plant	2	4	0

IQR Interquartile range, *PUC* Public Utility Commission.

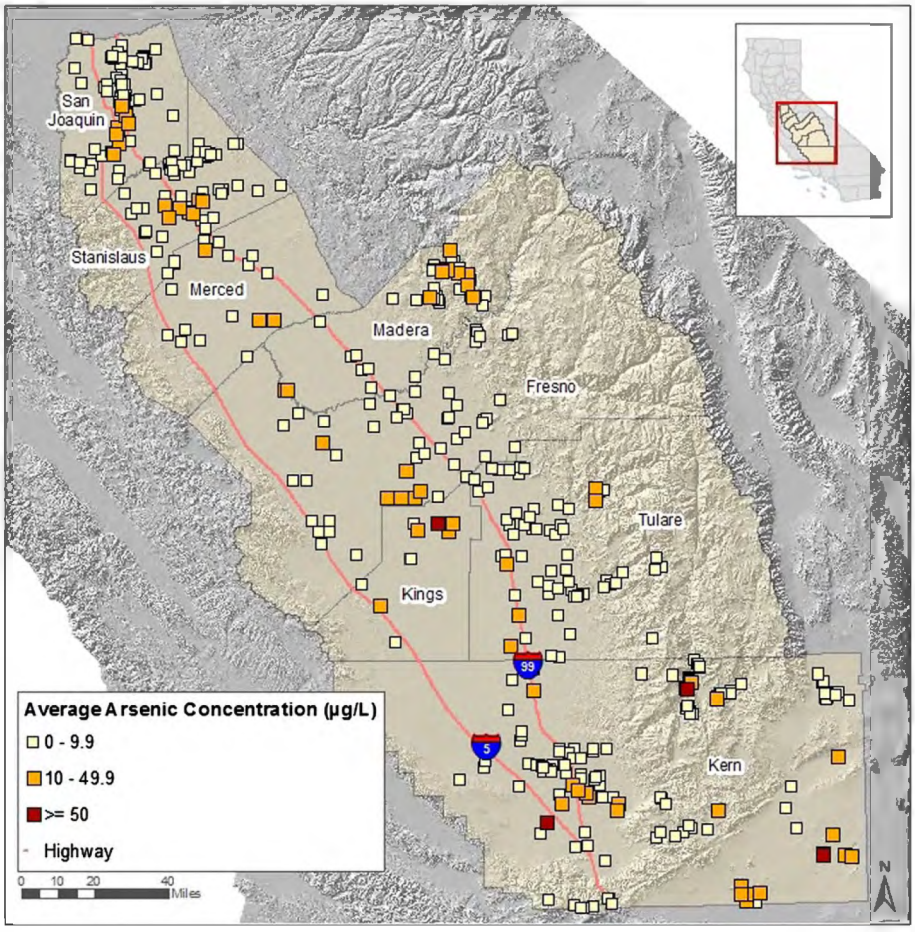


Figure 1 Average arsenic concentration[a] of community water systems (CWS [b,c]) in study sample, (n = 464), 2005 2007. [a] Estimate based on average of each point of entry source's average concentration; [b] Sources of data: CDPH Water Quality Monitoring and PICME databases (CDPH 2008a,b); [c] Approximate location of CWSs are depicted, but not true boundaries. Due to close proximity of some CWSs, map partially covers some CWSs.

homeownership. This suggests that, on average, a 10% decrease in homeownership was associated with a 2.7 μg As/L increase, or roughly one third the mean arsenic concentration across all CWSs (6.0 μg As/L, see Table 1). The beta coefficient for percentage people of color was −0.02 (95% CI, -0.13, 0.09). This suggests that a 10% increase in the percentage of people of color served by a CWS was associated with an increase of .2 μg As/L, though this association was not statistically significant.

Results from our stratified model (Table 6) suggest similar, but stronger, trends among smaller systems. Among systems with less than 200 connections, the beta coefficient for homeownership was −0.43 (95% CI, -0.84, -0.03). This suggests that, on average, a 10% decrease in homeownership is associated with a 4.3 μg As/L increase, or nearly 70% of the mean arsenic concentration across all CWSs. The beta coefficient for percentage people of color was −0.17 μg As/L (95% CI, -0.36, 0.02), although this result was not statistically significant. In systems with at least 200 connections, the coefficients on percent homeownership and people of color were −0.19 (95% CI, -0.40, 0.02) and 0.03 (95% CI, -0.09, 0.15), respectively; neither of these results was statistically significant. Using this final stratified model to predict expected values, we estimated that arsenic levels in

Table 3 Demographic profile of potentially exposed population (PEP [a]) by average arsenic levels, 2005–2007, San Joaquin Valley, CA

Population characteristics	Average arsenic concentration		
	< 10 μg/L	10 49.9 μg/L	≥ 50 μg/L
% Total Population (1,134,017)	86.1	13.7	0.2
% People of Color[b]	54	61	24
% Non Latino White	46	39	76

[a] Per water system, PEP = population count of demographic of interest x (# of sources in one of three arsenic level/total # of sources sampled). PEP displayed in table is equal to sum across all water systems. This value can also be interpreted as the estimated number of people served water at this level.
[b] People of color refer to both Latino and non Latino people of color.

Table 4 Fisher's exact tests and related odds ratio (OR) for maximum contaminant level (MCL) violations, 2005–2007, San Joaquin Valley, CA

Variable of interest	≥ 1 MCL violation	No MCL violation	OR (95% CI)	P value
High % Homeownership	12	269	.33 (.16, .67)	.003
Low % Homeownership	22	161		
High % People of Color	24	207	2.6 (1.2, 5.4)	.01
Low % People of Color	10	223		

Fisher's Exact test compares high and low category for variable of interest, where threshold is determined by median value across all CWS, and includes related odds ratio. Test compares demographics in community water systems that received at least one MCL violation to those with zero violations.

CWSs with 100% home ownership would be, on average, 3.1 μg As/L lower, compared to CWSs at the mean.

Discussion

This study analyzed demographic differences in exposure and compliance burdens associated with the Revised Arsenic Rule in the San Joaquin Valley. We found that communities with lower rates of home ownership and greater proportions of people of color had higher odds of having an MCL violation. We also found a negative association between homeownership rates and arsenic concentrations in drinking water, with a stronger effect among smaller CWSs. These results indicate that communities with fewer economic resources faced a dual burden—they were not only exposed to higher arsenic levels, but were also served by systems more likely to receive an MCL violation.

Nearly 14% of the population in the study sample was potentially exposed to average arsenic levels above the revised standard, highlighting the health risks faced by Valley residents. At the revised level, cancer risks are estimated to be 12 in 10,000 and 23 in 10,000 for bladder cancer among women and men, respectively, and 18 in 10,000 and 14 in 10,000 for lung cancer, among women and men [12]. While we did not find a significant association between race/ethnicity and arsenic levels, a disproportionate number of the population potentially exposed to levels of 10 μg As/L or more were people of color. This indicates that as a whole, this group may still face disproportionate exposure.

Our results are consistent with previous findings that CWSs with higher arsenic levels serve customers with lower income levels [19]. Our results differ somewhat from a previous study [5] that found that while percent Latino was positively associated with the likelihood of exceeding the arsenic MCL, so was high SES. This difference could be due to differences in trends across states (i.e. Arizona vs. California), our additional measurements of exposure and compliance, or our focus on CWSs rather than all public water systems.

Study limitations

Some limitations in our study are worth noting. As noted, the selection criteria we used (source location and arsenic samples) led to a slight under-representation of smaller systems in our final sample. Because the smallest systems had slightly higher arsenic levels and serve higher percentages of people of color and homeowners, this selection bias could also lead to an underestimate of our observed associations.

There are also several potential sources of measurement error in our dependent and independent variables. Under-reporting or under-issuing of violations could impact the count of MCL violations. However, sensitivity analyses comparing MCL violations in our final sample to results including all CWSs yielded consistent results. Similarly, sensitivity analyses comparing results using the binary MCL variable to binary measures that used average source-level concentrations were similar. Because of this consistent negative relationship between SES and each of these measures, we expect minimal impact on our results due to this potential under-reporting. This does not, however, explain why 41 CWSs (out of 72) had average system-level concentrations above the MCL but had no violation recorded; this may be related to selective enforcement and is worth further investigation.

Table 5 Fisher's exact tests and related odds ratio (OR) for average arsenic level, 2005-2007, San Joaquin Valley, CA

Variable of interest	≥ 10 μg As/L	< 10 μg As/L	OR (95% CI)	p value
High % Homeownership	28	233	.45 (.25, .72)	.002
Low % Homeownership	44	159		
High % People of Color	35	162	1.3 (.81, 2.2)	.3
Low % People of Color	37	230		

Fisher's Exact test compares high and low categories of the variable of interest to CWSs whose average arsenic was above or below the revised MCL. The threshold for the variable of interest is determined by median value across all CWS, and includes related odds ratio. Test compares demographics for community water systems whose average arsenic was above or below the revised MCL.

Table 6 Regression† for factors associated with arsenic concentration (μg/L) in community water systems (CWS), 2005-2007, San Joaquin Valley, CA (n=464)

Variable	Model A[a]	Model B[a]	Model C[b]	Model D (< 200 Conections)	Model E (≥ 200 Connections)
Constant	20.0 (6.7, 33.3)	11.2 (6.1, 16.4)	9.7 (11.8, 31.3)	18.2 (11.9, 49.1)	8.7 (11.7, 49.1)
% People of Color		0.01 (0.11, 0.08)	0.02 (.13, 0.09)	0.17* (0.36, 0.02)	.03 (0.09, 0.15)
% Home ownership	.14 (0.34, 0.05)		0.27** (0.50, 0.05)	0.43** (0.84, 0.03)	.19* (0.40, 0.02)
Groundwater or combined[c]			11.4*** (7.5, 15.2)	11.5*** (6.1, 16.9)	8.4*** (4.2, 12.6)
Private non PUC regulated[d]			5.6* (1.0, 12.2)	8.5** (0.73, 16.3)	1.2 (5.4, 7.9)
Public[d]			6.9** (0.61, 13.11)	7.5* (0.76, 15.8)	6.4* (0.99, 13.8)
< 200 service connections			2.6 (1.2, 6.5)	na	na
2006[e]			2.8** (0.52, 5.1)	4.4** (0.27, 8.4)	1.8 (.76, 4.3)
2007[e]			1.2 (0.51, 2.9)	2.4* (0.11, 4.9)	.52 (1.8, 2.9)
Summer/fall			.27 (1.9, 1.4)	.43 (3.1, 4.0)	.27 (2.1, 1.5)
Valley [f]			1.4 (6.5, 3.7)	6.4 (2.3, 14.9)	4.4 (10.6, 1.8)
Foothills [f]			6.9* (0.32, 13.5)	12.1*** (3.9, 20.4)	5.1 (1.0, 11.3)

†Regression with robust standard errors, clustered by CWS. Coefficients represent the estimated difference in mean concentration at the system level associated with a unit change in the covariate (95% CI); na=not applicable, as no CWSs in this model run contains this factor, or all CWSs have this factor.
[a]Unadjusted models, all CWSs included; [b]Adjusted model, all CWSs included; [c] Surface water is referent category; combined refers to combination of groundwater and surface water sources; [d]Privately owned PUC regulated CWS as referent category; [e] 2005 is referent year; [f] Mountains is referent category.
* p < .10, ** p < .05, *** p < .01; R^2 in Model B = .08; R^2 in Model C = .09.

There may also be some misclassification of points-of-entry into the distribution system. However, sensitivity analyses, including and excluding CWSs with treated and untreated point-of-entry sources yielded consistent regression coefficients for home ownership. While results for estimated exposure and compliance burdens are nearly five years old, we believe that, at a minimum, they capture current trends because unless CWSs have installed treatment plants or are using water from new wells (which is unlikely for small systems), temporal variability of arsenic levels is likely to be small [37]. Since our study focused only on CWSs, which excludes private well owners and communities with fewer than 15 service connections, the estimated number of potentially exposed people and impacted systems is likely to be an underestimate.

There may be errors in our demographic estimates, as we had to use data from the U.S. Census 2000 to approximate demographics between 2005 and 2007. There could also be error in our demographic estimates from: (1) surface intakes/well fields falling in Census block groups not served by the CWS, (2) not all Census block groups served by a CWS having an intake/field located within them, and (3) Latinos in Census data being undercounted due to legal status. For the majority of CWSs, sources fell within the same Census block groups that overlapped with the service area boundaries of CWSs [31]. But, because not all source/intake locations fell within block groups that intersect with service area boundaries of CWSs [31], this could lead to misclassification error of our demographic variables. This could result in a bias of the estimated association, but given the relatively small proportion of these systems, and the independence of SES status and inclusion in a linked census block group/water service boundary, this bias will be relatively trivial.

Study implications

In California's San Joaquin Valley, elevated arsenic levels are primarily derived from sedimentary deposits that can be mobilized by groundwater withdrawals and irrigation practices [10,11]. This means that our observed association could be partly explained by the location of low SES communities in relation to these agricultural activities. However, one would not necessarily expect a Valley-wide relationship between low SES and high arsenic levels, since arsenic is largely naturally occurring, and there are other areas in the Valley where low SES systems rely on shallower water.

Instead, our results can be understood as a reflection of the mediating role of system-level capacity. Smaller water systems often lack the economies of scale and resource-base to ensure the technical, managerial and financial (TMF) capacity to reduce contaminant levels [34,38]. They may be less able to install treatment, apply for funding, or drill new wells. The socioeconomic status of residents directly influences TMF capacity, because it affects the ability of a water system to leverage internal (e.g., rate increases) or external (e.g., loans) resources [34]. Thus, CWSs with lower SES customers may have been less able to support adequate TMF or to ensure compliance with the revised arsenic standard by 2007. That four of the six CWSs with treatment had more than 200 connections suggests that larger CWSs (with more resources and greater economies of scale) were

able to comply more quickly with the revised standard, a result supported by previous research and acknowledged by the U.S. EPA [14,38]. Furthermore, that the majority of CWSs with average arsenic concentrations over the revised standard were small and had a high fraction of their wells with high arsenic levels indicates that these systems had few alternative sources of clean drinking water to begin with, making short-term solutions unattainable.

Our joint burden analysis highlights the need to consider not only exposure and current states of compliance, but also the *future* mitigation potential of impacted water systems and the households they serve. We have shown that CWSs with lower SES residents faced the greatest exposure and compliance burdens. Looking forward in time, these same systems may be the least equipped to comply with EPA drinking water standards for three reasons. First, these CWSs are often less able to develop long-term plans to reduce contamination. For example, some low SES communities in the Valley have secured funding to upgrade their infrastructure, but their plans failed to include steps to enter into compliance with the new arsenic standard [39]. Second, low-SES CWSs may be less able to apply for funding. By 2010, 13 of the 72 CWSs in our study with medium and high arsenic levels were not listed as having applied to the State Revolving Fund to help pay for mitigation options [40]. These CWSs were mainly small (< 200 connections) and had lower rates of home ownership (60% vs. 65%, $p < .10$) compared to CWSs that were listed. Funding sources, such as the State Revolving Fund, may further disadvantage small CWSs' efforts to mitigate arsenic exposures and comply with the standard, because they require that systems have adequate TMF capacity to be eligible for funding. Finally, even with funding secured, low-SES water systems with low TMF capacity may be unable to maintain compliance. For example, some CWSs have installed arsenic treatment technologies, only to be forced to shut the plants down because they could not pay for ongoing treatment costs [41].

The combination of the low-SES of residents and low-TMF and compliance ability of CWSs not only impacts mitigation potential and exposure levels, it can also result in significant economic burdens for poorer households. In general, CWSs that are able to mitigate arsenic contamination will incur costs that are passed along to customers. Low-income residents find it hard to pay these higher rates, and may oppose mitigation efforts because of the impact on household budgets [42]. If a CWS cannot mitigate exposure, households may be forced to cope by buying bottled water, creating an additional economic burden. However, low-income residents may forgo such exposure-reduction measures, or only partially implement them [43]. In these cases, if a CWS remains in continuous non-compliance, chronic arsenic exposure risks will be prolonged.

Current debates regarding implementation of the Revised Arsenic Rule have discussed the option of using variances for small water systems, since the Safe Drinking Water Act allows for exemptions to meet compliance rules [23]. However, a short-term variance may only serve to create and perpetuate a two-tiered and inequitable system of regulation, in which low SES residents endure higher arsenic levels in their drinking water or are forced to rely on costly bottled water as an exposure reduction measure. Rather than variances, the regulatory system should provide targeted planning and technical support for small, disadvantaged communities to enter into compliance, so that provision of safe drinking water becomes logistically feasible. This support could include funding mechanisms to support regional system consolidation efforts that help small systems achieve economies of scale or draw on alternative water supplies.

Conclusions

Using a "joint burden" approach, we examined the extent of exposure and compliance burdens in the San Joaquin Valley from 2005 to 2007. Our findings suggest that environmental justice concerns related to arsenic contamination in drinking water must consider both exposure and compliance burdens. Our work also highlights the need to better address how water systems serving low-SES residents can apply for and secure resources to enter into compliance, particularly if current funding criteria are tied to the technical, managerial and financial capacity of CWSs. That small, disadvantaged communities face greater compliance challenges highlights the need for appropriate regulatory measures and technical support. Ultimately, regional solutions that consolidate smaller CWSs serving economically disadvantaged communities within larger CWSs may be the best approach to addressing these disparities. In the interim, however, small water systems serving low SES residents will need enhanced funding and technical support to reduce community-level arsenic exposures.

Additional files

Additional file 1: Table A1. Shows a comparison of the initial population of active water systems, to the final sub sample of systems.

Additional file 2: Figure A1. Presents a schematic of a community water system that explains selection of point of entry sources.

Additional file 3: Table A2. Presents results from two sets of sensitivity analyses using source level average arsenic concentrations.

Abbreviations

As: Arsenic; CDPH: California Department of Public Health; CI: Confidence Interval; CWS: Community water system; GIS: Geographic Information System; IQR: Interquartile range; MCL: Maximum contaminant level; OR: Odds ratio; PEP: Population potentially exposed; PICME: Permits, Inspections, Compliance, Monitoring and Evaluation; PUC: Public utility commission; SDWA: Safe drinking water act; SES: Socioeconomic status;

TMF: Technical, managerial and financial capacity; US EPA: United States environmental protection agency; µg As/L: Micrograms of arsenic per liter.

Competing interests
The authors declare they have no competing interests.

Authors' contributions
CB conceived of the study and its design, acquired the data, performed statistical analyses and was the lead author of the article. RMF contributed to the design of the study, statistical analysis, and the writing of this article. AH contributed to the study design and statistical analysis. IR contributed to the design of the study and results analysis and played a significant role in the writing of the manuscript. All authors read, edited and approved the final manuscript.

Acknowledgements
This research was supported by the NSF Graduate Research Fellowship, the California Endowment (through a collaborative grant between Community Water Center and UC Berkeley), the California Environmental Protection Agency (#07 020), and the Switzer Environmental Fellowship. We thank Laurel Firestone, Susana de Anda and Maria Herrera; Rich Haberman (former San Joaquin Valley Regional Engineer for CA Department of Public Health (CDPH) Drinking Water Program, Dave Spath (former Chief of the Division of Drinking Water and Environmental Management, CDPH), Dr. Karl Longley and Sarge Green (California State University, Fresno); the Energy and Resources Group's Water Group; and Bhavna Shamasunder for support and feedback on analysis; CDPH and Tulare County Environmental Health Services for water quality data; Barbara Nerness for research assistance.

Author details
[1]Energy and Resources Group, University of California, Berkeley, CA 94720, USA. [2]School of Public Health, University of California, Berkeley, CA 94720, USA. [3]Department of Environmental Science Policy and Management, University of California, Berkeley, CA 94720, USA.

Received: 9 May 2012 Accepted: 22 October 2012
Published: 14 November 2012

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doi:10.1186/1476 069X 11 84
Cite this article as: Balazs *et al.*: Environmental justice implications of arsenic contamination in California's San Joaquin Valley: a cross sectional, cluster design examining exposure and compliance in community drinking water systems. *Environmental Health* 2012 11:84.

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EXHIBIT E

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California Unincorporated:
Mapping Disadvantaged Communities in the San Joaquin Valley



In partnership with California Rural Legal Assistance, Inc.
and California Rural Legal Assistance Foundation

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Design by: Leslie Yang

COVER PHOTOS COURTESY OF: Hector Gutierrez.

California Unincorporated:
Mapping Disadvantaged Communities in the San Joaquin Valley

In partnership with California Rural Legal Assistance, Inc. and California Rural Legal Assistance Foundation

Chione Flegal
Solana Rice
Jake Mann
Jennifer Tran
POLICYLINK

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Acknowledgments

The Community Equity Initiative would like to thank the many people who have made this work possible. Foremost, we would like to acknowledge the following for their continued commitment and dedication to improving California's disadvantaged unincorporated communities:

Martha Guzman-Aceves
Brian Augusta
Erika Bernabei
Kara Brodfueherer
Juan Carlos Cancino
Cara Carrillo
Amparo Cid
Maria Sofia Corona
Olivia Faz
Niva Flor
Verónica Garibay
Rubén Lizardo
Emily Long
Laura Massie
Cristina Mendez
Enid Picart
Walter Ramirez
Ruby Renteria
Victor Rubin
Phoebe Seaton
Esmeralda Soria
Elica Vafaie
Ariana Zeno

Thank you to the following who contributed content and research expertise:

Carolina Balazs
Rebecca Baran-Rees
John Capitman
Dhanya Elizabeth Elias
Ann Moss Joyner
Jonathan London
Nathaniel Roth
Stephan Schmidt
Michelle Wilde Anderson

Thanks to the PolicyLink editorial and production teams.

Finally, this work would not have been possible without the generous support of:

The James Irvine Foundation
The California Endowment
The Open Society Foundations
The Women's Foundation of California
The Kresge Foundation

Preface

The Community Equity Initiative (CEI), a partnership of California Rural Legal Assistance Foundation, California Rural Legal Assistance, Inc. (CRLA, Inc.), and PolicyLink, is dedicated to advancing innovative solutions to address poor infrastructure quality and service delivery in communities with a particular focus on the unincorporated communities in California's San Joaquin Valley and the Coachella Valley. The initiative aims to improve the conditions in some of California's most underinvested communities, and provide models for forging new leadership and capacity within communities and developing effective policies to dismantle and overcome historical patterns of exclusion and neglect.

Early in the development of the Community Equity Initiative, the three partner organizations engaged a diverse set of stakeholders and advisors from within communities, universities, foundations, government, and the nonprofit sector to discuss how planning and infrastructure investment can build healthy, sustainable community change. As a result, the initiative pursues a four-pronged strategy that includes: increasing community capacity for political participation and advocacy, improving local and state policy, legal representation, and research.

As part of the research agenda, the initiative has developed a new methodology to shed light on and describe communities that have gone overlooked, ignored, and underinvested for decades. Using and analyzing 2000 census data and other publicly available data, the research has uncovered thousands of Californians who are living in these invisible communities, what the CEI calls "Disadvantaged Unincorporated Communities" or DUCs. Disadvantaged Unincorporated Communities are disproportionately low-income places that are densely settled and not within city limits. For the legal definition, please visit SB 244 Section 65302.10.

This document describes the new methods for identifying, measuring, and mapping disadvantaged unincorporated communities and a first account of the findings from applying these new methods to the San Joaquin Valley. For readers seeking the complete technical details of the data sources and methods, please see the Technical Guide on the Community Equity Initiative website.

All charts, tables, and maps within this report are derived from an analysis of 2000 census data, and county parcel and boundary data. This methodology will also be applied to 2010 census data with research findings to come. Ultimately, it is hoped that this new mapping methodology will help improve policies and decision-making practices not only within California's unincorporated communities but also in America's unincorporated communities at large.

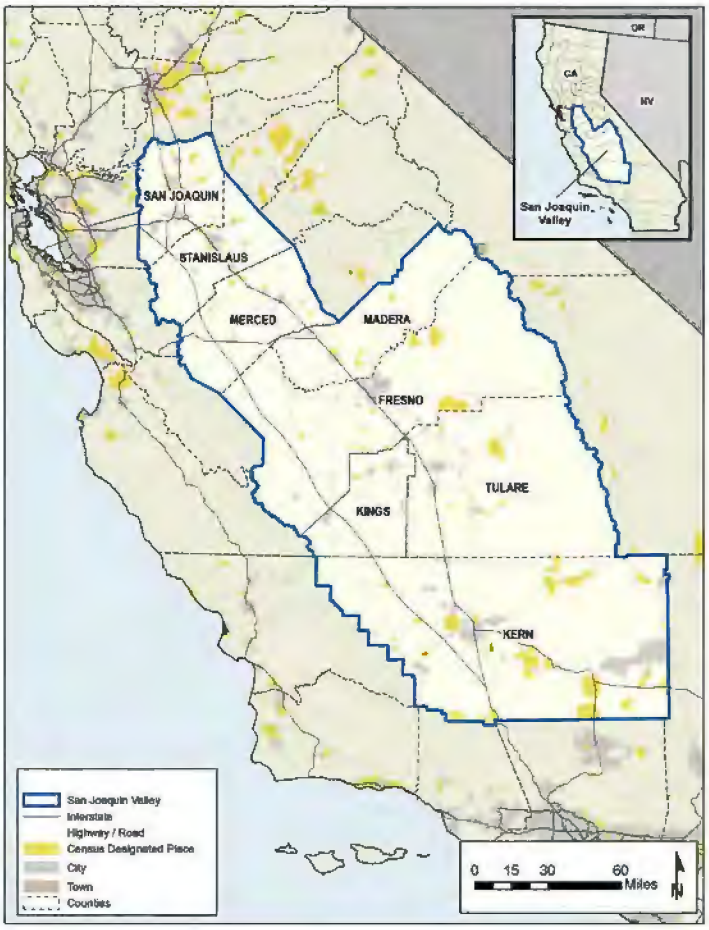
For more on the Community Equity Initiative, please click **here**.

Introduction

California's San Joaquin Valley is one of the most agriculturally rich regions in our nation, contributing over half of the state's total value in agricultural production.[1] It is also home to some of the nation's poorest communities. A 2010 study found the San Joaquin Valley's 20th congressional district ranked the lowest in the nation on resident well-being, based on an assessment of health, education, and income.[2] Among the poorest and most isolated of these communities are places outside of city limits that lack the most basic features of a safe, healthy, sustainable neighborhood—potable drinking water, sewer systems, safe housing, public transportation, parks, sidewalks, and streetlights. People of color make up 54 percent of those living in the San Joaquin Valley, and make up a disproportionate number of those living in underinvested neighborhoods. Historically, these communities have been home to mostly African American and Latinos, and a growing Southeast Asian population. Governed by counties, which were not set up to provide services to dense urban areas, and lacking the representation of a city council, they are systematically underserved in the overall allocation of public resources and are frequently left out of local decision-making processes. Concentrated poverty, institutional and individual racism, and California's systems of public finance and land use regulation exacerbate the plight of disadvantaged unincorporated communities.

To make matters worse, many decision makers and county officials do not know that these communities exist. A map delineates boundaries, records a name, facilitates (though does not guarantee) data collection by the United States Census Bureau and other data collection entities, and provides a basis for demographic and special analysis used to direct programs and services from the federal or state to local level. For residents and organizations living and working in these communities the lack of official recognition and the data that flow from it presents a huge barrier. It becomes very challenging to capture political attention, aggregate and provide a sense of scale to the challenges faced across communities, and readily access critical public resources that are distributed based on community-level data. Identifying the places and their particular challenges (drinking water, waste water systems, safe roads, etc.) is the first step in a longer process to develop strategies and priorities, and to organize, and mobilize to address these challenges.

Eight Counties of San Joaquin Valley



Source: 2000 U.S. census.

1 See Great Valley Center. "Assessing the Region Via Indicators, The Economy." 2009.

2 Based on the Human Development Index of the Social Science Research Council: http://www.measureofamerica.org/maps/.

Purpose of This Research

The Community Equity Initiative developed this report, and the methodology discussed within it, as part of a larger effort to make visible the hundreds of communities that have gone neglected and ignored and are suffering critical challenges of livability as a result. Through this work, the initiative seeks to provide local and state officials, policymakers, advocates, and community organizations with a better sense of where underserved, unincorporated communities are located, and seeks to bring the problems they face into the public view. The research presented here is the first step in quantifying and locating the number of places and people that have been left off the map in the eight-county San Joaquin Valley region. It brings attention to some of California's most forgotten and underinvested places, and starts to make the case for more coordinated long-range planning, targeted resources, and community capacity building for improved quality of life.

This research aims to:

- **equip residents, community-based organizations, and policymakers** with more tools for organizing, case-making, and advocacy;
- **increase public awareness** of the breadth and scale of disadvantaged unincorporated communities and the challenges they face; and
- **support better research and data collection** of disadvantaged unincorporated communities through a new tool that can be used as a basis for future research about quality of services and infrastructure.

Key Findings

The following are key takeaways from the analysis of 2000 U.S. census data and other publicly available data for California.

3.6 million

Californians found by the Census Bureau living in Census Designated Places in 2000

2.8 million

Additional number of Californians living in unincorporated neighborhoods not recognized by the 2000 census because their communities were not characterized as Census Designated Places

310,000

People living in low-income unincorporated communities in the San Joaquin Valley

This is 70,000 more than what the Census Bureau included in its low-income Census Designated Places in the San Joaquin Valley

People of color were disproportionately represented in Disadvantaged Unincorporated Communities in comparison to cities, counties, and Census Designated Places.

65%

Percentage of the population living in disadvantaged unincorporated communities that were of color

57%

Percentage of the population living in cities that were of color

64%

Percentage of households in the San Joaquin Valley's disadvantaged unincorporated communities that were low income

This was a significantly higher percentage than in cities and counties in California where 48% of households were low income, and in Census Designated Places where 51% of the households were low income.

Emerging Areas of Impact

This research is helping to make the case for advocacy, build public awareness, and contribute to new knowledge around inequities that exist.

Supporting Organizing, Case-Making, and Advocacy

There is power in being made visible. Once a community is visible, a shared collective identity can develop, which in turn serves as the foundation for residents' capacity to organize themselves and mobilize for change. Mapping equips residents with information about their communities and others', provides them with a tool in their advocacy, and facilitates recognition within the policymaking process. This work provides an important foundation for advocates, researchers, and policymakers to layer additional information and stories about the conditions and history of these communities.

Tulare Lake Basin Study – In 2008, SB1xx and AB2356 appropriated millions of dollars to address drinking water quality and waste water services in the Tulare Lake Basin region. With the tremendous support of community advocates, these bills provide targeted funding for planning and construction of projects in disadvantaged areas. The CEI mapping of low-income unincorporated areas was one of the many data points considered when identifying disadvantaged communities for targeted inclusion in the planning process and in the outreach phase of the project. The CEI mapping helped identify some of the smaller communities that may not have shown up in an initial scan of disadvantaged communities through the census.

Increasing Public Awareness

A community's needs cannot be properly addressed—or assets leveraged—if the community itself is not known to the larger world. Early work of the initiative indicated that many policymakers at the county and state level did not know of the existence of disadvantaged unincorporated communities generally, nor were they aware of the existence of such communities within their electoral districts. Many more continue to be unaware of the basic infrastructure deficits so many of these communities face. Once these communities are officially mapped, have a name to identify them, and are tracked and recorded by the U.S. Census Bureau or city or county agencies they stand a better chance of being well represented and well served.

Local Government Support – Several local and state-level policymakers have looked to this mapping to understand the scale, location, and character of the issues in previously invisible unincorporated areas. Specifically, the mapping has supported the implementation of SB 244 that requires local government agencies—specifically LAFCOs, cities, and counties—to plan for disadvantaged unincorporated areas. The Local Agency Formation Commissions (LAFCOs) of Fresno and Tulare Counties have requested the CEI mapping to help identify and prioritize underserved areas in their planning process.

Contributing to Research

The U.S. Census Bureau is the most accessible source of periodic demographic data for unincorporated communities, yet it does not capture all unincorporated communities. Many unincorporated communities, including many low-income unincorporated communities, are too small, lack clear boundaries, or are simply not sufficiently known or recognized to be included in the census as a place. With the exception of surveying individual households, communities

are left without a reliable source of data to describe their neighborhood. As a result, their needs are often unaccounted for, they are not acknowledged in planning processes, and they cannot compete for infrastructure investments on a level playing field. This is particularly true when eligibility for these programs is tied to being able to demonstrate that community-level demographics meet specified criteria. This research begins to fill this gap. It creates a set of maps that will continue to evolve, and that identify hundreds of communities not previously mapped. These new maps can serve as the basis for layering additional information about demographics, infrastructure, and quality of life.

Sharing with the U.S. Census Bureau – Most recently, the data have served to inform the Census Bureau about additional places to consider including as 2010 Census Designated Places (CDPs) which are unincorporated places that are surveyed and tracked much like cities and towns. Typically, counties submit the names of communities that they recommend become Census Designated Places.[3] Having CDP status means that residents and local governments have more and better access to information about their communities and how they have changed over time. This is particularly important when applying for grants and loans for infrastructure and services. As a result of this new mapping, CEI staff recommended that the Census staff include 39 additional communities in their 2010 Census Designated Places survey. Nearly half of these recommended communities became CDPs in 2010. CEI staff is currently analyzing 2010 data and will continue to share findings with the Census Bureau staff.

3 Counties use a process called Census Participant Statistical Area Program to recommend Census Designated Places. Census Designated Places are defined by the U.S. Census Bureau as places that are closely settled, named, unincorporated communities that generally contain a mixture of residential, commercial, and retail areas similar to those found in incorporated places of similar sizes.

U.S. Census Bureau: Current Definitions

The most accessible source of data about unincorporated communities comes from the U.S. Census Bureau, which calls these neighborhoods Census Designated Places (CDPs). In the year 2000, the U.S. Census Bureau identified 600 Census Designated Places across California that were home to 3.6 million people. Of the 600 CDPs in California in 2000, 250 (42 percent) of them were low income. For purposes of this research, low-income communities are defined as places where half of all households have a median household income of less than 80 percent of the state's median household income. Simply put, half of all households in these communities had annual incomes of $38,000 or less. One million people lived in these low-income Census Designated Places.

Census Designated Places are areas that are closely settled, named, unincorporated communities that generally contain a mixture of residential, commercial, and retail areas similar to those found in incorporated places of similar sizes.

COMPARING LOW-INCOME CENSUS DESIGNATED PLACES

	Number of Communities Total	2000 Population (% of state population)
Total California Population	N/A	33,871,648
Total CDPs in California*	600	3,669,329 (10.8%)
Total Low-Income CDPs in California	250	1,069,778 (3.2%)
Total Low-Income CDPs in San Joaquin Valley	80	241,968 (0.7%)

*CDPs with population greater than zero.
Source: 2000 U.S. census.

While low-income CDPs are found throughout California, they are most heavily concentrated in the San Joaquin Valley. This eight-county region is home to nearly one-third of all low-income CDPs in California. Eighty of the state's 256 low-income CDPs are located in the region. There are nearly a quarter million people living in these communities, approximately 25 percent of all Californians living in low-income CDPs.

While the 2000 census tracked 3.6 million people in CDPs, in that same year nearly 2.8 million additional people lived in unincorporated areas that were not defined as CDPs. Upon launching the Community

Equity Initiative, staff at the partner organizations saw that many, if not the majority, of communities the initiative is concerned with are not captured by the Census Bureau's CDPs. CRLA, Inc. staff working in the communities found that these places were usually either not on maps, or were mapped incorrectly. PolicyLink staff working to develop a clear picture of the communities struggled with the same absent or inaccurate data. Subsequent mapping and resident interviews confirmed how widespread this phenomenon of exclusion was.

As a result of not being a CDP, these communities are not only usually left off of maps; they are rarely tracked in any systematic way, and are largely invisible to the larger public and policymakers. The mapping methodology, discussed in the next section, has established a way to identify these places using publicly available data, making it possible to begin to address their challenges and needs.



Source: 2000 U.S. census.

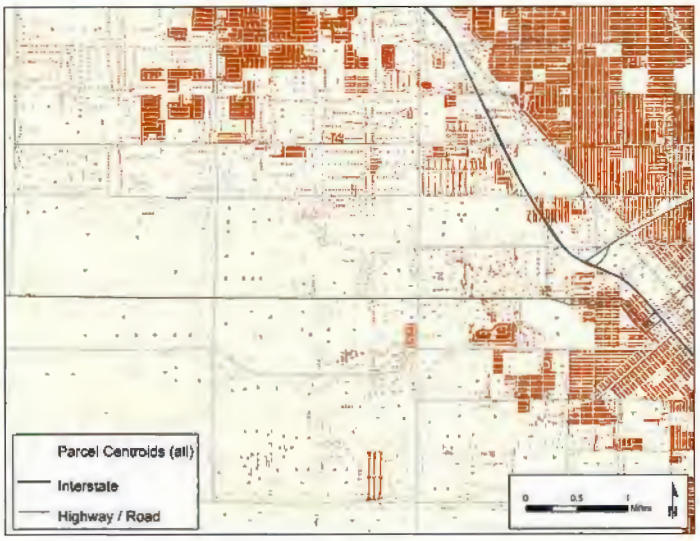
Mapping Disadvantaged Unincorporated Communities: The Methodology

This project used Geographic Information Systems (GIS) technology[4] to identify unincorporated communities in the eight-county San Joaquin Valley region. The following abbreviated methodology describes the steps and results for this initial phase of identifying what the Community Equity Initiative has termed as disadvantaged unincorporated communities or DUCs—places that are densely settled, outside of city limits, and low income.[5] For a more detailed explanation of the data and methods used, please refer to the **Community Equity Initiative** website for technical appendixes. The technical appendixes provide step-by-step guidance on data sources and methods to replicating this mapping research.

CEI used four basic types of data to identify these places:

Unincorporated Status: The project used boundary shape files from cities, counties, or from the U.S. Census Bureau to determine unincorporated status (all areas that are not within city limits).

Parcel Density: The project focused on identifying places that are closely settled with a large number of homes, rather than very spread out rural communities. From publicly available sources, the outlines of parcels (land that is subdivided into lots) were gathered. The areas with a density of at least 250 parcels per square mile were identified. This benchmark was chosen because it is comparable to the density of Census Designated Places (unincorporated communities tracked by the Census Bureau).



Sample map of parcels to determine density.



Sample map of visual inspection for each DUC.

4 ESRI ArcView for ArcMap 9.3.1 with the Spatial Analyst 9.3 extension, Windows machine with an Intel Core 2 Quad CPU.

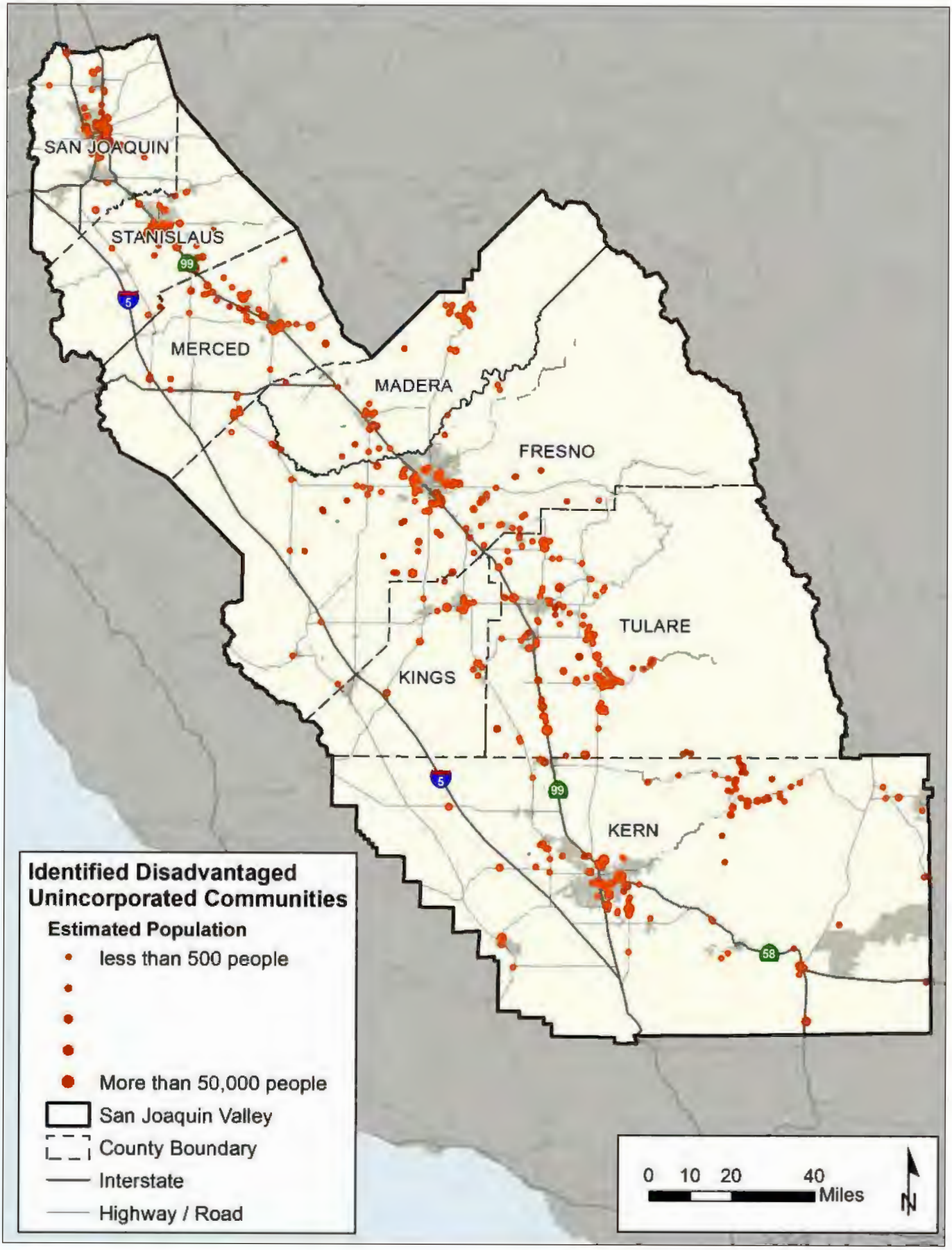
5 This term was developed by CEI to describe low-income, densely settled, unincorporated communities.

Low-Income Neighborhoods: In the work of the CEI, we have found that many low-income unincorporated communities also face infrastructure challenges. Because there is no single indicator, or discrete set of indicators, which allows us to assess infrastructure conditions, the initiative's work began by identifying low-income unincorporated communities. It used 2000 census[6] block group data to identify places of interest. Since the income status of households relative to those across the state is a frequently used criteria for state-funded programs, the initiative selected those block groups where the median household income was less than 80 percent of the median household income of the state. This is a benchmark used in several state-level infrastructure funding programs that target low-income communities, including the **Safe Drinking Water State Revolving Fund** and the **Storm Water Management program**. In 2000, the median household income of the state of California was $47,493, so any census block group with a median income of less than $37,994 was included in our analysis.

This threshold is not a perfect metric for identifying disadvantaged unincorporated communities because there are many places, like resort communities, that may have low recorded incomes, but are not actually home to significant populations of low-income people.

Visual Inspection & Additional Filters: The project mapped land use to help filter out agricultural land, and used information from aerial photography and Google street view to verify that the places highlighted by our analysis were indeed underserved communities. Through this review it was found that some communities at the edge of cities had been "low-income" agricultural fields during the 1990 census but have since been developed. Communities that had been identified as less than three-quarters of an acre in size were also removed as they often contained only one or two houses, if any.

6 While dated, the 2000 census provided a more accurate depiction of income levels at the block group level than more recent American Community Survey data.



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

525 Communities: Findings and Analysis

Once the four types of data were overlaid on one another, 525 distinct, low-income, densely settled, unincorporated areas emerged that are home to over 300,000 people in the San Joaquin Valley. In 2000, the U.S. Census Bureau recorded only 80 unincorporated communities that were low income. This research identified many communities that are smaller communities than Census Designated Places. One hundred forty-nine of these disadvantaged unincorporated communities were located within existing Census Designated Places and 23 of these 149 DUCs were small communities that fell within larger, wealthier Census Designated Places that would not have been identified by solely relying on an analysis of low-income CDPs. For those low-income communities that depend on Census Bureau data to inform their grants, advocacy, and communications work, being located and lumped in with a wealthier CDP could very well mask the challenges of the communities.

Many of the communities (188 to be exact) were named places either because they were existing CDPs or were recognized by community members. As part of the process of verifying the methodology, CEI staff hosted several workshop sessions with community members to solicit their input on maps. Participants were asked if they recognized the identified places as neighborhoods with names and did some "ground-truthing" to verify that the places highlighted were indeed places with infrastructure challenges. A listing of named places is included in Appendix 2: County Map Gallery. Those places without names were assigned a number.

Comparing Counties

The eight counties of the San Joaquin Valley vary significantly in terms of size and population distribution within incorporated and unincorporated areas. The research found that while Fresno is the most populated county, accounting for 24 percent of the valley's population, only 9 percent of the population living in the region's disadvantaged unincorporated communities are in Fresno County. On the other hand, Kern and Tulare Counties have disproportionately high percentages of their populations living in disadvantaged unincorporated communities. Kern is home to 20 percent of the region's population, but 42 percent of the population living in disadvantaged unincorporated communities, and Tulare has 11 percent of the

Comparing Disadvantaged Unincorporated Communities in the San Joaquin Valley

	Number of Communities	Population (% of San Joaquin Valley population)
Disadvantaged Unincorporated Communities in the Valley	525	310,231 (9.3%)
Disadvantaged Unincorporated Areas in CDPs in the Valley	149	187,180 (5.7%)
Low-income CDPs in the Valley	80	242,216 (7.3%)

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

total valley population but 18 percent of the valley's DUCs. This can largely be explained by the fact that a significant portion of the total population in Kern (46 percent) and Tulare (36 percent) Counties live in unincorporated areas. Tulare and Kern also have the highest percentages of their unincorporated populations living in low-income, densely settled communities, with 49 percent and 38 percent respectively.

Maps of each county are available in Appendix 2: County Map Gallery. The Appendix includes a breakdown of each type of community (Island, Fringe, and Legacy discussed later) listed, as well as population summaries.

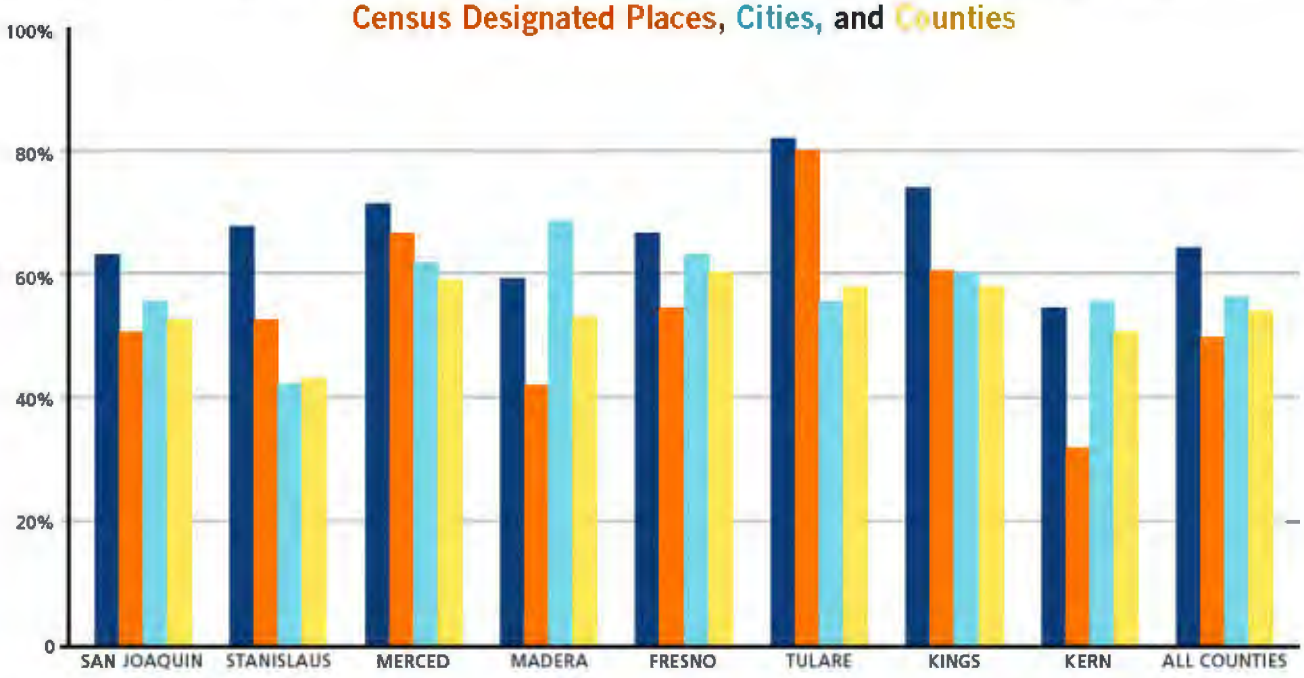
Demographic Analysis

Examining the racial makeup and economic status of DUCs and comparing those to cities, other parts of unincorporated counties, and to counties, helps demonstrate whether or not underinvestment in infrastructure is correlated to race and class. The work of the CEI in large part stemmed from litigation against discriminatory practices in Stanislaus County and the city of Modesto. This case revealed that the city of Modesto was excluding low-income neighborhoods and communities of color from its growth, development, and most basic infrastructure and services.

This current research looks to build from the evidence prepared for Modesto and other cases to better understand and describe the relationship between race, income, and infrastructure quality. The new mapping and analysis shows that disadvantaged unincorporated communities are largely home to people of color,[7] making up 65 percent of the population living in San Joaquin Valley's DUCs. This number is especially high compared to the fact that throughout all of the counties, people of color make up only 54 percent of the population.

The CEI compared the racial and ethnic makeup and number of low-income households in DUCs to Census Designated Places, cities, and counties. Since Census Designated Places are the only unincorporated communities that are tracked by the U.S. Census Bureau, this is an important scale of comparison. Comparing DUCs to cities is important for understanding how much incorporated status can influence and drive

Percent People of Color in Disadvantaged Unincorporated Communities, Census Designated Places, Cities, and Counties



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

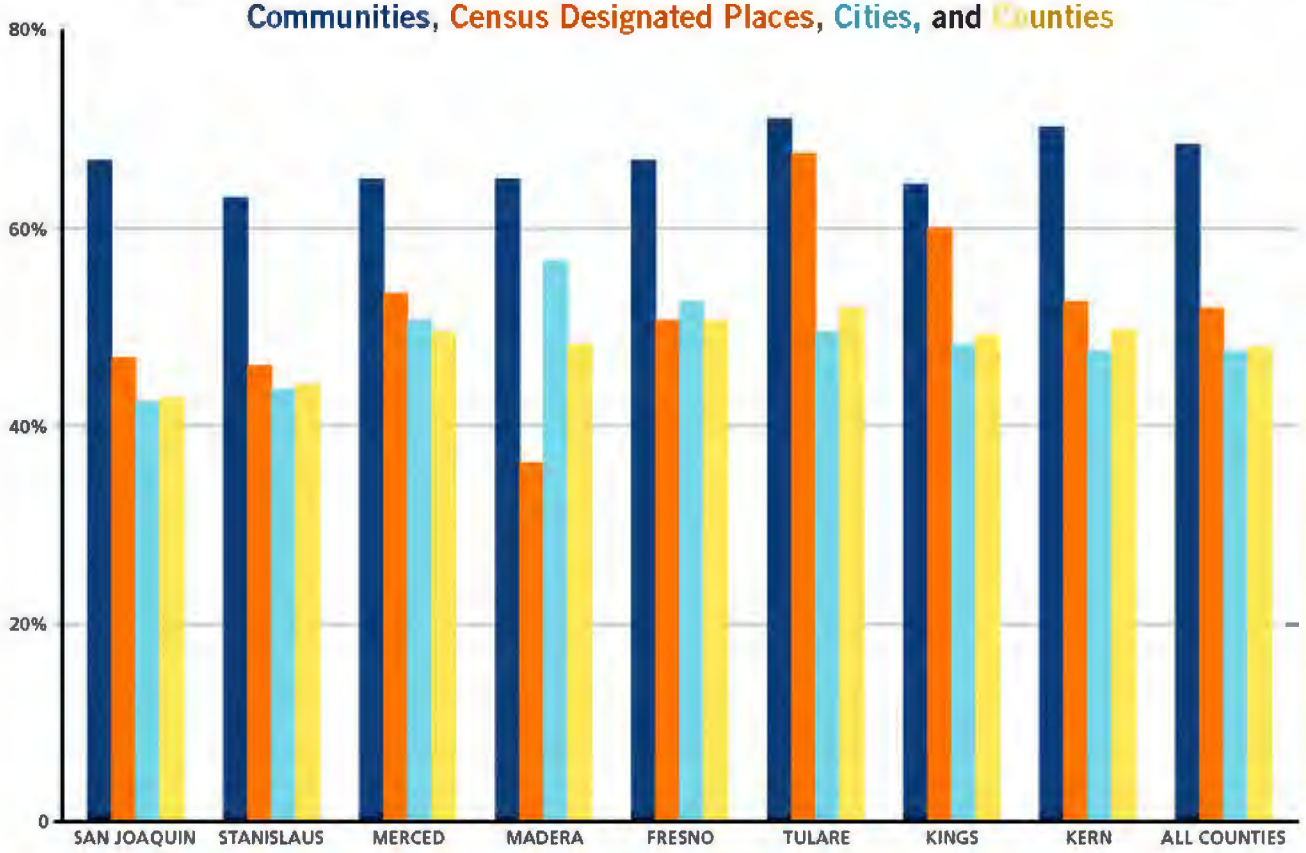
7 "People of color" describes the sum of all racial/ethnic groups that are not white (or non-Hispanic white).

disparities. A comparison to counties provides the context in which DUCs reside. Ideally, the research should find that low-income households and people of color are equally represented in all three scales.

As the graph on the previous page illustrates, in every county people of color in DUCs are overrepresented in comparison to the percentage of people of color living in CDPs, cities, and the county population as a whole.

Although the people who live in DUCs are partly defined by the fact that they meet specified income criteria, the study also wanted to understand how their income characteristics compared to other incorporated and unincorporated population groups in the region. The research found that low-income households are overrepresented in disadvantaged unincorporated communities in comparison to CDPs, cities, and counties. The results are conservative estimates due to the limitations of the census.[8] The graph below illustrates that the percentage of low-income households in DUCs across the San Joaquin Valley ranges between 11 and 20 percentage points higher than their respective counties. When compared to CDPs, DUCs generally have a much greater percentage of low-income households; the exception being in Tulare and Kings Counties where low-income households are proportionate in CDPs and DUCs. Across the entire San Joaquin Valley, it was estimated that 64 percent of households living in DUCs are low income compared to much lower rates in CDPs (51 percent), cities (48 percent), and counties (48 percent).

Percentage of Households that are Low-Income in Disadvantaged Unicorporated Communities, Census Designated Places, Cities, and Counties



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

8 For purposes of this research, low income is defined as household income below 80 percent of state household median, which is $37,994. The 2000 census only provides household income in ranges. These results include all households with income below $34,999.

Please refer to **Appendix 1** (Demographic Analysis) for a detailed table comparing the demographics of DUCs to counties, cities, and Census Designated Places.

Types of Communities

While documenting the number of communities is an important step in telling the story of the San Joaquin Valley's unincorporated communities, proximity to a neighboring community or city plays an important role in determining the opportunities that these places have to improve their infrastructure. A community that is, for example, 20 miles away from a city will have different concerns and opportunities for infrastructure investment than one that sits close or adjacent to a city, and different again from a neighborhood nearly or completely surrounded by the same city. Because of this, our work looked to further describe these communities based on their spatial relationship to incorporated areas.

Island and Fringe Communities

During the agricultural and industrial boom of the early and mid-twentieth century, communities developed on the edges of cities where industry was concentrated and housing was more affordable. As the cities grew, they annexed land around the unincorporated communities—avoiding and excluding communities of color and low-income communities. Decades of neglect and exclusion by cities and counties have been reinforced by the state's counterproductive system of taxation and land use policies. These communities find themselves stuck between the county and their neighboring city. The city does not want to invest in county territory, nor does the county wish to invest in a community that, once improved, will be more attractive for incorporation by a neighboring city.

Today there are unincorporated communities that are like an island, completely surrounded by incorporated city territory but are on county land and therefore do not receive city services. Fringe communities are neighborhoods that are adjacent to incorporated areas or within a city's sphere of influence[9] but are located on county land. The isolation faced by fringe and island communities is stark: their neighbors within city limits—across the street even—receive services that they do not. Some communities may literally have city infrastructure running under or through their community but are not linked into that infrastructure to receive its benefits. Seventy percent of the population of the disadvantaged unincorporated communities identified live in island or fringe communities. As the table below shows, this is over 200,000 people in 274 island and fringe communities. Distinguishing these communities in this way is important because

Comparing Types of Disadvantaged Unincorporated Communities

	Number	Estimated Population (% of DUCs)
Total Disadvantaged Unincorporated Communities	**525**	**310,231**
Island communities	**44**	**45,501 (14.7%)**
Fringe communities	**230**	**172,237 (55.5%)**
Legacy communities	**231**	**92,358 (29.8%)**

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

9 According to the California Association of Local Agency Formation Commissions, a sphere of influence is a planning boundary typically beyond a city or special district that ensures the provision of efficient services while discouraging urban sprawl and the premature conversion of agricultural or open space lands.

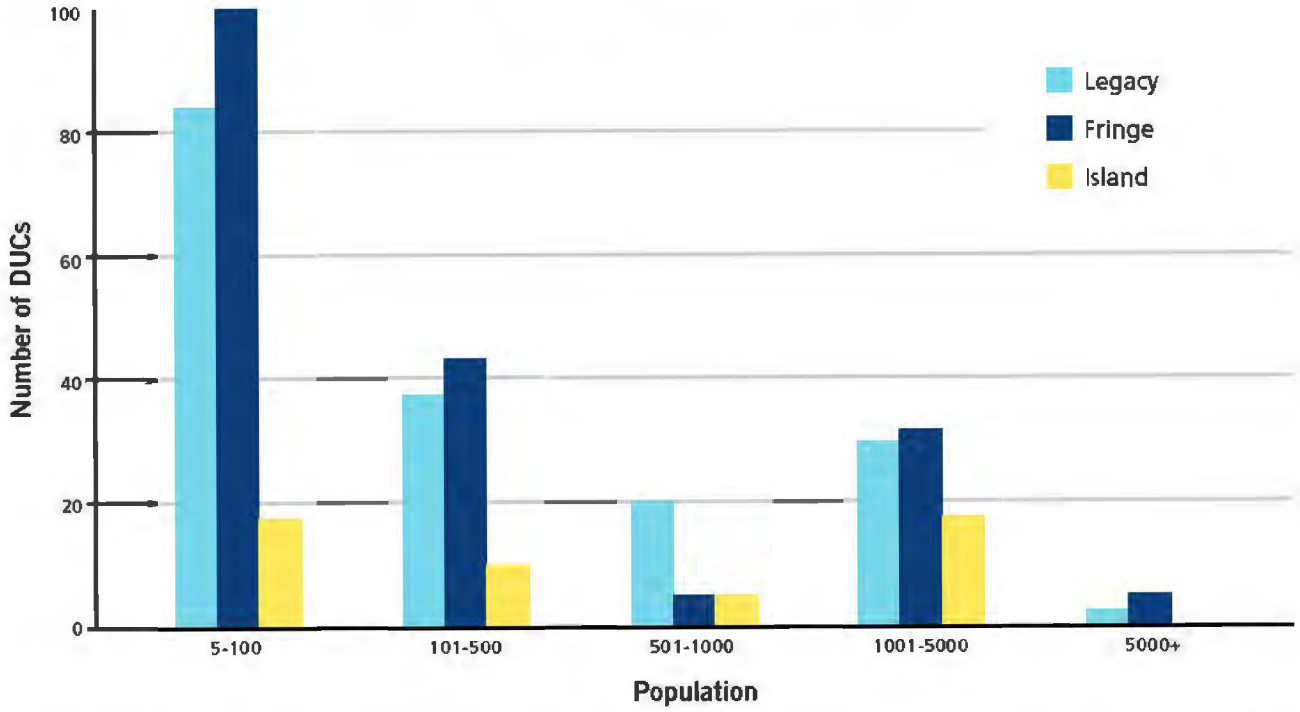
the potential strategies for addressing infrastructure deficits vary depending on the proximity to cities and other communities. For example, several fringe communities have worked out agreements with neighboring cities or townships for sharing service provision or infrastructure investments like water resources.

Legacy Communities

A third type—legacy communities—are more remote. These communities lie beyond the growth boundaries of incorporated cities, and have been in existence at least 50 years.[10] Legacy communities started growing in the early to mid 20th century, principally due to the advent of industrialized agriculture. As demand for low-wage agricultural labor increased, these communities became home to workers from the American South, the Depression-era Dustbowl, and Mexico seeking work as farm laborers. Legacy communities grew close to the farms where workers labored, and over time, these communities have become stable, year-round residential areas, but without the investment to make them healthy and sustainable. Nearly 100,000 people live in legacy communities. The geographic isolation of these places means that they cannot as readily rely on shared service provisions and the typically small population size means that privately funded infrastructure investment is cost prohibitive because of a lack of economies of scale. Leveraging targeted public funding is a necessity in legacy communities.

The graph below illustrates the distribution of disadvantaged unincorporated communities by population range, number of communities in each population range, and their spatial relationship to incorporated areas (Island / Fringe / Legacy). A majority (81 percent) of these communities are small—fewer than 500 residents. While only 12 communities have populations greater than 5,000, these 12 communities make up 45 percent of the total DUC population across the valley.

Number of Disadvantaged Unincorporated Communities by Type and Population



The methods tended to underestimate population size in very small rural communities. One hundred and thirty-five of the 525 communities have an estimated population of less than five people and are not displayed here.

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

10 Definition in part from the Senate Bill No. 244.

Next Steps

Cities and counties cannot plan for, and serve, communities that they do not even know exist. Administrators and elected officials must understand the scale and scope of issues within their jurisdiction. This research will help build their understanding of the scope of the issues impacting unincorporated communities and will support local and regional efforts to plan for infrastructure improvements and more coherent, sustainable land uses. The Community Equity Initiative will continue hosting sessions where community members and organizations can help verify and name places on maps identified by this methodology.

The data used for this first run of the model are limited because the census has historically undercounted minority and rural populations. Also, the income data are from 2000, which are dated and do not reflect changes brought by the most recent recession. The CEI will be updating its research with more recent American Community Survey data and 2010 U.S. census data. It is also adding demographic data such as median age, length and type of housing tenure, education, and more. We are in the process of undertaking additional investigation to better understand the breadth and depth of challenges that these communities face.

The next phase of mapping will include additional "ground-truthing" with residents, further exploration of the demographics of these communities, and gathering and analysis of information about the quality of infrastructure, amenities, and services. This foundational mapping will allow us to better describe potential infrastructure challenges, disparities in investments, and trends in population over time beyond the race and income data included here. The next phase of this work, for example, may draw closer parallels between race and income and infrastructure investment per capita.

The initiative will continue to share this information with community organizations and groups who find it useful. For example, it is currently sharing its findings with community organizations and researchers who are studying how nitrate contamination in groundwater is affecting communities in the San Joaquin Valley and across California. The pairing of these data sets will add dimension to both the water quality data and the mapping of disadvantaged communities. A clearer picture should emerge of the types of communities that do not have healthy drinking water, along with increased understanding about the water quality in underserved communities. This dual approach will inform the decision-making process around setting priorities for allocating resources to areas in need.

This mapping has also sparked interest in collecting and sharing data about unincorporated areas more broadly, including access to parks, air quality data, and environmental hazards. Ultimately, the Community Equity Initiative is committed to using the information that is gathered to empower residents in California and elsewhere as advocates for better, healthier communities.

For more information about the work of the Community Equity Initiative, our successes, and our research, visit: **www.PolicyLink.org/communityequityinitiative** or **www.crla.org/node/30**. You may also contact Chione Flegal at PolicyLink by email at chione@policylink.org or Phoebe Seaton at California Rural Legal Assistance, Inc. by email at **pseaton@crla.org**.

Appendix 1: Detailed Table of Demographic Analysis

The following tables compare demographics for counties, cities, Census Designated Places, and disadvantaged unincorporated communities by county. The data have been summarized in preceding charts but are presented here more comprehensively and include:

- **Total population and number** of households
- **Population and percentage** of people of color (people of color defined as the sum of all racial and ethnic groups that are not white or non-Hispanic white)
- **Total and percentage** of low-income households (households with income less than $34,999 annually)

Countywide Estimates

COUNTY	County Population	Unincorporated Population	Percentage of County Population Living in Unincorporated Areas
FRESNO	799,407	170,191	21%
KERN	661,645	266,821	40%
KINGS	129,461	37,369	29%
MADERA	123,109	69,074	56%
MERCED	210,554	78,738	37%
SAN JOAQUIN	563,598	129,891	23%
STANISLAUS	446,997	122,107	27%
TULARE	368,021	142,510	39%
COUNTIES	3,302,792	1,016,701	31%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Countywide Estimates

COUNTY	Population People of Color	Percentage of Countywide Population that are People of Color	Total People of Color Living in Unincorporated Areas	Percentage of Unincorporated Population that are People of Color
FRESNO	481,885	60%	85,749	50%
KERN	334,455	51%	114,373	43%
KINGS	75,644	58%	20,498	55%
MADERA	65,718	53%	28,676	42%
MERCED	124,969	59%	43,032	55%
SAN JOAQUIN	296,596	53%	56,544	44%
STANISLAUS	190,996	43%	54,617	45%
TULARE	214,105	58%	87,786	62%
COUNTIES	1,784,368	54%	491,275	48%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Countywide Estimates

COUNTY	Total Households in County	Households in Unincorporated Areas	Total Low-Income Households in County (Earning <$34,999)	Percentage of Households in Counties that are Low Income
FRESNO	253,304	72,329	127,527	50%
KERN	208,786	92,571	103,134	49%
KINGS	34,429	10,851	16,810	49%
MADERA	36,207	24,862	17,373	48%
MERCED	63,933	28,399	31,485	49%
SAN JOAQUIN	181,612	50,273	77,225	43%
STANISLAUS	145,253	42,784	63,291	44%
TULARE	110,356	50,336	56,563	51%
COUNTIES	1,033,880	372,405	493,408	48%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Citywide Estimates

COUNTY	Total City Population	Total Population People of Color in Cities	Percentage of City Population that are People of Color	Total Household in Cities	Estimated Total Households in Cities that are Low Income	Percentage of Households in Cities that are Low Income
FRESNO	629,216	396,136	63%	200,517	104,841	52%
KERN	394,817	220,079	56%	122,530	57,754	47%
KINGS	92,092	55,146	60%	25,032	11,928	48%
MADERA	54,035	37,042	69%	14,558	8,146	56%
MERCED	131,816	81,937	62%	40,999	20,673	50%
SAN JOAQUIN	433,707	240,052	55%	141,336	60,062	43%
STANISLAUS	324,890	136,379	42%	112,620	48,395	43%
TULARE	225,511	126,319	56%	70,442	34,491	49%
COUNTIES	2,286,084	1,293,090	57%	728,034	346,290	48%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Census Designated Places (CDPs)

COUNTY	Total CDP population	Population People of Color in CDPs	Percentage of CDP Population that are People of Color	Total Households in CDPs	Total Low-income Households in CDPs (Earning < $34,999)	Percentage of Households in CDPs that are Low Income
FRESNO	18,793	10,270	55%	5,956	3,005	51%
KERN	128,136	40,877	32%	45,380	23,758	52%
KINGS	13,453	8,159	61%	3,334	1,992	60%
MADERA	26,657	11,229	42%	8,466	3,034	36%
MERCED	29,175	19,533	67%	8,042	4,259	53%
SAN JOAQUIN	52,430	26,410	50%	16,350	7,602	47%
STANISLAUS	52,430	27,794	53%	14,900	6,801	46%
TULARE	56,125	45,154	80%	14,161	9,482	67%
COUNTIES	377,144	189,426	50%	116,589	59,933	51%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Disadvantaged Unincorporated Communities (DUCs)

COUNTY	Number of Disadvantaged Unincorporated Areas (DUCs)	Estimated Population in DUCs	Percentage of Countywide Population Living in DUCs	Percentage of Population in Unincorporated Areas Living in DUCs
FRESNO	93	27,704	2%	9%
KERN	105	130,388	2%	5%
KINGS	24	7,494	11%	39%
MADERA	44	8,558	12%	21%
MERCED	47	20,861	15%	21%
SAN JOAQUIN	51	29,203	14%	61%
STANISLAUS	47	31,127	7%	26%
TULARE	114	54,775	4%	10%
COUNTIES	525	310,230	9%	1%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Disadvantaged Unincorporated Communities (DUCs)

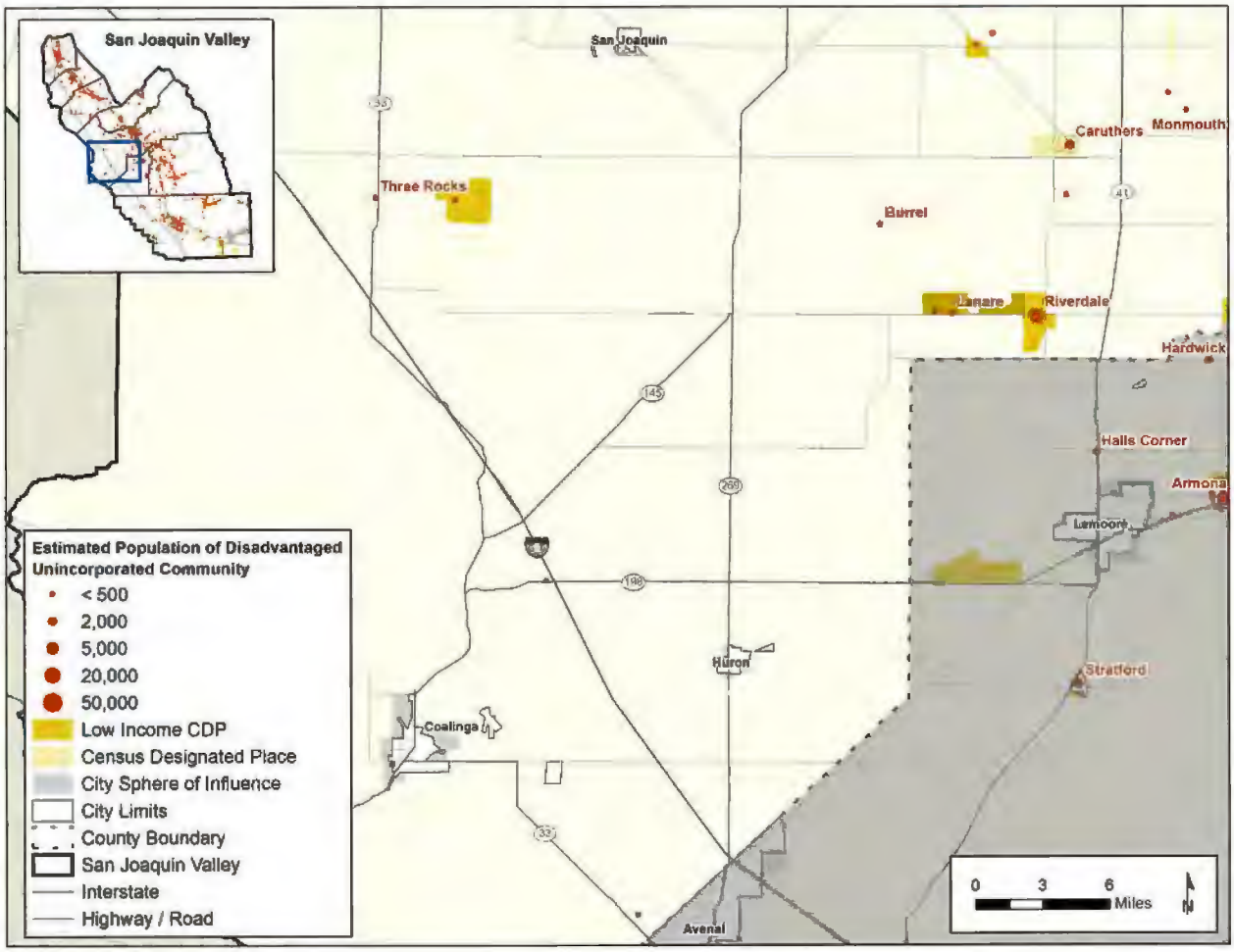
COUNTY	People of Color in DUCs	Percentage People of Color Countywide Living in DUCs	Percentage of DUC Population that are People of Color	Estimated Total households in DUCs	Estimated Total Low-Income Households in DUCs (Earning < $34,999)	Percentage of Households in DUCs that are Low Income
FRESNO	18,439	6%	67%	7,457	4,648	62%
KERN	71,561	39%	55%	28,820	17,715	66%
KINGS	5,561	10%	74%	458	276	60%
MADERA	5,106	13%	60%	983	598	61%
MERCED	14,926	17%	72%	3,001	1,814	60%
SAN JOAQUIN	18,433	10%	63%	7,456	4,627	62%
STANISLAUS	21,249	16%	68%	6,240	3,622	58%
TULARE	45,080	26%	82%	5,701	3,815	67%
COUNTIES	200,355	17%	65%	58,117	37,113	64%

Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

Appendix 2: County Map Gallery

The following maps illustrate the location and approximate population of disadvantaged unincorporated communities (DUCs) in each of the eight counties of the San Joaquin Valley. Tables associated with the maps show the estimated population by type of community (island, legacy, or fringe). Each county is accompanied by a list of the names of some DUCs.

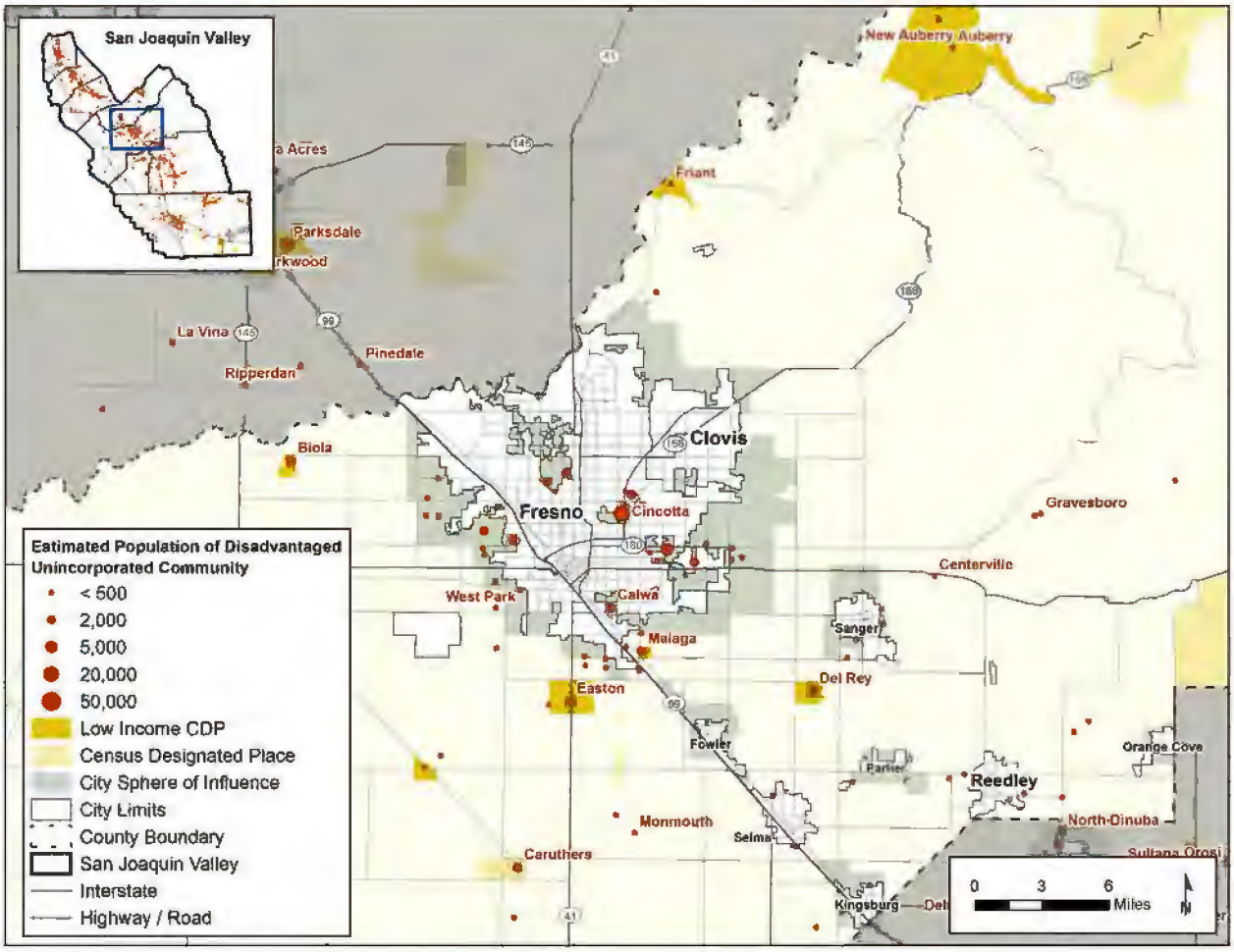
Fresno County (West)



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

FRESNO COUNTY	Number of DUCs	Estimated Total Population
Total	**93**	**27, 704**
Fringe	34	3,616
Legacy	49	8,156
Island	10	15,932

Fresno County (Central)

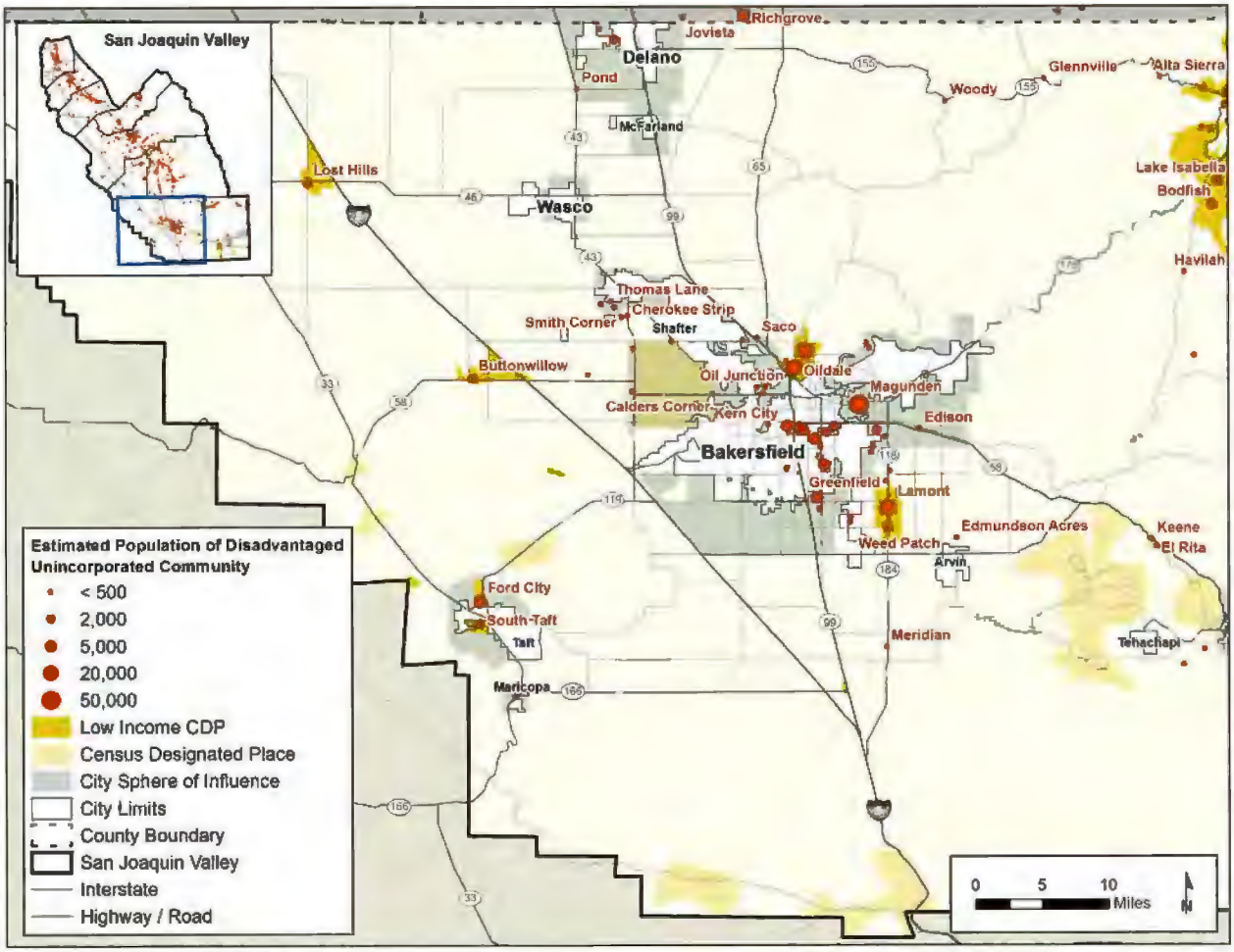


Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

DUCs with commonly recognized names in Fresno County:

Auberry	Del Rey	Laton
Biola	Del Rio	Malaga
Burrel	Dos Palos	Miramonte
Calwa	Easton	Monmouth
Caruthers	Friant	New Auberry
Centerville	Granz (historical)	Riverdale
Cincotta	Gravesboro	Three Rocks
Date Street	Lanare	West Park

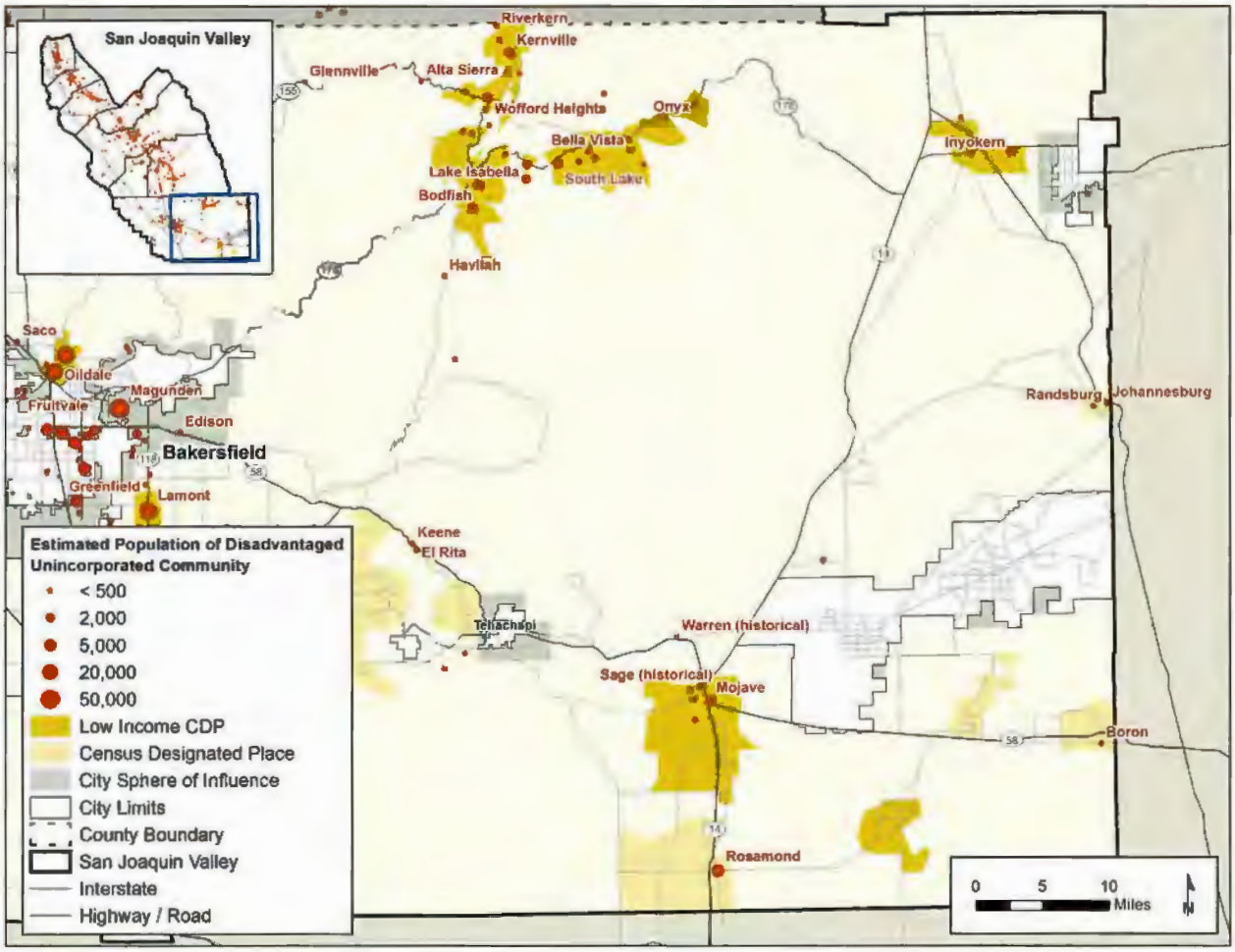
Kern County (West)



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

KERN COUNTY	Number of DUCs	Estimated Total Population
Total	**105**	**130,388**
Fringe	31	79,302
Legacy	64	33,083
Island	10	18,003

Kern County (East)

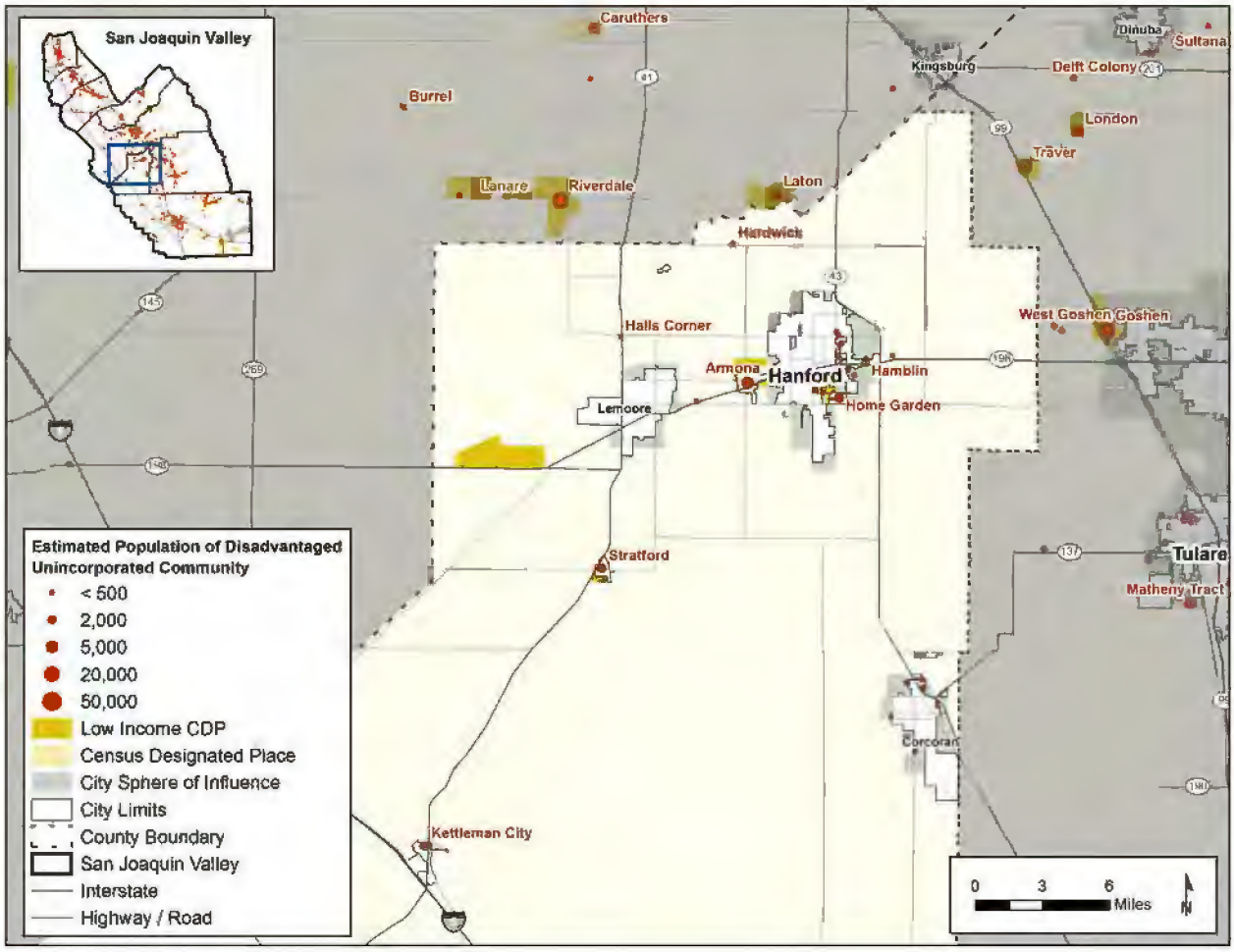


Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

DUCs with commonly recognized names in Kern County:

Alta Sierra
Bella Vista
Bodfish
Boron
Buttonwillow
Calders Corner
Cherokee Strip
Crome-Heights Corner
Edison
Edmundson Acres
El Rita
Ford City
Fruitvale
Fuller Acres
Glennville
Greenfield
Havilah
Inyokern
Johannesburg
Keene
Kern City
Kernville
Lake Isabella
Lamont
Lonsmith
Lost Hills
Magunden
Mayfair
Meridian
Mexican Colony
Mojave
Mountain Mesa
Oil Junction
Oildale
Onyx
Pond
Randsburg
Riverkern
Rosamond
Saco
Sage (historical)
Smith Corner
South Lake
South Taft
Squirrel Mountain Valley
Thomas Lane
Warren (historical)
Weed Patch
Weed Patch Highway
Wofford Heights
Woody

Kings County



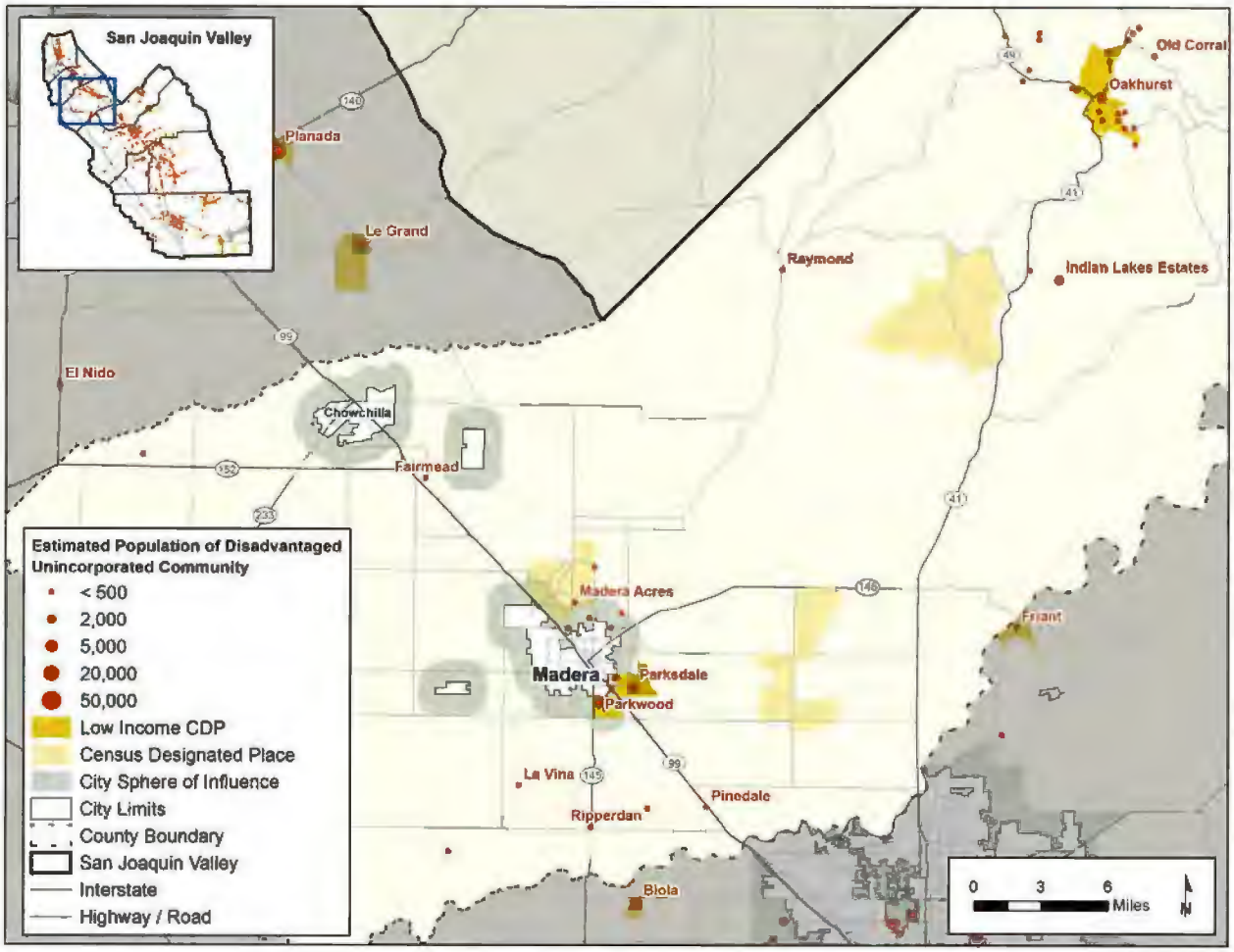
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

KINGS COUNTY	Number of DUCs	Estimated Total Population
Total	**24**	**7,494**
Fringe	20	7,428
Legacy	4	66
Island	0	0

DUCs with commonly recognized names in Kings County:

Armona
Halls Corner
Hamblin
Hardwick
Home Garden
Kettleman City
Stratford

Madera County



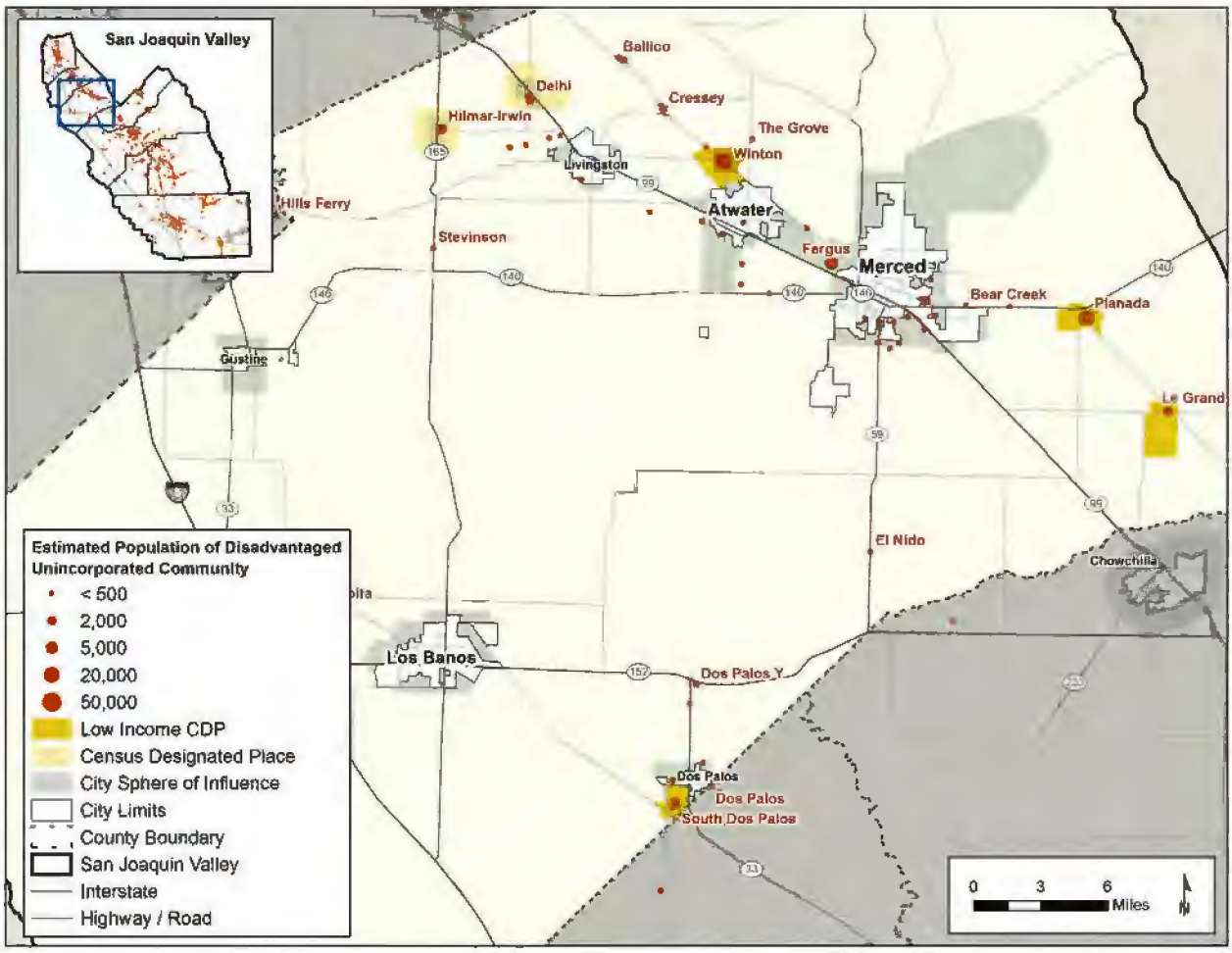
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

MADERA COUNTY	Number of DUCs	Estimated Total Population
Total	**44**	**8,558**
Fringe	10	3,074
Legacy	54	5,484
Island	0	0

DUCs with commonly recognized names in Madera County:

Fairmead
Indian Lakes Estates
La Vina
Madera Acres
Oakhurst
Old Corral
Parksdale
Parkwood
Pinedale
Raymond
Ripperdan

Merced County



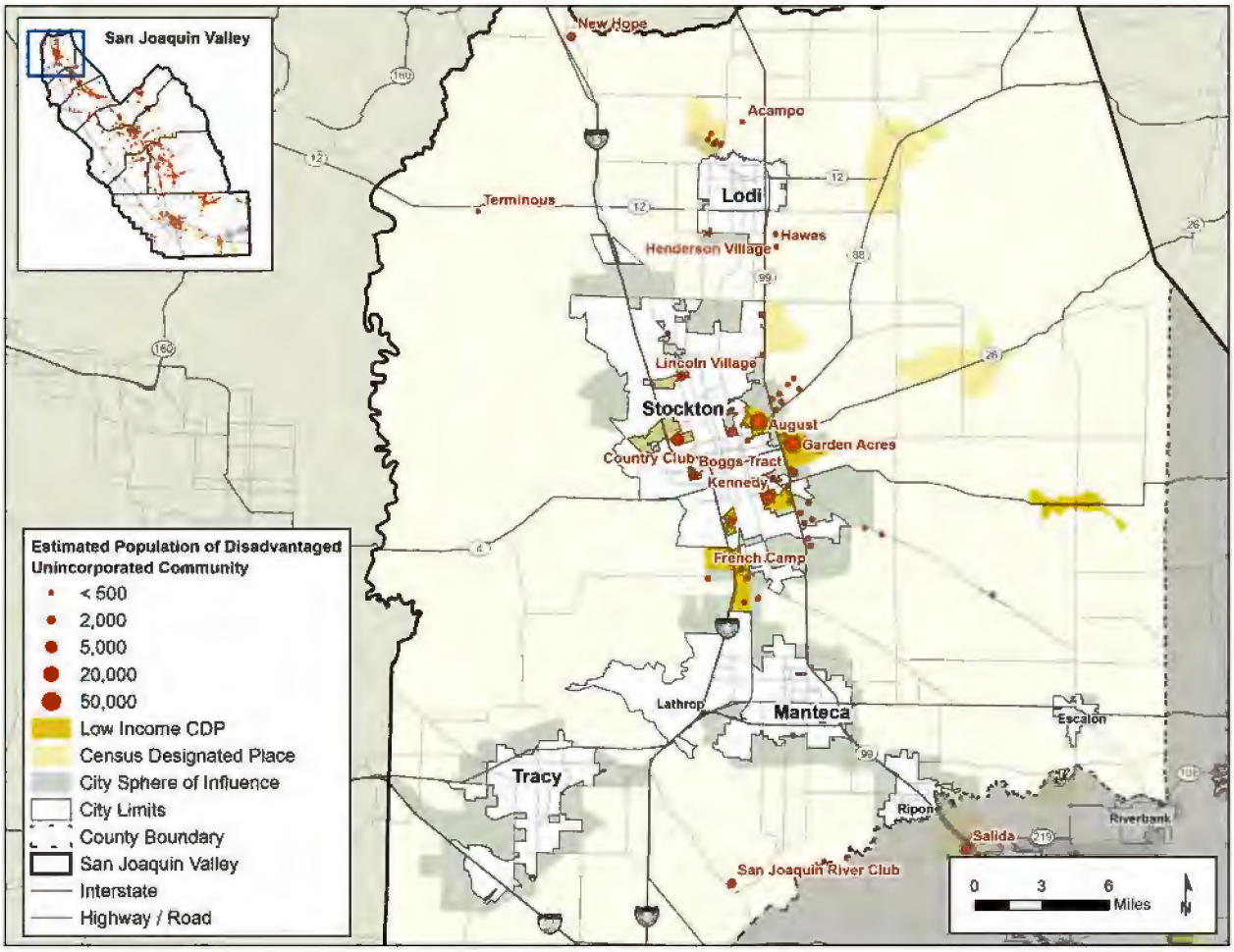
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

MERCED COUNTY	Number of DUCs	Estimated Total Population
Total	**47**	**20,861**
Fringe	29	20,537
Legacy	17	251
Island	1	73

DUCs with commonly recognized names in Merced County:

Ballico
Bear Creek
Cressey
Delhi
Dos Palos Y
El Nido
Fergus
Hilmar-Irwin
Le Grand
Planada
Santa Nella Village
Snelling
South Dos Palos
Stevinson
The Grove
Volta
Winton

San Joaquin County



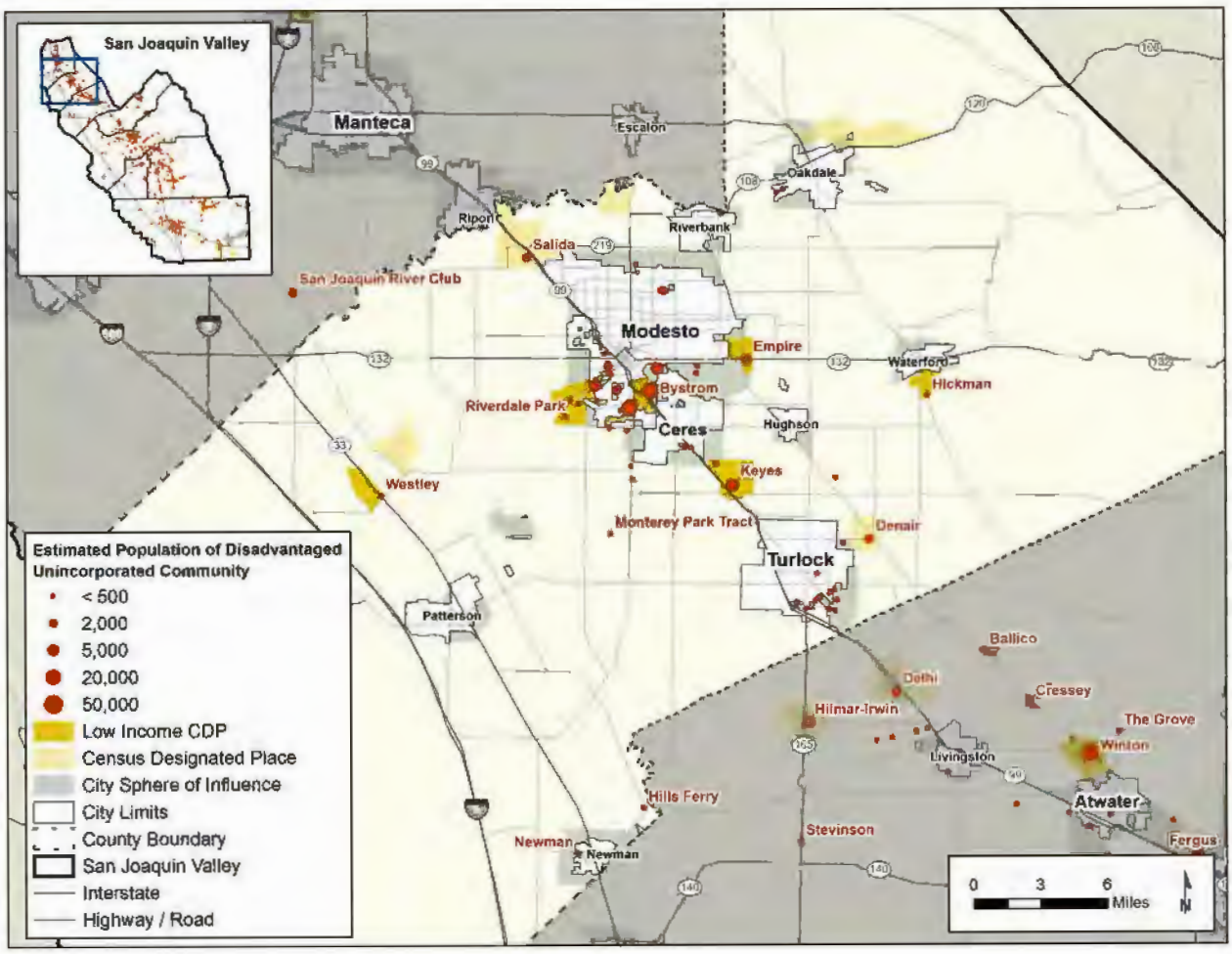
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

SAN JOAQUIN COUNTY	Number of DUCs	Estimated Total Population
Total	**51**	**29,203**
Fringe	26	21,678
Legacy	17	1,705
Island	8	5,820

DUCs with commonly recognized names in San Joaquin County:

Acampo
August
Boggs Tract
Country Club
El Pinal
French Camp
Garden Acres
Hawes
Henderson Village
Kennedy
Lincoln Village
New Hope
San Joaquin River Club
Terminous

Stanislaus County



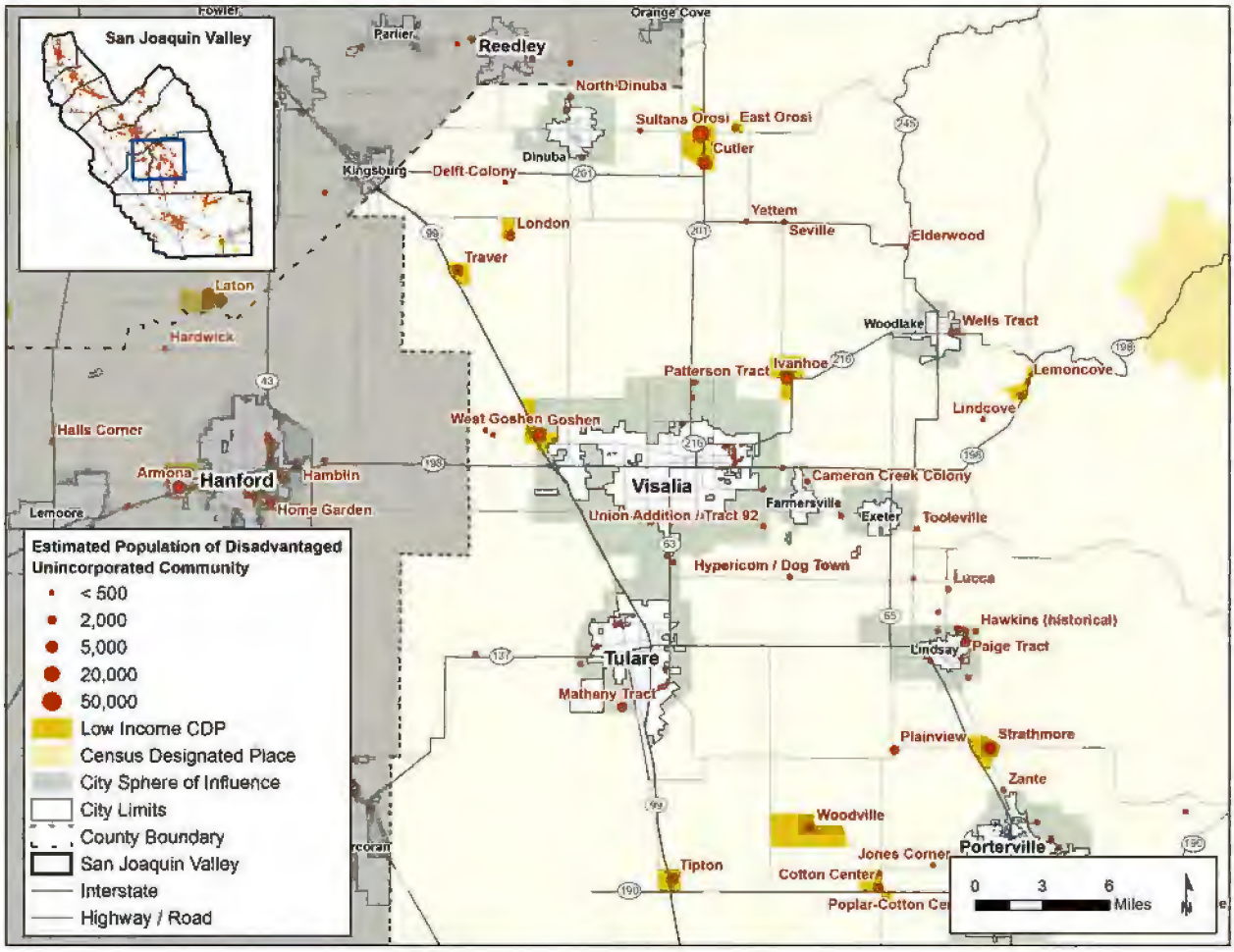
Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

STANISLAUS COUNTY	Number of DUCs	Estimated Total Population
Total	**47**	**31,247**
Fringe	27	24,569
Legacy	13	4,768
Island	7	1,910

DUCs with commonly recognized names in Stanislaus County:

Bystrom
Denair
Don Pedro area
Empire
Garden
Hickman
Hills Ferry
Keyes
Monterey Park Tract
Newman
Riverdale Park
Riverside
Salida
Shackelford
Westley

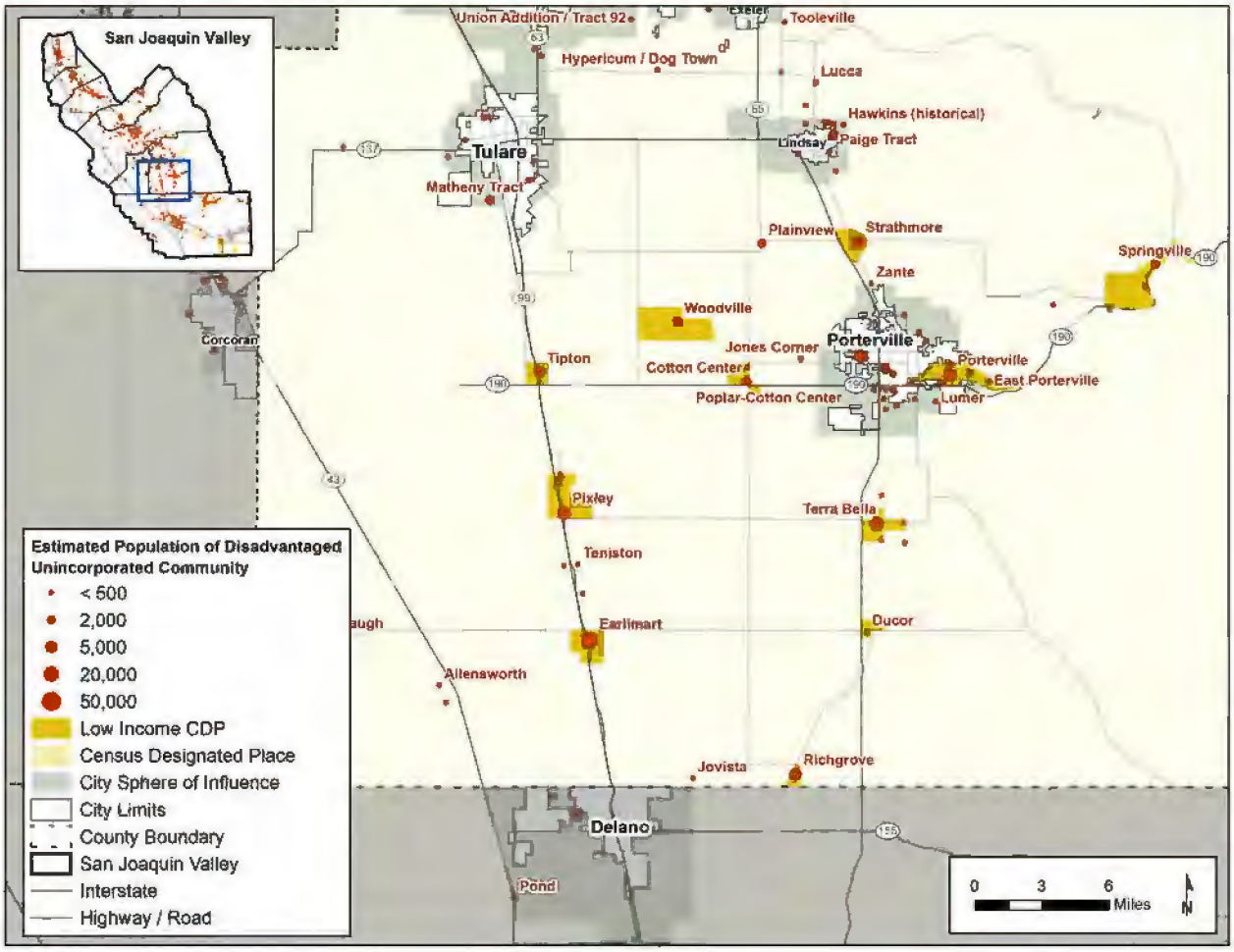
Tulare County (North)



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

TULARE COUNTY	Number of DUCs	Estimated Total Population
Total	**114**	**54,775**
Fringe	53	12,168
Legacy	53	38,846
Island	8	3,761

Tulare County (South)



Source: PolicyLink analysis of 2000 U.S. census and county parcel and boundary data.

DUCs with commonly recognized names in Tulare County:

Allensworth
Alpaugh
Cameron Creek Colony
Cotton Center
Cutler
Delft Colony
Ducor
Earlimart
East Orosi
East Porterville
Elderwood
Goshen
Hawkins (historical)
Hypericum / Dog Town
Idlewild
Ivanhoe
Jones Corner
Jovista
Lemoncove
Lindcove
London
Lucca
Lumer
Matheny Tract
North Dinuba
Orosi
Paige Tract
Patterson Tract
Pixley
Plainview
Plano
Poplar-Cotton Center
Porterville
Richgrove
Seville
Springville
Strathmore
Sultana
Teniston
Terra Bella
Tipton
Tooleville
Traver
Union Addition / Tract 92
Wells Tract
West Goshen
Woodville
Yettem
Zante

Authors' Biographies

Chione Flegal is an associate director with PolicyLink. She works to ensure that infrastructure and land use policy promote economic, social, and environmental equity. She leads the organization's policy work in California, as well as efforts to address disparities faced by low-income unincorporated communities.

Solana Rice is a senior associate with PolicyLink. As a researcher and policy advocate, she works to advance opportunity for low-income communities and communities of color by promoting equitable solutions to community development through wealth building, small business development, and other economically focused strategies.

Jake Mann is a temporary research assistant with PolicyLink supporting the mapping and analysis for the Community Equity Initiative.

Jennifer Tran is a program associate with PolicyLink. Her work focuses on equitable economic growth, conducting research, data analysis, and GIS mapping.

Lifting Up What Works®

PolicyLink

Headquarters:
1438 Webster Street
Suite 303
Oakland, CA 94612
t 510 663-2333
f 510 663-9684

Communications:
55 West 39th Street
11th Floor
New York, NY 10018
t 212 629-9570
f 212 768-2350

www.policylink.org

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EXHIBIT F

Chapter 7
Analysis of Underserved Disadvantaged Unincorporated Communities

A. Introduction

Senate Bill (SB) 244 (Wolk) was approved by the state in October 2011 and requires cities and counties to address the infrastructure needs of disadvantaged unincorporated communities (DUC) in city and county general plans, Local Agency Formation Commission (LAFCo) Municipal Service Reviews (MSR), and annexation decisions.

Government Code Section 65302.10(a) requires that before the due date for adoption of the next housing element after January 1, 2012, the general plan land use element must be updated to identify and describe each DUC (fringe community, legacy community, and/or island community) that exists within unincorporated areas of the county or in spheres of influence of each city; analyze for each identified community the water, wastewater, stormwater drainage, and structural fire protection needs; and identify financial funding alternatives for the extension of services to any identified communities. SB 244 defines a DUC as a place that meets the following criteria:

- Contains 10 or more dwelling units in close proximity to one another where 12 or more registered voters reside. For the purpose of this analysis, "close proximity" in the Kern County analysis was based on the threshold of more than one dwelling unit per acre. Information on the exact number of dwelling units was sometimes not available; in these cases, the number of residential units was used, and an assumption was made that one unit was equivalent to approximately one dwelling unit.

- Is either within a city sphere of influence (also known as a fringe community), is an island within a city boundary (also known as an island community), or is geographically isolated and has existed for at least 50 years (also known as a legacy community). **Figure 7a** graphically depicts these types of communities. Only legacy communities potentially occur in the unincorporated area of Kern County. The other two types of unincorporated communities occur in city spheres of influence or in unincorporated areas surrounded by incorporated cities.

- Has a median household income that is 80 percent or less of the statewide median household income. (According to the US Census Bureau, American Community Survey (ACS), the median household income for California between 2009 and 2013 was $61,094; therefore, communities with an area median income of $48,875 or lower qualify.)

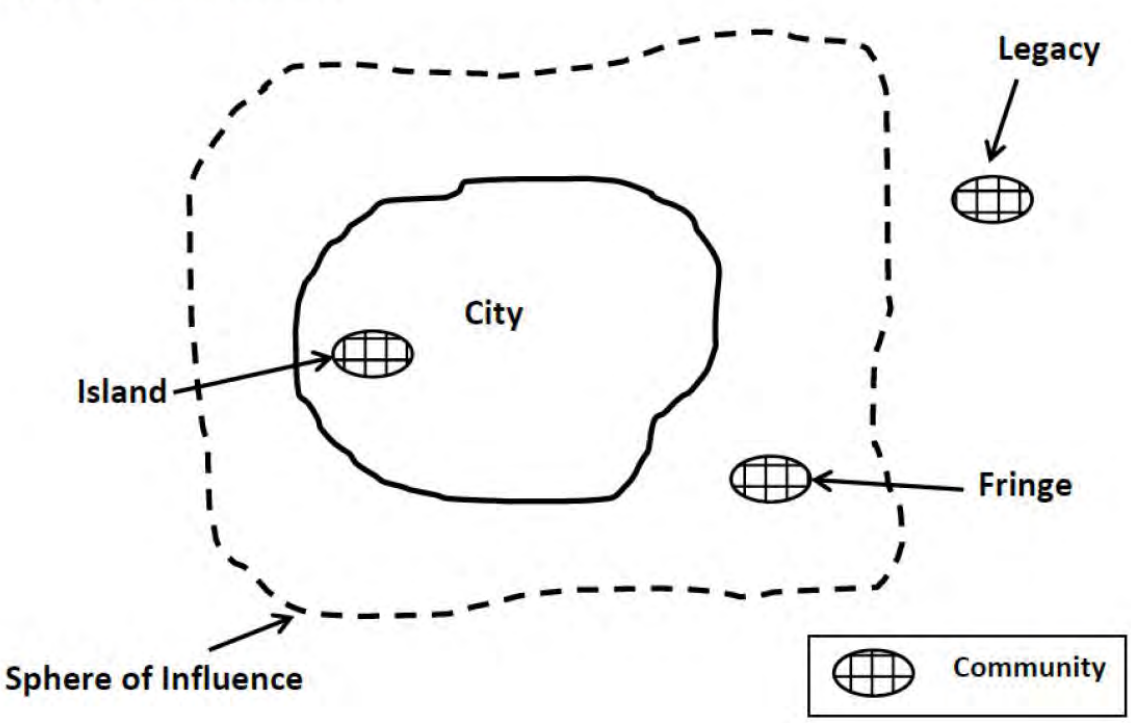
Table 70 lists the DUCs assessed in unincorporated Kern County.

Table 70. Assessed DUC Communities in Kern County

DUC Community
DUC 1: Bodfish
DUC 2: Boron
DUC 3: Buttonwillow
DUC 4: Cherokee Strip
DUC 5: Edmundson Acres
DUC 6: Fuller Acres
DUC 7: Johannesburg
DUC 8: Lake Isabella
DUC 9: Lake of the Woods
DUC 10: Lamont
DUC 11: Lost Hills
DUC 12: Mettler
DUC 13: Mexican Colony
DUC 14: Mojave
DUC 15: Mountain Mesa
DUC 16: Oildale
DUC 17: Onyx
DUC 18: Randsburg
DUC 19: USDA Ruben J. Blunt Village
DUC 20: Weedpatch
DUC 21: Weldon
DUC 22: Wofford Heights

Source: Kern County 2015

Figure 7a: Types of Communities That May Be DUCs



Source: OPR 2013

B. Analysis of Kern County Disadvantaged Unincorporated Communities

An analysis to identify DUCs in unincorporated Kern County was conducted in order to address the requirements of SB 244. In conducting the analysis, resources utilized included the SB 244 Technical Advisory (OPR 2013); the Municipal Service Reviews (MSR) of Kern County, independent agencies, and special districts in the county; and the city limit boundary maps of the cities in Kern County using geographic information systems (GIS).

Disadvantaged Unincorporated Communities

Twenty-two unincorporated communities were identified using Census Designated Place (CDP) information as possible DUCs and were considered for inclusion as communities for analysis. Several additional unincorporated agricultural labor communities were also identified for analysis as DUCs. Some CDPs and agricultural labor communities were eliminated because they did not meet the qualifications, based on census income data, mapping information, County staff knowledge, and plat records. Twenty-two communities met all of the criteria for analysis of services. Services to these communities were then assessed. **Figure 7b** shows the relative location of the disadvantaged unincorporated communities in the county. **Figures 7c** through **7g** show the more specific DUCs by region. In these figures, some of the DUCs are divided into several clusters of housing and are labeled A, B, C, D, etc.

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T:_GIS\Kern_County\MapsHousing_Element_2015\SB244\DUCs Countywide.mxd (2/29/2016)

Lost Hills
Cherokee Strip
Mexican Colony
Buttonwillow
Oildale
Fuller Acres
Lamont (includes USDA Lamont H.R. Olson)
Weedpatch
Edmundson Acres
USDA Ruben J. Blunt Village
Mettler
Lake of the Woods
Wofford Heights
Onyx
Mountain Mesa
Lake Isabella
Weldon
Bodfish
Johannesburg
Randsburg
Mojave
Boron

Richgrove
Posey
DELANO
Delano Muni Airport
Garces Hwy
155
Glennville
Woody
McFarland
Kernville
Wofford Heights
Onyx
Isabella Lake
Lake Isabella
Bodfish
Granite Rd
Porterville Hwy
WASCO
SHAFTER
W Lerdo Hwy
West Side Fwy
Westside Hwy
Kern River Canyon Rd
Fay Mountain Rd
501
178
Meadows Fld
OILDALE
Bakersfield
Bakersfield Muni Airport
Edison
McKittrick Hwy
Buttonwillow
58
Stockdale Hwy
Kern River
5
43
Tupman
McKittrick
119
LAMONT
Caliente
ARVIN
223
99
Fellows
Taft
Maricopa
166
New Cuyama
Grapevine
Lebec
Frazier Park
Ventucopa
Caswell
Keene
Bakersfield-Tehachapi Hwy
TEHACHAPI
Midland Trl
California City Blvd
CALIFORNIA CITY
Mojave
Mojave Airport
Edwards Af Aux North Base
Edwards
Edwards Afb
ROSAMOND
W Avenue D
138
14
70th St W
60th St W
General Wm J Fox
Bodfish Canyon Rd
Cantil
Redrock Randsburg Rd
Red Mountain
Inyokern
China Lake Naws
China Lake
RIDGECREST
395
Trona Rd
SAN BERNARDINO
VENTURA
LOS ANGELES

Legend

- Disadvantaged Unincorporated Community (DUC)
- County Boundary

Source: ESRI; Kern County, 2015; Michael Baker International, 2015

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Miles

Figure **7b**
Disadvantaged Unincorporated Communities (DUCs) in Kern County

Michael Baker INTERNATIONAL

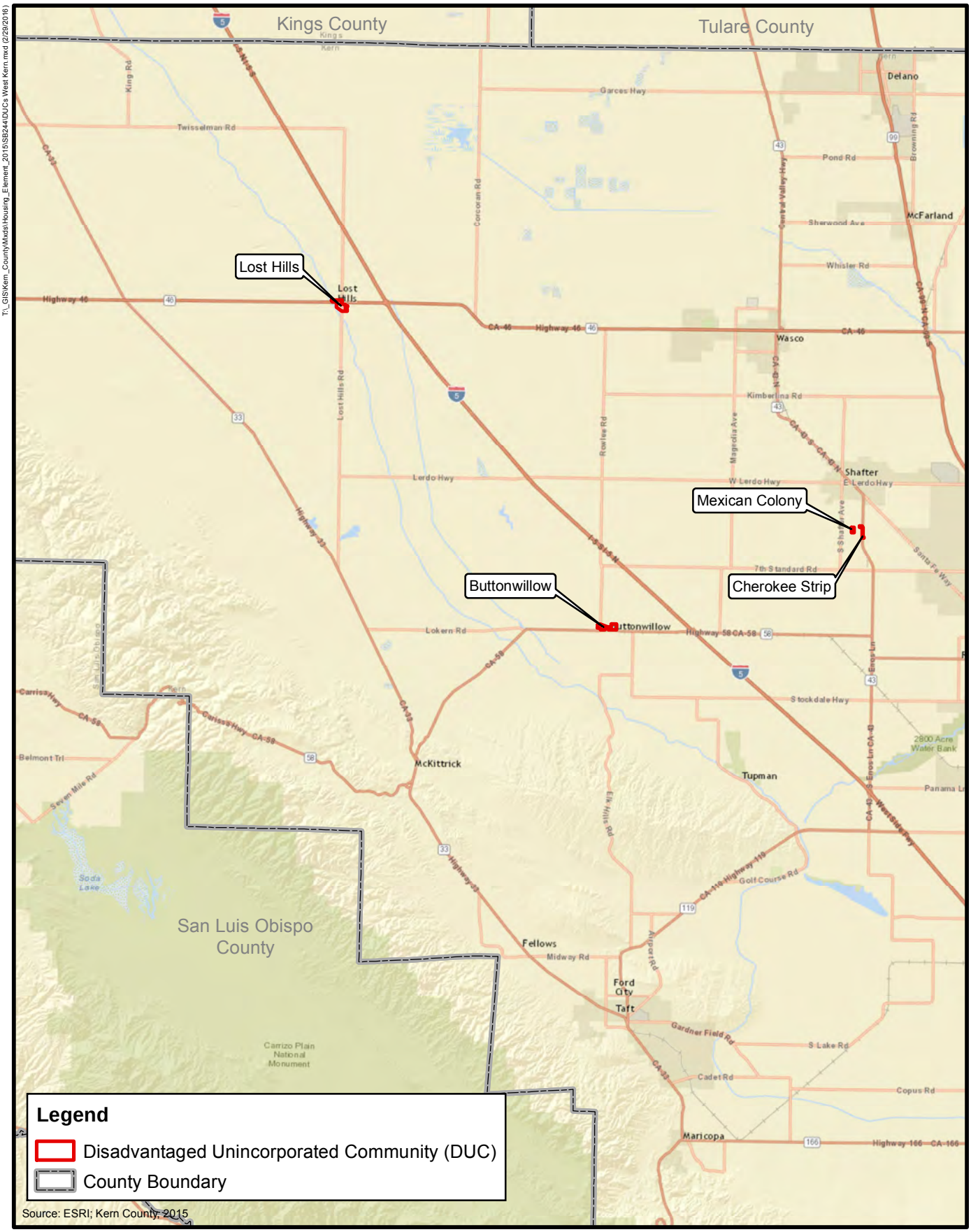


Figure **7c**
Disadvantaged Unincorporated Communities in Kern County
Western Kern

Michael Baker INTERNATIONAL

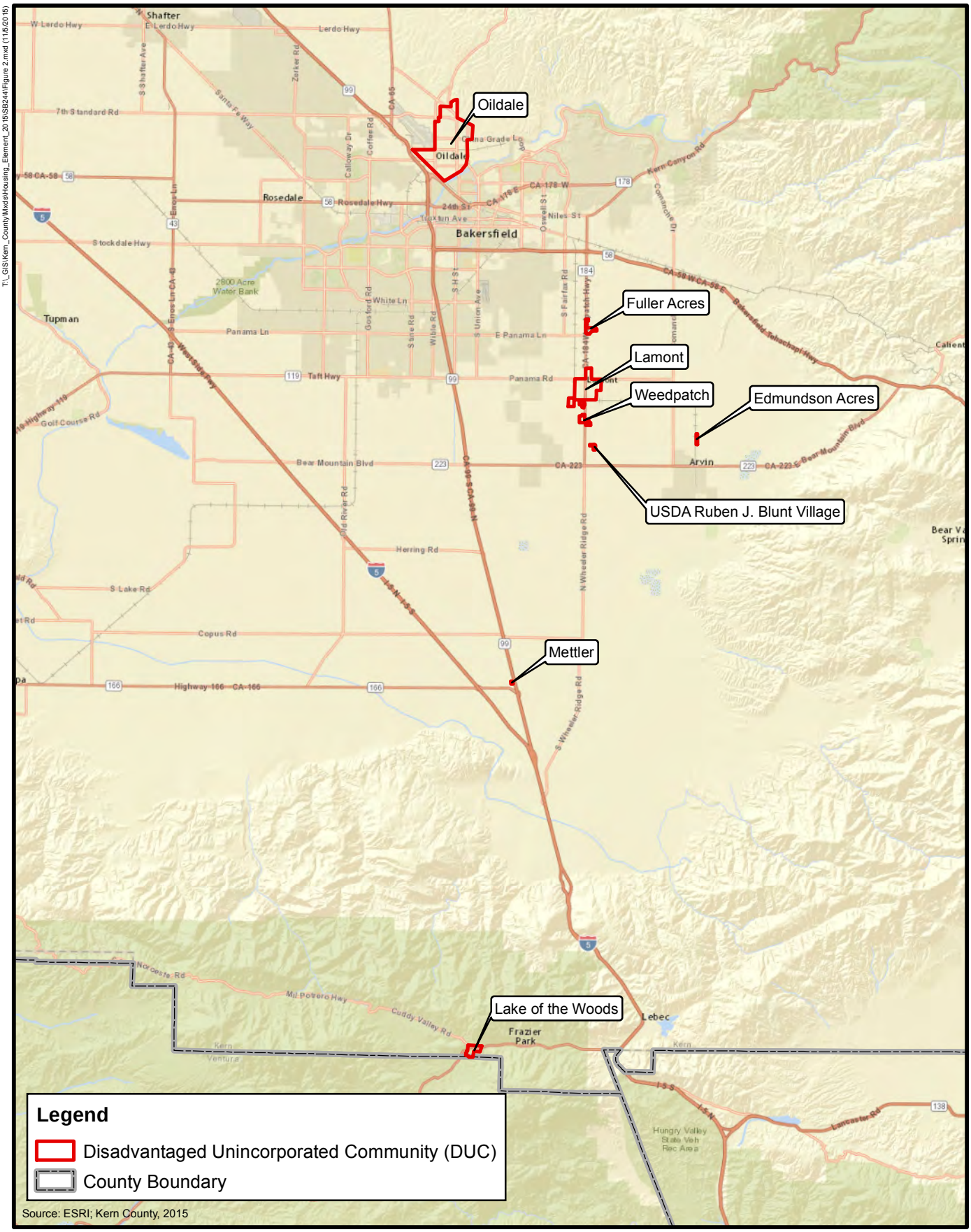


Figure **7d**
Disadvantaged Unincorporated Communities in Kern County
Metro Bakersfield and South Kern

Michael Baker INTERNATIONAL

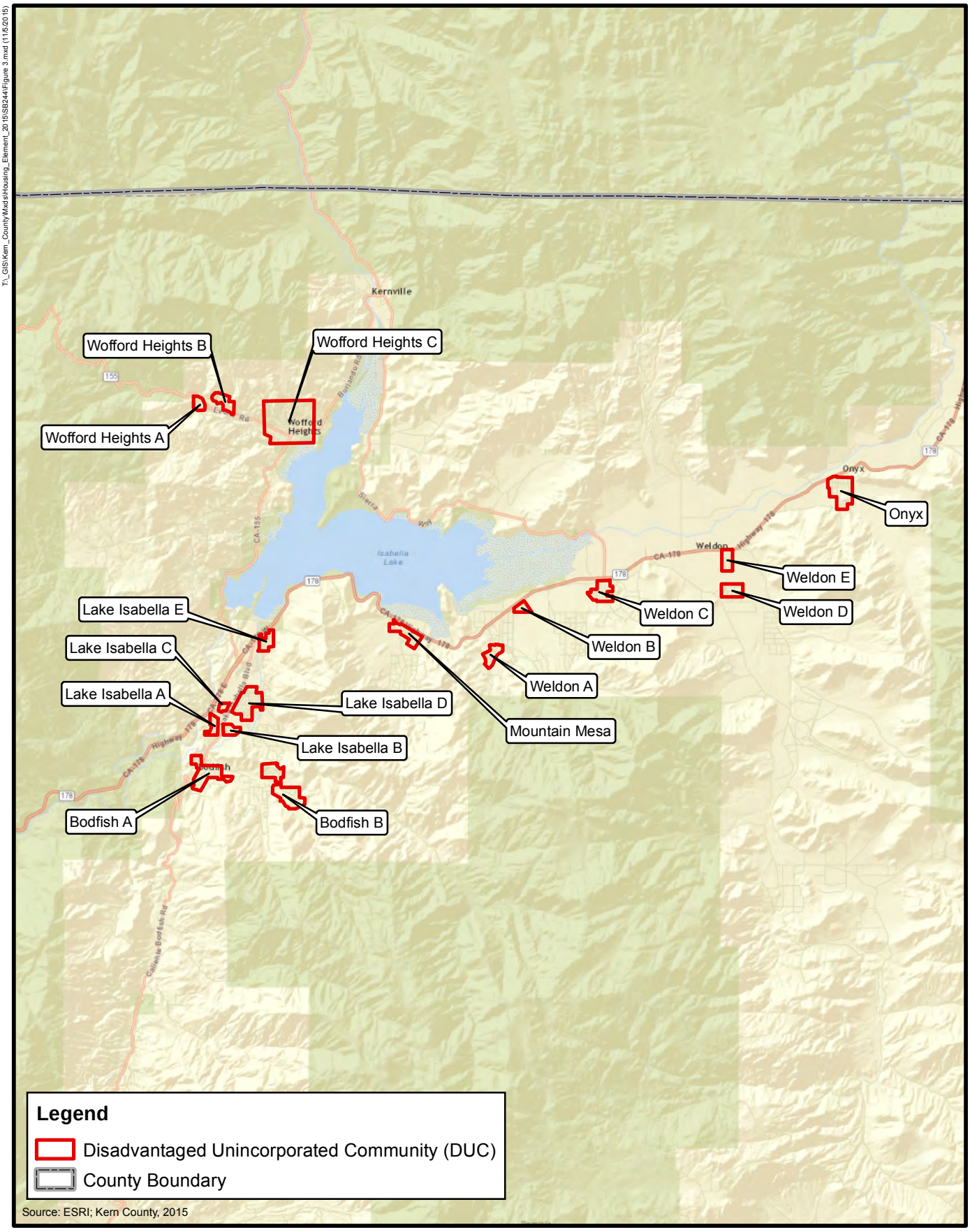


Figure **7e**
Disadvantaged Unincorporated Communities in Kern County
Isabella Lake/North Kern

Michael Baker INTERNATIONAL

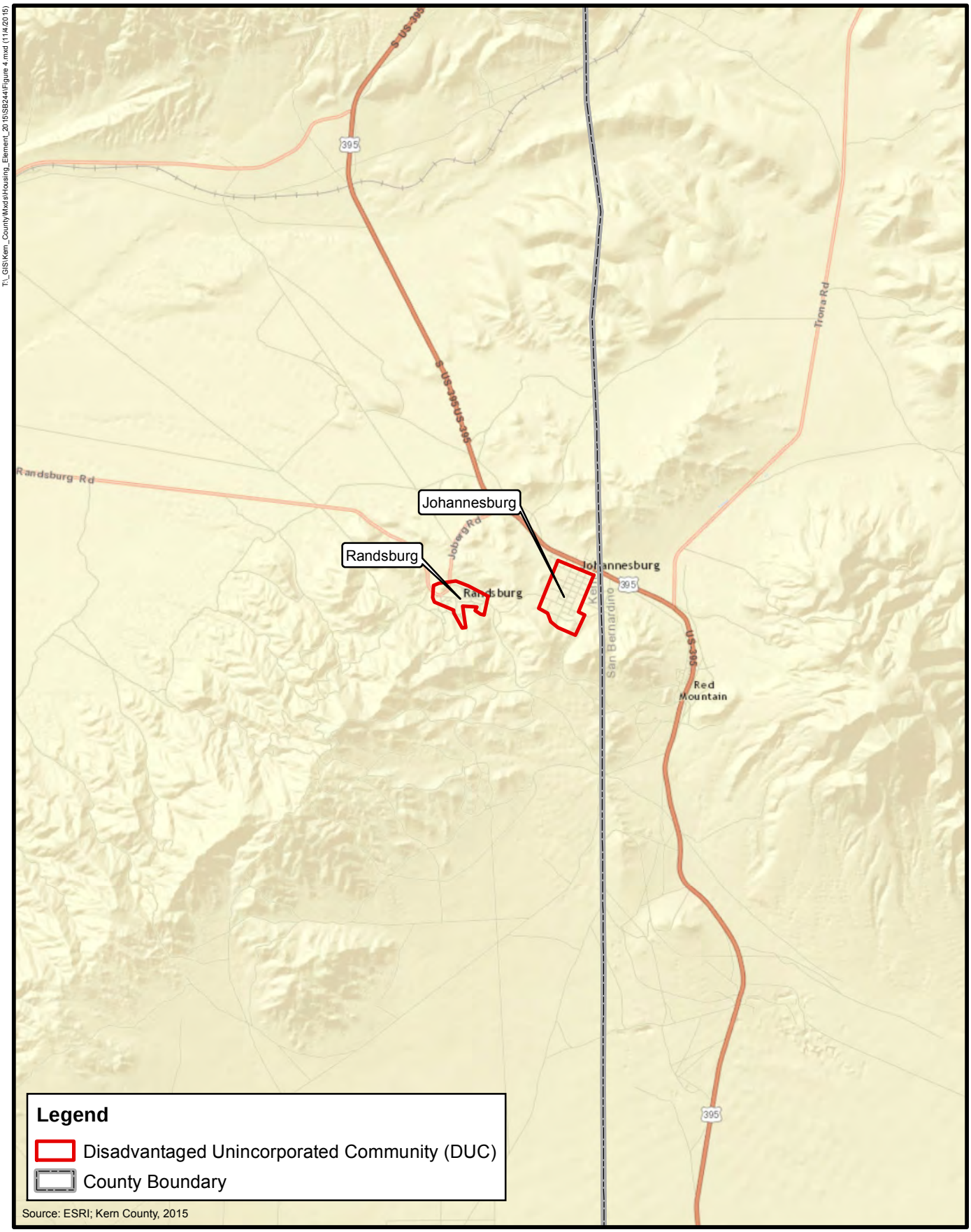


Figure **7f**
Disadvantaged Unincorporated Communities in Kern County
East Kern

Michael Baker INTERNATIONAL

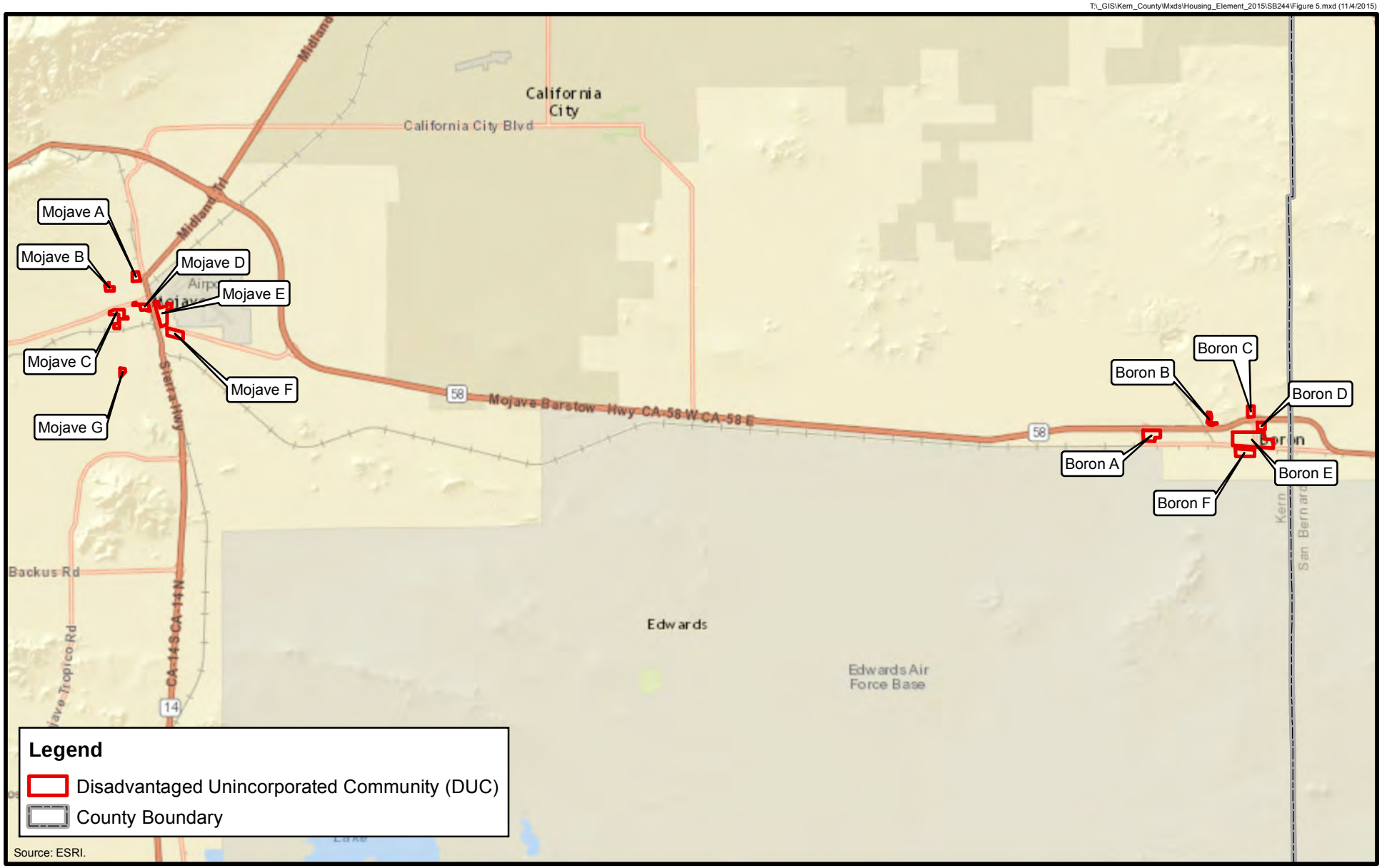


Figure 7**g**
Disadvantaged Unincorporated Communities in Kern County
Southeast Kern

Michael Baker INTERNATIONAL

DUC 1 (Bodfish)

DUC 1 is the Census Designated Place known as Bodfish, approximately 40 miles northeast of Bakersfield. The community is located off State Route (SR) 178, south of Lake Isabella, as shown on **Figure 7e**. Bodfish has two concentrations of residential development; together containing 838 units over 334 acres. This results in an approximate density of 2.51 units per acre. The CDP has a median household income of $21,461 according to the 2009–2013 ACS, according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 2 (Boron)

DUC 2 is the Census Designated Place of Boron, located on the southeast corner of Kern County, approximately 20 miles south of California City. The community is directly west of the intersection of SR 58 and US Route 395, as shown on **Figure 7g**. Boron has six clusters of residential units, covering 212 acres of land. This results in an approximate density of 3.53 units per acre. The median income in Boron, $36,308, is below the qualifying income threshold for DUCs.

DUC 3 (Buttonwillow)

DUC 3 is the Census Designated Place of Buttonwillow, approximately 25 miles west of Bakersfield. The community is a concentration of 336 units at the intersection of SR 58 with Interstate 5 (I-5), as shown on **Figure 7c**. The community is approximately 66 acres, with an overall density of approximately 5 units per acre. Buttonwillow has a median household income of $34,732, according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 4 (Cherokee Strip)

DUC 4 is the Census Designated Place known as Cherokee Strip, located approximately 17 miles northwest of Bakersfield, as shown on **Figure 7c**. The community is a small concentration of residences surrounded by agricultural fields west of SR 43. Cherokee Strip has 60 residential units making up 17 acres, which results in an overall density of approximately 3.5 units per acre. The CDP has a median household income of $43,125, according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 5 (Edmundson Acres)

DUC 5 is the Census Designated Place known as Edmundson Acres. This community is adjacent to the northern boundary of Arvin, as shown on **Figure 7d**. The community has a single concentration of residences on approximately 62 units making up 17 acres. The community has an overall density of approximately 3.6 units per acre. The 2009–2013 ACS reports that Edmundson Acres has a median household income of $35,833, which is less than the qualifying income threshold of $48,856.

DUC 6 (Fuller Acres)

DUC 6 is a Census Designated Place known as Fuller Acres, approximately 7 miles southeast of Bakersfield. The community is south of SR 58 and centered around SR 184, as shown on **Figure 7d.** Residences are concentrated in one area containing 213 units over 67 acres. The community has an overall density of approximately 3.2 units per acre. The 2009–2013 ACS reports that Fuller Acres has a median household income of $35,833, which is less than the qualifying income threshold of $48,856.

DUC 7 (Johannesburg)

DUC 7 is the Census Designated Place known as Johannesburg, approximately 15 miles northeast of California City. The community is located off US Route 395, as shown on **Figure 7f**. Johannesburg has a single concentration of residential development, containing 106 units over 29 acres, which results in an approximate density of 3.56 units per acre. The CDP has a median household income of $32,360according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 8 (Lake Isabella)

DUC 8 is the Census Designated Place of Lake Isabella, approximately 40 miles northeast of Bakersfield. The community is located off SR 178, adjacent to the south side of Lake Isabella, as shown on **Figure 7e**. The Lake Isabella CDP has five clusters of residences in close proximity, totaling 1,323 units on 278 acres. This results in an approximate density of 4.2 units per acre. The CDP has a median household income of $20,678 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 9 (Lake of the Woods)

DUC 9 is the Census Designated Place known as Lake of the Woods, approximately 40 miles northeast of Bakersfield. The community is located off SR 178, adjacent to the south side of Lake Isabella, as shown on **Figure 7d**. Lake of the Woods is a cluster of residences on 384 units in close proximity, making up 49.6 acres, which results in an approximate density of 7.74 units per acre. The CDP has a median household income of $48,750 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 10 (Lamont)

DUC 10 is the Census Designated Place of Lamont, approximately 10 miles southeast of Bakersfield. The community is south of SR 58 and centered around SR 184. Residences are concentrated in one area containing 2,361 units over 452 acres as shown on **Figure 7d**. This DUC contains the USDA Lamont H.R. Olson farmworker housing community. The community has an overall density of approximately 3.2 units per acre. The 2009–2013 ACS reports that Lamont has a median household income of $35,833, which is less than the qualifying income threshold of $48,856.

DUC 11 (Lost Hills)

DUC 11 is the Census Designated Place of Lost Hills, approximately 25 miles west of Wasco. The community is centered at the intersection of I-5 and CA-46. Residences are concentrated in one area containing 296 units over 56.8 acres, as shown on **Figure 7c**. The community has an overall density of approximately 5.2 units per acre. The 2009–2013 ACS reports that the Lost Hills CDP has a median household income of $30,795, which is less than the qualifying income threshold of $48,856.

DUC 12 (Mettler)

DUC 12 is the Census Designated Place known as Mettler, in the southeast portion of Kern County. The community is located along SR 99 just north of the intersection with I-5, as shown on **Figure 7d**. Mettler has roughly 26 residential units in close proximity across 5.3 acres, which results in an approximate density of 4.9 units per acre. The CDP has a median household income of $38,750 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 13 (Mexican Colony)

DUC 13 is the Census Designated Place known as Mexican Colony, in the northwest portion of Kern County. The community is located west of SR 43 just south of the City of Shafter, as shown on **Figure 7c**. Mexican Colony has roughly 78 residential units in close proximity across 20.48 acres, which results in an approximate density of 3.8 units per acre. The CDP has a median household income of $21,250 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 14 (Mojave)

DUC 14 is the Census Designated Place of Mojave, approximately 14 miles southwest of California City. The community is located along SR 14, as shown on **Figure 7g**. Mojave includes seven small clusters of residences, containing 894 units in close proximity on a total of 182 acres, which results in an approximate density of 4.9 units per acre. The CDP has a median household income of $48,750 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 15 (Mountain Mesa)

DUC 15 is the Census Designated Place known as Mountain Mesa, in the northeast portion of Kern County, located below the Sequoia National Forest. The community is 48 miles from downtown Bakersfield, as shown on **Figure 7e**. Mountain Mesa has roughly 349 residential units in close proximity across 73 acres, which results in an approximate density of 4.8 units per acre. The CDP has a median household income of $29,712 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 16 (Oildale)

DUC 16, Oildale, is a Census Designated Place located along Bakersfield's northern border, as shown on **Figure 7d**. Oildale contains 8,739 residential units across 1,832 acres, which results in an approximate density of 2.0 units per acre. The CDP has a median household income of $33,305 according to the 2009-2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 17 (Onyx)

DUC 17 is the Census Designated Place of Onyx in northeast Kern County. The community is located along SR 178 about 20 miles east of Lake Isabella, as shown on **Figure 7e**. Residences are concentrated in one area containing 259 units over 104 acres. The community has an overall density of approximately 2.5 units per acre. The 2009–2013 ACS reports that the Onyx CDP has a median household income of $32,679, which is less than the qualifying income threshold of $48,856.

DUC 18 (Randsburg)

DUC 18, Randsburg, is a Census Designated Place located along Kern County's eastern border, as shown on **Figure 7f**. The community is adjacent to US Route 395. Randsburg contains 77 residential units across 17 acres, which results in an approximate density of 4.5 units per acre. The CDP has a median household income of $26,280 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 19 (USDA Ruben J. Blunt Village)

DUC 19 is the Census Designated Place located along Bakersfield's northern border, as shown on **Figure 7d**. The CDP contains 8,739 residential units across 1,832 acres, which results in an approximate density of 2.0 units per acre. The community has a median household income of $33,305 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 20 (Weedpatch)

DUC 20, Weedpatch, is a Census Designated Place located in central Kern County 15 miles south of Bakersfield's northern border, as shown on **Figure 7d.** Weedpatch has two clusters of residential units in close proximity that together contain 363 residential units across 80 acres. This results in an approximate density of 4.5 units per acre. The CDP has a median household income of $28,508 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 21 (Weldon)

DUC 21, Weldon, is the Census Designated Place located along Lake Isabella in the northeastern part of Kern County, as shown on **Figure 7e.** The community has five clusters of residential units in close proximity that together contain 925

residential units across 332 acres, which results in an approximate density of 1.6 units per acre. The Weldon CDP has a median household income of $24,972 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

DUC 22 (Wofford Heights)

DUC 22 is a Census Designated Place known as Wofford Heights located along the northwestern side of Lake Isabella, as shown on **Figure 7e.** Wofford Heights contains three clusters of residential units that together contain 1,087 residential units across 327 acres. This results in an approximate density of 3.3 units per acre. The CDP has a median household income of $28,917 according to the 2009–2013 ACS, which is less than the qualifying income threshold of $48,856.

C. Municipal Infrastructure and Services Review

1. Water

DUC 1 (Bodfish)

The community of Bodfish has two water providers. The California Water Service (Cal Water) Kern River Valley District serves lower Bodfish, and the Canyon Meadows Water Company serves upper Bodfish. According to the Cal Water 2010 Urban Water Management Plan, it has adequate water supply to meet service connection needs throughout the district. The Canyon Meadows Water Company is a small co-op with 150 connections on several groundwater wells. The co-op president (Cannell 2015) indicates that water levels in the wells remain high and that the current wells have enough capacity to meet current need. The wells meet water quality standards.

DUC 2 (Boron)

Water service to Boron is provided by the Boron Community Services District. The district has 600 connections and is supplied by groundwater or through the Antelope Valley-Eastern Kern Water Agency (Dewar 2015). Supply from these sources is blended and then distributed. The current groundwater well owned by the district is contaminated with arsenic but it concentrations are below the US Environmental Protection Agency's (EPA) maximum contaminant level for arsenic. The district is drilling an additional well, due to be completed by 2016.

DUC 3 (Buttonwillow)

Buttonwillow is provided water by the Buttonwillow County Water District. The district has 150 connections and 434 residential and business units. The district solely uses groundwater, which is adequate to meet current water needs (Houchin 2015a). The groundwater wells owned by the district provide water that meets standards and is of good quality.

DUC 4 (Cherokee Strip)

This area receives water from the City of Shafter. According to Shafter's Public Works Director (James, 2016), this area does not have drinking water quality issues and they have sufficient capacity for their current needs. However, they do not have capacity for expansion or new development.

DUC 5 (Edmundson Acres)

Water to Edmundson Acres is provided by the Edmundson Acres Water System. The system provides all supply through groundwater. Future projects involve replacing old wells with new wells that will not require treatment for arsenic or other constituents. Arsenic is a contaminant that is above the maximum concentration limit of 10 ug/l in all of the system's older wells. Edmundson Acres Water System is upgrading its distribution system and being consolidated with neighboring Arvin Community Services District (ACSD) to correct high arsenic problems. The ACSD is currently under a compliance order from the EPA to solve the problem. Because of arsenic concerns, the Edmundson Acres Water System applied for a Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006 (Proposition 84) grant to help it achieve compliance with the order. The system is implementing a plan to drill new replacement wells in areas with unacceptable water quality, including arsenic contamination. If wells do not have acceptable levels of arsenic, centralized arsenic treatment will be installed.

DUC 6 (Fuller Acres)

According to County staff (Rojas 2016) most of the properties in the Fuller Acres DUC are served by a private water wells or water is provided by the Fuller Acres Water Company. For homes on private water wells, no information was available regarding capacity to serve current or future residents or water quality. Regarding Fuller Acres Water Company, according to Company Staff (Alcorn 2016), the Company has capacity to serve all of their current customers. However, they do not have sufficient capacity for expansion. There are no water quality issues.

DUC 7 (Johannesburg)

Water service in Johannesburg is provided by the Rand Communities Water District. The district provides water to Johannesburg, as well as to Randsburg and Red Mountain in San Bernardino County, serving a total population of 920. The district has roughly 220 connections in Kern County and another 40 connections in San Bernardino County. Based on communications with the district's general manager (Powell 2015), water levels in the district's three wells have remained constant, even during recent drought conditions, and the district has ample supply to meet existing and projected water demand. One of the wells does not meet the EPA's maximum contaminant level for arsenic. The district is currently able to meet demand with only one of the two remaining wells. In addition, the district's distribution system is failing due to age, and breaking or leaking occurs with relative frequency. The district has applied for funds through Proposition 84 grant

funding to make infrastructure improvements. This funding may result in an additional well but will not address all of the district's infrastructure needs.

DUC 8 (Lake Isabella)

Water service in Lake Isabella is primarily provided by the Lake Isabella Community Services District. Additionally, small numbers of residences are served by Cal Water and the Kern River Valley Community Services District. The Lake Isabella Community Services District has 184 total service connections, of which 145 are active. Based on communications with the district's office manager (Loseph 2015), the district purchases water from the Urston Creek Water District and operates three groundwater wells. The district reports that it has ample supply to meet existing and projected water demand. All water sources meet quality standards.

DUC 9 (Lake of the Woods)

Water service here is provided by the Lake of the Woods Water District. Currently the district is able to provide water to residents from their wells; however in the recent past they had to supplement this with water brought from the Lebec County Water District. This is because some of the wells are not as productive as they once were. The State is mandating that the Lake of the Woods Water District go to metering. They are looking into potentially annexing into the Frazier Park Public Utilities District (Jarecki, 2016).

DUC 10 (Lamont)

Water service in Lamont is provided by the Lamont Public Utility District, which currently serves a population of 19,152. Currently, the entire district is on groundwater wells. The district's 2014 Urban Water Management Plan reports that the district is currently in overdraft during the drought period and is working with neighboring water jurisdictions to secure additional supply. The district has adequate financing to develop projects to continue to meet current and projected demand. The district's water sources meet quality standards.

DUC 11 (Lost Hills)

County staff (Downs 2016) indicates that residents in this area receive water and sewer service from a local Public Utilities District.

DUC 12 (Mettler)

Water service in Mettler is provided by the Mettler County Water District. The district supplies water for 45 connections, supplied through two groundwater wells. District staff (Houchin 2015b) indicates that water supply is adequate to meet needs and that no water quality problems exist.

DUC 13 (Mexican Colony)

This area receives water from the City of Shafter. According to Shafter's Public Works Director (James, 2016), this area does not have drinking water quality issues and they have sufficient capacity for their current needs. However, they do not have capacity for expansion or new development.

DUC 14 (Mojave)

Water service in Mojave is provided by the Mojave Public Utility District, which currently has 112 water connections. The district has two sources of water, including local groundwater wells and contract supply through the Antelope Valley-East Kern Water Agency. Combined, the sources provide 1,600 acre-feet of water per year, which is greater than the current and projected needs of the community. The district's water sources meet water quality standards.

DUC 15 (Mountain Mesa)

Water service in Mountain Mesa is provided by the Mountain Mesa Water Company, which is operated by Cal Water by contract. The water supply has ongoing quality issues with nitrate and arsenic, but detected levels do not exceed standards. The district is currently making improvements to the treatment plant in order to reduce nitrate and arsenic concentrations in the groundwater supply.

DUC 16 (Oildale)

Water service in Oildale is provided by the Oildale Mutual Water Company, which has 10,200 connections supplied through groundwater wells. The company manager indicates that groundwater levels are sufficient and that the company has adequate supply to meet current and projected needs (Nunneley, 2015). All water sources meet water quality standards.

DUC 17 (Onyx)

Onyx is geographically isolated and topographically constrained. Residents there receive their water from private wells according to an employee (Aguirre, 2016) at the Lake Isabella Kern River KOA Campground. (This KOA is one of the "Possible Partnering Agencies" on the Integrated Regional Water Management Plan for the Weldon Regional Water Project.) No information on capacity or water quality was available.

DUC 18 (Randsburg)

Water service in Randsburg is provided by the Rand Communities Water District. The district also provides water to Johannesburg and Red Mountain in San Bernardino County, serving a total population of 920. The district has roughly 220 connections in Kern County and another 40 connections in San Bernardino County. Based on communications with the district's general manager (Powell 2015), water levels in the district's three wells has remained constant, even during

recent drought conditions, and the district has ample supply to meet existing and projected water demand. One of the wells does not meet the EPA's maximum contaminant level for arsenic. The district is currently able to meet demand with only one of the two remaining wells. In addition, the district's distribution system is failing due to age, and breaking or leaking occurs with relative frequency. The district has applied for funds through Proposition 84 grant funding to make infrastructure improvements. This funding may result in an additional well but will not address all of the district's infrastructure needs.

DUC 19 (USDA Ruben J. Blunt Village)

According to the Facilities Area Supervisor of the Kern County Housing Authority (Greenoe, 2016), water here is provided by the Lamont Public Utility District, which currently serves a population of 19,152. Currently, the entire district is on groundwater wells. The district's 2014 Urban Water Management Plan reports that the district is currently in overdraft during the drought period and is working with neighboring water jurisdictions to secure additional supply. The district has adequate financing to develop projects to continue to meet current and projected demand. The district's water sources meet water quality standards.

DUC 20 (Weedpatch)

Water service in Weedpatch is provided by the Lamont Public Utility District, which currently serves a population of 19,152. Currently, the entire district is on groundwater wells. The district's 2014 Urban Water Management Plan reports that the district is currently in overdraft during the drought period and is working with neighboring water jurisdictions to secure additional supply. The district has adequate financing to develop projects to continue to meet current and projected demand. The district's water sources meet water quality standards.

DUC 21 (Weldon)

According to County staff, Weldon gets its water supply from several small water co-ops and private entities, including the Long Canyon Water Company, Rainbird Valley Mutual Water Company, Tradewinds Water Association, Inc., Bella Vista Mutual Water Company, South Fork Women's Club, and Lake Isabella Kern River KOA Campground. Several of these private entities have arsenic and nitrate quality concerns.

DUC 22 (Wofford Heights)

County staff (Downs 2016) indicates that water here is provided by the California Water Service Company.

Wastewater

DUC 1 (Bodfish)

All of Bodfish depends on small private septic systems. County staff (Popiemlarp 2015) indicates that many of these systems are old and in need of replacement, but they are located on very small lot sizes and in some cases are in poor soils. Both lot size and soils can present challenges for replacement with modern and effective septic systems. Other infrastructure improvements may therefore be necessary.

DUC 2 (Boron)

All of Boron depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 3 (Buttonwillow)

The Buttonwillow County Water District provides wastewater collection, treatment, and disposal in limited areas of the community. The district has adequate infrastructure to meet current demand. The rest of the community is on private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 4 (Cherokee Strip)

County staff (Downs 2016) indicates that residences are on small private septic systems. The area has experienced numerous septic failures and resultant water quality impacts. State funding is currently being sought to remedy this situation.

DUC 5 (Edmundson Acres)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 6 (Fuller Acres)

All of Fuller Acres depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 7 (Johannesburg)

All of Johannesburg depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 8 (Lake Isabella)

As seen in **Figure 7e**, there are four portions (labeled A-D) which comprise the Lake Isabella DUC. County staff (Downs 2016) indicates that residents in Lake Isabella A are served by sewer. The sewer system in this area is 27 years old. A portion of residents in Lake Isabella D are on a private sewer that serves some commercial and a mobile home park. Lake Isabella areas B and C depend on small private septic systems. County staff (Popiemlarp 2015) indicates that many of these systems are old and in need of replacement, but they are located on very small lots and in some cases are in poor soils. Both lot size and soils can present challenges for replacement with modern and effective septic systems. Other infrastructure improvements may therefore be necessary.

DUC 9 (Lake of the Woods)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 10 (Lamont)

Wastewater service in Lamont is provided by the Lamont Public Utility District. The district's service area comprises approximately 2,000 acres, and it operates 35 miles of sewer collection pipes and one secondary-level wastewater treatment plant. The district does not indicate that there are currently any wastewater infrastructure needs.

DUC 11 (Lost Hills)

All of Lost Hills depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 12 (Mettler)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 13 (Mexican Colony)

County staff (Downs 2016) indicates that the area is on sewer. The sewer system has no known capacity or water quality issues.

DUC 14 (Mojave)

Portions of Mojave depend on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time. The remaining portions

of the community are served by the Mojave Public Utility District wastewater system, which has adequate infrastructure and wastewater treatment capacity to meet current needs.

DUC 15 (Mountain Mesa)

All of Mountain Mesa depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 16 (Oildale)

Wastewater service in Oildale is provided by the North of River Sanitary District. The district operates four treated effluent storage ponds and one wastewater treatment plant. The district has the infrastructure to meet sanitary needs. However, the existing sewers will eventually need to be paralleled and/or replaced with larger diameter sewers as flow from Oildale increases. The district's 2013 Master Sewer Plan establishes a timeline and financing options for making capacity improvements as demand increases.

DUC 17 (Onyx)

All of Onyx depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 18 (Randsburg)

All of Randsburg depends on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 19 (USDA Ruben J. Blunt Village)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 20 (Weedpatch)

Portions of Weedpatch depend on small private septic systems. County staff (Popiemlarp 2015) indicates that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time. The remaining portions of the community are served by the Lamont Public Utility Wastewater system, which has adequate infrastructure and wastewater treatment capacity to meet current needs.

DUC 21 (Weldon)

County staff (Downs 2016) indicates that residents in this area are on small private septic systems and that there are currently no issues of concern with the existing infrastructure and septic is adequate at this time.

DUC 22 (Wofford Heights)

All of Wofford Heights depends on small private septic systems. County staff (Popiemlarp 2015) indicates that many of these systems are old and in need of replacement. High groundwater levels, sloping geography, and erosion have led to water leaching issues in the area. Infrastructure improvements may therefore be necessary.

Stormwater

DUC 1 (Bodfish)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 2 (Boron)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 3 (Buttonwillow)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and pump station;
- Flood protection infrastructure capacity issues are known to exist; and
- The County has Drainage Improvement Plans for this area.

Stormwater and flood protection infrastructure is insufficient in this area.

DUC 4 (Cherokee Strip)

County staff (Hamilton, 2016) indicates that there is no stormwater infrastructure in place and it is not in a 100-year floodplain. Flooding is not a known issue here, according to County staff (Evans, 2016).

DUC 5 (Edmundson Acres)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Capacity issues are not known to exist; and
- The County has Drainage Improvement Plans for this area.

Stormwater and flood protection infrastructure is sufficient in this area.

DUC 6 (Fuller Acres)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain. County Staff (Evans, 2016) indicates that Caliente Creek has caused repeated historical flooding in Fuller Acres.

DUC 7 (Johannesburg)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place and that it is not in a 100-year floodplain. There is not a known history of flooding, as indicated by County staff (Evans, 2016).

DUC 8 (Lake Isabella)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Flood protection infrastructure capacity issues are known to exist;
- The County has Drainage Improvement Plans and Tract Improvement Plans for this area; and
- This area is in a 100-year floodplain.

According to the Kern County Roads Department *2015 Flood Map* for the Kern River Valley and correspondence with County staff (Evans, 2016), within this DUC, adjacent to Erskine Creek, Lake Isabella Boulevard at Lake Isabella Park (Tank Park) experiences frequent flooding and road closures. Major flooding occurs here approximately every ten years. This is a rural area and generally this road is the only access to towns in the Kern River Valley. Closures can impact a few hundred residents at a time.

Stormwater and flood protection infrastructure is insufficient in this area.

DUC 9 (Lake of the Woods)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain. County Staff (Evans, 2016) indicates that Cuddy Creek has caused historical flooding in this area.

DUC 10 (Lamont)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Flood protection infrastructure capacity issues are not known to exist;
- The County has Drainage Improvement Plans and Tract Improvement Plans for this area; and
- This area is within the NPDES Permit Boundary. Stormwater samples are collected by the Public Works Department biannually for analysis. No water quality issues are known to exist.

County staff (Downs 2016) indicates that there are known flooding issues in the USDA Lamont H.R. Olson farmworker community portion of this area. Stormwater and flood protection infrastructure is insufficient in this area.

DUC 11 (Lost Hills)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Capacity issues are not known to exist; and
- The County has Drainage Improvement Plans for this area.

Stormwater and flood protection infrastructure is sufficient in this area.

DUC 12 (Mettler)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place and it is in a 100-year floodplain. Furthermore, this area is known to flood routinely, as indicated by County staff (Evans, 2016).

DUC 13 (Mexican Colony)

County staff (Hamilton, 2016) indicates that stormwater infrastructure, in the form of a drainage basin, is in place. County staff (Hamilton, 2016) indicates that the County has a Drainage Improvement Plan for this area. County staff (Evans, 2016) indicates that there are flood protection infrastructure capacity issues.

DUC 14 (Mojave)

County staff (Hamilton, 2016) indicates that the area is in a 100-year floodplain. As seen on **Figure 7g**, Mojave includes seven small clusters of residences. Theses clusters are identified as A-G. County staff (Hamilton, 2016) indicates the following:

Area A. No stormwater infrastructure is in place.

Area B. No stormwater infrastructure is in place.

Area C. No stormwater infrastructure is in place in this area, except in the mobile home park, which has private streets and a private drainage basin. The County is in possession of a grading plan from the mobile home park.

Area D. No stormwater infrastructure is in place in this area, except in the apartment complex, which has a private drainage basin. The County is in possession of a grading plan from the apartment complex in this area.

Area E. Stormwater infrastructure is in place here, in the form of the Victor Avenue Basin. The County has a Drainage Improvement Plan.

Area F. No stormwater infrastructure is in place in this area, except in the apartment complex, which has a private drainage basin. The County is in possession of a grading plan from the apartment complex.

Area G. Stormwater infrastructure is in place, under the purview of the private community with private streets. The County is in possession of a grading plan and Tract 4522 improvement plans.

County staff (Evans, 2016) indicates that there are no known flood protection infrastructure capacity or flooding issues here.

DUC 15 (Mountain Mesa)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 16 (Oildale)

County staff (Hamilton, 2016) indicates the following about this area:

- Stormwater infrastructure is in place, in the form of curb/gutter, storm drain, and drainage basins;
- Flood protection infrastructure capacity issues are known to exist;
- The County has Drainage Improvement Plans Tract Improvement Plans and Parcel Map Improvement Plans; and
- No water quality issues are known to exist.

According to the Kern County Roads Department *2015 Flood Map* for Metro Bakersfield and correspondence with County staff (Evans, 2016), within this DUC, generally all of the Airport Drive underpasses are frequently flooded. This is because the pumps are not big enough to remove the water fast enough. It happens frequently- every normal rain year. It will happen numerous times in an El Nino Winter. While these events are not severe enough to shut down traffic and there are alternate routes available, the flooding poses an inconvenience to motorists. Stormwater and flood protection infrastructure is insufficient in this area.

DUC 17 (Onyx)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 18 (Randsburg)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place and that it is not in a 100-year floodplain. There is not a known history of flooding, as indicated by County staff (Evans, 2016).

DUC 19 (USDA Ruben J. Blunt Village)

According to staff from the Kern County Public Works Department (Hamilton, 2016), stormwater infrastructure in the form of curb/gutter, drainage areas and drainage basins are in place here. According to the Facilities Area Supervisor of the Kern County Housing Authority (Greenoe, 2016), this site had repairs to their drainage system last summer. No drainage issues currently exist. This site is located in a 100 year flood zone, however, the drainage basin located behind the property is of adequate size.

DUC 20 (Weedpatch)

This area straddles Highway 184, which runs north-south. County staff (Hamilton, 2016) indicates that the area is not in a 100-year floodplain.

West of highway 184: County staff (Hamilton, 2016) indicates that the portion of the area to the west of Highway 184 has stormwater infrastructure, in the form of a drainage basin. County staff (Hamilton, 2016) indicates that the County has a Drainage Improvement Plan for the area served by the drainage basin. County staff (Evans, 2016) indicates that there are flood protection infrastructure capacity issues.

East of highway 184: County staff (Hamilton, 2016) indicates that the portion of the area to the east of Highway 184 does not have stormwater infrastructure. County staff (Evans, 2016) indicates that there are considerable flooding issues in this area, especially northeast of Weedpatch (east Lamont).

DUC 21 (Weldon)

County staff (Hamilton, 2016) indicates that, in this area, no stormwater infrastructure is in place, there is a history of flooding and it is in a 100-year floodplain.

DUC 22 (Wofford Heights)

County staff (Hamilton, 2016) indicates that there is no stormwater infrastructure in place and that the area is in a 100-year floodplain. Despite this, flooding is not a known issue here, according to County staff (Evans, 2016).

Fire Protection

DUC 1 (Bodfish)

Kern County contracts with the California Department of Forestry and Fire Protection (Cal Fire) to provide fire services for certain unincorporated areas, including Bodfish. Station 72 is the nearest responding fire station.

DUC 2 (Boron)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Boron. Station 17 is the nearest responding fire station.

DUC 3 (Buttonwillow)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Buttonwillow. Station 25 is the nearest responding fire station.

DUC 4 (Cherokee Strip)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Cherokee Strip. Station 32 is the nearest responding fire station.

DUC 5 (Edmundson Acres)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Edmundson Acres. Station 54 is the nearest responding fire station.

DUC 6 (Fuller Acres)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Fuller Acres. Station 51 is the nearest responding fire station.

DUC 7 (Johannesburg)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Johannesburg. Station 75 is the nearest responding fire station.

DUC 8 (Lake Isabella)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Lake Isabella. Station 72 is the nearest responding fire station.

DUC 9 (Lake of the Woods)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Lake of the Woods. Station 57 is the nearest responding fire station.

DUC 10 (Lamont)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Lamont. Station 51 is the nearest responding fire station.

DUC 11 (Lost Hills)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Lost Hills. Station 26 is the nearest responding fire station.

DUC 12 (Mettler)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Mettler. Station 72 is the nearest responding fire station.

DUC 13 (Mexican Colony)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Mexican Colony. Station 32 is the nearest responding fire station.

DUC 14 (Mojave)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Mojave. Station 14 is the nearest responding fire station.

DUC 15 (Mountain Mesa)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Mountain Mesa. Station 71 is the nearest responding fire station.

DUC 16 (Oildale)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Oildale. Station 63 is the nearest responding fire station.

DUC 17 (Onyx)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Onyx. Station 71 is the nearest responding fire station.

DUC 18 (Randsburg)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Randsburg. Station 75 is the nearest responding fire station.

DUC 19 (USDA Ruben J. Blunt Village)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including USDA Ruben J. Blunt Village. Station 51 is the nearest responding fire station.

DUC 20 (Weedpatch)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Weedpatch. Station 51 is the nearest responding fire station.

DUC 21 (Weldon)

Kern County contracts Cal Fire to provide fire services for certain unincorporated areas, including Weldon. Station 71 is the nearest responding fire station.

DUC 22 (Wofford Heights)

Kern County contracts with Cal Fire to provide fire services for certain unincorporated areas, including Wofford Heights. Station 76 is the nearest responding fire station.

Table 71. Summary of Service to DUCs in Kern County

DUC	Water Sufficient	Wastewater Treatment Sufficient	Stormwater Infrastructure Sufficient	Fire Protection Sufficient	Underserved DUC
DUC 1: Bodfish	Yes	No	No	Yes	Yes
DUC 2: Boron	Yes	Yes	No	Yes	Yes
DUC 3: Buttonwillow	Yes	Yes	No	Yes	Yes
DUC 4: Cherokee Strip	Yes	No	Yes	Yes	Yes
DUC 5: Edmundson Acres	No	Yes	Yes	Yes	Yes
DUC 6: Fuller Acres	Yes	Yes	No	Yes	Yes
DUC 7: Johannesburg	No	Yes	Yes	Yes	Yes
DUC 8: Lake Isabella	Yes	No	No	Yes	Yes
DUC 9: Lake of the Woods	No	Yes	No	Yes	Yes
DUC 10: Lamont	No	Yes	Yes	Yes	Yes
DUC 11: Lost Hills	Yes	Yes	Yes	Yes	No
DUC 12: Mettler	Yes	Yes	No	Yes	Yes
DUC 13: Mexican Colony	Yes	Yes	No	Yes	Yes
DUC 14: Mojave	Yes	Yes	Yes	Yes	No
DUC 15: Mountain Mesa	Yes	Yes	No	Yes	Yes
DUC 16: Oildale	Yes	Yes	No	Yes	Yes
DUC 17: Onyx	Yes	Yes	No	Yes	Yes
DUC 18: Randsburg	No	Yes	Yes	Yes	Yes
DUC 19: USDA Ruben J. Blunt Village	No	Yes	Yes	Yes	Yes
DUC 20: Weedpatch	No	Yes	No	Yes	Yes
DUC 21: Weldon	No	Yes	No	Yes	Yes
DUC 22: Wofford Heights	Yes	No	Yes	Yes	Yes

D. Future Annexations Considered

Kern County Planning staff was consulted to determine whether any annexations from the County into any Kern County cities are anticipated. Annexations are considered on a case-by-case basis and at this time none of these DUCs have contacted the County or are under consideration for annexation into cities.

E. Conclusion

While Bakersfield average housing costs ($170,000) are shown to be consistent with the average housing costs in the United States, California's home prices and rents have risen faster than the U.S. average since the 1940's and resistance to density and the California Environmental Quality Act continue to delay or stop new housing development. Appendices B and C of this Housing Element contain two recent reports on housing development in California. Both reports were prepared by the California Legislative Analyst Office: Perspectives on Helping Low Income Californians Afford Housing, dated February 9, 2016, and California's High Housing Costs: Causes and Consequences, dated March 17, 2015. The reports indicate that "living in decent, affordable, and reasonably located housing is one of the most important determinates of well-being for every Californian. More than just basic shelter, housing affects our lives in other important ways, determining our access to work, education, recreation, and shopping. The cost and availability of housing also matters for the State's economy, affecting the ability of business and other employers to hire and retain qualified workers and influencing their decisions about whether to locate, expend, or remain in California." The report released in March 2015, and confirmed again in the report from February 2016, notes barriers to providing more housing for low income and special needs populations. The reports further identify and discuss the following challenges and concerns to expanding existing programs at the State level.

- Expanding Assistance Programs would be very expensive.
- Affordable housing construction requires large public subsidies.
- Expanding housing vouchers would be expensive and a scarcity of housing undermines the voucher program causing rents to rise.
- Environmental protection policies constrain housing development.
- Home builders are often forced to compete for limited development opportunities.

The reports conclude that while vouchers, inclusionary housing requirements and rent control have provided limited solutions, increasing the housing supply is the only factor that will ensure availability.

While there is a need to develop and identify new affordable housing developments, there is also a need to provide adequate infrastructure to those areas currently being underserved. Based on information contained in this analysis,

expansion of services will be required for 20 of the disadvantaged unincorporated communities (DUC) described above. Water quality or supply issues exist in Bodfish, Edmundson Acres, Johannesburg, Lake of the Woods, Lamont, Randsburg, U.S.D.A. Ruben J. Blunt Village, Weedpatch, and Weldon. Wastewater issues relating to private septic systems exist in Bodfish, Cherokee Strip, Lake Isabella, and Wofford Heights. Lack of stormwater and flood protection infrastructure is an issue in Bodfish, Boron, Buttonwillow, Fuller Acres, Lake Isabella, Lake of the Woods, Mettler, Mexican Colony, Mountain Mesa, Oildale, Onyx, Weedpatch, and Weldon. All of these DUCs are considered underserved. The County will continue to identify additional financing alternatives and mechanisms for improving water quality and providing better septic or installing sewer systems in these existing DUC's. **Table 72** provides an outline of potential infrastructure funding opportunities that the County can pursue to facilitate additional infrastructure projects within these identified DUC areas.

Table 72. Potential Funding Sources for Extension and Improvement of Services

Agency	Program (Year Passed or Created)	Funding Provided (in million $)	Funding Remaining/Available (in million $)	Limitations/Barriers on Use of Funds for Drinking Water Treatment (capital or O&M)
California Department of Public Health (CDPH)	Safe Drinking Water State Revolving Fund (SDWSRF) (1996) (grants and loans)	Generally $100-$150: Low-interest loans and some grants to support water systems with technical, managerial, and financial development and infrastructure improvements.	$130-$150 (revolving funds) (annually)	▪ 20 to 30% of annual federal contribution can be used for grants. The remainder must be committed to loans. ▪ Funds can be used only for capital costs. Cannot be used for O&M ▪ Only loans (not grants) for privately owned water systems. ▪ Some funds available for feasibility and planning studies for eligible projects/systems. ▪ Can only be used for Public Water Systems (not domestic wells or State Small Systems)
	Proposition 84 (2006) (grants)	$180: Small Community Improvements. --- $60: Protection and reduction of contamination of groundwater sources. $50 Matching funds for federal DWSRF --- $10: Emergency and urgent projects.	$0 (Over subscribed) --- $0 (Fully allocated) Will be fully committed with the current year grant but not yet liquidated --- ~$7	▪ Funds can be used only for capital costs. Cannot be used for O&M. ▪ Some funding available for feasibility and planning studies for eligible projects/systems. ▪ Can only be used for Public Water Systems not domestic wells or State Small Systems --- ▪ Used to address sudden unanticipated emergency situation such as fires, earthquakes and mud slides that damage critical water infrastructure. May fund short term mitigations such as hauled water.
	Proposition 50 (2002) (grants) (fully allocated)	$50: Water security for drinking water systems. --- $69: Community treatment facilities and monitoring programs. --- $105: Matching funds for federal grants for public water system infrastructure improvements.	$0 (fully allocated) --- $0 (fully allocated) --- $0 fully allocated, mostly liquidated	▪ Can only be used for capital costs. Cannot be used for O&M. ▪ Can only be used for Public Water Systems not domestic wells or State Small Systems

Agency	Program (Year Passed or Created)	Funding Provided (in million $)	Funding Remaining/Available (in million $)	Limitations/Barriers on Use of Funds for Drinking Water Treatment (capital or O&M)
State Water Resources Control Board (State Water Board)	Clean Water State Revolving Fund (Expanded Use Program) (CWSRF) (1987) (loans)	$200-$300 per year: Water quality protection projects, wastewater treatment, nonpoint source contamination control, and watershed management.	$50 per agency per year; can be waived	Eligible Uses: Stormwater treatment and diversion, sediment and erosion control, stream restoration, land acquisition. Drinking water treatment generally not eligible except under certain Expanded Use scenarios. Capital cost only. O&M not eligible.
	Small Community Groundwater Grants (Prop 40) (2004, amended 2007) (grants)	$9.5. Assist small disadvantage communities (<20,000pp) with projects where the existing groundwater supply exceeds maximum contaminant levels, particularly for arsenic or nitrate	$1.4 remaining- $0.3 available to encumber; $1.1 available to appropriate	Eligible Uses: Funds can go to local government or NGO. Must demonstrate financial hardship. Can only provide alternate water supply. No O&M costs. Program not currently active due to staff resource limitations
	State Water Quality Control Fund: Cleanup and Abatement Account (2009)	$10 in 2012 (varies annually): Projects to (a) clean up waste or abate its effects on waters of the state, when there is no viable responsible party, or (b) address a significant unforeseen water pollution problem (regional water boards only). Funds can be allocated to: Public Agencies, specified tribal governments, and not-for profit organizations that serve disadvantaged communities	$10, but varies.	Eligible Uses: Emergency cleanup projects; projects to clean up waste or abate its effects on waters of the state; regional water board projects to address a significant unforeseen water pollution problem. Recipient must have authority to clean up waste. Under certain circumstances this fund has been used to provide drinking water O&M for limited durations.
	Integrated Regional Water Management (IRWM) (2002) (grants) (fully allocated)	$380 (Prop 50): Planning ($15) and implementation ($365) projects related to protecting and improving water quality.	$0, fully committed	
California Department of Water Resources (DWR)	Integrated Regional Water Management (IRWM) (2002) (grants)	$600 remaining (Prop 84): Regional water planning and implementation.	~$28 (central coast projects) ~$33 (Tulare/Kern projects)	Must be consistent with an adopted IRWM Plan and other program requirements. For capital investment only

Agency	Program (Year Passed or Created)	Funding Provided (in million $)	Funding Remaining/Available (in million $)	Limitations/Barriers on Use of Funds for Drinking Water Treatment (capital or O&M)
(California Department of Water Resources (DWR))	Contaminant treatment or removal technology pilot and demonstration studies (2002) (grants)	Up to $5 per grant	$15 million available	Eligible applicants are public water systems under the regulatory jurisdiction of CDPH and other public entities For capital investment only
	Safe Drinking Water Bond Law (Prop 81) (1988)	Up to $74 to be awarded to current priority list. $0.025 max per project	Remaining balance to be determined	Provides funding for projects that investigate and identify alternatives for drinking water system improvements
	Drinking water disinfecting projects using UV technology and ozone treatment (2002) (grants)	$0.05 minimum, up to $5 m per grant	$19 m remaining	Eligible applicants are public water systems under the regulatory jurisdiction of CDPH For capital investment only
iBank (CA Infrastructure and Development Bank)	Infrastructure State Revolving Fund (ISRF) Program (2000) (loans)	$0.25 to $10 per project to finance water infrastructure that promotes job opportunities. Eligible projects include - construction or repair of publicly owned water supply, treatment, and distribution systems.	$52.6 million approved to date for Water Supply, Water Treatment and Distribution Applications continually accepted	Finances system capital improvements only. Must show job creation. Special loan tier for DACs was discontinued.
State Water Resources Control Board (State Water Board) & California Department of Water Resources (DWR)	Proposition 1 Water Quality, Supply and Infrastructure Improvement Act of 2014	Prop 1 was approved by voters on November 4, 2014 and authorizes $7.545 billion in general obligation bonds for water projects including surface and groundwater storage, ecosystem and watershed protection and restoration, and drinking water protection. DWR and the State Water Board will administer various Prop 1 funds.	Various. Applications ongoing.	See Appendix D for a detailed breakdown of various funding programs authorized under the passage of Proposition 1.

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EXHIBIT G

Regional Changes in Extreme Climatic Events: A Future Climate Scenario

JASON L. BELL, LISA C. SLOAN, AND MARK A. SNYDER

Department of Earth Sciences, University of California, Santa Cruz, Santa Cruz, California

(Manuscript received 10 July 2002, in final form 11 February 2003)

ABSTRACT

In this study a regional climate model is employed to expand on modeling experiments of future climate change to address issues of 1) the timing and length of the growing season and 2) the frequency and intensity of extreme temperatures and precipitation. The study focuses on California as a climatically complex region that is vulnerable to changes in water supply and delivery. Statistically significant increases in daily minimum and maximum temperatures occur with a doubling of atmospheric carbon dioxide concentration. Increases in daily temperatures lead to increases in prolonged heat waves and length of the growing season. Changes in total and extreme precipitation vary depending upon geographic location.

1. Introduction

Analysis of long-term temperature and precipitation records has revealed changes in the mean climatic state as atmospheric carbon dioxide (CO_2) levels have increased since the industrial revolution (Easterling et al. 1997; Gaffen and Ross 1998; Plummer et al. 1999; Salinger and Griffiths 2001). Research employing global climate models (GCMs) indicates potentially greater changes for future climate states (Cao et al. 1992; Zwiers and Kharin 1998; McGuffie et al. 1999; Yonetani and Gordon 2001). Changes in the mean climate state have been found to affect the frequency and intensity of extreme climatic events as well (Mearns et al. 1984; Katz and Brown 1992; Groisman et al. 1999; Meehl et al. 2000). Extremes in temperature and precipitation have important impacts on vital aspects of society, including crop yield, power consumption and production, and human health (Easterling et al. 2000; Meehl et al. 2000; Walther et al. 2002). Responses to climate change and mitigation of negative impacts must be resolved at regional and local levels in order for effective action to be taken; therefore, it is important to assess the potential for climate change on a regional level.

Regional changes in climate are highly variable and cannot be adequately represented by GCMs at this time. This inability necessitates the use of regional climate models (RCMs) to address potential climate change on the regional scale. Snyder et al. (2002) used an RCM to demonstrate the potential for significant changes in the mean climate of the California region due to a doubling of atmospheric CO_2 levels. The present study addresses potential changes in the frequency and intensity of extreme daily temperatures and precipitation events for the same region and CO_2 scenarios.

Corresponding author address: J. L. Bell, Department of Earth Sciences, University of California, Santa Cruz, Santa Cruz, CA 95064.
E-mail: jbell@es.ucsc.edu

2. Model description and experiment design

The model description and experiment design is similar to that of Snyder et al. (2002) with a few key differences. Snyder et al. (2002) performed a sensitivity study of California climate with doubled CO_2 using a limited ensemble approach. The limited ensemble approach utilized identical GCM boundary conditions with multiple RCM simulations. Two CO_2 scenarios were compared and each scenario was comprised of three ensemble members of 5 years in length. While this approach was successful at limiting computational expense the results indicate that the GCM is responsible for the majority of the variability. Snyder et al. (2002) discovered that the year-to-year variability within a given simulation was much greater than the variability between ensemble members. Based on these conclusions we use a single 15-yr simulation for each of the CO_2 scenarios and present results based on twice-daily model output.

We used the National Center for Atmospheric Research (NCAR) Community Climate Model version 3.6.6 (CCM3) (Kiehl et al. 1998) as the global driver for our regional model. We first used a version of CCM3 with a slab ocean–thermodynamic sea ice model to perform two 15-yr simulations. The two simulations differed only in the atmospheric CO_2 concentrations, which were 280 ppm (preindustrial level) and 560 ppm (hereafter referred to as $1 \times CO_2$ and $2 \times CO_2$ scenarios, respectively). Due to the model output only being saved at monthly intervals the calculated sea surface temper-

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atures (SSTs) were used to drive a second set of CCM3 simulations. These simulations, using the prescribed SSTs for the corresponding CO_2 concentrations, were run for 22 years and results were saved at 12-h intervals. The first 4 years of each simulation were removed as equilibration time and the remaining 18 yr of results were used to drive the RCM.

This study employs a modified version of the second-generation NCAR Regional Climate Model (RegCM2) (Giorgi and Shields 1999) (hereafter referred to as RegCM2.5) as described by Snyder et al. (2002). RegCM2.5 was run with a horizontal resolution of 40 km and a domain centered over California. We performed two 18-yr simulations with the first three years removed for equilibration. These simulations varied only in the specified atmospheric CO_2 concentrations (280 and 560 ppm).

3. Validation

It is important when discussing the need for more regional and local scale studies of climate change and impacts to be able to demonstrate the capability for such studies. Here we demonstrate 1) the ability of the regional model to adequately capture both the general (seasonal temperature and precipitation) and specific [diurnal temperature range (DTR), growing season length, frequency and intensity of extreme events] characteristics of regional climate observed for the modern day and 2) that regional models are currently better suited for this type of analysis than global models. Mearns et al. (1999) have performed a similar validation for RegCM2 with a domain centered on Nebraska while Snyder et al. (2002) performed a more general validation over California.

a. Modern climate

Here we compare the results of a modern-day regional climate simulation to observations. The model simulation of present-day conditions is similar in design to our $1 \times CO_2$ and $2 \times CO_2$ scenarios. CCM3 was run for 22 years forced with a single climatological year of SSTs (calculated from observations for the period from 1950 to 1979). The first 4 yr were removed for equilibration and the last 18 yr were used to drive RegCM2.5. The first 3 yr of the RegCM2.5 simulation were removed for equilibration and the last 15 yr are used for the analysis presented here. The atmospheric CO_2 concentration in both models was 360 ppm.

The observational data used are historical weather station data collected by the Western Regional Climate Center (2003). The types and scope of data available vary depending on the climate characteristics of interest. For each comparison with the model results we treat all data in as similar a manner as possible. For the analyses of seasonal temperature and precipitation we used climatological data calculated with a minimum of 22 yr of data from the period 1971–2001. For the more specific analyses (DTR, growing season, and extremes) the available data ranges from 27 to 100 yr in length (on average 49.4 yr) for the period from 1901 to 2001. We began our analysis with ~55 stations and, due to the shear volume of available data, narrowed it to stations where the actual and model-derived elevations differed by no more than 100 m. What remained were 16 stations representing a wide range of latitude, longitude, and elevations across California.

TABLE 1. Summary of comparison between observations (obs) and RegCM2.5 (rcm) modern-day simulation.

	obs	rcm	obs−rcm
	Temperature		
Annual mean (°C)	32.7	32.0	0.7
DJF (°C)	25.3	23.9	1.4
MAM (°C)	31.4	29.0	2.4
JJA (°C)	40.4	40.8	−0.4
SON (°C)	33.6	34.1	−0.5
$T \geq 32.2$°C (days)	71.4	43.8	27.6
$T \geq 0$°C (days)	68.5	38.2	30.3
1-day max (°C)	44.1	40.1	4.0
1-day min (°C)	−15.2	−12.9	−2.3
	DTR		
Annual mean (°C)	15.4	9.7	5.7
DJF (°C)	12.2	6.0	6.2
MAM (°C)	15.0	9.2	5.8
JJA (°C)	18.3	13.4	4.9
SON (°C)	15.9	10.2	5.7
	Precipitation*		
Annual mean (cm)	52.9	56.7	−3.8
DJF (cm)	26.6	31.6	−5.0
MAM (cm)	13.9	16.6	−2.7
JJA (cm)	2.2	0.5	1.7
SON (cm)	8.6	8.1	0.5
Light (days)	88.9	97.1	−8.2
Moderate (days)	12.3	13.3	−1.0
Heavy (days)	5.5	5.7	−0.2
1-day max (cm)	12.1	10.8	1.3

* Precipitation intensities are defined as: light days < 1.27 cm, moderate days < 2.54 cm, and heavy days ≥ 2.54 cm.

Overall the comparison between modern-day regional model results and weather station data is very good. This is especially the case considering the data record is much longer than the model simulation and therefore provides a larger sample population. Furthermore the weather stations provide point data, while the model results are derived from single grid cells with 40-km horizontal resolution. Still there are some issues with the model results, especially for the DTR and the seasonality of precipitation.

The regional model adequately captures the seasonal changes in temperature as well as the annual mean temperature. On average the RCM is only 0.7°C cooler for the annual mean and no more than 2.4°C different seasonally than the observations (Table 1). The RCM more accurately captures the summer [Jun–Aug (JJA)] and fall [Sep–Nov (SON)] temperatures than the winter [Dec–Feb (DJF)] and spring [Mar–May (MAM)] tem-

peratures. The DTR is too small by ~5° to 6°C annually and seasonally (Table 1). The growing season starts on average 16.5 days too soon and ends 13.8 days too late. For extremes the model simulates ~28 too few hot (32.2°C) days per year and ~30 too few cold (0°C) days per year (Table 1). While the model simulates too few extreme events it does not overestimate the intensity of simulated extreme events. The historic 1-day events simulated by the model fall within the range of historic events in the longer observational record (Table 1).

The regional model outputs temperature twice a day at noon and midnight. These temperatures are used as proxies for the daily maximum and minimum and are not the actual maximum and minimum temperatures. As a result, the proxy maximum temperatures are too cool and the proxy minimum temperatures are too warm, producing a dampened DTR. The use of the proxy minimum also affects the calculated beginning and end of the growing season. The growing season appears to start earlier and end later due to the use of the proxy minimum temperature. Finally the use of these proxy temperatures results in extreme events that do not appear as extreme as those in the observational record.

Annually the regional model slightly overestimates total precipitation (+3.8 cm yr^{-1}) and poorly captures the seasonality of precipitation. The model overestimates winter and spring precipitation and underestimates summer and fall precipitation (Table 1). The model also simulates ~8 too many light rainfall days per year (<1.27 cm day^{-1}). For moderate (1.27–2.54 cm day^{-1}) and heavier (>2.54 cm day^{-1}) rainfall days the model is much more accurate (Table 1). The model simulates one day too many per year of moderate precipitation and only 0.2 too many days per year of heavier rainfall. The model does a good job simulating historic 1-day events considering the differences in sample sizes. The average 1-day high is 1.3 cm less in the model than in the observations (Table 1).

b. GCM versus RCM

A RCM offers higher spatial resolution than a GCM, allowing for greater topographic complexity and smaller-scale atmospheric dynamics to be simulated and investigated. Theoretically, higher resolution should lead to more realistic simulations of regional-scale climate. The biggest weakness with RCMs is the dependence on lateral boundary input either via GCM, reanalysis, or observational data. If an RCM receives poor quality input it is not likely to output much higher quality results. So, if quality GCM input is needed, then is the use of an RCM necessary? The answer to that question depends on the inquiry to be addressed. Obviously a RCM would be inadequate to address issues of global, or even hemispheric, changes in atmospheric circulation. Likewise a GCM may not be appropriately suited for questions that are subcontinental in scale, especially for complex regions. California is a climatically and topographically complex region and therefore a study of the regional climate there warrants the use of a RCM.

Having already demonstrated that RegCM2.5 does a good job of simulating the modern observed climate of California we must answer another question: Does the RCM do a better job of simulating California climate than the GCM? The modern-day CCM3 simulation was analyzed in the same manner as the RCM output. We compared the CCM3 results for temperature and precipitation to the 16 weather stations discussed earlier. For over 540 individual comparisons of GCM and RCM versus observational data the GCM compared more favorably than the RCM only 25% of the time. Furthermore there was no one specific climatic feature or characteristic that the GCM consistently simulated better than the RCM. Clearly there is utility in using the RCM, and not just the GCM, to address issues of changes in climate for a complex region.

Overall RegCM2.5 does a good job simulating the main features of the modern-day climate, though it is not perfect. RegCM2.5 also does a much better job simulating the California climate than CCM3. Any inherent biases in RegCM2.5 will be present in both of our CO_2 scenarios. Therefore, since this is a sensitivity study, these model biases will be mitigated when calculating changes in the climate due to the doubling of CO_2.

4. Analysis methods

California spans a wide latitudinal range and contains a variety of microclimates. Due to this diversity of microclimates, we perform our analysis on the hydrologic basin scale, as defined by the California Department of Water Resources (1998) (Fig. 1). The methods for analysis of changes in extreme events are similar to those of Salinger and Griffiths (2001). Annual extreme events are defined based on the 5th and 95th percentiles of the $1 \times CO_2$ results.

a. Temperature

We define three types of extreme temperature events and examine changes between the $1 \times CO_2$ and $2 \times CO_2$ scenarios. The first type of extreme event is based on the 95th and 5th percentiles of daily maximum and minimum temperatures, respectively. These percentiles correspond to the 18th hottest maximum and coldest minimum temperatures in a year (based on the number of events per year multiplied by the percentile). For all 15 years of the $1 \times CO_2$ simulation the annual 5th-percentile events were averaged together to create a long-term extreme cold index value, likewise for the annual 95th-percentile events. These long-term indices are used for the evaluation of changes in extreme events. The second type of extreme event examined is based on specific temperature thresholds. We examine the frequency of events below 0°C and above 32.2°C. The third type of extreme event is a prolonged extreme event.

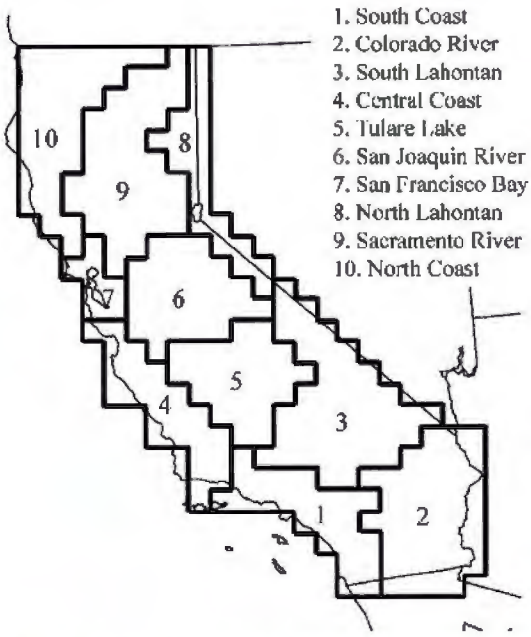


FIG. 1. The hydrologic basins of California shown here are adapted from the California Department of Water Resources (1998) to the 40-km RCM grid. Note the area shown here is a subset of the total regional model domain used in this study.

These are events where the maximum (or minimum) temperature exceeds the long-term 95th (or 5th) percentile for seven or more consecutive days.

Indices of temperature examined are the following:

- Changes in mean daily temperature maximum, minimum, and range: T_{max}, T_{min}, T_{range}, respectively.
- The frequency of days with maximum (minimum) temperatures above (below) the 95th (5th) percentile: T_{95} (T_{05}). (Extreme event of type 1 described above.)
- The frequency of days with temperatures above (below) 32.2°C (0°C): T_{32} (T_0). (Extreme event of type 2 described above.)
- Changes in prolonged extreme events, including frequency, mean length, and mean temperature of prolonged hot and cold extreme events. (Extreme event of type 3 described above.)
- Changes in the beginning and length of the annual growing season (based on the frost-free period).

b. Precipitation

Precipitation in California is highly variable on all temporal and spatial scales. For each basin we examine changes in daily and annual rainfall and the frequency of extremely heavy rainfall events. Heavy rainfall events are defined using the 95th percentile as explained above for extremely high temperatures.

Indices of precipitation examined are the following:

- Changes in mean annual rain.
- Changes in mean rain per rain day[1] and number of rain days per year.
- The frequency of extreme events exceeding the 95th percentile (as above): P_{95}.

5. Results

a. Temperature

In general the 2 × CO_2 scenario is hotter than the 1 × CO_2 scenario. For every basin the mean daily maximum and minimum temperatures are greater in the 2 × CO_2 scenario than in the 1 × CO_2 scenario (Table 2), with differences statistically significant at the 95% confidence level (5% significance level). While the increases in both maximum and minimum are similar, the increase in daily maximum is greater, for 9 of 10 basins, than the increase in daily minimum. This leads to an increased mean DTR in these regions. Although the change in DTR is relatively small, it is still significant in 7 of 10 basins (Table 2). Our results indicate an increase in extremely hot days (T_{95}), days exceeding 32.2°C, and in prolonged hot spells (Table 3). Not only are there more prolonged hot events in the 2 × CO_2 scenario, but these events are longer and hotter on average than the prolonged events in the 1 × CO_2 scenario (Table 3). While the maximum temperatures are rising in the 2 × CO_2 scenario, so are the minimum temperatures, resulting in a decrease in days below the 5th percentile (T_{05}) and in days below 0°C (Table 2). Due to the decrease in days with temperatures less than 0°C the frost-free period begins, on average, 25 days earlier in the 2 × CO_2 scenario and is on average 38 days longer. In our 2 × CO_2 scenario we also find that prolonged cold events occur less often and are shorter and warmer on average than in the 1 × CO_2 scenario.

b. Precipitation

We find decreases in mean annual rainfall across the state (Table 4). Only the North Coast and North Lahontan basins have increased rain, 1% and 3%, respectively. On average there is very little change in mean rainfall per rain day, although there are generally fewer rain days per year in each basin (~5 days). With the exceptions of the North Coast and North Lahontan basins there is also a decrease in extremely heavy rainfall (P_{95}) events as well (Table 4). On average, 2.4 fewer heavy events occur per year per basin, while the North Coast and North Lahontan basins average 2.5 *additional* heavy rainfall events per year compared to the 1 × CO_2 scenario.

[1] We define a rain day as any day with basin average of 0.1 mm or more of precipitation.

EXHIBIT H

nature COMMUNICATIONS

ARTICLE

DOI: 10.1038/s41467-018-04475-3 OPEN

Overpumping leads to California groundwater arsenic threat

Ryan Smith [1], Rosemary Knight[1] & Scott Fendorf [2]

Water resources are being challenged to meet domestic, agricultural, and industrial needs. To complement finite surface water supplies that are being stressed by changes in precipitation and increased demand, groundwater is increasingly being used. Sustaining groundwater use requires considering both water quantity and quality. A unique challenge for groundwater use, as compared with surface water, is the presence of naturally occurring contaminants within aquifer sediments, which can enter the water supply. Here we find that recent groundwater pumping, observed through land subsidence, results in an increase in aquifer arsenic concentrations in the San Joaquin Valley of California. By comparison, historic groundwater pumping shows no link to current groundwater arsenic concentrations. Our results support the premise that arsenic can reside within pore water of clay strata within aquifers and is released due to overpumping. We provide a quantitative model for using subsidence as an indicator of arsenic concentrations correlated with groundwater pumping.

[1] Department of Geophysics, Stanford University, 397 Panama Mall, Stanford, California 94305, USA. [2] Department of Earth System Science, Stanford University, 473 Via Ortega, Stanford, California 94305, USA. Correspondence and requests for materials should be addressed to R.S. (email: rgsmith@stanford.edu)

Globally, groundwater provides almost half of all drinking water[1], making it one of the world's most important resources. Within the United States, the Central Valley of California accounts for roughly 20% of groundwater withdrawals[2]. The Central Valley is an arid region that supports a $17 billion agricultural industry. In the southern, highly productive region of the valley (known as the San Joaquin Valley), aquifers are particularly stressed due to the high water demands. Further, groundwater is the main source of drinking water for roughly one million people in the San Joaquin Valley. Herein, we focus on threats to groundwater quality induced by naturally occurring arsenic, which may have devastating impacts on both human health and food production.

Arsenic is a ubiquitous, naturally occurring contaminant that is a common problem in many aquifers that are pumped for drinking water[3]; most notably, it is presently having a devasting impact on groundwater quality throughout Asia[4]. When present in significant amounts, it increases the risk of cancer, heart disease, and diabetes[5]. Hazardous levels of arsenic typically result from anaerobic conditions, as noted for the shallow, Holocene aquifers of Asia[4], or from high pH (pH > 8.5) often observed in high arsenic regions of the Andes[6]. In addition, overpumping an aquifer system has been noted to increase the arsenic levels in Southeast Asia by drawing arsenic from less permeable anaerobic clay strata into the aquifer[7].

Arsenic within pumped groundwater of the San Joaquin Valley has been noted for decades. Approximately 10% of the wells tested within the last 10 years have shown arsenic (As) concentrations above 10 µg/L (p.p.b.), the level recommended as the maximum acceptable by the World Health Organization (WHO). As groundwater is increasingly being pumped to meet agricultural and domestic needs, preserving groundwater resources (i.e., maintaining water quality) is imperative. Here we seek to determine the source of arsenic contamination within groundwater of the Central Valley, CA, and to develop quantitative means for predicting degradation of groundwater quality. We focus our study on the Tulare basin (Fig. 1), a highly productive agricultural region of the San Joaquin Valley where groundwater is essential for meeting water demands.

Groundwater pumping in the San Joaquin Valley has caused declines of ~ 60 m in groundwater levels over the past century, leading to subsidence as high as ~ 9 m from 1925 to 1970, a rate of 20 cm/year[8]. Rates of subsidence as high as 25 cm/year have been observed in more recent droughts spanning from 2007 to 2010 and from 2012 to 2016[9, 10]. Subsidence due to groundwater pumping is caused by a pore pressure drop in aquifer materials, which increases the effecive stress, σ_e, defined as $\sigma_e = \sigma_T - P_p$, where σ_T is the total stress and P_p is the pore pressure[11]. Increasing the effective stress results in aquifer compaction. The majority of compaction and linked subsidence of the overlying ground surface is caused by drainage of clays due to their weaker geomechanical properties, as indicated by their higher skeletal specific storage. Thus, the high subsidence levels provide a measure of overpumping in aquifers having substantial clay content, such as the aquifers of the San Joaquin Valley. In this region, the upper 500 m, which is the greatest depth typically drilled for groundwater pumping, consists of alternating layers of sand, gravel, and clay. In general, the aquifer system is divided into an upper aquifer, a thick clay confining unit known as the Corcoran clay, and a lower aquifer. The upper and lower aquifers contain sands and gravels, as well as numerous thin clay layers[12]. As a measure of overpumping, we use subsidence, derived from Interferometric Synthetic Aperture Radar (InSAR) data, to predict arsenic levels quantitatively.

We find that subsidence data have a strong correlation with concurrent arsenic concentrations. This demonstrates a quantitative link between overpumping of groundwater systems and arsenic contamination, a mechanism that has been proposed previously[7] but never statistically demonstrated.

Results and Discussion

Modeling arsenic concentration. We integrated estimates of subsidence with additional variables known from previous studies[13] to affect arsenic levels into a random forest model that accounts for nonlinear relationships, as well as interdependencies of different variables. Two models were developed, one that predicts recent (2007 to 2015) arsenic concentrations and a second that predicts historic (1986 to 1993) arsenic concentrations. These dates were chosen because they both span long droughts in the San Joaquin Valley, during which time appreciable groundwater decline and subsidence occurred (Supplementary Fig. 5). We did not include the mild drought conditions from 1999 to 2005, because we had limited subsidence data over that period, and because we considered more intense droughts to produce a stronger signal for our analysis. We used the output of the random forest models to assess the effect of overpumping as indicated by subsidence on arsenic levels. We found that in both models, concurrent subsidence markedly increases the risk of arsenic contamination. As both models establish similar relationships (capturing the time periods of recent and past periods of drought), we focus our discussion on the recent arsenic concentration model, pointing out where key differences exist. The full results of both models are shown in the Supplementary Information (Supplementary Figs. 1–4)

Mechanism for arsenic contamination from overpumping. The relationship between subsidence and arsenic concentration is linked to clay strata (Fig. 1). It has been noted that clay particles become enriched in arsenic due to their reactivity and high surface area to volume ratio relative to sand sized particles[4]. Arsenic has been transported to the San Joaquin Valley from the Sierra Nevada and coastal mountain ranges by rivers, which cut through arsenic bearing formations, for millions of years[14]. Clays at or near the surface at the time of deposition are the primary host of transported arsenic, which has been shown to adsorb on clay surfaces in significant amounts in the San Joaquin Valley[15], in a process similar to what occurs in other sedimentary basins, including those throughout Asia[4]. As the clays are buried over geologic time, their restricted oxygen supply results in reduction of the arsenic at depths > 60 m[14], resulting in dissolution of the arsenic within the clay pore water[7]. This mechanism for arsenic concentration in clays is supported by other studies in the area[13], who have found a positive relationship between aquifer clay content and arsenic concentration in the San Joaquin Valley.

When unperturbed, groundwater within the aquifer primarily flows horizontally through the sediments with highest permeability, typically sands and gravels. Thus, pumped groundwater comes mostly from sands and gravels, which have lower arsenic concentrations. When the aquifer system is stressed from overpumping, high vertical hydraulic gradients cause a larger volume of water to be drawn from less permeable clays, inducing the release of water with high arsenic concentrations. As a consequence, overpumping increases arsenic concentrations, as noted for the lower Mekong Delta, Vietnam[7]. Concomitant with decreased pore pressures is compaction of the aquifer and resulting land subsidence. Thus, the dual consequence of overpumping is land subsidence and increased extraction of pore water from clay layers, giving rise to a link between land subsidence and groundwater arsenic concentrations.

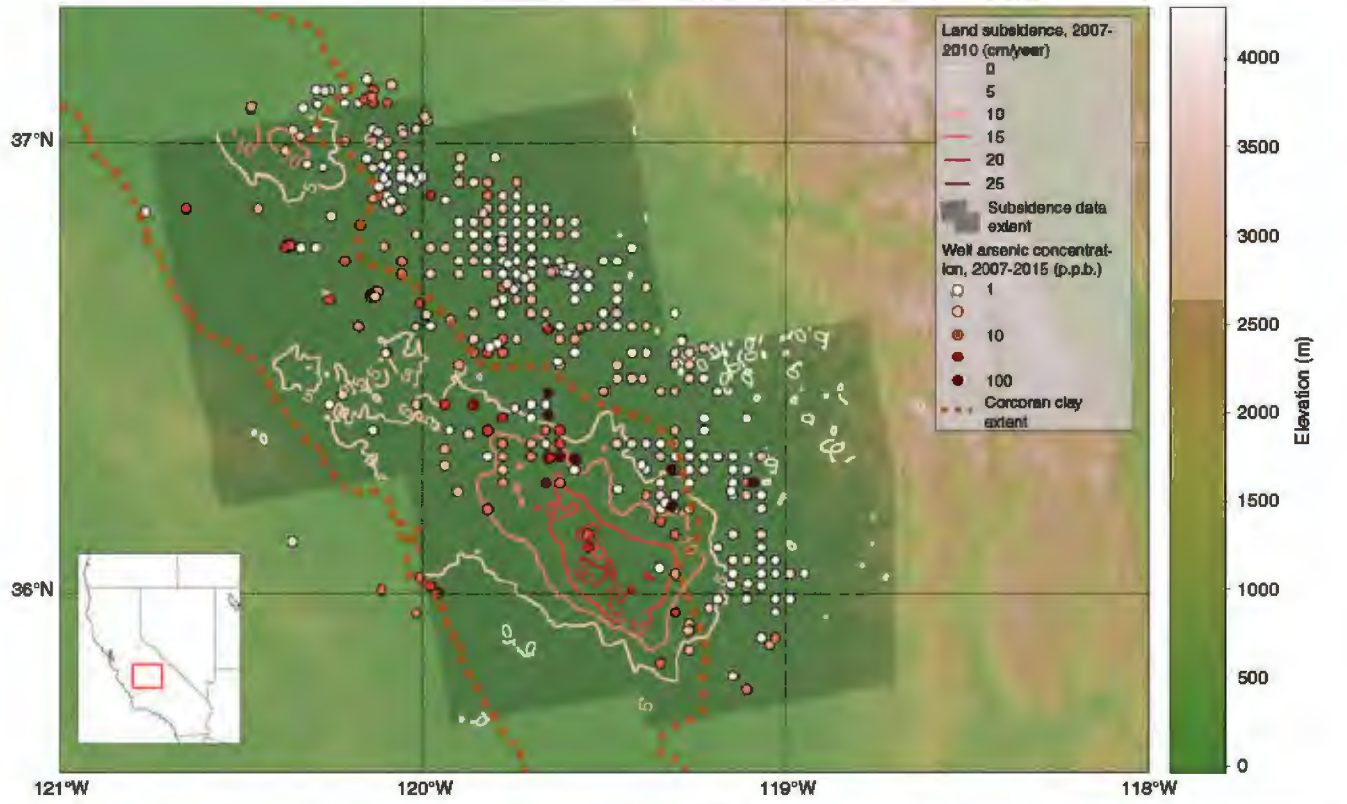


Fig. 1 Comparison of subsidence, arsenic concentration, and clay extent within the San Joaquin Valley, CA. Arsenic concentrations increase toward the center of the valley where subsidence is more extensive and a confining clay layer (known as the Corcoran clay) is present[12]. The grayed-out region is the area where recent subsidence data (obtained from InSAR) were processed. Arsenic concentrations vary by orders of magnitude and are thus shown with a logarithmic color bar (see Supplementary Fig. 8 for arsenic concentration histograms). The arsenic concentration data points were sourced from[17]. The basemap was created using elevation data from the Shuttle Radar Topography Mission[18]

Quantifying the impact of overpumping on groundwater arsenic concentrations. We highlighted four of the most important variables describing arsenic concentration within the Tulare Basin in the recent model, shown in Fig. 2a d. Of these, the thickness of the Corcoran Clay (a confining unit that overlies a lower aquifer) shows a positive correlation with arsenic con centrations due to increased clay content. Elevation has a negative correlation, as lower areas are more likely to have been water saturated and thus anaerobic. A positive correlation was found between $\log_{10}$(Mn) and arsenic concentrations, as the presence of manganese indicates an anoxic environment, in which arsenic tends to be more soluble. Significantly, recent subsidence from InSAR showed a positive correlation, as overpumping leads to increased pore water drainage from clays. The first three variables are well known from the literature and not related to human activity. The quantitative link between pumping induced sub sidence and arsenic concentrations has not been shown before, and is directly related to human activity.

By comparing the historic and recent arsenic concentration models, we see the transient nature of the relationship between pumping induced subsidence and arsenic concentrations (Fig. 2e). Although historic subsidence has a high impact on historic arsenic concentrations, it has virtually no impact on recent arsenic concentrations. A lack of correlation between present arsenic concentrations and historic subsidence (related to over pumping) suggests that arsenic levels due to overpumping slowly return to their original levels after the groundwater pumping is decreased, implying that arsenic is flushed from the auqifer. Thus, our findings indicated that avoiding overpumping of aquifers, easily seen in InSAR data, should improve water quality, at least for the San Joaquin Valley.

The historic arsenic concentration model shows a weaker, but still positive, correlation between Corcoran clay thickness and arsenic concentration, as well as manganese concentration and arsenic concentration. Due to the dynamic nature of groundwater chemistry, the relative importance of different mechanisms for arsenic contamination change over time, highlighting the need for regular calibration with up to date datasets.

To further quantify the impact of overpumping on arsenic concentrations, we simulated three different hypothetical scenar ios with our predictive random forest model: oxic, suboxic, and anoxic subsurface conditions. We used a variation of the partial dependence plot that averages all variables except subsidence, which is varied from 0 to 10 cm/year, and $\log_{10}$(Mn), which is set at 0, 1, and 2 for oxic, suboxic, and anoxic scenarios, respectively, to estimate the probability that the predicted arsenic levels exceeded the WHO's standard of 10 μg/L arsenic (Fig. 3). At ca. 8 cm/year subsidence, the probability that arsenic exceeds the WHO standard dramatically accelerates. This inflection point is also present at roughly the same location in the historic arsenic model (Fig. 2e). As inelastic deformation of clay beds begins, the rate of subsidence increases significantly[10]. As inelastic deforma tion occurs when pore pressure drops below the lowest level previously experienced, it releases pore water that has not been mixed with the main aquifer previously, which in the present case results in arsenic rich pore water being captured within the pumped groundwater.

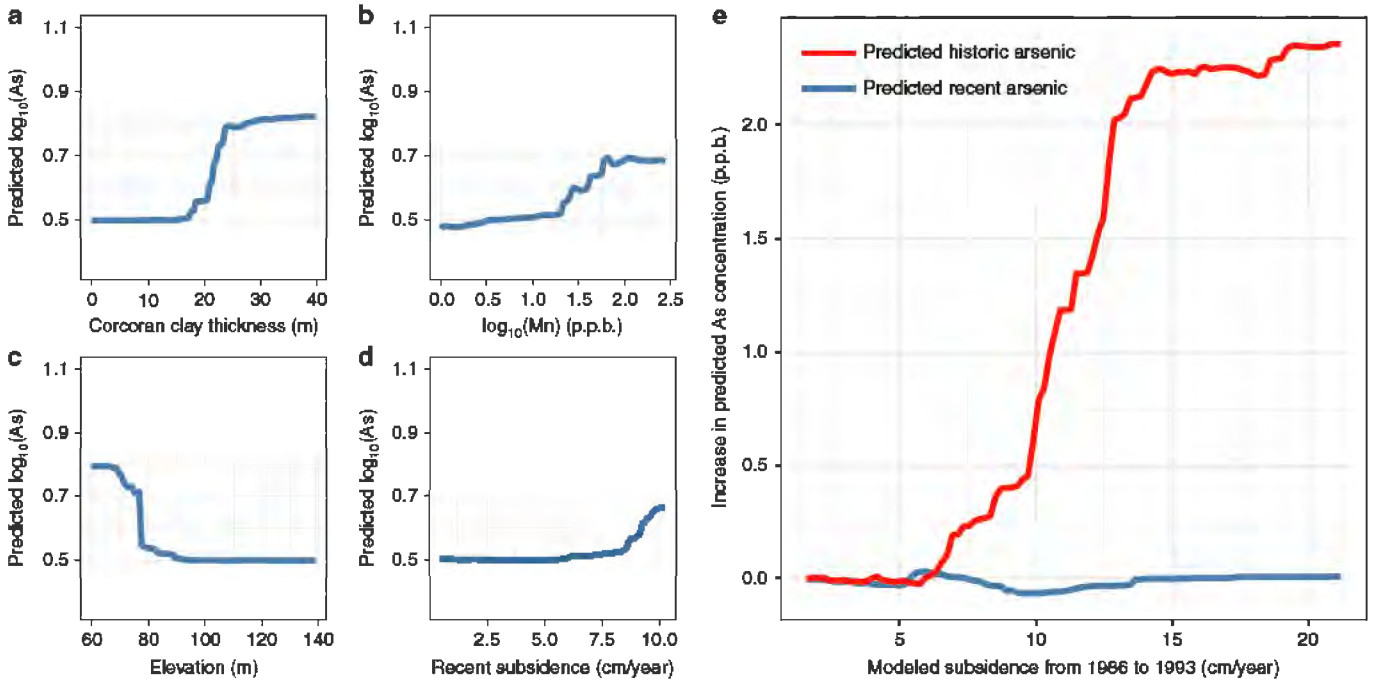


Fig. 2 Partial dependence plots of primary descriptors of groundwater arsenic concentrations. These include **a** confining clay thickness, **b** dissolved Mn concentrations, **c** elevation, and **d** recent subsidence. **e** Comparison of partial dependence plots of historic and recent subsidence. Note that historic subsidence has a great effect on historic arsenic levels but little effect on recent arsenic levels (**e**), whereas recent subsidence has a great effect on recent arsenic levels (**d**). All blue lines are derived from models predicting recent (2007–2015) arsenic concentrations, whereas the red line is derived from models predicting historic (1986–1993) arsenic concentrations

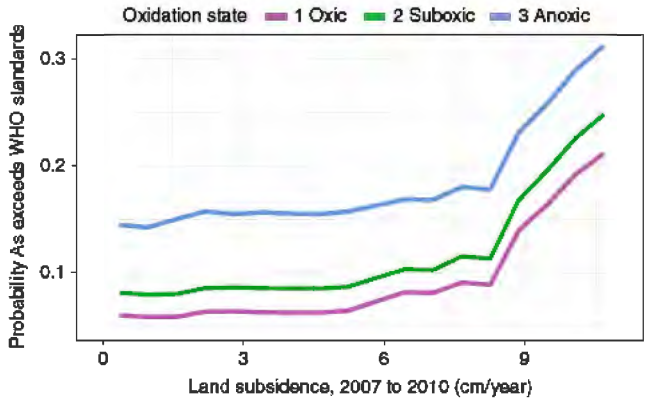


Fig. 3 Probability that arsenic levels exceeded the WHO standard. This was calculated based on recent subsidence for each arsenic risk category

Land subsidence due to overpumping increases the probability that groundwater is contaminated beyond the WHO drinking water standard by a factor of 2 to 3 for the San Joaquin Valley. Importantly, decreasing pumping below the threshold of inestastic aquifer compression will decrease arsenic concentra tions and the aquifers can recover to normal levels if over pumping is halted. Thus, subsidence maps produced by InSAR provide a means of measuring the increased risk of arsenic contamination due to overpumping of aquifers, a critically important factor as groundwater is the main source of drinking water for roughly one million people in our study area alone[16]. Moreover, with a global trend toward increase use of ground water, effectively managing water quality with quantity is essential to preserve the use of this critical resource.

Methods

Data acquisition and processing. There are many factors that control natural variation in arsenic concentration. We developed a statistical model using numerous datasets to asses the role each plays as a predictor of arsenic concentrations. We obtained arsenic level data, as well as proxy information on redox potential from manganese and sulfate concentrations, from 838 wells over the 2007 to 2015 time frame, and 424 wells over the 1986 to 1993 time frame, from the GAMA database[17], which monitors groundwater quality in California (http://geotracker.waterboards.ca.gov/gama/datadownload). We used a previously developed groundwater model[2] which provided us with several useful predictors of arsenic concentrations: percent of total water use from groundwater, which is directly related to pumping; total aquifer clay content, which sets an upper limit on available arsenic from clays; top and bottom of perforated well interval, both of which indicate the depth from which pumping occurred, a soft indicator of the oxidation state; subsidence from 1962 to 1976 and subsidence from 1986 to 1993, which provide historic measures of pumping-induced clay drainage. Elevation was also used as a predictor, obtained from the Shuttle Radar Topography Mission[18]; this is an indicator of closed-basin conditions, where contaminants such as arsenic tend to be concentrated. Slope was also derived from this dataset. As slope closely tracks predevelopment head[19], we used this with the clay content to estimate historic groundwater flow, which was also included as a predictor; our assumption being that enhanced groundwater flow would flush the system over time and reduce arsenic concentrations. We used average temperature data from PRISM; temperature variations have been related to changes in arsenic in previous work[13]. We also used evapotranspiration (ET) estimates (both from 2002 to 2007 and from 2007 to 2015)[20]; this can be used as a proxy of groundwater pumping that is independent of our InSAR measurements.

We chose not to include pesticide application as a predictor of groundwater arsenic contamination. Arsenic-bearing pesticides are largely restricted to lead arsenicals that were used predominantly on cotton and specific tree fruits (largely apples) but have been banned since the 1970's within the United States. Within the aerated surface soils, arsenic exists as arsenate[15], and would have limited mobility[4]. Thus, downward migration of surface applied arsenic is unlikely to contribute to groundwater contamination. Further, our analysis shows a correlation of groundwater arsenic with recent (last 10 years) subsidence and no correlation with older periods of subsidence. Our time series therefore further removes the possibility of arsenic pesticides impacting groundwater.

The arsenic levels, manganese levels and sulfate levels were obtained from GAMA. These levels were assumed to have a lowest detectable value of 2 p.p.b. from histogram analysis, so all values less than this were set to 2 p.p.b. As measurements of arsenic, sulfate, and manganese vary greatly with high outliers,

Table 1 Summary of scenes used for InSAR processing

Frame (region)	Path	No. of scenes	No. of interferograms
Tulare	218	15	82
Fresno	218	17	71
Mendota	219	19	82
Porterville	217	17	84

the logarithm of each was used in the statistical model to dampen the effect of outliers.

The historic groundwater flow was calculated using hydraulic conductivity (K) estimates across the Central Valley from the aforementioned groundwater model[2]. We assumed that the historic groundwater gradient ($\frac{\partial h}{\partial l}$) was equal to the land surface gradient[18]. We then used Darcy's equation to estimate flow:

$$q = K\left(\frac{\partial h}{\partial l}\right) \quad (1)$$

where q is the flux per unit area.

The distance to the nearest river was computed by determining the distance from each well to all major rivers in the study area, and taking the minimum distance as the distance to the nearest river.

InSAR processing. InSAR provides high-quality estimates of subsidence over large regions. InSAR measures subsidence over time with centimeter- to millimeter-scale accuracy over large regions with high (10 s to 100 s of meters) spatial resolution.

We acquired 68 SAR scenes from the ALOS PALSAR sensor, covering the time period from 2007 to 2010, over four frames (see Table 1) for InSAR processing from the Alaska Satellite Facility (https://www.asf.alaska.edu/). We then processed 319 interferograms using these scenes. We used 30 looks in azimuth and 10 looks in range to reduce noise in the pixels, resulting in a pixel size of roughly ~ 250 m by 250 m. We unwrapped the interferograms using the snaphu code[21]. Next, we used the small baseline subset method[22] to estimate the long-term deformation signal. This produced maps of the mean subsidence velocity for each of the four frames, which we merged to create one map of mean subsidence velocity. Overlapping areas were averaged. We then applied a moving average filter to further smooth the results, with a window size of 15 by 15 pixels. As the long-term signal dominated the total signal, seasonal fluctuations are muted over a multi-year time period. Thus, because of the temporal resolution of our arsenic measurements, we only considered the long-term signal. The resulting subsidence map is shown in Fig. 1 of the paper.

Random forest model. Groundwater overpumping, as indicated by subsidence, is one of many complex mechanisms that influence groundwater arsenic contamiantion. In order to account for additional mechanisms, as well as the interplay between various mechanisms, we employed the random forest model[23]. Random forest models can account for nonlinear relationships between multiple variables and handle outliers well . The random forest model creates ntree number of decision trees. Each decision tree makes an independent prediction of the variable of interest, in our case arsenic concentration. The best estimate is the average of the estimates from all decision trees.

Each decision tree is built using a subset of the total data. The subset is selected using random sampling without replacement, or bagging. At each split (node), the variables to be considered for that node are also randomly sampled from the list of total variables. The values of the split are chosen to maximize the variance reduction, defined as the difference between the variance before the split and the sum of the variance of the points for which the split is true, and the variance of the points for which the split is false[24].

The number of variables to be considered at each node is described by the variable *mtry*. The variables ntree and mtry are known as tuning parameters. The overall fit of the model is dependent on these tuning parameters.

In practice, increasing ntree both improves the accuracy of the results and increases the computational cost of the algorithm. Typically, increasing ntree does not significantly improve the results after roughly 100. To be conservative we chose a value of 500 for ntree. We determined the optimal value for mtry using a validation dataset. We randomly selected 75% of the dataset to calibrate the random forest model, and used the remaining 25% of the dataset as the validation to test the accuracy of the model. We chose the value for mtry that minimized the mean squared error (MSE) in the validation dataset.

We created two random forest models, one that predicted arsenic concentrations from 2007 to 2015 (recent) and one that predicted arsenic concentrations from 1986 to 1993 (historic). The response variable was $\log_{10}$(As). The variables used in calibrating both models were identical except that the recent subsidence from InSAR was not included in the historic arsenic concentrations model. In addition, the concentrations of arsenic, manganese and sulfate used to calibrate the models were taken from each respective time window (Supplementary Table 1). The resulting values for mtry were both 5, with an MSE of 0.05 and 0.10, for the recent and historic random forest models, respectively. We used these calibrated, tuned random forest models to predict arsenic concentrations and establish relationships between the variables used in the model and arsenic concentrations.

Random forests are one of many machine learning regression algorithms. In this study, we also developed models using neural networks, support vector machines, and boosted gradient trees. Our analysis showed that random forests provided the best fit to the observed data. However, similar relationships between subsidence and arsenic were observed with these additional machine learning methods.

Variable importance. With random forests, the impact of each variable in the outcome can be assessed in multiple ways. One way is to randomly shuffle (permute) each variable, and observe the increase in MSE between predicted and observed arsenic concentrations. The higher the MSE, the more important that variable is to the outcome. Another way to assess variable importance is to use partial dependence plots.

Partial dependence plots. Partial dependence plots are a common way to visualize random forest models[25]. The goal of a partial dependence plot is to show how varying one variable impacts the outcome of the prediction, while accounting for all possible values from the other variables. The partial dependence plot is calculated as shown below:

$$\tilde{f}(x) = \frac{1}{n}\sum_{i}^{n} f(x, x_{ic}) \quad (2)$$

where $\tilde{f}(x)$ is the partial dependence, n is the number of rows of the dataset, x is the predictor variable of interest, x_{ic} are the values of all other variables, and f is a function representing the random forest model The output can either be the best estimate of $\log_{10}$(As), or the probability that arsenic concentration exceeded 10 p.p.b. For the latter, we used all trees from the random forest model. Our random forest model produced 'best guess' estimates of arsenic levels, which are the mean of the estimates from all trees. It also produced an estimate for each of the 500 trees, for each observation. This provided us with a distribution which we used to determine the probability that the predicted arsenic levels exceeded the WHO standard.

Random forest models are limited in their predictions to observed data. For this reason, in the partial dependence plots of the main article (Figs. 2 and 3), we restricted the independent variable at the 5th and 95th percentile of each predictor variable. With those limits, 90% of the available data are displayed in the partial dependence plots. This reduces the likelihood of presenting results which are unconstrained by data. In the Supplementary Information section, we presented all of the data, but displayed dashed lines indicating the 5th and 95th percentiles (Supplementary Figs. 1-4).

Data availability. The geological, elevation, precipitation, temperature, ET, and water quality data have been cited throughout the paper, are listed in Supplementary Table 1, and are publicly available. The SAR data used for processing interferograms are available from the Alaska Satellite Facility following registration. The datasets developed by the authors, i.e., the processed deformation maps, estimated historic groundwater flow, and distance from each point to the nearest river, as well as the code used to produce the results, are available upon request from the corresponding author.

Received: 27 September 2017 Accepted: 26 April 2018
Published online: 05 June 2018

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Acknowledgements

R.S.'s contribution was supported by a National Science Foundation Fellowship (Award Number DGE-114747). S.F.'s contribution was supported, in part, by the US Department of Energy, Office of Biological and Environmental Research, Subsurface Biogeochemistry Program (Award Number DE-SC0016544) and the SLAC SFA Project, FWP 10094). We thank Joseph Ayotte and Kenneth Belitz for providing feedback on arsenic concentration databases in California.

Author contributions

R.S., R.K., and S.F. conceived of the study. R.S. acquired, processed, and analyzed the data. R.S. developed and interpreted the models with input from S.F. and R.K. R.S., R.K., and S.F. wrote the manuscript.

Additional information

Supplementary Information accompanies this paper at https://doi.org/10.1038/s41467-018-04475-3.

Competing interests: The authors declare no competing interests.

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EXHIBIT I

Protecting Groundwater Quality in California

MANAGEMENT CONSIDERATIONS FOR AVOIDING NATURALLY OCCURRING AND EMERGING CONTAMINANTS

Environmental Defense Fund
Sarah Fakhreddine
Christina Babbitt

Stanford School of Earth, Energy, and Environmental Sciences
Allison Sherris
Alandra Lopez
Arden Wells
Randall Holmes
Scott Fendorf

Green Science Policy Institute
Tom Bruton

Earth and Environmental Sciences Area, Lawrence Berkeley National Laboratory
Peter Nico

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The Stanford School of Earth, Energy & Environmental Sciences works to gain a better understanding of our planet's history and its future, the energy and resource base that supports society, geologic hazards that impact a growing population, a changing climate, and the challenge of sustainability.

The Green Policy Institute is made up primarily of Ph.D. scientists who specialize in the publication and communication of peer-reviewed research. We collaborate with leading scientists on policy-relevant research projects and translate scientific information to educate key decision makers, the press, and the public.

The Earth and Environmental Sciences Area of Berkeley Lab is committed to a future where society can make informed decisions about the sustainable use of our planets' energy, water, and environmental resources based on advanced scientific knowledge of the integrated Earth System.

Support for this report was provided by the Wyncote Foundation and the Water Foundation.

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The complete report is available online at edf.org/groundwater-contaminants-report.

1. Introduction

Protecting groundwater quality is an essential component of sustainable water management. However, active groundwater management often focuses on maintaining groundwater quantity – a target that does not always ensure groundwater quality goals are met. In fact, there are many ways in which both supply- and demand-side management actions can inadvertently impact groundwater quality. These impacts range from improving groundwater quality to unintentionally creating new groundwater quality problems. For example, the implementation of a managed aquifer recharge (MAR) project aimed to increase groundwater supplies can mobilize soil contaminants (e.g., nitrate) into the underlying groundwater. Similarly, water trading programs can alter the timing, magnitude, and spatial distribution of pumping, potentially resulting in changes to irrigation return flows and contaminant loading. Potential water quality impacts of management actions are particularly important to consider in the context of the Sustainable Groundwater Management Act (SGMA) (see Box 1). However, if management actions are planned in a holistic way that incorporates both water quantity and quality considerations, unintended contamination can be avoided, and in some cases, groundwater quality can even be improved.

The purpose of this document is to provide guidance to groundwater managers, consultants, and stakeholders on groundwater quality considerations associated with management actions and methods for preventing unintended groundwater contamination. Specifically, this document focuses on naturally occurring (or geogenic) contaminants (e.g., iron, manganese, arsenic, chromium, uranium, vanadium, and selenium) and other contaminants for which limited guidance currently exists (e.g., 1,2,3-trichloropropane (TCP) and per- and polyfluoroalkyl substances (PFASs)). We focus on these specific contaminants due to their prevalence in California, their impacts to human and ecosystem health, and the lack of existing guidance for addressing these types of contaminants. This document does not address groundwater contamination by nitrate and salts; nitrate and salts are only discussed in the context of their interactions with geogenic and emerging contaminants. While nitrate and salts threaten groundwater quality in many regions throughout California, there are already a number of helpful resources and regulatory programs available that are specifically aimed at addressing these contaminants.[1,2,3,4]

Water Quality and the Sustainable Groundwater Management Act

The 2014 Sustainable Groundwater Management Act (SGMA) requires local agencies to achieve sustainable groundwater conditions within 20 years. SGMA defines sustainability as the avoidance of six "undesirable results" including: (1) declining groundwater levels, (2) reduction of groundwater storage, (3) seawater intrusion, (4) degraded water quality, (5) land subsidence, and (6) depletions of interconnected surface water.

Degraded water quality is unique from other undesirable results in that it can be caused or exacerbated by water management actions aimed to help achieve sustainability goals. For example, a managed aquifer recharge project can improve groundwater levels and groundwater storage, mitigate seawater intrusion and land subsidence, and provide benefits to interconnected surface waters (avoiding all other undesirable results). However, the same managed aquifer recharge project can also adversely impact groundwater quality by transporting or releasing contaminants into groundwater.

Briefly, geogenic contaminants are naturally abundant in Earth's soils and sediments and can be released to groundwater under certain geochemical and hydrological conditions. Emerging contaminants are contaminants that have not previously been identified as water quality concerns and pose a risk to human and ecosystem health. They are typically unregulated, but often expected to become regulated as research and awareness of their health impacts grows.

In this paper, we first present a set of key considerations for protecting water quality to set the context for why it is important to consider groundwater quality outcomes at the onset of initiating any new management action. We then describe geogenic and emerging contaminants and their importance to water management (Section 2), and then outline the main processes controlling groundwater quality as it relates to these contaminants (Section 3). Section 4 highlights management considerations and guidance for protecting groundwater quality during the planning and implementation of new management actions. Finally, Section 5 provides expanded summaries of key contaminants and the processes controlling their fate and transport.

Summary of key groundwater quality considerations

A summary of the key groundwater quality considerations discussed in Section 4 are briefly described here. If management actions are planned in a holistic way that incorporates both water quantity and quality considerations, unintended contamination can be avoided, and in some cases, groundwater quality can even be improved. Some key considerations include:

1. Careful site selection for both groundwater quantity and quality

Management actions can cause improvements or unintended impairments to water quality depending on the type of action and site conditions that existed prior to the action. For instance, if a management action is planned in an area with pristine drinking water wells and no current groundwater quality problems, a shift in geochemical and hydrological conditions can cause the release of geogenic contaminants and/or the introduction and/or migration of other contaminants. However, if a project is being considered in an aquifer with previous contamination, it is possible that the proposed management action can provide groundwater quality improvements. Careful consideration should be given to both the site suitability for the management action and its proximity to drinking water supplies.

2. Characterization of current and anticipated geochemical and hydrological conditions

Understanding the current geochemical and hydrological conditions of a site is critical for both (1) identifying any existing water quality issues and (2) defining the existing conditions in order to avoid perturbations. If possible, avoiding any significant shifts in geochemical and hydrological conditions can help minimize the likelihood of causing or exacerbating contamination.

3. Development of a monitoring program

Anticipating potential changes in geochemical and hydrological conditions can help to inform a water quality monitoring program. For example, certain contaminants are more likely to appear in groundwater when dissolved oxygen is introduced into an aquifer without previous exposure to oxygen. Based on the anticipated geochemical and hydrological shifts and site characterization, a list of the most likely contaminants can be determined. Monitoring programs should focus on these contaminants and on capturing critical geochemical and hydrological perturbations. Additionally, where possible, monitoring programs should be designed to allow sufficient response time between identification of water quality problems and arrival of contaminated water to users so that the problem can be addressed prior to reaching users.

4. Implementation of managed aquifer recharge projects

Managed aquifer recharge projects are the most likely management action to cause significant shifts in geochemical and/or hydrological conditions. Accordingly, such projects deserve special attention when evaluating potential water quality impacts. Recharging water, even clean water, into a previously uncontaminated aquifer can potentially alter the existing geochemistry and hydrology and subsequently cause the release of geogenic contaminants from soils and sediments. Specific considerations should be made for MAR projects including characterizing baseline aquifer geochemistry, the source recharge water chemistry and historical land use of the area selected for recharge. These considerations vary slightly depending on the type of MAR. A thorough understanding of the site-specific geochemical and hydrological conditions can inform the design of MAR projects that not only avoid new water quality problems, but also potentially offer water quality improvements.

5. Development of contingency plans

While precautions should be taken to avoid groundwater quality problems, a plan should be in place to address potential groundwater contamination events. This is particularly relevant if groundwater supplies are used for drinking water.

2. Geogenic and emerging contaminants

What are geogenic contaminants?

Geogenic contaminants are elements that naturally occur in Earth's soils and sediments. Some common geogenic contaminants include: iron, manganese, arsenic, chromium, uranium, vanadium, and selenium. These contaminants occur naturally in groundwater. Shifts in geochemical and hydrological conditions within an aquifer can cause new mobilization of these contaminants from primary minerals or release from soils and sediments into groundwater, where they pose a much larger risk to human and ecosystem health. Additionally, if groundwater is used for irrigation, these contaminants can threaten agricultural productivity.

Iron and manganese are only toxic at very high concentrations compared to the other geogenic contaminants discussed in this document; they are more commonly associated with taste and odor issues in water. However, iron and manganese are highly reactive in groundwater and can control the occurrence of other contaminants in an aquifer through their interactions with other contaminants. Arsenic, some forms of chromium, and uranium are toxic at very low (or trace) concentrations (on the order of micrograms per liter (µg/L)) and have both anthropogenic (man-made) and naturally occurring sources.

Naturally occurring contaminants have been increasingly associated with groundwater quality issues throughout California, particularly in the Central Valley. Vanadium is also increasingly being recognized as a groundwater contaminant, and health effects of vanadium exposure are actively being researched. While vanadium is currently not subject to enforceable regulation, it does have state drinking water Notification and Response Levels[5], and it is anticipated to be considered for more formal regulation in the future.

Selenium toxicity is a greater threat to fish and waterfowl than human health, and notable issues of geogenic selenium exposure in waterfowl have occurred in the San Joaquin Valley as a result of irrigated agriculture drainage to wetlands.

Since the source of these contaminants is natural soils and sediments, which exist in spatially extensive layers and formations, contamination can occur over large areas. This potentially large scale and diffuse source poses a significant and costly challenge for remediation once a contaminant has been released, emphasizing the importance of preventing their mobilization to groundwater.

Protection of groundwater quality requires managing aquifers so that geochemical and hydrological conditions are unlikely to cause contaminants to be released from soils and sediments into groundwater. These conditions are specific to each contaminant, can sometimes be contradictory (i.e., what is good for one is bad for another), and are further complicated by the complex interactions between contaminants and other water quality parameters.

Importantly, geogenic contaminants of concern occur in most groundwater at very low concentrations due to the ubiquity of many of these natural elements in the earth's crust – the materials and sediments derived from those rocks through which groundwater flows. Some of these elements are essential nutrients (e.g., some forms of chromium, selenium, iron, and manganese) and are important to human health. However, at contaminant-specific, higher concentration thresholds these geogenic elements become contaminants in drinking water or other beneficial uses of water and begin to pose a risk to human and ecosystem health.

What are emerging contaminants?

Emerging contaminants are contaminants that have not previously been identified or have only recently been identified as a water quality concern. Emerging contaminants often do not have established regulatory standards. Emerging contaminants may pose a risk to human and ecosystem health, though these risks may not be well understood.

Notably, vanadium is an emerging contaminant as it has no current regulation. Since it is also a geogenic contaminant, we include it in the discussion of other geogenic contaminants that behave similarly in the environment. We also discuss considerations related to 1,2,3-trichloropropane (TCP) and per- and polyfluoroalkyl substances (PFASs) which are both anthropogenic contaminants. PFASs have anthropogenic (man-made) sources and are currently unregulated. Similarly, TCP remained unregulated until 2017. We consider TCP an emerging contaminant despite its recent regulation because there remains a need for research and guidance to address TCP contamination in groundwater.

Anthropogenic contaminants can be *point source contaminants*, meaning they have specific, identifiable sources, or *nonpoint contaminants*, which originate from diffuse sources (e.g., runoff from large agricultural areas containing elevated concentrations of pesticides). TCP has both agricultural and industrial sources and can fall under either category. TCP is highly persistent in groundwater and is toxic at extremely low concentrations (on the order of nanograms per liter (ng/L)). It is important to prevent inadvertently placing new wells in areas with TCP contamination. Additionally, a disturbance to a groundwater aquifer can transport TCP into previously uncontaminated wells within the aquifer.

3. Factors controlling groundwater quality

Groundwater quality is controlled by the geology of an area, historic land use, and the resulting geochemical and hydrological conditions within the aquifer. While the geology and historic land use cannot be changed, management can significantly impact geochemical and hydrological conditions. Knowing the historic land use of a given region can help determine possible anthropogenic sources of contaminants. For example, the use of certain soil fumigants introduced TCP into groundwater at specific sites (see Section 5.8). Here, we provide an overview of relevant geological information related to the occurrence of geogenic contaminants. We also describe key geochemical and hydrological processes as they relate to overall groundwater quality.

3.1 Geology

The geology of an area determines which types of earth materials (minerals and organic material that make up soils and sediments) are present in an aquifer. Different sediment types have distinct chemical properties and concentrations of geogenic contaminants. While groundwater quality will ultimately be determined by how these particles respond to the geochemical and hydrological conditions in the aquifer, an understanding of the underlying and regional geology will provide some insight into which geogenic contaminants may be more problematic than others in a given region. During rock weathering, geogenic contaminants are deposited within the soils and sediments that compose groundwater aquifers.

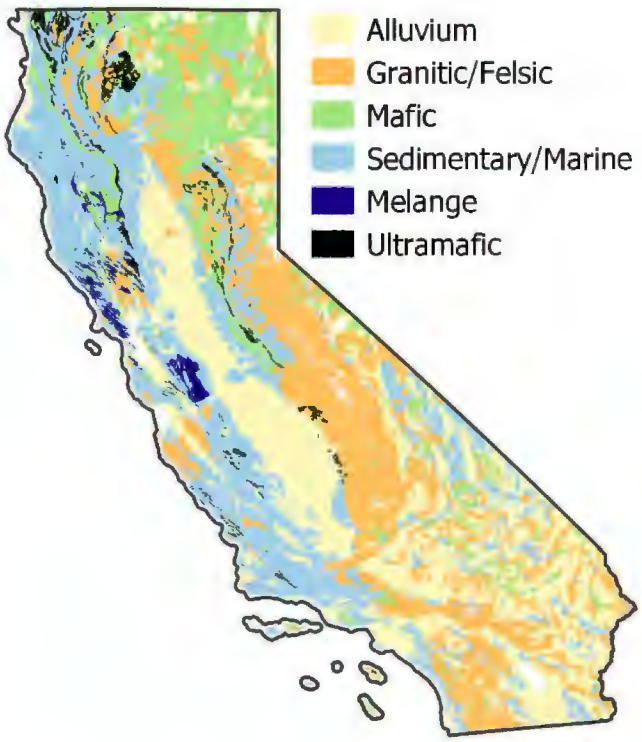


Figure 1: Map of relevant geologic features associated with various geogenic contaminants in California. Shales are included in the Sedimentary/ Marine category. Map is adapted from the California Department of Conservation and California Geological Survey's geologic map of California (Jennings et al., 2010).

Figure 1 highlights key geologic features within California that are relevant to the geogenic contaminants discussed within this document. Following aluminum, iron and manganese are the second and third most abundant metal elements in Earth's crust, respectively. Therefore, they are found in high concentrations in soils and sediments and are ubiquitous within most geologic features especially in *mafic rocks*. Arsenic and uranium are found in higher abundance in granitic materials like those comprising the Sierra Nevada. The Sierra Nevada has weathered over time, leading to the deposition of sediments containing these elements within the Central Valley. Chromium is elevated in mafic and *ultramafic rocks*. Vanadium is also enriched in mafic rocks although generally not in ultramafic rocks. Both vanadium and selenium are also associated with the marine *shales* of the California Coast Range, with selenium particularly concentrated in the Southern Coast Range and in areas affected by hydrothermal fluids (naturally heated water found in the environment).

Continued rock and mineral weathering followed by alluvial (water) transport and deposition leads to the formation of soils and sediments that compose groundwater aquifers. While not all the aquifers in California are alluvial aquifers, they are the most relevant to the water management actions described here and we use them to introduce and describe concepts related to groundwater quality.

Most groundwater aquifers, including those comprised of alluvial sediments, are heterogeneous, meaning they have multiple discontinuous layers of different types of earth materials and sediments (Figure 2). These layers vary in both their chemical and physical properties. In general, shallow portions of an aquifer have higher amounts of dissolved oxygen (DO) in groundwater as they are closer to the surface and have likely been recharged more recently, while deeper portions of an aquifer typically have older groundwater with limited DO concentrations.

The presence of oxygen and other substances affects the types of minerals and associated elements present in the aquifer. Portions of an aquifer with abundant dissolved oxygen (DO) tend to be rich in minerals like iron oxides (or rust particles/surfaces). Iron oxides are a critical mineral affecting the overall chemistry of groundwater and are discussed in Section 5.1. Deeper portions of an aquifer that typically have less abundant oxygen do not support the formation of iron oxides. Both the geochemical and physical heterogeneity of aquifers means that contaminant fate and transport can vary greatly throughout various zones of an aquifer, both vertically and laterally.

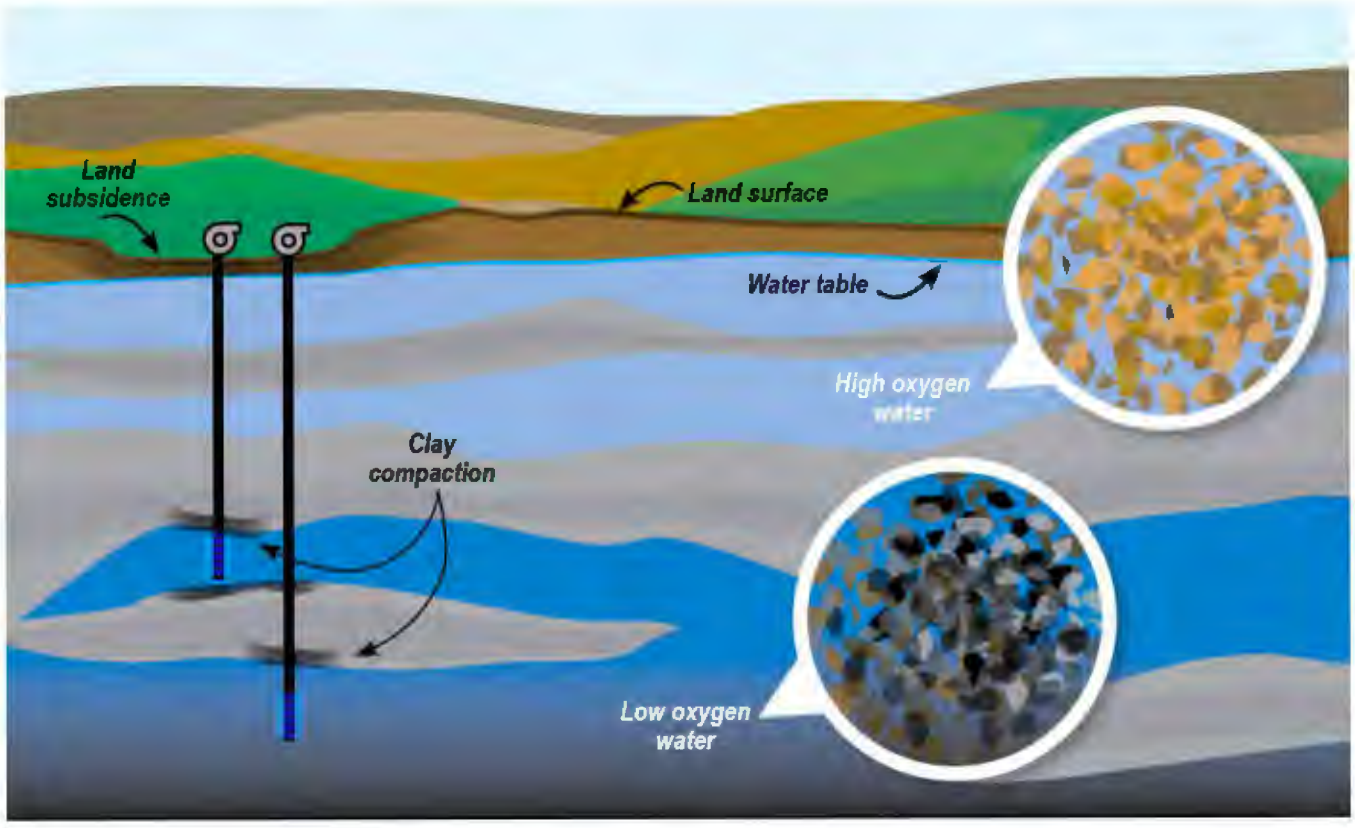


Figure 2: Generalized cross-section showing the physical and chemical heterogeneity of an alluvial groundwater aquifer system with interbedded clay layers. Shallower regions with higher oxygen abundance in groundwater tend to be enriched in minerals including orange-colored iron oxides while deeper regions with low oxygen content in groundwater tend to be enriched in darker-colored sulfide-bearing minerals. Additionally, activities like heavy pumping can compact clay layers affecting the physical (hydraulic) and chemical properties of the aquifer system.

3.2 Geochemistry

The fate and transport of contaminants depends on the geochemical reactions occurring within the aquifer system. The reactions of primary concern are those that occur at the interface between sediment materials and the surrounding groundwater. In general, contaminants are either incorporated into minerals, adsorbed to mineral surfaces, or dissolved in groundwater where they are transported by groundwater flow (Figure 3).

A contaminant that is dissolved in groundwater is considered mobile and is readily transported with the flow of groundwater. When contaminants are adsorbed to aquifer materials, they are no longer dissolved in groundwater. They can be transported when small particles (called colloids) move with the water; however, these particles are relatively easy to filter or settle out of water. In general, adsorption processes make groundwater contaminants relatively immobile unless a geochemical or hydrological trigger causes them to desorb from their host surface. Under some conditions, groundwater contaminants precipitate (form solids) and are removed from groundwater where they become immobile and remain on the aquifer solids.

Different contaminants have different levels of partitioning between the water and mineral surfaces (i.e., varying tendencies to adsorb to solids versus dissolve in groundwater) and are controlled by various chemical reactions. To avoid degrading water quality, management actions should promote geochemical conditions that favor maintaining contaminants on aquifer solids rather than geochemical conditions that release them into groundwater, or those that ensure that any such mobilization is spatially limited such that it does not materially affect extracted groundwater quality. This is a technically challenging task as multiple contaminants co-occur within aquifer solids and have varying, sometimes opposite, geochemical conditions leading to release.

Examples of the types of geochemical conditions that can control contaminant retention and release include **red**uction-**ox**idation (*redox*), *pH* (a measure of acidity), and *solubility* (ability to dissolve in water). Redox and pH refer to the state of the groundwater while solubility refers to properties of different substances found in both an aquifers' materials and groundwater. Below is a brief overview of redox, pH, and solubility as they relate to contaminant release. While the ionic strength and hardness of water can also influence its reactivity, these tend to be less concerning than shifts in redox and pH.

3.2.1 Redox reactions

Redox reactions are reactions that involve the transfer of electrons (particles with negative charge) from one substance to another. The *oxidation state* of a substance is a measure of how many electrons it has gained or lost relative to its elemental state (its pure, uncharged, and unreacted state). *Reduction* is a gain of electrons resulting in a decrease in oxidation state. Conversely, *oxidation* is a loss of electrons resulting in an increase in oxidation state. Substances gain or lose electrons by reacting with other substances. Dissolved oxygen (DO) is involved in many redox reactions and is a strong *oxidant* (it causes the oxidation of another substance, meaning it strips them of electrons).

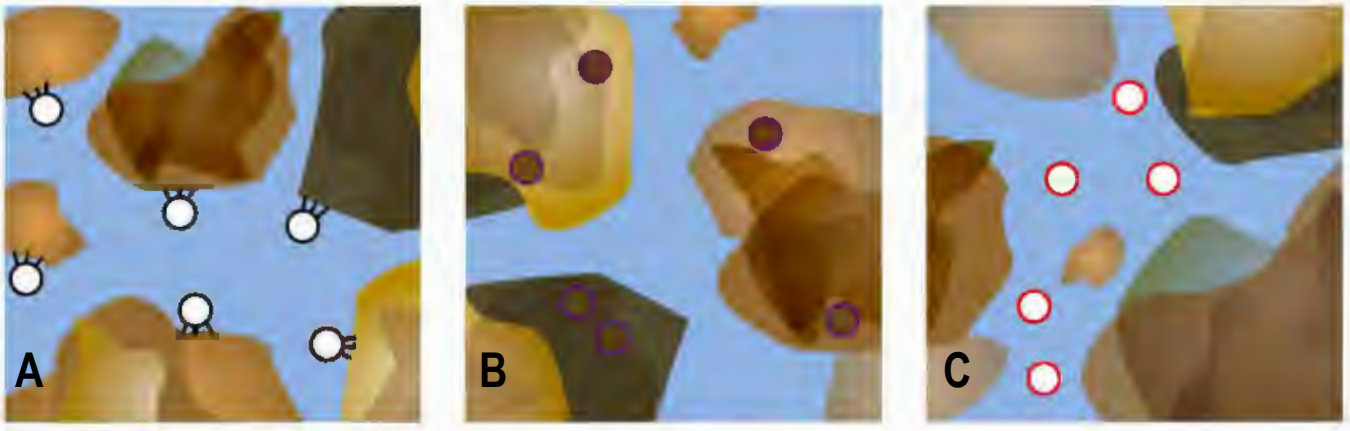


Figure 3: Contaminants in groundwater aquifers can either be (A) adsorbed to aquifer particles, (B) incorporated into aquifer particles, or (C) released to the surrounding groundwater.

Most geogenic contaminants are redox active, meaning that they are commonly found in more than one oxidation state, and each of these states may have different mobility and toxicity. For example, chromium in the environment can be found in both a trivalent (+3) oxidation state and in a hexavalent (+6) oxidation state. Trivalent chromium, Cr(III), is considered a micronutrient in human nutrition and is relatively immobile due to its low solubility and propensity to adsorb on aquifer minerals.

Generally, when oxygen is abundant, substances are more likely to be present in their more oxidized form.

By contrast, hexavalent chromium, Cr(VI), binds poorly to aqu1ifer solids and is thus mobile in groundwater. It is also toxic to humans (at concentrations greater than 0.02 µg/L according to the Public Health Goal (PHG), see Section 5). Changes in redox conditions in an aquifer can cause trivalent chromium, Cr(III), to turn into the toxic, mobile hexavalent chromium, Cr(VI), and vice versa. Therefore, it is critical to understand the redox conditions in an aquifer and how management actions can cause redox conditions to shift. Even a small change in redox condition can have a large impact on contaminant behavior in groundwater.

There are methods for determining the redox conditions within an aquifer. Groundwater monitoring wells can be measured for oxidation reduction potential (ORP), which is a commonly used metric for redox condition. Interpreting ORP as a standalone measurement can be challenging because the measurement depends on a reference measurement that can vary depending on the ORP method used. However, ORP is useful as a relative indicator of changes in redox condition. Sharp changes in ORP can signal that redox conditions within an aquifer are changing, and therefore shifts in groundwater quality could also be occurring.

Dissolved oxygen (DO) is also often used as a proxy for redox conditions within an aquifer. Generally, when oxygen is abundant, substances are more likely to be present in their more oxidized form. When oxygen is absent or very low, contaminants are more likely to be present in their more reduced form. For simplicity, we will use the terms *oxygen-abundant* (DO > 2 mg/L) and *oxygen-limited* (DO < 2 mg/L) to describe the redox conditions of an aquifer.

For example, the impacts of DO on redox condition can be visually observed with iron. In groundwater with no exposure to oxygen, iron is well-dissolved and mobile in groundwater. With exposure to DO, iron oxidizes and forms rusty solid particles (or iron oxide minerals) that separate out of water and/or coat other mineral surfaces (Figure 4). These rust particles range in color from yellow to red, with orange predominating, and can be seen in soils and sediment which have been exposed to oxygen.

Knowing the DO concentration of water is a strong indicator of whether iron will be dissolved in water or present as an iron oxide solid. More generally, knowledge of oxygen concentrations can serve as a useful proxy for redox condition and understanding of which geogenic contaminants may exist in groundwater. Measurement of DO is typically easier and more cost-effective than analyzing trace metal concentrations. Therefore, it can be measured more frequently than other *analytes* (the substances being measured) in a monitoring program. Based on which redox-sensitive analytes are measured, the redox processes occurring can be more thoroughly characterized using existing United States Geological Survey (USGS) resources for characterizing redox chemistry.[6]



Figure 4: Oxygen-limited (anoxic) groundwater rich in dissolved iron seeping into a stream, oxidizing due to exposure to the atmosphere where oxygen is abundant. This causes oxidization of the dissolved iron to occur, converting it into solid iron oxides (rust particles). (Photo credit J. Walton http://windowoutdoors.com/WindowOutdoors/Iron%20in%20Springs%20and%20Seeps.html)

3.2.3 pH

pH is one of the most important groundwater quality parameters and often strongly correlates with the presence of different contaminants. Low pH values are acidic and higher pH values are basic. Typical groundwater pH values fluctuate near neutral (pH of 7). Groundwater pH depends on the composition of the groundwater (i.e., which substances are present) and the chemical reactions occurring within the aquifer. For example, aquifers with high carbonate concentrations tend to have a higher pH and a high buffering capacity (meaning pH does not easily change). pH affects the substances dissolved in groundwater because certain chemical reactions are more likely to occur at higher or lower pH values.

Similarly, a solid mineral surface can be positively or negatively charged depending on the pH, and this in turn affects the ability of contaminants to adsorb to those surfaces and be removed from the groundwater (Figure 5). pH can also make certain minerals in sediment particles or within the rock structure more or less likely to dissolve in groundwater. In general, negatively charged ions (such as arsenic) are more mobile at high pH (> 8.5), while positively charged ions (such as iron and manganese) are mobilized at low pH.

3.2.4 Solubility and groundwater age

Solubility in the context of groundwater geochemistry refers to the maximum concentration at which a substance can be found dissolved within groundwater. Solubility can refer to solids (e.g., minerals), liquids (e.g., solvents, pesticides), and gases (e.g., oxygen, carbon dioxide) and their ability to dissolve in water. Some of these substances are more likely to dissolve (i.e., more soluble) compared to others. For example, table salt (sodium chloride) is highly soluble and dissolves when mixed with water, releasing both sodium and chloride ions into the surrounding water.

The materials that adsorb or contain contaminants have varying degrees of solubility. In the presence of water, highly soluble materials will not retain their solid form in water and will dissolve, releasing contaminants embedded within the sediment particle/rock matrix to groundwater. Insoluble contaminants will stay in the sediment particle/rock matrix and will not contaminate groundwater unless conditions promoting their dissolution evolve. For example, under certain geochemical conditions arsenic will reside in a sulfidic (sulfide-containing) mineral called arsenian pyrite. This mineral has limited solubility but can dissolve under certain low pH and/or oxygen-abundant conditions, causing arsenic to be released into groundwater.

The rate (how quickly) a substance dissolves also determines how likely it is to be found in groundwater. Near natural recharge sources, such as streams, groundwater may contain relatively small amounts of total dissolved solids (TDS) which is a measure of the amount of dissolved *species*. This is because the water is not in equilibrium with the soils and sediments (i.e.,

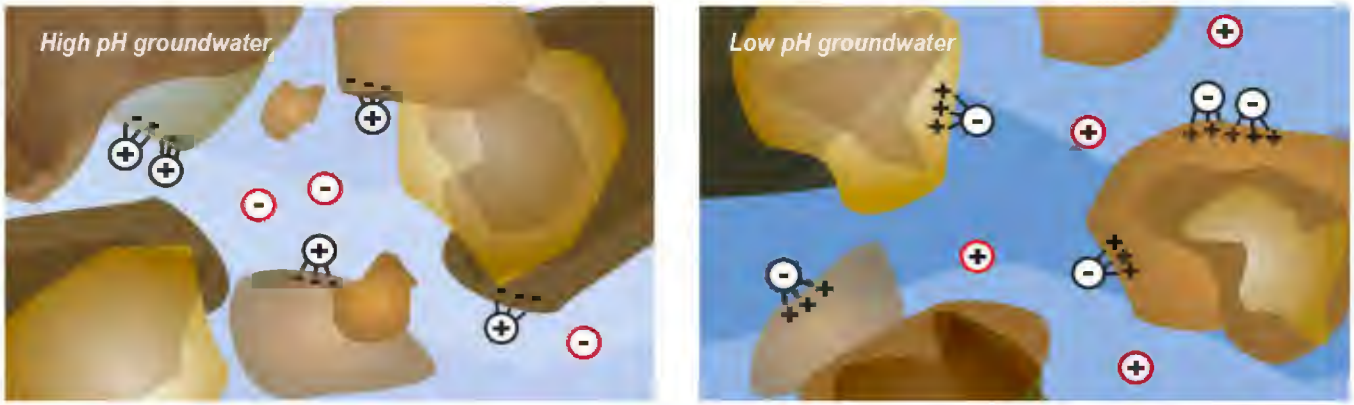


Figure 5: Schematic showing pH effects on charged particles. Mineral surface charge changes with the pH of the surrounding groundwater, causing changes in the type of contaminant likely to occur in groundwater.

the minerals in soils and sediments have not had time to dissolve because freshwater is recharging faster than the minerals are dissolving). The mineral surfaces of the sediment particles gradually dissolve over time.

These rates are an important concept relating groundwater chemistry to groundwater age. Older groundwater is typically more enriched in TDS (including naturally occurring contaminants) compared to younger groundwater. However, younger groundwater will often respond quicker to management actions owing to shorter recharge times. More information relating groundwater age to groundwater vulnerability is available through the USGS.[7]

3.3 Hydrological impacts on geochemistry

The hydrology and geochemistry of a groundwater system are closely intertwined. As water flows in the subsurface, it carries contaminants as well as other dissolved (or aqueous) substances which can react with each other. Additionally, many of the chemical reactions occurring in groundwater occur at different timescales; some are very fast while others are extremely slow. Generally, groundwater moves slowly, allowing enough time for reactions to occur between aquifer solids and groundwater. However, in heavily pumped or managed systems, groundwater movement can be accelerated and the aqueous substances in the groundwater may have less time to react with aquifer solids.

A significant rise or fall in the depth of the water table in response to pumping or recharge will also change the interaction between groundwater and the overlying unsaturated (vadose) zone, potentially affecting contaminant partitioning between the solid and mobile, dissolved phase. Depending on which chemical reactions are possible in a given aquifer, this can either have a positive, negative, or minimal impact on groundwater quality. In summary, the physical movement of groundwater can induce different types of geochemical responses.

4. Protecting groundwater quality

4.1 Managing for both groundwater quantity and quality

To the extent possible, management actions should be planned in a holistic way that incorporates both water quantity and quality considerations. Special caution should be taken if a new management action is planned in an area containing drinking water wells with no current groundwater quality problems. In these locations, there is a risk of causing groundwater contamination by changing the geochemical and hydrological conditions within the aquifer that may lead to the release of geogenic contaminants.

By the same token, if a project is being considered in an aquifer with existing contamination, it is important that the problem not be worsened by management actions. It is possible to design a proposed management action in ways that may provide groundwater quality improvements. For example, if a proposed managed aquifer recharge project does not create adverse shifts in water quality (i.e., no shifts in redox or pH which release contaminants), it has the potential to reduce existing contaminant concentrations.

Understanding the geochemical and hydrological conditions in these cases will be critical to anticipating whether contaminated water can potentially be diluted or will spread contamination to previously uncontaminated areas of the aquifer. Table 1 lists common water management actions and how they might impact groundwater quality. As mentioned previously, these projects can also offer water quality improvements. However, here we focus on the protection of groundwater supplies and prevention of unintentional, new contamination resulting from management actions. Additionally, while we provide general guidance, much of the considerations will depend on site-specific characteristics and local contaminants of concern.

TABLE 1

Common water management actions and potential impacts

Management action	Common examples	Potential water quality impacts
Managed aquifer recharge (MAR)	**Infiltration ponds**	If the infiltrating water is of a different chemistry than the native groundwater, geochemical changes can occur during infiltration (e.g., change in pH, redox chemistry). Infiltration processes gradually introduce recharge water which can allow enough time for the aquifer sediments to buffer changes in water chemistry. Infiltration can alter the shallow groundwater levels and/or cause a fluctuating water table. Resulting changes in the water table and the wetting and dewatering of shallow sediments can induce changes in redox chemistry.
	Injection wells	Potential impacts are similar to those of infiltration ponds (i.e., differences in recharge water chemistry and native groundwater chemistry can cause adverse interactions). However, during direct injection, these changes are likely to be more abrupt compared to infiltration processes as injection wells can also alter the flow regime and can cause faster transport between different zones of the aquifer.
	Agricultural managed aquifer recharge (Ag-MAR)	Ag-MAR involves the use of irrigation water for recharge on agricultural lands during fall, winter, and/or spring. Because the water has continuously been introduced to the aquifer through previous irrigation, it is unlikely to create new, abrupt changes to geochemical conditions. Since volumes of recharge water are similar to past recharge volumes, hydrological conditions would not be expected to deviate strongly from historic conditions. These areas can still mobilize contaminants, but new and significant water quality problems are less likely to occur compared to other types of recharge.
	Flood-managed aquifer recharge (Flood-MAR)	Flood-MAR involves the use of flood water from rainfall or snow melt for recharge on agricultural and working lands (e.g., refuges, floodplains). Here, the recharge water may be of differing chemistry than the native groundwater or previously applied irrigation water which may cause geochemical changes releasing geogenic or other existing contaminants. Additionally, hydrological changes may also occur and contribute to the transport of contaminants and/or changes in the underlying water table. The Department of Water Resources is working to identify research needs, including water quality, for Flood-MAR projects (see Section 4.4).
Changing timing, magnitude, and/or spatial distribution of pumping	**Water trading**	Trading programs can change the volume and use of groundwater supplies in ways that may affect return flows, magnitude and timing of pumping, and contaminant loading. Some examples include (1) increasing pumping in an area with deteriorated water quality and subsequently causing the migration of contaminants or (2) increased water use by a user with higher contaminant loading, resulting in higher contaminant concentration in return flows.
	New pumping	New pumping can increase vertical and lateral movement of water, resulting in transport of contaminants or reactants that may induce contaminant mobilization. Pumping in new regions of an aquifer can also cause fluctuating water tables which can alter geochemical conditions.
	Retiring wells	While inactive wells are no longer causing movement of groundwater via pumping, they can still serve as conduits for groundwater. Shallow groundwater, often of poorer quality, can migrate downward and degrade deeper water supplies (Gailey, 2017).

When planning and selecting locations for a new management action, careful consideration should be given to the proximity of the management action to production wells and the ultimate end use of water produced from those wells. As a first principle, it is best to exercise caution to avoid actions that are likely to cause significant geochemical and/or hydrological changes in the vicinity of clean drinking water supplies.

If a management action in the vicinity of clean drinking water supplies is required, appropriate stakeholder engagement is necessary to ensure that the whole suite of community and stakeholder considerations is acknowledged in shaping the proposed project. To aid in this process, Community Water Center (CWC) has developed guidance focused on protecting drinking water under SGMA.[8,9] Projects in these areas can take the three steps outlined below to help protect groundwater quality.

Step 1. Characterize existing groundwater quality issues where new management actions are planned.

Any existing groundwater quality issues should be identified when first planning management actions in order to avoid exacerbating or spreading existing contamination. Precautions should also be taken to avoid causing new contamination. Any available groundwater quality data should be analyzed to understand which contaminants are currently present and what trends exist for those contaminants, both spatially and temporally (i.e., Do concentrations vary seasonally? Is it a constant problem? Are concentrations increasing over time or is it getting worse?).

A summary of publicly available datasets is included in a report by Stanford University's Program on Water in the West, titled "A Guide to Water Quality Requirements under the Sustainable Groundwater Management Act" (Moran and Belin, 2019). All water quality data collected by water agencies is also publicly available via formal public records request if it is not otherwise accessible via a state or local database.

Additionally, if groundwater age data is available, it can help estimate how quickly groundwater quality will respond to new management actions. Younger groundwater tends to be more responsive to new management actions than older groundwater supplies.

Step 2. Anticipate how aquifer geochemistry and hydrology might change as a result of the planned management action.

Anticipating changes to aquifer geochemistry and hydrology requires a knowledge and understanding of the existing geochemical and hydrological conditions. Of key concern are indicators of redox condition (both DO and ORP), pH, and water composition (concentrations of substances including salts, carbonates, sulfates, phosphate). A change in redox condition is the most likely to trigger the release of geogenic contaminants, followed by a change in pH and then ionic composition (the type and concentration of different ions in the water). If the management action involves introducing a new water source into the aquifer (e.g., MAR with surface water in a region where previous recharge has been primarily from irrigation reliant on groundwater), characterizing the chemistry of this new water source will help determine if any adverse shifts may occur.

The principal means by which a shift in redox can occur is either the influx of water with differing oxygen levels or influx of an organic carbon compound that stimulates biological (e.g., bacterial) activity and the subsequent consumption of oxygen. For example, if a MAR project introduces high concentrations of organic carbon (e.g., recycled wastewater) into an oxygen-abundant aquifer, oxygen may be consumed and reducing conditions may evolve within the now oxygen-limited aquifer. Similarly, if a recharge project introduces water with high DO concentrations into a previously oxygen-limited aquifer, a shift in redox will occur.

pH-related release of certain contaminants can occur when infiltrating or injecting recharge water with a differing pH than the native groundwater. A shift in pumping regime can also cause the mixing of groundwaters with various chemistry if water from various regions within the aquifer is being transported to new locations. Therefore, it is important to obtain information on baseline geochemical conditions (including pH, DO, ORP) and, if available, any previously collected soil and/or sediment analyses or samples (e.g., soil cores and drill cuttings). These samples can be used for laboratory analysis to determine their composition and likelihood of contaminant release.

Step 3. Potential management strategies can be identified to minimize adverse changes in geochemical conditions.

Limiting changes in geochemical and hydrological baseline conditions will help limit potential adverse impacts. For instance, if recharging water, is it possible for the recharge water to have a more similar geochemical composition to the native groundwater? This could be achieved by pretreating recharge water or using an alternate source of water for recharge. If matching source water chemistry is not possible, see Table 2 to determine which contaminants to prioritize in a robust monitoring program.

Soil and aquifer sediment samples (e.g., soil cores and drill cuttings) also provide valuable information about the aquifer solids and the chemical state of contaminants residing within those solids, but are more expensive than water sampling. If there is potential for significant geochemical shifts, sediment samples should be obtained to measure the abundance of various natural contaminants in the region where the management action is taking place and what chemical form these contaminants are in.

In some areas, it may be possible to retrieve old samples from previous well drilling or core activity as a more cost-effective way of obtaining samples. While older samples may not retain the same chemical properties as those found *in situ*, they can provide valuable information about the total contaminant concentrations. It is possible that soils or sediments can contain high concentrations of certain contaminants either naturally or as a result of historic anthropogenic inputs that accumulate. Soil and sediment heterogeneity pose a complex challenge to sampling as concentrations can vary greatly within small spatial areas. Priority sampling locations should be in the region closest to the proposed management actions where the most significant shifts in geochemical and/or hydrological conditions are likely to occur. For a MAR project that includes use of recycled water, the construction of required monitoring wells presents an opportunity to collect aquifer solids samples.

For the installation of new water supply wells and associated well screening, it should be taken into account that wells can affect the transport and mixing of water from different zones within an aquifer (Gailey, 2018). For example, if contamination exists in a shallow portion of the aquifer, high rates of deep pumping can draw shallow groundwater down over time. Additionally, production wells with large screened intervals can serve as a preferential pathway connecting and transporting groundwater from different depths and potentially of varying quality. Generally, clay layers are likely to have more elevated concentrations of geogenic contaminants. While wells are typically not screened in clay layers because of their poor hydraulic conductivity, caution should be taken to avoid these layers for groundwater quality considerations as well.

4.2 Managing for co-occurring contaminants

It is likely that there will be multiple contaminants to consider and monitor, including geogenic and emerging contaminants as well as nitrates and salts. As an oxidant, nitrates create problems for geogenic contaminants that are released under oxidizing conditions, which include uranium and selenium. The co-occurrence of contaminants can be exacerbated in projects that mobilize nitrate into systems with limited prior exposure to oxygen or other oxidants.

The migration of dissolved salts into groundwater supplies can also have adverse impacts for other contaminants. One concerning example of this is the migration of high calcium and carbonate waters into groundwater prone to uranium release. Calcium and carbonate can react with uranium to form a complex that prevents uranium from adsorbing to solids and releases it into groundwater (see Section 5.5).

Table 2 describes the geochemical conditions that can cause the release of each contaminant. Rather than considering each contaminant as an individual management concern, contaminants can be conceptually grouped by the geochemical conditions that cause their release. Then, management actions can be taken to avoid specific geochemical conditions and the group of contaminants associated with those conditions. In general, trying to maintain native aquifer geochemical conditions will minimize the likelihood of releasing new contaminants.

TCP and PFASs are not included in Table 2 as they are not geochemically released like geogenic contaminants. Sections 5.8 and 5.9 provide specific information related to the management of TCP and PFAS contaminated aquifers, respectively.

TABLE 2

Groundwater conditions that can result in an increase or decrease in the mobility of each contaminant

	Contaminant Mobility Due to Aquifer Conditions				
Contaminant	Oxygen-abundant	Oxygen-limited	High pH	Low pH	Aquifer conditions to avoid
Iron (Fe)	↓	↑	↓	↑	Oxygen-limited, low pH
Manganese (Mn)	↓	↑	↓	↑	Oxygen-limited, low pH
Arsenic (As)	↓	↑	↑	↓	Oxygen-limited, high pH, high phosphate, compaction of clay layers from overpumping
Chromium (Cr)	↑	↓	↑	↓	Oxygen-abundant, high pH, fluctuating water table
Uranium (U)	↑	↓	↑	↓	Oxygen-abundant, high pH, high bicarbonate, high nitrate
Vanadium (V)	↑	↓	↑	↓	Oxygen-abundant, high pH
Selenium (Se)	↑	↓	↑	↓	Oxygen-abundant, high pH

4.3 Developing a monitoring program

A monitoring program will be critical for new management projects where an initial assessment determined that existing geochemical and hydrological conditions may be perturbed. A survey of existing wells appropriate for monitoring and resources available for drilling additional monitoring wells will help determine how best to deploy new monitoring efforts.

Detailed design of a water quality monitoring program is beyond the scope of this report, but the following are some suggestions to inform early thinking and conceptualization of a rigorous monitoring program. Design of an appropriate water quality monitoring program should be conducted by a qualified professional in an adaptive process with thorough stakeholder engagement. More detailed resources and guidance on monitoring networks and programs are available through the California Department of Water Resources (DWR).[10, 11]

Monitoring wells should provide adequate spatial and temporal coverage to identify groundwater quality problems in a timely manner. Spatial requirements will depend on the scale of the project and regulatory requirements. Understanding the flow and transport conditions in the aquifer will be critical for determining the spatial extent of monitoring. Accordingly, groundwater flow (level) monitoring should be used to help design appropriate groundwater quality monitoring programs, since groundwater gradients determine the direction and speed of groundwater flow.

Coupled with and informed by the groundwater level monitoring, groundwater flow models with particle tracking and/or mass transport capabilities or planned empirical tracer tests can help determine how fast and in which directions groundwater is movingfurther informing the appropriate design of water quality monitoring programs. This is important because there are often delayed effects; problems can arise as water moves downgradient. Monitoring wells should be placed in locations between the new project and production wells/users in such a way that provides sufficient response time should a migrating groundwater problem be observed. If groundwater quality issues are first observed in drinking water wells or in monitoring wells placed too close to the supply well to provide an adequate response time, it will be too late to address the issue before contaminated water reaches users.

Additionally, monitoring wells should span the impacted depths of the aquifer. Multi-screened wells and/or nested wells provide depth resolved data and should be used where appropriate.

Temporal coverage should allow enough frequency of monitoring to capture seasonal and short-term trends in groundwater quality. Seasonal variation in geochemical and hydrological conditions occurs naturally, and similarly, management projects often have seasonal variation (e.g., recharging in specific seasons). Looking at historical seasonal trends of groundwater quality data can provide some insights into the timescales of seasonal trends in a given location. It should be noted that seasonal timescales may vary year to year and with future variations in dry and wet conditions.

Lastly, measuring contaminants at trace concentrations is often expensive and requires laboratory instrumentation. If it is not feasible to directly measure trace contaminants on a regular basis, then close attention should be paid to the measurement of other common water quality parameters that control contaminant concentrations. Most critically, monitoring programs should include regular measurement of pH, dissolved oxygen, and ORP as proxies for the geochemical conditions in the aquifer. These parameters can be measured *in situ* at relatively low cost. Should shifts in pH, DO, and/or ORP be observed in monitoring data, there is a higher likelihood that contaminant mobilization is occurring, and samples should be taken immediately to assess whether contaminants are present. Table 2 summarizes which contaminants are most likely to occur under various geochemical conditions.

4.4 Careful implementation of managed aquifer recharge

Managed aquifer recharge is an increasingly applied method of artificially recharging groundwater aquifers. Of the possible management actions discussed in this document, MAR projects are the most likely to alter the native or preexisting geochemical and hydrological conditions within an aquifer. Accordingly, in addition to the above general guidelines, we highlight some specific recommendations for MAR. There are various types of MAR projects and each can have differing impacts on the geochemistry and hydrology of a site as summarized in Table 1.

First, the extent to which MAR will cause new changes to geochemical and hydrological conditions depends on historic recharge and land use in the area. For example, in the case of Ag-MAR, the volume and chemistry of the recharge water is the same (or very similar) to historic irrigation. Therefore, geochemical and hydrological conditions are not likely to deviate substantially from preexisting conditions, which may be less concerning for the release of geogenic contaminants as compared to other types of recharge. For Ag-MAR, knowing the historical nutrient and pesticide application is important for determining the likelihood of anthropogenic contaminants like TCP and nutrient release to groundwater. By contrast, MAR via injection wells can cause a direct, abrupt change in water chemistry. For example, if an injection well is drilled in a deep, confined aquifer with limited prior exposure to oxygen and oxic water is used for recharge, a sudden shift in redox chemistry can occur and cause the release of geogenic contaminants.

In general, sandy soils are less likely to contain, and subsequently release, geogenic contaminants. Agricultural areas will have additional water quality considerations related to legacy pesticides, nitrate, and salts. Recharge projects can be designed to help dilute pesticides, nitrate, and salt. However, in addition to mobilizing these substances, introducing nitrate and salts into the underlying groundwater can impact geogenic contaminants in the area. For example, nitrate can transform uranium into a more mobile form (see Section 5.5).

Calcium and carbonate can be introduced into underlying groundwater supplies and can also react with uranium to increase its mobility in groundwater. In general, prioritizing areas with sandy soils that have high infiltration rates and low calcium and carbonate contents is beneficial to avoiding issues related to uranium release. Additionally, continued use of the same infiltration site will deplete calcium and carbonate concentrations, decreasing the threat of contaminant mobilization over time compared to developing new recharge sites.

Water quality impacts of MAR remain a subject of ongoing research. Information and expertise specific to managed aquifer recharge on agricultural lands using flood water from rainfall or snowmelt (Flood-MAR) is currently being developed by DWR.[12] Current research at the University of California Santa Cruz includes the use of permeable reactive barriers made of woodchips for changing redox chemistry to remove nitrates during MAR via infiltration at a site in Pajaro Valley, CA (Beganskas et al., 2018).

4.5 Developing a contingency plan for groundwater contamination

After all necessary precautions have been taken to avoid creating new contamination or exacerbating existing issues, a plan should be developed if a groundwater contamination event occurs. This is particularly important if groundwater supplies are used for drinking water. The plan should account for how to (1) increase or augment monitoring, (2) assess the potential for end user well contamination, (3) notify users of water supplies, and if necessary, (4) provide alternate, safe water supplies, (5) discontinue use of affected water supplies as needed, (6) address the contamination by remediation or permanently discontinuing use, and (7) develop targeted future monitoring once the problem has been addressed to ensure it does not occur again. Having a plan for how to address these points will lead to improved response times and protection of water users.

5. Contaminant summary overview

Each contaminant behaves uniquely in the environment and is affected differently by various management actions. In this section, we provide a brief summary of each contaminant and its mobility in the environment. We include the public health considerations and regulatory limits. Some contaminants are regulated using a primary maximum contaminant level (MCL) while others have a secondary MCL. In California, the State's primary and secondary MCLs are enforceable. MCLs are determined based on the technical and economic feasibility of water treatment for each contaminant in addition to their toxicity to human health.

Notification Levels exist for certain contaminants that do not have MCLs and represent the concentration at which certain public notification requirements and recommendations apply depending on the contaminant. Notification Levels may turn into MCLs as toxicological and public health knowledge of a contaminant increases.

Finally, California's Office of Environmental Health Hazard Assessment (OEHHA) has public health goals (PHGs) for certain contaminants that are non-enforceable goals based only on toxicity and health hazards. These are summarized for each contaminant in Table 3. Detailed information on regulatory requirements surrounding groundwater quality is provided in a report recently published by Stanford University's Program on Water in the West titled "A Guide to Water Quality Requirements under the Sustainable Groundwater Management Act" (Moran and Belin, 2019).

TABLE 3

Regulatory limits and public health goals for California

Contaminant	Level of regulation	Limit	Public Health Goal (OEHHA)
Arsenic	Primary MCL	10 µg/L	0.004 µg/L
Chromium	Primary MCL	50 µg/L (total)	0.02 µg/L (hexavalent)
Uranium	Primary MCL	20 pCi/L	0.43 pCi/L
Vanadium	Notification level	50 µg/L	-
Manganese	Secondary MCL	50 µg/L	-
Iron	Secondary MCL	300 µg/L	-
Selenium	Primary MCL	50 µg/L	30 µg/L
1,2,3 TCP	Primary MCL	0.005 µg/L	0.0007 µg/L
PFASs	Notification level	0.013 µg/L for PFOA	-
		0.014 µg/L for PFOS	-

Each contaminant summary in this section shows maps of groundwater concentrations over the last year (January 2018 – January 2019) of available data from the Groundwater Ambient Monitoring and Assessment (GAMA) Program (SWRCB, 2018a). Groundwater concentrations are listed as mass of contaminant in micrograms per liter of water. These data are obtained from multiple sources including the GAMA Domestic Well Project, the USGS, Lawrence Livermore National Lab (LLNL), and public water system well data collected by the State Water Resources Control Board's (SWRCB's) Division of Drinking Water (DDW). For PFASs which are more data-limited, we include all available measurement for public supply wells on the GAMA website, which spans a measurement period from August 2016 – May 2019.

It should be noted that these data are collected at various times of year and different aquifer depths. Variation in temporal trends and depth often occurs and cannot be inferred from these maps. Additionally, these data include contamination from both anthropogenic and natural sources. We present these data to provide an overview of the magnitude of concentrations generally observed in California as well as the spatial extent of each contaminant's impact on groundwater quality.

Similarly, we show soil concentrations for each map from the USGS mineralogical database (Smith et al., 2014). Soil concentrations are listed as mass of contaminant in milligrams per kilogram of bulk soil, with the exception of iron which is listed at percent iron by weight of the bulk soil owing to iron's high abundance in soils. The soil concentrations are shown for the C horizon, which is approximately 2.6-3.3 feet deep within the soils examined, and consists primarily of unconsolidated, weathered parent material (i.e., rock or deposited sediments).

Soil C horizons are much shallower than groundwater aquifers and wells. These soil concentration maps do not provide depth information about geogenic contaminants. Ultimately, contaminant concentrations within the aquifer waters will depend on several factors including the chemical conditions of the aquifer and historic anthropogenic inputs. We show the soil C horizon maps to offer a general summary of the abundance of these contaminants as well as their relationship with underlying geologic formations.

5.1 Contaminant Summaries

Within this section, we begin with summaries of iron and manganese. Iron has limited toxicity and is of concern only at very high concentrations. Furthermore, iron and manganese solids are highly reactive in groundwater systems and are presented first because they (1) have major impacts on the overall chemistry of an aquifer, often regulating the concentration of contaminants through adsorption processes, and (2) are excellent indicators of the redox condition of an aquifer. Next, we provide summaries for arsenic, chromium, uranium, vanadium, and selenium. Finally, we discuss TCP as an emerging contaminant of critical concern.

5.2 Iron

5.2.1 Background

Iron is an essential nutrient for human health at low concentrations and has a secondary MCL of 300 µg/L. Compared to other contaminants discussed in this document, it is much less toxic and is generally associated with taste and odor issues in drinking water. Iron is highly reactive and is involved in many important chemical reactions that affect the concentrations of other toxic contaminants including arsenic, chromium, and uranium. It is important to understand iron geochemistry, as it plays a critical role in controlling overall groundwater quality.

5.2.2 Iron in the environment

In most natural systems, iron exists as either "ferrous iron" or "ferric iron." In oxygen-limited environments, ferrous iron exists and is dissolved in groundwater. By contrast, under oxygen-abundant conditions, ferric iron exists and readily forms iron oxide solids of limited solubility. There are various types of iron oxides, which collectively are commonly known as "rust." Iron oxides have colors ranging from yellow to red, with orange solids predominating, and they are a critical component of aquifer solids that control the overall groundwater quality by interacting with numerous contaminants as discussed below. From an operational standpoint, iron oxide solids can also cause clogging and biofouling issues in wells. Biofouling occurs when bacteria that consume iron are active near the well and create a slimy film of

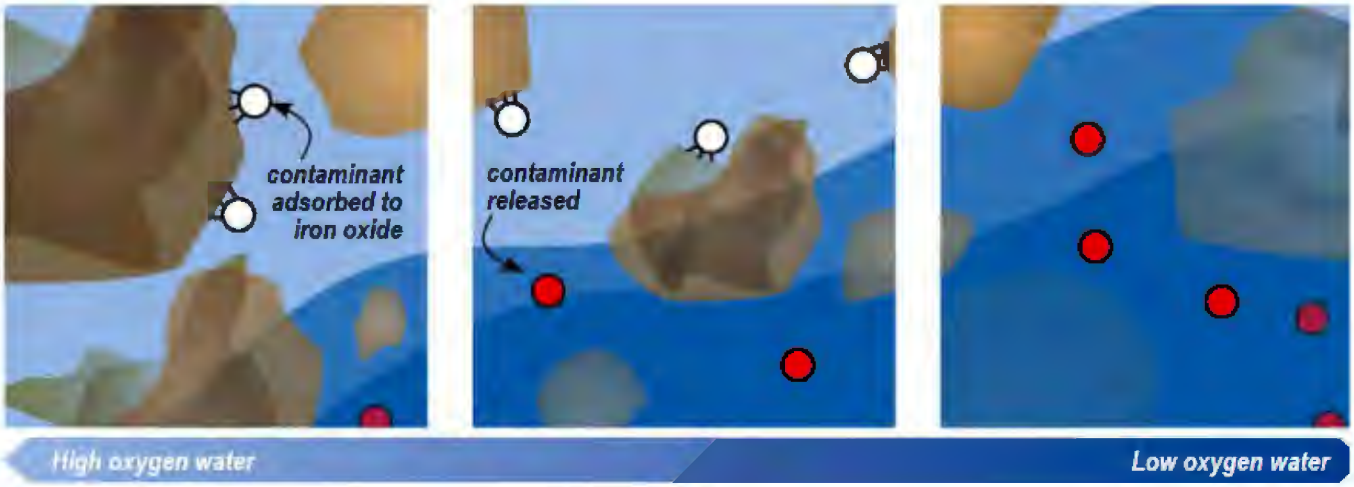


Figure 6: Iron oxides dissolving as DO concentrations become limited and subsequent release of contaminants adsorbed to the iron oxides.

bacterial residue. Both clogging and biofouling reduce water flow in a well and can cause staining.

5.2.3 Iron oxides as contaminant sinks

Dissolved contaminants including arsenic, chromium, and uranium have a strong ability to adsorb or "stick to" iron oxide solids. This adsorption process removes contaminants from groundwater and immobilizes them on iron oxide solids. Subsequently, the concentration of groundwater contaminants often depends on the stability of these iron oxide solids. For example, if oxygen becomes limited within an aquifer, the redox conditions will shift and iron oxides will no longer be stable. Once the iron oxides dissolve, they will release any adsorbed contaminants, causing an increase in iron and previously adsorbed contaminant concentrations into groundwater (Figure 6). Each contaminant has a varying ability to adsorb on iron oxides and some contaminants adsorb more strongly than others. Additionally, the extent of contaminant adsorption on iron oxides is usually pH dependent -- and may also change with the composition of the surrounding water.

5.2.4 Iron in California

Iron is widely distributed across rock types and associated soils and sediments. It is the second most

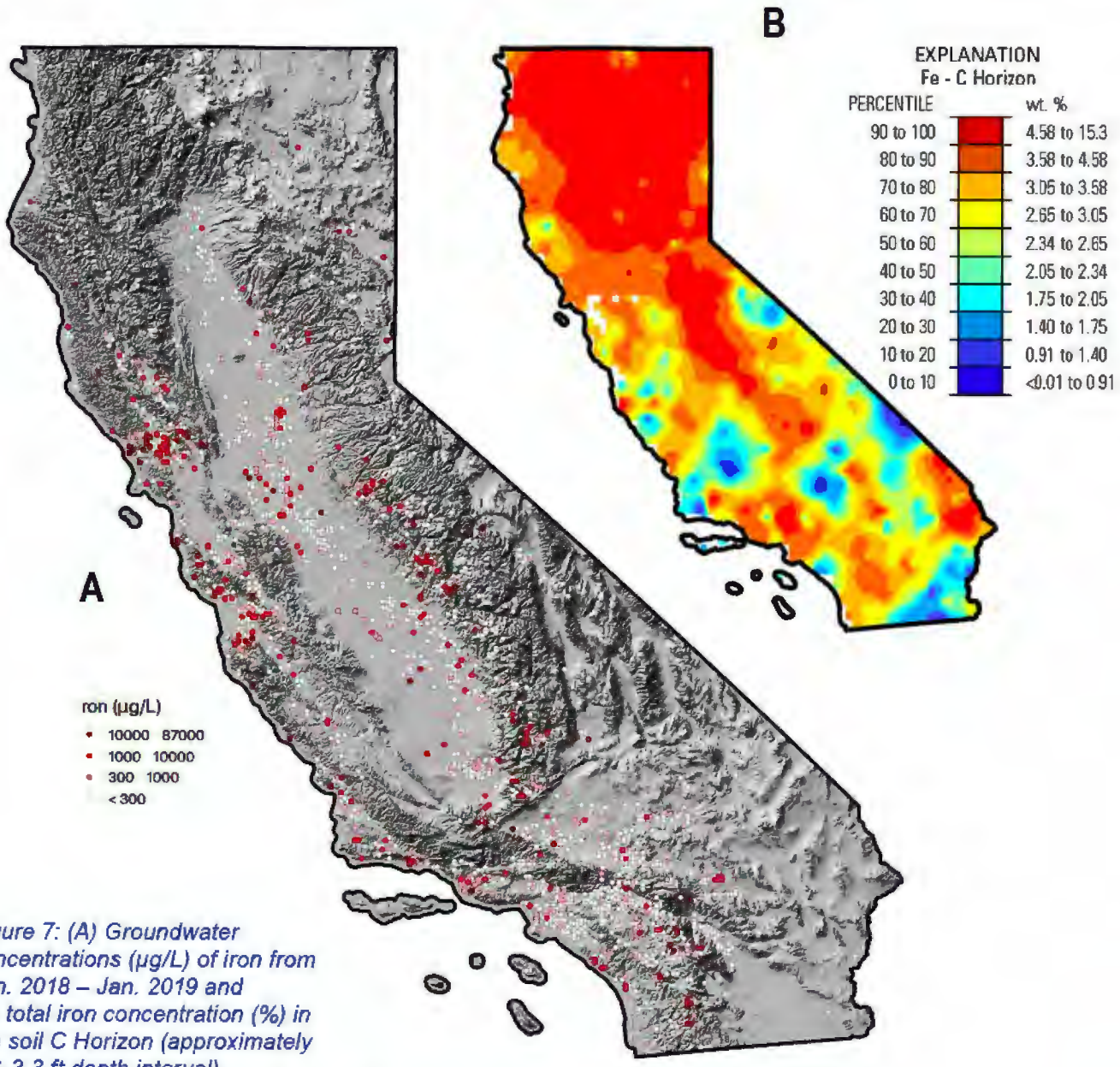


Figure 7: (A) Groundwater concentrations (µg/L) of iron from Jan. 2018 – Jan. 2019 and (B) total iron concentration (%) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The secondary MCL for iron is 300 µg/L.

abundant metal element in the Earth's crust and can be found at much higher concentrations than other geogenic metals throughout soils (Figure 7). Subsequently, iron in groundwater can occur at any location with geochemical conditions conducive to iron release. Generally, oxygen-limited groundwaters have higher iron concentrations in groundwater.

5.2.5 Management considerations for iron

If an aquifer has abundant oxygen, iron will generally reside as an iron oxide solid, and thus dissolved concentrations of iron are low. The largest threat to the stability of iron oxides is a shift in the oxygen content of an aquifer; if oxygen becomes limiting, iron oxides will dissolve. Should iron oxides dissolve, iron concentrations will increase in the groundwater, which can cause operational problems including clogging and biofouling in production wells. Conversely, if water with high concentrations of DO is introduced into an aquifer with perennially low DO, significant quantities of iron oxides could be produced through the oxidation of existing iron. This could decrease the concentration of other contaminants in the water by providing mineral surfaces with iron oxides to adsorb them.

5.3 Manganese

5.3.1 Background

Manganese is geochemically similar to iron in many ways. At low concentrations, manganese is an essential nutrient for human health. However, at high concentrations manganese causes neurological disorders, particularly in children, who are more susceptible to manganese exposure. Manganese has a secondary MCL of 50 µg/L, and a notification level of 500 µg/L. Like iron, manganese causes operational problems in wells, including clogging and staining. In drinking water, it is often associated with odor and a metallic taste. Manganese also forms oxide minerals which can adsorb and subsequently immobilize groundwater contaminants on aquifer solids, much like iron oxides.

5.3.2 Manganese in the environment

Manganese is the third most abundant metal element in Earth's crust. Under oxygen-limited conditions, manganese can dissolve in groundwater. At pH values greater than 7, manganese increasingly adsorbs to mineral surfaces within aquifer solids and groundwater concentrations will decrease. It forms solid manganese carbonates above pH 7.5, further removing it from groundwater. Under oxygen-abundant conditions, manganese forms manganese oxide solids which limit its groundwater concentrations.

5.3.3 Manganese interactions with other contaminants

Similar to iron oxides, manganese oxides play a critical role in determining the overall groundwater quality of an aquifer. Several toxic contaminants including arsenic, uranium, and selenium adsorb strongly to manganese oxides, limiting their concentrations in groundwater. However, in most oxygen-abundant groundwater systems, iron oxides will be more prevalent than manganese oxides owing to the higher abundance of iron. Therefore, iron oxides generally exert a greater control than manganese oxides on contaminant retention. Additionally, manganese oxides can have a large impact on groundwater quality through their ability to oxidize contaminants. After DO, manganese oxides are among the most reactive oxidants found in the environment and are capable of reacting with other contaminants. Manganese oxides have the most notable effect on chromium; they have the ability to transform chromium from its benign form (trivalent chromium) into a highly toxic and mobile form (hexavalent chromium), as discussed in Section 5.4.

5.3.4 Manganese in California

Similar to iron, manganese is widely distributed and abundant in rocks and associated soils and sediments (Figure 8). Manganese concentrations can be observed in groundwater in any aquifer under oxygen-limiting conditions. Historically, approximately 30 percent of drinking water supplies which monitor for manganese have observed manganese above the detection limit (SWRCB, 2019).

5.3.5 Management considerations for manganese

To promote the stability of manganese oxides and avoid manganese concentrations in groundwater, oxygen-limited conditions should be avoided. In oxygenated groundwater, manganese (like iron) will usually persist as manganese oxides. Similar to management considerations for iron, a depletion of oxygen will dissolve manganese oxides, increasing dissolved manganese concentrations and releasing adsorbed contaminants.

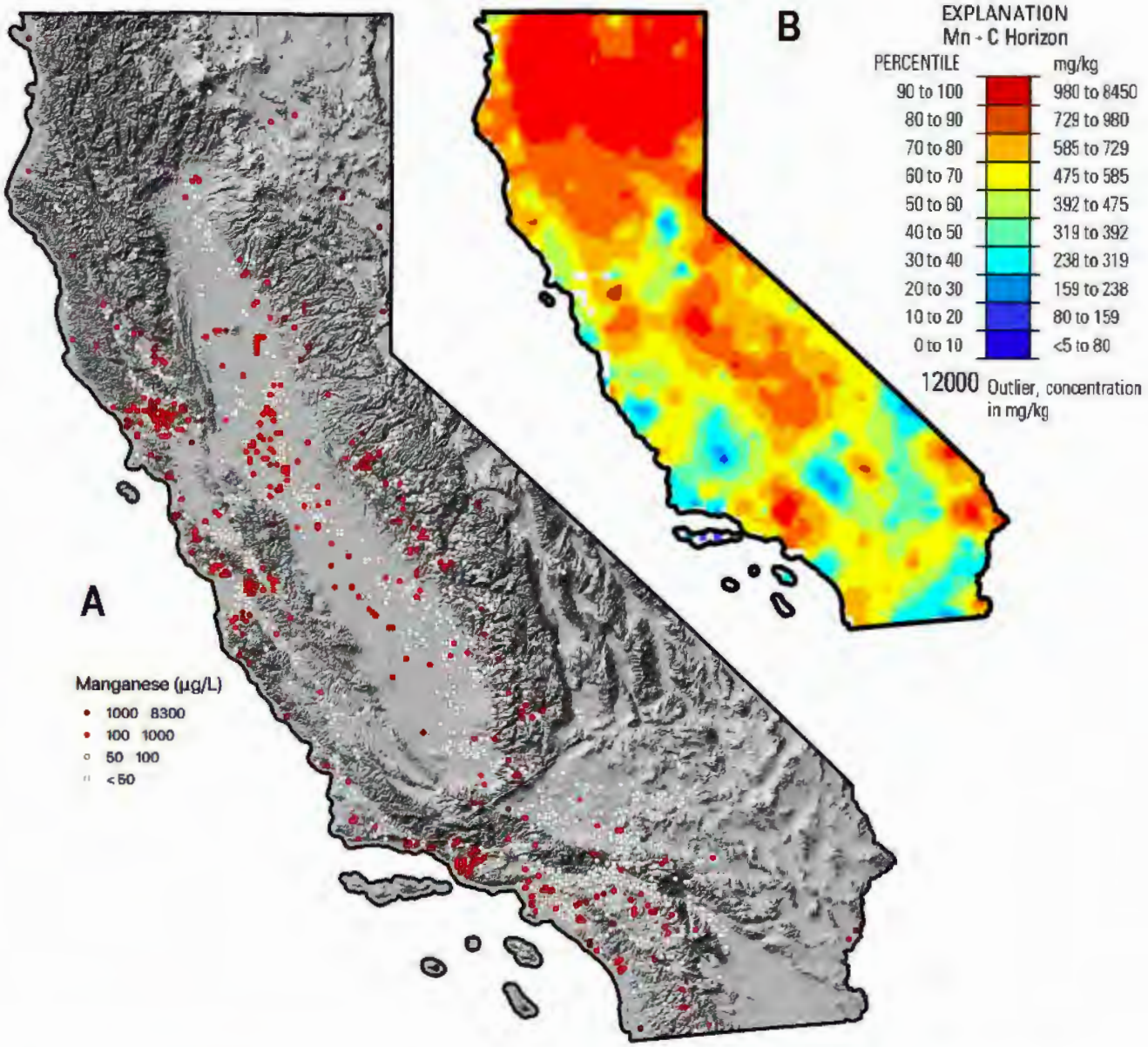


Figure 8: (A) Groundwater concentrations (µg/L) of manganese from Jan. 2018 – Jan. 2019 and (B) total manganese concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The secondary MCL for manganese is 50 µg/L.

5.4 Arsenic

5.4.1 Background

Arsenic is one of the most toxic and ubiquitous geogenic contaminants. While arsenic can be incorporated into food supplies (e.g., rice crops) through contaminated soil and irrigation water, it poses the greatest threat to public health in drinking water supplies. Chronic exposure to arsenic-contaminated drinking water is known to cause cancers of the lungs, skin, bladder, and kidneys. The primary MCL for arsenic in drinking water is 10 µg/L and the PHG is set at 0.004 µg/L. While anthropogenic sources of arsenic, including mining and pesticide application, have historically led to point source contamination of groundwater, both natural and anthropogenic mobilization of arsenic has led to wide-scale contamination of groundwater aquifers.

5.4.2 Arsenic in the environment

Under most environmental conditions, arsenic can be found in one of two forms. Under oxygen-limited conditions, arsenic exists as arsenite in the +3 oxidation state (AsIII). Arsenite is generally considered more soluble in groundwater and more toxic than the oxidized form, arsenate, which occurs in the +5 oxidation state (AsV). This is because arsenate binds strongly to minerals found in soils and sediments under oxygen-abundant conditions including iron oxides. Under oxygen-limited conditions, these oxidized host minerals are not stable, and arsenic is more likely to exist as arsenite.

There are three primary biogeochemical triggers that mobilize arsenic from soils and sediments into groundwater. First, the most common trigger is a change in redox condition from an oxygen-abundant environment to oxygen-limited conditions. This can transform arsenate to the more soluble arsenite and/or dissolve the iron oxides hosting the adsorbed arsenate which releases it to groundwater. Shifts in redox condition can result in concentrated releases of arsenic. A second trigger of arsenic release is an increase in pH to values greater than 8.5. At these elevated pH values, iron oxides are less effective sorbents for arsenic due to changes in surface charge characteristics and lead to the release of arsenic to groundwater. Third, competitive ions can cause the mobilization of arsenic. Competitive ions are ions that closely resemble arsenic in structure and chemistry and will therefore compete for the same surface sites to bind onto minerals (Figure 9). Competitive ions like phosphate can replace arsenate on the surface of an iron oxide mineral and cause its release into groundwater.

5.4.3 Arsenic in California

In addition to the geochemical triggers of arsenic release described above, arsenic is increasingly being linked to historic pumping. Several regions within California have existing problems with geogenic arsenic, particularly the Central Valley, where arsenic release has been exacerbated by historic pumping. In the Central Valley, arsenic is deposited by granitic materials from the Sierra Nevada. Additionally, recent work has attributed arsenic release to land subsidence due to overpumping in the Tulare Basin in the San Joaquin Valley (Smith et al., 2018). Arsenic can reside in the porewater of clay layers (where oxygen-limited conditions persist). As aquifer pressures decrease and these layers compact during subsidence (Figure 2), arsenic is released and mobilized

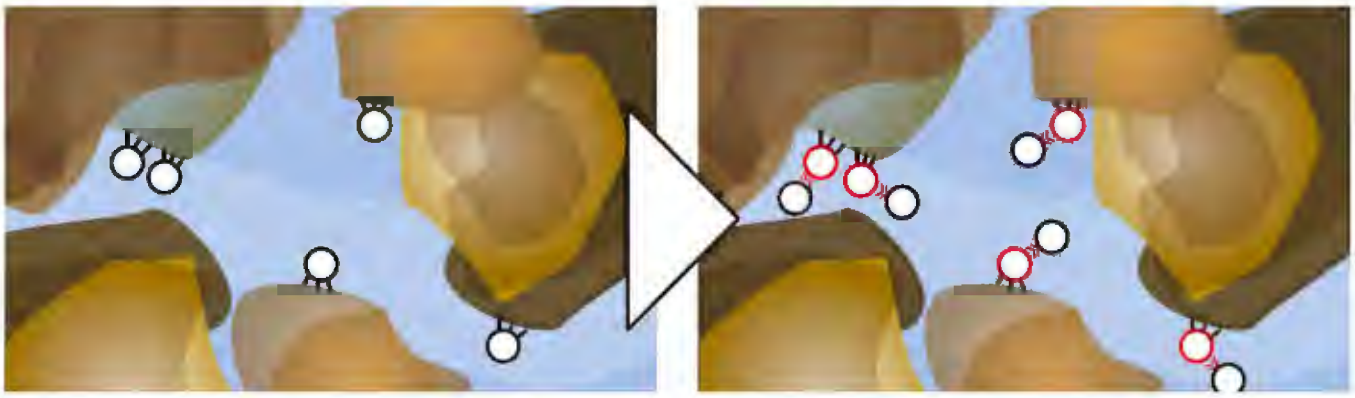


Figure 9: Competitive ion displacement. Ions with similar properties displace each other and limit adsorption to aquifer particles.

into productive aquifer units where it can reach pumping wells. This has been analogized to the release of dirty water when a sponge is squeezed. Once overpumping stops, arsenic concentrations can gradually decrease, declining to background levels as the aquifer is flushed.

5.4.4 Management considerations for arsenic

Conditions to avoid due to arsenic concerns are primarily oxygen-limited conditions and high pH (> 8.5). Inputs of competitive ions including phosphate, sulfate, and carbonate are a secondary concern. In other words, arsenic is generally not expected to be a problem in well-aerated, oxygen-abundant environments with pH values below 8.5. With respect to arsenic release from overpumping, managing for land subsidence will concurrently limit the arsenic release associated with compaction of clay layers and allow impacted aquifers to recover to background concentrations.

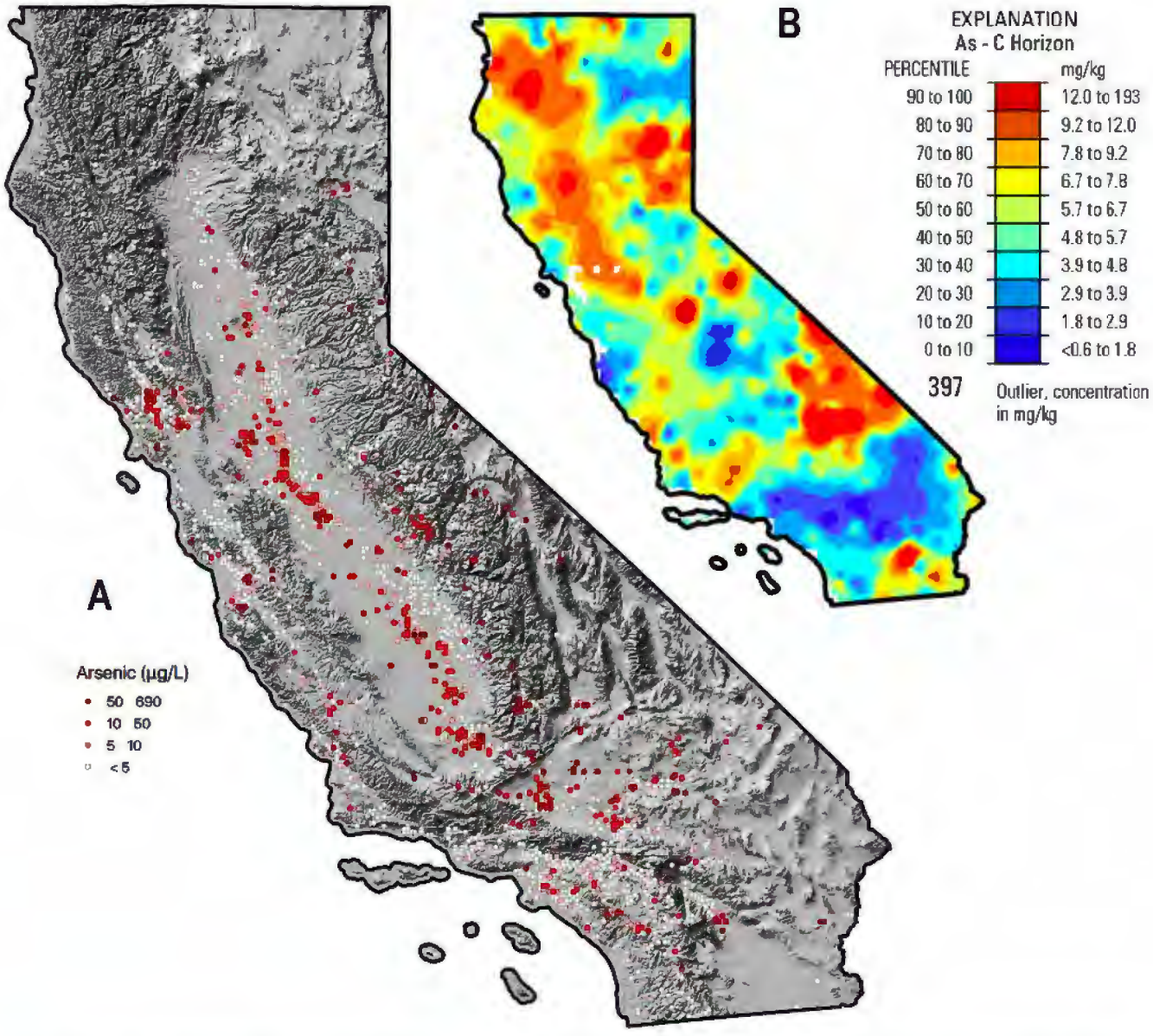


Figure 10: (A) Groundwater concentrations (µg/L) of arsenic from Jan. 2018 – Jan. 2019 and (B) total arsenic concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The primary MCL for arsenic is 10 µg/L.

5.5 Chromium

5.5.1 Background

Chromium is a naturally occurring metal that is widely used in industrial processes (e.g., electroplating, automobile and steel manufacturing, leather tanning, pigmentation, wood treatment). It persists in two forms within natural environments: trivalent chromium (Cr3+) and hexavalent chromium (Cr6+). Hexavalent chromium is toxic, mutagenic, and carcinogenic, while trivalent chromium is non-hazardous and considered an essential micronutrient in human nutrition. Hexavalent chromium is known to damage the lungs, GI tract, liver, and kidneys and is a known carcinogen that causes cancer by inhalation and possibly by ingestion. The federal MCL for total chromium in drinking water is 100 µg/L. California currently enforces a limit of 50 µg/L. In 2014, California's Department of Public Health set a separate MCL for hexavalent chromium (not total chromium) at 10 µg/L, but this MCL was repealed in 2017 due to the analytical limitations of many water districts (SWRCB, 2018b). The PHG for hexavalent chromium is 0.02 µg/L, stressing the severe toxicity of the chemical to human health. The conversion of hexavalent chromium to trivalent chromium by human stomach acid has been documented, but this was not incorporated in the development of the PHG.

5.5.2 Chromium in the environment

Hexavalent chromium is much more mobile in groundwater than trivalent chromium because it does not bind extensively to minerals within soils and sediments. By contrast, trivalent chromium binds strongly to organic matter and mineral surfaces and may exist as solid minerals (e.g., chromite, aluminosilicate clays, hydroxides). Trivalent chromium is generally stable in oxygen-limited environments. The primary natural pathway for trivalent chromium transformation to hexavalent chromium occurs by reaction with manganese oxides. Although both trivalent chromium and manganese oxides reside in solids of limited solubility, they can react when in close proximity, leading to the generation of toxic hexavalent chromium. Oxygen can also generate hexavalent chromium, but this reaction is only significant at pH values greater than 9. For example, within high-pH, oxygen-abundant aquifers with very slow recharge rates or long residence times — such as in parts of the Mojave Desert, California — indigenous hexavalent chromium generation is appreciable (Izbicki et al., 2008). Once oxidized, hexavalent chromium does not adsorb to aquifer solids extensively and is easily replaced on surfaces by competitive ions such as sulfate and phosphate. Hexavalent chromium is more likely to remain in groundwater and pose a water quality threat.

5.5.3 Hexavalent chromium in California

Industrial activities that use chromium are important point sources of hexavalent chromium contamination in California, particularly in the San Francisco Bay and Los Angeles areas. In addition, geogenic chromium can be unintentionally oxidized by oxidants (e.g., permanganate, persulfate, hydrogen peroxide) injected during *in situ* chemical oxidation, a clean-up process for organic solvent pollution. Hexavalent chromium contamination in groundwater has historically been linked to industrial practices; however, widespread natural occurrences of hexavalent chromium concentrations approaching or exceeding the MCL also occur in groundwater wells unaffected by upstream industrial sources (Hausladen et al., 2018). These high hexavalent chromium levels in oxygen-abundant, alkaline groundwater are associated with the natural oxidation of geogenic chromium and typically affect larger geographic areas and more people than industrial sources.

In California, mafic and ultramafic rocks extend throughout the Coast Range, Klamath Mountains, northern Sierra Foothills, and San Gabriel Mountains. Soils derived from mafic/ultramafic parent material contain high amounts of geogenic chromium-bearing minerals. This leads to soil chromium concentrations exceeding the global average. Recent work proposed that distance from ultramafic outcrops is a primary control on hexavalent chromium concentrations in groundwater in some areas of California, like the western Sacramento Valley (Hausladen et al., 2018, Manning et al., 2015). The western Sacramento Valley receives extensive chromium-rich sediment deposition from the Coast Range Mountains. Here, hexavalent chromium concentrations reach up to 46 µg/L, and 11% of the measured public supply wells have hexavalent chromium levels that exceed 10 µg/L (Izbicki et al., 2015). Groundwater with mafic/ultramafic contributions also tends to be alkaline, which supports hexavalent chromium mobility. It is important to highlight that the high correlation with mafic/ultramafic outcrop proximity does not hold across all of California due in part to sediment transport processes. In these locations, hexavalent chromium contamination in groundwater may also be strongly influenced by human activities, such as agriculture.

5.5.4 Management considerations for hexavalent chromium

Multiple studies have examined geochemical signatures of groundwater in California and posited links between high hexavalent chromium concentrations and human activities, including agriculture (Izbicki et al., 2015, 2008, Hausladen et al., 2018, Manning et al., 2015, Mills et al., 2011). For example, hexavalent chromium is commonly correlated with nitrate concentrations in public-supply wells across the Central Valley. It is presumed that water management practices, like irrigation regimes, influence the geochemical processes driving hexavalent chromium contamination; however, we currently lack direct scientific evidence to confirm and explain how agricultural practices contribute to hexavalent chromium concentrations. Below is a summary of considerations about hexavalent chromium for water management based on laboratory experiments and spatial analyses of groundwater chemistry.

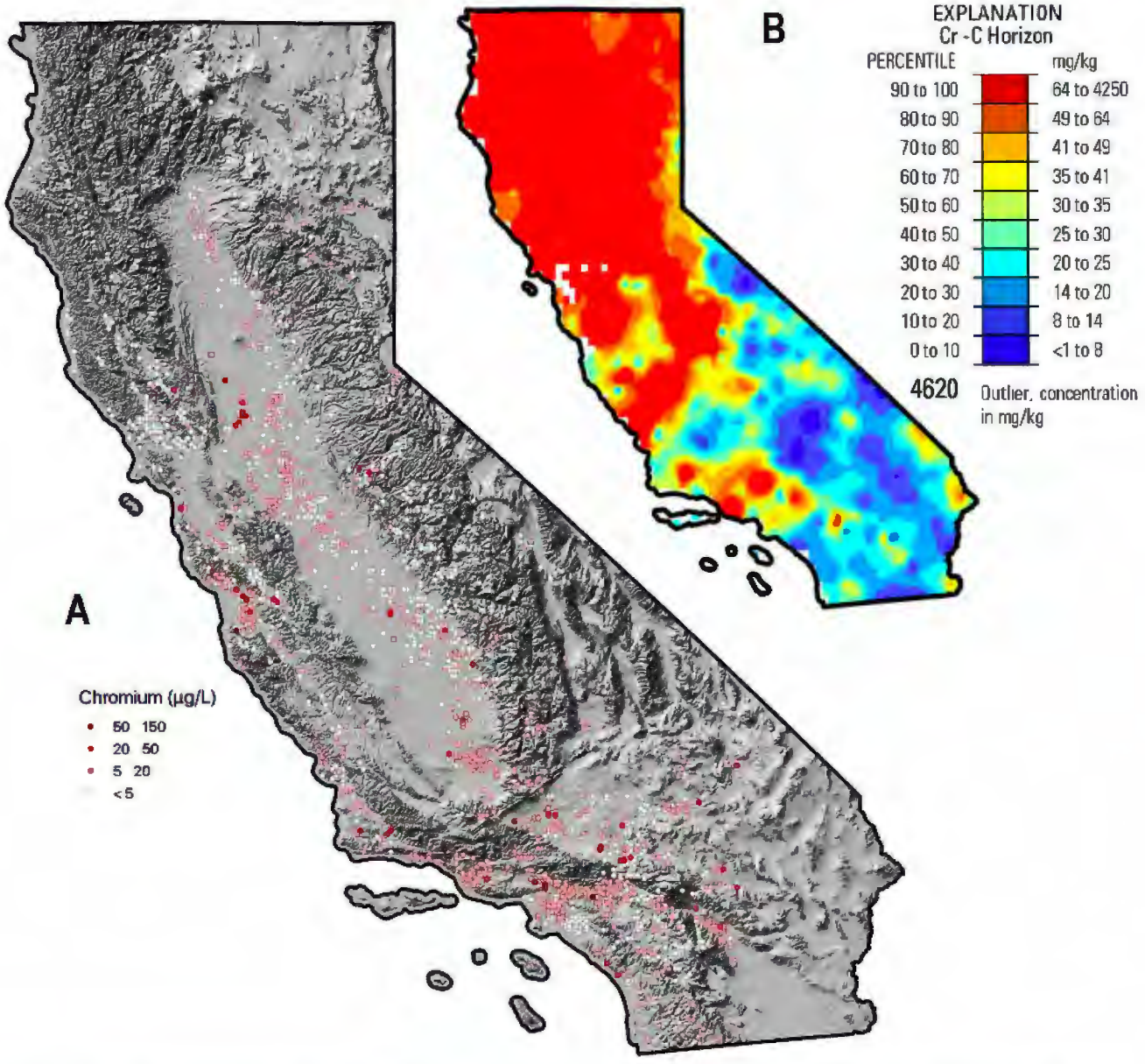


Figure 11: (A) Groundwater concentrations (µg/L) of chromium from Jan. 2018 – Jan. 2019 and (B) total Cr concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The primary MCL for chromium is 50 µg/L.

In environments containing mafic/ultramafic-derived sediments, biogeochemical conditions to avoid for hexavalent chromium in groundwater are oxygen-abundant, alkaline (pH > 7.5) conditions. Hexavalent chromium is not considered a concern in oxygen-limited aquifers where dissolved iron is present. The use of ammonium fertilizers can introduce acidity to soil and multiple studies suggest that nitrification enhances trivalent chromium release, which leads to greater oxidation by manganese oxides (Mills et al., 2011, 2012). The downward migration of hexavalent chromium generated in the unsaturated zone to shallow aquifers can be accelerated by irrigation recharge.

Although the process remains poorly understood, hexavalent chromium concentrations have been shown to correlate with heavily pumped agricultural areas. One hypothesis is that irrigation schemes which cause the regular wetting and drying of soils leads to manganese oxides dissolving and reforming in new locations at the water table, which in turn leads to the formation of hexavalent chromium. This suggests that irrigation schemes can be modified to decrease or inhibit hexavalent chromium contamination in aquifers. When the water table fluctuates frequently, such as on a weekly basis from turning pumps on and off, soil redox conditions oscillate and activate manganese cycling. Dissolved manganese migrates in the soil during oxygen-limited, saturated conditions, and reforms manganese oxides near chromium-bearing minerals during unsaturated conditions, inducing greater hexavalent chromium production. It is suspected that by changing the pumping schedule to allow for gradual declines in the water table and more stable redox conditions in the subsurface soil and sediments, manganese cycling can be disrupted or stopped, which minimizes hexavalent chromium generation. If an irrigated area does not currently have problems with hexavalent chromium in groundwater and a management action may lead to new irrigation practices which cause intermittent wetting and drying, it should be noted that this can potentially cause the release of hexavalent chromium particularly in areas near ultramafic outcrops.

5.6 Uranium

5.6.2 Background

Uranium is a metal that naturally occurs in rocks. Igneous rocks, like the Sierra Nevada granites, typically contain more uranium than other types of rocks. The MCL for uranium in California is 20 picocuries per liter (pCi/L), which is roughly equivalent to the federal drinking water limit of 30 µg/L. While uranium is radioactive, radioactivity is not a health concern near the MCL. However, the chemical toxicity of uranium in drinking water above the MCL can lead to kidney damage.

5.6.2 Uranium in the environment

Uranium exists in the environment in two different forms: the more reduced form, uranium(IV) and the more oxidized form, uranium(VI). Uranium in groundwater is almost always uranium(VI). Uranium(IV) typically occurs in oxygen-limited environments and forms a solid that precipitate out of water and are sparingly soluble. Dissolved uranium also adsorbs to aquifer solids and organic matter. Uranium(IV) can be transformed to uranium(VI) by reacting with oxygen and nitrate within groundwater. Shallow groundwater tends to contain

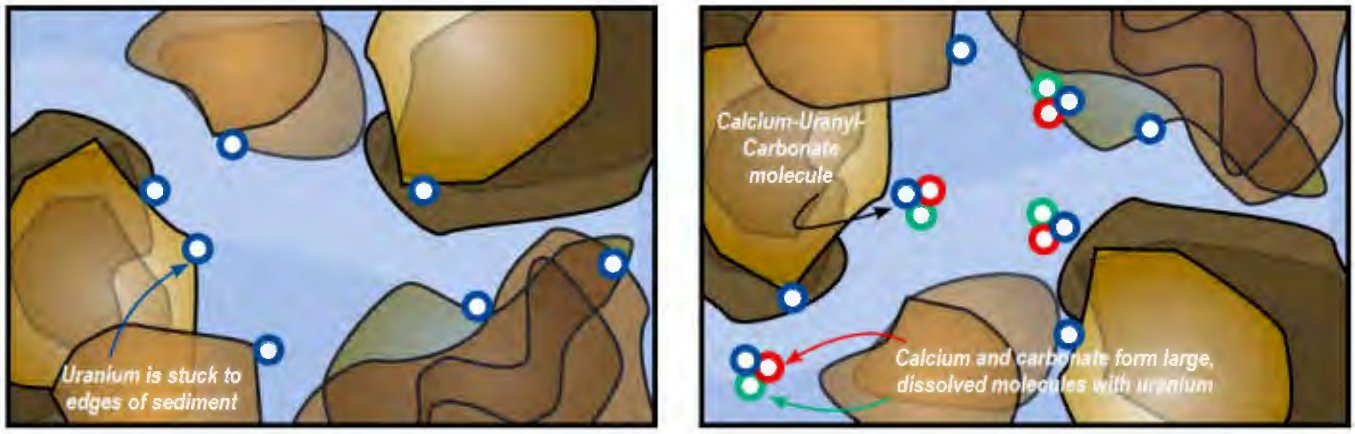


Figure 12: Schematic of calcium-uranyl-carbonate molecule keeping uranium concentrations in groundwater and preventing adsorption.

more DO, leading to uranium(VI). Deeper aquifers often have lower DO, and resulting oxygen-limited conditions promote uranium(IV) solids and subsequently lower uranium concentrations in groundwater. This is one reason why shallower wells tend to pump water with higher uranium concentrations whereas deeper wells have lower concentrations. Additionally, nitrate, when present, also tends to be higher in shallower aquifers, making uranium(VI) a concern in agricultural areas with legacy nitrate contamination.

Although uranium(VI) does not form solids regularly, it does adsorb on aquifer solids, which can limit its dissolved concentrations and mobility. However, uranium(VI) also forms molecules with calcium and carbonate that limit its ability to stick to aquifer solids, thus leading to higher groundwater concentrations of uranium. Groundwater with high levels of calcium and carbonate lead to calcium-uranyl-carbonato complexes (Figure 12) that do not easily adsorb to sediments. Studies have identified a link between increasing uranium concentrations in the Central Valley and increasing bicarbonate concentrations in groundwater due to the effects of increased plant productivity and irrigation return flow (Jurgens et al, 2009). Increased pCO2 in the root zone results in increased bicarbonate in shallow groundwater; high bicarbonate concentrations lead to higher uranium concentrations.

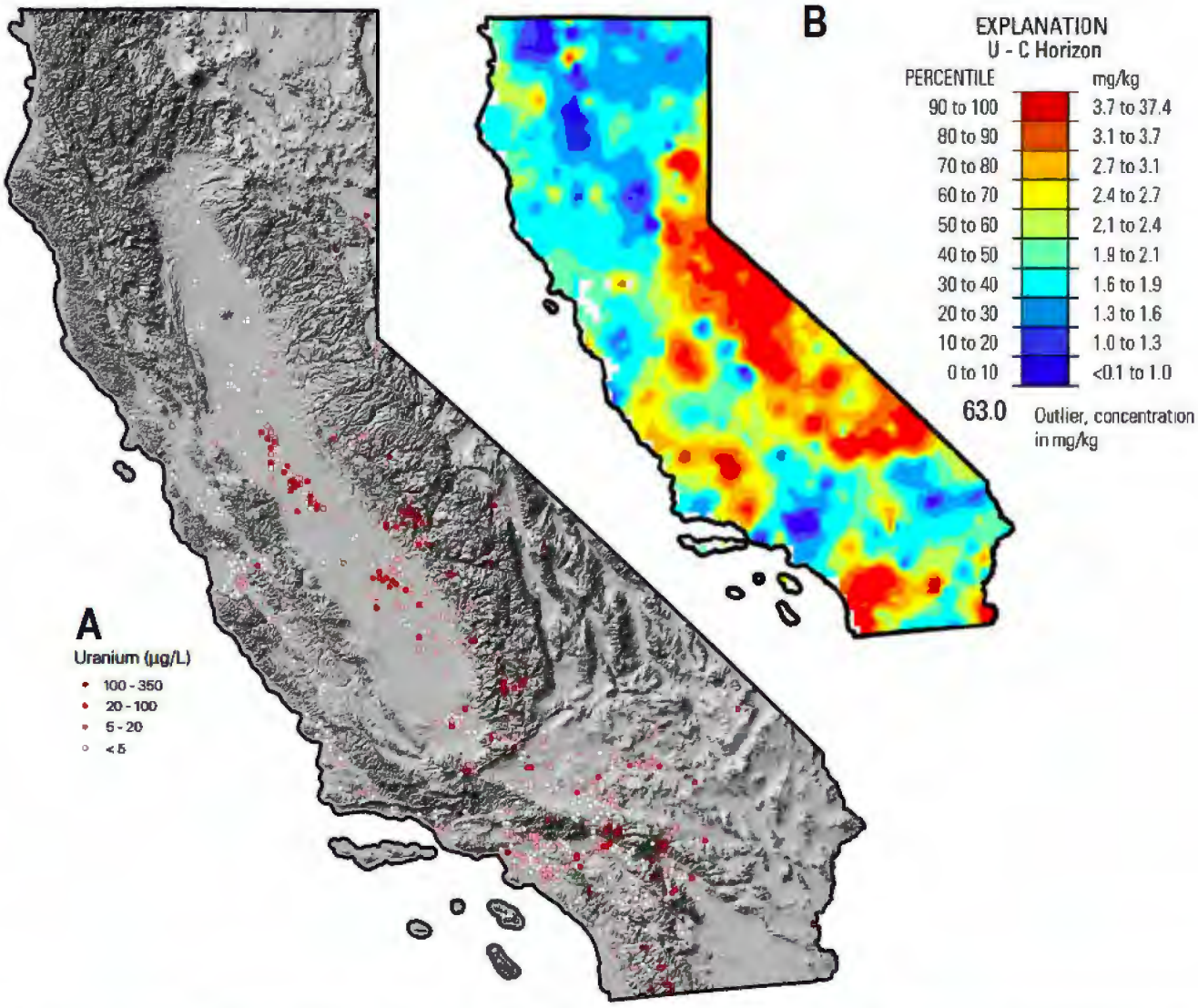


Figure 13: (A) Groundwater concentrations (pCi/L) of uranium from Jan. 2018 – Jan. 2019 and (B) total uranium concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The primary MCL for uranium is 20 pCi/L.

5.6.3 Uranium in California

In California, wells with high uranium concentrations often occur near the Sierra Nevada (Figure 13). This is because the groundwater picks up uranium from the granitic rocks in the Sierra Nevada or from sediments in valleys that are derived from granitic materials in the Sierra Nevada (like the Eastern San Joaquin Valley). Uranium concentrations in these regions are higher in shallow wells as opposed to deeper wells. Increased pumping can transport uranium from shallow to deeper parts of the aquifer. In parts of the Eastern San Joaquin Valley, uranium levels in some wells have increased significantly over the past 30 years.

5.6.4 Management considerations for uranium

Conditions to avoid to prevent uranium contamination include increasing concentrations of DO or nitrate in an aquifer with limited prior concentrations. The transport of calcium and carbonate to the groundwater below is an additional concern. For example, during managed aquifer recharge via infiltration, when recharge water flows through shallow, calcareous (calcium carbonate containing)-alkaline soils, it can dissolve calcium and carbonate. This also can occur by when waters have elevated carbon dioxide concentrations, which leads to increased carbonates in the water. The calcium- and carbonate-rich water can then react with uranium adsorbed to sediment, promoting release (desorption) of uranium from the sediments into the groundwater. By infiltrating through sandy areas or by removing shallow, calcareous layer of soil in an infiltration basin, calcium and carbonate can be prevented from entering the groundwater. This is particularly relevant for field flooding in the Eastern San Joaquin Valley with legacy agricultural contamination.

5.7 Vanadium

5.7.1 Background

Vanadium is becoming more recognized as a geogenic groundwater contaminant. There is no formal MCL for vanadium, but a Notification Level of 50 µg/L exists. Daily exposure through food is assumed not to have negative impacts, but experiments on rats and mice have shown elevated developmental problems correlated with increasing exposure to vanadium. Concern over potential health effects has led the US Environmental Protection Agency (EPA) to list vanadium on its Contaminant Candidate List 4, which lists contaminants that are not currently regulated at the federal level but may become so in the future.

5.7.2 Vanadium in the environment

Vanadium has three forms most commonly found in the environment: vanadium(III), vanadium(IV), and vanadium(V). Vanadium is considered immobile under oxygen-limited conditions because the reduced form, vanadium(III), forms a solid of limited solubility and will thus be separate from groundwater. The geochemistry of vanadium(IV) and vanadium(V) is more complex owing to their ability to adsorb on various mineral surfaces. Vanadium(IV) is only appreciably present and mobile in groundwater at very low pH, which is generally not relevant to most natural systems. Vanadium(V) tends to partition into groundwater and is thus mobile; it is found under oxygenated conditions. If vanadium is observed in groundwater, it most likely exists as vanadium(V). While vanadium(V) can adsorb to aquifer solids including iron oxides, adsorption is limited at pH values greater than 9.

5.7.3 Vanadium in California

Vanadium is generally more abundant in mafic rocks, and shales have been shown to have extremely high concentrations reaching 16,000 mg/kg in some parts of the world (Nriagu, 1998). In California, vanadium concentrations above 25 µg/L are associated with oxygen-abundant and alkaline (pH > 8) groundwater that interacts with vanadium-bearing source rock. This interaction can take place two ways. First, the water can be located with the source rock. Second, the water can be on the borders of areas with vanadium-bearing source rock. This is evident in the eastern San Joaquin Valley near the western Mojave,Temecula Valley, and in the Tule River Basin of the Sierra Nevada. However, the presence of source rock does not necessarily mean that there will be groundwater vanadium concentrations above 25 µg/L. For instance, the Cascades, Modoc Plateau, and Sonoma Volcanics of the Northern Coast Ranges have vanadium-bearing source rocks but low vanadium concentrations in the groundwater. This is attributed to their oxygen-limited and low pH conditions. However, areas such as the Owens Valley have been shown to have volcanic source rock and oxygen-abundant, alkaline groundwater, but also have low vanadium concentrations. Other areas, such as parts of the North Coast Range and the Owens Valley, also have vanadium-bearing source rocks but do not have groundwater vanadium concentrations above 25 µg/L. This indicates the need to establish and pay close attention to the hydrologic flow paths of the

regions, as well as establishing the redox conditions of the groundwater in areas of concern (Wright and Belitz, 2010).

5.7.4 Management considerations for vanadium

General conditions which cause vanadium release to groundwater are oxygen-rich and alkaline (pH > 8) waters. This is also true for uranium and chromium, and vanadium has similar management considerations to both uranium and chromium. If an aquifer has previously limited exposure to oxygen, any management practice that introduces oxygen can cause vanadium mobilization to groundwater. Additionally, uranium and vanadium concentrations are often correlated in groundwater. If an aquifer is experiencing issues with uranium, it is recommended to also monitor for vanadium as there is a possibility these contaminants will co-occur.

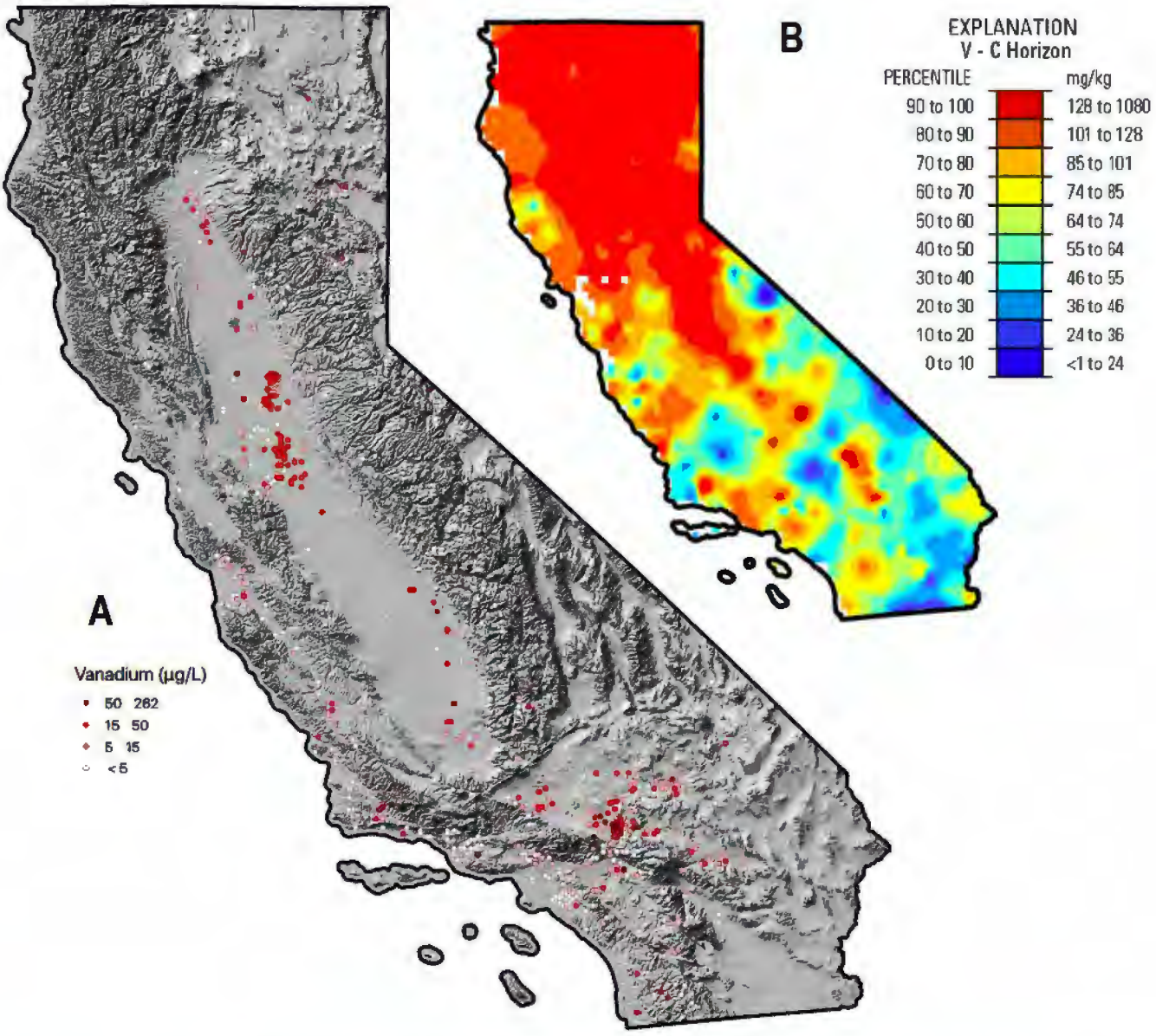


Figure 14: (A) Groundwater concentrations (µg/L) of vanadium from Jan. 2018 – Jan. 2019 and (B) total vanadium concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The notification level for vanadium is 50 µg/L.

5.8 Selenium

5.8.1 Background

Selenium is an essential nutrient at low, trace concentrations. However, excessive selenium concentrations are toxic to human and ecosystem health. The current MCL is 50 µg/L and long-term exposure of selenium at concentrations above the MCL has been shown to cause damage to kidneys, livers, and nervous and circulatory systems in humans. Historically, selenium has been more dangerous for fish and waterfowl, for whom it is known to cause congenital disorders and death through ingestion of high doses which bioaccumulate in food sources. Anthropogenic sources of selenium include mining metal ores and coal burning.

5.8.2 Selenium in the environment

Under most environmental conditions, selenium can be found as either the oxidized selenate or the reduced selenite. Under oxygen-abundant conditions, selenium exists as selenate and is more likely to be found in groundwater owing to selenate's limited ability to adsorb to aquifer solids. Selenate is also the more toxic form of selenium. By contrast, under oxygen-limited

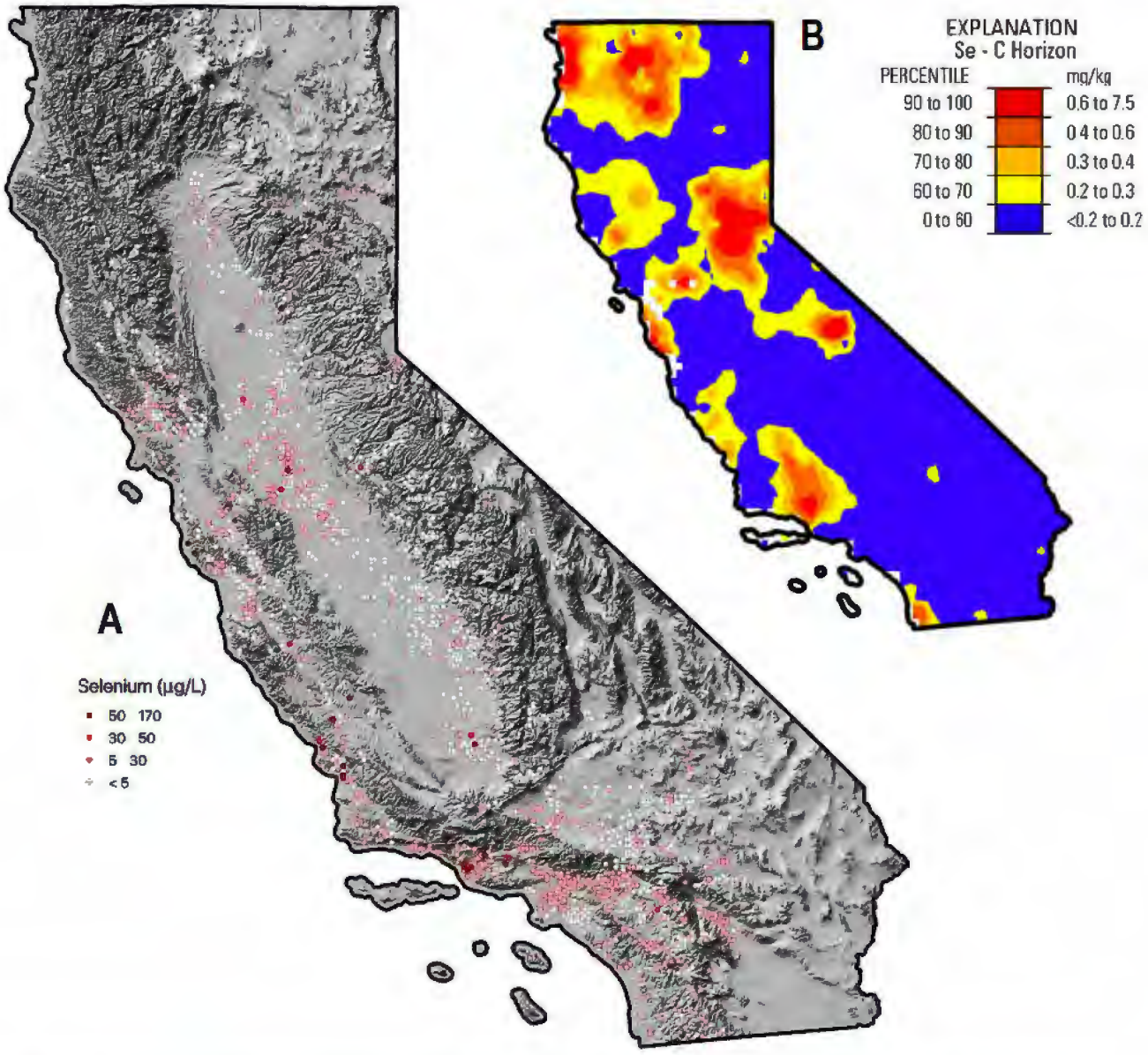


Figure 15: (A) Groundwater concentrations (µg/L) of selenium from Jan. 2018 – Jan. 2019 and (B) total selenium concentration (mg/kg) in the soil C Horizon (approximately 2.6-3.3 ft depth interval). The primary MCL for selenium is 50 µg/L.

conditions, selenium exists as selenite and will adsorb strongly to aquifer particles, limiting its concentration in groundwater. High selenium concentrations are typically found under oxygen-abundant conditions. Additionally, at high pH values, both selenate and selenite do not adsorb strongly to aquifer solids and concentrations will increase in groundwater. Similar to arsenic, selenium can be mobilized through the presence of competitive ions (e.g., phosphate). While groundwater selenium concentrations are typically low (Plant et al. 2003) and not problematic for human health, contaminated groundwater that may reach surface water bodies, particularly surface water bodies subject to high evaporation, can have adverse impacts on fish and waterfowl.

5.8.3 Selenium in California

Generally, groundwater selenium concentrations are low and soil concentrations tend to correlate with the source bedrock of the California Coast Ranges (Figure 15). Selenium is concentrated in shallow groundwaters in semi-arid regions under irrigation (Deverel et al., 1994). Irrigation water can mobilize geogenic selenium and high evaporation rates can subsequently concentrate salt and selenium concentrations on the surface. Historically, this phenomenon has been observed in the San Joaquin Valley. In the 1980's in the San Joaquin Valley, this led to one of the most documented cases of selenium toxicity in animals. Near the Kesterson reservoir, agricultural drainage tiles were installed to mitigate soil salinization problems. The agricultural drainage water that flowed into the reservoir had high selenium concentrations (250 – 650 µg/L) which were further concentrated due to evaporation losses in the reservoir. This caused significant health effects on fish and wildlife, leading to the death of at least 1,000 birds (Plant et al., 2003).

5.8.4 Management considerations for selenium

Conditions to avoid for selenium release to groundwater include oxygen-abundant and high pH environments. Of secondary concern is a high influx of phosphate concentrations. Introducing nitrate (e.g., infiltration from nitrate-contaminated areas) can also transform selenium to its more mobile form and cause an increase in groundwater concentrations. Additionally, the pumping of groundwater for irrigation can concentrate selenium in addition to concentrating salts. Selenium mobilization could be an issue during changes to irrigation methods, agricultural drainage, or on-farm recharge.

5.9 TCP

5.9.1 Background

1,2,3-Trichloropropane (TCP) has recently been identified as a widespread, emerging contaminant in California. Unlike the geogenic contaminants described above, TCP does not have natural sources. This clear, colorless liquid was present in certain agricultural products applied in California throughout the 20th century, leading to widespread nonpoint contamination. In addition, TCP was historically used as an industrial solvent and cleaning agent, and therefore has many urban point sources. Because TCP does not easily break down, groundwater contamination from these historic practices remains an issue today.

TCP is of concern for human health because of its cancer-causing properties. Research by the National Toxicology Program (NTP) found that TCP causes tumors in multiple sites in both rats and mice at low doses (Irwin, Haseman, & Eustis, 1995). Based on these and other findings, TCP is considered a known human carcinogen by the State of California. California established an MCL for TCP in drinking water (0.005 µg/L) in December 2017, recognizing TCP's health risks and widespread distribution (Figure 16).

5.9.2 TCP in the environment

TCP is not known to have the same geochemical controls as redox-sensitive and ionic contaminants. Nonetheless, TCP is detected at much higher frequencies within oxic groundwater, suggesting it could be impacted by redox conditions; however, this mechanism is currently not well documented (Burow, 2019). Transport of TCP in groundwater is therefore controlled primarily by the physical properties of TCP, the mode of source application, and the characteristics of the affected aquifer, rather than geochemical or redox conditions.

TCP is a short hydrocarbon molecule with a chlorine atom bonded to each carbon. TCP is dense, slightly water soluble, and moderately volatile (prone to evaporation). While less volatile than industrial counterparts like trichloroethylene (TCE), TCP tends to evaporate from surface water. However, TCP does not adsorb easily to soil, and TCP that does not volatilize will migrate into groundwater.

Because it is denser (heavier) than water, TCP is classified as a dense non-aqueous phase liquid (DNAPL). Like all DNAPLs, TCP that enters an aquifer will sink downward, and eventually dissolve into groundwater.

TCP that originates from a diffuse, nonpoint source will tend to dissolve relatively quickly into groundwater. However, when a large amount of TCP enters the aquifer at a single location (generally from a point source), the pure, "free product" TCP can remain in the application source zone for decades – or centuries. This free product may be trapped in large pore spaces as "residual" free product or "pooled" above low-permeability sediments, often with highly irregular distribution within the source zone. Because TCP free product dissolves very slowly over time, groundwater passing through source zones may become enriched in TCP even after application has ceased.

Once dissolved into groundwater, TCP will be transported with groundwater flow. TCP is chemically stable and resistant to degradation. A typical molecule of TCP has a half-life of 44-74 years (i.e., it takes 44-74 years to degrade to half the initial concentration in water) (Ellington, 1986). Therefore, TCP plumes persist until they are diluted by diffusion or mixing.

5.9.3 TCP in California

TCP was detected above the MCL in 8% of domestic wells and 5% of public-supply wells recently sampled in California (Burow 2019). These detections are concentrated in the San Joaquin Valley, with some affected wells in the Los Angeles basin and Salinas Valley (Figure 16). In the San Joaquin Valley, 16-18% of domestic and public supply wells have TCP concentrations above the MCL.

Unlike geogenic contaminants, the distribution of TCP is largely determined by the location of historic source applications. In agricultural regions, TCP in groundwater likely originates from the use of TCP-containing soil fumigants marketed as D-D and, later, Telone, Telone II, and Vidden D. These fumigants were composed primarily of 1,3-dichloropropene (1,3,-DCP) and 1,2-dichloropropene (1,2-DCP) but contained up to 7% TCP by weight (Cheremisinoff & Rosenfeld, 2011). TCP-containing fumigants were widely applied beginning in the 1940s to many of California's croplands, including citrus fruits, pineapples, soy beans, cotton, tomatoes, sugar beets, grapes, potatoes, and various row crops, until they were discontinued in 1984 (CH2M Hill, 2005).

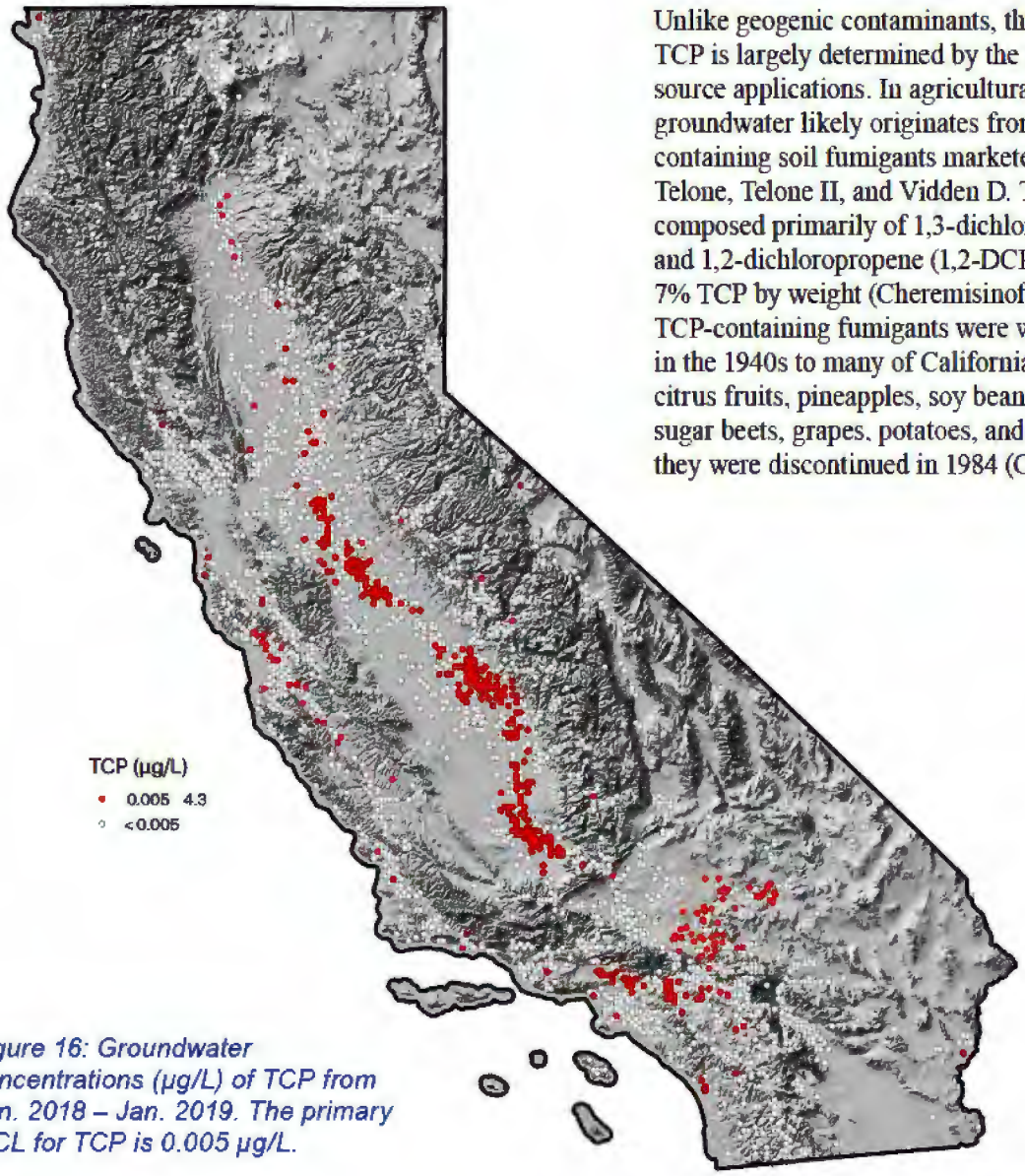


Figure 16: Groundwater concentrations (µg/L) of TCP from Jan. 2018 – Jan. 2019. The primary MCL for TCP is 0.005 µg/L.

TCP also has many point sources. These include facilities where TCP-containing fumigants were stored or where TCP was used as a solvent or cleaning agent. Suspected point sources of TCP in California include agricultural chemical supply sites, aviation facilities, chemical processing and manufacturing plants, and waste disposal sites (CH2MHill 2005, Burow 2019).

A recent evaluation of TCP in California groundwater identified several factors that are associated with TCP occurrence and concentrations: oxygen-abundant conditions; young, shallow groundwater; orchard/vineyard land use in the early 1990s; and high recharge rates (Burow 2019). Overall, TCP was found to be most prevalent and at highest concentrations near alluvial fans in the central and southern San Joaquin Valley, where orchards and vineyards are common and coarse-grained sediments and irrigation lead to high recharge. TCP was prevalent at similar rates in wells of all depths, though TCP concentrations were slightly higher in shallower wells. The authors also found that TCP co-occurs with 1,2-dibromo-3-chloropropane (DBCP, another soil fumigant) and 1,2-DCP (a TCP breakdown product and primary component of TCP-containing fumigants).

5.9.4 Management considerations for TCP

Active groundwater remediation is not a focus of this document. Best practices for TCP *in situ* remediation are still under study and will depend on the specific conditions of each plume. In general, *in situ* remediation of TCP can be achieved by injection of a strong oxidant and catalyst or by reductive dechlorination with zero-valent iron. However, California considers pump-and-treat with Granular Activated Carbon (GAC) as the Best Available Technology for affected water systems (SWRCB, 2018c).

Without active treatment, TCP plumes are likely to persist for many years. However, an awareness of aquifer characteristics, hydrology, and current/former land use can help water managers to avoid increasing TCP concentrations. Managers can avoid siting new wells in areas known to be associated with higher TCP concentrations, particularly shallow groundwater near orchards and vineyards in the central and southern San Joaquin Valley. Wells with elevated concentrations of DBCP and 1,2-DCP are also more likely to have elevated TCP.

Water managers should also be aware of historic point sources of TCP. As described above, residual or pooled TCP may be found near application zones in the pore spaces of coarse sediments or in lenses above low-permeability sediments. If water pumped from these strata becomes enriched in TCP relative to up-gradient wells, free product may be present. Subsurface soil samples can also reveal whether free product remains in source zones.

Depending on hydrological conditions of the site, managed aquifer recharge can help to reduce TCP concentrations through dilution of existing contamination. However, recharge zones should also avoid historic point source TCP contamination, as free product in the subsurface may dissolve into percolating groundwater and reach previously unaffected water supplies. Monitoring groundwater conditions down-gradient of the recharge will also allow water managers to track changes in TCP concentrations following recharge.

5.10 PFASs

5.10.1 Background

Per- and polyfluoroalkyl substances (PFASs) are a large and diverse class of fluorinated organic compounds. Like TCP, PFASs are synthetic chemicals that have no natural sources. PFASs are used to make consumer products stain-, soil-, and water-repellent, and in aqueous film-forming foam (AFFF) to extinguish flammable liquid fires. The carbon-fluorine chemical bonds that give PFASs their useful properties also make many of these chemicals extremely persistent. Interest in PFASs has increased due to recent discoveries of their widespread environmental occurrence and potential impacts on human health and biota.

Perfluoroalkyl acids (PFAAs) are a subclass of PFASs that are the focus of much scientific and regulatory attention. Exposure to PFAAs such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) is associated with human health harm including immune suppression, liver damage, high cholesterol, cancer, thyroid disease, reduced fertility, low birth weight, and effects on children's cognitive and neurobehavioral development. In 2016, U.S. EPA issued a Lifetime Health Advisory Level of 70 ng/L for PFOA, PFOS, or the sum of both. Researchers know less about the prevalence and toxicity of other PFASs, but the science is evolving rapidly.

PFOA, PFOS, and other long-chain PFASs have been phased out in the U.S. due to concerns over their

persistent, bioaccumulative, and toxic properties. Over the past 15 years, industry has replaced long-chain PFASs with short-chain PFASs and perfluoroether carboxylic and sulfonic acids. One notable perfluoroether carboxylic acid called GenX is used as a PFOA replacement in fluoropolymer manufacturing. GenX contamination has recently been detected in several watersheds in the eastern U.S.

5.10.2 PFASs in the environment

PFOA, PFOS, and other PFAAs are highly persistent. They are not expected to degrade at appreciable rates under environmental conditions. PFAAs are strong acids that usually carry a negative charge, which contributes to their relatively high water solubility and low volatility. PFAA releases are often associated with dissolved phase plumes. However, considerable PFAA mass can also be retained in source zones, especially in unsaturated soils. Partitioning to sediment and bioaccumulation are more pronounced for longer-chain PFAAs.

In contrast to PFAAs, polyfluorinated compounds contain a fluorinated carbon chain and at least one nonfluorinated carbon. The nonfluorinated carbons make polyfluorinated compounds more reactive than PFAAs, and some are susceptible to oxidation reactions. Polyfluorinated compounds that produce PFAAs are known as PFAA-precursors. Little is known about the fate, transport, or toxicity of many PFAA-precursors. Most are not included in standard analytical methods. PFAA-precursors are likely to serve as an ongoing source of PFAAs (e.g., PFOA) in the environment. Analytical techniques for measuring PFAA-precursors, such as the total oxidizable precursor (TOP) Assay, are increasingly available.

Important point sources of PFAS contamination include manufacturing facilities that make or use PFASs, locations where AFFF firefighting foam was used, landfills, and wastewater treatment plants.

5.10.3 PFASs in California

PFASs are not regulated under the Safe Drinking Water Act and public water systems are not required to perform routine monitoring of these chemicals. PFASs were detected in 133 drinking water samples from California through EPA's Third Unregulated Contaminant Monitoring Rule (UCMR3). The same study identified nine public water systems in the state with detections of PFOA and/or PFOS above EPA's 70 ng/L health advisory.

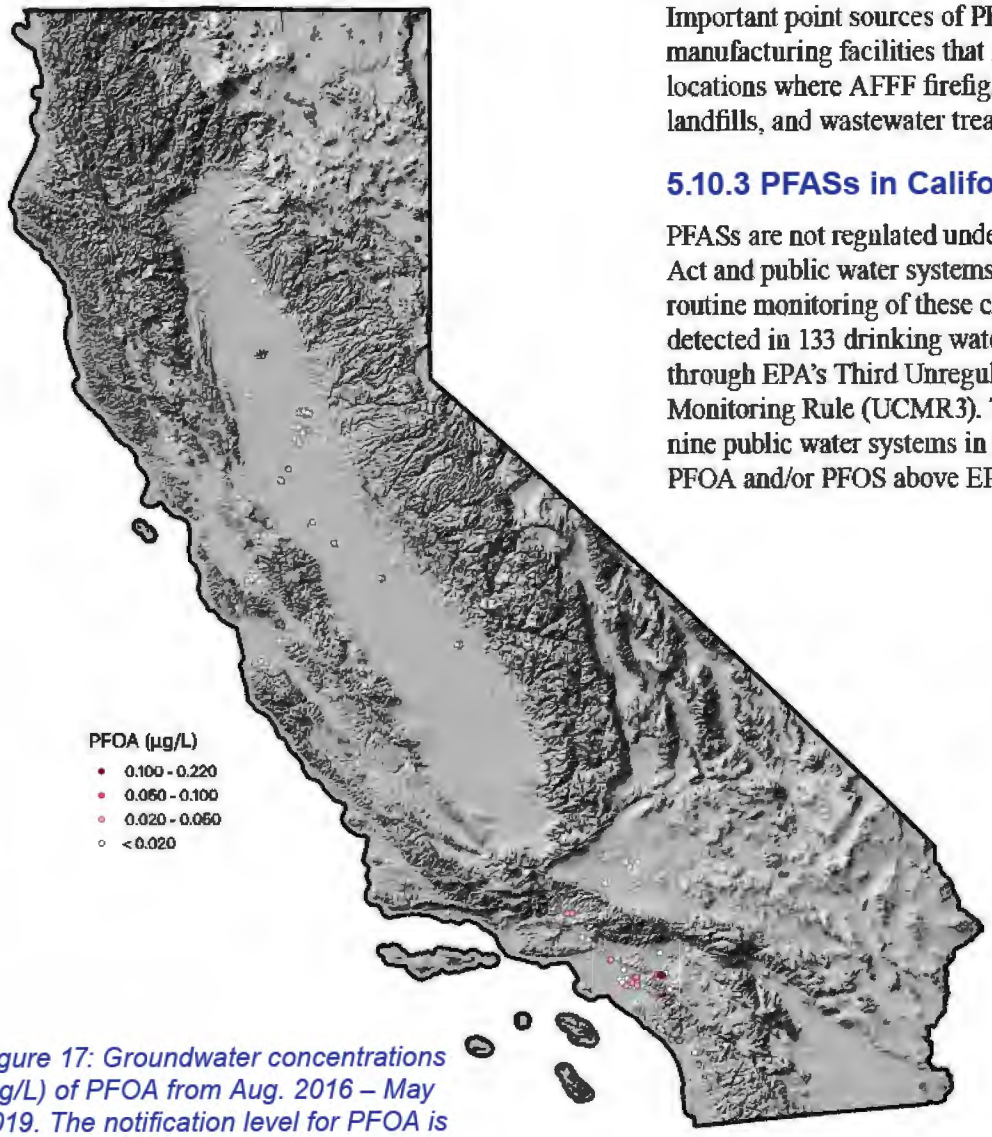


Figure 17: Groundwater concentrations (µg/L) of PFOA from Aug. 2016 – May 2019. The notification level for PFOA is 0.013 µg/L.

Aside from the UCMR3 study, there is a lack of drinking water monitoring data for PFASs in California. The Department of Defense has identified high PFAS concentrations in groundwater at military sites where AFFF was used, but none of these sites are known to have impacted drinking water off-base in California. In 2019, the State Water Resources Control Board announced a plan to require PFAS monitoring at hundreds of suspected release sites around the state, including manufacturing facilities, airports, landfills, refineries, wastewater treatment plants, and urban wildfire areas. The results of this monitoring should increase our understanding of the extent and sources of PFASs in California groundwater. When the state of Michigan carried out a similar testing program in 2018, it identified dozens of previously unknown PFAS contamination sites.

California's Division of Drinking Water has established notification levels of 13 ng/L and 14 ng/L, respectively, for PFOS and PFOA, and a response level of 70 ng/L for each individual compound of the sum of both.

5.10.4 Management considerations for PFASs

Under aerobic conditions, PFAA-precursors can undergo biotic transformation reactions to form PFAAs. Thus, if PFAA-precursors are present, management actions that introduce oxygen to an aquifer may have the unintended effect of increasing PFAA concentrations. Examples of such actions include remedial activities designed to treat contaminants other than PFASs, such as biosparging or in-situ chemical oxidation.

Recycled water is a potential source of PFASs in receiving aquifers. Given the decreasing trend in PFAS regulatory values, water managers should consider monitoring for PFASs before implementing aquifer recharge with recycled water.

Glossary

Analytes: substances being measured

Anoxic: Condition with low concentrations of dissolved oxygen

Anthropogenic: Man-made

Aqueous: Dissolved in water

Calcareous: rich in calcium carbonate

Cation: positively charged substance

Competitive ion: an ion (or charged substance) that behaves similar to another ion. Because they behave similarly, they

Desorption: The process of a substance adsorbed to a particle surface being released into the surrounding water

Felsic: describes type of volcanic rock that is rich in minerals like feldspar and quartz

Geogenic: naturally occurring in rocks

Mafic: describes a type of volcanic rock that is rich in magnesium and iron

Mobility: ability of a substance to move or be transported with water

Nonpoint source: contamination resulting from a diffuse source

Oxidant: a substance which causes the oxidation of another substance

Oxidation: the process of losing electrons or increasing oxidation state

Oxidation reduction potential: a measure of redox conditions

Oxidation state: a measure of the number of electrons a substance has gained or lost relative to its native state

Oxyanion: negatively charged substance

pH: a measure of the acidity of water

Point source: contamination resulting from a single, specific source (e.g., a leaking waste container)

Redox: chemistry related to the gain or loss of electrons also called the reduction or oxidation of substances

Reductant: a substance which causes the reduction of another substance

Reduction: the process of gaining electrons or decreasing oxidation state

Sediment: sediments are materials consisting of rocks and minerals, and remains of plants and animals; they are moved to new locations and deposited by water, ice, or wind

Sedimentary: describes rocks formed by deposition of other rocks

Shale: a fine-grained, sedimentary rock that forms when silt and clay-size mineral particles compact

Soil: unlike sediments, soil weathers in place and requires time and a stable ground surface to develop. It is a mixture of organic material, rock and mineral particles

Solubility: ability to dissolve in water

Sorption: the process of a substance adsorbing to a particle surface

Specie: a chemical substance or entity such as an atom, ion, or molecule

Ultramafic: describes a type of volcanic rock with very low silica content

Unsaturated zone: zone of an aquifer above the water table

Acknowledgements

Thank you to the following reviewers for providing valuable feedback during the preparation of this document. The views expressed in this document are those of the authors and do not necessarily represent the views of the individuals and organizations listed.

Andrew Ayres, Environmental Defense Fund

Letty Belin, Water in the West, Stanford University

Karen Burow, United States Geological Survey

Jason Dadakis, Orange County Water District

Katherine Dlubac, State Water Resources Control Board

Ana Lucia Garcia Briones, Environmental Defense Fund

Melissa Rohde, The Nature Conservancy

Arturo Keller, University of California, Santa Barbara

Maurice Hall, Environmental Defense Fund

Thomas Harter, University of California, Davis

Christopher Higgins, Colorado School of Mines

Lisa Hunt, American Rivers

Ronna Kelly, Environmental Defense Fund

Aysha Massell, American Rivers

Deborah Ores, Community Water Center

Andrew Renshaw, State Water Resources Control Board

Endnotes

1 SWRCB's Nitrate Project https://www.waterboards.ca.gov/water_issues/programs/nitrate_project/

2 CV-SALTS https://www.cvsalinity.org/

3 SWRCB's Irrigated Lands Regulatory Program (ILRP) https://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/

4 Sustainable Conservation's Nutrient Management Field Guide https://suscon.org/pdfs/dairies/pdfs/NMFieldGuideFinal.pdf

5 For certain contaminants, the SWRCB has contaminant-specific thresholds for which it is recommended to notify users. The response level refers to a concentration threshold greater than the notification level where the SWRCB recommends the water source be taken out of service. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/NotificationLevels.html

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7 USGS Report "Factors affecting public-supply-well vulnerability to contamination: understanding observed water quality and anticipating future water quality" https://pubs.usgs.gov/circ/1385/pdf/Cir1385.pdf

8 Community Water Center and Stanford's "Groundwater Quality in the Sustainable Groundwater Management Act: Scientific Factsheet on Arsenic, Uranium, and Chromium" https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1560371896/CWC_FS_GrndwtrQual_06.03.19a.pdf?1560371896

9 Community Water Center's "Guide to Protecting Drinking Water Quality Under the Sustainable Groundwater Management Act" https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1559328858/Guide_to_Protecting_Drinking_Water_Quality_Under_the_Sustainable_Groundwater_Management_Act.pdf?1559328858

10 DWR's Best Management Practices 1 'Monitoring Protocols Standards and Sites' https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-1-Monitoring-Protocols-Standards-and-Sites.pdf

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12 DWR's Flood-MAR website https://water.ca.gov/Programs/All-Programs/Flood-MAR

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257 Park Avenue South
New York, New York 10010

(212) 505-2100

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EXHIBIT J

ground water

Case Study/

Effects of Groundwater Development on Uranium: Central Valley, California, USA

by Bryant C. Jurgens[1,2], Miranda S. Fram[2], Kenneth Belitz[3], Karen R. Burow[2], and Matthew K. Landon[3]

Abstract

Uranium (U) concentrations in groundwater in several parts of the eastern San Joaquin Valley, California, have exceeded federal and state drinking water standards during the last 20 years. The San Joaquin Valley is located within the Central Valley of California and is one of the most productive agricultural areas in the world. Increased irrigation and pumping associated with agricultural and urban development during the last 100 years have changed the chemistry and magnitude of groundwater recharge, and increased the rate of downward groundwater movement. Strong correlations between U and bicarbonate suggest that U is leached from shallow sediments by high bicarbonate water, consistent with findings of previous work in Modesto, California. Summer irrigation of crops in agricultural areas and, to lesser extent, of landscape plants and grasses in urban areas, has increased Pco_2 concentrations in the soil zone and caused higher temperature and salinity of groundwater recharge. Coupled with groundwater pumping, this process, as evidenced by increasing bicarbonate concentrations in groundwater over the last 100 years, has caused shallow, young groundwater with high U concentrations to migrate to deeper parts of the groundwater system that are tapped by public-supply wells. Continued downward migration of U-affected groundwater and expansion of urban centers into agricultural areas will likely be associated with increased U concentrations in public-supply wells. The results from this study illustrate the potential long-term effects of groundwater development and irrigation-supported agriculture on water quality in arid and semiarid regions around the world.

Introduction

The Central Valley is one of the most productive agricultural regions in the world, with a cash value of more than $20 billion in 2007 (U.S. Department of Agriculture 2007). Seven counties within the Central Valley are among the top 10 counties in the United States for agricultural products sold (U.S. Department of Agriculture 2007). Nearly two-thirds of all groundwater withdrawals in California occur in the Central Valley, primarily for agricultural irrigation (Hutson et al. 2004; Maupin and Barber 2005). The San Joaquin Valley makes up the southern two-thirds of the Central Valley, and most of the population and associated municipal or public groundwater use is in the eastern San Joaquin Valley (ESJV). Reliance on groundwater as a source of drinking water in the ESJV is expected to increase with rapid population growth and diminishing availability of surface water supplies.

Uranium (U) concentrations above the California Maximum Contaminant Level (CA-MCL) of 20 picocuries per liter (pCi/L)—approximately equivalent to the U.S. Environmental Protection Agency Maximum Contaminant Level (U.S. EPA MCL) of 30 micrograms per liter (µg/L)—has led to the removal of at least 23 public-supply wells (PSWs) from service within the last 20 years in the ESJV (based on data from the California

[1]Corresponding author: U.S. Geological Survey, California Water Science Center, 6000 J St Placer Hall, Sacramento, CA 95819; bjurgens@usgs.gov

[2]U.S. Geological Survey, California Water Science Center, 6000 J St Placer Hall, Sacramento, CA 95819.

[3]U.S. Geological Survey, California Water Science Center, 4165 Spruance Road, Ste 200, San Diego, CA 92101.

Received May 2009, accepted August 2009.

Journal compilation © 2009 National Ground Water Association. No claim to original US government works.

doi: 10.1111/j.1745-6584.2009.00635.x

Department of Public Health [CDPH] Database, accessed September 2008). Groundwater from several other wells affected by high U is either blended with water containing low U or removed by ion exchange to meet regulatory requirements (Ashton 2006).

Previous studies have shown that anthropogenically introduced contaminants, such as pesticides and nitrate, have degraded the quality of groundwater within the ESJV (Nightingale 1972; Schmidt and Sherman 1987; Domagalski 1997; Burow et al. 2008; Wright et al. 2004). The spatial distribution of these contaminants in groundwater is linked to patterns of fertilizer and pesticide use and their rate of application at the surface. In contrast to these agricultural contaminants, U is naturally abundant in soils and aquifer sediments in the ESJV and is not linked to the application of fertilizers or pesticides (Jurgens et al. 2008).

Uranium is mobile in oxygenated groundwater and generally only forms stable minerals in sulfate-reducing environments; formation of stable U minerals in oxic environments requires very high concentrations of U (greater than 1000 µg/L). Uranium in oxic groundwater has a valence of +6 [U(VI)] and will form the oxycation uranyl (UO_2^{+2}) in the absence of complexing ions, such as dissolved inorganic carbon (DIC) (Langmuir 1978). The aqueous concentration of U(VI) is normally limited by uranyl adsorption to iron oxyhydroxide coatings on sediment grains, clay mineral edges, or to organic matter (Hsi and Langmuir 1985; Waite et al. 1994; Davis and Curtis 2004; Catalano and Brown 2005). However, the presence of complexing ions, particularly DIC species, can increase the solubility and mobility of U(VI) (Langmuir 1978; Hsi and Langmuir 1985; Waite et al. 1994; Davis and Curtis 2004). Recent work has also shown that calcium can enhance desorption of uranyl-carbonate ternary complexes (Fox et al. 2006) and that the calcium-uranyl-carbonate complex, $Ca_2UO_2(CO_3)_3^0$, may be the dominate species of dissolved U(VI) in calcium-rich groundwater systems (Bernhard et al. 2001).

Plant root respiration and microbial oxidation of organic matter in soils produce carbon dioxide (CO_2), resulting in CO_2 partial pressures (Pco_2) in the soil zone that are greater than atmospheric pressure (Russell 1973). Water percolating through the soil equilibrates with the soil atmosphere by dissolving $CO_2(g)$ to form carbonic acid. The carbonic acid participates in mineral weathering reactions that increase DIC concentrations in water, primarily in the form of bicarbonate. Soil calcite will also dissolve under high Pco_2 pressures and therefore can be an added source of DIC to water (Appelo and Postma 1996). Water that is not taken up by plants or evaporated from the soil eventually percolates to the groundwater system as recharge. ESJV climate is characterized by cool, wet winters and hot, dry summers; thus, under natural conditions, biological productivity is limited by the lack of soil moisture during the summer season. During the last 100 years, the ESJV has been extensively developed for agricultural use, and increasingly for urban use. Warm-season irrigation (March through September) of agricultural crops and urban landscapes has greatly increased biological productivity. It is our hypothesis that increased soil zone Pco_2 beneath irrigated lands has resulted in increased bicarbonate concentrations in groundwater, and that this bicarbonate has enhanced the mobility of U.

In addition, the application of surface water and groundwater for agricultural irrigation and pumping from deep parts of the aquifer for irrigation and public supply has increased the rate of downward groundwater flow (Williamson et al. 1989; Phillips et al. 2007). The vertical movement of water from the water table to deeper parts of the groundwater flow system has increased by more than sixfold in many parts of the valley since development and caused head gradients to be in a downward direction almost everywhere (Williamson et al. 1989). It is also our hypothesis that these changes in groundwater flow patterns have caused U concentrations to increase in many PSWs throughout the ESJV.

Because the developed portion of the ESJV aquifer system is largely oxic, uranium is expected to remain mobile in groundwater and therefore poses a significant threat to the long-term sustainability of groundwater as a potable source.

This paper describes the likely linkage between the development of groundwater resources in the ESJV since the 1850s and temporal increases in U concentrations in groundwater. Data collected by the U.S. Geological Survey (USGS) for the California Ground Water Ambient Monitoring and Assessment program Priority Basin Project (USGS-GAMA), data previously collected by the USGS National Water Quality Assessment (NAWQA) program and other USGS studies (USGS historical), and data compiled by the CDPH are used to demonstrate that high U concentrations are associated with shallow, modern-age groundwater that has high concentrations of bicarbonate. We show that bicarbonate concentrations in ESJV groundwater have increased with time and that bicarbonate is likely associated with warm-season irrigation return water. Finally, we show that U concentrations in the deeper portions of the aquifer system tapped by PSWs are increasingly affected by shallow U-laden groundwater that is driven downward in response to pumping. The paper also shows that irrigation and development of lands for agricultural and urban uses can mobilize inorganic contaminants that may otherwise be sequestered under natural conditions. The results of this paper therefore illustrate the potential long-term effects of groundwater development and irrigation-supported agriculture on water quality in arid and semiarid regions around the world.

Description of Study Area

The study area is the eastern half of the San Joaquin Valley, which occupies the southern two-thirds of the Central Valley of California (Figure 1). The Central Valley is a large, northwest-trending, asymmetric structural trough

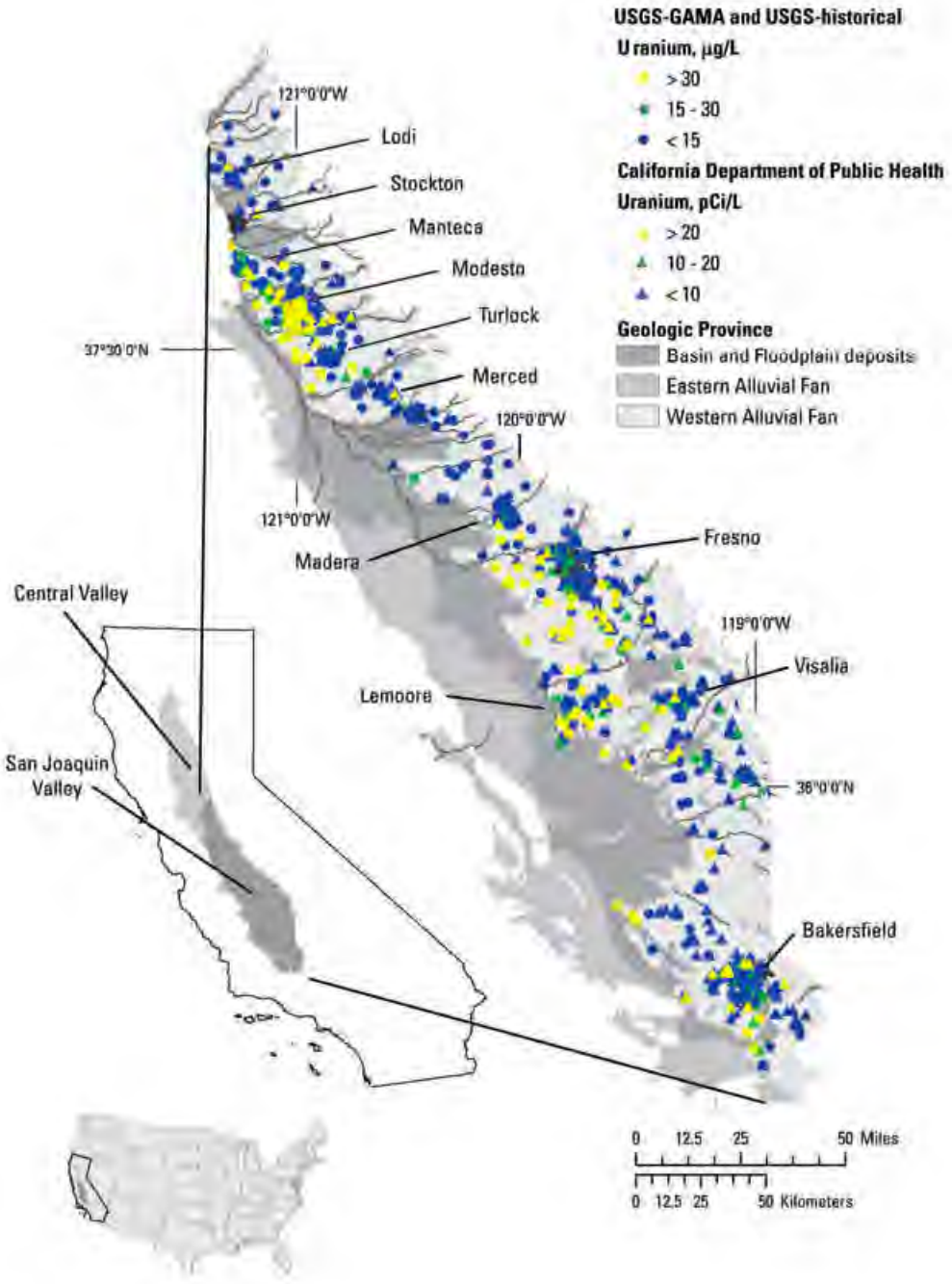


Figure 1. Location, physiographic features, and concentration of uranium in groundwater in the eastern San Joaquin Valley, California.

filled with marine and continental sediments up to 6 miles (mi) thick (Page 1986). The San Joaquin Valley is more than 248 mi long and 19 to 56 mi wide. East of the valley, the Sierra Nevada rise to an altitude of more than 8000 feet; west of the valley, the Coast Ranges form a series of parallel ridges up to 5000 feet high (Gronberg et al. 1998). Streams in the northern part of the San Joaquin Valley drain northward through the San Joaquin River to the San Francisco Bay; the southern part of the valley is a hydrologically closed basin.

Land-surface elevation rises from near sea level along the axial trough in the center of the valley to more than 300 feet at the top of dissected older alluvium near the valley margins. The climate is arid-to-semiarid, characterized by cool, wet winters and hot, dry summers. Mean annual precipitation ranges from less than 5 inches in the south to about 16 inches in the north (Gronberg et al. 1998).

Hydrogeology

Most groundwater withdrawals in the ESJV are from the upper 1000 feet of the basin-fill deposits. This part of the aquifer system mainly comprises a series of overlapping, stacked alluvial fan sequences deposited by streams draining the Sierra Nevada during the Holocene, Pleistocene, and Pliocene (Page 1986; Bartow 1991;

Weissmann et al. 2005). These unconsolidated to semiconsolidated deposits are primarily derived from granitic rocks of the Sierra Nevada, with minor contributions from metavolcanic and metasedimentary rocks of the foothills (Page 1986; Bartow 1991). Beneath these sediments, Miocene and Pliocene deposits of andesitic volcanic detritus occur in areas draining the central and northern parts of the Sierra Nevada (Burow et al. 2004).

The aquifer system can be generally described as an unconfined to semiconfined aquifer underlain by a confined aquifer, particularly where separated by a regional lacustrine clay unit commonly referred to as the Corcoran Clay (Williamson et al. 1989; Bertoldi et al. 1991). Aquifer materials are dominated by eastern and western alluvial fan deposits interspersed with fine-grained basin and floodplain deposits, and coarser-grained fluvial deposits (Figure 1).

Predevelopment Groundwater Flow

A numerical model of the predevelopment (prior to about 1850) groundwater flow system in the Central Valley suggests that recharge and discharge averaged about 2 million acre-feet/year (Williamson et al. 1989). The groundwater system was recharged primarily by streams entering the valley near the mountain fronts, and to a lesser extent by precipitation. Groundwater generally moved from areas of recharge along the valley margins toward the central low-lying areas in the basin, where artesian conditions were common. Groundwater in the northern half of the ESJV discharged to the San Joaquin River and surrounding marshlands, whereas groundwater in the southern half discharged to perennial lakes in closed basins.

Postdevelopment Groundwater Flow

Since 1850, diversion of surface water from streams and intensive groundwater pumping associated with agricultural irrigation and urban growth have significantly altered the natural flow system (Davis et al. 1959; Page and Balding 1973; Londquist 1981; Williamson et al. 1989). Development of the groundwater resource accelerated after about 1930 due to improvements to the turbine pump, which allowed farmers to pump groundwater from greater depths at greater rates (Williamson et al. 1989). Currently, percolating irrigation water is the primary form of groundwater recharge, and pumping is the primary form of groundwater discharge (Faunt 2009). Recharge and discharge are now approximately 12 million acre-feet/year (Faunt 2009).

The application of irrigation water and pumping from deep parts of the groundwater system have caused increased downward movement of groundwater. Williamson et al. (1989) simulated the predevelopment and postdevelopment groundwater flow system and found that vertical flow had increased by more than six times in many parts of the valley. In addition, repeated irrigation and pumping cycles can cause water moving laterally along the regional groundwater flow direction to be pumped and reapplied at the surface multiple times (Burow et al. 2004).

The widespread use of groundwater has caused water level declines in many parts of the valley and has greatly reduced the extent of artesian conditions. The depth-to-water table varies east-to-west and north-to-south. In the northern half of the valley, depth-to-water can be more than 60 feet near the valley margins in the east and less than 10 feet near the axial trough in the center of the basin. In the southern half of the valley, depth-to-water can be greater than 150 feet near the valley margins and less than 60 feet near the center of the basin (Faunt 2009). In urban areas, focused groundwater pumping and relatively low recharge rates have caused water level depressions within many cities in the valley (Bertoldi et al. 1991).

Methods

Description of Well Networks and Datasets

Between December 2004 and June 2008, 120 wells were sampled for U in the ESJV as part of the Priority Basin Project of the California Ground Water Ambient Monitoring and Assessment (GAMA) program (Bennett et al. 2006; Landon and Belitz 2008; Shelton et al. 2008, 2009; Burton et al. 2008). GAMA's Priority Basin Project is a statewide assessment of water quality in groundwater resources used for public supply in California (Belitz et al. 2003). The project is administered by the California State Water Resources Control Board and the USGS is the project's technical lead. Groundwater samples, primarily from PSWs, were collected for the GAMA program to assess groundwater quality in the ESJV. Samples for major ions, nitrate, and trace elements, including U, were collected from 120 wells. Additional wells were sampled by the GAMA program but were not analyzed for U. Tritium (^{3}H) and dissolved noble gas samples were analyzed from 83 of the 120 wells and carbon-14 (^{14}C) was collected from 88 wells. This dataset is referred to as USGS-GAMA.

Additional chemistry data were compiled from previous and ongoing USGS investigations in the ESJV, including the San Joaquin-Tulare Basin NAWQA program (Dubrovsky et al. 1998; Burow et al. 1998, 2008), the NAWQA Transport of Anthropogenic and Natural Contaminants project (Jurgens et al. 2008), and the San Joaquin Valley Drainage program (Fujii and Swain 1995). Combined, these sources provided data from 230 wells analyzed for major ions and trace elements since 1989 in the study area; these data are publically available in the USGS National Water Information System (NWIS) database (http://waterdata.usgs.gov/ca/nwis/). The median U concentration was used for wells that had more than one analysis. A subset of the wells also had tritium data. This dataset is referred to as USGS historical.

The CDPH maintains a database of water quality data collected from public-supply sources for regulatory purposes. The database contains U data for 941 wells sampled between 1986 and 2006. The maximum U

concentration from each well was used to describe the occurrence and distribution of high U in PSWs in the ESJV. Most of these wells were sampled for U more than once. Because U was not widely collected from wells between 1986 and 1990 (less than 10% of the total number of wells), recent U trends were examined with U data beginning on January 1, 1990, and ending on December 31, 2005 (16 years).

Sample Collection and Analysis

USGS-GAMA data were collected in accordance with the protocols established by the USGS NAWQA program (Koterba et al. 1995) and the USGS National Field Manual (USGS, variously dated). These sampling protocols ensure that a representative sample of the raw groundwater resource is collected from each well and that samples are collected and handled in a way that minimizes the potential for contamination. All public-supply well samples were collected at discharge points upstream of any chlorination or well-head treatment systems. Detailed descriptions of sample collection procedures, analytical methods, and quality-assurance results, and compilations of data can be found in Bennett et al. (2006); Burton et al. (2008); Landon and Belitz (2008); and Shelton et al. (2008, 2009). Historical chemistry data from other USGS investigations in the ESJV were collected and analyzed using the same or similar methods.

Samples for major ions, nitrate, uranium, and other trace elements were analyzed at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Carbon-14 was analyzed at the University of Waterloo and IsoTrace Laboratory (Ontario, Canada) by accelerated mass spectrometry. The activity of ^{14}C—expressed as percent modern carbon (pmc)—is reported with a one-sigma estimate of precision relative to the 1950 National Bureau of Standards oxalic acid standard. Samples for the noble gases, neon (Ne), argon (Ar), krypton (Kr), and xenon (Xe), were collected in copper tubes (25-cm-long, 3/8-inch [0.95] diameter) using reinforced nylon tubing connected to a hose bib at the wellhead. Copper tubes were flushed with groundwater and clamped at both ends to seal the sample. Tritium was collected in a 1-L glass bottle with each noble gas sample. Tritium, Ne, Ar, Kr, and Xe were measured at Lawrence Livermore National Laboratory (LLNL). Tritium was determined by the helium in-growth method (Bayer et al. 1989). Helium was analyzed using a VG-5400 noble gas mass spectrometer; dissolved Ne, Kr, and Xe were analyzed using a quadrupole mass spectrometer and argon was measured using a high-sensitivity capacitive manometer (Beyerle et al. 2000; Moore et al. 2006; Cey et al. 2008).

Uranium data reported in the CDPH database were collected for regulatory compliance, and California regulates U activity, rather than U mass concentration. Uranium results from the CDPH database were analyzed using standard radiochemical methods and reported in pCi/L (U.S. Environmental Protection Agency 1980). These data were assumed to be adequate for describing the occurrence, distribution, and trends in U concentrations in those PSWs having U analyses. The mass to activity conversion factor in groundwater depends on the activity of each U isotope, particularly the ratio of ^{234}U to ^{238}U. Because the U activity ratio (UAR) of ^{234}U to ^{238}U is not constant in groundwater, the mass to activity conversion factor varies. Therefore, U reported in activity units by the CDPH was not compared directly with U results reported in mass units by the USGS.

Nonparametric, rank-based methods were used for statistical analysis because the data were not normally distributed. The significance level (α) used for hypothesis testing was 5% ($\alpha = 0.05$). Correlations were investigated using Spearman's method to calculate the rank-order correlation coefficient (ρ, rho) between continuous variables. The Kruskal-Wallis rank sum test was used to test differences among groups (Conover 1980). If the Kruskal-Wallis rank sum test indicated a significant difference in more than two groups, the multiple stage Kruskal-Wallis test was used to determine whether a significant difference exists between successive groups (Helsel and Hirsch 2002). The significance level used for the multiple stage Kruskal-Wallis test was $\alpha_p = 0.025$. The signed-rank test was used to evaluate the differences in matched pairs of data.

Reduction/oxidation (redox) conditions were evaluated on the basis of dissolved oxygen (DO), nitrate (NO_3^-), manganese (Mn^{2+}), iron (Fe^{2+}), and sulfate (SO_4^{2-}) concentrations using the classification scheme of McMahon and Chapelle (2008). Because redox processes in groundwater tend to segregate into zones dominated by a single electron-accepting process, the redox framework uses the concentration of the redox sensitive species above to assign the predominant redox process to groundwater samples. An automated workbook program was used to assign the redox classification to each sample (Jurgens et al. 2009).

Recharge temperatures for 83 samples were determined from dissolved Ne, Ar, Kr, and Xe using methods described in Aeschbach-Hertig et al. (1999). Only modeled recharge temperatures having a probability greater than 1% were accepted ($P < 0.01$; Aeschbach-Hertig et al. 2000).

Speciation of dissolved U, calculated partial pressure of carbon dioxide (Pco_2), and saturation indices of U minerals and calcite in groundwater were calculated using PHREEQC, version 2.15 (Parkhurst and Appelo 1999). Data for the following species were included in the calculations: calcium, magnesium, sodium, potassium, chloride, alkalinity, sulfate, fluoride, nitrate, phosphate, barium, and strontium. Not all samples had nitrate, phosphate, barium, or strontium data, although more than 90% of the samples had data for each of these constituents. The LLNL thermodynamic database, included with PHREEQC, was modified for speciation calculations. Formation constants for U complexes were updated using thermodynamic data reported by Grenthe et al. (1992), and ternary complexes of uranyl and carbonate with the alkaline earth metals reported by Dong and Brooks (2006)

were added to the database. A two-site surface complexation model (SCM) was developed with the diffuse double layer model (Dzombak and Morel 1990) using PHREEQC. The surface species and formation constants for surface reactions were taken from Waite et al. (1994). The bidentate surface reaction expressions of Waite et al. (1994) were formatted for use with PHREEQC by Payne (1999) so that the mass action equation uses one mole of hydrous ferric oxide while the mole balance equation uses two. Model solutions contained 10^{-5} M U(VI) and aqueous U(VI) concentrations were calculated for pH values ranging from 6.25 to 9.5, the predominant pH range of ESJV groundwater. Moles of iron were estimated from ten 0.5 M HCl-hydroxylamine extractions (Jurgens unpublished data 2008). The average iron concentration was 80 mmol/L and was used to calculate site densities. The site densities were those of Waite et al. (1994): 0.8732 moles of weak sites per mole of iron and 0.0018 moles of strong sites per mole of iron. Three models were created for varying concentrations of total DIC: $10^{-3.0}$, $10^{-2.5}$, and $10^{-2.0}$ M. Each of these models had two forms: one without calcium and one with calcium at 1.2475 mmol/L (50 mg/L), a typical concentration in ESJV groundwater.

Land use was classified using an "enhanced" version of the satellite-derived (30-m pixel resolution), nationwide USGS National Land Cover Dataset (Vogelmann et al. 2001; Price et al. 2003). This dataset has been used in previous national and regional studies relating land use to water quality (Gilliom et al. 2006; Zogorski et al. 2006). The data represent land use during approximately the early 1990s. The imagery is classified into 25 land-cover classifications (Nakagaki and Wolock 2005). These 25 land-cover classifications were further classified into three principal land-use categories: urban, agricultural, and natural. Land-use statistics for circles with a radius of 500 m around each well were calculated for classified datasets using ArcGIS (version 9.2) (Johnson and Belitz 2009). Wells were then categorized by dominant land use. Mixed use was assigned where neither agricultural, urban, or natural land uses comprised more than 50% of the land surrounding the well.

Results and Discussion

Spatial Distribution of Uranium in Groundwater

Groundwater with high U content has been found throughout the ESJV (Figure 1). U concentrations for the 350 wells from the USGS-GAMA and USGS-historical datasets range from less than the detection limit (0.04) to 2,500 µg/L (Table 1). Approximately 19% of the wells (65 of 350) had a concentration greater than the US-MCL of 30 µg/L, and an additional 12% of the wells had U concentrations greater than one-half of the US-MCL.

PSWs from the CDPH database are not uniformly distributed across the ESJV and tend to be clustered in urban areas and along major transportation corridors (Figure 1). Approximately 11% (103 of 941) of the PSWs had at least one U analysis greater than the CA-MCL of 20 pCi/L, and an additional 5% of the wells had at least one U analysis greater than one-half of the CA-MCL. U concentrations ranged from less than the detection limit (1) to 102 pCi/L. Of the 941 CDPH wells, 848 wells remained active as of 2006. Twenty-three of the 93 inactive wells were abandoned because of high U concentrations.

Most of the U values greater than the CA-MCL in the CDPH dataset were in PSWs near Modesto, Fresno, and Bakersfield, major population centers in the ESJV. However, because the density of PSWs was also greatest in these areas, the clustering of high U values may reflect increased sample density. The USGS-GAMA and USGS-historical datasets show a wider distribution of wells with U concentrations above the US-MCL. USGS-GAMA wells were selected using a spatially distributed, randomized method (Scott 1990) to provide a statistically robust representation of the areal extent of the portion of the ESJV aquifer system used for public supply. The USGS-historical dataset was dominated by domestic and monitoring wells, which generally have perforation intervals in shallower portions of the aquifer than do PSWs. For example, the cluster of wells near Lemoore primarily includes monitoring and domestic wells. The USGS-GAMA and USGS-historical datasets therefore represent a larger portion of the aquifer system than the CDPH dataset, and show that groundwater with high U concentrations is indeed widespread in the ESJV.

The occurrence of groundwater with high U concentrations appears to be significantly greater in the ESJV than in other areas of the United States. In a recent survey of domestic wells in the United States (Focazio et al. 2006), U concentrations above 30 µg/L (US-MCL) were found in less than 4% of the wells (note that domestic wells are not subject to regulation). In contrast, 25% of the domestic wells in USGS-historical and USGS-GAMA datasets in the ESJV had U concentrations above the US-MCL.

High concentrations of U may not be as widespread as nitrate is in ESJV groundwater, which is above the US-MCL (10 mg/L as N) in 32% of domestic wells and 24% of all the wells in the USGS datasets. However, the percentage of wells affected by high U approaches that of nitrate and indicates that U does pose a significant threat to the continued operation of many PSWs in the ESJV.

Relation of Uranium Concentrations to Depth below Water Table and Age Tracers

The USGS-GAMA and USGS-historical datasets include well construction information and can therefore be used to estimate the vertical distribution of U within the aquifer system. Monitoring wells had the highest U concentrations, highest percentage of wells above the US-MCL, and the shallowest depths below the water table (Figure 2; Table 1). These wells are typically screened over short intervals (less than 5 feet) and provide water quality at discrete points in the aquifer system. Domestic wells, which tend to be located in rural areas, also had a high percentage of wells with U greater than 30 µg/L, but a lower median U concentration and greater depth

Table 1
Summary of Uranium Concentrations in Groundwater from Different Well Types in Eastern San Joaquin Valley, California; U.S. Geological Survey National Water Information System (NWIS)

Well Type	Number of Wells with U Analysis	Uranium (µg/L)			Number of Wells with U > 30 µg/L	Range in Depth below Water Table to Top of Uppermost Perforated Interval (feet)	Median Screen Length
		Minimum	Median	Maximum			
Observation	98	0.09	18.0	2500	31 (32%)	0.66–307 [55]	5
Domestic	122	0.04	8.7	503	30 (25%)	9.6–454 [82]	20.5
Public supply	121	0.04	1.8	41.3	3 (2.5%)	7.0–917 [140]	211
Irrigation	9	0.20	7.8	91.9	1 (11%)	42–557 [160]	175
All USGS data[1]	350	0.04	6.7	2500	65 (19%)	0.66–917 [98]	50

Notes: Percent of wells in parentheses. Median in brackets. [1]Uranium was not detected in six wells.

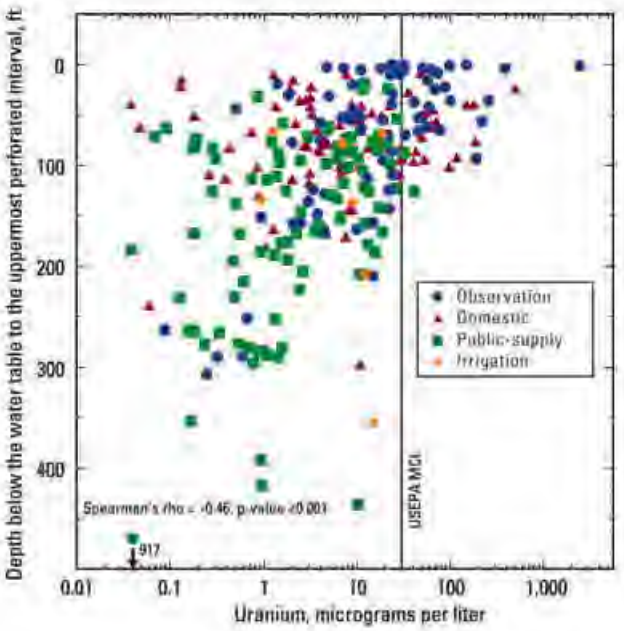


Figure 2. Relation between uranium in groundwater and depth below the water table to the uppermost perforated interval among well types in the eastern San Joaquin Valley, California.

below the water table than monitoring wells. PSWs had the lowest median U concentration. These wells tend to be located within urban areas, are perforated at deeper depths than monitoring and domestic wells, and generally have long screens (greater than 50 feet). PSWs in the ESJV typically withdraw water at rates between 200 and 2,500 gpm, much greater than those for domestic wells. Irrigation wells had the greatest depth below the water table of all the wells, but had higher U concentrations than PSWs. However, only nine irrigation wells were sampled for U in this study, and therefore may not accurately represent U concentrations in irrigation wells throughout the ESJV.

Uranium concentrations were significantly correlated to depth below the water table with the highest concentrations near the water table and decreasing with depth (Figure 2; Spearman's rho $= -0.46$, P-value < 0.001). Groundwater having U above 30 µg/L occurred in wells having perforated intervals beginning less than 150 feet below the water table, and most groundwater above 10 µg/L occurred in wells with perforated intervals starting less than 200 feet below the water table. Groundwater from less than 200 feet below the water table had a median U concentration of 8.4 µg/L; that from greater than 200 feet had a median U concentration of 0.73 µg/L.

Uranium concentrations also were significantly higher in wells with ^{3}H concentrations greater than 1 tritium unit (TU) and ^{14}C greater than 90 pmc (Kruskal-Wallis test; P-value < 0.001; Figure 3). ^{3}H activities greater than 1 TU indicate the presence of groundwater recharged after 1950 and ^{14}C activities greater than 90 pmc indicate the likely absence of groundwater with residence times greater than about 1,000 years. Together, these two age-dating criteria identify "modern" groundwater, that is, groundwater that was recharged since large-scale agricultural and urban development began in the ESJV. The median U concentration in groundwater samples with ^{3}H greater than 1 TU was 9.0 µg/L, compared with 0.60 µg/L for samples with less than 1 TU. Likewise, the median U concentration in groundwater samples with ^{14}C greater than 90 pmc was 7.2 and 0.93 µg/L for samples with less than 90 pmc. These results indicate that high U concentrations in the ESJV are preferentially associated with modern, shallow groundwater.

Uranium Mobilization

Source of Uranium

Uranium is naturally abundant in sediments in the ESJV, which are derived from granitic rocks of the Sierra Nevada. Aerial gamma-ray surveys of U in the ESJV show that U concentrations in surficial sediments range from 1.22 to 4.20 ppm and average about 3 ppm (Phillips et al. 1993). In contrast, surficial sediments of the conterminous United States have an average U concentration of 1.83 ppm. The average abundance of U in the ESJV is above the 90th percentile of U for surficial sediments of the United States. Because most of the geologic formations used for domestic and public

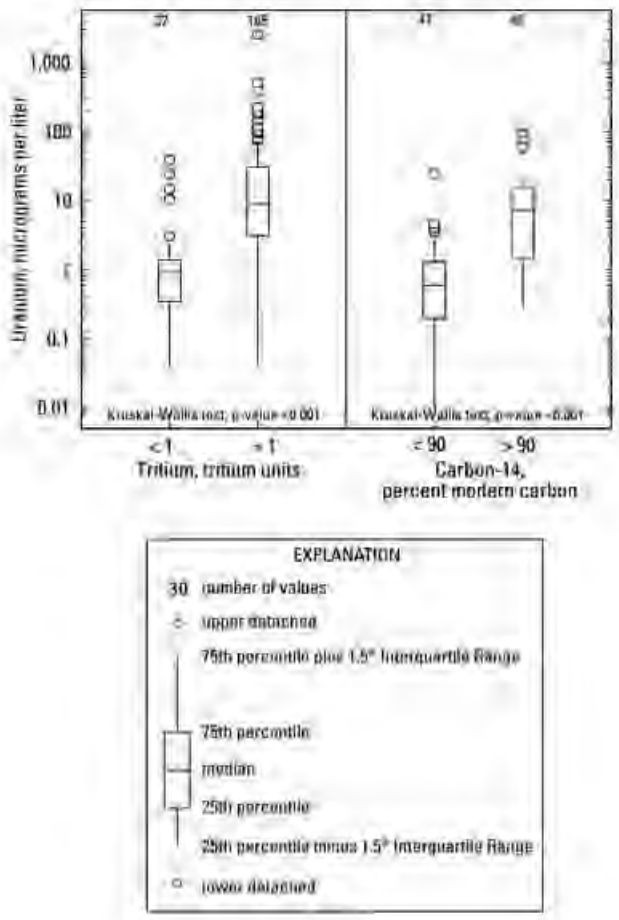


Figure 3. Uranium concentration in samples having tritium less than (<) 1 tritium unit (TU), tritium greater than (>) 1 TU, carbon-14 < 90 percent modern carbon (pmc), and carbon-14 > 90 pmc.

supply are also derived from the granitic rocks of the Sierra Nevada, it is probable that the concentration of U in aquifer sediments is similar to the concentrations in surficial sediments. However, the amount of U that may be easily mobilized is typically only a small fraction of the total U content of the sediment. This fraction is normally adsorbed to mineral surfaces on sediment grains, primarily iron oxide and oxyhydroxide coatings, and the edges of clay minerals (Hsi and Langmuir 1985; Waite et al. 1994; Davis and Curtis 2004; Catalano and Brown 2005).

Jurgens et al. (2008) measured the labile portion of U in sediments from core collected in Modesto (Figure 1). U was extracted from aquifer sediment samples using a 0.1-M sodium bicarbonate solution at a pH of 9.45 (Kohler et al. 2004). The labile portion of U in aquifer sediments ranged from less than 0.02 to 0.11 ppm (mg/kg), although the bulk U composition of the sediments was nearly constant. Leachates from the shallowest sediments (less than 60 feet below land surface [bls]) contained the least U, suggesting that some of the labile U had already been leached out. Leachates from the deepest sediments (greater than 200 feet bls) contained the most U, suggesting that deeper parts of the aquifer had not yet experienced leaching.

More strongly bound U was also extracted from sediments using 10% HNO_3 and ranged from 0.23 to 1.2 mg/kg and increased with depth below land surface (Spearman's rho = 0.75, P-value < 0.03; Jurgens et al. 2008). These results indicate that both the labile and more strongly bound fractions of U of shallow sediments have experienced leaching. Inorganic carbon was undetectable (less than 0.01%) in all sediment samples collected from the aquifer (Jurgens et al. 2008). Although calcite has been shown to host U in its structure (Kelly et al. 2006), the amount of U that could potentially be associated with undetectable levels of calcite in the aquifer would be minor in comparison to fractions associated with the labile and more strongly bound fractions.

Jurgens et al. (2008) also evaluated the potential for adsorption of U to aquifer sediments under similar pH values and bicarbonate concentrations found at the depths from which the sediment samples were collected. Adsorption experiments for the shallower sediments (less than 180 feet bls) showed no adsorption of U. In contrast, the deeper sediments (greater than 200 feet bls) showed linear type adsorption of U. The difference in adsorption behavior was not likely because of a difference in abundance of adsorption sites for U. Iron oxyhydroxide coatings on mineral grains (the primary location of absorption sites) were dissolved from sediment samples using 0.5 M HCl-hydroxylamine solutions, and the iron concentrations of resulting leachates did not vary systematically with sediment depth or U-adsorption behavior (Jurgens unpublished data 2008). These results suggest that higher U concentrations in shallower groundwater compared with deeper groundwater are because of differences in groundwater geochemistry with depth, not to reduction in the abundance of adsorption sites in the shallow sediments.

Mechanism of Mobilization—the Role of Bicarbonate

Three-hundred and ten of the 350 wells in the USGS-GAMA and USGS-historical datasets had data for DO concentrations; DO data are not compiled by CDPH. Approximately 86% (268 out of 310) of the groundwater samples had DO concentrations above 0.5 mg/L and were classified as oxic in the McMahon and Chapelle (2008) classification system. Median concentrations of DO, NO_3^-, Mn^{2+}, Fe^{2+}, and SO_4^{2-} in ESJV groundwater were 4.5, 4.8, < 0.02, < 0.1, and 22.7 mg/L respectively. Uranium in oxic groundwater had a median concentration of 6.5 µg/L. Uranium was significantly lower in anoxic groundwater (median = 0.93 µg/L; multiple stage Kruskal-Wallis rank sum test, P-value = 0.003). The reduced mobility of U under reducing conditions is likely because of reduction to U(IV) and the low solubility of U(IV) phases. Anoxic conditions occurred in less than 6% of wells and were mostly found in wells located near the basin and floodplain deposits (Figure 1). It is possible that some of the extremely high occurrences of U near the center of the basin was caused by the oxidation of U(IV) minerals as a result of irrigation and groundwater pumping; although past studies have attributed some of the high U occurrences in shallow wells in and near the center of

the basing to evaporative concentration (Fujii and Swain 1995). However, remobilization of U from redox fronts in the system does not appear to cause the vast majority of high U concentrations in groundwater. About 8% of wells had mixed redox conditions, where DO > 0.5 mg/L and manganese or iron was above 50 µg/L. Wells with mixed redox conditions had a wide range of U concentrations (0.04 to 503 µg/L; median = 16.0 µg/L). However, wells in the eastern alluvial fans that represent the bulk of the used groundwater resource in the ESJV were generally oxic.

Dissolved U species in oxic groundwater samples (262 oxic wells had measurable U) were calculated using PHREEQC. More than 85% of the dissolved U in almost all groundwater samples was in the form of ternary complexes of uranyl carbonate with calcium ($Ca_2UO_2(CO_3)_3^0$, $CaUO_2(CO_3)_3^{-2}$) and was primarily in the form of the neutral calcium-uranyl-carbonate complex. Calcium-uranyl-carbonate species comprised less than 50% of the dissolved U in just 2% of the oxic groundwater samples. Phosphate complexes comprised less than 1% in all groundwater samples. Speciation calculations indicate that magnesium-uranyl complexes are present ($MgUO_2(CO_3)_3^{-2}$), but generally comprise about 1% and at most 5% of dissolved U.

Strong correlations between U and bicarbonate (Figure 4; Spearman's rho = 0.74, P-value < 0.001) and U and calcium (Spearman's rho = 0.77, P-value < 0.001) concentrations are consistent with speciation calculations. Although the species is a complex between uranyl and the carbonate anion, the formation of the species is likely between uranyl and any one of the three inorganic carbon ions ($H_2CO_3^{0*}$, HCO_3^-, CO_3^{-2}). The predominant form of DIC species in water is pH dependent. Groundwater from this study had pH values that ranged from 6.7 to 9.7 (median pH = 7.6), and bicarbonate is the principal form of DIC in that pH range (Appelo and Postma 1996).

$$UO_2^{+2} + 2Ca^{+2} + 3HCO_3^- \leftrightarrow Ca_2UO_2(CO_3)_3^0 + 3H^+$$
$$\log K = -0.29 \text{ (modified from Dong and Brooks [2006])}$$

Calcium in groundwater is mostly a result of the dissolution of minerals in the soil zone and partly from the application of soil amendments and fertilizers at the land surface. Calcium is present in all sediments, primarily as plagioclase feldspar, and most soils contain some calcite. In many agricultural parts of the valley, gypsum is often added to irrigated soils to promote infiltration and nitrate fertilizers often contain calcium (Jurgens et al. 2008).

Strong correlations between U and bicarbonate and the results of the U extractions indicate that high concentrations of U in shallow groundwater were at least partially mobilized from adsorption sites from shallow sediments. Adsorption of U to sediments is mainly dependent on pH and the concentration of DIC (Hsi and Langmuir 1985; Waite et al. 1994; Davis et al. 2004). Calculations from

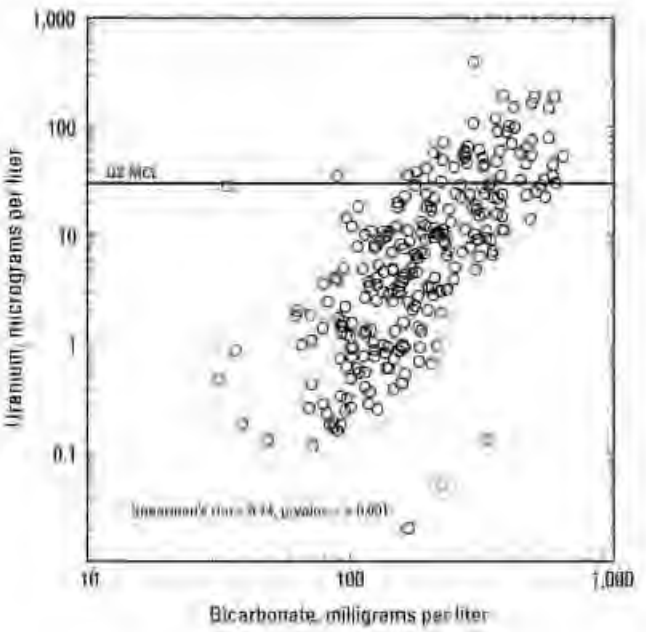


Figure 4. Relation between uranium and bicarbonate in oxic groundwater in the eastern San Joaquin Valley, California.

PHREEQC predict that U(VI) minerals are highly undersaturated in the 262 groundwater samples, suggesting that U concentrations are most likely controlled by adsorption processes. Adsorption of U(VI) is strongest at near circumneutral pH values while high pH values tend to weaken adsorption of U(VI). However, high concentrations of DIC can limit the adsorption of U. In the ESJV, U decreases with increasing pH (Spearman's rho = −0.23, P-value < 0.001; Figure 5). Consequently, U is highest in groundwater with more neutral pH values and higher concentrations of DIC, whereas groundwater with low U tends to have higher pH values and lower concentrations of DIC.

To demonstrate the effect that DIC has on U(VI) adsorption, the SCM of Waite et al. (1994) was used to calculate the dissolved U(VI) concentrations at different total DIC concentrations and pH values observed in groundwater (Figure 5; dashed lines). Dissolved U(VI) was at least an order of magnitude greater in the presence of high concentrations of DIC (0.01 M) than at lower concentrations of DIC (0.001 M). However, the SCM tended to underpredict U(VI) concentrations in groundwater at high concentrations of DIC. Fox et al. (2006) showed that the presence of calcium in solution can also reduce the adsorption of U(VI) to iron oxyhydroxides under conditions that favor the formation of the neutral calcium-uranyl-carbonate complex, $Ca_2UO_2(CO_3)_3^0$. By including a typical calcium concentration (50 mg/L) in each model, the predicted behavior of U(VI) in equilibrium with iron oxyhydroxides is remarkably similar to U and DIC concentrations observed in ESJV groundwater, especially for higher concentrations of U(VI) and DIC (Figure 5;

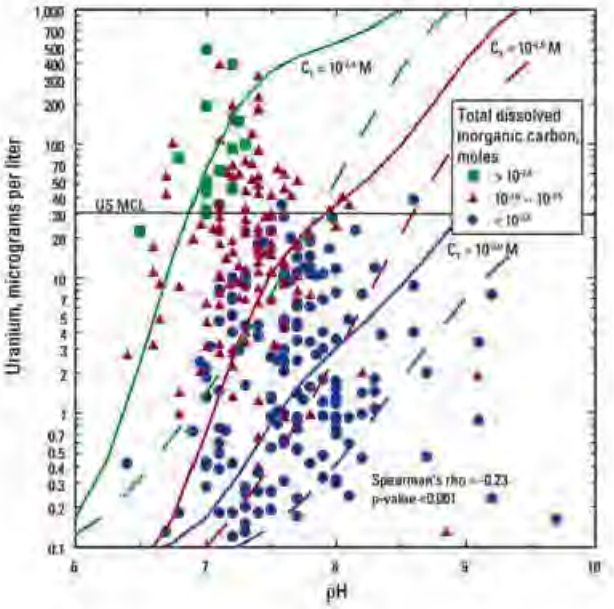


Figure 5. Relation between pH and uranium [U(VI)] in groundwater in the eastern San Joaquin Valley, California. Symbols are colored according to the concentration of total dissolved inorganic carbon (DIC). Dashed lines are equilibrium concentrations of dissolved U(VI) from a surface complexation model (SCM) based on the work of Waite et al. (1994). Solid lines are equilibrium concentrations of U(VI) from the same SCM with a calcium concentration of 1.2475 mmol/L. Each line color represents the equilibrium concentration of U(VI) for different concentrations of total DIC. $T = 25°C$; $I = 0.1$ M; U(VI) total = 0.01 mmol/L; Fe = 80 mmol/L (average concentration of 10 aquifer core samples using 0.5 M HCl-hydroxylamine extraction). Site densities were from Waite et al. (1994): total sites 0.875 moles/mole of Fe; strong sites = 0.0018 moles/mole of Fe; and weak sites = 0.8732 moles/mole of Fe.

solid lines). These results are also consistent with speciation calculations that predict the calcium-uranyl-carbonate species to predominate in ESJV groundwater.

Long-Term Bicarbonate Trends and Relation to Land Use

Comparison between data from Mendenhall et al. (1916) and data from the USGS-GAMA and USGS-historical datasets showed that concentrations of bicarbonate in ESJV groundwater have increased over the last 100 years (Figure 6). In 1910, the median bicarbonate concentration of groundwater in the ESJV was 119 mg/L. The median bicarbonate concentration from this study was 178 mg/L and is statistically greater than concentrations in 1910 (Kruskal-Wallis rank sum test, P-value < 0.001).

Wells from 100 years ago were typically shallower. The median well depth in Mendenhall's dataset was 95 feet compared to 205 feet in this study. Of course, the water table was not as deep 100 years ago as it is in many parts of the valley today. Most wells 100 years ago were probably perforated in shallower parts of the groundwater system than modern wells because of construction limitations and because the yield and quality of groundwater at those depths were sufficient for most purposes (Mendenhall et al. 1916).

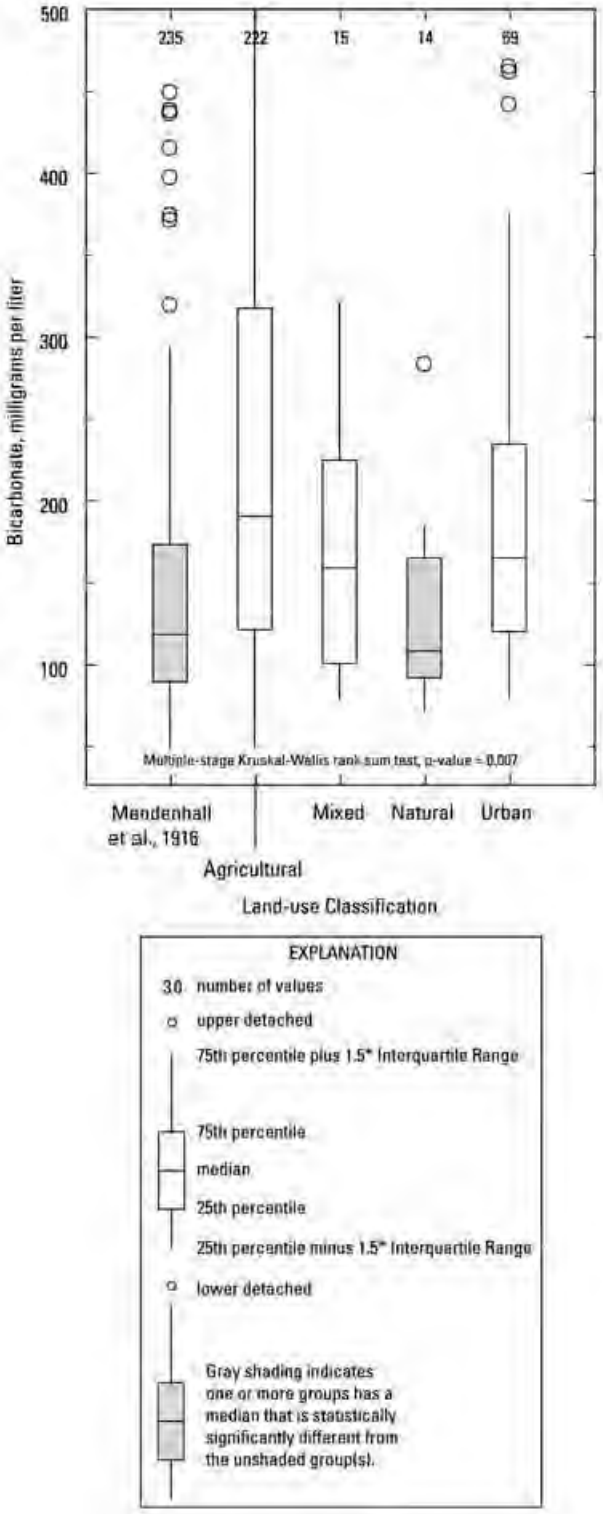


Figure 6. Bicarbonate concentrations in groundwater in 1910 (Mendenhall et al. 1916) and from this study (GAMA + USGS historical [since 1989]) among different land uses surrounding the wells in the eastern San Joaquin Valley, California. The mixed use category was assigned to wells where neither agricultural, urban, or natural land uses were more than 50% of the land surrounding the well.

The increase in bicarbonate concentration over the last 100 years is related to land-use patterns. Bicarbonate concentrations in wells surrounded predominantly

by natural land use (median = 108 mg/L) and in wells sampled in 1910 (median = 119 mg/L) were significantly lower than bicarbonate concentrations in wells surrounded predominantly by agricultural (median = 191 mg/L), urban (median = 166 mg/L), and mixed (median = 160 mg/L) land uses (Figure 6) (multiple stage Kruskal-Wallis rank sum test, P-value < 0.001). Although many of the wells sampled in 1910 were in agricultural areas, large-scale irrigation had not yet been developed, and thus water use on the landscape more closely resembled natural conditions.

Urban areas in the ESJV are typically surrounded by agricultural land, and urban groundwater pumping is areally concentrated. Consequently, bicarbonate concentrations beneath urban areas are likely affected by adjacent agricultural land use, which tends to be associated with higher bicarbonate concentrations.

Connection between Increased Bicarbonate Concentrations and Irrigation

The relations between bicarbonate concentrations, Pco_2, recharge temperature, and depth in groundwater in the ESJV suggest that high bicarbonate concentrations in shallow groundwater are the result of groundwater recharge by water that has percolated through irrigated soils. Pco_2 in the soil zone can range from equal to atmospheric Pco_2 (0.035%) to greater than 100 times atmospheric Pco_2, and is generally positively correlated with soil moisture, soil temperature, and plant growth (e.g., Russell 1973). In arid to semiarid climates, plant growth and microbial decomposition of soil organic matter are generally limited by low soil moisture. Addition of water via precipitation or irrigation results in a rise in biological activity and thus a rise in soil zone Pco_2.

Equilibrium Pco_2 values were calculated from groundwater major ion chemistry and pH data using PHREEQC. Groundwater Pco_2 ranged from 0.1 to 430 times atmospheric Pco_2 and decreased with depth below the water table (Spearman's rho = −0.51, P-value < 0.001; Figure 7). Most groundwater within 50 feet of the water table had Pco_2 pressures greater than 40 times atmospheric Pco_2, indicating that the biological activity within the soil zone has influenced the chemistry of recent recharge.

In addition, Pco_2 pressures were higher in groundwater beneath agricultural land than in groundwater beneath other land uses (multiple stage Kruskal-Wallis rank sum test, P-value < 0.001; Figure 7). The median Pco_2 pressure for groundwater beneath agricultural land was $10^{-2.1}$ atmospheres (atm) or approximately 22 times atmospheric concentrations. The median Pco_2 pressure for groundwater beneath other land uses was $10^{-2.5}$ atm or approximately nine times atmospheric concentrations. pH was not collected in data from Mendenhall et al. (1916), and therefore, Pco_2 pressures could not be directly compared. However, groundwater beneath natural land had similar bicarbonate concentrations to groundwater from 100 years ago and Pco_2 pressures beneath natural land were lowest among all land uses (median = $10^{-3.0}$ or approximately three times atmospheric concentrations). Therefore, the increase in bicarbonate concentrations in shallow groundwater over the last 100 years likely resulted from recharge water having higher Pco_2 pressures as a result of irrigation.

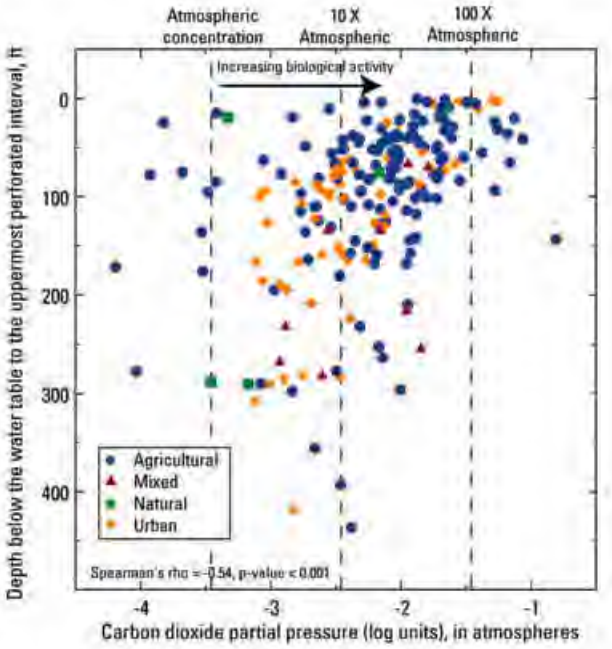


Figure 7. Relation between calculated equilibrium carbon dioxide partial pressures in groundwater and depth below the water table to the uppermost perforated interval in the eastern San Joaquin Valley, California.

Higher Pco_2 pressures can also cause the dissolution of carbonate minerals, namely calcite, within the soil zone (Appelo and Postma 1996). Calcite is present in most soils in the ESJV, but is generally much less than 5% (Schoups et al. 2005) and calcite was below detectable levels (0.01%) in core from Modesto, California (Jurgens et al. 2008). Bicarbonate and calcium (and uranium) were correlated with increasing calcite saturation (log ratio of the ion activity product to the equilibrium solubility constant). Most groundwater with elevated and high concentrations of U (U > 15 µg/L) was saturated with calcite (median = 0.13), whereas groundwater with lower U concentrations (U < 15µg/L) was mostly undersaturated (median = −0.16). The dissolution of calcite under high Pco_2 pressures could give rise to increases in bicarbonate and calcium concentrations with concomitant high calcite saturation in recharge water. Recent research also shows that calcite can accommodate uranyl in its structure and that the occurrence of uranyl in calcite formed in near-surface environments may be more common than previously thought (Kelly et al. 2006). Although the amount of U from soil calcite that would potentially contribute to groundwater is unknown, extraction results and extremely low abundance of calcite in the aquifer sediments suggest that calcite dissolution may not be an important source of

U to groundwater. Furthermore, the results of the extraction experiments indicated that the amount of U mobilized from adsorption sites would likely be sufficient to account for the increase in dissolved U concentrations in groundwater.

Higher recharge temperatures, calculated from dissolved noble gas concentrations, are associated with higher Pco_2pressures (and bicarbonate) in groundwater (Spearman's rho = 0.49, P-value $\leq$ 0.001; Figure 8). Calculated median recharge temperatures were one degree higher (18.8°C) for wells surrounded by agricultural land than for those surrounded by urban, natural, and mixed land (multiple stage Kruskal-Wallis rank sum test, P-value $<$ 0.02). High recharge temperatures and high Pco_2 pressures are consistent with recharge derived from summer irrigation, as would be found in agricultural areas in the ESJV. Under natural conditions, recharge occurred almost entirely during winter months (November through May) and therefore recharge temperatures were likely more influenced by winter air temperatures. Most of the recharge now occurs from the application of irrigation water during the summer months when air temperatures are highest.

Recharge temperatures and Pco_2 pressures were positively correlated to total dissolved solids (TDS) and $\delta^{18}O$. As stated earlier, the acidity derived by the rise in Pco_2 pressures in the soil zone is buffered by the dissolution of minerals (mainly plagioclase), such that the primary products are an increase in pH, formation of bicarbonate, and addition of cations to the residual water. Consequently, higher Pco_2 pressures will tend to lead to increases in these weathering products and in the overall TDS of the water. Calculated Pco_2 pressures (and U) were correlated with all of the major cations in ESJV groundwater. TDS has also increased in the last 100 years. The median TDS in wells from 1910 was 210 mg/L and was 311 mg/L in the USGS-GAMA and USGS-historical dataset (Kruskal-Wallis rank sum test, P-value $<$ 0.001). Correlations with $\delta^{18}O$ also suggest that the increase in bicarbonate concentrations may be partly because of evaporation of irrigation water during the summer growing season; although strong evaporation trends were not evident from stable isotope values.

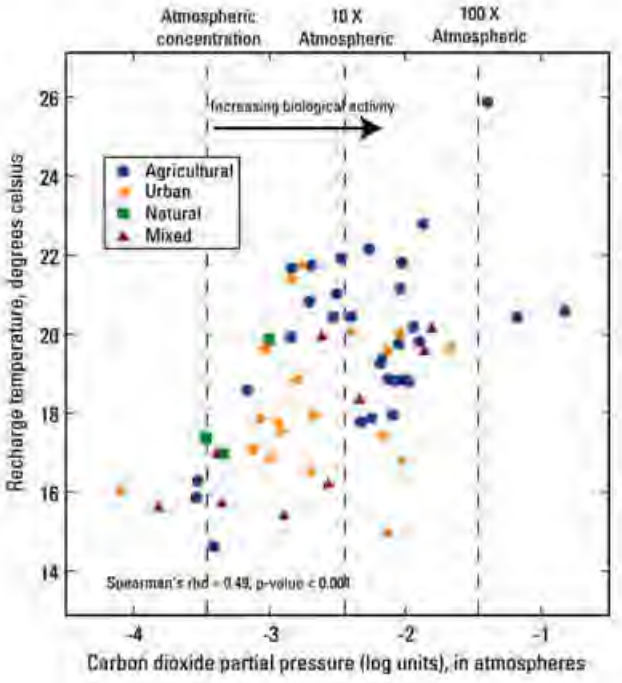


Figure 8. Relation between recharge temperature and the partial pressure of carbon dioxide in groundwater beneath different land-use settings in the eastern San Joaquin Valley, California.

Recent Uranium Trends

Recent U trends in wells from the CDPH database were evaluated using data for wells that were sampled from January 1, 1990, to December 31, 2005. This time period provided an even split in years (8), and similar number of wells analyzed during the two time periods (Table 2). For wells with more than one U analysis, the median activity from each well was used to calculate population statistics. The number of wells having at least one U sample above the CA-MCL of 20 pCi/L increased from 38 for samples collected from 1990 to 1998 to 56 from 1998 to 2006 (Table 2).

U data were available in both time periods for 317 wells. The median activity of U in these wells increased from 4.3 pCi/L between 1990 and 1998 to 5.0 pCi/L between 1998 and 2006 (signed-rank test, P-value $<$ 0.001). The average change in concentration was 1.2

Table 2
Summary of Uranium Concentrations in Groundwater from Public-Supply Wells Sampled between 1990 and 2006 in Eastern San Joaquin Valley, California; California Department of Public Health

		Uranium (pCi/L)			
Uranium Date Range	Number of Wells	Minimum	Median	Maximum	Number of Wells with U > 20 pCi/L
1990–2006	848	<1	3.7	63.9	81 (9.6%)
1990–1998	556	<1	3.6	49.4	38 (6.8%)
1998–2006	610	<1	4.2	102	56 (9.2%)

Note: Percentage of wells in parentheses.

pCi/L. U activity increased by more than 0.2 pCi/L in 53% of the wells, decreased by more than 0.2 pCi/L in 35% of the wells, and changed by less than 0.2 pCi/L in the remaining 12% of wells. These results indicate that U has increased in the majority of PSWs in the ESJV. Bicarbonate concentrations in paired samples also increased for the same time period by about 2.7 mg/L. Wells that had increased U concentrations had a median increase in bicarbonate of 6.3 mg/L, whereas wells that had decreased U concentrations had a median decrease in bicarbonate of 1.6 mg/L. These results indicate that increased U concentrations are accompanied with increased bicarbonate concentrations.

The median U concentration for unpaired samples also increased over the 16-year period (Table 2). The median for these samples increased by 0.6 pCi/L for the time period evaluated.

Conclusions

Development of the groundwater resource since the 1850s has caused two major changes that have resulted in uranium concentrations above drinking water standards in domestic and PSWs in the ESJV: (1) changes in the chemistry of recharge water and (2) increases in the rate of downward groundwater flow.

ESJV sediments have comparatively high concentrations of uranium and a fraction of this uranium is readily leachable by bicarbonate solutions. Uranium is strongly correlated with calcium and bicarbonate, the principal form of DIC in groundwater. Speciation calculations indicate that the primary form of U in oxic groundwater is a calcium-uranyl-carbonate complex. The results of the U extractions and co-occurrence of elevated concentrations of U, bicarbonate, and calcium are consistent with results from the SCM, suggesting that U likely has been leached from adsorption sites on mineral surfaces in sediment. Because bicarbonate concentrations have increased over the last 100 years, it is reasonable to assume that dissolved U has also increased during this period.

The increase in bicarbonate in groundwater over the last 100 years is primarily related to the agricultural development of the ESJV. Bicarbonate concentrations in groundwater have increased in response to an increase in recharge and the growth of crops in agricultural areas and, to lesser extent, the growth of landscape plants and grasses in urban areas. Both recharge and the growth of crops occur mostly during the summer growing season when temperatures are warmest. Consequently, groundwater beneath agricultural land tends to have higher recharge temperatures and higher P_{CO_2} pressures. Ultimately, the increase in bicarbonate concentrations in recharge water has led to the widespread occurrence of high U in shallow groundwater.

Groundwater pumping, primarily from deeper parts of the aquifer system, and increased recharge from the application of irrigation water have increased the downward movement of groundwater. Consequently, constituents that enter the groundwater system at shallow depths are moved downward at a faster rate than would be expected under natural conditions. Shallow high U groundwater has thus moved downward, resulting in increasing U in PSWs. The overall increase in the median U concentration for all wells is small (0.6 pCi/L), but the percentage of wells with at least one U analysis greater than 20 pCi/L (CA-MCL) has increased from 7% to 9% in just 16 years. Continued irrigation and pumping in the ESJV will likely be followed by additional U increases in PSWs.

This paper also shows that irrigation and development of lands for agricultural and urban uses can mobilize inorganic contaminants that may otherwise be sequestered under natural conditions. The results of this paper therefore could have broader implications for other agriculturally based arid and semiarid regions around the world.

Acknowledgments

This work was supported by the California State Water Resources Control Board with help from landowners and water purveyors throughout the San Joaquin Valley. We thank the three anonymous reviewers for their constructive comments and helpful suggestions. Major improvements also resulted from reviews by Robert A. Zielinski and Steven P. Phillips. We also thank David L. Parkhurst for his helpful guidance with the surface complexation model used in this paper.

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EXHIBIT K

COMMUNITY WATER CENTER
EL CENTRO COMUNITARIO POR EL AGUA

Stanford
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Groundwater Quality in the Sustainable Groundwater Management Act (SGMA):

Scientific Factsheet on Arsenic, Uranium, and Chromium

Groundwater is an important resource that we depend on to drink, bathe, grow food, and more. Through the implementation of the Sustainable Groundwater Management Act (SGMA) local groups called Groundwater Sustainability Agencies (GSAs) are developing Groundwater Sustainability Plans (GSPs) that indicate how they will manage groundwater in their area. One requirement of the Groundwater Sustainability Plans is to *"avoid significant and unreasonable degradation of groundwater quality"* (Water Code Section 10721(x)(4)).

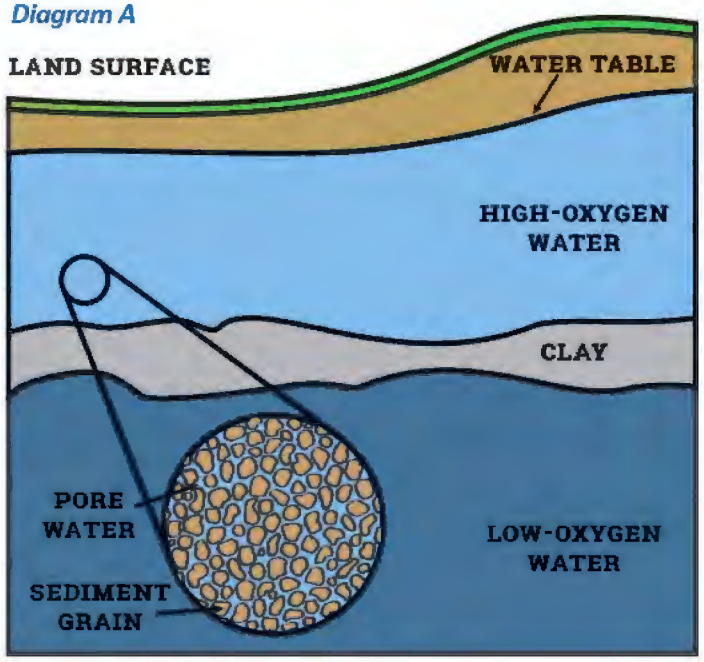
Groundwater can become contaminated through the use of human-made chemicals, fertilizers, or improperly managed waste facilities. Groundwater contamination can also occur naturally from elements in soils and sediments (See Box 1). Some elements naturally present in rocks are toxic and harmful to health when they are dissolved in water, sometimes even at low concentrations. The most widespread of these metals are **arsenic** and **uranium. Chromium** is also of concern, primarily in a specific form (hexavalent chromium).

This factsheet explains how three elements — arsenic, uranium, and chromium — enter groundwater from soils and sediments, and how to address these already present impacts and work to prevent, limit, or reverse issues related to these contaminants. If you know these contaminants are present in your groundwater basin, we recommend you encourage your Groundwater Sustainability Agency to invest in additional monitoring and management practices to keep from worsening the problem. This factsheet provides illustrations based on recent scientific research to inform the design of those monitoring and management programs. For more information about best management practices for addressing drinking water in Groundwater Sustainability Plans, review Community Water Center's ***Protecting Drinking Water Under SGMA Guide.***

What Is Groundwater? How Can Naturally Occurring Metals Like Arsenic and Uranium Enter Groundwater?

Groundwater is water that exists below the earth's surface, either in the space between grains of sand, gravel, and clay, or in the fractures of solid rocks. The layers of rock and sand that contain groundwater are called aquifers *(Diagram A)*. Underground sediments and rocks contain many different minerals and metals, either attached to the surface of the grain, or as part of the sediment/rock itself. Under certain conditions, these minerals and metals can move into the groundwater, or become dissolved.

Diagram A



There are many conditions that affect and accelerate the movement of metals from rocks into groundwater including the pH (level of acidity) and the amount of dissolved oxygen in the water. Changes in pH and oxygen can lead to higher concentrations of dissolved metals in groundwater but each metal responds differently to these conditions.

Importance of Monitoring and Using Groundwater Information to Manage Groundwater Quality:

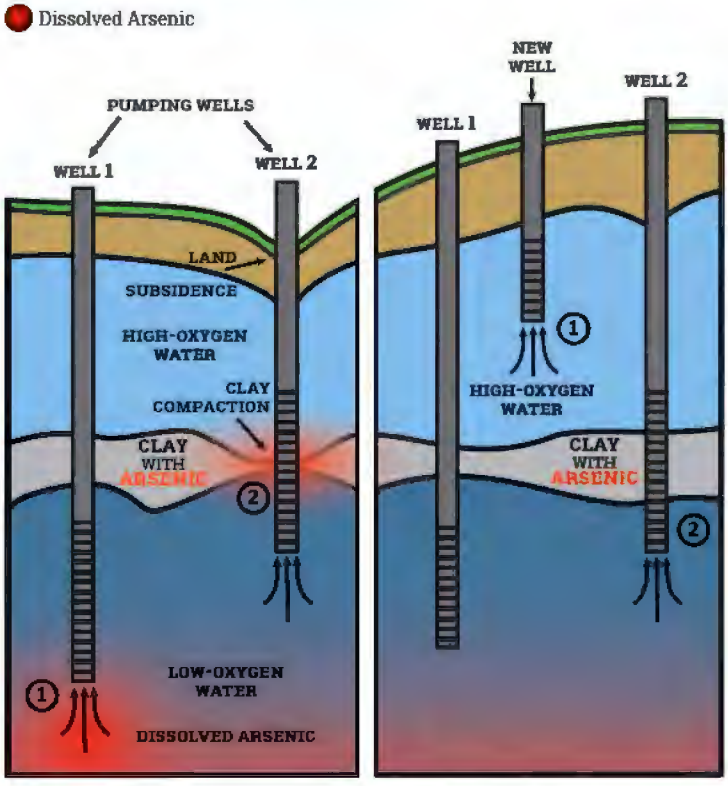
Many of the factors that cause naturally occurring contaminants to enter groundwater can be prevented or mitigated using a robust groundwater monitoring and information gathering strategy. Determining the best management technique often requires some trial-and-error. Recommendations include:

- Regularly measure levels of naturally occurring contaminants (arsenic, uranium, and chromium) in well as the conditions that can cause contamination (changes in pH, dissolved oxygen, nitrate, and electrical conductivity)
- Evaluate groundwater flow paths (for example, through the use of groundwater tracer tests) to know where contaminated water may travel over time, and use this information to strategically install monitoring wells that are upgradient of supply wells.
- Use well logs during well installation to ensure screen intervals are a maximum distance from clay layers.

ARSENIC *(Diagram B)*

PROBLEMS	SOLUTIONS
Low-oxygen conditions *(Diagram C)* When an aquifer becomes low in oxygen (~1% or lower dissolved oxygen), bacteria will dissolve the iron minerals that contain arsenic, and the arsenic itself will also change forms (from the molecule arsenate to arsenite). The outcome is an increase in dissolved arsenic in the groundwater. This is the most common cause of arsenic contamination of groundwater.	For a new well design or a well modification, avoid drawing groundwater from low oxygen zones if there is a concern about arsenic in that area.
Over-pumping Most wells draw groundwater from aquifers made of sand and gravel sediments, where water can be pumped out of the spaces between sediment grains. Aquifers can also have clay layers that may contain low-oxygen conditions and dissolved arsenic. When an aquifer is over-pumped, the clay layers can be compressed, squeezing the water with arsenic out from the clay and into the main aquifer.	Avoid over-pumping from confined aquifers to the point of clay compression (subsidence). Avoid drilling wells in aquifers with high clay content, or where pumped water may draw from clays containing arsenic.
An increase in pH When the pH of groundwater goes above 8.5, arsenic is displaced from mineral surfaces and dissolves into the groundwater.	Limit drawing from groundwater with pH greater than 8.5.

Diagram B: Problems and Solutions



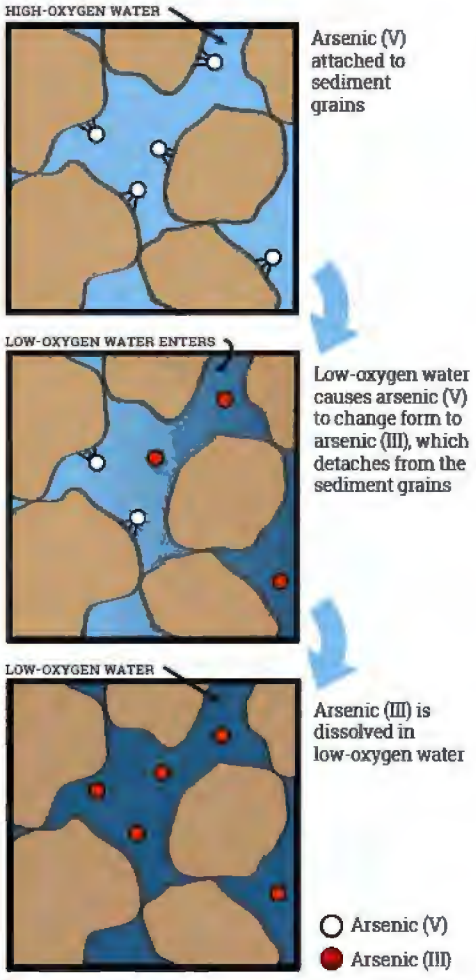
PROBLEMS

1. Low-oxygen conditions cause arsenic to dissolve into water pumped by Well 1.
2. Well 2 pumps at a high flow rate, causing the clay with arsenic to compact and high-arsenic pore water is "squished" out.

MANAGEMENT SOLUTIONS

1. New well drilled in an area with high-oxygen water and low dissolved arsenic.
2. Well 2 uses a lower flow rate, which stops high-arsenic water from coming out of the clay.

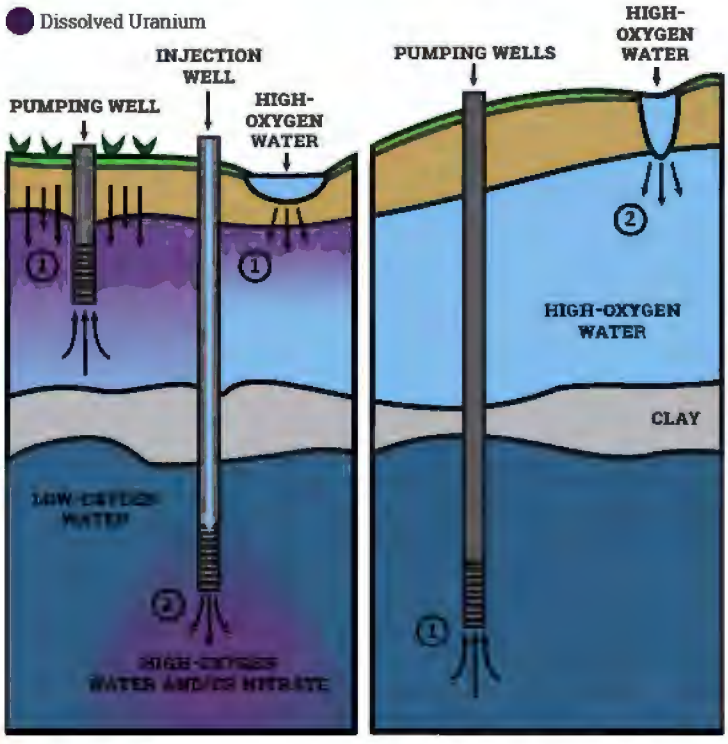
Diagram C: Arsenic dissolves in low-oxygen water (desorption)



URANIUM *(Diagram D)*

PROBLEMS *(Diagram E)*	SOLUTIONS
An increase in dissolved bicarbonate and calcium Uranium is often "stuck" (adsorbed) to the edges of sediments. When uranium comes into contact with dissolved bicarbonate and calcium, it can form large molecules that are easily dissolved, increasing uranium concentrations in groundwater. Bicarbonate and calcium are naturally present in soils and are usually more concentrated at the surface because of higher biological activity (plants and microorganisms) and evaporation. As a result, water percolating through the soils, will increase in calcium and bicarbonate, which increases dissolved uranium concentrations as well.	Natural infiltration through soil from rain or drip irrigation cannot be avoided. However, if uranium is present in the proposed recharge area, managed aquifer recharge (MAR) should limit percolation through soil with high bicarbonate and/or calcium content. If there are high levels of bicarbonate or calcium in the upper layers of the soil, using recharge ponds or ditches/canals excavated through the soil (~6 to 8 ft deep) may prevent uranium contamination.
An increase in nitrate or high-oxygen conditions When uranium is present in low-oxygen conditions, it does not dissolve into groundwater. However, when nitrate or high-oxygen water enter the aquifer, they can react with uranium and change it into a form that readily dissolves, increasing uranium concentrations in groundwater.	Avoid over-pumping from confined aquifers to the point of clay compression (subsidence). Avoid drilling wells in aquifers with high clay content, or where pumped water may draw from clays containing arsenic.
Drawdown of shallow groundwater Dissolved uranium concentrations are often higher in shallow groundwater, where there are high-oxygen conditions and more dissolved bicarbonate and calcium. High rates of pumping in deep wells may draw down this shallow water, increasing the amount of dissolved uranium in extracted water.	Monitor uranium content and prevent drawdown of shallow, uranium-rich groundwater by reducing pump rates or promoting injection wells as necessary.

Diagram D: Problems and Solutions



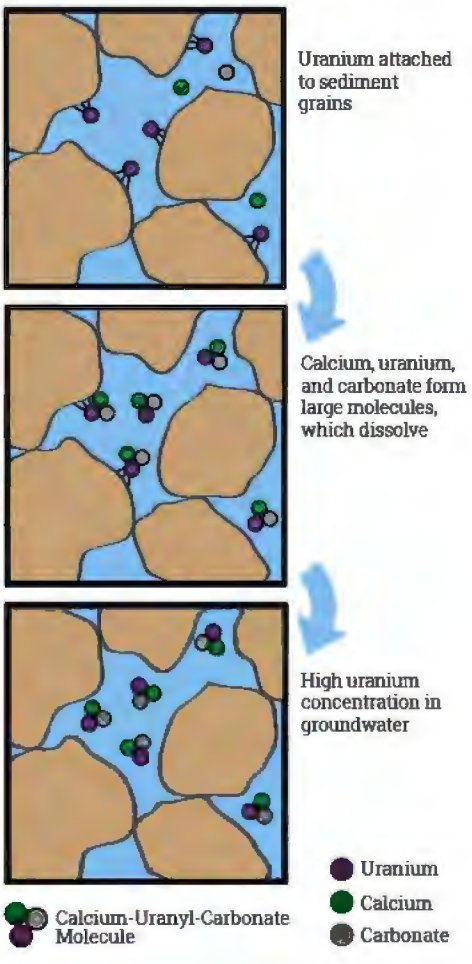
PROBLEMS

1. Recharge through vegetated area and infiltration pond leads to an increase in bicarbonate and calcium, which causes uranium to dissolve.
2. Injection well introduces high-oxygen water or nitrate, releasing uranium.

MANAGEMENT SOLUTIONS

1. Well pumps water from deeper aquifer without bicarbonate and calcium.
2. Managed aquifer recharge through excavated ditch prevents uranium contamination.

Diagram E: Uranium dissolves as part of molecule



Arsenic and Uranium, Combined Management

When dissolved arsenic and uranium are both present in groundwater, certain management practices can help to reduce concentrations of both elements:

- Maintain pH below 8.5 to limit dissolved arsenic. If pH exceeds 8.5, more investigation is necessary.
- If uranium is present in oxygen-rich zones, keep calcium and bicarbonate concentrations low to help to keep it out of the water.
- Prevent high rates of pumping that draw uranium from shallow groundwater or arsenic from low-oxygen zones.
- Monitor levels of arsenic, uranium, dissolved oxygen and oxidation-reduction potential (ORP) in groundwater. If arsenic concentrations increase, the aquifer may be low in oxygen. If uranium concentrations increase, the aquifer may be too oxygenated.
- For recharge project recommendations, please consult CWC's Protecting Drinking Water Under SGMA Guide.

What about CHROMIUM?

When dissolved arsenic and uranium are both present in groundwater, certain management practices can help to reduce concentrations of both elements:

- Increased groundwater pumping and fluctuations in groundwater levels;
- High-oxygen conditions at the surface generate hexavalent chromium, which is pulled down into the aquifer through recharge or pumping;
- Naturally occurring manganese converts trivalent to hexavalent chromium.

More research is needed to determine the best way to minimize hexavalent chromium production and concentrations in groundwater. Where active recharge is being conducted, following strategies for uranium mitigation is likely the best practice.

GLOSSARY:

- **Adsorbed:** "Stuck" to the edges of sediments.
- **Dissolved:** In liquid form; part of the groundwater.
- **High-oxygen and low-oxygen:** Conditions that reflect how much oxygen is dissolved into groundwater. High-oxygen conditions are sometimes called "aerated", while low-oxygen (~1% or lower dissolved oxygen) is called "reduced".
- **pH:** A measure of the acidity of the water. Groundwater pH is generally between 6.5 and 8.5. Water with lower pH is more acidic, while higher pH indicates alkaline (basic) conditions.
- **Naturally occurring:** Present within the rocks that make up the aquifer; not due to human activity.

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ACKNOWLEDGEMENTS:

This guide was made possible through generous support from Proposition 1 Sustainable Groundwater Planning grant funding from the California Department of Water Resources as well as with the support from the California Water Foundation, an initiative of the Resources Legacy Fund.

Factsheet authors from Stanford University:
Scott Fendorf
Allison Sherris
Aria Hamann
Arden Wells

Thank you to the many individuals who contributed their time and expertise to the development of this guide including:

Community Water Center staff:
Adriana Renteria, David Okita, Debi Ores, Heather Lukacs, Kelsey Hinton

Liesbet Olaerts
Self-Help Enterprises

Jennifer Clary
Clean Water Fund

Sarah Fakhreddine
Environmental Defense Fund

To learn more, contact Adriana Renteria at adriana.renteria@communitywatercenter.org or 559-733-0219.

COMMUNITY WATER CENTER
EL CENTRO COMUNITARIO POR EL AGUA
www.communitywatercenter.org

900 W. Oak Avenue
Visalia, CA, 93291
Tel. (559) 733-0219

716 10th Street, Suite 300
Sacramento, CA 95814
Tel. (916) 706-3346

406 Main Street, Suite 421
Watsonville, CA 95076
Tel. (831) 288-0450

Recycled Produced Water

Recycled Oilfield Produced Water Program

Cawelo Water District has been relying on produced water from oil operations for more than two decades — a reliable additional source of water that helps offset severe restrictions imposed due to the drought and environmental measures.

Kern County has a rich history in oil production, responsible for generating nearly three-quarters of California's oil production under some of the nation's most stringent environmental standards. Every barrel of oil produced also naturally generates approximately 15 barrels of water, called produced water.

Cawelo's produced water is treated by oil producers, filtered and then delivered to Cawelo, where it is blended with other supplies for agricultural use. Our District has a long history of complying with the water quality standards and testing/monitoring protocols established by the Central Valley Regional Water Quality Control Board (Regional Board).

It's important to note and clarify, water generated during hydraulic fracturing (also known as "fracking") is not used for agricultural purposes – a point that has been incorrectly reported in certain publications and promoted by opponents of oil production. Cawelo does not accept, use, or deliver water generated from hydraulic fracturing.

As the use of produced water expands, the Regional Board requested additional analysis from water districts relying on produced water – requiring testing for nearly 70 additional elements in order to evaluate water quality. Cawelo proactively engaged a third-party environmental toxicologist to analyze the data submitted to the Regional Board – studying levels of organic compounds in the irrigation water.

The third-party environmental toxicologist found that detected organic compounds were well within safe drinking water standards and Cawelo's produced water is safe for agricultural use. Initial water quality laboratory analysis reported the levels of acetone in Cawelo's produced water were 280 times below the maximum concentration considered safe for drinking water; and the level of petroleum hydrocarbons in Cawelo's produced water were 750 times below the maximum concentration considered safe for drinking water. What's more, the third-party environmental toxicologist conducted preliminary crop testing and found that crops irrigated with Cawelo's produced water had the same chemical composition as crops irrigated with other water supplies.

Cawelo is committed to working with the Regional Board and its expert panel in the next steps in this process to do its part and ensure produced water is governed within a strict regulatory framework and is a safe, reliable supply for California agriculture.

Cawelo is committed to working with the Regional Board and its expert panel in the next steps in this process to do its part and ensure produced water is governed within a strict regulatory framework and is a safe, reliable supply for California agriculture.

RPW INFORMATION

Recycled Produce Water Information

Fact Sheet

Root Crop Study Statement, Nov 2016

Citrus Study Statement

In Case You Missed It, Oct 2016

In Case You Missed It, July 2016

REPORTS

Citrus Crop Sampling Report, October 11, 2016

Water Quality Testing Results Presentation

Irrigation Water Quality Evaluation Report

Root Crop Sampling and Analysis Report Technical Memorandum, November 2, 2016

MEETING INFORMATION, FOOD SAFETY EXPERT PANEL

Food Safety Expert Panel, Central Valley Regional Water Quality Control Board

Food Safety Panel Presentation, October 28, 2017

Hazard Assessment of Chemical Additives Used in Oil Fields that Reuse Produced Water for Agricultural Irrigation, Livestock Watering, and Groundwater Recharge in The San Joaquin Valley of California: Preliminary Results

Authors:

Seth B.C. Shonkoff, PhD, MPH[1,2,3]

William T. Stringfellow, PhD[3,4]

Jeremy K. Domen, MS[3,4]

[1] PSE Healthy Energy, Inc., Oakland, CA

[2] Department of Environmental Science, Policy, and Management, University of California, Berkeley

[3] Earth & Environmental Sciences Area, Lawrence Berkeley National Laboratory

[4] Ecological Engineering Research Program, University of the Pacific









Technical Report

September 2016

About PSE Healthy Energy

PSE Healthy Energy is a non-profit energy science and policy research institute dedicated to supplying evidence-based, scientific and technical information and resources on the public health, environmental and climate dimensions of energy production and use. Our work predominantly focuses on oil and gas development, power generation, and clean energy transitions. The mission of PSE Healthy Energy is to bring scientific transparency and clarity to energy policy discussions, helping to level the playing field for citizens, communities, the media, and decision makers by generating, translating, and disseminating scientific information. No other interdisciplinary collaboration of physicians, scientists, and engineers exists to focus specifically on health and sustainability at the intersection of energy science and policy. PSE Healthy Energy has offices in Oakland, CA, Ithaca, NY, and New York, NY.

About Berkeley National Laboratory

Berkeley Lab is a member of the national laboratory system supported by the U.S. Department of Energy through its Office of Science. It is managed by the University of California (UC) and is charged with conducting unclassified research across a wide range of scientific disciplines. Berkeley Lab was founded in 1931 by Ernest Orlando Lawrence, a UC Berkeley physicist who won the 1939 Nobel Prize in physics for his invention of the cyclotron, a circular particle accelerator that opened the door to high-energy physics. It was Lawrence's belief that scientific research is best done through teams of individuals with different fields of expertise, working together. His teamwork concept is a Berkeley Lab legacy that continues today.

About the University of the Pacific

University of the Pacific's mission is to provide a superior, student-centered learning experience integrating liberal arts and professional education and preparing individuals for lasting achievement and responsible leadership in their careers and communities. University of the Pacific is an independent, coeducational university serving more than 6,400 students on three campuses in Stockton, San Francisco and Sacramento. It was established by pioneering Methodist ministers in 1851 as California's first chartered institution of higher learning.

Please Cite This Report as:
Shonkoff, SBC, Stringfellow, WT, Domen, JK. 2016 (September 2016). Preliminary Hazard Assessment of Chemical Additives Used in Oil and Gas Fields that Reuse Their Produced Water for Agricultural Irrigation in The San Joaquin Valley of California. Technical Report. PSE Healthy Energy, Inc. Oakland, CA.

INTRODUCTION

Oil field produced water has been used to irrigate food crops in the Cawelo Water District since the mid-1990s. The practice has recently been expanded to the North Kern Water Storage District and produced water is being examined widely as a potential source of water for agriculture, livestock watering, drinking water and other uses. One important knowledge gap with respect to assessing potential human health and environmental hazards associated with reuse of oil field produced water for irrigation is an understanding of the types and amounts of chemical additives used during oil and gas development.

Disclosure of chemical use during oil and gas development is considered an important component for understanding the potential risks associated with hydraulic fracturing and other well stimulation activities and disclosure is an important component of creating effective regulation of hazardous chemicals. For instance, regulations developed under California Senate Bill 4 require the reporting and public disclosure of chemical additives used for hydraulic fracturing and other well stimulation activities common to oil and gas development. These disclosure requirements, however, do not apply to other common or routine oil and gas field activities such as drilling, well maintenance, routine acidizing, and well completions (State of California 2013). Hazardous chemicals are used throughout the entire oil and gas development process, not just during well stimulations (Economides et al. 2013; Fink 2015; Hudgins 1992; Hudgins 1994; Kelland 2014). Recent research shows that many of the same chemicals used in hydraulic fracturing and well stimulation are also used for other purposes in oil and gas development (Shonkoff et al. 2016; Shonkoff et al., under review).

The Central Valley Regional Water Quality Control Board (CVRWQCB) is investigating the use of produced water for agriculture and one of the issues being examined by the CVRWQCB and other stakeholders is how the use of chemicals for oil and gas production, including chemicals used in produced water management, may impact the quality and safety of produced water used for agriculture, including livestock watering, and recharging regional aquifers (CVRWQCB 2012).

To understand chemical use in fields that provide produced water for agricultural irrigation, livestock watering, and recharging aquifers, under the authority of the California Water Code section 13267, the CVRWQCB ordered seven California oil and gas operators (Chevron USA, Inc.; Valley Water Management Company; California Resources Production Corporation; Bellaire Oil Company; Hathaway, LLC; Little Creek Properties/Daybreak Oil and Gas, Inc.; and Modus, Inc.) to provide information regarding chemical use in the oil and gas fields that provide

produced water for crop irrigation and livestock watering in the Cawelo Water District and the North Kern Water Storage District in the San Joaquin Valley pursuant to section 13267 of the California Water Code. The resulting chemical disclosures included information from oil and gas development operations in the Deer Creek, Mount Poso, Jasmin, Kern Front, and Kern River oil fields from the period of January 2014 to June 2016. This information included the types and amounts of chemical additives used in oil and gas development operations as well as the volume of produced water provided for irrigation.

Here we report the preliminary findings of our analysis of the chemical data disclosed in response to the 13267 orders from the CVRWQCB. In this preliminary analysis, we provide the list of chemicals reported in the context of their acute mammalian and ecological toxicities, biodegradability, bioaccumulation potential, carcinogenicity, and whether chemicals are included on specific chemical priority lists. The purpose of this analysis is to identify potential chemicals of concern as a first step prior to more complete human health and environmental hazard and risk analyses. Actual hazards associated with a chemical are dependent on numerous factors, including the mass of chemical used, the physical properties of the chemical, and many other variables that are not explored in this report of preliminary findings. Assessing the risks associated with chemical use (e.g., the probability that a chemical or group of chemicals will cause harm) requires an understanding of the frequency, mass, and context of chemical use, including potential exposure pathways, and is beyond the scope of this short technical report of preliminary findings.

The findings of this report belong to the co-authors and do not necessarily represent the opinions of the Food Safety Expert Panel convened by the Central Valley Regional Water Quality Control Board in California, or any other party.

METHODS

Data collected under the authority of the California Water Code section 13267 by the CVRWQCB from Chevron USA, Inc.; Valley Water Management Company; California Resources Production Corporation; Bellaire Oil Company; Hathaway, LLC; Little Creek Properties/Daybreak Oil and Gas, Inc.; and Modus, Inc. was downloaded from the Oil Fields – Food Safety website[1] for analysis. The disclosures included operations in the Deer Creek, Mount Poso, Jasmin, Kern Front, and Kern River oil fields from the period of January 2014 to June 2016.

[1] http://www.waterboards.ca.gov/centralvalley/water_issues/oil_fields/food_safety/index.shtml

Chemical entries were edited to standardize chemical names and to validate the assigned Chemical Abstracts Services Registry Number (CASRN). Changes to names of proprietary chemicals that could not be identified by CASRN were limited to correcting obvious spelling errors, changing capitalization, and altering punctuation. For chemical constituents identified with unique CASRN, physical, chemical, and toxicological data were collected from material safety data sheets (MSDS) and various online chemical databases including: U.S. National Library of Medicine TOXNET, Japan's National Institute of Technology and Evaluation Chemical Risk Information Platform, U.S. EPA's ECOTOX, U.S. EPA's Aggregated Computational Toxicology Resource (ACToR), European Chemical Agency's International Uniform Chemical Information Database (IUCLID), American Chemical Society's SciFinder, and International Agency for Research on Cancer (IARC) Monographs. Computational estimates from U.S. EPA EPISuite software were used to fill in data gaps when available.

In addition to chemical, physical, and toxicological properties, the disclosed chemicals were compared to various state, federal, and international lists of chemicals of concern. These lists included the California Proposition 65 Chemicals Known to the State of California to Cause Cancer or Reproductive Toxicity List, European Union REACH Substances of Very High Concern (SVHC) Candidate and Authorization Lists, U.S. EPA National Primary Drinking Water Standards (NPDWS) and Advisory Chemicals, U.S. EPA Contaminate Candidate List 4 (CCL4), California EPA Toxic Air Contaminant List (TAC), U.S. EPA Clean Air Act Hazardous Air Pollutant List, and the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) Substances that Pose Little or No Risk (PLONOR) to the environment, Substances of Possible Concern, and Priority Action Chemicals lists.

Rat, mouse, and rabbit acute oral toxicity data were collected to represent mammalian toxicity; and data for water flea (*Daphnia magna*), fathead minnow (*Pimephales promelas*), rainbow trout (*Oncorhynchus mykiss*), and green algae were collected to represent ecotoxicity. All green algae toxicity data were computational estimates from U.S EPA's EPISuite software. Toxicity ratings were assigned according to the United Nations Globally Harmonized System (GHS) of Classification and Labelling of Chemicals (United Nations 2015) for acute toxicity and acute ecotoxicity hazards. In the GHS system, lower numbers indicate higher toxicity, with a designation of "1" indicating the most toxic category.

Biodegradability data were categorized according to OECD criteria for biodegradability (OECD 1992). Bioconcentration-factor (BCF) data were calculated using U.S. EPA EPISuite software and categorized according to U.S. EPA criteria for bioaccumulation (Federal Register 1999).

RESULTS & DISCUSSION

A total of 173 chemical constituents were identified by unique name or CASRN. Of these 173 chemicals, 66 (38%) were classified as "trade secret" or did not have an associated valid CASRN and could not be positively identified. The remaining 107 chemicals (62%) were identified by CASRN, a definitive identifier, and could therefore be further evaluated for physical, chemical, and toxicological properties.

An evaluation of acute toxicity data (Table 1) shows that only five chemicals were classified GHS category 2 for oral mammalian toxicity and no chemicals were GHS category 1, the most toxic category. In contrast, a total of 39 chemicals (36%) were classified as GHS category 1 or 2 for ecotoxicity, indicating that the chemicals may pose a significant hazard to aquatic environments. Fourteen chemicals (13%) had no available ecotoxicity or mammalian toxicity data and could not be ranked or evaluated (Table 2). Chemicals without published toxicity data should be evaluated further.

Table 1. Summary of the numbers of chemicals with available toxicity data and a CASRN in each GHS toxicity category

	Acute Oral Mammalian Toxicity GHS (rat, mouse, and rabbit)	Acute Ecotoxicity GHS (*Daphnia magna*, fathead minnow, rainbow trout, and green algae [computational])
GHS 1	0	18
GHS 2	5	21
GHS 3	11	15
GHS 4	22	-
GHS 5	19	-
> GHS 5*	22	34
No data	28	19
Total	107	107

*Greater than GHS 3 for ecotoxicity values

Of the 107 chemicals with CASRN, eight appeared on California's Prop 65 list, eight were on the U.S. EPA NPDWS and Health Advisory Chemical list, three were on the U.S. EPA CCL4, twenty-two were on the California EPA Toxic Air Contaminant list, and eleven are considered hazardous air pollutants according to the Clean Air Act (Table 3). A total of ten chemicals were classified by the International Agency for Research on Cancer (IARC) as either carcinogenic or possibly carcinogenic in humans (Table 4). Inclusion on these lists suggests that these chemicals are recognized as being hazardous and subject to regulatory control under at least some circumstances.

Table 2. Chemicals with a CASRN for which no ecotoxicity or mammalian toxicity data was found.

Chemical Name	CASRN
Aluminum chloride hydroxide	12042-91-0
Gypsum	13397-24-5
Lignite	1415-93-6
Xenon radionuclide	14932-42-4
Silica, crystalline, tridymite	15468-32-3
Aluminum stearate	300-92-5
Lithium chlorate	36355-96-1
Polyamine	64114-46-1
Coke, petroleum, calcined	64743-05-1
Cottonseed hulls	68308-87-2
Fatty acid oxyalkylate	70142-34-6
Krypton	7439-90-9
Hydroxyethyl cellulose	9004-62-0
Cellophane	9005-81-6

Table 3. Chemicals with a CASRN that are on National and State Priority Lists

Chemical Name	CASRN	California Prop 65	EPA NPDWS and Health Advisory Chemical	EPA CCL4	CA EPA Toxic Air Contaminant List*	Clean Air Act Hazardous Pollutant
Ethylbenzene	100-41-4	X	X		2a	X
Ethylene glycol	107-21-1	X	X	X	2a	X
Toluene	108-88-3	X	X		2a	X
Antimony trioxide	1309-64-4	X			2a	
Lithium carbonate	554-13-2	X				
Methanol	67-56-1	X		X	2a	X
Naphthalene	91-20-3	X	X		2a	X
Cumene	98-82-8	X	X		4a	X
1,3,5 Trimethylbenzene	108-67-8		X			
Xylene	1330-20-7		X		2a	X
1,2,4 Trimethylbenzene	95-63-6		X		4b	
Acrolein	107-02-8			X	2a	X
Glutaraldehyde	111-30-8				2b	
2-Butoxyethanol	111-76-2				2a	
Hydroquinone	123-31-9				4a	X
Sodium hydroxide	1310-73-2				2b	
Isopropanol	67-63-0				2b	
Amorphous silica	7631-86-9				3	
Hydrochloric acid	7647-01-0				2a	X
Phosphoric acid	7664-38-2				2b	
Hydrofluoric acid	7664-39-3				2a	X
Sulfuric acid	7664-93-9				2b	
Ammonium sulfate	7783-20-2				4b	
Peroxyacetic acid	79-21-0				4b	

*CA EPA Toxic Air Contaminant List Categories:

2a: Substances identified as Toxic Air Contaminants, known to be emitted in California, with one or more health values under development by the Office of Environmental Health Hazard Assessment (OEHHA) for review by the Scientific Review Panel.
2b: Substances NOT identified as Toxic Air Contaminants, known to be emitted in California, with one or more health values under development by the OEHHA for review by the Scientific Review Panel.
3: Substances known to be emitted in California and are NOMINATED for development of health values or additional health values
4a: Substance identified as Toxic Air Contaminants, known to be emitted in California and are TO BE EVALUATED for entry into Category III.
4b: Substance NOT identified as Toxic Air Contaminants, known to be emitted in California and are TO BE EVALUATED for entry into Category III.

Table 4. Chemicals with a CASRN categorized as carcinogenic or possibly carcinogenic by the IARC

Chemical Name	CASRN	IARC Group	IARC Meaning
Crystalline silica (quartz)	14808-60-7	1	Carcinogenic to humans
Xenon radionuclide	14932-42-4	1	Carcinogenic to humans
Silica, crystalline, tridymite	15468-32-3	1	Carcinogenic to humans
Ethanol	64-17-5	1	Carcinogenic to humans
Sulfuric acid	7664-93-9	1	Carcinogenic to humans
Nickel sulfate	7786-81-4	1	Carcinogenic to humans
Ethylbenzene	100-41-4	2B	Possibly carcinogenic to humans
Antimony trioxide	1309-64-4	2B	Possibly carcinogenic to humans
Naphthalene	91-20-3	2B	Possibly carcinogenic to humans
Cumene	98-82-8	2B	Possibly carcinogenic to humans

Twenty-five chemicals (23%) were found on the OSPAR Commission List of Substances that Pose Little or No Risk (PLONOR) to the environment (Table 5). OSPAR is a treaty governing oil and gas development in the North Sea (OSPAR 2016) and chemicals on the PLONAR list are allowed for use during off-shore development and may be discharged with produced water at low concentrations to marine environments with no expected negative impacts. These chemicals are primarily inert minerals, salts, and readily biodegradable substances. However, it is important to note that the OSPAR list was developed for discharge into saline, marine environments and may not be directly applicable to irrigation, livestock watering, groundwater recharge, and other reuse practices that may have different human and environmental consequences. For instance, methanol and ethylene glycol are on the OSPAR list, but also are found on National and State Priority lists (Table 3).

Table 5. Chemicals on the OSPAR List of Substances that Pose Little or No Risk (PLONOR) to the Environment

Chemical Name	CASRN	Chemical Name	CASRN
Ammonium bisulfate	10192-30-0	Methanol	67-56-1
Ethylene glycol	107-21-1	Isopropanol	67-63-0
Xanthan gum	11138-66-2	Potassium chloride	7447-40-7
Ammonium chloride	12125-02-9	Amorphous silica	7631-86-9
Sodium acetate	127-09-3	Sodium chloride	7647-14-5
Bentonite	1302-78-9	Citric acid	77-92-9
Sodium bicarbonate	144-55-8	Sodium sulfate	7757-82-6
Crystalline silica (quartz)	14808-60-7	Disodium dihydrogen diphosphate	7758-16-9
Calcium carbonate	471-34-1	Graphite	7782-42-5
Sodium carbonate	497-19-8	Carboxymethyl cellulose sodium salt	9004-32-4
Urea	57-13-6	Cellulose	9004-34-6
Ethanol	64-17-5	Hydroxyethyl cellulose	9004-62-0
Acetic acid	64-19-7		

The OSPAR Commission and other European agencies also have lists of banned chemicals or chemicals of concern (ChemSafetyPro 2016). No chemicals reported under the 13267 order appeared on the OSPAR List of Substances of Possible Concern, the OSPAR List of Chemicals for Priority Action, or the European Chemicals Agency Candidate List of Substances of Very High Concern for Authorization.

Biodegradability is a major determinant for environmental persistence of chemical compounds, and it is known that that chemicals susceptible to rapid biodegradation are less likely to cause long term environmental impacts if released into the environment. The biodegradability of organic chemicals can be measured and compared using standardized tests (e.g. 40 CFR 796.3100 - Aerobic aquatic biodegradation). Of the 107 chemicals with CASRN, 40 were classified as inorganic and were not evaluated using standard organic chemical biodegradation protocols. The majority of the organic chemicals for which data could be found were biodegradable, but twelve chemicals were determined to be resistant to biodegradation (not readily biodegradable) and three were found to be not biodegradable in the standard aerobic test (Table 6). Of the compounds found to be non-biodegradable in standardized tests, scientific literature suggests that the trimethylbenzene isomers should biodegrade eventually in the environment (e.g. Häner *et al*. 1997). In addition, bioconcentration-factor data, a standard measure for bioaccumulation potential, was available for 86 chemicals, of which only one fell in the bioaccumulative range. The remaining 85 chemicals were classified as non-bioaccumulative (Table 7). These results suggest that most additives that could be characterized are unlikely to persist or accumulate in the environment if released, but some compounds should be further evaluated for persistence and bioaccumulation in the environment. Standardized measurements should be made on chemicals that are not yet characterized. We were unable to evaluate the

biodegradation and bioaccumulative properties of those chemicals that lacked a disclosed CASRN.

Table 6. Summary of available biodegradability data

Category	Count
Readily Biodegradable	34
Inherently Biodegradable	4
Biodegradable	2
Not readily biodegradable	12
Non-biodegradable	3
Inorganic	40
No Data	12

A separate list of chemicals approved by Chevron and California Resources Corporation (CRC) for use their oil and gas operations that provide produced water for irrigation was provided by the Central Valley Regional Water Quality Control Board in California. This list contained a total of 108 chemicals, 72 of which were identified by unique CASRN. When these two lists were cross referenced, only 52 chemicals with CASRN appeared on both lists.

Table 7. Bioconcentration-factor categorization

Category	Criteria (BCF)	Count
Non bioaccumulative	<1000	85
Bioaccumulative	1000-5000	1*
Very bioaccumulative	≥5000	0

*The one chemical is Siloxanes and Silicones (63148-62-9)

Table 8 is a list of potential chemicals of concern identified through this initial screening process. This list contains the chemicals with GHS 1 ecotoxicity, GHS 2 mammalian toxicity, California Proposition 65, IARC Groups 1 and 2b, NPDWS, non-biodegradable, and bioaccumulative chemicals identified in our analysis. Since the focus of this analysis is on water, we excluded CA EPA TAC and Clean Air Act Chemicals unless they met one of the other criteria for inclusion. Hydrofluoric acid was also included on the potential chemicals of concern list as it is classified as a GHS 1 hazard based on mammalian inhalation toxicity. Inhalation toxicity analysis was otherwise left of out of this preliminary chemical screen, but has been included as a criteria in previous studies (Stringfellow *et al.* 2015). Finally, chemicals with no toxicity data available that were minerals (lignite, gypsum) or not expected to be toxic (hydroxyethyl cellulose, krypton, cottonseed hulls) were not included in Table 8. Chemicals that did not have a unique CASRN or are marked as trade secrets are also of potential concern given the lack of information available for a hazard assessment.

Table 8. Oil and gas field chemical additives with CASRN identified by preliminary analysis as potential chemicals of concern. The last column on the right indicates why they appear on this table.

Name	CASRN	Why compound appears on table*
Ethylbenzene	100-41-4	Prop 65, NPDWS, IARC 2B, CA TAC, CAA
Ethylene glycol	107-21-1	Prop 65, NPDWS, CCL4, CA TAC, CAA
Toluene	108-88-3	Prop 65, NPDWS, CA TAC, CAA
Antimony trioxide	1309-64-4	Prop 65, IARC 2B, CA TAC
Lithium carbonate	554-13-2	Prop 65
Methanol	67-56-1	Prop 65, CCL4, CA TAC, CAA
Naphthalene	91-20-3	Prop 65, GHS1 ECO, IARC 2B, NPDWS, CA TAC, CAA
Cumene	98-82-8	Prop 65, IARC 2B, NPDWS, CA TAC, CAA
Xylene	1330-20-7	NPDWS, CA TAC, CAA
1,3,5 Trimethylbenzene	108-67-8	Non-biodegradable[§], NPDWS
Isoquinoline	119-65-3	Non-biodegradable[§]
1,2,3 Trimethylbenzene	526-73-8	Non-biodegradable[§], NPDWS
Siloxanes and silicones	63148-62-9	Bioaccumulative, GHS1 ECO
Glutaraldehyde	111-30-8	GHS1 ECO, CA TAC
Hydroquinone	123-31-9	GHS1 ECO, CA TAC, CAA
Lithium hypochlorite	13840-33-0	GHS1 ECO
Sodium dichloroisocyanurate	2893-78-9	GHS1 ECO
Heavy aromatic naphtha	64742-94-5	GHS1 ECO
Iodine	7553-56-2	GHS1 ECO
Zinc chloride	7646-85-7	GHS1 ECO
Hydrochloric acid	7647-01-0	GHS1 ECO, CA TAC, CAA
Sodium hypochlorite	7681-52-9	GHS1 ECO
Copper sulfate pentahydrate	7758-99-8	GHS1 ECO
Hydrotreated light distillate	64742-47-8	GHS1 ECO
Stearic acid	57-11-4	GHS1 ECO
Kerosene	8008-20-6	GHS1 ECO
Dinonylphenyl polyoxyethylene	9014-93-1	GHS1 ECO
Acrolein	107-02-8	GHS2 MAM, GHS1 ECO, CCL4, CA TAC, CAA
Propargyl alcohol	107-19-7	GHS2 MAM
Cyclohexylamine	108-91-8	GHS2 MAM
Ethyl acetate	141-78-6	GHS2 MAM
Stoddard solvents	8052-41-3	GHS2 MAM, GHS1 ECO
Crystalline silica (quartz)	14808-60-7	IARC 1
Xenon radionuclide	14932-42-4	IARC 1, No toxicity data
Silica, crystalline, tridymite	15468-32-3	IARC 1, No toxicity data
Ethanol	64-17-5	IARC 1
Sulfuric acid	7664-93-9	IARC 1, CA TAC
Nickel sulfate	7786-81-4	IARC 1
Hydrofluoric acid	7664-39-3	CA TAC, CAA
Aluminum chloride hydroxide	12042-91-0	No toxicity data
Aluminum stearate	300-92-5	No toxicity data
Lithium chlorate	36355-96-1	No toxicity data
Polyamine	64114-46-1	No toxicity data
Coke, petroleum, calcined	64743-05-1	No toxicity data
Fatty acid oxyalkylate	70142-34-6	No toxicity data
Cellophane	9005-81-6	No toxicity data

*GHS1 ECO = GHS Category 1 for Acute Ecotoxicity

GHS2 MAM = GHS Category 2 for Acute Mammalian Oral Toxicity
IARC 1 = International Agency for Research on Cancer Group 1 (Carcinogenic to humans)
IARC 2B = International Agency for Research on Cancer Group 2B (Possibly carcinogenic to humans)
NPDWS = U.S. EPA National Primary Drinking Water Standards and Health Advisory Chemical
CCL4 = U.S. EPA Contaminant Candidate List 4
Prop 65 = California Proposition 65
CA TAC = CA EPA Toxic Air Contaminant
CAA = Clean Air Act Hazardous Pollutant
§Found non-biodegradable in standard aerobic test.

SUMMARY

In this preliminary assessment, we evaluated the list of chemicals reported as used in oil fields from which produced water is deployed for irrigation, for watering livestock, and for recharging groundwater in the San Joaquin Valley of California. We found a total of 173 different chemical additives were used in these oil and gas fields, of which more than one-third (38%) were not able to be sufficiently identified for preliminary hazard evaluation, largely due to the withholding of information under proprietary claims. Over 100 chemicals (62% of the total list) were identified by CASRN for acute toxicological properties, biodegradability, and environmental persistence using publically available data and toxicological screening software. The CASRN identified oil and gas field additives were also cross-referenced with a variety of lists used to identify or regulate chemicals suspected or known to cause negative environmental or health impacts if released into the environment. Of the chemicals that had a CASRN, we found that 46 (43%) of them can be classified as potential chemicals of concern from human health and/or environmental perspectives and require a more thorough investigation (Table 8).

RECOMMENDED NEXT STEPS

Standardized measurements for toxicity and environmental persistence, including biodegradability, should be made on all chemicals that are not yet characterized. Our analysis suggests that most additives that could be characterized are unlikely to persist or accumulate in the environment if released, but some compounds need to be further evaluated for persistence and bioaccumulation. In addition to acute toxicity data, chronic toxicity data should be collected for all chemicals and analyzed to assess potential longer-term human health or environmental hazards associated with the use of oil field produced water for agricultural irrigation, livestock watering, and aquifer recharge. Screening chemical constituents for other attributes that may cause human health or environmental impacts, such as endocrine disrupting activity should also be considered.

Future analysis should evaluate the mass and frequency of chemical use, which is an important determinant of both hazard and risk (Shonkoff *et al.* 2015; Stringfellow, *et al.* 2015). The chemical disclosures evaluated in this study frequently provided chemical constituent concentrations and chemical usage data on a volumetric basis, however density values are also needed for mass calculations. We recommend that the *mass* of each chemical used be provided by the operators as part of disclosures, to avoid miscommunication and possible error in determining how much of each chemical additive is used in the oil and gas fields.

We did not evaluate chemicals that were not identified by CASRN and the use of proprietary chemicals should be further evaluated. It is difficult or impossible to estimate risks to consumers, farmworkers, or the environment, when identification of chemical additives remains in trade secret form and/or lacks toxicity and environmental profile information.

Hazardous chemical are only a risk if they are released into the environment in sufficient quantities to cause harm and have a pathway to reach sensitive receptors, such as animals or humans. Hazardous chemicals potentially found in produced water include both the oil field chemical additives, identified here, and naturally occurring contaminants such as metals and hydrocarbons that originate from the geological reservoir. In order to identify potential pathways for environmental release and exposure, it is recommended that a literature review be conducted to establish what is known about the fate and transport of these contaminants, especially in the context of agricultural ecosystems. It is recommended that a thorough literature review include chemical uptake by crops and livestock. The review should be interpreted specifically in the context of current produced water reuse practices in California.

Oil field produced water is being used to recharge aquifers to maintain regional groundwater supplies for agriculture, however regional aquifers can also be used for domestic water supply (including drinking water). Given the direct nature of this potential human exposure pathway, further investigation of the use of produced water for groundwater recharge is warranted. This investigation could include a scientific analysis of existing data combined with field studies as needed.

Many of the chemicals used on oil fields do not have standard analytical protocols for their detection in water, so current water quality monitoring programs are mainly focused on naturally occurring contaminants (e.g. hydrocarbons, metals). It is recommended that standard methods for the analysis of oil field chemicals be developed and validated for use in water quality monitoring. The development of monitoring tools would be a useful step for insuring adequate protections are in place. Methods for monitoring these chemicals in soils and crops may also be needed if an analysis of pathways suggest the potential for crop uptake.

Finally, naturally occurring chemical constituents and chemical additives when combined in various surface and subsurface oil and gas development and produced water processing activities may interact under envrionments of elevated temperatures and pressures to form new substances. An investigation beyond the individual chemical constituents to evaluate chemical hazard and risk attributable to these synergistic products may also be warranted.

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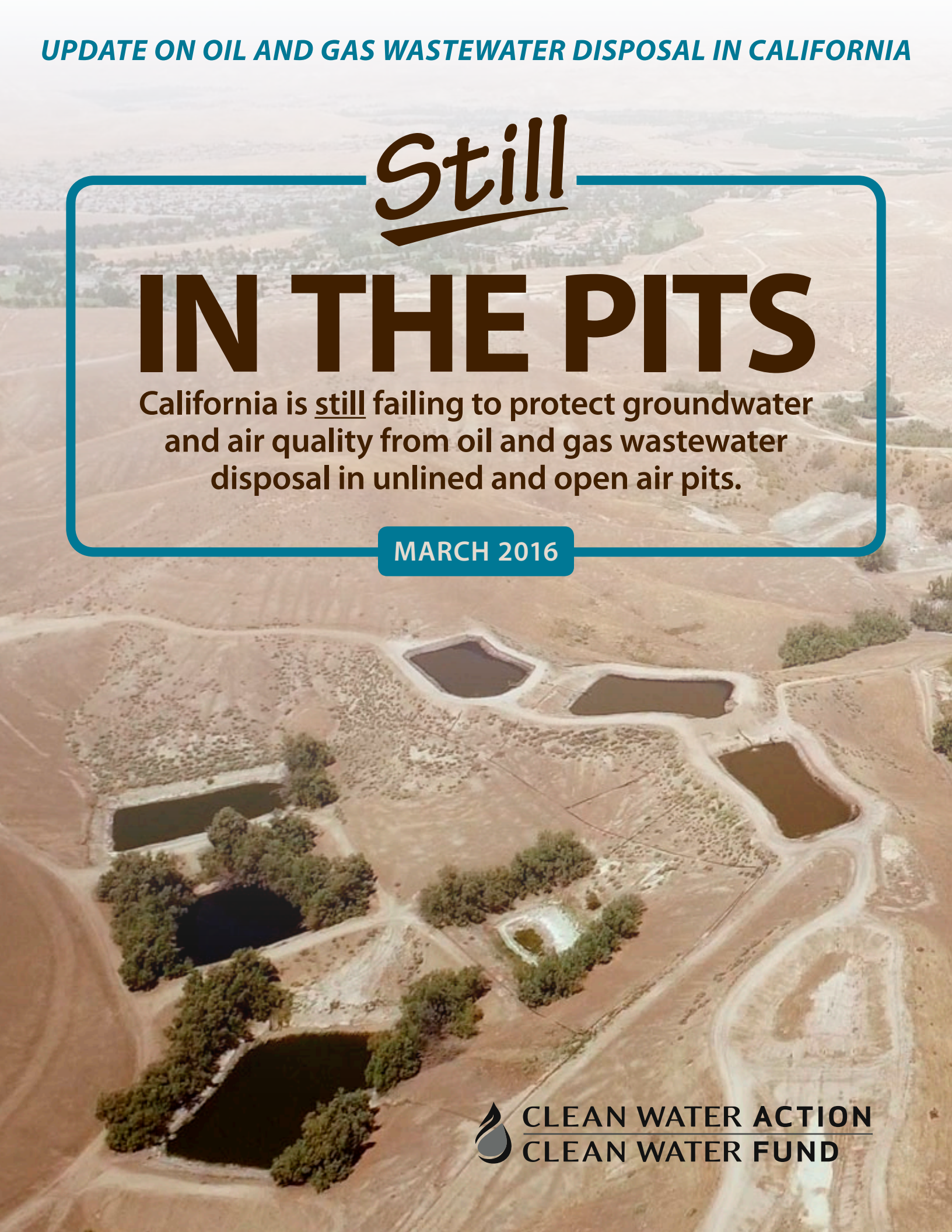
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UPDATE ON OIL AND GAS WASTEWATER DISPOSAL IN CALIFORNIA

Still IN THE PITS

California is <u>still</u> failing to protect groundwater and air quality from oil and gas wastewater disposal in unlined and open air pits.

MARCH 2016



CLEAN WATER ACTION
CLEAN WATER FUND

Acknowledgements

This report was written by Andrew Grinberg, Clean Water Action/Clean Water Fund.

Kyle Ferrar from the FracTracker Alliance provided technical support for this report, conducting the analysis and mapping contained within. An interactive map of pits in California, created by FracTracker, can be viewed at: **http://bit.ly/CAPitMap**

The following Clean Water Action/Clean Water Fund staff provided review and assistance: Miriam Gordon, Keith Nakatani, Matt Davis and Michael Kelly.

Clean Water Fund is grateful to the following funders for supporting this work:

The Broad Reach Fund

The 11th Hour Project

NextGen Climate Action

Patagonia

Clean Water Action thanks The Tides Advocacy Fund for supporting this work.

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Cover Photo: Racetrack Hills facility, Kern County, CA. Photo courtesy of 'Pistachio Production'.

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Executive Summary

In 2014, Clean Water Action released *In the Pits: Oil and Gas Wastewater Disposal into Open Unlined Pits and the Threat to California's Water and Air*. Our investigation found evidence of harm to both groundwater and air quality, and major regulatory and enforcement gaps. We called for an immediate prohibition on open pit disposal, insisted that the state hold polluters accountable for cleaning up contamination, and demanded increased monitoring for water and air pollution.

Since *In the Pits* was released, the public and regulatory communities' understanding of oil and gas wastewater pits has increased and state and regional agencies have made significant progress in their approach to regulating oil and gas wastewater disposal. However, there are still substantial deficiencies in the state's oversight of these disposal practices. The report includes our findings that:

The continued gaps in data and monitoring indicate that regulators are unable to ensure the protection of drinking and irrigation water. Following increased scrutiny from the environmental community, the media, and the public, there has been a significant increase in scientific study, data collection and thereby the public's understanding of the historic use and threats posed by disposal pits. There is growing evidence of pollution and the California Council on Science and Technology (CCST) has recommended ending this disposal method, a recommendation that Clean Water Action made in *In the Pits*. However, there are still major gaps in data collection and dissemination, including inadequate chemical testing of produced water in pits. The continued shortcomings in data collection, monitoring and chemical disclosure highlight the inadequacies of the state's efforts to regulate disposal of wastewater into unlined pits and its inability to protect drinking and irrigation water from this disposal method.

Improved regulatory action, but still not enough. Oversight of pits has increased and agencies have begun to regulate the hundreds of unpermitted pits. The Central Valley Regional Water Quality Control Board has increased staffing and focused attention on the problem of disposal pits. There are new plans for monitoring air and groundwater near pits, and pit disposal from stimulated wells is now prohibited. However, in most cases, the Regional Water Boards have continued to allow discharge that threatens groundwater, and have failed to close pit facilities, even where monitoring has identified underground migration of harmful chemicals, or when they are operating illegally — either without permits, or impacting water quality. This regulatory inaction demonstrates that the public cannot rely on the current regulatory approach to protect public health and the environment.

Improved understanding of where pits are located and their regulatory status. Since 2014, the known number of pits has changed dramatically: Updated numbers as of February 2016:

- 1165 total pits, 790 of which are active — compared to 2014 inventories showing 630 total and 432 active pits. The vast majority (1113 total, 746 active) are in the Central Valley. The Central Coast Regional Water Quality Control Board has now also identified 52 pits (44 of which are active).

The public now knows how many pits are not regulated adequately either by failing to have a permit to operate or possessing a permit that is so old that it predates regional water policies.

- 60.1% (475) active pits, and 68.9% (803) of all pits are inadequately permitted. These pits either do not have a permit, or have a permit that was issued prior to adoption of the local Basin Plan.

Failure to shut down polluting facilities. State and regional agencies continue to fall short in regulating effectively and shutting down pits that are, or may be polluting vital aquifers. There are still hundreds of sites where operators discharge toxic wastewater, threatening groundwater and air quality, and are out of compliance with water quality laws and policies. This report highlights evidence from three pit facilities that show impacts to groundwater in Kern County, yet regulators allow all three continue to operate. Regulators have found the Racetrack Hills, Fee 34, and McKittrick 1 and 1-3 facilities to be sources of migration of wastewater into, or threatening to enter, sources of drinking or irrigation water.

Updated recommendations: Based on our increased understanding and improved data, this report contains a revised set of recommendations to reduce, and ultimately end, air and water pollution from open-pit disposal.

1. **We continue to call for the state to implement an immediate prohibition on disposal into open pits, a recommendation supported by CCST, an independent and politically neutral scientific review panel.**

In addition, we recommend that regulators:

2. Enforce existing water quality laws and shut down pits that are polluting, will likely pollute high quality groundwater, or do not have up to date permits.
3. Enforce SB 4 regulations more broadly and prohibit waste from wells that have been stimulated from being disposed of in pits.
4. Require complete chemical disclosure for all fluids used in oil and gas wells and comprehensive testing of chemicals that may be present in produced water.
5. Ensure that the wastewater reporting mandate established by SB 1281 is fully implemented.
6. Maintain an accurate and up to date database of pits.
7. Develop guidance for the regional boards on data collection and dissemination.

8. Include a prohibition on open pits in the California Air Resources Board's (ARB) new regulations on methane from oil and gas production, and at a minimum, expedite planned air monitoring.
9. Undertake a thorough investigation of inactive and historical pits to identify potential legacy pollution.

I. Introduction

Clean Water Action's 2014 report *In the Pits: Oil and Gas Wastewater Disposal into Open Unlined Pits and the Threat to California's Water and Air* highlighted the threats to public health and the environment posed by disposal of oil and gas wastewater into open pits in California and recommended ending their use. At the time, the state was failing to address the potential harm posed by this disposal method. More than a year later both regulators and the public have a much better understanding of the problem. However, regulatory protections are still lacking.

Before Clean Water Action published *In the Pits*, there was a very limited understanding of the scope of the problem. For example, the number and locations of pits was largely unknown, though it was suspected that the problem extended well beyond the 432 active and 198 idle pits that the Central Valley Regional Water Quality Control Board (Central Valley Water Board) had inventoried in its region. As a result of increased scrutiny, this has been confirmed. This follow-up report highlights changes in knowledge,



PHOTO COURTESY OF 'PISTACHIO PRODUCTION'

Racetrack Hills Unlined Pit and Spray Field Facility, operated by Valley Water Management. Kern County, CA.

data, and oversight since 2014. It also includes updated recommendations based on the increased understanding of the problem and the inadequate progress by regulators to address the threats to the environment and public health posed by this disposal method.

II. The continued gaps in data and monitoring indicate that regulators are unable to ensure the protection of drinking and irrigation water.

There have been numerous changes in data and public information about oil and gas wastewater disposal into open and unlined pits in the last year. Some of the developments that contributed to an increased understanding of the problems posed by this type of disposal include:

- ***Scientific review.*** In July 2015, the California Council on Science and Technology (CCST) released Volumes II and III of *An Independent Assessment of Well Stimulation in California*, as mandated by Senate Bill 4 (Pavley, 2013).* The CCST study found that from 2011 through 2014 operators reported 58% of wastewater from stimulated (hydraulically fractured or acidized) wells was dumped into unlined pits in California.[1] The CCST study notes: "Because the primary intent of unlined pits is to percolate water into the ground, this practice provides a direct pathway for the transport of produced water constituents, including returned stimulation fluids, into groundwater."[2]

  The CCST study also states: "**If the presence of hazardous concentrations of chemicals cannot be ruled out, [agencies] should phase out the practice of discharging produced water into percolation pits.** Agencies should investigate any legacy effects of discharging produced waters into percolation pits including the potential effects of stimulation fluids."[3] [Bold added for emphasis.]

- ***Increased reporting by the media.*** In the last year, open pit disposal has garnered significant media attention. The Los Angeles Times,[4] San Francisco Chronicle,[5] and many other media outlets and blogs have covered the issue. This increased media attention has helped educate both the public and decision makers and has spurred increased oversight.

- ***Improved, but imperfect, data collection and dissemination by regulators.*** Increased data collection is improving the overall understanding of how the oil and gas industry manages its wastewater. While there has been progress in data collection, there are still serious deficiencies.

  PROGRESS: A better understanding of the scope of the problem has emerged from more complete inventories by the Regional Water Boards that specify

*Hereafter referred to as "the CCST study." Available online at: https://ccst.us/projects/hydraulic_fracturing_public/SB4.php

location, permit status and the operator of known pits. The State Water Board has begun to update its Geotracker database with the locations and some information on pits.

DEFICIENCIES: Data collection and dissemination is not consistent. For example, the Central Valley and Central Coast Regional Water Quality Control Boards do not collect or report the same information, such as whether or not multiple pits at the same facility are counted as one pit or individually. These inconsistencies make statewide analysis challenging and limit understanding.

Data on inactive pits is also incomplete. The reported numbers of "inactive" pits do not include all pits that may have been shut down years ago, yet could have polluted nearby groundwater or soil. State records indicate that there were thousands of pits across Kern County, yet a complete dataset of their locations is not available — Division of Oil, Gas and Geothermal (DOGGR) had kept "rough estimates" of active and idle pits. One inventory document, sent from DOGGR to the Central Valley Regional Water Board in 2014, displays pit counts as high as 2,074 dating back to 1990. See chart and graph on p. 12 to see changes in pit counts over time.



PHOTO: ANDREW GRINBERG

Wastewater tank. Mt. Poso Oil Field. Kern County, CA.

- ***Legislatively mandated data on disposal methods: improved but incomplete reporting.***

  PROGRESS: Senate Bill 1281 (Pavley), passed in 2014, requires operators to report disposal methods for all oil and gas wastewater on a quarterly basis to DOGGR. The State now collects data on the total volume of wastewater disposed of into open pits and by other methods.* SB 1281 also requires DOGGR to provide the State Water Board with a complete inventory of pits on an annual basis. Operators disclosed that 691 acre feet (more than 225,000,000 gallons) of produced water were disposed of into unlined pits in the first quarter of 2015. Second quarter reporting showed that operators dumped 718 acre feet (nearly 233,000,000 gallons) of wastewater into unlined pits, and another 14 acre feet (more than 4,561,000 gallons) into lined pits for evaporation. This volume represents about 7% of all produced water disposal reported under SB 1281.

  DEFICIENCIES: The first SB 1281 reports were late and incomplete, with only 60% of operators' data publicly available months after reporting was due. Second quarter reporting was more complete, covering nearly 90% of all oil production. DOGGR has yet to provide its first annual inventory on pits to the State Water Board as mandated by SB 1281. Since the Regional Water Boards have taken over as the lead agencies on inventorying pits, the State Water Board should take on the role of producing an annual report on the use of pits and the state's actions to address them. To date, no agency has produced such a report.

- ***Inadequate chemical data.***

  PROGRESS: There has been limited testing of chemical constituents in pits. As the Regional Water Boards investigate and create inventories of pits, some testing has been required and made public on a case-by-case basis. The results show high levels of salts, boron and other harmful chemicals including carcinogens such as benzene. A limited number of test results are available to the public on the State Water Board's Geotracker website and the Central Valley Board's website.**

  DEFICIENCIES: Operators are not required to report chemicals used in all oil production activities such as enhanced oil recovery (EOR) and routine well maintenance. There is evidence that the same, or similar chemicals used for well stimulation (subject to mandatory disclosure), are also used in other oil and gas processes (not subject to mandatory reporting requirements).[6] This

*SB 1281 data is available online at: http://www.conservation.ca.gov/dog/SB%201281/Pages/Index.aspx

** Central Valley Water Board has posted test results on this web page: http://www.waterboards.ca.gov/centralvalley/water_issues/oil_fields/information/disposal_ponds/index.shtml

means there are potentially hundreds of unknown added chemicals in oil and gas wastewater and regulators lack the information needed to effectively regulate disposal. This lack of data also renders monitoring less effective because testing is not tailored to the actual chemicals that may be present or potential interactions between chemical additives and naturally occurring chemicals. Additionally, there is no systematic, required testing of oil and gas wastewater in general, or for specific disposal techniques.

The many deficiencies in data collection, monitoring and chemical information demonstrate that regulators would be unable to ensure protection of water resources from open pits. Without accurately characterizing the volumes, locations, chemical makeup and geologic conditions there is no way to ensure that harmful chemicals do not enter groundwater that may have beneficial uses.

III. Improved regulatory action, but still not enough

Armed with new data and increased pressure from the public and Legislature, regulators have begun to address the issue, but their efforts fall short. Some of the progress and the deficiencies are highlighted below.

- ***Increased staffing to enforce water quality laws.***

  PROGRESS. The Central Valley Water Board has expanded staffing in its oil and gas program. In roughly two years, the staff size will have increased from just two full time staff to 17. This additional staff will allow for more oversight and increase capacity to enforce the law.*

- ***Increased, yet inadequate oversight by Central Valley regulators.***

  PROGRESS: The Central Valley Water Board has begun to regulate disposal pits more actively and has developed a work plan to address the hundreds of non-compliant pits throughout the region.** The work plan establishes a timeline to bring all pits under Waste Discharge Requirement (WDR) permits by the end of 2016 and develop a general order specifying requirements for protection of water quality. Proactively working to bring all disposal pits into compliance with water quality laws is an important step.

  DEFICIENCIES. The compliance schedule allows hundreds of pits to continue to threaten water quality, and many to operate illegally without adequate permits. The work plan falls well short of a truly effective policy such as prohibiting disposal pits, and instead continues to threaten groundwater with contamination. Unless the general order that the Regional Board adopts

*For a discussion of the State and Regional Water Boards mandate to protect water quality from disposal pits, see "In the Pits," p.11-13.

**More information on the Central Valley Water Board's program on disposal pits can be found online at: http://www.waterboards.ca.gov/centralvalley/water_issues/oil_fields/index.shtml



PHOTO: CENTRAL VALLEY REGIONAL WATER QUALITY CONTROL BOARD

The Fee 34 facility, operated by Valley Water Management, Bakersfield CA.

includes a prohibition of pit disposal, water quality protections will continue to be inadequate.

- ***Unregulated disposal pits are common in the Central Coast region.***

  PROGRESS: The Central Coast Regional Water Quality Control Board (the Central Coast Board) has initiated an investigation of pits in its region, identifying 52 total (44 active) pits across Santa Barbara, Monterey, and San Luis Obispo counties. Only three Central Coast pits have WDR permits to operate.

  DEFICIENCIES: The Central Coast Board has not publicly announced a compliance schedule or a plan to address disposal pits in its region. Additionally, the Central Coast inventory does not count all pits, but rather each location where there are pits, but does not specify if there are multiple pits at each location.

- ***Confirmed contamination.***

  PROGRESS: Central Valley Board staff have demonstrated that Valley Water Management Company ("Valley Water") is contaminating groundwater

east of Bakersfield at the "Racetrack Hills" and "Fee 34" disposal facilities. Groundwater monitoring at these sites shows that a plume of wastewater containing salts, boron, and potentially other harmful constituents has spread out beneath the pits into an aquifer that serves numerous drinking water and irrigation wells. The Racetrack Hills site also contains a "spray field" where Valley Water runs sprinklers around the clock to dispose of produced water on a hillside. Natural drainage at the site flows into Cottonwood Creek, a tributary of the Kern River, which is a major drinking water source for the city of Bakersfield.[7]

DEFICIENCIES: The Central Valley Board, despite evidence of groundwater pollution, and in conflict with recommendations of its own staff, has allowed these facilities to continue to operate until at least 2018, adopting a lenient Cease and Desist Order (CDO) that includes an unnecessarily slow timeline for compliance. Clean Water Action has challenged the decision with a legal petition to the State Water Board, and is calling for an immediate shutdown of these facilities.*

- ***Interest from air regulators.***

PROGRESS: As part of the plan by the California Air Resources Board (ARB) to address short-lived climate pollutants, such as methane, the state plans to launch a monitoring program to study the air emissions from open pits.[8] The plan is still in development and the effectiveness of monitoring remains to be seen.

DEFICIENCIES: This monitoring falls short of what is needed to stop air pollution from pits. ARB is developing regulations on methane emissions from oil and gas production activities, yet the discussion draft of the rules does not include measures to address air pollution from pits. Additionally, oversight from regional air regulators remains insufficient — there have been no changes to air district rules or oversight practices concerning pits. Independent air monitoring at the McKittrick 1 and 1–3 pit facilities in West Kern, conducted as part of a Clean Water Action investigation in 2014, found elevated levels of methane and dozens of volatile organic compounds (VOC's), including Benzene and Hexanone levels exceeding long-term health effects screening levels (ESL's).** A more proactive and protective approach would be to include a prohibition on disposal pits as part of the upcoming ARB regulations on methane emissions from oil and gas production.

*Clean Water Action, represented by Earthjustice, filed an administrative petition to the State Water Board to intervene and stop the pollution at these sites. Petition available online at: http://bit.ly/CWAPitPetitionSWRCB

** A discussion of air quality threats and inadequacies of the San Joaquin Air Pollution Control District oversight of pits can be found in "In the Pits" pp. 18–20.

- ***New regulations prohibit unlined pits for wastewater from SOME stimulated wells.***

  PROGRESS: Regulations developed pursuant to Senate Bill 4 (Pavley) were implemented in July, 2015. These new rules prohibit open pit disposal for wastewater originating in wells that were subject to a well stimulation treatment, such as hydraulic fracturing or acidizing. They provide that "fluids shall be stored in containers and shall not be stored in sumps or pits." (SB 4 Well Stimulation Treatment Regulations. Cal Code of Regs. tit. 14, § 1786) Data reported by operators to DOGGR pursuant to SB 4, show that newly stimulated wells are not sending any produced water to open pits for disposal, and that 99.8% of wastewater associated with wells stimulated since January 1, 2014 has been disposed of via Class II injection wells — less than 0.2% of wastewater from stimulated wells in this period has been recycled.[9]

  DEFICIENCIES: The new regulations do not ensure that ALL wastewater that contains stimulation fluids and well stimulation treatment chemicals is not dumped into open pits — wastewater produced from wells that filed a well stimulation notice (regulated by the interim well stimulation regulations) with DOGGR prior to July 2015 are not subject to these regulations. Additionally, the regulations do nothing to keep chemicals from other processes, such as enhanced oil recovery (EOR), acid intensive maintenance or any other production activities, out of unlined pits. As noted above, many of the same chemicals used in well stimulation treatments are also used in these processes.

- ***Plans for expanded groundwater monitoring.***

  PROGRESS: As required by SB 4, the State Water Board developed "Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation." The adopted criteria require unlined pits to be included when the state designs regional monitoring plans in oil fields that are or may be subject to well stimulation.[10]

  DEFICIENCIES: Regional monitoring plans under SB 4 have not yet been designed or implemented. It may take several years to produce monitoring results. It is unclear how effective the monitoring will be and whether or not the plans will be designed to actually detect pollution from pits. As designs for regional groundwater monitoring move forward, monitoring wells should be located appropriately to monitor migration from both active and legacy pits. Plans should be designed to detect contaminant plumes close to original pit sites, so any migration is detected as early as possible.



PHOTO: ANDREW GRINBERG

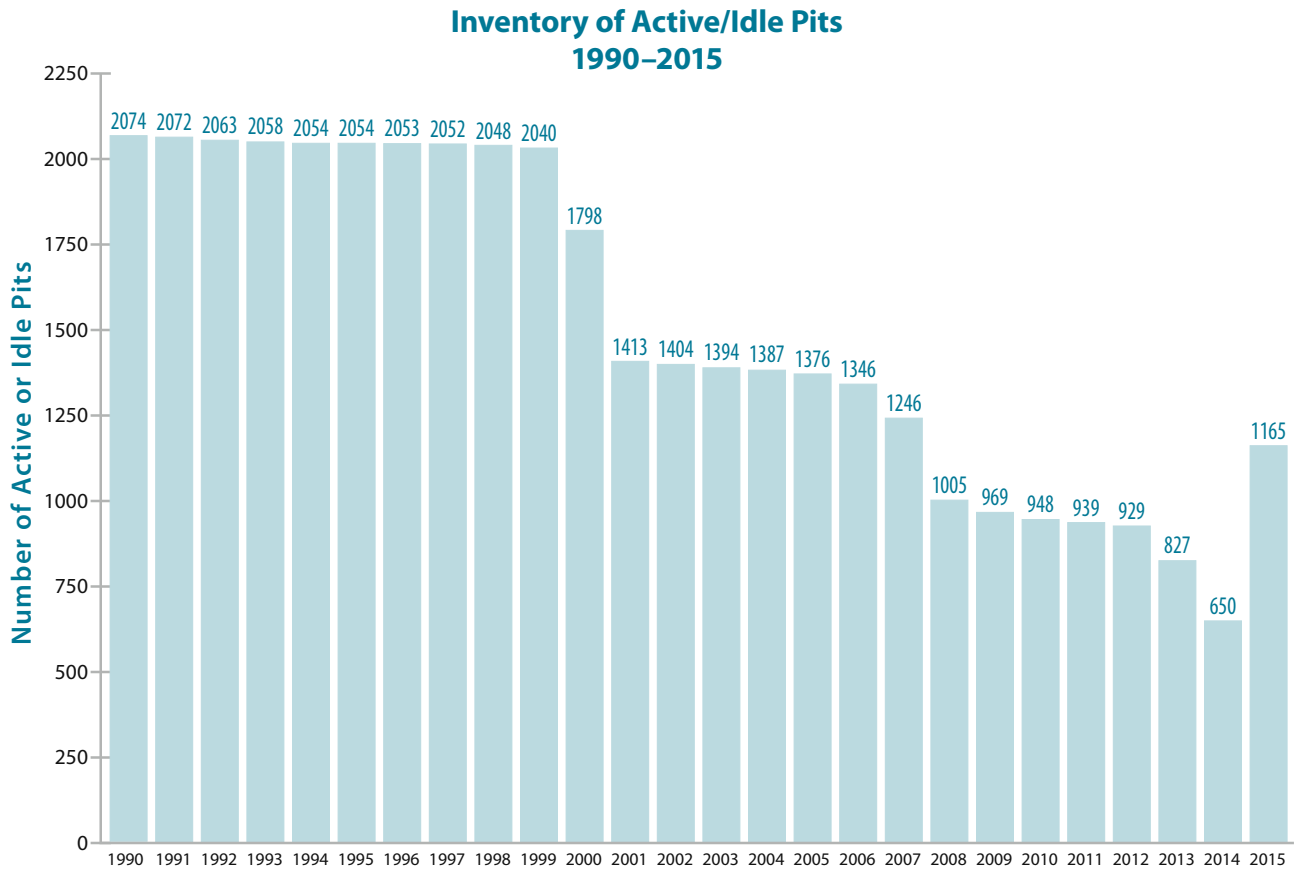
A pipe gushes wastewater into an unlined pit in Kern County.

IV. Improved understanding of pit locations and their regulatory status

The first result of increased oversight has been a better understanding of pit locations and their activity status, either "active" or "inactive." The new information also changes the historical understanding of how many pits exist. ***Chart 1*** shows DOGGR's data from a 2014 inventory of active and idle pits. Because the number of identified pits has increased dramatically since 2014, the accuracy of the historical record is questionable. The 2,074 known pits in 1990 may significantly underreport number of active and idle pits at that time, as record keeping and inventories have been inadequate. Without accurate historical information, the impacts of legacy pits remain largely unknown.

In order to use newly available data, FracTracker Alliance has created inventory charts and maps. All maps and analyses are based on data provided by the Regional Water Quality Control Boards. Both the Central Valley and Central Coast Boards have reported active pits in their regions. Actual pit status and location has not been independently verified in all cases, and initial review of data suggests there may be some errors and inconsistencies between datasets. ***Table 1*** shows where there are active and inactive pits by county and region. ***Map 1*** shows all known pits in California, their

Chart 1. Historic pit counts



1990–2014 data provided by DOGGR. Described as "rough estimates based on number of sumps newly-designated as removed in California Well Information management System (CALWIMS)."

2015 data based on Regional Water Board inventories.

activity status and whether or not they have a Waste Discharge Requirement (WDR) permit.

- ***Permit status of pits — most pits are not properly regulated.***

All legally operating and fully regulated disposal facilities must be issued a WDR permit from the State or a Regional Water Board. Many pits, both active and inactive, do not have a permit ***(See Table 2)***, and the majority of permits were issued prior to the adoption of current policies established by local Basin Plans. ***(Table 3)***.

In the Central Valley, the Tulare Lake Basin Plan was adopted in 1975 and establishes how water quality laws and regulations are enforced in that region. WDR permits that were issued prior to 1975 in the Central Valley, unless subsequently updated, should be considered out-of-date and may not adequately enforce the standards in the Basin Plan. For example, the Tulare Lake Basin plan sets specific guidelines for discharge into unlined pits and addresses common produced water constituents such as boron and

Table 1. Pits by location and activity status

Region	County	Total	Active	Inactive
Central Valley		**1113**	**746**	**367**
	Kern	1020	673	347
	Fresno	45	31	14
	Tulare	29	28	1
	Kings	14	14	0
	San Benito	5	0	5
Central Coast		**52**	**44**	**8**
	Santa Barbara	40	35	5
	Monterey	9	9	0
	San Luis Obispo	3	0	3
CALIFORNIA TOTAL		**1165**	**790**	**375**

Table 2. Pits by permit status

Region	Number of Pits		Number Unpermitted	% Unpermitted
Central Valley	**Total Pits:**	**1113**	**444**	**39.9**
	Total Active Pits:	746	187	25.1
Central Coast	**Total Pits:**	**52**	**49**	**94.2**
	Total Active Pits:	44	41	93.2
CALIFORNIA TOTAL	**Total Pits:**	**1165**	**493**	**42.3**
	Total Active Pits:	790	228	28.9

Table 3. Permit age of pits

Region	Number of Permitted Pits		Out of Date Permit*	% Out of Date
Central Valley	**Total Permitted Pits:**	**644**	**310**	**48.1**
	Active Permitted Pits:	532	247	46.4
Central Coast	**Total Permitted Pits:**	**3**	**0**	**0**
	Active Permitted Pits:	3	0	0
CALIFORNIA TOTAL	**Total Permitted Pits:**	**647**	**310**	**47.9**
	Active Permitted Pits:	535	247	46.2

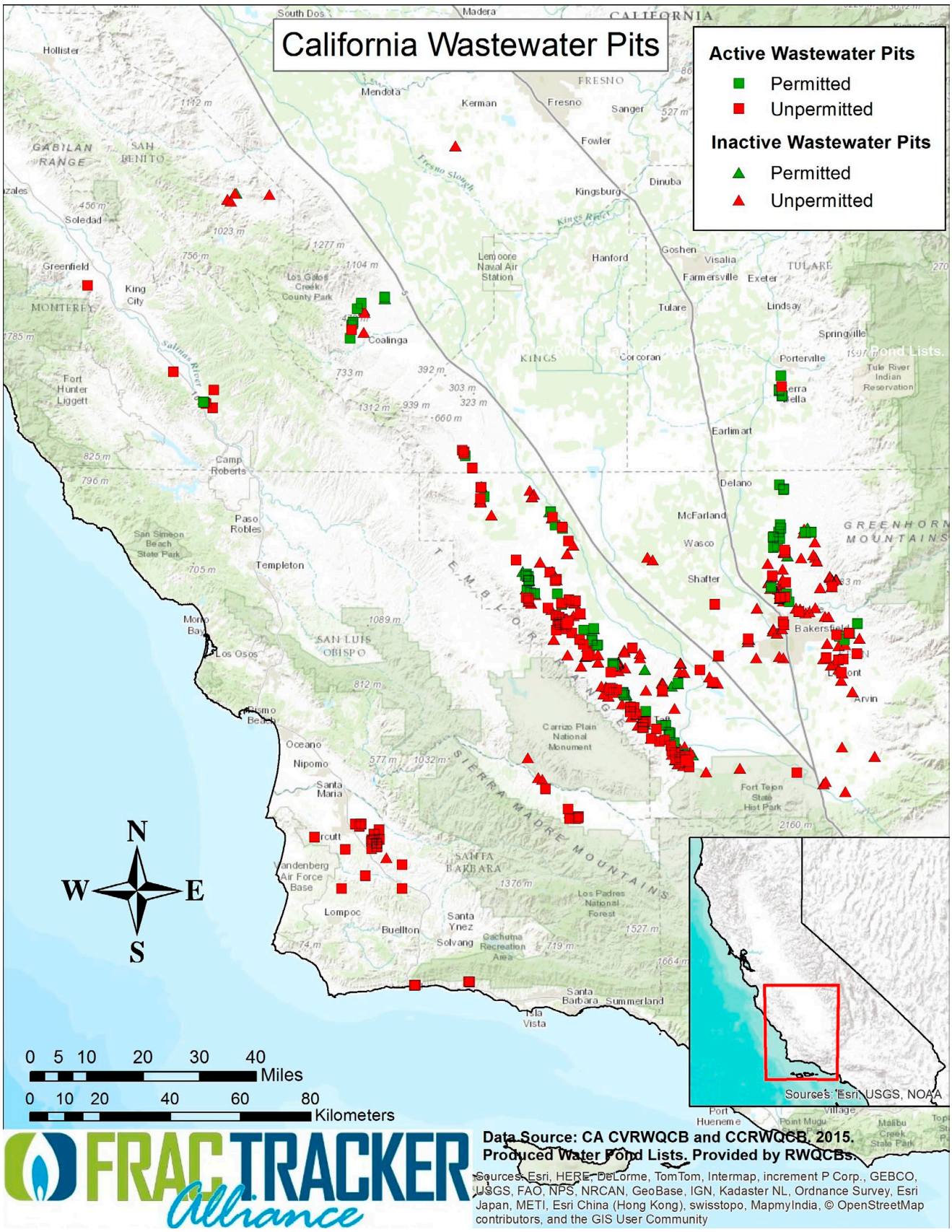
*Out of date permits are defined as permits issued prior to adoption of the applicable basin plan: 1975 for the Tulare Lake (Central Valley); 1971 for the Central Coast.

Table 4. Inadequate permit status

Region	Number of Pits		Inadequate Permit*	% Inadequate
CALIFORNIA TOTAL	**Total Pits:**	**1165**	**803**	**68.9**
	Total Active Pits:	790	475	60.1

*Inadequate permit status is defined as any pit that is either 1) not covered by a WDR permit, or 2) was issues a WDR permit prior to the initial adoption of the appropriate basin plan.

Map 1. Wastewater pits in California showing activity and permit status



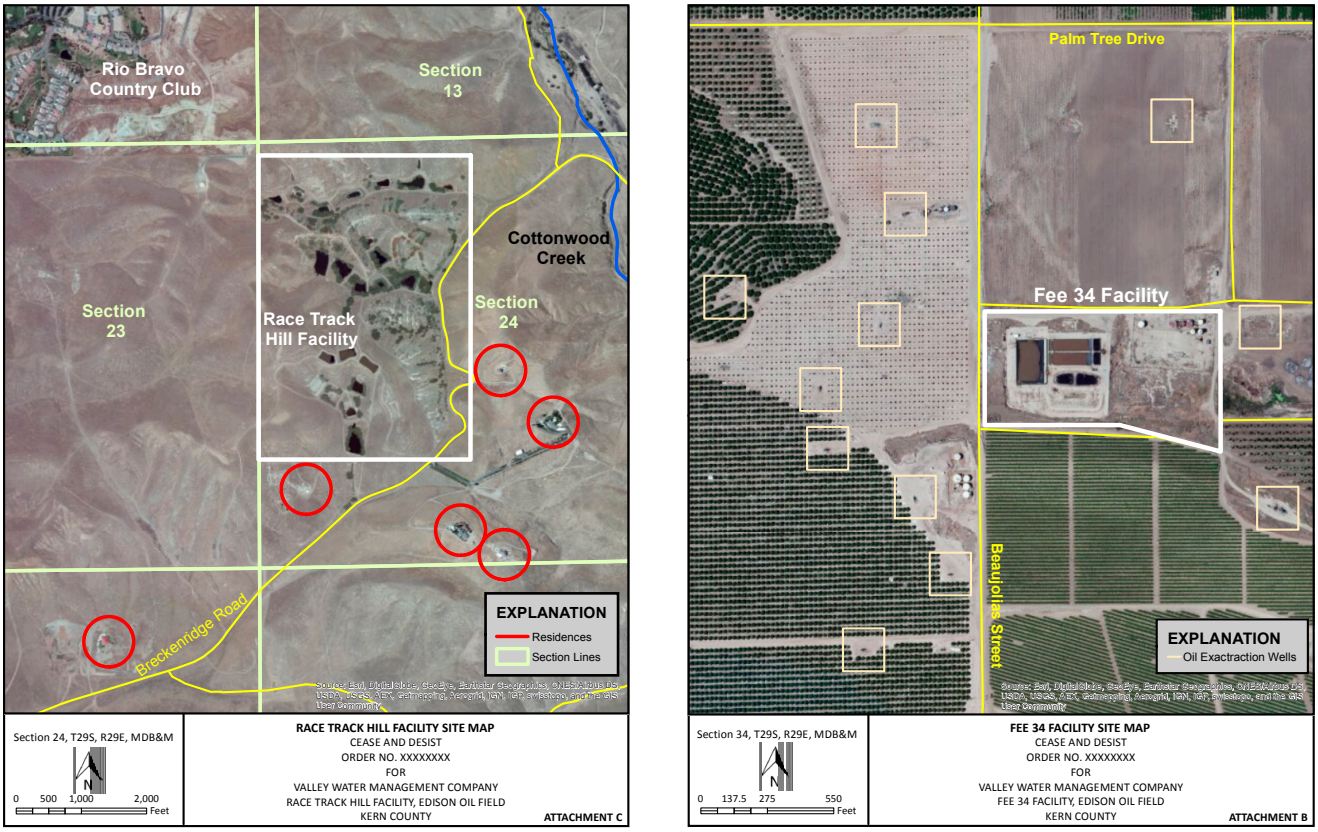
chlorides. More than half of the permits for active pits in the Central Valley were issued prior to 1975 ***(Table 3)***.

The Central Coast Interim Water Quality Control Plan (the precursor to the Central Coast Basin Plan) was adopted in 1971. There are three permitted active pits in the Central Coast region, which were all issued after the adoption of the Central Coast plan, meaning that they should be considered up-to-date ***(Table 3)***.

As shown in ***Table 4***, the vast majority of pits statewide are either not permitted, or received a permit prior to the adoption of the applicable Basin Plan. More than 60% of active pits and more than 68% of all pits are inadequately permitted, meaning that these pits may not be in compliance with water quality protections.

V. Failure to shut down polluting facilities

Example 1: Regulators adopting weak enforcement orders. Considerable progress has been made in exposing and understanding this problem. The Central Valley Water Board has established a compliance schedule to bring all pits either under active permits or other enforcement orders (such as shutting them down) by the end of 2016. The pace of enforcement has increased as the Regional Water Board has added staff who are



Aerial photos of the "Racetrack Hills" pit and spray field facility (left) and the "Fee 34" pit facility. Images courtesy of the Central Valley Regional Water Quality Control Board.

investigating oil and gas wastewater more thoroughly than ever before. Increased staff and more proactive regulatory enforcement environment are encouraging signs.

Unfortunately, regulators and lawmakers are failing to provide real protections for surface and groundwater. The Central Valley Water Board has not shut down pit facilities, even when evidence is sufficient to warrant aggressive enforcement action, as demonstrated by the case of the Fee 34 and Racetrack Hills facilities.

These two sets of pits on the East Side of Kern County, operated by Valley Water, are currently allowed to discharge despite evidence that they are polluting the underlying groundwater, a high quality aquifer that is currently being used as a drinking water source by nearby homes and farms.

At the "Racetrack Hills" facility in the Edison Oil Field, Valley Water operates 27 unlined pits as well as a spray field, where sprinklers run around the clock spreading produced water on a hillside. The pits at Racetrack Hills received a WDR permit in 1958. The spray field was never granted a permit. Regional Water Board staff determined that a plume of contamination has spread out beneath the facility into the aquifer, and that it was likely that runoff from the facility could enter Cottonwood Creek, a tributary of the Kern River — a source of drinking and irrigation water for Bakersfield.

At the "Fee 34" facility, which received a WDR permit in 1992, staff found inadequate oversight of the six oil wastewater pits on site, including a lined wastewater storage pit that is leaking, and the likely migration of chemicals into the underlying aquifer.



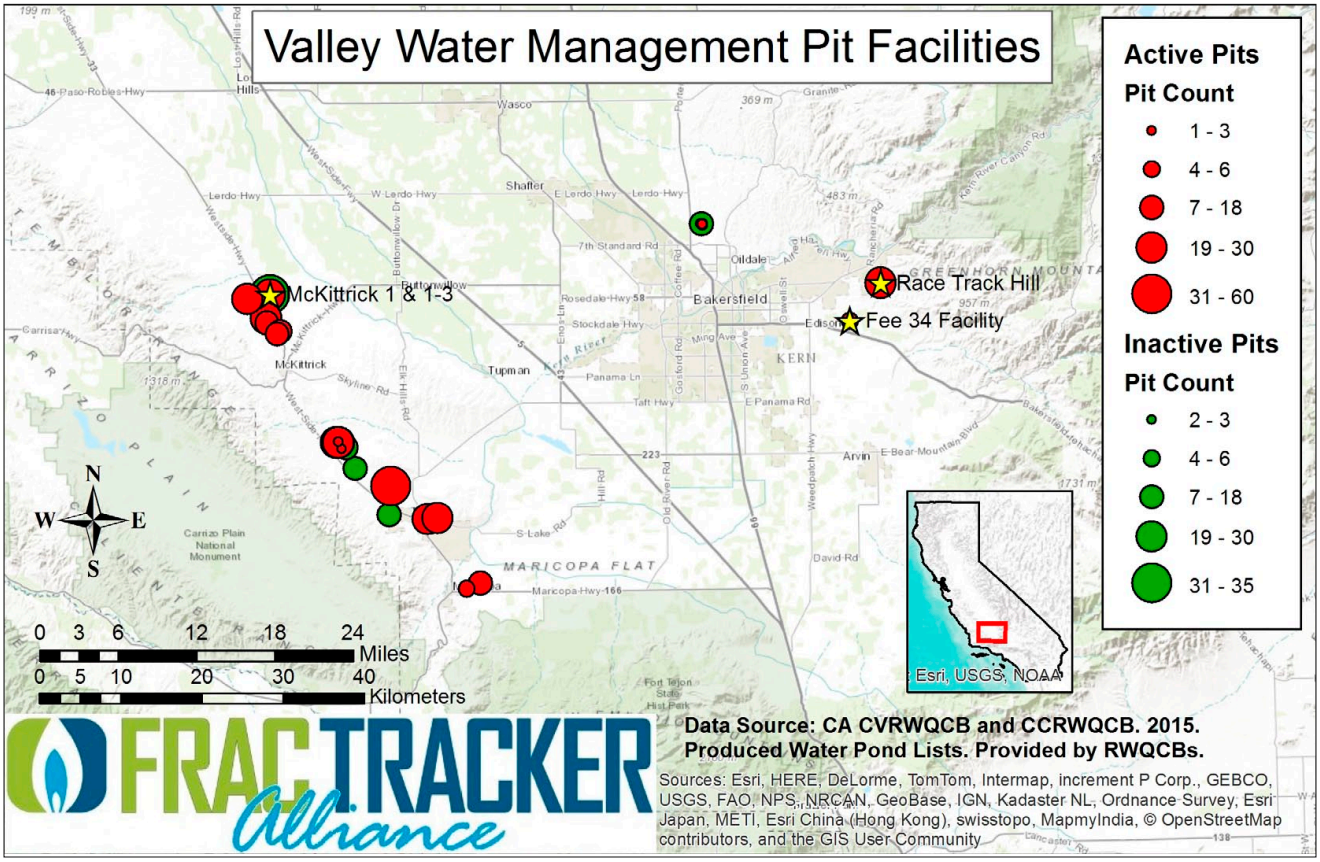
PHOTO COURTESY OF 'PISTACHIO PRODUCTION'

Aerial photo of unlined pits at the Racetrack Hills facility. Kern County, CA.

Despite the recommendation of staff that the spray field operations be halted immediately and the remainder of the operations of the two facilities brought into compliance with water quality laws by the end of 2016, the Central Valley Board voted to allow the spray field to remain open and the deadline for compliance for the ponds to be delayed until 2018.*

Valley Water Management Company

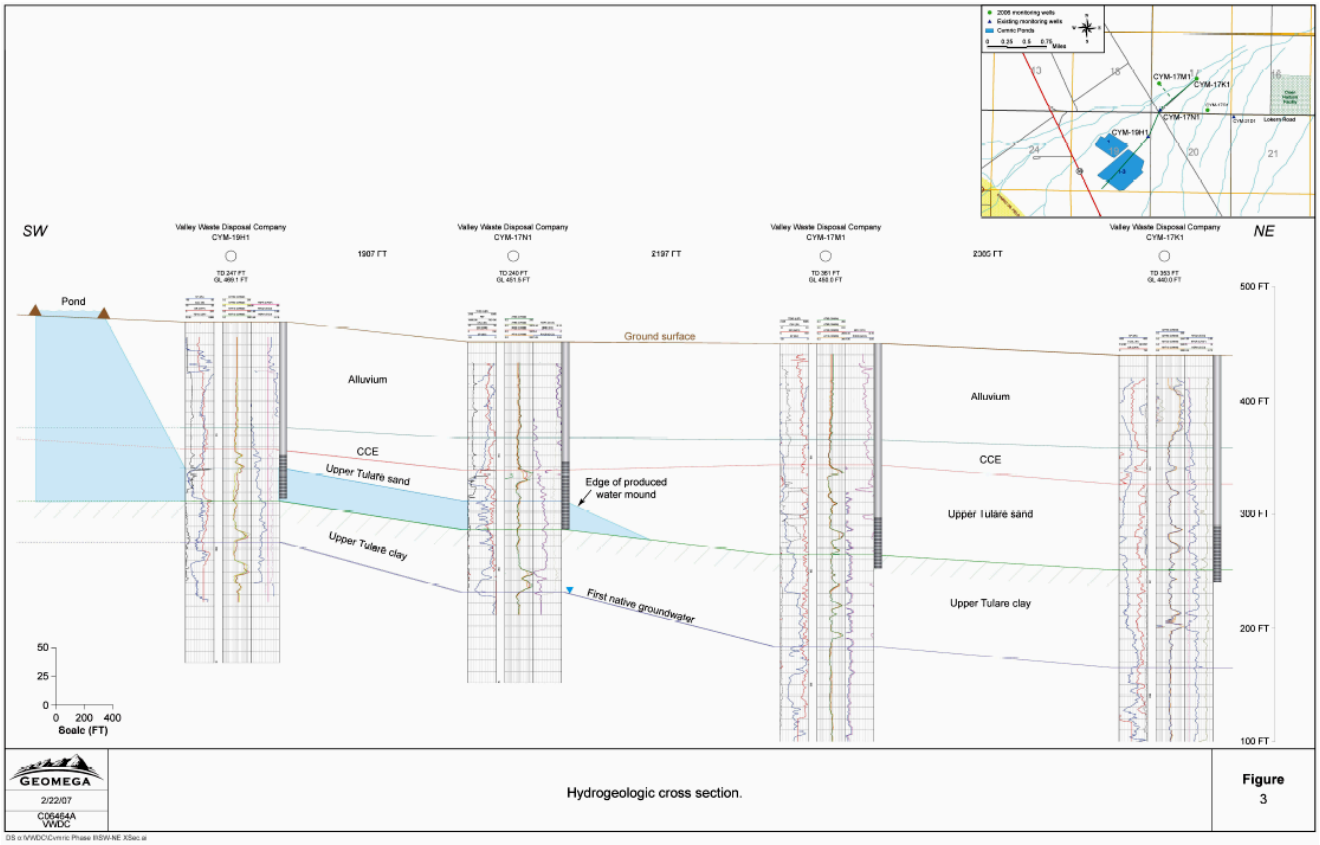
Valley Water Management Company ("Valley Water") is the largest operator of individual pits in the state. ***Map 2*** shows all of Valley Water's pits. Racetrack Hills, Fee 34 and McKittrick 1 and 1-3 are shown with stars. According to the Central Valley Board's inventory, Valley Water operates 462 individual ponds, at 28 facilities. The next largest operators are Aera Energy, which operates 67 pits at 26 facilities, California Resources Corporation which operates 62 pits at 51 facilities, and E&B Natural Resources Management Corporation, which operates 53 pits at 28 facilities. Valley Waste Disposal Company (the predecessor of Valley Water) was formed in 1932 to dispose of oil and gas wastewater in the Central Valley, and was granted nonprofit status in in 1992, and in 2011/12 changed its name from Valley Waste to Valley Water Management Company. One Valley Water facility in the Midway-Sunset Field is listed as containing 60 active pits. The McKittrick 1 and 1-3 facility, which was featured in Clean Water Action's *In the Pits* report, is listed as containing 62 pits, 27 of which are listed as active. Both of these large facilities are located on the West Side of Kern County. Racetrack Hills is the largest facility on the East Side of Kern, with 27 pits and a spray field.



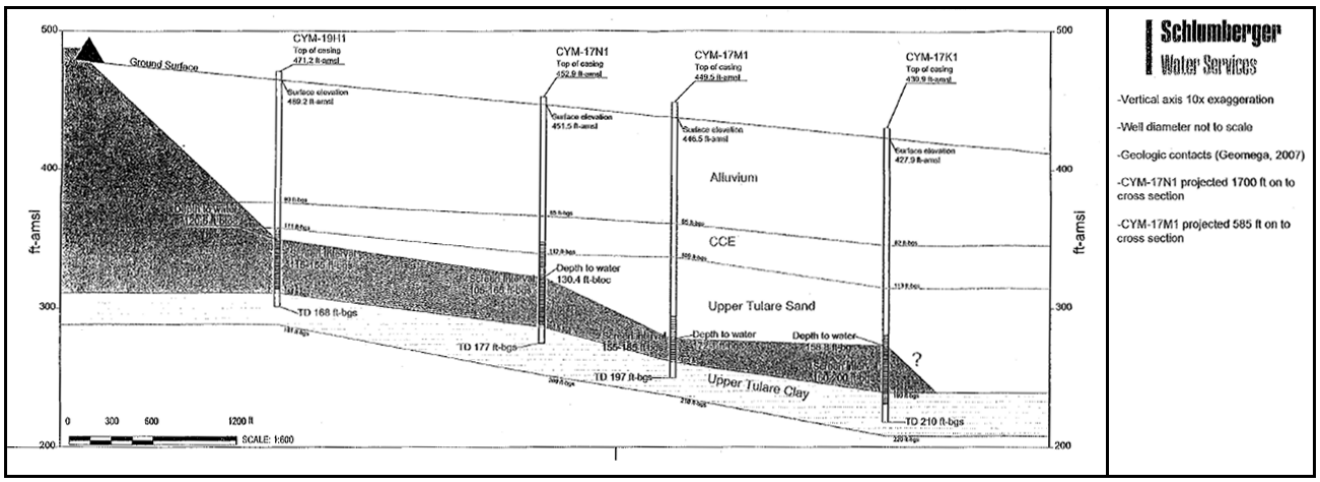
Map 2: Pit facilities operated by Valley Water Management. *Facilities with larger dots are made up of more individual pits. Facilities featured in this report are marked with stars.*

*A full description of the Fee 34 and Racetrack Hills facilities, as well as enforcement measures can be found in the Cease and Desist order issued on July 30, 2015: California Regional Water Quality Control Board Central Valley Region. Order No. R5-2015-0093.

Example 2: Monitoring shows spread of pollution; still no regulatory action taken (update on case study from 2014 report). *In the Pits* focused on the McKittrick 1 and 1–3 pits in West Kern. At the time of publication, Valley Water Management, the operator of that facility had been monitoring groundwater quality in the vicinity of the pits, and since 2004 had detected a plume of wastewater that had migrated roughly 1 mile from the site of the pits. The report highlighted monitoring results and a cross section showing that the plume of contaminated wastewater had spread past the first two of four



Cross section of McKittrick 1 and 1-3 pits plume of wastewater from 2007 monitoring report.



Cross section of McKittrick 1 and 1-3 plume of wastewater extending to an unknown distance of at least 6,550 feet, and an increase of at least 2,385 feet since 2007.

monitoring wells.[11] In March 2015, Valley submitted updated monitoring results, to the Central Valley Water Board.* The monitoring report includes evidence that the underground plume of wastewater has migrated past the fourth monitoring well.[12] Since the exact extent of the plume was unknown in 2007 and it now extends beyond the most distant monitoring well, its size is still not fully understood. However, the monitoring results show that the plume now stretches at least 6,550 feet from the edge of the pits, an increase of at least 2,385 feet since 2007. Valley Water continues to discharge millions of gallons of wastewater at this facility. The Central Valley Water Board continues to allow discharge at this site.

VI. Updated Recommendations

In the Pits urged the state to adopt an immediate prohibition on open pit disposal, hold polluters accountable for closing the pits and cleaning up contamination, and increase monitoring to detect air and water pollution. As the recommendations in the 2014 report are largely unmet, and new data outlined in this report sheds light on additional issues that need to be addressed, this follow-up provides an expanded set of recommendations to aid in ensuring that the state fulfills its regulatory mandate to protect public health and air and water resources.

1. **Prohibit disposal into open pits.** The urgency of California's water crisis requires more protective policy and enforcement to safeguard valuable water resources. **The first and most important step is to end all disposal into open pits immediately.** The CCST study recommends that, unless the absence of any harmful chemicals can be proven, disposal into unlined pits should be prohibited. Due to the current lack of knowledge, reporting, testing and monitoring that would enable ruling out the presence of harmful chemicals, the only way to implement this recommendation would be to halt this disposal method. The Central Valley and Central Coast Water Boards must adopt a general order that phases out and prohibits the operation of pits. In the absence of adequate protections from the Regional Water Boards, the State Water Board should adopt a statewide order that prohibits open pit disposal.

Actions needed while pits are being phased out. Until dumping into unlined pits is phased out, there are steps that the State can take to aid in pollution prevention, remediation, improved oversight and transparency of these sites:

2. **Enforce existing water quality laws.** The Regional Water Boards have a responsibility to shut down facilities that may be contaminating high quality groundwater. Operators must prove that their facilities are safe in order to

*This monitoring report, and other documentation of this facility is publicly accessible through the State Water Resources Control Board's Geotracker site at: http://geotracker.waterboards.ca.gov/profile_report.asp?global_id=L10007494132

remain open, rather than the current practice that places the burden of proof and enforcement costs on regulators and the public. The following classes of facilities should be shut down immediately:

- → Facilities that do not have a WDR permit.
- → Facilities that do not have an up to date WDR permit. Permits issued prior to adoption of the local Basin Plan, or statewide water quality laws and regulations should be considered inadequate and permits should be immediately reviewed.
- → Facilities adjacent to or overlaying beneficial use groundwater. Operating disposal pits in close proximity to high quality groundwater should be prohibited immediately.
- → Facilities that have not demonstrated geologic isolation from any water resources with beneficial uses.

3. **Enforce SB 4 regulations more broadly.** In order to keep well stimulation fluids out of unlined pits, DOGGR's regulations that prohibit open pit disposal of well stimulation wastewater must be applied to any well that has ever been stimulated, not just wells stimulated after adoption of the SB 4 permanent regulations.
4. **Require complete chemical transparency for all fluids injected or emplaced in oil and gas wells.** Complete chemical disclosure of additives and comprehensive testing of produced water would be necessary in order for regulators at DOGGR and/or the Water Boards to ensure wastewater in unlined pits does not contain harmful chemicals — following the recommendation of the CCST study.
5. **Ensure that the wastewater reporting mandate established by SB 1281 is thoroughly and accurately implemented.** DOGGR's efforts to collect more complete data under SB 1281 and to publicly post and disseminate this data expeditiously has improved compliance with this law but there are still deficiencies. DOGGR and operators must continue to improve reporting and dissemination of this data.
6. **Maintain an accurate and up to date database of pits.** The State Water Board has begun to map the locations of pits using the existing Geotracker database. The State Water Board should continue to improve and maintain data on pits in this database. Geotracker can serve as the public tool for gathering and analyzing information on pits, their permit status and monitoring results. The location of disposal pits could also to be added to the well finder tool on the DOGGR website.

7. **Greater consistency in investigation and inventory can be achieved through the development of State Water Board guidance for the Regional Water Boards.** The guidance would be used to ensure quality control, data consistency, and to facilitate the public dissemination of information.

8. **Prohibit open pits in the California Air Resources Board's (ARB) new regulations on methane from oil and gas production**. Short of a prohibition, ARB should expedite monitoring of open pits in order to better understand, and mitigate health and climate impacts of open pits.

The state must also address the legacy pollution that may have resulted from historical use of pits. Billions of gallons of toxic wastewater have been dumped all across areas of oil and gas development, yet the state has never attempted to comprehensively measure the impacts on groundwater, surface water, and soil. The State should:

9. **Undertake a thorough investigation of inactive and historical pits to identify potential legacy pollution.** The State Water Board has a clear responsibility under the Porter-Cologne Water Quality Act to launch this effort in order to expeditiously identify and remediate polluted sites and protect communities and drinking water sources. The State Water Board has indicated that it will characterize impacts from disposal pits as part of the SB 4 groundwater monitoring plans, but has not identified a timeline or more specific plan for the regional monitoring plans. It is likely that only a few oil fields will be subject to regional groundwater monitoring plans initially, and it will likely take many years or decades before every area with current or historic pit disposal is examined for legacy pollution under this scheme. Clean Water Action urges a comprehensive program dedicated to legacy pollution from pits that builds on the SB 4 regional monitoring plans.

Endnotes

1 California Council on Science and Technology (CCST) "An Independent Assessment of Well Stimulation in California: An Examination of Hydraulic Fracturing and Acid Stimulations in the Oil and Gas Industry" July 2015, Vol. II, Chapter 2, p. 99

2 CCST, Vol. II, Chapter 2, p. 110

3 CCST, Study Recommendation 4.1, Summary Report p. 43

4 Cart, Julie. "Hundreds of illicit oil wastewater pits found in Kern County" Los Angeles Times. Feb 26, 2015. Available at: http://www.latimes.com/local/lanow/la-me-ln-pits-oil-wastewater-20150226-story.html

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6 Taylor, Kim, et al. "Oil, Gas and Groundwater Quality in California - a discussion of issues relevant to monitoring the effects of well stimulation at regional scales" U.S. Geological Survey. December 4, 2014. p. 8. Available online at: http://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/docs/usgs_discussion_paper.pdf

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8 California Air Resources Board. "Draft Short-Lived Climate Pollution Reduction Strategy" September 2015 p. 53. Available online at: http://www.arb.ca.gov/cc/shortlived/2015draft.pdf

9 Division of Oil, Gas, and Geothermal Resources. "Well Stimulation Treatment First Annual Report" Dec. 31, 2015. p. 12-15. Available at: http://www.conservation.ca.gov/index/Documents/Well%20Stimulation%20Treatment%20Report%202015%20-%20FINAL.PDF

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Groundwater contamination: Facility operator wins time, but appeal awaits

bakersfield.com/news/groundwater-contamination-facility-operator-wins-time-but-appeal-awaits/article_36673931-50fb-5650-9dc3-879a45c26b96.html

BY JOHN COX
jcox@bakersfield.com

September 5, 2015



A unique sprinkler system northeast of Bakersfield has run night and day for more than half a century without attracting much notice, despite supporting a healthy-looking green patch that easily stands out from the golden foothills around it.

But lately the installation has received lots of attention as regional water quality officials contend the sprinklers' constant disposal of oil field wastewater has helped create a mound of groundwater pollution that may one day threaten water supplies as far away as Bakersfield.

Tests performed by the site's nonprofit operator show the groundwater beneath Race Track Hill contains chloride concentrations up to 19 times the facility's maximum allowable discharge of 150 parts per million. The groundwater's boron levels are in some spots 16 times the disposal limit of 1 part per million, and total dissolved solids, the primary measure of water quality, are as much as seven times the site's discharge cap of 1000 parts per million.

“The groundwater at Race Track Hill is polluted, and there’s no other way to state it,” Clay Rodgers, assistant executive officer of the Central Valley Regional Water Quality Control Board’s Fresno office, said during testimony at a quasi-judicial hearing on the matter July 30 in Rancho Cordova near Sacramento.

Board members, unconvinced the operation presents an immediate danger, decided against a staff proposal to shut down the sprinkler system in the middle of last month. They instead ordered more testing and other work in a cease-and-desist order allowing the irrigation system to continue operating through 2017.

On Monday an environmental group appealed the board’s decision to the State Water Resources Control Board, alleging the regional panel had bowed to pressure from the oil industry and neglected its duty to enforce California’s water quality laws.

The operation

The system along Breckenridge Road at Race Track Hill discharges 168,000 to 189,000 gallons a day of Edison Oil Field “produced water,” a naturally occurring fluid that comes up along with crude. Tamarisk trees and bermuda grass —- non-native species selected for their tolerance to the salty, high-boron waste stream — help absorb water using the natural process of evapotranspiration, a combination of evaporation and plant transpiration.

Valley Water and its hydrogeologists maintain the sprinklers pose little risk for a few reasons, and that the mound of pollution more likely was created by large oil companies that operated in the Edison field decades ago, not by the medium and small companies that remain.

Immense quantities of produced water have been disposed of in the Edison area over the years. Often the wastewater was dumped into large, unlined ponds to evaporate and seep slowly underground.

Valley Water still uses unlined ponds at Race Track Hill and at Fee 34, a related but much smaller wastewater gathering site and pumping station the company operates less than two miles to the southwest. In fact, sprinklers handle just 45 percent of wastewater at Race Track Hill, with unlined ponds disposing of the rest.

Regional water board staff have also expressed concern about the ponds' capacity for containing runoff during heavy rains. Dale Harvey, supervising engineer at the agency's Fresno office, testified at July's hearing Valley Water has built nothing to keep runoff on the site, and that signs of erosion at the facility's edges suggest contaminants built up at the site could wash into nearby Cottonwood Creek, and possibly into the Kern River, in the event of a big storm.

The regional board, cracking down amid a wider, multi-agency focus on produced water disposal in California, has moved to raise pond disposal standards sharply starting in 2017. This may well force pond closures at Race Track Hill and Fee 34, along with hundreds of other percolation facilities across Kern County, many operated by Valley Water.

The company has offered to investigate alternatives for dealing with the wastewater. Watering a nearby golf course might be one option, as might diluting it with enough freshwater to bring the fluid's contamination down to what regulators would consider a negligible level.

The preferred and most common solution is to inject it deep underground. Valley Water Manager Larry Bright testified at July's hearing that the company intends to pursue that option, but the permit application process was sure to extend many months beyond the Aug. 15 shutoff date originally proposed at the meeting.

Surprised by the attention

Bright asserted the company would have taken immediate action years ago, had it been aware of the board's concerns. But he noted Valley Water had received only passing inspection reports for decades, and never got a violation notice until 2013.

"Obviously something changed from (the board's) perspective," he said, adding maybe there had been a shift amid "different political influences."

Regardless, evapotranspiration at Race Track Hill constitutes an inappropriate disposal practice that should halt immediately, Andrew Grinberg, oil and gas program manager for Washington, D.C.-based environmental group Clean Water Action, told the board.

Speaking at the Rancho Cordova meeting one month before Clean Water Action appealed the decision letting the sprinklers continue running, Grinberg pointed out that a state-commissioned scientific panel earlier this summer recommended phasing out ground application of produced water.

"The job of this board is to protect the waters of the state, not to protect the business interests of a few companies," he said.

Valley Water's original Race Track Hill waste discharge permit from 1958 neither allowed nor banned the use of sprinklers. And although the water board has had the facility inspected regularly for many years, Rodgers said he stumbled across an inspection report on the facility a couple of years ago. He decided to go take a look at it, which led to ground monitoring around the site and, more recently, July's proposal for a cease-and-desist order.

Oil producers who send their produced water to Race Track Hill testified that turning off the sprinklers Aug. 15 would have forced them to shut in wells, which would likely cost jobs, investment, property tax revenues and oil royalty payments to people who rely on them.

Chris Morrison, owner of Bakersfield's Morrison Oil Co., Race Track Hill's second-largest contributor of produced water, said his company is pursuing other options for disposing of produced water, including reverse osmosis filtration, but that "we just need some time."

A different direction

Consultants for Valley Water downplayed the risk the groundwater pollution may present. Showing slides of geological diagrams and nearby well data, they concluded the plume is moving north-northwest at about 100 feet per year, not toward Bakersfield's center, 15 miles to the west.

Moreover, geological barriers including a virtually impermeable layer of shale rock appear to separate the plume from aquifers serving nearby water wells, a hydrogeologist testifying for Valley Water told the board.

Another consultant said storm runoff is not a problem because the facility has pumps to send storm runoff back up Race Track Hill, which they estimated can hold 152 acre-feet of water, nearly twice as much he calculated would fall in a weeklong, once-in-a-century deluge. This assumes the facility's ponds are not substantially filled when such a storm hits.

Senior water agency staff concluded, and the board ultimately agreed, that more information was necessary before the sprinklers could be shut off responsibly.

The regional board's executive director, Pamela Creedon, said Rodgers and the rest of the case's prosecution staff failed to demonstrate Valley Water could still handle its regular incoming waste stream without sprinkling the spray fields. She called for a detailed comparison of the facility's incoming waste volume with its disposal capacity, as well as more engineering work to bring the operation up to the board's standards.

The board approved her proposed cease-and-desist order giving the company much testing and investigation to do during the next year, along with a likely closure deadline of Jan. 1, 2018.

Water well owners and operators near Race Track Hill, and others in Bakersfield, generally knew little of Valley Water's disposal operation or the water board's proceedings regarding the wastewater sprinklers.

Unaware of the sprinklers

One who was aware of the operation is Jim Nickel, whose family owns the Rio Bravo Ranch development less than a mile northwest of Race Track Hill. He said he thinks the pollution is moving west. At any rate, quarterly tests of his wells to the northeast of the disposal area show his groundwater continues to meet drinking standards.

"I don't think (the plume) is coming this way," he said, adding, "I don't have a dog in this fight."

Rudy Valles, the Bakersfield district manager of California Water Service Co., which has water wells on the city's east side, said he had not heard about the sprinklers in his 22 years at the utility, and he was unsure whether potential stormwater runoff from Race Track Hill and Fee 34 had the potential someday to "complicate" Cal Water's treatment process.

The city of Bakersfield's water resources manager, Art Chianello, did not return repeated calls requesting comment. Jason Meadors, who ranks just below Chianello as the city's water resources director, said he was unaware of Valley Water's disposal operation or the regional water board's proceedings. But he emphasized the city's wells are concentrated in southwest Bakersfield, and municipal water taken from the Kern River is tested regularly to screen for pollution.

Edison farmer Dennis Johnston, head of a diversified operation that gets some of its irrigation water from a well not far from Fee 34 on Edison Highway west of Comanche Drive, said he knew about Valley Water's sprinklers because he had seen them while riding motorcycles at Race Track Hill in the 1960s and '70s.

Although he had not been aware of the water board's pollution concerns, Johnston said he hasn't seen any adverse impacts on his groundwater.

"Oftentimes you hear these things and it's a matter of degrees," he said. "A little bit of salt's OK. A lot is not."

If ever polluted groundwater from Valley Water's Race Track Hill operation were found to have impaired the beneficial use of domestic or irrigation water supplies, Rodgers said, the agency could order the company to replace that water. He said the company could potentially be held liable for civil penalties as well.

Land Use, Open Space, and Conservation Element

Chapter 1

1.1 INTRODUCTION

This chapter presents the Land Use, Open Space, and Conservation Element of the Kern County General Plan. This Element supersedes all previous Land Use, Open Space, and Conservation Elements affecting the Kern County unincorporated areas. Because of the close interrelationship between land use, conservation, and open space issues, Kern County's Land Use, Conservation, and Open Space Element provides for a variety of land uses for future economic growth while also assuring the conservation of Kern County's agricultural, natural, and resource attributes.

AUTHORITY AND PURPOSE

The State of California Government Code includes requirements and authority for the Land Use, Conservation, and Open Space Elements.

Government Code 65302(a):

A land use element which designates the proposed general distribution and general location and extent of the land for housing, business, industry, open space, including agriculture, natural resources, recreation, and enjoyment of scenic beauty, education, public buildings and grounds, solid and liquid waste disposal facilities, and other categories of public and private uses of land. The land use element shall include a statement of the standards of population density and building intensity recommended for the various districts and other territory covered by the plan. The land use element shall identify areas covered by the plan which are subject to flooding and shall be reviewed annually with respect to those areas. The land use element shall designate, in a land use category that provides for timber production, those parcels of real property zoned for timberland production pursuant to the California Timberland Productivity Act of 1982.

General Code 65302(d):

A conservation element for the conservation, development, and utilization of natural resources including water and its hydraulic force, forests, soils, river, and other waters, harbors, fisheries, wildlife, minerals, and other natural resources. That portion of the conservation element, including waters, shall be developed in coordination with any Countywide water agency and with all district and city agencies which have developed, served, controlled or conserved water for any purpose for the County or city for which the plan is prepared. Coordination shall include the discussion and evaluation of any water supply and demand information described in Section 65352.5, if that information has been submitted by the water agency to the city or County. The conservation element may also cover:

(1) The reclamation of land and waters.
(2) Prevention and control of the pollution of streams and other waters.
(3) Regulation of the use of land in stream channels and other areas required for the accomplishment of the conservation plan.
(4) Prevention, control, and correction of the erosion of soils, beaches, and

shores.

(5) Protection of watersheds.

(6) The location, quantity and quality of the rock, sand, and gravel resources.

(7) Flood control.

Government Code 65302(e):

An open-space element as provided in Article 10.5 (commencing with Section 65560).

Government Code 65560:

(a) "Local open-space plan" is the open-space element of a County or city general plan adopted by the Board or council, either as the local open-space plan or as the interim local open-space plan adopted pursuant to Section 65563.

(b) "Open-space land" is any parcel or area of land or water which is essentially unimproved and devoted to an open-space use as defined in this section and which is designated on a local, regional, or State open-space plan as any of the following:

(1) Open space for the preservation of the natural resources including, but not limited to, areas required for the preservation of plant and animal life, including habitat for fish and wildlife species; areas required for ecologic and other scientific study purposes; rivers, streams, bays, and estuaries; and coastal beaches, lakeshores, banks of rivers and streams, and watershed lands.

(2) Open space used for the managed production of resources, including but not limited to, forest lands, rangeland, agricultural lands, and areas of economic importance for the production of food or fiber; areas required for recharge of groundwater basins; bays, estuaries, marshes, rivers, and streams which are important for the management of commercial fisheries; and areas containing major mineral deposits, including those in short supply.

(3) Open space for outdoor recreation, including but not limited to, areas of outstanding scenic, historic, and cultural value; areas particularly suited for park and recreation purposes, including access to lakeshores, beaches, and rivers and streams; and areas which serve as links between major recreation and open-space reservations, including utility easements, banks of rivers and streams, trails, and scenic highway corridors.

(4) Open space for public health and safety, including, but not limited to, areas which require special management or regulation because of hazardous or special conditions such as earthquake fault zones, unstable soil areas, flood plains, watersheds, areas presenting high fire risks, areas required for the protection of water quality and water reservoirs, and areas required for the protection and enhancement of air quality.

FIGURE 4. LAND USE DESIGNATIONS

1. NONJURISDICTIONAL LAND
- 1.1 STATE AND FEDERAL LAND
- 1.2 INCORPORATED CITIES

2. PHYSICAL CONSTRAINTS OVERLAY
- 2.1 SEISMIC HAZARD
- 2.2 LANDSLIDE
- 2.3 SHALLOW GROUNDWATER
- 2.4 STEEP SLOPE
- 2.5 FLOOD HAZARD
- 2.6 ▪ 2.9 Land use designations unique to adopted Specific Plans
- 2.10 NEARBY WASTE FACILITY
- 2.11 BURN DUMPS

3. PUBLIC FACILITIES AND SERVICES
- 3.1 PARKS AND RECREATION AREAS
- 3.2 EDUCATIONAL FACILITIES
- 3.3 OTHER FACILITIES
- 3.4 SOLID WASTE DISPOSAL FACILITY
- 3.4.1 SOLID WASTE DISPOSAL FACILITY BUFFER
- 3.5 HAZARDOUS WASTE DISPOSAL FACILITIES LAND DISPOSAL METHOD
- 3.6 HAZARDOUS WASTE DISPOSAL FACILITIES UNDERGROUND INJECTION METHOD
- 3.7 OTHER WASTE FACILITY
- 3.7.1 OTHER WASTE FACILITY BUFFER

4. SPECIAL TREATMENT AREAS
- 4.1 ACCEPTED COUNTY PLAN AREAS
- 4.2 INTERIM RURAL COMMUNITY PLAN
- 4.3 SPECIFIC PLAN REQUIRED

5. RESIDENTIAL
- 5.1 MAXIMUM 29 UNITS/NET ACRE (1502 SQ. FT. SITE AREA/UNIT)
- 5.2 MAXIMUM 16 UNITS/NET ACRE (2722 SQ. FT. SITE AREA/UNIT)
- 5.3 MAXIMUM 10 UNITS/NET ACRE (4356 SQ. FT. SITE AREA/UNIT)
- 5.4 MAXIMUM 4 UNITS/NET ACRE (10,890 SQ. FT. SITE AREA/UNIT)
- 5.45 MAXIMUM 2 UNITS/ NET ACRE (21,780 SQ. FT. SITE AREA/UNIT)
- 5.5 MAXIMUM 1 UNIT/NET ACRE (43,560 SQ. FT. SITE AREA/UNIT)
- 5.6 MINIMUM 2.5 GROSS ACRES/UNIT
- 5.7 MINIMUM 5 GROSS ACRES/UNIT
- 5.75 MINIMUM 10 GROSS ACRES/ UNIT
- 5.8 MINIMUM 20 GROSS ACRES/UNIT

6. COMMERCIAL
- 6.1 REGIONALCOMMERCIAL
- 6.2 GENERAL COMMERCIAL
- 6.3 HIGHWAY COMMERCIAL

7. INDUSTRIAL

7.1 LIGHT INDUSTRIAL
7.2 SERVICE INDUSTRIAL
7.3 HEAVY INDUSTRIAL

8. RESOURCE

8.1 INTENSIVE AGRICULTURE (MIN. 20- ACRE PARCEL SIZE)
8.2 RESOURCE RESERVE (MIN. 20- OR 80- ACRE PARCEL SIZE)
8.3 EXTENSIVE AGRICULTURE (MIN. 20- OR 80-ACRE PARCEL SIZE)
8.4 MINERAL AND PETROLEUM (MIN. 5-ACRE PARCEL SIZE)
8.5 RESOURCE MANAGEMENT (MIN. 20- OR 80-ACRE PARCEL SIZE)

Non-Jurisdictional Land

1.2 NONJURISDICTIONAL LAND

ASSUMPTIONS: NONJURISDICTIONAL LAND

Federal and State ownership of land will increase over the next 20 years as a result of conservation programs and related acquisitions. Management of federal lands under the jurisdiction of the Bureau of Land Management and the U.S. Forest Service could change if the focus continues to shift from multiple use and sustained yield to preservation to ensure continued military readiness and enhancing national security. Incorporated cities will continue to expand through annexation to accommodate the anticipated population growth during the planning period.

ISSUES: NONJURISDICTIONAL LAND

A potential for land use conflict is created when land management jurisdictions promote more intensive land uses and activities than occurs in unincorporated areas. This often occurs, for example, where urban growth is taking place on the fringe of an incorporated city.

A similar situation could occur on the periphery of a State wildlife refuge or a military installation. Other conflicts can occur with regard to resource uses or mineral production, energy development, livestock grazing, and outdoor recreation.

GOALS: NONJURISDICTIONAL LAND

1. To promote harmonious and mutually beneficial uses of land among the various jurisdictions and land management entities present in Kern County.

MAP PROVISIONS: NONJURISDICTIONAL LAND

Map Code 1.1 (State and Federal Land) - Applied to all property under the ownership and control of the various State and federal agencies operating in Kern County (military, U.S. Forest Service, Bureau of Land Management, Department of Energy, etc.).

Map Code 1.2 (Incorporated Cities) - Used to identify the areas of cities within the County, which are responsible for the preparation and maintenance of their own General Plans.

POLICIES: NONJURISDICTIONAL LAND

1. Coordination and cooperation will be promoted among the County, the incorporated cities, military bases, and the various special districts where their planning decisions and actions affect more than a single jurisdiction.

2. All nonjurisdictional land, when coming under the jurisdiction of the County such as through a detachment process, shall be deemed to have a Map Code 8.5 (Resource Management) designation if vacant or the map code that most closely represents the established designation in the previous jurisdiction, as determined by the Planning Director. For developed land, the map code which most closely represents the actual land use, as determined by the Planning Director, shall be utilized.

3. The County retains the maximum discretion allowed by law over land use issues of local concern, which impact the development of private and public property in the County.

4. The County will solicit comments and coordinate with local governments, the military, and other federal or State jurisdictions on projects which are proposed within a peripheral area established mutual agreement between the County and the jurisdicti0on.

5. The County land use regulations do not apply to property administered by the State or federal Government in the absence of Memorandums of Understanding indicating otherwise. However, County land use regulations may apply to other public entities subject to provisions of State law.

6. The County will solicit a city's comments on land use planning proposals within the city's adopted sphere of influence or within one mile of the city limits, whichever is greater.

IMPLEMENTATION MEASURES: NONJURISDICTIONAL LAND

A. Develop a procedure to assure that the County, the incorporated cities, and other jurisdictions refer major planning and land use proposals to all affected jurisdictions for review, comment, and recommendation. Comments and discussion should occur if requested by the affected jurisdiction(s).

B. Review proposed revisions to or amendments of a city's General Plan in either the affected fringe area or adopted sphere of influence to ensure compatibility with County land use plans.

C. Classify nonjurisdictional lands in a zoning category which is consistent with a resource management category.

D. Establish a "Review Area" around each State, military, or other federal jurisdiction.

Review development proposals or proposed General Plan Amendments and revisions within the established area with the appropriate agency.

E. Seek Memorandums of Understanding with other governmental entities when the land use proposed requires a discretionary application or coordination through the County Planning Agency as required by State or federal law. These applications include permit(s) subject to the Surface Mine and Reclamation Act (SMARA) of1975.

F. The County shall consider all public agency comments for land use projects and promote intergovernmental coordination in the provision of land use designations and related public infrastructure.

Physical and Environmental Constraint

1.3 PHYSICAL AND ENVIRONMENTAL CONSTRAINTS

ASSUMPTIONS: PHYSICAL AND ENVIRONMENTAL CONSTRAINTS

Natural hazards are a long-term constraint that may affect developed uses of land. Throughout the County, sufficient land that is free from natural hazards is available for such uses without incurring the risks associated with development in hazardous areas.

ISSUES: PHYSICAL AND ENVIRONMENTAL CONSTRAINTS

Over the years, development has occurred in areas that have a variety of natural hazards. Expansion pressures in some existing communities would site new development in areas that are known to have documented hazardous conditions. In a few instances, entire communities are located in areas of significant natural hazards. The extent to which natural hazards can be mitigated is frequently debated, thus further complicating the issue of development in hazardous areas.

GOALS: PHYSICAL AND ENVIRONMENTAL CONSTRAINTS

1. To strive to prevent loss of life, reduce personal injuries, and property damage, minimize economic and social diseconomies resulting from natural disaster by directing development to areas which are not hazardous.

MAP PROVISIONS: PHYSICAL AND ENVIRONMENTAL CONSTRAINTS

Map Code 2.1 (Seismic Hazard) - Alquist-Priolo Special Study Zone and other recently active fault zones.

Map Code 2.2 (Landslide) - Areas of down slope ground movement identified on the Kern County Seismic Hazard Atlas.

Map Code 2.3 (Shallow Groundwater) - Groundwater within 15 feet of the land surface is delineated on the Kern County Seismic Hazard Atlas.

Map Code 2.4 (Steep Slope) - Land with an average slope of 30 percent or steeper.

Map Code 2.5 (Flood Hazard) – Special Flood Hazard Areas (Zone A), as identified on the Flood Insurance Rate Maps (FIRM) of the Federal Emergency Management Agency (FEMA) and supplemented by floodplain delineating maps that have been approved by the Kern County Engineering and Survey Services Department.

Map Codes from 2.6 to 2.9: Areas with special physical or environmental constraints which are located within a Specific Plan.

Map Code 2.10 (Nearby Waste Facility): Areas which are not owned by the waste facility that are within 1,320 feet of a permitted solid waste disposal facility (Map Code 3.4).

Map Code 2.11 (Burn Dump Hazard): A site where municipal solid waste has been burned at low temperature and the residual burn ash and debris have been landfilled or stockpiled on site. Burn dumps typically contain little biodegradable organic material because of the combustion of waste materials and the age of the sites. Therefore, typically little or no landfill gas is being generated at burn dumpsites. Farm and ranch dumpsites are excluded from this designation.

POLICIES: PHYSICAL AND ENVIRONMENTAL CONSTRAINTS

1. Kern County will ensure that new developments will not be sited on land that is physically or environmentally constrained ((Map Code 2.1 (Seismic Hazard), Map Code 2.2 (Landslide), Map Code 2.3 (Shallow Groundwater), Map Code 2.5 (Flood Hazard), Map Codes from 2.6 – 2.9, Map Code 2.10 (Nearby Waste Facility), and Map Code 2.11 (Burn Dump Hazard)) to support such development unless appropriate studies establish that such development will not result in unmitigated significant impact.

2. In order to minimize risk to Kern County residents and their property, new development will not be permitted in hazard areas in the absence of implementing ordinances and programs. These ordinances will establish conditions, criteria, and standards for the approval of development in hazard areas.

3. Zoning and other land use controls will be used to regulate and, in some instances, to prohibit development in hazardous areas.

4. Special requirements will be applied to new housing within recently active fault zones.

5. New residential uses in fault zones should be limited to single-family housing units.

6. Regardless of percentage of slope, development on hillsides will be sited in the least obtrusive fashion, thereby, minimizing the extent of topographic alteration required and reducing soil erosion while maintaining soil stability.

7. Ensure effective slope stability, wastewater drainage, and sewage treatments in areas with steep slopes are adequate for development.

8. Encourage the preservation of the floodplain's flow conveyance capacity, especially in floodways, to be open space/passive recreation areas throughout the County.

9. Construction of structures that impede water flow in a primary floodplain will be discouraged.

10. The County will allow lands which are within flood hazard areas, other than primary floodplains, to be developed in accordance with the General Plan and Floodplain Management Ordinance, if mitigation measures are incorporated so as to ensure that the proposed development will not be hazardous within the requirements of the Safety Element (Chapter 4) of this General Plan.

11. Protect and maintain watershed integrity within Kern County.

12. General Plan Amendments for new residential development shall be discouraged in areas that are within 1,320 feet of a permitted solid waste disposal facility (Map Code 3.4) or within 200 feet of other waste facilities (Map Code 3.7).

13. Development, which is located adjacent to a burn dumpsite and requires a discretionary permit, shall be reviewed for land use compatibility and possible soil contamination.

IMPLEMENTATION MEASURES: PHYSICAL AND ENVIRONMENTAL CONSTRAINTS

A. Adopt requirements and procedures in zoning, subdivision, and site development regulations and building criteria for Seismic Hazard designated areas. Include the following in these requirements and procedures:

(1) The preparation of special geologic and seismic studies consistent with the requirements of the Safety Element (Chapter 4) of this General Plan.

(2) The following specific and detailed criteria shall apply within special studies zones and shall be included in any planning program, ordinances, rules and regulations adopted by the County pursuant to said SPECIAL STUDIES ZONES ACT (PRC Division 4, Part 2). If the precise location of a fault trace cannot be established, or if a portion of an active fault trace is depicted as "inferred" on the Kern County Seismic Hazard Atlas, require a setback of 100 feet from the appropriate location depicted:

(a) No structure for human occupancy, public or private, shall be permitted to be placed across the trace of an active fault. Furthermore, the area within 50 feet of an active fault shall be assumed to be underlain by active branches of that fault unless and until proven otherwise by an appropriate geologic investigation and submission of a report by a geologist registered in the State of California. This 50-foot standard is intended to represent minimum criteria only for all structures. Certain essential or critical structures, such as high-rise buildings, hospitals, and schools should be subject to more restrictive criteria at the discretion of the Board of Supervisors.

(b) Application for a development permit for any project (as defined in the Public Resources Code Section 2621.6) within a special studies zone

shall be accompanied by a geologic report prepared by a geologist registered in the State of California and directed to the problem of potential surface fault displacement through the project site, unless such report is waived pursuant to PRC Section 2623.

(c) Geologic reports shall be filed with the State Geologist.

(d) A geologist registered in the State of California, within or retained by the County, must evaluate the geologic reports required herein and advise the Kern County Planning Department of the findings.

(e) Comprehensive geologic and engineering studies should be required for any critical or essential structure as previously defined whether or not it is located within a special studies zone.

(f) In accordance with Section 2625 of the Public Resources Code, each application for approval of a project within a delineated special studies zone may be charged a reasonable fee by the County.

(g) As used herein, the following definitions apply:

(1) A "project" includes any structure for human occupancy or new real estate development as defined under Section 2621.6 of the Public Resource Code.

(2) A "structure for human occupancy" is one that is regularly, habitually, or primarily occupied by humans; excluding there from freeways, roadways, bridges, railways, airport runways, and tunnels. The excluded transportation structures should be sited and designed with due consideration to the hazard of surface faulting. Mobilehomes, whose body width exceeds eight (8) feet, are considered structures for human occupancy.

(3) A "new real estate development" is defined as any new development of real property which contemplates the eventual construction of "structures for human occupancy."

B. A seismic analysis may be required for those areas in Kern County which are susceptible to landslides.

C. Cooperate with the Kern County Water Agency to classify lands in the County overlying groundwater according to groundwater quantity and quality limitations.

D. Review and revise the County's current Grading Ordinance as needed to ensure that its standards minimize permitted topographic alteration and soil erosion while maintaining soil stability.

E. Development proposed in areas with steep slopes (Map Code 2.4) will be reviewed for conformity to Chapter 19.88 Hillside Development Ordinance or Chapter 19.52 Special Planning (SP) District to ensure that appropriate soil stability, drainage, and sewage treatment will result.

F. The County will comply with the Colbey-Alquist Floodplain Management Act in regulating land use within designated floodways.

G. Continue to identify areas in which the Kern County Engineering and Survey Services Department should initiate studies for flood hazard where studies have not previously been made and for which urban development is proposed.

H. Development within areas subject to flooding, as defined by the appropriate agency, will require necessary flood evaluations and studies.

I. Designated flood channels and water courses, such as creeks, gullies, and riverbeds, will be preserved as resource management areas or in the case of urban areas, as linear parks whenever practical.

J. Compliance with the Floodplain Management Ordinance prior to grading or improvement of land for development or the construction, expansion, conversion or substantial improvements of a structure is required.

K. The Waste Management Department and the Environmental Health Services Department shall be consulted when discretionary residential development has been proposed in areas that are within 1,320 feet of a permitted solid waste disposal facility (Map Code 3.4), within 200 feet of an other waste facilities (Map Code 3.7), or 660 feet from a commercial organic composting facility or transformation facility.

L. The County shall amend the General Plan maps to include the 2.10 Map Code around solid waste disposal facilities as necessary.

M. The State Water Resources Control Board and the Local Enforcement Agency (Environmental Health Services) shall be consulted when discretionary development has been proposed near a known burn dumpsite.

N. Applicants for new discretionary development should consult with the appropriate Resource Conservation District and the California Regional Water Quality Control Board regarding soil disturbances issues.

O. The Kern County Engineering and Survey Services Department should perform, as funding permits, additional floodplain studies to better define the extent of flood-prone areas in order to ensure compatibility with future land use.

Public Facilities and Services

1.4 PUBLIC FACILITIES AND SERVICES

ASSUMPTIONS: PUBLIC FACILITIES AND SERVICES

As development occurs, the public will demand certain levels of public services and facilities. These levels may, however, vary from region to region within the County. Public funds available to provide such services can be anticipated to be significantly less than adequate to meet all public service needs. As a result, it can be anticipated that there will be an increase in the provision of public facilities through the use of private capital and user fees.

Important segments of the economy temporarily require facilities to dispose of hazardous waste until safer methods are implemented. Waste generators include the oil industry, agriculture, military, and many businesses which generate small volumes of hazardous waste. Hazardous waste disposal facilities in Kern County will be operated as private commercial enterprises under conditional use permits. Although generally referred to as "hazardous", much of the petroleum drilling and production waste is of relatively low toxicity. This is the basis on which these wastes are exempted from federal Resource and Conservation Recovery Act regulations.

It is also assumed that many areas of the County will continue to use individual septic systems for liquid waste disposal due to the absence of community sewage systems.

Vital public facilities and services such as law enforcement (Sheriff), health services, and fire protection will be continued, improved, and expanded where needed.

Educational services and facilities will continue to be provided.

Recreational facilities and parks will continue to be provided by public and private means on an as needed basis.

ISSUES: PUBLIC FACILITIES AND SERVICES

The economical and efficient delivery of public services is one of the main purposes and benefits of effective land use planning. Kern County, as well as numerous special districts, the incorporated cities, and the many school districts within the County, are faced with fiscal constraints and continuing inflationary trends. In some portions of the County, and for some countywide services, the costs of providing the services are exceeding traditional sources of revenue available to finance them. As a result, levels of service are reduced and public facilities are deteriorating.

The new residential, industrial, and commercial land uses indicated on the General Plan map will demand the provision of public services and facilities. In several areas, major public service or facility deficiencies already exist. Projected growth will add to this problem and may create new problems in other areas as well. Locating adequate sites for public facilities will become more difficult as incompatible uses compete for increasingly

limited and expensive sites suitable for public facilities.

Hazardous waste disposal facilities pose substantial environmental threats to soil, groundwater and air quality. Disposal facilities must be justified in terms of beneficial effects for County residents and operated in a manner which ensures environmental safety. Conflicts may exist between the operation of certain disposal facilities as profitable businesses, necessary services for industry, and preservation of natural resources for the common good.

Though the County will continue to provide facilities for solid waste disposal for the residents of Kern County, these facilities will continue to be financed by the implementation of a land use fee and commercial tipping fees.

Many of the County=s landfills were converted from burn dumps or established prior to 1979 and are reaching capacity. Solid wastes may need to be transferred long distances to be properly disposed of. Adequate capacity in some areas of the County may pose a problem.

Continued use of individual septic systems may cause an impact on the groundwater quality.

The determination of needed recreational services and facilities should be an ongoing process. The continued funding for the acquisition, development, and maintenance of recreation and parks is questionable.

Because planning and development of recreational facilities is very often accomplished by special districts that develop individual master plans and implementation schedules, it is difficult to properly designate the location of future facilities.

Within these special districts, as facilities are developed, the County will retroactively designate them with the appropriate map code. The development of public or private recreational facilities in map code designations other than Map Code 3.1, if allowed either as a matter of right or by conditional use permit, shall be considered consistent with the intent and purpose of this General Plan.

Because planning and development of educational facilities is often accomplished by various school districts in Kern County which develop individual plans and implementation schedules it is difficult to properly designate the location of future facilities.

The Kern County Zoning Ordinance allows the establishment of public facilities such as parks, schools, libraries, and other similar facilities in various zone classifications upon approval of a conditional use permit (CUP). It is not the intent of this General Plan to require a General Plan amendment as a prerequisite to the approval of such facilities when, as a part of the CUP process findings, of consistency with the goals, policies, and provisions of this General Plan are made by the approving body.

GOALS: PUBLIC FACILITIES AND SERVICES

1. Kern County residents and businesses should receive adequate and cost effective public services and facilities. The County will compare new urban development proposals and land use changes to the required public services and facilities needed for the proposed project.

2. Promote an urban growth pattern in areas where adequate public service infrastructure exists or can be provided.

3. Distribute the cost of new services or facilities equitably among the beneficiaries.

4. Provide coordination between public entities to ensure infrastructure standards and equitable fiscal support.

5. Ensure that adequate supplies of quality (appropriate for intended use) water are available to residential, industrial, and agricultural users within Kern County.

6. Provide a healthful and sanitary means of collecting, treating, and disposing of sewage and refuse for the residents and industries of Kern County.

7. Facilitate the provision of reliable and cost effective utility services to residents of Kern County.

8. Provide recreation opportunities for all citizens of Kern County while avoiding duplication between jurisdictions.

9. Serve the needs of industries and Kern County residents in a manner that does not degrade the water supply and the environment and protect the public health and safety by avoiding surface and subsurface nuisances resulting from the disposal of hazardous wastes, irrespective of the geographic origin of the waste.

10. Ensure landfill capacity for Kern County residents and industries.

11. Reduce residential contamination of groundwater by encouraging sanitary sewer systems.

12. Provide a balanced system of parks and recreational facilities to meet Kern County=s diverse needs, and clearly define responsibility for the provision of these facilities.

13. Provide a variety of park and recreation programs that offer safe, equitable, and balanced recreation opportunities for all residents and visitors.

MAP PROVISIONS: PUBLIC FACILITIES AND SERVICES

Map Code 3.1 (Parks and Recreation Areas) - Existing public and private recreation facilities and park areas. The purpose of this designation is to provide a wide variety of facilities to serve the many recreational interests of County residents. Permitted uses shall include, but are not limited to, public and private parks containing facilities for day use, hiking, camping, walking, picnicking, riding, and other recreational activities.

Map Code 3.2 (Educational Facilities) - Existing public and private educational facilities. Permitted uses include, but are not limited to, public and private educational facilities of all levels, including higher education institutions, and some recreational facilities, such as neighborhood parks.

Map Code 3.3 (Other Facilities) - Existing facilities used for public or semi-public services. Permitted uses include, but are not limited to, airports, sewer farms, treatment plants, and water spreading areas.

Map Code 3.4 (Solid Waste Disposal Facility) – Existing or planned public, semi-public, or private municipal solid waste facilities, organic waste disposal facilities, and segregated waste stream disposal facilities. (see Appendix E)

Map Code 3.4.1 (Solid Waste Disposal Facility Buffer) – Areas, which are owned by the solid waste disposal facility, within 1,320 feet of a permitted disposal area as defined by the 3.4 Map Code designation (see Appendix E).

Map Code 3.5 (Hazardous Waste Disposal Facilities Land Disposal Method) - Permitted land uses include the primary activity of surface disposal of hazardous waste. There are no compatible uses. This map code applies to land within the facility perimeter.

Two concentric buffer zones extend from the facility perimeter, as illustrated in the Kern County and Incorporated Cities Hazardous Waste Management Plan. The Inner Buffer Zone is shown to extend 2,000 feet from the facility perimeter consistent with current State law. Map Code 8.X, which are various resource designations, will apply to land within this buffer zone. In the Outer Land Use Buffer Zone, which extends to one mile (5,280 feet) from the facility perimeter, all preexisting map code designations will be retained and may be developed as designated. However, no new more intensive land use designations of a sensitive nature will be allowed.

Map Code 3.6 (Hazardous Waste Disposal Facilities Underground Injection Method) - Permitted land uses include a deep injection well for disposal of hazardous wastes as a primary activity. There are no compatible uses. This map code applies to land within the facility perimeter.

Two concentric buffer zones extend from the facility perimeter, as illustrated in the Kern County and Incorporated Cities Hazardous Waste Management Plan. The Inner Buffer Zone is shown to extend 2,000 feet from the facility perimeter consistent with current State law. Map Code 8.x, which are various Resource designations, will apply to land

within this buffer zone. In the Outer Land Use Buffer Zone, which extends to one mile (5,280 feet) from the facility perimeter, all preexisting map code designations will be retained and may be developed as designated. However, no new more intensive land use designations of a sensitive nature will be allowed.

Map Code 3.7 (Other Waste Facilities) – Non-hazardous waste facilities which manage and process various types of waste materials but do not have on-site disposal. Examples include but are not limited to large and medium volume transfer facilities; materials recovery facilities; composting facilities (green waste and biosolids); wood waste (chipping and grinding facilities); tire recycling; soil remediation; transformation facilities; ash operations and facilities as defined in §17376 of Title 14; and construction and demolition recycling (see Appendix F).

Map Code 3.7.1 (Other Waste Facilities Buffer) – Areas which are owned by the waste facility, restricted by easement, or have a compatible use to the waste facility within 200 foot of a permitted waste area as defined by the 3.7 land use designation or for a commercial organic composting and transformation facilities a minimum buffer of 660 foot shall be required (see Appendix F).

POLICIES: PUBLIC FACILITIES AND SERVICES

1. New discretionary development will be required to pay its proportional share of the local costs of infrastructure improvements required to service such development.

2. The efficient and cost-effective delivery of public services and facilities will be promoted by designating areas for urban development which occur within or adjacent to areas with adequate public service and facility capacity.

    a. Ensure that water quality standards are met for existing users and future development

    b. Ensure that adequate storage, treatment, and transmission facilities are constructed concurrently with planned growth.

    c. Ensure the maintenance and repair of existing water systems.

    d. Encourage the utilization of wastewater treatment facilities which provide for the reuse of wastewater.

    e. Encourage the consolidation or elimination of small water systems.

    f. Encourage the conversion of private sewer systems (septic tanks) to public systems.

g. Ensure that adequate collection, treatment, and disposal facilities are constructed concurrently with planned growth.

h. Ensure that appropriate funding mechanisms are in place to fund the needed improvements which result from development and subsequent growth.

3. Individual projects will provide availability of public utility service as per approved guidelines of the serving utility.

4. The provision of parks and recreational facilities of varying size, function, and location to serve County residents will be encouraged. Special attention will be directed to providing linear parks along creeks, rivers, and streambeds in urban areas.

5. Seek to provide recreational facilities where deficiencies have been identified.

6. The County will ensure adequate fire protection to all Kern County residents.

7. The County will ensure adequate police protection to all Kern County residents.

8. Environmentally safe locations for the disposal of solid waste will be assured by locating sites in accordance with the criteria set forth in Appendix E of this General Plan.

9. Applicants for all solid waste disposal facilities (Map Code 3.4) and other waste facilities (Map Code 3.7) shall submit closure plans and financial assurance estimates to guarantee closure in conjunction with approval of the required conditional use permit. The requirement for financial assurances may also be satisfied if a State or federal agency will have lead permit responsibility for approval or operational oversight of the facility and which also will require the posting of financial assurances to guarantee site closure. In conjunction with the financial assurances filed with the County, applicants shall enter into a contract with the County to guarantee site closure.

10. A designated site for solid waste disposal facilities (Map Code 3.4) shall be protected from encroachment of incompatible land uses and intensive urban development. General Plan map code designations which may be compatible for properties adjacent to or within 1,320 feet of solid waste disposal facilities include the following: Resource designations (8.x), 1.2, 3.3, 5.8, 7.1, 7.2, and 7.3. Other map code designations may be compatible subject to project-specific CEQA evaluation. Intensive residential uses, community care facilities, schools, hospitals, recreational vehicle parks, and other uses involving sensitive populations, concentrations of people, and other activities will usually be incompatible adjacent to or near solid waste disposal facilities.

    Health risk assessment analysis prepared by the land use project applicants may be warranted when considering proposals for General Plan amendments, zone

changes, conditional use permits, and sensitive uses within 1,320 feet of a designated solid waste facility site.

11. A solid waste disposal facility (Map Code 3.4) and other waste facilities (Map Code 3.7) shall pay its pro-rata share of upgrading of pertinent County roads.
12. For solid waste disposal facilities, all necessary permits shall be obtained from the Kern County Environmental Health Services Department, Kern County Waste Management Department, State of California Integrated Waste Management Board, State of California Regional Water Quality Control Board, the appropriate Air Pollution Control District, and all other responsible agencies prior to the commencement of operations.

13. The County shall ensure landfill capacity for the residents and industry of Kern County.

14. All solid waste disposal facilities shall designate a buffer around the permitted disposal area as defined by the Map Code 3.4 land use designation.

15. All other waste facilities (non-hazardous/non-disposal) shall designate a buffer around the permitted waste area as defined by the 3.7 land use designation.

16. The proposed siting or expansion of hazardous waste facilities will be in conformance with the adopted Kern County and Incorporated Cities Hazardous Waste Management Plan.

17. For other policies and implementation measures, see General Provisions, Section 1.10 of this General Plan.

IMPLEMENTATION MEASURES: PUBLIC FACILITIES AND SERVICES

A. Continue to administer the Capital Improvement Program (CIP) and coordinate with public utility providers listing the necessary improvements to Kern County's public services and facilities in collaboration with key service providing agencies and the County Administrative Office as a first step toward the preparation of a long-term Public Services Plan for Kern County. This plan addresses the projected demand for public services throughout the County in comparison with projected revenues and identifies long-term financial trends for the major public service providers. The CIP and General Plan can assure compliance with the provisions of Government Code Sections 65401 and 65402 which require review of all capital facility decisions for consistency with this General Plan.

B. Determine local costs of County facility and infrastructure improvements and expansion which are necessitated by new development of any type and prepare a schedule of charges to be levied on the developer at the time of approval of the Final Map. This implementation can be effectuated by the formation of a County work group.

C. Project developers shall coordinate with the local utility service providers to supply adequate public utility services.

D. Involve utility providers in the land use and zoning review process.

E. Continue to establish coordinated efforts between government entities and private enterprise to identify and preserve unique scenic qualities of existing natural resources and to enhance the image of the County as a whole.

F. Continue to use the accepted California and National Design Standards for both passive and active park development to accommodate programmed and spontaneous activities. Some usable area should be held as open turf for free play and community festivals.

G. Continue to encourage coordination between appropriate jurisdictions in the acquisition (including cooperative agreements), development, and use of parks to avoid duplication of facilities and provide economic use of public funds.

H. Continue to pursue federal, State, and private grant funding for the rehabilitation and acquisition of parks and recreation facilities.

I. Developers of new residential subdivisions will be required to dedicate land and/or pay fees in lieu of dedication for the acquisition and development of recreational facilities which directly serve the needs of the subdivision.

J. Ensure that the Superintendent of Schools and the respective school districts are informed of development proposals and are afforded the opportunity of evaluating their potential effect on the physical capacity of school facilities.

K. The appropriate agency should develop sewer and water master plans in areas where these services are lacking or deficient and in areas where urban development exists or is designated.

L. Prior to the approval of development projects, the County shall determine the need for fire protection services. New development in the County shall not be approved unless adequate fire protection facilities and resources can be provided.

M. Conditional use permits shall be required for solid waste facilities to establish the standards and conditions necessary to protect the public's health and safety and to protect characteristics associated with diverse communities and regions of Kern County.

N. Secure complete and accurate information on all hazardous wastes generated, handled, stored, treated, transported, and disposed of within or through Kern County.

O. Reduce to the greatest degree possible the amount of waste to be disposed of by encouraging private industry to construct and manage a high quality system of transfer stations, recycling facilities, treatment plants, and incinerators located near

the generators of hazardous waste.

P. Develop formal relationships with the federal and State governments to define federal, State, regional, and local responsibilities for the enforcement of hazardous waste laws and the inspection of hazardous waste disposal facilities.

Q. The County shall develop a program to update the Kern County and Incorporated Cities Hazardous Waste Management Plan.

R. Roads and highways utilized for commercial shipping of hazardous waste destined for disposal will be designated as such pursuant to Vehicle Code Sections 31303 et seq. Permit applications shall identify commercial shipping routes they propose to utilize for particular waste streams.

S. County permits for new or expanding hazardous waste disposal facilities shall be approved for a period not to exceed five (5) years. No renewal of a permit will be granted if federal or State law or regulations do not then authorize the issuance of permits to operate new disposal facilities of the proposed type. If the County renews a permit, it may impose any new conditions and restrictions, which are required to bring the permit into conformity with law or the Kern County and Incorporated Cities Hazardous Waste Management Plan.

T. Amend the County's EIR Procedures to include consideration of fiscal impacts of development proposals, so that the character and extent of possible public service or facility deficiencies can be identified during the course of the normal project review process.

U. Each adopted site for a solid waste disposal facility (Map Code 3.4) shall be depicted on the General Plan map and on a map in Appendix E, delineating the boundaries of the facility and existing permanent dwelling units within 1,320 feet of the facility's boundary. Modifications to a permitted disposal area shall require a General Plan Amendment to a Map Code 3.4 for the expansion area and shall simultaneously amend the Map Code 3.4.1 (Other Waste Facility Buffer) boundary to maintain a 1,320-foot buffer area from the permitted disposal area. The General Plan Amendment process shall include amending the facilities map in Appendix E.

V. All new solid waste disposal facilities (non-hazardous) (Map Code 3.4) shall own a minimum of 1,320-foot buffer around the permitted operational area as defined by the Map Code 3.4 land use designation and the buffer shall be designated Map Code 3.4.1 (Solid Waste Disposal Facility Buffer). This requirement may be waved or lessened by the Planning Director if adjacent land uses are compatible with the disposal facility such as Heavy and Medium Industrial.

W. Solid waste disposal facilities approved prior to the adoption of this General Plan shall strive to have a 660-foot buffer around the permitted disposal area as defined by the Map Code 3.4 (Solid Waste Disposal Facility) land use designation. Land, which is not owned by the solid waste disposal facility and is within 1,320 feet of a permitted disposal facility, shall include a Map Code 2.10 (Nearby Waste Facility)

combining land use designation.

X. The uses that are allowed within the Map Code 3.4.1 (Solid Waste Disposal Facility Buffer) land use designation shall be listed within the conditional use permit approved for the solid waste disposal facility or as provided for in the approved solid waste facility permit.

Y. Each adopted site for other waste facilities (Map Code 3.7) shall be depicted on the General Plan map, and on a map in Appendix F delineating the boundaries of the facility, and existing permanent dwelling units within 200 foot of the facility's boundary or 660 foot for a commercial organic compost and transformation facilities. Modifications to the permitted waste area of an Other Waste Facilities shall require a General Plan Amendment to a Map Code 3.7 for the expansion area and shall simultaneously amend the Map Code 3.7.1 (Other Waste Facilities Buffer) boundary to maintain the required buffer area from the permitted waste area. The General Plan Amendment process shall include amending the facilities map in Appendix F.

Z. All new Other Waste Facilities (non-hazardous/non-disposal) (Map Code 3.7) shall own a minimum of 200-foot buffer around the permitted operational area as defined by the Map Code 3.7 land use designation and the buffer shall be designated Map Code 3.7.1 (Other Waste Facility Buffer). Commercial organic compost and transformation facilities shall require a minimum of 660-foot buffer.

AA. Other Waste Facilities approved prior to adoption of this General Plan shall strive to have a 200-foot buffer around the permitted disposal area as defined by the 3.7 land use designation. Land, which is not owned by the other waste facility and is within 200-foot of a permitted disposal facility, shall include a Map Code 2.10 (Nearby Waste Facility) combining land use designation, except for commercial organic compost and transformation facilities which require a 660-foot designated buffer.

BB. The uses, which are allowed within the Map Code 3.7.1 (Other Waste Facility Buffer) land use designation, shall be listed within the approved conditional use permit or as provided by the appropriate permit.

CC. Existing designated solid waste facilities are consistent with the General Plan. To further clarify the nature of future facilities, the County shall apply the following land use map codes.

2.10 (Nearby Waste Facility)
2.11 (Burn Dumps)
3.4.1 (Solid Waste Disposal Facility Buffer)
3.7 (Other Waste Facilities)
3.7.1 (Other Waste Facilities Buffer)

DD. Existing Map Code 3.4 (Solid Waste Disposal Facility) facilities that have approved permits consistent with Map Code 3.7 (Other Waste Facilities) may not **expand** their allowed land uses without a consistency finding with this General Plan. To be consistent a General Plan Amendment from Map Code 3.4 (Solid Waste Disposal Facility) to Map Code 3.7 (Other Waste Facilities), and a buffer designated Map Code 3.7.1 (Other Waste Facilities Buffer) may be required.

EE. Existing Map Code 3.4 (Solid Waste Disposal Facility) facilities that have approved permits consistent with Map Code 3.7 (Other Waste Facilities) may not **intensify** their allowed land uses without a consistency finding with this General Plan. To be consistent a new conditional use permit and a buffer designated Map Code 3.4.1 (Solid Waste Disposal Facility Buffer) may be required.

FF. A traffic study/analysis shall be required for all discretionary new or expanded solid waste facilities. The study shall include an analysis of the status of facility access roads and the need to upgrade those roads. Mitigation may be imposed to address impacts to these roads.

GG. Implement a level of service standard of 2.5 acres of park area per 1,000 residents.

HH. The County shall periodically investigate the level of service standards for parks and recreation services to ensure that adequate recreation facilities are provided for County residents.

II. The Kern County Parks and Recreation Department will evaluate the possibility of alternative funding sources for the development, rehabilitation, and operation of park and recreational facilities. These funding sources shall include the possible implementation of development fees and/or special assessment districts such as used for lighting and landscaping, under a County Service Area (CSA).

Special Treatment Areas

1.5 SPECIAL TREATMENT AREAS

ASSUMPTIONS: SPECIAL TREATMENT AREAS

Localized issues, problems, and opportunities will continue to require specific, individualized treatment to ensure that a solution to problems or realization of opportunities is reflective of the needs of local residents. The size and complexity of Kern County forces recognition of localized needs. Use of area and specific plans will continue as basic tools under State law for addressing local needs.

For the purposes of this General Plan, a "Land Project" shall be defined as follows:

1. The subdivision contains 50 or more parcels of which any 50 are both (a) not improved with residential, industrial, commercial, or institutional buildings; and (b) offered for sale, lease, or financing for purposes other than industrial commercial, institutional, or commercial agricultural uses.

   and

2. The subdivision is located in an area in which less than 1,500 registered voters reside within the subdivision or within two miles of the proposed project boundary.

   and

3. The subdivision does not constitute a community apartment project as defined in Business and Professions Code Section 11004, a project consisting of condominiums as defined in Section 783 of the Civil Code, or a stock cooperative as defined in Business and Professions Code Section 11003.2.

ISSUES: SPECIAL TREATMENT AREAS

Specific Plans and Rural Community Plans have been prepared in past years for a number of locations in the County. There are also small rural communities located throughout the County which would be impractical to address at a General Plan level of detail. The identity and character of these communities could easily be damaged by inappropriate treatment in a General Plan. Finally, areas have been identified through analysis of data and by identification during public involvement in the plan preparation process which has the potential for intensified, yet localized, development in the future.

GOALS: SPECIAL TREATMENT AREAS

1. To recognize the validity of existing Specific Plan and Rural Community Plan decisions and to identify areas for which similar detailed planning efforts should be undertaken in the future so as to best meet the needs and concerns of local residents.

MAP PROVISIONS: SPECIAL TREATMENT AREAS

Map Code 4.1 (Accepted County Plan Areas) - A designation of areas for which specific land use plans have already been prepared and approved. These plans are accepted and incorporated by this reference and the respective land use map associated with each such plan is hereby adopted as the General Plan diagram for each such area. Each plan area is indicated on the General Plan map. See Appendix A for details of accepted County plans.

Map Code 4.2 (Interim Rural Community Plan) - A designation used to identify settlements in the County that have individual character which, in past plans, have been broadly merged with the surrounding countryside. These settlements are recognized as unique communities; each with its own character, special advantages, and problems which should more appropriately be addressed at a specific plan level of detail. See Appendix B for details and maps of interim rural community plans.

Map Code 4.3 (Specific Plan Required) - A designation applied to areas wherein large-scale projects have been previously proposed by the project landowner(s). This map code recognizes the need for additional assessment and evaluation of these proposals and does not create a commitment on the part of Kern County to approve any such proposals. The project proponent bears the burden of demonstrating the suitability of the property for the conceptual uses and densities.

Areas designated Map Code 4.3 shall be subject to development, consideration, and adoption of a specific plan in accordance with all applicable local and State requirements pertaining thereto.

The Maximum Allowed Land Use Density tables (Appendix C) showing acreages and densities are conceptual and shall be used as guidelines should a specific plan be developed. Actual land uses and densities shall be based on consistency with the General Plan goals, policies and environmental review and may require reduction or elimination.

POLICIES: SPECIAL TREATMENT AREAS

1. The land use map diagrams adopted for special treatment areas establish the land use patterns for these areas.

2. Applicant-initiated Specific Plans, adopted after the 2004 General Plan Update, that have not been implemented through the application of zoning and/or land division (where applicable) within five years of County approval shall be viewed as inactive. Applicant-initiated Specific Plans, adopted prior to the adoption of the 2004 General Plan Update shall also be viewed as inactive if not implemented within ten years of the 2004 General Plan Update. The County utilizing a County-initiated General Plan Amendment process shall consider inactive applicant-initiated Specific Plans for rescission.

3. Rural communities are historically identifiable small-scale non-urban settlements located in outlying areas of the County which contain a mixture of residential and supportive commercial and other uses serving the community and the surrounding rural population. The County will ensure that the unique character of these communities is preserved and enhanced by recognizing the scale, density, size, and composition of development as summarized in Appendix B.

4. The County shall require the adoption of a specific plan prior to development approval in areas (1) designated Map Code 4.3 (Specific Plan Required) on the General Plan maps; (2) for a development classified as a "Land Project" (see Special Treatment Areas' Assumptions section for a definition of "Land Project"); or (3) proposing to amend a resource designation (Map Code 8.x) equal to or greater than 40 acres to commercial/industrial map codes. Until a Specific Plan is adopted, the Map Code 4.3 (Specific Plan Required) areas will have the following interim General Plan land use designation:

   (a) In areas designated Specific Plan Required the interim designations will reflect the existing zoning pattern pending the owner's or multiple owners' submission of an acceptable plan pursuant to stipulated guidelines found in Appendix C of this General Plan and subsequent County adoption of a Specific Plan. (Appendix C contains a summary of the Specific Plan Required areas)

5. Specific Plan Areas guidelines shall be used to ensure adequate consideration of the General Plan goals and policies governing development and resource management. (These guidelines are presented in Appendix C.)

6. If a Specific Plan Required area, Map Code 4.3, is subdivided prior to adoption of a formal Specific Plan, the Map Code 4.3 designation shall be reviewed for amendment or recession. The recession, through a publicly noticed General Plan Amendment process, shall be based on the practicality of a Specific Plan on the remainder of the property.

IMPLEMENTATION MEASURES: SPECIAL TREATMENT AREAS

A. Where particular policies or standards are not addressed within a Special Treatment Area, the provisions of the Kern County General Plan shall govern.

B. As each special treatment area, Map Code 4.3 (Specific Plan Required) or Map Code 4.2 (Interim Rural Community Plan), has a Specific Plan adopted pursuant to Government Code Section 65450 et seq., the map provision shall concurrently be changed to Map Code 4.1 (Accepted County Plan Area).

C. Zone the accepted plan areas in a manner which is consistent with their equivalent General Plan designation.

D. Portions of accepted County plan areas (Map Code 4.1) classified, as Reserve or Undesignated, shall be considered as Resource Management (Map Code 8.5).

E. The County shall continually review adopted Specific Plans. Inactive Specific Plans, as noted in Policy No. 2, may be considered for County initiated rescission.

F. The Map Code 4.2 (Interim Rural Community Plan) areas shall have the same force and effect as any other accepted County plan area. These areas should be zoned consistently with the maps appended to this document. A proposed change in zoning not consistent with the adopted plan will necessitate the preparation of an appropriate General Plan Amendment.

G. Develop and adopt Specific Plans for each interim Rural Community Plan area.

H. Prepare and adopt Interim Map Code 4.3 maps which contain General Plan designations that reflect consistency with the existing zoning patterns for all areas until a Specific Plan is adopted.

I. Upon adoption of a Specific Plan for a Map Code 4.3 area, the applicable Interim Map Code 4.3 map within the General Plan Appendix C shall be removed, and the plan included on the Adopted Specific Plan list within Appendix A.

Residential

1.6 RESIDENTIAL

ASSUMPTIONS: RESIDENTIAL

It has been assumed that the population of Kern County will continue to grow at its current rate of less than 2 percent annually over the next 20 years, with increments generated both by a continuing influx of new residents from outside the County and by the natural increase of the population in the area.

New residential development should be relatively hazard free and should not intrude on economically important natural resources and should be provided with necessary services.

ISSUES: RESIDENTIAL

A major issue in recent years has been the increase of scattered urban density residential development throughout the County.

The provision of public schools, water, sewers, and public safety protection to low density residential has become increasingly difficult.

There is a need to balance the need for new residential development against all the other land use requirements facing the County. This means linking the additional land to be made available for residential uses to the County's actual anticipated growth.

Increased rural residential land use in the resource areas has put pressure to convert prime agriculture lands to residential. In addition, it is more difficult to farm next to residential areas.

Urban expansion into agriculture areas creates the potential for land use conflicts.

GOALS: RESIDENTIAL

1. Guide the development of new residential uses within the County so as to ensure that the supply of land designated for residential use is extensive enough to meet anticipated demand.

2. Ensure the provision of safe and amenable living environments and the promotion of efficient and economical use of land.

3. Discourage scattered urban density development within Kern County that is not supported by adequate infrastructure.

4. Promote higher-density residential development within the County of Kern in areas with adequate public services and infrastructure.

5. Promote mixed-densities within developments to increase average density, increase greenbelts and paths, reduce consumption of agriculture land, open space, and reduce costs of infrastructure.

6. Promote the conservation of water quantity and quality in Kern County.

7. Minimize land use conflicts between residential and resource, commercial, or industrial land uses.

8. Ensure compatible land uses around airports.

MAP PROVISIONS: RESIDENTIAL

Map Code 5.1 (29 Dwelling Units/Net Acre Maximum) - Designed to allow high-density apartments and condominiums in proximity to and within walking distance of urban commercial centers, with a minimum of 1,502 square feet of site area per unit, yielding a maximum of 29 units per net acre.

Map Code 5.2 (16 Dwelling Units/Net Acre Maximum) - Primarily intended for small multiple-family structures such as duplexes, triplexes, and mobilehome parks which require a full array of urban services, with a minimum of 2,722 square feet of site area per unit and yielding a maximum of 16 units per net acre in conformance with precise development, cluster, or other special planning ordinance standards.

Map Code 5.3 (10 Dwelling Units/Net Acre Maximum) - This category is designed to accommodate urban single-family development on lots with a minimum average size of 4,356 square feet (1/10 of an acre), yielding a maximum of 10 units per net acre in conformance with precise development, cluster, or other special planning ordinance standards.

Map Code 5.4 (4 Dwelling Units/Net Acre Maximum) - This category is designed to accommodate urban single-family development on lots with a minimum average size of 1/4 net acre.

Map Code 5.45 (2 Dwelling Units/Net Acre Maximum) ▪ This category is designed to accommodate urban single-family development on lots with a minimum average size of ▪ net acre.

Map Code 5.5 (1 Dwelling Unit/Net Acre Maximum) - This constitutes a single-family designation with rural service needs in the valley and desert regions, while in the mountain region, residential uses of this density will require urban service provision.

Map Unit 5.6 (Residential - Minimum 2.5 Gross Acres/Unit) - This constitutes a single-family designation with rural service needs in the valley and desert regions, while in the mountain region residential uses of this density will require urban service provision.

Map Code 5.7 (5.0 Gross Acres/Dwelling Unit Maximum) - Designated in the outlying, less densely settled areas, often characterized with physical constraints and not requiring connections to public water and sewer infrastructure.

Map Code 5.75 (10.0 Gross Acres/DU Maximum) ▪ Designated in the outlying, less densely settled areas, often characterized by areas with physical constraints and not requiring connections to public water and sewer infrastructure.

Map Code 5.8 (20+ Gross Acres/DU Maximum) - Designated in the outlying, less densely settled areas, often characterized by physical constraints and not requiring connections to public water and sewer infrastructure.

POLICIES: RESIDENTIAL

1. Varied approaches to residential development will be actively encouraged and given favorable consideration, in order to foster a variety of housing types and densities and a more efficient use of the land, while preserving the character of individual communities.

2. The County will encourage the creation of residential developments as provided for in the Cluster Combining District of the Zoning Ordinance as a means of preserving open space.

3. Owners of individual legal residentially zoned lots of record will, in any event, retain the right to develop a housing unit structure regardless of the General Plan designation, provided County development ordinance criteria are met.

4. Limited neighborhood type of commercial uses will be permitted in all residential map code designations provided that the specific commercial use being proposed is determined through site review to be of a neighborhood nature and appropriate and compatible with surrounding uses provided findings of consistency with the policies and provisions of this plan are met.

5. Discourage premature urban encroachment into areas of intense agriculture areas.

6. Encourage mixed-use developments that allow residential use of the upper levels of multistory commercial buildings.

7. The County shall offer density incentives for residential projects that provide desired elements including infrastructure, affordable housing, day care, and clustered development.

8. The extent, type, and location of new residential development designated by the plan will be in accordance with the goals and objectives of the Housing Element.

9. Development in areas without adequate infrastructure or development that places a burden on public services (i.e. fire, sheriff, parks, and libraries) shall be

discouraged.

10. Encourage new development to infill existing development areas such as by-passed parcels.

11. Provide for an orderly outward expansion of new urban development so that it maintains continuity of existing development, allows for the incremental expansion of infrastructure and public service, minimizes impacts on natural environmental resources, and provides a high-quality environment for residents and businesses.

12. Prior to approval, all new discretionary residential projects located in the Airport Influence Areas will be reviewed for compatibility with the Airport Land Use Compatibility Plan.

13. For other policies and implementation measures, see General Provisions, Section 1.10 of this General Plan.

IMPLEMENTATION MEASURES: RESIDENTIAL

A. Review existing development ordinances and, if necessary, adopt additional standards to ensure that the design and siting of new residential development is compatible with adjacent land uses.

B. Amend the County's zoning maps and residential zoning district regulations to achieve consistency with the General Plan map and residential land use classifications.

C. Encourage innovative residential development through the use of a Cluster Plan approved in conjunction with the Cluster Combining District to permit flexible design and siting standards (such as setbacks, yards, building relationships); and to promote clustering as a means of achieving more efficient housing construction and providing larger areas of usable common open space; and establish a system to award density bonuses in return for special design, infrastructure improvements, extra amenities, usable open space, or other developer efforts.

D. All General Plan Amendments, zone changes, conditional use permits, discretionary residential developments of five or more dwelling units, and variations from height limits established by zoning for properties which are located in the Airport Influence Areas or near a military airport shall be reviewed by the Planning Department for compatibility with the Kern County Airport Land Use Compatibility Plan.

E. Projects that propose creative or innovative housing types and mixed unit densities shall be encouraged by the County based on the following criteria:

    1. Compatibility with the existing character of the surrounding land uses.
    2. Residential development utilizing the existing infrastructure.

3. Infill residential developments
4. Location of the residential development in close proximity to one or more of the following:
    a) Public Transportation.
    b) Parks and/or open space.
    c) Employment opportunities.
    d) Public amenities for the project distinctly over and above the Ordinance requirements.

F. The Density Bonus chapter of the Zoning Ordinance (Chapter 19.92) is required to conform to State law and shall be amended and maintained to comply with California Government Code Sections 65915-65918.

G. Discretionary project applicants shall provide documentation of adequate public infrastructure and services which include, but are not limited to:

1. Fire protection.
2. Police protection.
3. Sewage disposal.
4. Water service including quality and quantity.
5. Documentation that water conservation measures have been considered.

H. Residential development shall be designed in such a way so as to conserve water and energy.

I. Discretionary projects located within a Moderate, High, or Extreme Fire Hazard Zone shall abide by building materials and construction requirements set forth by the Kern County Fire Department and Office of Emergency Services.

Commercial

1.7 COMMERCIAL

ASSUMPTIONS: COMMERCIAL

Employment in the service industries, including wholesale and retail trade, professional services, and health and social services, will continue to grow at a rate comparable to that which is presently occurring. This will continue in response to growth in the basic industries and increasing number of residents and visitors. Agriculture, mineral and petroleum production, and local government will continue to represent the basic industries in the County, whereas manufacturing will be a less significant and well-developed sector of the economy. Government employment will continue to be primarily represented by the military population stationed at Edwards Air Force Base near Mojave and at the China Lake Naval Weapons Center near Ridgecrest.

ISSUES: COMMERCIAL

Adequate land areas must be provided for future growth and development of commercial uses. These commercial services must be located so as to best serve the needs of new residential development, as well as existing populations.

GOALS: COMMERCIAL

1. Ensure that an adequate and geographically balanced supply of land is designated for a range of commercial uses.

2. Pursue a strong economy through logical placement and distribution of commercial development within the rural and urban areas of Kern County.

3. Ensure that adequate infrastructure and public services are available for all proposed commercial projects.

4. Diversify and broaden the commercial base within Kern County.

5. Provide highway commercial along interstates and highways to provide services for the traveling public without being a detriment to existing rural communities.

6. Ensure compatible land uses around airports through the use of the Airport Land Use Compatibility Plan.

MAP PROVISIONS: COMMERCIAL

Map Code 6.1 (Regional Commercial) - Concentrated large-scale retail operations providing a broad range of goods and services. Establishments in this category have a regional market area and receive a large number of customers. Usually pertains to operations close to residential and is generally 20 acres or greater in size.

Uses shall include, but are not limited to, the following:

Regional shopping centers, and major central business districts (CBDs), "big box" commercial centers, and outlet centers.

Map Code 6.2 (General Commercial) - Retail and service facilities of less intensity than regional centers providing a broad range of goods and services which serve the day-to-day needs of nearby residents.

Uses shall include, but are not limited to, the following:

Neighborhood shopping centers, convenience markets, restaurants, offices, wholesale business facilities, resort hotels and motels, hospitals, schools (including trade schools), churches, and commercially related light manufacturing or storage within fully enclosed facilities.

Map Code 6.3 (Highway Commercial) - Uses which provide services, amenities, and accommodations at key locations along major roadways to visitors and through traffic.

Uses shall include, but are not limited to, the following:

Hotels, motels, restaurants, garages, service stations, recreational vehicle parks, fast-food restaurants, truck stops, and truck washes.

POLICIES: COMMERCIAL

1. Kern County will promote a pattern of commercial development that contributes to the economic and physical development of existing unincorporated communities as well as to the incorporated cities.

2. Future commercial uses will be encouraged where residential development exists or is occurring. Designations will not be made far in advance of actual current demand in isolated, remote, or rural areas.

3. The development of specialized clusters of related and mutually supportive commercial activities will be encouraged and supported in appropriate locations by means of the Zoning Ordinance and Specific Plans.

4. Prior to approval, all new discretionary commercial projects located in the Airport Influence areas will be compatible with the Airport Land Use Compatibility Plan.

5. Regional Commercial may be sited in urban areas with adequate infrastructure and should consist of at least 20 acres.

6. Linear commercial development of shallow depth, lacking demonstrated demand, will be discouraged along streets or highways when it can be shown that it impairs the traffic-carrying functions of the highways, it detracts from the aesthetic enjoyment of the surroundings, or if it can be demonstrated that equally effective services can be provided in an alternative configuration.

7. The development of Highway Commercial (Map Code 6.3) shall demonstrate adequate infrastructure.

8. All commercial development equal to or greater than 40 acres in a rural area will require the adoption of a Specific Plan prior to development approval.

9. For other policies and implementation measures, see General Provisions, Section 1.10 of this General Plan.

IMPLEMENTATION MEASURES: COMMERCIAL

A. Review and amend the necessary commercial districts of the Zoning Ordinance to distinguish clearly between the different types of functions, intensities of activities, and site requirements of the commercial designations in the General Plan.

B. Evaluation of applications for any General or Specific Plan Amendment to commercial designation will include sufficient data for review of new commercial development proposals consistent with General Plan policies, using the following criteria and guidelines on:

   i. Location suitability with respect to market area demand.

   ii. Provision of adequate ingress and egress and the mitigation of traffic impacts.

   iii. Provision of adequate water, sewer, and other public services to be used.

   iv. Provision of adequate on-site nonpublic water supply and sewage disposal, if no public systems are available or used.

v. Compatibility with adjacent uses (scale, noise, other nuisances, etc.) and methods for buffering.

vi. Design, layout, and visual appearance within a coordinated commercial setting.

vii. Overall consistency with the General Plan.

C. The depth of new commercial developments shall be at least half the length of the street frontage. Exceptions may be made where existing development or physical constraints provide a more logical shape.

D. Requests for commercial designations and zoning adjacent to residentially designated and other sensitive uses should incorporate a Precise Development Combining District as a means to ensure land use compatibility.

E. Require all new commercial designations be assigned to sites where the aggregate of all contiguous parcels designated for commercial use is no less than five (5) acres, except for:

i. Commercial development located within an approved Specific Plan
ii. Commercial development for highway-oriented service uses at freeway on and off ramps
iii. Where physical conditions are such that commercial is the only logical use of the property.
iv. Neighborhood commercial areas approved in accordance to Residential Policy 4.

F. Proposed commercial developments shall demonstrate compatibility with adjacent residential development through:

i. Attention to noise impacts
ii. Reduction or minimization of light and glare
iii. Buffering of residential from the commercial development through use of walls, landscaping, etc.
iv. Placing loading/unloading areas as far as practicable from residences.

G. All General Plan Amendments, zone changes, conditional use permit, discretionary commercial developments, and variations from height limits established by zoning for properties which are located in the Airport Influence areas or near a military airport shall be reviewed by the Planning Department for compatibility with the Kern County Airport Land Use Compatibility Plan.

H. Discretionary applications for all commercial projects shall provide documentation of adequate public infrastructure and services which include, but are not limited to:

1. Fire protection
2. Police protection
3. Sewage disposal
4. Water service including quality and quantity

I. New General Plan Amendments for Regional Commercial (Map Code 6.1) sited in urban areas shall demonstrate adequate infrastructure and consist of a minimum of 20 acres.

J. Discretionary projects located within a Moderate, High, or Extreme Fire Hazard Zone shall abide by building materials and construction requirements set forth by the Kern County Fire Department and Office of Emergency Services.

Industrial

1.8 INDUSTRIAL

ASSUMPTIONS: INDUSTRIAL

Because Kern County exports the bulk of its agricultural and mineral products in a raw form, manufacturing will continue to be a relatively small sector of the economy. The future of the manufacturing sector appears promising. Some reasons for anticipating growth in the future include convenient access to the Los Angeles and southern California markets, availability of industrial land with adequate transportation and public services, a stable labor force, an affordable housing market, and proximity to sources of raw materials and products. The growth of the manufacturing sector can add greatly to economic activity and wealth. The value added by the processing of raw products could be captured in Kern County and could provide new jobs in the basic (exporting) sector of the economy which, in turn, could support increased demand in the service sector.

ISSUES: INDUSTRIAL

Of primary concern to industrial development is a location relative to resources, labor supplies, transportation, and energy sources. Conflicts can occur when industrial development takes place in areas that are then precluded from resource production or which cause problems of incompatibility with adjacent land uses.

Infrastructure for industrial projects, while well established in the urban areas of Kern County, should be carefully analyzed for any future development. Appropriate siting of industrial development in consideration of the available water and sewer connections, proper access, and road level of service must be determined to prevent any undue burden on established industries or other established developments.

GOALS: INDUSTRIAL

1. Ensure that an adequate and geographically balanced supply of land is designated for a range of industrial purposes.

2. Promote the future economic strength and well being of Kern County and its residents without detriment to its environmental quality.

3. Ensure compatibility with land use designations such as residential, commercial, or other land uses that may be affected by such activities.

MAP PROVISIONS: INDUSTRIAL

Light Industrial (Map Code 7.1) - Unobtrusive industrial activities that can locate in close proximity to residential and commercial uses with a minimum of environmental conflicts. These industries are characterized as labor-intensive and nonpolluting and do not produce fumes, odors, noise, or vibrations detrimental to nearby properties.

Uses shall include, but are not limited to, the following:

Wholesale businesses, storage buildings and yards, warehouses, manufacturing, and assembling.

Service Industrial (Map Code 7.2) - Commercial or industrial activities which involve outdoor storage or use of heavy equipment. Such uses produce significant air or noise pollution and are visually obtrusive.

Uses shall include, but are not limited to, the following:

Automobile and truck parking, storage and repair shops, freighting or trucking yards, bottling plants, breweries, welding shops, cleaning plants, and other manufacturing and processing activities.

Heavy Industrial (Map Code 7.3) - Large-scale industrial activities that are incompatible with other land uses because of potential severe environmental impacts and/or high employee densities.

Uses shall include, but are not limited to, the following:

Manufacturing, assembling and processing activities, transportation facilities, material and equipment storage, sawmills, foundries, refineries, and petroleum product storage.

POLICIES: INDUSTRIAL

1. Locations for new industrial activities shall be provided with adequate infrastructure (water, sewage disposal systems, roads, drainage, etc.) to minimize effects on County services.

2. Map code designations for future industrial development shall not be made far in advance of demand.

3. The land areas best suited for industrial activity by virtue of their location and other criteria will be protected from residential and other incompatible development.

4. Protect existing industrial designations from incompatible land use intrusion.

5. Provide for the clustering of new industrial development adjacent to existing industrial uses and along major transportation corridors.

6. Encourage upgrading the visual character of existing industrial areas through the use of landscaping, screening, or buffering.

7. Require that industrial uses provide design features such as screen walls, landscaping, increased height and/or setbacks, and lighting restrictions between the boundaries of adjacent residential land use designations so as to reduce impacts on residences due to light, noise, sound, and vibration.

8. The County shall give priority to proposed industrial developments where:

    i. Specific uses are proposed in conjunction with submittal of a concurrent precise development plan; and

    ii. Where multiple phases, tenants, or lots are proposed through the adoption of a master precise development plan in conjunction with a General Plan Amendment.

9. Prior to approval, all new discretionary industrial projects located in the Airport Influence Areas will be reviewed for compatibility with the Airport Land Use Compatibility Plan.

10. Light Industrial (Map Code 7.1) may be considered near a residential neighborhood and other sensitive uses provided there is an adequate means of establishing compatibility.

11. Requests for new Map Code 7.2 (Service Industrial) and Map Code 7.3 (Heavy Industrial) designations should be discouraged on sites contiguous to or located within 1/4 mile of residentially designated property.

12. All industrial development equal to or greater than 40 acres in a rural area will require the adoption of a Specific Plan prior to development approval.

13. Where feasible, locate future industrial activities in close proximity to railroad facilities and inter- and intra-State transportation corridors to minimize extensive travel through urban areas and to promote alternative transportation of goods.

14. For other policies and implementation measures, see General Provisions, Section 1.10 of this General Plan.

IMPLEMENTATION MEASURES: INDUSTRIAL

A. Evaluation of applications for any General or Specific Plan Amendment to an industrial designation will include sufficient data for review to facilitate desirable new industrial development proposals consistent with General Plan policies, using the following criteria and guidelines:

   i. Location suitability with respect to market demand area.

   ii. Provision of adequate access, ingress and egress facilities and services, and the mitigation of traffic impacts.

   iii. Provision of adequate water, sewer, and other public services to be used.

   iv. Provision of adequate on-site, nonpublic water supply and sewage disposal if no public systems are available or used.

   v. Compatibility with adjacent uses (scale, noise, emissions, or other nuisances, etc.) and methods for buffering.

   vi. Design, layout, and visual appearance coordinated with existing adjacent industrial uses.

   vii. Overall consistency with the General Plan.

B. Develop information and data on industrial land use, trends, employment, and production. Monitor changes in location of industrial land supply and demand. Identify opportunities and constraints for new industrial development.

C. Amend the industrial districts of the Zoning Ordinance to distinguish clearly between the different types of functions, intensities of activities, location, and site requirements of the Light Industrial, Service Industrial, and Heavy Industrial provisions designated in the General Plan.

D. Amend the permitted use sections of the Zoning Ordinance to limit the range of non-industrial uses permitted in industrial districts so as to protect integrity and ability to achieve their economic functions. Agriculture and mineral and petroleum exploration and extraction, however, should be recognized specifically as permitted and consistent within vacant, industrial-zoned areas. Amend the provisions of agricultural districts to restrict new nonagricultural industrial uses in areas best suited for agricultural use.

E. Identify discrepancies, if any, between the location of industrially designated areas shown on the General Plan map and those reflected on zoning maps, recommend rezoning actions consistent with the General Plan, and amend the Zoning Ordinance.

F. All General Plan Amendments, zone changes, conditional use permits, discretionary industrial developments, and variations from height limits established by zoning for properties which are located in the Airport Influence areas or near a military airport shall be reviewed by the Planning Department for compatibility with the Kern County Airport Land Use Compatibility Plan.

G. Require a Specific Plan for industrial land projects (as defined in the Assumptions Section of the Special Treatment Areas) to identify site specific issues and implementation, such as infrastructure, circulation, compatibility, and public services and facilities.

H. Requests for industrial designations and zoning adjacent to residentially designated and other sensitive uses should incorporate a Precise Development Combining District as a means to ensure land use compatibility.

I. Discretionary projects located within an Extreme, High, or Moderate Fire Hazard Zone shall abide by building materials and construction requirements set forth by the Kern County Fire Department and Office of Emergency Services.

Resource

1.9 RESOURCE

ASSUMPTIONS: RESOURCE

Agriculture has been, and will continue to be, vital to the economy of Kern County. The development of major water projects has greatly increased the amount of land in agricultural production during the last two decades. Similarly, mineral and petroleum resources are basic to Kern County's economy. Kern County has the distinction of producing more oil than any other County in California. In addition, borax, cement production, and construction aggregates constitute major economic mineral resources. As new recovery technologies come into use, petroleum extraction should continue in economic importance. Current trends of increasing demand for borax, cement, and construction aggregates, as well as other minerals found in the County, are expected to continue. As long as new urbanization is restricted in areas having important mineral and petroleum resources, the future production of these resources remains promising.

ISSUES: RESOURCE

Conflicts over the use of agricultural land frequently occur. As is the case for other urbanizing regions, the loss of valuable agricultural lands to urban development is a prime concern.

Land division, even where actual development does not take place, can also adversely affect the County's agricultural resource base. This is particularly a problem in extensive agriculture areas, such as rangeland, where land values can be significantly increased beyond values based on agricultural productivity.

A similar issue arises when oil and other mineral extraction activities, such as sand and gravel pits, are located in close proximity to residential or other incompatible land uses. Incompatible uses located in close proximity to one another, as well as health and safety questions, tend to reduce the availability of the various mineral resources and are but a few of the potential conflicts that may occur.

The availability, proximity, and cost of construction aggregates are a major concern to the local economy. Without knowledge of these resources, land use conflicts could occur and preclude future excavation.

GOALS: RESOURCE

1. To contain new development within an area large enough to meet generous projections of foreseeable need, but in locations which will not impair the economic strength derived from the petroleum, agriculture, rangeland, or mineral resources, or diminish the other amenities which exist in the County.

2. Protect areas of important mineral, petroleum, and agricultural resource potential for future use.

3. Ensure the development of resource areas minimize effects on neighboring resource lands.

4. Encourage safe and orderly energy development within the County, including research and demonstration projects, and to become actively involved in the decision and actions of other agencies as they affect energy development in Kern County.

5. Conserve prime agriculture lands from premature conversion.

6. Encourage alternative sources of energy, such as solar and wind energy, while protecting the environment.

MAP PROVISIONS: RESOURCE

Map Code 8.1 (Intensive Agriculture) - Areas devoted to the production of irrigated crops or having a potential for such use. Other agricultural uses, while not directly dependent on irrigation for production, may also be consistent with the intensive agriculture designation. Minimum parcel size is 20 acres gross.

Uses shall include, but are not limited to, the following:

Irrigated cropland; orchards; vineyards; horse ranches; raising of nursery stock ornamental flowers and Christmas trees; fish farms' bee keeping' ranch and farm facilities and related uses; one single-family dwelling unit; cattle feed yards; dairies; dry land farming; livestock grazing; water storage; groundwater recharge acres; mineral; aggregate; and petroleum exploration and extraction; hunting clubs; wildlife preserves; farm labor housing; public utility uses; and agricultural industries pursuant to provisions of the Kern County Zoning Ordinance, and land within development areas subject to significant physical constraints.

Map Code 8.2 (Resource Reserve) - Areas of mixed natural resource characteristics, such as rangeland, woodland, and wildlife habitat which occur within an established County water district. Minimum parcel size is 20 acres gross, except lands subject to a Williamson Act Contract/Farmland Security Zone Contract, in which case the minimum parcel size shall be 80 acres gross.

Uses shall include, but are not limited to, the following:

Livestock grazing; dry land farming; ranching facilities; wildlife and botanical

preserves; and timber harvesting; one single-family dwelling unit; irrigated croplands; water storage or groundwater recharge areas; mineral; aggregate; and petroleum exploration and extraction; recreational activities, such as gun clubs and guest ranches; and land within development areas subject to significant physical constraints.

Map Code 8.3 (Extensive Agriculture) - Agricultural uses involving large amounts of land with relatively low value-per-acre yields, such as livestock grazing, dry land farming, and woodlands. Minimum parcel size is 20 acres gross, except lands subject to a Williamson Act Contract/ Farmland Security Zone Contract, in which case the minimum parcel size shall be 80 acres gross.

Uses shall include, but are not limited to, the following:

Livestock grazing; dry land farming; ranching facilities; wildlife and botanical preserves; and timber harvesting; one single-family dwelling unit; irrigated croplands; water storage or groundwater recharge areas; mineral; aggregate; and petroleum exploration and extraction; and recreational activities, such as gun clubs and guest ranches; and land within development areas subject to significant physical constraints.

Map Code 8.4 (Mineral and Petroleum) - Areas which contain producing or potentially productive petroleum fields, natural gas, and geothermal resources, and mineral deposits of regional and Statewide significance. Uses are limited to activities directly associated with the resource extraction. Minimum parcel size is five acres gross.

Uses shall include, but are not limited to, the following:

Mineral and petroleum exploration and extraction, including aggregate extraction; extensive and intensive agriculture; mineral and petroleum processing (excluding petroleum refining); natural gas and geothermal resources; pipelines; power transmission facilities; communication facilities; equipment storage yards; and borrow pits.

Map Code 8.5 (Resource Management) - Primarily open space lands containing important resource values, such as wildlife habitat, scenic values, or watershed recharge areas. These areas may be characterized by physical constraints, or may constitute an important watershed recharge area or wildlife habitat or may have value as a buffer between resource areas and urban areas. Other lands with this resource attribute are undeveloped, non-urban areas that do not warrant additional planning within the foreseeable future because of current population (or anticipated increase), marginal physical development, or no subdivision activity.

Minimum parcel size is 20 acres gross, except lands subject to a Williamson Act Contract/Farmland Security Zone Contract, in which case the minimum parcel size shall be 80 acres gross.

Uses shall include, but are not limited to, the following:

Recreational activities; livestock grazing; dry land farming; ranching facilities; wildlife and botanical preserves; and timber harvesting; one single-family dwelling unit; irrigated croplands; water storage or groundwater recharge areas; mineral; aggregate; petroleum exploration and extraction; open space and recreational uses; one single-family dwelling on legal residentially zoned lots on effective date of this General Plan; land within development areas subject to significant physical constraints; State and federal lands which have been converted to private ownership.

POLICIES: RESOURCE

1. Appropriate resource uses of all types will be encouraged as desirable and consistent interim uses in undeveloped portions of the County regardless of General Plan designation.

2. In areas with a resource designation on the General Plan map, only industrial activities which directly and obviously relate to the exploration, production, and transportation of the particular resource will be considered to be consistent with this General Plan.

3. The County will support programs and policies that provide tax and economic incentives to ensure the long-term retention of agriculture, timber, and other resource lands.

4. Approval of any Confined Animal Facility (CAF), including dairies and feedlots, shall consider proximity to incorporated areas of urban development and sensitive receptors such as schools and hospitals. Environmental documentation shall analyze distances to these areas, as well as potential impacts and mitigation.

5. Areas of low intensity agriculture use (Map Code 8.2 (Resource Reserve), Map Code 8.3 (Extensive Agriculture), Map Code 8.5 (Resource Management)) should be of an economically viable size in order to participate in the State Williamson Act Program/Farmland Security Zone Contract.

6. The creation of “homesite parcels” for financing purposes in areas designated Map Code 8.1 (Intensive Agriculture), Map Code 8.2 (Resource Reserve), Map Code 8.3 (Extensive Agriculture), and Map Code 8.5 (Resource Management) shall be allowed when creation of the homesite parcel is found to be accessory and contiguous to a commercial agricultural use. Homesite parcels shall only be permitted when the property supporting the contiguous commercial agricultural use

is subjected to a Williamson Act Land Use Contract or Farmland Security Zone Contract.

The maximum size of a homesite parcel shall be three (3) acres, unless special circumstances exist which warrant the creation of a larger homesite parcel. In no case shall a homesite parcel exceed five (5) acres.

Only one homesite parcel shall be created from an existing parcel of record, although it may contain more than one dwelling, provided that a Contract Amending Land Use Contract restricts an area within the parent parcel sufficient to ensure that the resulting overall density permitted by the underlying General Plan designation will not be exceeded. Homesite parcels shall not be created from any parcel with a size of 20 acres or less.

7. Areas designated for agricultural use, which include Class I and II and other enhanced agricultural soils with surface delivery water systems, should be protected from incompatible residential, commercial, and industrial subdivision and development activities.

8 Provide for the orderly expansion of new urban-scale infrastructure and development and the creation of new urban-scale centers in a manner that minimizes adverse effects on agriculture and natural resource uses.

9. When evaluating General Plan Amendment proposals to change a Map Code 8.1 (Intensive Agriculture) designation to accommodate residential, commercial, or industrial development, the County shall consider the following factors:

   a. Approval of the proposal will not unreasonably interfere with agricultural operations on surrounding lands.

   b. Necessary public services (fire, sheriff, etc.) and infrastructure are available to adequately serve the project.

   c. There is a demonstrated need for the proposed project location based upon population projections, market studies and other indicators.

   d. The requested change in land use designation is accompanied by a zone change and other implementing land use applications for a specific development proposal.

   e. The site is contiguous to properties that are developed or characterized by nonagricultural land uses.

   f. Past agricultural use of the site has led to soil infertility or other soil conditions which render the property unsuitable for long-term agricultural use.

g. Approval of the proposed project outweighs the need to retain the land for long-term agricultural use.

h. Where adjacent or within proximity (1/2 mile) to existing urban areas, the County shall discourage agricultural conversion that is discontinuous with urban development.

10. To encourage effective groundwater resource management for the long-term economic benefit of the County the following shall be considered:

(a) Promote groundwater recharge activities in various zone districts.

(b) Support for the development of Urban Water Management Plans and promote Department of Water Resources grant funding for all water providers.

(c) Support the development of groundwater management plans.

(d) Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water and groundwater and desalination.

11. Minimize the alteration of natural drainage areas. Require development plans to include necessary mitigation to stabilize runoff and silt deposition through utilization of grading and flood protection ordinances.

12. Areas identified by the Natural Resource Conservation Service (formerly Soil Conservation Service) as having high range-site value should be conserved for Extensive Agriculture uses or as Resource Reserve, if located within a County water district.

13. Any property in an Agriculture Preserve proposing to be subject to a Williamson Act Contract or Farmland Security Zone Contract must have a Resource designation.

14. Emphasize conservation and development of identified mineral deposits.

15. Agriculture and other resource uses will be considered a consistent use in areas designated for Mineral and Petroleum Resource uses on the General Plan.

16. The County will encourage development of alternative energy sources by tailoring its Zoning and Subdivision Ordinances and building standards to reflect Alternative Energy Guidelines published by the California State Energy Commission.

17. Lands classified as MRZ-2, as designated by the State of California, should be protected from encroachment of incompatible land uses.

18. Actively monitor the actions of local, State, and federal agencies related to energy development in Kern County and lobby and present its position on such matters as needed to protect County interests.

19. Work with other agencies to define regulatory responsibility concerning energy-related issues.

20. Areas along rivers and streams will be conserved where feasible to enhance drainage, flood control, recreational, and other beneficial uses while acknowledging existing land use patterns.

21. The County shall encourage qualifying agricultural lands to participate in the Williamson Act program or Farmland Security Zone program.

22. The County shall encourage efforts through the State legislature to increase subvention payment rates for State reimbursement to the County to more realistically offset the loss of property tax revenues associated with participation with the Williamson Act program or the Farmland Security Zone program.

23. The County should encourage the merger of largely undeveloped antiquated subdivisions which are designated Map Code 8.1 (Intensive Agriculture), Map Code 8.2 (Resource Reserve), Map Code 8.3 (Extensive Agriculture), or Map Code 8.5 (Resource Management) into larger holdings to achieve density consistency with the underlying land use designation.

24. Urban residential or commercial development on property contiguous to property designated Map Code 8.1 (Intensive Agriculture) should employ landscaping, lot size, open space buffering, increased building setbacks, or other techniques to reduce the potential for land use conflicts when it can be demonstrated that such measures will provide for public welfare and benefit and promote continued agricultural uses.

25. Discourage incompatible land use adjacent to Map Code 8.4 (Mineral and Petroleum) areas.

IMPLEMENTATION MEASURES: RESOURCE

A. Periodically update the General Plan's Resource Data maps with new information, such as annexations, as it becomes available from the various data sources. Land use designations may be revised by amending the plan to more appropriate uses at the time of the Annual Report to reflect more accurate data or information.

B. Areas designated as Resource Reserve (Map Code 8.2), Extensive Agriculture

(Map Code 8.3), Resource Management (Map Code 8.5) that are under Williamson Act Contracts or Farmland Security Zone Contracts will have a minimum parcel size of 80 acres until such time as a contract is expired or is cancelled, at which time the minimum parcel size will become 20 acres.

C. The County Planning Department will seek review and comment from the County Engineering and Survey Services Department on the implementation of the National Pollution Discharge Elimination System for all discretionary projects.

D. The minimum lot size requirements of the A Zone District shall provide for the creation of homesite parcels consistent with the density required of the General Plan designations.

E. Designate the riparian community abutting rivers and streams with an appropriate resource use (e.g. Map Code 8.2 (Resource Reserve), Map Code 8.3 (Extensive Agriculture), or Map Code 8.5 (Resource Management)) or resource management designation where feasible to do so.

F. Prime agricultural lands, according to the Kern County Interim-Important Farmland map produced by the Department of Conservation, which have Class I or II soils and a surface delivery water system shall be conserved through the use of agricultural zoning with minimum parcel size provisions.

G. Property placed under the Williamson Act/Farmland Security Zone Contract must be in a Resource designation.

H. Use the California Geological Survey's latest maps to locate mineral deposits until the regional and Statewide importance mineral deposits map has been completed, as required by the Surface Mining and Reclamation Act.

I. Periodically review the Zoning Ordinance to reflect new technology and energy sources, and encourage these types of uses for new development.

J. The County shall continue to monitor new legislation as it relates to energy production and periodically review the General Plan and Zoning Ordinance for any required updates.

K. Protect oilfields and mineral extraction areas through the use of appropriate implementing zone districts: A (Exclusive Agriculture), DI (Drilling Island), NR (Natural Resource), or PE (Petroleum Extraction).

General Provisions

1.10 GENERAL PROVISIONS

ASSUMPTIONS: GENERAL PROVISIONS

The goals, policies, and implementation measures presented in the General Provisions section address issues or situations that are not addressed in the previous sections of the General Plan and apply to all types of discretionary projects. This evolving section will be continually updated to address planning issues as they arise within Kern County.

ISSUES: GENERAL PROVISIONS

A basic issue which the General Plan must address is how anticipated growth and development will be accommodated over the next 20 years. Related to this are economic considerations which may or may not be reflected in actual physical development. Land is often divided into smaller parcels in several sequences yet often is never developed for productive uses such as residences or businesses. In other cases, intensive development takes place on land not well suited to such development, such as areas of natural hazards or areas having significant economic resources.

Oak woodlands and larger individual oaks have aesthetic and historical value, provide for wildlife and game and enhance scenic values for all Kern County residents and visitors. Development represents an opportunity, through site planning, to preserve this important resource while allowing for economic growth.

GOALS: GENERAL PROVISIONS

1. Ensure that the County can accommodate anticipated future growth and development while maintaining a safe and healthful environment and a prosperous economy by preserving valuable natural resources, guiding development away from hazardous areas, and assuring the provision of adequate public services.

POLICIES: GENERAL PROVISIONS

1. The County will administer the General Plan in conformance with State laws and mandates, which includes an annual status report in accordance with Government Code Section 65400 (b)(1).

2. Densities specified in the map provisions are maximums and may be reduced if it is determined that such reduction is warranted by conditions specifically applicable to the site, such as geological and flood hazards, shallow groundwater, steep slopes, significant wildlife habitat, or botanical communities. However, densities may be increased under density bonus and cluster option programs and policies to be

developed and adopted during the implementation phase of this General Plan program.

3. For policy purposes, the County will be divided into three geographic regions, as discussed in the Introduction chapter: Valley, Mountain, and Desert. Urban densities shall be defined as: greater than or equal to one unit per acre in the valley and desert regions, and less than or equal to 2 ½ acres per unit in the mountain region.

4. If any section, subsection, paragraph, sentence, clause, or phrase of this General Plan is for any reason held to be invalid or unconstitutional by the decision of any court of competent jurisdiction, such decision shall not affect the validity of the remaining portions of this General Plan. The Board of Supervisors, hereby declares that it would have passed this General Plan and each section, subsection, sentence, clause, and phrase, thereof, irrespective of the fact that any or one or more sections, subsections, sentences, clauses, or phrases may be declared invalid or unconstitutional.

5. Higher density development and in-filling should be encouraged within urbanized and built-up areas of the County.

6. The County shall ensure the fair treatment of people of all races, cultures, incomes and age groups with respect to the development, adoption, implementation and enforcement of land use and environmental programs.

7. In administering land use and environmental programs, the County shall not deny any individual or group the enjoyment of the use of land due to race, sex, color, religion, ethnicity, national origin, ancestry, lawful occupation or age.

8. The County shall ensure that new industrial uses and activities are sited to avoid or minimize significant hazards to human health and safety in a manner that avoids over concentrating such uses in proximity to schools and residents.

Implementation Measures

A. The Kern Council of Governments (Kern COG) will monitor population growth and its subsequent developmental effects to identify the distribution of population increases and the capabilities of governmental and public agencies to provide new development with adequate services and facilities in a fiscally acceptable manner.

B. The County shall develop fiscal impact guidelines and shall be responsible for reviewing fiscal impact analysis to identify the cost to the County of services, facilities, and infrastructure expansion which new discretionary development necessitates.

C. Prepare and distribute on an annual basis, as required by Government Code Section 65400 (b)(1), a report on the status of the General Plan and the progress achieved in its application.

1.10.1 Public Services and Facilities

Policies

9. New development should pay its pro rata share of the local cost of expansions in services, facilities, and infrastructure which it generates and upon which it is dependent.

10. Community sewage treatment and disposal facilities with collection systems will be required for all developments of 75 or more lots proposed as one development or cumulatively with other developments in a community area, unless soils engineering studies performed at the time of any land division project and approved by the Kern County Environmental Health Services Department, indicate that alternative septic systems, either individual or community design, are equal to or better than a community collection, treatment, and disposal system.

11. Should an urban area not be presently serviced by any sewage collection system, a timetable will be established in cooperation with the California Regional Water Quality Control Board for siting and construction of necessary collection, treatment, and disposal facilities.

12. All methods of sewage disposal and water supply shall meet the requirements of the Kern County Environmental Health Services Department and the California Regional Water Quality Control Board. The Environmental Health Department shall periodically review and modify, as necessary, its requirements for sewage disposal and water supply, and shall comply with any new standards adopted by the State for implementation of Government Code Division 7 of the Water Code, Chapter 4.5 (Section 13290-13291.7). (Assembly Bill 885)(2000).

13. A compact and orderly urban expansion pattern adjacent to established communities will be encouraged in order to avoid uneconomic investment by the public sector for excessive or premature extension of public facilities and services.

14. The County will explore financing and methods of installation of public sewage systems, which will be encouraged both in areas of existing urban density served by septic systems and in existing communities experiencing repeated septic system failures.

15. Prior to approval of any discretionary permit, the County shall make the finding, based on information provided by California Environmental Quality Act (CEQA)

documents, staff analysis, and the applicant, that adequate public or private services and resources are available to serve the proposed development.

16. The developer shall assume full responsibility for costs incurred in service extensions or improvements that are required to serve the project. Cost sharing or other forms of recovery shall be available when the service extensions or improvements have a specific quantifiable regional significance.

17. The extent of community-type public services and facilities required for urban densities in the Mountain, Valley and Desert regions vary according to the following criteria:

    a. Within the Valley and Desert regions, new residential development sites less than or equal to one acre net lot size density, commercial, and industrial land uses shall be serviced by necessary and appropriate sewer and water systems.

    b. Within the Mountain Region, new residential development sites less than or equal to 2 1/2 acres gross lot size density, commercial, and industrial land uses shall be serviced by necessary and appropriate sewer and water systems.

Implementation Measures

D. The appropriate agency should develop sewer and water master plans in areas where these services are lacking or deficient and in areas where urban development exists or is designated. Seek non-local sources of funding for implementing capital improvement plans.

E. All new discretionary development projects shall be subject to the Standards for Sewage, Water Supply and Preservation of Environmental Health Rules and Regulations administered by the Environmental Health Services Department. Those projects having percolation rates of less than five minutes per inch shall provide a preliminary soils study and site specific documentation that characterizes the quality of upper groundwater in the project vicinity and evaluation of the extent to which, if any, the proposed use of alternative septic systems will adversely impact groundwater quality. If the evaluation indicates that the uppermost groundwater at the proposed site already exceeds groundwater quality objectives of the Regional Water Quality Control Board or would if the alternative septic system is installed, the applicant shall be required to supply sewage collection, treatment and disposal facilities.

1.10.2 Air Quality

Policies

18. The air quality implications of new discretionary land use proposals shall be considered in approval of major developments. Special emphasis will be placed on minimizing air quality degradation in the desert to enable effective military operations and in the valley region to meet attainment goals.

19. In considering discretionary projects for which an Environmental Impact Report must be prepared pursuant to the California Environmental Quality Act, the appropriate decision making body, as part of its deliberations, will ensure that:

    (a) All feasible mitigation to reduce significant adverse air quality impacts have been adopted; and

    (b) The benefits of the proposed project outweigh any unavoidable significant adverse effects on air quality found to exist after inclusion of all feasible mitigation. This finding shall be made in a statement of overriding considerations and shall be supported by factual evidence to the extent that such a statement is required pursuant to the California Environmental Quality Act.

20. The County shall include fugitive dust control measures as a requirement for discretionary projects and as required by the adopted rules and regulations of the San Joaquin Valley Unified Air Pollution Control District and the Kern County Air Pollution Control District on ministerial permits.

21. The County shall support air districts' efforts to reduce PM_{10} and $PM_{2.5}$ emissions.

22. Kern County shall continue to work with the San Joaquin Valley Unified Air Pollution Control District and the Kern County Air Pollution Control District toward air quality attainment with federal, State, and local standards.

23. The County shall continue to implement the local government control measures in coordination with the Kern Council of Governments and the San Joaquin Valley Unified Air Pollution Control District.

24. Kern County shall consult with transit providers to determine project effects and ensure that impacts are mitigated.

Implementation Measures

F. All discretionary permits shall be referred to the appropriate air district for review and comment.

G. Discretionary development projects involving the use of tractor-trailer rigs shall incorporate diesel exhaust reduction strategies including, but not limited to:

   a. Minimizing idling time.
   b. Electrical overnight plug-ins.

H. Discretionary projects may use one or more of the following to reduce air quality effects:

   a. Pave dirt roads within the development.
   b. Pave outside storage areas.
   c. Provide additional low Volatile Organic Compounds (VOC) producing trees on landscape plans.
   d. Use of alternative fuel fleet vehicles or hybrid vehicles.
   e. Use of emission control devices on diesel equipment.
   f. Develop residential neighborhoods without fireplaces or with the use of Environmental Protection Agency certified, low emission natural gas fireplaces.
   g. Provide bicycle lockers and shower facilities on site.
   h. Increasing the amount of landscaping beyond what is required in the Zoning Ordinance (Chapter 19.86).
   i. The use and development of park and ride facilities in outlaying areas.
   j. Other strategies that may be recommended by the local Air Pollution Control Districts.

I. Work with transit providers to develop long-range transit strategies based on future and anticipated land use plans.

J. The County should include PM_{10} control measures as conditions of approval for subdivision maps, site plans, and grading permits.

1.10.3 Archaeological, Paleontological, Cultural, and Historical Preservation

Policy

25. The County will promote the preservation of cultural and historic resources which provide ties with the past and constitute a heritage value to residents and visitors.

Implementation Measure

K. Coordinate with the California State University, Bakersfield's Archaeology Inventory Center.

L. The County shall address archaeological and historical resources for discretionary projects in accordance with the California Environmental Quality Act (CEQA).

M. In areas of known paleontological resources, the County should address the preservation of these resources where feasible.

N. The County shall develop a list of Native American organizations and individuals who desire to be notified of proposed discretionary projects. This notification will be accomplished through the established procedures for discretionary projects and CEQA documents.

O. On a project specific basis, the County Planning Department shall evaluate the necessity for the involvement of a qualified Native American monitor for grading or other construction activities on discretionary projects that are subject to a CEQA document.

1.10.4 Wireless Communication Facilities

Policy

26. Discretionary development of wireless communication facilities shall be consistent with the Federal Telecommunication Act.

Implementation Measure

P. Discretionary development of wireless communication facilities shall be in accordance with Chapter 19.91 of the Zoning Ordinance and the Federal Telecommunication Act.

1.10.5 Threatened and Endangered Species

Policies

27. Threatened or endangered plant and wildlife species should be protected in accordance with State and federal laws.

28. County should work closely with State and federal agencies to assure that discretionary projects avoid or minimize impacts to fish, wildlife, and botanical resources.

29. The County will seek cooperative efforts with local, State, and federal agencies to protect listed threatened and endangered plant and wildlife species through the use of conservation plans and other methods promoting management and conservation of habitat lands.

30. The County will promote public awareness of endangered species laws to help educate property owners and the development community of local, State, and

federal programs concerning endangered species conservation issues.

31. Under the provisions of the California Environmental Quality Act (CEQA), the County, as lead agency, will solicit comments from the California Department of Fish and Game and the U.S. Fish and Wildlife Service when an environmental document (Negative Declaration, Mitigated Negative Declaration, or Environmental Impact Report) is prepared.

32. Riparian areas will be managed in accordance with United States Army Corps of Engineers, and the California Department of Fish and Game rules and regulations to enhance the drainage, flood control, biological, recreational, and other beneficial uses while acknowledging existing land use patterns.

Implementation Measures

Q. Discretionary projects shall consider effects to biological resources as required by the California Environmental Quality Act.

R. Consult and consider the comments from responsible and trustee wildlife agencies when reviewing a discretionary project subject to the California Environmental Quality Act.

S. Pursue the development and implementation of conservation programs with State and federal wildlife agencies for property owners desiring streamlined endangered species mitigation programs.

1.10.6 Surface Water and Groundwater

Policy

33. Water related infrastructure shall be provided in an efficient and cost effective manner.

34. Ensure that water quality standards are met for existing users and future development.

35. Ensure that adequate water storage, treatment, and transmission facilities are constructed concurrently with planned growth.

36. Ensure that appropriate funding mechanisms for water are in place to fund the needed improvements resulting from growth and subsequent development.

37. Ensure maintenance and repair of existing water systems.

38. Encourage utilization of wastewater treatment facilities which provide for the reuse of wastewater.

39. Encourage the development of the County's groundwater supply to sustain and ensure water quality and quantity for existing users, planned growth, and maintenance of the natural environment.

40. Encourage utilization of community water systems rather than the reliance on individual wells.

41. Review development proposals to ensure adequate water is available to accommodate projected growth.

42. Encourage water supply purveyors to prepare master water plans for those areas of the County approaching existing design thresholds, including documentation of areas in need of system maintenance and repair.

43. Drainage shall conform to the Kern County Development Standards and the Grading Ordinance.

44. Discretionary projects shall analyze watershed impacts and mitigate for construction-related and urban pollutants, as well as alterations of flow patterns and introduction of impervious surfaces as required by the California Environmental Quality Act (CEQA), to prevent the degradation of the watershed to the extent practical.

45. New high consumptive water uses, such as lakes and golf courses, should require evidence of additional verified sources of water other than local groundwater. Other sources may include recycled stormwater or wastewater.

46. In accordance with the Kern County Development Standards tank-truck hauling of domestic water for land developments or lots within new land developments is not permitted.

Implementation Measures

T. The Kern County Environmental Health Services Department will develop guidelines which will establish criteria for development of proposed new water systems when an existing water system, within a reasonable distance, is able to supply water.

U. The Kern County Environmental Health Services Department will develop guidelines for the protection of groundwater quality which will include comprehensive well construction standards and the promotion of groundwater protection for identified degraded watersheds.

V. Water and sewer purveying agencies should develop long-term sewer and water master plans in areas where these services are lacking or deficient and in areas where urban development exists or is designated.

W. Applications for General or Specific Plan Amendments will include sufficient data for review to facilitate desirable new development proposals consistent with General Plan policies, using the following criteria and guidelines:

i. The provision of adequate water, sewer, and other public services to be used.

ii. The provision of adequate on-site nonpublic water supply and sewage disposal if no public systems are available or used.

X. Encourage effective groundwater resource management for the long-term benefit of the County through the following:

i. Promote groundwater recharge activities in various zone districts.

ii. Support for the development of Urban Water Management Plans and promote Department of Water Resources grant funding for all water providers.

iii. Support the development of Groundwater Management Plans.

iv. Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water, and groundwater and desalination.

Y. Promote efficient water use by utilizing measures such as:

i. Requiring water-conserving design and equipment in new construction.

ii. Encouraging water-conserving landscaping and irrigation methods.

iii. Encouraging the retrofitting of existing development with water conserving devices.

Z. General Plan Amendments subject to environmental review and not otherwise subject to California Water Code Section 10910 shall demonstrate through a water supply assessment that a long-term water supply for a 20-year timeframe is available. The water assessment shall include, but not limited to, the following:

i. Source and quantity of historical water use on the site.

ii. Estimated water consumption of the proposed development.

iii. Estimated storage, if any, in meeting the projected need.

iv. Recommendations for additional sources of water to address demand shortage. Such measures may include, but not limited to, development of future sources of additional surface water and groundwater, including water transfers, conjunctive use, recycled water, conservation, and additional storage of surface water, groundwater, and desalination.

Written acknowledgement that water will be provided by a community or public water system with an adopted Urban Water Management Plan shall constitute compliance with this requirement.

1.10.7 Light and Glare

Policy

47. Ensure that light and glare from discretionary new development projects are minimized in rural as well as urban areas.

48. Encourage the use of low-glare lighting to minimize nighttime glare effects on neighboring properties.

Implementation

AA. The County shall utilize CEQA Guidelines and the provisions of the Zoning Ordinance to minimize the impacts of light and glare on adjacent properties and in rural undeveloped areas.

1.10.8 Smart Growth

Policy

49. Discretionary development projects should be encouraged to incorporate innovative or “smart growth” land use planning techniques as design features, as follows:

a. Higher density development, where compatible, to maximize the efficient use of land.

b. Mixed use developments that promote reduced vehicle trips by having residential, commercial, and public uses proximate to each other.

c. Variety of housing types, including those using energy efficient design, and densities to address Kern County's housing needs.

d. Master planned communities that feature interconnected roads, transit stops, sidewalks, landscaping, and trails to encourage efficient multi-modal movements.

e. Compact development that conserves open space, agricultural land, flood-prone areas, creeks, hillsides, ridge tops, wetlands, and other natural features.

f. Adequate infrastructure (i.e. roads, sewer, water, parks, etc.) is provided as a condition of development approval by the project proponent.

g. Aesthetically pleasing and unifying design features that promote a visually pleasing environment.

Implementation Measures

BB. Wherever feasible accommodate new growth by infilling development, redeveloping existing sites, reusing vacant buildings and using under-utilized sites more efficiently before developing peripheral agricultural or resource lands.

CC. Promote the creation of innovative development through the use of smart growth principles and various implementing tools including, but not limited to: Community Plans, Specific Plans, Combining Zone districts CL (Cluster), SP (Special Planning), OS (Open Space), Density Bonuses, Transit facilities, etc. Allow the flexibility to assess traffic and safety impacts through means other than Level Of Service (LOS) when development utilizes Smart Growth policies that encourage efficient multi-modal movements, and is proposed as part of a Community Plan or Specific Plan.

1.10.9 Economic Development

Policies:

50. Employ land use policies that protect the County's businesses from physical degradation and ensure orderly growth, thereby, sustaining opportunities for current and future generations to enjoy economic vitality.

51. Promote tourism-based businesses throughout the County.

52. Support initiatives to develop private/public sector partnerships to beautify communities.

53. Encourage the use of festivals and sporting events that take advantage of the large open spaces and recreational facilities throughout the County.

54. Recognize the importance of major transportation corridors, airports, and rail

lines as important economic tools for the establishment of commercial and industrial development and promotion.

55. Promote the utilization of the County by the film industry.

56. Provide for a mixed land uses that offer a variety of employment opportunities and enhances the County's economic assets to allow the capture of regional growth.

57. Support and work closely with local jurisdictions and other organizations concerned with economic development to minimize inter-jurisdictional competition.

58. Support and work toward the elimination of disincentives for business and industry to prosper in Kern County, and create special economic development programs to encourage commerce and industry to locate in Kern County.

59. Support efforts to promote the County and its cities as an area with a positive business climate for commerce and industry.

60. Support the revision of taxes, workers compensations, and programs that discourage commerce and industry from locating in California and Kern County.

61. Support efforts to provide assistance to small businesses.

62. Periodically review and update procedures for granting development approvals and permits and facilitate the processing of land use entitlements.

63. Promote improved public transportation service between major job centers and areas of transit dependency and high unemployment.

64. Provide infrastructure and coordinate local land use, regulatory practices and job training to foster and maintain a robust economy.

Implementation Measures

DD. Utilize the County's Economic Strategy and the Economic Incentive Program to promote economic growth and to maintain a strong local economy.

EE. Work with the Chamber of Commerce and the Visitor Centers throughout the County to promote the tourism industry.

FF. Work with Caltrans in implementation of the Scenic Highway Corridor designation for various highways as described in the Circulation Element and protect viewsheds with the use of the SC (Scenic Corridor Combining) District.

GG. Provide for temporary events in accordance with the Kern County Zoning Ordinance.

HH. Develop Specific Plans for communities throughout the County which provide for a mix of land uses to promote employment opportunities and housing, while maintaining a good quality of life.

II. Allow for development of complementary businesses that take advantage of transportation corridors when providing infrastructure and services necessary to maintain adequate health and safety concerns.

JJ. Allow for compatible industrial and commercial growth, in conjunction with airport facilities, in accordance with the Airport Land Use Compatibility Plan.

1.10.10 Oak Tree Conservation

Policies

65. Oak woodlands and large oak trees shall be protected where possible and incorporated into project developments.

66. Promote the conservation of oak tree woodlands for their environmental value and scenic beauty.

Implementation Measures

KK. The following applies to discretionary development projects (General Plan Amendment, zone change, conditional use permit, tract maps, parcel maps, precise development plan) that contains oak woodlands, which are defined as development parcels having canopy cover by oak trees of at least ten percent (10%), as determined from base line aerial photography or by site survey performed by a licensed or certified arborist or botanist. If this study is used in an Environmental Impact Report, then a Registered Professional Forester (RPF) shall perform the necessary analysis.

a. Development parcels containing oak woodlands are subject to a minimum canopy coverage retention standard of thirty percent (30%). The consultant shall include recommendations regarding thinning and diseased tree removal in conjunction with the discretionary project.

b. Use of aerial photography and a dot grid system shall be considered adequate in determining the required canopy coverage standard.

c. Adjustments below thirty percent (30%) minimum canopy standard may be made based on a report to assess the management of oak woodlands.

d. Discretionary development, within areas designated as meeting the minimum canopy standard, shall avoid the area beneath and within the trees unaltered drip line unless approved by a licensed or certified arborist or botanist.

LL. The following applies to development of parcels having oak tree canopy cover of less than ten percent (10%), but containing individual oak trees equal to or greater than a 12-inch diameter trunk at 4.5 feet breast height.

a. Such trees shall be identified on plot plans.

b. Discretionary development shall avoid the area beneath and within the trees unaltered drip line unless approved by a licensed or certified arborist or botanist.

c. Specified tree removal related to the discretionary action may be granted by the decision making body upon showing that a hardship exists based on substantial evidence in the record.

1.11 GENERAL PLAN AND ZONING COMPATIBILITY MATRIX

The State (Planning and Zoning Law Section 65860) requires that consistency exist between the General Plan, which represents long-range public policy, and the Zoning Ordinance, a set of specific development regulations. The General Plan and Zoning Consistency Matrix is a method of defining consistency by comparing each zone district with land use categories set forth in the General Plan. The Matrix illustrates the suitability of the specific zoning districts with the policies specified in the text of the General Plan.

The Matrix, which follows, applies two degrees of compatibility to land use designation and zoning:

a. Consistent: Zones which specifically implement the policies specified in the General Plan or allow uses found to be conditionally acceptable in such zones.

b. Inconsistent: Zones which are inconsistent with General Plan policies for a particular land use designation.

KERN COUNTY GENERAL PLAN DESIGNATIONS AND ZONE DISTRICT CONSISTENCY MATRIX

ZONE CLASSIFICATION DISTRICT

GENERAL PLAN DESIGNATIONS

	A(20)	A(80)	A-1	E(1/4)	E(1/2)	E(1)	E(2 1/2)	E(5)	E(10)	E(20)	R-1	R-2	R-3	MP		CO	C-1	C-2	CH		M-1	M-2	M-3		RF	OS	NR(5)	NR(10)	NR(20)	NR(40)	DI	FPP	SP	PL
1.1 State and Federal Land	•	•																							•	•	•	•	•	•		•	•	
1.2 Incorporated Cities																																		
3.1 Parks and Recreation	▲		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲											▲	▲	▲	▲	▲	▲		▲	▲	
3.2 Educational Facilities	▲		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲											▲	▲						▲	▲	
3.3 Other Facilities	▲		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲		▲	▲	▲	▲		▲	▲	▲		▲	▲	▲	▲	▲	▲		▲	▲	
3.4 Solid Waste Disposal Facility	•																					•	•				•	•	•	•				
3.4.1 Solid Waste Disposal Facility Buffer	•																					•	•				•	•	•	•				
3.5 Hazardous Waste Disposal Facilities Land Disposal Method	•																						•				•	•	•	•				
3.6 Hazardous Waste Disposal Facilities Underground Injection Method	•																						•											
3.7 Other Waste Facility	•																	•	•		•	•	•		•		•	•	•	•				
3.7.1 Other Waste Facility Buffer	•																	•	•		•	•	•		•		•	•	•	•				
4.1 Accepted County Plan Areas	•		•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•		•	•	•		•	•	•	•	•	•	•	•	•	
4.2 Interim Rural Community Plan	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•		•	•			•	•					•	•	•	
4.3 Specific Plan Required	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•		•	•	•		•	•	•	•	•	•	•	•	•	
5.1 Max. 29 DU/Net Acre	•			•	•	•	•	•	•	•	•	•	•	•												•					•	•	•	
5.2 Max. 16 DU/Net Acre	•			•	•	•	•	•	•	•	•	•		•												•					•	•	•	
5.3 Max. 10 DU/Net Acre	•			•	•	•	•	•	•	•	•			•												•					•	•	•	
5.4 Max. 4 DU/Net Acre	•			•	•	•	•	•	•	•				•												•					•	•	•	
5.45 Max. 2 DU/Net Acre	•				•	•	•	•	•	•				•												•					•	•	•	
5.5 Max. 1 DU/Net Acre	•					•	•	•	•	•				•												•					•	•	•	
5.6 Min. 2.5 Gross Acres/1 DU	•		•				•	•	•	•				•												•	•	•	•	•	•	•	•	
5.7 Min. 5 Gross Acres/1 DU	•							•	•	•				•											•	•	•	•	•	•	•	•	•	
5.75 Min. 10 Gross Acres/1 DU	•							•	•	•				•												•			•	•	•	•	•	
5.8 Min. 20 Gross Acres/1 DU	•									•				•												•			•	•	•	•	•	
6.1 Regional Commercial	•															•	•	•	•		•					•					•	•	•	
6.2 General Commercial	•															•	•	•	•		•				•	•					•	•	•	
6.3 Highway Commercial	•															•	•	•	•		•				•	•					•	•	•	
7.1 Light Industrial	•															•	•	•	•		•					•					•	•	•	
7.2 Service Industrial	•															•	•	•	•		•	•				•					•	•	•	
7.3 Heavy Industrial	•															•	•	•	•		•	•	•			•					•	•		
8.1 Intensive Agriculture (Min. 20 Acres)	•	•																								•			•	•		•	•	•
8.2 Resource Reserve (Min. 20 Acres)	•	•																								•			•	•		•	•	•
8.3 Extensive Agriculture (Min. 80 or 20 Acres)	•	•																								•						•	•	•
8.4 Mineral and Petroleum (Min. 5 Acres)	•	•																								•	•	•	•	•		•	•	•
8.5 Resource Management (Min. 20 Acres)	•	•																								•						•	•	•

NOTE: THE MATRIX IS A GUIDE THAT SHOULD BE USED IN CONJUNCTION WITH THE POLICIES AND PROVISIONS OF THE GENERAL PLAN

NOTE: THE COMBINING ZONE DISTRICTS ARE NOT INCLUDED IN THIS MATRIX, BUT ARE CONSIDERED CONSISTENT WITH THE GENERAL PLAN DESIGNATIONS FOR WHICH THEIR PRIMARY ZONE DISTRICT ARE CONSISTENT.

▲ PUBLIC/PRIVATE FACILITIES ONLY ● CONSISTENT □ INCONSISTENT

Golf Course Environmental Profile

Volume II

Water Use and Conservation Practices on U.S. Golf Courses











With Forewords by Greg Norman, World Golf Hall of Fame Member, and David S. Downing II, CGCS, 2008 GCSAA President

GCSAA

Environmental Institute for Golf

The Environmental Institute for Golf is the philanthropic organization of the Golf Course Superintendents Association of America.

Golf Course Superintendents Association of America

Golf Course Environmental Profile
Volume II
Water Use and Conservation Practices on U.S. Golf Courses

Funded by:
The Environmental Institute for Golf
and
The Toro Foundation

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Our Mission

GCSAA is dedicated to serving its members, advancing their profession and enhancing the enjoyment, growth and vitality of the game of golf.

Environmental Institute for Golf

The Environmental Institute for Golf is committed to strengthening the compatibility of the game of golf with our natural environment.

Acknowledgments

The Golf Course Superintendents Association of America and The Environmental Institute for Golf wish to thank:

The Toro Foundation for providing a grant to help fund this research.

The thousands of golf course superintendents who took the time and effort to complete the survey.

Golf's allied associations for their support in this endeavor.

Foreword

Measuring the Sustainability of Golf



The game of golf touches millions of people worldwide, from those of us who regularly enjoy the thrill of a perfect shot to those who have dedicated their careers to design, build and maintain golf courses for us to enjoy. All of us associated with the game must realize that our commitment to environmental sustainability is crucial to the future of the game.

The Golf Course Environmental Profile Project is a key component to charting our sustainable future. Few other industries have committed to evaluating the operation of their properties in the way golf is doing through this process. *The Water Use and Conservation* report, the second report in the series, provides important data regarding water management within the United States. Through this effort, the golf course industry is stepping up and providing an inside look at the environmental aspects associated with the game and, most importantly, its water use and conservation methods.

Water management on the golf course drives to the heart of sustainability. Golf course superintendents invest considerable resources to provide optimal playing surfaces that meet golfer expectations. However, in order to ensure sustainability, we must have conservation awareness, and continue to be efficient and wise when using water resources.

This assessment will allow golf courses to express current sustainability practices, establish goals, and continually track our progress for the future.

Regards,



Greg Norman
Advisory Council Chair
The Environmental Institute for Golf

Foreword

Achieving Progress through Participation



Golf has a strong track record when it comes to research. For many years, the industry has analyzed, measured and investigated a broad spectrum of issues, giving it the basis to make informed and high-quality decisions.

One area of strength has been in the evaluation of the environment. Since the early 1980s, millions of dollars have been pledged by a variety of organizations, universities and businesses to better understand golf's potential impact on the environment. This effort has been invaluable in developing programs and best management practices to ensure golf's environmental compatibility. In recent years, the Environmental Institute for Golf and the Golf Course Superintendents Association of America have committed to establish baseline information for the golf industry through the Golf Course Environmental Profile Project.

This Water Use and Conservation report provides information about golf's water use, conservation practices and irrigation systems. The data will facilitate setting goals and objectives for the industry that will advance our techniques and encourage new technology. It will allow for strong communication platforms and education programs to promote continued progress for golf. This report, along with the results of the first phase on land use and environmental stewardship, put us well on our way to establishing important baseline information and providing a factual look of golf's environmental practices.

I thank the more than 2,500 golf course superintendents who participated in the Water Use and Conservation survey. Your commitment to this project makes a strong statement as professionals and for the industry. The Golf Course Superintendents Association of America and its 21,000 members understand the importance of meeting golfer expectations and the investment of resources required to ensure playability.

Water is a precious resource, and it is our responsibility to use it judiciously so that future generations will continue to enjoy the benefits of these facilities. Through our efforts the industry will be able to demonstrate sustainability through the wise and professional use of our most precious resource – water.

David S. Downing II, CGCS
2008 GCSAA President

Executive Summary

GCSAA's Golf Course Environmental Profile is a data collection project that provides new insight into the property features, management practices and inputs associated with golf courses across the United States.

Water Use and Conservation Practices on U.S. Golf Courses is the second report produced from the project. The first report was the *Property Profile and Environmental Stewardship of Golf Courses* released in November 2007. These reports are available at **www.eifg.org**.

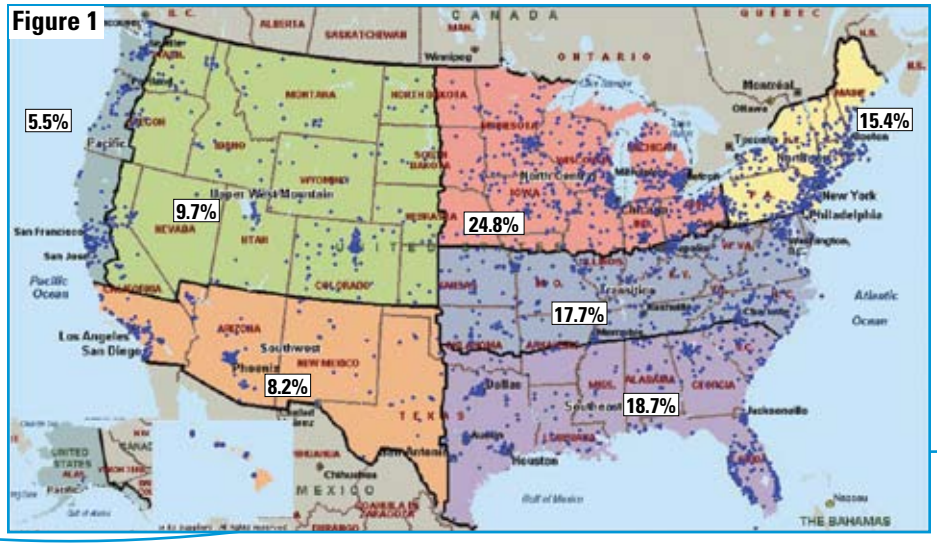
This volume provides the most accurate portrayal of water use and conservation practices on golf courses in the United States. It establishes a definitive baseline that will be compared to data from future surveys to identify change over time. It will help to guide the golf industry's agronomic and environmental initiatives in the future.

The objectives of the water use and conservation survey were to measure:

- Number of irrigated turfgrass acres for the U.S. and in agronomic regions
- Total water use in the U.S. and in agronomic regions
- Water cost averages for the U.S. and in agronomic regions
- Water sources used for irrigation
- Recycled water use in the U.S. and in agronomic regions
- Water quality
- Irrigation system characteristics
- Water management and conservation practices

Superintendents at all golf facilities in the U.S. (16,797) were invited to participate in the survey. A total of 2,548 golf facilities participated in the survey, accounting for 15 percent of the nation's superintendents. Analysis of returned surveys indicated that there was statistically valid representation of all types of golf facilities – public, private, resort, municipal, 9-hole, 18-hole, etc. Golf courses were stratified by agronomic region, course type and number of holes.

Figure 1 – Agronomic regions and total percentage of survey participation among golf facilities by region.



Executive Summary

Highlighting the report are the following results:

- There are an estimated 1,504,210 acres of maintained turfgrass (greens, tees, fairways, rough) on golf facilities in the U.S.[1] An estimated 1,198,381 acres or 80 percent of maintained turfgrass are irrigated.

- Approximately 80 percent or 80 acres of an average 18-hole golf course's 100 acres of maintained turfgrass are irrigated.

- From 2001-2005, an estimated net total of 31,877 acres of irrigated turfgrass were added to existing golf facilities in the U.S.

- The greatest net gain in irrigated acreage occurred in the North Central and Northeast regions, where 13,513 and 8,442 new acres were irrigated, respectively. The Southwest region had an estimated net decrease of 12 acres.

- From 2003-2005, the average water use for golf course irrigation in the U.S. was estimated to be 2,312,701 acre-feet per year.
  - That equates to approximately 2.08 billion gallons of water per day for golf course irrigation in the U.S.
  - According to the U.S. Geological Survey's "Estimated Use of Water in the United States in 2000" report, approximately 408 billion gallons of water per day are withdrawn in the U.S. Golf course irrigation accounts for 0.5 percent of this total.[2]

- Water use varies significantly by agronomic region.
  - An average 18-hole golf facility in the Southwest region uses an average of 4 acre-feet of water per irrigated acre per year and an 18-hole golf facility in the Northeast region uses an average of 0.8 acre-feet of water per irrigated acre per year.

- Annual irrigation water cost also varies significantly by agronomic region.
  - Golf course facilities in the Southwest region had the highest water costs – approximately $107,800 per year for an average 18-hole golf course.
  - 18-hole golf facilities in the North Central, Northeast and Transition regions had the lowest water costs, paying $4,700, $6,300 and $6,900 per year, respectively.

- Multiple sources are utilized for irrigation water and many golf facilities have more than one source available for irrigation. Most 18-hole golf facilities utilize surface waters like ponds, lakes or on-site irrigation wells. Approximately 14 percent of golf facilities use water from a public municipal source and approximately 12 percent use recycled water as a source for irrigation. Specific water sources for 18-hole courses as indicated by participants are noted below:
  - 52 percent use water from ponds or lakes.
  - 46 percent use water from on-site wells.
  - 17 percent use water from rivers, streams and creeks.
  - 14 percent use water from municipal water systems.
  - 12 percent use recycled water for irrigation.

Executive Summary

- As previously noted, 12 percent of 18-hole courses use recycled water for irrigation. The most common reason cited for not using it was a lack of an available source for recycled water as indicated by 53 percent of respondents.

- In general, irrigation water quality is acceptable or better in all agronomic regions, although there are golf facilities in all agronomic regions that face significant agronomic challenges due to the quality of their irrigation water.

- Approximately 46 percent of 18-hole golf facilities treat their irrigation water or distribute products via the irrigation system. The most common products distributed through the irrigation system are wetting agents and fertilizers.

- Nearly all 18-hole golf facilities use multiple irrigation scheduling techniques to aid in making water application decisions.

- Most facilities utilize direct observations of turfgrass and soil conditions to aid in irrigation scheduling decisions. Approximately 35 percent routinely utilize evapotranspiration data and approximately 3 percent use soil moisture sensors to aid in irrigation scheduling.

- Superintendents at 18-hole golf facilities utilize numerous methods to conserve water. The top three conservation methods and the percent of golf facilities utilizing that method are: wetting agents (92%); hand watering (78%); and keeping turfgrass drier (69%).

- An estimated 25 percent of all 18-hole golf facilities are subjected to recurring annual water allocations. Facilities in the Southwest (40%), Upper West/Mountain (39%) and Southeast (36%) are most likely to be subjected to a recurring annual irrigation water allocation.

- From 2001 to 2005, 16 percent of 18-hole golf facilities in the U.S. were subjected to mandatory irrigation water restrictions more stringent than the normal recurring annual irrigation water allocation for at least one year. Facilities in the Northeast and Upper West/Mountain agronomic regions were more likely to experience more stringent restrictions.

- Approximately 28 percent of 18-hole golf facilities in the Northeast agronomic region have written drought management plans, more than any other agronomic region.



Introduction

This report focuses on golf facility water use and conservation. Past research examined property features, such as acreage, land use and turfgrass species, as well as environmental stewardship efforts. Future research will examine nutrient use, pesticide use, energy use and environmental practices in order to evaluate change over time.

Since 2004, golf course superintendents, golf industry leaders, golf association leaders, environmental advocates, university turfgrass scientists and environmental regulators have participated in meetings, symposiums and conferences hosted by **The Environmental Institute for Golf (The Institute)** to discuss environmental issues facing the golf industry and identify future research, education and outreach needs. The group reached several important conclusions about the environmental aspects of golf, including:

- The golf industry did not have comprehensive national data on the property features, management practices, and inputs associated with golf courses and golf course maintenance.
- Although many individual golf courses are environmentally proactive, there was no systematic process in place to document current practices or track changes that the golf industry nationwide has made to protect and enhance the environment.
- A reliable environmental review of golf facilities was needed to provide an in-depth look into the golf industry, land and water management, and environmental stewardship practices on a national basis.

In 2006, the **Golf Course Superintendents Association of America (GCSAA)** initiated a project, funded by The Institute through a grant from **The Toro Foundation**, to collect data nationally on the property features, management practices, and inputs associated with golf courses and golf course maintenance. A series of surveys will be conducted over multiple years to collect the data. The surveys will be repeated so that change in golf courses and golf course maintenance practices over time can be measured.

The first survey was conducted in 2006, and the first report, *Property Profile and Environmental Stewardship of Golf Courses*, was published in November 2007 in *Applied Turfgrass Science*, a peer-reviewed scientific journal. The water use and conservation survey, the second survey of the series, was conducted in late 2006. The scientific manuscript presenting the results of the water use and conservation survey was published in *Applied Turfgrass Science* in 2009.

Both the *Property Profile and Environmental Stewardship of Golf Courses* and *Water Use and Conservation Practices on U.S. Golf Courses* reports and journal articles are available for online viewing or downloading on The Institute's Web site at **www.eifg.org**.



Methodology

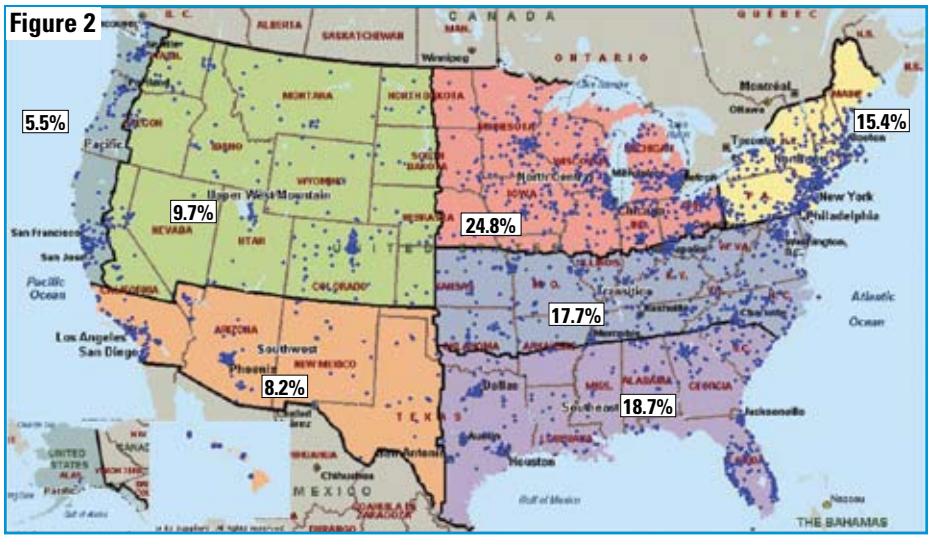
Input on the survey questions was collected from golf, environmental, academic and regulatory sources. GCSAA staff drafted survey questions, which were reviewed and revised by a group of golf course superintendents, golf association leaders and environmental advocates.

The National Golf Foundation (NGF) was contracted to conduct the survey, manage the recruitment of participants and complete the analysis of the data in collaboration with GCSAA. The NGF adheres to The Code of Marketing Research Standards developed by the Marketing Research Association.[3] The NGF refined and formatted the survey instrument for online and paper versions.

An attempt was made to contact and invite superintendents at 16,797 golf facilities nationwide to complete the survey. Surveys were distributed via e-mail and U.S. Postal Service in October 2006. In addition, reminders to complete and submit the survey were sent by e-mail and mail. Surveys were accepted until late November 2006.

A total of 2,548 usable surveys were returned, yielding a 15 percent return rate. The analysis classified the golf courses by agronomic region, course type (daily fee, municipal or private) and number of holes. Agronomic regions were determined by grouping geographic areas with similar climatic characteristics, and boundaries were drawn using county borders. Analysis of the returned surveys indicated that a proportional sample of all types of U.S. golf facilities was received (Appendix Table 1).

Figure 2 – Agronomic regions and total percentage of survey participation among golf facilities by region.



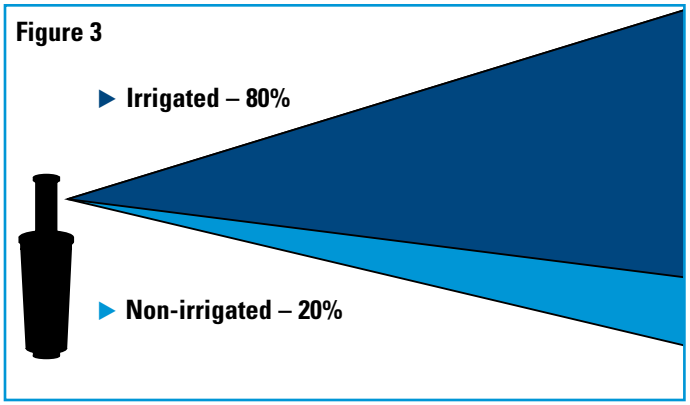
Data were analyzed to run descriptive statistics and explore relationships between the variables such as agronomic region, course type and number of holes. Where 18-hole equivalent data are presented, data within a region were averaged over facility type and budget. The number of 18-hole equivalents in the U.S. is 14,969, and was determined by taking the total number of golf holes and dividing by 18.[4]

Survey Results

Irrigated Turfgrass Acres on U.S. Golf Facilities

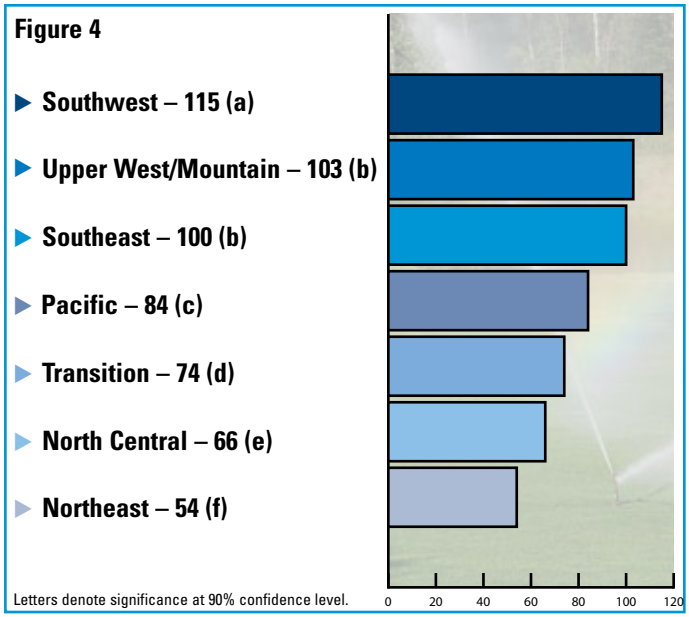
There are an estimated 2,244,512 total acres of land on golf facilities in the U.S., including 1,504,210 acres of maintained turfgrass and 740,302 acres of non-turfgrass landscapes, buildings and parking lots.[1] There are an estimated 1,198,381 acres of irrigated turfgrass, which is approximately 80 percent of the maintained turfgrass acres. The number of acres of irrigated turfgrass increases as the number of golf holes increases (Appendix Table 2).

Figure 3 – Percentage of irrigated and non-irrigated maintained turfgrass acreage.



- An average 18-hole facility irrigates approximately 80.7 acres of turfgrass out of an average of 150 acres. Irrigated acres for select features as reported by participants is as follows (Appendix Table 3):
  - 3.7 acres of greens
  - 3.4 acres of tees
  - 30.7 acres of fairways
  - 33.8 acres of rough
  - 5.6 acres of practice areas
  - 3.5 acres of clubhouse grounds
- Nationally, nearly 100 percent of greens, tees, and fairways are irrigated. Approximately 64 percent of turfgrass in the rough and 74 percent of turfgrass used for the driving range/practice areas are irrigated.
- There are significant differences in the number of irrigated turfgrass acres among agronomic regions. In the Southwest region, there are approximately 115 acres of irrigated turfgrass compared to approximately 54 acres in the Northeast region (Figure 4, Appendix Table 4).

Figure 4 – Irrigated turfgrass acres for average 18-hole golf facilities in the U.S. by agronomic region (Appendix Table 4).



Water use varies across agronomic regions due to climatic conditions, including temperature, sunlight intensity and rainfall, species of turfgrass grown and length of growing season. Turfgrasses grown in the Southwest agronomic region require irrigation for year-round playability because of low rainfall and high temperatures. Rainfall is more consistent in the Pacific, Transition, North Central and Northeast agronomic regions, and supplemental irrigation is needed only during dry periods of the growing season.

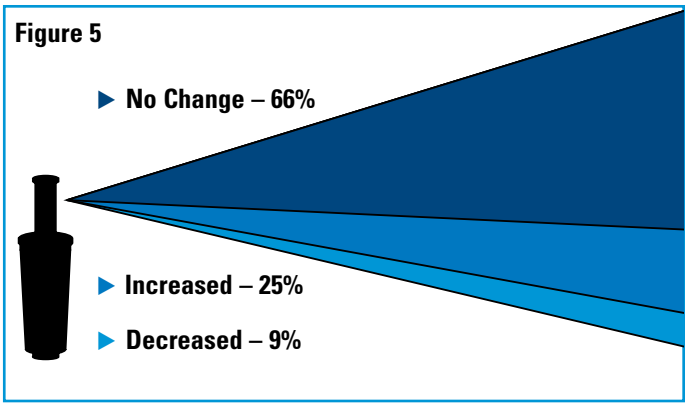
Changes In Irrigated Turfgrass Acres

From 2001-2005, approximately 25 percent of 18-hole golf facilities in the U.S. have increased their irrigated turfgrass acres and 9 percent have reduced irrigated turfgrass acres. Approximately 66 percent of 18-hole golf facilities have had no change in number of irrigated turfgrass acres (Figure 5, Appendix Table 5).

For those 18-hole golf facilities that changed irrigated turfgrass acreage:

- The average increase was 13 acres.
- The average decrease was 12.3 acres.

Figure 5 – Changes in irrigated turfgrass acres from 2001-2005 for U.S. 18-hole golf facilities (Appendix Table 5).



From 2001-2005, an estimated 31,877 acres of irrigated turfgrass were added to existing golf facilities in the U.S. The greatest net gain occurred in the North Central and Northeast regions, where 13,513 and 8,442 new acres were irrigated, respectively. The Southwest region had an estimated net decrease of 12 acres (Figure 6).

Based upon additional feedback from golf course superintendents, the net gain in irrigated turfgrass acres is due to golf facilities converting non-irrigated rough to irrigated rough to meet the demands of golfers.

Figure 6 – Estimated change in irrigated acres from 2001-2005 in the U.S. by agronomic region.

Figure 6

Acres	*Agronomic Regions							
	NE	NC	Trans	SE	SW	UW/ Mtn	Pac	U.S. Total
Increase	10,091	16,635	8,301	6,005	3,085	3,151	1,397	48,664
Decrease	1,649	3,112	3,552	3,633	3,097	828	905	16,787
Net Change	8,442	13,523	4,749	2,372	-12	2,323	492	31,877

*** Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

Irrigation Water Use

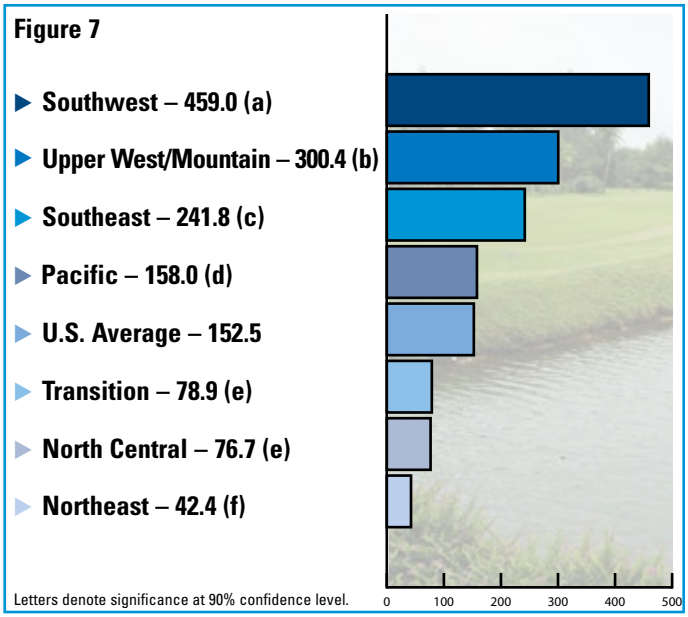
From 2003-2005, the average total water use for golf course irrigation in the U.S. was estimated to be 2,312,701 acre-feet of water per year. Using water use data nationally, an 18-hole golf course uses an average of 152.5 acre-feet of water per year to irrigate 80.7 acres of turfgrass. This is an average of 1.9 acre-feet of irrigation water per irrigated acre (Figure 7, Appendix Table 6).

- *One acre-foot or 12 inches of water over one acre equals 325,851 gallons.*

- *Water use figures for 18-hole facilities are based upon the following measures: 50 percent metered, 37 percent estimated, 13 percent both.*

- *50 percent of 18-hole golf facilities are required to report water use volumes to a state or local governing entity.*

Figure 7 – Average water use in acre-feet for 18-hole golf facilities in the U.S. by agronomic region (Appendix Table 6).

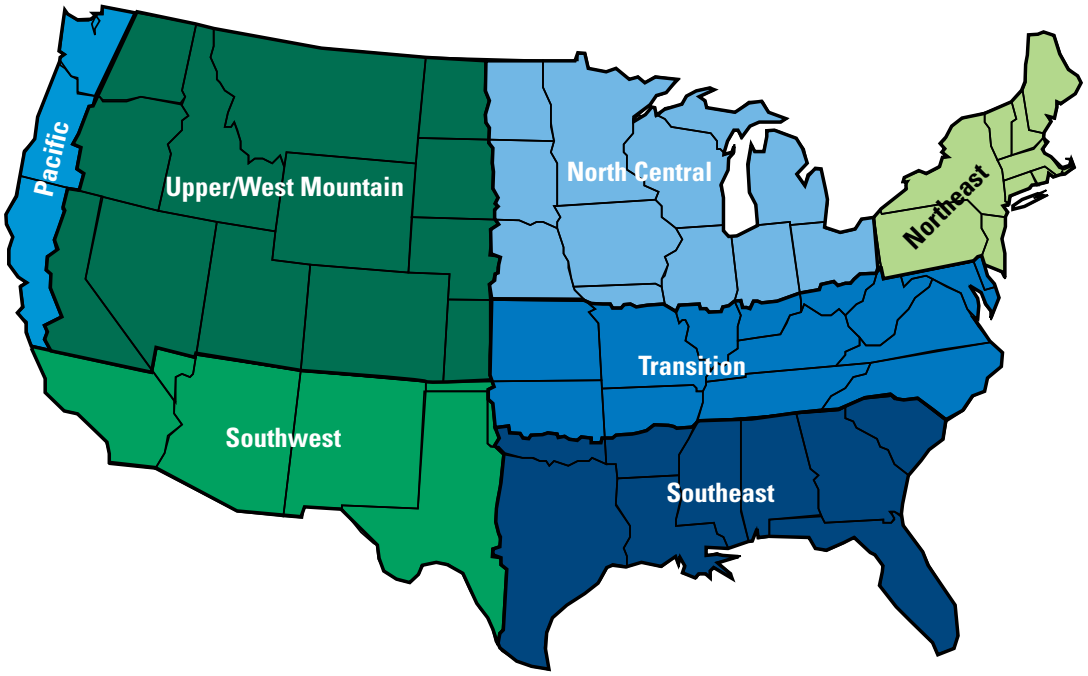




Irrigation Water Use Across Agronomic Regions

Water used for irrigation on golf courses varies significantly across agronomic regions. Arid areas of the country have higher water demands due to the climate, continual turf growth and because courses are open for golf use throughout the year. Water use was compared across agronomic regions by water use per acre, per number of holes (9, 18 and 27) and total use per agronomic region (Appendix Table 6).

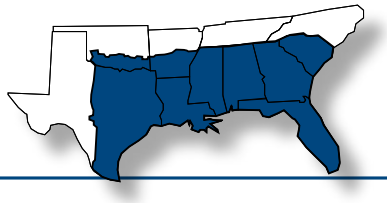
The statements below are summarized from data in Appendix Tables 1, 4 and 6.



Southeast

The Southeast agronomic region has the greatest water use per agronomic region. This is due to the large number of golf facilities, climate and year-round turf growth.

- An 18-hole facility in the Southeast agronomic region irrigates, on average, 100 acres of turfgrass.
- An 18-hole facility in the Southeast agronomic region irrigates with an average 241.8 acre-feet annually.
- An 18-hole facility in the Southeast agronomic region irrigates with 2.4 acre-feet (29 inches) of water per irrigated turfgrass acre annually. This is lower than the Southwest and Upper West/Mountain region and higher than the other regions on a per-acre basis.
- In the Southeast agronomic region, there are 3,518 golf facilities that include 9-hole, 18-hole and greater-than-18-hole golf facilities.
- The total irrigation water use for all facilities in the Southeast agronomic region is estimated to be 801,105 acre-feet per year.

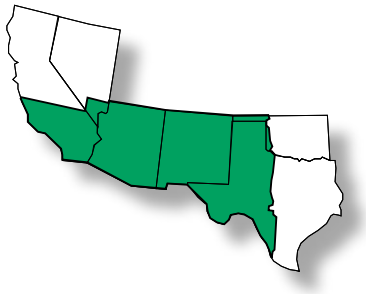


Irrigation Water Use Across Agronomic Regions

Southwest

The Southwest agronomic region has the greatest use of irrigation water per acre, the largest irrigated acreage per 18-hole golf facility and uses the second greatest total volume of water per agronomic region.

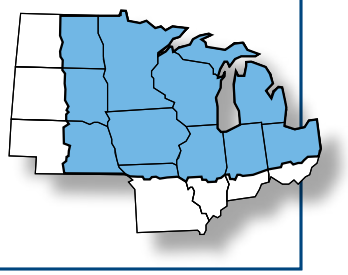
- An 18-hole facility in the Southwest agronomic region irrigates, on average, 115 acres of turfgrass.
- An 18-hole facility in the Southwest agronomic region irrigates with an average 459 acre-feet annually.
- An 18-hole facility in the Southwest agronomic region irrigates with 4 acre-feet (47.9 inches) of water per irrigated turfgrass acre annually.
- There are 1,272 golf facilities in the Southwest agronomic region including 9-hole, 18-hole and greater-than-18-hole golf facilities, approximately 7.5 percent of the total nationally.
- The total irrigation water use for all facilities in the Southwest agronomic region is estimated to be 553,442 acre-feet per year.



North Central

The North Central agronomic region has more facilities than any other region. The water use per irrigated acre is comparable to the Transition region and is significantly lower than all other regions except the Northeast. Because of the relatively large number of facilities, it ranks third in the total water use per region.

- An average 18-hole facility in the North Central agronomic region irrigates, on average, 66 acres of turfgrass.
- An 18-hole facility in the North Central agronomic region irrigates with an average of 76.7 acre-feet annually.
- An 18-hole facility in the North Central agronomic region irrigates with 1.2 acre-feet (13.9 inches) of water per irrigated turfgrass acre annually.
- There are 4,238 golf facilities in the North Central agronomic region including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the North Central agronomic region is estimated to be 313,037 acre-feet per year.

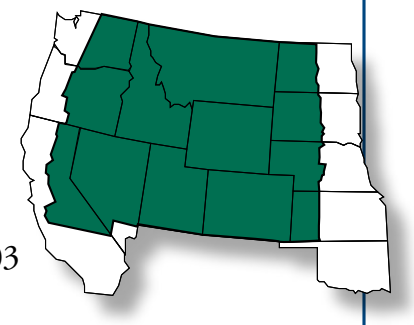


Irrigation Water Use Across Agronomic Regions

Upper West/Mountain

The Upper West/Mountain agronomic region uses slightly more water per acre than golf facilities in the Southeast region but less per acre than those in the Southwest region.

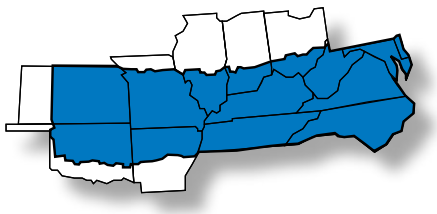
- An average 18-hole facility in the Upper West/Mountain agronomic region irrigates, on average, 103 acres of turfgrass.
- An 18-hole facility in the Upper West/Mountain agronomic region irrigates with an average of 300.4 acre-feet annually.
- An 18-hole facility in the Upper West/Mountain agronomic region irrigates with 2.9 acre-feet (35 inches) of water per irrigated turfgrass acre annually.
- There are 1,100 golf facilities in the Upper West/Mountain agronomic region, including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the Upper West/Mountain agronomic region is estimated to be 214,603 acre-feet per year.



Transition

The Transition agronomic region has similar water use per irrigated acre as the North Central region. Overall use is lower because the region does not have as many golf facilities when compared to the North Central region.

- An average 18-hole facility in the Transition agronomic region irrigates, on average, 74 acres of turfgrass.
- An 18-hole facility in the Transition agronomic region irrigates with an average of 78.9 acre-feet annually.
- An 18-hole facility in the Transition agronomic region irrigates with 1.1 acre-feet (12.8 inches) of water per irrigated turfgrass acre annually.
- There are 3,116 golf facilities in the Transition agronomic region including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the Transition agronomic region is estimated to be 206,829 acre-feet per year.

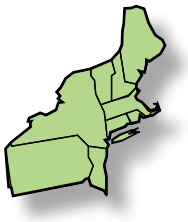


Irrigation Water Use Across Agronomic Regions

Northeast

The Northeast agronomic region has the lowest water use per acre, lowest irrigated acreage per 18-hole facility and the second lowest total water use per geographic region.

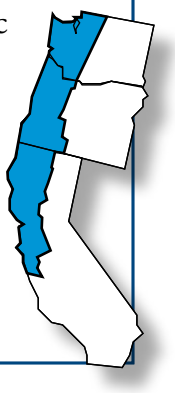
- An average 18-hole facility in the Northeast agronomic region irrigates, on average, 54 acres of turfgrass.
- An 18-hole facility in the Northeast agronomic region irrigates with an average of 42.4 acre-feet annually.
- An 18-hole facility in the Northeast agronomic region irrigates with 0.8 acre-feet (9.4 inches) of water per irrigated turfgrass acre annually.
- There are 2,871 golf facilities in the Northeast agronomic region including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the Northeast agronomic region is estimated to be 102,581 acre-feet per year.



Pacific

The Pacific agronomic region irrigates with the lowest total volume of water among the regions due to the climate and relatively low number of facilities.

- An average 18-hole facility in the Pacific agronomic region irrigates, on average, 84 acres of turfgrass.
- An 18-hole facility in the Pacific agronomic region irrigates with an average of 158 acre-feet annually.
- An 18-hole facility in the Pacific agronomic region irrigates with 1.9 acre-feet (22.6 inches) of water per irrigated turfgrass acre annually.
- There are 682 golf facilities in the Pacific agronomic region including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the Pacific agronomic region is estimated to be 94,115 acre-feet per year.



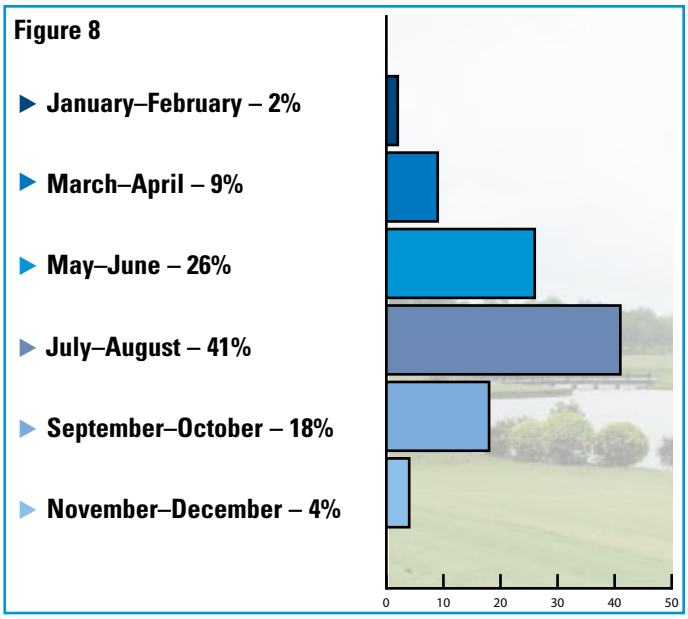
Monthly Irrigation Water Use

On a national basis, approximately 85 percent of irrigation water is used from May through October. Nearly half (41 percent) of the water use during that period is used during July and August (Figure 8, Appendix Table 7).

Monthly water-use patterns vary by agronomic region, with water use concentrated in May to October in the Northeast, North Central, Transition, Upper West/Mountain and Pacific agronomic regions.

In the Southeast and Southwest regions, water use is spread more evenly throughout the year because of year-round evaporative demand, turf growth and golf course use.

Figure 8 – Average 18-hole golf facility water use in the U.S. (percentage of total irrigation by month) (Appendix Table 7).



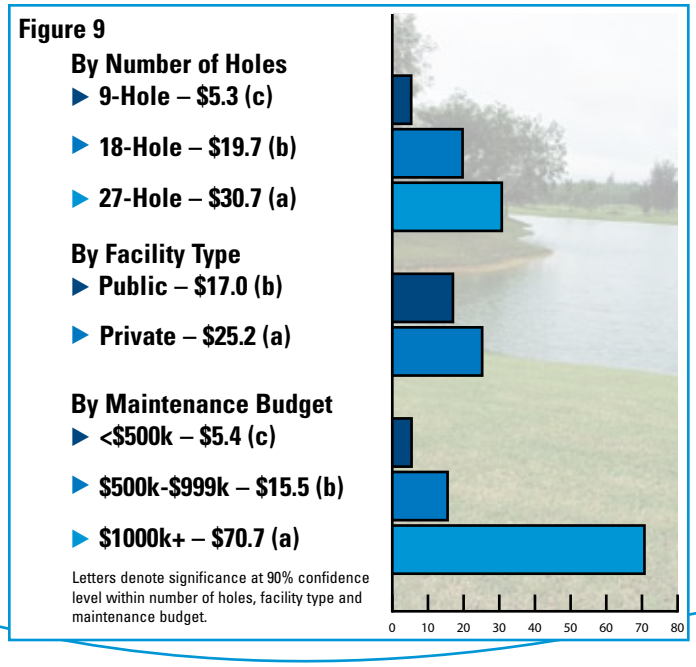


Irrigation Water Expenditures

Annual expenditures for irrigation vary by agronomic region, number of golf holes at the facility, maintenance budget and course types.

- As the number of holes increase at a golf facility, significantly more is spent on water for irrigation.
- Private facilities spend more on water for irrigation than public facilities.
- Golf facilities with higher budgets spent significantly more on water. Those with maintenance budgets exceeding $1,000,000 spend more than four times the amount on water than those with less than $1,000,000 budgets. There is a higher proportion of golf courses with maintenance budgets greater than $1,000,000 located in the Southwest and Southeast regions. These facilities have a longer growing season, year-round turf growth, higher demands for water and, as a result, higher maintenance budgets.

Figure 9 – Irrigation water cost for the average golf facility in the U.S. (average total expenditure by number of holes, facility type and maintenance budget – in thousands of dollars).

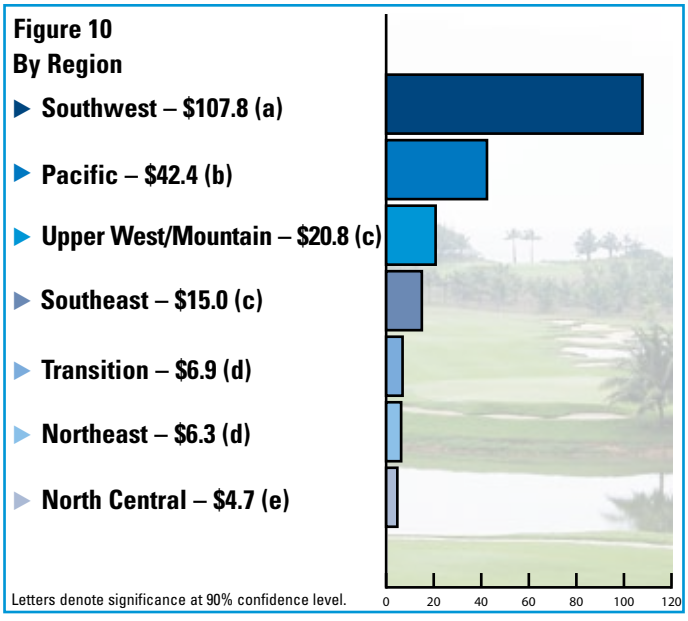


Irrigation Water Expenditures by Agronomic Region

Survey participants were asked to identify the expenditure for the purchase of water for irrigation. Costs associated with operating pumps or delivery systems are not included in the expenditures reported in this survey. Irrigation water expenditures vary significantly among the agronomic regions for 18-hole golf facilities (Appendix Table 8).

- 18-hole golf facilities in the Southwest region spend significantly more for irrigation water than golf facilities in any other agronomic region, an estimated $107,800 dollars.
- The agronomic regions with the lowest expenditures for irrigation water are the North Central ($4,700), Northeast ($6,300) and Transition ($6,900) regions.

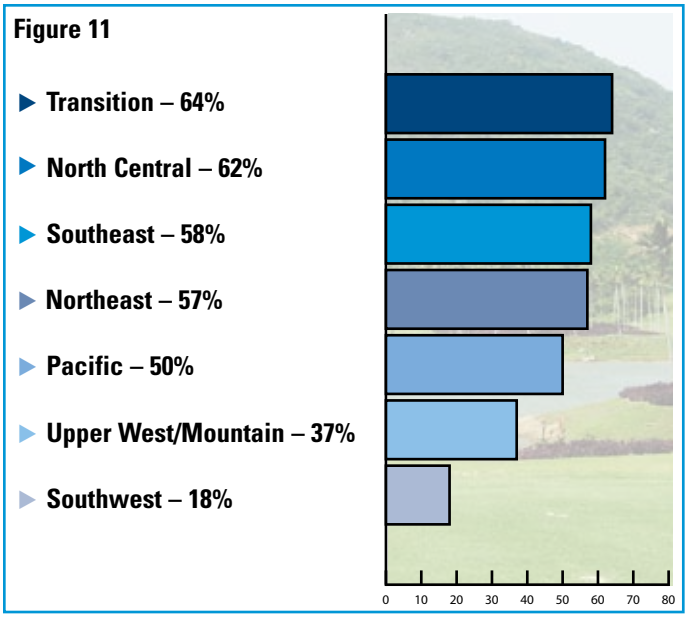
Figure 10 – Irrigation water cost for average 18-hole golf facilities in the U.S. by agronomic region (in thousands of dollars).



Irrigation Water Expenditures

At least 50 percent of golf facilities in all regions, except the Southwest and Upper West/Mountain regions, do not pay for irrigation water (Appendix Table 8). This can be attributed to the differences in the amount of precipitation and relative abundance of surface and/or groundwater in each region.

Figure 11 – Percentage of 18-hole golf facilities that do not pay for water in the U.S. by agronomic region (Appendix Table 8).



Changes in Water Expenditures

Survey participants were asked to identify changes in water costs from 2001-2005. Water costs have increased over this period for 53 percent of golf facilities, stayed the same for 43 percent, and decreased for 4 percent (Appendix Table 9).

- Irrigation water cost was most likely to have increased for golf facilities in the Southwest and Pacific regions and stayed the same in the Northeast, Transition and Southeast regions.
- The average percentage increase was greatest in the North Central agronomic region at 45 percent and smallest in the Transition region at 15 percent.
- The percentage of golf facilities that experienced a decrease in irrigation water cost ranged from 6 percent in the Transition, Southwest, and Upper West/Mountain regions to 2 percent in the Pacific region.

Cost of Irrigation Water from Various Sources

Average annual expenditures for irrigation water from different water sources for an 18-hole golf facility in 2005:

Municipal water – $52,400
Recycled water – $44,400
Well water – $6,900
River, streams, etc. – $4,600
Open waters (ponds, lakes, etc.) – $3,900

Note: Expenditures are associated with water costs only and do not reflect cost to operate pumps or the delivery system.



Irrigation Water Sources

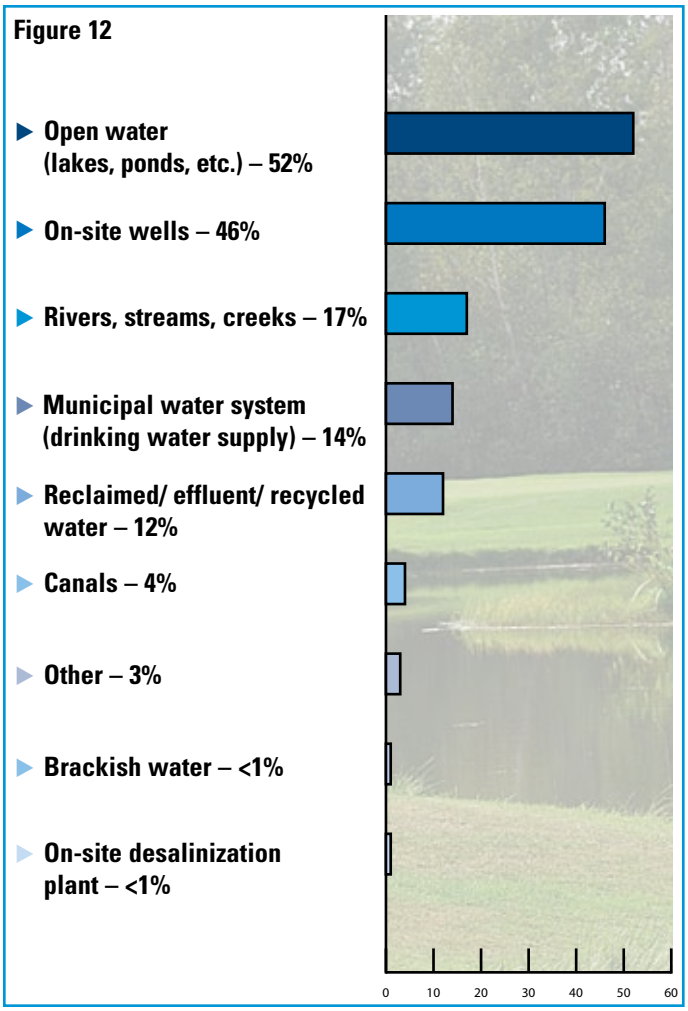
Golf facilities utilize multiple sources for irrigation ranging from surface water (ponds, lakes, streams) and ground water sources to water provided by a local municipality (Appendix Table 10).

Many golf facilities have more than one source of water to use for irrigation. Most of the water for 18-hole golf facilities comes from surface waters such as ponds or lakes, or on-site irrigation wells.

Approximately 14 percent of irrigation water is supplied by municipal drinking water sources, and 12 percent of golf facilities nationally use recycled water as an irrigation source.



Figure 12 – Irrigation water sources for average 18-hole golf facilities in the U.S. (Appendix Table 10).

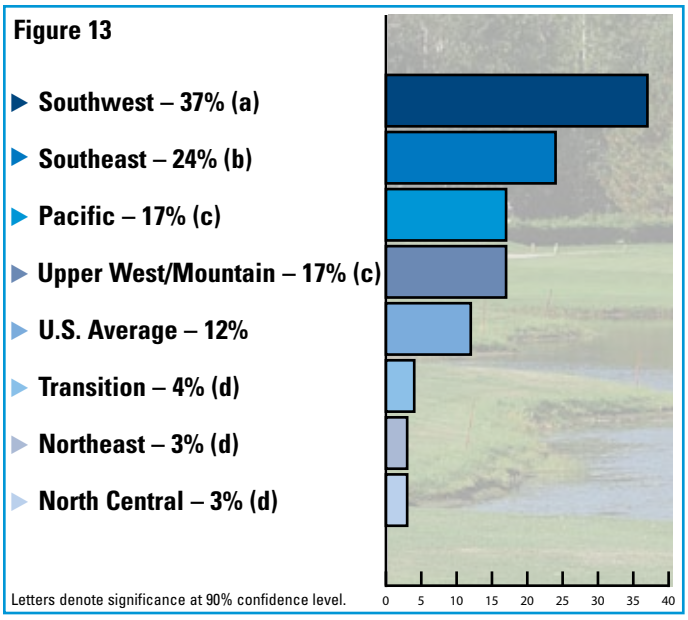




Recycled Water Use

Recycled water, often called effluent or reclaimed water, is produced by water treatment facilities and sold for irrigation or other purposes. Approximately 12 percent of golf courses nationally use recycled water as a source for irrigation. The use of recycled water varies significantly by agronomic region. More golf facilities in the Southwest (37 percent) use recycled water as an irrigation source than any other region. The Southeast region has the next highest use with 24 percent of golf course facilities using recycled water. Recycled water use is significantly lower in all other regions (Figure 13, Appendix Table 10).

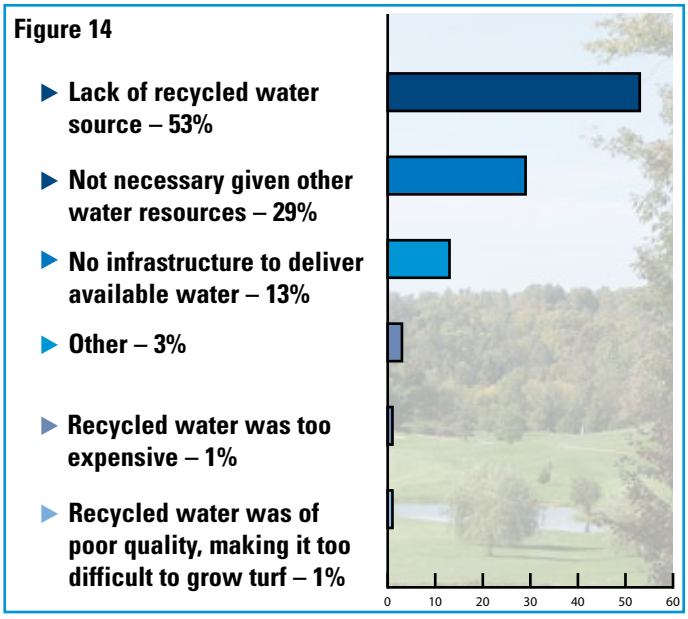
Figure 13 – Percentage of golf facilities that use recycled irrigation water in the U.S. by agronomic region (Appendix Table 10).



Survey respondents were asked to identify why they were not currently using recycled water. The most common reason cited for not using recycled water (by 53 percent of respondents) was the lack of a source. Other responses were:

- Not necessary given other water resources (29%)
- No infrastructure to deliver available recycled water (13%)
- Recycled water was too expensive (1%)
- Recycled water was of poor quality making it too difficult to grow turfgrass (1%) (Figure 14)

Figure 14 – Reasons cited for not using recycled water for irrigation by percent of U.S. golf facilities.



- *Private and public golf facilities showed no difference in recycled water use, but more golf facilities with a greater number of holes and higher maintenance budgets used recycled water for irrigation.*
- *Recycled water was a more prevalent water source for golf facilities in the Southwest (37 percent) than in any other agronomic region.*
- *The Southeast agronomic region ranked second in its use of recycled water with 24 percent of golf facilities using it for irrigation.*
- *Use of recycled water for irrigation was significantly lower in the Northeast (3 percent), North Central (3 percent), and Transition (4 percent) agronomic regions.*

Irrigation Water Quality

Many golf course superintendents include irrigation water quality testing as part of their turfgrass management program. Golf facilities with more holes, higher budgets and private facilities are more likely to test the quality of their irrigation water.

- More than half of the 18-hole golf facilities in the Southwest, Southeast, and Upper West/Mountain agronomic regions have had their irrigation water analyzed since 2003.
- Irrigation water quality was generally acceptable or better in all agronomic regions for growing turfgrass. There are individual golf courses in each agronomic region that face challenges with irrigation water quality.
- Irrigation water quality, as determined by total dissolved solids, sodium absorption ratio, pH, and residual sodium carbonate, was poorest in the Southwest agronomic region (Figures 15a and 15b, Appendix Table 11).



Figure 15a – Total dissolved solids in irrigation water for golf facilities in the U.S. by agronomic region (Appendix Table 11).

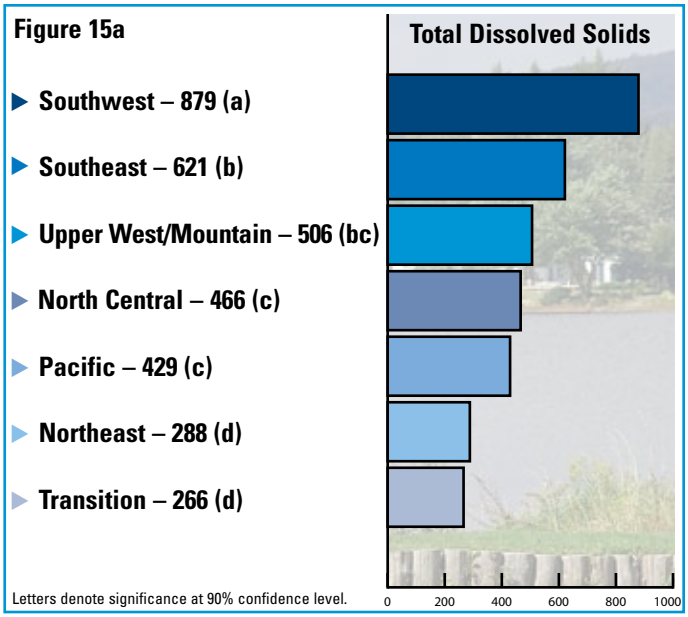
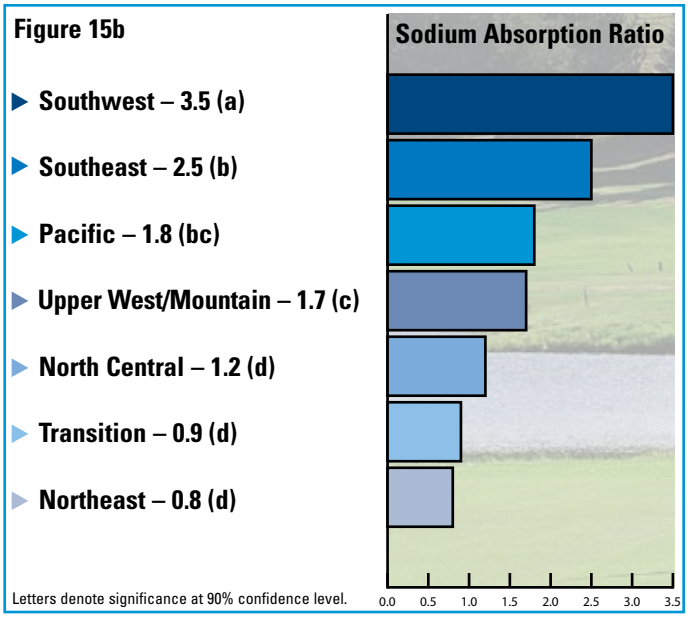


Figure 15b – Sodium absorption ratio for irrigation water for golf facilities in the U.S. by agronomic region (Appendix Table 11).

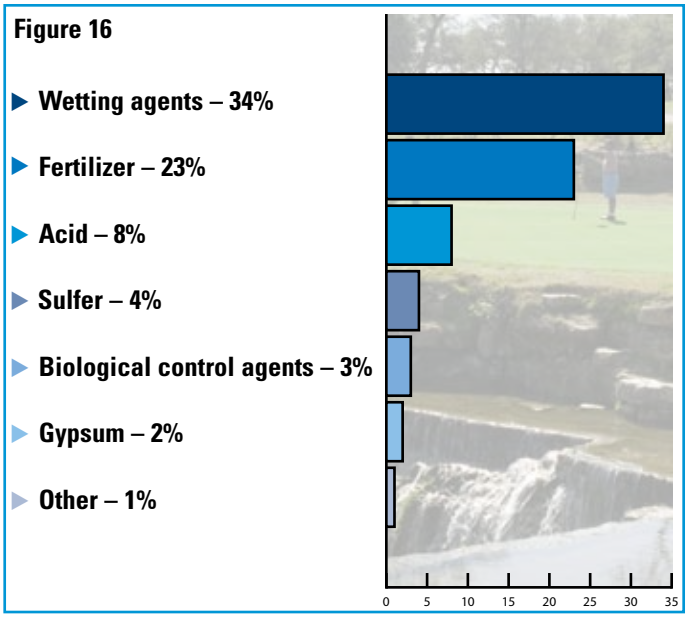


Irrigation Water Treatments and Products Delivered Through the Irrigation System

Approximately 46 percent of 18-hole golf facilities treat irrigation water or add products for distribution with irrigation water through the irrigation system as part of their turfgrass management programs (Figure 16, Appendix Table 12).

- The most common products delivered through the irrigation system are wetting agents and fertilizers.
- The use of wetting agents and fertigation units increases at 18-hole facilities as the maintenance budget increases.
- More than 70 percent of 18-hole golf facilities with annual maintenance budgets less than $500,000 do not treat irrigation water or deliver products through their irrigation system.
- The majority of 18-hole golf facilities using wetting agents and fertigation units are in the Southeast and Southwest agronomic regions.

Figure 16 – Water treatments and products delivered through the irrigation system at 18-hole golf facilities in the U.S. (Appendix Table 12).





Irrigation Systems

Golf facilities with irrigation systems that are fully automatic or semi-automatic are more common than those controlled manually (Appendix Table 13).

- Only 9 percent of public golf facilities and 2 percent of private golf facilities use manual irrigation systems.
- Fully automatic irrigation systems are found on 80 percent of 27-hole facilities, 75 percent of 18-hole facilities and 33 percent of 9-hole facilities.
- Golf facilities with 18 or more holes, private facilities and those with maintenance budgets greater than $1,000,000 are more likely to have a fully automatic irrigation system.

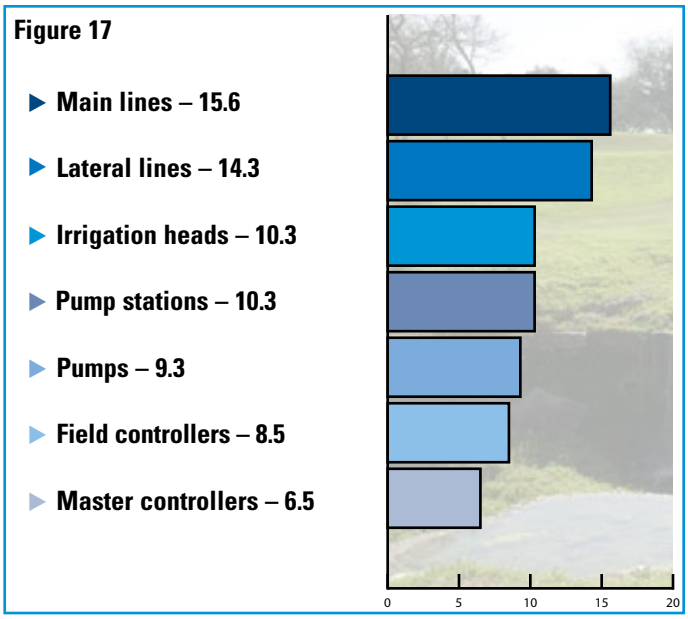
Age of Irrigation System Components

Survey participants were asked to identify the age of various components of their irrigation systems.

- Main and lateral lines are the oldest components typically, averaging 16 and 14 years old respectively.
- Master controllers are much newer – only about 6.5 years old on average (Figure 17).

- *Nearly one-half of 18-hole facilities added new software to better control irrigation from 2001–2005.*
- *Sprinkler heads (new and additional) and new nozzles were the most common improvement measures 18-hole facilities installed from 2001–2005.*

Figure 17 – Average age (years) of irrigation system components in the U.S. averaged over all golf facilities.







Irrigation Systems

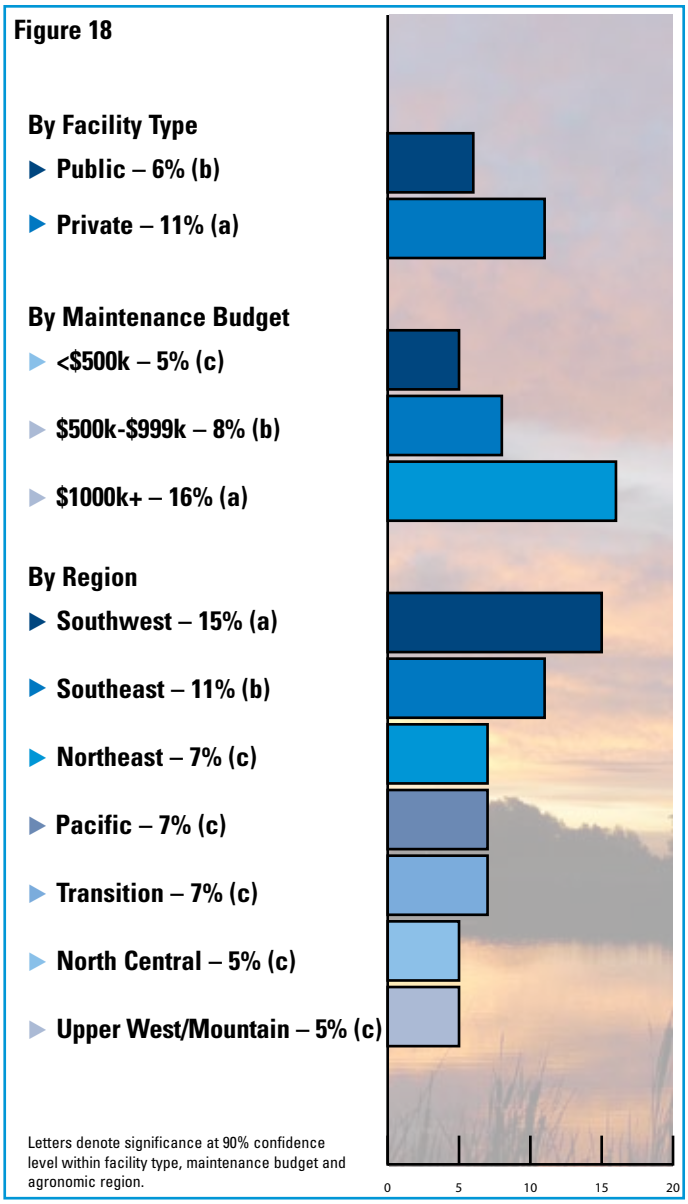
System Audits

From 2001–2005, approximately 8 percent of 18-hole golf facilities nationally had their irrigation systems audited by a certified irrigation auditor.

- Irrigation system audits are more prevalent among private facilities and facilities with larger maintenance budgets.
- Irrigation system audits are more common in the Southwest and Southeast agronomic regions, where 15 percent and 11 percent, respectively, have conducted an audit. In other regions, 5 to 7 percent of 18-hole golf facilities have conducted an irrigation system audit.
- For those 18-hole golf facilities that conducted an irrigation audit, the average overall distribution uniformity for the irrigation system was 72 percent.



Figure 18 – Percent of golf facilities that have conducted an irrigation system audit by facility type, maintenance budget and agronomic region.



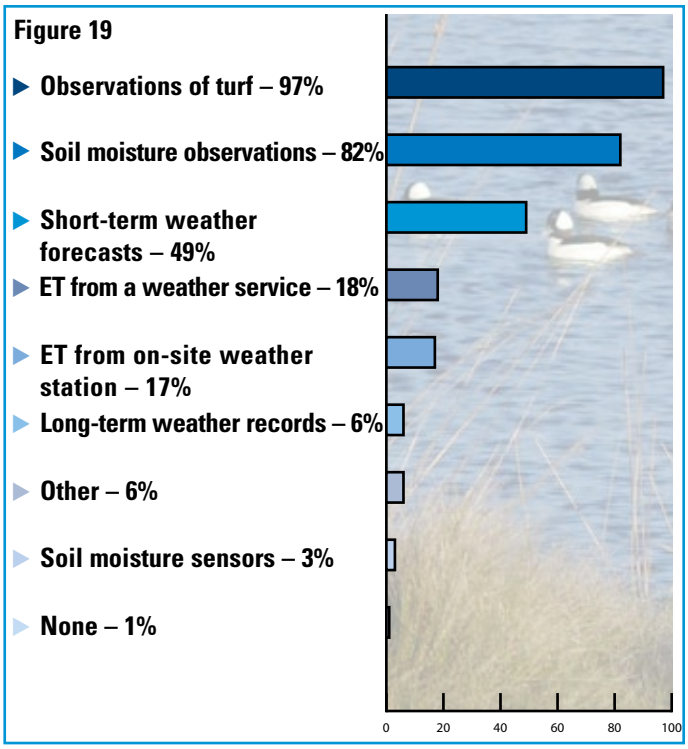
Irrigation Water Management and Conservation

Survey participants were asked to indicate techniques used to determine when to irrigate and how much water to apply to the golf course. Nearly all 18-hole golf facilities use one or more techniques to aid in scheduling irrigation. The majority of 18-hole golf facilities directly observe the turf and soil moisture to aid their irrigation scheduling decisions.

Short-term weather forecasts also play a role in the decision-making process for nearly half of the participants. Evapotranspiration (ET) readings from a local weather service or on-site weather station were used by approximately 35 percent of the respondents. Soil moisture sensors were only used by approximately 3 percent of survey respondents. At the time the survey was conducted, soil moisture-sensing technology had limited capabilities resulting in the low adoption rate by superintendents (Figure 19).



Figure 19 – Percent of 18-hole golf facilities in the U.S. that used the listed irrigation scheduling technique.



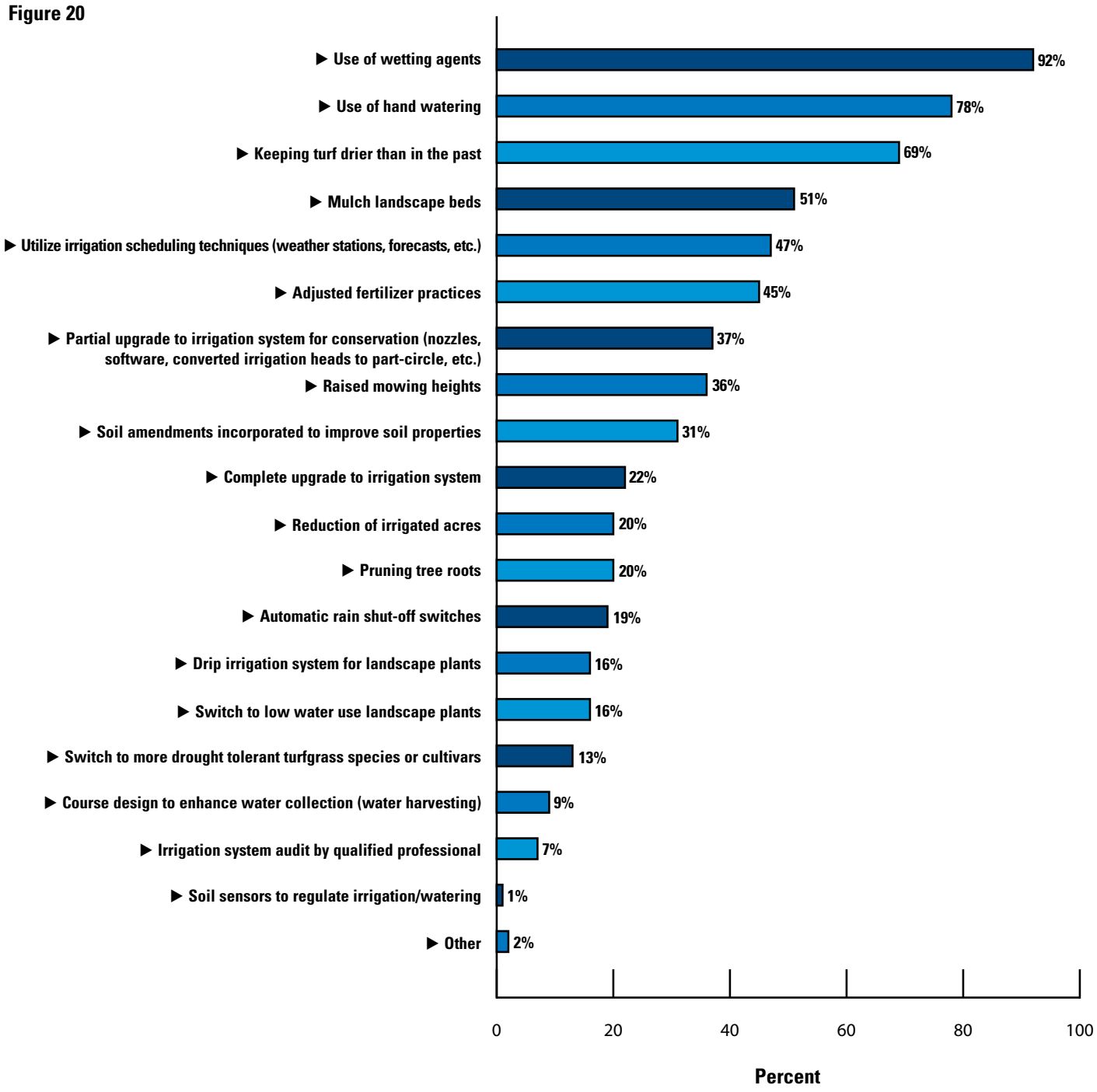
Irrigation Water Conservation Methods

Survey participants were asked to describe practices utilized to conserve irrigation water. Nearly all 18-hole golf facilities have incorporated several practices to conserve irrigation water (Figure 20, page 31). The top three practices are:

- The use of wetting agents (92%)
- Hand-watering (78%)
- Keeping turfgrass drier than in the past (69%)

Irrigation Water Management and Conservation

Figure 20 – Percent of 18-hole golf facilities in the U.S. that use the listed irrigation water conservation method.

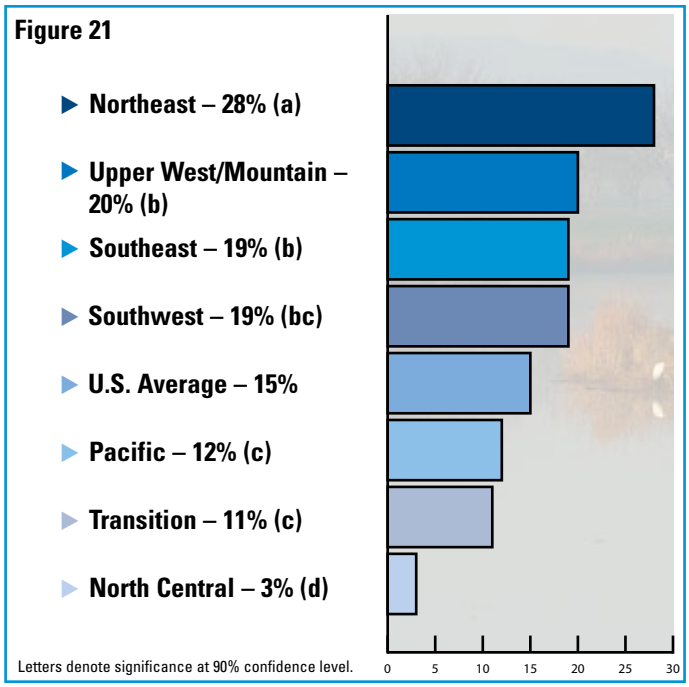


Written Drought Management Plans

Written drought management plans provide superintendents with a documented procedure to reduce irrigation water use during drought. These plans can be developed on a voluntary basis and also can be required by a government entity. Approximately 15 percent of 18-hole golf facilities in the U.S. have a written drought management plan (Figure 21, Appendix Table 14). Sixty-three percent of 18-hole golf facilities that have developed a plan were required to do so by a state or local governing authority. Private golf facilities and those with an annual maintenance budget greater than $500,000 are more likely to have a written drought management plan.

There are differences among the agronomic regions for 18-hole golf facilities that have written drought management plans. Twenty-eight percent of 18-hole golf facilities in the Northeast agronomic region have written drought management plans and are more likely to have them than any other agronomic region (Figure 21, Appendix Table 15).

Figure 21 – Percentage of 18-hole golf facilities that have a written drought management plan in the U.S. by agronomic region (Appendix Table 15).

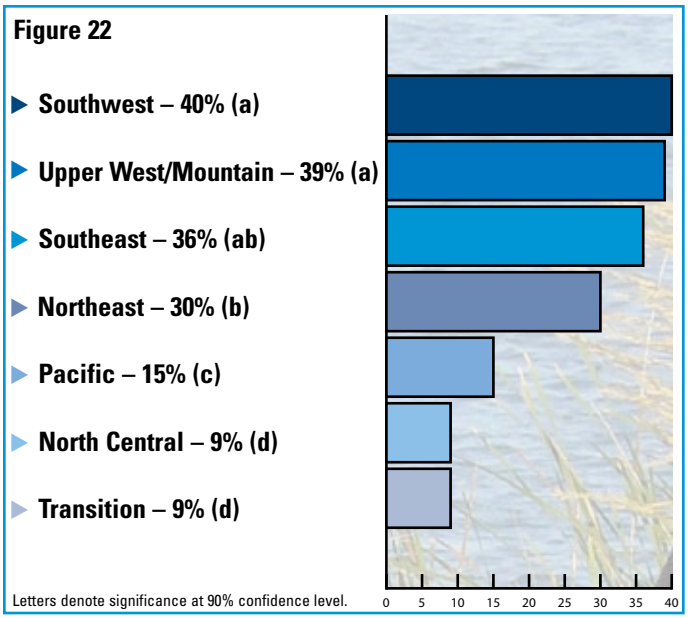




Irrigation Water Allocations and Restrictions

An estimated 25 percent of all 18-hole golf facilities are subject to a recurring annual irrigation water allocation. Recurring annual irrigation water allocations are most common on 18-hole golf facilities in the Southwest (40%), Upper West/Mountain (39%), Southeast (36%), and Northeast (30%) agronomic regions (Figure 22, Appendix Table 15).

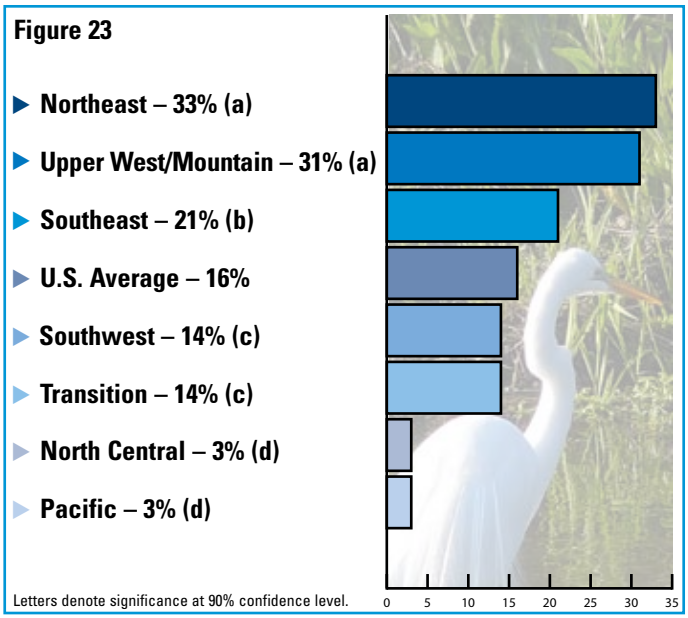
Figure 22 – Percentage of 18-hole golf facilities subjected to an annual recurring irrigation water allocation in the U.S. by agronomic region.



Additional Mandatory Irrigation Water Restrictions

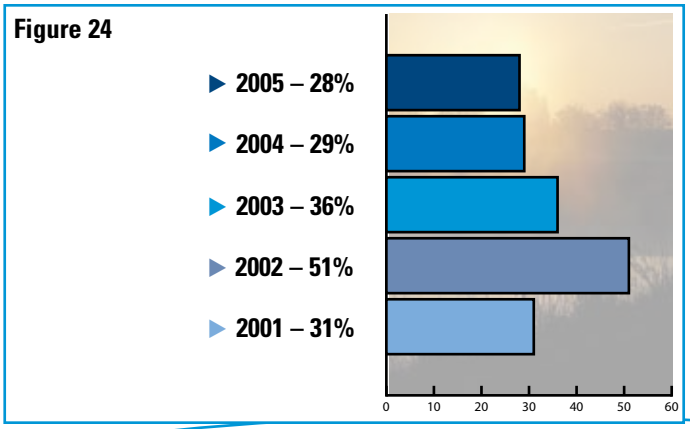
From 2001-2005, 16 percent of U.S. golf facilities were subject to mandatory irrigation water restrictions that were more stringent than normal recurring irrigation water allocations (Figure 23, Appendix Table 15). These additional mandatory restrictions have been more common in the Northeast (33%) and Upper West/Mountain (31%) agronomic regions.

Figure 23 – Percentage of 18-hole golf facilities subjected to additional mandatory irrigation water restrictions in the U.S. by agronomic region.



In the period of the study, 2001 to 2005, 2002 saw the highest percentage of golf facilities (51%) impacted by additional mandatory irrigation water restrictions (Figure 24).

Figure 24 – Percentage of 18-hole golf facilities subjected to additional mandatory irrigation water restrictions by year in the U.S.



Conclusions

This survey has provided the GCSAA and The Institute a baseline for water use and conservation on golf facilities in the U.S. and the means to document change over time. The water use and conservation survey results, in conjunction with results of the property profile and environmental stewardship of golf courses survey, present an accurate portrayal of land use and water use on golf facilities in the U.S.

Golf facilities are economic, environmental and recreational assets to local communities. Water is essential for golf. Communities derive direct value from the water applied to golf facilities by generating an economic return while adding social and environmental benefits. Water availability, cost and quality of the water used for irrigation remain important issues for the long-term sustainability of golf in the U.S., particularly in the Southwest. This report indicates that golf course superintendents and the golf industry are well positioned to professionally manage and protect water resources in the future.

Golf facilities must proactively conserve water. Conserving water on golf facilities is essential to becoming a sustainable business. The GCSAA and The Institute are providing research, education, best management practices, membership standards and other resources to assist golf facilities in advancing their environmental sustainability. Optimizing the acreage of irrigated turfgrass, implementing best management practices, utilizing technology to make water application decisions, conducting an irrigation system audit along with an audit of the non-golf course water uses at the entire facility are key to becoming responsible users of water.

The GCSAA supports working collaboratively with the golf industry, citizens, communities and all levels of government to develop practical public policy related to water issues.

Economic Data

Golf facilities play an important role within their communities not only as an environmental asset and a recreational resource, but also as a significant economic contributor. The golf industry provides considerable value to national and local economies. A 2005 economic survey[8] of the industry indicates:

- *Golf attracted more than 40 million participants in 2005.*
- *The U.S. golf economy generated $76 billion of goods and services in the year 2005. This is larger than newspaper publishing ($50.1 billion), performing arts and spectator sports ($64.7 billion), and the motion picture and video ($73.9 billion) industries.*
- *Golf generated a total economic impact of $195 billion in 2005, creating approximately 2 million jobs with a wage income of $61 billion.*
- *The amount of charitable giving attributed to the game of golf in the U.S. was estimated to be $3.5 billion in 2005.*

Irrigated Turfgrass Acreage in the U.S.

Nationally, golf facilities irrigate approximately 80 percent of the maintained turfgrass acres. Golf facilities located in areas of limited water supplies should irrigate only the turfgrass essential for the play of the game.

Overall, irrigated turfgrass acreage increased in the five-year period from 2001-2005. This is due to the extension of irrigation into the rough in the Transition, North Central and Northeast regions. Given the relative availability and low cost of water in these regions, this trend is likely to continue in the future as irrigation systems are updated in order to meet the expectations of golfers for improved playing conditions.

Conclusions

- There are an estimated 2,244,512 total acres of land on golf facilities in the U.S., including 1,504,210 acres of maintained turfgrass and 740,302 acres of non-turfgrass landscapes, buildings and parking lots.[1]

- There are an estimated 1,198,381 acres of irrigated turfgrass, which is approximately 80 percent of the maintained turfgrass acreage.[1]

- From 2001-2005, an estimated 31,877 acres of irrigated turfgrass were added to existing golf facilities in the U.S. The greatest net gain occurred in the North Central and Northeast regions, where 13,513 and 8,442 new acres were irrigated, respectively. The Southwest region had an estimated net decrease of 12 acres.

Acreage estimates for lawns in the U.S., including golf courses, is approximately 31.7 million acres as reported in 2005 within NASA's earth observatory features section.[5]

Golf's 1,198,381 acres of irrigated turfgrass would account for approximately 3.2 percent of the 31.7 million total estimated acres of lawns.

Irrigation Water Sources

Golf facilities utilize multiple water sources for irrigation, and the most commonly used water sources for 18-hole golf facilities are listed below. Golf courses should maximize the use of non-potable water to irrigate golf courses when economically and practically feasible. Most golf course facilities utilize open water or on-site irrigation wells as a source for water. Approximately 12 percent of golf facilities utilize recycled water as a source for irrigation water and 14 percent use potable water from a municipal source for irrigation.

- 52% – open water (lakes, ponds, etc.)
- 46% – on-site wells
- 17% – rivers, streams and creeks
- 14% – municipal water systems
- 12% – recycled water

Irrigation Water Use Nationally

From 2003-2005, the average water use for golf course irrigation in the U.S. was estimated to be 2,312,701 acre-feet of water. The U.S. Geological Survey (USGS) estimated total water withdrawals in the U.S. in 2000 at 457,000,000 acre-feet and agricultural irrigation water use, including golf courses, at 153,000,000 acre-feet. Irrigation water use on U.S. golf courses is estimated to be 0.5 percent of the annual total water withdrawal for the country and 1.5 percent of the estimated annual total agricultural irrigation water use.

USGS estimates between 80 and 100 gallons of water use per day per person.[7]

In 2005, the population estimate for the U.S. was 295,896,000. Using a 100-gallon, per-day per person value for the population equates to approximately 33 million acre-feet per year of water for personal/home use in the U.S.

Conclusions

According to Golf Digest's 2007 Golf and The Environment Survey:

- *Forty-one percent of the golfers surveyed felt that the amount of water used on a golf course should only be enough to keep the grass alive, not make it green and lush.*
- *Seventy-five percent felt that golfers should be willing to play on brown grass during periods of low rainfall, but 72 percent felt that golf courses should be uniformly maintained throughout the year for the enjoyment of golfers and enhancement of scenery.*

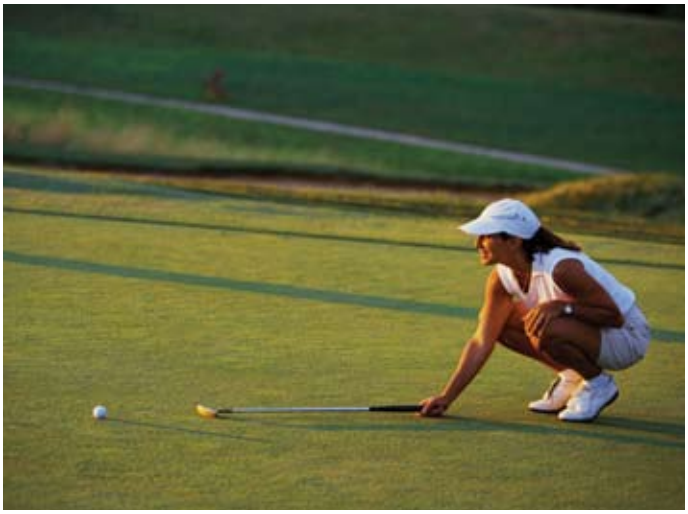
Recycled Water Use for Irrigation

The use of recycled water is a win-win proposition for the golf course industry. Golf course facilities provide a valuable long-term customer for local treatment facilities, and the turfgrass is an effective biological filter to further treat the water. Water quality, particularly salt content, can be a long-term problem for golf facilities if they have no other source of water or no control over the quality of the recycled water they receive for irrigation. The golf industry should strive to maximize the use of recycled water when the availability, quality, and cost are sustainable for the golf facility and it is practical given the local water resources available. Results of this survey indicate that the reason recycled water is not utilized more is because it is not available.

- Recycled water is used as an irrigation source by 12 percent of golf facilities in the U.S. More facilities in the Southwest (37%) and Southeast (24%) regions are using recycled water as compared to other regions.
- The most common reasons cited for not using recycled water was the lack of a source by 53 percent of respondents, not necessary given other water resources (29%), no infrastructure to deliver available water (13%), recycled water was too expensive (1%), recycled water was of poor quality making it too difficult to grow turf (1%) and other (3%).

Irrigation Water Management and Conservation

Superintendents at nearly all 18-hole golf facilities utilize information from multiple sources as part of their decision-making process for scheduling irrigation. Most facilities utilize direct observations of turfgrass and soil conditions. Approximately 35 percent routinely utilize evapotranspiration data, and approximately 3 percent use soil moisture sensors to aid in irrigation scheduling. Golf course superintendents should take advantage of technology as part of the irrigation decision-making process to conserve water. The utilization of data from soil sensors for irrigation scheduling decisions is likely to increase in the future as the equipment becomes more reliable and affordable.



Conclusions

Superintendents at 18-hole golf facilities utilize numerous methods to conserve water. The top three conservation methods and the percent of golf facilities utilizing that method are: wetting agents (92%); hand watering (78%); and keeping turfgrass drier (69%).

Irrigation Water Expenditures

Eighteen-hole golf facilities in the Southwest region spend significantly more for irrigation water than 18-hole golf facilities in any other agronomic region, an estimated $107,800 annually. The agronomic regions with the lowest expenditures for irrigation water are the North Central, Northeast and Transition regions, spending $4,700, $6,300 and $6,900, respectively.

Golf facilities use multiple sources of water for irrigation. The average annual expenditure for common sources of irrigation water are listed below. Expenditures do not include pumping or irrigation system operation costs.

- Municipal water – $52,400
- Recycled water – $44,400
- Well water – $6,900
- Rivers, streams, etc. – $4,600
- Open waters (ponds, lakes, etc.) – $3,900

Irrigation Water Quality

In general, irrigation water quality is acceptable or better in all agronomic regions, although there are golf facilities in all agronomic regions that face significant agronomic challenges due to the quality of their irrigation water. The Southwest region has the poorest quality of irrigation water compared to other regions.

Irrigation Water Treatments

Approximately 46 percent of 18-hole golf facilities treat their irrigation water or distribute products via the irrigation system. The most common products distributed through the irrigation system are wetting agents and fertilizers. The majority of facilities using irrigation water treatments or distributing products through the irrigation system are located in the Southwest and Southeast agronomic regions.

Irrigation Systems and Audits

Golf facilities should utilize irrigation system audits as a means to increase the effectiveness of the irrigation system and conserve water. Approximately 8 percent of 18-hole golf facilities nationally have had their irrigation systems audited by a certified irrigation auditor since 2001. More golf course facilities should take advantage of an irrigation system audit to become more responsible users of water. For those that conducted an audit, the average distribution uniformity was 72 percent. This lies within the average of 70 to 85 percent measured on golf courses by Kah and Willig.[6]



Conclusions

Fully automatic irrigation systems are found on 80 percent of 27-hole and 75 percent of 18-hole golf facilities. New sprinkler heads and nozzles were the most common improvements installed, and nearly 50 percent of 18-hole golf facilities added new control systems from 2001-2005.

Written Drought Management Plans

A written drought management plan provides a documented procedure to reduce the use of irrigation water during drought. These written plans are a helpful tool for individual golf facilities and are valuable for the golf industry in developing practical public policy at the local and state level. Approximately 28 percent of 18-hole golf facilities in the Northeast agronomic region have written drought management plans, more than any other agronomic region. Written drought management plans should be adopted by golf facilities that are subject to drought cycles.

Irrigation Water Allocations and Restrictions

An estimated 25 percent of all 18-hole golf facilities are subjected to recurring annual irrigation water allocations. Facilities in the Southwest (40%), Upper West/Mountain (39%) and Southeast (36%) are most likely to be subjected to a recurring annual water allocation.

From 2001 to 2005, 16 percent of 18-hole golf facilities in the U.S. were subjected to mandatory irrigation water restrictions more stringent than the normal recurring annual irrigation water allocation for at least one year. Facilities in the Northeast and Upper West/Mountain agronomic regions were more likely to experience more stringent restrictions. Access to irrigation water will continue to be a primary issue for the golf industry. Written drought management plans, practical public policy and water conservation will be important to the future sustainability of individual golf facilities and the golf industry in general.



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Appendix

Table 1. Number of golf facilities, percent of total number of golf facilities, completed surveys received, percent of the total completed surveys received, response rate within the category and margin of error for agronomic region, course type, and number of holes.

	Golf facilities		Completed surveys*			
	Number**	% of total no.	Number received	% of total	Response rate (%)***	Margin of error (%)****
Region						
Northeast	2,871	17.1	391	15.4	13.6	3.9
North Central	4,238	25.2	630	24.8	14.9	3.0
Transition	3,116	18.6	449	17.7	14.4	3.6
Southeast	3,518	20.9	475	18.7	13.5	3.5
Southwest	1,272	7.6	208	8.2	16.4	5.2
Upper West/ Mountain	1,100	6.5	247	9.7	22.5	4.6
Pacific	682	4.1	140	5.5	20.5	6.2
Type						
Daily fee	9,408	56.3	1,147	45.2	12.2	2.3
Municipal	2,460	14.7	443	17.4	18.0	3.5
Private	4,831	28.9	950	37.4	19.7	2.4
No. of holes						
9	4,557	28.5	284	11.2	6.2	4.7
18	9,965	62.2	1,893	74.5	19.0	1.7
27+	1,487	9.3	363	14.3	24.4	3.8

*** The total number of completed surveys was 2,548.**

**** The total number of golf facilities was 16,797.**

***** Response rate is the percentage of the total number of completed surveys received for each region, course type and course classification (9, 18 or 27+ holes).**

****** At 90% confidence interval.**

Table 2. Irrigated turfgrass acres, irrigation water expenditure, water expenditure per irrigated turfgrass acre, and percentage of golf facilities using recycled water in the U.S. by golf facility characteristic.

Golf facility characteristic	Irrigated turfgrass (acres)*	Water expenditure (US$)*	Water expenditure/ irrigated turfgrass acre (US$)	% of golf facilities using recycled water*
No. of holes				
9	26c	5,300c	204	5c
18	81b	19,700b	243	12b
27	127a	30,700a	242	19a
Facility type				
Public	77b	17,000b	221	12
Private	88a	25,200a	286	12
Maintenance budget				
< $500,000	63c	5,400b	86	8c
$500,000 to $999,999	91b	15,500b	170	13b
$1,000,000 or >	111a	70,700a	637	24a

***Within a column and golf facility characteristic, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 3. Number of irrigated acres and percentage of total irrigated acres by golf course component for an average 18-hole golf facility in the U.S.

Component	Irrigated acres	% total irrigated acres
Greens	3.7	4.6
Tees	3.4	4.2
Fairways	30.7	38.0
Rough	33.8	41.9
Practice area	5.6	6.9
Clubhouse grounds	3.5	4.3
Total	80.7	99.9

Table 4. Irrigated turfgrass acres, water use, and water use per irrigated turfgrass acre on an average 18-hole golf facility by agronomic region.

	Agronomic region*						
	NE	NC	Trans	SE	SW	UW/Mtn	Pac
Irrigated turfgrass (acres)**	54f	66e	74d	100b	115a	103b	84c
Water use (acre-feet)**	42.4f	76.7e	78.9e	241.8c	459.0a	300.4b	158.0d
Water use/ irrigated turfgrass acre (acre-feet)	0.8	1.2	1.1	2.4	4.0	2.9	1.9
Water use/irrigated turfgrass acre (inches)	9.4	13.9	12.8	29.0	47.9	35.0	22.6

*** Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 5. Changes in irrigated turfgrass acres on U.S. golf facilities since 2001.

Changes in turfgrass acres since 2001	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
% increased**	25	33a	28ab	25b	18c	16c	26ab	28ab
Avg. increase (acres)	13.0	14.0	20.5	10.7	5.1	16.7	9.5	7.7
% stayed the same**	66	60c	66abc	66abc	71a	70ab	63bc	60c
% decreased**	9	7b	6	9ab	11ab	14a	11ab	12ab
Avg. decrease (acres)	12.3	9.4	14.1	14.5	10.0	17.9	8.2	12.7

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 6. Average and total water use in acre-feet for 9-, 18- and 27-hole golf facilities in the U.S. and by agronomic region.

	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/ Mtn	Pac
Facility type	Acre-feet							
9-hole								
Avg. water use	48.2	13.8	52.5	24.9	54.0	99.7	89.9	66.3
Total water use	219,376	10,625	73,813	20,118	34,311	27,440	38,950	14,125
18-hole								
Avg. water use**	152.5	42.4f	76.7e	78.9e	241.8c	459.0a	300.4b	158.0d
Total water use	1,518,070	74,733	181,900	152,750	521,093	352,950	175,827	58,816
27-hole								
Avg. water use	386.2	84.4	164.2	164.9	580.9	988.9	394.5	325.7
Total water use	575,255	17,223	57,324	33,961	245,701	173,052	26,826	21,174
Total water use	2,312,701	102,581	313,037	206,829	801,105	553,442	241,603	94,115

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 7. Water use by two-month periods for an average 18-hole golf facility in the U.S. and within each agronomic region.

	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
	% water use**							
January - February	2	0d	0d	1c	8a	6b	1c	1c
March - April	9	6d	5d	10c	15a	13b	10c	7c
May - June	26	27ab	27a	25bc	23d	24c	27ab	25bc
July - August	41	50a	49b	42d	26f	29e	41d	45c
September - October	18	16d	18c	19a	18bc	20a	19ab	19ab
November - December	4	1e	1f	3c	10a	8b	2d	3cd

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 8. Irrigation water expenditure and water expenditure per irrigated turfgrass acre for an average golf facility, and the percentage of 18-hole golf facilities that do not pay for water by agronomic region.

	Agronomic region*						
	NE	NC	Trans	SE	SW	UW/ Mtn	Pac
Irrigation water expenditure (US$)**	6,300d	4,700d	6,900b	15,000c	107,800a	20,800c	42,400b
Water expenditure/ irrigated turfgrass acre (US$)	117	71	93	150	937	202	504
% golf facilities that do not pay for water	57	62	64	58	18	37	50

*** Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 9. Changes in water cost on U.S. golf facilities since 2001.

Changes in water cost since 2001	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
% of golf courses with increased costs**	53	42c	61b	44c	47c	72a	41c	69a
Avg. % of cost increase	40	19	45	15	32	30	31	22
% of golf courses with no change**	43	54a	35b	50a	50a	22d	53a	29c
% of golf courses with decreased costs	4	4	4	6	3	6	6	2
Avg. % of cost decrease	33	23	31	39	36	26	39	76

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 10. Percentage of golf courses that use various types of irrigation water sources in the U.S. and within each agronomic region.

	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
Water source	%**							
Open water (lakes, ponds)	52	64b	55c	74a	62b	8e	24d	17d
Wells	46	41bc	62a	32c	45b	46b	37c	49b
Rivers, streams, creeks	17	22a	16b	16b	12c	4d	28a	15bc
Municipal water supply	14	16c	7d	18bc	8d	31a	13c	25ab
Re-use water (effluent, reclaimed)	12	3d	3d	4d	24b	37a	17c	17c
Canals	4	2d	1e	1e	3cd	9b	18a	6bc
Brackish water	<1	<1	0	<1	<1	0	0	1
On-site desalinization plant	<1	0	0	0	<1	0	0	0
Other	3	2	3	2	2	3	7a	5a

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 11. Water characteristics for golf facilities in the U.S. and within each agronomic region.

Water characteristic	Agronomic region*						
	NE	NC	Trans	SE	SW	UW/Mtn	Pac
Total dissolved solids (TDS) (ppm)**	288d	466c	266d	621b	879a	506bc	429c
Sodium absorption ratio (SAR)**	0.8d	1.2d	0.9d	2.5b	3.5a	1.7c	1.8bc
pH**	7.2d	7.6b	7.4c	7.4c	7.7a	7.7a	7.5bc
Residual sodium carbonate (RSC)**	0.3a	0	0.5a	0	0.6a	0	1.7a

*** Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 12. Water treatments or products delivered through irrigation systems at golf facilities in the U.S. and within each agronomic region.

Water treatment/ delivery system	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
	%**							
Wetting agents	34	35bc	27	25	42ab	49a	35b	30c
Fertigation	23	19c	5e	11d	50a	48a	27b	13c
Acid injection	8b	7b	9b	2d	10ab	15a	11ab	0d
Sulfer burner	4	0c	1c	0c	6b	12a	7ab	8ab
Biological control agents	3	2b	3b	2b	3b	10a	3b	1b
Gypsum	2	0b	1b	0b	2b	10a	6a	6a
Other	1bc	1bc	1bc	0c	1bc	2ab	1bc	1bc
None	54	57b	66a	70a	36cd	28cd	46c	62ab

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 13. Percentage of U.S. golf facilities that have fully or semi-automated, manual or other types of irrigation systems by golf facility characteristic.

Facility characteristic	Degree of automation			
	Fully automated	Semi-automated	Manual system	Other
	%*			
No. of holes				
9	33b	41a	25a	1
18	75a	18b	7b	0
27	80a	15b	5b	0
Facility type				
Public	70b	21a	9a	0
Private	86a	12b	2b	0
Maintenance budget				
< $500,000	58c	29a	12a	1
$500,000 to $999,999	88b	10b	2b	0
$1,000,000 or >	97a	2b	1b	0

***Within a column and golf facility characteristic, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 14. The percentage of golf facilities that have a written drought management plan and are subject to a recurring annual water allocation by golf facility characteristic.

Facility characteristic	Written drought management plan (%)*	Recurring annual water allocation (%)*
No. of holes		
9	9	18c
18	15	23b
27	20	27a
Facility type (18-hole)		
Public	13b	19b
Private	19a	28a
Maintenance budget (18-hole)		
< $500,000	9b	17c
$500,000 to $999,999	19a	26b
$1,000,000 or >	22a	36a

***Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 15. The percentage of 18-hole golf facilities that have a written drought management plan, are subject to recurring annual water allocation and are subject to temporary additional mandatory water restrictions more stringent than normal water allocation.

	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/ Mtn	Pac
	%**							
Drought management plan	15	28a	3d	11c	19b	19bc	20b	12c
Recurring annual water allocation	25	30b	9d	9d	36ab	40a	39a	15c
Temporary additional mandatory water restrictions more stringent than normal water allocation	20	33a	3d	14c	21b	14c	31a	3d

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**